MSD

Metropolitan Sewer District

DESIGN MANUAL

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT
700 WEST LIBERTY STREET
LOUISVILLE, KENTUCKY 40203-1911

MSD DESIGN MANUAL
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CHAPTER 1
INTRODUCTION
EXHIBITS

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CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THE MSD DESIGN MANUAL

This MSD Design Manual is a guide for the planning and design of stormwater systems, flood protection works, sanitary sewers, erosion control structures, small sanitary pump stations, small wastewater treatment plants and associated activities for the Louisville and Jefferson County Metropolitan Sewer District. The guidelines and general design procedures in this manual are approved by the MSD Board.

This Manual:

a. Enumerates design standards that have been authorized by the MSD Board and/or KRS 76 to facilitate MSD's compliance with local, state and federal regulations.

b. Identifies submittal requirements and procedures for the review of infrastructure projects within the MSD service area.

c. Serves as a reference document for professional consultants in the design of infrastructure projects within the MSD service area.

1.2 DESCRIPTION AND USE OF THE MSD DESIGN MANUAL

The Manual identifies a single set of standards, submittal requirements and approval procedures to be used in the planning and design of projects within the MSD service area.

This Manual is not intended to serve as a step-by-step design methodology nor can this Manual address every situation, which may arise. The application of sound engineering/surveying principles and judgment combined with the information contained herein are necessary to complete the planning, design, and preparation of related construction documents for stormwater, sanitary sewer, and/or wastewater projects.

Approval of plans by MSD shall not relieve the designer or developer from required compliance with the provisions of this manual unless a written variance is received from MSD.

1.3 STRUCTURE OF THE MSD DESIGN MANUAL

The Manual contains 18 chapters. A general table of contents is found at the beginning of the Manual. To facilitate use of the Manual, a detailed table of contents can be found at the beginning of each chapter for text and exhibits.

The Manual is structured as follows:

a. Chapters 2 and 3 describe MSD's general planning and design approach, required submittals and approval procedures.

b. Chapters 4 through 7 detail MSD standards regarding drafting (manual and computer-aided), construction drawings, record drawings, surveying and easement documents.

c. Chapters 8 through 14 relate to the specific design of sanitary sewers, stormwater systems, erosion control structures, native revegetation, and tree preservation.

d. Chapters 15 and 18 relate to small pump stations, small wastewater treatment plants, odor control, and geotechnical procedures.

1.4 MSD Web Page

The MSD Web Page can be accessed at http://www.msdlouky.org. **The Design Manual is available under the "Reports and Documents" → "Design and Construction Documents" path.**

MSD **no longer distributes hardcopy versions of the manual. Printable PDF versions of the respective chapters are available for download.**

1.5 UPDATES TO THE MSD DESIGN MANUAL

The Manual is intended to be a dynamic document. As design criteria and technology evolve, the Manual will require revisions and improvements. As changes are made, **updates will be posted to the website version. MSD no longer maintains a registered holder list where updates are mailed to manual owners.** . It will be **the designer's** responsibility to **stay updated on the manual.**.

Comments and suggestions concerning the content and format are welcomed from the users of the Manual. Exhibit 1-1 may be used for this purpose.

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Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
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502-587-0603 – WWW.MSDLOUKY.ORG

MSD DESIGN MANUAL
COMMENT FORM

FROM: Name: _____ Date: _____

Company: _____

Street: _____

City: _____ State: _____ Zip: _____

The Louisville and Jefferson County Metropolitan Sewer District is most interested in your comments regarding this MSD Design Manual. Please indicate your responses below and return this form to us.

1. List any specific errors detected (with page numbers): _____

2. List any recommended revisions for future editions: _____

3. List any general comments: _____

Return to: Louisville and Jefferson County
Metropolitan Sewer District
700 West Liberty Street
Louisville, KY 40203-1911
Attn: Design Manual Comments

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CHAPTER 2
GENERAL INFORMATION
EXHIBITS

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CHAPTER 2
GENERAL INFORMATION

2.1 PURPOSE

This chapter:

a. Provides an overview of the Louisville and Jefferson County Metropolitan Sewer District's planning and design approach relating to sanitary and stormwater sewers and their appurtenant facilities.

b. Defines MSD's process for submittal, review and approval of construction documents for sanitary sewer facilities and stormwater facilities.

c. Provides information relating to area utility and public works agency coordination.

d. Provides direction relating to the preparation of opinions of capital, operation, and maintenance costs.

2.2 DESIGN APPROACH

Proposed construction or expansion of sanitary sewer or stormwater facilities within Jefferson County shall be in compliance with MSD's approved countywide 201 Facilities Plan, **approved** action plans, the Sanitary and the Stormwater Drainage Master Plan, **MSD's Wastewater/Stormwater Discharge Regulations**, and guidelines defined in the MSD Design Manual. Additionally, plan development will need to conform to the Louisville and Jefferson County Erosion Prevention and Sediment Control (EPSC) and Floodplain Ordinances and the **other applicable land use planning documents**. Any person, company, corporation, or other entity proposing to develop land or to install new or replacement sanitary sewer or stormwater facilities in Jefferson County must prepare planning and design documents in accordance with the standards and requirements of this Manual for review and approval by MSD. Planning and Construction Documents must be prepared and signed by both a Professional Engineer and Land Surveyor, currently licensed in the Commonwealth of Kentucky. The service level of proposed facilities should be in accordance with standards referenced in these documents. Design standards shall also be those referenced herein.

2.3 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit to MSD for their review and approval, a concept plan and design documents as specified in subsequent chapters of this Manual. Design

documents may include, but are not limited to, calculations, plans and specifications. Approval by MSD will be required prior to authorization of any succeeding phase.

Submittal of concept plans shall be prepared in report format (8.5" x 11") and shall be spiral bound, three-ring bound or bound in some other permanent manner. Appended to or included in the submittals shall be maps, figures, and drawings as necessary.

2.4 SUBMITTAL REVIEW AND APPROVAL

The design of new sanitary sewer facilities or an expansion to existing facilities in Jefferson County, whether privately owned or MSD-owned, requires the approval of:

a. MSD
b. Kentucky Division of Water
c. **Louisville-**Jefferson County Health Department

The design of new stormwater facilities or an expansion to existing facilities in Jefferson County, that will become a part of or impact the MSD stormwater infrastructure or other public entity, requires the approval of MSD. Construction within blue-line streams and regulatory floodplains also requires the approval of and permit by the Kentucky Division of Water. The U.S. Army Corps of Engineers approval may also be required. Work within federal and state highway rights-of-way requires approval and/or a permit by the Kentucky Transportation Cabinet. Cities not within the MSD service area are to be informed of improvements by MSD.

Sanitary sewer and stormwater facilities shall be designed according to the appropriate sections of this Manual. Construction documents (plans and specifications) shall be reviewed by MSD prior to submittal to other review agencies.

2.5 UTILITIES/AGENCIES COORDINATION

The Design Engineer shall coordinate the design of all sanitary sewers and of all stormwater facilities improvements with all utilities and/or appropriate public works agencies actively involved in the provision of service in Jefferson County. Contact shall be made with such agencies and preliminary plans provided no later than the initial design submittal to MSD. MSD should be given a copy of all correspondence with utilities and public works agencies. A listing of contact persons, their respective agencies, and the number of plan sets required is included in Exhibit 2-1.

2.6 OPINIONS OF COST

Opinions of probable cost shall be based on the best professional judgement of the Design Engineer. The Design Engineer should use recent bid tabulations, and information from suppliers and contractors in formulating opinions of cost.

Opinions of capital cost shall be in the Construction Specification Institute (CSI) format and shall be grouped by category. Opinions of capital cost should include a construction contingency, allocations for planning and design, and a cost for necessary land, easement, or right-of-way acquisition. The amount or percentage of these contingencies and allocations are dependent upon project specifics and the stage of project development. Opinions of operation and maintenance cost shall include costs for labor, utilities, maintenance and repair.

2.7 PERMIT REQUIREMENTS

A summary of requirements for permits is shown as Exhibit 2-2. The Exhibit contains individual lists for drainage projects, pump station/structural projects, and pipeline projects. The list should not be considered all-inclusive, and the designer will need to confirm all permit requirements as a part of the preliminary scope of the project. The following is a brief summary and the applicability of the three major permits that impact projects in the MSD service area.

a. **Section 404 - Nationwide Permit No. 12 of 33 CFR Part 330** from the U.S. Army Corps of Engineers. Conditions of this permit may require Item b. A permit is required for discharges of soil, sand, gravel or dredged material into a blueline stream if the Average Annual Flow of the stream is greater than 5 CFS. In Jefferson County, this usually requires a drainage area of about 3.5 acres but Design Engineers must inquire from the U.S. Army Corps of Engineers if a certain stream requires this permit.

b. **Section 401 - Application for Water Quality Certification** from the Commonwealth of Kentucky, Natural Resources & Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Water Quality Branch. This application is required when more than 200 lineal feet of blueline stream is impacted.

c. **Application for Permit to Construct Across or Along a Stream** from the Commonwealth of Kentucky, Natural Resources & Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Floodplain Management Section - Water Resources Branch. This application is required if the drainage area for the impacted stream is one square mile or greater.

Electrical Service Department
Louisville Gas & Electric Company
820 West Broadway
Louisville, KY 40202
Phone: 627-3162
FAX: 627-2650
2 sets

Gas Department
Louisville Gas & Electric Company
820 West Broadway
Louisville, KY 40202
Phone: 627-3019
FAX: 627-3789
2 sets

ATT
3719 Barddstown Rd.
Louisville, KY 40218
Phone: 454-9854
Fax: 454-2320
2 sets

Relocations Process Owner
Louisville Water Company
550 South Third Street
Louisville, KY 40202
Phone: 569-3600
2 sets

Louisville - Metro Department of Public Works
444 S. Fifth Street suite 400
Louisville, KY 40202
Phone: 574-5810
2 sets

Texas Gas Transmission Corp.
10327 Gas Light Way
Louisville, KY 40299
Phone: 491-0251
FAX: 491-0251
(call prior to transmitting)
2 sets

Insight Communications
11505 Electron Drive
Louisville, KY 40299
Phone: 357-4376
2 sets

Kentucky Transportation Cabinet
District 5
8310 Westport Road
Louisville, KY 40202
Phone: 210-5400
FAX: 210-5494
2 sets

Jefferson County Public Schools
P.O. Box 34020
Louisville, KY 40232-4020
Phone: 473-3011
FAX: 473-3976
2 sets

MSD Stormwater Department or
Planning Department (Sanitary)
700 West Liberty Street
Louisville, KY 40203-1913

REQUIRED PERMITS FOR DRAINAGE PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a Stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream, in a floodplain, or when impounding water.
		2. Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	Kentucky Division of Water	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Necessary only at the direction of Corps of Engineers.
		4. Stormwater Discharge Permit	Application/ **NOI (Notice of Intent)**	Kentucky Division of Water	For all projects disturbing >**1 acre**
		5. Water withdrawal Permit	Application/ Letter	Kentucky Division of Water	When necessary to withdraw more than 10,000 gpd of water from a blueline stream
		6. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		7. Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: To be submitted at 80% design stage.
		8. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		9. Building Permit for Temporary Office	Site Plan	Louisville Metro – Code Enforcement or City of Louisville Public Works	For any temporary office/trailer.
		10. Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic.
		11. Planning Commission Approval	Site Plan(s)	Louisville Metro – Planning Commission	For all projects.
		12. MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects.
		13. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept of Public Works	For any project which requires obstruction of a roadway.
		14. Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and Corps of Engineers	When encroaching on the floodwall right-of-way.

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EXHIBIT 2-2
REQUIRED PERMITS

EFFECTIVE DATE: JUNE 30, 2009

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EXHIBIT 2-2
REQUIRED PERMITS

EFFECTIVE DATE: JUNE 30, 2009

REQUIRED PERMITS FOR PUMP STATION/STRUCTURES PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a Stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream, in a floodplain, or when impounding water.
		2. Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	Kentucky Division of Water	Any activity that requires a Section 404 permit from the Army Corps of Engineers will require a Water Quality Certification from the DOW, if a total of 200 linear feet of impact is proposed.
		4. Water Withdrawal Permit	Application/Letter	Kentucky Div. of Water	
		5. Temporary Discharge Permit	Letter detailing source, treatment analysis, location of discharge	Kentucky Division of Water	For WTP Eliminations, UST dewatering, pump tests, etc.
		6. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		7. Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: To be submitted at 80% design stage.
		8. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		9. Building Permit for Temporary Office	Site Plan	Louisville Metro – Dept. of Public Works	For any temporary office/trailer.
		10. Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic.
		11. Health Dept. Approval	Plans	Louisville / Jefferson Co. Health Department	For all projects.
		12. Planning Commission Approval	Site Plan(s)	Louisville / Jefferson Co. Planning Com.	For all projects.
		13. MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects.
		14. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept. of Public Works	For any project which requires obstruction of a roadway.
		15. Building Permit	Application/Plan/ Specs	Louisville Metro - Code Enforcement Board	Necessary for all pump stations and waste treatment plants.
		16. Certificate of Occupancy	Plans/Specs	Louisville Metro - Code Enforcement Board	For any project with a building.
		17. Community Facilities Review	Plans/Letter	Louisville Metro Planning Commission	For waste treatment plants.
		18. Air Contaminant Source Permit	Application and Location/Details	Air Pollution Control District	For any fuel tanks.
		19. Fire Marshall Approval	Site Plan(s)	State Fire Marshall	For any enclosed buildings.

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EXHIBIT 2-2
REQUIRED PERMITS

EFFECTIVE DATE: JUNE 30, 2009

REQUIRED PERMITS FOR PIPELINE PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream or in a floodplain.
		2. Section 404 - Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401 – Clean Water Act, Water Quality Certification	Application/ Erosion Control Plans	Kentucky Division of Water	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Necessary only at the direction of Corps of Engineers.
		4. Storm water Discharge Permit	Application/ Site Plan(s)	Kentucky Division of Water	For all projects
		5. Water Withdrawal Permit	Application/Letter	Kentucky Division of Water	When necessary to withdraw more than 10,000 GPD of water from a blueline stream.
		6. Temporary Discharge Permit	Letter detailing source, treatment, analysis, location of discharge	Kentucky Division of Water	For WTP eliminations, UST dewatering, pump tests, etc.
		7. Construction Permit	Plans/Specs	Kentucky Division of Water	For all projects
		8. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		9. Encroachment Permit	Application	Louisville Metro – Dept of Public Works	When encroaching on county right-of-way.
		10. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		11. Building Permit for Temporary Office	Site Plan	Louisville Metro - Code Enforcement Board	For any temporary office/trailer.
		12. Parking Meter Permit	Application	Louisville Metro	When necessary to remove meters from service
		13. Lane Closure Permit	Application	Louisville Metro	When necessary to close lanes of traffic.
		14. Health Dept. Approval	Plans	Louisville / Jefferson Co. Health Dept.	For all projects
		15. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept of Public Works	For any project which requires obstruction of a roadway.
		16. Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and Corps of Engineers	When encroaching on the floodwall right-of-way.

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CHAPTER 3
GENERAL PLANNING INFORMATION

3.1 PURPOSE

This chapter:

a. Documents Louisville and Jefferson County Metropolitan Sewer District's philosophy for a regional (watershed) approach for the provision of sanitary sewer and stormwater service in the MSD service area.

b. Identifies the sources of planning and design information for development of sanitary sewer and stormwater drainage infrastructure in the MSD service area.

c. Identifies the goals of the Facilities Plan, Area Action Plans and the Stormwater Drainage Master Plan.

3.2 PLANNING APPROACH

MSD's regional approach for the planning, design, construction, operation and maintenance of sanitary sewer and stormwater facilities is structured to ensure a level of service that protects the general health, safety, and welfare of the citizens of the MSD service area. This approach will also further MSD's efforts to satisfy local, state and federal regulations as they relate to water quality.

MSD's 201 Facilities Plan and approved Area Action Plans provide the framework for planning and design of sanitary sewer facilities in the MSD service area. The Sanitary Master Plan, the Stormwater Drainage Master Plan, **MSD's Wastewater and Stormwater Discharge Regulations,** and the Watershed Master Plan provide the required technical information necessary for the regional planning and design of sanitary and stormwater facilities in the MSD service area. The Design Engineer should use these documents for planning and as reference documents for the development of sanitary and stormwater facilities in the respective MSD service areas.

3.3 FACILITIES PLAN/AREA ACTION PLANS (SANITARY)

The original master plan prepared for MSD for sewering portions of Jefferson County, Kentucky outside the City of Louisville dates back to 1964. In 1973 and 1974, updates of that plan and the area's 201 Facilities Plan were prepared to conform to the requirements of the Federal Water Pollution Control Act Amendments of 1972. The 201 Facilities Plan was deemed by EPA to be substantially complete in May 1975. The 201 Facilities Plan

designated MSD as the local agency to implement the approved program, which became known as the Master Plan Expansion Program.

The goal of the Master Plan Expansion Program was to provide the best solutions, both cost-effectively and environmentally, to the problems of wastewater collection and treatment in Jefferson County. The Master Plan Expansion Program covers a 300-square mile portion of Jefferson County.

Since the 201 Facilities Plan was approved, MSD has initiated and completed the development of the watershed area action plans to address the problems in areas without sanitary sewer service and to facilitate growth in the MSD service area. Action plans are considered to be updates to the 201 Facilities Plan. **The MSD/OCSD Regional Wastewater Facilities Plan 2000 – 2020, dated January 2002 now overrides the original North County Action Plan, dated February 1987.** A list of the remaining area action plans and the date they were adopted by the MSD Board is as follows:

Action Plan	Adopted
Upper Pond Creek	November 1989 (Updated 1998)
Cedar Creek	May 1990 **(Updated July 2000)**
Mill Creek	May 1993
Floyds Fork	July 1993
Regional WCWTP	**Updated March 2002**

3.4 STORMWATER DRAINAGE MASTER PLAN

In order to improve and enhance stormwater drainage services to the City of Louisville and Jefferson County, Agreements of Interlocal Cooperation between MSD, the City of Louisville, and Jefferson County were signed to clearly identify MSD as the responsible agency for providing flood and stormwater services. These agreements became effective January 1, 1987, and supplemented where needed, the powers MSD already possessed pursuant to the Kentucky Revised Statutes, Chapter 76. To facilitate this transition and provide regional guidelines for management of the overall program, the Stormwater Drainage Master Plan (SWDMP) was prepared.

The goal of the SWDMP is to provide a regional approach to develop a consistent level of drainage service and maintain or improve water quality across the County. The Watershed Plan Report of the SWDMP includes the technical information and recommendations to manage the 11 designated watersheds both area-wide and on a local level to meet this goal.

3.5 REGIONAL FACILITIES

In June of 1996 the MSD Board adopted a revised policy for regional wastewater and stormwater facilities serving more than a single development. MSD realized that in some

cases regional facilities are more appropriate, cost effective, and assure proper operation and maintenance compared to on-site detention facilities.

The requirement to build or participate in the cost of regional facilities shall be determined concurrently with the review by MSD of the developer's proposed development plans and by an analysis of the development's impact on the general community. This impact includes watershed, other development, existing service facilities, and its conformance with MSD's master plans.

3.6 FLOODPLAIN ORDINANCE

With the issuance of **Louisville Metro's** Floodplain Ordinance, it is important that before planning/design begins on any lot with possible floodplain or minimum opening impacts, the builder must obtain a determination from MSD on the need for a floodplain permit and clarification on exactly what restrictions apply. Construction in the local regulatory floodplain without a valid permit is a violation of the ordinance and is subject to possible fines. Per the ordinance, **"No Development"** is permitted in the local conveyance zone. The conveyance zone is further defined in Section 10.4.

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CHAPTER 4
CADD STANDARDS

4.1 GENERAL

MSD has adopted CADD standards to provide consistency with respect to plan and document development and for compatibility with respect to the sharing of data and document storage. MSD operates in the AutoCAD environment. Emphasis has been placed on developing standards that are in line with current industry procedures, but can be easily adapted to change with industry advancements.

Development plans for sanitary sewer and stormwater construction shall be prepared in a neat and professional manner **and shall conform to the standards detailed in this chapter.** It is very important that information be presented in such a manner that it will be legible when the plans are scanned, reproduced, or reduced. The following section presents the standards that shall be adhered to on all MSD and Private Development plans. **Private Development Plans, with the exception of lateral extensions, do not have to comply with the final plan submittal requirements of section 4.2.2.** The standard **Layer Names, Colors, Text Heights,** Line Weights, Standard Symbols, and Standard Abbreviations are shown in **Exhibits 4-1 through 4-7** at the end of this chapter**, and will be available on MSD's website at some point in the future.**

It should be noted that the sample sheets shown in Exhibits 4-8 thru 4-17 have not been updated to incorporate the new standards. This will be done in conjunction with making the drawing template, standards and exhibits available in digital form on MSD's website. As previously mentioned, this will be done at some point in the future.

4.2 CADD Structure

4.2.1 CADD Environment

<u>General</u>

- **The electronic files will be shared and referenced by many different individuals. Therefore, this chapter outlines the minimum standards, conventions, and formats necessary to ensure a usable electronic file data set to all users.**

- **It must be stressed that while the CADD Standards are to be applied to the deliverable files for design plans, they should not be used to restrict the user's options or workflows during plan development. Interim drawings for public meetings, reviews, etc. may deviate from**

the suggested workflows and standards if needed for particular display or presentation requirements.

- **All drawings shall be in AutoCAD format, compatible with the current version that MSD is running. The project manager should check with MSD for version information before any CADD work begins.**

- **In addition to hard copy drawings, , all final drawings are to be submitted in digital format per the requirements of this chapter.**

- **Model space shall be used for all drafting. Paper space shall be used for borders, viewports, and plotting. Modelspace contains the model at "real life" size. Printing is from paperspace at 1:1 scale for full-size prints**.

Scales

The appropriate scales for original plans are 1" = 50' horizontal with vertical scale of 1" = 5' and 1" = 20' horizontal with vertical scale of 1" = 2'. Other scales may be allowed with prior approval of MSD for the purpose of clarity. A graphic scale is required. In addition, crossings of state highways may require additional sheets at differenct scales. Coordination between MSD project manager and KYTC – District 5 will be necessary.

AutoCAD Template File

An AutoCad template will be created to incorporate the standards as described in this chapter. This file will contain the standard layers, linetypes, fonts, symbols (blocks), and sheets and can be downloaded from the MSD website at some point in the future.

Standard Layers and Line Types

The standard MSD layers are presented in Exhibit 4-1. All drawing elements shall be placed on one of these layers. The color and line style attributes for all drawing elements shall be set to "By Layer". Custom Linestyles are also shown in exhibit 4-1.

Standard Symbols

The standard symbols presented in Exhibit 4-3. These symbols will be pre-loaded as blocks in the future MSD standard template file.

Standard Sheets

The standard sheet size is 24" x 36" for all sanitary and stormwater projects. The sheets are presented in Exhibit 4-4 and will also be pre-loaded as blocks into the future MSD standard template file.

Pen Size Assignments

The chart in exhibit 4-5 shows the relationship between colors and pen sizes (weights). The corresponding ctb file will be made available through MSD's website at some point in the future.

Screening

For screening options - See Exhibit 4-4. The intent is for existing features (topography) to be screened.

Text Fonts, Sizes, and Weights

All fonts, sizes, and weights will be preset attributes in the future MSD template drawing file. The standard font style on MSD projects is "simplex.shx".

The text heights used are synonymous with the Leroy Scale of hand drafting. The following chart shows the height for each text style used. In general, Upper and Lower Case shall be used to denote existing text and UPPER case shall be used to denote proposed text.

TEXT STYLE	HEIGHT (inches)	Notes
L60	0.06	For existing text on plats where space is limited. (Upper & Lower Case)
L80	0.08	All existing text. (Upper & Lower Case)
L100	0.10	For Proposed Item Annotation where space is limited (UPPER CASE)
L120	0.12	For Proposed Item Annotation / Construction Notes. (UPPER CASE)

L140	**0.14**	**For Note Titles & Other Misc. Labels (UPPER CASE)**
L175	**0.175**	**Misc. Titles / Labels (UPPER CASE)**
L200	**0.20**	**Misc. Titles / Labels (UPPER CASE)**

4.2.2 Submittal of Final Plans

General

- **Every sheet in the final plan set shall have a corresponding AutoCAD file. That is, one AutoCAD file per plan sheet. A one to one relationship between the design file content and the plotted sheets shall be maintained.**

- **No external references shall be allowed for the final submittal. Paper space shall be used to represent the actual sheet at a 1:1 scale. All sanitary and storm projects performed for MSD shall be submitted digitally per the requirements of section 4.2.1.**

- **All mapping features and all design features in plan view located in model space of the CAD drawings shall maintain their true coordinate location values. Please reference Chapter 6, "Surveying" for additional details on coordinate systems. Detail sheets do not have to be shown in true coordinate location.**

- **A one-to-one relationship between the design file content and the plotted sheets shall be maintained. i.e., there is no "hidden" information that is turned "off" or "frozen" to make the final plot.**

- **The AutoCad files are submitted as a supplemental deliverable to the stamped and signed mylars, to be used at MSD's discretion.**

- **An AutoCAD (dwg) version of each sheet is submitted per the requirements of this section. The stamped and signed mylars take precedence over the CAD files should any discrepancies airse between the CAD file and the mylars.**

File Naming

At the completion of the plans, the CADD files are to be delivered with the following naming sequence:

AAAAA-SBBB.dwg

where:

AAAAA = Record Number

BBB = sheet number. Use zeroes as necessary.

The "S" stands for sheet(s) and it is not to be changed.

Example: The digital AutoCAD file for Sheet 47 of Drawing Record Number 12345 would be named as follows: 12345_S047.dwg

The files shall be stored in a parent folder named for the Record Number and name of the project and be delivered to MSD on a CD or DVD media format.

A final set of plans shall be printed on 24"x36" paper. This set of plans shall be stamped, signed and dated by the professional engineer of record.

4.3 STANDARD AND TYPICAL DRAWINGS

4.3.1 Definitions

a. Standard Drawings – Details issued by MSD that indicate the acceptable procedure, dimensions, or timetable for a particular facet of construction. The details are not to be modified and can be made a part of the plan set by referencing the respective drawing number on the front Title Sheet. The Standard Drawings are not included in this Design Manual**, but can be found on the MSD webpage under the "Inside MSD" link.** If changes are made to a particular Standard Drawing, the detail ceases to be a Standard Drawing and becomes a Special Detail. The Special Detail will then need to conform to the requirements of Section 4.3.6.

b. Special Details – There are numerous exhibits and design aids found in other chapters of this manual. The details will vary from project to project. Use of the details is encouraged; however, the detail, in its final form, will need to conform to the requirements of Section 4.3.6.

c. Typical Drawings – Examples of typical sheets illustrating the format and information required on MSD contract plans are provided as reference. The respective sheets and exhibit numbers are listed below.

Exhibit	Title
4-8	Sample Title Sheet
4-9	Sample Plan Index Sheet
4-10	Sample Drainage Map (Sanitary Collector System)
4-11	Sample Drainage Map (Storm Collector System)
4-12	Sample Horizontal and Vertical Control Map
4-13	Sample Plan Sheet
4-14	Sample Profile Sheet
4-15	Sample Cross Section Sheet
4-16	Sample Property Acquisition Summary Sheet
4-17	Sample Apportionment Map

4.3.2 Title Sheet Requirements

A MSD Sample Title Sheet can be found on Exhibit 4-7. For each MSD project, t**he title sheet shall have at least the minimum information listed on it:**

a. Contract No., Budget ID No. and Record No.

b. Name of Project -

c. Index of Drawings -

d. Name and Address of Engineer -

e. Design Segment Designation (where applicable)

f. Sheet____of____

g. For sanitary interceptor and major storm sewer contracts, the proposed sewers for which the plans are drawn shall be shown.. The stations at the extremities of the project shall be shown and identified with leaders and arrows. For example: BEGIN PROJECT MC-1, STA. 5+42.00 and END PROJECT MC-1, STA. 10+51.03.

h. To notify the Contractor of the procedure required for the location of utilities prior to construction, the following note should be placed on the Title Sheet.

"NOTE: CAUTION EXISTING UTILITIES"
"THE INFORMATION SHOWN ON THESE DRAWINGS CONCERNING TYPE AND LOCATION OF UNDERGROUND UTILITIES IS NOT GUARANTEED TO BE ACCURATE OR ALL-INCLUSIVE. LOCATION, SIZE, AND MATERIAL SHOWN ON UTILITIES ARE FROM AVAILABLE RECORDS SUPPLIED BY THE RESPECTIVE UTILITY COMPANY. Kentucky 811-Before You Dig (BUD) MUST BE NOTIFIED 2 BUSINESS DAYS PRIOR TO ANY EXCAVATION FOR VERIFICATION OF LOCATION, SIZE AND MATERIAL, Dial 811 or 1-800-752-6007.

i. Other Agency's Standard Drawings pertaining to project (MSD & KYTC) with standard drawing number and description.

j. Revision Block with date & comments

4.3.3 Title Block Requirements

All sheets included in the plans, except the Title Sheet and the MSD Standard Drawings, shall contain a title block, which conforms to the sample shown in the **Exhibit 4-7.**. Information in the Title Block should include the project title indicating sanitary or drainage plans, what type of sheet, and the specific information on the sheet.

4.3.4 Plan Index Sheet Requirements

A Plan Index Sheet shall be prepared to identify the location of the work shown on each Plan Sheet. A Sample Plan Index Sheet is shown on Exhibit 4-8. The Plan Index Sheet shall include a reference to the location of the profile for the sewer lines on each plan sheet if the profile is on a separate sheet. For most projects, the Plan Index Sheet may be shown on the Project Map, which is located on the Title Sheet.

4.3.5 Apportionment Map Requirements

An Apportionment Map shall be prepared for Guaranteed Maximum Assessment apportionment (sanitary collector sewer) projects at a minimum scale of 1" = 100' on a standard size plan sheet. Exhibit 4-16 shows a Sample Apportionment Map. The information shall include, but not be limited to, the following:

a. County Tax Block and Lot Number

b. Property Lines and Dimensions

c. Address of Property

d. Street Names

e. Sewer Sizes

f. Approval and Title Block

g. North Arrow

h. Record Number followed by Letters AM (11732AM)

Those Design Engineers who have sanitary collection system contracts, which contain property that is to be served by a sanitary interceptor, shall include that property on their Apportionment Maps. The property served by the interceptor will be assessed on the collector system.

4.3.6 Special Details

The Design Engineer should show any proposed construction that is not covered by the MSD Standard Drawings as a detail on a Special Detail sheet. The detail should clearly and accurately depict the proposed construction Junction chambers, special pipe bedding, railroad crossings, pump stations, select erosion control measures, and modifications to MSD Standard Drawings are typical examples of items that may require a Special Detail.

Pump station generic details that shall be modified for each project are shown as exhibits in Chapter 15.

4.3.7 Drawing Number Convention (Projects using Multiple Disciplines)

The drawing number shall consist of two parts: The 1st part is the letter corresponding to the discipline. The second part is the numerical page number in that subset.

List of Disciplines
General (G)
Civil/Site (C)
Process (D)
Structure (S)
Architectural (A)
Mechanical/HVAC (M)
Electrical (E)
Instrumentation & Control (I)

Examples: G-1, G-2, S-1, S-2, etc.

4.4 PLAN, PROFILE, AND CROSS-SECTION FORMAT

4.4.1 General Criteria

The plan view of proposed sewer or drainage construction generally should be shown on the same sheet as the profile with the plan view located at the bottom of the sheet and the profile at the top. Samples of the plan and profile sheets can be found in Exhibits 4-12 and 4-13. However, if drafting efficiency can be achieved, the plan view may be shown on a separate sheet from the profile. In this case, the plan sheet and profile sheets shall be cross-referenced. The entire profile for each line shall be shown on one sheet when possible. A profile sheet with profiles for more than one plan sheet can be accepted. Profiles shown on sheets separate from the plan views should follow the plan views in a logical order. The information, which appears, on both the plan and profile views shall, at the minimum, include:

a. The location of all proposed manholes, cleanouts, inlets, catch basins and all associated stations shall be shown.

b. House numbers for all residences and businesses shall be shown and drawn parallel with the streets in the plan view.

c. All existing pipes, culverts and appurtenances shall be hatched.

d. The sizes,locations, and invert elevations, if applicable, of the following items shall be shown:

- Stubs
- Drop Inlets
- Stacks
- Borings and Soundings
- Catch Basin Inlets
- Downspout Connections
- Property Service Connections

e. All existing pipes, culverts, conduits, and utilities of any nature, crossing the proposed improvement location, shall be plotted and labeled in the plan and profile.

f. A beginning and ending contract note and station shall be shown on the Title Sheet and in the plans for all interceptor sewers, major through channels and major storm sewers.

g. **Match lines shall be used for transitioning coverage from one sheet to the next.** A cross-reference shall be shown on each sheet to identify the location of the attendant profile or plan sheet

h. **No overlap of plan coverage from one sheet to the next is permitted.** Match lines are **to be used** in plan view with proper referencing station and attendant sheet number.

i. Title Blocks are required for all sheets except cross-sections. Cross-section information to be used should be similar to that shown in Exhibit 4-14.

j. One-hundred-foot stations shall be shown.

k. Plan sheets must include a north arrow.

4.4.2 Plan View

In addition to those items listed in Section 4.5.1, the information to appear in the plan view shall include, but not be limited to, the following:

a. Locations of future connections (PSC, stubs, etc.).

b. The delta angle of all PI's, except where more than one line intersects at the same manhole or inlet. In those instances, the angles relating all lines shall be shown. When the delta angle is shown, its direction shall be noted (left or right), as the stations increase. All angles shall be shown to the nearest second.

c. The location of the centerline shall be referenced by dimensions to the easement lines and to the appropriate property lines.

d. When it is necessary to orient the alignment to a general locality, indicate the name and direction of the nearest street intersection with a distance to that intersection.

e. Bench marks shall be accurately plotted and labeled on the plans. A description and location of each bench mark, including its station and offset relative to the proposed line, shall be plotted and labeled. When bench marks cannot be plotted with the plan coverage, their location and description should still be shown on the plans where it would have appeared.

f. The precise location of all soundings and borings.

g. Houses, fences and drives shall be shown for a minimum of 50 feet beyond the right-of-way or to the fronts of the houses for lines located in the street or rights-of-way. Trees, steps, walks and other topographic features shall be shown to the extent that they may be pertinent to the improvement location or construction. These items must be field located. LOJIC mapping may be used outside critical areas to supplement the base topography. Trees shall be shown with a designation of size and type **with the dripline depicted graphically**.

h. Property lines, lot lines, easement lines and other boundary lines shall be shown a minimum of 75 feet beyond any proposed or existing right-of-way. In instances where additional information might be required, the limit shall be extended.

i. Property Service Connection symbols for sanitary sewers, as shown in Exhibit 4-2, shall be shown near the lot line where service is expected to be required. For consistency, the symbol should be shown approximately 20 feet behind the property line. If a specific location for the connection needs to be shown, an arrow shall be added to the symbol indicating the desired location of service and a note shall be shown in the area indicating the station of the proposed Property Service Connection.

j. Generally, only the outside lines of a pipe shall be shown on the plans. However, a thin centerline shall be shown within these outside lines where any of the following conditions exist:

   1. A distance is shown from a point or line to the centerline of the pipe.

   2. The delta angle is shown.

   3. The angle of intersection is shown.

   Pipes larger than 24 inches in diameter should be drawn to scale to depict the true impact limits.

k. Existing ditches with a bottom width of 4 feet or less should be drawn using the centerline of the ditch. If the ditches and channels have a bottom width greater than 4 feet, each side of the ditch should be drawn and its width be noted. Where ditch paving exists, the width of the paved area shall be shown.

l. Existing and proposed sewers, their direction of flow, size, and MSD Record Number shall be shown. The Deed Book and Page Number shall be shown for existing Sewer or Drainage Easements, which are impacted

by sewer construction.

m. All water lines, gas lines, oil lines, electric and telephone conduits, fiber optic cables, and any other underground or overhead utilities shall be shown with the size or primary voltage and ownership identified.

n. All existing or proposed sewers, manholes and catch basins.

o. When sanitary sewers are to be in existing streets, the front dimension and bearing, if possible, of each lot shall be shown. When sanitary sewers are to be placed in easements or rights-of-way, property line dimensions adjacent to the proposed sewer construction shall be shown.

p. Highways, street names, alleys, or major streams and ditches shall be shown. The width and type of all surfaces shall be indicated.

q. Street right-of-way widths shall be shown adjacent to and after the street name. For example: ROBIN ROAD (50' R/W) or ROBIN ROAD (R/W varies) - if the width is not uniform.

r. The name of **all baselines** shall be shown. The pipe size and direction of flow shall be noted **on all pipes**, above the pipe and between all manholes.

s. The general notes and a legend of the standard symbols used throughout the plans shall be shown on the Plan Index Sheet or on the first plan sheet if the plan index is shown on the Title Sheet.

t. Stations shall be shown above each 100-foot station on 50-scale and 20-scale plans and above each 500-foot station on 100-scale plans. For example: 1+00, 5+00, etc. All horizontal curve data shall be shown on the plans, if applicable.

u. The phrase, "Do Not Disturb", shall be used to indicate existing conditions or facilities, which are to remain in place during construction. The phrase or abbreviation, "DND", shall be shown adjacent to all such items on the plans. If used, "DND" must be shown and defined in the legend. Likewise "DNR", "Do Not Remove", may be used to indicate existing conditions or facilities which are to remain in place during construction but which some level of disturbance is anticipated. The size and type of items, which are within the construction area, must be clearly identified. This information is critical to assist in the easement acquisition process.

v. The resurfacing limits will be shown for all projects receiving final resurfacing.

w. Where applicable, add the following: storm sewer pipe and PSC charts

4.4.3 Profile View

In addition to those items listed in Section 4.4.1, the information to appear in the profile view shall include the following as a minimum:

a. Stations and grid elevations shall be shown. . The grid shall be set up on a 2-inch square basis. The vertical scale for 50-scale plans shall be 1" = 5' and for 20-scale plans shall be 1" = 2'.

b. The limits, by station, shall be shown for all concrete caps, cradles and encasements, tunnels, and bored segments.

c. When a line located in an easement crosses a public right-of-way, the limits of that right-of-way, including its width, shall be shown.

d. Information relative to whether the line will be constructed in an easement, right-of-way, or existing MSD property shall be shown. directly above the profile grid.

e. The type of backfill used, when not identified in the general notes, shall be placed directly above the profile grid with a leader and arrow defining the limits of each type of backfill.

f. The ASTM or AASHTO designation (whichever applies) and pipe classification shall be shown below the pipe profile if different from the designation and classification shown in the General Notes or Standard Specifications.

g. The pipe size, grade, and distance between the centerline if the manholes shall be indicated between all manholes. This information shall be parallel to and shown above smaller pipes; however, on pipes of sufficient diameter, this information should be placed inside the pipe. Grades shall be shown as a percent, i.e., 0.50%.

h. Invert elevations shall be shown to the nearest hundredth of a foot and at the following locations:

   1. All breaks in the grade.

   2. Breaks necessary for profile continuation onto another sheet.

   3. Centerline of standard manholes with continuous grade.

4. Other conduits critical to the pipe gradient.

5. Intersecting pipe.

6. All locations necessary to substantiate the profile grade.

7. Both pipe invert edges when there is a drop or slant inlet.

8. Other conditions shown on the typical drawings.

9. Each catch basin or surface inlet connection.

10. Labeled similar to: IE 479.48.

i. Manholes shall be indentified by station, line and manhole number. Proposed manhole rim elevations shall be shown to the nearest tenth (Rim El. 424.9±) in earth areas and to the nearest hundredth in paved areas. Surface inlet grates shall also be shown to the nearest hundredth (Gr. El. 418.76).

j. The water surface elevations of ponding and/or 100-year flooding areas shall be shown.

k. Borings indicating depths and type of soils encountered shall be shown if not shown on a separate soils sheet.

l. The results of all soundings shall be shown using the proper symbol.

m. The vertical height of manhole collars shall be shown.

n. The flow line of all ditches having impact on sewer depth or location which are deeper than one foot shall be plotted and labeled as flowline ditch, left or right. On large channels, it may be necessary to show left and right tops of bank.

o. Existing ground profile including street grades or other improvements shall be shown as dashed lines. Proposed ground profile, including any proposed street grades or improvements, shall be shown as a solid line. See Exhibit 4-2.

p. If basements exist, the basement floor elevation shall be shown for sanitary plans. For houses without basements, the first floor elevations shall be shown. When an existing basement floor elevation absolutely cannot be obtained, a first floor elevation shall be obtained and a basement elevation estimated. When the basement elevation is estimated, this fact

shall be duly noted in the profile by using the word "Assumed" adjacent to the elevation. House numbers or lot numbers shall be indicated on the profile along with elevations indicated above.

q. In order to show on which side of the sewer a house is located, houses on the left (when facing up station) shall be drawn using a solid line, and houses on the right (when facing up station) shall be drawn using a dashed line as shown in Exhibit 4-1.

r. Any stacks to be shown on the profile, such as for interceptor sewers, shall be shown solid on the left side and dashed on the right side and should be labeled pipe size stack and left or right.

s. Any underground telephone conduit, water lines, gas lines, etc. shall be shown when crossing proposed MSD facilities.

4.4.4 Cross-Sections

The information to be shown on cross-sections shall be, but not limited to, the following:

a. Horizontal and vertical scales shall be equal. Generally a scale of 1" = 5' shall be used, however, 1" = 10' may be used in special circumstances. Any other scale to be used requires prior approval of the MSD Project Manager.

b. Pre-printed colored grid sheets shall not be used because they cannot be scanned on computer for record.

c. Cross-sections shall be required for all proposed ditch projects as well as roadway or alley construction.

d. Cross-sections should show the existing and proposed ground lines, utilities, fences, structures, property lines, easement lines, and right-of-way lines.

e. Cross-sections shall be shown looking up station and shall be placed on the sheet progressing from bottom of sheet for lower station to top of sheet for higher station and left to right if more than one row of cross-sections is presented on one sheet.

f. Cross-sections shall generally be on even 50-foot stations along the improvement centerline or baseline.

g. If cross-sections are required on a project, pipe crossings may be shown

on a cross-section rather than creating a separate profile for each pipe crossing.

h. Half-sections shall be shown for all driveways and a minimum of one half-section between driveways.

i. All water lines, gas lines, telephone conduit, and others shall be shown in the cross-section. .

j. Existing ground shall be shown as dashed lines and proposed grade shall be shown with solid lines.

4.4.5 General Notes

General Notes are notes common to the complete set of plans and shall be shown on the first plan sheet, if space permits, or Title Sheet, if necessary. The type of backfill, pipe material and classification may be shown in the General Notes if the majority of the pipes on a particular project have these items in common. Additionally, a Legend shall be shown on the first plan sheet, which defines the standard symbols used in the plans.

4.4.6 Certification

4.4.6.1 Basement Elevation Certification (Sanitary Projects Only)

The registered Land Surveyor shall place the following certification on the preliminary plan cover sheet, or other appropriate location, prior to the request for a field review. The certification should also be placed on the first plan sheet or other appropriate location in the final plans prior to their submission to MSD for approval.

CERTIFICATION

I hereby certify that the houses shown on these plans, which have basement facilities controlling the elevation of the sanitary sewer, have been entered and controlling elevations determined under my supervision, and that these elevations are correct to the best of my knowledge and belief.

_____

Surveyor's Signature, L.S. # and Date

4.4.6.2 Surveyor's Certification

The following certification paragraph and signature is to placed on all

sanitary and drainage projects. This note will need to be adjusted if survey procedures deviate from the language as shown.

CERTIFICATION

I hereby certify that the topography for this plan was located under my supervision, and that the property lines shown hereon were obtained from recorded deeds or plats, and that only the property corners noted as monumented were located in the field.

_____

Surveyor's Signature, L.S. # and Date

NOTE: ON SANITARY PROJECTS THE CERIFICATIONS CAN BE COMBINED AS A SINGLE NOTE IF APPLICABLE.

Reference is made to Section 6.3.7 of the Manual - Surveying for information on field references.

CERTIFICATION

I hereby certify that the topography for this plan was located under my supervision, and that the property lines shown hereon were obtained from recorded deeds or plats, and that only the property corners noted as monumented were located in the field.

_____

Surveyor's Signature, L.S. # and Date

NOTE: ON SANITARY PROJECTS THE CERIFICATIONS CAN BE COMBINED AS A SINGLE NOTE IF APPLICABLE.

Reference is made to Section 6.3.7 of the Manual - Surveying for information on field references.

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EXHIBIT 4-1 PAGE 1
STANDARD LAYERS

EFFECTIVE DATE: JUNE 30, 2009

NAME	DESCRIPTION	COLOR	LINETYPE	LINETYPE EXAMPLES
BM	BENCH MARK	50	CONTINUOUS	
BORDER-0	BASE SHEET LAYER	12	CONTINUOUS	
BORDER-1	BASE SHEET LAYER	20	CONTINUOUS	
BORDER-2	BASE SHEET LAYER	40	CONTINUOUS	
BORDER-3	BASE SHEET LAYER	50	CONTINUOUS	
BORDER-4	BASE SHEET LAYER	150	CONTINUOUS	
BORDER-ROLL	BASE SHEET LAYER	2	CONTINUOUS	
DRNA	DRAINAGE AREA	230	HIDDEN	
E-ASPH	EXISTING ASPHALT	12	HIDDEN	
E-BASE	EXISTING BASELINE	130	CONTINUOUS	
E-BLDG	EXISTING BUILDING	32	CONTINUOUS	
E-CONC	EXISTING CONCRETE	12	HIDDEN	
E-CONT-MJR	EXISTING MAJOR CONTOUR	22	HIDDEN2	
E-CONT-MNR	EXISTING MINOR CONTOUR	12	HIDDEN2	
E-CONT-TXT	EXISTING CONTOUR TEXT (L80)	12	CONTINUOUS	
E-CRST	EXISTING CRUSHED STONE	172	HIDDEN4	
E-DTCH-E	EXISTING EARTH DITCH	102	FLOW LINES	
E-DTCH-P	EXISTING PAVED DITCH	102	DASHED2	
E-ESMNT	EXISTING EASEMENTS	102	PERM ESMT	
E-FENC	EXISTING FENCES	12	FENCE	X X
E-FLTS	EXISTING FAULTS	7	CONTINUOUS	
E-GRND	EXISTING GROUND (TOP OF BANK)	22	EXIST SHOULDER	
E-PL	EXISTING PROPERTY LINES	162	CONTINUOUS	
E-PL-CH	EXISTING PROPERTY LINE CHORD	162	HIDDEN2	
E-ROAD	EXISTING EDGE OF ROAD, PAVEMENT	162	EXIST EDGE PVMT	
E-RR	EXISTING RAILROADS	32	CONTINUOUS	
E-RW	EXISTING RIGHT OF WAY	115	RIGHT OF WAY	
E-SANI *	EXISTING SANITARY SEWERS	102	HIDDEN 2	
E-SPOT	EXISTING SPOT ELEVATION (L80)	195	CONTINUOUS	
E-STRM *	EXISTING STORM SEWERS	102	EXIST PIPE OR STRUCT	
E-STRP	EXISTING PAVEMENT STRIPING	16	CONTINUOUS	
E-TOPO	EXISTING TOPOGRAPHY	12	CONTINUOUS	
E-U-CBTV	EXISTING OVERHEAD CABLE TELEVISION	12	OHC	OHC
E-U-CBTV2	EXISTING UNDERGROUND CABLE TELEVISION	12	CABLETV	CTV
E-U-ELEC	EXISTING OVERHEAD ELECTRIC	22	OHE	OHE
E-U-ELEC2	EXISTING UNDERGROUND ELECTRIC	12	ELEC	UGE
E-U-GAS *	EXISTING GAS	92	GAS	G G
E-U-TELE	EXISTING OVERHEAD TELEPHONE	92	OHT	OHT
E-U-TELE2	EXISTING UNDERGROUND TELEPHONE	92	TELE	UGT
E-U-WATR *	EXISTING WATER	172	WATER	W W
E-VEG	EXISTING VEGETATION, TREES, SHRUBS	12	CONTINUOUS	
FILE-INFO	FILE INFORMATION	7	CONTINUOUS	
GL	GRID LINE	252	CONTINUOUS	
GT	GRID TEXT (L120)	7	CONTINUOUS	
HT	HATCH	92	CONTINUOUS	
P-ASPH	PROPOSED ASPHALT	215	CONTINUOUS	
P-ASPH-HT	PROPOSED ASPHALT HATCH PATTERN	182	CONTINUOUS	
P-BASE	PROPOSED BASELINE	230	CONTINUOUS	
P-BLDG	PROPOSED BUILDING	230	CONTINUOUS	
P-CONC	PROPOSED CONCRETE	214	CONTINUOUS	
P-CONC-HT	PROPOSED CONCRETE HATCH PATTERN	188	CONTINUOUS	

* SEE EXHIBIT 4-2 FOR ADDITIONAL EXPLANATION.

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EXHIBIT 4-1 PAGE 2
STANDARD LAYERS

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NAME	DESCRIPTION	COLOR	LINETYPE	LINETYPE EXAMPLES
P-CONT-MJR	PROPOSED MAJOR CONTOUR	210	CONTINUOUS	
P-CONT-MNR	PROPOSED MINOR CONTOUR	200	CONTINUOUS	
P-CONT-TXT	PROPOSED CONTOUR TEXT (L100)	210	CONTINUOUS	
P-CRST	PROPOSED CRUSHED STONE	213	CONTINUOUS	
P-CURB	PROPOSED CONCRETE CURB	40	CONTINUOUS	
P-DSTB	PROPOSED DISTURB LIMITS	89	DOT2	
P-DTCH-E	PROPOSED EARTH DITCH	210	FLOW LINES	
P-DTCH-P	PROPOSED PAVED DITCH	210	CONTINUOUS	
P-EPSC	PROPOSED SILT CONTROL DEVICES	50	CONTINOUS	
P-FENC	PROPOSED FENCE	210	FENCE	
P-FLOW	PROPOSED DRAINAGE DIRECTIONAL FLOW ARROW	20	CONTINUOUS	
P-GRND	PROPOSED GROUND	210	CONTINUOUS	
P-PERM	PROPOSED PERMANENT EASEMENTS	210	PERM ESMT	
P-PL	PROPOSED PROPERTY LINE	245	CONTINOUS	
P-ROAD	PROPOSED EDGE OF ROAD, PAVEMENT	240	CONTINUOUS	
P-RW	PROPOSED RIGHT OF WAY	233	RIGHT OF WAY	
P-SANI *	PROPOSED SANITARY SEWERS	210	CONTINUOUS	
P-SF	PROPOSED SILT FENCE \ TREE PROTECTION FENCE	50	SF	SF
P-SPOT	PROPOSED SPOT ELEVATION (L80 w/o obliquing)	40	CONTINUOUS	
P-STRM *	PROPOSED STORM SEWERS	211	CONTINUOUS	
P-STRP	PROPOSED PAVEMENT STRIPING	52	CONTINUOUS	
P-TEMP	PROPOSED TEMPORARY EASEMENT	190	TEMP ESMT	
P-U-CBTV	PROPOSED OVERHEAD CABLE TELEVISION	200	PROP OHC	OHC
P-U-CBTV2	PROPOSED UNDERGROUND CABLE TELEVISION	200	PROP UGC	UGC
P-U-ELEC	PROPOSED OVERHEAD ELECTRIC	201	PROP OHE	OHE
P-U-ELEC2	PROPOSED UNDERGROUND ELECTRIC	201	PROP UGE	UGE
P-U-GAS *	PROPOSED GAS	205	GAS	G
P-U-TELE	PROPOSED OVERHEAD TELEPHONE	203	PROP OHT	OHT
P-U-TELE2	PROPOSED UNDERGROUND TELEPHONE	203	PROP UGT	UGT
P-U-WATR *	PROPOSED WATER	200	WATER	W
P-VEG	PROPOSED VEGETATION, TREES, SHRUBS, ETC.	205	CONTINUOUS	
PAPER	PAPER	7	CONTINUOUS	
PNTS	POINTS MADE FROM LDD / CIVIL 3D	7	CONTINUOUS	
PRELIM	PRELIMINARY	7	CONTINUOUS	
SL	STATION LABELS (L140)	7	CONTINUOUS	
SNDG	ROCK SOUNDINGS	55	CONTINUOUS	
TX0	TEXT L60	12	CONTINUOUS	
TX1	TEXT L80	20	CONTINUOUS	
TX2	TEXT L100	40	CONTINUOUS	
TX3	TEXT L120	50	CONTINUOUS	
TX4	TEXT L140	70	CONTINUOUS	
TX5	TEXT L175 AND ABOVE	80	CONTINUOUS	
XREF	EXTERNAL REFERENCE	7	CONTINUOUS	

* SEE EXHIBIT 4-2 FOR ADDITIONAL EXPLANATION.

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EXHIBIT 4-2
STANDARD LINETYPE EXHIBITS AND MISCELLANEOUS FEATURES

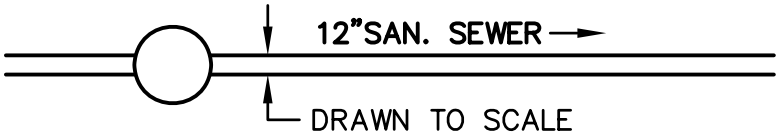
EFFECTIVE DATE: JUNE 30, 2009

LINETYPES

EXISTING SANITARY SEWER



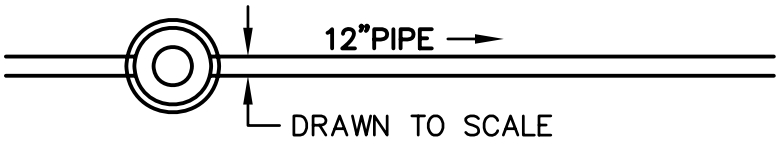
PROPOSED SANITARY SEWER



EXISTING STORM SEWER



PROPOSED STORM SEWER



APPLIES TO GAS AND WATER

EXISTING UTILITY UP TO 10"



EXISTING UTILITY 12"AND LARGER SHOWN WITH ACTUAL WIDTH ASSIGNED TO LINE,



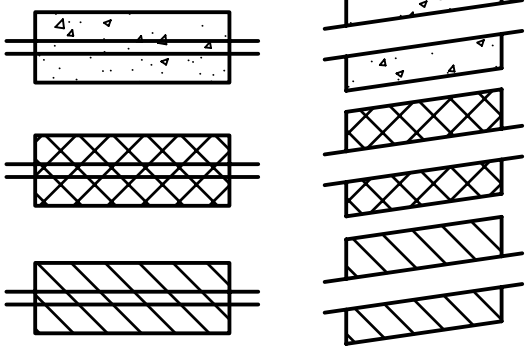
MISCELLANEOUS FEATURES

PLAN PROFILE

CONCRETE ENCASEMENT

TUNNELING OR PIPE JACKING

BORE & JACK OR DIRECTIONAL DRILLING



EXISTING BUILDINGS IN PLAN (FIELD LOCATED)



EX BUILDINGS IN PROFILE LEFT AND RIGHT OF BASELINE



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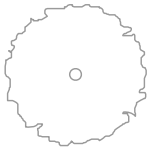
EXHIBIT 4-3 PAGE 1

STANDARD SYMBOLS

EFFECTIVE DATE: JUNE 30, 2009

SYMBOLS	DESCRIPTION	FILE NAME (.dwg)
	*Existing Tree (with size, type & drip line diameter)** * When locating tree sizes for plan views, measure diameter of trunk at breast height (in inches) and measure actual diameter of Drip line to the nearest foot.	MSDATREE.dwg
	*Existing Pine or Spruce W/Size*	MSDPINE.dwg
	*Existing Bush W/Size*	MSDSHRUB.dwg
Wooded Area	*Edge of Woods*	
	Existing Traffic Sign	MSDSIGN.dwg
MB	*Existing Mailbox*	MSDMB.dwg
PB	*Existing Paperbox*	MSDPB.dwg
	*Contract Bench Mark*	MSDBM.dwg
	Existing Guy Anchor	MSDANCHOR.dwg
	Existing Power Pole	MSDPP.dwg
	Existing Pole W/Light	MSDLS.dwg
	*Existing Light Post*	MSDLTSTD.dwg
EPED	*Existing Electrical Pedestal*	MSDELECPED.dwg
	*Existing Electrical Manhole*	MSDEMH.dwg
	*Existing Telecommunications Manhole*	MSDTMH.dwg
TPed	*Existing Telecommunications Pedestal*	MSDTPED.dwg
CATV-PED	*Existing Cable T.V. Pedestal*	MSDCPED.dwg
437.2±	*Overhead Power Lines (Profile)*	
GM	*Existing Gas Meter*	MSDGM.dwg
GV	*Existing Gas Valve*	MSDGV.dwg
GLM	*Existing Gas Line Marker*	MSDGLM.dwg
	*Existing Fire Hydrant*	MSDFH.dwg
WM	*Existing Water Meter*	MSDWM.dwg
WV	*Existing Water Valve*	MSDWV.dwg
	*Existing Water Manhole*	MSDWMH.dwg
WLM	*Existing Water Line Marker*	MSDWML.dwg

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SYMBOLS	DESCRIPTION	FILE NAME (.dwg)
CO	Existing Sewer Clean-out	MSDCO.dwg
S	Existing Sanitary Manhole	MSDSMH.dwg
M.H.	Existing Storm Manhole	MSDSTMH.dwg
	Existing Catch Basin (Single)	MSDCB.dwg
	Existing Catch Basin (Double)	MSDCBD.dwg
	Existing Catch Basin (Round)	MSDCBR.dwg
Steel	Bridge (type of bridge shall be noted)	MSDBRDG.dwg
R.P.	Railway Pole	MSDRP.dwg
	Railroad Rails (Profile)	MSDRR.dwg
P.L. (PIPE)	Existing Property Line Pipe (TYPE)	MSDPLP.dwg
	Right Of Way Marker	MSDRWM.dwg
3	Parcel Number	MSCPN.dwg
C-3	Consent and Release Parcel Number	MSDCRN.dwg
S•	Sounding Location (Plan)	MSDSND.dwg
	Sounding To Rock or Refusal (Profile)	MSDSNDRK.dwg
	Sounding No Rock (Profile)	MSDSNDNRK.dwg
B-0	Boring Location And Number. Geotechnical borings were drilled utilizing a truck-mounted drill rig. Borings were taken to a depth of one foot below flow line or until refusal.	
	PROPOSED EMBANKMENT OR EXCAVATION SLOPE	
	PROPOSED STORM MANHOLE	MSDPSTMH.dwg
	PROPOSED DOUBLE CURB INLET	MSDPDCI.dwg
	PROPOSED CATCH BASIN DOUBLE	MSDPCBD.dwg
	PROPOSED SANITARY MANHOLE	MSDPSMH.dwg

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SYMBOLS	DESCRIPTION
	*Denotes 4" property service connection to be constructed to property or easement line as directed.*
	*Denotes 4" Y or T branch with stopper. Property service connection is not to be constructed.*
	*Denotes 4" property service connection to be constructed from stack at sewer to property or easement line as directed. (See note below)*
	*Denotes 4" Y or T branch with stopper to be constructed from stack at sewer. Property service connection is not to be constructed. (See note below)*
	*Denotes a 4" property service connection (PSC) to be constructed. The PSC is <u>not</u> available for connection until the capacity charge, applicable at the time, is paid.*

Note: ***The following must be added to the general*** notes:

All stacks must conform to the requirements of section 8.14 of the MSD Design Manual.

4" connections are for single family only all others are 6".

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SYMBOLS	DESCRIPTION
	*Denotes 6" property service connection to be constructed to property or easement line as directed.*
	*Denotes 6" Y or T branch with stopper. Property service connection is not to be constructed.*
	*Denotes 6" siamese property service connection to be constructed to property or easement line as directed.*
	*Denotes 6" property service connection to be constructed from stack at sewer to property or easement line as directed. (See note below)*
	*Denotes 6" Y or T branch with stopper to be constructed from stack at sewer. Property service connection is not to be constructed. (See note below)*
	*Denotes a 6" property service connection (PSC) to be constructed. The PSC is <u>not</u> available for connection until the capacity charge, applicable at the time, is paid.*

Note: *The following must be added to the general* notes:

All stacks must conform to the requirements of section 8.14 of the MSD Design Manual.

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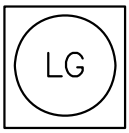
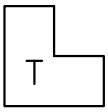
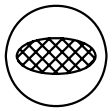
MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES

DESCRIPTION	SYMBOL
SITE PREPARATION:	
LAND GRADING:	
SURFACE ROUGHENING:	
BULLDOZER TRACKED:	
TREE PRESERVATION AND PROTECTION:	
TEMPORARY GRAVEL CONSTRUCTION ENTRANCE/EXIT:	
BENCH TERRACING:	
TOPSOILLING:	

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MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
SURFACE STABILILIZATION:	
TEMPORARY SEEDING:	TS
PERMANENT SEEDING:	PS
SODDING:	SO
MULCHING:	M
DUST CONTROL:	DC
EROSION CONTROL BLANKET:	ECB
TURF REINFORCEMENT MAT:	TRM

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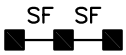
MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
OUTLET PROTECTION:	
OUTLET STABILIZATION STRUCTURE:	OS
INLET PROTECTION:	IP
GRAVEL AND WIRE MESH INLET SEDIMENT FILTER:	GWI
FILTER FABRIC DROP INLET PROTECTION (TEMPORARY):	FDI
BLOCK AND GRAVEL INLET PROTECTION (TEMPORARY):	BGDI
STONE BAG INLET PROTECTION:	SIP
SEDIMENT TRAPS AND BARRIERS:	
TEMPORARY SEDIMENT TRAP:	TS

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
SEDIMENT TRAPS AND BARRIERS (CONT):	
SEDIMENT BASIN:	
SILT FENCE (SEDIMENT FENCE):	
DITCH CHECK:	
TEMPORARY SEDIMENT BASIN:	
REINFORCED SILT FENCE:	
STREAM PROTECTION:	
TEMPORARY STREAM CROSSING:	
RIPRAP:	
VEGETATED FILTER STRIPS:	

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MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
RUNOFF CONTROL MEASURES:	
PERMANENT CLEAN WATER:	PCW
TEMPORARY CLEAN WATER:	TCW
TEMPORARY SEDIMENT LADEN:	TSL
ROCKFILL:	RF
RUNOFF CONVEYANCE MEASURES:	RCM RCM RCM
GRASS-LINED CHANNELS:	GC GC GC
SOD LINED CHANNELS:	SC SC SC
RIPRAP-LINED CHANNELS:	RRC RRC RRC
TURF REINFORCED CHANNELS:	TRC TRC TRC
PAVED CHANNELS:	PC PC PC
TEMPORARY SLOPE DRAINS:	TSD TSD TSD
PIPE SLOPE DRAINS:	PSD PSD PSD
RUNOFF CONVEYANCE MEASURES (CONT):	
STONE BAG CHECK DAM:	SBCD SBCD SBCD
OTHER RELATED PRACTICES:	
SUBSURFACE DRAIN:	SSD SSD
CONSTRUCTION DEWATERING:	

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EXHIBIT 4-4
PEN SIZE ASSIGNMENTS

EFFECTIVE DATE: JUNE 30, 2009

STANDARD ASSIGNMENTS

PEN SIZE	*COLOR*	*COLOR RANGE 1*	*COLOR RANGE 2*	*COLOR RANGE 3*	*COLOR RANGE 4*
0.18mm	1, 9, 250	10-19	90-99	170-179	
0.25mm	2, 251	20-29	100-109	180-189	
0.30mm	3, 252	30-39	110-119	190-199	
0.35mm	4, 253	40-49	120-129	200-209	160-169
0.50mm	5, 254	50-59	130-139	210-219	
0.60mm	6, 255	60-69	140-149	220-229	
0.70mm	7	70-79	150-159	230-239	
0.90mm	8	80-89		240-249	

SHADING

All pens in the following ranges ending with the number 2 except "2" will plot shaded as follow

COLOR			**PLOTS**		
12-172			40% of black		
182			6% of black		
192-242			40% of black		
188			2% of black		
16			30% of black		

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EXHIBIT 4-5
STANDARD ABBREVIATIONS

EFFECTIVE DATE: JUNE 30, 2009

DESCRIPTION

LG&E	Louisville Gas & Electric Company
PUE	Public Utility Easement
ATT	AT&T
Conc	Concrete
Asph	Asphalt
Culv	Culvert
Hdwl	Headwall
Hdw	Headwater
RCP	Reinforced Concrete Pipe
CMP	Corrugated Metal Pipe
CIP	Cast Iron Pipe
VCP	Vitrified Clay Pipe
PE	Polyethylene
DIP	Ductile Iron Pipe
PVC	Polyvinylchloride
HERCP	Horizontal Eliptical Reinforced Concrete Pipe
HDPE	High Density Polyethylene
HP	High Pressure
MH	Manhole
CB	Catch Basin
CI	Curb Inlet
TG	Top Of Gratr Elevation
I.E.	Invert Elevation
BM	Bench Mark
TBM	Temporary Bench Mark
CSB	Crushed Stone Base
R.R.	Railroad
R/W	Right-of-Way
DND	Do Not Disturb
DNR	Do Not Remove
TBR	To Be Removed
TYP.	Typical

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EXHIBIT 4-6
STANDARD BORDER
MSD PROJECTS

EFFECTIVE DATE: JUNE 30, 2009

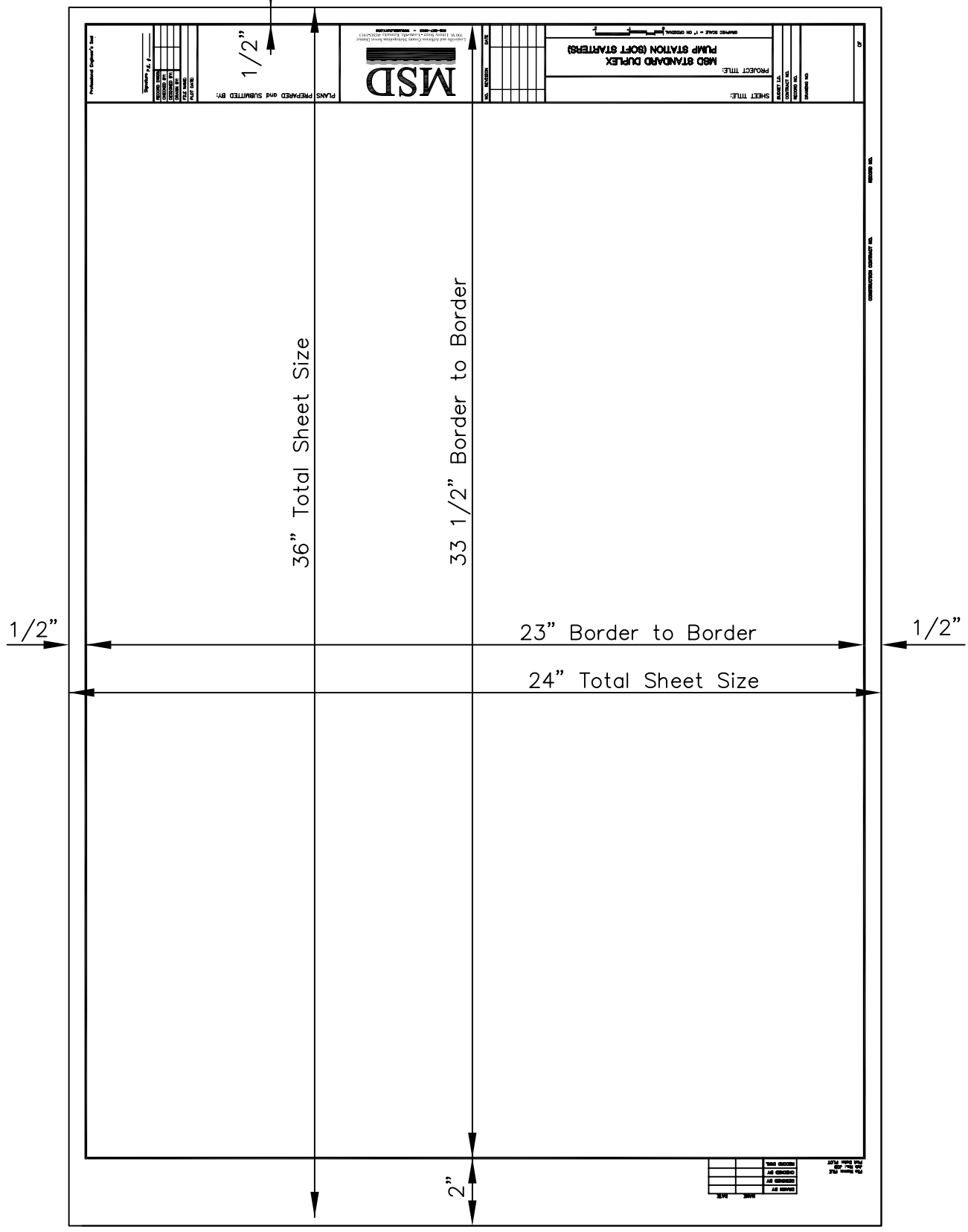

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EXHIBIT 4-7
STANDARD TITLE BLOCKS
MSD PROJECTS

EFFECTIVE DATE: JUNE 30, 2009

SHEET TITLE:
MSD STANDARD TITLE BLOCK

PROJECT TITLE:
MSD STANDARDS
SAMPLE DRAWINGS

GRAPHIC SCALE = 1" ON ORIGINAL
0 1" 2"

TITLE BLOCK

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT

DESIGN
APPROVED: _____

APPROVED FOR
CONSTRUCTION: _____
DIRECTOR OF ENGINEERING DATE

MSD APPROVAL BLOCK

NO.	REVISION	DATE

REVISION BLOCK

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EXHIBIT 4-8
STANDARD TITLE SHEET

EFFECTIVE DATE: JUNE 30, 2009

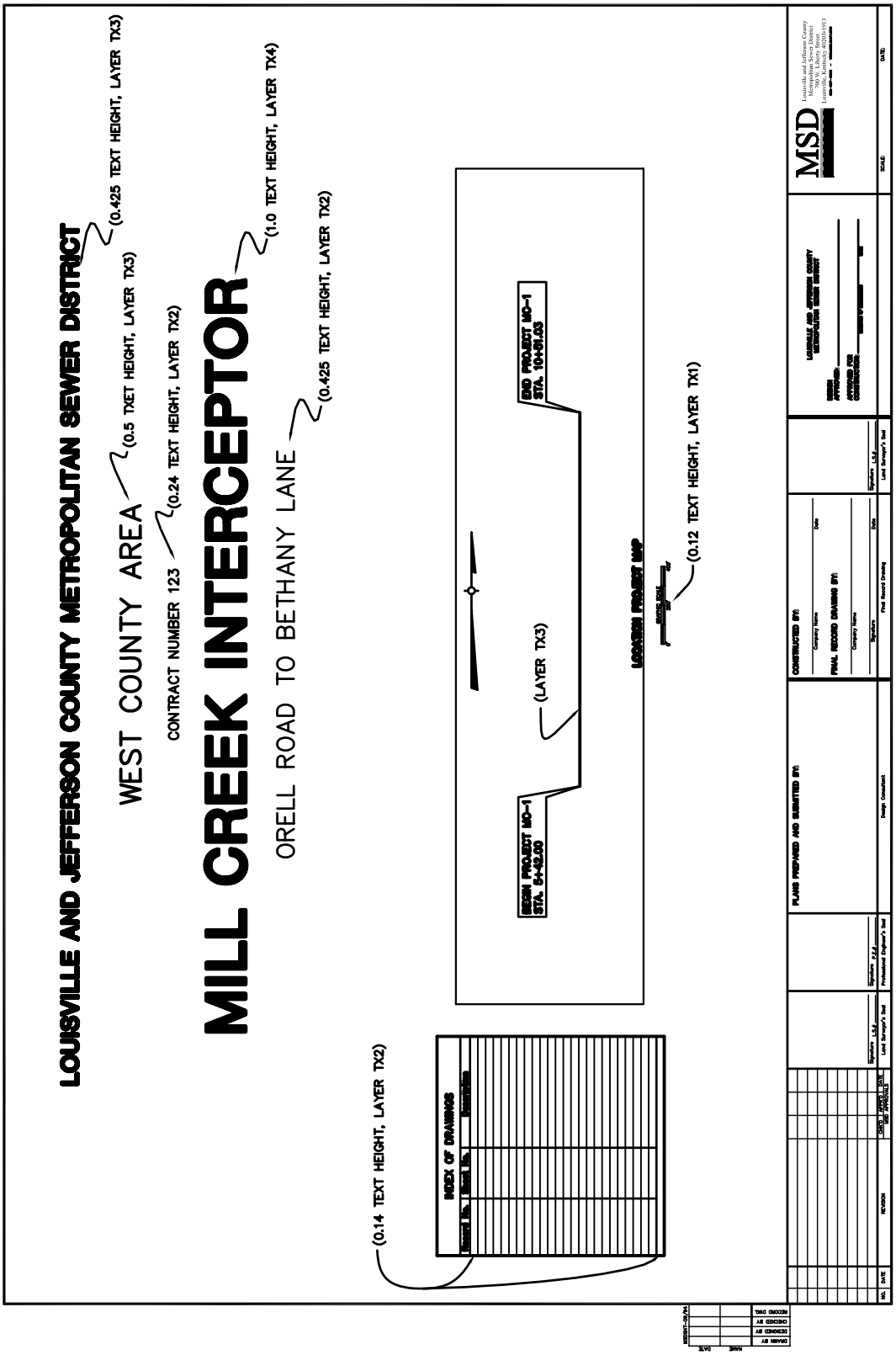

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EXHIBIT 4-9
SAMPLE PLAN INDEX SHEET

EFFECTIVE DATE: JUNE 30, 2009

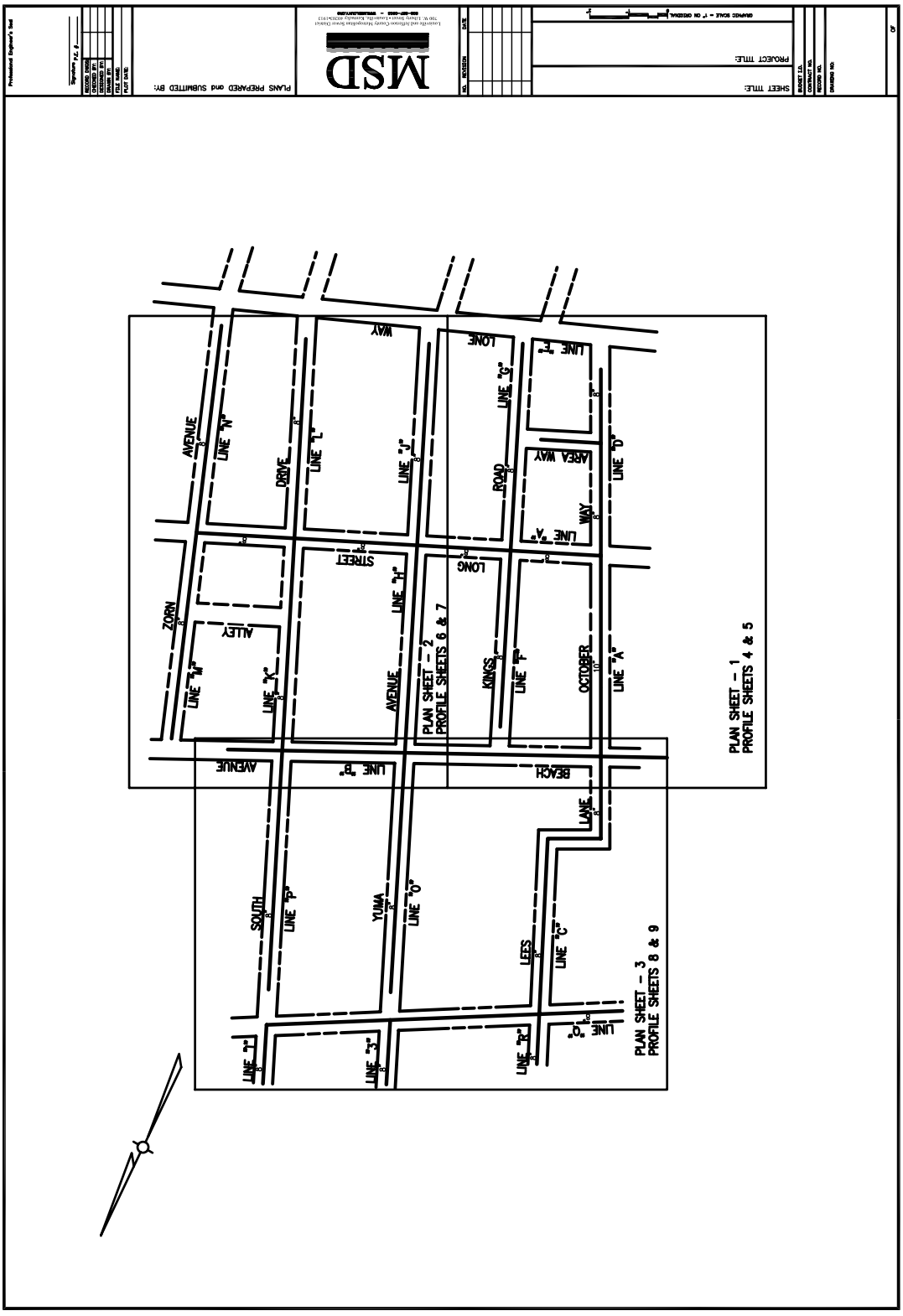

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EXHIBIT 4-10
SAMPLE DRAINAGE MAP
(SANITARY COLLECTOR SYSTEM)

EFFECTIVE DATE: JUNE 30, 2009

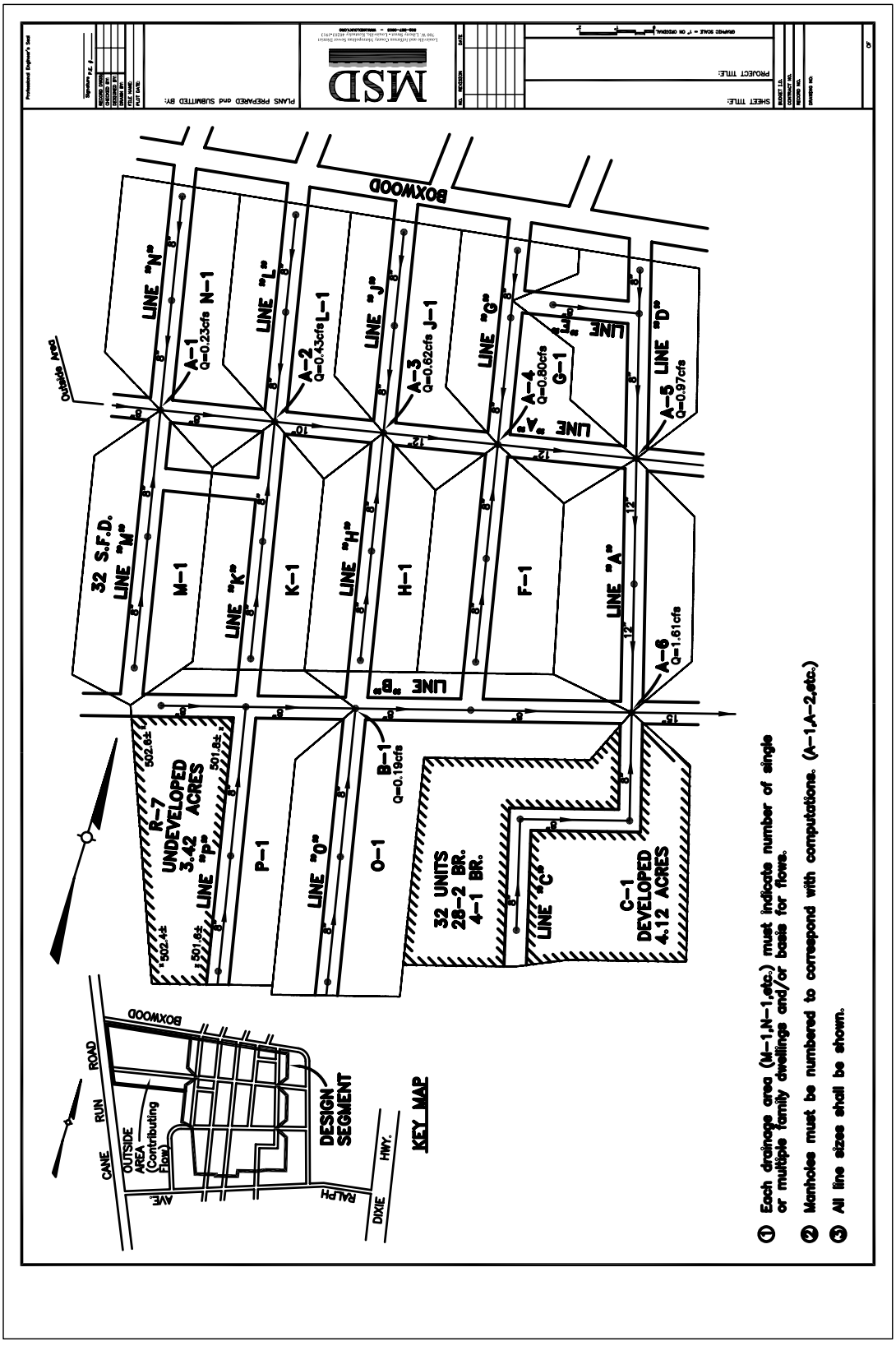

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EXHIBIT 4-11
SAMPLE DRAINAGE MAP
(STORM COLLECTOR SYSTEM)

EFFECTIVE DATE: JUNE 30, 2009

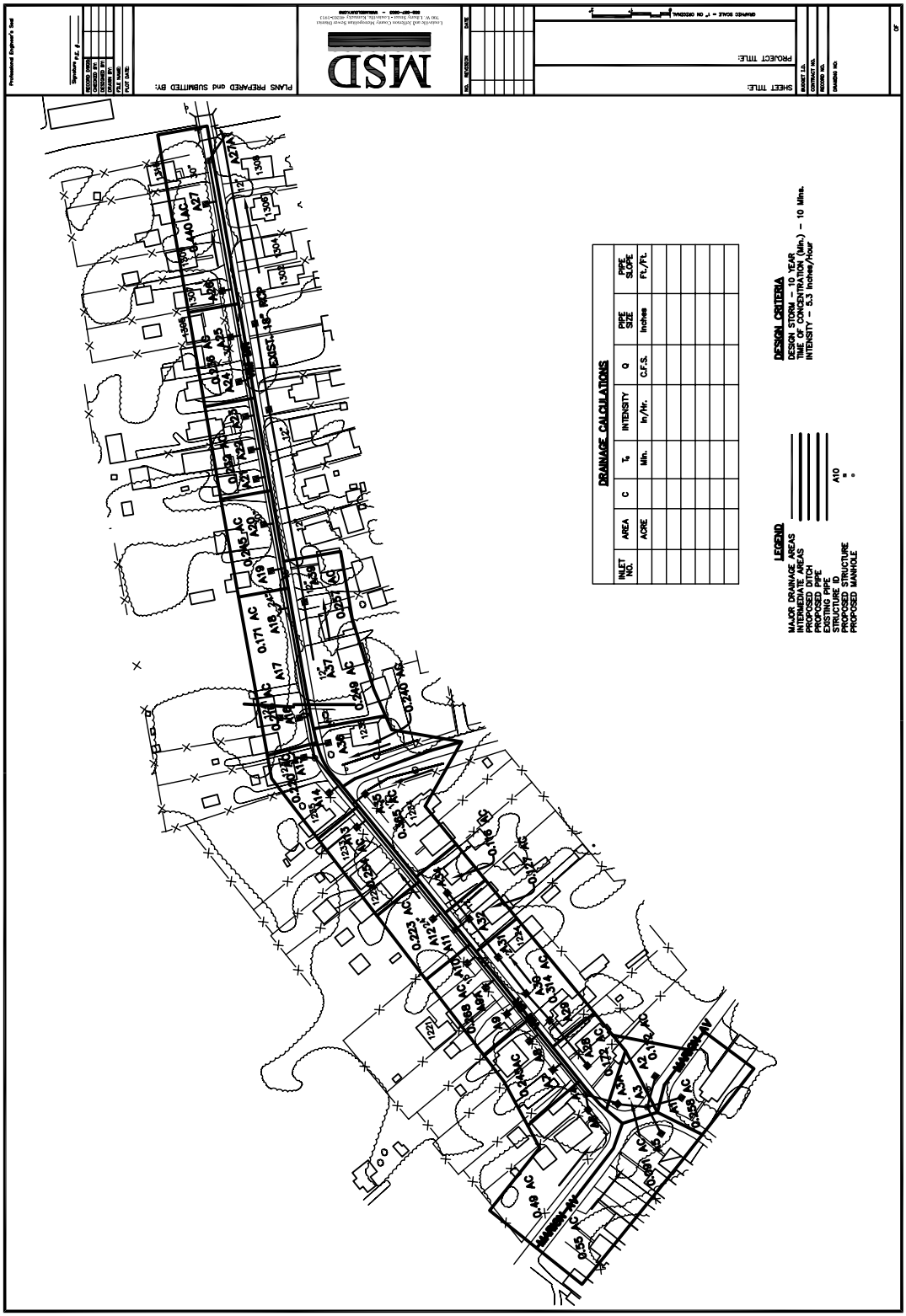

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EXHIBIT 4-12
HORIZONTAL & VERTICAL CONTROL MAP

EFFECTIVE DATE: JUNE 30, 2009

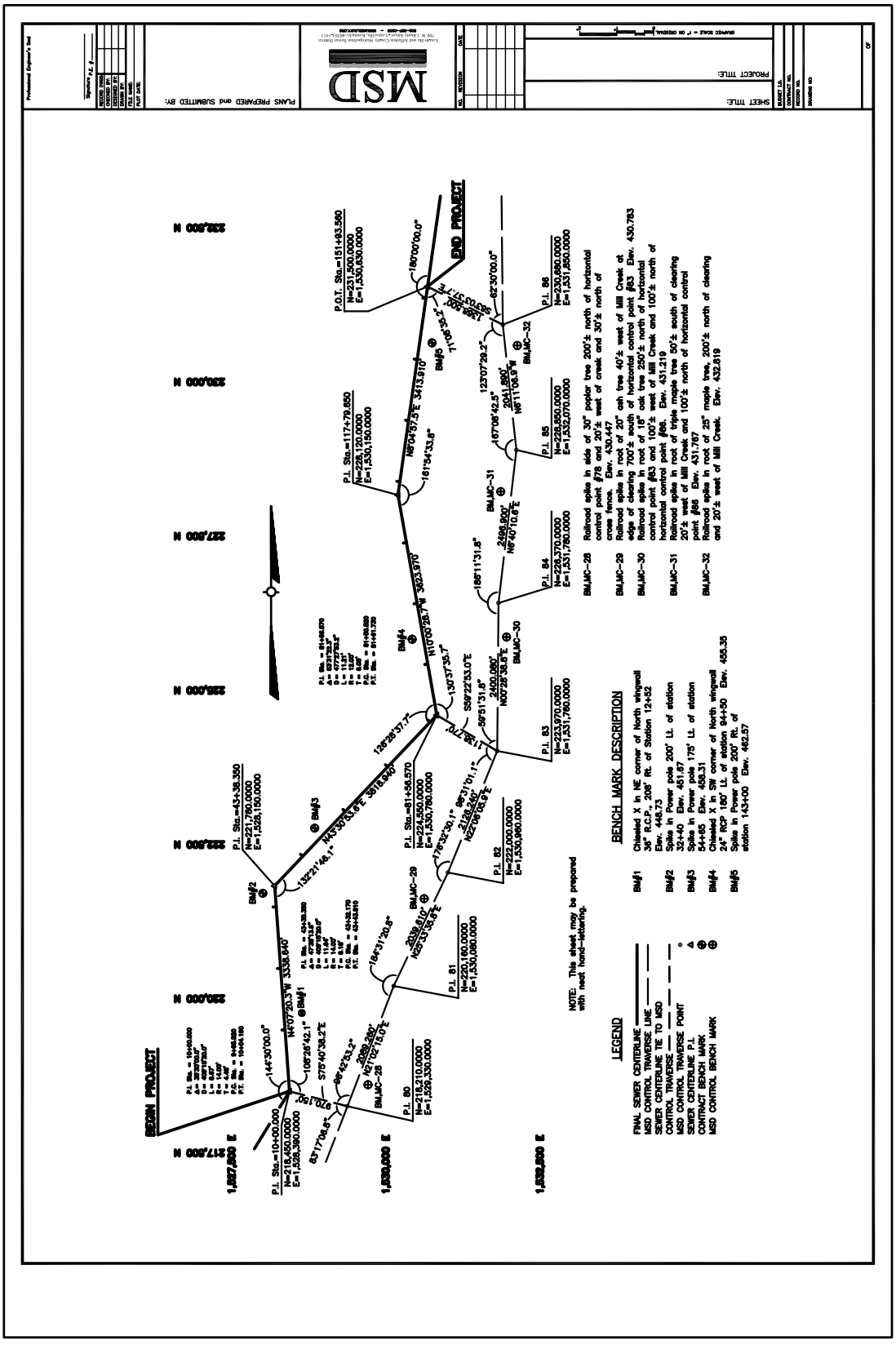

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EXHIBIT 4-13
SAMPLE PLAN SHEET

EFFECTIVE DATE: JUNE 30, 2009

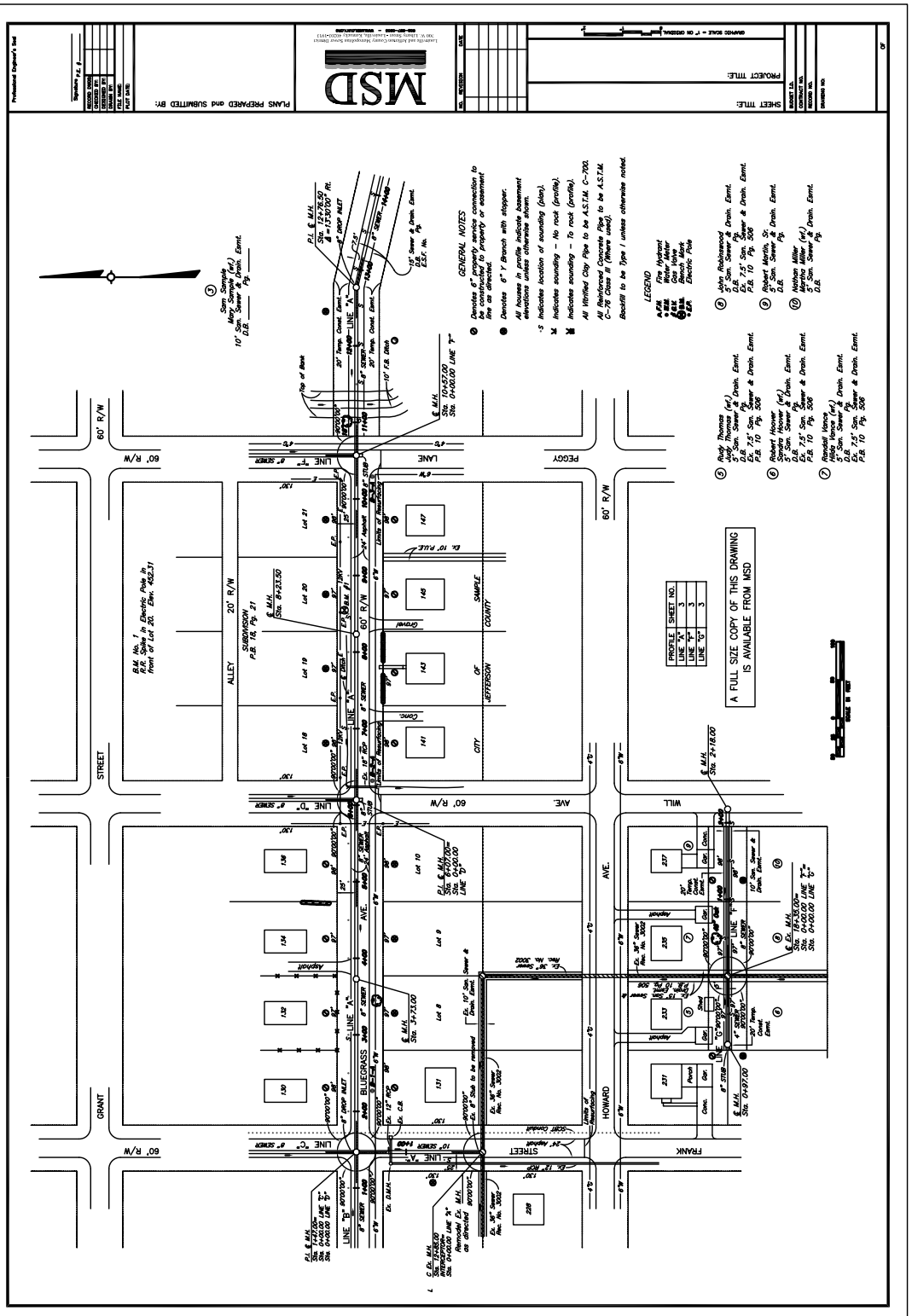

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EXHIBIT 4-14
SAMPLE PROFILE SHEET

EFFECTIVE DATE: JUNE 30, 2009

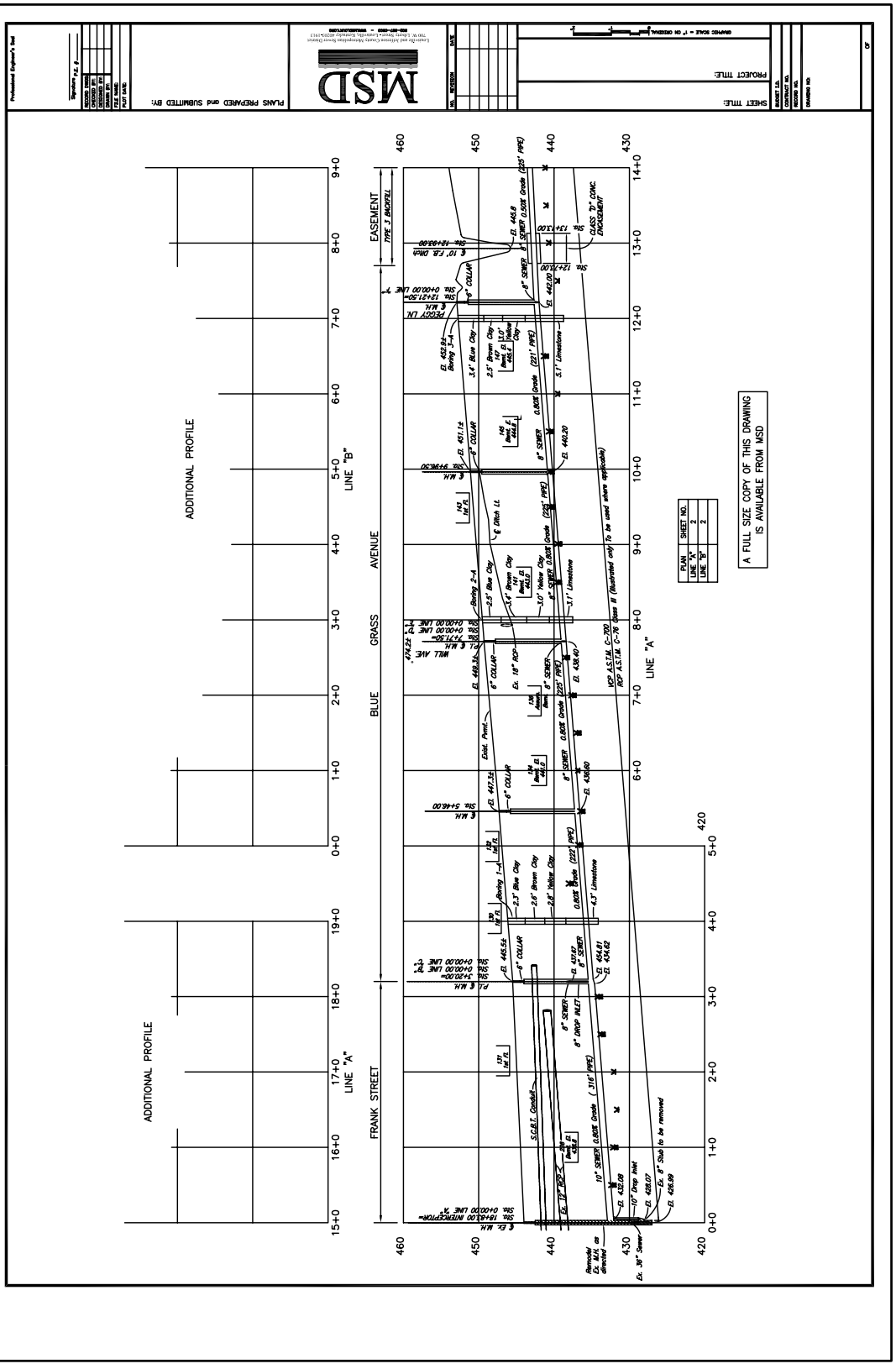

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EXHIBIT 4-15
SAMPLE CROSS SECTION

EFFECTIVE DATE: JUNE 30, 2009

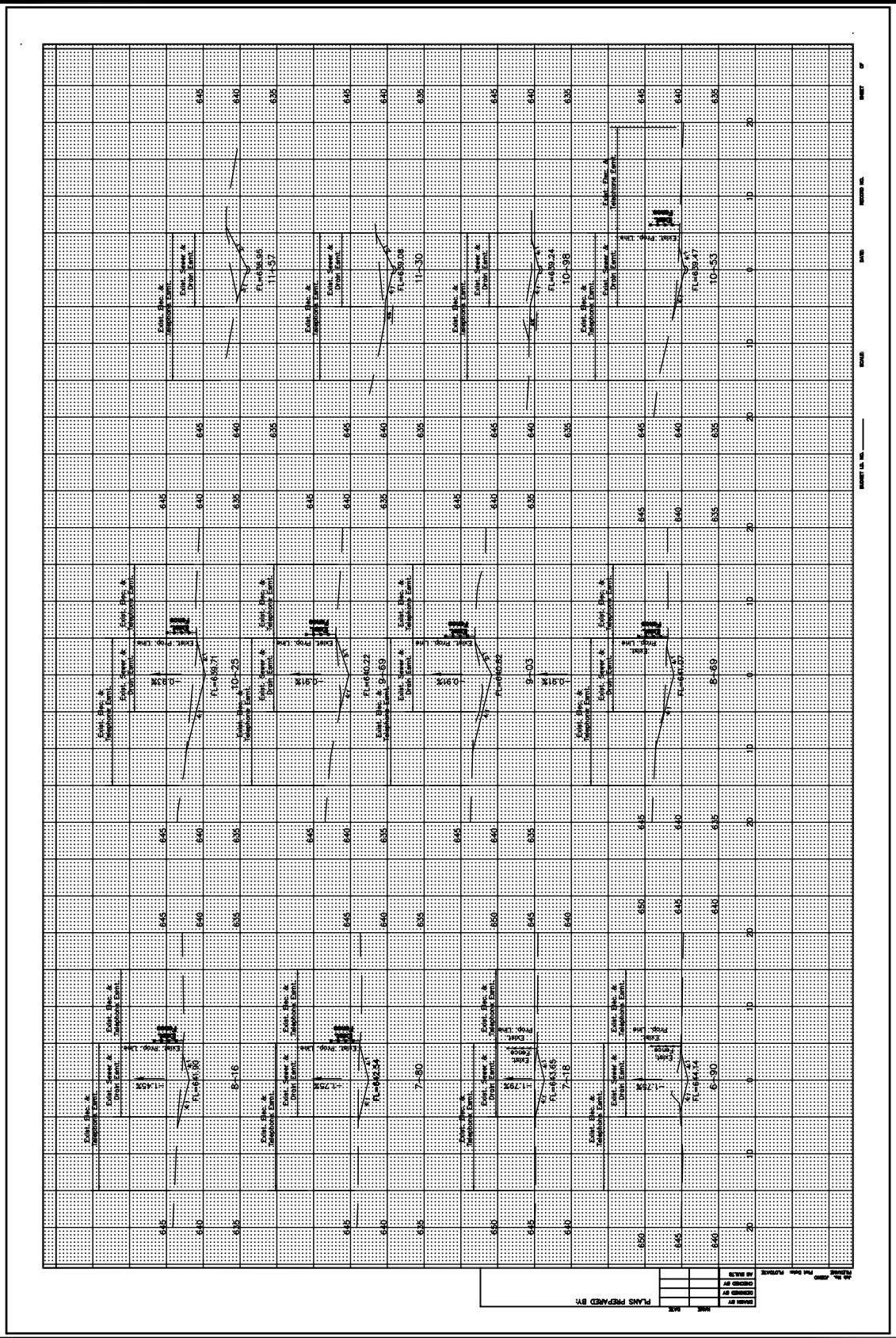

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EXHIBIT 4-16
PROPERTY ACQUISITION SUMMARY SHEET

EFFECTIVE DATE: JUNE 30, 2009

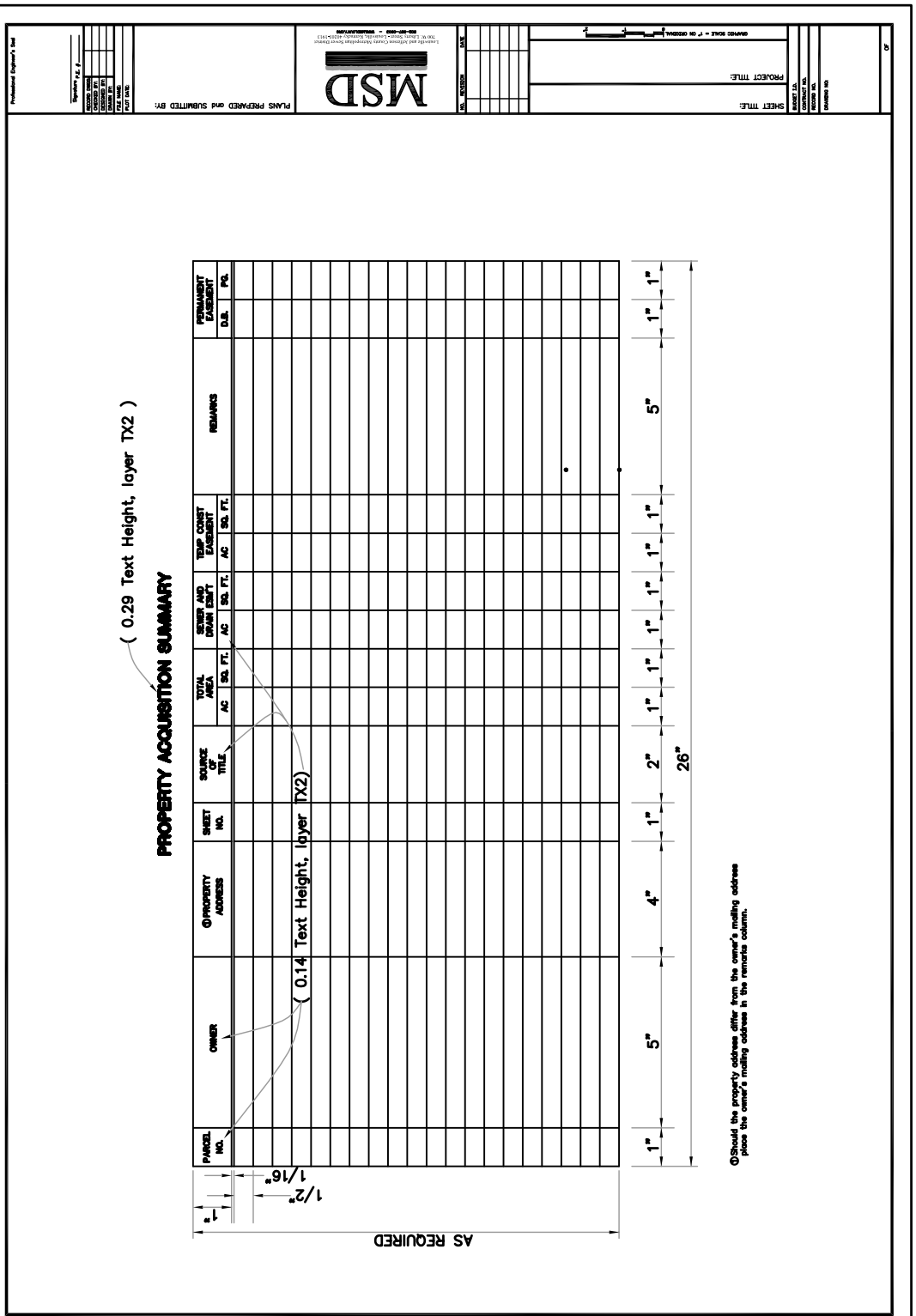

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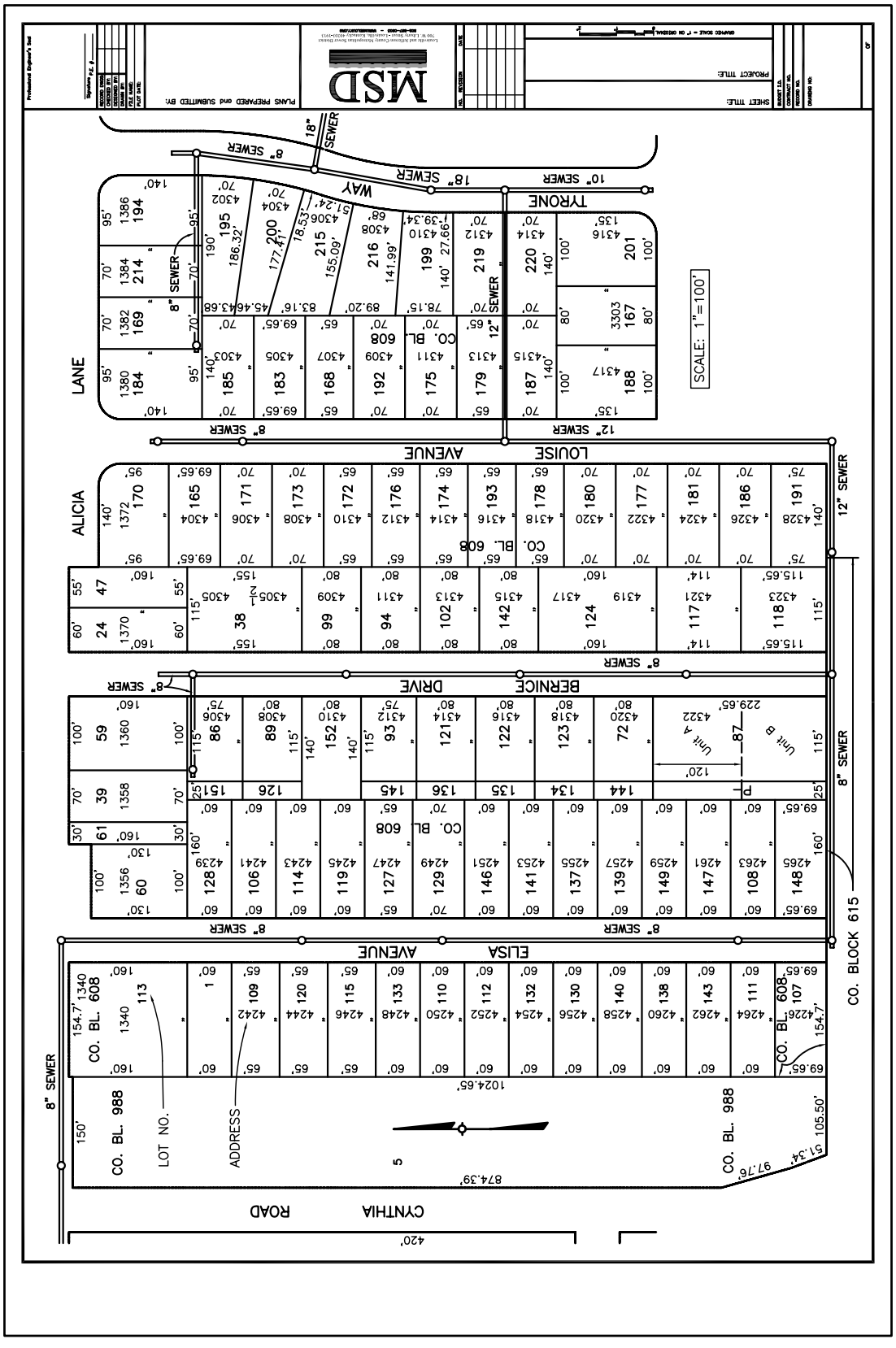
EXHIBIT 4-17
SAMPLE APPORTIONMENT MAP

EFFECTIVE DATE: JUNE 30, 2009



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CHAPTER 5
FINAL RECORD DRAWINGS

5.1 PURPOSE

This chapter establishes the procedures that must be followed by Design Engineers, Land Surveyors, Contractors, Developers, and MSD concerning Final Record Drawings to ensure that all proposed **wastewater treatment and conveyance** plans correctly depict the facilities as constructed. **The final record drawings are the "Bid Plans" that have been revised to identify changes that occurred during construction.** This chapter also applies to MSD drainage projects, but not privately developed drainage plans.

5.2 GENERAL

On MSD projects, the Final Record Drawings will be prepared by MSD, or the project design engineer/consultant, based on record information provided to MSD by the contractor. At the completion of the project, the contractor will be responsible for providing MSD a set of "Red Line Drawings" and "As-Built Survey Information". The information will be incorporated into the "Bid Plans" design AutoCAD files to become the "Final Record Drawings" file. The Final Record Drawings are then saved in PDF format, with the file name format in accordance with the requirements of Chapter 4. The file will contain a "FRD" reference, differentiating it from the original "bid plans" file.

Note - On private development projects, the project owner will be responsible for preparing the Final Record Drawings, subject to the same requirements as a MSD project.

Red Line Drawings

As the project progresses, the Contractor shall maintain a record of all deviations in location or elevation of any installation from that shown on the Plans. The information will be compiled in a red-lined format on a copy of the Bid Plans. At the completion of the project the information is submitted to MSD. The information should be recorded in a clear and concise format, allowing for an easy transfer of information. For development projects four copies of proposed red line changes on the plans must be submitted for review and approval prior to execution of the changes. Approved changes will be shown on the as-builts.

As-Built Survey Information

The Contractor's Licensed Professional Land Surveyor-will be responsible for "as-builting" the items listed below. The survey information will be compiled in an

electronic fashion, compatible with the .dwg format, and submitted to MSD. Location and elevations shall be tied to the project survey control.

5.3 PROCESS

On MSD projects, the noted as-built information will be provided to MSD as soon as possible after completion of the project. Final payment to the contractor will not occur until the as-built information is provided.

On private development projects, final project acceptance will not occur until the completed Final Record Drawings are reviewed by MSD's Inspection Department for verification of information. Once verified, the plans are returned to Engineering Records for final review and acceptance. If the plans are accepted they become Final Record Drawings. If they are rejected the above process is repeated until accepted.

Reference is made to Chapter 4 for a detailed explanation of the documentation requirements. The as-built information is assigned to a specific layer within the drawing file. Predetermined font and pen sizes have also been established. The parameters are preset if the MSD standard drawing template file was used to generate the base drawing file.

5.4 DRAWING INFORMATION

Where constructed information differs from the **bid** information, the **plans will reflect** a line through the **bid** information and **show** the corrected information near the crossed-out original data. Original information shall under no circumstances be **removed** from the original plans. No red line markings will be accepted. A check mark should be placed beside the original plan information, which has been verified to be correct as constructed. **MSD will not accept Final Record Drawing that have color ink other than black or have plan information overlayed on aerial photos.**

5.5 AS-BUILT ITEMS

The following construction items, at a minimum, should be reviewed and verified to produce the Final Record Drawings:

5.5.1 Alignment Changes

5.5.1.1 Changes in Location

a. Manholes
b. Catch Basins or Surface Inlets
c. Headwalls
d. Retaining Walls
e. Slope Protection
f. Channel Linings

g. Pump Station Wet Wells
h. Pump Station Valve Vaults
i. Air Release Valves
j. Property Service Cleanouts

5.5.1.2 Changes in Elevation

To the nearest hundredth
a. Inverts
b. Rims
c. Surface Inlet Grates
d. Paved Ditches

To the nearest tenth
e. Turf Ditches
f. Miscellaneous Structures

5.5.2 Structure Changes

5.5.2.1 General

a. Manhole collar sizes
b. All revisions in pipe sizes, lengths, slopes, and angles
c. Identify pipe material if different from the plans

5.5.2.2 Pump Stations and Wastewater Treatment Plants

a. All revisions in pipe sizes
b. All revisions to electrical controls
c. All revisions to exhaust and ventilation systems
d. Pump modifications
e. Changes in elevation for inverts and level controls
f. Equipment layout modifications
g. Building modifications

5.5.3 Miscellaneous Changes

5.5.3.1 Property Service Connections

a. Size
b. Length
c. Depth at R/W or Property Line
d. Sewer Station
e. End Location, if the PSC is not perpendicular to the sewer

5.5.3.2 Changes in Lot or Unit Designations

a. Lot Numbers
b. Tract Numbers
c. Apartment Unit Designations
d. Condominium Unit Designations
e. Patio Home Designations

5.5.4 General

a. Any unverified data shall show +/- thereby indicating that information has not been verified.

b. The following stamp will be inserted into each plan sheet after all as-built information has been added.

c. For Private Development see the Record Drawings section of the Lateral Extension Procedures on the MSD Web site.

Final Record Drawing
By_____Date_____
Contractor_____
Record Drawings have been prepared based on information provided by the Contractor in accordance with the specifications.

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SURVEYING

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SURVEYING
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CHAPTER 6
SURVEYING

6.1 PURPOSE

This chapter describes the various field surveys for design, construction and approvals required for MSD projects. Private development requiring MSD approval and/or acceptance of constructed facilities shall also follow these guidelines. Project engineers and field survey crew chiefs should familiarize themselves with this and all other chapters of this Design Manual prior to the start-up of any field survey effort. Familiarity with this Manual will enable the field survey crew to obtain the necessary field information for design and construction and also minimize the occurrence of improper activities.

6.2 GENERAL

6.2.1 Conduct

The members of the survey crew are normally the first representatives of a firm or organization to come in contact with the property owners or residents along the route of the proposed improvement. It is imperative, therefore, that the survey crews conduct themselves properly, both on the project and in the surrounding community. **Survey vehicles should be adequately identified with their corresponding firm name. All survey crew members shall obtain an identification badge from MSD, and wear the badge at all times and be visible to the public.**

Their work should be explained to the property owners and to the public, as necessary, but the survey crew should carefully refrain from outlining any plans or policies, which might be misconstrued. If approached, the survey crew should not convey any project specific information to the property owners. The property owner should be referred to the respective MSD **Project Manager** if he/she has project specific questions. The crew must be courteous at all times when talking with the public and the crew members must maintain a **written** record of the names of owners or residents with whom they converse. During these conversations, **the survey crews should inquire about** the location of survey corners or monuments located on the owner's property.

6.2.2 Right of Entry

When it is obvious that the survey work will require entry onto private property, the owner shall be contacted, the survey work described, and permission to enter obtained. No project specific information should be conveyed to the property owner. Efforts to contact property owners shall include telephone calls and the

leaving of letters and a door hanger for those who are not at home. A sample copy of the current MSD Insert Card as shown on Exhibit 6-1 shall also be presented to the property owner. Copies of these may be obtained from the MSD **Project Manager**. It should be explained in the notice that field inspection and soils investigation personnel might require entry from time to time during the course of the project. In the event that the owner does not grant permission and it is evident that the survey work will be delayed, MSD should be notified, in writing, immediately. It is the responsibility of MSD to take whatever course of action deemed necessary to obtain legal right of entry in accordance with state statutes.

6.3 HORIZONTAL AND VERTICAL CONTROL

6.3.1 General

When required, centerline and/or baselines shall be established using acceptable survey procedures. These survey lines shall be established in the general vicinity of the anticipated sanitary sewer or storm drainage system location, within the public right-of-way or easement limits and parallel to the expected location of the improvements. **When horizontal and vertical control monuments have been established in the area of the survey, all centerlines, and/or baselines, and level circuits shall be referenced to these monuments.** These monuments or coordinated positions and/or benchmarks **published by NGS or Louisville/Jefferson County Information Consortium (LOJIC) Geodetic Control Network** shall be shown and identified on the plans.

Trees are not to be used for surveying purposes except in remote areas where there is no other practical alternative. No spikes or nails are to be driven into a tree as described previously. Trees shall not be "blazed" under any circumstances, and only water-based paint may be used if it is necessary to mark a tree.

6.3.2 Guidelines

Horizontal and vertical control shall be established according to the guidelines defined by these publications:

a. **Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-003, FGDC-STD-007.1 through FGDC-STD-007.5 or the current** Federal Geodetic **Data Committee standards.**

b. All pertinent statute laws and regulations.

6.3.3 Datum

All control shall be related to existing monuments that have been **published by**

NGS or referenced on Louisville/Jefferson County Information Consortium (LOJIC) Geodetic Control Network and must reference the appropriate datum as indicated below:

a. Horizontal control shall be referenced to the Kentucky State Plane Coordinate System, North Zone/NAD **HARN** (1983).

b. Vertical control shall be referenced to the **North American Vertical Datum 1988**

6.3.4 Placement

All horizontal control shall be located within the easement or public right-of-way whenever possible. Each monument should be placed to avoid movement caused by construction or other activities. Every horizontal control marker that is not being specifically set for individual project control points should be set at maximum intervals of one-half mile on all projects.

A vertical control marker that is not being specifically set for individual project control points should be placed similarly to horizontal control marker at maximum intervals of one-quarter mile.

6.3.5 Monuments

All horizontal and vertical control markers shall be MSD approved and be of ferrous materials where applicable.

6.3.6 Project Control and Bench Marks

Project horizontal control shall be as described in this chapter. Project vertical control shall be referred to as bench marks. Bench marks shall be established at a maximum interval of 500 and must maintain a minimum distance of 25 feet from the improvement centerline. Each bench mark should be placed to avoid movement caused by construction or other activities.

All bench marks must conform to specifications for quality as referenced in Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-007.4. Sidewalks, steps (unless massive), small concrete slabs and similar structures are not acceptable. Each project must contain at least one bench mark, which conforms Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-007.4.

6.3.7 Survey Control Point References

With the advent of GPS and the coordinate control capabilities of most survey equipment, field references for horizontal survey control points are no longer required. All control information is identified on the Horizontal and Vertical Control Map, Exhibit 4-14.

All bench marks are to be field located and shall be referenced to the centerline of sewer by line designation, station, and offset. In addition, these other field references, such as addresses, etc., should be referenced the same in field notes, plans, and any other pertinent documents submitted. **If a spike in a power pole is used as a benchmark, the field notes, plan sheets, and the horizontal and vertical control sheet shall list the power pole number.**

6.3.8 Vandalized Survey Project Points and Bench Marks

MSD will not assume the responsibility for any damage done to project centerline control points and bench marks until after the final plans, contract documents, and field notes with proper references have been accepted by MSD. Any damage done to those points up to that time will be repaired or replaced by the Land Surveyor at the Land Surveyor's expense. It is advised that these points are accurately field referenced at the earliest possible time.

6.3.9 Horizontal and Vertical Control Review

MSD retains the right to request any corresponding field notes either digital or hard copies that pertain to the horizontal and vertical control for the project together with horizontal and vertical closure statements for their review.

The control data sheets, as shown in Exhibit 6-2, shall be submitted for each newly set horizontal and vertical control monument.

6.3.10 Horizontal and Vertical Control Map

A horizontal and vertical control map is required for all sanitary sewer surveys and major storm drainage projects as designated by the MSD Project Manager. This map shall be prepared on a standard plan sheet and shall be included in the final plans. The final horizontal and vertical control map, similar to Exhibit 4-14, shall include final stations, station equations, all curve data, and the final location and description of bench marks. In addition, the following information shall be shown.

6.3.10.1 Horizontal Information

a. Coordinate ties with adjacent projects.

b. Final coordinates of all horizontal control points, PI's , beginning and ending stations.
c. All bearings, coordinates, angles and point designations on MSD baselines in the design segment.
d. Source of horizontal datum. **(List the bearing and distance of the control line, and the deflection angle of the proposed centerline.)**

6.3.10.2 Vertical Information

a. New bench marks - their designations, locations, description and elevation.
b. **Existing Vertical Control Monuments as referenced in 6.3.3** - their designations, elevation and location.
c. Source of vertical **datum**. (If a spike in a power pole is used for a bench mark, list the power pole number and the height of the spike above the ground, and house number(s) of adjacent homes.

6.4 DEGREE OF ACCURACY

6.4.1 General

The specified criteria for surveys will vary accordingly to their function. All surveys are subject to the guidelines indicated in Section 6.3, Horizontal and Vertical Control.

The instruments used shall meet the specifications indicated in these guidelines or in following sections. All instruments shall be certified to National Institute of Standards and Technology (NIST) standards and manufacturer's specifications. NIST, the instrument manufacturer, or a certified instrument repairs facility must perform the certification.

All **instruments** should be serviced regularly by a certified repair facility and checked at a National Geodetic Survey baseline. EDM instruments should be calibrated by a certified repair facility annually. Field notes of all calibration checks **can be requested by** MSD's Survey Supervisor.

Instrumentation for second order leveling as defined by the Federal Geodetic Control Subcommittee (FGCS) of the FGDC shall be used for any projects requiring second order, class II specifications.

6.4.2 Accuracy Criteria

6.4.2.1 Sanitary Interceptor or Through Drainage System

Horizontal surveys will adhere to Second Order, Class II specifications, except that the error of closure shall equal or exceed 1:50,000.

Vertical control will adhere to Second Order, Class II specifications.

6.4.2.2 Sanitary Collector or Local Drainage Systems

Horizontal surveys will adhere to Third Order, Class I specifications, except the adjustments being made by either the Least Squares or Compass Rule Method.

Vertical control will adhere to Third Order specifications, except the error of closure will be equal to or exceed Second Order, Class II requirements.

6.5 FIELD PROFILE AND TOPOGRAPHY

6.5.1 Field Profile Requirements

Profile elevations shall be determined along sanitary sewer or through drainage system centerlines at 25-foot intervals, where possible, or at 50-foot intervals on paved streets, and at all necessary intermediate breaks. Profiles shall delineate existing structures, roads, streams, etc. Elevations shall be established to the nearest one-tenth of a foot on natural terrain and to one-hundredth of a foot on artificial surfaces.. Cross-sections shall be taken at critical locations when it is necessary to determine what effect open cuts or trenching might have on other facilities such as structures, utilities, pavements, fences, trees, or landscaping. Sufficient original ground elevations must be determined in order to establish the slopes necessary to adequately serve the property. The MSD Project Manager may modify these requirements to suit specific projects.

Roadside ditches within 30 feet, parallel to the sewer, and greater than 1.5 feet in depth shall be shown in profile with the sewer. These ditches and other elevations critical to design and/or construction must be shown on the plans.

6.5.2 Sanitary Service Connection Survey

A sanitary service connection survey shall be made along each street to properly determine the controlling elevations for design of a particular sanitary sewer line. The form found in Exhibit 6-3 shall be used in accomplishing this survey. The following information shall be shown on the form for each unit surveyed:

a. Type of structure.

b. Basement facilities present.

c. Size, type and location of service line.

d. Elevation of the lowest possible living area floor.

e. Any additional information that may be required for design of the sanitary sewer line.

All elevations should be determined by actual field measurements; however, if a unit cannot be entered, an estimated lowest living area floor elevation shall be made from a known elevation from some other point on the unit. In this case, the elevation must be clearly marked as being estimated. Should an estimated elevation control or have the potential to control the vertical elevation of the sewer, the MSD Project Manager shall arrange provision for entry and actual determination of the service elevation.

The completed forms shall be submitted along with the preliminary plans for review. They need not be included in the final plan submission but shall be included with the original drawings submitted at the conclusion of the project.

6.5.3 Topographic Requirements

In addition to the topographic requirements established in Chapter 4, the following information shall be obtained in the field:

a. All topography critical to the design of the improvement shall be located and recorded in the field notes.

b. Topography generated from aerial photography (including LOJIC planimetric and topographic base mapping) shall be identified and field checked for any errors or omissions. Omitted topography shall be located by field survey and appropriately recorded. This work is the specific responsibility of the Engineer or Land Surveyor, even though the aerial photography may have been provided from other sources. All topography within the project construction limits and/or easements and rights-of-way shall be field located.

6.5.4 Survey Information Needed for Trees

a. Species of Tree (Use the Audubon Society Field Guide to North American Trees, Eastern Region)

b. Size (DBH - Diameter at Breast Height)

e. Dripline (Diameter)

f. Encroachment Allowed within the Dripline

g. Location

1. All trees 6 inches in diameter or greater within the temporary or permanent easement shall be located and the species given within 30-feet of the centerline for pipe projects or 15 feet outside the top of slope for ditches.

2. All trees less than 6 inches in diameter shall be located and species given, when within an existing or proposed sewer and drainage easement.

3. When trees are grouped together, at a very close interval, locate the approximate center of the grouping and list the most dominant species of the group.

6.5.5 Soundings

Soundings shall be taken to a depth of 2 feet below the invert of the proposed improvement or to rock, whichever is encountered first. Soundings shall be taken on 50-foot stations in areas where rock is encountered and 100-foot stations where rock is not encountered. In areas of rapidly changing rock elevation, additional rock soundings will be required to identify the rock surface at a minimum of 25-foot stations. All soundings shall be documented for location, surface elevation, rock elevation (depth), and depth of sounding not encountering rock (no rock).

6.6 SPECIAL SURVEYS

6.6.1 Property Surveys

Where the relationship of the improvement location and adjacent property line is critical, the location of existing property lines and other boundaries shall be established by a property survey sufficient to define the easement. All property surveys shall comply with the "Minimum Standards of Practice for Land Surveying in Kentucky", latest revision, as set forth and enforced by the Kentucky Revised Statutes. Property lines, boundary lines, easements, etc. shall be referenced by stations and offsets from the centerline or baseline to the nearest one-hundredth of one foot, by measurement of the angles at the PI with the centerline, and by other means of comparable accuracy. Surveys shall ascertain

the names of owners, lessees or tenants, sources of title and date of acquisition and shall be verified from the appropriate Jefferson County records. Copies of all field notes can be requested to be submitted to MSD.

6.6.2 Utility Surveys

All publicly and privately-owned surface and subsurface utilities affected by the proposed improvement shall be located and identified by field survey and by use of maps supplied by the utilities. Locations, elevations, and other pertinent data as may be required for possible relocation or adjustment shall be secured for all such utilities to the limits of information currently available. Overhead power lines near the intended improvement alignment, or those which may be a construction hazard, should be shown on the plans using the proper symbol and labeled with their primary voltage.

6.6.3 Railroad and Highway Surveys

When the centerline of improvements crosses a railroad or highway, all existing and proposed railroad tracks, roadways, and affected structures shall be tied to the improvement centerline. The topography shall be provided on either side of the proposed crossing to the extent required by the affected reviewing agency. **. An attempt to contact the railroad owners shall be made prior to the survey work in the railroad R/W.** Typical information shall include, but not be limited to, the following sections.

6.6.3.1 Railroads

a. Top of rails - 300 feet minimum in either direction locate horizontally and vertically at 50-foot intervals.

b. Angle between centerline of tracks and centerline of improvement.

c. Name and address of railroad company.

d. Location of railroad right-of-way and easements (source of record where possible).

e. Horizontal and vertical information relative to transmission lines, such as telephone or electric.

f. Stations on the centerline of each track.

g. Mile post locations, measured from centerline crossing.

6.6.3.2 Highways

a. Station on centerline of highway and each edge of pavement, or front face of curb, as may be appropriate.

b. Angle between highway centerline and centerline of improvement.

c. Location of highway rights-of-way and easements (source of record where possible).

d. Location of any crossings, parallel utilities, or drainage structures, which may be in conflict with the improvement construction.

e. Number and width of lanes and the type and condition of the surface.

Additional information relative to requirements in the vicinity of railroads and highways may be found in Chapter 8, Sections 8.18, 8.19 and 8.20.

6.7 STAKING SANITARY SEWER AND THROUGH DRAINAGE SYSTEM CENTERLINES

6.7.1 Preliminary Centerlines

Improvement centerlines shall be staked for a preliminary field review by using highly visible temporary markers. These markers shall be placed on the centerline at convenient locations, such as fence lines, streets, and borders of timber areas. Intermediate markers shall be placed as necessary to maintain continuous visibility. Plastic flagging shall be used on the markers to increase their visibility. Approximate stations and line designation shall be placed on the markers. The method of designating the centerline in urban areas may be modified as required to provide the information previously noted, including the use of paint on streets. Final staking of improvement lines and the assignment of final line designations before a preliminary field review is not encouraged. These requirements are subject to revision by the MSD Project Manager to suit specific projects.

6.7.2 Final Centerlines

6.7.2.1 Staking

Prior to acceptance of the final plans, the centerline shall be staked at PI's and as needed to maintain line of sight for purposes of easement acquisition, bidding, MSD field reviews, etc. Stations and line designation shall be clearly marked with an indelible marker on 1" x 2" x 18"

(minimum) flat stake adjacent to the PI. Guard stakes of 1" x 1" x 48" (minimum), marked "Centerline Sewer" shall be provided at all PI's, manholes, structures, and other control points.

Stake markings shall include the designation of the sewer, such as Line "A" and the station of the point for which the guard stake is provided.

Points in pavement areas shall be identified by painting the necessary information adjacent to the permanently located point. PK nails or spikes are to be used for final centerline staking. Where necessary, offset stakes shall be utilized to identify points in streets, highways, and railroads.

6.7.2.2 Monuments

Iron pins shall be placed at all PI's and POT's necessary to establish the centerline, beginning and ending stations of the contract, and at those points specifically requested by MSD. These points shall be field referenced, per MSD specifications, so they may be located or reestablished at a later date. Iron pins shall be placed at all other manhole locations but do not need to be field referenced. Iron pins shall be made of or contain ferrous material and be a minimum of 30 inches in length and 5/8 inches in diameter. . In lieu of iron pins, railroad spikes, 6 inches minimum length, or PK nails shall be used in bituminous pavements and a scribed cross ("X") shall be used on concrete surfaces.

6.7.2.3 Centerline Verification

The Design Consultant shall verify the improvement alignment by obtaining field angles and distances along all segments of the improvement centerline. This shall include tying the final centerline alignment by traverse into the MSD control baseline. The alignment shown on the Horizontal and Vertical Control Map described in Section 6.3.10 shall be the final approved alignment.

6.7.2.4 Acceptance

The Design Consultant shall verify, in writing, that the alignment shown on the final construction plans has been located correctly in the field. This shall include returning to the field and verifying that all permanent points are intact and reestablishing all damaged or missing points. This must be accomplished before MSD will accept the original drawings, contract documents, and authorize final payment to the Design Engineer.

6.8 Certification Notes

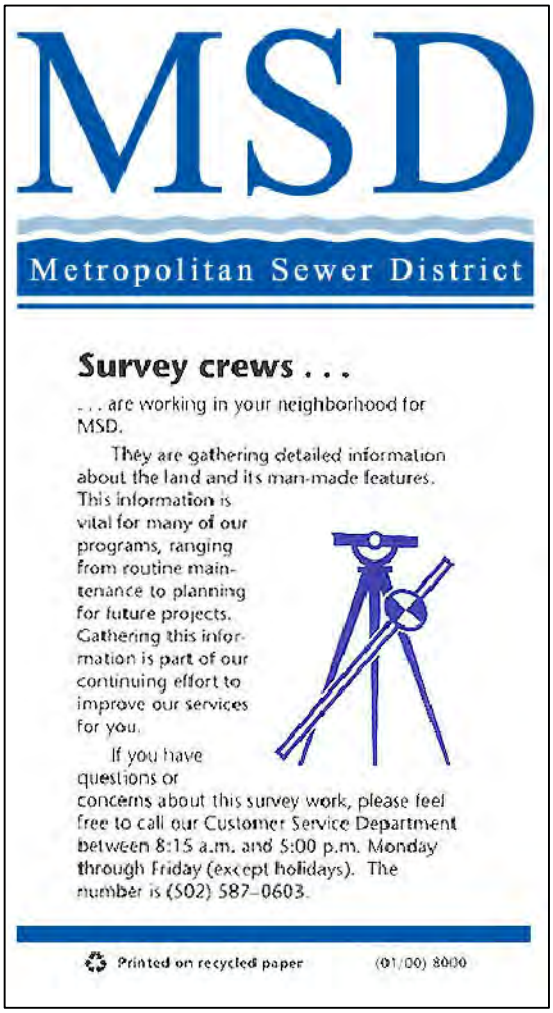
Example Surveyor Certification notes can be found in section 4.5.6. A certification note, placed on the project title sheet, is required for all projects and should reflect the specific type of survey performed.

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-1
IDENTIFICATION CARD
SUMMARY SHEET

EFFECTIVE DATE: JUNE 30, 2009







MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-2
SAMPLE CONTROL DATA CARD

EFFECTIVE DATE: JUNE 30, 2009

MSD

Louisville and Jefferson County
Metropolitan Sewer District

CONTROL DATA

JEFFERSON COUNTY, KENTUCKY
KENTUCKY STATE PLANE COORDINATE SYSTEM,
NORTH ZONE

NO. OF STATION 28 X FB
ELEVATION OF STATION 456.244 (NAD 1983)
DATE STATION ESTABLISHED 2–1–93

1983 Horizontal Datum

N–Coordinate	E–Coordinate
1239123.1234	287912.5678

Grid Distance and North Azimuth to Objects Observed

Object	Grid Distance – Ft.	North Azimuth
29 X FB	1321.48	218°15'33"

TRY AND MAKE OBSERVATION > 100'

DESCRIPTION AND REFERENCES:

Monument is aluminum disk set on a concrete post 36" X 10" flush with the ground.

To reach station from intersection Brown Street and Barker Road, City of Louisville, County of Jefferson, proceed 21.5' north of north face curb of Brown Street and 11.7' east of east face curb of Barker Road to aluminum disk set in concrete post.

SKETCH

Control set by: _____ Date _____

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-3
SERVICE CONNECTION SURVEY FORM

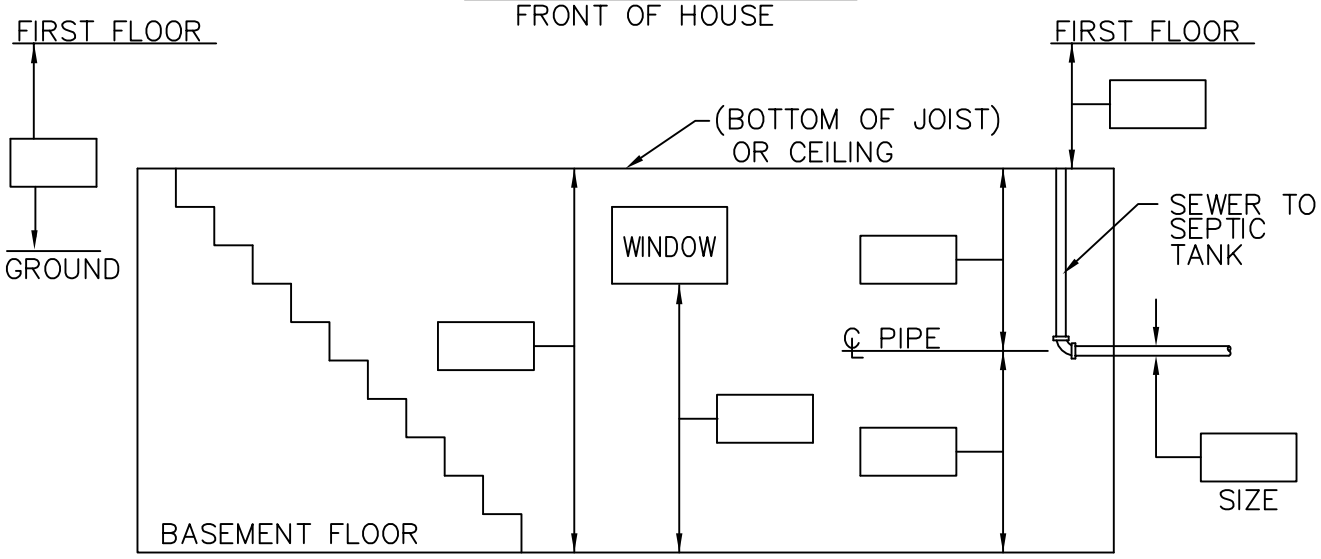
EFFECTIVE DATE: JUNE 30, 2009

PROPERTY OWNER: _____

SHOW LOCATION OF SEWER SERVICE EXITING RESIDENCE:



IF HOUSE SITS ON CORNER, SHOW AND LABEL EACH STREET



TYPE OF STRUCTURE:

Basement _____ BiLevel _____ TriLevel _____ Slab on Grade _____ Crawl Space _____

Other _____

BASEMENT FACILITIES:

		DISCHARGE TO: Septic Tank (Gravity)	Sanitary Pump
Sink	Yes _____ No _____	_____	_____
Shower	Yes _____ No _____	_____	_____
Toilet	Yes _____ No _____	_____	_____
Washer	Yes _____ No _____	_____	_____
Sump Pump	Yes _____ No _____	_____	_____
Sanitary Pump	Yes _____ No _____	_____	_____
Floor Drain	Yes _____ No _____	_____	_____
Other	Yes _____ No _____	_____	_____

COMMENTS: _____

_____

_____

Date: _____ Survey By: _____

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CHAPTER 7
EASEMENTS

7.1 PURPOSE

All public sanitary sewers, storm drains, and open channels must be constructed in public rights-of-way, easements, publicly owned, or MSD- owned properties. No approval will be given for construction or improvement of any public sewer, storm drain, or channel without provision of suitable permanent easement or right-of-way. MSD will acquire and record all easements for MSD funded projects. The developer on private development projects will be responsible for acquiring all easements. Document recording will be the responsibility of MSD.

7.2 EXISTING EASEMENTS

Each existing easement to be used shall be shown on the plans submitted for review and approval. The information shown on the plans shall include the Deed Book and Page Number of the recorded instrument. All restrictive clauses as to the use of the easements, i.e., for utility purposes, drainage, sanitary sewers, etc., shall be noted on the plan adjacent to the pertinent easement. Construction of sanitary sewers or drainage systems will not be permitted in existing exclusive gas, electric, water, or telephone easements unless a sanitary sewer and Drainage Easement is acquired overlapping the existing easement with prior approval of MSD and the affected agency.

There are existing drainage easements in MSD's service areas. These drainage easements generally do not provide for the construction of sanitary sewers. In order to use these easements for sanitary sewer construction a new easement will be required to convert the existing Drainage Easement into a Sanitary Sewer and Drainage Easement. Construction plans and easement plats shall be prepared accordingly and the proposed new easement should be shown in the same manner as an entirely new easement.

The plats for Drainage Easements, in some cases, were recorded by previously assigned parcel numbers. The new plat converting these parcels will be assigned new parcel numbers. The parcel numbers for the existing Drainage Easements, as well as the Deed Book and Page Number or Plat Book and Page Number, shall be shown in the "remarks" column on the Property Acquisition Summary Sheet when these are available.

7.3 DEFINITIONS

The following terms define the methods under which MSD currently acquires interest in property for the purpose of constructing, operating, and maintaining wastewater treatment, drainage facilities and sanitary sewers:

7.3.1 Fee Simple Title

For the purpose of constructing major aboveground structures, MSD will normally acquire all rights to the required property in fee simple and permanently retain ownership. This generally refers to large pumping stations, wastewater treatment plant sites, and major detention basins.

7.3.2 Sanitary Sewer and Drainage Easement

For the purpose of constructing facilities (sanitary sewers, storm drainage systems, etc.), MSD will acquire the right to construct facilities within the limits of easements. They will have the right to operate and maintain those facilities within the same limits and also have reasonable ingress and egress over each affected property to the easements for construction, operation, maintenance and reconstruction. These easements are permanent in nature and are referred to as Sanitary Sewer and Drainage Easement. See Section 7.6 for the proper terminology to be used on easement plats and acquisition documents.

The limits of Sanitary Sewer and Drainage Easement shall be set for permanent structures. Existing structures shall not be within the easement area, unless the sewer construction actually requires the removal of such buildings or structures.

A property owner generally is restricted from constructing any facility within the limits of the easement that might interfere with the maintenance and operation of the facility.

7.3.3 Temporary Construction Easement

A temporary construction easement will be required adjacent to all new Sanitary Sewer and Drainage Easements when necessary for construction operations. Temporary construction easements shall be required for structure removal, access roads, stockpiling, and other construction activities when necessary. Structure removal includes the removal of treatment plants, pump stations, etc. Sufficient area shall be supplied for movement of equipment and materials to accomplish the intended activity within the Temporary Construction Easement. If at all possible, Temporary Construction Easements will not be acquired on adjacent private property when the proposed facility lies within a dedicated right-of-way or an existing Sanitary Sewer and Drainage Easement. Only under certain unusual conditions will a Temporary Construction Easement be acquired from a parcel if a new permanent easement is not being acquired from that same parcel. Accordingly, no plats shall be prepared showing Temporary Construction Easements only, without the prior approval of MSD. "Consent and Release" may be used in lieu of temporary easement. A "Consent and Release" form is shown on Exhibit 7-4. Temporary Construction Easement lines may be drawn through

permanent structures; however, the Contract Documents shall contain language, which clearly indicates that all such permanent structures shall not be disturbed during construction. After the project is completed and the property is restored to its prior condition, all rights to the property are relinquished.

7.4 EASEMENT WIDTHS

Whenever possible, the total easement width, permanent and temporary, should be sufficient to permit the contractor to have flexibility in the method of construction.

Suggested minimum widths of Sanitary Sewer and Drainage Easements and Temporary Construction Easements using trench construction are tabulated below; however, in no case shall these guidelines be a substitute for sound engineering judgement:

Table 1. Minimum Easement Widths

Size of Pipe	Sanitary Sewer and Drainage	Temporary	Total
8" - 12" & Property Service Connections 8" or Less	15'	**20'** on each side	**55'**
15" - 48"	15'	20' on each side	55'
54" - 72"	20'	25' on each side	70'
84" and larger	30'	30' on each side	90'

7.5 CONSTRUCTION PLAN REQUIREMENTS

7.5.1 General

Construction plans shall be prepared in a manner, which will show clearly, and correctly, the information necessary for the acquisition of each parcel of land required. They must accurately show the location of each parcel and its relationship with surrounding areas. The alignment, as shown on the construction

plans and easement plats, must agree with the alignment staked in the field. The information shown must be authentic and thoroughly checked since it will become legal evidence regarding the parcels of land required. The plans shall carry appropriate certifications and seals indicating that the surveying has been accomplished under the supervision of a Land Surveyor registered with the Commonwealth of Kentucky. They shall also meet the Minimum Standards of Practice for Land Surveying in Kentucky and the following guidelines:

a. An effort should be made to parallel property lines with the facility when topographic features permit.

b. Easements shall be referenced to property corners and/or known landmarks to the degree that they can be accurately reestablished prior to construction.

c. In residential areas, all topographic features, such as trees, shrubs, sheds, etc., which are located within the easements shall be properly identified on the plans. When undeveloped wooded areas are encountered, only those trees of unusual size or nature need to be specifically identified on the plans. Any items within these easements, which are definitely not to be disturbed during the construction, shall be clearly noted "Do Not Disturb" (DND). Items, which remain, but disturbance is necessary for construction shall be noted "Do Not Remove" (DNR).

7.5.2 Easement Description Criteria

The construction plans shall show the following information for each parcel from which easements are to be acquired:

a. Property owner's name of record, address, and spouse's name, if married. If a Property Acquisition Summary Sheet is included in the plans, this requirement will not apply.

b. Subdivision name, section number and lot number (when a deed has not been recorded) or Deed Book and Page Number.

c. Existing rights-of-way and easements.

d. Existing Sanitary Sewer and Drainage Easements, their Deed Book, Page Number, and MSD Record Number, if available.

e. Property lines with label.

f. Parcel numbers.

In addition, the Deed Book and Page Number for the new easement shall be added to the plans when the information is made available by MSD. Therefore, the abbreviations "D. B. and Pg." shall be added to the plans adjacent to the new easement with enough space to the right of each for this information to be added at a later date.

7.6 EASEMENT PLAT CRITERIA

7.6.1 General

Sanitary Sewer and Drainage Easements

Easement plats shall be prepared for each property having a Sanitary Sewer and Drainage Easement or other type of acquisition. The phrase "Sanitary Sewer and Drainage Easement" shall be used on all plats and acquisition documents. Easement plats, in general, shall be prepared on 8.5" x 14" sheets. A sample plat can be found on Exhibit 7-1.

All plats shall have the title block in the lower right corner of the plat and the Land Surveyor's Certification and Seal in the lower left corner. No other format should be submitted and none will be accepted.

Permanent easement on all plats is to be hatched for clarity. Temporary easements are not to have hatching, cross-hatching, or shading.

Release of Existing Easements

Any release of easement is to have its own plat and the area of easement to be released is to be crosshatched. No plat containing both easement dedication and release of easement will be accepted. The MSD Director of Engineering must approve the release of easement and the applicable fees must be paid. All other requirements of easement plats shall apply to easement release plats. A sample "Release of Easement Plat" is shown on Exhibit 7-2. The easement release ("Quitclaim") requirements and procedures are found on the MSD web page.

Encroachment Plats

On occasion a permanent structure is found to be, or required to be, encroaching upon an existing easement. In such situations, an easement encroachment plat must be prepared and recorded. A sample plat is shown on Exhibit 7-3.

Easement plats should contain sufficient information to enable a Land Surveyor to locate and stake the easements in the field.

7.6.2 Plat Information

The "Easement Plat Checklist" indicates the plat requirements and should be referenced prior to all submittals to MSD. It is located on the MSD web page.

7.6.3 Property Service Connection Easement

Occasionally, a Sanitary Sewer may be located such that the permanent easement does not extend to the property line of an adjacent property to be served with a proposed property service connection. This occurs due to topographic or geographic considerations such as parallel streams. In these instances, a 15' Sanitary Sewer and Drainage Easement shall be provided from the proposed service facility easement to the property line at the most likely location of the property service connection. Sufficient Temporary Construction Easement shall also be depicted.

7.6.4 Easements on Railroad Rights-of-Way

Sanitary Sewer and Drainage Easements may be acquired on railroad rights-of-way. However, acquisition of easement on a railroad right-of-way does not eliminate the requirement of submitting a Railroad Crossing Conflict Drawing to MSD for approval of conduits crossing under rails of the affected railroad.

7.6.5 Certificates

A Certificate of Easement, Certificate of Easement Release, or Certificate of Encroachment Agreement, as applicable, must be made a part of each easement plat submittal. The certificate forms are available on the MSD web page.

It is the responsibility of the Land Surveyor to attach the proper certificate to each easement plat submitted. No changes in the format of these certificates by the Land Surveyor shall be permitted.

7.6.6 Submission

After the easement requirements have been defined, one set of preliminary plats shall be submitted for review. After incorporating any review comments, the final submittal will be in the following form:

- The original of each plat, signed in ink.
- One copy of each plat.
- One copy of each plat with the appropriate easement certification sheets attached.

Copies of all easement plats submitted shall be clearly legible and shall be made on bond, or better grade, paper using an electrostatic or equivalent copier utilizing a dry process. Plats submitted that are not clearly legible or do not meet the above requirements, will not be accepted.

Easement plats submitted shall contain a Land Surveyor's original stamp, signature and date. If MSD makes any changes or modifications to the final plans after they have been accepted by MSD, the Land Surveyor will receive a copy of the revised sheets. If any changes or revisions are necessary on the easement plats, the Surveyor shall be notified and must make the necessary revisions and resubmit the plats as previously described.

Easement location and requirements shall be determined as early as possible on all projects in order to initiate the acquisition procedures as early as possible. The estimated number of easement plats used in determining easement plat cost during the proposal period shall be given to the Acquisition Department. Adherence to this procedure should minimize the possibilities of project delays due to unavailability of required easements.

7.7 PROPERTY ACQUISITION SUMMARY SHEET

Certain property data shall be shown on the Property Acquisition Summary Sheet, as well as on the construction plan sheet and easement plat. However, a separate Property Acquisition Summary Sheet will not be required if a project has five parcels or less. In such instances, the property acquisition information in the same format may be placed on the Plan Sheet Index, on the first plan sheet if adequate space is available, or be included in the plan index on the cover sheet.

An example of the layout for the Property Acquisition Summary Sheet is shown on Exhibit 4-15. The Property Acquisition Summary Sheet shall show the following data for each parcel required for right-of-way purposes:

7.7.1 Parcel Number

Parcel numbers shall be assigned to each parcel of property to be acquired and shown on the plans. Parcel number 1 shall be assigned to the first parcel, and the remaining parcels shall be numbered consecutively from the beginning to the end of the project. Parcel numbers shall not be assigned to publicly-owned rights-of-way; however, they will be required for privately-owned rights of way, such as Louisville Gas and Electric Company, AT&T, Riverport Authority, railroad companies, private roads, etc.

Parcel numbers assigned to each tract shall not be changed after submission of the

final easement plats. If it is then determined that acquisition from any parcel will not be required, that number shall be removed from the plans and the notation "NOT USED" shall be placed in the owner's block on the Property Acquisition Summary Sheet.

7.7.2 Owner's Name

The name of the current owner of the property and address, at the time of the preparation of the plans, shall be shown. These can be obtained from the Louisville and Jefferson County Property Valuation Administration Office. Final changes to the Property Acquisition Summary Sheet will be made when the property is being acquired.

7.7.3 Property Address

The address of the property served shall be shown. Should the owner's mailing address differ from that of the property, the owner's mailing address should be shown in the remark's column.

7.7.4 Plan Sheet Number

The sheet number is the number assigned to the plan sheet on which the particular parcel is shown. Some parcels, of course, will appear on more than one plan sheet and all sheet numbers must be included.

7.7.5 Source of Title

This column shall show the Deed Book and Page Number of the parcel or the subdivision name, section number and lot number when a deed has not been recorded, or such other evidence of title information as may be available.

7.7.6 Total Area of Tract

The total area of the tract from which an easement is being obtained shall be shown in either acres or square feet in the appropriate column. In general, the area of subdivision tracts shall be shown in square feet, while the area of larger tracts, generally more than an acre, shall be shown in acres.

7.7.7 Area of Easements

The area required for a Sanitary Sewer and Drainage Easement shall be shown in square feet or acres in the appropriate column. The area required for a Temporary Construction Easement shall be shown in square feet or acres in the appropriate column. Areas shall be shown to the nearest square foot or one-thousandth of an

acre as appropriate.

The easement areas required on the Property Acquisition Summary Sheet shall generally be shown in square feet for easements of one acre or less and shown in acres for easements of more than one acre.

7.7.8 Permanent Easement

The Deed Book and Page Number of the newly recorded easement will be entered in the appropriate columns by MSD or the Design Engineer if the information is available prior to the submittal of final plans.

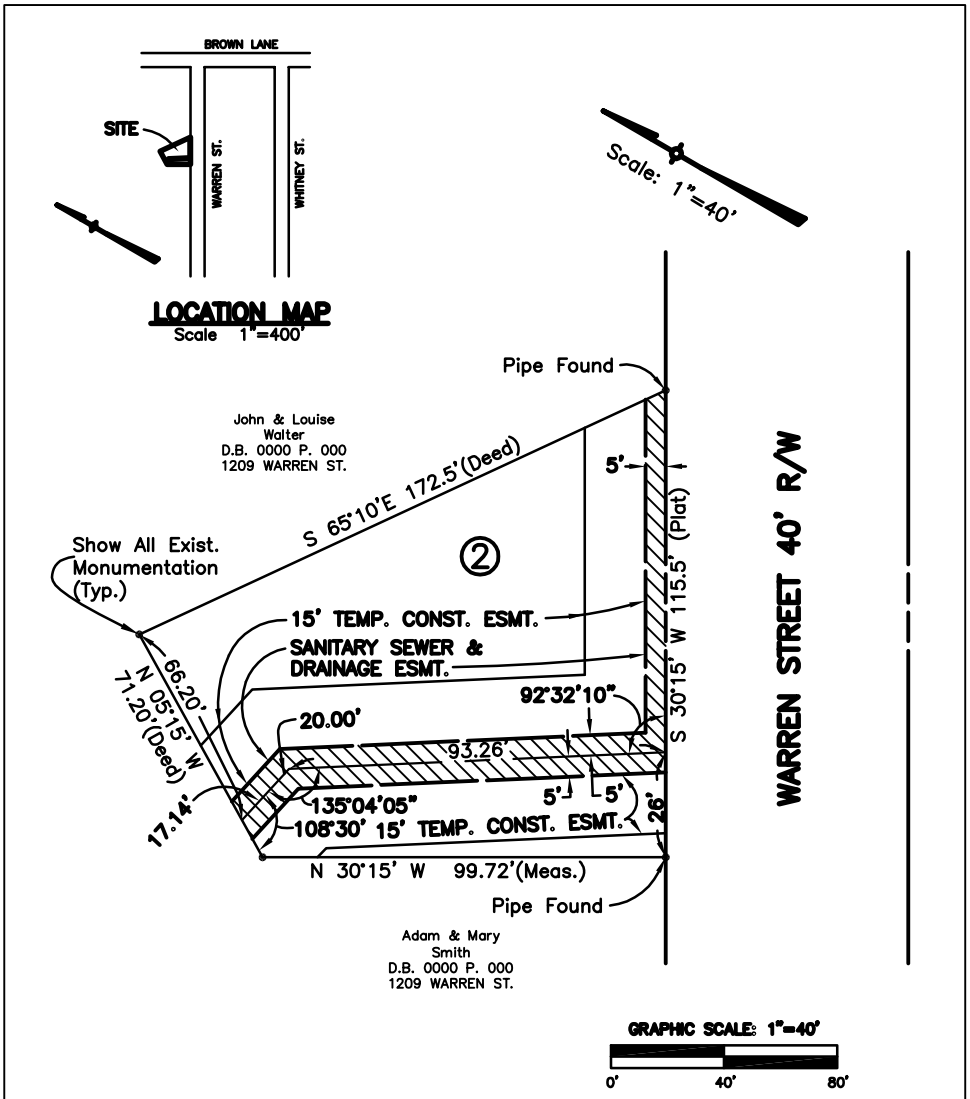
MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 7-1
SAMPLE SEWER & DRAINAGE EASEMENT PLAT

EFFECTIVE DATE: JUNE 30, 2009



GRAPHIC SCALE: 1"=40'

0' 40' 80'

PERMANENT EASEMENT = 1,502.5 SQ. FT.
TEMPORARY CONSTRUCTION EASEMENT = 4,506 SQ. FT.

The reference meridian used on this plat to determine the directions of survey lines was based on the deed bearing of the NORTH line of the tract.

LAND SURVEYOR'S STAMP

I hereby certify that this plat was made under my supervision and is correct to the best of my knowledge and belief. Distances as shown on this plat have not been adjusted for closure. This easement Plat meets or exceeds the minimum standards of governing authorities.

LAND SURVEYOR'S SIGNATURE Surveyor

Being a part of the same property conveyed to the GRANTOR by deed dated January 1980, recorded in Deed Book 4911, Page 125, in the office of the Clerk of the Jefferson County Court.

Tax Block _____ Lot No. _____

SAMPLE ENGINEERING COMPANY
&
ADDRESS/PHONE NO.

SANITARY SEWER & DRAINAGE EASEMENT

Property of
TOM & JANE POWERS
2001 GREEN CIRCLE WAY
LOUISVILLE, KY. 40218

Property Address
DICK & JANE DOE
1207 WARREN STREET
LOUISVILLE, KY. 40220

Parcel No. 2 Record No. 5199

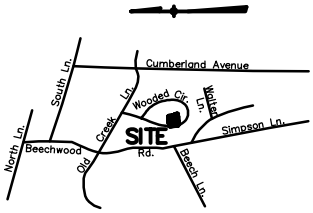
Date 10-01-00

Sheet 1 of 3

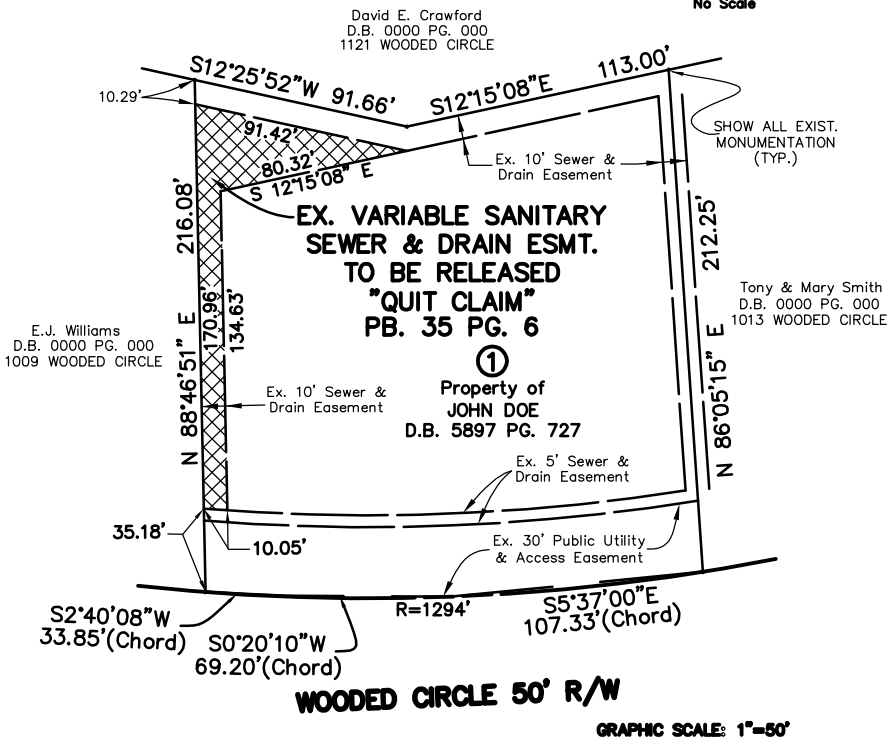
MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 7-2
SAMPLE RELEASE OF EASEMENT PLAT

EFFECTIVE DATE: JUNE 30, 2009



LOCATION MAP
No Scale



WOODED CIRCLE 50' R/W

GRAPHIC SCALE: 1"=50'
0' 50' 100'

LEGEND

Area to be released = 3,075 Sq.Ft.

All lot dimensions are per deed of record.

The reference meridian used on this plat to determine the directions of survey lines was based on the deed bearing of the NORTH line of the tract.

LAND SURVEYOR'S STAMP

I hereby certify that this plat was made under my supervision and is correct to the best of my knowledge and belief. Distances as shown on this plat have not been adjusted for closure. This easement Plat meets or exceeds the minimum standards of governing authorities.

LAND SURVEYOR'S SIGNATURE Surveyor

Being a part of the same property conveyed to the Grantor by deed dated SEPTEMBER 14, 1989, recorded in Deed Book 5897, Page 727, in the office of the Clerk of the Jefferson County Court.
Tax Block _____ Lot No. _____

SAMPLE ENGINEERING COMPANY
&
ADDRESS\PHONE NO.

RELEASE OF SANITARY SEWER & DRAINAGE EASEMENT

Property of
TOM & JANE POWERS
2001 GREEN CIRCLE WAY
LOUISVILLE, KY. 40218

Property Adress
JOHN DOE
1011 WOODED CIRCLE
LOUISVILLE, KY. 40223

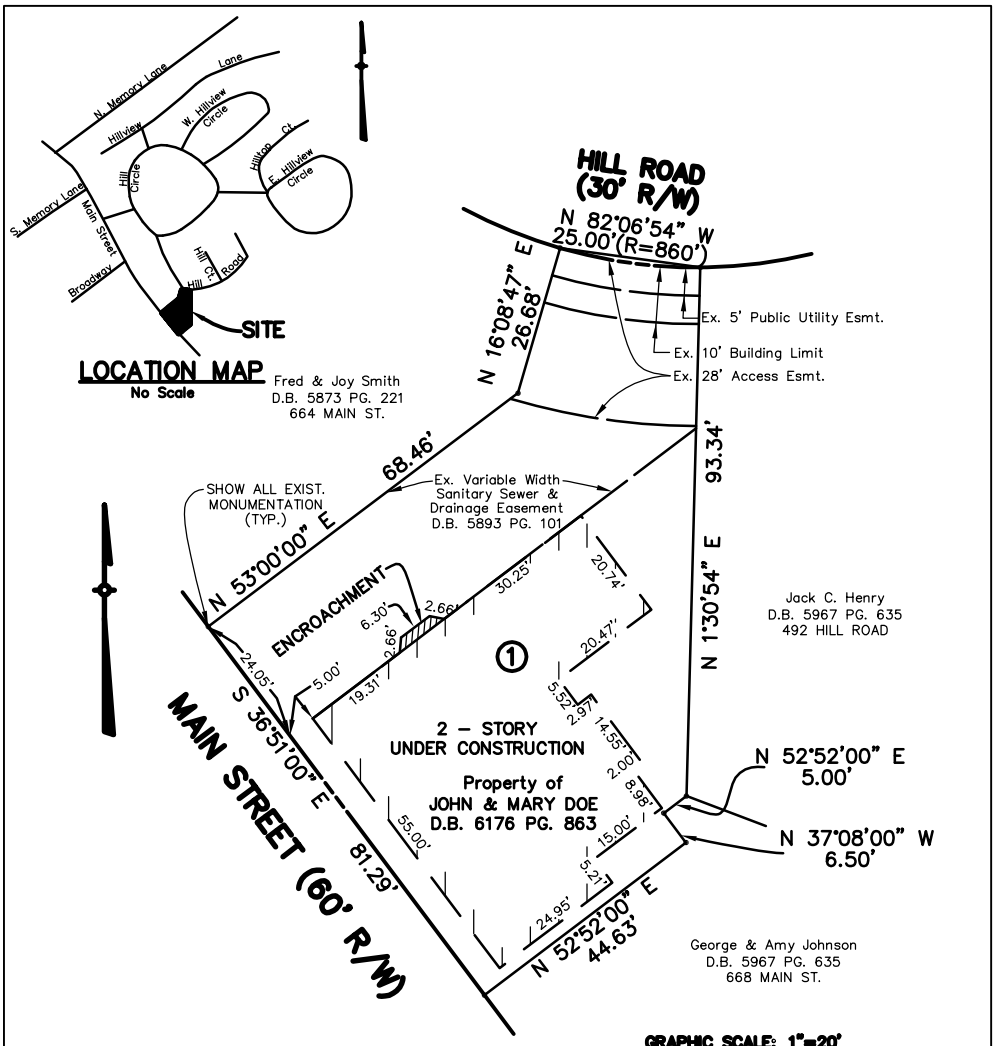
Parcel No. 1 Record No. 11105
Date 10-01-00

Sheet 1 of 3

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 7-3
SAMPLE EASEMENT ENCROACHMENT PLAT

EFFECTIVE DATE: JUNE 30, 2009



LEGEND

Area of Encroachment 16.24 Sq.Ft.

All lot dimensions are per deed of record, unless noted.

The reference meridian used on this plat to determine the directions of survey lines was based on the deed bearing of the NORTH line of the tract.

LAND SURVEYOR'S STAMP

I hereby certify that this plat was made under my supervision and is correct to the best of my knowledge and belief. Distances as shown on this plat have not been adjusted for closure. This easement Plat meets or exceeds the minimum standards of governing authorities.

LAND SURVEYOR'S SIGNATURE Surveyor

Being a part of the same property conveyed to the Grantor by deed dated AUGUST 2, 1985, recorded in Deed Book 6176, Page 863, in the office of the Clerk of the Jefferson County Court.
Tax Block _____ Lot No. _____

SAMPLE ENGINEERING COMPANY
&
ADDRESS\PHONE NO.

EASEMENT OF ENCROACHMENT

Property of
TOM & JANE POWERS
2001 GREEN CIRCLE WAY
LOUISVILLE, KY. 40218

Property of
JOHN & MARY DOE
666 MAIN STREET
LOUISVILLE, KY. 40211

Parcel No. 1 Record No. 6100

Date 10–01–00

Sheet 1 of 3

MSD Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 — WWW.MSDLOUKY.ORG

EXHIBIT 7-4
SAMPLE CONSENT AND RELEASE FORM

EFFECTIVE DATE: JUNE 1, 2009

CONSENT AND RELEASE

This Consent and release made and entered into this _____ day of _____, 20____, by and between _____, parties of the first part, and

Metropolitan Sewer District

WHEREAS, the Metropolitan Sewer District deems it necessary to perform the following work in order to improve the storm drainage for the following described property, and

WHEREAS, the parties of the first part, being the owners of said property and desirous of having said work performed.

Address of Property: _____
_____

Description of Work: _____
_____
_____

NOW THEREFORE, in consideration of the benefits accruing to said property, the parties of the first part hereby consent and agree that Metropolitan Sewer District. its agents, employees and assigns may enter ant come upon the above described property for the purpose of performing the work as described above and further expressly agree that the parties of the first part will assert no claim whatsoever, of any kind or type, against Metropolitan Sewer District, its agents, employees or assigns by reason of the performing of said work, but by these presents shall be forever barred except that Metropolitan Sewer District shall be liable for any damage to persons or property which results from its acts or omissions during the course of the project as it is performed on party of the first part's property and which occurs during such performance.

IN TESTIMONY WHEREOF, witness the signatures of the parties this _____ day of _____, 20____.

PROPERTY OWNERS

_____
Party of the First Part

_____
Party of the First Part

BY: _____
Louisville and Jefferson County..
Metropolitan Sewer District.

(Provide one copy for property
owner and one copy for MSD files

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CHAPTER 8
SANITARY SEWER SYSTEMS

8.1 PURPOSE

This chapter establishes the minimum standards and technical design criteria for sanitary sewer systems in the MSD service area. Adherence to these will expedite review and approval of plans. Hydraulic design presented herein represents acceptable procedures not necessarily to the exclusion of other sound and technically supported design procedures. Any departure from these design requirements should be brought to the attention of MSD before submission of plans for approval and should be justified and documented. Sanitary sewer plan preparation for private development must conform to Chapter 9 requirements and in all cases plan development shall conform to the Chapter 12 EPSC requirements.

8.2 BASIC ELEMENTS

The design of sanitary sewers basically consists of the determination of the following:

a. The location of the horizontal alignment, which most efficiently provides service to existing and potential users.

b. The vertical restrictions on establishing the sewer alignment including: depths required to serve users, minimum cover, elevations of other sewers in the system, conflicts with other underground facilities, solid rock considerations, and maintaining the required hydraulic gradients.

c. The design flow generated by the existing and future users, which must be transported by the sewer.

d. The size, material, bedding and method of construction required.

e. The necessary appurtenances and special structures required.

8.3 GENERAL LOCATION CRITERIA

Sewers shall be located using sound engineering judgment to determine the most cost-effective and environmentally sensitive alignment that best serves the needs of the entire tributary area. Additionally, it is imperative that all alternatives worthy of consideration receive maximum and equal consideration with regard to environmental impact. The costs and acquisition time for easements can be significant; therefore, sewers should be located within existing easements and rights-of-way whenever feasible and practical. Sewers designed within existing pavements shall be located 5 feet from the edge of pavement on the side opposite the existing water main. Sewers designed within the rights-

of-way of proposed streets and highways shall be located in the center of **one of** the proposed **traffic lanes** whenever possible. When the proposed street or highway has a curved alignment, an effort shall be made to locate the sewer a minimum of 5 feet inside the edge of pavement, unless exceptional considerations dictate to the contrary. When selecting the sewer alignment, consideration should be given to the following general location criteria:

a. Elevation requirements necessary to provide appropriate service with due consideration of sanitary facilities in basements.

b. For protection of the environmentally sensitive areas and constraints such as creeks, wetlands, trees, protected habitats, etc.

c. Existing utilities, railroads, highways, and overhead facilities.

d. Location of other existing and proposed sewerage and stormwater facilities.

e. Property values, easement needs and potential damages to the affected properties.

f. Existing and proposed high water elevations, including high water for appropriate design periods.

g. Anticipated extension of existing streets and the potential for the development of contiguous areas.

h. Continuity with adjacent design segments.

i. Maintenance of traffic.

j. Availability of materials.

k. Foundation conditions.

l. Construction cost.

The location of proposed sanitary sewers should also meet the intent of the Kentucky Administrative Regulations, specifically title 401 KAR 5:005 – "Permits to Construct, Modify, or Operate a Facility", Section 7 (Design Considerations), Paragraphs 14 and 15.

8.4 HORIZONTAL ALIGNMENT CRITERIA

8.4.1 General

With the exceptions noted hereafter, all sewers shall be constructed with a straight

alignment between manholes. For alignment changes in sewers 36 inches in diameter and larger, curved monolithic sewer sections with a radius equal to four times the diameter of the sewer may be required.

8.4.2 Straight Streets

Generally, sewers shall be located in the traffic lane on the opposite side of the street from the water main and at least 10 feet from the water main; however, the centerline of the sewer should be a minimum of 5 feet from the edge of pavement. Extraordinary circumstances may require placing the sewer closer to the edge of pavement, but every effort shall be made to place the entire manhole frame and cover entirely within the pavement. In areas where this location will conflict with gas and water valves or other utilities, the sewer location shall be adjusted to avoid these conflicts. Consideration of other factors, such as the width of the pavement, depth of rock, and possible conflict with other utilities, will still be required so the sewer can be built without modification during construction. In areas where concrete pavement is encountered, consideration shall be given to placing the sewer in a location whereby one edge of the pavement to be removed would coincide with existing construction joints, which are generally in the centerline of the streets. This procedure would require that only one side of the pavement would have to be sawed for removal. In areas where lots slope abruptly away from the street, consideration shall be given to locating the sewer near the property line on the low side.

8.4.3 Curved Streets

The sewer line may be located outside the pavement if such an alignment proves to be cost-effective. The manholes may be either within the pavement or completely outside the pavement, but shall not be partially in the pavement. The existence of curbs shall be considered in evaluating the benefit of reducing the number of manholes in curved streets. In all cases, the centerline of the manhole shall be a minimum distance of 3 feet from the edge of pavement, and a minimum distance of 5 feet inside the street right-of-way line.

8.4.4 Curve Data

Curve data, based on the arc definition, shall be used for all curved monolithic sewer segments. The curve data shall be shown on the plans near the respective curve (preferably on the inside of the curve) in the following manner:

P.I. Sta. = 10+00.00	(Point of Intersection Station)
Δ = 35° 30' 00" Lt.	(Delta Angle)
D = 409° 15' 20"	(Degree of Curve)
L = 8.67'	(Length of Curve)

R = 14.00'	(Radius)
T = 4.48'	(Tangent Length)
P.C. Sta. = 9+95.52	(Point of Curvature Station)
P.T. Sta. = 10+04.19	(Point of Tangency Station)

8.4.5 Stationing

All sewer stations shall increase upstream. Every effort shall be made to begin the stationing of a sewer with Station 0+00.00 at the downstream end. When an existing sewer is to be extended, the stationing should be continued from the end of the existing sewer whenever possible. For sewers not requiring curved sections, the PI stations and deflection angles or interior angles shall be shown on the plans at all changes in alignment. The arc and tangent lengths of curved sections shall be used in determining the sewer alignment stationing.

8.4.6 Sewer Designations

The designation of the first sewer in a collection system shall be LINE "A". The next sewer upstream contributing to LINE "A" shall be designated LINE "B", and the station of LINE "B" at this point shall be Station 0+00.00. This method shall continue throughout the collection system and subsequent sewers shall be assigned appropriate designations by ascending letters. Lines beyond LINE "Z" shall continue with double letter designations starting with LINE "AA", "AB", etc. For very short segments not extending beyond one manhole, designations such as LINE "B-1" will be allowed.

8.5 VERTICAL ALIGNMENT CRITERIA

8.5.1 Sewer Depths

Sanitary sewers shall have a minimum cover of 4 feet in easements and a minimum cover of 5 feet in rights-of-way. Specific exceptions to these minimum requirements may be made with prior approval by MSD.

In developed areas, the criteria, found in Exhibit 8-2, should be used to establish the flow line of the sewer unless otherwise directed by MSD. The "Service Connection Survey" form, found on Exhibit 6-3, should be used when determining the controlling elevations of a sanitary sewer line. In instances where only a few houses on a sanitary sewer have existing basement facilities, the impact on the entire system shall be considered prior to providing gravity basement service. Additionally, in areas having substantial amounts of solid rock, consideration shall be given to the omission of basement service. This omission must be approved in writing by MSD.

In establishing the elevation of the proposed sanitary sewer, the elevations of existing or proposed interceptor sewers or the elevations of inflow pipes to existing pump stations or wastewater treatment plants and all other utilities shall be considered.

A minimum cover of 2 feet shall generally be maintained when crossing under existing streams, existing ditches, and existing or proposed channel improvements **and storm sewers**, provided the sanitary sewer line is encased in concrete **(or capped if approved by MSD)**. With respect to streams, restoration of the channel invert will conform to the applicable standard drawings (EC-01-01, EC-02-01, or EC-03-01).

The sanitary sewer elevation necessary to serve the entire tributary area shall be considered in establishing the upstream flow line of any sanitary sewer segment including the area beyond the boundary of a design section.

A separate parallel sanitary collector sewer shall be considered in lieu of individual property service connections into the interceptor sewer in areas where the sanitary interceptor sewer reaches excessive depths. The collector sewer, at a higher elevation, should end in a drop manhole or vertical stacks into the interceptor sewer. A cost-effectiveness study shall be submitted to MSD for review and approval.

8.5.2 Sewer Gradients

All sewer gradients shall be referenced to the **North American** Vertical Datum of 19**88**. When connecting into or extending existing sewer facilities that were constructed using another datum, an elevation equation should be shown on the plans. The hydraulic criteria, established in Section 8.9, should be used to determine sewer flow line elevations in manhole structures and curved segments of the sewer.

8.5.3 Flooding and Ponding Areas

In general, the top of sanitary manhole elevations shall be a minimum of 2 feet above existing, proposed, or projected 100-year high water elevations. However, when this minimum elevation causes the manhole to be above the natural ground creating obstructive mounds, the top of the manhole elevation shall be lowered to the natural ground elevation and a watertight manhole lid and frame shall be specified.

8.5.4 Minimum Water Main Clearances

The following minimum clearances between the sewer and existing or proposed

water mains shall be used in establishing the sewer alignment:

8.5.4.1 Horizontal Clearance

The horizontal clearance shall be 10 feet minimum. Where this is not possible, the Design Engineer should reference the "Ten State Standards" Section 38.31 **(2004 Edition).**

8.5.4.2 Vertical Clearance

The vertical clearance shall be at least 18 inches. If at all possible, the sewer shall be located below the water main. Should it become necessary for the sewer to cross over the water main, special precautions and exfiltration testing of the sewer will be required. Such cases shall require written approval by MSD.

8.6 GENERAL PROCEDURES

The design flow for each segment of the sewer system shall be determined as the following:

a. Prepare a Drainage Map, which defines the area's tributary to each element of the sewer.

b. Examine each area to determine its potential land use and equivalent population.

c. Determine the average daily flow based upon the equivalent population.

d. Determine the design or peak flow based upon the average daily flow and the appropriate peaking factor.

8.7 DRAINAGE MAP REQUIREMENTS

A Drainage Map shall be prepared showing the actual area to be served by the proposed project, the location of the sewers, the portion of the project area tributary to each individual sewer element, and any points of inflow which contribute additional flow from adjacent areas. The Drainage Map shall be prepared on a standard size sheet at an appropriate scale to show the entire project and adjacent future contributing areas. Two or more sheets may be used for large-scale projects. A sample Drainage Map is shown on Exhibit 4-13. The purpose of the Drainage Map is to graphically depict the basis for the design flow calculations. The Drainage Map and design calculations shall be presented for review with submittal of the preliminary and construction plans. The minimum specific information required includes the following:

a. A key map showing the general location of the project area, including any areas not within the project area that contributes to the proposed system.

b. A general layout of the proposed system with the drainage area tributary to each major element of the system defined.

c. The basis for determining the number of existing and future users and the equivalent population for each drainage area: i.e., the number of single-family or multi-family dwelling units; type and size of existing commercial, industrial and institutional users; and the number of acres of undeveloped land by zoning classification.

d. A zoning designation, such as M-1, for each drainage area.

e. A designation for each sewer line.

f. A numbering system for manholes, which shall be added to the computation sheets.

g. All proposed sewer sizes.

h. The location of estimated or actual flow entering the proposed system from outside areas, developed or undeveloped. These areas are to be shown in entirety on the Drainage Map and shall include the same types of information required for the proposed service area.

i. An adequate number of spot elevations must be obtained in areas of undeveloped land to show the natural drainage of the area if necessary.

j. LOJIC maps may be used to prepare the Drainage Map.

k. An indication of the existing system's ability to receive the proposed flow with sufficient capacity.

8.8 DESIGN FLOW

8.8.1 Collector Sewers

Collector sewers are primarily installed to receive wastewater directly from property service connections. A major change in land use within a tributary area can have a significant impact on the collector system's ability to transport the necessary flow. Collector sewers should be designed to transport the saturation population flow, which might be expected during their service life (flowing full). The appropriate equivalent population and design flows should be calculated as

described in Sections 8.8.3 and 8.8.4.

8.8.2 Interceptor Sewers

An interceptor sewer is a principal sewer to which collector sewers are tributary. All interceptor sewers should be designed for saturation population (flowing full) unless otherwise directed by MSD.

For a major industrial water user or for undeveloped industrial land in the tributary area, MSD will generally specify the estimated average daily flows in determining the equivalent population (refer to Exhibits 8-2 and 8-3). Otherwise, a flow of 10 persons per acre shall be assumed for all industrially zoned land, except in areas where specific reliable information is available to more correctly analyze the anticipated flows.

8.8.3 Equivalent Population Sewer Design

8.8.3.1 Current Equivalent Population

A current equivalent population estimate shall be made using the most current aerial photographs or LOJIC maps, a field inventory, or other data sources. The equivalent population per unit factors, as shown in Exhibit 8-2, shall be combined with the land use categories of the tributary area. The factors are then multiplied by the unit count of each land use category to determine the equivalent population.

8.8.3.2 Future Equivalent Population

An estimate of the equivalent population for future development, which can reasonably be expected, shall be made and added to the current equivalent population for each drainage area (see appropriate Action Plan provided by MSD). The equivalent population for the remaining developable land shall be determined by multiplying the number of acres of land in each zoning category by the equivalent population per acre factors given in Exhibit 8-3. Design recommendations should be made relative to the land's potential development if a variance from the standards established in Exhibit 8-3 is suggested.

8.8.4 Design Flows

a. **Design** Average Daily Flow =
100 Gallons/person/day x Total Equivalent Population

b. Design Peak Design Flow =

Design Average Daily Flow x Peaking Factor (Exhibit 8-4)

8.9 HYDRAULIC DESIGN CRITERIA

8.9.1 General

Manning's Equation shall be used to determine proper pipe size and slope to transport the design flow. Design shall be for full flow at saturation conditions with the following characteristics:

a.	Roughness coefficient – n	= 0.013 (Sanitary Sewers Only – Ten State Standards)
b.	Minimum velocity – v	= 2 feet/second
c.	Minimum pipe size – D	= 8 inches
d.	Minimum allowable slopes	= (See Exhibit 8-5)

8.9.2 Hydraulic Grade Line

The hydraulic grade line should not rise above the crown of the sewer pipe. When critical, the hydraulic grade line shall be computed to show its elevation at manholes, transition structures, and junction points of flow in pipes and provide for the losses and the differences in elevation. If velocity entering a manhole is above critical, the hydraulic grade line must be computed to ensure that no service connections are surcharged. The pipe exiting the manhole must be adjusted in elevation to ensure that the energy gradient remains level across the manhole.

8.9.3 Velocity

All sanitary sewers shall be designed to carry the design flow at a minimum velocity of 2.0 ft/s (Reference paragraph 8.9.4 for exceptions). The maximum allowable design velocity shall be 15 ft/s based on the design flow. When severe topographic or unusual conditions require a design velocity greater than 15 ft/s, the hydraulic design and pipe material must be approved in writing by MSD.

8.9.4 Minimum Slopes

The minimum allowable slopes will be as required to obtain the minimum velocity as required in Section 8.9.3 above. In no case shall the slopes be less than those identified in Exhibit 8-5 (stubs shall have a minimum slope of 0.005 ft/ft). Note – For 8" pipe the minimum slope is 0.007 ft/ft (based upon pipe at one-fourth full depth) in cases where the minimum required velocity, at design flow, cannot be achieved at a lesser slope.

8.9.5 Sewer Size Changes

Sewer size changes shall only take place within a manhole or junction box structure. To ensure that the energy gradient is maintained, use the following:

a. Pipes 24" in Diameter or Smaller

1. When increasing the sewer size by 6 inches or less, crown elevations shall match at the centerline of the manhole.

2. When increasing the sewer size by more than 6 inches, the springlines of the smaller and larger sewer shall match at the centerline of the manhole. However, **if** the hydraulic design calculations **show unacceptable losses resulting in a surcharge condition**, the Design Engineer **may** match crown elevations at the centerline of the manhole by raising the elevation of the smaller sewer.

b. Pipes 27" in Diameter or Larger

Manholes or junctions involving sewers 27 inches or larger shall first be designed by matching the crown elevation at the centerline of the structure. The **hydraulic grade line shall then be determined. If the HGL shows a surcharging condition, the downstream pipe may be lowered as needed.**

8.10 HYDRAULIC COMPUTATIONS

Exhibit 8-1 is a sample computation sheet for designing interceptor and collector sewers. The procedure used in completing this form can be found at the bottom of the Exhibit. Blank computation sheets are available on the MSD web page and may be used for the computations. This computation sheet, or similar form, shall be submitted with the plans for review.

8.11 SEWER PIPE

a. The minimum allowable inside diameter for sewer pipe, other than property service connections, shall be 8 inches. All property service connections shall have a minimum inside diameter of 4 inches; however, commercial or industrial connections shall be individually considered with the minimum size of 6 inches.

b. **Pipe material will be selected from the products identified in the MSD Standard Specifications. Alternate products can be specified by the designer, but prior approval from MSD will be required. Designers will indicate "pipe" on the plan unless a particular product or group of products has been**

identified and the decision can be justified. Approved products from the specifications that are not advantageous for a particular project and <u>not allowed</u> will need to be identified in the Contract (must be approved by MSD).

c. Pipe testing and bedding requirements shall be in accordance with the MSD Standard Specifications, except for unusual conditions requiring special design and specifications.

d. Backfill classifications, materials, and methods of compaction shall be in accordance with MSD Standard Specifications, except in unusual conditions requiring special design and specifications.

e. All sewers shall be designed to prevent damage from superimposed loads during and after construction. Proper allowance for loads on sewers shall be made, based on trench width and depth. When standard strength sewer pipe is not sufficient, extra strength pipe or special construction methods shall be specified. Live and dead loads shall be determined for all sewers and calculations submitted to MSD for review. Dead load, live load and impact loading requirements must be met in the selection of pipe materials and installation methods.

f. Sewers 60 inches in diameter and larger shall be designed using the "D" loading method as specified in the "Concrete Pipe Design Manual" published by the American Concrete Pipe Association, latest revision. The cost savings using the actual "D" loading is required to meet the structural requirements, rather than standard class pipe and should be examined. If substantial cost savings can be realized, the actual "D" loading of the pipe required shall be specified and shown on the plans. However, the "D" load design shall be limited to increments of 200 feet or more, and should not vary between manholes unless unusual conditions exist. The "D" load design shall be based on a trench width approved by MSD prior to the actual design.

8.12 MANHOLES

8.12.1 Manhole Locations

Manholes shall be required at the following locations:

a. Changes in sewer grades or alignment (except approved curvilinear alignments)

b. Sewer junctions.

c. Where required, not to exceed the maximum manhole spacing.

d. Changes in sewer diameters

e. The location of the terminal manhole in each sewer line should be based on many factors including manhole spacing, driveway locations, the position of improvements on the lots being served, and the location of temporary sanitary facilities, such as septic tanks. A definitive single policy cannot be established for all circumstances, although the sewer line would normally terminate in the vicinity of the downstream property line.

f. Where vertical stacks connect to large (>48 inches) sewers an additional manhole or cleanout (if connecting sewer is 6 inches) shall be required approximately 5 feet from the stack.

8.12.2 Maximum Manhole Spacing

Size of Sewer	Distance
8" to 15" diameter	400'
18" to 30" diameter	500'
Over 30" diameter	600'

When certain conditions warrant, such as the elimination of a manhole, the manhole spacing can be exceeded with the approval of MSD and DOW.

8.12.3 Diameter

The minimum diameter of manholes shall be 48 inches, although larger diameters are necessary in special instances, such as acute angle considerations with pipe diameters greater than 24 inches. **The minimum elevation drop across new manholes and larger diameter manholes shall be 0.1 feet for changes in pipe direction greater than 45 degrees.** All manholes must be checked to ensure that sufficient wall is supplied between pipe openings to meet all precast manhole criteria. See Appendix G.

8.12.4 Watertight

Watertight manholes and covers are to be used **everywhere unless a waiver is granted by MSD**.

8.12.5 Drop Inlets

A vertical or slanting drop inlet shall be provided for a sewer entering a manhole at an elevation higher than the sewer leaving the manhole. A drop inlet will not be

allowed for elevation differences less than 2 feet.

8.12.6 Manhole Collars

A 6-inch collar shall be used when it is certain the manhole rim will not be lowered in the future and a 12-inch or greater collar when lowering is anticipated.

8.12.7 Manhole Numbering

All newly constructed public or private manholes will be assigned identification numbers. It is the designer's responsibility to contact MSD to obtain the required sequence of numbers for the proposed project. The assigned number for the respective manhole will be shown on both the plan and profile sheets as part of the structure note. During construction it is the responsibility of the contractor to stamp the number into the structure rim.

8.12.8 Chimney Seals

Internal, mechanical chimney seals are required on all new MSD manholes. Chemical chimney seals are to be used only for rehabilitation and only in non-paved areas.

8.12.9 Manhole Barrel Joints

See Specification section 5.3.4 for information on the two-way sealing system required for all sanitary manhole sections.

8.12.10 Manhole Frame and Collar Connections

All standard manhole frames shall be bolted to the collar with two 1-inch diameter anchor bolts positioned 180 degrees apart and all watertight manhole frames shall be bolted to the collar with four 1-inch diameter anchor bolts positioned 90 degrees apart.

8.12.11 Manhole Personnel and Equipment Access

Personnel access is required at manholes sufficient for MSD maintenance crews to enter the area. A waiver is required in the event access cannot be provided.

8.13 STUBS

Generally, stubs shall be provided in cul-de-sacs, at points of possible future extension, and at the terminus of the sewer line, unless otherwise directed by MSD. Stubs shall be

one foot long measured from outside of manhole barrel for PVC or PE pipe or one pipe length for concrete pipe. The allowable length for cul-de-sac stubs is 20 feet without specific approval from MSD.

8.14 PROPERTY SERVICE CONNECTIONS

a. The property service connection (PSC) is the section of pipe between the R/W or easement line and the mainline sewer. Standard symbols and general notes pertaining to the size, type and length of "Y" or "T" branches and property service connections are shown on Exhibit 4-2 and shall be used on the plans. The standard connection for single-family residences will be 4 inches; however, commercial or industrial connections shall be individually considered with the minimum size being 6 inches. Green metallic “locater” tape labeled “SEWER” must be installed above the PSC at a depth of not more than 30 inches. Each PSC must have a Two–Way Cleanout conforming to MSD Standard Drawing SC-02-01 installed just inside the R/W or easement line.

b. A minimum slope of 2.00% (1/4” /ft.) for property service connections shall be used for determining design elevations. However, in all cases, the invert elevation of the property service connection at the easement or property line shall be equal to or higher than the crown of the sewer. The depth of the property service connection at the R/W line will conform to Exhibit 8-8. The minimum slope for the house connection will be 1.0% (1/8”/ft.).

b. Stacks shall be used when they are more economical than the typical property service connection. Stacks shall also be used in areas where the depths of the mainline sewer, existing utilities, or other obstructions are located at elevations that prevent the use of the typical property service connections. As a rule of thumb, two guidelines must be satisfied for a stack to be used. The receiving sewer must have a minimum cover of 12 feet and the length of stack (measured vertically) must be at least 3 feet. An additional requirement is to provide the minimum 3 feet of fall between the top of stack and house discharge point as indicated on Exhibit 8-8. Example (Assume level ground) - if a receiving sewer has 12 feet of cover and the discharge point at the house is 7 feet below ground, a stack would not be used; however, if the discharge depth was 6 feet or less, a stack would be required. Obviously field conditions may dictate deviations.

c. Property service connections 6 inches in diameter and smaller may be jacked without a casing.

d. Jointless pipe shall be used for new or rehabilitated PSCs. VCP shall not be used for new or rehabilitated PSCs.

8.15 FLOATATION

All sewers and sewer structures to be constructed where high groundwater conditions exist or where flooding of the trench is anticipated shall be designed to prevent floatation or excessive pipe flexing.

8.16 ANCHORS

When sewer slopes of 20 percent or greater are encountered, the sewer shall be securely anchored by using concrete anchors or other specially designed anchoring devices to prevent slippage. The design and method used should be approved by MSD.

8.17 CONCRETE ENCASEMENTS

Concrete encasement shall extend a minimum length of 2 feet beyond the point where a 4-foot depth of cover is reached or to a point 5 feet beyond the tops of banks when crossing a ditch or stream. Concrete encasements shall be used when it is necessary to prevent floatation, when crossing streams, ditches or existing storm drains. They shall also be used where soil conditions may indicate the possibility of heavy erosion, where crossing over utilities with less than 2-feet of clearance, or in areas where the sewer has less than the required cover. The minimum length of the concrete encasement shall be 2 feet beyond the outside diameter of the storm drain or utility conduit.

8.18 TRENCHLESS PIPE INSTALLATION - DESIGN AND CONSTRUCTION REQUIREMENTS

When open cutting is not permitted, the design plans will identify an appropriate pipe installation method and required information for the contractor to bid the project. The engineer will design the trenchless pipe installation using one of the following methods:

- **Tunneling**
- **Boring and Jacking**
- **Horizontal Directional Drilling**
- **Pipe Bursting**

The contractor will have the option to offer a different method of trenchless pipe installation than the one proposed on the plans, subject to approval and acceptance by MSD. When an alternate method is proposed by the contractor he will be responsible for the final design calculations. A plan of operation and list of proposed materials will be submitted for MSD approval. Structural calculations will be required for all components. Items include: casing and carrier pipe, tunnel liner plates, the working pits, sheeting and shoring, electrical facilities, ventilation, and communications. All design calculations and plans must be signed and sealed

and submitted by a professional engineer licensed in the Commonwealth of Kentucky. The contractor will also need to coordinate their excavations beforehand with Kentucky 811- Before you Dig (BUD).

The following criteria shall be followed whenever a trenchless pipe installation is used. Any deviation from this criterion will require prior approval from MSD: Additional reference is made to the MSD Standard Specifications.

Tunneling

- Tunnels shall be constructed using steel liner plates.
- The tunnel liner shall have a minimum outside diameter of 48 inches.
- The carrier pipe shall be installed at least 4 inches above the invert of the liner, and there shall be a minimum distance of 8 inches between the top of the carrier pipe and the top of the tunnel liner.
- Tunnel liner plates and joints shall be of leak proof construction, capable of withstanding E80 loading for railroads and H25 loading for roadways.
- Liner plates shall have minimum yield strength of 28,000 psi.
- It will not be necessary to use a protective coating or cathodic protection on tunnel liners, casing or sewer pipes.
- The space between tunnel liner plates and carrier pipe shall be filled with grout or with pneumatic backstowed pea gravel or No. 9 crushed stone.

Boring/Jacking

- Steel casing pipe shall either be a minimum of 30 inches in diameter or 12 inches greater than the largest outside diameter of the carrier pipe.
- All casing pipe must have a minimum thickness of 3/8-inch unless otherwise determined by designer.
- Steel casing pipe shall have minimum yield strength of 35,000 psi.
- In boring excavation, the carrier pipe shall be encased in a ductile steel casing pipe of sufficient size to provide clearance for the proper installation of the sewer pipe. The inside diameter of the casing pipe shall be at least 12 inches greater than the largest outside diameter of the carrier pipe, joints or couplings, thus providing

a clearance of at least 8 inches between the casing pipe and the carrier pipe. The entire void between the carrier pipe and the casing pipe shall be filled with grout or with pneumatic backstowed pea gravel or No. 9 crushed stone. Any void space outside the casing pipe shall be pressure-filled with cement grout. The cement grout mixture and method of grouting is called for in the MSD Standard Specifications.

Horizontal Directional Drilling

- **Horizontal Drilling is used to install 2 inch to 30 inch diameter pipes in segments up to 1,000 feet.**

- **Completed in three phases: boring of pilot hole, enlarging of hole by reaming, and pulling of pipe through enlarged hole.**

Pipe Bursting

- **Pipe Bursting is used is used to replace existing lines that have defects that cannot be rehabilitated by normal rehabilitation methods.**

- **A static, hydraulic, or pneumatic pipe bursting tool with an expander is launched through the old pipe, fragmenting it and compacting the old pipe fragment into the surrounding soil, creating a path for the new pipe.**

Refer to Section 7 of the MSD Standard Specifications applicable specifications for the performance of trenchless pipe installation.

8.19 RAILROAD CROSSINGS

8.19.1 Criteria

The following criteria shall be strictly adhered to when the planning for sewer construction affects railroad rights-of-way and facilities (railroad companies may specify more stringent requirements):

a. Sewers shall cross tracks at an angle as close to 90 degrees as practical, but preferably never less than 45 degrees. Sewers shall not be placed under railroad bridges where there is a likelihood of restricting the required waterway area of the bridge or where there is a possibility of endangering the foundations.

b. Sewer lines crossing under railroad tracks and rights-of-way shall be constructed **using one of the trenchless methods outlined above and as** permitted by the railroad company.

c. **Sewers** under railroad tracks and across railroad rights-of-way shall extend to a point, a minimum distance of 25 feet from the centerline of the outside track or the right-of-way line, whichever occurs first.

d. Sewer lines laid longitudinally along railroad rights-of-way shall be located as far as practical from any tracks or other important structures. If located within 25 feet of the centerline of any track or should there be danger of damage from leakage to any bridge, building, or other important structure, the sewer shall be encased or shall be of a special design as approved by MSD and the affected railroad.

e. When placed along railroad rights-of-way, the top of the pipe shall have a minimum cover of 4 feet.

g. **Trenchless sewer installations** under railroad tracks and across railroad rights-of-way shall be no less than 4 feet deep measured from the bottom of the rail to the top of the **sewer installation** at its nearest point. The top of the **installation** shall not be above the invert of existing or proposed ditches.

8.19.2 Railroad Conflict Drawings

Railroad conflict drawings shall conform to the following criteria:

a. Railroad conflict drawings, as shown in Exhibit 8-9, shall be prepared on 8.5" x 11" sheets. The plan and profile may be placed on one or more sheets as dictated by the scale. The record number of the plan and/or profile sheet that shows the conflict shall be added to the conflict drawing.

b. Drawings shall be prepared to scale showing the relationship between the proposed sewer and the railroad, angle of crossing, location of utilities, original survey station of the railroad (when available), right-of-way lines, topography, and general layout. The profile established from a field survey shall show the sewer in relation to the actual ground and tracks. The limits of **installation** by station, sewer line soundings and borings, and all other pertinent information shall be shown on the drawing.

c. MSD will furnish any necessary General Notes to be placed on the plans or included in the Special Provisions.

d. Railroad conflict drawings shall be submitted along with a complete questionnaire, which shall be furnished by the railroad company.

8.20 HIGHWAY CROSSING

Sewer pipe installations constructed under State, County, or City maintained roadways, will need to confirm to the design requirements of the respective governing agency. One of the designer's first tasks will be to determine if open cutting will be allowed. Construction shall meet the following requirements (more stringent criteria may be required on a project specific basis):

a. Sewers shall cross the roadways at an angle as close to 90 degrees as practical, but preferably never less than 45 degrees. Sewers shall not be placed under roadway bridges where there is a likelihood of restricting the required area of the bridge or where there is a possibility of endangering the foundations.

b. **Sewer lines crossing under highways and rights-of-way shall be constructed using one of the trenchless methods outlined above and as permitted by the governing agency.**

c. **Sewer installations** under roadways shall have a minimum depth of 3 feet from the surface elevation to the top of the **installation**. The top of the **installation** shall not be above the invert of existing or proposed ditches.

d. **Sewer installations** under roadways shall extend a minimum of 10 feet outside the existing paving, as measured at right angles to the roadway, or to the toe of the slope when the roadway is on fill and the toe of slope exceeds 10 feet outside the existing paving. **Installations** should likewise extend to the top of slope furthest from the roadway on ditches if the top of slope is greater than 10 feet from the edge of pavement.

e. Sewer lines laid in a longitudinal direction on highway rights-of-way shall be located a sufficient distance from the edge of the pavement to allow adequate working room and to provide maximum safety to the motorist when the roadway is to remain open to traffic. Those sewer lines within the roadway right-of-way, but not located under paved areas, shall have no less than 5 feet of cover.

f. Metallic tape shall be laid in the trench above the pipe from the edge of pavement to the right-of-way line or from the end of the tunnel to the right-of-way line on all crossings of State highways.

8.21 CREEK, STREAM OR DITCH CROSSINGS

Sanitary sewer pipes for crossing a creek, stream or ditch shall be a jointless pipe and shall be encased in concrete as required in Section 8.17 Concrete Encasements.

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EXHIBIT 8-1
COMPUTATIONS FOR SANITARY SEWER DESIGN

EFFECTIVE DATE: JUNE 30, 2009

MSD — Louisville and Jefferson County Metropolitan Sewer District, 700 W. Liberty Street, Louisville, Kentucky 40203-1913, 502-587-0603 – WWW.MSDLOUKY.ORG

COMPUTATIONS FOR SANITARY SEWER DESIGN

ENGINEER _____ Project Name _____ Sheet ___ of ___
Record No. _____ Computed By _____
Checked By _____
Date _____

1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Drain. Area Designation	LOCATION: Sewer Line Designation	Manhole Designation: From	Manhole Designation: To	Increment Total Eq. Pop.	Accumulated Total Eq. Pop.	Average Daily Flow	Peak Factor	Total Sewage Flow	Design Flow "Q"	Length	Slope	Size	"Q" Full	"V" Full	Design "Q" / "Q" Full	Design Flow Depth Ratio	Design "V" / "V" Full	Design "V"	Drop	Invert Elev. of Sewer: Upper End	Invert Elev. of Sewer: Lower End	REMARKS
		Sta.	Sta.			GPD		MGD	c.f.s.	L.F.	ft/ft	In.	c.f.s.	f.p.s.	Ratio	d/D	Ratio	f.p.s.				

Col. 1 Drainage Area Designation
Col. 2 Sewer Line Designation
Col. 3 Manhole Designation by Station
Col. 4 Total Equivalent Population obtained from each individual drainage area analysis
Col. 5 Total Equivalent Population accumulated to this point (Col. 4 + previous Col. 5)
Col. 6 Average Daily Flow (Col. 5 x 100 Gallons per person per day)
Col. 7 Peak Factor from Exhibit 8-4
Col. 8 Total Sewage Flow (Col. 6 x Col. 7 divided by 1,000,000)
Col. 9 Design Flow (Col. 8 x 1.5472 cfs/MGD)
Col. 10 Length of Pipe measured from centerline of Manhole to centerline of Manhole
Col. 11 Design Slope
Col. 12 Pipe Size
Col. 13 "Q" Full
Col. 14 "V" Full
Col. 15 Design "Q" to "Q" Full ratio (Col. 9 divided by Col. 13)
Col. 16 Ratio of Pipe Diameter (D) to Design Flow Depth (d) in feet (Exhibit 8-6)
Col. 17 Design "V" Full to "V" Full Ratio (Exhibit 8-6)
Col. 18 Design Velocity (Col. 14 x Col. 17)
Col. 19 Difference in Invert Elevations

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EXHIBIT 8-2
DEVELOPED AREA
WASTEWATER FLOWS

EFFECTIVE DATE: JUNE 30, 2009

DEVELOPMENT	POPULATION PER UNIT	AVERAGE GAL/UNIT/DAY
Single Family Dwelling	4	400
Two Family Dwelling	8	800
Apartments		
1 Bedroom	2	200
2 Bedroom	3	300
3 Bedroom	4	400
Motel Rooms	1	100

DEVELOPMENT	UNIT	EQUIVALENT POPULATION PER UNIT	AVERAGE GAL/UNIT/DAY
Schools *	Students	0.15	15
Mobile Homes	Persons	2.0	200
Nursing Homes	Bed	1.0	100
Offices	Employee	0.15	15
Laundromats	Washer	4.0	400
Non-developable Land	Acres	1.0	100
Commercial *	Acres	20.0	2000
Industrial *	Acres	10.0	1000

* Actual measured wastewater flows should be used when available – with allowance for future expansion.

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EXHIBIT 8-3
UNDEVELOPED AREA
WASTEWATER FLOWS

EFFECTIVE DATE: JUNE 30, 2009

ZONING DISTRICT	DWELLING UNITS/ACRE	POPULATION PER UNIT	POPULATION PER ACRE	AVERAGE GAL/ CAP/DAY	AVERAGE GAL/ ACRE/DAY
R-E & R-1	1	4	4	100	400
R-2 *	2	4	8	100	800
R-3 *	3.5	4	14	100	1400
R-4 **	3.75	4	15	100	1500
R-5	6	4	24	100	2400
R-6	15	3	45	100	4500
R-7	30	3	90	100	9000
R-8 & R-8A	50	3	150	100	15000

ZONING DISTRICT	EQUIVALENT POP/ACRE	AVERAGE GAL/ CAP/DAY	AVERAGE GAL/ ACRE/DAY
R-9	150	100	15000
R-10	150	100	15000
Commercial	20	100	2000
Industrial ***	10	100	1000
Non-developable Land	1	100	100

* Saturation standards applicable to the design of collector or interceptor systems.

** In general, for undeveloped areas, the R-4 density is to be considered as a minimum for collection system design unless present development in the vicinity indicates that design for the actual zoning, with MSD approval, would be more prudent.

*** This figure may be adjusted by MSD if a major industrial user is anticipated.

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EXHIBIT 8-4
PEAK FACTOR CURVE

EFFECTIVE DATE: JUNE 30, 2009

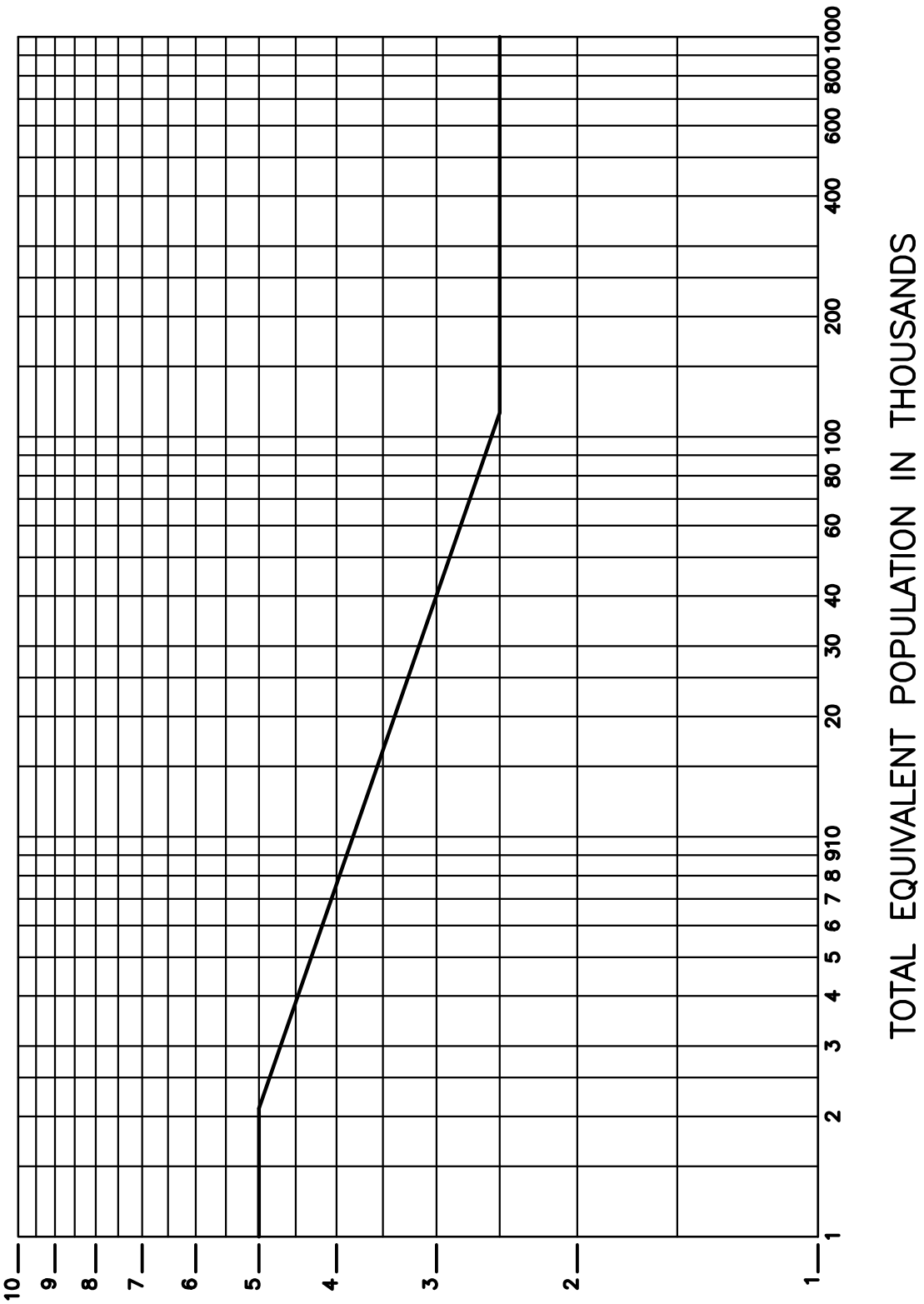

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EXHIBIT 8-5
MINIMUM ALLOWABLE SLOPES

EFFECTIVE DATE: JUNE 30, 2009

Manning's "n" = 0.013

PIPE DIA. (inches)	SLOPE (ft/ft)	VELOCITY FULL (ft/sec)
8	0.0040*	2.2
10	0.0028	2.1
12	0.0022	2.1
15	0.0015	2.0
18	0.0012	2.0
21	0.0010	2.1
24	0.0008	2.0
27	0.00067	2.0
30	0.00058	2.0
36	0.00046	2.0
42	0.00037	2.0
48	0.00030	2.0
54	0.00026	2.0
60	0.00026	2.0
66	0.00026	2.3
72	0.00026	2.4
78	0.00026	2.6
84	0.00026	2.7
96	0.00026	3.0
108	0.00026	3.2
120	0.00026	3.4
132	0.00026	3.6
144	0.00026	3.8

* If 2.0fps can not be achived with the design flow, the minimum slope will be 0.0070. ft/ft

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EXHIBIT 8-6
HYDRAULIC ELEMENTS OF CIRCULAR SEWERS

EFFECTIVE DATE: JUNE 30, 2009

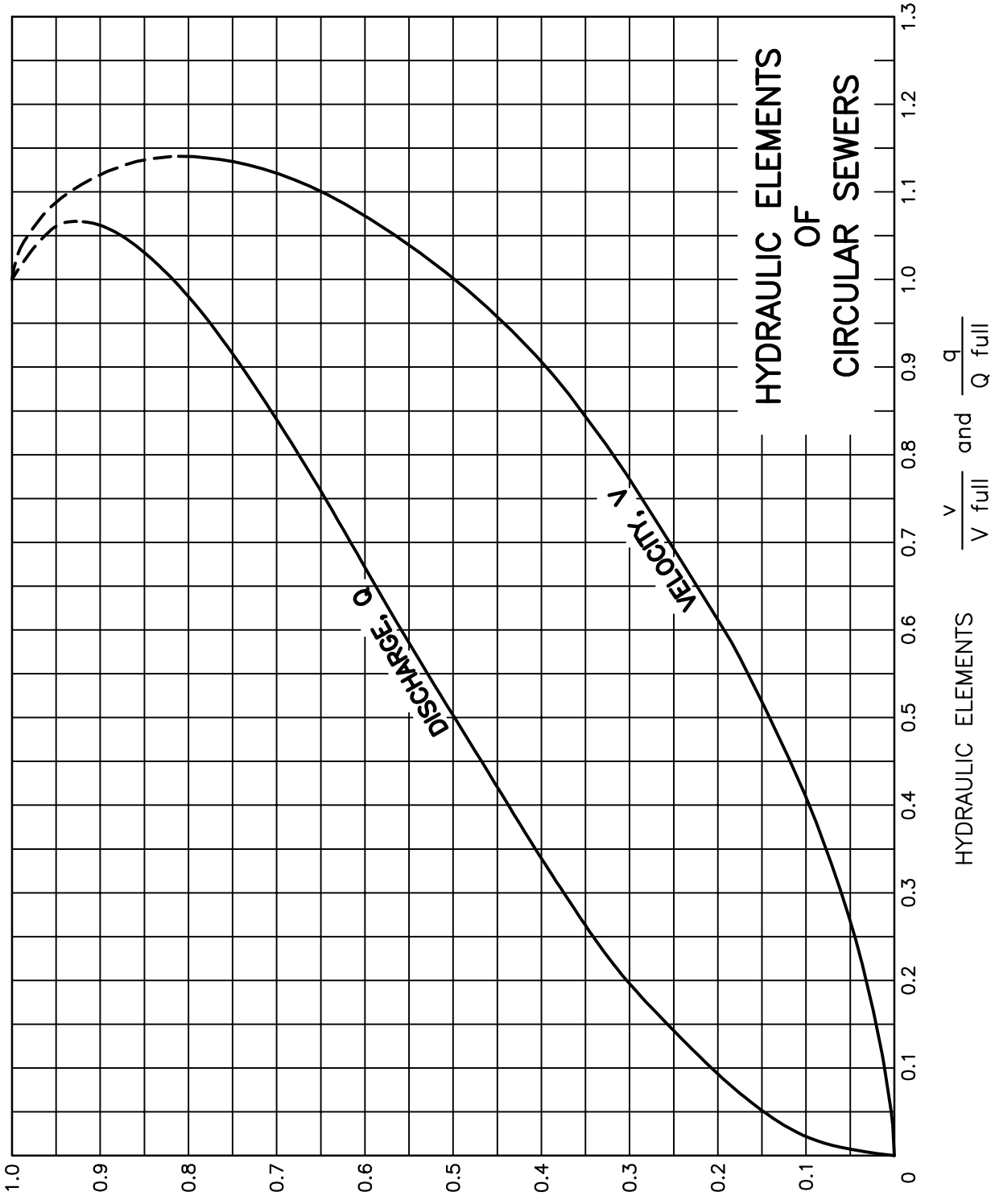

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EXHIBIT 8-7
PIPE FLOW CHART FULL (6" - 54")

EFFECTIVE DATE: JUNE 30, 2009

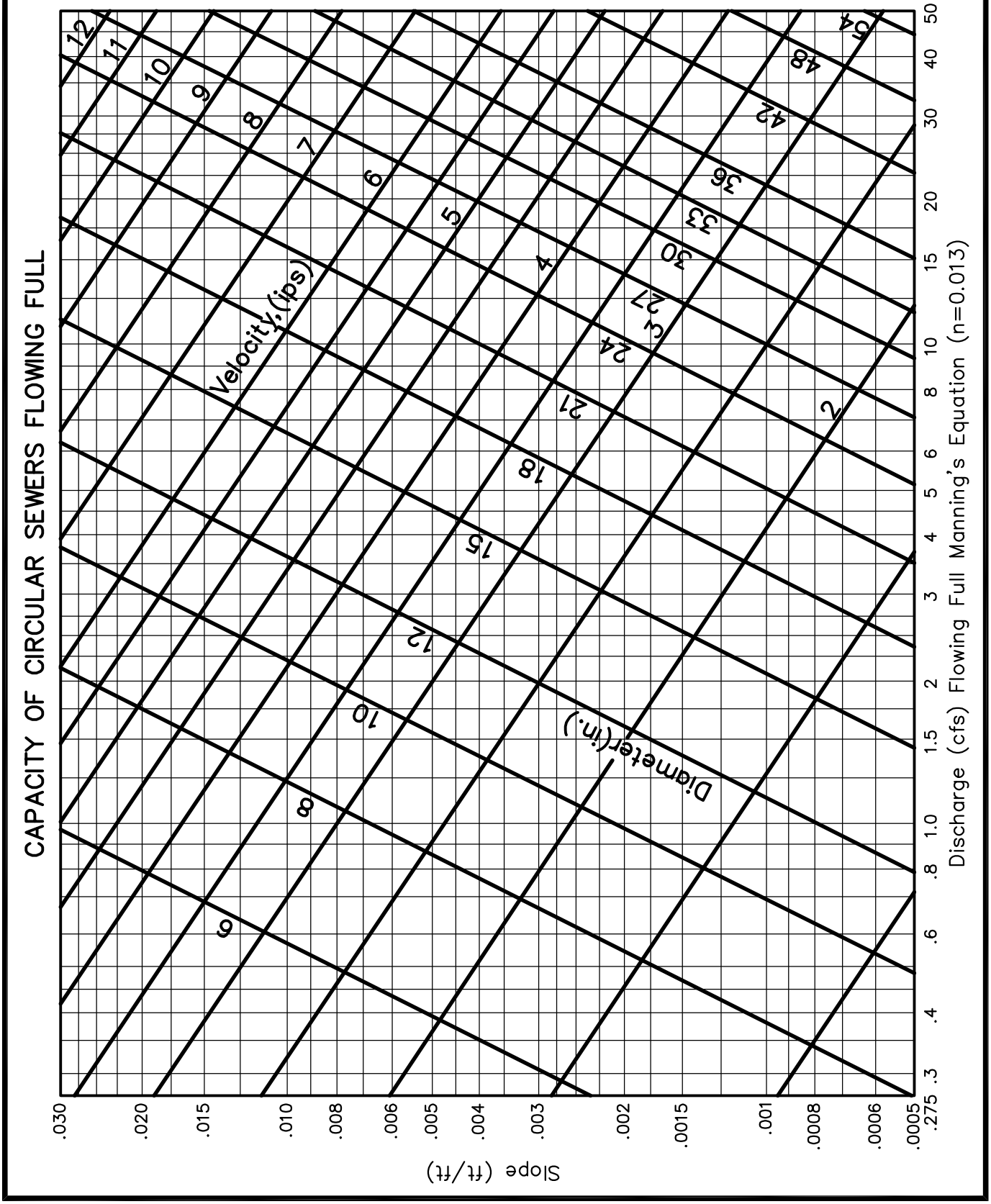

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EXHIBIT 8-7 PAGE 2
PIPE FLOW CHART FULL (21"-144")

EFFECTIVE DATE: JUNE 30, 2009

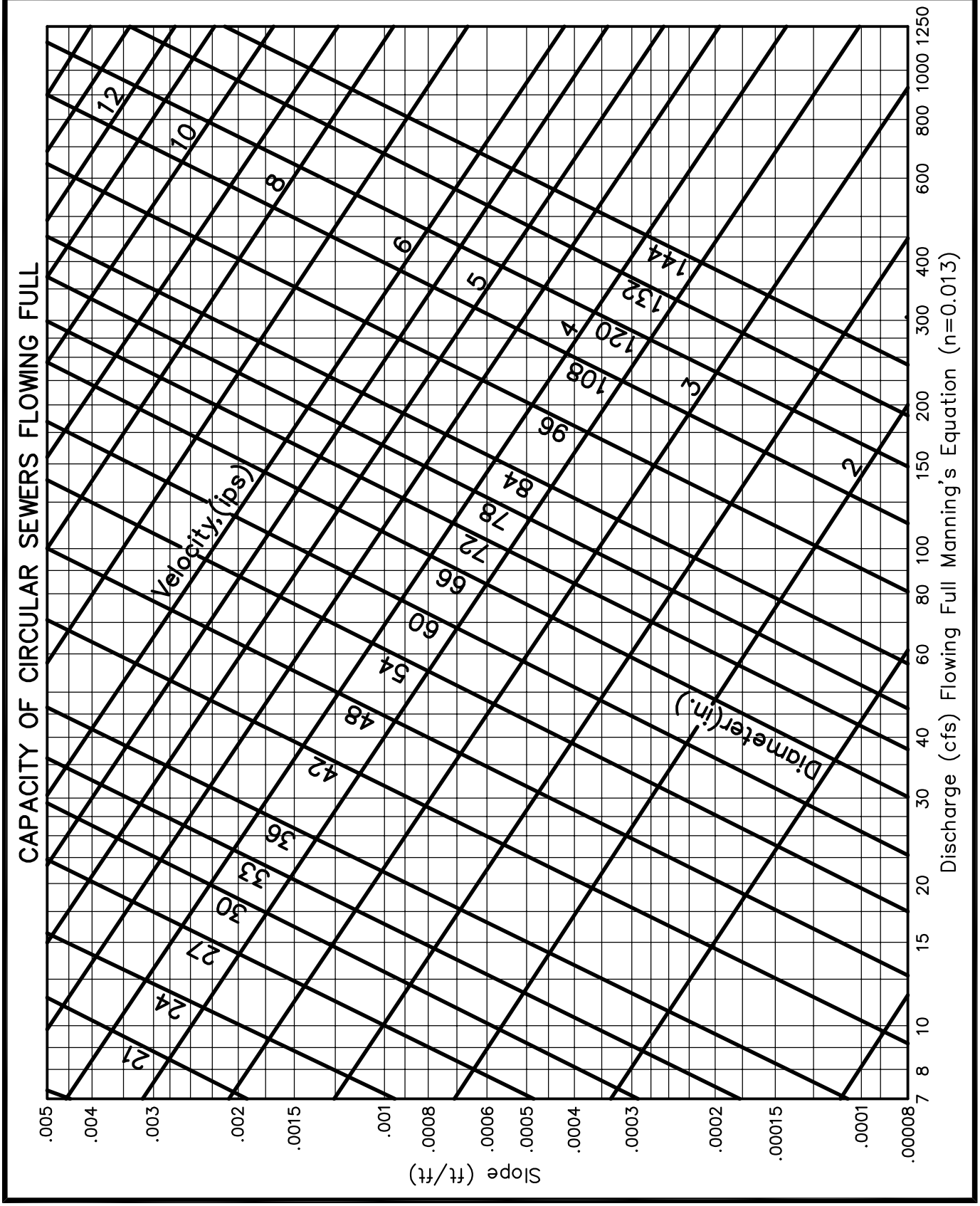

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EXHIBIT 8-8
TYPICAL SERVICE CONNECTIONS

EFFECTIVE DATE: JUNE 30, 2009

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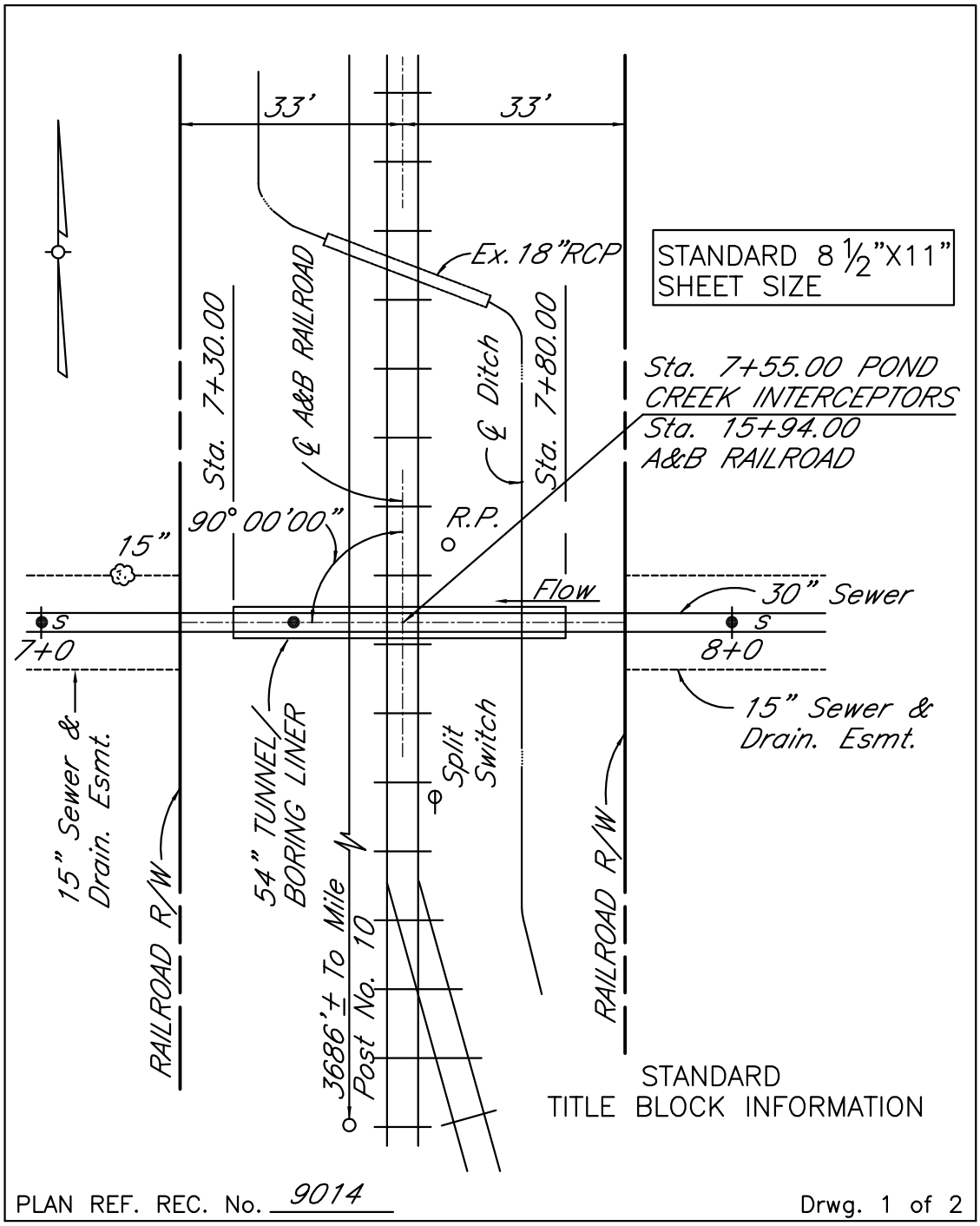
EXHIBIT 8-9 PAGE 1
RAILROAD CONFLICT DRAWING

EFFECTIVE DATE: JUNE 30, 2009



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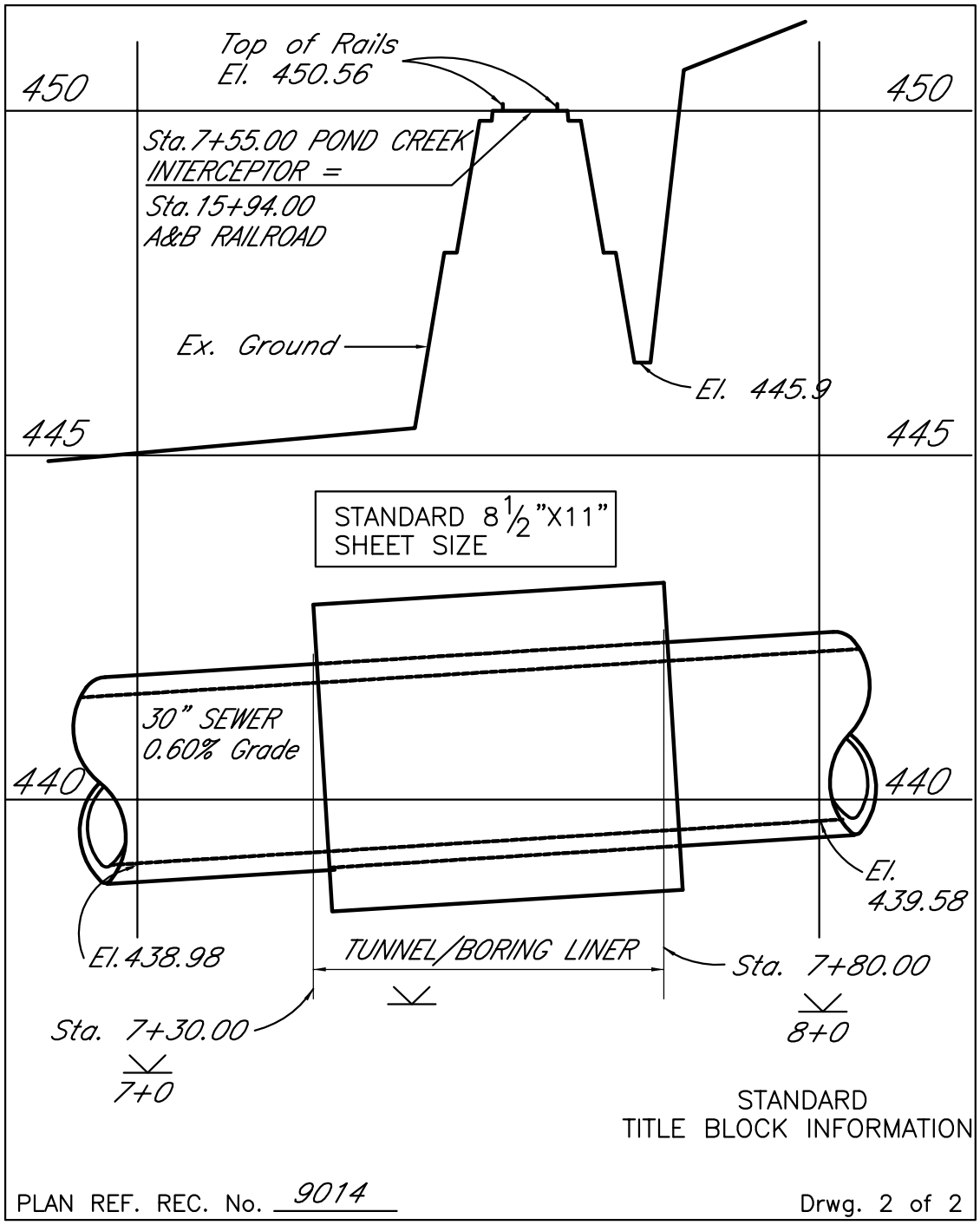

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CHAPTER 9
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CHAPTER 9
DEVELOPMENT SANITARY SEWER CONSTRUCTION

9.1 PURPOSE

This chapter establishes the minimum sanitary sewer construction plan submittal requirements and MSD procedures for submittal, construction inspection, and final approval of construction for private development **sanitary sewer** projects. Sanitary sewer systems should be designed in accordance with the applicable provisions of this and other chapters of the MSD Design Manual. Particular attention is directed to the EPSC requirements of Chapter 12. Adherence to these procedures will facilitate timely review and approval for construction.

Additional guidance and applicable forms may be retrieved from:

http://www.msdlouky.org/insidemsd/formssanitary.htm

9.2 GENERAL PROCEDURES

a. A meeting should be arranged to discuss a proposed sewer plan. The plan submittal should generally show the lot layout, sewer alignment, and drainage areas in each segment.

b. MSD will review this plan and advise as to which of the three sewer classifications will control the submittal route.

1. **Lateral Extension (LE)**
   A MSD sanitary sewer system in which the sewer system and the treatment facility is owned and operated by MSD once constructed and approved.

2. **Private Sewer - MSD System (PS)**
   A sanitary sewer flowing from a private property to an MSD sewer system and is treated at an MSD-owned facility.

3. **Non-MSD System (NLE)**
   A sanitary sewer system and treatment facility owned and operated by another city, as a private individual, corporation, or agency.

c. If MSD determines that the situation is a LE or PS served by one of MSD's wastewater treatment plants, the development of design plans may proceed.

d. If MSD determines that the sewers are NLE and they are not served by a MSD owned wastewater treatment plant, a preliminary plan must also be submitted to the Jefferson County Health Department. This is to determine if the wastewater treatment plant has adequate capacity to allow for the proposed sewer expansion.

1. If the plant does not have sufficient capacity, the plant owner must apply for Waste Load Allocation (WLA) determination from the Kentucky Department for Environmental Protection, Facilities Construction Branch. Design drawings can proceed simultaneously with the treatment plant expansion plan once the WLA approval has been issued.

2. If the plant has sufficient capacity, design plans may proceed.

9.3 SUBMITTALS

Submittal requirements for construction plans are listed on the **Sanitary Sewer Document Review Checklist** on (http://www.msdlouky.org/insidemsd/formssanitary.htm). Submittal packages will be addressed to MSD's Development Plan Review Section and must include a completed copy of the checklist. Variations from the checklist will require prior approval from MSD. Any conditions of the Approved Preliminary Plan must be addressed at the time of construction plan submittal.

9.4 PLANS

Plan requirements for the respective sheets are identified on the **Minimum Requirements Checklist for Sanitary Sewer Construction Plans** (Same web address as above).

9.4.1 Standard Drawings / Nonstandard Details

The use of MSD's Standard Drawings is highly encouraged. When a particular drawing is utilized, a copy of the drawing is not required to be shown on the plan set. Reference can be made to the drawing by identifying the drawing number on the plan set "Title Sheet".

Nonstandard details or deviations from MSD's Standard Drawing will need to be shown within the plan set.

9.4.2 Property Service Connection Inlet Sheets

The information for all connections must be shown on a Property Service Connection Inlet Sheet. An example sheet can be found on the MSD web page. A copy of the sheet should be placed on the plans for construction and as-built reference.

9.5 PROPOSED PROJECT PLAN

An 8 ½ x 11 inch drawing identifying the limits of the proposed project must be submitted to MSD for all public and private sewer projects. In order to provide consistency of the Proposed Project Plan (PPP), the use of the template provided on the web page should be used. The PPP should be submitted with the original submission.

9.6 MSD DESIGN APPROVAL

After all MSD concerns are satisfied, a letter **certifying compliance with KAR 5:005 will be sent to the KYDOW along with copies of the approved plans. The Louisville and Jefferson County Health Department will be sent copies of the certification letter and plans.**

9.7 LATERAL EXTENSION OF BOUNDARIES AGREEMENT

For LE projects, the applicant shall submit to MSD's Development Plan Review, a "Lateral Extension **of Boundaries Agreement**". This document is a legal agreement, **required by the State**, between the developer and MSD regarding the construction of the sanitary sewerage facilities. The contract conveys the sewerage facilities to MSD, upon completion and acceptance by MSD.

9.8 NOTICE-TO-PROCEED

A formal Notice-To-Proceed letter will be issued when the following conditions are met.

a. **LE Project**

- All MSD fees are paid pertaining to the sanitary sewer project
- The "**Lateral Extension of Boundaries Agreement**" has been executed
- The "Performance Bond" has been received and accepted
- The "Maintenance Bond" has been received and accepted
- The "Certificate of **Liability** Insurance" has been received and accepted
- The "Accepted Bid Proposal" has been received and accepted
- **The KYDOW construction permit has been received**
- Easement plats have been received and are easily recorded by MSD
- Permits have been issued for work within the right-of-way
- A MSD inspector has been assigned
- Notice of Construction has been received
- Site Disturbance Permit from MSD has been issued

b. **Private Sewer Project**

- All MSD fees are paid pertaining to the sanitary sewer project

- **The KYDOW construction permit has been received**
- A MSD inspector has been assigned
- Notice of Construction has been received
- Site Disturbance Permit from MSD has been issued

9.9 INSPECTION OF CONSTRUCTION

9.9.1 General

MSD has a program of on-site inspection for the construction of all sanitary sewer systems within **District Boundaries**.

9.9.2 Inspector Assignment

Construction of sewers shall not begin in a development until an MSD inspector has been assigned to the construction site. In certain situations, which will be identified during construction plan review, full-time inspection may be required. A MSD inspector shall be present during all testing. MSD requires a 48-hour advance notice to schedule an inspector for a project.

9.10 CONSTRUCTION FIELD CHANGES

Deviations from approved construction plans as a result of unexpected field conditions will require documentation and approval by MSD. To obtain this approval, the developer's engineer shall submit four (4) copies of the marked-up (REDLINE) plans showing the proposed revisions wanting to be made. Upon acceptance of the changes, MSD will mark the REDLINE drawings approved, sign and date the approval and send the REDLINES to the construction site via the inspector. One copy will be for the contractor, two copies for the inspector and one copy for MSD's reviewer file.

9.11 RECORD PLANS

At the completion of construction, a final record (As-Built) **drawings** of the construction plans (including inlet sheet information) bearing the Land Surveyor's original seal, signature, and date, and incorporating all approved changes shall be submitted to MSD. Final Record Drawings shall be prepared in accordance with Chapter 5. MSD's inspector will coordinate and check the work prior to submittal to MSD. The as-builts must be completed and approved before MSD will make the sewers available for connection.

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CHAPTER 10
STORMWATER FACILITIES DESIGN

10.1 PURPOSE

This chapter establishes the minimum standards for the planning and design of drainage systems and stormwater management facilities within Jefferson County. The guidelines presented must be used in connection with the Stormwater Management Master Plans contained in the Stormwater Drainage Master Plan (SWDMP), the EPSC requirements of Chapter 12, the Water Quality requirements of Chapter 18 and the Louisville Metro Floodplain Management Ordinance.

The criteria in this section shall apply to all drainage facility design in both the local and through drainage systems except where facilities have significant and immediate impact upon State or Federal property or highways. In those cases, the most restrictive of State, Federal or MSD standards shall govern.

Some requirements of this chapter may be superseded by the requirements of Chapter 18 if Green Infrastructure is incorporated into the stromwater design. These instances will be handled on a case-by-case basis.

Additional stormwater design information may be retrieved from MSD's web page. The path is as follows:

http://www.msdlouky.org/insidemsd/stormwater.htm

10.2 HYDROLOGY FOR STORMWATER FACILITIES DESIGN

10.2.1 General

This section describes the recommended procedures for calculating the runoff generated from a project site. Correct utilization of these procedures should result in the best available estimation of existing and projected runoff. The procedure will also provide the consistency of results necessary when applied to project sites throughout Louisville Metro and Jefferson County.

It is assumed that practicing Engineers involved with preparing drainage plans have adequate knowledge of the recommended procedures. There is, therefore, no attempt in this Design Manual to provide step-by-step calculation methodologies. The information provided in this chapter is geared toward assimilating the runoff calculation process with the regional planning aspects of the SWDMP. Contact MSD if there is reason to believe that these procedures are not applicable in particular project areas.

The runoff calculation procedures to be utilized depend upon the size of the proposed development or project as follows:

a. If the total tributary area to an existing or proposed stormwater facility on the project site is 50 acres or less, and no storage design is required, the method of runoff calculation shall be the **Rational Method** as described in Section 10.2.3.1.

b. If the total project drainage area is greater than 50 acres, or storage design is required, a discharge hydrograph must be calculated using the **NRCS Method** or another method that has been approved by MSD.

c. The Rational Method may be used to design through drainage channels if the drainage area of the channel is 50 acres or less; otherwise, the channel shall be designed by NRCS runoff calculation methodology or another method that has been approved by MSD.

Note: See Exhibit 10-1 for guidance in selecting the appropriate method.

10.2.2 Design Storm

10.2.2.1 Frequency/Return Period

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The selection of a design storm is the basis for all runoff calculations and facility design for a project site. The facility specific requirements and associated check frequencies are found in Section 10.3. The table below summarizes the associated Return Interval for various types of analyses.

Design Storm Return Interval								
Situation		Return Interval (years)						
Type of Analysis	Limiting Values	2	5	10	25	50	100	500
Bridge	ADT< 400			●			●	
	400<ADT<1,500				●		●	
	ADT>1,500					●	●	
Culvert Capacity	ADT< 400			●			●	
	400<ADT<1,500				●		●	
	ADT>1,500				●		●	
Bridge Scour Analysis							●	●
Storm Sewer				●			●	
Channel Change		●		●			●	
Roadway Ditch				●			●	
Drop Inlets				●			●	
Detention or Retention Basin		●		●			●	

Note: ADT=Average Daily Traffic

Localized restrictions may be placed on some areas, based upon the hydrologic and hydraulic models developed for the area. Design criteria in such cases shall be established by MSD during the Preliminary Plan Review Process. **The elevation of the 100-year pre- and post-development discharge shall be checked for all drainage system designs to assure conformance with the guidelines of the National Flood Insurance Program and Louisville Metro Floodplain Management Ordinance.** In areas of the County not covered by a Flood Insurance Study, the Design Engineer must determine the pre-development 100-year Flood Elevation. The elevation for the 100-year post-development discharge shall be conveyed within the limits of the proposed easement.

10.2.3 Runoff Calculation Methods (Design Flow)

10.2.3.1 Rational Method

10.2.3.1.1 General

The Rational Method is the recommended runoff calculation procedure for project sites where:

a. The total drainage area is 50 acres or less.

b. Detention/Storage design is not required.

10.2.3.1.2 Calculation

a. The Rational Method shall be performed as follows:

$$Q = C \times I \times A$$

Where:

Q = Peak runoff (cu. ft. per sec.)
C = Runoff coefficient
I = Rainfall intensity (inches/hour)
A = Contributing area (acres)

b. Rainfall Intensity-Duration Curves, Exhibit 10-2, shall be utilized in the Rational Method to determine rainfall depths and storm intensities for Louisville and Jefferson County. Rainfall intensity may also be computed as described in the Kentucky

Transportation Cabinet Drainage Guidance Manual, most current edition.

c. The time of concentration (duration), Tc, shall be determined by calculating the time for a particle of water to travel from the most hydrological remote point of the project area to the point of interest. Acceptable methods to derive time of concentration are **the TR-55 (Technical Release - 55, available from the NRCS) and the Kinematic Wave method. The minimum Tc shall not be less than 10 minutes to any given inlet or analysis point.** Manning's Equation should be used to estimate any in-pipe or channel travel.

d. The runoff coefficient, C, must represent a composite of the surface condition tributary to the point under consideration.

To determine the appropriate C-Factor, the hydrologic soil group, described in Exhibit 10-4, and land use for each surface condition must be obtained. Exhibit 10-5 then combines this information with surface slope to provide the correct C-Factor for that area. The C-Factors given may be used directly when the drainage area is homogeneous. When it is not, an appropriately weighted C-Factor must be determined and reviewed by MSD.

For areas where no hydrologic soil group information can be obtained, the C-Factor should be the values for soil group C.

If the project site conditions differ significantly from those used as the basis for the C-Factor figures, the Design Engineer must develop a specific composite C-Factor for the area. To determine the composite C-Factor for the entire project site, a weighted average must be calculated based upon the percentages of the areas with different C-Factors. (NOTE: Land use regulations in Jefferson County permit the use of higher

percentages of impervious surface than may be reflected in the coefficients from Exhibit 10-5. The Design Engineer should select or calculate runoff coefficients, which reflect actual proposed designs. For subdivisions, the Design Engineer should accommodate the maximum imperviousness permitted under land use guidelines.)

e. To calculate flowrates in series, (i.e. in ditch or storm sewer design) the C*A term shall be summed for all contributing drainage areas. The intensity shall be selected from the time of concentration to that point. The Tc selected shall be the larger of these two: 1) Tc for the subject inlet or analysis point based on overland flow to said inlet/anaylsis point and 2) the Tc from the previous in-line inlet or analysis point plus the travel time from the previous inlet or analysis point.

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10.2.3.2 Natural Resource Conservation Service (NRCS) Methods

10.2.3.2.1 General

The NRCS Methods are required for runoff calculation procedures for project sites where:

a. The total project drainage area is greater than 50 acres or

b. Detention/Storage design is required.

When these project conditions exist, the Design Engineer should confer with MSD to determine if there is a hydrologic or hydraulic model available for the area. If a model exists, site calculations must be performed and correlated with this data.

If models do not exist, the Design Engineer must use the NRCS Methodology in model preparation.

10.2.3.2.2 Methods

The NRCS Methods also include the TR-20 and TR-55 Methods. Detailed descriptions, example calculations, and worksheets for these methods are available in:

a. Project Formulation - Hydrology, Technical Release No. 20 User's Manual;

b. Urban Hydrology for Small Watersheds, Technical Release No. 55; and

c. A Guide to Hydrologic Analysis Using NRCS Methods.

10.2.3.2.3 Curve Number

The curve number is similar to the Rational Method C-Factor in that it is based on the surface conditions of the project site.

The appropriate figures and hydrologs in the Watershed Plans should be utilized to determine the hydrologic soil group and land use definition for the particular area. The correct CN can be determined from Exhibit 10-6.

For through drainage systems, post developed curve numbers shall be based on a fully developed watershed as zoned at the time of design.

Maps depicting the NRCS Hydrologic Soil Groups, Existing Land Use, and Projected Land Use for each watershed in Jefferson County are included in the Watershed Plans available through MSD's Stormwater Department and ERSI coverages provided by LOJIC. This information may be used to determine the appropriate surface condition factors for use in runoff calculation as described in Section 10.2.3. Contact MSD regarding any discrepancies between the maps and the proposed project site.

10.2.3.2.4 Antecedent Runoff Condition

The index of runoff potential before a storm event is termed the Antecedent Runoff Condition (ARC). The ARC is an attempt to account for the variation in CN at a particular site for various storm conditions. The CNs in Exhibit 10-6 are for average ARC, which are used primarily for design applications. Please refer to the NRCS National Engineering Handbook, Section 4 - Hydrology (NEH-4, NRCS) for a detailed discussion of storm-to-storm variations and upper and lower CN limits. ARC will normally be involved only in calibration.

10.2.3.2.5 Directly Connected Impervious Areas

Directly connected impervious areas should be considered where applicable in NRCS runoff calculations.

NOTE: Land use regulations in Jefferson County permit the use of higher percentages of impervious surface than may be reflected in the coefficients from Exhibit 10-6. The Design Engineer should select or calculate runoff coefficients, which reflect actual proposed designs. For subdivisions, the Design Engineer should accommodate the maximum imperviousness permitted under land use guidelines.

10.2.3.2.6 Rainfall Duration

The minimum design storm duration for planning and design is dependent upon the runoff method used.

a. The NRCS Method will utilize the **NRCS Type II, 24-hour rainfall distribution.** Critical storm analysis shall be performed when warranted as determined by MSD.

10.2.3.2.7 Rainfall Depth

Exhibit 10-3, shall be utilized to determine total rainfall depths for Jefferson County for use by the NRCS methods. These values are derived from Engineering Memorandum No. 2, Revised June 1, 1979, published by the Commonwealth of Kentucky, Division of Water Resources - Department for Natural Resources and Environmental Protection. MSD may require use of local rain gage data where available. The Design Engineer should inquire if MSD has such data available.

10.2.3.2.8 Rainfall Distribution

Synthetic rainfall distributions shall be used for design storm generation. When critical storm analyses are not required, the distributions shall match the NRCS Type II curve as published in NRCS Technical Report 55, with **5-minute time steps.**

In some cases MSD may require a critical storm analysis to determine the rainfall duration and distribution that produces the worst runoff conditions for a specific site. Since the NRCS Type II distribution represents a 24-hour duration storm only, it is not applicable to the critical storm analysis. This analysis will be based on dimensionless Huff Distributions as presented in *Rainfall Frequency Atlas of the Midwest* by Floyd Huff and James Angel, Midwestern Climate Center, NOAA, and the Illinois State Water Survey, A Division of the Illinois Department of Energy and Natural Resources.

10.2.3.2.9 Surface Condition Data

Maps depicting the NRCS Hydrologic Soil Groups, Existing Land Use, and Projected Land Use for each watershed in Jefferson County are included in the Watershed Plans available through MSD's Stormwater Department and ERSI coverages provided by LOJIC. This information may be used

to determine the appropriate surface condition factors for use in runoff calculation as described in Section 10.2.3. Contact MSD regarding any discrepancies between the maps and the proposed project site

10.3 HYDRAULICS FOR STORMWATER FACILITIES DESIGN

This section contains the technical criteria required for the design of stormwater facilities. The Design Engineer must make adequate reference to other chapters of this manual and the MSD web page for additional design guidelines.

10.3.1 General Guidelines

10.3.1.1 Design Flows

a. Design flows must be calculated by the appropriate method described in Section 10.2. **At a minimum, the facility must have the capacity to transport the 10-year post-development discharge** except in unusual cases, such as retrofit projects. MSD will determine design criteria for retrofit projects or other unusual cases. **The water surface profile and through system capacity shall be checked for the 100-year post-development discharge. All systems must be capable of passing the 100-year design flow within the drainage easement**. Additional facility-specific requirements are found in following portions of this Section.

10.3.1.2 Combined Sewer Area

a. All development in the Combined Sewer Area (CSA) shall limit the 100 year post-developed discharge to the 10 year pre-developed discharge using the methods described in Section 10.2. **The pre-developed condition shall be defined as: *the condition of the site when either a preliminary plan or a construction plan is submitted to MSD for review*, whichever is first.**

b. The tributary area that must meet the Pre10-Post 100 requirement shall be limited to the *area of disturbance.*

Note: ***Land Disturbing Activity*** is defined by the **Jefferson County Erosion Prevention and Sediment Control Ordinance** as: "*Any land change which may result in soil erosion from water or wind and the movement of sediments into water or onto lands, including but not limited to clearing, grading, excavating, transporting and filling of land."*

Furthermore**, the exposure of bare soil shall be considered a land disturbing activity by MSD.**

c. Development disturbing less than ½ acre and without a storm drainage system shall be exempt from the Pre10-Post 100 requirement.

d. Connections to the combined sewer system shall be no less than 6" in diameter. If calculations show that a connection should be less than 6", the difference of the two volumes must be compensated for in the pipe system.

e. Basins connected to the combined sewer system or in a flood prone area shall be fitted with a backflow device, have an overflow above the flood elevation, and have the last storm structure be "trapped".

f. All designs attempting to meet the Pre10-Post 100 requirement will be subject to the specifications in Section 10.3.8 and Chapter 18 of this Manual.

10.3.1.3 Allowable Pipe Materials

a. Pipe material will be selected from the products identified in the MSD Standard Specifications. Alternate products can be specified by the designer, but prior approval from MSD will be required. Designers will indicate "pipe" on the plan unless a particular product or group of products has been identified and the decision can be justified. Approved products from the specifications that are not advantageous for a particular project and not allowed will need to be identified in the contract.

10.3.1.4 Roughness Coefficients "n" (See Exhibit 10-7)

a. Concrete (Pipe or Finished): 0.012

b. Plastic (Smooth Interior Wall): 0.011

c. Corrugated Metal Pipe: 0.024

d. Sod: 0.030

e. Placed Riprap: 0.030

f. Dumped Riprap: 0.035

g. Gabions: 0.028

h. Coefficients for other approved materials shall be source documented for review.

10.3.1.5 General Pipe Design Requirements

a. Minimum velocity shall be 2 feet per second at design flow or 3 feet per second at full flow; whichever requires the greater slope.

b. Minimum pipe size shall be 12 inches except that driveway entrance pipe may be 10 inches with prior approval by MSD. Smaller pipe sizes may be approved by MSD for detention basin outlets on a case-by-case basis. Such pipes shall not be smaller than 6 inches.

c. Maximum manhole spacing
   1. Less than 18" diameter- 400'
   2. 18" to 30" diameter- 500'
   3. 33" and greater diameter- 600'

d. All pipes are to have end treatments. Design of end treatments shall consider traffic safety.

e. Stubs for storm sewers when required shall be 1 foot long measured from the outside of the manhole or surface inlet for PVC and PE pipe or one length of pipe for concrete pipe.

f. Submerged pipes are not desirable, but may be approved by MSD on a case-by-case basis.

g. When a drainage system is designed to enter a combined sewer, the last manhole or catch basin shall be trapped to prevent the possible release of harmful gases and odors.

10.3.2 Storm Sewers

10.3.2.1 Design Methodology/Design Storm

The Design Engineer may refer to the Kentucky Transportation Cabinet Drainage Guidance Manual for design methodology for storm sewers. The exception being that **all storm sewer systems will be designed for the 10-year event. The 100-year discharge elevation must be checked to ensure the system does not surcharge out of any inlets and/or manholes.** Manning's Equation is recommended to calculate pipe flow and velocity. The storm sewer hydraulic grade line shall be at least 1.0 foot below the ground surface or building drain elevation, whichever is lower, at all points for the design event. For the 100-year event, the hydraulic grade line may not rise higher than the ground line or building drain elevation, whichever is lower. Where the storm sewer hydraulic grade line exceeds the pipe crown, it must be shown on the Profile Drawing. Losses at all inlets, junction structures and bends are to be considered. Refer to MSD Standard Casting Details for all surface inlets and manhole castings. Pipes on grades greater than or equal to 20% shall have anchors at each pipe joint. The Design Engineer shall check to ensure that all pipes have sufficient cover and that all structures, inlets and manholes have sufficient dimension to receive pipes, bells, frames, and grates.

10.3.3. Culverts

10.3.3.1 Design Methodology/Design Storm

A method as described in the Kentucky Transportation Cabinet Drainage Guidance Manual should be used. The design methodology utilized must be submitted for review.

10.3.3.2 Maximum Allowable Headwater

The most stringent requirement of the following will apply:

a. Cul-de-sacs, alleys, local streets, and collectors: Use the subgrade elevation of the adjacent roadway for the 10-year discharge.

b. Major and minor arterials: Use 12 inches below the shoulder elevation of the adjacent roadway for the 100-year discharge.

c. Headwater for the 10-year discharge should not exceed 1.2 times the structure rise except as specifically approved by MSD on a case-by-case basis. For pipes 30" in diameter and larger, the headwater should not exceed 1.0 times the structure rise except as specifically approved by MSD on a case-by-case basis.

d. If a culvert has a drainage area greater than one square mile or is in a regulated floodplain the 100-year storm headwater depth shall not be greater than 1.0 times the structure rise except as specifically approved by MSD on a case-by-case basis.

10.3.3.3 General

a. Downstream channel must receive appropriate protection or energy dissipation if the design outlet discharge would cause erosive conditions.

b. Traffic safety must be considered in the design of culvert end treatments. This may include extending the culvert beyond the right-of-way limits, installing catch basins to intercept roadside swales, and installing guardrails. Designs must conform to meet the requirements of the agency responsible for road maintenance and safety.

10.3.4 Trenchless Pipe Installation

Trenchless pipe installation for storm sewers and culverts is described in Chapter 8 of this manual.

10.3.5 Conventional Channels and Ditches

This section describes the technical criteria necessary to design stormwater channels and ditches using conventional design procedures. These procedures shall be applied to roadside and rear yard ditches and highly urbanized channels. Where possible, all blueline streams (especially in undisturbed areas) shall be designed using Natural Channel Design techniques as described in Section 10.3.6. This criterion represents minimum requirements. Justification should be submitted to MSD for review and approval in cases where different slopes or other protective measures are recommended.

10.3.5.1 Design Methodology/Design Storm

Manning's Equation is recommended, except in cases where backwater conditions are significant. All calculations must be submitted for review. Software programs utilized must be approved by MSD.

a. Design Storm

1. **Channels and ditches should be capable of conveying the 10-year storm flow within their banks**. Through drainage systems shall generally be designed to collect and transport the post-development rate of runoff for the 100-year design storm. **In all cases, the 100-year discharge elevation must be checked to ensure that adjacent structures do not suffer flood damage.**

2. **All systems must be capable of passing the 100-year design flow within the drainage easement.**

b. Channel Criteria

Minimum Channel Slope - 0.5%, except in special cases such as retrofit projects or major channels.

c. Maximum Side Slope

1.	Earth	3:1 (when depth < 8.0 feet) 4:1 (when depth > 8.0 feet) 2:1 (may be allowed on case-by-case basis)
2.	Riprap and Aggregate	1.5:1
3.	Concrete	1:1

4. No maintenance ground cover 2:1
5. Bioengineered systems on various slopes

d. Channel Depth

Channels created for new residential subdivisions shall not have a design depth of greater than 2.0', unless otherwise approved by MSD.

e. Channel Lining

1. Channel slope 0.5% or less – Concrete. Evaluate the use of a low flow channel. As-builts may be required.
2. Channel Slope between 0.5% and 2.0% - Concrete low flow channel with durable lining for the remainder of the protected section.

3. Channel Slope greater than 2.0% - Natural vegetation and geosynthetic turf reinforcement.

4. If the design parameters are beyond the limits of natural vegetation, then a non-degradable durable material must be used. Durable channel lining is required to the depth of the 10-year storm as outlined in Section 10.3.5.3. Durable channel lining may be low maintenance ground cover, sod, soil bioengineered systems, turf reinforcement mats or concrete. Rip-Rap, Aggregate Channel Lining and Gabion Baskets are to be limited to areas immediately downstream of an outlet pipe to reduce velocities and erosion potential. The use of these materials shall be a last alternative and approved on a case by case basis. All linings must be approved by MSD on a case-by-case basis.

5. Trapezoidal or rectangular paved channels shall have bottom slopes no less than 1:12 sloping either to the center or to one side of the channel to provide self cleaning.

6. Channel and channel lining design should consider the effects of open channel junctions, curved alignment, obstructions, transitions, constrictions, changes in slope and other characteristics including the effects of subcritical and supercritical flow.

10.3.5.2 General

a. Roadside ditches on retrofit projects, which have less than a 4-foot shoulder, shall not exceed 1'-6" in depth, measured from the edge of pavement.

b. Roadside ditches and channels must have a minimum 4-foot shoulder from the edge of the pavement to the top of the bank.

c. Roadside ditches and channels in through systems must have a minimum 8-foot shoulder from the edge of the pavement to the top of the bank.

d. In areas where new sidewalks are proposed to cross-swales, ditches, or channels, a culvert meeting design storm requirements must be installed extending past the sidewalk sufficiently to allow a maximum 4:1 slope.

e. Ditches and channels adjacent to state highways may require more stringent criteria. The Design Engineer must obtain the criteria from the KYTC.

f. Cutoff walls shall be placed at the beginning and end of all paved channels.

g. Utilities and their facilities should not be located within or interfere with swales, ditches, detention/retention facilities, stormwater quality treatment devices and facilities, manholes, pipes or landscaping such as trees and bushes.

10.3.5.3 Channel Design Procedure

a. The method of designing channels and ditches as presented agrees with Hydraulic Engineering Circular HEC-15 that is based on the tractive force theory. The calculated shear stress resulting from flow in a channel is compared to the maximum permissible shear stress for the channel lining selected. If the shear force induced by the flowing water equals or exceeds the permissible shear stress of the lining, failure may occur and a more resilient lining must be proposed. This concept allows for calculation of the maximum discharge a channel can carry by equating the

calculated and permissible shear[1]. The procedure is applicable to channels of uniform cross section and constant bottom slope.

The suggested step-by-step design procedure shown below is taken from the Kentucky Transportation Cabinet's Drainage Design Manual. Additional information is taken from the Federal Highway Administration's HYDRAIN software documentation manual. Obviously additional procedures and references are available and they should be utilized as designer preference dictates. However, it will be the designer's responsibility to satisfy all MSD reviews.

b. The design procedure as shown assumes steady uniform flow with the energy slope equal to the bed slope and flow calculated using Manning's equation. For conditions other than these, the designer should consult other references; one of which is HEC-11, which focuses on natural channels with irregular cross sections, varying bottom slopes, and flows exceeding 50 cfs.

The maximum shear stress on the side slopes is always less than or equal to that on the channel bottom and does not limit the design of a single, rigid, vegetative, gabion, or temporary lining, but may affect the design of composite linings[1]. The designer is alerted to this situation and should consult the previously noted references.

c. Design Procedure

1. Determine Drainage Area Contributing to the Channel.

2. Select Channel Cross Section- Side Slopes & Bottom Width

3. Determine Channel Longitudinal Grade

4. Calculate Design Flow - Adjust channel cross-section and grade as necessary for capacity. (Reference Section 10.3.1.2)

5. Select Channel Lining

[1] Federal Highway Administration's HYDRAIN Software Documentation (GKY and Associates, Inc.).

a. Determine maximum permissible shear stress (τ_p) for the selected lining. See Table 5-3 in the KYTC Drainage Manual for a summary list of various protection measures or the manufacturer's recommendations for specific Turf Reinforcement products.

b. Estimate flow depth in the channel.

c. Determine Manning "n" for selected lining and depth of flow.

d. Calculate flow using Manning's equation and the estimated flow depth.

e. If calculated flow varies from design flow, repeat steps (b) and (d) until flows agree.

f. Calculate actual shear stress(τ_d)

$$\tau_d = \gamma\, d_n\, s,$$

Where: τ_d = actual shear stress 1b/ft^2
γ = specific weight of water 62.4 lbf/ft^3
d_n = flow depth in ft.
s = energy slope (bed slope); ft/ft

g. If $\tau_d < \tau_p$, the lining selected is acceptable

If $\tau_d > \tau_p$, consider the following:

- Select a lining with a higher permissible shear stress
- Decrease slope
- Increase the channel width and/or flatten side slopes

10.3.6 Natural Channel Design Procedures

This section describes Natural Channel Design procedures to be utilized where possible for the design of streams especially along blueline streams and in undisturbed areas. It should be noted that Natural Channel Design techniques promote enhanced stormwater quality and aquatic habitat over conventionally designed channels and ditches and is the preferred method for the design of streams.

10.3.6.1 Design Methodology

Streams designed using natural channel design techniques shall emulate naturally formed streams. The design shall be based upon measurements from reference reaches in similar physiographical regions exhibiting similar characteristics to the desired stream. The designed stream shall exhibit characteristics consistent with stream types expected to occur within the given valley type. Both the pre-existing stream type and the designed stream shall be classified in accordance with the Rosgen Stream Classification system[2].

10.3.6.2 Design Discharge

Streams designed using Natural Channel Design techniques shall include a bankfull channel design based on the bankfull discharge (also commonly referred to as the channel forming discharge). On average, the bankfull discharge approximates a 1.5-year storm event and can range between a 0.8 to 2.0-year storm event. The bankfull discharge used for design shall be determined based on field bankfull indicators and shall be checked against regional curves developed from gauged streams within the same physiographical region as the stream to be designed. Where flooding of nearby structures may occur, the floodplain area adjacent to the bankfull channel shall be designed to convey a 100-year storm event.

10.3.6.3 Design Submittals

All parameters/information used for the basis of design shall be submitted for review. Where an existing stream is present, the design submittal should include calculations for the proposed channel as well as measurements from the existing channel. Information submitted should include reference reach data and location of reference reaches.
As a minimum, the following design parameters/information shall be included in the design submittal: longitudinal profile; cross sectional geometry for pool, riffle and cross-over reaches; stream type; drainage area; bankfull width; mean bankfull depth; bankfull cross sectional area; bankfull discharge; mean bankfull velocity; maximum bankfull depth; width to depth ratio; width of flood prone area; entrenchment ratio; ratio of pool depth to mean bankfull depth; ratio of pool width to mean bankfull width; average

[2] Applied River Morphology (Dave Rosgen, 1994)

riffle, pool, run and glide slope; average water surface slope; valley slope; meander length; belt width; radius of curvature; ratio of meander length to bankfull width; ratio of radius of curvature to bankfull width; meander width ratio; sinuosity; pool to pool spacing; ratio of pool to pool spacing to bankfull width; D50 of bed materials; D84 of material which will be transported during a bankfull event; critical dimensionless shear stresses; minimum mean bankfull depth calculated using dimensionless shear stress equations.

10.3.6.4 Channel Stabilization Methods

Methods to be utilized to stabilize channel banks below the bankfull depth should be included within the design submittal. The use of rock should be limited to areas exhibiting shear stresses above allowable shear stresses for vegetation. The use of native vegetation and soil bioengineering treatments is the preferred method to stabilize channel banks.

10.3.6.5 Aquatic Habitat Enhancements

The use of aquatic habitat enhancements should be included where possible and consistent with stream types. Enhancements may include a variety of structures consistent with stream types such as woody material, rock or wood overhangs, rock vanes, cross vanes, W-weirs, J-hook weirs, stream gravel/boulders, etc. Details for all structures shall be included with the design submittal. In most instances, it is not necessary to extend any in-stream structures or bank revetments above the bankfull depth.

10.3.6.6 Riparian Corridor Enhancements

Where practical, the design shall include enhancements to the riparian corridor on either side of the reconstructed stream. Riparian corridor enhancements shall include native plantings consistent with anticipated inundation periods. Submittals shall include a description of existing vegetation within the riparian corridor as well as proposed plantings and frequency schedules.

10.3.7 Surface Inlets and Gutter Spreads

This section describes the technical criteria necessary to design surface inlets/catch basins. Please reference HEC -12, Drainage of Highway Pavements for a more in-depth discussions and procedures.

10.3.7.1 Design Storm

Curb inlets and gutter spreads and other stormwater inlets shall be designed for the 10-year storm return period and checked against the 100 year storm for overtopping of the roadway crown.

10.3.7.2 Maximum Flow Spread on Pavement

Maximum flow spreads on pavement should be set by MSD in the preliminary stages of all projects.

a. Cul-de-sacs, Alleys, and Local Streets - 6 feet; 8 feet with 2 foot wide concrete curb and gutter

b. County Through Roads - 4 feet; 6 feet with 2 foot wide concrete curb and gutter.

c. **The gutter spread shall not cross the crown of the roadway during the 100 year storm.**

Flow spread is measured from the face of curb. Gutter grades of less than 0.50% should be avoided, if possible. In addition, the flow depth at any location along the curb shall not exceed 4 inches.

10.3.7.3 General

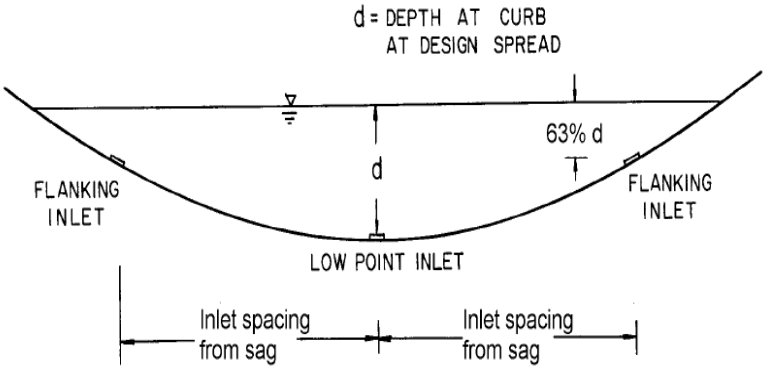
a. Inlets shall be placed immediately upstream of pedestrian walkways and intersections and designed to intercept as close to 100% of the flow as possible

b. Inlets placed at locations other than that described in Section 10.3.7.4a shall be placed at locations that prevent the allowable spread or depth at curb criteria from being exceeded. Vane grates shall be used at all inlet locations.

c. Inlets upstream of a detention basin shall have a grate elevation above the 100 year ponding elevation of the basin

d. Inlets for drains connected to the combined sewer system shall be trapped and may be designed with flow-throttling capabilities if required by MSD.

e. Inlets at sags in curb and gutter applications shall receive careful design to prevent violation of the gutter spread requirements of Section 10.3.7.3. In addition, it is good engineering practice to place flanking inlets on each side of the low point inlet when in a depressed area that has no outlet except through the system. This is illustrated in figure below.



The purpose of the flanking inlets is to act in relief of the inlet at the low point if it should become clogged or if the design spread is exceeded. Flanking inlets can be located so they will function before water spread exceeds the allowable spread at the sump location. The flanking inlets should be located so that they will receive all of the flow when the primary inlet at the bottom of the sag is clogged. They should do this without exceeding the allowable spread at the bottom of the sag. If the flanking inlets are the same dimension as the primary inlet, they will each intercept one-half the design flow when they are located so that the depth of ponding at the flanking inlets is 63 percent of the depth of ponding at the low point. If the flanker inlets are not the same size as the primary inlet, it will be necessary to either develop a new factor or do a trial and error solution using assumed depths with the weir equation to determine the capacity of the flanker inlet at the given depths.

10.3.8 Detention Basins

This section describes the technical criteria necessary to design stormwater detention basins. Detention basins are typically designed to remain empty during dry weather and to backup or detain excessive runoff generated during a storm. The designer is directed to the Detention Analysis Checklist located in the stormwater-sanitary section of MSD's web page.

10.3.8.1 Detention Basin Design

a. A minimum basin volume shall be the difference in runoff volume discharged from the project area to the basin site between the pre-development and post-development 100-year storm, or such volume to sufficiently reduce post-development discharges to pre-development rates whichever is greater. Reference Section 10.2.2.2b for the rainfall duration unique to Detention Basin Design. In cases where the volume requirement governs, the design calculations must not only show that the required volume has been created, but that the basin functions to detain the volume difference. Basin volume may also be dictated by limitations of downstream conditions or other requirements on a case-by-case basis as decided by MSD.

In many areas of the county the increased runoff volumes can be as critical, if not more critical, than the rate of discharge. MSD will address this issue on a site-specific basis. All development submittals will be evaluated for the impacts of increased runoff and volume control. Satisfying the volume requirement may be met onsite, at approved off-site locations, or by purchase of volume in a Flood Compensation Bank if one is available in the watershed.

In the Pond Creek watershed, the volume of increased runoff must be mitigated at a ratio of 1.5:1. The ratio may be increased on a site-specific basis as determined by MSD. See section 10.4.2 for other areas that have been identified with the 1.5:1 mitigation ratio. Check with MSD before during work in an area to find out the correct mitigation factor.

If the basin is to be located directly on a portion of the through drainage system, volume calculations must also consider the total system flow reaching the basin. The Design Engineer must contact MSD for direction in these

cases. If the basin is to be constructed on a solid or intermittent blue line stream, it must be beneficial to the stream corridor or the public.

b. Maximum basin side slopes shall be 3:1, unless retaining walls are provided.

c. Low flow channels may be grass if the channel grade is greater than 2.0%.

d. Basin design must include maintenance accessibility and responsibility.

e. Requirements of the Dam Safety Law shall be observed. **Any detention basin classified as a high hazard dam by the Kentucky Division of Water (KDOW) shall submit a dam breach analysis and emergency action plan to MSD.**

f. The Design Engineer shall address provisions for anti-seep collars, extended detention basins, wet ponds, soil bioengineering, baffles, outlet protection and length to width ratios.

g. No sanitary sewer manholes shall be placed within the detention basin.

h. Detention basins in Single Family Developments are to be placed in recorded "Open Spaces". All other detention basins must be completely within a recorded Permanent Detention Basin Easement.

i. Retention basins (permanent pools basins or wet basins) shall have a minimum depth of 5'.

j. The bottom of the detention basin shall have a minimum cross slope of 2% .

k Vegetated recessed islands, bio-swales, or micro-detention are acceptable alternatives in appropriate soil conditions and will be approved by MSD on a case-by-case basis. Such designs are subject to the specifications of Chapter 18 in this Manual.

l. No trees shall be allowed within the berm of the detention basin,

m. **Outlets connecting to the combined sewer system shall require backflow devices and the last structure shall be "trapped".**

10.3.8.2 Basin Discharge

a. Discharge control structures shall be multi-stage and capable of limiting 2, 10, 25, and 100-year post-development discharges to pre-development peak discharge rates or downstream system capacity and shall be constructed of concrete or approved alternate.

b. **The emergency spillway shall be sized to accommodate a flow equal to the design overflow of the 100-year storm post-development discharge, assuming all other outlets are completely blocked, without overtopping the dam**. Discharge must be conveyed to a public outlet of sufficient capacity. Erosion protection must be provided for the spillway and receiving stream and energy dissipation must be employed.

c. **The dam elevation shall not be less than one foot above the 100-year storm storage and overflow elevation.**

d. Appropriate downstream channel protection must be installed and the basin outlet pipe must be placed no closer than 15' from an adjacent property line.

e. Storage, discharge, and routing calculations for the 2, 10, 25, and 100-year discharges must be submitted for review and have a Professional Engineer's stamp and signature.

f. **The top of dam shall be at least one foot below the lowest opening of any structure adjacent to and upstream of the dam.**

g. **Detention basins shall be fully discharged, or return to normal pool elevation in the case of wet basins, within 36 hours** after the storm event unless specifically approved by MSD on a case-by-case basis.

h. **The detention basin shall be the first item of construction and must be designed to function as a sediment basin through the construction period.** The

basin design must be checked for capacity due to additional runoff generated by disturbed site conditions. The detention basin may be designed with over-excavation to account for planned sedimentation during construction. Excess sedimentation shall be removed and disposed of properly to establish design capacity of the detention basin.

10.3.8.3 Parking Lot Storage

a. Parking lot storage involves shallow ponding in a specifically graded area of a parking lot.

The major disadvantage is the inconvenience to users during the ponding function. Clogging of the flow control device and icy conditions can be maintenance and safety problems. This method is intended to control the runoff directly from the parking area and is not appropriate for storing large volumes.

Parking lot storage shall generally be limited to those areas served by combined sewers, primarily in the central business district of Louisville. Parking lot storage may be approved in separate sewer areas on a case-by-case basis.

b. The general design requirements are:

1. Maximum water depth: 8 inches
2. Minimum ponding area distance from buildings: 10 feet
3. Maximum surface grade: 5.0%
4. Minimum surface grade: 1.0%
5. Maximum discharge to combined sewer system: 10-year pre-development discharge unless otherwise determined by MSD

10.3.8.4 Underground Detention

a. All applicable standards from Sections 10.3.8.1 and 10.3.8.2 shall apply.

b. **All underground detention (including oversized piping) shall be bonded.** Bond quantities shall be submitted to MSD during the review period by the engineer or contractor. The system shall be tele-inspected prior to bond release.

c. The maximum tributary area to one underground detention system shall be no greater than 25 acres.

d. No through drainage shall be allowed in an underground detention system (exceptions may be made for small amounts of offsite sheet flow).

e. All adjacent buildings and equipment shall be at least one foot above the 100 yr Water Surface Elevation

f. All underground detentions systems shall be setback no less than 50’ from a septic field or water well.

g. **All underground detention systems shall have a grit removal system at the basin inlet.**

h. All underground detention systems shall be of sufficient capacity to hold the 100 year storm without surcharging.

i. All underground detention systems shall have an emergency overflow.

j. The minimum pipe size and vault height for underground storage structures shall be no less than 36”.

k. **All underground detention systems shall have a Long Term Maintenance Agreement that shall be recorded.**

l. Underground detention systems connected to the combined sewer system shall require backflow devices and the last structure shall be "trapped".

10.3.9 Sinkholes

10.3.9.1 General

A sinkhole is any closed depression in a limestone region formed by the removal of water, surfacial soil, rock or other material that is connected to a cavern or underground passage. The sinkhole drainage area shall include any area that contributes surface water directly to the sinkhole.
The use of sinkholes as stormwater management facilities is not permitted, unless there are no other cost-effective alternatives. Then a submittal must be sent to MSD for approval.

10.3.9.2 Design

Specific design considerations for the use of sinkholes, when permitted, include but are not limited to:

a. **The sinkhole shall have the volume to store a 100-year, 24-hour NRCS storm with a no outlet condition**.

b. The capacity of the sinkhole outlet shall be verified by a Hydro-geologic study and dye test.

c. Protection measures for the sinkhole inlet.

d. Trash barriers.

e. Detention requirements.

f. An alternate means of surface water disposal in the event of sinkhole failure.

g. Restriction of development in floodplain areas adjacent to the sinkhole.

h. Review of construction methods and staging.

i. **The design of sinkhole structures must be supervised by a Geotechnical Engineer, licensed in the Commonwealth of Kentucky.** The engineer shall also inspect and certify the construction of the sinkhole structure and certify the ability of the sinkhole to accept anticipated

flows without flooding or causing property damage in the case of failure.

j. A member of MSD's Maintenance Division must be present on all final inspections for bond release for new subdivisions.

k. Any structural failures must be fully documented and a Geotechnical Engineer, licensed in the Commonwealth of Kentucky, must supervise design of, inspect and certify construction of repairs prior to bond release.

10.4 LOCAL REGULATORY FLOODPLAIN AND CONVEYANCE ZONE

For background information on the Louisville and Jefferson County Floodplain Ordinance and the associated restrictions, refer to section 3.7. It is suggested that MSD be contacted in the early stages of any project if clarification is needed concerning requirements and restrictions. This section defines Floodplain Compensation and describes the methodologies to be used when determining the Local Regulatory Floodplain (LRFP) and Local Regulatory Conveyance Zone (LRCZ).

10.4.1 Definitions:

"Local Regulatory Flood" means the flood having a one-percent (1%) probability of being equaled or exceeded in any given year based on a fully developed watershed.

"Local Regulatory Floodplain" means any stream course or normally dry land area susceptible to being partially or completely inundated by the overflow of water from sources of public water or by the unusual and rapid accumulation or runoff of public surface waters and subject to a local regulatory flood.

"The Local Regulatory Conveyance Zone" is the channel of a river or a solid blue line stream and the land adjacent to that river or stream which, if unobstructed, will discharge a local regulatory flood without cumulatively increasing the water surface elevation more than one tenth of one foot. The conveyance zone is determined by an equal loss of conveyance (at higher elevation) occurring on each side of the channel.

"Floodplain Storage Compensation" means an artificially excavated, hydraulically equivalent volume of floodplain storage sufficient to offset a reduction in floodplain storage resulting from filling or construction within the local regulatory floodplain.

10.4.2 Floodplain Compensation

Floodplain compensation at a ratio of 1:1 is required throughout Jefferson County as part of the Floodplain Ordinance. Due to the severe flooding problems in the lower portion of the **Pond Creek watershed**, **the required ratio is 1.5:1 for any fill placed in the fully developed local regulatory floodplain. The 1.5:1 ratio also applies in Chenoweth Run of the Floyds Fork watershed and Big Run of the Mill Creek watershed.** These ratios may be increased on a site-specific basis as determined by MSD.

10.4.3 Determinations

a. MSD has approximate elevations for the LRFP in many locations. Additionally, hydraulic modeling currently exists for many streams in Jefferson County; these models may be utilized to determine the LRFP and LRCZ. If information is not available from MSD, then it will need to be defined as a part of the project.

b. Natural Resource Conservation Service Methodology (NRCS) shall be used for runoff calculation. A 24-hour Type II storm distribution with five-minute increments is required. Other distribution methods may be approved by MSD on a case-by-case basis.

c. Curve numbers (CN) and time of concentrations (T_c) shall be based on a fully developed watershed as zoned at the time of design.

d. Hydrology information may be computed using HEC-HMS, POND PACK, or Hydraflow. Hydraulic modeling should be based on HEC-RAS. In each case, other software can be utilized if approved by MSD.

10.5 HYDROLOGIC AND HYDRAULIC MODELING STANDARDS

Development of uniform modeling standards is a means by which MSD can regulate the quality of the floodplain models in Jefferson County. Successful floodplain management requires that the hydrologic and hydraulic floodplain models be updated as changes in watersheds occur. These changes include those resulting from continued development in the watershed, as well as from physical changes in the drainage system. As the watersheds evolve over time, the modeling standards provide guidance on how changes should be incorporated into the models. The implementation of a comprehensive set of modeling standards promotes consistency in floodplain modeling, standardizes MSD review effort, and provides a means to educate the engineering/development community.

Hydrologic and hydraulic modeling criteria have been established in Jefferson County through the combined efforts of MSD, U of L, the Kentucky Division of Water, KYTC, the Louisville District Army Corps of Engineers and local engineering consultants.

The following modeling guidelines are consistent with current engineering standards of practice not necessarily to the exclusion of other sound and technically supported procedures. A licensed professional engineer should justify the use of methods other than those described below in writing prior to the model submittal and review process.

Contact the MSD Development Team for surface stormwater models.

10.5.1. Software Selection

HEC-HMS is the recommended program for rainfall/runoff hydrologic simulations requiring hydrograph analysis at one or more points along a stream. HEC-RAS is the recommended program for open channel flow or floodplain calculations excluding streams with extremely low or high gradient. The most current versions of these software packages are available from the Hydrologic Engineering Center's website at www.hec.usace.army.mil. The HEC manuals offer guidance for conversions to the newer versions of their software. Other software may be accepted for floodplain analysis in Jefferson County if approved by FEMA for NFIP usage. A list of accepted models may be found at www.fema.gov. Civil site analysis, local detention basin design, water quality analysis, natural channel design, and interior drainage system design may be performed with models not on FEMA's approved NFIP list if approved by MSD prior to use on a case by case basis.

10.5.2. Hydrologic Modeling

The following methods and/or parameters should be used for single event hydrologic analyses for streams and/or detention basin calculations.

10.5.2.1. Basin Parameters

a. Subbasin Delineation. Depending on the size and location of the watershed being analyzed, and the extents of previous modeling attempts, tributary boundaries may need to be redefined or subdivided. Drainage areas must be delineated using LOJIC mapping with 2-ft contours in Jefferson County. In areas where watersheds extend into other counties and LOJIC data is not available, supplement the topographic data with 7-1/2 Minute USGS Topographic Quadrangles. Subbasin size in developable watershed areas should be 50 to 200 acres. Areas that are not

expected to develop due to land use or zoning criteria, such as the Jefferson Memorial Forest, can have larger subbasin areas based on natural drainage patterns.

b. Loss Rate. The NRCS Runoff Curve Number (CN) Method, as described in TR-55 (NRCS 1986) and NEH-4 (NRCS 1985), shall be used to estimate runoff from design storms. Continuous simulations, if necessary, may use other loss rate methodology where applicable.

c. Transform. Rainfall excess shall be transformed into runoff using the NRCS Unit Hydrograph approach.

d. Base Flow. Unless modeling the Ohio River, base flow may be ignored during floodplain analyses.

e. Time of Concentration (T_c). The time of concentration shall be calculated for each subbasin using the combined travel times for sheet flow, shallow concentrated flow, and open channel flow in accordance with TR-55 (NRCS 1986).

f. Antecedent Runoff Conditions (ARC). Average ARC shall be used in all cases except for model calibration.

g. Infiltration. Runoff infiltration will be calculated using the NRCS Runoff Curve Number Method, as discussed above. CN's should be developed for both the "existing watershed conditions" (EX) and the "fully developed watershed conditions" (FD) and analyzed separately. EX CN's shall be estimated using LOJIC data for hydrologic soil groups, land cover type and treatment, hydrologic condition, and percentage of impervious area (connected or unconnected). Impervious area calculations should include LOJIC data sources for buildings, roads, and miscellaneous transportation such as sidewalks and driveways. FD CN's shall be estimated using soils data, existing zoning regulations, and lookup tables relating zoning designations with maximum impervious area limitations to CN values.

h. Channel Routing. Hydrograph routing through a subbasin or along a reach of stream shall use either the Modified Puls (low gradient) or Muskingum-Cunge (moderate to high gradient) routing techniques. Muskingum-Cunge 8-point cross sections are recommended for natural channels. Routing results in the hydrologic model must correlate with the hydraulic model for the same reach.

i. Reservoir Routing. Reservoir routing may be used for modeling storage effects at bridges or culverts, or may be used for detention facility analysis. In either case, the routing method shall use an elevation-volume-outflow relationship developed by the engineer with consideration of backwater effects on the outlet hydraulics. The initial conditions of reservoir elements shall be controlled by normal dry-weather water surface elevations. Documentation of methods used to derive the hydraulic response and storage capacity of structures associated with reservoir routing should accompany the submittal.

10.5.2.2. Meteorological Parameters

a. Rainfall Duration. All models used for hydraulics analysis shall use 24-hour duration design storms.
b. Total Rainfall Depth. Rainfall depths associated with various annual exceedence probabilities are referenced from *Rainfall Frequency Atlas of the United States*, U.S. Department of Commerce, Weather Bureau, 1961 (also known as TP-40). The 24-hour duration rainfall values used for analysis in Jefferson County are as follows (also see Exhibit 10-3):

- 2-year 3.2 inches
- 10-year 4.5 inches
- 25-year 5.2 inches
- 100-year 6.2 inches

c. Temporal Distribution. The NRCS Type II rainfall distribution (5-minute increment) will be used for design storm definition in Jefferson County.

d. Spatial Distribution. Design storms shall be applied uniformly and simultaneously to subbasins of the hydrologic simulation.

10.5.2.3. Control Specifications

a. Calculation Time Step. There are five-minute (or less) calculation steps required for hydrologic modeling.

b. Simulation Length. Hydrologic models must simulate the 24-hour design storm and describe watershed response until all elements are within 5% of their initial discharge conditions.

10.5.3. Hydraulic Modeling

Water surface profile modeling is required for analyzing impacts to blue line and intermittent blue line streams in Jefferson County. The one-dimensional, steady flow calculations performed by HEC-RAS are suitable for most watershed conditions. HEC-RAS also has the ability to calculate LRCZ boundaries.

10.5.3.1. Study Limits

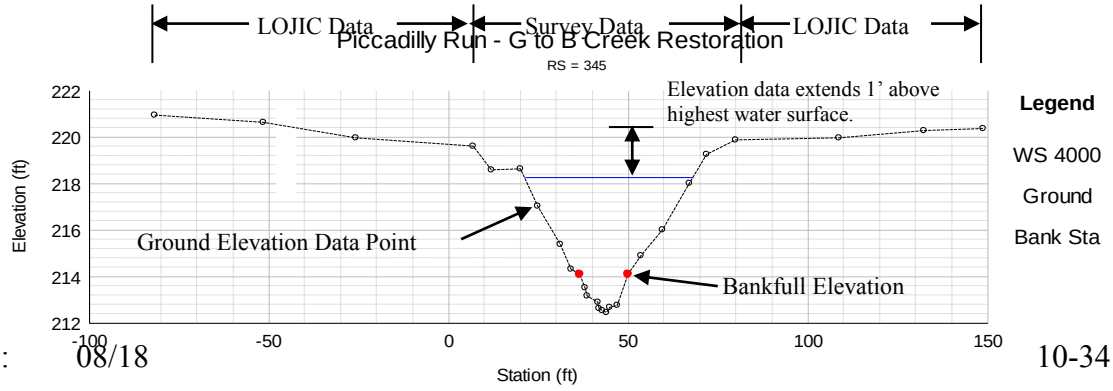
The hydraulic study should extend upstream and downstream of the impacted reach to a point that the modified profile converges with the existing condition profile for the same event. When creating new models, verify modeling extents with MSD prior to the project. GIS coverage of watershed boundaries, floodplains and conveyance zones are available with existing H-H models on the MSD web page. Changes to models typically require modification to the existing subbasins and/or cross section coverage.

10.5.3.2. Cross Sectional Geometry

a. Width. The minimum width is set by extending the left and right ends of the cross section to one foot above the LRFP elevation.

b. Spacing. Cross section locations should be based on sound engineering judgment. Higher density is required at tributary locations, slope changes, roughness changes, valley morphology changes, and at bridges or other structures. In general, cross section locations should be based on the riffle spacing of the stream being studied. Pool cross sections may be necessary for geomorphic channel design, but are not required for floodplain determination. Cross section spacing on any stream in Jefferson County should not exceed 500 feet (excluding the Ohio River).

c. Number of Data Points. A minimum of seven data points is required to describe each cross section. The maximum number of data points is limited by software constraints.



d. Source of Geometry Data. Elevation data in the active channel shall be collected with field survey and tied to the North American Vertical Datum of 1988 (NAVD 88) . The cross section geometry should have the density of points necessary to accurately quantify the area under bankfull elevation and the location of the stream thawleg. LOJIC 2-ft contour mapping may be used to supplement cross section data in the floodplain (overbanks). A licensed Land Surveyor or Professional Engineer must document the accuracy of survey information at cross sections and structures. An example of a suitable cross section is as follows:

e. Bank Stations. Bank stations in natural cross sections should be placed at the geomorphic bankfull elevation. Variations in roughness values should be included for the channel bed, left and right banks, and left and right floodplains.

f. Reach Lengths. The distances measured between cross sections at similar points are called reach lengths. HEC-RAS uses this information to compute discharge-weighted reach overbank segments. Floodplain models should use the distance measured along the stream thawleg for the centerline reach length. Left and right overbank reach lengths should be estimated as the center of mass of the floodplain discharge.

g. Roughness Values. Channel and floodplain roughness values significantly influence model accuracy. Roughness values should be reflective of the natural variations in the bed materials and overbank vegetation. Consistent with models developed in the past, Manning's n should be used to describe frictional energy losses. There are a variety of methods available for calculating Manning's n from particle size distributions of channel materials (USDA, Rosgen, and others). Listed below are some additional references available that have photographs of reaches with measured values. A listing and description of roughness values with photographs should be included in the documentation of the model development.

h.

References:

Open-Channel Hydraulics, Chow, 1959
Roughness Characteristics of Natural Channels, Barnes, Harry H., USGS, 1967
Roughness Characteristics of New Zealand Rivers, Hicks and Mason, 1991
Stream Corridor Restoration Principles, Practices, and Processes, USDA, 1998
The Reference Reach Field Book, Rosgen, 1998

i. Expansion and Contraction Coefficients. Subcritical flow contraction and expansion coefficients are used to estimate energy losses caused by abrupt changes in the flowing cross sectional area. Typical losses occur upstream and downstream of bridge or culvert crossings and flow through a narrower portion of the valley. Where contraction and expansion losses are expected to occur, contraction coefficients should vary between 0.1 and 0.3, expansion coefficients should vary between 0.3 and 0.5. FEMA requires documentation of loss coefficients higher than these ranges.

j. Ineffective Flow Areas. Effective flow, in one-dimensional modeling, is the portion of the flow traveling in the downstream direction. Portions of the cross section that are occupied by water but not flowing in the downstream direction are described as ineffective flow areas and should be specified. A definition of ineffective flow areas should be justified in the report. Ineffective flow areas in urban watersheds must reflect current development. It is typical to have ineffective flow areas upstream and downstream of bridges.

k. Levees. The use of the levee option in HEC-RAS must be used to describe a levee in accordance with FEMA regulations and justified for NFIP use. Use of the levee option in the hydraulic model for other reasons than the description of a legitimate flood control measure must be approved by MSD in advance.

10.5.3.3. Structures

a. Required Structures. Bridges, culverts, significant pedways and other stream crossings should be included in the hydraulic model. The geometry of the obstruction should be surveyed and related to NAVD 88. Normal stream debris should be reflected in the reach's roughness values.

b. Analysis Methods. Refer to *Hydraulic Reference Manual* Version 2.0 or higher (HEC). The selected method is at the discretion of the engineer but must be documented in the report.

10.5.3.4. Steady Flow and Boundary Conditions

a. Frequency of Flow Data. The hydrologic model must be sufficiently subdivided to provide flow change locations along the study reach. New flow data should be added to the hydraulic model when the flow rate changes by ±10%.

b. Upstream or Downstream Boundary Conditions. Within each of the eleven major watersheds of Jefferson County, hydraulic models should be connected by junctions or downstream boundary conditions representing larger streams. Normal depth is used to represent the upstream or downstream boundary condition, or starting water surface, when the study reach is sufficiently remote from streams with existing models. If the study reach can be extended to a modeled reach then either a junction should be used or the downstream boundary of the new reach should be set at the water surface elevation of the larger tributary modeled with the same storm event. This conservative "simultaneous peak" approach is used for regulatory models to define the worst possible case of floodplain inundation. A minimum of ten cross sections should be placed between the boundary conditions and the study reach. LRCZ boundary conditions are set at the LRFP elevation plus 0.1 feet.

c. Internal Boundaries (Junctions). Where possible, newly modeled tributaries will be connected to larger streams with junctions. Under most floodplain modeling conditions in Jefferson County the energy losses occurring at locations where streams come together can be calculated with the Energy Equation option in HEC-RAS. The reach distance across junctions should be minimized to reduce errors when using this option.

10.5.3.5. HEC-RAS Methodology

a. Friction Slope. Use the HEC-RAS Average Conveyance Method.

b. Calculation Tolerances. Use the HEC-RAS Defaults.

c. Conveyance Method. The suggested method, for consistency, is to use the HEC-RAS default, which calculates conveyance in areas defined by changes in Manning's "n" values only.

d. Floodway Methodology. Floodway determinations are required for blue line or intermittent blue line streams in Jefferson County. The LRCZ is determined by using the encroachment options available in HEC-RAS. LRCZ boundaries are established by encroaching into the LRFP, producing equal loss in conveyance from both sides of the channel until the water surface has risen 0.1 feet. Floodway determination should include consideration of expansion and contraction losses at bridges and valley nick points. For additional guidelines refer to HEC-RAS and *Floodway Determination Using Computer Program HEC-2*, TD-5, USACE, 1988.

10.5.4. Submittals

10.5.4.1. The LRFP/LRCZ Report Details

The report should include the following:

a. Discussion of the reasons for development or modifications of floodplain models and the standards or assumptions made. The report should be a document including a cover letter signed by a licensed professional engineer.

b. Include a table defining the changes to LRFP and LRCZ limits containing the information provided in HEC-RAS with the standard table "Encroachment 1". HEC-RAS results should be submitted for the existing, or effective model, if available, the corrected effective model showing additional geometry information from the study reach, and the proposed model.

c. Tables of the watershed and basin parameters, i.e. time of concentrations, curve numbers for existing and fully developed conditions and watershed areas.

d. Photographs of representative reaches and all bridges or culverts in the hydraulic model.

e. A table of HEC-HMS elements that correspond to flow change locations in HEC-RAS including junction name, cross section name, the road name at road crossings, and LRFP discharge.

f. Water surface profiles for all events modeled.

g. Typical cross sections showing water surface elevations and encroachment limits.

h. Hardcopies of existing HEC data files used to generate the updated models.

i. A hardcopy summary of HEC-HMS results (standard output table).

j. Digital versions of models prepared for the analysis.

10.5.4.2. Watershed Analysis Mapping

a. Mapping shall include soils, land use, zoning, streams, buildings, roads, existing and proposed LRFP/LRCZ boundaries, hydraulic cross sections and study reach limits, at a minimum. The standard scale for paper maps is 1" = 400' or less using 2-ft contours. Contact LOJIC for digital or paper mapping**.** Contact MSD for guidance and methodology for mapping the LRCZ from model results. Encroachment stations shown on final mapping shall be represented in the final model runs.

b. Digital copies of cross section or subbasin modifications are required. Submittals may be as ESRI shapefiles or *.DXF files referenced to LOJIC coordinate systems.

10.5.4.3. Transmittal Medium

All digital materials, including HEC models, ESRI shapefiles, DXF files, digital photographs, H-H modeling parameters, etc. should accompany submittals on a CD bound into the report.

10.6 Combined Sewer Floodprone Development Requirements

10.6.1 Definitions

"Accessory structure" - A structure located on the same parcel of property as the principal structure, the use of which is incidental to the use of the principal structure. Accessory structures shall constitute a minimal initial investment, shall not be used for human occupancy, and shall be designed to have minimal flood damage potential. Examples of accessory structures are detached garages, carports, storage sheds, pole barns, and hay sheds.
"Combined Sewer Floodprone Area" – Area delineated as having a 1% annual chance or greater of flooding due to surcharging of the combined sewer system.
"Combined Sewer Floodprone Elevation" – Elevation of the 1% annual chance or greater flood as determined by hydraulic modeling of the combined sewer system.
"Critical Facility" - Any facility which if unusable or unreachable because of flooding would seriously and adversely affect the health and safety of the public. Critical facilities, to include, but not limited to schools, hospitals, nursing homes, and housing likely to contain occupants not sufficiently mobile to avoid injury or death unaided during a flood; police stations, fire stations, emergency vehicle and emergency equipment storage facilities, and emergency operations centers likely to be called upon before, during and after a flood; public and private utility facilities important to maintaining or restoring normal services before, during and

after a flood; and those structures or facilities which produce, use, or store highly volatile, flammable, explosive, toxic, and/or water reactive materials.
"Floodprone Area Storage Compensation" - An artificially excavated, hydraulically equivalent volume of storage sufficient to offset a reduction in storage resulting from filling or construction within the combined sewer floodplain area as determined by the administering agency. Such storage compensation shall be provided on the same property or at an alternate site if the administering agency so approves.

10.6.2 Determinations

a. Limits of the combined sewer floodprone area can be found on the LOJIC Online Map. Limits of this area are also available from LOJIC. The combined sewer floodprone area was determined using two dimensional hydraulic modeling software (Innovyze InfoWorks ICM) to determine the surcharge from the combined sewer system during a 1% annual chance or greater storm.
b. A 24-hour Type II Storm distribution with 5 minute increments was used. Runoff calculations are based on an assigned percent impervious for each basin. The Horton Infiltration methodology was used in pervious areas. Runoff response was based on a calibrated slope/basin dimension using the EPA-SWMM runoff methodology.
c. Mapping of the floodprone area inundation limits is based on 3-foot LIDAR data, which was used as the basis for a 2D surface flow-routing mesh in InfoWorks ICM.
d. Elevations for the combined sewer floodprone area are available upon request from MSD.

10.6.3 Development Standards

a. For any new residential structure or new addition located in the combined sewer floodprone area, the lowest finished floor must be elevated to at least two feet above the combined sewer floodprone elevation.
b. For any new non-residential structure or new addition, the lowest finished floor must be elevated to at least one foot above the combined sewer floodprone elevation or the structure must be dry floodproofed to at least one foot above the combined sewer floodprone elevation so that those areas including all mechanical and utility equipment and ductwork below the required elevation are watertight with walls substantially impermeable to the passage of water and structural components are used which have the capability to resist hydrostatic and hydrodynamic loads and the effects of buoyancy which capabilities shall be certified by a licensed professional engineer or architect and provided to MSD.

c. Mechanical and utility equipment and ductwork associated with a new structure or addition must be elevated to at least two feet above the combined sewer floodprone elevation or for non-residential structures, dry floodproofed to at least two feet above the combined floodprone elevation.
d. If solid foundation perimeter walls are to be used to elevate the structure to at least freeboard elevation,

    1. If flood depths are more than 1', foundation walls must be designed by a professional engineer to withstand hydrostatic pressures from the 1% annual chance elevation, and
    2. All space within the area created by the solid perimeter walls shall be designated undevelopable space with a restriction recorded with the deed of such designation evidence of which recorded restriction shall be provided to the administering agency before approval of the floodplain permit, and
    3. The interior portion of the area shall not be partitioned or finished into separate rooms.
    4. Any openings, including vents, shall be elevated to at least the 1% annual chance elevation.

e. Accessory structures shall be exempt from section 10.6.
f. An elevation certificate bond shall be required for any new structure or addition located in the combined sewer floodprone area prior construction approval.
g. Any development which displaces any storage capacity for floodwaters in the combined sewer floodprone area shall provide equivalent floodprone area storage compensation.

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EXHIBIT 10-1
HYDROLOGIC METHOD SELECTION FLOWCHART

EFFECTIVE DATE: JUNE 30, 2009

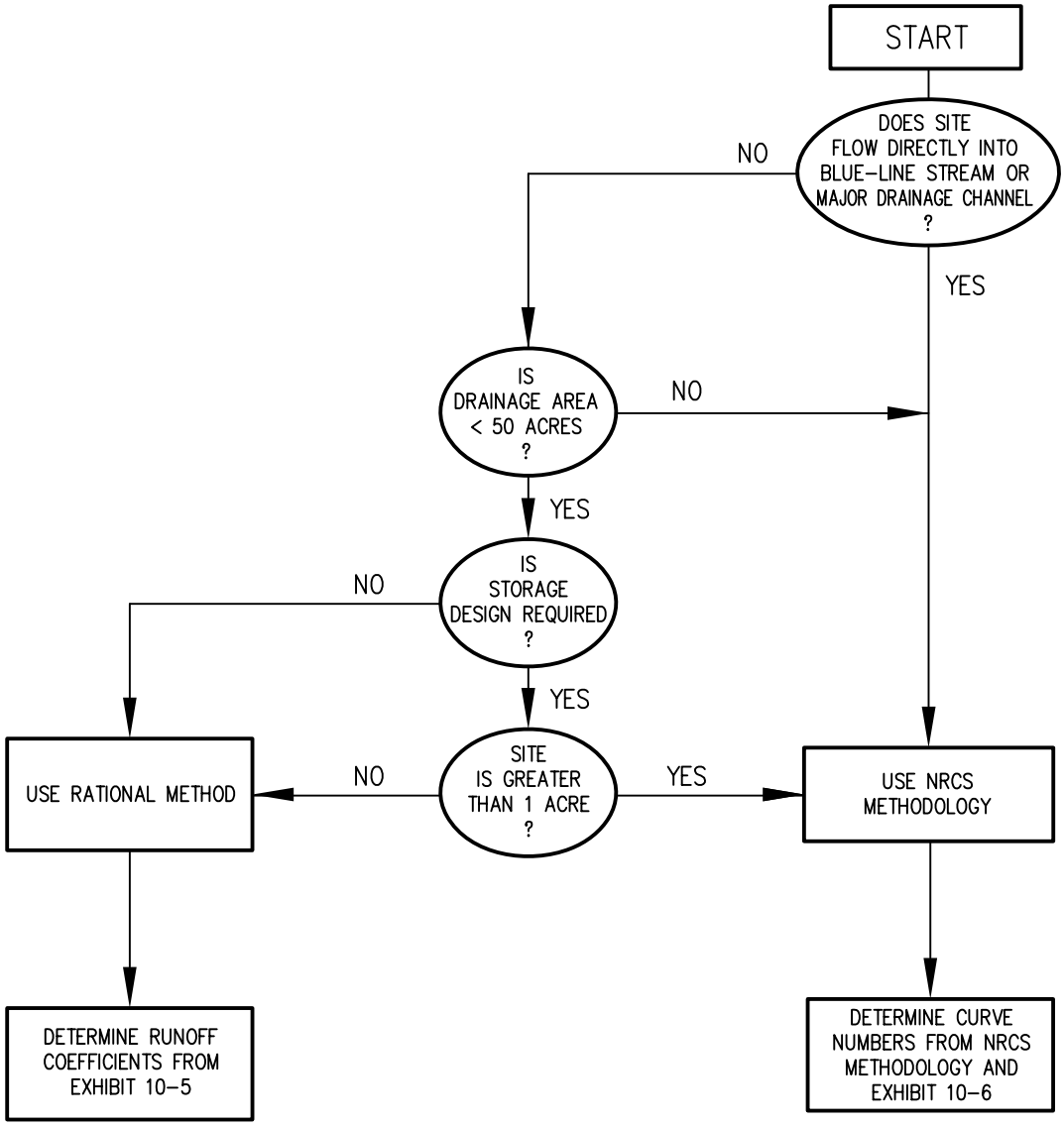

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EXHIBIT 10-2
RAINFALL INTENSITY-DURATION CURVES

EFFECTIVE DATE: JUNE 30, 2009

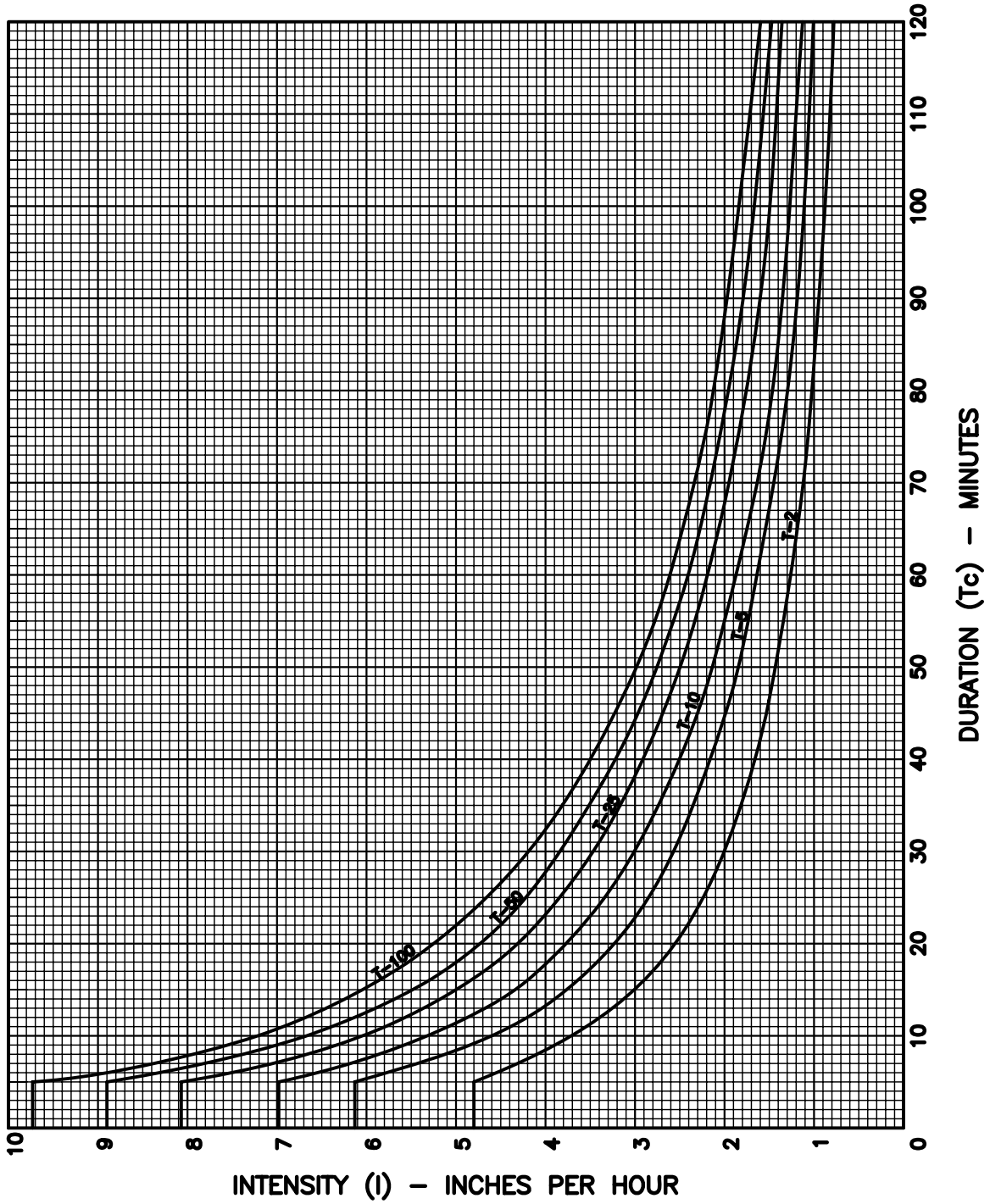

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EXHIBIT 10-3
RAINFALL FOR JEFFERSON COUNTY * (INCHES)

EFFECTIVE DATE: JUNE 30, 2009

FREQUENCY (YEARS)

DURATION	1	2	5	10	25	50	100	PMP
30 min.	1.0	1.1	1.4	1.6	1.9	2.0	2.3	
1 hour	1.2	1.4	1.8	2.0	2.3	2.6	2.8	
2 hour	1.5	1.7	2.2	2.5	2.8	3.2	3.5	
3 hour	1.6	1.9	2.4	2.7	3.2	3.4	3.8	
6 hour	2.0	2.3	2.8	3.3	3.7	4.2	4.5	28.0
12 hour	2.4	2.8	3.4	3.9	4.4	4.9	5.4	33.0
24 hour	2.7	3.2	4.0	4.5	5.2	5.7	6.2 **	35.0
2 day	0.0	3.6	4.4	5.1	6.1	6.4	7.3	38.5
4 day		4.3	5.3	6.0	6.9	7.6	8.4	
7 day		5.0	6.1	6.8	8.0	8.8	9.6	

* SOURCE:
DIVISION OF WATER RESOURCES
DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
ENGINEERING MEMORANDUM NO. 2 (4-30-71), REVISED (6-1-79)

** NOTE:
RAINFALL RANGED FROM 7.5 TO 12.5 INCHES DURING THE FEBRUARY 28/ MARCH 1, 1997 EVENT.

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EXHIBIT 10-4
HYDROLOGIC SOIL GROUPS

EFFECTIVE DATE: JUNE 30, 2009

Hydrologic Soil Group *(HSG)* is NRCS's way of summarizing soil's hydrologic effects. This classification, with land use, is one of the determinants of NRCS's Curve Number. NRCS has categorized every soil in the country into four groups, lettered A to D. Group A is the lease likely to create runoff; group D is the most likely.

The four groups are defined by NRCS soil scientists as follows:

- **Group A** soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr). This group also includes sand, loamy sand and sandy loam that have experienced urbanization but not been significantly compacted.
- **Group B** soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr). This group also includes silt loam and loam that have experienced urbanization but not been significanly compacted.
- **Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 to 0.15 in/hr). This group also includes sandy clay loam that has experienced urbanization but not been significantly compacted.
- **Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr). This group also includes clay loam, silty clay loam, sandy clay, silty clay and clay that have experienced urbanization but not been significantly compacted.

Compound classification A/D indicates that the natural soil is in group D because of a high water table which impedes infiltration and transmission, but following artificial drainage using such methods as perforated pipe underdrains, the soil's classification is changed to A.

For a specific site, *HSG* designations can be obtained by refering to a local NRCS soil survey where one is available. If the survey does not specify *HSG*s, you can look up the soil names in the complete national listing given in NRCS's *Technical Release 55.* If there is no NRCS survey at all, you can make an on-site investigation of soil charateristics, and compare them with the above definitions.

Information about HSG on this page is from page A-1 of U.S. Soil Conservation Service, 1986, *Urban Hydrology for Small Watersheds,* Technical Release 55.

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EXHIBIT 10-5 PAGE 1
RATIONAL METHOD
RUNOFF COEFFICIENTS

EFFECTIVE DATE: JUNE 30, 2009

RUNOFF COEFFICIENTS BASED ON LAND USE, SOIL GROUP AND SLOPE RANGE

LAND USE		A			B			C			D		
		0-2	2-7	7+	0-2	2-7	7+	0-2	2-7	7+	0-2	2-7	7+
Residential	%Imp												
RE, R-1, R-2	25	.31	.35	.39	.33	.38	.43	.37	.41	.48	.40	.44	.52
R-3, R-4, R-5	38	.42	.45	.49	.44	.48	.52	.47	.50	.56	.50	.53	.59
R-5A, R-6, R-7, CN, OR-1	65	.65	.67	.69	.66	.68	.71	.68	.70	.73	.69	.71	.75
R8A OR-2, OR-3, OFT	75	.73	.75	.77	.75	.76	.78	.76	.77	.79	.77	.78	.80
Commercial Business C-M, C-1 thru C-5	85	.82	.83	.84	.83	.84	.85	.84	.85	.86	.84	.85	.86
Industrial RT, M-1, M-2, M-3	72	.71	.73	.74	.72	.74	.76	.73	.75	.77	.75	.76	.79
Roofs, Driveways Streets, Etc.	100	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Open Spaces, Lawns, Parks, Etc.	0	.09	.15	.21	.13	.19	.26	.18	.23	.32	.22	.27	.37
Woodlands,	0	.09	.15	.20	.13	.18	.23	.17	.22	.26	.20	.25	.30
Pasture, Grass, and Farmland	0	.15	.20	.25	.18	.23	.30	.22	.26	.35	.25	.30	.40
Newly Graded/Disturbed,		.65	.67	.69	.66	.68	.71	.68	.70	.73	.69	.71	.75

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Unclassified Areas – These are areas where the Natural Resources Conservation Service has not identified any hydrologic soil groups

		0–2	2–7	7+
Residential	%Imp			
RE, R–1, R–2	25	.37	.41	.48
R–3, R–4, R–5	38	.47	.50	.56
R–5A, R–6, R–7, CN, OR–1	65	.68	.70	.73
R8A OR–2, OR–3, OFT	75	.76	.77	.79
Commercial Business C–M, C–1 thru C–5	85	.84	.85	.86
Industrial RT, M–1, M–2, M–3	72	.73	.75	.77

Notes:

1. Where the imperviousness is significantly different from the assumed values, a weighted coefficient should be computed using the actual percent impervious.
2. Consideration should be given to whether the soil group has been changed due to soil compaction by heavy equipment or mixing of the surfaces and subsurface soils

References:

1. Rossmiller, Ronald L., The Rational Formula Revisited, Proceedings International Symposium on Urban Storm Runoff, University of Kentucky, Lexington, Kentucky, July 28 – 31, 1980.

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Runoff Curve Numbers for Urban Areas
(See Section 10.2.3.2)

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type and Hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Fully Developed Urban Areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.):					
Poor Condition (grass cover < 50%)		68	79	86	89
Fair Condition (grass cover 50% to 75%)		49	69	79	84
Good Condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right of way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (previous areas only)		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1 to 2 inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c)					

Reference Table 2-2a. pg.2-5 of 210-VI-TR-55, Second Ed., June 1986

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Runoff Curve Numbers for Cultivated Agricultural Lands

Cover Description			Curve Numbers for Hydrologic Soil Group			
Cover Type	Treatment	Hydrologic Condition	A	B	C	D
Fallow	Bare Soil	–	77	86	91	94
	Crop Residue Cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight Row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR and CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T and CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR and CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C and CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T and CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Table 2-2b. pg. 2-6 of 210-VI-TR-55, Second Ed., June 1986

Runoff Curve Numbers for Other Agricultural Lands

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition	A	B	C	D
Pasture, grassland, or range – continous forage for grazing.	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continous grass, protected from grazing and generally mowed for hay.	–	30	58	71	78
Brush – brush–weed–grass mixture with brush the major element.	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods – grass combination (orchard or tree farm).	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots.	–	59	74	82	86

Table 2–2c. pg. 2–7 of 210–VI–TR–55, Second Ed., June 1986

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

Land Use Definition	Soil Group A	Soil Group B	Soil Group C	Soil Group D	Unclassified
High Density	89	92	94	95	93
Medium Density	77	85	90	92	87
Low Density	61	75	83	87	79
Open/Undisturbed	49	69	79	84	74

The Land Use Definitions are based upon the following conditions:

- High Density – 85% Impervious – Commercial
- Medium Density – 65% Impervious – 1/8 Acre lots
- Low Density – 38% Impervious – 1/4 Acre lots
- Open/Undisturbed – Grass cover on 50% to 75% of the area

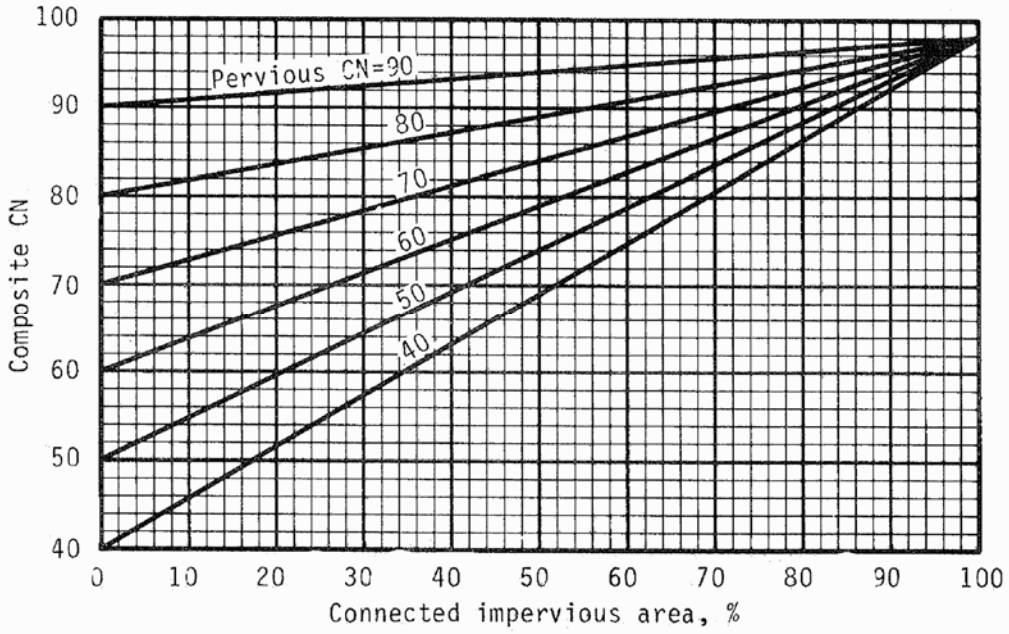

Figure 4-5 - NRCS Composite CN with connected impervious area

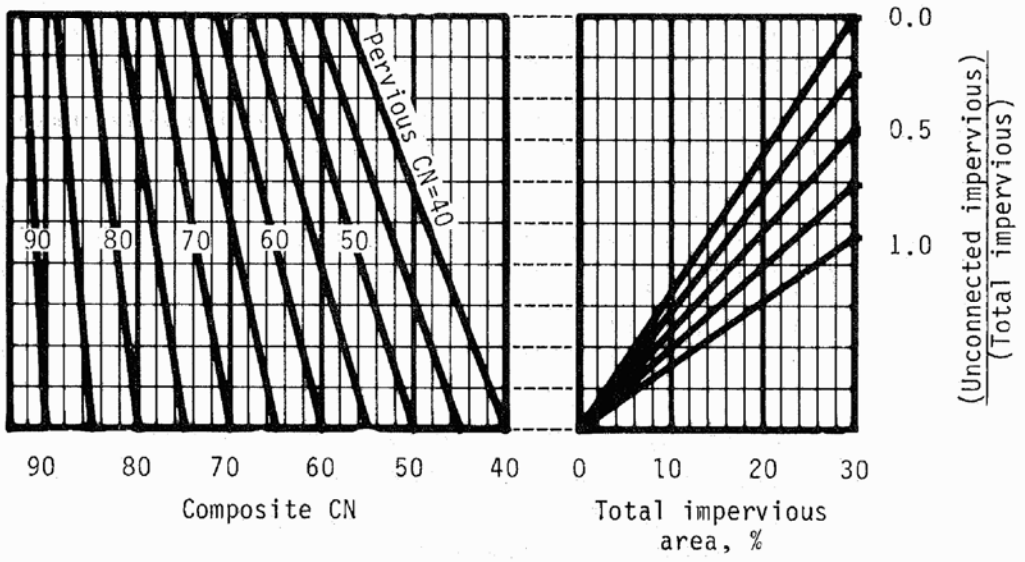

Figure 4-6 - NRCS Composite NC with connected impervious area and total impervious area less than 30%

MSD
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Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
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MANNING ROUGHNESS COEFFICIENTS, (n)

EFFECTIVE DATE: JUNE 30, 2009

		Manning's n Range
I.	CLOSED CONDUITS: *	
A.	Concrete pipe	0.012
B.	Smooth wall PVC	0.011
C.	Corrugated-metal pipe or pipe-arch:	
1.	2-2/3 by 1/2 in. corrugation (riveted pipe):	
a.	Plain or fully coated	0.024
b.	Paved invert (range values are for 25 and 50 percent of circumference paved:	
(1)	Flowing full under pressure	0.021-0.018
(2)	Flowing part full, depth 0.8D	0.021-0.016
2.	6 by 2 in. corrugation (field bolted)	0.030
D.	Vitrified clay pipe	0.012-0.014
E.	Cast-iron pipe, uncoated	0.013
F.	Steel Pipe	0.009-0.011
G.	Brick	0.014-0.017
H.	Monolithic Concrete:	
1.	Wood forms, rough	0.015-0.017
2.	Wood forms, smooth	0.012-0.014
3.	Steel forms	0.012-0.013
I.	Cemented rubble masonry walls:	
1.	Concrete floor and top	0.017-0.022
2.	Natural floor	0.019-0.025
J.	Laminated treated wood	0.015-0.017
K.	Vitrified clay liner plates	0.015
II.	OPEN CHANNELS, NONVEGETATED LINING, (Straight Alignment): *	
A.	Concrete, with surfaces as indicated:	
1.	Formed, no finish	0.013-0.017
2.	Trowel finish	0.012-0.014
3.	Float finish	0.013-0.015
4.	Float finish, some gravel on bottom	0.015-0.017
5.	Gunite, good section	0.016-0.019
6.	Gunite, wavy section	0.018-0.022
B.	Concrete, bottom float finished, sides as indicated:	
1.	Dressed stone in mortar	0.015-0.017
2.	Random stone in mortar	0.017-0.020
3.	Cement rubble masonry	0.020-0.025
4.	Cement rubble masonry, plastered	0.016-0.020
5.	Dry rubble (riprap)	0.020-0.030

		Manning's n Range
II.	(CONTINUED)	
	C. Gravel bottom, sides as indicated:	
	1. Formed concrete	0.017–0.020
	2. Random stone in mortar	0.020–0.023
	3. Dry rubble (riprap)	0.023–0.033
	D. Brick	0.014–0.017
	E. Asphalt:	
	1. Smooth	0.013
	2. Rough	0.016
	F. Wood, planed, clean	0.011–0.013
	G. Concrete–lined excavated rock:	
	1. Good section	0.017–0.020
	2. Irregular section	0.022–0.027
III.	HIGHWAY CHANNELS AND SWALES WITH MAINTAINED VEGETATION (Values shown are for Velocities of 2 and 6 f.p.s.): *	
	A. Depth of flow up to 0.7 foot:	
	1. Bermudagrass, Kentucky bluegrass, buffalograss:	
	a. Mowed to 2 inches	0.070–0.045
	b. Length 4–6 inches	0.090–0.050
	2. Good stand, any grass:	
	a. Length about 12 inches	0.180–0.090
	b. Length about 24 inches	0.200–0.100
	3. Fair stand, any grass:	
	a. Length about 12 inches	0.140–0.080
	b. Length about 24 inches	0.250–0.130
	B. Depth of flow 0.7–1.5 feet:	
	1. Bermudagrass, Kentucky bluegrass, buffalograss:	
	a. Mowed to 2 inches	0.050–0.035
	b. Length 4–6 inches	0.060–0.040
	2. Good stand, any grass:	
	a. Length about 12 inches	0.120–0.070
	b. Length about 24 inches	0.200–0.100
	3. Fair stand, any grass:	
	a. Length about 12 inches	0.100–0.060
	b. Length about 24 inches	0.170–0.090

IV. STREET AND EXPRESSWAY GUTTERS: *	Manning's n Range
A. Concrete gutter, troweled finish	0.012
B. Asphalt pavement:	
1. Smooth texture	0.013
2. Rough texture	0.016
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. For gutters with small slope, where sediment may accumulate, increase above values of n by	0.002

V. OPEN CHANNELS, EXCAVATED OR DREDGED **	Minimum	Normal	Maximum
A. Earth, straight and uniform	0.016	0.018	0.020
1. Clean, recently completed	0.018	0.022	0.025
2. Clean, after weathering	0.022	0.025	0.030
3. Gravel, uniform section, clean	0.022	0.027	0.033
B. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
C. Dragline–excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
D. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
E. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

VI. NATURAL STREAM CHANNELS: **

	Minimum	Normal	Maximum
A. Minor streams (top width at flood stage < 100 ft)			
1. Streams on Plain			
a. Clean, straight, full stage, no rifts or deep pools. . .	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as 4, more stones .	0.045	0.050	0.060
g. Sluggish reaches, winding, deep pools	0.050	0.070	0.080
h. Very winding reaches, deep pools, floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. Bottom: gravels, cobbles, few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070
B. Flood Plains			
1. Pasture, no brush			
a. Short grass	0.025	0.030	0.035
b. High grass	0.030	0.035	0.050
2. Cultivated area			
a. No crop	0.020	0.030	0.040
b. Mature row crops.	0.025	0.035	0.045
c. Mature field crops	0.030	0.040	0.050
3. Brush			
a. Scattered brush, heavy weeds	0.035	0.050	0.070
b. Light brush and trees in winter.	0.035	0.050	0.060
c. Light brush and trees in summer.	0.040	0.060	0.080
d. Med. to dense brush, in winter.	0.045	0.070	0.110
e. Medium to dense brush, in summer	0.070	0.100	0.160

VI. (CONTINUED)

		Minimum	Normal	Maximum
4.	Trees			
A.	Dense Willows, summer, straight	0.110	0.150	0.200
B.	Cleared land w/ stumps, no sprouts	0.030	0.040	0.050
C.	Same as b., with heavy growth of spouts	0.050	0.060	0.080
D.	Heavy timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
E.	Same as d., with flood stage reaching branches .	0.100	0.120	0.160

C. Major Streams (top width at flood stage > 100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.

1.	Regular section with no boulders or brush	0.025	*****	0.060
2.	Irregular and rough section . . .	0.035	*****	0.100

* SOURCE:
KENTUCKY DEPARTMENT OF HIGHWAYS DESIGN MANUAL
EFFECTIVE DATE 3-77, EXHIBIT 2-507.1
MANNING ROUGHNESS COEFFICIENTS, n

** SOURCE:
KENTUCKY DEPARTMENT OF HIGHWAYS DESIGN MANUAL
EFFECTIVE DATE 01-01-93, EXHIBIT DR-05.901
MANNING ROUGHNESS COEFFICIENTS, n

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CHAPTER 11
PRIVATE DEVELOPMENT DRAINAGE PLAN SUBMITTAL REQUIREMENTS

11.1 PURPOSE

This chapter delineates the purpose and legal responsibility through KRS Chapter 76 and the Louisville-Jefferson County Planning Commission Development Code whereby MSD reviews and approves private development plans. Drainage systems should be designed in accordance with the applicable provisions of this and other chapters of this Design Manual and the requirements of the Floodplain and Erosion Prevention and Sediment Control (EPSC) Ordinances. Plans and specifications submitted for review should meet or exceed the minimum construction plan standards as outlined in Section 11.4. Procedures and applicable forms may be retrieved from http://www.msdlouky.org/.

The review primarily examines the development for the following:

a. Potential impacts to upstream, downstream, and adjacent properties.

b. Adequacy of drainage system outlet.

c. Public or "defined" outlet for drainage.

d. Floodplain impact.

e. Erosion Prevention and Sediment Control

f. Adherence to any applicable composite drainage master plan criteria.

11.2 PLANS SUBJECT TO REVIEW AND APPROVAL

MSD has developed checklists to assist in the submittal process. The checklist forms, which are updated periodically, can be downloaded from the MSD web page. For each situation shown below, the applicable checklist is listed. In all cases, an initial “Plan Review Application” will be submitted.

11.2.1 Preliminary Plans for the Louisville-Jefferson County Planning Commission and Board of Zoning Adjustment

a. Request for change of zoning plans.

b. Conditional use permit plans.

c. General district development plans.

d. Detailed district development plans.

e. Preliminary subdivision plans (major subdivision).

f. Board of Zoning Adjustment plans.

g. Submit **Preliminary Plan Checklist**

11.2.2 Technical Review Committee

Reviews preliminary subdivision plans that require no zoning changes.

11.2.3 Minor Subdivision Plats

Subdivision plats dividing tracts of land into two (2) or more lots not designated by the Planning Commission as a major subdivision.

11.2.4 Site Construction Plans

a. Commercial Tracts

b. Industrial Tracts

c. Fills and/or excavations not related to building construction

d. Floodplain Encroachments

e. Stream Crossings

f. Roadway Projects

g. Submit **Site Plan Review Checklist**

11.2.5 Subdivision Construction Plans (Major Subdivision)

Subdivision construction plans shall be reviewed and approved in accordance with the Louisville and Jefferson County Development Code, Metropolitan Subdivision Regulations. Submit **Subdivision Review Checklist**.

11.2.6 Record Plats

Submit in accordance with Metropolitan Subdivision Regulations.

11.2.7 Single Family Construction Plans

a. Lots located in the 100-year F.E.M.A. or Local Regulatory floodplain.

b. Lots not in a recorded subdivision or lots with sensitive features.

c. Lots in a recorded subdivision with **construction** restrictions (i.e. minimum opening elevations, lowest finished floor elevations, **steep slopes and geotechnical evaluations,** etc.) on the recorded plat.

11.2.8 Industrial Waste/Hazardous Materials Spill Prevention and Control Plans

Submit an information checklist available by contacting MSD.

11.3 LEVELS OF REVIEW

11.3.1 Preliminary Plan Approval

Plans specifically prepared for the Planning Commission or the Board of Zoning Adjustment (BOZA) showing conceptual drainage conditions which identify and address potential impacts on public sewer and drainage facilities shall be submitted for MSD review. If significant or sensitive features exist on a site, see Chapter 12, a conceptual EPSC plan will also be required. Plans must receive MSD's stamp of approval in order to be placed on the Planning Commission Land Development and Transportation Committee or BOZA docket. The **Preliminary Plan Checklist** must be submitted before MSD will review the plans.

11.3.2 Construction Plan Approval

Plans for which building or construction permits are being sought must be reviewed and approved by MSD prior to obtaining these permits. Either the MSD **Subdivision Review Checklist** or the **Site Plan Review Checklist** must be submitted**, as well as Detention Checklist and EPSC Checklist**.

11.4 MINIMUM CONSTRUCTION PLAN SUBMITTAL STANDARDS

11.4.1 Major Subdivision Plans

All correspondence and plan submittals should reference the Water

Management Number as assigned by MSD's **Development Plan Review Team**.

Major Subdivision Plans for the development of more than four (4) lots require dedication of roadways for access.

All plans must be submitted on 24 x 36 inch sheets.

Submit "Extension of Stormwater Boundary Agreement" **with Corporate Resolution and plat showing development boundaries** (if applicable).

11.4.1.1 Cover Sheet

a. Location Map with the site outlined.

b. Title Block: Title of Subdivision, name and address of developer, name address and email address of Engineer, date of preparation, revision dates.

c. Index of Sheets and Legend

d. Engineer's and Land Surveyor's seals, signatures, and dates

e. Water Management Number: As assigned by MSD's **Development Plan Review Team**

f. Utility Notes

11.4.1.2 Composite Drainage Plan

a. Topography: Minimum Scale 1" = 100' with existing contours at 2-foot intervals, **NAVD 88** datum. Contours to extend a minimum of 50 feet beyond property lines.

b. Proposed Development: Street rights-of-way, street names, street centerline stationing, lot lines, lot numbers, property boundary, existing drainage structures, proposed drainage structures (labeled by number or other designation) and easements with widths shown.

c. Hydrologic Designate drainage areas

Data: (in acres) to individual inlets, and off-site drainage areas (acres), which generate through drainage.

d. Pipe Chart: Pipe number, drainage area, coefficient of runoff (c), time of concentration, intensity, discharge (Q), size, length, slope, capacity, velocity, and headwater depth for both the 10-year and 100-year Qs.

e. 100-year FEMA and Local Regulatory floodplain and conveyance zone, if applicable, with flood elevations noted.

g. Identification of outlet system.

11.4.1.3 Grading and Erosion Prevention and Sediment Control Plan

a. Existing and Proposed Contours

b. Erosion Prevention and Sediment Measures (Reference Chapter 12 and **EPSC Checklist**).

c. Proposed Development: Street rights-of-way, street names, street centerline stationing, lot lines, lot numbers, property boundary, existing drainage structures, proposed drainage structures (labeled by number or other designation) and easements.

d. Grading Plan may be combined with Composite Drainage Plan provided the plan remains legible.

e. Areas of slope greater than or equal to 20% shall be identified.

f. Stream Buffers if applicable.

g. **Limits of disturbance and number of acres disturbed.**

11.4.1.4 Plan and Profile (Road) Sheets

Plan View

a. Catch Basins: Line and station number (structure number),

grate type and elevation, and invert elevation.

b. Pipes: Length, size, type, slope, pipe number or designation.

c. Headwalls: Type, invert elevation.

d. Ditches and Swales: Number or designation, type, stations

e. Easements: Type, size, existing with deed book and page numbers, proposed.

f. Utilities: Existing and proposed (including sanitary sewers).

g. Other drainage structures to be labeled accordingly.

Profile View

a. Storm lines and structures to be shown on road profiles.

b. Utility and sanitary sewer crossings.

11.4.1.5 Storm Drainage Profiles (pipes, ditches, box culverts)

a. Catch Basins: Station or number, type, grate type and elevation, invert elevation, and headwater elevation (10 and 100 year).

b. Pipes: Length, size, type, class, grade, line number if applicable, HGL (10 and 100 year).

c. Ditches:

- Type
- Grade
- Flow line elevation at grade changes (P.V.I)
- Design Depth
- Mannings “n”
- Slope
- 10 and 100 year discharge depths
- **Channel Shear Stress**

d. Headwalls: Type and invert elevation.

e. Existing and proposed ground surfaces.

11.4.1.6 Standard Detail Sheet

Reference sections 4.4.1 and 4.4.6 for the incorporation of MSD Standard Drawings and Special Details unique to the project. If pre-cast structures are used from sources not on the current MSD Pre-approved source list, then shop drawings of the structures must be approved by MSD prior to construction.

11.4.1.7 Additional Submittal Items

a. **Specifications – All storm drainage construction is expected to conform to MSD Standard Specifications. Any deviations from the specifications must be noted on the plans and be approved by MSD.**

b. **Quantities** - Detailed breakdown of all items, related to storm drainage construction needed by MSD to determine the amount of the subdivision bond.

c. **Approved Preliminary Plan -** including sanitary sewer layout.

d. **Clearing and Grading Plan** - required if site clearing and grading is to precede approval.

e. **Detention Basin Calculations** - if applicable and in accordance with the provisions of Chapters 10 and 12.

f. **Highway Encroachment Permit** - (if applicable).
All construction plans for major subdivisions shall conform to Article 6 of the Louisville and Jefferson County Planning Commission Subdivision Regulations.

g. **Section 404 Permit -** (if applicable) from the U.S. Army Corps of Engineers.

h. **Application for Water Quality Certification** - (if applicable) from the Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Water Quality Branch.

i. **Application for Permit to Construct Across or Along a Stream** - (if applicable) from the Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Floodplain Management Section - Water Resources Branch.

j. Copy of Demolition Permit or General Permit (if applicable).

k. Copy of Approval Letter for private WWTP (if applicable).

i Request for sanitary sewer capacity.

11.4.1.8 Submittal

Two sets of construction plans and specifications are to be submitted for initial review by MSD. Variations from the Minimum Construction Plan Submittal Standards will require prior approval from MSD. Any conditions of the Approved Preliminary Plan (such as geotechnical report, state approvals, etc.) must be addressed at the time of construction plan submittal to MSD.

11.4.2 All Other Development Plans (Site, etc.)

Submit "Extension of Stormwater Boundary Agreement" with Corporate Resolution and plat showing development boundaries (if applicable).

11.4.2.1 Existing Topography Plan

This plan shall conform to Development Code Section 8.1.B.4 requirements with the following additional data:

a. Spot elevations at critical points.

b. 100-year FEMA **Floodway** and Local Regulatory floodplain and conveyance zone, if applicable, with flood elevations noted.

c. Off-site drainage area in acres, which generate through drainage.

11.4.2.2 Proposed Development and Grading Plan

This plan may be combined with the plan described in paragraph 11.4.2.1 if existing features can still be discerned. This plan shall also

conform to the requirements of Section 8.1.B.4 of the Development Code with the following additional data:

a. Revised hydrologic data, runoff calculations, and detention basin design, if applicable.

b. Hydraulic data, such as pipe charts and ditch data on profiles, showing quantity of flow, velocities, and degree of protection.

c. Erosion prevention and sediment control measures and details.

d. Show public outlet and evaluate capacity of downstream facilities.

e. Proposed easements for through drainage, detention facilities, and/or offsite increase in runoff.

f. Note specific conflicts with other utilities.

g. Written explanation of any proposed deviation from Planning & Design or MSD policies, standards, or design criteria and any supplemental data that would aid the understanding of the proposed plan work.

h. The stamp of a professional engineer licensed in Kentucky shall be affixed to the plan when the proposed facilities affect public drainage, downstream properties**, Regulatory Floodplain or detention**.

11.5 INSPECTION OF MAJOR SUBDIVISION CONSTRUCTION

11.5.1 General

MSD has a program of on-site inspection for the construction of **public** drainage systems in public rights-of-way or public easements. Drainage construction may begin following MSD approval of the construction plans and issuance of a **Site Disturbance Permit.**

11.5.2 Inspector Assignment

Construction of drainage structures and pipes shall not begin in a development until a MSD inspector has been assigned to the construction site. In certain situations, which will be identified during construction plan review, full-time inspection may be required. In the event that MSD personnel are not available

to provide the level of inspection necessitated by a contractor's schedule, the owner may retain (at the owner's expense) an independent inspector working under the direct supervision of a professional engineer approved by MSD. The independent inspector will be required to certify to MSD that the materials and methods of construction are in compliance with the approved plans and specifications. Arrangements for owner-provided inspection including schedule and level of effort must be approved by MSD in advance. MSD inspector shall be present during testing.

MSD requires three (3) working days advance notice to schedule an inspector for a project. To schedule an inspector, please fax the "Notice of Construction Form" to MSD.

11.5.3 Construction Plan Revisions

MSD will require the final approved construction plans bearing the Engineer's original seal, signature, and date prior to beginning storm drainage construction. Deviations from approved construction plans as a result of unexpected field conditions will require documentation and approval by MSD. To obtain this approval, the developer's engineer should submit a marked print of the plans showing the proposed revisions to MSD for review.

11.5.4 Subdivision Bond

In accordance with the Metropolitan Subdivision Regulations, MSD sets the drainage portion of the subdivision bond at 100% of the estimated construction cost consistent with past practice. When projects constructed under MSD drainage inspection are completed, they may have the drainage bond reduced to 20% of the estimated construction cost. When a subdivision is finished and at least 80% of the lots have been developed, the subdivision bond may be released following satisfactory inspections by the Board of Health, the local Fire Department, MSD and the Public Works Department.

11.5.5 Construction Initiation

Recognizing the developer's need to initiate construction in a timely fashion, MSD will allow certain construction activities to proceed prior to the approval of the entire set of construction plans. General clearing and site grading, <u>not</u> involving construction of drainage structures, roadway grading, nor significantly affecting existing drainage in the area, may be performed following approval of a Grading and EPSC Plan by MSD, Jefferson County Department of Public Works and the Planning Commission and the issuance of the necessary work order. A Grading Plan, prepared by a licensed engineer, must be submitted if site clearing and grading is to proceed prior to

construction plan approval. The three working days notice of construction form must also be submitted before clearing and grading can begin. Erosion prevention and sediment control measures in accordance with Chapter 12 of this design manual must be clearly described on the plan and must be installed prior to initiating any construction at the project site. Application for approval of a Clearing and Grading Plan may be made at the time of construction plan submittal to MSD. A notice of violation and stop-work order may be issued for failure to implement proper EPSC measures.

11.6 FEES

11.6.1 Plan Review Fees

Only applicable to development outside MSD stormwater service area including the Cities of Anchorage, Jeffersontown, Prospect, Shively, and St. Matthews. These fees must be paid prior to MSD's approval of the plans. Additionally, fees may be required for sites with extensive review of hydrologic and hydraulic modeling.

11.6.2 Stormwater Fees

11.6.2.1 Regional Facility Fee

This is a stormwater impact fee, paid by the developer on sites where MSD has determined on-site detention will not be required. This fee allows the developer to pay a proportionate share of MSD's cost of constructing Regional Stormwater Detention Facilities. For development outside MSD's drainage service area, a twenty percent (20%) surcharge will be added to the regional facility fee.

11.6.3 Compensation Fees

Fees are applicable to sites in floodprone watersheds where runoff volume compensation is required.

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CHAPTER 12
EROSION PREVENTION AND SEDIMENT CONTROL

12.1 PURPOSE OF THIS CHAPTER

This chapter of the MSD Design Manual provides the user with the tools to meet the requirements of the **Jefferson County Erosion Prevention and Sediment Control (EPSC) Ordinance**. Some of the information contained in this chapter, such as the application forms, and checklists are available in digital format and can be downloaded from www.msdlouky.org. Sensitive Features information can be obtained by consulting the LOJIC Standard Information Map at www.lojic.org.

This chapter also establishes requirements to be used when preparing plans for minimizing soil erosion and sedimentation during and after construction of any land development, improvement or retrofit project. Guidelines on how to select and design EPSC Best Management Practices (BMPs) for specific construction activities have been developed in accordance with several references from across the country. **Sections 12.5, 12.6, and 12.7 are organized as collections of BMP sheets. Each sheet describes a particular BMP, appropriate applications, design and implementation measures, and maintenance requirements.**

12.2 OVERVIEW OF EPSC ORDINANCE AND REQUIREMENTS

The EPSC Ordinance requires that an EPSC plan be developed and be approved by MSD. A Site Disturbance Permit should also be obtained from MSD prior to initiating construction or land disturbing activities that are in excess of 2,000 square feet and are situated closer than 50 feet to a drainageway,

The Ordinance also establishes standards for the design of EPSC plans to minimize the adverse impact and offsite degradation that may result from construction site runoff.

There are two types of EPSC plans that may be required as part of an application for approval of a land disturbing activity: Concept EPSC plans and Detailed EPSC plans.

- Concept EPSC plans are a preliminary presentation of techniques, measures, and controls intended to prevent erosion and control sedimentation arising from land disturbing activities on a specific development site or parcel of land.

- Detailed EPSC plans are required at the construction plan stage for all land disturbing activities. The detailed EPSC plan shall contain the information required by the MSD **EPSC Detailed Construction Plan Checklist**, and if Sensitive Features are identified, a narrative description of how the delineated Sensitive Features will be protected when conducting the proposed land-disturbing activity must be included on the plans. Submit the MSD **EPSC Detailed Construction Plan Checklist** with the detailed EPSC plans for review and approval.

- Tree Removal only: A Site Disturbance Permit will not be required for a site where trees are removed by hand tools and the stumps are left in place. Equipment shall disturb ground cover or distub sensitive features.

12.3 SENSITIVE FEATURE IDENTIFICATION

Sensitive Features include land containing any one the following features:

- Local Regulatory Floodplain and Conveyance Zone as defined by local ordinance (Reference Section 10.4 for more details).
- Stream corridors (including blue line and intermittent) as mapped by United States Geological Survey.
- Karst features with a well-defined surface opening (such as a cave, sinkhole, vadose shaft, or other karst anomaly).
- Lakes and impoundments.
- Jurisdictional wetlands as determined by the US Army Corps of Engineers.
- Slopes greater than 20%.
- "Erodible" and "severely erodible" soils as determined by the Natural Resources Conservation Service.
- Sites with the potential to drain stormwater directly into a sensitive feature listed above (including any designated buffer area for that feature) or into a designated greenway.

12.4 EPSC PLAN DEVELOPMENT STANDARDS

EPSC plans shall be developed to achieve an 80% design removal efficiency goal. When a site is completely denuded of vegetation, the structural and nonstructural EPSC measures are designed to trap 80% of the total suspended solids (TSS) that are generated by the site. The design storm event associated with this level of control is the ***10-year 24-hour NRCS Type II storm event***. NRCS procedures should be used to determine runoff amounts. It is important to note that when a BMP is designed for this event, it will have a greater trapping efficiency for more frequent events (i.e., 2-year storm).The Rational Method may be used when using the design aids.

Each EPSC Plan must delineate the following elements:

- All Sensitive Features as defined above.
- Potential sources of sediment that may potentially leave the site
- The location and depth of all structural and non-structural BMPs necessary to achieve the 80% design removal efficiency goal and protect the Sensitive Features
- Installation and maintenance of required BMPs
- The sequencing of construction activities to be utilized on the project
- Standard EPSC notes (see exhibit)
- MSD Standard Drawing Numbers for EPSC BMPs used on the plan.

Primary BMPs receiving over one acre of contributing watershed must have calculations demonstrating that the BMP achives a Total Suspended Solids (TSS) removal efficency of 80% or greater.The following non-structural site management practices shall be utilized during construction : :

- Minimize site disturbance to preserve and maintain existing vegetative cover;
- Limit the number of temporary access points to the site for land disturbing activities;
- Phase and sequence construction activities;
- Locate temporary and permanent soil disposal areas, haul roads, and construction staging areas to minimize erosion, sediment transport, and disturbance to existing vegetation.

Detailed EPSC plans shall comply with the following standards and review criteria:

- Sediment Tracking Control. Stabilized construction entrances shall be located and utilized at all points of ingress/egress on a construction site. The transfer of soil, mud and dust onto public rights-of-ways shall be prevented.
- Construction Dewatering Operations. Whenever construction dewatering operations are required on a site, they shall be conducted according to the specifications set forth in this Manual, the Standard Specifications and Drawings.
- Crossings of waterways during construction shall be minimized and approved by MSD. Encroachment into stream buffers, riparian areas, and wetlands shall be avoided.
- Topsoil shall be stockpiled and preserved from erosion or dispersal both during and after site grading operations.
- Temporary Stabilization Measures. Where construction or land disturbance activity will or has temporarily ceased on any portion of a site, temporary site stabilization measures shall be required as soon as practicable, but no later than 14 calendar days after the activity has ceased.
- Final Stabilization. Final Stabilization of the site shall be required within 14 calendar days of construction completion.
- Temporary Structural Controls installed during construction shall be designed to accomplish maximum stabilization and control of erosion and sedimentation, and shall be installed, maintained, and removed according to the specifications set

forth in the MSD Design Manual, Standard Specifications and Standard Drawings. All temporary structural controls shall function as designed when controlling the peak runoff resulting from the storm event identified in the MSD Design Manual, Standard Specifications and Standard Drawings.

- All Permanent Structural Controls, including drainage facilities such as channels, storm sewer inlets, and detention basins, shall be designed according to the standards set forth in the this Manual, the Standard Specifications and Drawings.
- Show BMPs for existing and proposed grading/topography.
- If a site is over 5 acres and/or the site is to undergo significant topography changes, a series of progressive EPSC plans will be required to demonstrate the changing nature of the site. For example, if a site's current topography slopes to the east but in the proposed condition it will slope to the west, then two or more EPSC plans depicting this transition will be needed. Furthermore, other intermediate BMPs such as sediment laden or clean water diversion ditches, sediment traps, and basins may be needed as the site transitions to the final condition.
- If a change in topography necessitates the relocation of a sediment basin, an interm plan and phasing sequence will be required to show how EPSC will be mantinaed during the transition.

To encourage the development and testing of alternative EPSC BMPs, alternative management practices that are not included in the MSD Design Manual, Standard Specifications and Standard Drawings may be allowed upon review and approval. To use an alternative BMP, submit substantial evidence that the proposed measure will perform at least equivalent to a currently approved control contained in the MSD Design Manual, Standard Specifications and Standard Drawings. Evidence may include, but is not limited to, peer-review by a panel of licensed professional engineers and research results as reported in professional journals or other literature.

If MSD finds the alternative BMP has failed or is inadequate to contain sediment onsite, the alternative BMP shall be removed and replaced with a BMP approved by MSD and found in the MSD Design Manual, Standard Specifications and Standard Drawings.

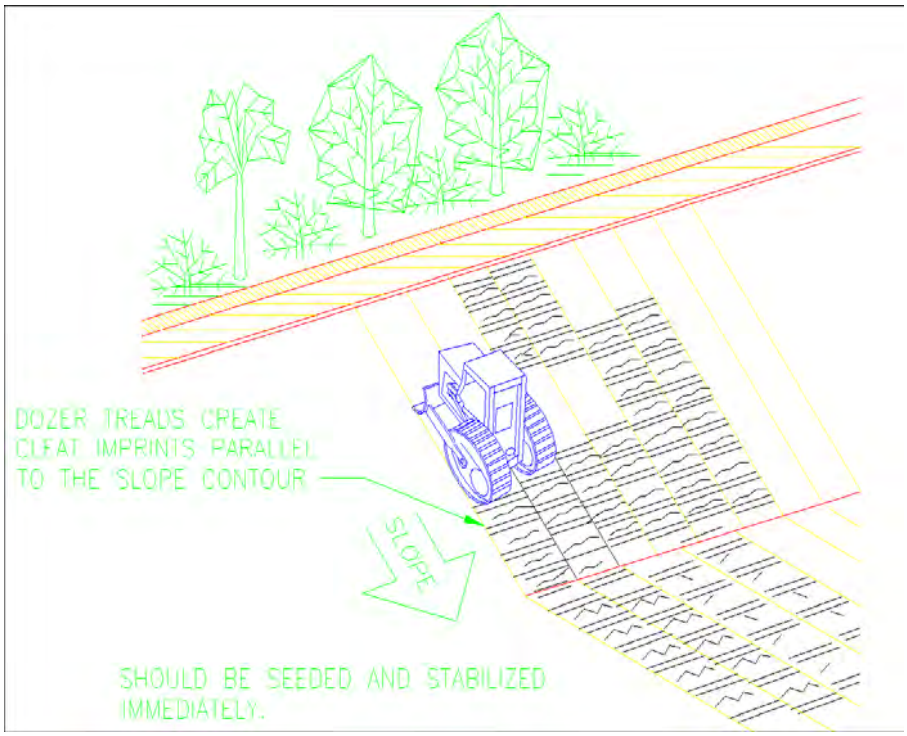
12.5 EROSION PREVENTION MEASURES

Erosion prevention measures shall be used during and after construction site preparation in order to safely convey clean water to storm drains or adequate watercourses. One or more measures should be utilized as appropriate during the project's construction phase. Such measures may include but are not limited to: phasing and construction sequencing, surface roughening, temporary seeding, mulching, matting, and geotextile blankets. Each of these measures is discussed in the sections to follow.

In addition to site-specific erosion control measures, the grading plan should include the following general measures as a minimum:

- The finished cut and fill slopes to be vegetated should not be steeper 3H:1V.
- Cuts or fills should not be so close to property lines as to endanger adjoining property without adequately protecting such properties against erosion, sedimentation, slippage, settlement, subsidence, or other damages.
- Subsurface drainage should be provided in areas having a high water table to intercept seepage that would affect slope stability, bearing strength or create undesirable wetness.
- No fill shall be placed where it can slide or wash onto another property.
- Fill shall not be placed adjacent to channel banks where it can create bank failure, reduce the capacity of the stream, or result in downstream sediment deposition.
- All borrow and disposal areas should be included as part of the grading plan.
- Adequate channels and floodways should be provided to safely convey increased runoff from the developed area to an adequate outlet without causing significant channel aggradation, degradation, or increased off-site flooding.
- The site should be graded to direct flows to appropriate controls.

12.5.1 Surface Roughening EPM-1: SR



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SR

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Surface roughening is the creation of horizontal grooves, depressions, or steps that run parallel to the contour of the land. **The purpose is to aid in the establishment of vegetation cover from seed, reduce runoff velocity, increase infiltration, reduce erosion, and provide sediment trapping.**

The following surface roughening measures are approved for use: tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints parallel to the slope contour) as shown in Standard Drawing EC-04-**01**; stair-step grading as shown in Standard Drawing EC-05-**02**; and slope grooving (using disks, spring harrows, or teeth on the bucket of a front-end loader) as shown in Standard Drawing EC-06-**01**.

APPLICATION

- **Construction slopes where seeding, planting, and mulching to stabilize soils.**
- **Graded areas with smooth, hard surfaces, and the potential for erosion.**

APPROACH

Cut slopes with a gradient steeper than 3H:1V but less than 2H:1V should be stair-step graded or groove cut. Stair-step grading works well with soils containing large amounts of small rock. Stairs should be wide enough to work with standard earth moving equipment. Grooving can be done by any implement that can be safely operated on the slope, including those described above. Grooves should not be less than 3 inches deep or more than 15 inches apart.

Fill slopes with a gradient steeper than 3H:1V but less than 2H:1V should be compacted every 9 inches of depth. The face of the slope should consist of loose, uncompacted fill 4

to 6 inches deep that can be left rough or can be grooved as described above, if necessary.

Any cut or filled slope that will be maintained should have a gradient less than 3H:1V and in no case greater than 2H:1V. Such a slope can be roughened with shallow grooves parallel to the slope contour by using normal tilling. Grooves should be close together (less than 10 inches) and not less than 1 inch deep.

Immediately seed and mulch roughened areas to obtain optimum seed germination and growth. Use erosion control blankets or turf reinforcement mats on long (>50 feet) steep (>2H:1V) slopes as necessary, or hydroseed.

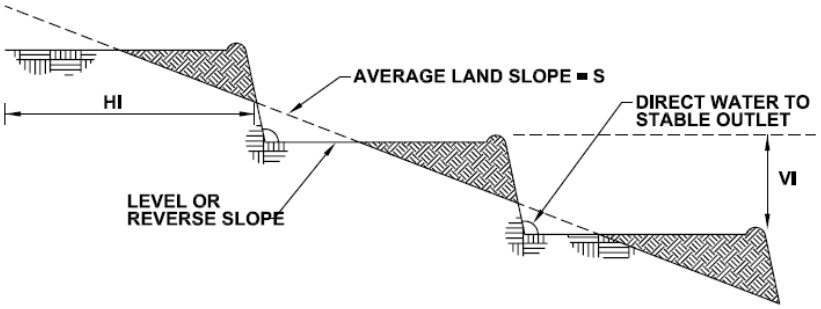
MAINTENANCE

- **Inspect roughened surfaces every seven days and within 24 hours after each rain event that produces 0.5 inches or more of precipitation for rills and washes. Fill these areas slightly above the original grade, then reseed and mulch or cover with blanket or mat as soon as possible.**

LIMITATIONS

- **Surface roughening may not be appropriate for certain soil types including sandy, steep, or shallow soils.**
- **Surface roughening, seeding, and mulching may need to be repeated after significant rain events.**
- **Excessive surface roughening may be undesirable when area is to be mowed.**

12.5.2 BENCH TERRACING EPM-2: BT



EQUATION FOR HORIZONTAL AND VERTICAL INTERVALS

$$HI = VI \times \frac{100}{S}$$

$$VI = aS+b$$

WHERE a = 0.5 FOR LOUISVILLE
b = 1 FOR ERODIBLE CONDITION
2 FOR RESISTANT SOILS WITH GOOD COVER.

S = AVERAGE LAND SLOPE IN PERCENT
HI = HORIZONTAL INTERVAL BETWEEN TERRACES
VI = VERTICAL INTERVAL BETWEEN TERRACES

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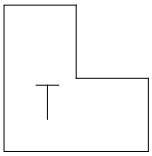

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Bench terraces are permanent earth embankments or ridges constructed along the face of a slope at regular intervals creating a stair-step effect. Bench terraces reduce slope lengths and direct surface **runoff** to stable outlets. **The stair-stepping effect will help vegetation establish and also trap eroding soil from the above slope.** The proper orientation of a bench terrace is shown in Exhibit 12-1 in Supplemental Section D.

APPLICATION

- **Construction slopes steeper than 3:1.**
- **Graded areas where the length of slopes needs to be reduced by terracing.**

APPROACH

Bench terraces are designed for highly erodible, steep slopes ranging from 3:1 to 1.5:1, and should not be constructed on slopes with sandy or rocky soils. They are effective only where there are suitable runoff outlets such as grassed waterways, or piped outlets.

The design of a bench terrace system involves proper spacing and location. Terrace spacing is expressed as the vertical distance between the channels of successive terraces. For each terrace, the spacing is the vertical distance from the top of the hill to the bottom of the channel, commonly known as the vertical interval or VI. Although the horizontal spacing is useful in determining row arrangement, the VI is more convenient for terrace layout and construction.

12.5.2 BENCH TERRACING EPM-2: BT

Terrace spacing is expressed by the empirical formula:

$$VI = aS + b$$

Where:

VI = vertical interval between consecutive terraces in ft.,
a = constant for geographical location (**0.5 for Louisville**),
b = constant for soil erodibility (**1 for erodible conditions, 2 for resistant soils with good ground cover**), and
S = average land slope in **percent**

The horizontal interval HI or bench width can be calculated by the formula:

$$HI = VI \times 100/S$$

Where:

HI = horizontal interval of each terrace in ft.,
VI = vertical interval between consecutive terraces in ft., and
S = average land slope in **percent**.

MAINTENANCE

- Periodically inspect seeded areas, particularly after rain events, for rills and washes.
- Remove debris from outlets and excessive silt from terraces.
- Inspect benches for **destabilizing gully** formation. Gullies may require rock placement to stabilize the area.
- Reseed and mulch as necessary.

LIMITATIONS

- Bench terracing is not applicable for sandy or rocky soils.
- Must only be used when adequate drainage channels and runoff diversions are provided.

12.5.3 TEMPORARY SEEDING EPM-3: TS



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TS

Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

The purpose of temporary seeding is to reduce erosion and sedimentation by stabilizing disturbed areas that would otherwise lay bare for long periods of time **(>14 days)** before they are worked or stabilized. Temporary seeding is also used where permanent vegetation growth is not necessary or appropriate.

APPLICATION

- **Apply to areas left in rough grade condition that will not be disturbed for 14 days or more**

APPROACH

Any disturbed areas that will not be worked for 14 days or more must have temporary cover applied by the 14th day. Seeded areas should be covered with mulch to provide protection from the weather. If the vegetation does not grow quickly or thick enough to prevent erosion, the area should be re-seeded as soon as possible. Seeded areas should be kept adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water, waste water, and fuel can cause **or worsen** erosion. Seed selection should be based on the requirements of the MSD Standard Specifications **and applied at recommended rates.**

MAINTENANCE

- **Inspect frequently for the first six weeks following planting to assure seed is adequately moist and to determine if vegetation is uniform and dense.**
- **Damaged areas should be repaired, fertilized, seeded, and mulched where appropriate.**

LIMITATIONS	• **Some types of grasses (e.g. annual rye) may outcompete desirable permanent vegetation.** • **Uneven application may cause patchy growth and erosion. Over application of fertilizer or lime causes stormwater runoff pollution.** **Areas to be seeded may require compaction, disking, or other activity to prepare the seedbed.**

12.5.4 MULCHING EPM-4: M



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Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	**Borrow Areas**	Adjacent Properties

DESCRIPTION

Mulching is a temporary soil stabilization erosion control method where materials such as grass, **straw, cellulose,** wood chips, wood fibers, **or other suitable materials** are placed on the soil surface. In addition to stabilizing soils, mulching can enhance the absorption of water by the soil, reduce evaporation losses, regulate soil temperatures and reduce the speed of **stormwater** runoff over an area. **Mulching is used in conjunction with seeding and hydroseeding of critical areas for the establishment of temporary or permanent vegetation.**

APPLICATION

- **Temporary stabilization of freshly seeded and planted areas, or during periods unsuitable for growing permanent vegetation.**
- **Short-term ground cover on steep slopes to reduce rainfall impact, decrease the velocity of sheet flow, and trap sediment.**

APPROACH	Erosion control mulching may be used on level areas, slopes up to 50%, and in waterways with caution. Where soil is highly erodible, nets should only be used in connection with organic mulch, such as straw and wood fiber. Mulch is an effective **temporary** ground cover when the establishment of vegetation is improbable due to severe weather conditions (winter conditions), poor soil, or steep slopes. **If using mulch for temporary ground covers without seeding, the mulch should be applied to an appropriate depth for the material used and should have greater than 95% coverage of the soil surface. On steep slopes (>2.5H:1V), or where the mulch is susceptible to movement by wind or water, the mulch should be hydraulically applied or the mulch should be anchored appropriately (e.g. covered by degradable netting).**
MAINTENANCE	• **Avoid traveling on mulched and seeded areas.** • **Periodically inspect mulched and seeded areas, particularly after rainfall events, for damage or deterioration. Replace as necessary.** • **Continue inspections until vegetation is established.**
LIMITATIONS	• **Organic mulches tend to lower the soil surface temperature, and may delay germination of some seeds.** • **Organic mulches may also affect the pH of the soil.** **Mulching of waterways may cause flow impediments at water inlets and is not appropriate for areas that receive high stream flows.**

12.5.5 EROSION CONTROL BLANKETS AND TURF REINFORCEMENT MATS

EPM-5: ECB/TRM



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MSD

ECB

TRM

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	**Borrow Areas**	Adjacent Properties

DESCRIPTION

A variety of Rolled Erosion Control Products (RECPs) are available for the stabilization of seeded slopes and channel banks. MSD distinguishes between the different types of products using two categories: Erosion Control Blankets (ECBs) and Turf Reinforcement Mats (TRMs).

ECBs and TRMs are preferred alternatives to traditional hard channel protection such as concrete, riprap, gabions and revetment mattresses. These products improve the quality of stormwater discharges by creating a stronger, vegetated **armament** that filters the flow, allows infiltration, and **protects and encourages the establishment of** wildlife habitat. **This BMP prevents soil erosion, promotes seed germination, protects young vegetation and prevents seed or mulch from washing away.** The proper orientation of netting and matting is shown in Standard Drawing EC-07-**01**.

ECBs are used for the temporary stabilization of soil immediately following seeding until the vegetative cover has grown and become well established. They provide temporary protection because they degrade over time as the vegetation becomes established. Some products are effective for a few months while others degrade slowly and are effective for a

few years.

TRMs are nondegradable products that enhance the ability of living plants to stabilize soils. They bind with roots to reinforce the soil matrix. TRMs are used in situations where vegetation alone will not hold a slope or stream bank. TRMs **provide potential** "green" solutions in many areas where only "hard" solutions such as riprap or concrete linings were viable in the past.

APPLICATION

- **Any area subject to erosive action particularly where permanent vegetation has been planted.**
- **Graded slopes, stormwater channels, detention structures, stream banks or swales.**

APPROACH

When designing a permanent conveyance (as described in Chapter 10) with a grassed or vegetative lining, the design should address the bare condition prior to vegetation being established. A geotextile lining may be applied to protect the conveyance during this period. It is important to use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of ECBs and TRMs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, a corresponding ECB or TRM that meets the conditions may be selected from the list of approved ECB and TRM products. This list can be found on the MSD web page.

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning's channel roughness coefficient (n) of the TRM or ECB or final vegetation, and

Normal channel flow depth (d_n) based on peak flow rate and channel dimensions.

The governing equation for maximum velocity is Manning's Equation:

$$V = (1.49 / n) * R^{2/3} * S^{1/2}$$

Where:

V = maximum velocity (ft/sec)
n = Manning's channel roughness coefficient
R = Hydraulic radius of the flow based on d_n (ft)
S = Channel bed slope (ft/ft)

The governing equation for maximum channel shear stress is:

$$\tau = \gamma\, d_n\, S$$

Where:

τ = maximum shear stress (lbs/ft^2)
γ = unit weight of water = 62.4 lbs/ft^3
d_n = normal channel flow depth (ft)
S = channel bed slope (ft/ft)

MAINTENANCE	• **Inspect ECBs and TRMs periodically and especially after rain events to check for movement of blanket/mat, topsoil, or mulch and any significant erosion.** • **Continue inspections until vegetation is firmly established.** • **Repair or replace ECBs or TRMs that have been washed out, broken, or eroded. Repair ground surface with topsoil, re-seed, re-mulch and fertilize where necessary prior to installing new ECBs or TRMs.**
LIMITATIONS	• **Inadequate coverage or anchoring will result in erosion, washout, and poor vegetation establishment.** • **Do not install within the wetted perimeter of a stream or drainage channel that carries water continuously.** • **The type of ECB or TRM chosen must be appropriate for the specific project needs.**

12.5.6 FINAL STABILIZATION EPM-6: FS



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SO

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	**Large Flat Areas**	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Final stabilization measures include topsoiling, permanent seeding and planting of grasses, and sodding. Implementation of these items will occur after all construction activities on site have been completed.

These measures reduce stormwater runoff velocity, maintain sheet flow, protect soil surface from erosion, promotes infiltration of runoff into the soil and can improve wildlife habitat.

APPLICATION

- **Any area where soil disturbance activities have taken place.**

APPROACH

12.5.6.1 Topsoiling

When and Where to Use It

Topsoil should be used when vegetative stabilization is used, where soils are dense or impermeable, or where mulching and fertilizers alone cannot improve soil quality.

Design Criteria

Stockpiling of topsoil onsite requires good construction sequencing and planning so the stockpiles will not obstruct other operations. If topsoil is to be stockpiled, the use of temporary seeding, mulching, or silt fence to control erosion should be considered.

12.5.6.2 Permanent Seeding and Planting of Grasses

Design Criteria

The use of native species is preferred when selecting vegetation. Seedbed preparation, seed type, application rate, fertilizer rate and planting windows should be designed according to the MSD Standard Specifications.

12.5.6.3 Sodding

When and Where to Use It

Sodding is appropriate for any graded or cleared area that may erode, and where a permanent, long-lived plant cover is immediately needed. Examples of where sodding can be used are yards, buffer zones, stream banks, dikes, swales, slopes, outlets, and filter strips.

Design Criteria

Sodding should be installed per MSD Standard Specifications as shown in Standard Drawing EC-08-**01**. Sodding should not be used on slopes steeper than 2H:1V, unless the sodding is to be mowed, then it should not be placed on slopes greater than 3H:1V

MAINTENANCE

- **Inspect areas where topsoiling, permanent seeding and planting of grasses, and sodding measures have been implemented at a minimum of every seven days and within 24 hours after each storm event that produce 0.5 inches or more of precipitation.**

12.5.7 RIPRAP OR AGGREGATE EPM-7: RR



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RR

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Riprap is a permanent, erosion-resistant channel lining aggregate consisting of large, loose, angular stone with a filter fabric or granular underlining. The purpose of riprap is to:

- Protect the soil from the erosive force of concentrated runoff; and
- Slow runoff velocities while enhancing the potential for infiltration.

The purpose of filter fabric or granular underlining is to prevent undermining the riprap layer by migration of soil particles under seepage forces through the riprap.

APPLICATION

- **Along streams or within drainage channels as a stable lining resistant to erosion.**
- **On lakefronts and riverfronts, or any other area subject to wave action.**
- **Protection of culvert inlets and outlets to prevent scour and undercutting.**
- **In channels to reduce velocities, dissipate hydraulic energy and promote infiltration and settle sediment.**

APPROACH

The preferred method of slope and channel protection is the use of vegetation. If vegetation cannot withstand the design flows, ECBs and TRMs (see Section 12.5.5) are the preferred and suggested method of protection. When conditions are too severe for vegetation and TRMs, riprap may be used for erosion control and protection. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, drop structures, at the toe of slopes, and in transitions from concrete channels to vegetated channels. Table 12-1 lists several KTC sizes of coarse aggregates along with the corresponding stone diameter.

Table 12-1. Coarse Aggregates

Aggregate Size (KTC Size No.)	Mean Spherical Diameter (d_{50}) (inches)
1	3.5
2	2.5
23	2.5
3	2.0
357	2.0
4	1.5
467	1.5
5	1.0
57	1.0
610	1.0
67	0.75
68	0.75
710	0.75
78	0.50
8	0.375

Riprap sizes can be designed by the diameter or by the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical. Table 12-2 lists some typical riprap classes and the corresponding dimensions.

Table 12-2. Weight and Size of Riprap Stones

Channel Lining Riprap Class	**Corresponding Size**
IA	Limestone with 100% passing a 5-inch sieve, and no more than 20% passing though square openings 1.5" by 1.5"
II	Limestone with 100% passing a 9-inch sieve, and no more than 20% passing though square openings 5" by 5"
III (Cyclopean Riprap)	> 80% by volume of individual stones ranging from ¼ to 1-½ cubic feet

General

Geotextile Underlining: Place a lining of geotextile filter fabric or granular filter material between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

Riprap at Outlets: Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are given in Section 12.5.8 of this chapter; Outlet Stabilization**.**

Riprap for Channel Stabilization: Riprap for channel stabilization should be designed to be stable for the condition of bank-full flow in the reach of channel

being stabilized. The Federal Highway Administration (FHWA) design procedure as presented in this section should be used. This method establishes the stability of the rock material relative to the forces exerted upon it.

Riprap should extend up the banks of the channel to a height equal to the maximum 10-year flow depth, or to a point where vegetation can be established to adequately protect the channel.

Riprap placed in channel bends should extend upstream and downstream from the point of curvature at least 5 times the channel bottom width. The riprap should extend across the bottom and up both sides of the channel.

Freeboard and Height of Bank: For riprap and other lined channels, the height of channel lining above the water surface should be based on the size of the channel, the flow velocity, the curvature, inflows, wind action, flow regulation, etc.

The designer shall obtain a minimum freeboard for placement of riprap relative to the top of bank from Chapter 10.

Design of Riprap Channel Linings

Design of erosion protection within the channel should be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

For Straight Channel Sections:

The Exhibits used in this section are found in Supplemental Section D of this chapter.

1. Enter the graph of Exhibit 12-2 with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line above the point of intersection.)

2. If the channel side slopes are steeper than 3H:1V, continue with Step 3; if not, the procedure is complete.

3. Enter the graph in Exhibit 12-3 with the side slope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to read K_1.

4. Determine from the graph in Exhibit 12-4 the angle of repose for the d_{50} stone size and the channel side slope. (Use an angle of 42° for d_{50} >10 inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Enter graph in Exhibit 12-5 with the side slope of the channel and the angle

of repose for the d_{50} stone size. Where the two lines intersect, move vertically down to read K_2.

6. Compute d_{50} x K_1/K_2 = d_{50} to determine the correct size stone for the bottom and side slopes of straight sections of channel.

MAINTENANCE

- **Check riprap and channel linings after rain events that produce greater than 0.5 inches of precipitation for slumping, displacement, scour and undermining of riprap. Replace or reposition as necessary.**
- **Remove excessive vegetative growth if stability of area is compromised.**

LIMITATIONS

- **Displacement of riprap or channel lining may occur if the slope is too steep or if riprap is improperly sized or installed.**
- **Weeds may be difficult to control.**
- **Riprap placement in waterways may require permitting with the U.S. Army Corps of Engineers and the Kentucky Division of Water.**

12.5.8 OUTLET STABILIZATION EPM-8: OS



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Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Outlet **stabilization** dissipates the energy of concentrated **stormwater** flows thereby reducing erosion or scouring at **stormwater** outlets and paved channel sections. In addition, outlet **stabilization** lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including permanent turf reinforcement mats (TRMs), stone or riprap, concrete aprons, and paved sections.

APPLICATION

- **Wherever discharge velocities and energies at the outlets of culverts, pipes, conduits, channels or ditches are sufficient to erode the immediate downstream reach.**

APPROACH

The design of lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection. This causes re-concentration of the flow **which** results in large velocities when the flow leaves the apron. Outlet protection should be designed according to the following criteria:

Round Pipe Flowing Full:

1. Tailwater Depth: The tailwater depth immediately below the pipe outlet must be determined for the design capacity of the pipe. The depth may be determined using Manning's Equation. If the tailwater depth is less than ½ the diameter of the outlet pipe, it should be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than ½ the pipe

diameter, it should be classified as a Maximum Tailwater Condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition.

2. Apron Length: The required apron length, L_a, according to the tailwater condition, should be determined from the appropriate graphs provided in the following exhibits found in Supplemental Section D of this chapter:

   Minimum Tailwater Condition - Use Exhibit 12-6
   Maximum Tailwater Condition - Use Exhibit 12-7

3. Apron Width: When the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less). If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows:

   - The upstream end of the apron, adjacent to the pipe, should have a width three times the diameter of the outlet pipe (3D).
   - For a Minimum Tailwater Condition, the downstream end of the apron should have a width equal to the pipe diameter plus the length of the apron ($D + L_a$).
   - For a Maximum Tailwater Condition, the downstream end should have a width equal to the pipe diameter plus 0.4 times the length of the apron ($D + 0.4 * L_a$).

4. Bottom Grade: The apron shall be constructed with no slope along its length (0% grade). The downstream invert elevation of the apron should be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

5. Side Slopes: If the pipe discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

6. Alignment: The apron should be located so there are no bends in the horizontal alignment.

7. Materials:

   - The preferred apron lining shall be with an appropriate permanent turf reinforcement matting (TRM). The shear stress and maximum velocity should be calculated to determine which type of TRM is applicable for the situation (see Section 12.5.5).
   - When conditions are too severe for TRMs the apron may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap should be determined from the curves in Exhibit 12-6 and 12-7 according to the tailwater condition. The gradation, quality, and placement of riprap should conform to the requirements presented in Section 12.5.7.

8. Filter Cloth: In all cases, filter cloth should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the physical properties for filter cloth found in

the requirements presented in Section 12.5.7.

Paved Channel Outlets (Standard Drawing DD-05-**01**):

1. The flow velocity at the outlet of paved channels flowing at design capacity **must not** exceed the permissible velocity of receiving unprotected grass-lined channels as provided in Table 12-3.

2. The paved channel end should merge smoothly with the receiving channel section with no overfall at the end of the paved section. When the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section should be provided with a maximum side divergence of 1 in 3F with;

$$F = \frac{V}{(gd)^{0.5}}$$

Where:
F = Froude number
V = Velocity at beginning of transition (ft./sec.)
d = Depth of flow at beginning of transition (ft.)
g = Acceleration due to gravity (32.2 ft./sec.^{2})

3. Bends or curves in the horizontal alignment at the transition are not allowed unless the Froude number (F) is 1.0 or less, or the section is specifically designed for turbulent flow.

Table 12-3. Maximum Permissible Velocities For Unprotected Grass Lined Channels

Channel Slope	Lining	Velocity (ft./sec.)**
0 – 5 %	Bermuda Grass	8
	KY-31 Tall Fescue	7
	Kentucky Bluegrass	7
	Grass-legume Mixture	5
	Small Grains	3.5
	Temporary Vegetation	3.5
5- 10 %	Bermuda Grass	7
	KY-31 Tall Fescue	6
	Kentucky Bluegrass	6
	Grass-legume mixture	4
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended
Greater than 10%	Bermuda Grass	6
	KY-31 Tall Fescue	5
	Kentucky Bluegrass	5
	Grass-legume mixture	Not Recommended
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended

***Allow velocities over 5 ft/sec only where good cover and maintenance will be provided.**
****For highly erodible soils, decrease permissible velocities by 25%.**
Source: Elementary Soil and Water Engineering, Shwab et. al. 1971

MAINTENANCE

- **Inspect outlet stabilization periodically, particularly after rain events, for erosion, sedimentation, scour or undercutting.**
- **Repair or replace riprap, TRM, or concrete structures as necessary.**

12.5.8 OUTLET STABILIZATION EPM-8: OS

- **Remove trash, debris, vegetation, and sediment as necessary.**

LIMITATIONS

- **An easement may be necessary to maintain riprap outlet protection given that outlet protection is usually at or near the project boundary.**

12.5.9 DUST CONTROL EPM-9: DC



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Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	**Borrow Areas**	**Adjacent Properties**

DESCRIPTION

Wind erosion can occur when the surface soil is loose and dry, vegetation is sparse or absent, the wind is sufficiently strong, and when construction traffic disturbs the soil. Wind erodes soils and transports the sediment offsite in the form of fugitive dust, where it may be washed into receiving water bodies by the next **rain event**.

Fugitive dust is a nuisance for neighbors. It settles on automobiles, structures and windows and finds its way into homes. It also can make breathing difficult (for those with respiratory problems) and becomes a safety problem when it blinds motorists, equipment operators and laborers.

Dust control methods should be utilized whenever there are offsite impacts, such as periods of drought, and implemented until final stabilization is reached. **Selection of particular dust control techniques depends primarily on cost and potential environmental hazards (particularly near Sensitive Features). The effectiveness of each technique will depend on soil type, properties of chemical agent, traffic volume, climate, environmental requirements, and frequency of application.**

APPLICATION

- **Clearing and grading activities.**
- **Construction vehicle traffic on temporary or unpaved roads or construction site access paths.**
- **Sediment tracking on paved roads.**
- **Soil and debris storage piles.**
- **Areas with unstabilized soil.**

12.5.9 DUST CONTROL EPM-9: DC

APPROACH

There are many methods to control dust on construction sites including:

- Vegetative Cover - For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control.
- Mulch - Offers a fast, effective means of controlling dust.
- Sprinkling Water – Used on haul roads and other traffic routes as dust control.
- Spray-on-Adhesive - Latex emulsions, or resin in water can be sprayed onto mineral soils to prevent their blowing away and reduce dust caused by traffic.
- Calcium Chloride - May be applied by mechanical spreaders as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.
- Barriers - Broad, wind, or sediment fences can control air currents and blowing soil. These fences prevent erosion by obstructing the wind near the ground, stopping the soil from blowing offsite. Barriers are not a substitute for permanent stabilization. Perennial grass and **stands** of existing trees may also serve as wind barriers.

Spray exposed soil areas only with approved dust control agents as indicated in the MSD Standard Specifications

MAINTENANCE

- **Reapplication of dust control agents must be appropriate to the agent type and intensity of traffic areas.**

LIMITATIONS

- **Watering prevents dust only for a short period and should be applied daily (or more often) to be effective.**
- **Overwatering may cause erosion.**

12.6 TEMPORARY SEDIMENT CONTROL MEASURES

MSD emphasizes erosion prevention in EPSC plans. However, there are always instances where erosion cannot be prevented. For these situations, temporary sediment controls must be implemented to control the migration of eroded sediment off site. The following sediment control measures are applicable as temporary practices for use during construction. One or more of the measures should be utilized as appropriate during the project's construction phase. A discussion of the planned measures will be required during the Preliminary Plan Review phase for sites containing sensitive features.

12.6.1 STORAGE VOLUMES AND MAINTENANCE SCHEDULES

SCM-1: SV



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Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION **This section provides the basic formulas needed for temporary sediment basin and sediment trap design.**

APPROACH

Calculating the appropriate sediment storage volume is very important in sediment basin and sediment trap design. This volume is the storage occupied by the sediment deposited over the given design period. Design periods may be the life of the basin, or the time between scheduled clean outs. Using computed sediment yields from the Universal Soil Loss Equation (USLE) found in Supplemental Section B, along with the sediment bulk density, the sediment storage volume can be calculated by

$$V_S = \frac{Y_D}{W * 43{,}560}$$

Where: $\mathbf{V_S}$ is the sediment storage volume (acre-feet), $\mathbf{Y_D}$ is the sediment deposited over the design period (pounds), and **W** is the weight density (bulk density) of the deposited sediment (lbs./ft^3). **W** can be found from soil survey data (usually given in grams/cm^3) or by the equation:

$$W = W_c P_c + W_m P_m + W_s P_s$$

Where: W_c, W_m, and W_s are unit weights of clay, silt, and sand in (lbs./ft^3) taken from Table 12-4, and P_c, P_m, and P_s are the primary soil matrix percent clay, silt, and sand as listed in soil survey (used as a decimal).

Table 12-4. Unit Weight Values of Basin Sediment

Type of Basin Operation	Wc (#/ft^3)	Wm (#/ft^3)	Ws (#/ft^3)
Sediment always submerged (Wet Pond)	26	70	97
Basin normally empty (Dry Pond)	40	72	97

R Factors and EI Values

When designing for sediment storage volume, the sediment deposited over the design period Y_D, must be calculated. This value can be obtained by converting the sediment yield calculated by the Universal Soil Loss Equation (USLE) into pounds of sediment. One of the variables used in the USLE is the R factor. R is the factor in the USLE that accounts for the damaging effects of rainfall. The R factor indicates the erosivity of the rainfall, not the average annual precipitation in a locality. The R factor is defined as the number of erosion index (EI) values in a normal year's rain. The EI index value of a given storm is equal to the kinetic energy of the storm (hundreds of foot-tons per acre) times its maximum 30-minute intensity (inches/hour). The EI values of individual storms may be summed to get an EI value for a month, six months, or for any period of time. When EI values are summed and averaged over a period of years, they become R factors.

The distribution of EI values become important when soil losses need to be calculated for a period of time less than one year, such as a construction season. The distribution of the EI values over a known period of time is used to calculate an R factor for that time period. Table 1 in Supplemental Section B of this chapter shows the distribution of EI values for Jefferson County as a percentage of the R factor for Jefferson County. MSD requires a minimum EI value of 50 for any construction period.

The following steps are used to determine the storage volume for a sediment trapping structure. All **USLE** input values are found in Supplemental Sections B and C of this chapter.

1. Determine the site sediment yield using the Universal Soil Loss Equation

$$A = R \bullet K \bullet LS \bullet CP$$

Where:
A = Average soil loss per unit area(tons/acre/specified design period)
R = Rainfall erosive index (100-ft-tons/acre x in/hr)
(EI Value for given design period * average annual R Value)
K = Soil erodibility factor (tons/acre per unit R)
LS = Length-slope steepness factor where length is the slope distance from the point of origin of overland flow to the point of concentrated flow or until deposition occurs (dimensionless)
CP = Control practice factor (dimensionless).

2. Determine the weight density **(W)** of the specific soil.

   - The Jefferson County Soil Survey gives a soil bulk density in grams/cm^3
   - Convert (grams/cm^3) to (lbs/ ft^3) by multiplying by 62.43

   W = (bulk density in grams/cm^3) x (62.43) = lbs/ft^3

3. Convert sediment yield from (tons/acre) to acre-feet of sediment storage.

   - Determine the total disturbed area **DA** (acres)
   - Determine the sediment yield in tons

   Multiply **A** from step 1. * **DA** from step 3. (tons/acre * Acres = tons)

   - Convert tons to pounds to get $\mathbf{Y_D}$

   $\mathbf{Y_D}$ = (tons) * (2000 lbs/ ton) = pounds

$$V_S = \frac{Y_D}{W * 43{,}560} = acre - feet$$

4. The designer can now determine what level the required sediment storage corresponds to, and require a clean out marking stake to be installed at this elevation. The contractor shall be required to clean out the basin or trap when this level is reached. Or the designer can simply state that based on the calculations, the basin or trap will be required to be cleaned out on a time period basis such as weeks, months or years.

12.6.2 TEMPORARY SEDIMENT BASIN SCM-2: TSB



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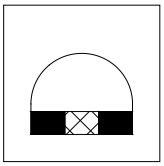

Slope Protection	**Waterway Protection**	**Surface Protection**	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A sediment basin is an impoundment for the purpose of detaining runoff to allow excessive sediment to settle.

Temporary sediment basins should be used on sites where 5 or more acres are disturbed. A temporary sediment basin shall not be built in wetlands, any active or live streams, or in Waters of the Commonwealth. Temporary sediment basins shall be utilized until the contributing flow areas to the basin have undergone final stabilization.

Basins shall be designed to have an 80% design removal efficiency goal for total suspended solids (TSS) in the inflow. Drop inlet spillways, pipe spillways, rock fill outlets and weir spillways may be used for the design of the principal spillway. Typical sediment basin schematics are Exhibits 12-8A and 12-8B in Supplemental Section D of this chapter.

APPLICATION

- **Used for retaining stormwater from disturbed areas where 5 to 150 acres are disturbed.**
- **At locations with steep slopes, sloughing or severely eroded soils, or industrial activities that generate sediment and soil particles.**

APPROACH

- Dam Safety –Design criteria such as those used by the USDA Soil Conservation Service (previously the Natural Resources Conservation Service), U.S. Army Corps of Engineers and the Dam Safety and Floodplain Compliance Section of the Kentucky Division of Water must be followed.

- Safety, Signage, and Fencing - Ponds, which are readily accessible to populated areas, should incorporate all possible safety precautions. The inside pond slopes shall be no steeper than 3H:1V.

- General Design Criteria -The design aids located in Section 12.8.2 of this chapter shall be used to properly size the sediment basin. Sedimot III, SEDCAD and other computer models may also be utilized.

- Riser Structure Design- The outlet riser shall be properly designed to meet the discharge capacity of the 10-year 24-hour storm.

Flow control devices can operate as either open channel flow, in which the flow has a free water surface, or pipe flow in which the flow is in a closed conduit. In either situation, an increase in head on a structure increases the discharge flow rate through the structure.

The stage discharge relationship for basin outlet structures is controlled by weir, orifice or pipe flow. A given riser spillway can have a variety of stage discharge relationships depending on the head. When the water level is just above a riser crest (a very low head on the riser), the riser crest acts like a weir, and flow is weir controlled. As the water level in the basin increases, water begins flowing in from all sides including directly above the inlet, and the inlet begins to act like an orifice. As the head continues to increase, the outlet eventually begins to flow full, and pipe flow dictates. To determine which of the three flow mechanisms is controlling at a particular water level in the basin, all three equations should be utilized at each level. The minimum flow for a given stage indicates the actual discharge from the basin and the flow mechanism that is controlling at that water level.

Weir Flow:

$$Q = C\,L\,H^{\frac{3}{2}}$$

Where: Q is the discharge (cfs), C is the weir coefficient (dependent upon units and weir shape but C is typically between 3.0 and 3.2), L is the weir length (feet), which is the total length over which flow crosses the weir (L = circumference of a pipe for circular drop inlets), and H is the water head (feet).

Orifice Flow:

$$Q = C'a\left(2gH\right)^{\frac{1}{2}}$$

Where: Q is the discharge (cfs), C' is the orifice coefficient (C' = 0.6 for sharp-edged orifices), a is the cross sectional area of the orifice (ft^2), g = 32.2 ft/sec^2, and H is the head on the orifice (feet).

Pipe Flow:

$$Q = \frac{a\left(2gH'\right)^{\frac{1}{2}}}{\left(1 + K_e + K_b + K_c L\right)^{\frac{1}{2}}}$$

Where: Q is the discharge (cfs), a is the cross sectional area of the pipe (ft^2), g = 32.2 ft/sec^2, H' is the head (feet) defined as the distance from the water surface in the basin to a point 0.6 D above the invert of the outlet barrel where D is the outlet barrel diameter in feet, K_e and K_b depend on the configuration of the pipe entrance and bend (typical values are K_e = 1.0 and K_b = 0.5), K_c is the head loss coefficient due to friction ($K_c = 5087*n^2 / D^{4/3}$, where: n = Manning's roughness coefficient of the barrel and D is the barrel diameter in inches), and L is the total length of the pipe (feet).

Other required design criteria are as follows:

a. Minimum Drainage Area - 5 acres
b. Maximum Drainage Area - 150 acres
c. 80% design removal efficiency goal for TSS.
d. The required draw down time of the basin will be the time to detain flows to meet the 80% design removal efficiency. In many cases this will result in a draw down time longer than 36-hours.
e. Basin Shape - the effective flow length should be at least twice the effective flow width (L=2W minimum).
f. Sediment Volume Storage Accounted For In Design Volume
g. Outlet Riser and Barrel Requirements
    1. Discharge Capacity - 10-year 24-hour storm.
    2. Minimum Outlet Pipe Diameter of 8-inches.
    3. Required 6-inch low flow orifice at bottom of riser structure.
    4. Perforations and orifices shall be designed to keep the 2-year and 10-year 24-hour storm disturbed-state peak flow rates from the basin less than or equal to the pre-disturbance peak flow rates.
    5. Anti-Vortex Device / Trash Rack Required.
    6. Minimum one-foot elevation difference from top of riser to crest of the emergency spillway.
    7. Sediment Volume Storage Accounted For In Design Volume.

h. Embankment Requirements
    1. Maximum Upstream Slope – 3H:1V.
    2. Maximum Downstream Slope – 3H:1V.
    3. Freeboard - 12-inch minimum.
    4. Antiseep collars are required on all penetrations through the dam.
    5. Typical dam height to top width dimensions are provided below in Table 12-5.

Table 12-5. Sediment Basin Width/Height Relationship

Dam Height (Ft)	Top Width (Ft)
< 10	8
11-14	9
15-19	10
20-25	12

i. Emergency Spillway Requirements
   1. Shall be designed to discharge a flow equal to the design overflow of the 100-year 24-hour storm post-development discharge.
   2. Shall have a minimum one-foot of freeboard from the 100-year 24-hour storm water surface elevation to the top of the dam.

MAINTENANCE

- **Inspect temporary sediment basins periodically and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color and perform necessary repairs when appropriate.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level and dispose of sediment at a protected location onsite to prevent resuspension of sediment.**

LIMITATIONS

- **Sediment basins may kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **May not be effective for fine-grained soils such as silt or clay. Additional upstream controls may be necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

12.6.3 MULTIPURPOSE BASINS SCM-3: MB



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Slope Protection	**Waterway Protection**	**Surface Protection**	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Multipurpose basins are permanent detention basins that are designed for use as temporary sediment basins during the construction phase of a project.

APPLICATION

- **Modification of a permanent detention basin for the purpose of handling large amounts of silt and eroded soil.**

APPROACH

Two spillway configurations are commonly used in the life of a multipurpose basin. The first configuration is the sediment basin spillway, which is typically a CMP riser and RCP barrel configuration. When conversion of the spillway is required, this configuration makes the most sense because the riser section can be removed and the barrel section can be utilized as part of the spillway for the detention basin.

For steps on the design of the principal and emergency spillways for multipurpose basins, refer to Chapter 10. Design the sediment basin principal spillway to reduce the construction-phase conditions to pre-development levels for the 2 and 10-year 24-hour storm events. Design the emergency spillway to pass and provide flow reduction for the 100-year 24-hour storm permanent detention basin using post-development conditions.

Design the principal spillway for the permanent detention basin to reduce post-development flows to pre-development flows for the 2 and 10-year 24-hour storm events as described in Chapter 10. Design the emergency spillway to pass and provide flow reduction for the 100-year detention basin using post-development conditions.

When the sediment pond phase has expired, the temporary riser structure shall be removed and the permanent structure shall be installed. The basin shall be cleaned of deposited sediment and re-graded to meet the permanent basin contours if necessary.

General Design Criteria

a. Minimum Freeboard for both basin phases is 1 ft.
b. Design must include maintenance accessibility and responsibility.
c. Provide erosion protection for the emergency spillway and channel protection for the receiving channel.
d. Storage, discharge, and routing calculations for the 2, 10, and 100-year storm events must be submitted for review.
e. Multipurpose basins shall be fully discharged within 36 hours after the storm event unless specifically approved by MSD.
f. Multipurpose basins shall be the first item of construction.

MAINTENANCE

- **Inspect temporary sediment basins periodically and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color and perform necessary repairs when appropriate.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level and dispose of sediment at a protected location onsite to prevent resuspension of sediment.**

LIMITATIONS

- **Sediment basins may kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **May not be effective for fine-grained soils such as silt or clay. Additional upstream controls may be necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

12.6.4 TEMPORARY SEDIMENT TRAP SCM-4: TST



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Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Temporary sediment traps are small temporary ponds that detain sediment-laden runoff from disturbed areas allowing sediment to settle out. A temporary sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out. Sediment traps shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. Temporary sediment trap details are Exhibits 12-9A and 12-9B in Supplemental Section D.

APPLICATION

- **Any disturbed area which is less than 5 acres.**
- **Along the perimeter of a project site to prevent sediment-laden runoff from being discharged off-site or areas where runoff can enter stabilized areas or waterways.**
- **Immediately upstream from temporary storm drain inlet protection measures.**

APPROACH

A sediment trap may be formed completely by excavation or by constructing a compacted embankment. The outlet should be a rock fill weir/spillway section, with the area below the weir acting as a filter for sediment and the upper area as the overflow spillway depth.

To complete the design of the temporary sediment trap:

- Determine the required sediment storage volume.

- Determine the bottom and top surface area of the sediment storage volume using 3H:1V side slope from the bottom of the trap.

- Determine the total trap dimensions by adding the depth required for the 10-year, 24-hour design storm above the surface of the sediment storage volume, while not exceeding 3H:1V side slopes.

- General Design Criteria – the design aids located in Section 12.8.5 shall be used to properly size the sediment trap. Sedimot III, SEDCAD and other computer models may also be utilized.

- Other design requirements are as follows:
    a. Maximum Drainage Area - 5 acres
    b. Maximum Design Life - 18 months
    c. 80% design removal efficiency goal for TSS
    d. Basin Shape - The flow length should be 2 times the flow width.
    e. Embankment Requirements:
        1. Maximum Dam Height - 5 feet.
        2. Maximum Stone Height – 3.5 feet.
        3. Minimum Rock Bottom Width – 3 feet.
        4. Discharge and treatment capacity for the 10-yr. 24-hr. storm event.

MAINTENANCE

- **Inspect traps periodically and after each rain event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color; identify and perform repairs to improve water quality.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level.**

LIMITATIONS

- **Sediment traps can kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **Temporary sediment traps only remove coarse particles which settle quickly. They are not effective for fine-grained soils such as silt or clay. Additional upstream erosion control measures are necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

12.6.5 SILT FENCE SCM-5: SF



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Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

A silt fence is a temporary measure for sediment control. It shall be designed to have an 80% design removal efficiency goal of the TSS in the inflow. Silt fence consists of posts with **a synthetic** filter fabric stretched across the posts and a wire support fence. The lower edge of the fence is vertically trenched and covered by compacted backfill. Typical silt fence details, with and without reinforcement, are shown in Standard Drawings EF-09-**02** and EF-10-**02**.

APPLICATION

- **Any disturbed area accepting sediment-laden sheet flow conditions.**
- **Along the downstream perimeter of a disturbed site, below the toe of a cleared slope, upstream of sediment traps or basins, along streams and channels and around temporary spoil areas.**

APPROACH

- Maximum sheet or overland flow path length to the fence is 100 feet.
- Maximum slope steepness (normal [perpendicular] to fence line) 2H:1V.
- Not to be placed across channels.
- General Design Criteria - The design aids located in Section 12.8.4 shall be used to properly design silt fence.
- Standard non-reinforced silt fence shall be used when the contributing slope is less than or equal to 3% and the design life of silt fence is less than 6 months.

- Reinforced silt fence shall be required when the contributing slope is greater than 3% and the design life of the silt fence is greater than 6 months.

Land Slope	Max. Slope Distance
< 5%	100 ft.
5% - 10%	50 ft.
10% - 20%	25 ft.
20% - 50%	15 ft.

- Other design requirements are as follows:
  a. 80% design removal efficiency goal for TSS
  b. Maximum Slope Length - 100 feet
  c. Maximum Slope Gradient – 2H:1V
  d. Minimum Installed Fence Height - 18 inches
  e. Maximum Installed Fence Height - 24 inches
  f. Minimum Post Bury Depth – 18 inches
  g. Maximum Reinforced Fence Post Spacing - 6 feet
  h. Maximum Non-reinforced Post Spacing - 6 feet

MAINTENANCE

- **Inspect silt fence periodically and after each rainfall event for damage or loosened fabric, excessive sediment buildup, undercutting flows or flows around end of silt fence. Repair or replace as necessary.**
- **Remove sediment whenever it reaches one-third of the silt fence height.**
- **Maintain silt fence until disturbed areas have been properly stabilized.**
- **Silt fence should be removed within 30 days after final site stabilization is achieved or after temporary BMPs are no longer needed.**

LIMITATIONS

- **Cannot be used in continuously-flowing streams.**
- **Installation and removal may damage vegetation and channel grades.**
- **May kill vegetation by excessive sediment or by long periods of submergence.**
- **Should not be installed along the slope contour and not up or down the slope.**

12.6.5B HARD SURFACE SEDIMENT BARRIERS



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Slope Protection	Surface Protection	Enclosed Drainage	Flat Areas	Adjacent Properties

DESCRIPTION

Hard surface controls shall be used when silt fence cannot be installed due to a concrete or asphalt surface. BMPs such a fiber rolls, silt socks, and straw waddles shall not be used as a primary control and only when larger BMPs are impractical

APPLICATION

- **To be used for small, flat areas where silt fence or other BMPs cannot be used due to asphalt or other hard surface.**

MAINTENANCE

- **Inspect periodically and after each rainfall event for damage or loosened fabric, excessive sediment buildup, undercutting flows or flows around end of barrier. Repair or replace as necessary.**
- **Remove sediment whenever it reaches one-third of the height of the particular BMP.**
- **Maintain until disturbed areas have been properly stabilized.**
- **Should be removed within 30 days after final site stabilization is achieved or after temporary BMPs are no longer needed.**

LIMITATIONS

- **Not a primary control**

12.6.6 ROCK DITCH CHECK SCM-6: RDC



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Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A rock ditch check is a small, temporary or permanent rock fill dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows. Rock ditch checks shall be designed to have an 80% design removal efficiency goal of the TSS in the inflow. A typical rock ditch check section is shown in Standard Drawing EB-03-003

APPLICATION

- **Sediment and erosion control in small open channels (<5-acre drainages).**
- **Flow velocity reduction.**

APPROACH

- Rock ditch checks should be used only in small open channels. The checks should not be placed in Waters of the Commonwealth, unless approved by the State. The center section of a rock ditch check should be lower than the edges.

- Spacing varies with the bed slope of the ditch. The maximum spacing between the rock checks should be such that the toe of the upstream check is at the same elevation as the top of the downstream check.

- In the case of grass-lined ditches and swales, ditch checks should be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4%. The area beneath the ditch checks should be seeded and mulched immediately after dam removal. Geotextile filter fabric shall be installed under all rock fill.

- General Design Criteria - The Design Aids located in Section 12.8.3 shall be used to properly design rock ditch checks.

- Other design requirements are as follows:
  a. 80% design removal efficiency goal for TSS
  b. Maximum Drainage Area – 5 acres
  c. Maximum Height - 2 feet

- If the rock ditch check is not properly sized, the flow will overtop the structure and the Trapping Efficiency is assumed 0% when this takes place.

MAINTENANCE

- **Inspect every seven days and within 24 hours after each rain event that produces 0.5 inches or more of precipitation to check for excessive sedimentation or instability.**
- **Sediment must be removed before it reaches one-half of the device's original height.**

LIMITATIONS

- **Not for use in continuously-flowing streams.**
- **May damage vegetation and channel grades.**

12.6.7 STABILIZED CONSTRUCTION ENTRANCES

SCM-7: SCE



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Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A stabilized construction entrance is a temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site to reduce the amount of mud, dirt, rocks, etc. transported onto public roads by motor vehicles equipment and runoff. A diagram of a typical temporary gravel construction entrance is shown in Standard Drawing ER-01-03.

Stabilized construction entrances should be used whenever repetitive traffic will be leaving a construction site and be moving directly onto a public road. Construction entrances provide an area where mud can be removed from vehicle tires before entering a public road.

APPLICATION

- **All points of construction ingress and egress.**

APPROACH

If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road. If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried offsite. Washdown facilities shall be required as directed by MSD. Washdown areas, in general, must be established with crushed gravel and drain into a sediment trap or sediment basin. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles. Limiting traffic from the site in wet conditions is a means of controlling mud on streets.

12.6.7 STABILIZED CONSTRUCTION ENTRANCES

SCM-7: SCE

The General Design Criteria **are:**

a. Minimum Entrance Dimensions

1. Thickness - 6 inches
2. Width of entrance area - 24 feet
3. Length – 100 feet or required length for 10 tire revolutions

b. Material - #3stone size or larger. Non-woven geotextile fabric is required to underlie the stone.

MAINTENANCE

- **Maintain entrance area to ensure mud, dirt, rocks, etc. are not tracked onto roadways. Remove all mud or sediment deposited on paved roadways as necessary.**
- **Remove gravel material and filter fabric at completion of construction, or as paved surfaces are finished.**
- **Periodic top dressing of the area may be required.**

LIMITATIONS

- **Construction entrances on slopes may require diversions to prevent stormwater from leaving the site.**

12.6.8 STORM DRAIN INLET PROTECTION SCM-8: SIP



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SIP

Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Storm drain inlet protection allows sediment to settle prior to entering into a stormwater catch basin or inlet. Storm drain inlet protection can be achieved by placing a temporary filtering device around any inlet to trap sediment. This mechanism prevents sediment from entering inlet structures. Additionally, it serves to prevent the silting-in of inlets, storm drainage systems, or receiving channels.

Four different materials/methods that can be used to provide inlet protection are: filter fabric, block and gravel, gravel and stone with a wire mesh filter, and stone bags. **Straw bales are not permitted for this purpose because of plugging.** In addition, excavating immediately around the drop inlet and using gravel to restrict sediment flow can also be used to protect the inlet. Typical diagrams for each of these filter types are: Filter Fabric Inlet Protection Standard Drawing EF-01-**02**, Block and Gravel Drop Inlet Protection Standard Drawing EF-13-**01**, Gravel and Wire Mesh Inlet Sediment Filter Standard Drawing EF-14-**01**, and Stone Bag Inlet Protection Standard Drawing EF-03-**02**.

APPLICATION

- **Every storm drain inlet, catch basin, curb inlet, culvert or similar drainage structure that receives sediment-laden runoff.**
- Storm drain inlet protection is not meant for use in drainage areas exceeding one (1) acre or for large concentrated **stormwater** flows. Inlet protection is to be used as a last resort for sediment control when no other means are practical.
- Stone bag inlet protection is not to be used in an active roadway.

APPROACH

Inlet protection shall be avoided on roadways due to the potential of ponding and street flooding. Inlet protection may be installed prior to the construction of roads however,

once the sub base is laid, the inlet protection shall be removed.

Inlet protection is required on all inlets that have outfalls that bypass sediment trapping structures and directly discharge off-site. General design criteria for each of the materials/methods of inlet protection are provided below.

- Filter Fabric is used for inlet protection when **stormwater** flows are relatively small (0.5 cfs or less) with low velocities and where the inlet drains a relatively flat area (slopes no greater than 5%). This practice cannot be used where inlets are paved or where inlets receive concentrated flows, such as in streets or highway medians.

- Filter Fabric Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

- Block and Gravel filters can be used where heavy flows and higher velocities are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure.

- Block and Gravel Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.3 shall be used to properly design rock ditch checks.

- Gravel and Mesh filters can be used where heavy concentrated flows are expected and subject to disturbance by site traffic. Gravel and Mesh filters should not be used where ponding around the structure might cause excessive inconvenience or damage to adjacent structures and unprotected areas. Gravel and Mesh filters have no overflow mechanism; therefore ponding is likely, especially if sediment is not removed regularly. Gravel and Mesh filters must never be used where overflow may endanger an exposed fill slope.

- Gravel and Mesh filters shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

- Stone Bag Inlet Protection is used when **stormwater** flows are relatively small (0.5 cfs or less) with low velocities and where the inlet drains a relatively flat area (slopes no greater than 5%). The immediate land area around the inlet should be relatively flat (less than 1% slope).

- Stone Bag Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

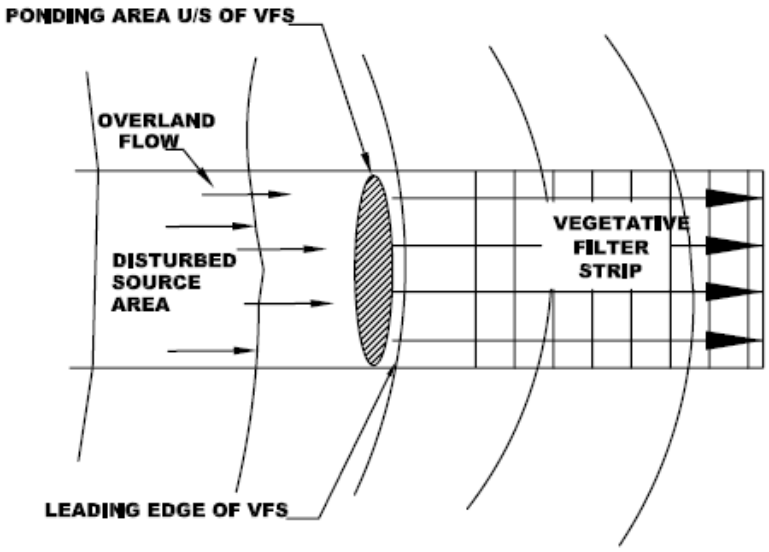
MAINTENANCE

- **Inspect storm drain inlet protections periodically and after every rain event to check for damage caused by large flows and clogged fabric. Repair or replace as necessary.**
- **Remove sediment when depth exceeds one-third the height of the filter or half the depth of the sediment trap.**
- **Inlet protection should be removed and the area restored once the contributing watershed has been permanently stabilized.**

12.6.8 STORM DRAIN INLET PROTECTION SCM-8: SIP

LIMITATIONS	• **Some types of inlet protection may cause ponding that could encroach onto access roads, streets, parking lots, driveways or highway traffic.**

12.6.9 VEGETATED FILTER STRIPS SCM-9: VFS



PLAN VIEW

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VFS VFS

Slope Protection	**Waterway Protection**	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Vegetated **f**ilter **s**trips (VFS) are zones of vegetation through which sediment and pollutant-laden runoff are directed before being discharged to a concentrated flow channel. Proper orientation of VFS is shown in Exhibit 12-10 in Supplemental Section D.

APPLICATION

- **Often used in conjunction with other stormwater management practices to reduce the amount of sediment and treat runoff from impervious surfaces.**

APPROACH

In the design of VFS, the designer must select a vegetation type, a ground slope, filter strip width, and strip length. To be effective, VFS should be located on the contour perpendicular to the general direction of flow. Vegetation should be selected to be dense, turf-forming grass in order to minimize water channelization. The designer should never assume that natural vegetation is adequate for VFS. A ponding area shall be constructed at the leading edge of the VFS for bedload deposition.

The design process for VFS requires a series of detailed equations found in Design Hydrology and Sedimentology for Small Catchments, Hann et. al. 1994: pages 359-375. Software packages such as SEDIMOTII, or SEDCAD should be utilized to determine trapping efficiencies for VFS.

- The General Design Criteria to Design Filter Length are:
  a) Select a vegetation type.

  b) Select the design life and maximum allowable sediment deposition. A design life of 10 years and deposition of 0.5 feet is recommended.

c) Estimate the long-term sediment yield entering the filter strip and a 10-year 24-hour design single-storm sediment yield.

d) Determine desired Trapping Efficiency- 80% design removal efficiency is the goal of the total suspended solids (TSS) in the inflow.

e) Estimate the filter length necessary to prevent deposition within the filter greater than 0.5 feet. (Assume filter width is equal to disturbed area width but no smaller than 15 ft.)

f) Use the filter length to calculate Trapping Efficiency for the design storm.

g) Repeat (d) and (e) until **the filter length achieves appropriate removal efficiency.**

- Minimum Ground Slope = 1%
- Maximum Ground Slope =10%

MAINTENANCE

- **Inspect periodically and after significant rain events until vegetation is established. Repair or replace damaged vegetation or eroded areas.**
- **Vegetation should not be mowed shorter than three inches.**

LIMITATIONS

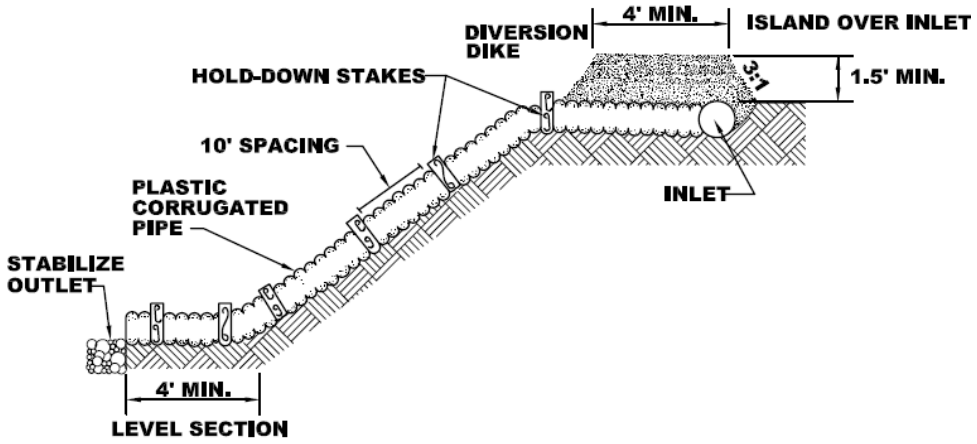
- **Vegetated filter strips only treat sheet flow and are effective only on gentle slopes.**
- **Proper maintenance is required to maintain the health and density of vegetation.**
- **Filter strips typically require a large amount of space.**

12.7 RUNOFF CONTROL AND CONVEYANCE MEASURES

The following flow control measures are applicable as temporary and/or permanent practices for use during construction.

12.7.1 PIPE SLOPE DRAINS

RC&CM-1: PSD



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PSD PSD PSD

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Pipe slope drains reduce the risk of erosion by discharging concentrated runoff from the top to the bottom of slopes. Pipe slope drains can be temporary or permanent depending on installation and material used. A typical pipe slope drain layout is shown in Exhibit 12-11 in Supplemental Section D of this chapter.

Temporary pipe slope drains, usually flexible tubing or conduit, may be installed prior to construction of permanent drainage structures. Permanent slope drains shall be buried beneath the ground surface. The inlets and outlets of a pipe slope drain shall be stabilized with flared end sections, Erosion Control Blankets (ECBs), Turf Reinforcement Mats (TRMs) or riprap. The soil around the pipe entrance should be fully compacted to prevent bypassing and undercutting of the structure. The soil at the discharge end of the pipe should be stabilized along the bottom of any swales that lead to sediment trapping structures or other stabilized areas.

APPLICATION

- Pipe slope drains are used when it is necessary for water to flow down a slope without causing erosion, especially before a slope has been stabilized or before permanent drainage structures are installed.

APPROACH

- The capacity should handle a 10-year, 24-hour storm peak flow.
- The maximum drainage area allowed per pipe is 2 acres.
- The inlet section should be securely connected to the slope drain and have watertight connecting bands.

- Slope drains sections should be securely fastened together, have **watertight** gasket fittings, and be securely anchored properly into the soil.
- Diversion channels should direct runoff to slope drains. The height of the dike should be at least 1-foot higher than the top of the inlet pipe and be compacted around the pipe with an anti-seep device.
- The area below the outlet must be properly stabilized with ECBs, TRMs, riprap or other applicable stabilization technique.
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Permanent slope drains should be buried beneath the soil surface a minimum 1.5 feet.

MAINTENANCE

- **Inspect periodically and after each rain event. Remove sediment buildup and debris from inlets and outlets as necessary.**
- **Inspect outlet for erosion and downstream scour. Repair damage as necessary.**
- **Install energy dissipaters if appropriate.**

LIMITATIONS

- **Severe erosion may result when downdrains fail.**
- **Should not be used in drainages exceeding 2 acres.**

12.7.2 TEMPORARY STREAM CROSSING RC&CM-2: TSC



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Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A temporary stream crossing is a bridge or culvert across a stream or watercourse for short-term use by construction vehicles and heavy equipment. A stream crossing provides a means for construction vehicles to cross streams or watercourses without moving sediment to streams, damaging the streambed or channel, or causing flooding. A typical layout for a temporary stream low water crossing is shown in Standard Drawing ER-02-**02**.

APPLICATION

- **Any area where construction vehicles must cross a stream or watercourse.**

APPROACH

Prior to constructing a temporary stream crossing, the owner/person financially responsible for the project must submit an Application for Permit to Construct Across or Along a Stream to the Kentucky Division of Water (KDOW). Temporary stream crossings require a Section 404 Permit from the Army Corps of Engineers that is subject to Section 401 Water Quality Certification from KDOW. If the crossing creates more than 200 linear feet of fill or more than 1/3 acre of fill, an Individual Permit may be necessary instead of a Nationwide Permit. A copy of **the Army Corps of Engineers** permit needs to be submitted with the proposed construction plans prior to receiving construction approval.

When feasible, one should always attempt to minimize or eliminate the need to cross streams. Temporary stream crossings are a direct source of pollution; therefore, every effort should be made to use an alternate method (e.g., longer detour), when feasible. When it becomes necessary to cross a stream, a well-planned approach will minimize the

damage to the stream bank and reduce erosion. The design of temporary stream crossings requires knowledge of the design flows and other information; therefore, the services of a professional engineer to deal with specific state and local requirements should be considered. The specific loads and the stream conditions will dictate what types of stream crossing to employ.

Design Criteria

Temporary Bridge Crossing

- Structures may be designed in various configurations. However, the materials used to construct the bridge must be able to withstand the anticipated heavy loading of the construction traffic.

- Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the centerline of the stream at the intended crossing location. However, every effort shall be taken to install the crossing perpendicular to the stream. All fill materials associated with the roadway approach shall be limited to a maximum height of two feet above the existing **floodplain** elevation.

- A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. The flow captured in these dikes and swales shall be directed to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

- Appropriate perimeter controls such as silt fences, must be employed when necessary along banks of stream parallel to the same.

- All crossings shall have one traffic lane. The minimum width shall be 12 feet with a maximum width of 20 feet.

Temporary Culvert Crossing

- Limit the width of fill to that only necessary for the actual crossing.

- Where culverts are installed, coarse aggregate of clean shot limestone rock, riprap, and/or concrete with **#57** stone or greater will be used to form the crossing.

- Clean shot rock and/or riprap may be used as fill for crossings that will be in place for 6 to 12 months. A concrete cap shall be constructed over the rock for crossings that will be in place for more than 12 months.

- The depth of stone cover over the culvert shall be equal to ½ the diameter of the culvert or 12 inches; whichever is greater, but no greater than 18 inches. To protect the sides of the stone from erosion, riprap shall be used.

- The culvert crossing shall be large enough to convey the flow from a two-year frequency storm without appreciably altering the stream flow characteristics. A qualified professional must design the structure.

- The maximum number of pipes as possible should be placed within the stream banks with a maximum spacing of 12 inches between pipes.

- The minimum-sized pipe culvert that may be used is 24 inches.

- All culverts shall be strong enough to support their cross-sectional area under the maximum expected heavy equipment loads.

- The length of the culvert shall be adequate to extend the full width of the crossing, including side slopes.

- The slope of the culvert shall be at least 0.25 feet per foot.

- Crossing Alignment – A temporary culvert crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the centerline of the stream at the intended crossing location. However every effort shall be taken to install the crossing perpendicular to the stream. All fill materials associated with the roadway approach shall be limited to a maximum height of two feet above the existing **floodplain** elevation.

- The approaches to the structure shall consist of stone pads meeting the following specifications:

    1. Clean stone or concrete fill only
    2. Minimum thickness: 6-inches
    3. Minimum width: equal to the width of the structure
    4. 20-foot minimum approach length

- A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. The flow captured in these dikes and swales shall be directed to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

A temporary culvert crossing should be in place no longer than 24 months.

MAINTENANCE

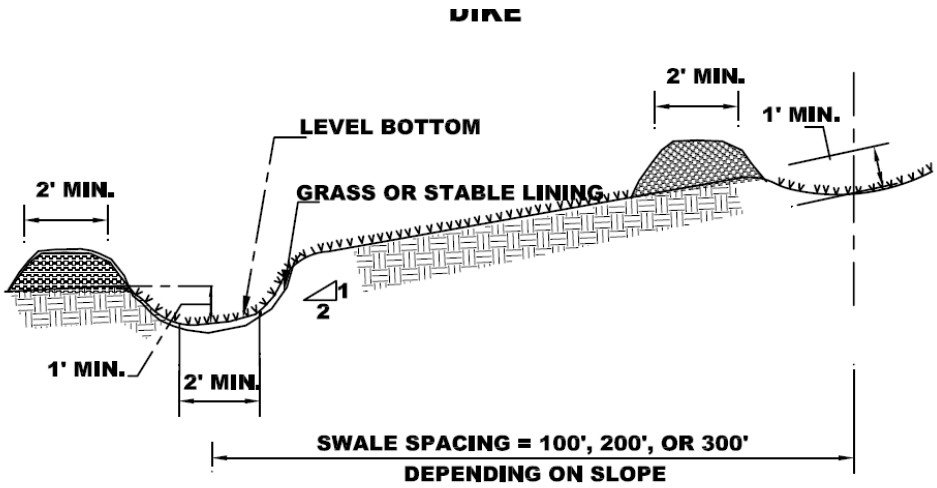
- **Inspect every seven days and after each rain event that produces 0.5 inches or more precipitation and repair any eroded areas immediately.**
- **The crossing should be removed immediately after construction. The stream bed and banks must be stabilized and restored to pre-construction conditions.**

12.7.2 TEMPORARY STREAM CROSSING — RC&CM-2: TSC

LIMITATIONS

- **Temporary stream crossings may increase velocity of flows within the channel in excess of those normally encountered, resulting in stream bed and bank scour.**
- **Crossings require coordination with the U.S. Army Corps of Engineers and the Kentucky Division of Water.**

12.7.3 RUNOFF CONVEYANCE MEASURES RC&CM-3: RCM



SWALE

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Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
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RCM RCM RCM

Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	**Borrow Areas**	**Adjacent Properties**

DESCRIPTION

Dikes and berms and swales are used to divert upslope runoff from crossing areas where there is a high risk of erosion. Runoff conveyance structures may be used as temporary clean water diversions, temporary sediment-laden **water** diversions, or permanent clean water diversions. Runoff conveyance measures can be either temporary or permanent **stormwater** control structures. Typical cross sections for dikes and swales are shown in Exhibit 12-12 in Supplemental Section D.

When constructed along the upslope perimeter of a disturbed or high-risk area (though not necessarily all the way around it), clean water diversions prevent clear water runoff from flowing over unprotected **downslope** areas. Sediment-laden diversions located on the downslope side of a disturbed or high-risk area will prevent sediment-laden runoff from leaving the site before sediment is properly removed. For short slopes, runoff conveyance measures at the top of the slope reduce the amount of runoff reaching the disturbed area. For longer slopes, several dikes or swales are placed across the slope at intervals. This practice reduces the amount of runoff that accumulates on the face of the slope and carries the runoff safely down the slope. In all cases, runoff is guided to sediment trapping areas or a stabilized outfall before release.

APPLICATION

- Runoff conveyance measures are generally built around the perimeter of a construction site before any major disturbing activity takes place.
- Runoff conveyance measures are used in areas of overland flow.
- Convey stormwater to sediment trapping area.
- Convey clean stormwater around construction areas.

12.7.3 RUNOFF CONVEYANCE MEASURES RC&CM-3: RCM

APPROACH

Runoff channeled by dikes or swales should be directed to an adequate sediment trapping structure or stabilized outfall. Care should be taken to provide enough channel slope for drainage but not too much slope to cause erosion due to high runoff flow speed. Temporary runoff conveyance measures may remain in place as long as 12 to 18 months (with proper stabilization). Dikes or swales should remain in place until the area they were built to protect is permanently stabilized.

Permanent controls should be designed to handle runoff after construction is complete; should be permanently stabilized; and should be inspected and maintained on a regular basis. Refer to Chapter 10 for temporary and permanent diversion channel stabilization requirements. **Examples of runoff conveyance measures include: grass-lined channels, sod-lined channels, riprap-lined channels, turf reinforced channels, paved channels, and temporary slope drains.**

Dikes and Berms

- Top Width - 2 foot minimum
- Height - 18" minimum measured from upslope toe.
- Side Slopes - 2H:1V or flatter
- Grade - Limited to grades between 0.5% and 1.0%.
- Spacing

Percent Slope	< 5%	5% - 10%	10% - 40%
Horizontal Spacing (ft)	300	200	100

- Stabilization - Slopes shall be stabilized immediately using vegetation, sod, erosion control blankets, or turf reinforcement mats to prevent erosion.
- Outlet - The upslope side of the dike should provide positive drainage so no erosion occurs at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
- Other - Minimize construction traffic over temporary dikes.

Swales

- Bottom Width - 2 feet minimum, the bottom should be level.
- Depth - 1-foot minimum.
- Side Slope - 2H:1V or flatter.
- Grade - Maximum 5%, with positive drainage to a suitable outlet.
- Stabilization - Stabilize with erosion control blankets or turf reinforcement mats immediately.

- Spacing

Percent Slope	< 5%	5% - 10%	10% - 40%
Horizontal Spacing (ft)	300	200	100

- Outlet - riprap to stabilize outlet/sedimentation pond.

MAINTENANCE

- **Inspect periodically and after every rain event to check for erosion and accumulation of debris and sediment. Remove debris and sediment buildup as necessary.**
- **Any decrease in the berm height due to settling or erosion should be repaired immediately.**

LIMITATIONS

- **Severe erosion may result when dikes, berms or swales become unstable or or not installed properly.**
- **Concentrated flow within conveyance increases the potential for erosion.**
- **Conveyance should be designed to avoid vehicular crossings.**

12.7.4 CONSTRUCTION DEWATERING RC&CM-4: CD



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Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	**Large Flat Areas**	**Borrow Areas**	Adjacent Properties

DESCRIPTION

Construction dewatering involves removing stormwater or groundwater from bore pits, trenches, and other excavations on the construction site. Usually this removal involves the pumping of this water to an appropriate receiving area. Direct pumping to lakes and streams **is illegal** and must be avoided.

APPLICATION

- **Removal of stormwater or groundwater from bore pits, trenches, and other excavations on the construction site.**

APPROACH

The pump utilized for dewatering purposes must be properly sized. Each pump has its own unique rating curve; therefore it is not feasible to list them in this chapter. The pump rating curve is used to calculate pump design flows based on head loss through the pump system.

The sediment-laden groundwater should be pumped directly to:

- A sediment control structure (i.e., sediment basin or sediment trap);
- An infiltration trench; or
- A vegetated buffer strip or zone.

Pumping to a Sediment Control Structure:

- It is recommended that sediment basins or temporary sediment traps receive sediment-laden water from bore pits and trenches. This will ensure that the 80%

trapping efficiency goal will be upheld. Special care should be taken to ensure that the pumping of this water does not cause the sediment control structure to fail. Also, care should be taken at the outlet of the hose from the pump to ensure that erosion does not occur due to high concentrated flows.

Pumping to an Infiltration Trench:

- An infiltration trench is a shallow, excavated trench back-filled with stone to form a reservoir. This reservoir may contain a subsurface drainage pipe or just stone. This trench allows water to filter through the stone and then be diverted to a suitable discharge point. The soils and the depth to the water table must be suitable for this sort of **dewatering.** Typical trench depths range from 2 to 8 feet. The stone fill material consists of washed aggregate 1.5 to 3 inches in diameter.

Pumping to a Vegetated Buffer Strip or Zone:

- Buffer zones are capable of filtering sediment-laden water. One option is to pump the water to a discharge device that will evenly spread the water over a wooded or vegetated buffer zone. An appropriate buffer zone can be determined from Section 12.6.9.

- A plan and profile for dewatering operations with pumping to a vegetated buffer zone is provided in Exhibit 12-13 in Supplemental Section D.

A detail for an outlet structure to the buffer zone is provided in Exhibit 12-14 in Supplemental Section D. This discharge device uses Schedule 40 PVC pipes. The discharge hose from the pump is connected to a flow diffuser constructed using PVC pipe. The diffuser pipes are capped at the ends and the water is discharged through evenly spaced holes drilled into the diffuser. The size and length of the diffuser and the size and spacing of the holes are dependent upon the flow capacity of the pump being used for the **dewatering** process. The **Exhibit provides** recommended pipe sizes, pipe lengths, hole sizes, and hole spacing are based on pump discharge rates for pumps of 5 HP and less.

MAINTENANCE	• **Inspect receiving area frequently to ensure capacity is not exceeded.**
LIMITATIONS	• **If the presence of polluted water is identified, the contractor shall implement appropriate dewatering pollution controls.**

12.7.5 STONE BAG CHECK DAM IN SMALL DITCH

RC&CM-6: SBCD



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MSD

SBCD ▶ SBCD ▶ SBCD

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Stone **b**ag **c**heck **d**ams can reduce flow velocities in small man-made swales and ditches, which reduces the erosive potential of the flow and also promotes sediment deposition. A typical layout for a stone bag check dam in a small ditch is shown in Standard Drawing EF-12-**02**.

APPLICATION

- Stone **b**ag **c**heck **d**ams are to be placed in front and rear yard swales only. Stone bag check dams should not be built in wetlands, any active or live streams, and in Waters of the Commonwealth.
- Stone bag check dams are applicable in situations where flow velocities are too high and are causing channel scour. They should not be used as a primary sediment-trapping device. They should be used as velocity checks only as a short-term temporary solution.
- Specific conditions for use include new diversion ditches that will not or cannot be stabilized for several days, and temporary diversion channels that are eroding due to high flow rates or steep slopes.

APPROACH

The bags shall be filled with KTC No. 57 stone. The dam shall span the banks of the ditch or swale. The height of the dam on the stream centerline should equal the height of flow for the 2-year 24-hour storm event. Bags should be placed on the bank to a height at least 6 inches higher than the center of the dam.

Space **s**tone **b**ag **c**heck **d**ams such that the crest of the downstream dam is at the same elevation of the toe of the dam located immediately upstream. Show the designed spacing

12.7.5 DITCH	STONE BAG CHECK DAM IN SMALL	RC&CM-6: SBCD
	on the EPSC plans.	
MAINTENANCE	• **Inspect every 7 days and after each rain event that produces 0.5 inch or more precipitation to check for excessive sedimentation or debris and trash buildup.** • **Remove sediment, debris and trash before it reaches one-half of the device's original height.** • **Loose or displaced stone bags should be repaired to the original specifications or replaced.**	
LIMITATIONS	• **Not to be used in streams or rivers.** • **Not a primary control**	

12.8 ENGINEERING AIDS AND DESIGN GUIDELINES FOR SEDIMENT CONTROLS

This section presents design aids that were developed for use in designing four types of sediment control structures; temporary sediment basins (Section 12.6.2), temporary sediment traps (Section 12.6.4), silt fences (Section 12.6.5), and rock ditch checks (Section 12.6.6) for Jefferson County, Kentucky. These design aids will each be briefly described and then examples will be used to demonstrate their use in realistic problems. Settling velocity will be discussed to begin.

12.8.1 Characteristic Settling Velocity and Eroded Particle Size

A common feature of each of the design aids is that a characteristic settling velocity for the eroded soil must be obtained. For Jefferson County conditions, this velocity corresponds to an eroded size such that 15% of the sediment has particles smaller than the size specified. The procedure for empirically estimating eroded size distributions is best described by Hayes et.al (1996). Characteristic settling velocity corresponds to an eroded particle diameter that is referred to as D_{15}. This diameter represents the point on the eroded particle size distribution curve where 15% of the particles (by weight) are equal to or smaller than this size. Estimated eroded size distributions for Jefferson County soils using an adaptation of the method described by Foster et al. (1985) were developed. The procedure uses the primary particle size information reported by SCS as part of county soil surveys. This procedure may be used with USDA Soil Survey Data or site specific soil boring data. Other procedures are given by Haan et.al. (1994) for physically based estimating procedures. If D_{15} is less than 0.01 mm, then settling velocity based upon a simplified form of Stokes Law is:

$$\mathbf{V_s = 2.81d^2} \qquad (1)$$

Where: V_s is settling velocity in ft/sec and d is diameter in mm. If D_{15} is greater than or equal to 0.01 mm, then settling velocity should be found using

$$\mathbf{\log_{10}V_s = -0.34246\,(\log_{10}d)^2 + 0.98912\,(\log_{10}d) - 0.33801} \quad (2)$$

Where: V_s, is settling velocity in ft/sec and d is particle diameter in mm (Wilson et al., 1982). The characteristic settling velocity can be obtained using Figure 12.1 and the eroded particle size (D_{15}) for soils found in Jefferson County, which is provided in Supplemental Section D.

It is important to remember that the eroded size distribution is the most critical parameter in sizing sediment controls. The eroded size distributions vary greatly from primary particle size distributions that are often determined as a result of soil strength investigations for construction purposes. Primary particle sizes will yield erroneous results and should not be used. The user should note that D_{15} is often

smaller for coarse textured (more sandy soils) because of the reduced clay content and the lack of aggregation.

Table 12-7. Soil Classification by Texture

Jefferson County Soil Classification by General Texture			
Texture	Coarse	Medium	Fine
Soil Type	Sandy Loam	Silt Loam	Clay Loam

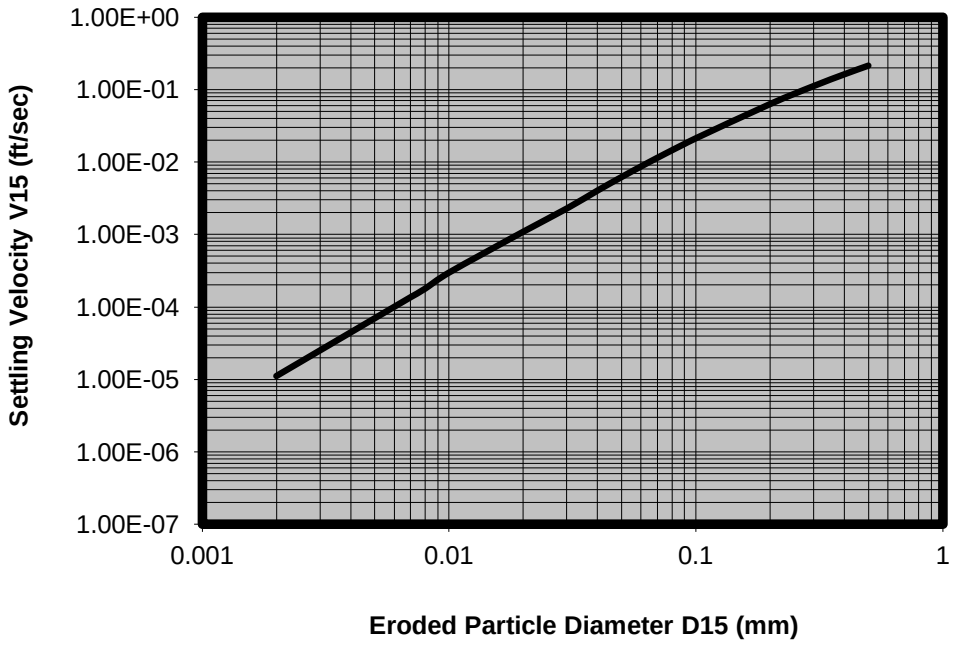

Figure 12.1. Characteristic Settling Velocity as a Function of Eroded Particle Diameter

12.8.2 Sediment Basin Design Aids

Figure 12.2 plots the basin ratio (qpo/AV_{15}) versus percentage of trapping efficiency. For basins, the ratio is defined by:

$$\textbf{Basin Ratio} = \mathbf{q_{po}/AV_{15}} \qquad (3)$$

Where: q_{po} = peak outflow rate from the basin (cfs), A =surface area of the pond at riser crest (acres), V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Figure 12.2 is for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam) as shown in Table 12-8. The ratio should be less than or equal to the curve value at any given trapping efficiency. For example, at 80% trapping efficiency, the basin ratio equals 2.0E+**0**5 as shown in Figure 12.2. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

Basin Ratios above the design curves are not recommended for any application of the design aids. Constraints for use of Figure 12.2 are:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 %
- Outlet diameter less than or equal to 6 feet

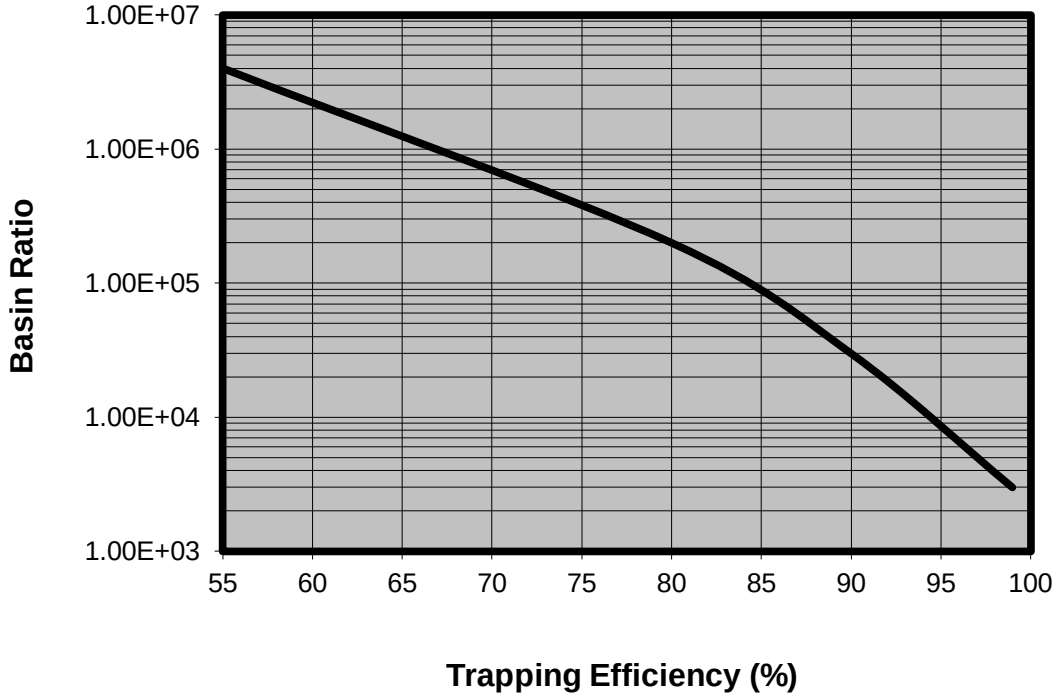

Figure 12.2. Design Aid for Estimating Trapping Efficiency of Sediment Basins.

12.8.3 Rock Ditch Check Design Aids

Design aids for rock ditch checks were developed similarly to those for **basins.** Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity. The ratio for ditch checks is defined by:

$$\textbf{Ditch Check Ratio} = Sq^{(1-b)}/aV_{15} \qquad (4)$$

Where: S = channel slope (%),
q = flow through the check (cfs/ft),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Table 12-8. Stone Flow Coefficient a and Exponent b

Stone D_{50} (m)	Exponent b	dl= 1m Coefficient a	dl = 2m Coefficient a	dl = 3m Coefficient a
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

Coefficients *a* and Exponent *b* can be interpolated from Table 12-8 (Haan et.al. (1994) pg. 151).
D_{50} = rock ditch check average stone diameter in **meters**.
dl = average flow length through the rock ditch check in **meters**.

If the check overtops, the trapping efficiency is assumed to be zero. Figures 12.3a, 12.3b, and 12.3c can be used for estimating trapping efficiency of rock ditch checks. Table 12-8 provides guidance to determine which plot is appropriate.

Ditch Check Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figures 12.3a, 12.3b, and 12.3c are:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500 feet
- Overland slope is less than or equal to 15 %

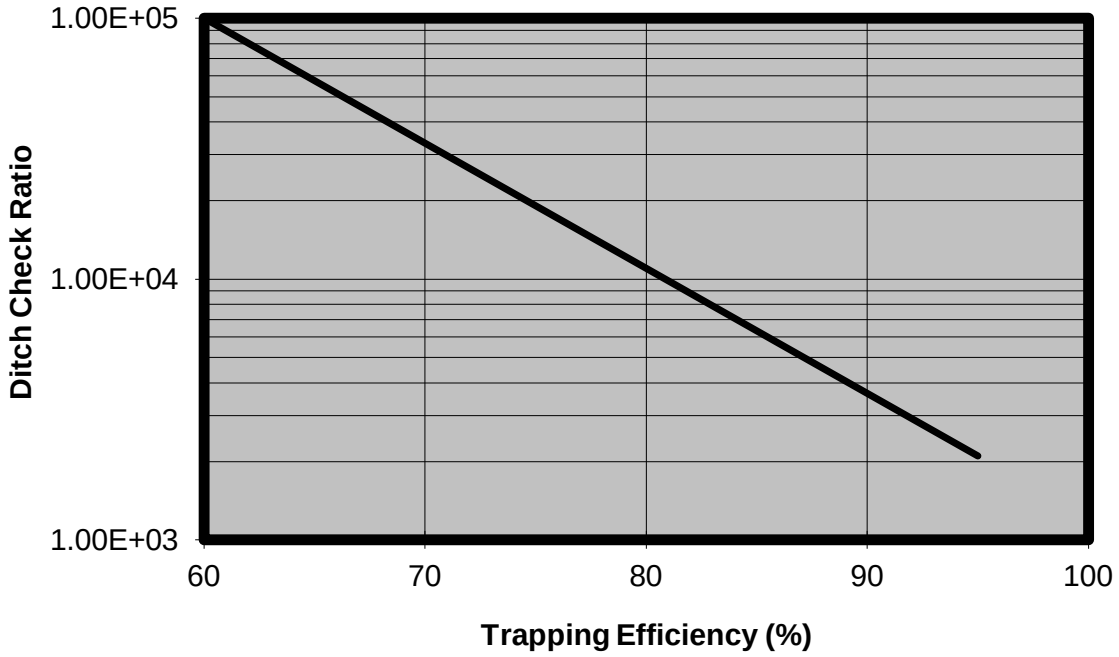

Figure 12.3a. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Fine Texture Soils.

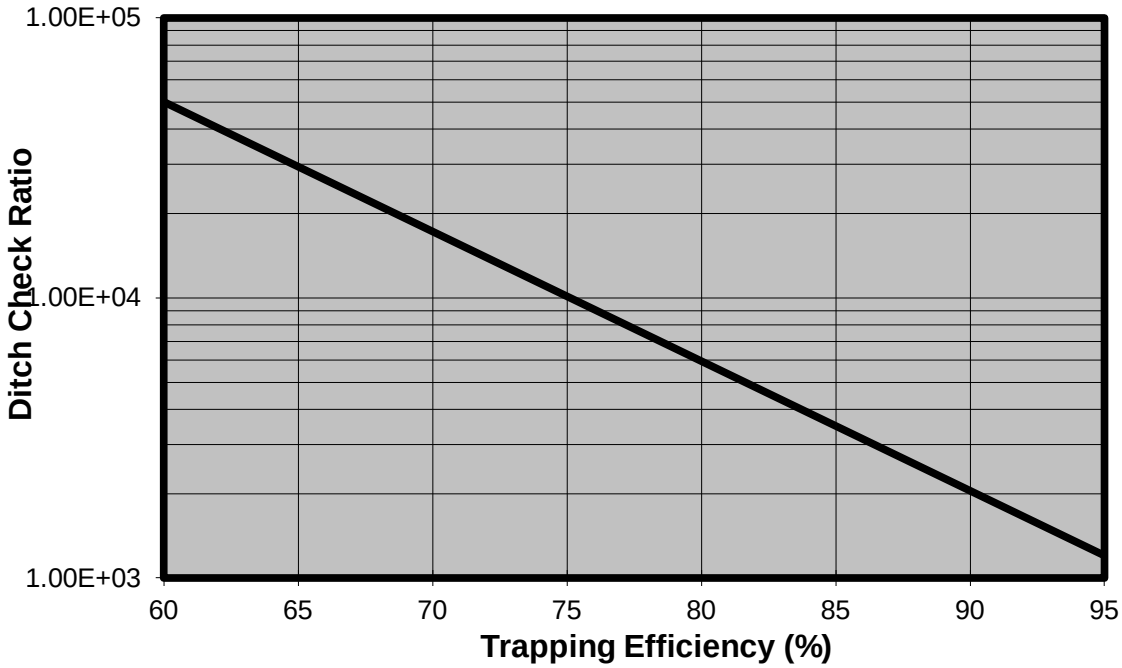

Figure 12.3b. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Medium Texture Soils.

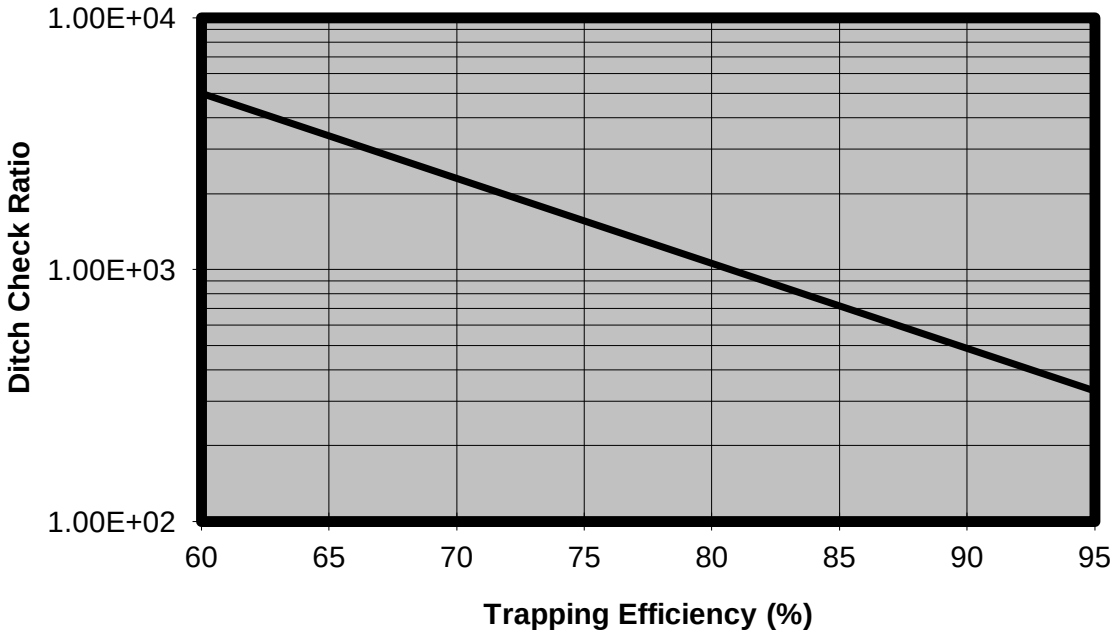

Figure 12.3c. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Coarse Texture Soils.

12.8.4 Silt Fence Design Aids

The design aid for silt fences applies to silt fence placed in areas down slope from a disturbed area where it serves to retard flow and cause settling. Two conditions must be met for a satisfactory design.

- Trapping efficiency must meet the desired level of control.
- Overtopping of the fence must not occur.

One of the most important considerations in silt fence design is to specify regular maintenance. The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the **basins** and rock checks. For the silt fence, the ratio is:

$$\textit{Silt Fence Ratio} = q_{po}/V_{15}P_{area} \qquad (5)$$

Where:

q_{po} = peak outflow through the fence (cfs),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm),
P_{area} = potential ponding area up slope of the fence (ft^2).

The ponded area can be estimated by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. This is described by the available fence height times the ground slope. Multiply this distance by the available length of fence for ponding to obtain the potential ponding area. Then calculate the ratio and enter the value to Figure 12.4 to determine the efficiency. Once an acceptable trapping efficiency is determined, a calculation for overtopping must be done. The overtopping calculation must be done using the slurry flow rate through the fence. This rate must be checked against the incoming flow to determine if enough storage exists behind the fence to prevent overtopping.

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figure 12.4 are:

- Watershed area is less than or equal 5 acres
- Overland flow length is less than or equal to 500 feet
- Overland slope is less than or equal to 6 %
- Slurry flow rate through the fence is less than or equal to 10 gpm / ft
- Maximum height of the silt fence is less than or equal to 3 feet

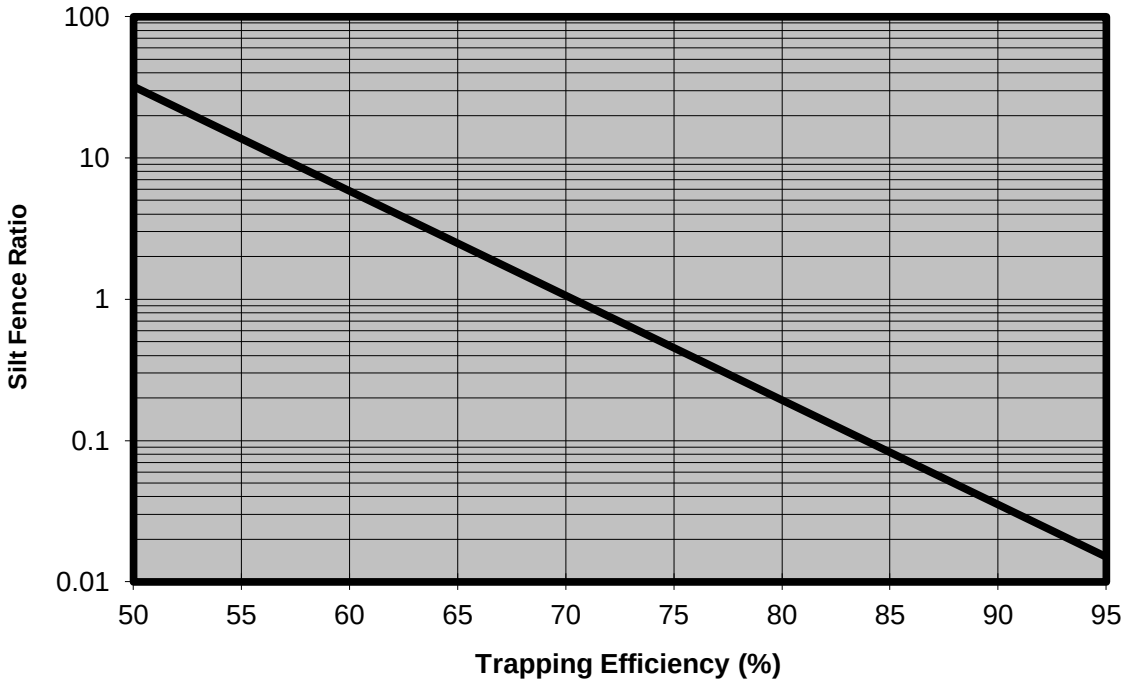

Figure 12.4. Design Aid for Estimating Trapping Efficiency of Silt Fence

12.8.5 Sediment Trap Design Aids

Sediment traps, for the purposes of this document, are small excavated **basins** with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure, thus the design aid is slightly different. Trapping efficiencies for sediment traps are plotted in Figure 12.5 as a function of the sediment trap ratio:

$$\textit{Sediment Trap Ratio} = q_{po}/A/V_{15} \qquad (6)$$

Where:

q_{po} = peak outflow (cfs),
A = surface area at the elevation equal to the bottom of the rock fill outlet (acres),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Figure 12.5 is for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam) as shown in Table 12-8. The ratio should be less than or equal to the curve value at any desired trapping efficiency.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figure 12.5 are:

- Watershed area less than or equal to 5 acres
- Overland slope less than or equal to 20%
- Rock fill diameter greater than 0.2 ft and less than 0.6 ft.
- Rock fill height less than 5 ft.
- Top width of rock fill between 2 and 4 ft.
- Maximum Side slopes 1:1 to 1.5:1.

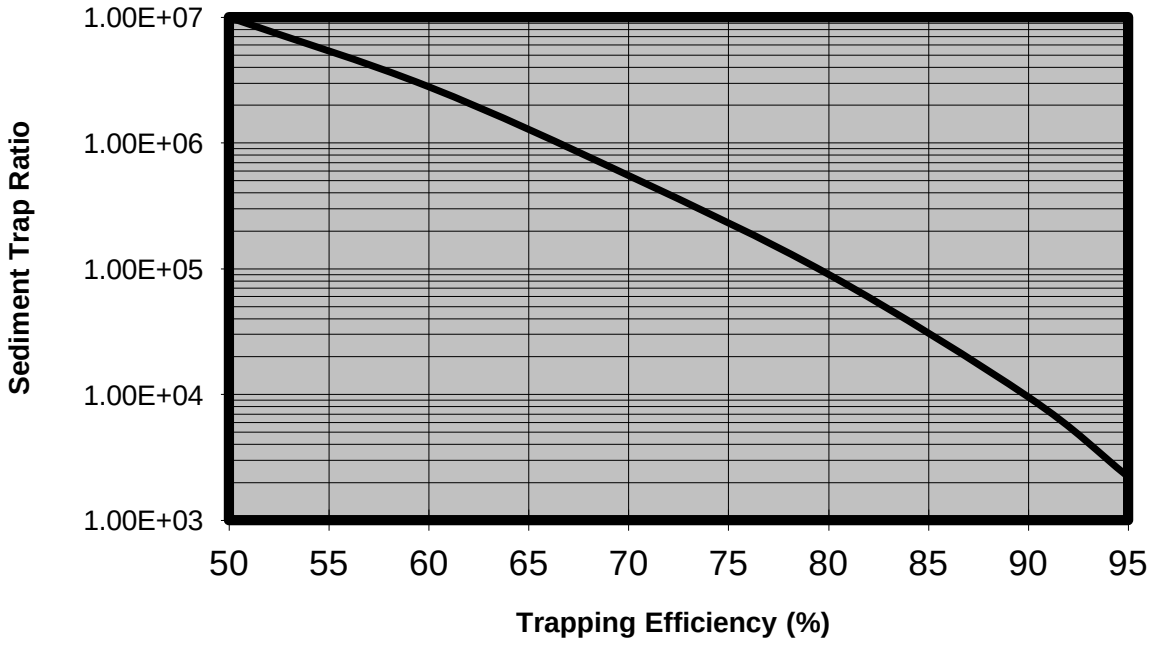

Figure 12.5. Design Aid for Estimating Trapping Efficiency of Sediment Traps.

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION A

EROSION PREVENTION & SEDIMENT CONTROL BMP SELECTION PROCESSES, SUGGESTED USES, & GUIDELINES

BMP Suggested Uses

Erosion Prevention Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Erosion Prevention Measures	12.5	X	X	X	X	X	X	X
Surface Roughening	12.5.1	X		X				
Bench Terracing	12.5.2	X		X				
Temporary Seeding	12.5.3	X		X		X	X	X
Mulching	12.5.4	X				X	X	
Erosion Control Blankets and Turf Reinforcement Mats	12.5.5	X	X	X			X	
Final Stabilization	12.5.6	X		X		X		X
Topsoiling	12.5.6.1			X		X		
Permanent Seeding and Planting of Grasses	12.5.6.2	X		X		X		X
Sodding	12.5.6.3	X		X		X		X
Riprap or Aggregate	12.5.7	X	X	X				
Outlet **Stabilization**	12.5.8		X		X			X
Dust Control	12.5.9					X	X	X

BMP SUGGESTED USES

Temporary Sediment Control Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Temporary Sediment Control Measures	12.6	X	X	X	X	X	X	X
Storage Volumes and Maintenance Schedules	12.6.1		X		X			X
Temporary Sediment Basin	12.6.2		X	X	X			X
Multipurpose Basin	12.6.3		X	X	.X			X
Temporary Sediment Trap	12.6.4		X	X				X
Silt Fence	12.6.5	X	X					X
Rock Ditch Check	12.6.6			X				X
Stabilized Construction Entrance	12.6.7					X		X
Storm Drain Inlet Protection	12.6.8		X		X			X
Vegetated Filter Strips	12.6.9		X					X

BMP SUGGESTED USES

Runoff Control and Conveyance Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Pipe Slope Drains	12.7.1	X		X				
Temporary Stream Crossing	12.7.2		X	X				X
Runoff Conveyance Measures	12.7.3	X					X	X
Construction Dewatering	12.7.4		X		X	X	X	
Stone Bag Check Dam in Small Ditch	12.7.**5**		X	X				X

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION B

JEFFERSON COUNTY RAINFALL & UNIVERSAL SOIL LOSS EQUATION INFORMATION

Rainfall Data

Table 1. Distribution of Rainfall Erosion Index (EI Curves) for Jefferson County

Date	EI Curve Number
January 1	0.0
January 15	1.0
February 1	3.0
February 15	6.0
March 1	9.0
March 15	12.0
April 1	16.0
April 15	21.0
May 1	26.0
May 15	31.0
June 1	37.0
June 15	43.0
July 1	50.0
July 15	57.0
August 1	64.0
August 15	71.0
September 1	77.0
September 15	81.0
October 1	85.0
October 15	88.0
November 1	91.0
November 15	93.0
December 1	95.0
December 15	97.0
January 1	100.0

Minimum Value to be used is 50
Average Annual R Factor = 175

Table 2. Universal Soil Loss Equation CP Factors

Condition	CP Factor
Bare Soil	1.0
Compacted Root Raked Soil	1.2
Compacted Bulldozer Scraped Soil	1.2
Fresh Unprepared Seedbed	0.64
Temporary Seeding 0-60 Days	0.40
Temporary Seeding After 60 Days	0.05
Permanent Seeding 2-12 Months	0.05
Brush	0.35
Erosion Control Blankets	0.01-0.10

Table 3. Universal Soil Loss Equation LS Factors

% Slope	Slope Length in Feet																	
	20	50	75	100	120	150	200	250	300	350	400	450	500	600	700	800	900	1000
0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.114	0.12	0.12	0.13	0.13	0.13	0.137	0.141	0.145	0.148	0.152
1.0	0.1	0.11	0.12	0.13	0.14	0.14	0.15	0.15	0.17	0.18	0.19	0.20	0.20	0.22	0.23	0.24	0.25	0.25
2.0	0.12	0.16	0.18	0.20	0.21	0.22	0.24	0.26	0.27	0.29	0.0	0.31	0.32	0.34	0.36	0.37	0.38	0.40
3.0	0.17	0.23	0.26	0.28	0.30	0.32	0.35	0.37	0.38	0.41	0.43	0.45	0.46	0.49	0.51	0.53	0.55	0.57
4.0	0.21	0.30	0.35	0.40	0.43	0.47	0.52	0.57	0.62	0.66	0.69	0.73	0.76	0.81	0.87	0.91	0.96	1.00
5.0	0.23	0.37	0.46	0.53	0.58	0.65	0.75	0.84	0.92	1.00	1.07	1.13	1.19	1.31	1.41	1.51	1.60	1.69
6.0	0.30	0.47	0.58	0.67	0.73	0.82	0.95	1.06	1.16	1.25	1.34	1.42	1.50	1.64	1.78	1.90	2.01	2.12
7.0	0.36	0.58	0.71	0.82	0.90	1.01	1.16	1.30	1.42	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.60
8.0	0.44	0.70	0.85	0.99	1.08	1.21	1.40	1.56	1.71	1.85	1.98	2.10	2.21	2.42	2.62	2.80	2.97	3.13
9.0	0.52	0.82	1.01	1.17	1.28	1.43	1.65	1.85	2.03	2.19	2.34	2.48	2.62	2.87	3.10	3.31	3.52	3.71
10.0	0.61	0.96	1.18	1.36	1.50	1.67	1.93	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.10	4.33
11.0	0.70	1.11	1.36	1.58	1.73	1.93	2.23	2.49	2.73	2.95	3.16	3.35	3.53	3.87	4.18	4.46	4.74	4.99
12.0	0.80	1.27	1.56	1.80	1.97	2.21	2.55	2.65	3.12	3.37	3.60	3.82	4.03	4.42	4.77	5.10	5.41	5.70
13.0	0.91	1.44	1.76	2.04	2.23	2.50	2.88	3.23	3.53	3.82	4.08	4.33	4.56	5.00	5.40	5.77	6.12	6.46
14.0	1.02	1.62	1.98	2.29	2.51	2.81	3.24	3.62	3.97	4.29	4.58	4.86	5.13	5.62	6.07	6.49	6.88	7.25
15.0	1.14	1.81	2.21	2.56	2.80	3.13	3.62	4.04	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
16.0	1.26	2.00	2.45	2.83	3.11	3.47	4.01	4.48	4.91	5.31	5.67	6.02	6.34	6.95	7.51	8.02	8.51	8.97
17.0	1.40	2.21	2.71	3.13	3.42	3.83	4.42	4.94	5.42	5.85	6.26	6.64	7.00	7.66	8.28	8.85	9.39	9.89
18.0	1.53	2.42	2.97	3.43	3.76	4.20	4.85	5.43	5.94	6.42	6.86	7.28	7.68	8.41	9.08	9.71	10.3	10.9
19.0	1.67	2.65	3.24	3.75	4.10	4.59	5.30	5.93	6.49	7.01	7.50	7.95	8.38	9.18	9.92	10.6	11.3	11.9
20.0	1.82	2.88	3.53	4.07	4.46	4.99	5.76	6.45	7.06	7.63	8.15	8.65	9.12	10.0	10.7	11.5	12.2	12.9
25.0	2.63	4.16	5.1	5.89	6.45	7.21	8.33	9.31	10.2	11.0	11.8	12.5	13.2	14.4	15.6	16.7	17.7	18.6
33.3	4.22	6.67	8.17	9.44	10.3	11.6	13.4	14.9	16.4	17.7	18.9	20.0	21.1	23.1	25.0	26.7	28.3	29.9
40.0	5.65	8.94	8.94	12.7	13.9	15.5	17.9	20	21.9	23.7	25.3	26.8	28.3	31.0	33.5	35.8	38.0	40.0
50.0	7.97	12.6	12.6	17.8	19.5	21.8	25.2	28.2	30.9	33.3	35.6	37.8	39.9	43.7	47.2	50.4	53.5	56.4
66.6	11.9	18.9	18.9	26.7	29.2	32.7	37.7	42.2	46.2	49.9	53.3	56.6	59.6	65.3	70.5	75.4	80.0	84.3
100.0	18.9	29.9	29.9	42.2	46.3	51.7	59.7	66.8	73.2	79.0	84.5	89.6	94.5	103.	112	120	126	134

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION C

JEFFERSON COUNTY SOIL INFORMATION

Soils Information and Eroded Size Distributions for Jefferson County, Kentucky.

PERCENT FINER FOR SPECIFIED PARTICLE DIAMETERS

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	Percent Finer Than 1.4	1.0	0.063	0.044	0.038	0.004 (mm)	0.003	0.001
ASHTON –HSG B										
0-9	0.32	0.0063	100.0	91.9	73.5	56.0	53.1	5.5	3.4	0.0
9-44		0.0053	100.0	91.9	73.4	64.9	62.9	8.0	5.1	0.0
44-80		0.0065	100.0	85.2	51.5	42.5	42.5	7.5	4.9	0.0
BEASLEY –HSG C										
0-7	0.43	0.0048	100.0	87.4	58.6	53.8	52.7	11.7	8.0	0.0
7-29		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0
29-50		0.0046	100.0	80.9	37.3	35.5	35.5	13.7	9.8	0.0
CAPTINA –HSG C										
0-9	0.43	0.0066	100.0	93.3	78.0	55.6	51.8	4.4	2.7	0.0
9-25		0.0055	100.0	89.1	64.2	57.0	56.1	8.4	5.4	0.0
25-39		0.0063	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
39-58		0.0079	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0
58-80		0.0754	100.0	72.9	11.0	8.0	8.0	12.9	9.8	0.0
CORYDON –HSG D										
0-9	0.43	0.0052	100.0	87.3	58.4	53.2	52.6	9.9	6.5	0.0
9-15		0.0048	100.0	84.9	50.5	47.6	47.4	12.1	8.3	0.0
CRIDER –HSG B										
0-12	0.32	0.0054	100.0	93.1	77.4	67.1	64.4	7.3	4.6	0.0
12-38		0.0052	100.0	91.5	72.0	64.2	62.1	9.0	5.8	0.0
38-50		0.0239	100.0	75.1	18.1	15.5	15.5	13.1	9.8	0.0
50-96		0.0037	100.0	80.7	36.7	35.6	35.6	16.2	11.7	0.0
DICKSON -HSG C										
0- 7	0.43	0.0058	100.0	92.4	74.9	61.5	58.8	6.4	4.0	0.0
7-25		0.0054	100.0	92.4	75.1	65.4	63.1	7.5	4.7	0.0
25-45		0.0054	100.0	91.3	71.4	63.1	61.4	8.0	5.1	0.0
45-65		0.0052	100.0	82.1	41.3	38.6	38.6	11.8	8.3	0.0
DUNNING -HSG D										
0-15	0.37	0.0050	100.0	89.3	64.9	58.7	57.1	10.5	7.0	0.0
15-72		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
ELK -HSG B										
0-9	0.37	0.0053	100.0	88.8	63.3	56.8	55.8	9.1	5.9	0.0
9-42		0.0054	100.0	91.3	71.4	63.1	61.4	8.0	5.1	0.0
42-69		0.0061	100.0	85.4	51.9	44.7	44.7	8.2	5.4	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	Percent Finer Than 0.063 (mm)	0.044	0.038	0.004	0.003	0.001
ENNIS -HSG B										
0-10	0.24	0.0083	100.0	85.6	52.7	34.7	34.6	5.7	3.6	0.0
10-60		0.0080	100.0	83.3	45.3	32.6	32.6	7.3	4.9	0.0
FAIRMOUNT -HSG D										
0-11	0.24	0.0044	100.0	83.1	44.4	43.0	43.0	13.9	9.8	0.0
11-17		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
GINAT -HSG D										
0-9	0.43	0.0058	100.0	89.4	65.2	54.8	53.7	7.2	4.5	0.0
9-23		0.0054	100.0	88.3	61.7	55.4	54.6	9.0	5.8	0.0
23-48		0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
48-74		0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
74-80		0.0056	100.0	90.9	70.1	60.1	58.4	7.3	4.6	0.0
GUTHRIE -HSG D										
0-8	0.43	0.0059	100.0	94.3	81.1	64.8	60.6	5.5	3.4	0.0
8-32		0.0054	100.0	92.4	75.1	65.4	63.1	7.5	4.7	0.0
32-53		0.0055	100.0	90.4	68.6	60.2	59.0	7.8	4.9	0.0
53-68		0.0055	100.0	89.5	65.6	57.9	56.9	8.2	5.2	0.0
HOLSTON -HSG B										
0-8	0.28	0.0079	100.0	87.1	57.5	37.7	37.3	5.4	3.4	0.0
8-44		0.0071	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
44-75		0.0073	100.0	81.2	38.1	31.0	31.0	9.1	6.3	0.0
HUNTINGTON -HSG B										
0-11	0.32	0.0057	100.0	89.6	65.9	56.6	55.6	7.5	4.7	0.0
11-64		0.0057	100.0	89.6	65.9	56.6	55.6	7.5	4.7	0.0
64-74		0.0079	100.0	84.2	48.0	34.0	34.0	6.7	4.4	0.0
LAKIN -HSG A										
0-11	0.17	0.0379	100.0	94.8	83.0	16.1	15.0	1.2	0.8	0.0
11-60		0.0441	100.0	92.9	76.6	14.5	14.1	1.7	1.1	0.0
60-80		0.0449	100.0	97.1	90.5	10.7	9.8	0.6	0.4	0.0
LAWRENCE -HSG C										
0-10	0.43	0.0057	100.0	93.7	79.2	65.0	61.4	6.1	3.8	0.0
10-25		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
25-50		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
50-75		0.0049	100.0	87.9	60.3	55.1	53.9	11.2	7.6	0.0
LINDSIDE -HSG C										
0-8	0.32	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
8-44		0.0054	100.0	90.0	67.1	59.3	58.1	8.2	5.2	0.0
44-60		0.0065	100.0	84.7	49.7	41.0	41.0	7.9	5.2	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	Percent Finer Than 0.063 (mm)	0.044	0.038	0.004	0.003	0.001
LITZ -HSG C										
0-12	0.32	0.0093	100.0	84.9	50.5	30.9	30.9	5.6	3.6	0.0
12-24		0.0461	100.0	79.7	33.1	12.4	12.4	6.0	4.4	0.0
LORING -HSG C										
0-7	0.49	0.0061	100.0	96.4	88.0	67.8	61.9	4.1	2.5	0.0
7-28		0.0053	100.0	93.3	78.0	69.0	66.5	7.8	4.9	0.0
28-50		0.0054	100.0	93.9	80.0	68.8	65.5	7.0	4.4	0.0
50-65		0.0060	100.0	93.3	78.1	61.2	57.6	5.5	3.4	0.0
LOWELL -HSG B										
0-11	0.37	0.0050	100.0	90.6	69.1	62.0	60.1	9.9	6.5	0.0
11-23		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
23-53		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0
MARKLAND -HSG C										
0- 7	0.43	0.0051	100.0	89.8	66.6	59.9	58.3	10.0	6.6	0.0
7-28		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
28-60		0.0048	100.0	86.3	55.1	51.1	50.4	12.1	8.3	0.0
MCGARY -HSG C										
0-11	0.43	0.0052	100.0	87.9	60.1	54.7	53.8	10.0	6.6	0.0
11-39		0.0046	100.0	89.2	64.4	58.1	56.4	12.1	8.3	0.0
39-60		0.0047	100.0	88.5	62.1	56.4	54.9	12.1	8.3	0.0
MELVIN -HSG D										
0-9	0.43	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
9-30		0.0055	100.0	92.3	74.8	64.7	62.3	7.3	4.6	0.0
30-62		0.0057	100.0	90.1	67.6	57.7	56.3	7.3	4.6	0.0
MEMPHIS -HSG B										
0-9	0.49	0.0060	100.0	95.8	86.3	68.0	62.7	4.7	2.9	0.0
9-23		0.0052	100.0	92.7	76.0	67.5	65.0	8.4	5.4	0.0
23-77		0.0057	100.0	94.9	83.3	68.3	64.0	5.8	3.6	0.0
MUSKINGUM -HSG C										
0-5	0.28	0.0072	100.0	88.3	61.6	42.0	41.4	5.5	3.4	0.0
5-26		0.0074	100.0	84.7	49.8	37.2	37.2	6.8	4.4	0.0
NEWARK -HSG C										
0-7	0.43	0.0059	100.0	89.6	65.8	54.8	53.6	7.0	4.4	0.0
7-38		0.0054	100.0	90.0	67.1	59.3	58.1	8.2	5.2	0.0
38-60		0.0053	100.0	90.5	68.8	61.5	60.8	8.3	5.2	0.0
OTWAY –HSG D										
0-18	0.43	0.0046	100.0	87.9	60.1	54.9	53.4	12.7	8.8	0.0
18-36		0.0052	100.0	90.0	67.0	60.7	60.1	9.0	5.7	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	Percent Finer Than 0.063 (mm)	0.044	0.038	0.004	0.003	0.001
PURDY -HSG D										
0-9	0.43	0.0052	100.0	92.9	76.8	68.1	65.6	8.2	5.2	0.0
9-42		0.0048	100.0	84.9	50.5	47.6	47.4	12.1	8.3	0.0
42-60		0.0048	100.0	85.6	52.8	49.4	48.9	12.1	8.3	0.0
ROBERTSVILLE -HSG D										
0-6	0.43	0.0058	100.0	93.2	77.6	63.2	59.9	6.1	3.8	0.0
6-21		0.0054	100.0	92.2	74.2	65.5	63.5	7.8	4.9	0.0
21-45		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
45-65		0.0054	100.0	88.3	61.7	55.4	54.6	9.0	5.8	0.0
ROCKCASTLE -HSG D										
0-6	0.43	0.0044	100.0	83.1	44.4	43.0	43.0	13.9	9.8	0.0
6-28		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
SCIOTOVILLE -HSG C										
0-13	0.37	0.0059	100.0	91.2	71.0	58.1	56.0	6.6	4.1	0.0
13-34		0.0055	100.0	89.6	65.7	57.9	56.9	8.0	5.1	0.0
34-59		0.0053	100.0	90.6	69.2	61.6	60.9	8.2	5.1	0.0
59-69		0.0071	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0
SEQUATCHIE -HSG B										
0-12	0.24	0.0087	100.0	85.9	53.5	33.5	33.4	5.4	3.4	0.0
12-46		0.0060	100.0	87.4	58.5	49.5	49.2	7.4	4.7	0.0
46-72		0.0098	100.0	84.7	49.9	29.4	29.4	5.5	3.6	0.0
SHELBYVILLE -HSG B										
0-9	0.32	0.0058	100.0	94.5	81.8	66.6	62.5	5.8	3.6	0.0
9-38		0.0053	100.0	92.3	74.9	66.3	64.1	8.2	5.2	0.0
38-65		0.0043	100.0	83.8	46.8	44.8	44.5	13.9	9.8	0.0
TAFT -HSG C										
0-9	0.43	0.0060	100.0	93.3	78.1	61.2	57.6	5.5	3.4	0.0
9-24		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
24-64		0.0054	100.0	91.6	72.4	63.8	62.0	7.8	4.9	0.0
64-80		0.0066	100.0	84.4	48.8	39.6	39.6	7.8	5.2	0.0
TYLER -HSG C										
0-14	0.43	0.0058	100.0	92.5	75.5	61.5	58.6	6.2	3.9	0.0
14-18		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
18-59		0.0055	100.0	89.7	66.2	58.2	57.2	7.9	5.0	0.0
59-70		0.0061	100.0	89.6	65.9	52.9	51.5	6.6	4.1	0.0
WEINBACH -HSG C										
0-15	0.43	0.0059	100.0	89.6	65.8	54.8	53.6	7.0	4.4	0.0
15-23		0.0055	100.0	89.9	66.7	58.5	57.5	7.8	4.9	0.0
23-40		0.0055	100.0	89.9	66.7	58.5	57.5	7.8	4.9	0.0
40-52		0.0053	100.0	90.6	69.2	61.6	60.0	8.7	5.6	0.0
52-65		0.0071	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	Percent Finer Than 0.063 (mm)	0.044	0.038	0.004	0.003	0.001
WESTMORELAND -HSG ZZ										
0-7	0.99	0.0058	100.0	90.1	67.6	56.5	55.1	7.0	4.4	0.0
7-36		0.0062	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
36-49		0.0081	100.0	82.7	43.3	31.2	31.2	7.6	5.2	0.0
WHEELING -HSG B										
0-14	0.37	0.0069	100.0	90.8	69.7	48.9	46.6	5.0	3.1	0.0
14-60		0.0067	100.0	85.1	50.9	40.7	40.7	7.2	4.7	0.0
60-72		0.0255	100.0	87.5	59.1	17.5	17.5	3.4	2.2	0.0
WOOLPER -HSG C										
0-6	0.37	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
6-15		0.0047	100.0	86.9	57.0	52.6	51.6	12.2	8.4	0.0
15-65		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0
ZANESVILLE -HSG C										
0-7	0.43	0.0052	100.0	90.6	69.1	61.8	60.0	9.3	6.0	0.0
7-28		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
28-39		0.0055	100.0	89.7	66.2	58.2	57.2	7.9	5.0	0.0
39-60		0.0079	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0
ZIPP -HSG D										
0-6	0.28	0.0047	100.0	88.5	62.1	56.4	54.9	12.1	8.3	0.0
6-36		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
36-60		0.0046	100.0	85.7	53.1	49.6	48.9	12.7	8.8	0.0

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION D

EXHIBITS

CHAPTER 12

EROSION PREVENTION AND SEDIMENT CONTROL
SUPPLEMENTAL SECTION D
EXHIBITS

EXHIBIT	TITLE	PAGE
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12-2	MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS	12-94
12-3	DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNEL	12-95
12-4	ANGLE OF REPOSE FOR RIPRAP STONES	12-96
12-5	RATIO OF CRITICAL SHEAR STRESS ON SIDES TO CRITICAL SHEAR STRESS TO BOTTOM	12-97
12-6	MINIMUM TAILWATER CONDITION	12-98
12-7	MAXIMUM TAILWATER CONDITION	12-99
12-8	TEMPORARY SEDIMENT BASIN	12-100
12-9	TEMPORARY SEDIMENT TRAP	12-102
12-10	VEGETATED FILTER STRIPS	12-104
12-11	PIPE SLOPE DRAIN	12-105
12-12	DIKES AND SWALES	12-106
12-13	DEWATERING OPERATIONS FOR PUMPING TO A VEGETATED BUFFER ZONE	12-107
12-14	DETAIL FOR DEWATERING OUTLET STRUCTURE	12-108

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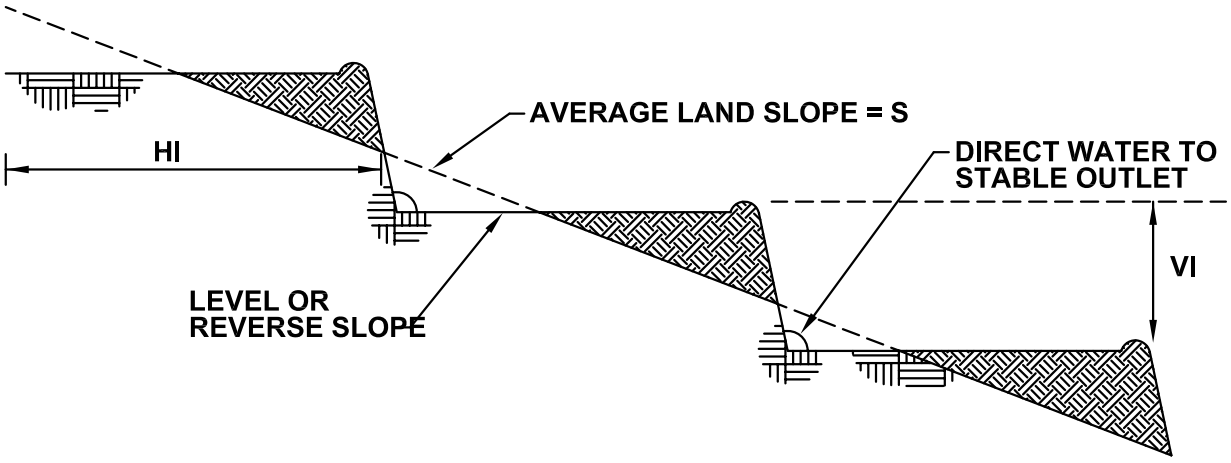
EXHIBIT 12-1
BENCH TERRACES
FOR URBAN AREAS

EFFECTIVE DATE: JUNE 30, 2009



EQUATION FOR HORIZONTAL AND VERTICAL INTERVALS

$$HI = VI \times \frac{100}{S}$$

$$VI = aS+b$$

WHERE a = 0.5 FOR LOUISVILLE
b = 1 FOR ERODIBLE CONDITION
2 FOR RESISTANT SOILS WITH GOOD COVER.

S = AVERAGE LAND SLOPE IN PERCENT
HI = HORIZONTAL INTERVAL BETWEEN TERRACES
VI = VERTICAL INTERVAL BETWEEN TERRACES

BENCH TERRACES

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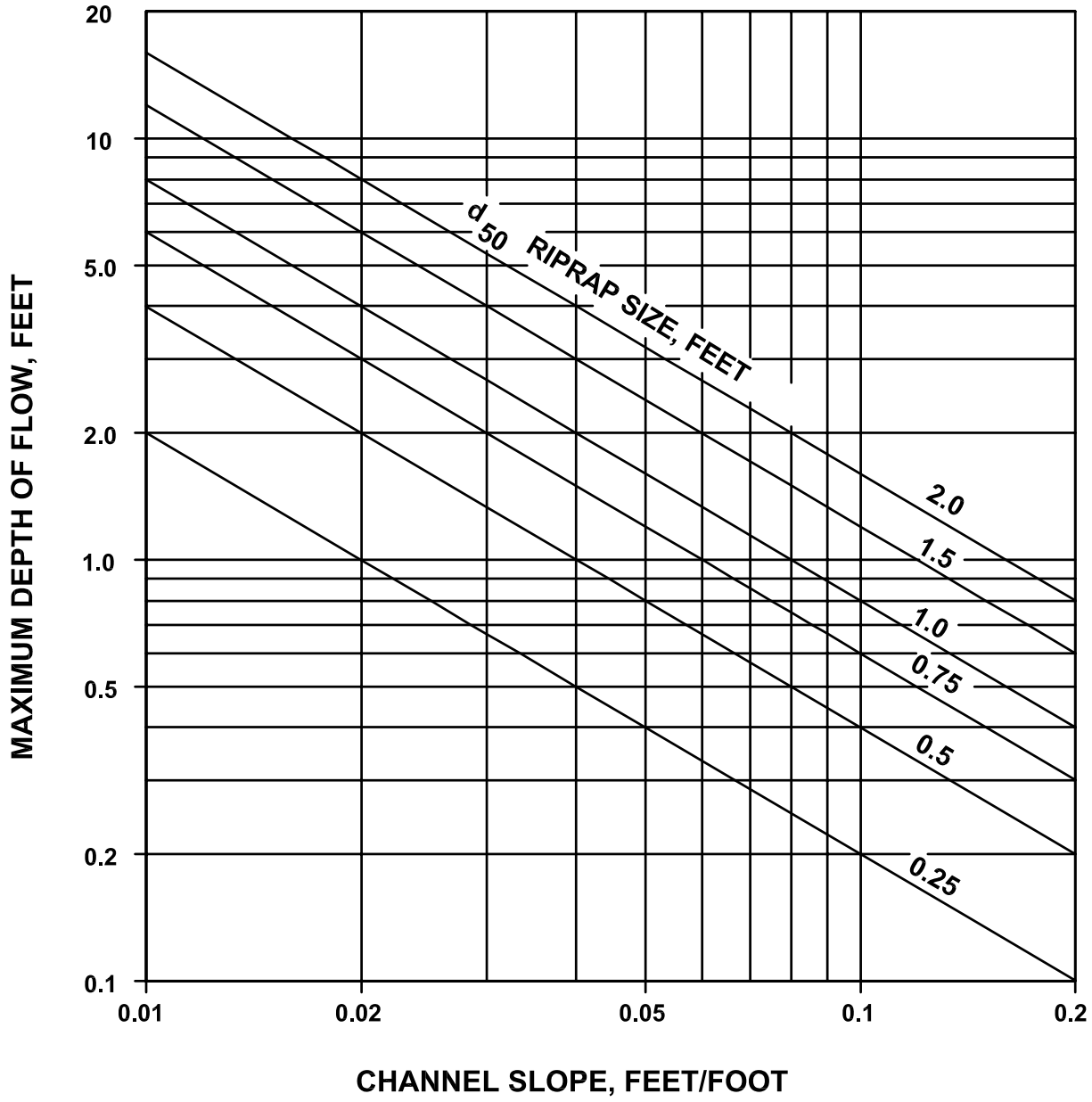
EXHIBIT 12-2
MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

EFFECTIVE DATE: JUNE 30, 2009



MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

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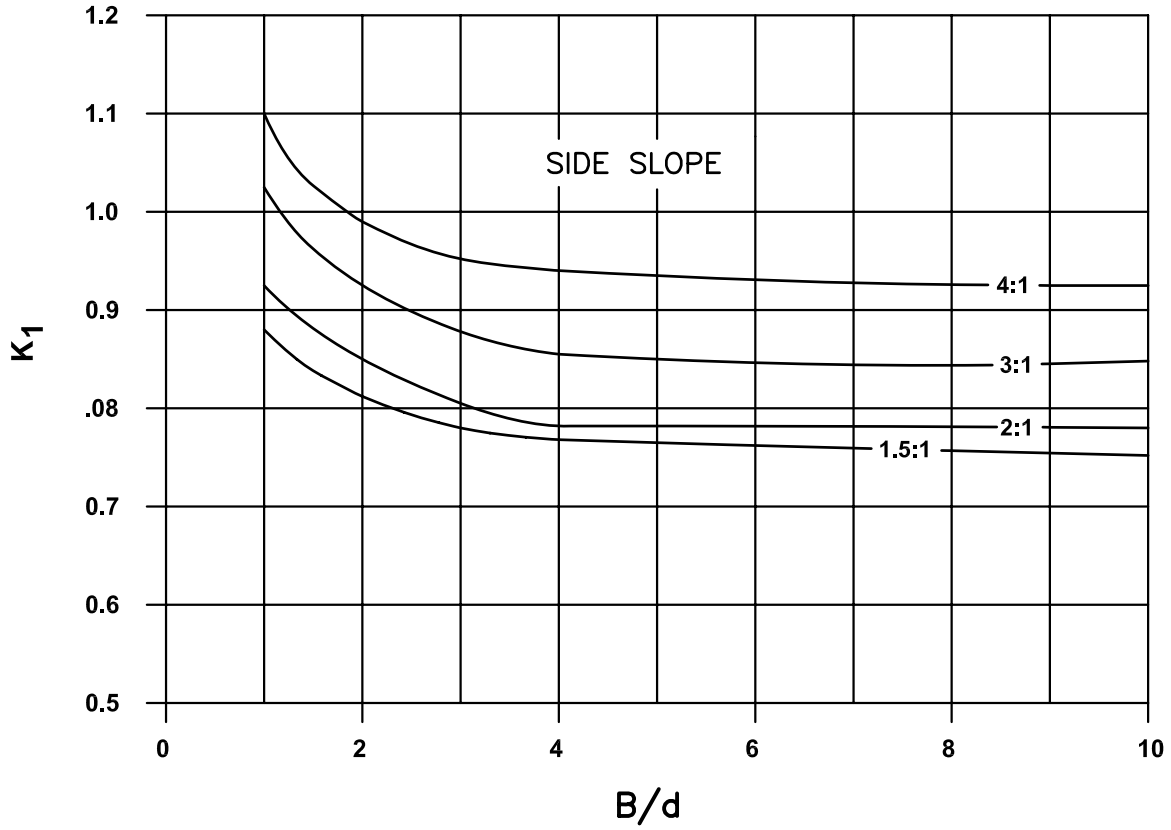
EXHIBIT 12-3
DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPAZOIDAL CHANNEL

EFFECTIVE DATE: JUNE 30, 2009



DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPAZOIDAL CHANNEL

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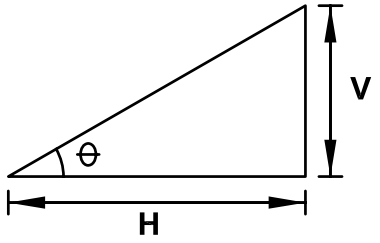
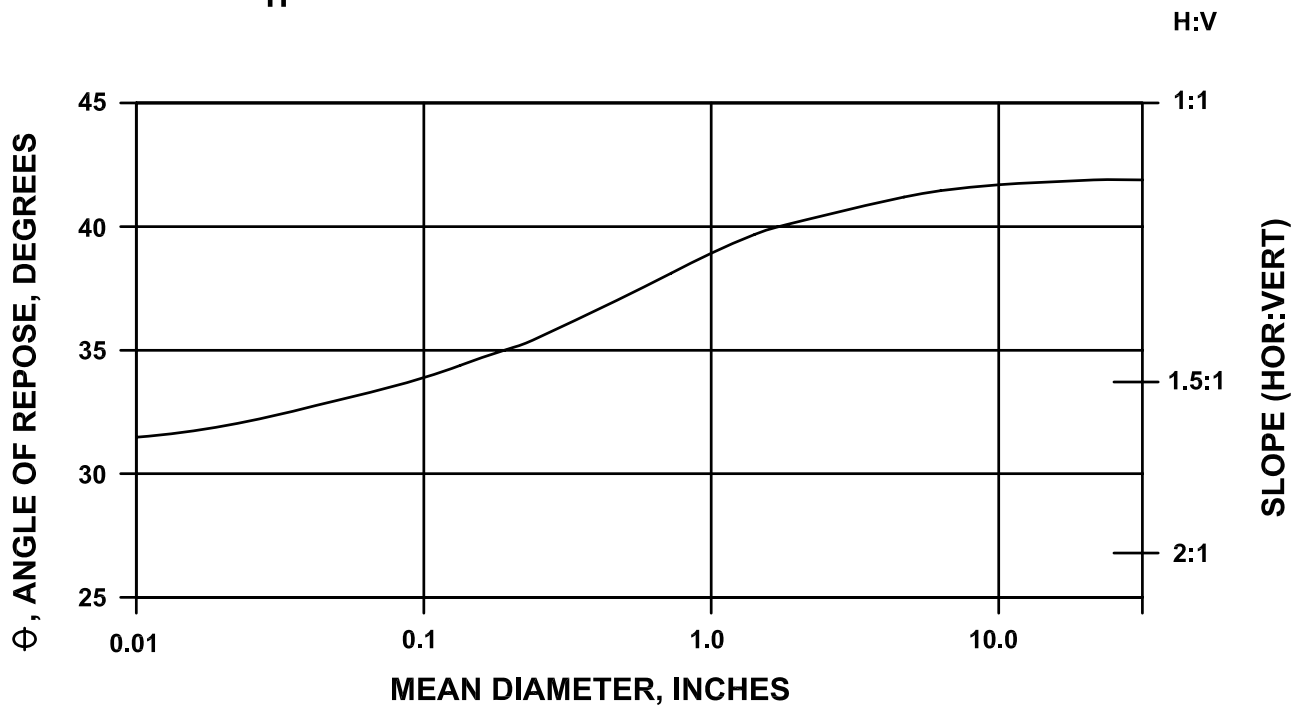
EXHIBIT 12-4
ANGLE OF REPOSE FOR RIPRAP STONES

EFFECTIVE DATE: JUNE 30, 2009





ANGLE OF REPOSE FOR RIPRAP STONES

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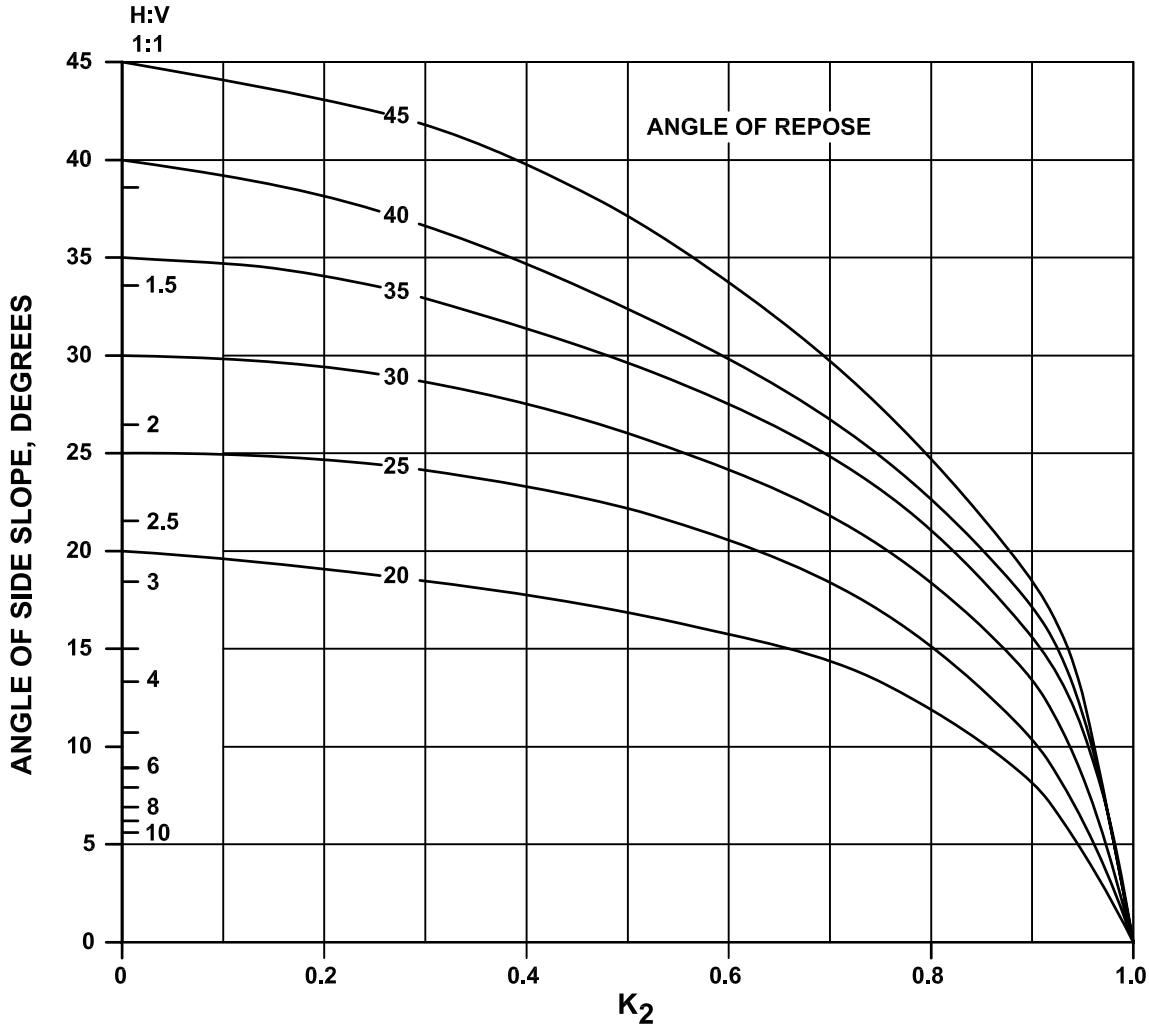
EXHIBIT 12-5
RATIO OF CRITICAL SHEAR STRESS ON SIDES TO CRITICAL SHEAR STRESS ON BOTTOM

EFFECTIVE DATE: JUNE 30, 2009



RATIO OF CRITICAL SHEAR ON SIDES TO CRITICAL SHEAR ON BOTTOM

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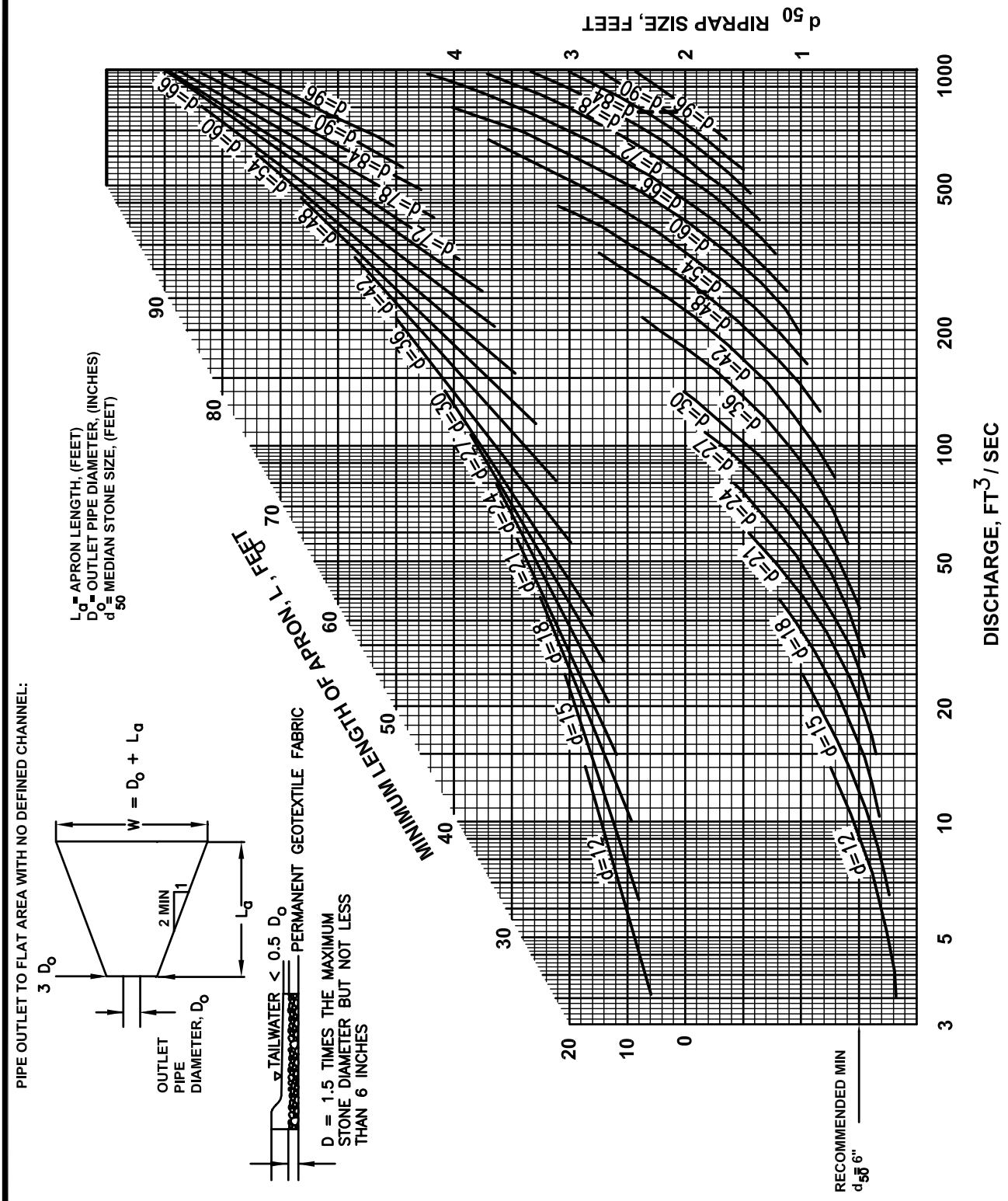
EXHIBIT 12-6
MINIMUM TAIL WATER CONDITION

EFFECTIVE DATE: JUNE 30, 2009



DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T < 0.5 DIAMETER)

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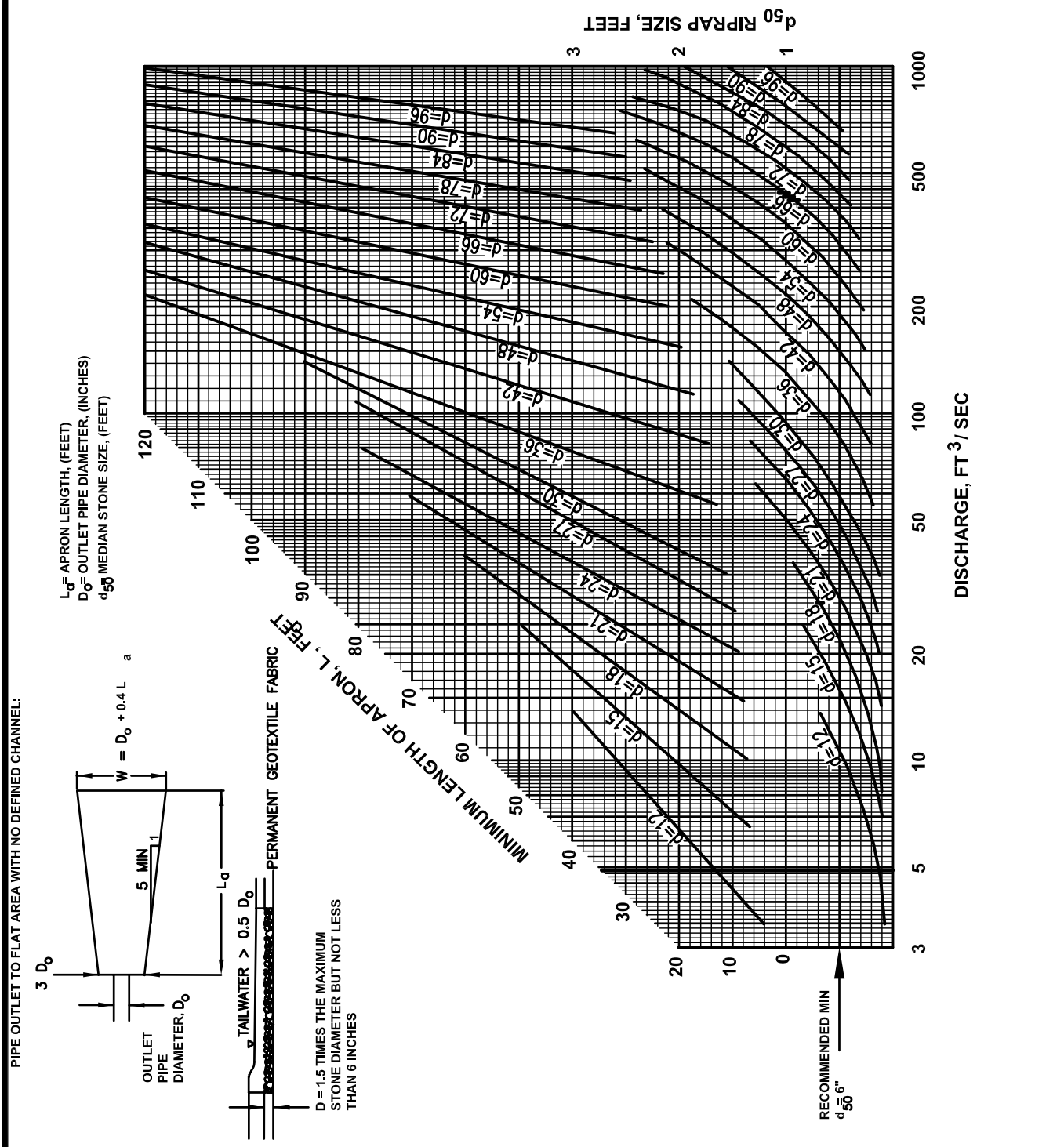
EXHIBIT 12-7
MAXIMUM TAILWATER CONDITION

EFFECTIVE DATE: JUNE 30, 2009



DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MAXIMUM TAILWATER CONDITION (T < 0.5 DIAMETER)

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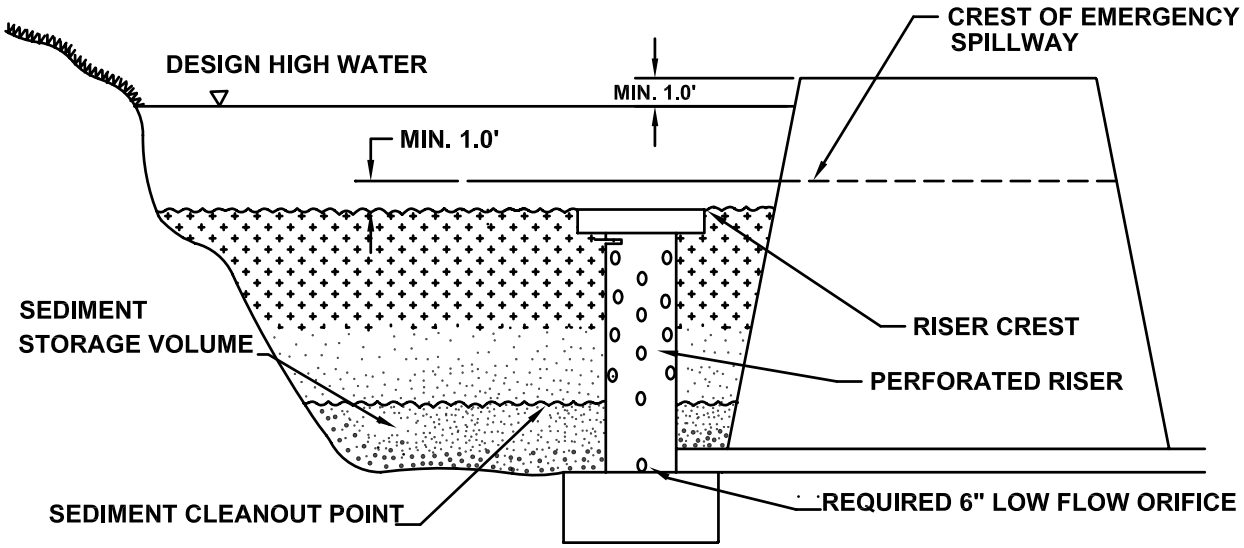
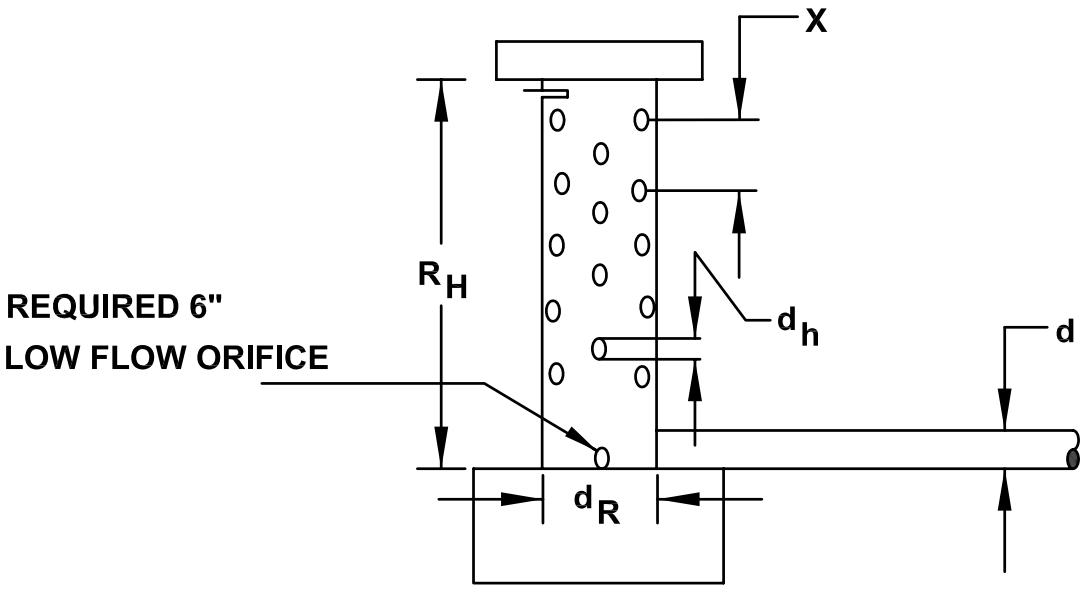
EFFECTIVE DATE: JUNE 30, 2009



DESIGN ELEVATIONS WITH REQUIRED EMERGENCY SPILLWAY



RISER PIPE DETAIL

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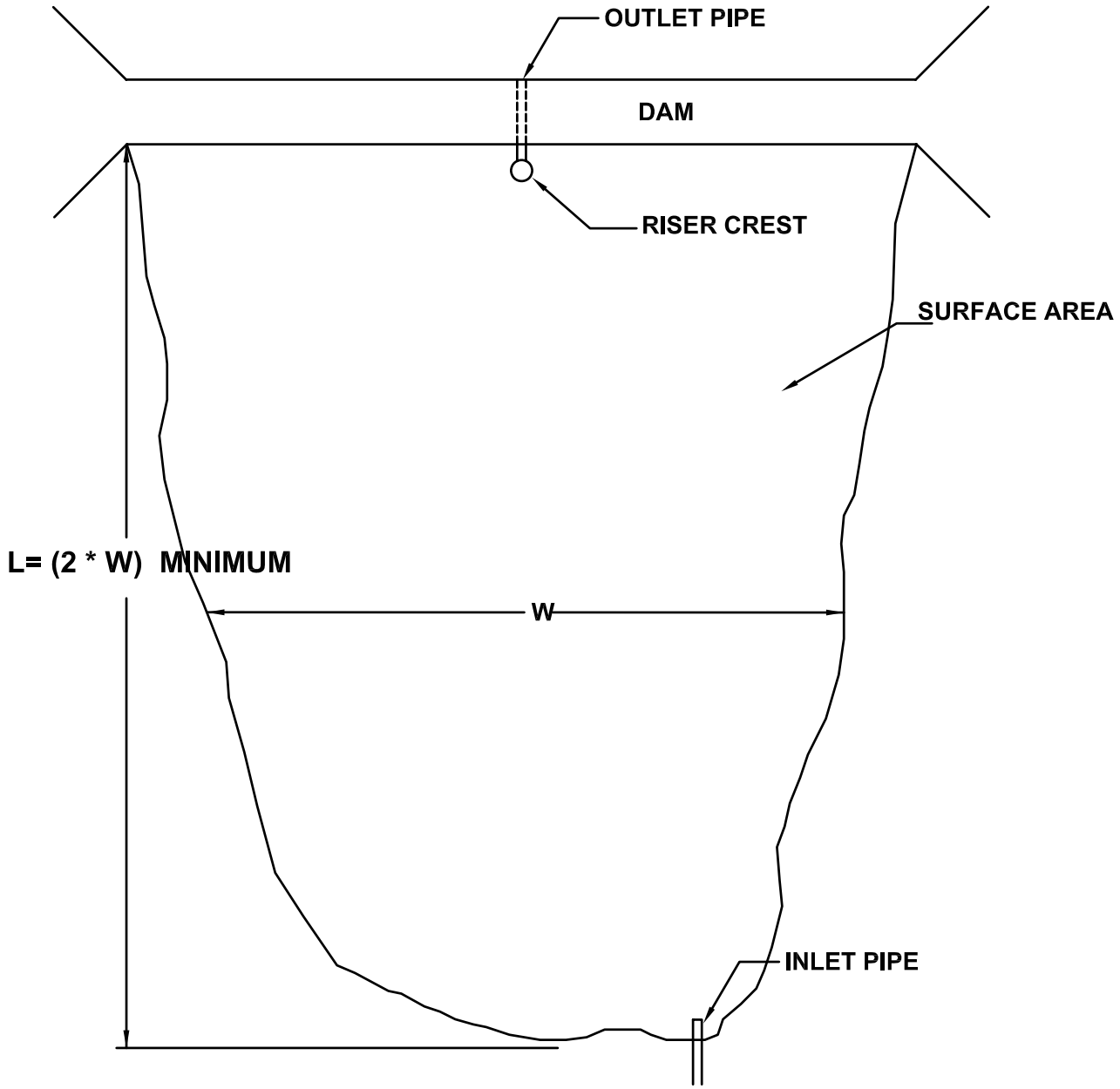
EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

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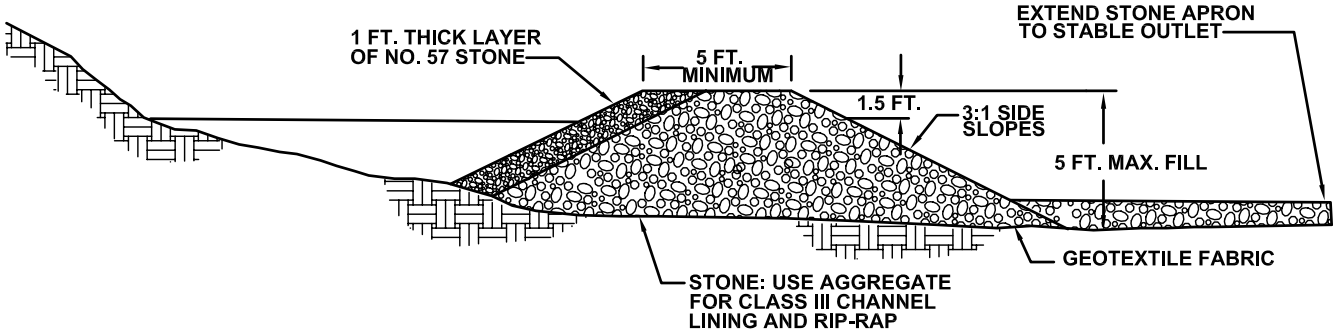
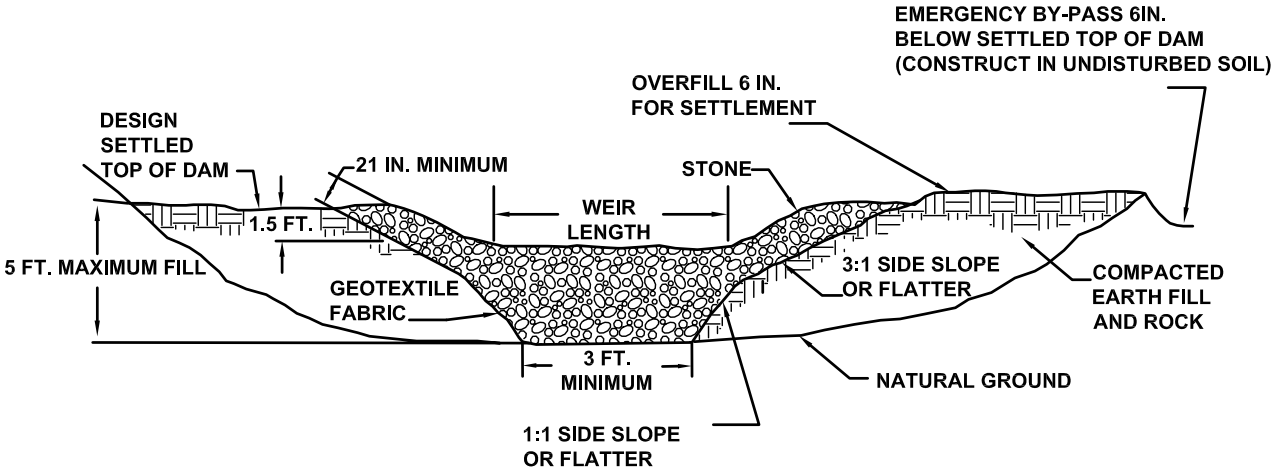
EXHIBIT 12-9A PAGE 1
TEMPORARY SEDIMENT TRAP
FOR URBAN AREAS

EFFECTIVE DATE: JUNE 30, 2009



STONE SECTION



EMBANKMENT AND SPILLWAY ELEVATION

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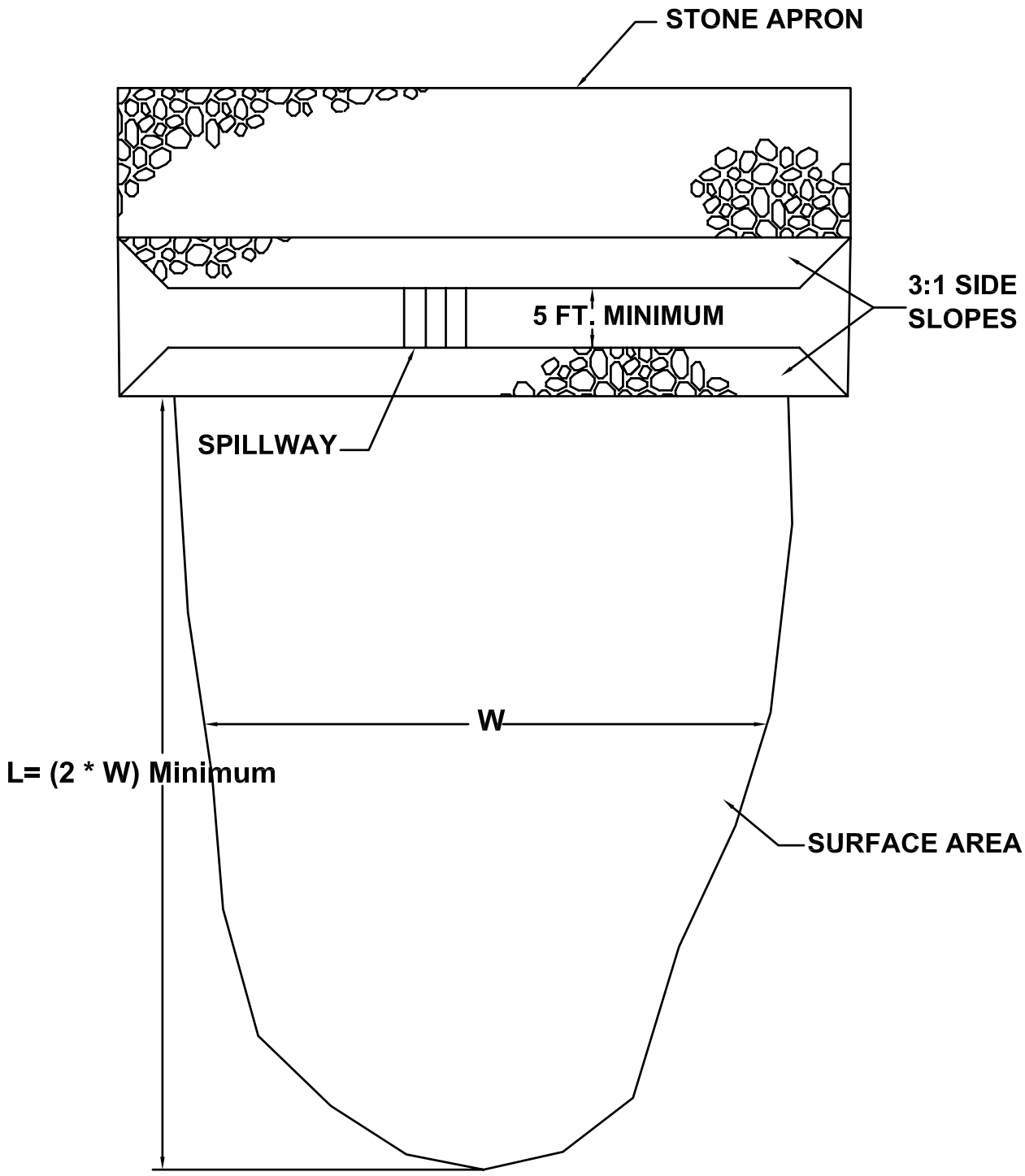
EXHIBIT 12-9B PAGE 2
TEMPORARY SEDIMENT TRAP

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

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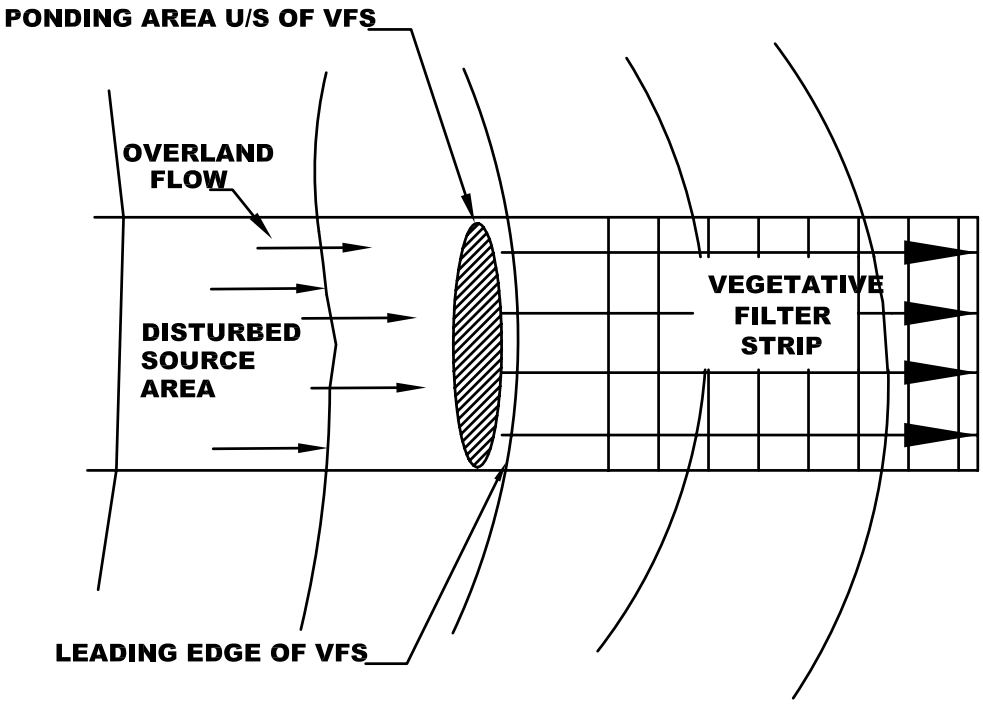
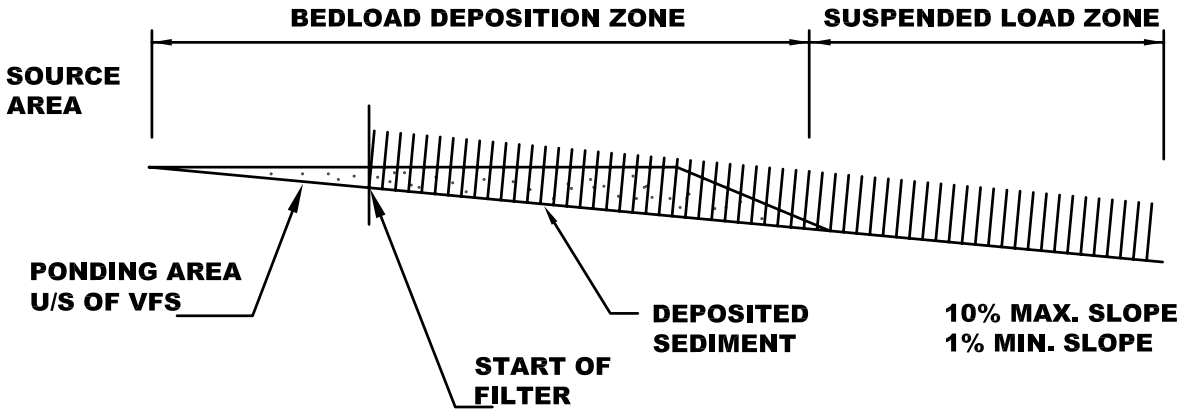
EXHIBIT 12-10
VEGETATED FILTER STRIPS

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW



PROFILE VIEW

SCHEMATIC OF A TYPICAL VEGETATIVE FILTER STRIP

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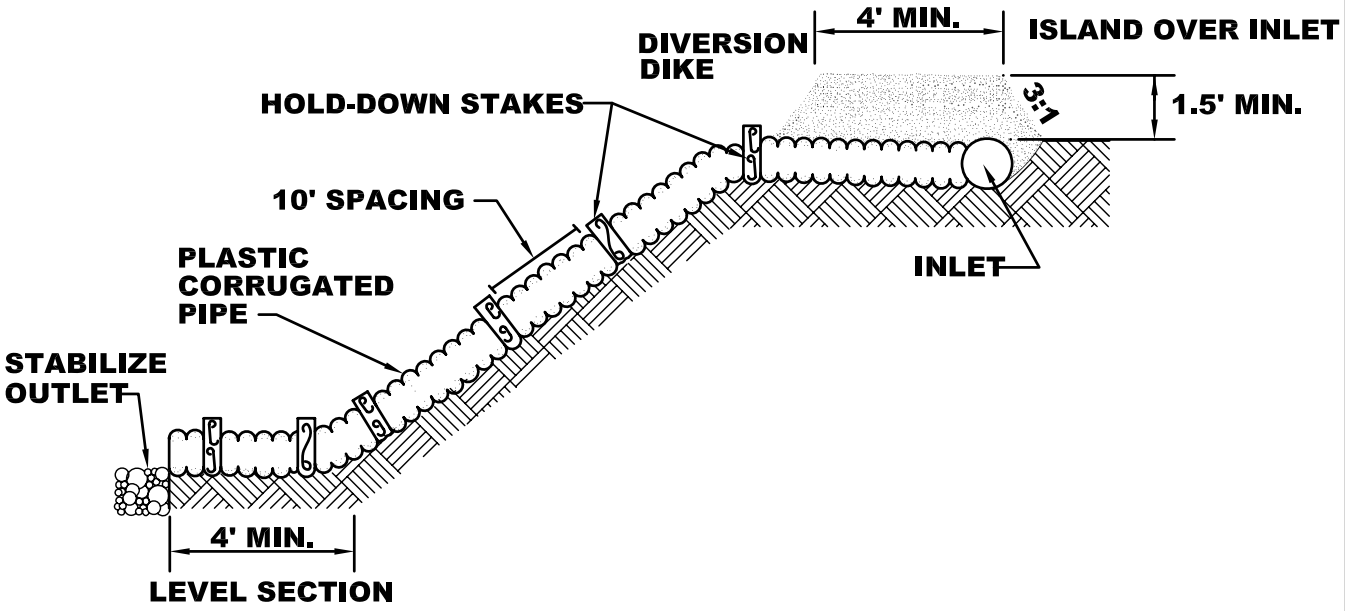
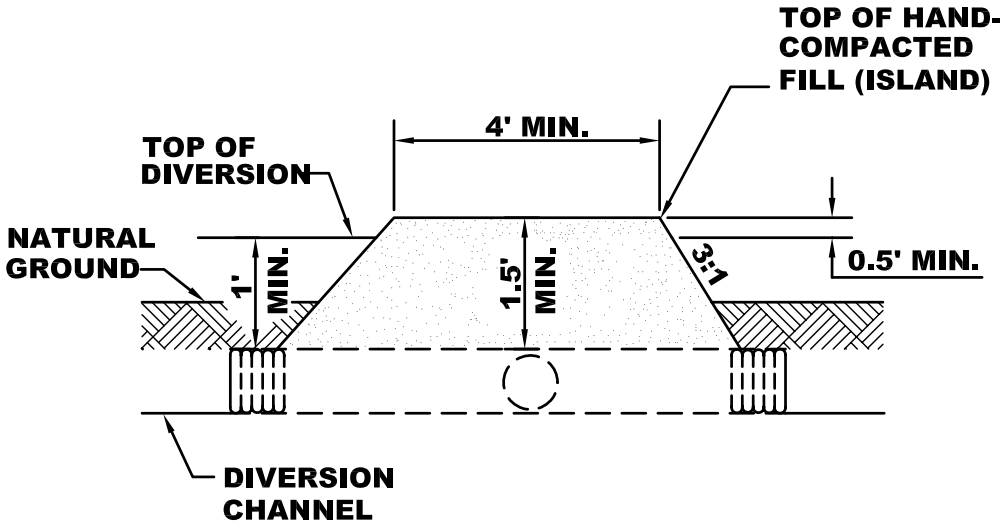
EXHIBIT 12-11
PIPE SLOPE DRAIN

EFFECTIVE DATE: JUNE 30, 2009





TYPICAL PIPE SLOPE DRAIN LAYOUT

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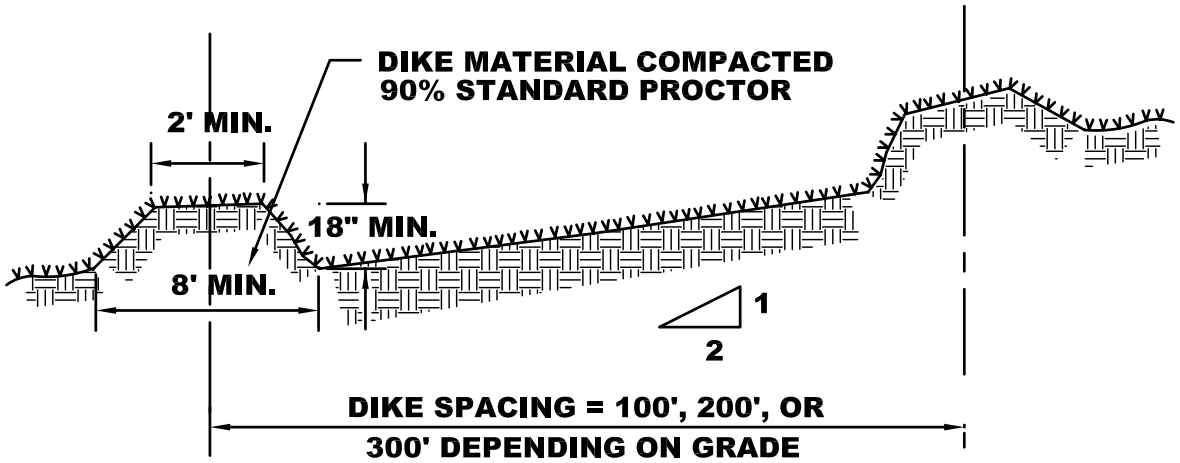
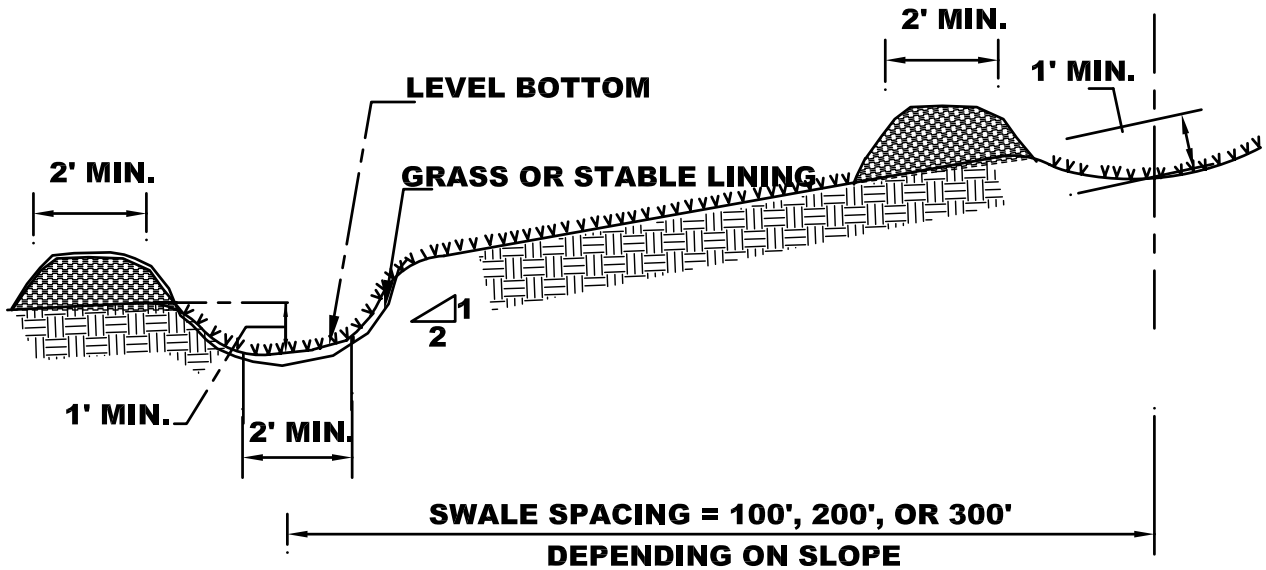
EXHIBIT 12-12
DIKES AND SWALES

EFFECTIVE DATE: JUNE 30, 2009



DIKE



SWALE

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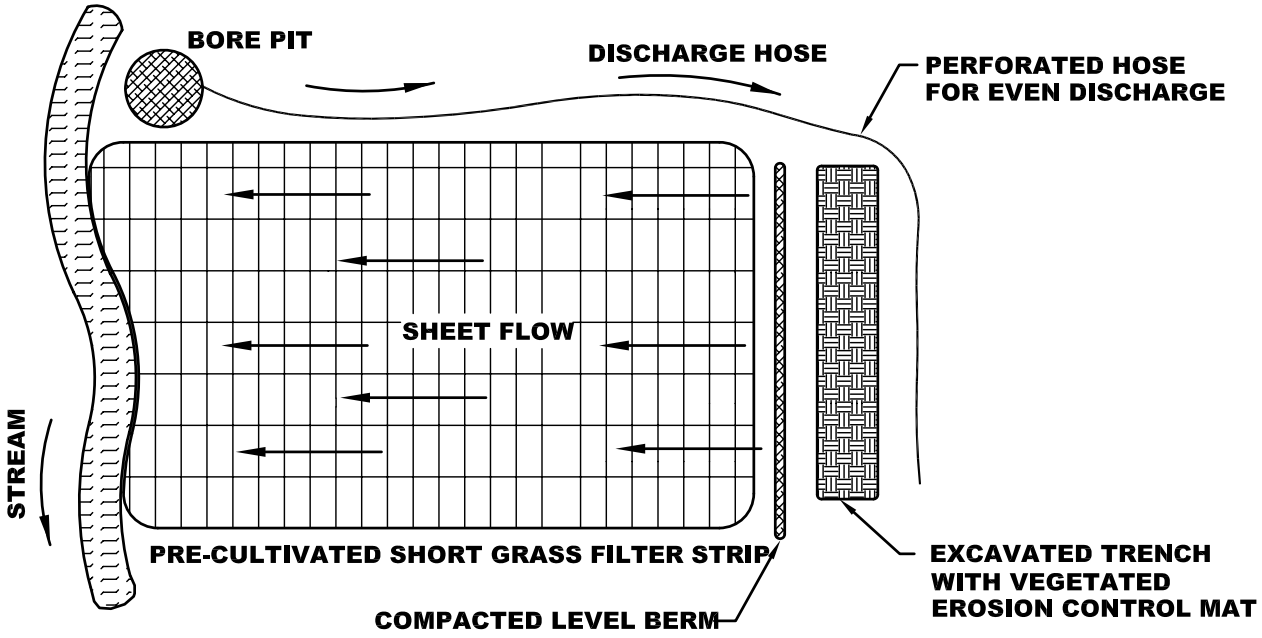
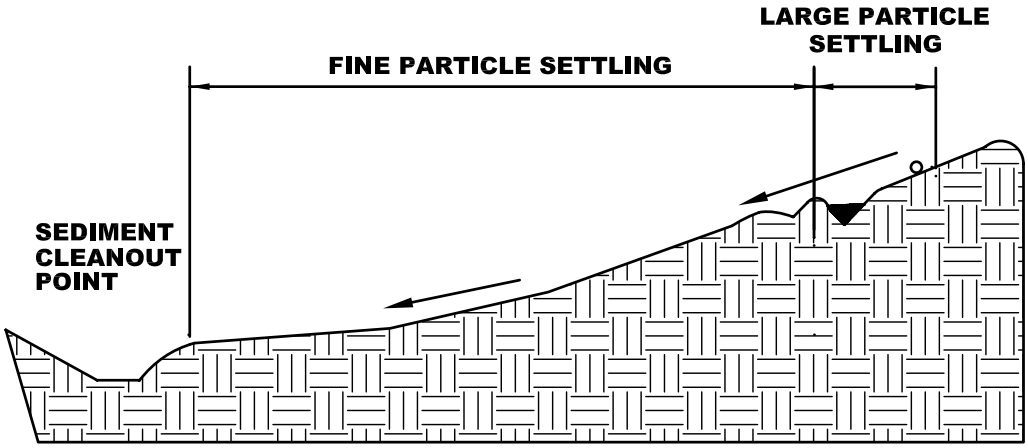
EXHIBIT 12-13
DEWATERING OPERATIONS FOR PUMPING TO A VEGETATED BUFFER ZONE

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW



PROFILE VIEW

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EXHIBIT 12-14
DETAIL FOR DEWATERING OUTLET STRUCTURE

EFFECTIVE DATE: JUNE 30, 2009

- TWO 15-FT. SECTIONS OF 3-INCH DIAMETER SCHEDULE 40 PVC PIPE ATTACHED TO 3" PVC TEE SECTION. EACH OPEN PIPE END SHALL BE CAPPED.
- EACH 15-FT. SECTION HAS 20, 0.50-INCH DIAMETER HOLES LOCATED 0.5 INCHES FROM THE BOTTOM OF THE PIPE LINEARLY SPACED 9 INCHES ON CENTER, WITH THE FIRST HOLE STARTING 8 INCHES FROM THE EXTREME END OF THE PIPE.
- EACH 15-FT. SECTION HAS 18, 1.00-INCH DIAMETER HOLES LOCATED 1.5 INCHES FROM THE BOTTOM OF THE PIPE LINEARLY SPACED 9 INCHES ON CENTER, WITH THE FIRST HOLE STARTING 10 INCHES FROM THE EXTREME END OF THE PIPE.

DEWATERING OUTLET STRUCTURE TO VEGETATED BUFFER ZONE

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION E

EROSION CONTROL BLANKETS
&
TURF REINFORCEMENT MATS

Erosion Control Blankets

A list of ECB products for each of the following classes and types is given in the MSD Standard Specifications.

Temporary Erosion Control Blanket (ECB) -Class I & II

For any ECB that has netting attached, the netting shall be photodegradable and/or biodegradable as specified for that Class and type of ECB. The weight of the netting shall not exceed 15% of the total blanket weight.

- **Class I:** Short-term Degradable Products – Defined as products composed primarily of biologically, photochemically or otherwise degradable constituents with longevity of approximately 1 year. Non-organic, photodegradable or biodegradable netting is allowed.

  Urban- Either netted with biodegradable material or non-netted, used in urban and residential areas where the slopes do not exceed 4H:1V. No minimum shear stress required, but the minimum mat thickness allowed is 9mm (3/8 inch). The product should be capable of withstanding moderate foot traffic without tearing or puncturing. Not to be used in channels.

  Type A- Maximum Product Permissible Shear Stress (0 - 1.0 lb/ft^2):

  A netted product for use on slopes 2.5H:1V and flatter where the calculated design shear stress is 1.0 lb/ft^2 or less. Not to be used in channels.

  Type B- Maximum Product Permissible Shear Stress (1.0 - 2.0 lb/ft^2):

  Double netted, used on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less.

- **Class II:** Long-term Degradable Products- defined as products composed primarily of biologically, photochemically or otherwise degradable constituents with a longevity of up to 5 years.

  Type A-Maximum Product Permissible Shear Stress (0 - 1.0 lb/ft^2):

  For use on slopes 3H:1V or, in channels where the calculated design shear stress is 1.0 lb/ft^2 or less flatter

Jute fabric used for erosion mats shall be a woven fabric of a uniform open weave of single jute yarn.

Type B- Maximum Product Permissible Shear Stress (0 - 2.0 lb/ft^2):

For use on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less. Non-organic, photodegradable or biodegradable netting is allowed. 12-107

Type C- Maximum Product Permissible Shear Stress (0 - 2.0 lb/ft^2):

For use in environmentally sensitive areas on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less. Only organic fiber woven mats are allowed with a maximum opening of 12 mm (1/2 inch).

Turf Reinforcement Mats

MSD Class III TRM physical properties are identified in the MSD Standard Specifications.

- **Class III:** Non-degradable Products- defined as products composed of non-degradable constituents with an unlimited longevity.

  Type A- Maximum Product Permissible Shear Stress (0 – 6.0 lb/ft^2):

  A TRM mat for use on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 6.0 lb/ft^2 or less.

  Type B- Maximum Product Permissible Shear Stress (6.0 - 8.0 lb/ft^2):

  A TRM mat for use on slopes 1H:1V or flatter or, in channels where the calculated design shear stress is 8.0 lb/ft^2 or less.

  Type C- Maximum Product Permissible Shear Stress (8.0 - 10.0 lb/ft^2):

  A TRM mat for use on slopes 1H:1V or steeper or, in channels where the calculated design shear stress is 10.0 lb/ft^2 or less.

Table of Contents
Chapter 13: Native Revegetation

Number	Section
13.1	Native Plants
Appendix I	Plant List
	Plant Guide
Appendix II	Invasive Species



Louisville and Jefferson County
Metropolitan Sewer District

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13.1 Native Plants



Native plants for use in rain garden (Photo: Louisville & Jefferson County MSD)

13.1 Purpose

This chapter establishes guidelines to be used when preparing planting plans and implementing permanent revegetation of disturbed natural areas. Revegetation is needed after the loss of natural habitat from construction of any development, improvement, or retrofit project. Loss of habitat could take the form of deforestation, forest fragmentation, wetland disturbance, or native grassland converted to agriculture or developed land. By definition, natural areas are plant communities and habitats indigenous to the region, and include many types as upland forests, forested wetlands, stream bank buffers, dry upland or moist bottomland meadows, and emergent wetlands. Planning for native plant restoration is essential for successful revegetation and should occur before construction, during the design and planning phase.

This chapter provides guidance for revegetating and restoring natural areas. In some cases, it may be appropriate to consult a professional restoration ecologist or biologist. This may be especially true when the habitat to be disturbed is of high ecological value or is threatened within Kentucky, such as wetlands, glades, or barrens. In such cases, you may need to hire professional help to evaluate your site and design a planting plan.

13.2 General

The guidelines presented here are intended to provide:

a. an understanding of the approach to native revegetation and contributing factors;
b. an understanding of MSD's goals and objectives for native revegetation; and
c. familiarization with native revegetation planting plan procedures and elements.

13.3 Principles of Native Revegetation Planning

There are several foundational principals to follow when planning native revegetation and restoration of a project site. Following these guidelines will encourage biodiversity and help to create a balanced ecosystem in the disturbed area.

a. Relate plans proposed for the native revegetation of natural areas to existing site conditions and surrounding or adjacent natural habitats.
b. Provide restoration or buffering of environmental features such as stream corridors, wetlands, steep slopes, erodible soils, and critical habitats.
c. Always emphasize the use of native plants in planting plans. Native plants are indigenous to the State of Kentucky and distributed within the regional area of Louisville and Jefferson County. Plan for the integration of proposed native revegetation areas to other areas of existing habitat, and the revegetation of areas causing forest fragmentation.
d. Native Revegetation should be self-sufficient, low-maintenance plantings that require minimal watering, weeding, pest and disease control, fertilization, and pruning.
e. Specify diversity in native plant species selection representative of natural communities of Kentucky to establish various planting zones in planting plans.
f. Specify the required materials including plant form and size, soil amendments, seeding, protective devices, and erosion control materials.
g. Establish required planting densities and spacing. Develop any necessary Special Provisions including specific requirements for monitoring, inspection, and warranty.

Use the site characteristics checklist in Table 13.1-B to narrow the group of potential plants before any plant selection is made. Use this information in conjunction with Appendix 1 in creating a planting plan.

Although this chapter focuses primarily on revegetation areas, many of these same principles can be utilized in green infrastructure. The benefits of using Kentucky natives and cultivars equally apply in the planning of green roofs, bioswales, rain gardens, dry and wet basins, and constructed wetlands, which are further discussed in Chapter 18.



Sedum being used in a green roof application
(Photo: Courtesy of The Green Building)

13.4 Planning Approach

13.4.1 Define Planning Area—Site Constraints and Revegetation Area Extent

To begin, determine the planning area. The primary factors that determine the extent of the native revegetation area are the size of the disturbed area and limitations due to the site's physical features. Consider adding areas within the site's easement or right-of-way to help connect and expand the planting zones. Examine the possibility of creating connections between the area to be planted and existing areas of natural vegetation. Small, isolated areas of natural vegetation are difficult to protect and manage. Creating connections between existing small fragments can result in larger, more stable natural areas.

Other goals and objectives for the project site may factor into determining the type(s) and extent of the revegetation areas. These may include creating vegetative buffer zones around existing streams, managing shading, controlling erosion, preserving wildlife habitat, developing screening, and establishing greenway corridors. Some suggested minimum vegetative buffer or corridor widths for certain goals are included in Table 13.1-A.

Table 13.1-A. Minimum Buffer/Corridor Widths

Resource Protection Goal	Minimum Width
Water quality protection and Stream bank stabilization	35 feet*
General riparian corridor or greenway	50 feet*
Corridor connections for general wildlife habitat and/or sensitive forest interior dwelling wildlife habitat	300 feet **

* On each side of a centerline or stream bank edge
** Total for both sides of a stream channel or the entire width for a terrestrial corridor

As a general rule the revegetation area should be maximized to the extent possible, given site and situation constraints, and should naturally take into account cost considerations. Distinct planting zones may be as small as several hundred square feet for intentional micro-habitats such as wetland depressions, and may be as large as several acres or more for reforestation areas and large corridors. In general the

13.1-B. Revegetation Site Physical Characteristics

	Site Characteristics	Explanation/Description/Comments	Picture Taken/Reference Number
1.	Aspect		
2.	Slope		
3.	Flood Potential		
4.	Soil Type		
5.	- Soil Depth		
6.	- Internal Drainage		
7.	- pH		
8.	Existing Vegetation by class (mowed grass, un-mowed weeds, grass, shrubs, small trees, young forest, closed canopy forest, etc)		
9.	Area Size		
10.	Aesthetic or Visual constraints (line of site or road intersections, etc)		
11.	Are there overhead power lines at the site?		
12.	Are there known underground pipelines or sewers?		
13.	Are there existing invasive plant species?		

size and layout of planting zones should be clear and straightforward. Plans should be easy to understand and practical for a contractor to implement.

13.4.2 Identify Habitat Type

Once the revegetation area has been defined, identify the vegetation community type that was originally found at the site. There are a myriad of native habitat types that exist in Kentucky. Determining this native habitat may be difficult, depending on how disturbed the site has already been. Planting plan designers should look at characteristics such as soil type, aspect, topography, and existing native plant species. If the site has already been significantly disturbed, such as in a developed residential area, determining the native habitat type for that area may be impossible for a non-professional. In such cases, the designer should consult with county agricultural extension agents or the MSD restoration ecologist.

13.5 Planning Design and Planting Plan

13.5.1 Identifying Planting Zones

Now the designer is ready to look at site specifics that will help determine planting zones within the revegetation area. Planting zones account for the differences within the site that create better environments for certain types of plants. The specific land form and features of the project site will govern the planting zones and help to identify any microhabitats within the revegetation area. Depending on the size of the project site, there may be numerous planting zones defined by differences in aspect, proposed degree of shading or openness, slope, soil fertility and type, pH, drainage and moisture, hydrologic regime (flooding, inundation), existing vegetation cover, and propagule source (seed bank, root and rhizome distribution, and recolonization sources). Working with the natural planting zones of the site helps to make for a healthier, more self-sustaining ecosystem.

13.5.2 Site Constraints

Proper design of native revegetation areas must take into account site-specific constraints. The location of existing and proposed features within the project area, such as buildings, roads, bridges, culverts, head walls, outfalls, fences, sewer lines, buried and above-ground utilities, etc., must also be considered. Vegetation patterns, including trees to be retained, existing wetlands, forested areas, and other natural community types adjacent to or within the project site, must be evaluated.

13.5.3 Plan for a Changing Site

When identifying planting zones, the designer should factor in changes to the tree canopy that may affect the types of plants and seeds selected for the site. Restoration of a forest community may need to be done in steps if the tree canopy is absent. Woodland shrubs and herbaceous plants cannot be planted into an area that currently receives full sun.

Capitalize on opportunities presented by existing conditions and design within the limitations of a given site. Keep in mind the growth rates, spread, and typical mature size of the plants being chosen for the site. Plan spacing and placement so that the plants will not directly compete for resources in the coming years.

13.5.4 Use of Native Plants

MSD advocates the use of native plants for all revegetation of natural areas. Native plants are important because they have specially adapted to the specifics of the region and require much less maintenance. They are built to thrive with the soil, weather, and seasons that the area provides.

Native organisms including plants, insects, birds, mammals, and amphibians have a complex interdependence that composes a balanced ecosystem. Establishing a healthy native plant community encourages a robust population of pollinators and the animals that feed on them. The revegetated area is then better equipped for filtering air and water pollution that can result from human development.

Preserving local biodiversity can also be highly asthetically rewarding. Native plant species are one of the most visible elements of the local ecosystem, and express the uniqueness of the region, enhancing the sense of place. They often offer bright colors and pleasing scents through different seasons. Many plant species that can be used in revegetation projects attract showy pollinators, like butterflies, that add a vibrant element to what could otherwise be a mundane area.

Plant species chosen should be those that occur within the habitat type(s) identified for the site. Use of a nearby "remnant", or undisturbed habitat of the same type as the project site, may be helpful as a reference to create a plant species list.

Native plants used for restoration plantings should be native to Jefferson County, KY. The origin of the plant material should be as close to Jefferson County as possible, preferably within 200 miles. Using local sources of plant material will help to ensure the protection of genetic biodiversity and the success of the plantings.

Some non-native plants have been found to be invasive in natural areas should not be used in any revegetation project. Appendix 2 provides a list of non-native species that have been found to be invasive. Many are available for sale at local nurseries or on the internet and are to be avoided. Others establish in disturbed areas such as your project site and may out-compete native plants. Appendix 2 includes

plants to avoid in your planting plan and will serve as an identification tool and how-to for detecting and removing non-native site invaders.

13.5.5 Plant Species Selection

It is not the intent of this manual to identify exact plant composition lists for all potential habitats, but rather to provide a general framework and list of plant species suitable for a variety of conditions. Included in this document is a list of potential plants for Kentucky restoration sites and green infrastructure, organized by site condition and plant type (Appendix I). This list includes species that can be planted as seeds or live plants for native revegetation.

The Appendix I provides images of the plants as well as additional information on the natural history, management, and growing tips for each species. This chapter, should be used with the Appendix I Plant Guide to design a site's planting plan.

Plant composition should include a broad diversity of native species as is appropriate to the site and should take into consideration a number of factors. Species selection should take into account the flood or saturation tolerance, the shade tolerance of the species, and the adaptability to projected site conditions. Local wildlife species require specific plants for food and shelter; these needs should be considered in the selection of plant material. For a forested area to become established, it is recommended that a minimum of four to five species of trees and three to four species of shrubs be selected. If a shrub community is desired, at least four species of shrubs should be selected.

The designer should review and incorporate items in the Native Revegetation Design Checklist, Exhibit 13-1, when creating plans for natural area revegetation. They include native seeding and native tree, shrub and herbaceous planting.

13.5.6 Writing the Planting Plan

The planting plan should consist of a design drawing, an accompanying report, and a construction time table. The plan should be multi-lingual where possible and should use symbols when necessary. The design drawing will identify the site area and size, planting zones, any natural and physical site constraints, locations for construction equipment including storage and unloading zones, and sensitive areas that should be protected from construction impact.

The written report will clarify the type of construction equipment expected including any special equipment, such as a native seed drill, and specifics of how sensitive areas will be protected. During construction, any environmental features such as stream corridors, wetlands, steep slopes, erodible soils, and critical habitats must be buffered or protected.

When protecting existing trees and natural areas, the root zones should be avoided to protect them from damage and impaction by heavy equipment. The Critical Root Zone is generally considered to be a 12" radius for every tree inch diameter. For example, a tree with a 10" diameter at 4.5' above the ground (diameter breast height, or DBH) should have at least a 10' root protection area around it. **Keep heavy equipment away from areas underneath and around trees—do not park vehicles or store equipment underneath trees!**

The plan should include instructions on how to treat soil and other site amenities and identify any potential erosion areas and control devices.

Accompanying the plan will be the planting list for each planting zone. All planting lists should include the plants' common and scientific names, size, form, spacing, quantity, and any special characteristics of the plants to be established. Both the common and scientific name of each plant should be used when placing a plant order to avoid any confusion. Any substitution by a nursery from the design specification plant list should be approved by the designer before anything is shipped.

a. Seeding vs. Live Plants

Planting native revegetation areas with seed, rather than live plants, provides an effective and cost-efficient method of revegetation. Seeds can easily be spread in large areas or focused sites, sprouting naturally and becoming established in a very organic presentation, mimicking the original site.

Table 13.1-C. Typical Plant Spacing and Density Summary*

Spacing (feet)	Plants Per Acre	Spacing (feet)	Plants Per Acre
1x1	43,560	10x10	435
2x2	10,890	12x12	302
4x4	2,722	15x15	194
5x5	1,742	18x18	134
7x7	889	20x20	109



Native and Cultivar plants used in a residential rain garden. (Photo: David Dods, URS)

However, some plant species may establish better by the use of live plants rather than seed and should be planted accordingly. Similarly, some site conditions, such a stream edges or wetlands, may lend themselves to the use of live plants rather than seed due to the persistent of the flow of water in the area.

b. Planting Type, Size, and Form

The planting plan should specify the size of the plants to be used. The size of plants selected is important to the success of the revegetation plan and to the overall cost of construction. There are many sizes and forms available for plants. Below is a summary of some of the commonly available plant units from native plant nurseries and seed suppliers.

Trees typically come in the following forms: container grown, balled and burlapped, and bare root stock/whips. The size of trees varies from less than a foot tall for bare root stock (seedlings) to 10-12 feet tall or more for balled and burlapped plants and larger bare root tree saplings. Project revegetation goals and cost may dictate size of trees used in the replanting, however a general rule of thumb is that smaller plants have a higher success rate at long-term establishment than larger plants and cost less to acquire. If you have the option to use them, bare root stock will establish better in the soil, require less water to help them establish, and within three to five years will often have caught up in growth with larger caliber trees planted at the same site. In order to ensure the success of bare root stock establishing, it is essential that the roots remain moist and covered at all times until seconds before being put into the ground.

Shrubs can be obtained as small as one foot or less up to four to five feet (4'-5') tall for larger container-grown plants. Shrubs may also be obtained as bare root plants or live cuttings.

Herbaceous plants (grasses, forbs/wildflowers) can be purchased as bare root stock, peat pots/plugs, or container-grown in pint, quart, and gallon(s) container size. Other typical units include multiple plant flats, two-inch (2") plugs, and four- to six-inch (4"-6") peat pots. The height of these plants is usually highly variable; however, certain plants, such as grasses, may be specified as single or multi-stem units.

If you determine that seeding is preferable for your site conditions, native seed should be specified in the form of Pure Live Seed (P.L.S) as per MSD Standard Specifications. Seeding is specified on planting plans by percent frequency of overall seeding rate, resulting in a corresponding application rate of pounds per acre (or square footage) for that particular species.

c. Spacing and Quantity

If you choose to use live plants, it is important to specify the spacing. Individual species spacing should be specified as the minimum planting distance between any two individuals of the same species. In proposed natural revegetation areas, a random planting pattern is generally recommended; however, regular, row, or cluster planting may be used if required by site conditions or project objectives. Row or cluster planting is most often used when planting an emergent wetland area or where a grove or grouping of a single species is desired (e.g., an evergreen tree copse). Examples of plant spacing details are provided in Exhibits 13-2, 13-3, and 13-4.

The actual spacing distances are highly variable and are subject to site conditions, growth rates and mature size, overall goals, and professional judgment. There are times, such as when planting an early successional woodland community, when a high density of tree saplings and a low density of shrubs are desired. A corresponding planting density may then be on the order of 435 trees per acre, corresponding to an overall on-center spacing of approximately 10 feet. For the lower density of shrubs, a corresponding density may be 222 shrubs per acre

corresponding to an overall on-center spacing of approximately 14 feet. Another approach may be to emulate a later stage of succession by planting larger trees in a less dense fashion. This may correspond to trees of a 25-30 foot on-center spacing or greater. The spacing selected should take into account the size of the plants specified.

Herbaceous plant densities can result in spacing as close as 1 foot on-center in order to achieve more rapid and dense coverage, or conversely, they may be planted further apart where supplementation, or initially sparse coverage, is the objective. A summary of several typical on-center plant spacing distances and their respective planting densities is provided in Table 13.1-C.

d. Soil Conditions and Treatment

According to MSD standards, the project designer shall specify the soil salvaging, furnishing, and amendment parameters needed before, during, and after construction to ensure a more successful restoration. The planting plan should determine the existing depth of topsoil on site, the soil's suitability for salvaging and re-use, and the total depth for topsoil placement (salvaged and/or furnished). The designer shall evaluate the existing soil by having analytical tests performed to determine if the existing topsoil meets MSD Standard Specifications in Section 2.2.1. If the topsoil is deemed to be deficient, the designer must identify in the project's Special Provisions the specific amendments required (e.g., fertilizer, organic matter, lime, etc.) or the volume and depth of suitable furnished topsoil to be provided by the contractor. Soil that has been compacted during construction activity must be loosened before planting!

The designer shall also specify areas where the existing soil is, or may be, infested with noxious weeds, other invasive plants, or any parts (seeds, rhizomes, roots, etc.) of these plants. Specification of the treatment for the infested area(s) should also be identified. This shall include infested soil removal and disposal requirements or specific treatments required for noxious weed and/or invasive species control, such as use of a pre-emergent herbicide. The control or removal of exotic invasive plants on a site should precede any clearing, grading, or other type of soil disturbance to prevent the spread of the invasives. Clearing without prior control may leave living roots that will re-sprout after the area is planted and make subsequent control much more difficult. The specific measures shall be specified in Special Provisions created for the project.

All land-disturbing activities in Jefferson County are subject to the Erosion Prevention and Sediment Control Ordinance of 2000 (EPSC). To ensure EPSC compliance, the planting plan designer should consult with the MSD website and information therein regarding requirements and specifications of the EPSC . The link may be found at http://www.msdlouky.org/insidemsd/epsc.htm.

e. Specifying Protective Devices

There are certain situations where protective devices are required for plant survival and vigor. These include the use of staking and guying or tree shelters. Staking and guying is recommended for all trees greater than 1-inch caliper and is particularly crucial for open areas where trees may be subject to high winds and windfall. Staking or guying trees requires follow-up to remove these devices, often several years later. If these devices are left on trees for too long they will inhibit or impede the tree's growth.

Tree shelters are plastic shelters or tubes used to foster young trees in their early stages of development. They protect saplings from browsing by local herbivores, and can accelerate growth rates by reducing water and weed stresses. The shelter creates a sort of greenhouse effect that channels growth into the main stem and roots.

Tree shelters are recommended in situations where seedlings or very small saplings are specified. They are also recommended where there is evidence of a strong deer population or where poor soils may contribute to desiccation and plant withering. When specified, either of these protective devices should be incorporated into the planting plans in the form of notes or symbols around individual trees.

Many wetland plants, particularly emergent grasses, must be protected from predation by waterfowl. This may include the use of traditionally named "Goose" or waterfowl exclusion fencing. The materials and execution of protective device placement shall be in accordance with MSD Standard Specifications in Section 13. Planting details for these devices are included in MSD Standard Drawings.

f. Timetable

A timetable is an important component of ecological restoration. Site preparation, such as disking or spraying of pre-emergent herbicides, should be coordinated with planting times to maximize long-term success of the restoration. Certain herbaceous plants and seeds should be planted during specific times of the year to maximize establishment. Preparation of some native seeds, in the form of cold stratification or scarification, is necessary before planting and should be part of timetable planning. As contract awarding may not coincide with the ideal timing of site preparation, a timetable needs to be finalized early and followed to the letter. Disregarding the timetable often results in a failed project.

g. Creating Special Provisions

If the designer wants to use planting techniques or processes not specified in this manual, a Special Provision is necessary. This is a text document that describes the purpose and required items for implementation of the provision. Development of these Special Provisions should follow the standard outline for MSD Standard Specifications including sections for Description of Work, Materials, and Execution. The execution of these items should also include a description of the appropriate Warranty and Maintenance.

h. Identifying Maintenance and Monitoring Protocols

Maintenance can be specified in Special Provisions and/or in a maintenance schedule containing a description of activities required, the methods required, the frequency, and the time of year. (See example in Exhibit 13-7). Long-term management of exotic species should be specified as well. Maintenance protocols may be identified according to specific plant warranty standard specifications, MSD specifications, and/or the landowner stipulations. Similarly, a derivation of the maintenance schedule may be used to identify a monitoring protocol schedule in order to address the execution of specific regulatory and permit condition requirements.

When feasible, management of exotic species should be specified in Special Provisions. Examples of exotic species to be managed include: burning bush, English ivy, periwinkle, Japanese honeysuckle, and garlic mustard. A detailed list of invasive species is provided in Appendix II Invasive Species.

Maintenance concerns: 1) staking or surveying trees requires follow-up to remove these devices, often several years later; and 2) maintenance or planting plans may need to be bilingual or use symbols when necessary.

Exhibit 13-1 Native Revegetation Plan Design Checklist

The Designer should review the project site including determining/accomplishing the following:

_____ Aspect, orientation, slope/topography
_____ Drainage, soil wetness/dryness
_____ Existing shading/tree cover
_____ Likely post-construction shading
_____ Existing native vegetation composition
_____ Evidence of noxious weed infested topsoil
_____ Site constraints and infrastructure features
_____ Depth of existing topsoil
_____ Take soil samples for analytical testing
_____ Invasive plant species for removal

Determine Native Revegetation Planting Plan needs and approach including the following:

_____ MSD project requirements
_____ Permit conditions/mitigation requirements
_____ Determine project area (sq. footage/acreage)
_____ Minimum planting widths for project goals

Determine plant establishment techniques to be used:

_____ Tree and shrub planting
_____ Herbaceous planting
_____Native seeding

Designate and develop planting zones including:

_____ Zone name and number
_____ Making necessary grading changes
_____ Definition of habitat type(s)
_____ Draw plan view of zones

Create Planting Tables and Composition Tables including:

_____ Plant species by zone and strata
_____ Specify quantity per acre
_____ Seeding rate (per acre) and by species
_____ Plant spacing (overall and by species)
_____ Calculate area and required plant quantities
_____Identify plants sizes and plant stock form

Identify and incorporate Planting Details from:

_____ MSD Standard Drawings (Native Revegetation section)

Review MSD Standard Specifications for applicability and project specific modification including:

Section 12 Native Seeding

Materials

_____ Seed (Section 12.2.1)
_____ Topsoil (Section 12.2.2)
_____ Organic Fertilizers (Section 12.2.3)
_____ Mulch (Section 12.2.4)
_____ Tackifier (Section 12.2.5)
_____ Anchors for Erosion (Section 12.2.6)
_____ Erosion Control Blankets (Section 12.2.7)
_____ Water (Section 12.2.8)

Execution

_____ Schedule (Section 12.3.1)
_____ Transporting Material (Section 12.3.2)
_____ Clearing and Grubbing (Section 12.3.3)
_____ Topsoil Salvaging, Storing (Section 12.3.5)
_____ Seeding (Section 12.3.6)
_____ Fertilization (Section 12.3.7)
_____ Mulch Stabilization (Section 12.3.8)
_____ Watering (Section 12.3.9)
_____ Clean-Up (Section 12.3.10)
_____ Maintenance (Section 12.3.11)
_____ Warranty (Section 12.3.12)

Section 13 Native tree, shrub, and herbaceous planting

Materials

_____ Native Plant Material (Section 13.2.1)
_____ Mulch (Section 13.2.2)
_____ Stakes and Wire (Section 13.2.3)
_____ Tree Shelters (Section 13.2.4)
_____ Waterfowl Exclusion Fencing (Section 13.2.5)
_____ Soil Amendments (Section 13.2.6)
_____ Root gel (Section 13.2.7)
_____ Water (Section 13.2.8)

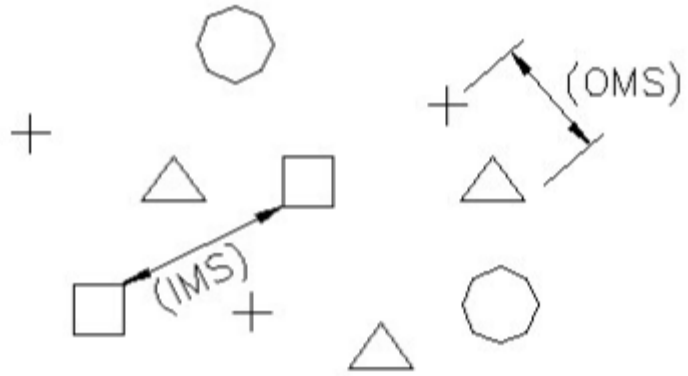
Execution

_____ General (Section 13.3.1)
_____ Planting (Section 13.3.2)
_____ Maintenance (Section 13.3.3)
_____ Warranty (Section 13.3.4)

Evaluate any additional needs and items for preparation including:

_____ Special Provisions (when necessary)
_____ Maintenance (Exhibit 17-7)
_____ Monitoring Schedule (e.g. permit conditions)
_____ Support documents (e.g. monitoring plan)

Exhibit 13-2 Plant Spacing - Random



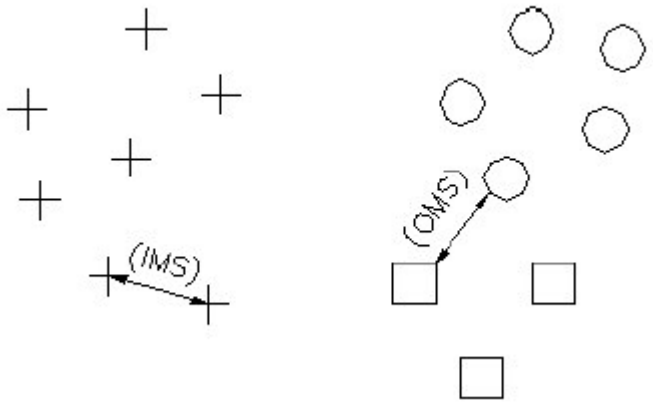
OMS-An overall minimum spacing distance (OMS) is assigned to the planting configuration (see plant schedule)

IMS-An individual minimum spacing distance (IMS) is assigned to each individual species (see plant schedule)

PLANT SPACING - RANDOM

PLAN VIEW **Not to Scale**

Exhibit 13-3 Plant Spacing - Cluster

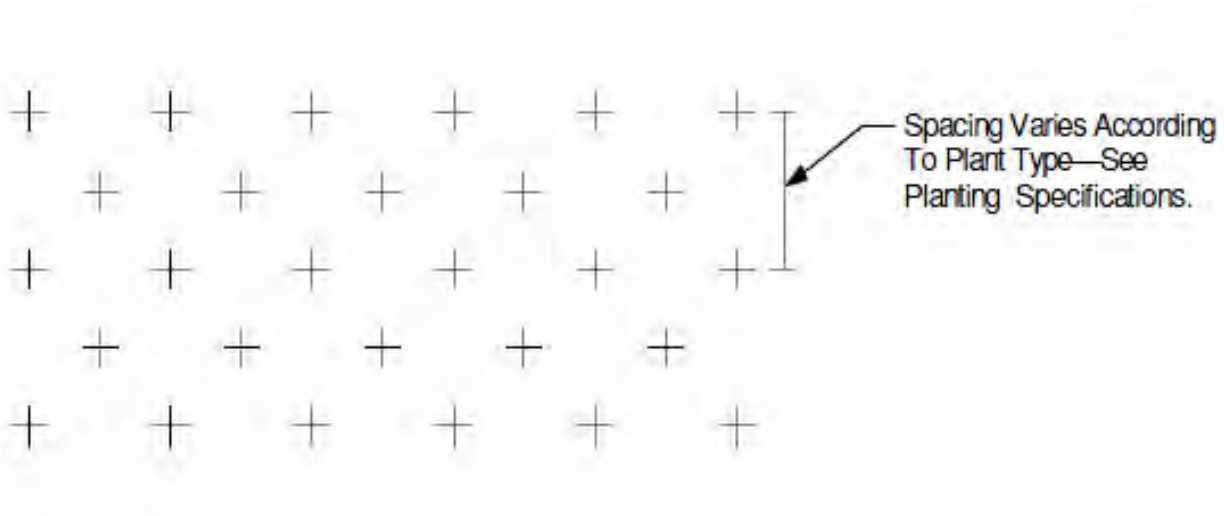


1. Plants are arranged in clusters consisting of the same species.
2. Spacing between each cluster is determined by the overall minimum spacing distance (OMS).
3. Spacing between each species within each cluster is determined by the individual minimum spacing distance (IMS).
4. Clusters, whenever possible, shall consist of odd numbers with no less than 3 and no more than 11 individuals of one species.

PLANT SPACING - CLUSTER

PLAN VIEW **Not to Scale**

Exhibit 13-4 Plant Spacing - Row



1. Space plants at even intervals-alternating rows
2. See plant schedule for specific plant spacing distances.

Exhibit 13-5 Plant Composition Table Example

COMPOSITION TABLE							
Planting Area: Anywhere, Kentucky			Zone: 2	Habitat: Floodplain Forest			
% Comp. per Strata (per acre)	**Overall Min Spacing (feet)**	**Total (per acre)**	**Vegetation Strata/ Species Name**	**Frequency (%)**	**Quantity (per acre)**	**Spacing Type**	**Individual Min. Spacing (feet)**
100	12	435	TREES				
			tree name 1	15	65	RANDOM	26
			tree name 2	25	109	RANDOM	20
			tree name 3	20	87	RANDOM	22
			tree name 4	25	109	RANDOM	20
			tree name 5	15	65	RANDOM	26
100	15 ft.	194	SHRUBS				
			shrub name 1	30	58	RANDOM	27
			shrub name 2	35	68	RANDOM	25
			shrub name 3	35	68	RANDOM	25
100	N/A	40	HERBACEOUS*				
			herb name 1	20	8	SEED	N/A
			herb name 2	15	6	SEED	N/A
			herb name 3	35	14	SEED	N/A
			herb name 4	15	6	SEED	N/A
			herb name 5	15	6	SEED	N/A

*Herbaceous unit of measure is lbs

Exhibit 13-6 Planting Table Example

PLANTING TABLE				
				Size (acres): 1.5
Planting Area: Anywhere, Kentucky		Zone: 2	Habitat: Floodplain Forest	
Quantity	**Botaical Name**	**Common Name**	**Unit**	**Size**
TREES				
98	tree species 1	tree name 1	balled in burlap	1 1/2 inch caliper
164	tree species 2	tree name 2	container grown	4-5 ft.
131	tree species 3	tree names 3	container grown	4-5 ft.
164	tree species 4	tree name 4	container grown	4-5 ft.
98	tree species 5	tree name 5	container grown	4-5 ft.
SHRUBS				
87	shrub species 1	shrub name 1	container grown	2-3 ft.
102	shrub species 2	shrub name 2	container grown	2-3 ft.
102	shrub species 3	shrub name 3	container grown	2-3 ft.
HERBACEOUS				
12	herb species 1	herb name 1	LBS	SEED P.L.S 75%
9	herb species 2	herb name 2	LBS	SEED P.L.S 75%
21	herb species 3	herb name 3	LBS	SEED P.L.S 75%
9	herb species 4	herb name 4	LBS	SEED P.L.S 75%
9	herb species 5	herb name 5	LBS	SEED P.L.S 75%

P.L.S.=Minimum
Pure Live Seed
Percentage

Exhibit 13-7 Maintenance Schedule Example

DESCRIPTION	METHOD	FREQUENCY*	TIME OF YEAR
1. Inspect & replace dead or diseased plants	Follow MSD Specifications	1	March 15 to June 15 & Sept. 15 to Nov. 15
2. Prune all woody plants (corrective pruning only)	Hand tools	1	November 15 to March 1
3. Watering of plants	Water truck/ hand hose	4	June, July, Aug., Sept.
4. Mowing of permanent seed areas (As required by Special Provisions)	Hand mower or tractor	1	March 1 to May 1 or October 1 to December 1

*Per Year

Commercial Planting Plan Example — Rain Garden/Bioretention

Quantities are based on a 400 square foot area with plants on 2-foot centers.

Plant List

Fall Flowering

Common Name *(Scientific Name)*	Quantity
Smooth Blue Aster (*Aster laevis*)	42
Fox Sedge (*Carex vulpinoidea*)	25
Gray Goldenrod (*Solidago nemoralis*)	33
Total	**100**

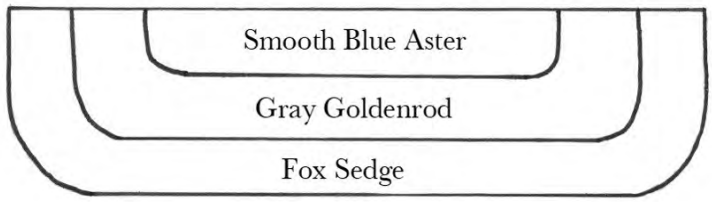


Figure 13.1-A. Typical parking lot bioretention cell (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)



Typical parking lot bioretention cell shown during fall blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Rain Garden/Bioretention

Quantities are based on a 400 square foot area with plants on 2-foot centers.

Plant List

Mid-Summer Flowering

Common Name *(Scientific Name)*	Quantity
Fox Sedge (*Carex vulpinoidea*)	25
Mist Flower (*Eupatorium coelestinum*)	42
Slender Mt. Mint (*Pycanthemum tenuifolium*)	33
Total	**100**

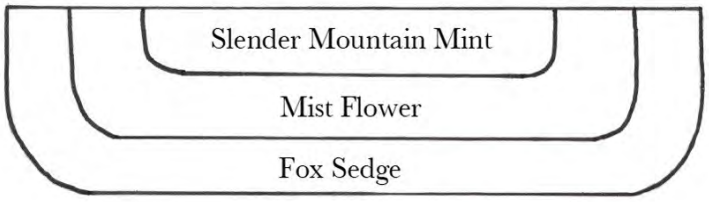


Figure 13.1-B. Typical parking lot bioretention cell (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)



Typical parking lot bioretention cell shown during mid-summer blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Green Roof

Quantities are based on a 5,000 square foot area with plants on 12-inch centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Stiff Aster (*Aster linariifolia*)	1,000
Poverty Grass (*Danthonia spicata*)	1,250
Gray Goldenrod (*Solidago nemoralis*)	1,075
Little Bluestem (*Schizachyrium scoparium*)	500
Prarie Dropseed (*Sporobolus heterolepis*)	1,000
Flower-of-the-hour (*Talinum calcaricum*)	175
Total	**5,000**



Typical extensive green roof shown during fall blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

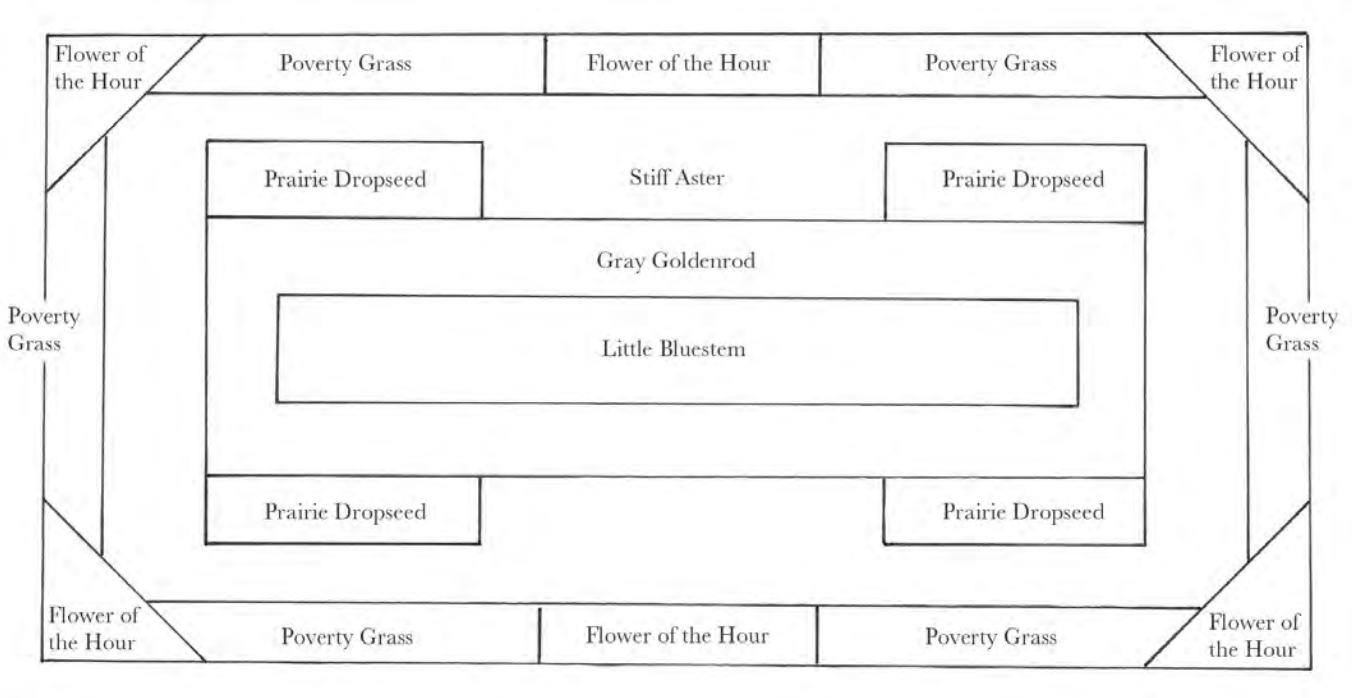


Figure 13.1-C. Typical extensive green roof (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Green Roof

Quantities are based on a 5,000 square foot area with plants on 12-inch centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Stiff Aster (*Aster linariifolia*)	1,525
Poverty Grass (*Danthonia spicata*)	1,250
Little Bluestem (*Schizachyrium scoparium*)	1,050
Prarie Dropseed (*Sporobolus heterolepis*)	1,000
Flower-of-the-hour (*Talinum calcaricum*)	175
Total	**5,000**



Typical extensive green roof shown during fall blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

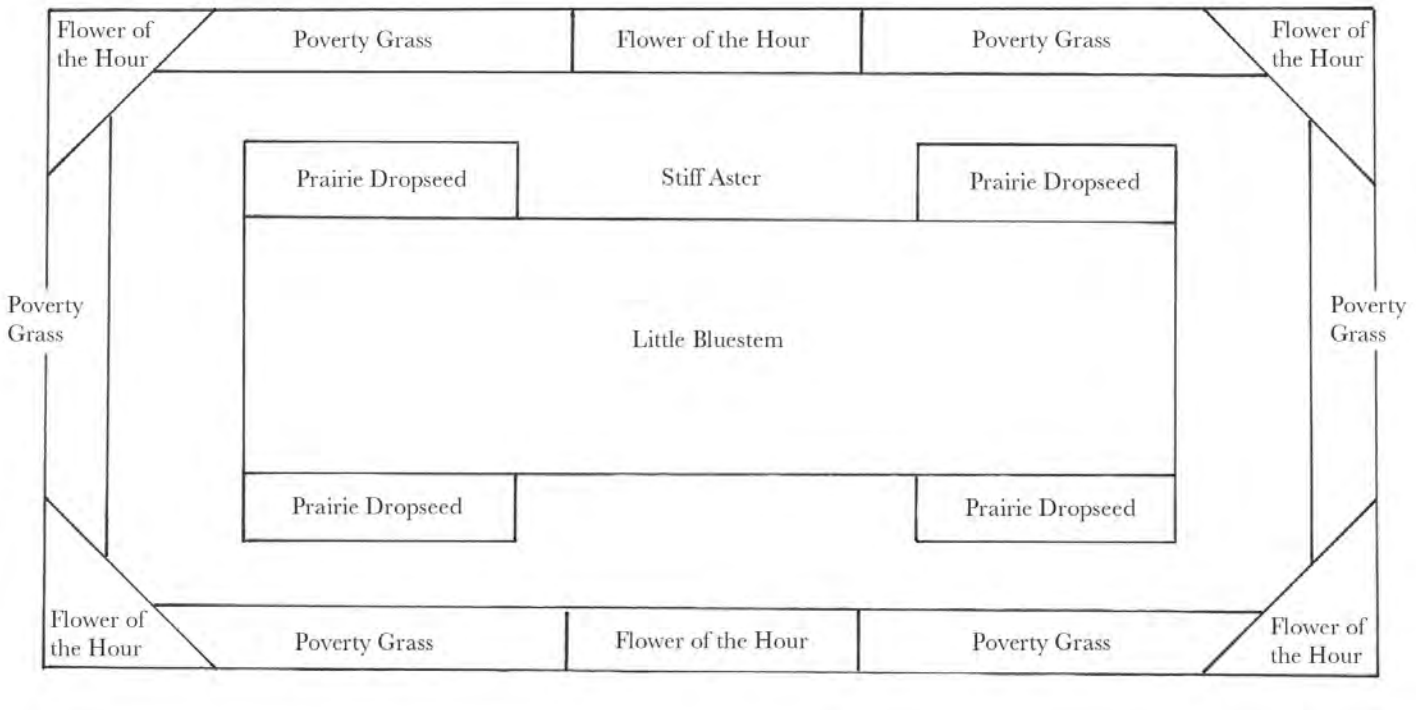


Figure 13.1-D. Typical extensive green roof (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Rain Garden

Quantities are based on a 450 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Eastern Bluestar (*Amsonia tabernaemontana*)	15
River Oats (*Chasmanthium latifolium*)	17
Purple Coneflower (*Echinacea purpurea*)	20
Narrow-leaved Sunflower (*Helianthus angustifolius*)	11
Dense Blazing Star (*Liatris spicata*)	11
Orange Coneflower (*Rudbeckia fulgida*)	23
Little Bluestem (*Schizachyrium scoparium*)	13
Total	**110**

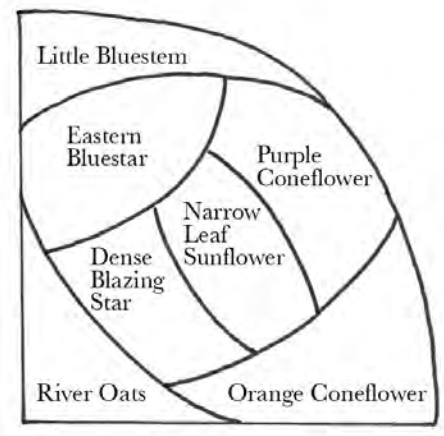


Figure 13.1-E. Typical parking lot rain garden (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)



Typical parking lot rain garden shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Rain Garden

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Autumn Bentgrass (*Agrostis perennans*)	9
Mist Flower (*Eupatorium coelestinum*)	13
Swamp Hibiscus (*Hibiscus moscheutos*)	9
Bee Balm (*Monarda fistulosa*)	11
Slender Mt. Mint (*Pycanthemum tenuifolium*)	21
Total	**63**

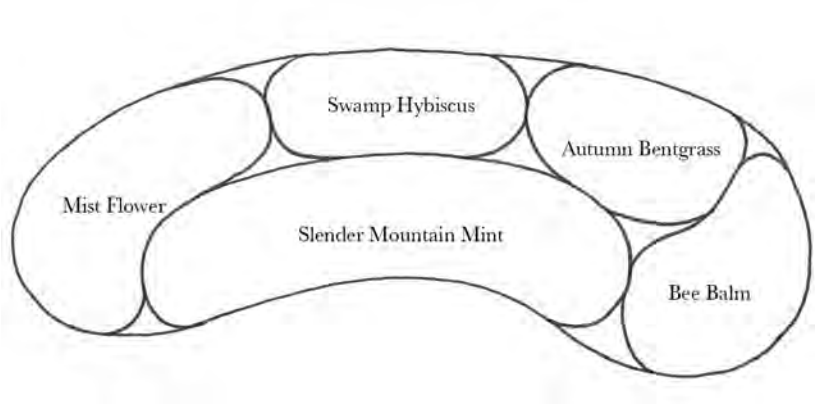


Figure 13.1-F. Typical residential rain garden (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)



Typical residential rain garden shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Curb Cut Bioswale

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Fox Sedge (*Carex vulpinoidea*)	15
River Oats (*Chasmanthium latifolium*)	8
Mist Flower (*Eupatorium coelestinum*)	11
Slender Mt. Mint (*Pycanthemum tenuifolium*)	11
Total	**45**



Typical residential curb cut bioswale shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

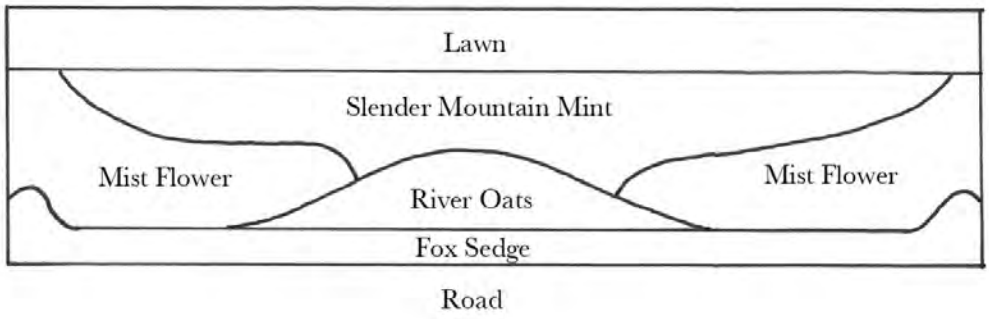


Figure 13.1-G. Typical residential curb cut bioswale (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Parkway Bioswale

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Bald Cypress (*Taxodium distychum*)	1
Pin Oak (*Quercus*)	1
Swamp Rose (*Rosa palustris*)	4
Black Chokeberry (*Aronia melanocarpa*)	3
Fox Sedge (*Carex vulpinoidea*)	19
River Oats (*Cuasmanthium latifolium*)	13
Foxglove Beardtongue (*Penstemon digitalis*)	19
Great Blue Lobelia (*Lobelia siphilitica*)	13
Sensitive Fern (*Onoclea sensibilis*)	11
Total	84



Typical residential parkway bioswale shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

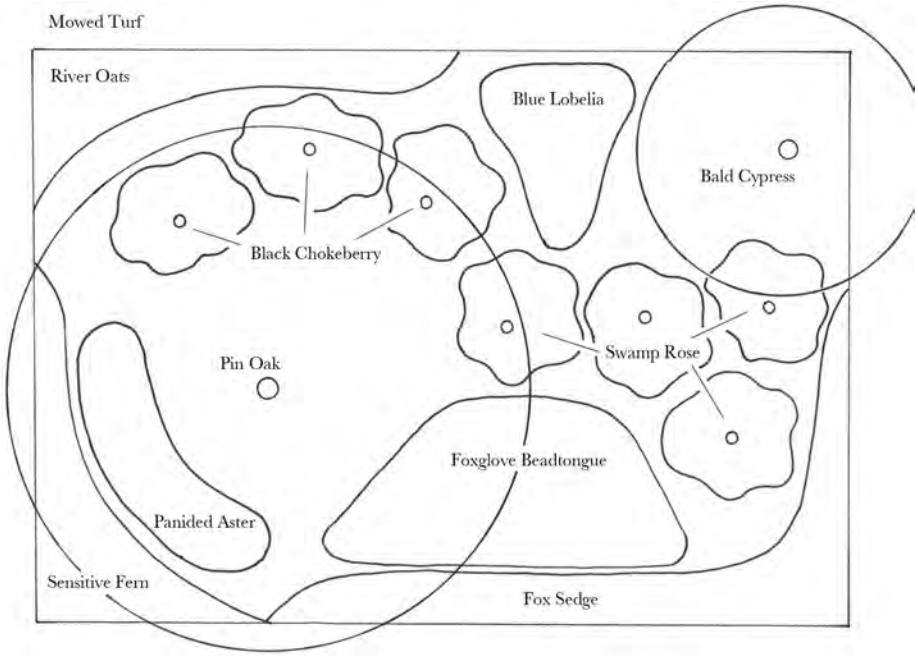


Figure 13.1-H. Typical residential parkway bioswale (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Appendix I: Plant List



Native plants at an educational display at the State Fair (Photo: Louisville & Jefferson County MSD)

Purpose

This purpose of this appendix is to provide guidance on selection of native or cultivar plants for use in green management practices (GMPs). For GMPs such as rain gardens, bioswales and planters, choose deep rooted native plants or non-invasive cultivars based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones. Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Invasive species shall not be used, and can be identified using the guide in Appendix II: Invasive Species.



Black-eyed susan (Photo: Louisville & Jefferson County MSD)

The following plant characteristics are used in the Plant List and these descriptions will facilitate plant selection for your site or GMPs. Plant characteristics include:

- Site Conditions
- Form
- Nativity
- Wetland Indicator Status
- Project Uses
- Spread (Coefficient of Conservatism)
- Height
- Flower Color
- Showy in Fall
- Flowering Time
- Root Depth
- Growth Rate

Site Conditions

A key consideration in plant selection in the site conditions where the plant will be located. Plants are commonly grouped and labeled for the following site condition categories:

- Sun
- Shade
- Partial sun
- Thrives in sun or shade

The plant list is organized first by site conditions and then by form type. When using the plant list, first determine the site conditions and then determine the type or types of plant forms that you would like to include in your planting plan.

Form

The plant form is the next plant characteristic that you should choose for your planting plan. Decide whether you would like trees, shrubs or flowers, or a combination thereof. The following are plant forms provided in the plant list:

- Trees, shrubs and vines
- Forbs/Flowers
- Grasses, sedges and ruches

Nativity

Plant nativity characterizes the plant as native, exotic (not native to Kentucky) or a cultivar of a Kentucky native species. The plant list uses the following abbreviations to indicate nativity:

- Native to Kentucky, N
- Exotic, not native to Kentucky, E
- Cultivar of a Kentucky native species, C

Wetland Indicator Status

Wetland indicator denotes the tolerance of a plant for wetland or non-wetland conditions. The wetland status of plants is determined by the U.S. Fish and Wildlife Service and is based on the occurrence of that species in wetlands in 13 separate regions of the United States. Wetland indicator categories are provided in table 13.1-A.

In selecting plant material for rain gardens and bioswales, site-specific design should be taken into careful consideration. In rain gardens with well-drained engineered soils using a high proportion of sand, species with wetland indicators of FACW or OBL will *not* be suitable. In rain gardens using native soil or using engineered soil with a higher proportion of compost, species with wetland indicators of FACW or OBL can thrive. Similar considerations should be taken for bioswales depending on their soils and length of time that stormwater will be retained in the areas.

Table 13.1-A. Wetland Indicator Categories*

Indicator Code**	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

* United States Department of Agriculture, Natural Resources Conservation Service

** A positive (+) or negative (−) sign is used for the facultative categories. The (+) sign indicates a frequency towards the wetter end of the category (more frequently found in wetlands) and the (−) sign indicates a frequency towards the drier end of the category (less frequently found in wetlands).

Project Uses

The following are defined project uses in the plant list. Please use the following key to select plants suitable for these project use categories:

- Riparian restoration, R
- Wetland restoration, W
- Bioretention/rain garden, B
- Green roof, GR
- Urban green street/green alley, U
- Upland restoration, UR

Spread (Coefficient of Conservatism)

Plant spread is designated as low, medium or high which indicates whether a plant species is faithful to a particular environment (high) or if it can grow easily in many environments (low). This scale also indicates weedy tendencies of a species or how easily it will spread when planted in a landscape. Plants that are more weedy species and tend to spread are classified as low or 0 where less weedy species that do not spread are classified as high.

The plant spread shown in the plant list is adapted from the coefficient of conservatism, a scale from 0 to 10. Each native taxon in the flora of Kentucky has been assigned a coefficient of conservatism from 10, for taxa that are associated with specific, intact, natural communities, to 0, for taxa able to withstand extensive, frequent, or ongoing site degradation.

The coefficients of conservatism can also be used to assess a species' likely behavior in a landscape planting or restoration project. Species with a high rank will be difficult to establish into highly disturbed sites. Species with low ranks will tend to be aggressive and have the potential to dominate sites where they are introduced.

Other Plant Characteristics

These remaining plant characteristics are provided in the plant list to aid in selecting plants that achieve the aesthetic goals of your GMP. To create year-round interest, select plants of varied forms, heights, flowering color and time. The following characteristics are included in the plant list:

- Height (plant height in feet)
- Flower color
- Showy in fall (yes/no indicates fall interest)
- Flowering time (Month of flowering time)
- Root depth (approximate root depth of plant in inches)
- Growth rate (slow, moderate, rapid)



Purple Coneflower (Photo: Louisville & Jefferson County MSD)



Oakleaf hydrangea (Photo: Louisville & Jefferson County MSD)

Louisville MSD Green Infrastructure Design Manual
Appendix I: Plant List

Project Uses
R =Riparian Restoration
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U = Urban Green Street/Green Alley
UR = Upland Restoration

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Salinity Tolerance
H = High
M = Moderate
L = Low
U = Unknown

Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Sun-Dry Site	**Grasses**											
Andropogon gerardii	Big Bluestem	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	1.6	M	
Andropogon virginicus	Broomsedge	N	FACU	UR, U, B	high	2-3	yellow	y	Aug-Sept	1.2	L	
Bouteloua curtipendula	Side-oats Grama	N	UPL	UR, GR, U	low	1.5-2.5	yellow	y	July-Aug	0.66	M	
Carex brevior	Shortbeak Sedge	N	UPL	UR, U	medium	1-2	yellow	n	May-June		L	
Carex cephalophora	Oval-headed Sedge	N	FACU	UR, B	medium	1	green	n	May	0.75	N	
Carex morrowii "Ice Dance"	Japanese Sedge	E	-	GR	-	.5-1	green	n	June-July		M	
Carex morrowii "Silver Sceptre"	Silver Sedge	E	-	GR	-	1	green	n	June-July		M	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Elymus villosus	Silky Wild Rye	N	FACU-	UR, B	medium	1-2	yellow	n	June		N	
Festuca amethystina "Superba"	Blue Fescue	E	-	GR	-	0.5	white	y	May-June		M	
Festuca glauca "Elijah Blue"	Blue Fescue	E	-	GR	-	.75-1	green	n	June-July		M	
Festuca ovina "glauca"	Blue Fescue	E	-	GR	-	1	green	y	June-July		M	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Koeleria macrantha	June Grass	N	UPL	UR, U, GR	low	1-2	yellow	n	May-June	1.6	M	
Panicum virgatum	Switchgrass	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	1	H	
Schizachyrium scoparium	Little Bluestem	N	FACU-	UR, B, U, GR	medium	2-3	yellow	y	Aug-Sept	1	H	
Schizachyrium scoparium "The Blues"	Little Bluestem	C	FACU-	B, U, GR	medium	2-4	purple	y	Aug-Oct	1	N	
Sesleria autumnalis	Autumn Moor Grass	E	-	GR	-	0.75-1	green	y	Sept-Oct		H	
Sorghastrum nutans	Indian Grass	N	UPL	UR, B, U, R	medium	4-6	yellow	y	Aug-Sept	2	M	
Sporobolus heterolepis	Prairie Dropseed	N	UPL	GR, U, B, UR	low	1-3	green	y	July-Sept	1	M	
Sporobolus heterolepis "Tara"	Prairie Dropseed	C		GR, U		1-3	brown	y	July-Sept	1	N	
Sun-Dry Site	**Forbs/Flowers**											
Adenophora confusa	Ladybells	E	-	GR	-	2-3	blue	n	May-July		L	
Allium cernuum	Nodding Wild Onion	N	NI	UR, U, GR	low	1-2	white	n	July		H	
Allium flavum	Small Yellow Onion	E	-	GR	-	1	yellow	n	July		U	
Allium schoenoprasum	Chives	E	-	GR	-	1-1.5	purple	n	April-May		U	
Allium stellatum	Prairie Onion	E	-	GR	-	1-1.5	pink	n	July-Sept		U	
Allium tanguticum "Summer Beauty"	Ornamental Onion	E	-	GR	-	1-1.5	purple	n	July		U	
Allium thunbergii "Ozawa"	Ornamental Onion	E	-	GR	-	.5-1	purple	n	August		U	
Antennaria dioica	Pussytoes	E	-	GR	-	.1-.2	white	n	May-July		U	
Armeria juniperifolia	Alpine Thrift	E	-	GR	-	.5-1	pink	y	May-July		M	
Armeria maritima	Sea Thrift	E	-	GR	-	.5-1	pink	n	April-May		M	
Sun-Dry Site	**Forbs/Flowers**											

Louisville MSD Green Infrastructure Design Manual
Appendix I: Plant List

Project Uses
R =Riparian Restoration
W = Wetland Restoration
B = Bioretention/Rain Garden
GR = Green Roof
U = Urban Green Street/Green Alley
UR = Upland Restoration

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Salinity Tolerance
H = High
M = Moderate
L = Low
U = Unknown

Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Arnoglossum atriplicifolium	Pale Indian Plantain	N	NI	UR	medium	3-6	white	n	July-Aug		NA	
Asclepias tuberosa	Butterfly Milkweed	N	NI	U, B, UR	medium	1-2.5	orange	n	June-Aug		M	
Symphyotrichum laeve (Aster laevis)	Smooth Blue Aster	N	UPL	U, B, UR	medium	2-4	blue	y	Sept-Oct	0.8	M	
Symphyotrichum pilosum (Aster pilosus)	Frost Aster	N	UPL	U, B, UR	0	2-5	white	n	Sept-Oct	0.8	N	
Baptisia australis	False Blue Indigo	N	NI	B, U, UR	low	3-4	blue	n	May-June		M	
Campanula rotundifolia	Harebell	E	-	GR	-	.5-1.5	blue	n	June-Sept		M	
Campanula trachelium	Bellflower	E	-	GR	-	1.5	blue	n	June-Aug		U	
Cerastium tomentosum "Silver Carpet"	Snow-In-Summer	E	-	GR	-	.5-1	white	n	May-June		M	
Coreopsis lanceolata	Tickseed	E	-	GR	-	1-2	yellow	n	May-July		N	
Coreopsis palmata	Tickseed	E	-	GR	-	1.5-2.5	yellow	n	May-July		N	
Coreopsis tripteris	Tall Coreopsis	N	FAC	U	medium	6-8	yellow	n	Aug-Sept		N	
Coreopsis verticillata "Zagreb"	Threadleaf Coreopsis	E	-	GR	-	1-1.5	yellow	n	May-June		N	
Corydalis lutea	Fumitory	E	-	GR	-	1-1,5	yellow	n	May-Sept		M	
Dalea purpurea	Purple Prairie Clover	N	UPL	GR, U, UR	low	1	purple	n	June-Sept	1.25	M	
Delosperma congestum	Hardy Ice Plant	E	-	GR	-	0.1-0.2	yellow	n	June-Sept		M	
Desmanthus illinoensis	Bundleflower	N	FAC	R, B	high	2-3	white	n	July	1	M	
Dianthus carthusianorum	Pinks	E	-	GR	-	1.5	pink	n	May-June		U	
Echinacea purpurea	Purple Coneflower	N	NI	GR, U, B, UR	low	3-5	purple	n	June-Aug	2	L	
Eryngium yuccifolium	Rattlesnake Master	N	FAC	B, U	low	3-4	white	y	July-Sept		N	
Eupatorium serotinum	Late Boneset	N	FAC	UR,U	high	2-4	white	n	July-Oct		NA	
Euphorbia cyparissias "Fen's Ruby"	Cypress Spurge	E	-	GR	-	1-1.5	yellow	n	April-June		M	
Euphorbia polychroma	Cushion Spurge	E	-	GR	-	1.5	yellow	y	May		M	
Euthamia graminifolia	Grass-leaved Goldenrod	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		L	
Geranium cantabrigiense "Biokovo"	Cranesbill	E	-	GR	-	.5-1	pink	n	May-June		U	
Geranium cantabrigiense "Karmina"	Cranesbill	E	-	GR	-	.5-1	red	n	May-June		U	
Geranium maculatum	Wild Geranium	N	FACU	UR, R	medium	1	violet	n	April-May		M	
Geranium sanguineum " Max Frei"	Cranesbill	E	-	GR	-	.5-.75	purple	n	May-June		U	
Geum triflorum	Geum	E	-	GR	-	.5-1.5	pink	n	May-July		N	
Gypsophila repens "Alba"	Creeping Baby's Breath	E	-	GR	-	.5	white	n	June-July		M	
Gypsophila repens "Rosea"	Creeping Baby's Breath	E	-	GR	-	.5	pink	n	June-July		M	
Helianthus mollis	Ashy Sunflower	N	NI	B, U, UR	low	2-4	yellow	n	Aug-Sept		M	
Heliopsis helianthoides	False Sunflower	N	NI	B, U, UR	medium	4-6	yellow	n	June-Oct		N	
Heuchera americana	Downy Alum Root	N	FACU-	UR, U	medium	1-2	white	n	June-Aug		M	
Sun-Dry Site	**Forbs/Flowers**											
Heuchera americana "Dale's Strain"	Downy Alum Root	C	-	GR	-	1-2	pink	n	June-Aug		M	

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C = Cultivar of a Kentucky Native Species

Salinity Tolerance
H = High
M = Moderate
L = Low
U = Unknown

Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Heuchera villosa	Hairy Alum Root	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		M	
Hypericum sphaerocarpum	St. John's Wort	N	FAC	U, UR, B	medium	1-2	yellow	n	June-Sept		L	
Iris pumila " Sarah Taylor"	Dwarf Bearded Iris	E	-	GR	-	1	blue and	n	June		U	
Knautia macedonica	Knautia	E	-	GR	-	1.5-2	burgandy	n	July-Sept		U	
Lamium maculatum "Aureum"	Spotted Dead Nettle	E	-	GR	-	1	purple	y	May-Sept		M	
Lamium maculatum "Chequers"	Spotted Dead Nettle	E	-	GR	-	1	purple	y	May-Sept		M	
Lespedeza capitata	Round-headed Lespedeza	N	FACU-	U, B, UR	low	1-2	purple	n	Aug-Sept	1.5	N	
Lewisia longipetala "Little Plum"	Bitter Root	E	-	GR	-	.5	pink	n	May-Sept		U	
Liatris aspera	Rough Blazing Star	N	NI	U, UR	low	1-3	purple	n	Aug-Sept		M	
Liatris cylindracea	Cylindrical Blazing Star	N	UPL	U, UR	low	1-2	purple	n	July-Oct		L	
Liatris ligulistylis	Meadow Blazing Star	E	-	GR	-	1-3	purple	n	July-Sept		U	
Manfreda virginica	False Aloe	N	UPL	UR, GR	medium	4	yellow	n	July		N	
Monarda clinopodia	Basal Balm	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		M	
Monarda fistulosa	Bee Balm	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	M	
Nepeta faassenii "Blue Wonder"	Catmint	E	-	GR	-	.5-1	blue	n	May-Sept		M	
Nepeta faassenii "Walker's"	Catmint	E	-	GR	-	1-3	blue	n	May-Sept		M	
Origanum laevigatum	Ornamental Oregano	E	-	GR	-	1-2	purple	n	July-Sept		U	
Parthenium integrifolium	Wild Quinine	N	UPL	U, UR	medium	2-3	white	n	July-Aug		M	
Penstemon digitalis "Husker Red	Beardtongue	C	-	GR	-	2-3	white	n	April-June		M	
Penstemon hirsutus	Hairy Beardtongue	N	NI	B, U, UR	medium	1-2	pink	n	May-June		M	
Penstemon hirsutus "pygmaeus"	Beardtongue	C	-	GR	-	.5	violet	n	June-July		M	
Petrorhagia saxifraga "Lady Marie"	Tunic Flower	E	-	GR	-	.5	pink	n	June-Oct		L	
Phlox paniculata	Phlox	N	FACU	UR, B	medium	3-5	pink	n	July-Sept		U	
Platycodon grandiflorus	Dwarf Balloon Flower	E	-	GR	-	1-2.5	blue	n	June-Aug		U	
Playtcodon grandiflorus "Sentimental Blue"	Balloon Flower	E	-	GR	-	0.5-1	blue	n	July-Aug		U	
Potentilla neumanniana "Nana"	Cinquefoil	E	-	GR	-	0.25-0.5	yellow	n	April-June		M	
Pulsatilla vulgaris	Pasque Flower	E	-	GR	-	0.75-1	violet	n	April-May		N	
Ratibida pinnata	Gray-headed Coneflower	N	NI	B, U, UR	medium	3-5	yellow	n	July-Aug	1.2	M	
Rudbeckia hirta	Black-eyed Susan	N	FACU-	B, U, UR	medium	2-3	yellow	n	June-Sept	0.8	M	
Salvia lyrata	Lyre-leaved Sage	N	UPL	B, U, UR	high	1-2	blue	n	April-June		M	
Salvia nemorosa "Rosenwein"	Rose Wine Sage	E	-	GR	-	1-1.5	rose	n	June-Sept		M	
Salvia nemorosa "Marcus"	Salvia	E	-	GR	-	0.5-1	violet	n	June-Sept		M	
Sun-Dry Site	**Forbs/Flowers**											
Saponaria lempergii "Max Frei"	Soapwort	E	-	GR	-	0.75-1.5	pink	n	March-April		U	
Sedum acre "Aureum"	Golden Stonecrop	E	-	GR	-	.25-.5	yellow	y	June-July		M	

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H = High
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Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Sedum acre "Octoberfest"	Sedum	E	-	GR	-	.25-.5	white	y	July-Aug		M	
Sedum album "Coral Carpet"	Stonecrop	E	-	GR	-	0.25-0.5	pink	y	May-June		M	
Sedum dasyphyllum "Blue Ridge"	Stonecrop	E	-	GR	-	0.5-1	white	n	June-July		M	
Sedum floriferum "Weihenstephaner Gold"	Russian Stonecrop	E	-	GR	-	0.3'	yellow	y	July-Aug		M	
Sedum hispanicum "Diploid"	Mexican Sedum	E	-	GR	-	0.3'	white	n	July-Aug		M	
Sedum hybridum "Immergrunchen"	Stonecrop	E	-	GR	-	0.5	yellow	y	July-Aug		M	
Sedum kamtschaticum "Akibono"	Russian Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum middendorffianum "Striatum"	Stonecrop	E	-	GR	-	0.5	yellow	y	June-July		M	
Sedum ochroleucum	Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum reflexum	Stonecrop	E	-	GR	-	0.3	yellow	n	June-July		M	
Sedum rupestre "Sandy's Silver Crest"	Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum sarmentosum	Stonecrop	E	-	GR	-	0.5	yellow	n	May-June		M	
Sedum sexangulare	Stonecrop	E	-	GR	-	0.3	yellow	y	June-July		M	
Sedum sichotense	Stonecrop	E	-	GR	-	0.5	yellow	y	July		U	
Sedum spurium "Eco Mt. Emei"	Two Row Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sempervivum montanum "Braunii"	Hens and Chicks	E	-	GR	-	0.5	magenta	y	June-July		M	
Sempervivum tectorum "Hart"	Hens and Chicks	E	-	GR	-	0.5-1	purple	y	June-July		M	
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		N	
Silphium laciniatum	Compass Plant	N	NI	B, U, UR	low	5-8	yellow	n	July-Sept	15	L	
Silphium terebinthinaceum	Prairie Dock	N	UPL	B, U, UR	low	5-10	yellow	n	July-Sept		L	
Silphium trifoliatum	Whorled Rosinweed	N	NI	B, U, UR	medium	4-6	yellow	n	July-Aug		L	
Sisyrinchium angustifolium "Lucerne"	Stout Blue-Eyed Grass	N	FACW-	U, UR	medium	1	blue	n	May-June	0.3	N	
Solidago nemoralis	Gray Goldenrod	N	NI	U, GR, UR	high	2-4	yellow	y	Sept-Oct	1	N	
Solidago caesia	Blue-Stemmed Goldenrod	N	FACU	U, B, UR	medium	1-2	yellow	n	Sept-Oct		M	
Solidago juncea	Early Goldenrod	N	UPL	U, UR	medium	2-4	yellow	y	June-Sept		N	
Solidago speciosa	Showy Goldenrod	N	UPL	UR, U	medium	1-3	yellow	y	Sept-Oct		M	
Solidago ulmifolia	Elm-leaved Goldenrod	N	UPL	UR, U	medium	3	yellow	y	July-Nov		N	
Stachys byzantina "Big Ears"	Lamb's Ears	E	-	GR	-	0.5-1	Purple	n	rarely flowers		M	
Stachys byzantina "Silver Carpet"	Lamb's Ears	E	-	GR	-	0.25-0.5	none	n	rarely flowers		M	
Tephrosia virginiana	Goat's Rue	N	UPL	UR, U	medium	1-3	pink	n	May-June		U	
Teucrium chamaedrys "Summer Sunshine"	Wall Germander	E	-	GR	-	0.75-1	purple	n	May		L	
Sun-Dry Site	**Forbs/Flowers**											
Thymus praecox	Creeping Thyme	E	-	GR	-	0.25-0.5	purple	y	June-Sept		M	
Tradescantia bracteata	Spiderwort	E	-	GR	-	1-1.5	purple	n	May-July		U	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	

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FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Vernonia gigantea	Ironweed	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		M	
Veronica longifolia "Blue John"	Speedwell	E	-	GR	-	1-1.5	blue	n	June-Sept		U	
Veronicastrum virginicum	Culver's Root	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		N	
Viola pedata	Bird's-foot Violet	N	UPL	GR		0.5	purple	n	April-May		U	
Viola sororia "Freckles"	Sweet Violet	C	-	GR	-	0.6	violet	n	April-May		M	
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		M	
Sun-Dry Site	**Trees, Shrubs, and Vines**											
Acer saccharum	Sugar Maple	N	FACU-	UR	medium	40-80	green	y	April	3.3	N	slow
Aesculus glabra	Ohio Buckeye	N	FACU+	U, UR	high	20-40	green	y	April-May	3	N	
Bignonia capreolata	Crossvine	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		N	
Calycanthus floridus	Sweet Shrub	N	UPL	U, UR	low	6-10	red	n	April-July		L	
Carya cordiformis	Bitternut Hickory	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	L	slow
Celastrus scandens	American Bittersweet	N	FACU-	U, UR	high	15-20	white	y	May-June		N	
Celtis occidentalis	Hackberry	N	FACU	UR	high	40-60	green	y	April-May	3	L	rapid
Cercis canadensis	Redbud	N	FACU-	U, R, B, UR	high	20-30	purple	n	April	2	N	
Cladrastis kentukea	Yellowwood	N	NI	U, UR	low	30-50	white	y	May	2	M	moderate
Cornus kousa	Chinese Dogwood	E	-	U	-	20-30	white	y	May-June		M	slow
Cornus mas	Cornelian Cherry Dogwood	E	-	U	-	15-25	yellow	y	March		N	slow
Cotinus obovatus	American Smoketree	E	-	U	-	20-30	pale gree	y	April-May		L	
Crataegus crus-galli	Cockspur Hawthorn	N	FACU	UR	high	25-35	white	y	May	2	M	moderate
Diospyros virginiana	Persimmon	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	L	slow - fruits may be messy in urban site
Euonymus atropurpureus	Wahoo	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	M	
Fagus grandifolia	American Beech	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	L	slow
Gleditsia triacanthos	Honeylocust	N	FAC-	R, UR	high	100	yellow	y	May-June	4	H	rapid
Gymnocladus dioicus	Kentucky Coffeetree	N	UPL	B, U, UR	medium	75-100	white	n	June	3	M	slow
Hamamelis virginiana	Witch Hazel	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	M	slow
Sun-Dry Site	**Trees, Shrubs, and Vines**											
Hypericum prolificum	Shrubby St. John's Wort	N	FACU	U, B, UR	medium	3	yellow	n	June-Aug	0.8	M	
Juglans nigra	Black Walnut	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	H	rapid
Juniperus virginiana	Eastern Red Cedar	N	FACU	U, UR	high	30-40	n/a	n	n/a		H	slow
Liriodendron tulipifera	Tulip Poplar	N	FACU	U, UR	high	60-90	yellow	y	May-June	3	L	rapid

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OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Lonicera sempervirens	Trumpet Honeysuckle	N	FACU	U, B, UR	medium	3-20	orange	n	Mar-Aug	0.8	M	
Ostrya virginiana	Eastern Hophornbeam	N	FACU-	U, UR	medium	25-40	yellow	n	April	1.3	M	slow
Prunus americana	Americum Plum	N	FACU-	U, UR	high	15-25	white	n	March	2	H	moderate
Prunus serotina	Black Cherry	N	FACU	U, UR	high	50-80	white	n	April-May	3	M	rapid
Prunus subhirtella	Higan Cherry	E	-	U	-	25-35	pink	n	March-April		L	rapid
Quercus alba	White Oak	N	FACU	B, UR	medium	50-80	yellow	y	May	4	M	slow
Quercus macrocarpa	Bur Oak	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	M	slow
Quercus marilandica	Blackjack Oak	N	UPL	U, UR	medium	20-40	yellow	y	May	2	M	slow
Quercus rubra	Red Oak	N	FACU-	U, UR	medium	50-75	yellow	y	May	3	M	moderate
Quercus prinus	Chestnut Oak	N	UPL	U, UR	medium	50-70	yellow	y	April	3	N	slow
Rhus aromatica	Fragrant Sumac	N	NI	B, U, UR	high	2-6	yellow	y	April		H	spreads to form thickets
Rhus typhina	Staghorn Sumac	N	UPL	UR	high	15-25	red	y	June-July	1.6	H	
Rosa carolina	Pasture Rose	N	UPL	U, UR	high	1-3	white	y	June-Sept	1	H	
Sassafras albidum	Sassafras	N	FACU-	U, UR	high	30-60	yellow	y	April-May	1.5	M	moderate
Viburnum prunifolium	Blackhaw Viburnum	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	M	
Viburnum rufidulum	Southern Blackhaw	N	UPL	U, UR	medium	10-20	white	y	April-May		M	
Shade-Dry Site	**Grasses**											
Bromus pubescens	Woodland Brome	N	NI	UR	medium	2-4	green	n	May-June		N	
Carex cephalophora	Oval-headed Sedge	N	FACU	UR, B	medium	1	green	n	May	0.75	N	
Carex normalis	Spreading Oval Sedge	N	FACU	UR	medium	1-3	green	n	May-June	1	N	
Carex radiata	Lance-fruited Oval Sedge	N	UPL	UR	medium	1	green	n	April-May		M	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Diarrhena americana	Beak Grass	N	NI	U, B, UR	medium	1-2	green	n	August		N	
Elymus villosus	Silky Wild Rye	N	FACU-	UR, B	medium	1-2	yellow	n	June		N	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Asarum canadense	Wild Ginger	N	FACU-	B, UR	medium	1	maroon	n	April-May		M	
Aster cordifolius	Wood Aster	N	UPL	U, UR	medium	1-3	purple	y	Sept-Oct	0.8	N	
Aster divaricatus	White Wood Aster	N	UPL	U, UR	low	1-2.5	white	n	Aug-Sept		U	
Shade-Dry Site	**Forbs/Flowers**											
Symphyotrichum shortii (Aster shortii)	Short's Aster	N	UPL	B, UR, U	medium	2-3	blue	n	Sept-Oct		U	
Blephilia ciliata	Downy Wood Mint	N	NI	B, U, UR	medium	1-2.5	blue	n	May-Aug		U	
Blephilia hirsuta	Hairy Wood Mint	N	FACU	U, UR	medium	1-3	blue	n	July-Aug		N	
Campanulastrum americanum	Bellflower	N	FACU	B, UR	high	2-6	blue	n	June-July	0.75	N	
Geranium maculatum	Wild Geranium	N	FACU	R, UR	medium	1	violet	n	April-May		M	

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Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Helianthus divaricatus	Woodland Sunflower	N	NI	U, UR	medium	2-5	yellow	n	Sept-Oct		M	
Heuchera americana	Downy Alum Root	N	FACU-	U, UR	medium	1-2	white	n	June-Aug		M	
Heuchera villosa	Hairy Alum Root	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		M	
Monarda clinopodia	Basal Balm	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		M	
Monarda fistulosa	Bee Balm	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	M	
Polemonium reptans	Jacob's Ladder	N	FACU	R, B, UR	medium	1-1.5	blue	n	April-June		U	
Polygonatum biflorum	Solomon's Seal	N	FACU	R, B, UR	medium	1-3	white	n	April-May		M	
Salvia lyrata	Lyre-leaved Sage	N	UPL	B, U, UR	high	1-2	blue	n	April-June		M	
Solidago caesia	Blue-Stemmed Goldenrod	N	FACU	U, B, UR	medium	1-2	yellow	y	Sept-Oct	0.6	M	
Solidago flexicaulis	Zig-Zag Goldenrod	N	FACU	B, R, UR	medium	1-2	yellow	y	Sept-Oct	0.6	M	
Solidago juncea	Early Goldenrod	N	UPL	U, UR	medium	2-4	yellow	n	June-Sept		N	
Stylophorum diphyllum	Celandine Poppy	N	NI	B, UR, U	medium	1-2	yellow	n	April-May		N	
Tephrosia virginiana	Goat's Rue	N	UPL	UR, U	medium	1-3	pink	n	May-June		U	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	
Veronicastrum virginicum	Culver's Root	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		N	
Shade-Dry Site	**Trees, Shrubs, and Vines**											
Acer saccharum	Sugar Maple	N	FACU-	UR	medium	40-80	green	y	April	3.3	N	slow
Aesculus glabra	Ohio Buckeye	N	FACU+	U, UR	high	20-40	green	y	April-May	3	N	
Betula lenta	Sweet Birch	N	FACU	U, UR	medium	72-100	yellow	n	April-May	2.25	M	
Bignonia capreolata	Crossvine	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		N	
Calycanthus floridus	Sweet Shrub	N	UPL	U, UR	low	6-10	red	n	April-July		L	
Carya cordiformis	Bitternut Hickory	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	L	slow
Carya ovata	Shagbark Hickory	N	FACU	U, UR	medium	70-90	yellow	y	April-May	4	H	slow
Celtis occidentalis	Hackberry	N	FACU	UR	high	40-60	green	y	April-May	3	L	rapid
Ceanothus americanus	New Jersey Tea	N	UPL	U, UR	medium	3	blue	n	Mar-Apr	1.2	N	

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Shade-Dry Site	**Trees, Shrubs, and Vines**											
Diospyros virginiana	Persimmon	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	L	slow - fruits may be messy in urban site
Euonymus americanus	Strawberry Bush	N	UPL	U, UR	medium	6-12	green	y	May-June	0.6	M	
Euonymus atropurpureus	Wahoo	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	M	
Fagus grandifolia	American Beech	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	L	slow
Gymnocladus dioicus	Kentucky Coffeetree	N	UPL	B, U, UR	medium	75-100	white	n	June	3	M	slow
Hamamelis virginiana	Witch Hazel	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	M	slow
Hydrangea arborescens	Wild Hydrangea	N	FACU	B, UR, U	medium	3-6	cream	y	June-Sept		M	
Juglans nigra	Black Walnut	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	N	rapid
Lonicera sempervirens	Trumpet Honeysuckle	N	FACU	U, B, UR	medium	3-20	coral	n	Mar-Aug	0.8	M	
Pinus strobus	White Pine	N	FACU	U, UR	medium	75-100	n/a	n	n/a	3.3	L	rapid
Prunus americana	Americum Plum	N	FACU-	U, UR	high	15-25	white	n	March	2	H	moderate
Prunus serotina	Black Cherry	N	FACU	U, UR	high	50-80	white	n	April-May	3	M	rapid
Rhus aromatica	Fragrant Sumac	N	NI	B, U, UR	high	2-6	yellow	y	April		H	will spread to form thickets
Rhus typhina	Staghorn Sumac	N	UPL	UR	high	15-25	red	y	June-July	1.6	H	
Symphoricarpos orbiculatus	Coralberry	N	UPL	B, U, UR	high	2-5	white	y	June-July	1.5	L	
Viburnum prunifolium	Blackhaw Viburnum	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	M	
Viburnum rufidulum	Southern Blackhaw	N	UPL	U, UR	medium	10-20	white	y	April-May		**M**	
Sun--Moist to Wet Site	**Grasses, Sedges and Rushes**											
Andropogon gerardii	Big Bluestem	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	9	M	
Arundinaria gigantea	River Cane	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	L	
Carex annectens	Yellow Fox Sedge	N	FACW	B, W	high	2-3	yellow	n	May-June		U	
Carex bromoides	Brome-like Sedge	N	FACW+	W, R, B	low	1-2	green	n	May		U	
Carex crinita	Fringed Sedge	N	OBL	W	medium	2-4	green	n	May-June	1.5	N	
Carex cristatella	Crested Sedge	N	FACW	W, B	medium	2-3	green	n	May-June	0.75	N	
Carex frankii	Frank's Sedge	N	OBL	W, B, R	high	1-2	green	n	June-July	0.75	N	
Carex granularis	Meadow Sedge	N	FACW+	W, B	medium	1-2	green	n	May-June	0.75	N	
Carex grayi	Gray's Sedge	N	FACW+	W	medium	1-2	green	n	May-June	0.75	N	
Carex lupulina	Hop Sedge	N	OBL	W	medium	1-2	green	n	May-June	1.5	N	
Carex lurida	Lurid Sedge	N	OBL	W	medium	1-2	green	n	May-June	1.3	N	

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H = High
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Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Sun--Moist to Wet Site	**Grasses, Sedges and Rushes**											
Carex scoparia	Large-Fruited Oval Sedge	N	FACW	W	medium	2-3	green	n	May	0.75	L	
Carex stipata	Awl-fruited Sedge	N	OBL	W	medium	2-3	green	n	May	0.75	L	
Carex vulpinoidea	Fox Sedge	N	OBL	W, B. R	high	2-3	green	n	May-June	1.3	N	
Elymus riparius	Riverbank Wild Rye	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	N	
Glyceria striata	Fowl Manna Grass	N	OBL	W, B, R	medium	2-4	green	n	May-June	0.3	N	
Juncus effusus	Soft Rush	N	FACW+	W, B, R	medium	2-4	green	n	May-June	1	L	
Leersia oryzoides	Rice Cutgrass	N	OBL	W, B	high	2-4	green	n	Aug-Sept	1.2	M	
Panicum virgatum	Switchgrass	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	11	H	
Scirpus atrovirens	Green Bulrush	N	OBL	W	high	3-5	brown	n	May-June	1	M	
Scirpus cyperinus	Woolgrass	N	FACW+	W	medium	3-5	green	n	July-Aug	1	M	
Scirpus validus	Softstem Bulrush	N	OBL	W	high	4-8	red	n	May-June		L	
Spartina pectinata	Prairie Cordgrass	N	OBL	B, W	medium	4-7	yellow	n	July-Aug	1.5	L	
Tripsacum dactyloides	Eastern Gamma Grass	N	FACW	U, B	medium	4-8	yellow	n	May-Sept	1.6	N	
Sun--Moist to Wet Site	**Forbs/Flowers**											
Acorus calamus	Sweet Flag	N	OBL	W	high	2-2.5	yellow	n	April	1	L	
Agrimonia parviflora	Many-flowered Agrimony	N	FACW	B,W	medium	6	yellow	n	July	0.5	NA	
Alisma subcordatum	Water Plantain	N	OBL	W	high	1-2	white	n	June	0.66	L	
Amsonia tabernaemontana "Short Stack"	Dwarf Bluestar	C	-	R	-	0.75-1	pale blue	y	April-May		M	
Asclepias incarnata	Swamp Milkweed	N	OBL	W, B, R	medium	4-5	pink	n	July-Aug	1.5	M	
Symphyotrichum novae-angliae (Aster novae-angliae)	New England Aster	N	FACW-	W, B, U, R	medium	3-6	purple	n	Aug-Sept		N	
Symphyotrichum puniceum (Aster puniceus)	Purple-stemmed Aster	N	OBL	W	low	6-8	blue	n	Aug-Sept		N	
Doellingeria umbellata (Aster umbellatus)	Flat-topped Aster	N	FACW	B, R	medium	3-5	white	n	Sept-Oct		M	
Bidens aristosa	Tickseed Sunflower	N	FACW	W	0	2-3	yellow	n	Sept-Oct	0.75	N	
Bidens cernua	Nodding Bur Marigold	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	L	
Chelone glabra	White Turtlehead	N	OBL	R, W, B	medium	2-4	white	n	Aug-Sept		N	
Conoclinium coelestinum	Mistflower	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	N	
Coreopsis "Jethro Tull"	Tickseed	E	-	B	-	1-1.5	yellow	n	June-Aug		M	
Echinacea purpurea "Vintage Wine"	Purple Coneflower	C	-	R	-	2-3	white	n	June-Aug	2	L	
Eryngium yuccifolium	Rattlesnake Master	N	FAC	B, U	low	3-4	white	y	July-Sept		L	
Eupatorium fistulosum	Joe-pye Weed	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		M	
Eupatorium maculatum	Spotted Joe-pye Weed	N	FACW	R, W	low	4-6	violet	n	Aug-Sept		M	
Eupatorium perfoliatum	Boneset	N	FACW+	R, U	high	3-5	white	n	Aug-Sept		M	
Sun--Moist to Wet Site	**Forbs/Flowers**											

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Eupatorium purpureum	Purple Joe-pye Weed	N	FAC	W, B	medium	4-6	violet	n	July-Aug		M	
Euthamia graminifolia	Grass-leaved Goldenrod	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		L	
Gaura lindheimeri "Siskiyou Pink"	Gaura	E	-	B	-	2.5-3	yellow	n	May-Aug		U	
Geranium "Gerwat" RIZANNE	Cranesbill	E	-	B	-	1-1.5	yellow	n	May-July		M	
Helenium autumnale	Sneezeweed	N	FACW+	W, B	medium	3-5	pink	n	Sept-Oct	0.5	L	
Helianthus angustifolius	Narrow-leaved Sunflower	N	FACW	B, U	low	4-6	blue	n	Sept-Oct	0.5	N	
Heuchera "Rave On"	Coral Bells	E	-	B	-	1-2	pink/whit	n	July-Aug		M	
Hibiscus "Fantasia"	Hardy Hibiscus	E	-	B	-	2-3	pink/whit	n	July-Sept		M	
Hibiscus laevis	Smooth Rose-mallow	N	OBL	W, B, R	medium	2	pink	y	July-Aug	1	M	
Hibiscus moscheutos	Swamp Hibiscus	N	OBL	W, B, R	high	3-5	pink	n	July	0.8	M	
Iris virginica	Blue Flag Iris	N	-	W, B	medium	2-3	blue	n	May-June	0.5	N	
Liatris spicata	Dense Blazing Star	N	FAC+	W, B	low	3-5	purple	n	July-Aug	1.2	L	
Lycopus americanus	Water Horehound	N	OBL	W, B	medium	1-2	white	n	July-Aug		L	
Mimulus ringens	Monkey Flower	N	OBL	W,B	medium	2-4	blue	n	July-Sept		NA	
Nepeta subsessilis "Candy Cat"	Nepeta	E	-	B	-	2-2.5	pink	n	May-Sept		L	
Peltandra virginica	Arrow Arum	N	OBL	W, R	medium	2-3	white	n	June-July	1.3	M	
Penstemon digitalis	Foxglove Beardtongue	N	FAC	W, R	high	2-3	white	n	June	0.6	M	
Phlox paniculata "Robert Poore"	Phlox	C	-	B	-	3-5	pink	n	July-Sept		M	
Physostegia virginiana "Miss Manners"	Obedient Plant	C	-	R	-	2-2.5	white	n	June-Sept		M	
Pontederia cordata	Pickerelweed	N	OBL	R, W	low	2-3	blue	n	July-Sept	0.8	L	
Potamogeton nodosus	Long-leaved Pondweed	N	OBL	W	medium	1-3	green	n	June-Sept		N	
Pycnanthemum tenuifolium	Slender Mountain Mint	N	FACW	B, U, R	high	1-2	white	n	July-Aug		U	
Pycnanthemum virginianum	Common Mountain Mint	N	FAC	W, B	medium	1-2	white	n	July-Aug		L	
Rudbeckia fulgida	Orange Coneflower	N	FAC	B, U, UR	medium	2-3	yellow	n	Aug-Sept	0.6	M	
Rudbeckia laciniata	Green-headed Coneflower	N	FACW	U, W, B	medium	5-8	yellow	n	July-Aug	1	M	
Sagittaria latifolia	Broad-leaf Arrow-head	N	OBL	R, W	medium	1-3	white	n	July-Sept	1.5	M	
Salvia nemorosa "Sensation Rose"	Sage	E	-	B	-	0.75-1	white	n	June-Sept		U	
Saururus cernuus	Lizard's Tail	N	OBL	W	medium	1-2	yellow	n	June-Sept		M	
Packera aureus	Golden Ragwort	N	FACW	B, R	medium	1	pink	n	May		M	
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		U	
Sparganium eurycarpum	Giant Burreed	N	OBL	W	low	3-6	green	n	June-July	1	M	
Stachys officinalis	Bishop's Wort	E	-	B	-	1.5-2	blue	n	May-June		M	
Teucrium canadense	Germander	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	L	
Sun--Moist to Wet Site	**Forbs/Flowers**											
Tradescantia ohiensis	Spiderwort	N	FAC	B, U	medium	2-3	Purple	n	June-July	0.3	M	

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Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Verbena hastata	Blue Vervain	N	FACW+	B, W	high	3-5	blue	n	July-Sept		H	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	
Vernonia gigantea	Ironweed	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		M	
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		M	
Sun--Moist to Wet Site	**Trees, Shrubs, and Vines**											
Alnus serrulata	Smooth Alder	N	OBL	W, R	medium	15	yellow	n	March-April	2	N	rapid
Amelanchier laevis	Allegheny Serviceberry	N	NI	B, U, R	low	14-40	white	y	April	2.5	L	moderate
Amorpha fruticosa	Leadplant	N	FACW	R, B	medium	1-3	purple	n	June-July	2	H	
Aralia spinosa	Devil's Walkingstick	N	FAC	U	medium	20	white	n	June-Aug	2.5	N	moderate
Aronia arbutifolia	Red Chokeberry	N	NI	R, U	medium	3-6	white	y	May	1.6	L	
Aronia melanocarpa	Black Chokeberry	N	NI	R, U	medium	3-6	white	y	May	2	M	
Betula nigra	River Birch	N	FACW	B, U, R	medium	40-70	brown	n	April-May	1.6	M	rapid
Carpinus betulus "Globosa"	European Hornbeam	E	-	U	-	15-20	green	n	April		N	slow
Carya laciniosa	Shellbark Hickory	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	N	slow
Celtis laevigata	Sugarberry	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	L	moderate
Cephalanthus occidentalis	Buttonbush	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	M	
Chionanthus virginicus	Fringe Tree	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	L	slow
Cornus mas	Cornelian Cherry Dogwood	E	-	U	-	15-25	yellow	y	March		N	slow
Crataegus viridis	Green Hawthorn	N	FACW	U	medium	20-35	white	y	May	1.6	N	moderate
Ilex decidua	Possumhaw Holly	N	FACW	R, B, U	medium	15-30	yellow	n	March-May	1	N	
Ilex verticillata	Winterberry	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	M	
Itea virginica	Virginia Sweetspire	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	N	
Liquidambar styraciflua	Sweetgum	N	FAC	R, U	high	60-80	green	y	April-May	3	H	rapid
Nyssa sylvatica	Black Gum	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	1.5	M	moderate
Physocarpus opulifolius	Common Ninebark	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	L	slow
Platanus occidentalis	Sycamore	N	FACW-	R, U	high	75-100	red	y	April	2.5	L	rapid
Quercus bicolor	Swamp White Oak	N	FACW+	W, U, R	low	50-60	yellow	y	April	3.3	M	rapid
Quercus macrocarpa	Bur Oak	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	M	slow
Quercus palustris	Pin Oak	N	FACW	W, B, U	medium	50-70	yellow	y	April	2.5	L	rapid
Quercus phellos	Willow Oak	N	FAC+	R, W, U	low	40-75	yellow	y	April	1	NH	rapid
Quercus shumardii	Shumard Oak	N	FAC+	U	medium	40-60	yellow	y	April	3.3	M	moderate
Sun--Moist to Wet Site	**Trees, Shrubs, and Vines**											
Rosa palustris	Swamp Rose	N	OBL	B, W, R	medium	2-7	pink	y	June-July	1.5	**N**	
Salix amygdaloides	Peach-leaf Willow	N	FACW	R, W	low	60	white	n	Apr-May	2.5	N	rapid

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Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Salix discolor	Pussy-Willow	N	FACW	W	low	25	white	n	Feb-Mar	1.6	H	rapid
Salix exigua	Sandbar Willow	N	OBL	W, R	high	15	white	n	Mar-Apr		L	rapid
Salix nigra	Black Willow	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	M	rapid
Sambucus canadensis	Common Elderberry	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		M	
Spiraea alba	Meadowseet	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	N	
Spiraea tomentosa	Steeplebush	N	FACW-	B, W	medium	2-5	purple	y	July-Sept	1.2	M	
Taxodium distichum	Bald Cypress	N	OBL	W, U, R	medium	50-70	n/a	y	n/a	3.3	H	rapid
Viburnum dentatum	Arrow-wood	N	FAC	R, B	medium	6-10	white	y	May-June		M	
Shade-Moist to Wet Site	**Grasses, Sedges and Rushes**											
Arundinaria gigantea	River Cane	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	L	
Carex bromoides	Brome-like Sedge	N	FACW+	W, R, B	low	1-2	green	n	May		U	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Elymus riparius	Riverbank Wild Rye	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	N	
Elymus virginicus	Virginia Wild Rye	N	FACW-	UR, B	medium	2-3	yellow	n	June-July		N	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Shade-Moist to Wet Site	**Forbs/Flowers**											
Aquilegia canadensis	Wild Columbine	N	FAC	R, U, B	medium	2-3	red	n	April-May		M	
Arisaema triphyllum	Jack-In-The-Pulpit	N	FACW-	R, B	medium	1-2	maroon	y	April-May		N	
Symphyotrichum lateriflorum (Aster lateriflorus)	Calico Aster	N	FACW-	R, U	high	1-3	purple	y	Sept-Oct	0.8	N	
Athyrium filix-femina	Lady Fern	N	FAC	B, R	medium	1-3	n/a	n	n/a		M	
Bidens cernua	Nodding Bur Marigold	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	L	
Conoclinium coelestinum	Mistflower	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	N	
Eupatorium fistulosum	Joe-pye Weed	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		M	
Eupatorium purpureum	Purple Joe-pye Weed	N	FAC	W, B	medium	4-6	violet	n	July-Aug		M	
Heuchera "Rave On"	Coral Bells	E	-	B	-	1-2	red	n	July-Aug		M	
Lobelia cardinalis	Cardinal Flower	N	FACW+	W, B, R	medium	1-3	blue	n	Aug-Sept	1	M	
Lobelia siphilitica	Blue Lobelia	N	FACW+	W, B, R	medium	1-3	pink	y	Aug-Sept		M	
Nepeta subsessilis "Candy Cat"	Nepeta	E	-	B	-	2-2.5	n/a	n	May-Sept		L	
Onoclea sensibilis	Sensitive Fern	N	FACW	R, B	medium	3-4	n/a	n	n/a		M	
Shade-Moist to Wet Site	**Forbs/Flowers**											
Osmunda cinnamomea	Cinnamon Fern	N	FACW	R, B	low	2-3	pink	n	n/a	1	L	
Osmunda regalis	Royal Fern	N	OBL	R, B	low	2-3	n/a	n	n/a	1.3	N	
Penstemon digitalis	Foxglove Beardtongue	N	FAC	W, B	high	2-3	white	n	June	0.6	M	

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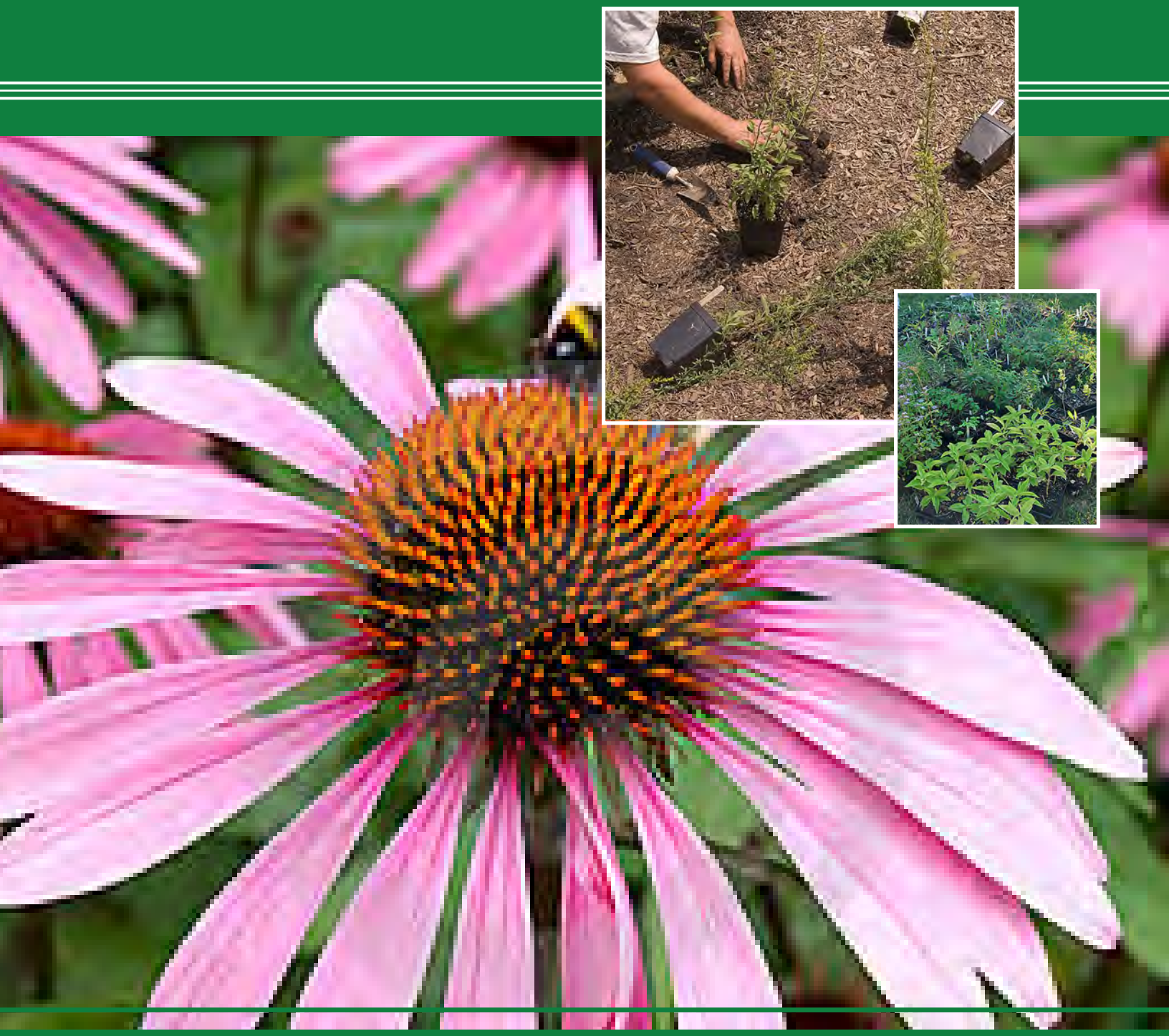
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		U	
Sisyrinchium angustifolium	Stout Blue-Eyed Grass	N	FACW-	U, B	medium	1	blue	n	May-Aug		N	
Symphyotrichum lanceolatum (Aster lanceolatus)	Panicled Aster	N	OBL	R,W	medium	5	white	n	Sept-Oct		NA	
Teucrium canadense	Germander	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	L	
Shade-Moist to Wet Site	**Trees, Shrubs, and Vines**											
Acer japonicum "Taki No Gawa"	Fullmoon Maple	E	-	U	-	10-15	red	y	May		L	slow
Alnus serrulata	Smooth Alder	N	OBL	W, R	medium	15	yellow	n	March-April	2	N	rapid
Amelanchier laevis	Allegheny Serviceberry	N	NI	B, U, R	low	14-40	white	y	April	2.5	L	moderate
Aralia spinosa	Devil's Walkingstick	N	FAC	U	medium	20	white	n	June-Aug	2.5	N	moderate
Aronia arbutifolia	Red Chokeberry	N	NI	R, U	medium	3-6	white	y	May	1.6	L	
Aronia melanocarpa	Black Chokeberry	N	NI	R, U	medium	3-6	white	y	May		M	
Carpinus caroliniana	American Hornbeam	N	FAC	W, B, U, R, UR	medium	20-35	orange	y	Feb	1.6	M	
Carya laciniosa	Shellbark Hickory	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	N	slow
Celtis laevigata	Sugarberry	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	L	moderate
Cephalanthus occidentalis	Buttonbush	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	M	
Chionanthus virginicus	Fringe Tree	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	L	slow
Clematis virginiana	Virgin's Bower	N	FAC	U, R, B	medium	4-8	white	n	Aug-Sept	1.2	N	
Cornus amomum	Silky Dogwood	N	FACW	W, B, U, R	medium	6-10	white	n	April	1.3	N	
Hydrangea quercifolia	Oak-leaf Hydrangea	E	-	B	-	6-8	yellow	n	May-July		M	
Ilex decidua	Possumhaw Holly	N	FACW	R, B, U	medium	15-30	white	y	March-May	1	N	
Ilex verticillata	Winterberry	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	M	
Itea virginica	Virginia Sweetspire	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	N	
Lindera benzoin	Spicebush	N	FACW-	R, W, B	medium	4-8	white	y	April	1.5	M	
Nyssa sylvatica	Black Gum	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	2.5	M	moderate
Physocarpus opulifolius	Common Ninebark	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	L	slow
Salix exigua	Sandbar Willow	N	OBL	W, R	high	15	white	y	Mar-Apr		L	
Salix nigra	Black Willow	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	M	rapid
Sambucus canadensis	Common Elderberry	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		M	
Spiraea alba	Meadowseet	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	N	
Shade-Moist to Wet Site	**Trees, Shrubs, and Vines**											
Spiraea tomentosa	Steeplebush	N	FACW-	B, W	medium	2-5	purple	n	July-Sept	1.2	M	
Viburnum dentatum	Arrow-wood	N	FAC	R, B	medium	6-10	white	y	May-June		M	

Green Infrastructure Plant Guide



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Introduction to Plant Guide

This Plant Guide is designed to be used in conjunction with Louisville Metropolitan Sewer District's Design Manual, Chapter 13 and its appendix of recommended plants. Chapter 13 will provide planning and design information that should be considered before making plant selection for a site. The appendix of recommended plants contains specific information on growing conditions, height, flower color, flowering time, etc. The Plant Guide provides images for the plants as well as additional information on the natural history, management, and growing tips for each species. The table and Plant Guide should be used together to get all the necessary information for each species.

The Plant Guide includes native species, cultivars of native species and non-native plants as choices for landscaping and restoration projects. Native species are species that were present in this region prior to European settlement of this area. Following European settlement of Kentucky, many species were introduced for agriculture and landscaping, and others were introduced accidentally as seed mixed in with other imported materials. This guide attempted to exclude any species considered to be invasive or harmful to nearby natural areas.

Benefits of working with native species are that these species have existed in these growing conditions for thousands of years. Given that you choose the right plant for the right location, native species, once established, will not require additional water or fertilizer inputs. Native species will also provide a source of food for dwindling wildlife species including birds and butterflies. A locally genetic source of native plants will be best adapted to our conditions. A consideration in using native plant materials is that they are a mix of unique individuals. While this makes for a healthy population of plants, it also results in variability in flower color, height, and other physical characteristics of the plants. Utilizing cultivars will provide more consistency in the physical characteristics of plants.

Alpine Thrift
Armeria juniperifolia

This species requires full sun and well drained soil. Drought tolerant. It does not tolerate competition from more aggressive plants. Susceptible to root rot. Good for rock garden, containers or small scale ground cover.

When deadheaded,the plant can give a second bloom. The evergreen leaves provide winter interest in the garden.

Habitat: Sun



Alpine Thrift in bloom in early Summer
© *Henrietta Kress*

Alpine Thrift in bloom
© *Magnus Manske*

Alum Root
Heuchera richardsonii

Drought tolerant. Good edging plant and if planted in mass can form a nice ground cover. Prefers well drained areas. Clumps can be divided every 3 to 4 years in spring. This shallow rooted plant can benefit from additional mulching prior to winter.

The flowers of Alum Root are attractive to native bees.



Alum Root in early Summer
© *J.S. Peterson*



Alum Root in bloom in early Summer
© *Bennie Bengston*

Aromatic Aster
Symphyotrichum oblongifolium

Drought tolerant. Thin regularly to control unwanted spread. Prune in early summer to control growth and height. Some support may be needed for taller plants when in bloom. Cut back dead plant material in late fall or early winter. Leaves are fragrant when crushed. Provides color into the late fall.

Attracts birds, butterflies and bees. Good cut flower.



Aromatic Aster in bloom in late Summer
© *Sally & Andy Wasowski*



Aromatic Aster in bloom
© *Sally & Andy Wasowski*

Arrow Arum
Peltandra virginica

Aquatic plant that requires wet soil. Easily grown in up to 6 inches of water. Plants will clump over time but do not colonize aggressively. Will spread by underground stems as well as by seed.

The flowers are pollinated by flies and wood ducks feed on the black berries.

Habitat: Sun



Arrow Arum colony
© *Dave Stephens bugwood.org*



Arrow Arum in flower
© *Ann Murray*



Arrow Arum at full height
© *Sally & Andy Wasowski*

Ashy Sunflower

Helianthus mollis

This plant is typically found growing in colonies. It can spread aggressively and may need to be weeded back to control. May need to be staked if it grows tall. Plants can be cut back in the early summer to control the height and increase flowering.

Attracts birds, bees and butterflies. Cut back dead plant material in the late winter to allow birds to feed on the seed during the winter months.

Habitat: Sun



Ashy Sunflower in bloom
© *Dropseed Nursery*



Ashy Sunflower in bloom
© *Tom Barnes*



Ashy Sunflower colony in bloom in late Summer
© *Mike Haddock*

Autumn Moor Grass

Sesleria autumnalis

This species spreads well and can be used for erosion control. Can be used as a ground cover under trees and shrubs and should be planted in clumps. Not entirely tolerant of high heat and humidity. Bold gold color display in autumn. Silvery flower stalks are produced in the late summer and are maintained through the winter, creating an attractive accent.

Attracts birds. Cut back the dead plant material in late winter. Plants can be divided in the early spring.

Habitat: Sun



Autumn Moor Grass in winter
© *The Battery Conservancy*



Autumn Moor Grass stand
© *Randy Stewart*



Autumn Moor Grass colony
© *The Battery Conservancy*

Awl-fruited Sedge

Carex stipata

Species tolerates inundation to a depth of up to 6 inches. If planted in the shade, Awl Fruited Sedge will tolerate dry soil. This species spreads quickly and is good for stabilizing disturbed sites. The golden yellow seed heads are attractive in the summer. The narrow leaves create a delicate texture.

The seed provides food for songbirds. The leaves are a food source for caterpillars of several species of butterfly.

Habitat: Sun



Awl Fruited Sedge colony
© *Paul Slichter*

Awl Fruited Sedge seed head
© *Paul Slichter*

Balloon Flower

Playtcodon grandiflorus "Sentimental Blue"

This species emerges late in the spring, so care must be taken not to disturb the soil before the plant emerges. Blooms most of the summer. Division and transplanting are possible but can be difficult because of the stringy root system.

Cut back dead plant material in the early spring.

Habitat: Sun



Balloon Flower in bloom in summer
© *Missouri Botanical Society*

Basal Balm
Monarda clinopodia

This plant forms widely spreading clumps. A member of the mint family, Basal Balm will spread, but not aggressively. The leaves are fragrant when crushed. Cut back dead plant material in the early spring.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun



Basal Balm in winter
© *Dropseed Nursery*



Basal Balm bloom in summer
© *William S. Justice*



Basal Balm at full height
© *Thomas L. Muller*

Beardtongue
Penstemon hirsutus "Pygmaeus"

Dwarf variety, the evergreen leaves will turn a bronze-red in the winter. One of the easiest penstemons to grow. Good for rock gardens. Plants can be divided in the spring.

Attracts butterflies, bees and hummingbirds. Makes a good cut flower. Spent blooms should be cut back in the late winter or early spring.

Habitat: Sun



Beardtongue in winter
© *Rob Broekhuis*



Beardtongue colony in bloom
© *Rob Broekhuis*



Beardtongue blossom
© *Rob Broekhuis*

Beardtongue

Penstemon digitalis "Husker Red"

Needs full sun for best red foliage color. Avoid wet, poorly-drained soil, root rot can occur. May need support during and after blooming. Spent seed heads can be cut back in early summer. The leaves are semi-evergreen and maintain a red color in the winter.

Attracts butterflies and birds. Makes nice cut flowers.

Habitat: Sun



Beardtongue blossom
© *Missouri Botanical Garden*



Beardtongue in winter
© *Dropseed Nursery*



Beardtongue at full height in summer
© *Missouri Botanical Garden*

Bee Balm

Monarda Fistulosa

Dead-head flowers to prolong summer bloom. Plant needs good air circulation and should not be crowded in order to avoid powdery mildew. Leaves are fragrant. This species can spread aggressively and may require weeding back to avoid excessive spread. Cut back dead plant material during the winter months.

Attracts butterflies, bees and hummingbirds.

Habitat: Sun



Bee Balm bloom
© *Lynn Crosby Gammill*



Bee Balm in winter
© *Dropseed Nursery*



Bee Balm stand in bloom in summer
© *Thomas L. Muller*

Bellflower
Campanulastrum americanum

Depending on moisture level and fertility of the soil, this plant can vary in size. Taller plants may need to be staked. During a drought, the plant often drops the lower leaves; however its deep tap root makes this species fairly drought tolerant. Cut back dead plant material during the winter months.

Attracts bees and butterflies. The flowers of this species are a treat for deer.

Habitat: Shade



American Bellflower blossom
© *Stan Gilliam*



American Bellflower stand in bloom
© *Sally & Andy Wasowski*

Bellflower
Campanula trachelium

This clump florming species creates a nice border. Dead-head flowers to prolong summer bloom. Cut back dead plant material during the winter months. Plants can be propagated by division in the spring or fall. This species is native to Denmark and England.

Good for cut flowers.

Habitat: Sun



Bellflower in bloom in summer
© *Rob Broekhuis*



Bellflower blossom
© *Rob Broekhuis*

Big Bluestem
Andropogon gerardii

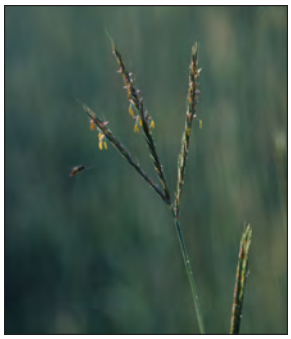
Strong fall color of reddish gold. Plants can be cut back in the early summer to maintain a shorter height. A dominate grass of the tallgrass prairie. Can be aggressive if left undisturbed. Species tends to flop over in winter months. Cut back dead plant material in the winter.

Prairie chickens and songbirds consume the seeds. One of the highest quality forage grasses on the prairie. Attracts butterflies and grasshoppers.

Habitat: Sun



Big Bluestem in summer



Big Bluestem flower
© *Sally & Andy Wasowski*



Big Bluestem in fall
© *Sally & Andy Wasowski*

Birdfoot Violet
Viola Pedatai

Prefers dry, rocky, sandy soils and full sun. Drought tolerant. Will not tolerant poorly drained soils. Considered one of the most beautiful violets in the world. Plants die back completely in the winter, leaving no visible plant remnants. Reproduction by seed only.

Several color forms of this species exist: pale purple, deep purple, and bicolor.

Attracts bees and butterflies. Adult butterflies use this species as a source of nectar, several caterpillar species feed on the petals and leaves. The seeds are dispersed by ants, which feed on the sugary gel coating the seeds.



Birdfoot Violet blossom
© *Jeff McMillan*

Bishop's Wort
Stachys officinalis

Clumps will spread over time to form a dense ground cover. This species makes a nice border plant. The leaves of Bishop's Wort are evergreen during mild winters. Flower color ranges from white and pink through reddish-purple. Spent flower spikes should be cut back in the fall

Good food source for bee and butterflies. Medicinal plant. This species grows well under Black Walnut Trees and is not attractive to deer.

Habitat: Sun



Bishop's Wort colony in bloom
© *Missouri Botanical Society*



Bishop's Wort bloom in early Summer
© *Missouri Botanical Society*

Bitter Root
Lewisia longipetala "Little Plum"

Blossom is typically bright rose-pink to red but can also open as orange initially making it possible to see three different color blossoms on the same plant. Very drought tolerant, Bitter Root prefers a well-drained rocky soil. Native to the Northwest U.S. The foliage of this species is evergreen. Cut back spent flowers in the late summer.

The flowers attract butterflies. This species is not attractive to deer.

Habitat: Sun



Bitter Root in bloom in Summer
© *Steven Perry*



Bitter Root bloom
© *Moon Rhythm*

Black-eyed Susan

Rudbeckia hirta

This species has a long flowering time from early through mid-summer. Biennial or short lived perennial. Can self-seed freely and may become aggressive. Weeding back may be required to prevent excessive spread. May need to be staked. Cut back dead plant material in the early spring to allow birds to feed on the seed during the winter months.

Attracts birds, bees and butterflies. This species can tolerate soils under Black Walnut trees. Makes good cut flowers.

Habitat: Sun



Black-eyed Susan in winter
© *Dropseed Nursery*



Black-eyed Susan blossom
© *Elaine Haug*



Black-eyed Susan colony in bloom
© *Sally & Andy Wasowski*

Bloody Cranesbill

Geranium sanguineum "Striatum"

Plants prefer full sun and well-drained soil. Drought tolerant. Makes a nice ground cover. Side stems may be removed at any time to control spread. If not deadheaded, some self-seeding may occur in ideal growing conditions. Foliage may decline after flowering in hot summer climates, at which point it may be lightly sheared back and shaped to revitalize. Foliage turns red in autumn. Native to Europe and Asia.

Deer resistant. Can be propagated from divisions in the spring or fall.



Bloody Cranesbill, in flower in spring
© *Missouri Botanical Garden*

Blue Fescue

Festuca glauca "Elijah Blue"

Clump forming. Can be used as a groundcover or edging plant. This drought tolerant species grows well in poor soil; however it can not tolerate poorly drained soil. Cut back in late winter or early spring. Plants are short lived and require frequent divisions. Foliage may decline in particularly hot or humid weather, but it remains evergreen during the winter.

Deer resistant.

Habitat: Sun



Blue Fescue clump in Spring
© *Missouri Botanical Garden*



Blue Fescue with seed heads
© *Missouri Botanical Garden*

Blue Fescue

Festuca ovina "glauca"

Clump forming. Works well as a ground cover or edging plant. Cut back in late winter or early spring. Does not tolerate high summer heat and humidity. Flowers have a red-purple color

Food source for several kinds of caterpillars. Deer resistant.

Habitat: Sun



Blue Fescue with seed heads in summer
© *Rob Broekhuis*

Blue Fescue

Festuca amethystina "Superba"

Clump forming. Cut back in late winter. Should be divided in winter to avoid clumps dying out in the center.

Habitat: Sun



Blue Fescue
© *Conservation Garden Park*

Blue Flag Iris

Iris virginica

Best grown in wet, boggy, acidic soils. In the wild, the roots of this iris are typically underwater for periods of time. Although the flowering period is brief in the spring, the broad, upright leaves are attractive throughout the growing season. A white form of the flower is rarely found.

Cut back dead leaves in the early spring to promote new growth.

Attracts bees and butterflies. Deer are not attracted to this plant since the leaves and roots are somewhat toxic.

Habitat: Sun



Blue Flag Iris blossom
© *Robert H. Mohlenbrock*



Blue Flag Iris in bloom in late Spring
© *Thomas Barnes*

Blue Lobelia
Lobelia siphilitica

Prefers partial sun and moist soil. Can tolerate full sun in moist soils. Divide clumps in spring as needed. May self seed in optimal conditions. Late summer blooms. Cut back dead plant material in the early winter through early spring. This species is longer-lived than its close relative, Cardinal Flower.

Attracts hummingbirds, bees and butterflies.

Habitat: Shade



Blue Lobelia in winter
© *Dropseed Native Plant Nursery*



Blue Lobelia in bloom
© *Dropseed Native Plant Nursery*



Blue Lobelia in bloom in late Summer
© *Dropseed Native Plant Nursery*

Blue Sage
Salvia azurea

This species prefers full sun and well drained soils. Drought tolerant. Has fragrant leaves. Also known as pitcher sage. Plant stems may be cut back to ½ inch in late spring to promote compactness and avoid stem flopping. Cut back again after flowering has concluded.

Attracts bees and butterflies.



Blue Sage in bloom in Spring
© *W.D. and Dolphia Bransford*



Blue Sage bloom
© *Campbell & Lynn Lougmiller*

Blue Vervain
Verbena hastata

Typically forms colonies in the wild by both thick, slowly spreading rhizomes and self-seeding. May self-seed in gardens in optimum growing conditions. Can be short-lived. Flowers on each spike bloom bottom to top, only a few at a time which prolongs the bloom period. Pinching off the tips of the plants several times during the growing season will encourage a bushier shape and increased number of flowers. Dead plant material should be cut back in the late fall through early spring.

Attracts bees, butterflies and birds. Although rabbits sometimes eat the plants, deer avoid it due to its bitter taste.

Habitat: Sun



Blue Vervain dormant in Winter
© *Dropseed Native Plant Nursery*



Blue Vervain in bloom
© *Missouri Botanical Garden*

Blue-Joint Grass
Calamagrostis canadensis

This species establishes easily and spreads quickly. Needs full sun and wet conditions. The flowers are purplish in mid-summer, turning to tan seed heads in the fall. Stands up well in the winter. Cut back in the early spring or later winter.

Attracts waterfowl. Is a forage species for Bison, Deer, and Elk.

Habitat: Sun



Blue-Joint Grass seed head
© *Robert H. Mohlenbrock*



Blue-Joint Grass in summer
© *Sally & Andy Wasowski*

Blunt Broom Sedge

Carex tribuloides

Prefers full sun andmoist conditions. Colonies often form over time. Produces attractive reddish brown seed heads in the summer. Cut back dead plant material during the winter months.

Several bird species feed on the seeds of this plants. The leaves of Blunt Broom Sedge are a food source for many moth and butterfly caterpillars.



Blunt Broom Sedge with seed head
© *Nicky Staunton*

Boneset

Eupatorium perfoliatum

Boneset has a fairly long flowering time from late summer into early fall. There is a faint floral scent. This species can spread by seed and by underground rhizome. May need to be staked depending on plant size. Dead plant material should be cut back during the winter months.

Attracts butterflies and bees. The flowers attract a species of wasp that can help control populations of pest insects. The bitter foliage is not attractive to deer or rabbits. Medicinal qualities.

Habitat: Sun



Boneset in bloom in late Summer
© *W.D. and Dolphia Bransford*



Boneset flower
© *Thomas Barnes*



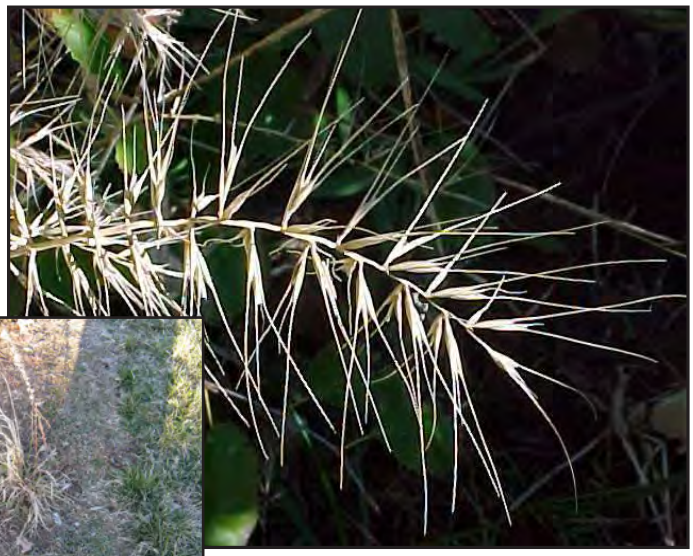
Boneset in winter
© *Dropseed Nursery*

Bottlebrush Grass
Hystrix patula

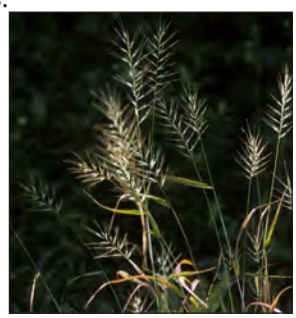
This very adaptable grass will grow in full sun or full shade and in moist or dry conditions. Bottlebrush Grass spreads primarily by re-seeding itself and may form small colonies of several plants. May become aggressive and require weeding to prevent its spread. Cut back in late winter or early spring. Can be used for erosion control.

Food source for many types of caterpillars. Attracts birds and butterflies.

Habitat: Shade



Bottlebrush Grass in summer
© *Missouri Botanical Garden*



Bottlebrush Grass seed head
© *Sally & Andy Wasowski*



Bottlebrush Grass in winter
© *Dropseed Nursery*

Broad-leaf Arrow-head
Sagittaria latifolia

Vigorous aquatic species. Flowers from July-September. Will self-seed and must dead-head spent flowers to prevent any unwanted self-seeding. Closely related to the Water Plantain. This species is reportedly tolerant of polluted water.

Underground tubers are a source of food for several species of ducks, muskrats and snapping turtles. Another common name for this species, Duck Potato, is related to the underground tuber that ducks enjoy to eat. The flowers attract bird and bees.

Habitat: Sun



Broad-leaf Arrow-head blossom
© *Missouri Botanical Garden*



© *Mike Haddock*



Broad-leaf Arrow-head in Summer
© *Sally & Andy Wasowski*

Cranesbill

Geranium cantabrigiense "Biokovo"

Cranesbill prefers full sun and well drained soil. Best grown as a groundcover. Has a long flowering time from early spring through the summer. This species spreads by underground stems, but is not invasive. Mostly evergreen. Names for its long, narrow seed pod that resemble a crane's bill

Attracts butterflies. Tolerates deer and rabbits. Can be propagated by division in the spring or early fall.

Habitat: Sun



Cranesbill in bloom in Spring
© *Missouri Botanical Garden*

Cranesbill

Geranium "Gerwat" Rizanne

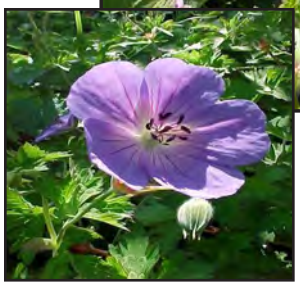
Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun



Cranesbill in bloom in Spring
© *Missouri Botanical Garden*



Cranesbill blossom
© *Missouri Botanical Garden*

Cranesbill

Geranium cantabrigiense "Karmina"

Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun



Cranesbill in bloom in Spring
© *Missouri Botanical Garden*



Cranesbill blossom
© *Missouri Botanical Garden*

Cranesbill

Geranium sanguineum "Max Frei"

Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun



Cranesbill in winter
© *Conservation Garden Park*



Cranesbill in bloom in spring
© *Rob Broekhuis*

Brome-like Sedge

Carex bromoides

Forms attractive, dense clumps. Dried remnants of older leaf blades are usually persistent around the base. Cut back late winter or early spring. Prefers wet to consistently wet conditions and full sun to part shade. There is an orange cast to the plants when they are in fruit.

Food source for several species of caterpillars. Attracts birds and ducks. Muskrats will sometimes feed on the roots.

Habitat: Sun



Brome-like Sedge
© *John Hilty*

Broomsedge

Andropogon virginicus

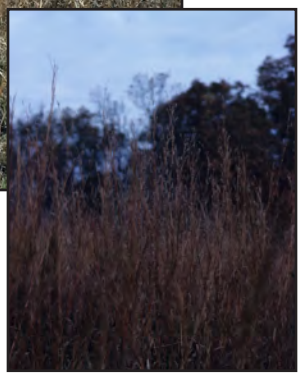
Very heat and drought tolerant. Adaptable to many soil types - good on dry, rocky soil as well as in bottomlands.The dried out foliage is a golden brown color andremains erect throughout the winter. Cut back in early spring. Most growth occurs in summer and early fall. Fast spreading and good for disturbed sites and erosion control.

Food source for several species of caterpillars and insects. Attracts birds. Provides nesting habitat for various birds and other wildlife.

Habitat: Sun



Broomsedge dormant in winter
© *Sally & Andy Wasowski*



Broomsedge with seed heads
© *Sally and Andy Wasowski*

Bundleflower
Desmanthus illinoensis

Erect plant. Can be weedy. Fern-like foliage can close up at night or in high heat.

Attracts birds, bees and butterflies. This plant fixes high amount of nitrogen into the soil and can help rejuvenate poor soil.

Habitat: Sun



Bundleflower colony in bloom
© *Sally & Andy Wasowski*



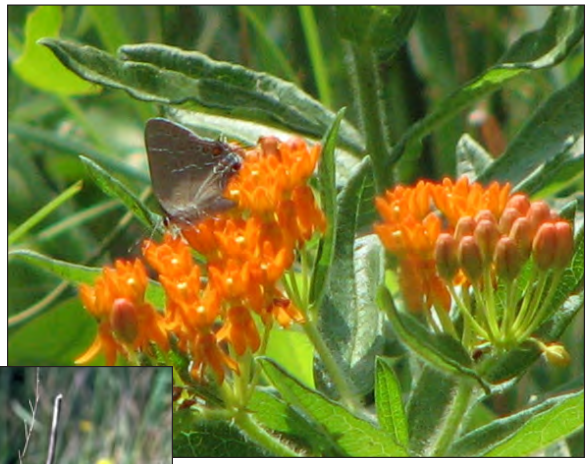
Bundleflower seed head
© *Joseph A. Marcus*

Butterfly Milkweed
Asclepias tuberosa

This species is slow to establish, but very drought tolerant once established. Butterfly Milkweed is susceptible to aphids, which can be taken care of by ladybugs or a soapy water spray. Does well in poor dry soils - is not tolerant of clay or poorly drained soils. Does not transplant well due to its deep taproot and is better left undisturbed. Flowers give way to prominent, spindle-shaped seed pods (3-6" long) which split open when ripe releasing numerous silky-tailed seeds for dispersal by the wind.

Attracts butterflies and hummingbirds. Important food source for adult and caterpillar Monarch butterflies.

Habitat: Sun



Butterfly Milkweed bloom
© *Sandy Smith*



Butterfly Milkweed seed pod
© *M.W. Carlton*



Butterfly Milkweed seed pod
© *Dropseed Nursery*

Calico Aster

Symphyotrichum lateriflorum (Aster lateriflorus)

Easily grown in full sun to partial shade. Taller plants may need to be supported, or plants can be pinched back in the early summer to create shorter, fuller plants. Dead plant material should be cut back in late winter. Has a fairly long flowering season from late summer through the fall.

Attracts butterflies.

Habitat: Shade



Calico Aster in bloom in late Summer
©W.D. and Dolphia Bransford



Calico Aster bloom
©W.D. and Dolphia Bransford

Cardinal Flower

Lobelia cardinalis

Plant can be propagated by bending a stem down into the mud and fastening it with a rock or stick. Clumps can be divided in the spring. Needs constant moisture. Great for open shady border areas. Can tolerate full sun with moist soil. Tends to be short-lived.

Attracts birds, butterflies and hummingbirds.

Habitat: Shade



Cardinal Flower in winter
© Dropseed Nursery



Cardinal Flower blossom
© Steven Faucette



Cardinal Flower in bloom in late Summer
©Tom Barnes

Catmint
Nepeta faassenii "Blue Wonder"

Drought and heat tolerant. Fragrant foliage. Will. flower for most of the summer. Variable habit ranging from upright to clumping to bushy. Cutting back seed heads after flowering will promote a second bloom. Does not self-seed, seeds are sterile. Propagate with divisions of root ball in the spring. Cut back dead plant material in the winter months. Grows well in urban areas; tolerant of air pollution.

Attracts bees, birds and butterflies. Resistant to deer and rabbits.

Habitat: Sun



Catmint in bloom in Summer
© *Missouri Botanical Garden*



Catmint bloom
© *Missouri Botanical Garden*

Catmint
Nepeta faassenii "Walker's"

Very drought and heat tolerant. Fragrant foliage. Will flower for most of the summer. Variable habit ranging from upright to clumping to bushy. Cutting back seed heads after flowering will promote a second bloom. Does not self-seed, seeds are sterile. Propagate with divisions of root ball in the spring. Cut back dead plant material in the winter months. Grows well in urban areas; tolerant of air pollution.

Attracts bees, birds and butterflies. Resistant to deer and rabbits.

Habitat: Sun



Catmint in bloom in Summer
© *Missouri Botanical Garden*



Catmint in bloom in Summer
© *Missouri Botanical Garden*

Celandine Poppy
Stylophorum diphyllum

Shade loving species with showy flower. Best grown in moist soil and will go dormant in early summer if the soil is too dry. An attractive seed pod forms following the flowers. Once dormant, the dead plant material breaks down quickly, so cutting back is not necessary. Chipmunks feed on the seeds. Ants dispers the seed, feeding on the attached fleshy material.

Habitat: Shade



Celandine Poppy in bloom in Spring
© *Henry Domke*



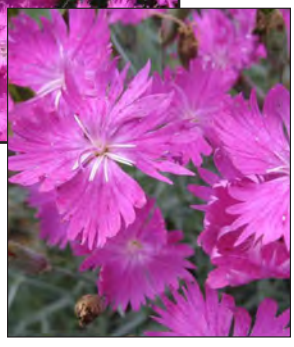
Celandine Poppy bloom
© *Lynn Crosby Gammill*

Cheddar Pinks
Dianthus feuerhexe "Firewitch"

Prefers full sun and well drained soil. Evergreen. Tolerates heat and humidity better than some Dianthus species. Produces clove-scented bright pink flowers. Deadhead flowers to promote new blooms. Mat-forming quality makes it great as a ground cover. Care should be taken when mulching the plants not to allow a build up of mulch around the plants which will cause rotting. Plants can be propagated by division in the spring or fall.



Cheddar Pink in bloom in Spring
© *Missouri Botanical Garden*



Cheddar Pink blossom
© *Missouri Botanical Garden*

Cheddar Pinks

Dianthus subacaulis "Gary Eichhorn"

Prefers full sun and well drained soil. Deadhead flowers to promote new blooms. Care should be taken when mulching the plant not to allow a build up of mulch around the plant which will cause rot. Evergreen mat-forming quality makes it great as a ground cover. Produces fragrant pink flowers.

Habitat: Sun



Cheddar pinks
© *The Trial Gardens at UGA*



Cheddar pinks
© *The Trial Gardens at UGA*

Chives

Allium schoenoprasum

This spring-flowering plant is drought tolerant. Prefers full sun and well drained soil. Forms dense clumps which are easily divided in spring or fall. Easily grown from seed and will self-seed in the garden if spent flower heads are not promptly dead-headed. Native to Asia and Eastern Europe.

Culinary uses. Deer resistant. Can be planted beneath Black Walnut trees. The flowers are pollinated by bees and flies.

Habitat: Sun



Chives dormant in winter
© *Conservation Garden Park*



Chives in bloom in spring
© *Missouri Botanical Garden*

Cinnamon Fern

Osmunda cinnamomea

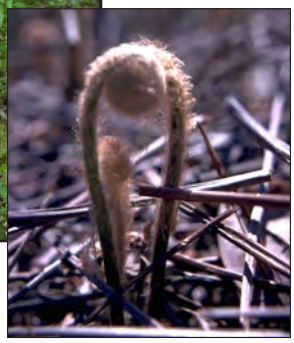
Prefers partial shade. The contrasting stature of fertile and infertile fronds can make for dramatic accents in a landscape. The common name refers to the cinnamon colored fibers near the base of the leaves. Slow growing. Requires moist soil or standing water. Cut back dead plant material in the early spring.

Attracts birds.

Habitat: Shade



Cinnamon Fern with fronds in summer
© *Andy & Sally Wasowski*



Cinnamon Fern fiddleheads
© *Campbell & Lynn Loughmiller*

Cinquefoil

Potentilla neumanniana "Nana"

Grows best in full sun and well drained soil. This species flowers in early summer, but will sometimes have a second bloom in the fall. This mat-forming plant can form a dense ground cover. When grown as a ground cover, it can be mowed occasionally on a high setting to trim up the plants. Leaves are fragrant. The plant is evergreen in mild winters. Easily propagated by division in the spring or fall.

Habitat: Sun



Cinquefoil in bloom in spring
© *Missouri Botanical Garden*

Cleft Phlox
Phlox bifida

Prefers full sun and well drained soil. Mat-forming phlox that grows to only 6" tall, and spreads by trailing or spreading tems and self-seeding to form large colonies over time. Can be used as groundcover or for erosion control. Consider the plant species that are placed near these plants, Cleft Phlox is easily taken over by more aggressive species.

The flowers attract adult butterflies and the leaves are a food source for caterpillars of several moth species.



Cleft Phlox blossom
© *George H. Bruso*

Common Mountain Mint
Pycnanthemum virginianum

This species prefers full sun, but is tolerant of a wide variety of soil types. Makes a nice border planting since the leaves are fragrant when you brush past them. Clusters of flowers open only a few at a time. Can be aggressive in moist soil. Cut back previous years' growth during the winter months.

Attracts butterflies and a wide variety of other beneficial insects.

Deer resistant.

Habitat: Sun



Common Mountain Mint in bloom
© *Sally and Andy Wasowski*



Common Mountain Mint
in bloom
© *Dropseed Nursery*

Common Wood Reed
Cinna arundinacea

Prefers light shade and moist soil. The green flowers are produced in the late summer into early fall and develop into tan seed heads in the later fall and winter. Commonly grows as scattered plants. Cut back in late winter.

Does not seem to attract deer.



Common Wood Reed in the fall
© *Paul Drobot*



Common Wood Reed
seed heads
© *Robert Freckman*

Compass Plant
Silphium lacinatum

Grows best in full sun, but is adaptable to many soil conditions. Tall prairie plant with large leaves and very deep tap root. Very drought tolerant. Long-lived blooms. Slow to establish and may not flower until the second or third year. May require staking. Planting this species next to Switchgrass can eliminate the need for staking. Cut back dead plant material in the early spring to allow birds to feed on the seeds over the winter months.

Attracts birds and butterflies.

Habitat: Sun



Compass Plant in winter
© *Dropseed Nursery*



Compass Plant blossom
© *Paul Cox*



Compass Plant in bloom
© *Sally & Andy Wasowski*

Coral Bells
Heuchera "Rave On"

Does best in well-drained soil and partial shade. May require watering during periods of drought. Remove stems of spent flowers to encourage more blooms. This is a heavy flowering cultivar. Mulch applied in winter will help to prevent root heaving. Divide clumps in spring every 3-4 years.

Makes nice cut flowers.

Habitat: Sun



Coral Bells
© *Missouri Botanical Garden*

Creeping Baby's Breath
Gypsophila repens "Alba"

Requires full sun and well drained soil. Easy to grow and drought tolerant. Dwarf hybrid forms a low mass of gray green leaves with an abundance of white flowers in early summer. Cut back dried flower stalks in the late winter. Can be evergreen in mild winters. Propagate by division in the spring or fall.

Attracts butterflies.

Habitat: Sun



Creeping Baby's Breath dormant in winter
© *Conservation Garden Park*



Creeping Baby's Breath
© *Conservation Garden Park*

Creeping Baby's Breath

Gypsophila repens "Rosea"

Requires full sun and well drained soil. Easy to grow and drought tolerant. Dwarf hybrid forms a low mass of gray green leaves with an abundance of white flowers in early summer. Cut back dried flower stalks in the late winter. Can be evergreen in mild winters. Propagate by division in the spring or fall.

Attracts butterflies.

Habitat: Sun



Creeping Baby's Breath dormant in winter
© *Conservation Garden Park*

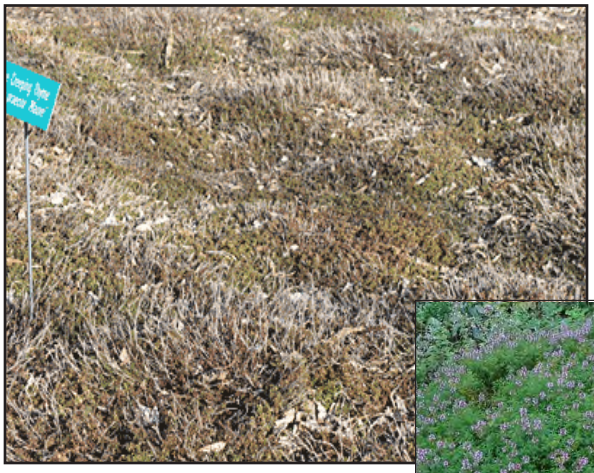
Creeping Thyme

Thymus praecox

Prefers full sun and well drained soil. This fast growing plant is very drought tolerant. This species forms a ground cover that will tolerate foot traffic.Cut back stems to control growth or appearance. Propagate by division in the spring or fall.

Attracts butterflies and bees. Deer resistant.

Habitat: Sun



Creeping Thyme dormant in winter
© *Conservation Garden Park*



Creeping Thyme in bloom
© *Rob Broekhuis*

Crested Sedge
Carex cristatella

This species requires moist soil with full sun to partial shaes. Forms an attractive brown fruit in the late summer.This sedge spreads by rhizomes and by reseeding itself. Most vegetative growth occurs during the spring and early summer. Cut the dead plant material back in the early spring to allow birds to feed on the seeds over the winter months.

Food source for caterpillars and birds.

Habitat: Sun



Crested Sedge seed head
© *Robert Mohlenbrock*

Culver's Root
Veronicastrum virginicum

Grows best in full sun and moist soil. Very dramatic when in flower. Seldom needs staking except when grown in too much shade. Cut back dead plant material during the winter months. Usually takes several years to establish itself in the garden.

Attracts butterflies and bees. Medicinal plant.

Habitat: Sun



Culver's Root in bloom
© *George H. Bruso*



Culver's Root in winter
© *Dropseed Nursery*

Cushion Spurge
Euphorbia polychroma

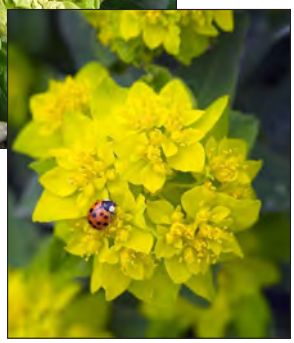
Requires well drained soil and full sun to partial shade.Cymes of inconspicuous greenish flowers (lacking both sepals and petals) bloom at the stem ends in spring followed by long-lasting, bright sulphur-yellow bracts which are exceptionally showy and last through summer. Leaves turn red, orange and purple in the fall. Freely self-seeds. Promptly remove spent flowers to prevent any unwanted self-seeding. Trim back plants to 4" in the early summer to keep a compact form.

Attracts butterflies and bees. Deer and rabbit resistant.

Habitat: Sun



Cushion Spurge in spring
© *Missouri Botanical Garden*



Cushion Spurge blossom
© *Missouri Botanical Garden*

Green-headed Coneflower
Rudbeckia laciniata

Grows in full sun and moist soil. Most appropriate for large sites that require quick coverage. Can plant with tall native grasses like Switchgrass and Big Bluestem to support the sometimes floppy stems. Remove spent blooms to encourage a fall rebloom. Divide clumps to control growth. This species spreads rampantly by underground stems. Cut back dead plant material in the early spring to allow birds to feed on the seeds during the winter months.

Attracts butterflies, bees and birds.



Green-headed Coneflower, in flower in mid summer
© *Sally & Andy Wasowski*



Geenheaded Coneflower, flower up close
© *Mike Haddock*

Cylindrical Blazing Star

Liatris cylindracea

Very showy and drought tolerant plant. Intolerant of wet soils in winter. Tolerant of summer heat and humidity. Cut back last years growth during the winter months.

Attracts birds, butterflies, hummingbirds and bees.

Habitat: Sun



Cylindrical Blazing Star in bloom
© *Thomas G. Barnes*

Cypress Spurge

Euphorbia cyparissias "Fen's Ruby"

Quite tolerant of poor soils, including rocky, sandy ones. Eight to ten plants per square yard are sufficient to quickly form a dense ground cover. Spreads by rhizomes and can be quite invasive, particularly in rich, moist soils. Also freely reseeds. The evergreen leaves turn orange in the fall. Plants are toxic.

Habitat: Sun



Cypress Spurge in bloom
© *Missouri Botanical Garden*



Cypress Spurge in winter
© *Conservation Garden Park*



Cypress Spurge foliage and bloom
© *Conservation Garden Park*

Deertongue Panic Grass
Dichanthelium clandestinum

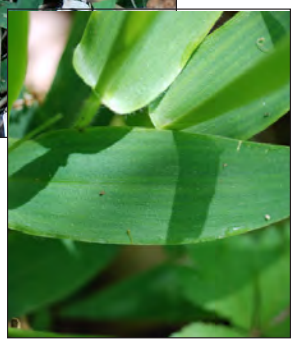
Prefers partial shade and moist conditions. In some situations, this grass can spread aggressively via its rhizomes.

Food source for caterpillars and grasshoppers. Seed heads are consumed by birds.

Habitat: Shade



Deertongue Panic Grass in summer
© *Mike Haddock*



Deertongue Panic Grass leaf blade
© *Mike Haddock*

Dense Blazing Star
Liatris spicata

Prefers full sun and moist soil. Taller plants may require staking or other support. Tolerant of summer heat and humidity. Cut back last year's growth during the winter months. Also known as Spiked Gayfeather.

Attracts bees, butterflies and hummingbirds. Makes nice cut flowers.

Habitat: Sun



Dense Blazing Star in bloom
© *Sally & Andy Wasowski*



Dense Blazing Star blossom
© *Julie Makin*

Downy Alumroot

Heuchera Americana "Dale's Strain"

Requires partial shade; drought tolerant. Good ground cover. Leaves are semi-evergreen. Remove stems of faded flower panicles to encourage continued bloom. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Leaves are semi-evergreen. Divide clumps in spring every 3-4 years. Foliage has attractive fall colors.

Seldom browsed by deer. Make nice cut flowers.

Habitat: Sun



Downy Alumroot foliage
© *Missouri Botanical Garden*

Downy Alumroot

Heuchera americana

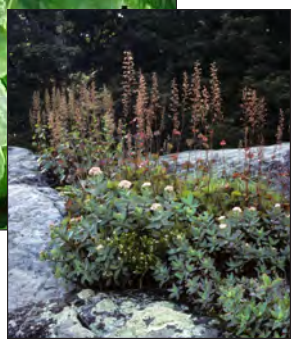
Requires partial shade; drought tolerant. Good ground cover. Leaves are semi-evergreen. Remove stems of faded flower panicles to encourage continued bloom. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Leaves are semi-evergreen. Divide clumps in spring every 3-4 years. Foliage has attractive fall colors.

Seldom browsed by deer. Make nice cut flowers.

Habitat: Sun



Downy Alumroot foliage
© *Missouri Botanical Garden*



Downy Alumroot colony in bloom
© *Sally & Andy Wasowski*

Downy Skullcap
Scutellaria incana

This easy to grow plant perfers partial shade and moist conditions. Can grow at light levels from deep shade to full sun. Best on dryish, sandy or clay soils. A very attractive plant withh a tidy form. Cut back previous year's growth during the winter months.

Attractive food source for bumblebees. The bitter foliage is not attractive to deer or rabbits.



Downy Skullcap in winter
© *Dropseed Nursery*



Downy Skullcap blossom
© *Sally & Andy Wasowski*



Downy Skullcap in bloom
© *Sally & Andy Wasowski*

Downy Wood Mint
Blephilia ciliata

This drought tolerant species prefers full to partial sun.Similar in appearance to the closely related Bee Balm. Leaves are mildly fragrant when crushed. Leaves are usually considered to be lacking in the pungency and quality needed for use as a culinary herb. Small basal leaves and shoots remain green throughout the winter. Cut back spent flower stalks in the late summer to encourage full growth of the foliage.

The flowers are attractive to bees and butterflies. Foliage is often nibbled on by insects and plants can become rather tattered and unkempt by late summer.

Habitat: Shade



Downy Skullcap blossom
© *Sally & Andy Wasowski*

Dwarf Balloon Flower

Platycodon grandiflorus

These plants emerge late in the spring, so take care not to disturb the soil before they emerge. Grows well in average soil in full sun to part shade. Deadheading spent flowers generally prolongs the bloom period. Taller plants often need to be staked because of floppy stems. Consider cutting back plant stems by 1/2 in May to reduce plant height and possibly avoid staking. Cut back last year's growth in the early spring.

Makes a good cut flower.

Habitat: Sun



Dwarf Balloon Flower in bloom
© *Missouri Botanical Garden*



Dwarf Balloon Flower blossom
© *Missouri Botanical Garden*

Dwarf Bearded Iris

Iris pumila "Baby Blessed-yellow"

Good soil drainage is essential to combat potential soft rot problems. Avoid use of mulch for the same reason. Fertilize lightly in early spring. Fertilize again after bloom and continue to provide uniform moisture throughout the summer to encourage the late summer to fall rebloom. Avoid overhead watering. Deadhead individual spent flowers and remove flowering stems to the ground after bloom. Divide plants when overcrowding occurs (every 3-4 years).

Habitat: Sun



Dwarf Bearded Iris Baby Blessed Yellow
© *Pittsburg Parks Conservancy*

Dwarf Bearded Iris

Iris pumila "Sarah Taylor"

Good soil drainage is essential to combat potential soft rot problems. Avoid use of mulch for the same reason. Fertilize lightly in early spring. Fertilize again after bloom and continue to provide uniform moisture throughout the summer to encourage the late summer to fall rebloom. Avoid overhead watering. Deadhead individual spent flowers and remove flowering stems to the ground after bloom. Divide plants when overcrowding occurs (every 3-4 years).

Habitat: Sun



Dwarf Iris Sarah Taylor
© *www.gardenworldimages.net*

Dwarf Bluestar

Amsonia tabernaemontana "Short Stack"

Requires moist soil. Foliage turns an attractive bright yellow in fall. Best fall foliage color usually occurs in full sun, but flowers generally last longer if given some afternoon shade in hot sun areas. If grown in too much shade, stems may open up and flop. Cut back last year's growth during the winter months. This cultivar is typically less than 1' tall. Best propagated by cuttings.

Habitat: Sun



Dwarf Bluestar in bloom
© *Missouri Botanical Society*

Early Goldenrod
Solidago juncea

Likes full sun. Earliest goldenrod to bloom. Tolerates poor, dry soils. Remove spent flower clusters to encourage additional bloom. May need to be divided every 2 to 3 years to control growth. This species is a good choice for large areas that require fast coverage. Cut back last year's growth during the winter months.

Attracts bees, butterflies and birds.

Habitat: Sun



Early Goldenrod in bloom
@ W.D. and Dolphia Bransford

Eastern Blue-eyed Grass
Sisyrinchium atlanticum

A grass-like, clumped perennial, to 20 in. high, with pale-green foliage and flattened flowering stems terminating in loose clusters of pale-blue, six-petaled, yellow-centered flowers. A member of the iris family. Grows best in moist conditions and full sun. This delicate plant makes a nice border.

Attracts bees.



Eastern Blue-eyes Grass in bloom
© Harry Cliffe

Eastern Bluestar

Amsonia tabernaemontana

When grown in full sun, plants often require no pruning or staking. Can tolerate poorly drained soil and some drought. When grown in some shade and/or in rich soils, however, plants tend to become more open and floppy and often require staking or pruning. For a neater appearance stems may be cut back by 1/2 to 1/3 after flowering to promote bushy growth and, if desired, a more rounded foliage mound. Foliage may turn an attractive yellow in fall. Cut back last season's growth during the winter months. This species is very easy to grow with few disease or pest problems.

Not attractive to deer.

Habitat: Sun



Eastern Bluestar in winter
© *Dropseed Nursery*



Eastern Bluestar blossom
© *Sally & Andy Wasowski*



Eastern Bluestar stand in bloom in spring
© *M.W. Carlton*

Eastern Gamma Grass

Tripsacum dactyloides

This species prefers full sun and moist soil. Typically grows in the wild in pure stands on rairies, limestone slopes, fields, thickets, wood margins and roadsides. Naturalizes by thick, creeping rhizomes and self-seeding. Interesting fall colors. Can become floppy- to avoid this, cut back plants in early summer to keep a shorter, erect form. Cut back to ground after frost kills the foliage.

Food source for caterpillars. Attracts birds and livestock.

Habitat: Sun



Eastern Gama Grass with flower spikes
© *Beth Anderson*



Eastern Gama Grass flower spikes
© *Mike Haddock*

Elm-leaved Goldenrod

Solidago ulmifolia

This species prefers moist to dry shade. Flowers occur on the upper side of hairy stalks which arch out and downward creating a vase-shaped flower cluster. Cut back in late winter. The plants can spread by underground rhizomes; however this is not a particularly aggressively spreading species of goldenrod. Cut back dead plant material in the early spring to allow birds to feed on the seeds over the winter months.

Food source for bees and caterpillars of several moth species. Seeds are a food source for birds.

Habitat: Sun



Goldenrod flowers
© *R.W. Smith*



Elm-leaved Goldenrod
in bloom
© *Mrs. W.D. Bransford*

False Aloe

Manfreda virginica

Drought tolerant, does best in full sun. Long summer bloom occasionally extends into fall. Flowers give way to capsule-like fruit. Fragrant flower. Cut back flowering stalk in the winter months.

Attracts hummingbirds and moths.

Habitat: Sun



False Aloe dormant in winter
© *Dropseed Native Plant Nursery*



False Aloe in Summer
© *Erin Wagoner*

False Blue Indigo

Baptisia australis

Prefers full sun. Over time, plants develop slowly expanding clumps with deep and extensive root systems and should not be disturbed once established. May be grown from seed, but takes several years to establish. Plants take on more of a shrubby appearance and tend to open up after bloom. Trimming or shearing foliage after bloom helps maintain rounded plant appearance and avoids a possible need for staking, but eliminates the developing attractive seed pods. Cut back last year's growth during the winter months.

Attracts butterflies and bees.

Habitat: Sun



False Blue Indigo in winter
© *Dropseed Nursery*



False Blue Indigo blossom
© *Harry Cliffe*



False Blue Indigo in Summer
© *R.W. Smith*

False Sunflower

Heliopsis helianthoides

Tolerates poor soil, grows best in full sun. Quick to establish and easy to grow. Remove spent flowers to extend the blooming season. Some susceptibility to aphids. Taller plants may need staking or other support. Lengthy summer to early fall bloom.

Attracts butterflies, hummingbrds and bees. Works well as a cut flower.

Habitat: Sun



False Sunflower dormant in early Winter
© *Robert L. Stone*



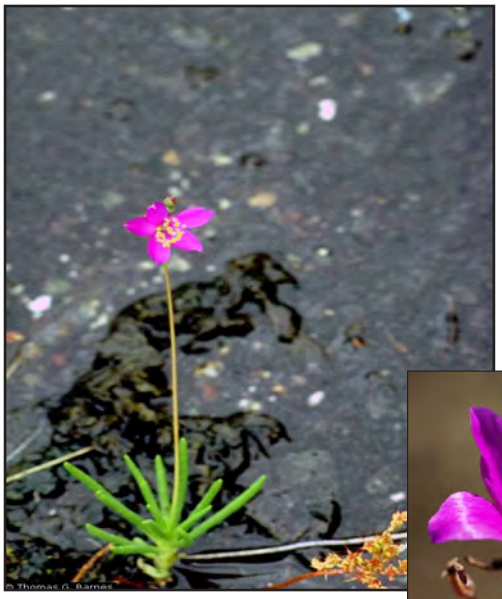
False Sunflower in Summer
© *Sally & Andy Wasowski*

Fame Flower

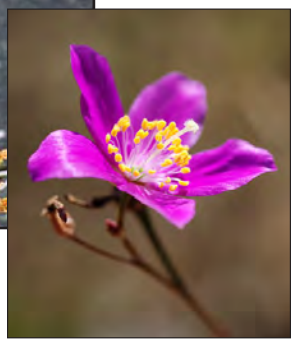
Talinum calcaricum

Prefers dry or sandy soil. The flowers open in the afternoon or in overcast conditions. This delivate plant is easily out-competed by other vegetation in moist soils. Works well on green roofs or in rock gardens. In good conditions the plants will spread by seed. Dies back completely in the witner - no cutting back needed.

Attracts bees and butterflies.



Fame Flower in bloom
© *Thomas G. Barnes*



Fame Flower blossom
© *Mike Haddock*

Flat-topped Aster

Doellingeria umbellata (Aster umbellatus)

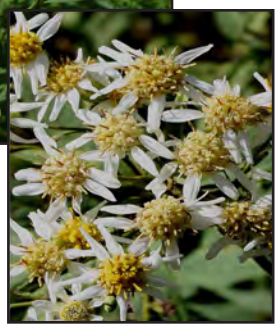
Prefers full or partial sun and moist conditions. This aster of wet meadows is one of the first asters to bloom - starting in August. Flat-topped Aster can be cut back early in the season to maintain a shorter, fuller form with more flowers. Cut back dead plant material in late fall or early winter.

Attracts bees and butterflies.

Habitat: Sun



Flat-topped Aster
© *Stefan Bloodworth*



Flat-topped Aster blossoms
© *R.W. Smith*

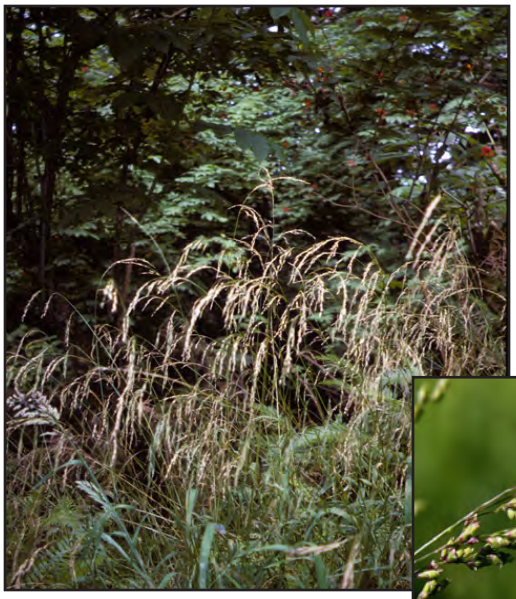
Fowl Manna Grass

Glyceria striata

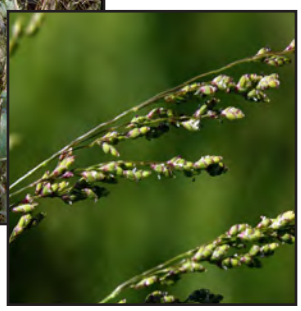
This grass requires more moisture in sunny areas than when it is growing in the shade. Most vegetative growth occurs during the spring and early summer. This is a good species for wetland restorations. If desired, cut back last season's growth during the winter months. In a wetland setting, leaving the previous year's growth will not inhibit new growth.

Attractive to livestock but not palatable to deer. Provides cover for wildlife.

Habitat: Sun



Fowl Manna Grass
© *Sally & Andy Wasowski*



Fowl Manna Grass flowers
© *R.W. Smith*

Fox Sedge

Carex vulpinoidea

Prefers full sun and moist soil. Good colonizer of disturbed, open, moist ground. This sedge may be weedy and spreads rapidly. Named for the brown cluster of fruit that forms mid-summer and looks like a fox tail. Cut back last year's dead plant material in the early spread to allow birds to feed on the seed during the winter months. This low-growing sedge makes a nice border in a moist area.

Attracts birds.

Habitat: Sun



Fox Sedge dormant in winter
© *Dropseed Native Plant Nursery*



Fox Sedge with seed heads
© *Sally & Andy Wasowski*

Foxglove Beardtongue
Penstemon digitalis

Avoid wet, poorly drained soils. Prefers full sun. Cut back the spent flowering stalks in mid-summer for a tidier look. Leaves remain evergreen during mild winters.

Attracts birds, hummingbirds, bees and butterflies.

Habitat: Sun



Foxglove Beardtongue in winter
© *Dropseed Native Plant Nursery*



Foxglove Beardtongue
© *W. D. and Dolphia Bransford*

Frank's Sedge
Carex frankii

This sedge grow abundantly in wet locations such as swamps, wet meadows, wet prairies and around rivers, lakes, streams and ponds. Prefers full sun. Cut back last year's dead plant material in the early spring to stimulate new growth. Makes a nice border planting in moist sites.

Food source for waterfowl.

Habitat: Sun



Frank's Sedge dormant in winter
© *Dropseed Native Plant Nursery*



Frank's Sedge with seed heads
© *Patrick J. Alexander*

Fringed Sedge

Carex crinita

Grows best in full sun or light shade and moist conditions. The distinctive long, dangling fruig are attractive. This sedge often forms colonies of plants. Some seasonal flooding is tolerated. This is a rather lanky sedge that leans to one side as the spikelets develop. Cut back last year's growth during the winter months.

Food source for caterpillars of moths and butterflies. Food source for wetland birds and ducks.

Habitat: Sun



Fringed Sedge with seed heads
© *Robert Mohlenbrock*

Frost Aster

Symphyotrichum pilosum (Aster pilosus)

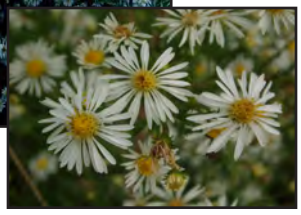
Prefers meadows and open woodlands. The disk flowers at the center of the flower heads open yellow, but turn reddish after they are pollinated. The plants can be cut back in June to create a fuller, shorter shaped plant with more flowers. Cut back last year's growth during the winter months.

Attracts birds, bees and butterflies.

Habitat: Sun



Frost Aster in bloom in fall
©*W. D. and Dolphia Bransford*



Frost Aster blossom
© *Julie Makin*

Fumitory
Corydalis lutea

This species prefers full sun to part shade and well drained soil. Wet soils in winter can be fatal. Generally intolerant of hot and humid summer conditions. May aggressively self-seed in the garden in optimum growing conditions. If foliage significantly depreciates in hot summers, plants may be cut back to basal leaves. Long bloom period. Native to southeastern Europe, this species is a weed in the cool climate of Great Britain. Best propagated by seed.

Habitat: Sun



Fumitory in bloom in Summer
© *Missouri Botanical Garden*



Fumitory blossoms
© *Missouri Botanical Garden*

Gaura
Gaura lindheimeri "Siskiyou Pink"

Good drainage is essential. A taprooted plant which tolerates heat, humidity and some drought. Remove spent flower panicles to prolong bloom period. Plants may be cut back in late spring by 1/2 to control size. May self-seed if spent flowers are left in place in autumn. Prefers full sun.

Attracts bees. Deer and rabbit resistant. Good cut flowers.

Habitat: Sun



Gaura dormant in winter
© *Conservation Garden Park*



Gaura in bloom in Summer
© *Missouri Botanical Garden*

Germander
Teucrium canadense

The dense flower spikes can be quite a show, especially when a good sized clump is planted. Plants spread on their own over time by rhizomes and may become aggressive if not kept in check periodically. Prefers moist or shallow, submerged soils and full sun. Cut back last year's growth during the winter months. A member of the mint family, this species has a long flowering period throughout the mid summer.

Attracts butterflies, bees, hummingbirds, and hummingbird moths. Makes a good cut flower.

Habitat: Sun



Germander in bloom in Summer
© *Steven Schwartzman*



Germander blossom
© *Kathleen Graves Cook*

Geum
Geum triflorum

This species prefers well drained soil and full sun. Drought tolerant. Root rot can be a problem in poorly drained soils, particularly in winter. Mature plants frequently form dense mats creating an attractive ground cover. Pink flowers are followed by attractive plume-tailed seeds. Leaves turn deep red in the fall and can be evergreen in mile winters.

Attracts butterflies. Deer resistant. Medicinal plant.

Habitat: Sun



Geum in bloom in Summer
© *John Hixson*



Geum fruiting heads
© *John Hixson*

Giant Bur-reed

Sparganium eurycarpum

Bur reeds are aquatic or marsh herbs with grass-like leaves, and small flowers densely crowded into globose heads in or above the axils of bract-like leaves. Prefers full sun and wet conditions. Good plant for wetland restorations. Last year's growth can be cut back during the winter months; however, plants will thrive in wetland settings without cutting back.

Food source for wetland birds and caterpillars of various moths.

Habitat: Sun



Giant Bur-reed in Summer
© *Mrs.W.D. Bransford*



Giant Bur-reed in flower
© *R.W. Smith*

Goat's Rue

Tephrosia virginiana

Prefers moist conditions and full sun. Good resistance to drought. Once established, plants are best left alone because division and transplanting are difficult. Roots fix nitrogen. A member of the pea family, this species forms long seed pods following flowering. Plant parts are toxic. Cut back last year's growth during the winter months

Attracts butterflies and bees. Wild Turkey feed on the seeds.

Habitat: Sun



Goat's Rue in Summer
© *W.D. and Dolphia Bransford*



Goat's Rue blossom
© *Sally and Andy Wasowski*

Golden Alexanders
Zizia aurea

Often occurs in small colonies. An easy to grow species that is not at all aggressive in the garden. Foliage tends to depreciate as the summer progresses. In ideal conditions can reseed heavily. Dry seedheads turn purple, adding summer interest. Cut back dead plant material in the early spring.

Attracts butterflies and bees. Food source for caterpillars.

Habitat: Sun



Golden Alexanderdormant in winter
© *Sally & Andy Wasowski*



Golden Alexander in Summer
© *Sally & Andy Wasowski*

Golden Ragwort
Packera aureas

Naturalizes into large colonies in optimum growing conditions. Remove flowering stems after bloom/seed dispersal. Basal foliage will serve as an attractive ground cover throughout the growing season as long as consistent moisture is provided. Can be aggressive and may require some weeding out to keep in check. Known for ability to thrive in shady locations. Leaves can be evergreen during mild winters. Plant parts are mildly toxic.

Attracts butterflies and bees.

Habitat: Sun



Golden Ragwort colony in bloom
© *Missouri Botanical Garden*



Golden Ragwort in Summer
© *Missouri Botanical Garden*

Golden Stonecrop
Sedum acre "Aureum"

Tolerates part shade, heat, drought and poor soils. Prefers full sun. Can be used as a groundcover and will withstand some foot traffic. Can be used as a lawn replacement. Fast growing and easy to propagate from cuttings. Leaves develop an attractive red color in the winter.

Attracts butterflies. Deer and rabbit resistant.

Habitat: Sun



Golden Stonecrop dormant in Winter
© *Conservation Garden Park*



Golden Stonecrop in Summer
© *Conservation Garden Park*

Blue-Stemmed Goldenrod
Solidago caesia

Prefers sun to partial shade and dry conditions. Does not spread as aggressively as other goldenrod species. Cut back last year's growth in the late winter so that birds can feed on the seeds during the winter months.

Attracts butterflies, birds, insects and bees. Food source for many species of caterpillars.

Habitat: Shade



Goldenrod
© *Stefan Bloodworth*



Goldenrod
© *Mrs. W.D. Bransford*

Grass-leaved Goldenrod
Euthamia graminifolia

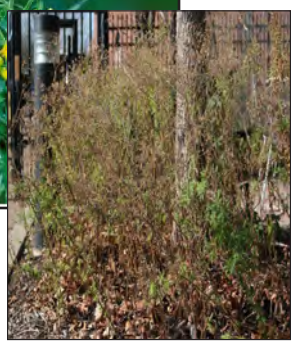
The flat-topped floral arrangement and narrow leaves of this Goldenrod are distinctive. Sometimes it is slender and little branched, while at other times it branches frequently, creating a bushy appearance. Can spread aggressively in moist sunny conditions. Cut back plants in the late winter.

Attracts bees and wasps. Food source for caterpillars. Seeds consumed by a small number of birds.

Habitat: Sun



Grass-leaved Goldenrod flowers
© *Tom Barnes*


Grass-leaved Goldenrod in winter
© *Dropseed Nursery*

Gray Goldenrod
Solidago nemoralis

Prefers full sun, can tolerate both well drained and clay soil. A small goldenrod, this plant seldom reaches 2 ft. in height. Flowers late into the fall. It's a good choice for difficult locations, such as slopes or areas with poor soil, where little else will grow. Not as aggressive as many goldenrod species. Cut back plants in late winter.

Attracts bees and butterflies. Food source for caterpillars. Seeds consumed by a small number of birds. Makes a nice cut flower.

Habitat: Sun


Gray Goldenrod in winter
© *Dropseed Nursery*


Gray Goldenrod in bloom in fall
© *Mrs. W.D. Bransford*

Gray-headed Coneflower
Ratibida pinnata

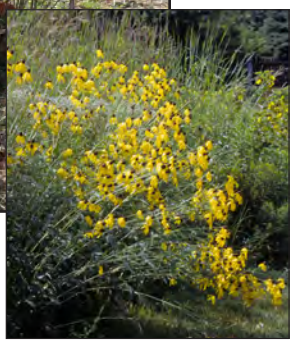
Yellow Coneflower is an excellent choice for a wildflower garden because of its long blooming period and attractive yellow flowers. Tall stalks may need to be staked; plants can be cut back in spring to create a shorter and fuller plant. This species can also be planted next to Prairie Switchgrass to support its stems from flopping over. Best if massed together when planted. Long summer bloom period. Cut back plants in late fall through late winter

Attracts bees and butterflies. Food source for caterpillars. Seeds consumed by birds.

Habitat: Sun



Gray headed Coneflower in winter
© *Dropseed Nursery*



Gray headed Coneflower in bloom in mid-summer
© *Sally & Andy Wasowski*

Gray's Sedge
Carex grayi

Prefers moist soil and full sun. The leaves are mostly evergreen. Propagation is through seeding in the fall and division in the spring. Under suitable conditions, this sedge may self-seed. The greenish yellow to brown seed heads of this sedge look like spiked clubs and remain on the plant in winter. The seeds float, allowing them to establish in new areas within a wetland. May not reach full height in hot climates and dry soil. Cut back in late winter or early spring.

Notes: Attracts insects and butterflies. Food source for waterfowl and gamebirds.

Habitat: Sun



Gray's Sedge in spring
©*Bugwood.org*



Gray's Sedge seed head
© *Mike Haddock*

Green Bulrush
Scirpus atrovirens

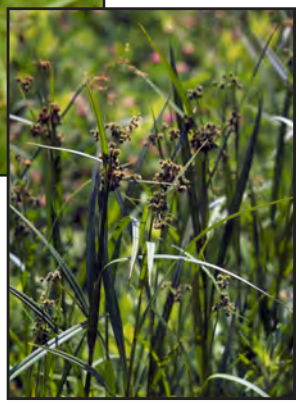
Prefers full to partial sun and moist conditions. Short-lived. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. Seed heads turn brown and remain on the plant through the growing season. Can be propagated by division in the early spring. Cut back in later winter or early spring.

Provides food and cover for caterpillars, waterfowl, songbirds and shorebirds.

Habitat: Sun



Green Bulrush in early spring
© *Mike Haddock*



Green Bulrush in bloom
© *Sally & Andy Wasowski*

Hairy Alum Root
Heuchera villosa

Requires shade, plants may require watering during periods of drought. Leaves can be evergreen in mild winters.Propagate by divisions in spring. Scorch and general foliage decline often occur if soils are allowed to dry out. Remove stems of faded flowers to encourage additional blooms. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Remove dead plant material in the early spring to promote new growth.

Attracts butterflies and huimmingbirds. Makes nice cut flowers.

Habitat: Sun



Hairy Alum Root in bloom in late summer
© *Sally & Andy Wasowski*



Hairy Alum Root in bloom
© *George H. Bruso*

Hairy Beardtongue
Penstemon hirsutus

Prefers full sun. The leaves can be evergreen in mild winters. This is a medium-height penstemon with bushy growth and soft green leaves. Drought tolerant and needs well-drained soil, but it's one of the easiest penstemons to grow. Cut back plants in the late winter. Slow growing, but will form good ground cover over time.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun



Hairy Beardtongue in bloom in spring
© *Rob Broekhuis*



Hairy Beardtongue in winter
© *Dropseed Nursery*



Hairy Beardtongue, blossom
© *Edward M. Martin*

Hairy Wood Mint
Blephilia hirsuta

Prefers full sun to part shade and moist soil. The leaves are fragrant. Foliage is often nibbled on by insects, and plants can become rather tattered and unkempt by late summer. Spent flower stalks can be cut back to create fuller leaves.

Attracts bees and butterflies.

Habitat: Shade



Hairy Wood Mint in bloom in mid-summer
© *Missouri Botanical Society*



Hairy Wood Mint, bloom
© *Thomas Barnes*

Hardy Hibiscus

Hibiscus "Fantasia"

Prefers full sun and moist soil. Japanese beetles can severely damage foliage if left unchecked. Leaf scorch will occur if soils are allowed to dry out. Healthy plants grown in the proper environment usually do not need staking. Cut back stems to 3-4" in late fall. Plants are slow to emerge in the spring. Very easy to grow and not invasive.

Attracts bees and butterflies. Deer tolerant.

Habitat: Sun



Hardy Hibiscus in bloom in late summer
© *Missouri Botanical Garden*

Hardy Ice Plant

Delosperma congestum

Prefers full sun and requires well drained soil. Drought tolerant, succulent that grows very low to the ground with yellow aster-like blooms. For about 4-6 weeks, numerous flowers open in the morning and close in the afternoon, with more blooms appearing the next morning. Evergreen leaves have a red color through the winter. Has a very long flowering season - from late spring through frost. Good for a ground cover.

Deer resistant

Habitat: Sun



Hardy Ice Plant close up of bloom
© *Rob Broekhuis*



Hardy Ice Plant in winter
© *Dropseed Nursery*



Hardy Ice Plant in bloom in summer
© *Philippe.pechoux*

Harebell

Campanula rotundifolia

Prefers full sun to part shade and moist to dry conditions. Easy to grown, but vulnerable to competition from more aggressive species. Deadhead spent flowers to encourage additional bloom. Plants are often short-lived, but will easily remain in the garden in optimum growing conditions by self-seeding. Spread by creeping roots. Long flowering season from June -September. Cut back plants in late winter.

Provides nectar for bees and hummingbirds.

Habitat: Sun



Harebell colony in bloom
© *Thomas Muller*



Harebell in bloom in summer
© *Rob Broekhuis*

Hens and Chicks

Sempervivum montanum "Braunii"

Prefers full sun and well drained soil. Drought tolerant. Spreads slowly. Evergreen. Hardy small succulent with tight rosettes to 2-3 inches in diameter crowded with mid-green colored fleshy leaves. Plants produce many offsetting rosettes that are held tightly crowded together. Clusters of reddish-purple star-shaped flowers rise up on short stalks in early summer. Remove old foliage in the late winter before the new leaves emerge. Can be propagated by division in the early spring.

Deer tolerant.

Habitat: Sun



Hens and Chicks in bloom in early summer
© *Rob Broekhuis*

Hens and Chicks

Sempervivum arachnoideum "Cobweb"

Prefers full sun and well drained soil. Drought tolerant. Low-growing, evergreen succulent. Spreads slowly. Evergreen. Great for rock gardens. Can be propagated by division in the early spring. Remove old foliate in the late winter before the new leaves emerge.

Deer tolerant.

Habitat: Sun



Hens and Chicks in winter
© *Rob Broekhuis*



Hens and Chicks in bloom
© *Daderot at Wikipedia*

Hens and Chicks

Sempervivum tectorum "Hart"

Prefers fulll sun and well drained soil. Drought tolerant. Spreads slowly. Evergreen. Hardy small succulent with tight rosettes to 2-3 inches in diameter crowded with mid-green colored fleshy leaves. Plants produce many offsetting rosettes that are held tightly crowded together. Clusters of reddish-purple star-shaped flowers rise up on short stalks in early summer. Remove old foliage in the late winter before the new leaves emerge. Can be propagated by division in the early spring.

Deer tolerant.

Habitat: Sun



Hens and Chicks colony before bloom
© *R.A.Howard*

Hop Sedge
Carex lupulina

Prefers full sun to part shade and moist to wet conditions. Useful for wetland restoration; also has a nice form and attractive seed head for wet gardens. This species will tolerate occasional flooding. The leaves become a lighter shade of green in bright sunlight. Cut back in late winter.

Attracts birds and waterfowl. Food source for caterpillars and certain insects.

Habitat: Sun



Hop Sedge seed head
© *Mike Haddock*

Indian Grass
Sorghastrum nutans

Prefers full sun and dry to moist soil. Cut back early in the season to keep plant at a lower height. Cut back last year's growth. in late winter or early spring. Fall color deep orange. Can spread aggressively. This species is tolerant of air pollution and can be grown under Black Walnut trees.

Attracts birds. Food source for caterpillars and grasshoppers. Consumed by livestock.

Habitat: Sun



Indian Grass seed head in winter
© *Dropseed Nursery*



Indian Grass seed head in Fall
© *Mike Haddock*



Indian Grass in prairie
© *Mike Haddock*

Ironweed
Vernonia gigantea

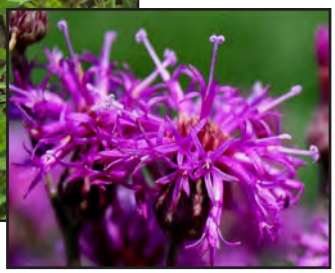
Very adaptable and hardy plant. Prefers full sun and dry to moist soil. May need support depending on height. Overall plant height may be reduced by cutting back plant stems in late spring. Remove flower heads before seed develops to avoid any unwanted self-seeding. Cut back in early to late winter.

Attracts bees and butterflies. This species' name refers to the very strong fibers of its stem.

Habitat: Sun



Ironweed in winter
© *Sally and Andy Wasowski*



Ironweed in bloom in late summer
© *R.W. Smith*

Jack-in-the-Pulpit
Arisaema triphyllum

Prefers partial shade and moist soil. This species can tolerate full sun in rich, moist soil. Slow growing perennial. A heavy, leafy winter cover should be left in place. Plant dies back completely in winter.

Berries attract birds. The swollen root is edible, but it must first be cooked, or it will cause a strong burning reacation.

Habitat: Shade



Jack in the Pulpit seed head while in bloom
© *Sally & Andy Wasowski*



Jack in the Pulpit blossom
© *Stefan Bloodworth*

Jacob's Ladder

Polemonium reptans

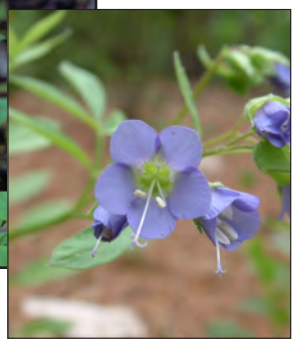
This species prefers shade and moist soil. Plants will go dormant in drought conditions. Divide clumps in early spring or late summer. This species' name alludes to the ladder-like appearance of the pinnate leaves. Plant dies back completely in the winter.

Attracts bees and butterflies.

Habitat: Shade



Jacob's Ladder clump in spring
© *Sally and Andy Wasowski*



Jacob's Ladder blossom in spring
© *Stefan Bloodworth*

Japanese Sedge

Carex morrowii "Ice Dance"

Clump-forming, semi-evergreen perennial similar in appearance to a grass. Prefers shady and moist conditions. Cut back in late winter. May benefit from a winter mulch. Forms an attractive ground cover in shady areas. This species spreads by underground rhizomes, but not aggressively.

Habitat: Sun



Japanese Sedge in winter
© *Conservation Garden Park*



Japanese Sedge seed head
© *Missouri Botanical Gardens*



Japanese Sedge colony in spring
© *Missouri Botanical Gardens*

Joy-Pye Weed
Eupatorium fistulosum

Joe-Pye Weed is a substantial plant which needs space, but when planted in groups or massed can provide spectacular flowering and architectural height. This adaptable plant can grow in full sun or partial shade, and tolerates a variety of soil conditions. Plants can be cut back in the early summer to reduce their height. Cut plants to the ground in winter.

Attracts bees and butterflies.

Habitat: Sun



Joe-Pye Weed bloom in late summer
© *Larry Allain*



Joe-Pye Weed in winter
© *Dropseed Nursery*



Joe-Pye Weed flowers
© *Thomas Barnes*

June Grass
Koeleria macrantha

June Grass is a cool-season grass that will go dormant in late summer in warmer climates. It is shorter in height and turns green earlier in the season than most short grasses. Prefers full sun and well drained soil. This very drought tolerant speceis makes a nice border for a garden. Not an aggressive spreader. Cut back in late winter or early spring.

Attracts birds. Food source for grasshoppers.

Habitat: Sun



June Grass dormant in winter
© *Kathyrn E. Bolin*



June Grass in spring
© *Dave Powell*

Kalimeris

Kalimeris incisa "Blue Star"

This very easy to grow species prefers full sun to part shade and medium moisture. Kalimeris has a long flowering season - from early summer through early fall. It performs well in hot and humid summers - but this species can't tolerate clay or other poorly drained soils. Foliage may be pinched back in early summer to stimulate new growth. Cut back after flowering to encourage a possible fall rebloom.

Attracts butterflies and makes a nice cut flower.



Kalimeris close up of blue blossom
© *Missouri Botanical Garden*



Kalimeris in bloom in summer
© *Missouri Botanical Garden*

Knautia

Knautia macedonica

Upright, clump-forming perennial. Likes full sun and moderately moist soil. Somewhat intolerant of the heat and humidity of the deep South. Remove spent flowers to encourage rebloom in early autumn. This species has a long flowering season - from early summer through early fall. Cut back last year's growth in the later winter.

This species makes a nice cut flower.

Habitat: Sun



Knautia colony in late summer
©*Missouri Botanical Garden*



Knautia close up of bloom
© *Rob Broekhuis*

Lady Fern
Athyrium filix-femina

This species prefers shady, moist conditions; however it tolerates drier soils than many other ferns. Will tolerate full sun if soil is kept constantly moist. Shelter from wind to protect fronds from breaking. Lady fern will spread, but very slowly. Divide clumps in spring every few years to reposition crowns at the soil level. Dies back completely in the winter.

Habitat: Shade



Lady Fern in spring
© *Sally & Andy Wasowski*



Lady Fern in spring
© *Lindsey Koepke*

Ladybells
Adenophora confusa

This species likes sun to part shade and moist conditions. It does have the potential to spread but unwanted growth can be pulled up in the spring. Remove seed pods before they develop to reduce excessive spread. Drought tolerant and very hardy.

Makes a nice cut flower.

Habitat: Sun



Ladybells bloom in summer
© *Rob Broekhuis*

Lamb's Ears

Stachys byzantine "Big Ears"

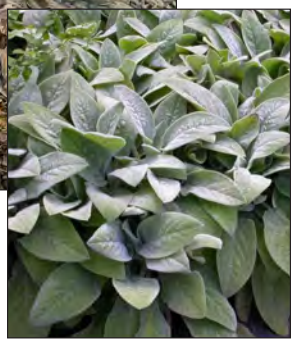
Prefers full sun and well drained soil. This drought tolerant species can be evergreen during mild winters. Tends to rot and develop leaf diseases in humid summer climates. Well-drained soils are essential in order to combat potential rot problems. Avoid overhead watering. If mid-summer foliage decline occurs, pick off damaged leaves as needed. Spreads by creeping stems that root as they go along the ground and can be mildly aggressive in rich soils. Forms an attractive groundcover. Rarely flowers. Divide in the fall or early spring.

Deer and rabbit resistant. Will grow under Black Walnut trees and is tolerant of air pollution.

Habitat: Sun



Lamb's Ears dormant in winter
© *Conservation Garden Park*



Lamb's Ears "Big Ears" colony in summer
© *Missouri Botanical Gardens*

Lamb's Ears

Stachys byzantine "Silver Carpet"

Prefers full sun and well drained soil. This drought tolerant species can be evergreen during mild winters. Tends to rot and develop leaf diseases in humid summer climates. Well-drained soils are essential in order to combat potential rot problems. Avoid overhead watering. If mid-summer foliage decline occurs, pick off damaged leaves as needed. Spreads by creeping stems that root as they go along the ground and can be mildly aggressive in rich soils. Forms an attractive groundcover. Rarely flowers. Divide in the fall or early spring.

Deer and rabbit resistant. Will grow under Black Walnut trees and is tolerant of air pollution.

Habitat: Sun



Lamb's Ears dormant in winter
© *Conservation Garden Park*



Lamb's Ears "Silver Carpet" colony in spring
© *Missouri Botanical Gardens*

Late Boneset

Eupatorium serotinum

Lower leaves sometimes discolor and fall off during a drought. The size of this plant is significantly affected by moisture levels. Cut back plants in the late winter.

Attracts bees, butterflies and birds.

Habitat: Shade



Late Boneset bloom in late summer
© *Mike Haddock*



Late Boneset in summer
© *Robert L. Stone*

Little Bluestem

Schizachyrium scoparium "The Blues"

This cultivar is notable for its very intense blue color during the growing season. Prefers full sun and dry to moist conditions. Does not require staking or cutting back during the growing season or winter months. Takes on an attractive golden brown color during the fall and into the winter. The fluffy white seeds are an attractive accent and are maintained into the winter. Very drought tolerant. Cut back to several inches above ground level in the early spring. Once established, plants can be divided in the early spring

Attracts birds. Food source for many insects.

Habitat: Sun



Little Bluestem "The Blues" in spring
© *Missouri Botanical Gardens*

Little Bluestem

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Attracts birds. Food source for many insects.

Habitat: Sun



Little Bluestem dormant in winter
© *Dropseed Nursery*



Little Bluestem seed head
© *Mike Haddock*

Lizard's Tail

Saururus cernuus

For water gardens, plant in containers in shallow water to 6" deep. For natural ponds, set plants or rhizomes in sandy or muddy pond margins under shallow water or in moist, boggy soils. Does best in full sun. Unrestrained rhizomes will spread to form colonies. Fragrant white flowers - the leaves and roots also have a pleasant citrus aroma. The foliage of this species is toxic.

Habitat: Sun



Lizard's Tail colony in summer
© *Sally & Andy Wasowski*



Lizard's Tail in bloom
© *Harry Cliffe*

Long-leaved Pondweed
Potamogeton nodosus

Use as oxygenator in water gardens. Decorative, trailing habit in ponds. Grow in aquatic containers of sandy loam, root in muddy pool bottoms at depth of 6 - 24. Can spread aggressively in shallow water. Prefers full sun

Attracts insects, wetland birds, ducks, turtles and muskrats. Pondweed provides protective cover for rish.

Habitat: Sun



Long-leaved Pondweed colony in summer
© *Joseph A. Marcus*

Lurid Sedge
Carex lurida

The seedheads resemble small sweetgum balls but do not grow above the foliage. This sedge is less prone to summer dieback and remains attractive during warm weather. Cut back in late winter or early spring. Prefers full sun and moist soil.

Attracts insects, birds, and butterflies.

Habitat: Sun



Lurid Sedge seed head
© *Robert H. Mohlenbrock*



Lurid Sedge in spring
© *Nicky Staunton*

Lyre-leaved Sage
Salvia lyrata

Lyre-leaved sage makes a great evergreen groundcover, with somewhat ajuga-like foliage and showy blue flowers in spring. It will reseed easily in loose, sandy soils and can form a solid cover with regular watering. It tolerates mowing and can be walked on. Best grown in full sun and moist soil

Attracts bees, hummingbirds, and butterflies. Not attractive to deer.

Habitat: Sun



Lyre-leaved Sage
dormant in winter
© *Dropseed Nursery*



Lyre-leaved Sage blue
blossom in spring
© *Harry Cliffe*



Lyre-leaved Sage colony in spring
© *Sally & Andy Wasowski*

Many-Flowered Agrimony
Agrimonia parviflora

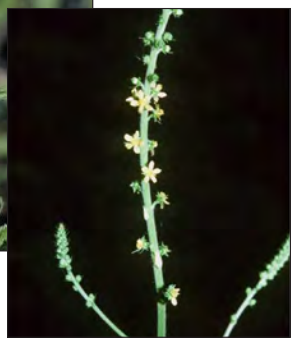
Immature fruits are green, while mature fruits are brown. Vegetative colonies of plants are often produced.

Attracts bees.

Habitat: Sun



Many-flowered Agrimony
in bloom in July
© *Larry Allain*



Many-flowered Agrimony
close up of blossom
© *Robert H. Mohlenbrock*

Meadow Blazing Star
Liatris ligulistylis

This species of blazing star is an upright, clump-forming perennial that typically grows to 2' (infrequently to 3') tall in the wild. It may grow taller in cultivation, particularly if planted in rich, fertile garden soils. May need staking. Intolerant of wet soils in winter. Tolerant of summer heat and humidity. Prefers full sun and moist to dry conditions.

Attracts bees, butterflies, hummingbirds and birds. Makes a nice cut flower.

Habitat: Sun



Meadow Blazing Star before bloom
© *Rob Broekhuis*



Meadow Blazing Star bloom in late Fall
© *Bennie Bengston*

Meadow Sedge
Carex granularis

Cut back in the late winter or early spring. Prefers partial sun and moist soil.

Attracts birds. Food source for caterpillars and other insects. Not attractive to deer or rabbits.

Habitat: Sun



Meadow Sedge seed head
© *Robert H. Mohlenbrock*

Mexican Sedum "Diploid"

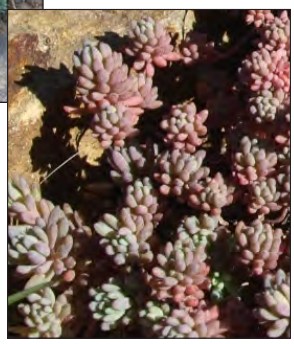
Sedum hispanicum "Diploid"

Drought tolerant. Grows best in full sun and well drained soil. Leaves turn purple in the winter.

Habitat: Sun



Mexican Sedum "Diploid" colony in spring
© *Rob Broekhuis*



Mexican Sedum "Diploid" in winter
© *Rob Broekhuis*

Mistflower

Conoclinium coelestinum

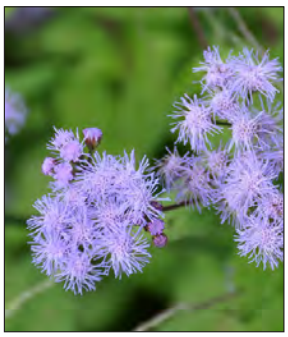
This plant can spread quickly. Divide every three years to control growth. Cut back in summer to promote denser habit. Cut back plant in late winter. Prefers full sun to partial shade and moist soil. When planted in a moss, the pale violet flowers resemble mist over the ground.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Sun



Mistflower dormant in winter
© *Dropseed Nursery*



Mistflower blue blossom in Fall
© *Mrs. W.D. Bransford*



Mistflower colony in bloom
© *Mike Haddock*

Monkey Flower
Mimulus ringens

This plant can spread, but it isn't a strong colonizer. Foliage will turn yellow and shrivel away in response to drought conditions. The size of a plant is strongly influenced by moisture conditions and soil fertility. Cut back in late winter.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Sun



Monkey Flower dormant in winter
© *Dropseed Nursery*



Monkey Flower in bloom in mid-summer
© *Mrs. W.D. Bransford*

Narrow-leaved Sunflower
Helianthus angustifolius

Prefers full sun and moist to dry conditions. May need to be staked. Pinch plants back in early summer to promote branching. Numerous small plantlets develop around the base and can be divided yearly to produce additional plants. May need to be weeded back - can spread aggressively. Cut back plants in late winter.

Attracts bees, butterflies, and birds.

Habitat: Sun



Narrow-leaved Sunflower flower dormant in winter
©*Dropseed Nursery*



Narrow-leaved Sunflower flower in Fall
© *Sally & Andy Wasowski*



Narrow-leaved Sunflower colony in bloom in Fall
© *Sally & Andy Wasowski*

Nepeta

Nepeta subsessilis "Candy Cat"

Prefers full sun to partial shade and moist to dry conditions. Drought tolerant. Plants may be cut back before first flowering to promote more compact size. Shear flower spikes after initial flowering to promote continued bloom. Fragrant flowers and leaves. Cut back last year's growth in the early spring. Good for rain gardens since this species will tolerate some flooding and also periods of drought.

Habitat: Sun



Nepeta "Candy Cat" in bloom in summer
© *Missouri Botanical Gardens*

New England Aster

Symphyotrichum novae-angilae (Aster novae-angliae)

New England Aster flowers until frost. Cut back plants in early summer to maintain a shorter and fuller shape. May require staking. Can be aggressive. The flower color is variable, ranging from lavender to blue to white. Cut back dormant plants in late winter. This species prefers full sun, but is tolerant of many soil types including clay.

Attracts bees and butterflies. Makes nice cut flowers.

Habitat: Sun



New England Aster dormant in winter
© *Dropseed Nursery*



New England Aster in bloom
© *Mariann Watkins*



New England Aster in bloom in Fall
© *Albert F.W. Vick*

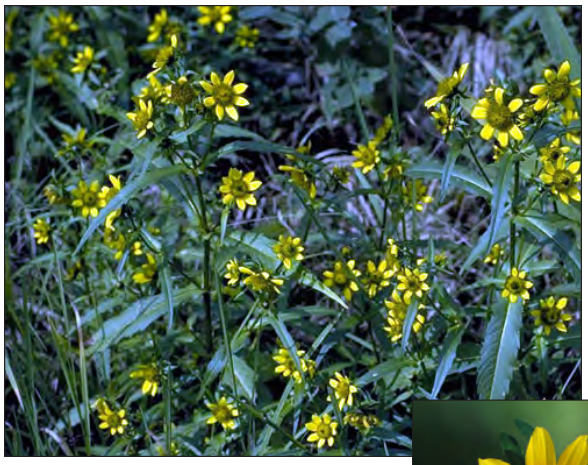
Nodding Bur Marigold

Bidens cernua

Numerous yellow flower heads nod increasingly as the flowers mature. This plant often forms colonies and spreads by reseeding itself. The leaves occasionally succumb to powdery mildew during the fall. This plant is less tolerant of dry conditions than other Bidens species. Cut back plants in late winter. This fairly aggressive species is a good choice for wetland restorations.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Nodding Bur Marigold colony in bloom
© *W.D. and Dolphia Bransford*



Nodding Bur Marigold bloom
© *Mike Haddock*

Nodding Wild Onion

Allium cernuum

Prefers full sun. This species is very drought tolerant; however, it is not able to withstand competition from more aggressive plant species. Best grown in rocky soils. All parts of the perennial have a mild, oniony scent. Plants benefit from being divided every third year or when 8-10 bulbs appear in the clump. Foliage persists past flowering into late summer before dying back.

Attracts hummingbirds, bees, and butterflies.

Habitat: Sun



Nodding Wild Onion dormant in winter
© *Dropseed Nursery*



Nodding Wild Onion in bloom
© *Rob Broekhuis*

Obedient Plant

Physostegia virginiana "Miss Manners"

"Miss Manners" is a patented cultivar that is distinguished by its non-spreading, clump-forming, compact growth habit and long season of bloom.

Obedient Plant is given its name because each individual flower will, upon being pushed in any one direction, temporarily remain in the new position as if it were hinged. Cut back dormant plant material in the early spring.

Attracts hummingbirds, bees, and butterflies.

Habitat: Sun



Obedient Plant "Miss Manners" in bloom in summer
© *Missouri Botanical Gardens*

Obedient Plant

Physostegia virginiana

May need staking, especially if grown in soils with high fertility. Prune back in early spring to reduce height and minimize tendency toward floppiness (optional). Spreads and can be aggressive in the garden. Divide every 2-3 years to control growth.

Obedient plant is given its name because each individual flower will, upon being pushed in any one direction, temporarily remain in the new position as if it were hinged. Cut back dormant plant material in the early spring.

Attracts hummingbirds, bees, and butterflies.



Obedient Plant colony in bloom in summer
© *Sally & Andy Wasowski*



Obedient Plant in bloom in summer
© *Mariann Watkins*

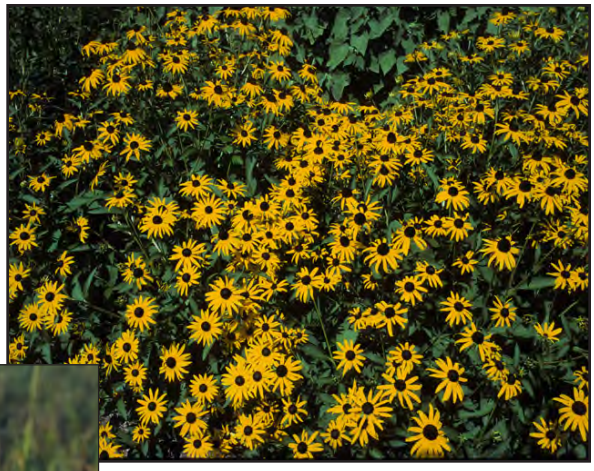
Orange Coneflower

Rudbeckia fulgida

Prefers full sun and moist to dry soil. This species flowers for a long period during the mid-summer. Dead heading spent flowers can prolong flowering time. Divide when clumps become overcrowded. Cut back dormant plant material in the early spring to allow birds to feed on the seed heads during the winter months.

Attracts butterflies.

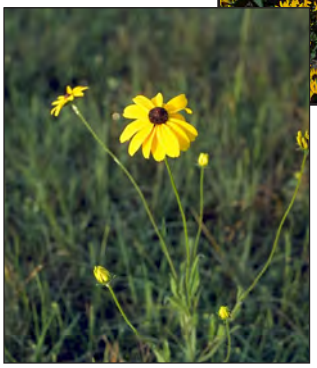
Habitat: Sun



Orange Coneflower colony in bloom in Fall
© *Sally & Andy Wasowski*



Orange Coneflower dormant in winter
© *Dropseed Nursery*



Orange Coneflower yellow bloom
© *George H. Bruso*

Ornamental Onion "Ozawa"

Allium thunbergii "Ozawa"

Prefers full sun to part shade and moist soil. This species is very drought tolerant. Red-violet florets in 1-2" diameter globular clusters appear atop thin stems in September and October. Leaves turn an attractive tawny orange at frost. Divide clumps to encourage more flowering. Fragrant flowers.

Not attractive to deer.

Habitat: Sun



Ornamental Onion "Ozawa" in bloom in August
© *Missouri Botanical Garden*

Ornamental Onion

Allium thunbergii "Ozawa"

This species prefers full sun to part shade and moist, well drained soil. Drought tolerant. In fall, the foliage turns an attractive yellow, a nice contrast to the reddish-brown flower stems that last well into the winter. Sterile flowers prevent spread by seed. Cut back last year's growth in the early spring.

Habitat: Sun



Ornamental Onion
© *Missouri Botanical Garden*

Ornamental Oregano

Origanum laevigatum

Prefers full sun and moist soil. This species makes a nice ground cover. Fragrant foliage. The species dies to the ground in cold winters. Leaves deepen in color as the summer progresses, with the best purple colors usually occurring in cool climates. Will spread by runners, but not aggressively.

Attracts butterflies and bees. Makes nice cut flowers.

Habitat: Sun



Ornamental Oregano in winter
© *Conservation Garden Park*



Ornamental Oregano in bloom in late summer
© *Missouri Botanical Gardens*



Ornamental Oregano foliage turning purple in Fall
© *Conservation Garden Park*

Oval-headed Sedge
Carex cephalophora

Cut back in late winter. A nice low-growing option for dry shade.

Food source for insects and caterpillars. Attracts birds.

Habitat: Shade



Oval-headed Sedge seed heads
© *Ted Bodner*

Pale Indian Plantain
Arnoglossum atriplicifolium

Pale Indian Plantain may need support – cut back plants early in the season to create a shorter, fuller shape. Cut plants back in the late winter.

Attracts bees and wasps.

Habitat: Sun



Pale Indian Plantain colony in bloom in summer
© *Sally & Andy Wasowski*



Pale Indian Plantain at full height
© *Mike Haddock*

Pale Purple Coneflower

Echinacea pallida

An adaptable plant that is tolerant of drought, heat, humidity and poor soils. Prefers full sun. Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Cut back last year's growth in the early spring to allow birds to feed on the seed head throughout the winter months.

Attracts bees butterflies and birds.



Pale Purple Coneflower in winter
© *Dropseed Nursery*



Pale Purple Coneflower bloom in spring
© *Sally and Andy Wasowski*



Pale Purple Coneflower in bloom in prairie
© *Thomas L. Muller*

Panicled Aster

Symphyotrichum lanceolatum (Aster lanceolatus)

Can tolerate both wet and dry conditions, may lose lower leaves in very dry conditions. Tolerant of disturbance.

Attracts bees and butterflies.

Habitat: Shade



Panicled Aster plant in late Fall
© *Mrs. W.D. Bransford*



Panicled Aster in bloom in Fall
© *George H. Bruso*

Pasque Flower
Pulsatilla vulgaris

Prefers full sun to part shade and moist soil. Flowers vary in color from blue to reddish purple with a bushy center clump of golden yellow stamens and give way to feathery seed heads which are quite showy. This low-growing plant is good for borders.

Habitat: Sun



Pasque Flower seed heads
© *Rob Broekhuis*



Pasque Flower in bloom in Spring
© *Rob Broekhuis*

Pennsylvania Sedge
Carex pennsylvanica

Foliage is pale-green in spring and summer, turning sandy-tan in fall. One of the first sedges to bloom in the spring. Cut back in late winter. Forms nice ground cover or lawn alternative.

Attracts birds. Food source for grasshoppers, caterpillars and other insects.



Pennsylvania Sedge in summer
© *Stefan Bloodworth*



Pennsylvania Sedge seed head
© *Stefan Bloodworth*

Phlox
Phlox paniculata "Robert Poore"

Prefers medium moisture and full sun to part shade. Needs good air circulation (space well and thin out stems as needed) to help combat potential powdery mildew problems. Avoid overhead watering. Appreciates a summer mulch which helps keep the root zone cool.

Attracts bees, hummingbirds, butterflies and birds. The fragrant blossoms make nice cut flowers. Not attractive to deer. Can thrive in clay soil and under Black Walnut trees.

Habitat: Sun



Phlox "Robert Poore"colony in bloom Summer
© *Missouri Botanical Gardens*



Phlox "Robert Poore" bloom in Summer
© *Missouri Botanical Gardens*

Phlox
Phlox paniculata

Prefers medium moisture and full sun to part shade. Needs good air circulation (space well and thin out stems as needed) to help combat potential powdery mildew problems. Avoid overhead watering. Appreciates a summer mulch which helps keep the root zone cool.

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Habitat: Sun



Phlox colony in late Summer
© *Andy & Sally Wasowski*



Phlox pink bloom in late Summer
© *Steven Faucette*

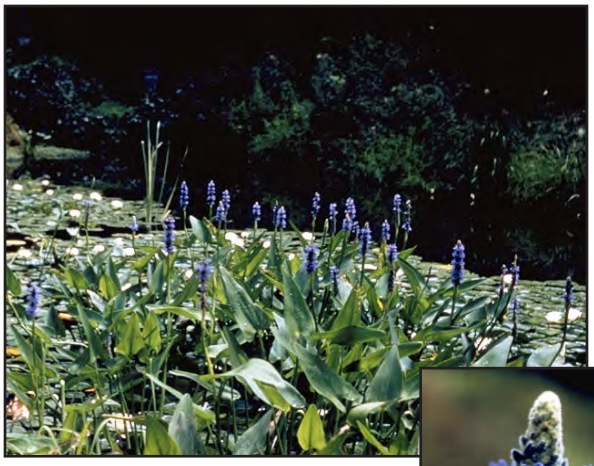
Pickerelweed

Pontederia cordata

This emergent aquatic, with its leaves and flowers above water and portions of the stem under water, is found typically in shallow, quiet water. Set plant roots in spring into mud at the margins of a pond or in containers (rich organic loams) in a water garden under 3-5" of water. Outside of containers, rhizomes can spread rapidly to form colonies under optimum growing conditions. If spread is a concern, grow plants in containers.

Dragonflies and damselflies commonly lay their eggs on plant stems near the water surface. Attracts bees and butterflies. Food source for ducks.

Habitat: Sun



Pickerelweed colony in bloom
© *Albert F.W.Vick*



Pickerelweed blue blossom in late Summer
© *Albert F.W.Vick*

Pinks

Dianthus carthusianorum

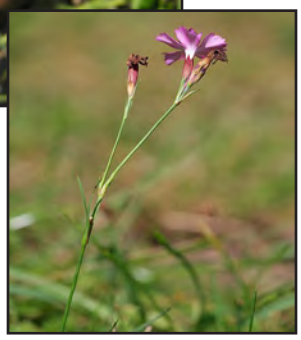
Tall growing dianthus topped with clusters of up to 50 deep magenta blooms on each stem. Prefers dry, sunny sites. Deadhead regularly to prolong flowering. This drought tolerant plant is evergreen in mild winters.

Attracts butterflies.

Habitat: Sun



Pinks in bloom in Spring
© *Audrius Meskauskas*



Pinks in Spring
© *Kristian Peters*

Large-Fruited Oval Sedge
Carex scoparia

This sedge adapts to full sun, wet to moist conditions, and various kinds of soil, including those containing mud, sand, or gravel. Cut back in late winter..

The leaves are a source of food for butterflies and moths and the seeds are food for a variety of birds.

Habitat: Sun



Pointed Broom Sedge colony in summer
© *Mike Haddock*



Pointed Broom Sedge seed head
© *Mike Haddock*

Poverty Grass
Danthonia spicata

Poverty grass is a perennial bunchgrass with wiry clumps of naked stems and tufts of curly, basal leaves. This grass does not tolerate competition from taller ground vegetation. Thrives in well-drained, nutrient poor soils.

Attracts butterflies.

Habitat: Sun



Poverty Grass
© *dropseed nursery*

Prairie Cordgrass
Spartina pectinata

Prairie cordgrass is fast-growing and has been used to prevent soil erosion. Stems often remain erect through the winter and provide good cover for wildlife. Fall color is an attractive yellow. Cut back in late winter or early spring.

Attracts ducks. Important source of protective cover and nesting habitat for many wetland birds and other kinds of wildlife.

Habitat: Sun



Prairie Cordgrass prairie in late Summer
© *Sally & Andy Wasowski*



Prairie Cordgrass with seed head
© *Sally & Andy Wasowski*

Prairie Dock
Silphium terebinthinaceum

Prefers full sun and can tolerate a wide variety of soil conditions. Very large, wide, spade-shaped basal leaves subtend a 3-8 ft. flowering stalk. Taprooted, slow-to-establish plant which may not flower until the second or third year. Usually does not need support, but often leans. Cut back plant material in the early spring to allow birds to feed on the seedheads during the winter months.

Attracts bees, hummingbirds and birds.

Habitat: Sun



Prairie Dock dormant in winter
© *Dropseed Nursery*



Prairie Dock bloom in late Summer
© *Thomas Barnes*



Prairie Dock at full height
© *Sally & Andy Wasowski*

Prairie Dropseed
Sporobolus heterolepis "Tara"

'Tara' is a dwarf version of the species. It typically grows in the form of a vase (more upright and less arching than the species) to 12" tall, with attractive flowering spikes rising in summer well above the foliage to 24" tall. Orange-red fall color can be spectacular.

Attracts birds.

Habitat: Sun



Prairie Dropseed "Tara" in summer
© *Missouri Botanical Garden*



Prairie Dropseed in winter
© *Dropseed Nursery*

Prairie Dropseed
Sporobolus heterolepis

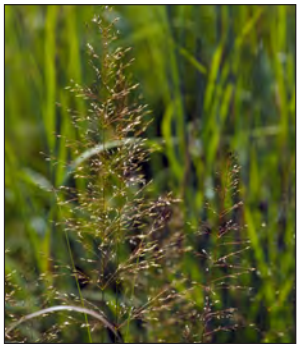
Great accent or ground cover for the landscape. Foliage turns copper-gold in fall, gradually fading to light beige by winter. Late summer flowers bloom in airy panicles above the foliage. Flowers are noted for their coriander-like fragrance. Cut back plants in the late winter.

Attracts birds.

Habitat: Sun



Prairie Dropseed in winter
© *Dropseed Nursery*



Prairie Dropseed seed head
© *Sally & Andy Wasowski*



Prairie Dropseed in bloom in late Summer
© *Bonnie L. Harper*

Prairie Onion
Allium stellatum

Prairie Onion prefers part shade and moist to dry soil. Deadhead flowers before seed set to help control any unwanted spread. Foliage persists to the time of or slightly past flowering in summer before dying back. Plants are easily grown from seed which should be planted in spring or from bulbs/bulb offsets which should be planted in autumn.

Attracts bees and butterflies.

Habitat: Sun



Prairie Onion pink blossom in late Summer
© *W.D. and Dolphia Bransford*



Prairie Onion bloom in late Summer
© *Sally & Andy Wasowski*

Prairie Sagewort
Artemisia frigida

This low-spreading, semi-evergreen shrub is very drought tolerant, prefering full sun and dry soils. A good soil stabilizer and ground cover. Prune plants in spring to control growth, but be careful to leave sufficient numbers of live buds on each stem to facilitate bushy growth. Never prune stems to the ground. Foliage may also be lightly sheared in summer to shape, but avoid pruning in fall. Susceptible to root rot in moist soils, particularly poorly drained ones.

Provides nesting material for native bees; attractive food source for deer.



Prairie Sagewort colony in Spring
© *Sally & Andy Wasowski*



Prairie Sagewort with bloom in mid-Summer
© *Phyllis Weyand*

Purple Coneflower

Echinacea purpurea "Vintage Wine"

'Vintage Wine' is noted for its upright plant habit and long bloom period. Ray flowers extend horizontally rather than droop. This is a patented plant.

Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Freely self-seeds if at least some of the seed heads are left in place. The dead flower stems will remain erect well into the winter and, if flower heads are not removed, are often visited by goldfinches.

Attracts bees, hummingbirds, birds and butterflies.

Habitat: Sun



Purple Coneflower "Vintage Wine" bloom in Summer
© *Missouri Botanical Garden*



Purple Coneflower dormant in winter with seed head
© *Dropseed Nursery*

Purple Coneflower

Echinacea purpurea

Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Freely self-seeds if at least some of the seed heads are left in place and can spread aggresively. The dead flower stems will remain erect well into the winter and, if flower heads are not removed, are often visited by goldfinches.

Attracts bees, hummingbirds, birds and butterflies.

Habitat: Sun



Purple Coneflower bloom in summer
© *Joseph A. Marcus*



Purple Coneflower in winter
© *Dropseed Nursery*



Purple Coneflower colony in bloom
© *Dropseed Nursery*

Purple Joe-Pye Weed

Eupatorium purpureum

Plants prefer full suny to partial shade and moist conditions. These very tall plants can be cut back in the early summer to keep at a shorter height. Cut dormant plants to the ground in late winter. Fragrant flowers are very attractive to butterflies. Flowers give way to attractive seed heads which persist well into winter.

Attracts bees, birds and butterflies.

Habitat: Sun



Purple Joe-Pye Weed bloom before opening
© *Mike Haddock*



Purple Joe-Pye Weed in winter
© *Dropseed Nursery*



Purple Joe-Pye Weed in bloom in late summer
© *W.D. Bransford*

Purple Prairie Clover

Dalea purpurea

This species prefers full sun and well-drained soil. Does not compete well with more aggressive species. A nitrogen-fixing plant; very drought tolerant. May self-seed in optimum growing conditions.

Attracts bees. Food source for caterpillars and other insects.

Habitat: Sun



Purple Prairie Clover bloom in Summer
© *R.W. Smith*



Purple Prairie Clover in Winter
© *Dropseed Nursery*



Purple Prairie full plant in bloom
© *R.W. Smith*

Purple-Stemmed Aster

Symphyotrichum puniceum (Aster puniceus)

This species prefers full sun and moist to wet soil. To control height, cut plants back in the early summer. Will spread by seed. Cut back dormant plants in the late winter.

Attracts butterflies and makes a good cut flower.

Habitat: Sun



Purple-stemmed Aster in bloom in late Summer
© *Missouri Botanical Gardens*

Pussytoes

Antennaria dioica

This drought tolerant species prefers full sun and dry soil.In optimum growing conditions, plants can spread by stolons to form an attractive ground cover. Plants are dioecious (male and female flowers on separate plants), with male flowers typically appearing on shorter flower stalks.

Habitat: Sun



Pussytoes in bloom in early Summer
© *Rob Broekhuis*



Pussytoe flowers
© *Missouri Botanical Garden*

Rattlebox

Ludwigia alternifolia

This species prefers full sun and can tolerate wet and dry conditions - making it a good candidate for a rain garden. The petals drop easily, often lasting less than a day. When the capsule is shaken, the seeds rattle, which gives rise to the common name "rattle-box". The dried stems and fruit have an attractive reddish-brown color in the winter. Cut back dormant plant material in the late winter.



Rattlebox stand in bloom
© *Edwin M. Martin*



Rattlebox in winter
© *Dropseed Nursery*



Rattlebox yellow blossom in Summer
© *Mike Haddock*

Rattlesnake Master

Eryngium yuccifolium

Prefers full sun and moist to dry soil. Plants tend to open up and sprawl if grown in overly fertile soils or in anything less than full sun. This is a taprooted plant which transplants poorly and is best left undisturbed once established. Taller plants may need support.

Attracts bees. Attracts parasatoid wasps, which can help control pest species in the garden.

Habitat: Sun



Rattlesnake Master at full height in Spring
© *Sally & Andy Wasowski*



Rattlesnake Master in bloom in late Summer
© *Dropseed Nursery*



Rattlesnake Master in Winter
© *Dropseed Nursery*

Rice Cutgrass
Leersia oryzoides

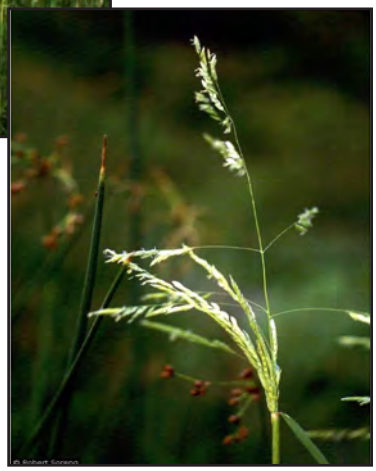
Prefers full sun and wet conditions. This species is somewhat aggressive in disturbed wetlands. Dense colonies of plants are often produced. Cut back in late winter or early spring. In a wetland restoration, it is not necessary to cut back the dormant plant material to maintain plant vigor

Attracts birds and butterflies.

Habitat: Sun



Rice Cutgrass colony in Spring
© *Patrick J. Alexander*



Rice Cutgrass seed head
© *Robert Soreng*

River Cane
Arundinaria gigantea

Plants prefer moist soil, but do not tolerate flooding. Prefer full sun in optimum growing conditions, it will naturalize to form immense, dense monocultural - commonly called canebrakes. Promising species for use in soil stabilization along streams. If naturalization is not desired, rhizomatous spread may be discouraged via constructing soil barriers or growing plant in a very large plastic pot sunk to the rim. Should not be cut back. This species flowers rarely, and the colony dies following flowering.

Habitat: Sun



River Cane colony at full height in Summer
© *Missouri Botanical Garden*



River Cane in Summer
© *Missouri Botanical Garden*

River Oats
Chasmanthium latifolium

This very adaptable species will grown in full sun as well as full shade, and will tolerate a wide variety of soil conditions. Self-seeds and may spread aggressively. Leaving foliage in place over winter adds interest to the landscape, helps protect crowns from the cold, and provides food for birds. Cut back to the ground in late winter.

Attracts butterflies and birds.

Habitat: Shade



River Oats with seed heads dormant in winter
© *Dropseed Nursery*



River Oats in Spring
© *Dropseed Nursery*

Riverbank Wild Rye
Elymus riparius

Prefers partial shade and moist soil. Used for erosion control and riverbank rehabilitation. Cut back in late winter.

Seeds are a food source for birds.

Habitat: Shade



Riverbank Wild Rye seed head
© *Robert H. Mohlenbrock*

Rose Wine Sage

Salvia nemorosa "Rosenwein"

Likes full sun and dry to medium soil. Plants may repeat bloom throughout the summer, but need regular moisture to encourage this. Remove spent flower spikes to help extend the bloom period. Plants may become somewhat floppy and open up as the summer progresses, particularly in humid climates. Cut back plants after flowering has ended.

Attracts bees and butterflies. Deer resisitant.

Habitat: Sun



Rose Wine Sage colony in bloom in Summer
© *Missouri Botanical Gardens*



Rose Wine Sage rose blossom
© *Missouri Botanical Gardens*

Rough Blazing Star

Liatris aspera

This drought tolerant species prefers full sun and well drained soil. Blooms later (late summer to fall) than most other Liatris species. May need support at the time of blooming.

Attracts bees, hummingbirds and butterflies. Provides nectar for butterflies such as: tiger swallowtail, clouded sulphur, orange sulphur, gray hairstreak, aphrodite fritillary, painted lady, red admiral, and wood nymph.

Habitat: Sun



Rough Blazing Star in prairie in late Summer
© *Sally & Andy Waswoski*



Rough Blazing Star with purple blossom
© *Henry Domke*

Rough Goldenrod
Solidago rugosa

Prefers full sun and moist soil. Tolerant of clay soil. Plants can be aggressive spreaders in optimum growing conditions, but are generally not considered to be invasive. Cut back plants in late winter.

Attracts bees, birds and butterflies. Not attractive to deer.



Rough Goldenrod in bloom in Fall
© *W.D. and Dolphia Bransford*



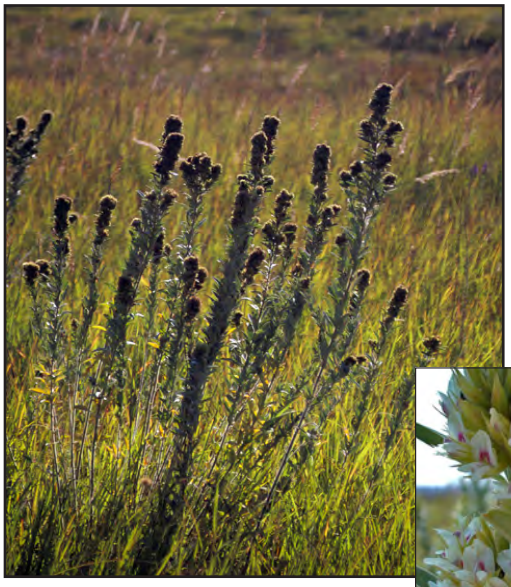
Rough Goldenrod flowers
© *R.W. Smith*

Round-headed Lespedeza
Lespedeza capitata

This species likes full sun and moist to dry soil conditions. Drought tolerant. Stems remain erect through the winter when the seedheads have turned dark brown. Adds nitrogen to the soil. Cut back plants in the late winter. Spreads primarily by seed, but does not spread aggressively.

Attracts bees and birds. Food source for caterpillars and other insects.

Habitat: Sun



Round-headed Bush Clover seed heads
© *Sally & Andy Wasowski*



Round-headed Bush Clover in bloom
© *Mike Haddock*

Royal Fern

Osmunda regalis

This fern requires shade and rich, moist soil. Divide in fall or spring.

Habitat: Shade



Royal Fern dormant in winter
© *Stephen Brown*



Royal Fern seed heads
© *Sally & Andy Wasowski*



Royal Fern colony in Summer
© *Sally & Andy Wasowski*

Sage

Salvia nemorosa "Marcus"

'Marcus' is a dwarf clump-forming perennial salvia with deep violet flowers that typically grows to only 8-10" tall. This cultivar does not set viable seeds. Cut back plants after flowering has ended. Prefers full sun and moist to dry soil.

Attracts bees, hummingbirds and butterflies. Not attractive to deer.

Habitat: Sun



Sage in bloom in Spring
© *Missouri Botanical Garden*



Sage flowers in Spring
© *Missouri Botanical Garden*

Sage
Salvia nemorosa "Sensation Rose"

"Sensation Rose" is noted for its compact form, free branching habit, long bloom period and lavender-pink flowers. Salvia nemorsa "Rose Wine" has a similar pink flower color and is shown in the image above. This cultivar does not set viable seeds. Cut back plants after flowering has ended.

Attracts bees, hummingbirds and butterflies. Not attractive to deer.

Habitat: Sun



Sage in bloom in Spring
© *Missouri Botanical Garden*

Sea Thrift
Armeria maritima

Compact and low-growing plant forms a good groundcover. Foliage mounds tend to rot in the center if grown in moist, fertile soils or in heavy clay. Good drainage is essential. Drought tolerant, prefers full sun.

Habitat: Sun



Sea Thrift in bloom in Spring
© *Missouri Botanical Garden*



Sea Thrift in bloom in Spring
© *Rob Broekhuis*



Sea Thrift dormant in winter
© *Conservation Garden Park*

Sedum

Sedum acre "Oktoberfest"

Sedum Acre "Oktoberfest" is a fast-spreading evergreen variety which forms a low carpet of tiny succulent green leaves, smothered by star-shaped creamy-white flowers all summer long. Many people even use this Sedum seed as a lawn substitute as it tolerates moderate foot traffic once it is well-established.

Attracts bees and butterflies.

Habitat: Sun



Sedum before bloom in Spring
© *Conservation Garden Park*



Sedum in winter
© *Conservation Garden Park*

Sensitive Fern

Onoclea sensibilis

Will grow in shade or full sun. Prefers moist soil. Usually grows taller in wet soils which it tolerates well. Spreads by both creeping rhizomes and spores, and can be somewhat aggressive in optimum growing conditions. Commonly called sensitive fern because the green vegetative fronds are sensitive to and suffer almost immediate damage from the first fall frost. Plants die back completely in the winter. Divide in fall or spring.

Attracts birds.

Habitat: Shade



Sensitive Fern colony in Spring
© *Sally & Andy Wasowski*



Sensitive Fern leaf in Spring
© *Jesse Gaudet*

Short's Aster

Symphyotrichum shortii (Aster shortii)

Prefers shade and moist soil. The centers of the flowers start out yellow but turn brick red after pollination. It will self-sow and spread throughout an area, but individual plants are short-lived. May need support. Cut back plants in the late winter.

Attracts bees, butterflies and hummingbirds. Also attracts birds such as cardinals, finches, grosbeaks, sparrows, thrashers, towhees, chickadees, nuthatches, titmice, and turkeys.

Habitat: Shade



Short's Aster colony in bloom in Fall
© *Sally & Andy Waswoski*



Short's Aster blue blossom in Fall
© *Stefan Bloodworth*

Shortbeak Sedge

Carex brevior

Cut back in late winter or early spring.

Attracts birds.

Habitat: Sun



Shortbeak Sedge stand in summer
© *Mike Haddock*



Shortbeak Sedge seed head
© *Mike Haddock*

Showy Goldenrod

Solidago speciosa

This is one of the showiest of about 125 species of goldenrod that occur throughout the United States; they are most common in the East. Prefers full sun and dry to moist soils. Can be aggressive in moist soils - will tolerate clay soil. Mature plants develop a woody stem. Cut back plants in the late winter.

Attracts bees, butterflies and birds. Deer resistant.

Habitat: Sun



Showy Goldenrod in bloom in Fall
© *Mike Haddock*



Showy Goldenrod flowers
© *Mike Haddock*

Side-oats Grama

Bouteloua curtipendula

Foliage turns golden brown in autumn, sometimes also developing interesting hues of orange and red. Cut back in late winter. This is a very drought tolerant medium-tall grass that mixes well in plantings with spring wildflowers because it stays short in the spring.

Attracts butterflies and birds. Food source for grasshoppers and caterpillars. Provides nesting material for birds.

Habitat: Sun



Side-oats Grama dormant in winter
© *Dropseed Nursery*



Side-oats Grama seed head
© *Mike Haddock*



Side-oats Grama in Summer
© *Sam C. Strickland*

Silky Wild Rye

Elymus villosus

Can thrive in sun or shade, prefers moist soil. Cut back in late winter.

Food source for leafhoppers and caterpillars.

Habitat: Sun



Silky Wild Rye stand in Fall
© *Sally & Andy Wasowski*



Silky Wild Rye seed head
© *Sally & Andy Wasowski*

Silver Sedge

Carex morrowii "Silver Sceptre"

'Silver Sceptre' is a Japanese grass sedge cultivar that is ornamentally grown in shade areas for its narrow, variegated foliage. It typically grows in a dense, arching, grass-like clump. Green leaf blades are variegated with white edges. Cut back in late winter.

Habitat: Sun



Silver Sedge "Silver Sceptre" dormant in winter
© *Conservation Garden Park*



Silver Sedge "Silver Sceptre" in Summer
© *Conservation Garden Park*

Slender Mountain Mint
Pycnanthemum tenuifolium

This species will tolerate full sun to partial shade and moist to wet soil. All parts of the plant emit a strong, mint-like aroma when crushed. A vigorous and sometimes aggressive plant. Cut back plants in the late winter.

Attracts bees, butterflies and wasps.

Habitat: Sun



Slender Mountain Mint dormant in winter with seed head
© *Dropseed Nursery*



Slender Mountain Mint white bloom in late Summer
© *Mike Haddock*

Small Yellow Onion
Allium flavum

Prefers full sun and dry soil. The bulbs should be planted fairly deeply. Most members of this genus are intolerant of competition from other plants. Divide bulbs in late summer or fall.

Attracts bees.

Habitat: Sun



Small Yellow Onion in bloom in July
© *Rob Broekhuis*



Small Yellow Onion scape
© *Rob Broekhuis*

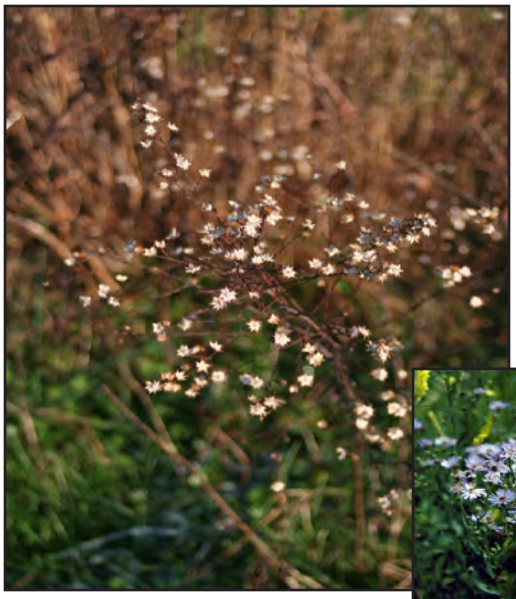
Smooth Blue Aster

Symphyotrichum laeve (Aster laevis)

Prefers full sun and moist to dry soil. Provides nice color in the late fall. Freely self-seeds. It is vulnerable to powdery mildew and other foliar disease to a moderate extent. Cut back in mid-summer to maintain a shorter form. Cut back dormant plant material in late winter.

Attracts bees and butterflies. Food source to caterpillars and insects.

Habitat: Sun



Smooth Blue Aster dormant in winter
© *Dropseed Nursery*



Smooth Blue Aster in bloom in Fall
© *W.D. and Dolphia Bransford*

Smooth Rose-Mallow

Hibiscus laevis

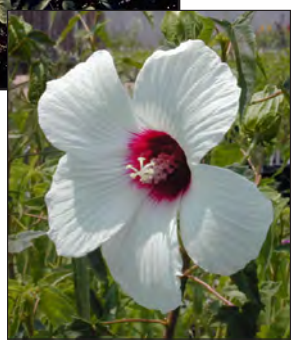
Prefers full sun and moist soil. Dried pods provide winter interest in the garden. Taller plants may need staking. Cut back dormant plant material in late winter. Flower color varies from white to pink.

Attracts bees and butterflies. Food source for caterpillars and insects. Japanese beetles will eat foliage and flowers and can be a problem.

Habitat: Sun



Smooth Rose-Mallow pink blossom
© *W.D. and Dolphia Bransford*



Smooth Rose-Mallow bloom in late Summer
© *Joseph A. Marcus*

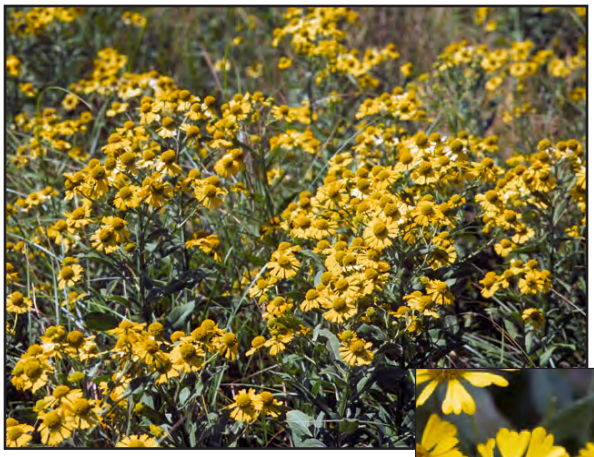
Sneezeweed

Helenium autumnale

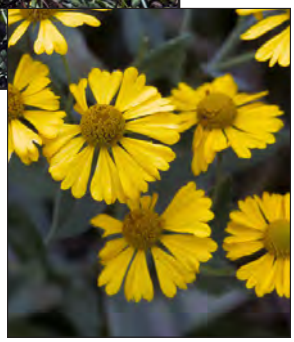
Prefers full sun and moist soil. Although not required, plants may be cut back in early June (at least six weeks before normal flowering) to reduce plant height and to encourage increased flowering, healthier foliage and less need for support. Remove spent flowers to encourage additional bloom. Can be aggressive. Provides late color in the garden. Cut back plants in late winter.

Attracts bees, wasps and butterflies. Food source for caterpillars and insects.

Habitat: Sun



Sneezeweed colony in bloom in Fall
© *Sally & Andy Wasowski*



Sneezeweed blossom in Fall
© *Sally & Andy Wasowski*

Snow-In-Summer

Cerastium tomentosum "Silver Carpet"

This species prefers full sun and dry soil. Forms a nice ground cover, spreading over time, but not aggressively. Shear back by one-third after flowering for fresh full foliage. Avoid shearing during hot dry conditions. Can be divided every year if necessary. Cut back in early spring.

Habitat: Sun



Snow-in-Summer flowers
© *Missouri Botanical Garden*



Snow-in-Summer foliage in Spring
© *Garden Soft*



Snow-in-Summer in bloom in Spring
© *Missouri Botanical Garden*

Soft Rush
Juncus effusus

Notwithstanding its preference for abundant moisture, soft rush will perform surprisingly well in average garden soils as long as they receive consistent irrigation. Will tolerate full sun or partial shade. Plants keep nice form and some green color during winter. No need to cut back plants in the fall or early spring. Clumps are often slow to establish, but once established will spread by creeping rhizomes.

Habitat: Sun



Soft Rush in Spring
© *Missouri Botanical Garden*



Soft Rush dormant in winter
© *Dropseed Nursery*

Softstem Bulrush
Scirpus validus

This plant require wet soil and full sun. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. This plant is good for habitat reconstruction and erosion control along areas with occasional flooding. Can spread aggressively.

Provides nesting habitat and food for waterfowl.

Habitat: Sun



Softstem Bulrush colony Spring
© *Sally & Andy Wasowski*



Softstem Bulrush seed head
© *Sally & Andy Wasowski*

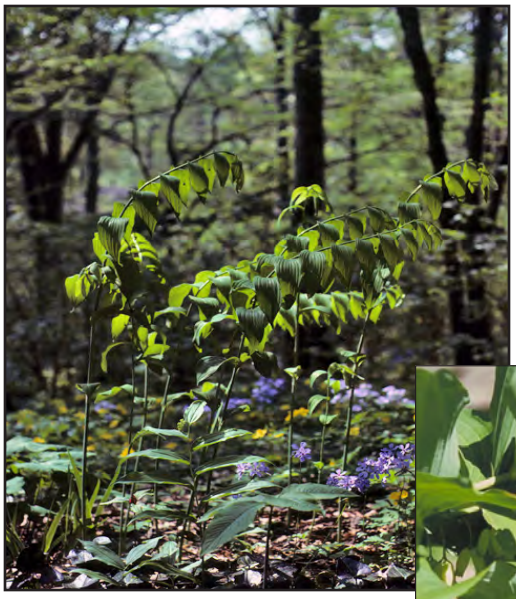
Solomon's Seal

Polygonatum biflorum

Solomon's Seal prefers shady conditions and moist soil. Good understory plant. White flowers are followed by blue-black berries in autumn. Foliage turns an attractive yellow in fall. Plant material dies back completely in the winter.

Attracts birds, bees, hummingbirds and butterflies.

Habitat: Shade



Solomon's Seal colony in Spring
© *Sally & Andy Wasowski*



Solomon's Seal bloom in Spring
© *Norman G. Flaigg*

Speedwell

Veronica longifolia "Blue John"

This species thrives in full sun and moist soil. Taller plants may need support. 'Blue John' is a compact long leaf speedwell cultivar that features dense, erect, terminal spikes of tiny pale blue flowers atop upright stems rising to 20" tall. Cut back spent blooms to lengthen flowering period. Cut back dormant plant material during the winter months.

Attracts bees, hummingbirds and butterflies. This species is not attractive to deer or rabbits.

Habitat: Sun



Speedwell blue blossom in Summer
© *Missouri Botanical Gardens*

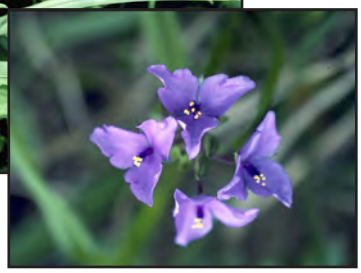
Spiderwort
Tradescantia bracteata

Good for full sun and moist soil, although this species will tolerate dry soils and can be quite drought resistant. Divide clumps when they become overcrowded. Foliage declines after flowering and should then be cut back almost to the ground to encourage new growth and a possible fall bloom. Young shoots are susceptible to snail damage. Foliage sprawls in an unattractive manner by mid-summer. Cut back dormant plant material during the winter months.

Habitat: Sun



Spiderwort colony in Spring
© *W.D. and Dolphia Bransford*



Spiderwort bloom in Spring
© *W.D. and Dolphia Bransford*

Spiderwort
Tradescantia ohiensis

This very drought tolerant species prefers full sun to part shade and will thrive in a variety of soil types. When touched in the heat of the day, the flowers shrivel to a fluid jelly. Divide clumps when they become overcrowded. Cut back to 6-12" in mid-summer to encourage new growth and a possible fall bloom. Young shoots are susceptible to snail damage. Foliage tends to sprawl in an unattractive manner by mid-summer. Cut back spent plant material during the summer months.

Habitat: Sun



Spiderwort colony in early Summer
© *W.D. and Dolphia Bransford*



Spiderwort bloom in early Summer
© *Mike Haddock*

Spotted Dead Nettle

Lamium maculatum "Aureum"

It is best to cut this plant back after the first bloom to promote compact growth. This plant can be invasive. When grown as a ground cover, starter plants may be spaced 6-10" apart for quick coverage. If mid-summer foliage decline occurs, plants may be cut back or sheared to stimulate new foliage growth.

The leaves of Lamium maculatum "Aureum" have a golden leaf color. Lamium maculatum "Ghost" is a cultivar with silver-white leaves. Lamium maculatum "Chequers" is a cultivar with a green leaf with a white stripe across the center.

Habitat: Sun



Spotted Dead Nettle with purple blossom in Summer
© *Garden Soft*

Spotted Joe-pye Weed

Eupatorium maculatum

This species thrives in part shade and moist soils. Taller plants may need to be staked - or plants can be cut back in the early summer to produce a shorter, fuller growth form. Divide the plants in fall as they go dormant, or in the spring just as shoots first appear. Cut back plants in the late winter.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Spotted Joe-pye Weed purple bloom in late Summer
© *W.D. and Dolphia Bransford*



Spotted Joe-pye Weed flowers
© *Stefan Bloodworth*

Spreading Oval Sedge
Carex normalis

Cut back in late winter or early spring.

Attracts birds. Food source for caterpillars.

Habitat: Shade



Spreading Oval Sedge seed head
© *Andrew Hipp*

St. John's Wort
Hypericum sphaerocarpum

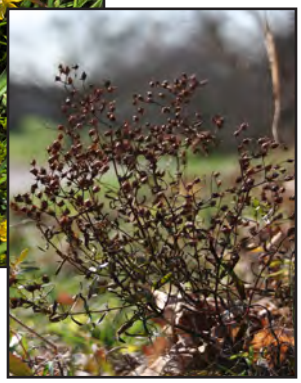
This species require full sun, but will grow in dry to moist soil. Spreads rapidly by underground runners creating a nice ground cover. The profuse flowers are open on the plant for a long period mid-summer. Requires thinning to prevent spread.

Attracts bees. Food source for caterpillars.

Habitat: Sun



St. John's Wort in bloom in Summer
© *Sally & Andy Wasowski*



St. John's Wort dormant in winter
© *Dropseed Nursery*

Lance-fruited Oval Sedge

Carex radiata

Drought tolerant groundcover for shady sites. Cut back in late winter.

Attracts birds.

Habitat: Shade



Star Sedge in Summer
© *Kansas State University*



Star Sedge in Summer
© *Kansas State University*



Star Sedge dormant in winter
© *Kansas State University*

Stiff Goldenrod

Solidago rigida

Stiff Goldenrod prefers full sun and dry to moist soil. This species has deep roots that allow it to compete well with native grasses. Can be weedy. May need to be divided every 2 to 3 years to control growth. Taller plants may need some support . Plants can be cut back mid-summer to create a shorter, fuller plant. Cut back plants in late winter.

Attracts bees and butterflies.

Habitat: Sun



Stiff Goldenrod in Fall
© *Mike Haddock*



Stiff Goldenrod in Winter
© *Dropseed Nursery*



Stiff Goldenrod bloom in Fall
© *Mike Haddock*

Stonecrop
Sedum ochroleucum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop in Summer
© *Qwertzy2*

Stonecrop
Sedum reflexum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop in Summer
© *Stonecrop in Summer*



Stonecrop in bloom in Summer
© *Stonecrop in bloom in Summer*

Stonecrop
Sedum sarmentosum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop as groundcover in Summer
© *Garden Soft*

Stonecrop
Sedum sexangulare

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop in Summer
© *Semolo75*

Stonecrop
Sedum sichotense

Mat-forming plant grows quickly and forms a nice groundcover. Leaves turn reddish orange in cooler temperatures.

Attracts butterflies.

Habitat: Sun



Stonecrop in Summer
© *Ghislain Chenais*

Stonecrop
Sedum dasyphyllum "Blue Ridge"

Mat-forming plant grows quickly and forms a nice groundcover. Leaves turn pink and purple in Autumn.

Attracts butterflies.

Habitat: Sun



Stonecrop "Blue Ridge" in Summer
© *Ghislain Chenais*

Stonecrop
Sedum album "Coral Carpet"

This small, spreading stonecrop typically grows 3-6" high and can somewhat quickly form a dense mat of foliage. New growth emerges salmon-orange (coral), matures to bright green and eventually turns reddish-bronze in winter.

Attracts butterflies.

Habitat: Sun



Stonecrop "Coral Carpet" in Spring
© *Missouri Botanical Gardens*



Stonecrop "Coral Carpet" as groundcover
© *Garden Soft*

Russian Stonecrop
Sedum kamtschaticum

Plants can be divided in the early spring. Stem or leaf cuttings can be taken in the early summer.

Attracts bees and butterflies.

Habitat: Sun



Golden Stonecrop
© *Stan Shebs*

Copy
© *Caption*

Russian Stonecrop

Sedum floriferum "Weihenstephaner Gold"

Low-growing stonecrop that forms a nice groundcover - prefers full sun and dry soil. Succulent leaves turn purple in fall and winter. Plants may be sited 12" apart when grown as a ground cover. Tip cuttings from plants may be rooted directly in soil around the plants.

Attracts bees and butterflies. Not attractive to deer and rabbits.

Habitat: Sun



Russian Stonecrop colony
© *Missouri Botanical Garden*

Stonecrop

Sedum rupestre "Sandy's Silver Crest"

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop "Sandy's Silver Crest" in bloom in July
© *Rob Broekhuis*

Stonecrop
Sedum middenorffianum "Striatum"

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun



Stonecrop in Summer
© *Qwertzy2*

Stout Blue-Eyed Grass "Lucerne"
Sisyrinchium angustifolium "Lucerne"

This low-growing perennial likes full sun and moist soil. Plants need to be divided at least every other year. "Lucerne" is noted for its profuse bloom of large, one inch diameter, star-like, intense blue flowers with yellow centers over a long May-June bloom period. This cultivar is not known for aggressively self-seeding. Makes a nice border planting.

Attracts bees.

Habitat: Sun



Stout Blue-Eyed Grass "Lucerne" foliage
© *Rob Broekhuis*



Stout Blue-Eyed Grass "Lucerne" in bloom in Spring
© *Missouri Botanical Garden*



Stout Blue-Eyed Grass flowers
© *Missouri Botanical Garden*

Stout Blue-Eyed Grass
Sisyrinchium angustifolium

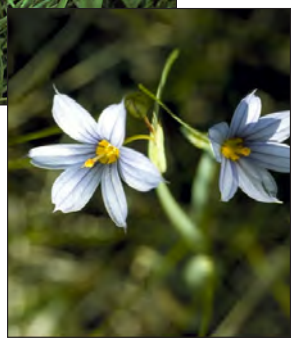
This species likes full sun and moist soil and makes a nice border planting. Plants need to be divided at least every other year.

Attracts bees.

Habitat: Sun



Stout Blue-Eyed Grass in bloom in Summer
© *Harry Cliffe*



Stout Blue-Eyed Grass blossom
© *Bennie Bengston*

Swamp Hibiscus
Hibiscus moscheutos

Although native to wetlands, this species grows well in soils that are just moist. Good for rain gardens. The flowers show a variety of colors varying from white with a red center to pale pink. Taller plants may need to be staked. Cut back in late winter. Japanese beetles can be a problem.

Attracts bees and hummingbirds. Food source for caterpillars.

Habitat: Sun



Swamp Hibiscus blossom
© *Sally & Andy Wasowski*



Swamp Hibiscus in winter
© *Dropseed Nursery*



Swamp Hibiscus in bloom in July
© *W.D. and Dolphia Bransford*

Swamp Milkweed
Asclepias incarnata

This plant require consistantly moist soil, and can grow in full sun or partial shade. Plants have deep taproots and are best left undisturbed once established. Foliage is slow to emerge in spring. Swamp milkweed will inevitably have aphids.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun



Swamp Milkweed blossom
© *Sally & Andy Wasowski*



Swamp Milkweed dormant in winter
© *Dropseed Nursery*



Swamp Milkweed in bloom in Summer
© *Mrs. Albert F.W. Vick*

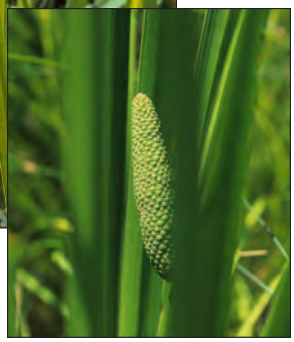
Sweet Flag
Acorus calamus

This plant requires wet soil and prefers full sun, but will tolerate dense shade. In water gardens, plant rhizomes slightly below the soil surface in moist soils at the water's edge or in containers set in shallow water. Rhizomes or existing clumps may also be planted in containers sunk into wet boggy areas to help prevent any possible invasive spread. Cut back dormant plant material in the winter months. Fragrant.

Habitat: Sun



Sweet Flag in Summer
© *R.A. Howard*



Sweet Flag seed head
© *Sally & Andy Wasowski*

Sweet Violet

Viola sororia "Freckles"

This plant prefers part to full shade and moist soil. Can be invasive in optimum growing conditions. Makes a nice groundcover.

Attracts butterflies and birds.

Habitat: Sun



Sweet Violet in bloom in Spring
© *Meneerke Bloem*

Switchgrass

Panicum virgatum

Bright green leaves occur up and down the stem with purple seed heads. Foliage turns bright yellow in fall. May form sizable colonies. One of the dominant tallgrass prairie species. Cut back dormant plant material in early spring

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun



Switchgrass in winter
© *Dropseed Nursery*



Switchgrass seed heads
© *Sally & Andy Waswoski*



Switchgrass at full height in Summer
© *Sally & Andy Waswoski*

Tall Coreopsis
Coreopsis tripteris

This very drought tolerant species prefers full sun and will thrive in moist to dry soils. Prompt deadheading of spent flowers may encourage additional bloom and prevents any unwanted self-seeding. Freely self-seeds, and in optimum growing conditions will naturalize to form large colonies. If grown in borders, division may be needed every 2-3 years to maintain robustness. Taller plants may need to be staked.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Tall Coreopsis in winter
© *Dropseed Nursery*



Tall Coreopsis blossom
© *Mike Haddock*



Tall Coreopsis in bloom in late Summer
© *W. D. and Dolphia Bransford*

Thimbleweed
Anemone virginiana

Spring blooming anemone that is not as aggressive as other varieties. Likes full sun to part shade and moist to dry soil. Flowers give way to thimble-shaped seed heads which remain on the plants well into winter. Three-parted leaves may carry a reddish tinge late into the season.

Attracts bees.



Thimbleweed bloom
© *Mike Haddock*



Thimbleweed in winter
© *Dropseed Nursery*



Thimbleweed in bloom in Spring
© *Thomas L. Muller*

Threadleaf Coreopsis

Coreopsis verticillata "Zagreb"

This drought tolerant species likes full sun and moist to dry soil. Plants may be sheared in mid to late summer to promote a fall rebloom and to remove any sprawling or unkempt foliage. 'Zagreb' can spread in the garden by rhizomes and self-seeding. 'Zagreb' is more compact (to 1.5' tall) and features bright yellow, daisy-like flowers (1-2" diameter).

Attracts bees. Not attractive to deer.

Habitat: Sun



Threadleaf Coreopsis flower
©*Missouri Botanical Garden*



Threadleaf Coreopsis in bloom in Spring
© *Conservation Garden Park*



Threadleaf Coreopsis dormant in winter
© *Conservation Garden Park*

Tickseed Sunflower

Bidens aristosa

This species prefers full sun to partial shade and moist soil. The prickly fruit of Bidens species are known as beggars-ticks, the very common, 2-pronged stickers that cling to clothing. It can be aggressive and is better suited to larger projects where spread is beneficial. Cut back plants in late winter.

Habitat: Sun



Tickseed Sunflower
©*Andy and Sally Wasowski*



Tickseed Sunflower blossom
© *Albert F.W. Vick*



Tickseed Sunflower in bloom in Fall
© *Lynn & Campbell Loughmiller*

Tickseed
Coreopsis "Jethro Tull"

This species prefers full sun and dry to moist soil. Plants may be sheared in mid to late summer (August) to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes, but reseeding will not occur. "Jethro Tull" is a compact golden-yellow coreopsis that grows inan upright, outward-spreading mound to only 18" tall. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Makes a good cut flower. Not attractive to deer. Will work planted in a container.

Habitat: Sun



Tickseed "Jethro Tull" in bloom in Summer



Tickseed "Jethro Tull" blossom
© *Missouri Botanical Garden*

Tickseed
Coreopsis lanceolata

This species will grow in either sun or shade and prefers dry soil. Very drought tolerant. Plants may be sheared in mid to late summer to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes and self-seeding to form large colonies. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Not attractive to deer.

Habitat: Sun



Tickseed seedling
© *Lady Bird Johnson Wildflower Center*



Tickseed blossom
© *Marcus A. Joseph*



Tickseed in bloom in Spring
© *Sally & Andy Wasowski*

Tickseed

Coreopsis palmata

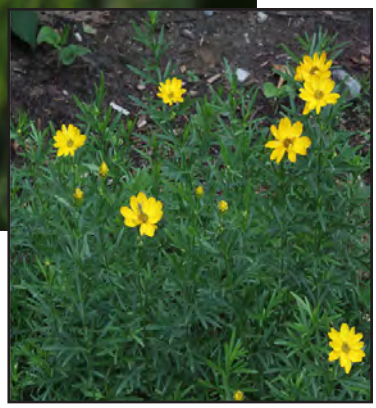
Grows in full sun to part shade and dry to moist soils. Very drought tolerant. Stiff-stemmed perennial. Plants may be sheared in mid to late summer (August) to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes and self-seeding. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Not attractive to deer. Make nice cut flowers.

Habitat: Sun



Tickseed in bloom in Spring
© *Sally & Andy Wasowski*



Tickseed in bloom in Spring
© *R.W. Smith*

Tunic Flower

Petrorhagia saxifraga "Lady Marie"

This very drought tolerant species prefers full sun. May self-seed. Good for borders or rock gardens. Cut back plants in late winter.

Habitat: Sun



Tunic Flower in bloom in Summer
© *Rob Broekhuis*



Tunic Flower blossom
© *Rob Broekhuis*

Tussock Sedge
Carex stricta

Used for erosion control. Forms large colonies. Older leaves turn straw brown as they die, and build up around the base of each clump surrounding the newer yellowish-green leaves. Cut back in late winter or early fall.

Attracts birds and butterflies. Food source for caterpillars. Provides cover for many wetland birds.



Tussock Sedge in Summer
© *Missouri Botanical Garden*

Two Row Stonecrop
Sedum spurium "Eco Mt. Emei"

Spreads quickly to form mats of dense stems and miniature foliage. Dead-head after flowering, to promote vegetative growth. Winter semi-evergreen with bronze foliage.

Attracts butterflies.

Habitat: Sun



Two Row Stonecrop in Summer
© *Conservation Water Park*

Virginia Wild Rye

Elymus virginicus

This plant will thrive in full sun and full shade. Prefers moist soild conditions. Characterized as a prairie grass it is often found in woodlands too. Cut back in late winter or early spring.

Attracts butterflies. Food source for ducks and Canadian geese.

Habitat: Shade



Virginia Wild Rye in Summer
© *Mike Haddock*



Virginia Wild Rye seed head
© *Mike Haddock*

Wall Germander

Teucrium chamaedrys "Summer Sunshine"

This species grows in full sun to part shade and moist soil conditions. Evergreen in mild winter regions. Plants may be pruned to maintain a low height, if desired.

Attracts butterflies and bees.

Habitat: Sun



Wall Germander flowers
© *Missouri Botanical Garden*



Wall Germander in bloom in Spring
© *Rob Broekhuis*



Wall Germander in bloom in Spring
© *Missouri Botanical Garden*

Water Horehound

Lycopus americanus

Prefers full sun and moist to wet soils. Spreads through taproot and abundant production of rhizomes. Good for controlling soil erosion and stabilizing restoration areas. Dormant plant material does not need to be cut back from plants in larger restoration areas to maintain plant vigor.

Attracts butterflies and bees.

Habitat: Sun



Water Horehound in bloom in Summer



Water Horehound blossom
© *Mike Haddock*

Water Plantain

Alisma subcordatum

Prefers full sun and wet soil. The small white flowers resemble baby's breaths. Leaves formed underwater are ribbon-like and soon rot; they are seldom seen on adult plants. Often forms colonies.

Attracts bees.

Habitat: Sun



Water Plantain in Summer
© *Sally & Andy Wasowski*



Water Plantain blossom
© *Harry Cliffe*

White Turtlehead
Chelone glabra

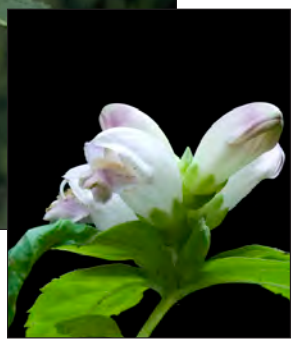
This species thrives in part shade and medium to moist soil. Appreciates a layer of composted leaf mulch, particularly in sunny areas. Pinching back the stem ends is encouraged in spring to reduce mature plant height, especially if growing plants in strongly shaded areas where they are more likely to need some support. In optimum environments, however, staking is usually not required. Cut back dead plant material during the winter months.

Attracts hummingbirds, bees and butterflies.

Habitat: Sun



White Turtlehead in bloom in late Summer
©W.D. and Dolphia Bransford



White Turtlehead blossom
© Steven Faucette

White Wood Aster
Aster divaricatus

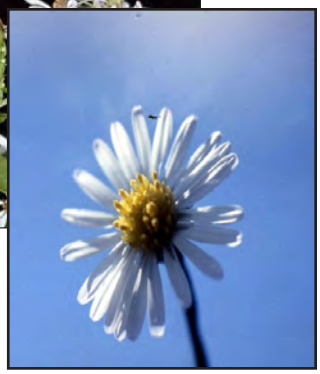
A good plant for dry, shady spots. White Wood Aster will flower in full shade and spreads readily.

Attracts bees and butterflies.

Habitat: Shade



White Wood Aster in bloom in late Summer
© George H. Bruso



White Wood Aster flower
© Robert Stone

Whorled Rosinweed
Silphium trifoliatum

This drought tolerant species prefers full sun and moist to dry soil. Taller stems may need support. Plants can be cut back in the early summer to promote a shorter statured form. Cut back dormant plant material in late fall or early spring.

Attracts birds, bees and butterflies.

Habitat: Sun



Whorled Rosinweed dormant in winter
© *Dropseed Nursery*



Whorled Rosinweed in bloom in late Summer
© *W.D. and Dolphia Bransford*

Wild Columbine
Aquilegia canadensis

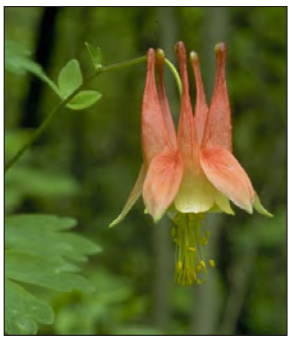
This species will grow in shade, or in sun with moist soil. Cut back the stems after flowering to promote a second bloom. This plant will self seed and spread. Wild Columbine is evergreen unless the temperature exceeds 110 degrees F or -10 degrees F, which will cause the leaves to go dormant until the temperature returns to a more tolerable level.

Attracts hummingbirds, butterflies and bees.

Habitat: Shade



Wild Columbine leaves in winter
© *Dropseed Nursery*



Wild Columbine blossom
© *Mariann Watkins*



Wild Columbine in bloom in Spring
© *Jerry Garrett*

Wild Geranium

Geranium maculatum

Prefers shade and moist, rich soil; however it will tolerate dry soil in shady conditions and will tolerate some sun if the soil is moist and rich. Plant colonizes by thick rhizomes but is not aggressive. Foliage may yellow in hot summers if soil is allowed to dry out. Leaves die back completely in the winter.

Attracts butterflies and bees.

Habitat: Shade



Wild Geranium in bloom in Spring
© *Sally & Andy Wasowski*



Wild Geranium blossom
© *Thomas L. Muller*

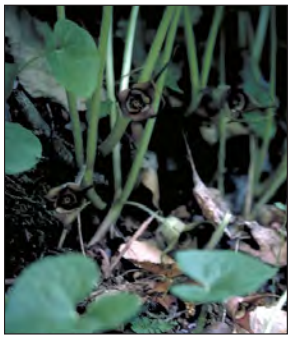
Wild Ginger

Asarum canadense

Prefers shade and moist, rich soil; however it will tolerate dry soil in shady conditions and will tolerate some sun if the soil is moist and rich. The solitary greenish-purple flower is at ground level, hidden below the leaves. Can create a dense groundcover over time. Evergreen in mild winters.

Attracts butterflies. Food source for caterpillars.

Habitat: Shade



Wild Ginger in bloom
© *Mrs.W.D.Bransford*



Wild Ginger flower
© *Stefan Bloodworth*



Wild Ginger colony in Spring
© *Sally & Andy Wasowski*

Wild Quinine

Parthenium integrifolium

Wild Quinine prefers full sun and tolerates a variety of soil conditions. This species spreads by underground rhizomes, but not aggressively. Cut back plants in late winter.

Attracts bees. Makes a nice cut flower.

Habitat: Sun



Wild Quinine blossom
© *Stefan Bloodworth*



Wild Quinine in winter
© *Dropseed Nursery*



Wild Quinine in bloom in late Summer
© *Thomas L. Muller*

Wild Senna

Senna hebecarpa

Prefers sun to part shade and moist soil. After the bloom period, long brown seed pods form and last through the winter. May need to be staked.

Attracts bees, butterflies and hummingbirds. Seed pods attract birds.

Habitat: Sun



Wild Senna blossom
© *Mike Haddock*



Wild Senna seed pods
© *Julie Makin*



Wild Senna in bloom in late Summer
© *Mike Haddock*

Wild Stonecrop
Sedum ternatum

Tolerates part shade and moist soils better than most other sedums. Stems break away and die in winter, leaving newly rooted plants separated from the mother plant. Spread by creeping by creeping stems. Makes a nice ground cover. Drought tolerant.

Attracts butterflies. Not attractive to deer or rabbits.



Wild Stonecrop blossom
© *Missouri Botanical Garden*



Wild Stonecrop blossom
© *W.D. and Dolphia Bransford*



Wild Stonecrop in bloom in Spring
© *W.D. and Dolphia Bransford*

Wingstem
Verbesina alternifolia

Will thrive in full sun or partial shade and moist soil. Weedy clump forming plant. Taller stems may need support. Cut back dormant plant material in the winter. This species provides winter interest in the garden - ice ribbons form along the stem of this species after the first winter's freeze.

Attracts butterflies and birds.

Habitat: Sun



Wingstem blossom
© *Mike Haddock*



Wingstem with ice ribbon in Winter
©*Glen Conner*



Wingstem in bloom in late Summer
©*Mike Haddock*

Wood Aster
Aster cordifolius

A good option for a dry, shady location. Occasionally the foliage is affected by powdery mildew and other kinds of disease during the fall. During hot dry weather, the lower leaves may wilt and fall off. The size of this plant is variable depending on the fertility of the soil and moisture conditions. Cut back dead plant material in the late winter.

Attracts butterflies and bees.

Habitat: Shade



Wood Aster in bloom in Fall
© *W.D. and Dolphia Bransford*



Wood Aster blossom
© *W.D. and Dolphia Bransford*

Woodland Brome
Bromus pubescens

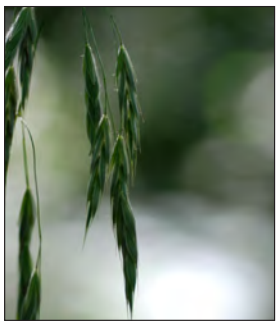
One of the taller grasses that will tolerate shade. Cut back in late winter or early spring.

Attracts birds.

Habitat: Shade



Woodland Brome flowers
© *Mike Haddock*



Woodland Brome seed head
© *Mike Haddock*



Woodland Brome in Summer
© *Mike Haddock*

Woodland Sunflower
Helianthus divaricatus

A plant for dry, shady sites. Very drought tolerant. Spreads over time by creeping rhizomes to form colonies. Divide every 3-4 years to control spreadand maintain vigor. Taller plants may need staking. Cut back plants in early spring to allow birds to feed on the seedheads during the winter months.

Attracts birds, bees and butterflies. Make nice cut flowers. Not attractive to deer.

Habitat: Shade



Woodland Sunflower in bloom in Fall
© *Albert F.W. Vick*



Woodland Sunflower blossom
© *Edwin M. Martin*

Woolgrass
Scirpus cyperinus

Good for erosion control when planted en masse. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. Cut back in late winter or early spring.

Attracts ducks and other wetland birds. Provides nesting habitat for many wetland birds. Food source for caterpillars.

Habitat: Sun



Woolgrass dormant in winter
© *Matthew L. Wagner*



Woolgrass in Summer
© *Elaine Haug*

Yellow Fox Sedge
Carex annectens

Prefers full to part sun and wet to moist conditions. Cut back in late winter or early spring. Good for erosion control.

Attracts birds. Food source for caterpillars. Not attractive to deer.

Habitat: Sun



Yellow Fox Sedge seed head in Spring
© *Sally & Andy Wasowski*



Yellow Fox Sedge seed head
© *R.W. Smith*

Zig-Zag Goldenrod
Solidago flexicaulis

This species will grown in full sun to full shade and moist soil. Will also grow in clay soils. Drought tolerant. Plants can be somewhat spreading in optimum growing conditions. Susceptible to powdery mildew and leaf spot.

Attracts birds and butterflies. Not attractive to deer.

Habitat: Shade



Zig-Zag Goldenrod in seed
© *Restoring the Landscape.com*



Zig-Zag Goldenrod blossom
© *Sally & Andy Wasowski*



Zig-Zag Goldenrod in bloom in Fall
© *Albert F.W. Vick*

Trees and Shrubs









Allegheny Serviceberry
Amelanchier laevis

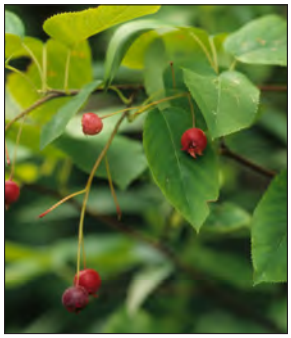
Serviceberry is a multiple-trunked tree or shrub, 15-25 ft. tall, with dense, fine-textured branching. Serviceberries are subject to many disease and insect problems, but damage from these problems is usually cosmetic rather than life threatening.

Attracts birds. Food source for caterpillars.

Habitat: Sun



Allegheny Serviceberry Flowers



Allegheny Serviceberry, edible berries ripen mid-summer
© *Sally & Andy Wasowski*



Allegheny Serviceberry in the spring
© *Mark Brand 1997-2001*

American Beech
Fagus grandifolia

Leaves turn copper-colored in the fall and hold on most of the winter. Beech develops suckers from its vast system of surface roots. Entire beech groves have often grown from the roots of a single tree. Shade tolerant. Long-lived. Not suitable for small areas. Resistant to many pests and diseases, though a barkfungus disease has proven fatal. Prune in summer or early fall. Root system is shallow, so it is difficult to grow grasses under beech.

Attracts butterflies, birds and other wildlife. Food source for caterpillars. Beechnuts is one of the most important food sources for wildlife.

Habitat: Sun



American Beech in early fall
© *Alfred Vick*



American Beech fruit
© *Benny Simpson*

American Bittersweet
Celastrus scandens

A high-climbing, twining, woody vine that produces small green flowers and distinctive bicolored fruits. Generally one male plant is needed for 6-9 female plants. Female plants may be vegetatively propagated to create more female plants. Prune in late winter to early spring.

Oriental Bittersweet is a very invasive introduced species that spreads easily into natural areas and reduces the diversity of native species. American Bittersweet fruits are arranged in clusters at the ends of the stems. Fruits of Oriental Bittersweet are located in the axils of the leaves along the entire length of the stem.

Attracts birds.

Habitat: Sun



American Bittersweet with early summer blossoms
© *Mike Haddock*

American Bittersweet, colorful fruit ripen in the fall
© *Mike Haddock*

American Hazelnut
Corylus americana

Prompt removal of root suckers will help maintain plant appearance, and, if desired, help prevent thicket formation. In spring before the leaves have emerged, male flowers appear in showy, 2-3" long, yellowish brown catkins and female flowers appear in small, reddish, inconspicuous catkins. Female flowers give way to small, egg-shaped, 1/2" long, edible nuts (maturing July-August) which are encased in leafy, husk-like, ragged-edged bracts. Fall color is quite variable, ranging from attractive combinations of orange, rose, purplish red, yellow and green to undistinguished, dull yellowish green. Plants can be pruned back to 50% of total size every 5 years to promote fruit production.

Attracts birds and other wildlife.



American Hazelnut, early spring with male flowers
© *Missouri Botanical Garden*



American Hazelnut female flower
© *Sally & Andy Wasowski*

American Hornbeam
Carpinus caroliniana

This slow-growing deciduous understory tree is known for its smooth gray trunk with muscle-like fluting, elliptic-oval dark green leaves and distinctive, pendulous seed clusters of winged nutlets, which appear in late spring after the flowering catkins. Leaves turn yellow, orange and red in fall. This species requires little pruning is not susceptible to disease or insect damage.

Habitat: Shade



American Hornbeam - fruit and fall color



American Hornbeam female flowers
© *Sally & Andy Wasowski*



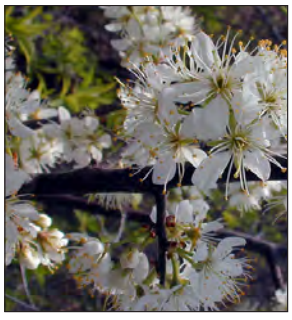
American Hornbeam's sinewy texture
© *Mark Brand 1997-2001*

American Plum
Prunus americana

A thicket-forming shrub or small tree with short trunk, many spreading branches, broad crown, showy large white flowers, and red plums. Fall foliage ranges from electric red to pale yellow. American Plum is sometimes grown for erosion control, spreading by root sprouts. This species has fragrant flowers and thorns. Plum curculio and brown rot can affect the fruit. Other potential disease problems include leaf spot, canker and black knot. Potential insect problems include aphids, scale, borers and tent caterpillars.

Attracts bees, birds and butterflies.

Habitat: Sun



American Plum, spring flowers
© *Mike Haddock*



American Plum, fruit
© *Mike Haddock*



American Plum with spring flowers
© *Mike Haddock*

American Smoketree
Cotinus obovatus

Once it is established within its range, this species thrives on tough conditions and neglect and should not be over-watered. Rich soil and too much water may create a weak plant. A small tree valued for its trunk and branches, cloud-like spring blooms, and standout fall foliage.

Attracts birds.

Habitat: Sun



American Smoketree, bark
© *Mark Brand 1997-2001*



American Smoketree, spring flowers
© *Albert F.W. Vick*



American Smoketree in fall color
© *Mark Brand 1997-2001*

Arrow-wood
Viburnum dentatum

Lustrous, dark-green foliage turns yellow to wine-red in fall. Suckers freely from base; suckers require periodic cutting unless a dense, thicket growth is desired. This species is adaptable to many soil types and moisture levels.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun



Arrow-wood, fruit
© *R.W. Smith*



Arrow-wood, spring flowers
© *Lynn & Campbell Loughmiller*



Arrow-wood in bloom, spring
© *Sally & Andy Wasowski*

Bald Cypress
Taxodium distichum

This lofty, deciduous conifer is slender and conical in youth, becoming flat-topped in very old age. Develops a buttressed trunk base. Exfoliating bark is red-brown to silver. Fall foliage is orange and red. Plants can experience damage from some insects and diseases; however are seldom severely damaged.

Attracts birds. Food source for caterpillars.

Habitat: Sun



Bald Cypress, in fall
© *Norman G. Flaigg*



Bald Cypress, in fall with developing cones
© *Marilyn Kircus*



Bald Cypress, mid-summer
© *David K. Northington*

Bitternut Hickory
Carya cordiformis

This is the most rapid growing of all hickory trees. It is difficult to transplant because of a large taproot, but perhaps less so than other hickories. Suffers from soil compaction and is sometimes weakened by its branching structure. In manicured areas, the small nuts can be a nuisance. Unlike other hickories, this species casts an open shade, allowing turf or ornamentals to thrive underneath. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun



Bitternut Hickory, mid-summer
© *Missouri Botanical Garden*

Black Cherry

Prunus serotina

This is a fast-growing, pioneer species. Young trees develop a long tap root which makes transplanting difficult. When open-grown it becomes oval-headed with spreading, pendulous limbs and arching branches. Crowded trees grow tall and slender. Aromatic tree; crushed foliage and bark have distinctive cherry-like odor. Fall foliage is yellow. Potential diseases include leaf spot, die back, leaf curl, powdery mildew, root rot and fireblight. Potential insects include aphids, scale, borers, leafhoppers, caterpillars, tent caterpillars and Japanese beetles. Spider mites may also be troublesome. Attracts bees, birds and butterflies. Food source for other wildlife.

Habitat: Sun



Black Cherry in flower
© *Missouri Botanical Garden*



Black Cherry with spring flowers
© *Mark H. Brand*



Black Cherry in winter
© *Paul Cox*

Black Chokeberry

Aronia melanocarpa

This very adaptable shrub will thrive in shade or sun, moist or dry soil. A native shrub option that stays fairly short - typically 5' tall. Remove root suckers to prevent colonial spread. Lustrous, dark green foliage turns an attractive purplish red in autumn. Deciduous shrub.

Attracts birds.

Habitat: Sun



Black Chokeberry, with fall color
© *Mark H. Brand*



Black Chokeberry, spring flowers
© *Missouri Botanical Garden*



Black Chokeberry, with ripe fruit in late summer
© *Missouri Botanical Garden*

Black Gum
Nyssa sylvatica

Tree with a dense, conical or sometimes flat-topped crown, many slender, nearly horizontal branches, and glossy foliage turning scarlet in autumn. Berries are small and blue. Female trees need a male pollinator to set fruit. This slow growing species transplants poorly due to a fleshy, non-fibrous root system. Black gum does not age gracefully and is occasionally troubled by insect and disease problems.

Attracts bees and birds.

Habitat: Sun



Black Gum in winter
© *Mark H. Brand*



Black Gum fruit forming in fall
© *Sally & Andy Wasowski*



Black Gum with fall color
© *Sally & Andy Wasowski*

Black Walnut
Juglans nigra

Slow-growing if not in its preferred moist, fertile, sunny site. Wide-spreading branches form an upright, umbrella-like crown in the woods or a round-topped crown in the open. The deep tap-root makes transplanting difficult. Nuts may become a nuisance as they litter and stain. Foliage is often attacked by caterpillars, and the species is susceptible to anthracnose which defoliates trees for the season. Certain plants such as azaleas, rhododendrons, blueberries, peonies and solanaceous crops (tomatoes, peppers, potatoes), will not grow under Black Walnut trees because of chemicals that the tree puts in the soil. Yellow fall foliage.

Attracts butterflies, bees, and birds. Food source for caterpillars, squirrels and other wildlife.

Habitat: Sun



Black Walnut mid-summer
© *Norman G. Flaigg*



Black Walnut in winter
© *Albert F.W. Vick*

Black Willow
Salix nigra

A fast-growing tree with an open crown and typically several trunks growing out at angles from one root. Short-lived and fast-growing. Susceptible to insect and wind damage. Used to control soil erosion.

Attracts bees, butterflies, birds and other wildlife. Food source for caterpillars.

Habitat: Sun



Black Willow fruit
© *Harry Cliffe*



Black Willow flowers
© *Joseph A. Marcus*



Black Willow in early spring
© *Joseph A. Marcus*

Blackhaw Viburnum
Viburnum prunifolium

Prune immediately after flowering to promote flowering in the following year. Black haw is usually grown as a large, upright, multi-stemmed, deciduous shrub with an irregular crown, but it also may be grown as a small, single trunk tree. Attractive shades of red and purple in the fall.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun



Blackhaw Viburnum in fall
© *Mark H. Brand*



Blackhaw Viburnum flowers
© *Missouri Botanical Garden*



Blackhaw Viburnum, spring flowering
© *Missouri Botanical Garden*

Blackjack Oak
Quercus marilandica

Slow-growing, long-lived, and able to survive on very poor soils. Susceptible to oak wilt. This tree can often have an irregular form in poor soil but develops a symmetrical attractive form in good soil with room to grow.

Attracts birds, butterflies and other wildlife. Food source for caterpillars.

Habitat: Sun



Blackjack Oak in fall
© *Missouri Botanical Garden*



Blackjack Oak leaves mid-summer
© *Missouri Botanical Garden*

Bur Oak
Quercus macrocarpa

Bur oak typically has a very wide, open crown. Usually wider than tall, the tree can exceed 100 ft. in height and width. The acorns of this species are the largest of all native oaks. Bur oak is drought resistant, long-lived and reasonably fast-growing for an oak. Tolerates limey soils better than other oaks. Resistant to oak wilt and a number of other problems. Sensitive to root zone disturbance caused by construction. Fall foliage is yellow.

Attracts birds, butterflies and other wildlife.

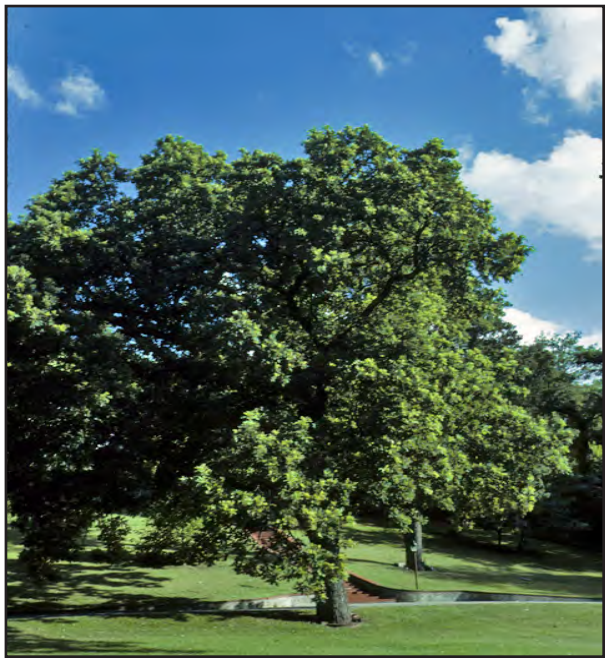
Habitat: Sun



Bur Oak in winter
© *Mark H. Brand*



Bur Oak leaves mid-summer
© *Sally & Andy Wasowski*



Bur Oak, mid-summer
© *Sally & Andy Wasowski*

Buttonbush
Cephalanthus occidentalis

Pruning is usually not necessary, but may be done in early spring to shape. If plants become unmanageable, however, they may be cut back near to the ground in early spring to revitalize. Trunks are often twisted. Fragrant flowers.

Attracts bees, birds and butterflies.

Habitat: Sun



Buttonbush fruit
© *Sandy Smith*



Buttonbush, late spring flowers
© *Norman G. Flaigg*



Buttonbush, mid-summer
© *Sally & Andy Wasowski*

Willow Oak
Quercus phellos

Willow Oak is a large sized deciduous oak with narrow, willow-like leaves. Fall foliage is yellow-brown. Grows best in moist soil.

Attracts birds and other wildlife.

Habitat: Sun



Chestnut Oak leaves in the fall
© *Missouri Botanical Garden*



Chestnut Oak in winter
© *Alfred F.W. Vick*



Chestnut Oak mid-summer
© *Missouri Botanical Garden*

Chinese Dogwood

Cornus kousa

Chinese Dogwood is a small, deciduous flowering tree or large multi-stemmed shrub with a vase-shaped habit in the early years, eventually maturing to a more rounded habit. Crimson and scarlet fall colors. This plant has better disease resistance and better cold hardiness than the native flowering dogwood, and is an excellent alternative to flowering dogwood in areas where dogwood anthracnose is a problem.

Attracts birds and butterflies.

Habitat: Sun



Chinese Dogwood, winter
© *Mark H. Brand*



Chinese Dogwood, spring blooms
© *Mark H. Brand*



Chinese Dogwood, spring
© *Mark H. Brand*

Cockspur Hawthorn

Crataegus crus-galli

Cock-spur hawthorn is a small, globular, deciduous tree with a short trunk; exfoliating bark; horizontal, thorny branches which sweep the ground; and thick, glossy foliage which turns bright orange or red in fall. The low, densely set branches make it difficult to grow grasses under this tree. The tree is susceptible to fire blight, several species of rust, and insect damage, but is tolerant of city pollution. Prune in winter or early spring.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun



Cockspur Hawthorn, winter
© *Mark H. Brand*



Cockspur Hawthorn, fall
© *Mark H. Brand*



Cockspur Hawthorn, mid-summer
© *Mark H. Brand*

Common Elderberry
Sambucus canadensis

This is a loose, graceful, deciduous shrub grows to 12 ft. in height. Prune heavily in winter to maintain shape. Elderberry is a fast grower and aggressive competitor with weeds and herbaceous species. Individual plants are very short-lived; however, root masses produce new shoots. Cutting the whole bush to the ground every other year may be necessary to keep the bushes in check.

Attracts bees, butterflies and birds.

Habitat: Sun



Common Elderberry, early summer flower
© *Mark H. Brand*



Common Elderberry, in winter
© *Mark H. Brand*



Common Elderberry, in flower
© *Mark H. Brand*

Common Ninebark
Physocarpus opulifolius

A mound-shaped, thicket-forming deciduous shrub, Common Ninebark offers spiraea-like flowers, attractive and persistent fruit pods, arching branches, yellow fall color, and exfoliating bark. It is a fast-growing shrub, insect and disease resistant, and drought-tolerant. Prune as needed immediately after bloom. Plants may be cut to the ground in winter to rejuvenate.

Attracts birds.

Habitat: Shade



Common Ninebark, in winter
© *Mark H. Brand*



Common Ninebark, spring flowers
© *Stefan Bloodworth*



Common Ninebark leaves
© *Mark H. Brand*

Coralberry

Symphoricarpos orbiculatus

The greenish-white flower clusters are not as showy as the clusters of coral-pink to purple berries up to 1/4 inch in diameter which remain on the plant through winter. Coralberry forms extensive colonies and spreads by rooting at the nodes where it touches the ground. Can be pruned to limit spread and maintain shape. Not susceptible to diseases or insect damage.

Attracts birds and small mammals.

Habitat: Shade



Coralberry in the winter
© *Dropseed Nursery*



Coralberry in the fall with fruit
© *Sally & Andy Wasowski*



Coralberry, mid-summer
© *Sally & Andy Wasowski*

Crossvine

Bignonia carpreolata

Crossvine is sometimes seen high in a tree, as the vine climbs by means of tendrils, allowing it to cling to stone, bricks and fences without support. Persistent, glossy, semi-evergreen leaves change from dark green in summer to reddish-purple in winter. Above ground stems are not reliably winter hardy throughout USDA Zone 5 where they may die to the ground in severe winters (roots are usually hardy therein and will sprout new growth the following spring).

Attracts bees, hummingbirds and butterflies.

Habitat: Sun



Crossvine
© *Ray Matthews*



Crossvine flowers
© *Campbell & Lynn Loughmiller*

Devil's Walking Stick

Aralia spinosa

Will grow in partial shade to full sun and in moist to dry soils. Colonizes freely by rhizomes and suckers. These can be dug out, however it is still too aggressive for small spaces. Has thorns.

Attracts bees, butterflies and birds.

Habitat: Sun



Devil's Walking Stick with flowers in the spring
© *Paul Cox*



Devil's Walking Stick with ripe fruit in the fall
© *Sally and Andy Wasowski*



Devil's Walking Stick, summer
© *Mark H. Brand*

Cornelian Cherry Dogwood

Cornus mas

This dogwood is a multi-stemmed, low-branching, round to oval, deciduous shrub or tree. Can be trained as a small tree by removal of suckers and lower branches. Fall foliage has a purple tinge. Very early spring bloom.

Attracts birds.

Habitat: Sun



Cornelian Cherry Dogwood, bark
© *Mark H. Brand*



Cornelian Cherry Dogwood, spring bloom
© *Mark H. Brand*



Cornelian Cherry Dogwood, summer
© *Mark H. Brand*

Eastern Hophornbeam

Ostrya virginiana

A tree with a trunk that looks like sinewy muscles and a rounded crown of slender, spreading branches. Fruits are borne in a hanging, hop-like structure. Resistantto insects (except the gypsy moth), disease, wind, ce, and most stresses of urban living. Notoriously sensitive to salt. Slow-growing. Yellow fall foliage.

Attracts birds and other wildlife.

Habitat: Sun



Eastern Hophornbeam in winter
© *Mark H. Brand*



Eastern Hophornbeam, emale flowers
© *Mike Haddock*



Eastern Hophornbeam in summer
© *Sally & Andy Wasowski*

Eastern Red Cedar

Juniperis virginiana

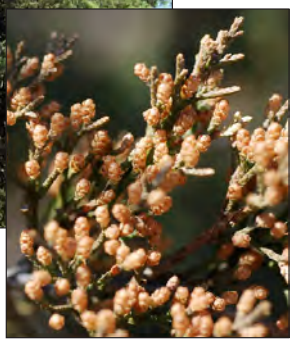
Evergreen, aromatic tree with trunk often angled and buttressed at base and narrow, compact, columnar crown; sometimes becoming broad and irregular. Pale blue fruits occur on female plants. Foliage may turn brown-green in winter. Root rot and cedar rusts are the most common diseases to harm this species; overall, fairly disease resistant.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun



Eastern Red Cedar- an evergreen
© *Sally & Andy Wasowski*



Eastern Red Cedar male flowers
© *Mike Haddock*

European Hornbeam

Carpinus betulus "Globosa"

Needs little pruning when grown as a tree, but respondswell to hard pruning if grown as a hedge. Best pruned during the period of late summer to mid-winter to avoid significant bleeding. Yellow and orange fall colors.

Attracts birds.

Habitat: Sun



European Hornbeam flowers in winter
© *Gary J. King*



European Hornbeam fruit and leaves
© *Bernheim Forest*



European Hornbeam in summer
© *Bernheim Forest*

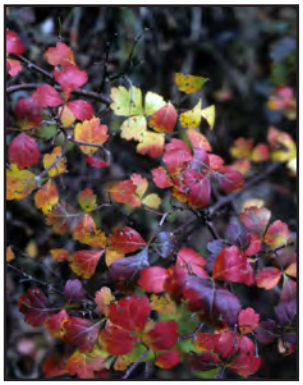
Fragrant Sumac

Rhus aromatica

This shrub turns fall colors of red, yellow and orange. Fragrant sumac colonizes to form thickets and looks best when planted en mass or in drift-like plantings as it occurs in nature. Leaves and twigs are aromatic when bruised. Separate male and female plants – only the female plants produce red berries.

Attracts bees, butterflies, and birds. Food source for a large variety of caterpillars.

Habitat: Sun



Fragrant Sumac, fall color
© *Sally & Andy Wasowski*



Fragrant Sumac berries



Fragrant Sumac in summer
© *Norman G. Flaigg*

Fringe Tree

Chionanthus virginicus

Shrub or small tree with short trunk, narrow, oblong crown, and showy masses of fragrant, lacy, white flowers. Seldom needs pruning. Fall foliage is yellow.

Attracts birds. Food source for caterpillars.

Habitat: Sun



Fringe Tree in winter
© *Mark H. Brand*



Fringe Tree flower
© *Sally & Andy Wasowski*



Fringe Tree in summer

Fullmoon Maple

Acer japonicum "Taki No Gawa"

Leaves emerge with bronze tones, mature to green and develop excellent deep purple, orange and red fall colors. Site in locations protected from strong winds. Stake trunk for more erect growth or leave alone for spreading effect.

Habitat: Shade



Fullmoon Maple in summer
© *Bernheim Forest*



Fullmoon Maple flowers in the spring
© *Bernheim Forest*

Green Hawthorn

Crataegus viridis

Thicket-forming tree with straight, often fluted, trunk and rounded, dense crown of spreading branches, shiny foliage, showy flowers, and small red to yellow fruit. Prune in winter or early spring. Purple and red fall color.

Attracts bees, birds and butterflies. Food source for caterpillars.

Habitat: Sun



Green Hawthorn in flower
© *Sally & Andy Wasowski*



Green Hawthorn flowers
© *Stefan Bloodworth*



Green Hawthorn in fruit
© *Sally & Andy Wasowski*

Hackberry

Celtis occidentalis

Branches of this and other hackberries may become deformed bushy growths called witches-brooms produced by mites and fungi. The leaves often bear rounded galls caused by tiny jumping plant lice. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun



Hackberry in summer
© *Mark H. Brand*



Hackberry in winter
© *Mark H. Brand*



Hackberry in fall
© *Mark H. Brand*

Higan Cherry
Prunus subhirtella

Potential diseases include leaf spot, die back, leaf curl, powdery mildew, root rot and fireblight. Potential insects include aphids, scale, borers, leafhoppers, caterpillars, tent caterpillars and Japanese beetles. Spider mites may also be troublesome.

Attracts bees, birds and butterflies.

Habitat: Sun



Higan Cherry with spring flowers
© *Missouri Botanical Garden*



Higan Cherry flowers
© *Missouri Botanical Garden*

Honey Locust
Gleditsia triacanthos

Fall color is yellow. Seed pods change from red-green to maroon-brown as they mature and persist into winter. Most wild trees are not thornless; the long, needle-sharp thorns are extremely vicious and are not desirable in urban areas. Gleditsia triacanthus "Inermims" Thornless Honey Locust is an ideal choice for domestic applications. Honey locust is fast-growing and long-lived. It suffers from mites, Mimosa webworm invaders, a number of cankers, and other pests. Exhibits drought-, heat-, high pH-, and salt-tolerance. Its filtered shade makes underplanting easy.

Attracts butterflies, bees, birds and other wildlife. Food source for caterpillars.

Habitat: Sun



Honey Locust in winter
© *Missouri Botanical Garden*



Honey Locust in summer
© *Missouri Botanical Garden*



Honey Locust in fall
© *Missouri Botanical Garden*

Kentucky Coffeetree

Gymnocladus dioicus

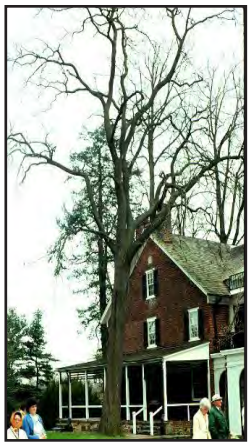
Kentucky coffeetree is resistant to disease and insect problems and adaptable to drought, heat, cold, salt and city conditions. The tree is slow-growing. Occasional root suckers should be pulled. Prune in winter or early spring. Large pods can be messy in manicured settings. When crowded by other trees, this species grows tall and slender. If more open-grown, it becomes a round-topped tree. Fall foliage is yellow-green.

Attracts butterflies, bees, and birds.
Food source for caterpillars.

Habitat: Sun



Kentucky Coffeetree with fruit on female tree
© *Mark H. Brand*



Kentucky Coffeetree in fall
© *Mark H. Brand*



Kentucky Coffeetree in summer
© *Mark H. Brand*

Leadplant

Amorpha fruticosa

Plants develop a leggy character with the majority of their pinnately compound, fine-textured foliage on the upper third of the plant. Can be weedy and invasive. Useful as a shrub to colonize erosion prone areas.

Attracts butterflies and bees. Food source for many species of caterpillars.

Habitat: Sun



Leadplant with mid-summer flowers
© *R.W. Smith*



Leadplant, mid-summer
© *R.W. Smith*



Leadplant in summer
© *Paul Cox*

Meadowsweet
Spiraea alba

Meadowsweet likes wet soil and full sun. Remove spent flower clusters to promote additional bloom.

Attracts bees, butterflies and birds. Food source for caterpillars. Not attractive to deer. Makes nice cut flowers.

Habitat: Sun



Meadowsweet flowers with butterfly
© *Missouri Botanical Garden*



Meadowsweet flowers
© *W.D. and Dolphia Bransford*



Meadowsweet in flower mid-summer
© *Sally & Andy Wasowski*

New Jersey Tea
Ceanothus americanus

Thick, woody, red roots go deep and help plant withstand droughty conditions, but make established shrubs difficult to transplant. Fragrant flowers.

Attracts bees, butterflies and hummingbirds.

Habitat: Shade



New Jersey Tea fruit
© *Julie Makin*



New Jersey Tea flowers
© *Missouri Botanical Garden*



New Jersey Tea flowering in spring
© *Sally & Andy Wasowski*

Oak-leaf Hydrangea
Hydrangea quercifolia

Susceptible to sunscald, chlorosis in alkaline soils, and winter dieback. Many weak, brittle canes are easily broken in wind and ice. Forms colonies from a shallow root system. Canes can be cut to the ground every two or three years to keep the shrub smaller, but if the canes are allowed to grow, the naturally peeling bark is attractive. Pest free. Prune immediately after flowering. Foliage turns bronze and crimson in the fall.

Habitat: Shade



Oak-leaf Hydrangea flowers
© *W.D. and Dolphia Bransford*



Oak-leaf Hydrangea in winter
© *Dropseed Nursery*



Oak-leaf Hydrangea flowering in July
© *W.D. and Dolphia Bransford*

Ohio Buckeye
Aesculus glabra

Branches bend toward the ground then arch back up, creating a rounded outline. Fall color is usually yellow, although foliage may develop interesting and attractive shades of orange and red in some years. It can be difficult to grow grass under Ohio buckeye because of the dense foliage. It is one of the first trees to leaf out in the spring and lose its foliage in fall. In hot, droughty situations, leaf blotch, leaf scorch and a variety of other physiological and pest problems can be serious.

Attracts hummingbirds, birds and squirrels.

Habitat: Sun



Ohio Buckeye leaves, fall color
© *Mark H. Brand*



Ohio Buckeye flowers
© *Julie Makin*



Ohio Buckeye in early spring
© *Julie Makin*

Pasture Rose
Rosa carolina

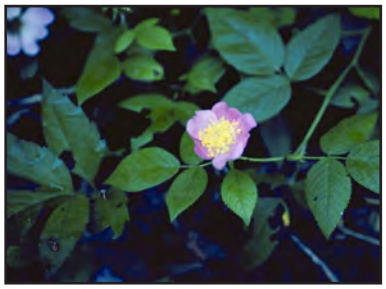
Remove and destroy diseased leaves from plants, and clean up and destroy dead leaves from the ground around the plants both during the growing season and as part of a thorough clean-up during winter. Crowns appreciate protection in cold winter climates. Prune in late winter to early spring. Fragrant flowers.

Attracts bees, butterflies and birds.

Habitat: Sun



Pasture Rose fruit
© *Missouri Botanical Garden*



Pasture Rose flowering in early summer
© *Mrs. W.D. Bransford*



Pasture Rose flowers
© *Sally & Andy Wasowski*

Peach-leaf Willow
Salix amygdaloides

Medium-sized tree with one or sometimes several straight trunks, upright branches, and spreading crown. Short-lived and fast-growing. Susceptible to insect, disease, and wind damage. Used for erosion control.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun



Peach-leaf Willow flowers
© *Robert L. Carr*



Peach-leaf Willow leaves
© *Robert L. Carr*



Peach-leaf Willow in spring
© *Robert L. Carr*

Persimmon

Diospyros virginiana

This tree is valued for its fruit and attraction to wildlife. Two trees are necessary for the production of fruit. Fruit is not edible until exposed to frost or consistent low temperatures. Promptly remove root suckers unless naturalized effect is desired. Because of a deep root system, successful underplanting is possible. Size of tree can vary greatly depending on soil.

Attracts birds. Food source for caterpillars.

Habitat: Sun



Persimmon bark
© *Mark H. Brand*



Persimmon fruit in fall
© *Mark H. Brand*



Persimmon, summer
© *Mark H. Brand*

Pin Oak

Quercus palustris

Pin oak is a strongly pyramidal tree with a straight-trunk, spreading horizontal branches, very slender pinlike twigs, and a broadly conical crown. Susceptible to iron chlorosis which causes yellow coloration in the leaves through the summer months and can eventually kill the tree. Pin oak is shallow-rooted and easily transplanted, and it will tolerate urban conditions. Fall foliage is red.

Attracts birds, butterflies, hummingbirds and other wildlife. Food source for caterpillars.

Habitat: Sun



Pin Oak leaves in fall
© *Mark H. Brand*



Pin Oak in winter
© *Mark H. Brand*



Pin Oak, mid-summer
© *Mark H. Brand*

Possumhaw Holly
Ilex decidua

Plants of this species are mostly separate male and female, although some plants have perfect flowers (complete flowers with functioning stamens and pistils). For best show of berries, plant female plants, with at least one male plant to insure that pollination will take place. Prune to shape in early spring just before new growth begins. Berries persist through the winter and into the early spring when new growth begins.

Attracts bees, birds and other mammals.

Habitat: Sun



Possumhaw Holly in winter
© *W.D and Dolphia Bransford*



Possumhaw Holly flowers
© *Harry Cliffe*



Possumhaw Holly mid-summer
© *Sally & Andy Wasowski*

Pussy-Willow
Salix discolor

Pussy willow is a narrow shrub or small tree to 20 ft. with multiple trunks and dark-gray, scaly bark. Short-lived and fast-growing, pussy willows should be cut back heavily every few years to encourage new growth. This plant is susceptible to insect, disease, and wind damage and tends to sucker to the point of being invasive if given continuously moist soil.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Pussy-Willow flower buds
© *Missouri Botanical Garden*



Pussy-Willow male flowers
© *Missouri Botanical Garden*



Pussy-Willow in winter
© *Missouri Botanical Garden*

Red Chokeberry
Aronia arbutifolia

A very adaptable shrub that will thrive in sun or shade and in moist or dry soil. Remove root suckers to prevent colonial spread. This species typically grows in a vase-shaped form to 6-10' tall and to 3-6' wide, but tends to sucker and form colonies. Foliage turns bright red in autumn.

Attracts birds.

Habitat: Shade



Red Chokeberry fruit
© *Mark H. Brand*



Red Chokeberry with spring flowers
© *Mark H. Brand*



Red Chokeberry, mid-summer
© *Mark H. Brand*

Red Oak
Quercus rubra

Its straight trunk is clear of branches for some distance above the ground and supports a wide canopy, commonly 3/4 that of height. Fall foliage can be crimson, golden-orange, or russet. One of the most rapid-growing oaks, it transplants easily, is hardy in city conditions, and endures cold.

Attracts butterflies, hummingbirds, birds and other wildlife. Food source for caterpillars.

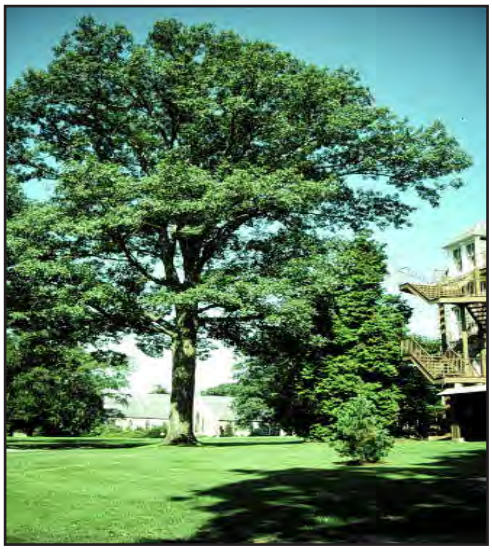
Habitat: Sun



Red Oak in falls
© *Mark H. Brand*



Red Oak in winter
© *Mark H. Brand*



Red Oak, mid-summer
© *Mark H. Brand*

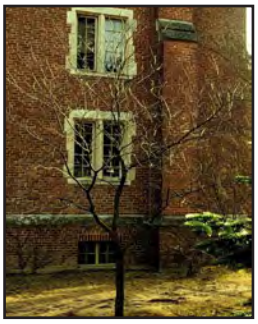
Redbud

Cercis canadensis

Single or multi-stemmed trunk with a wide umbrella-like crown. Showy pink flowers hug the branches and trunk in the spring. Since this tree does not transplant easily, it should be planted when young. Fall foliage may turn yellow. Redbuds are subject to damage by insect pests such as tree hoppers, caterpillars, scale, and leafhoppers. Diseases include Verticillium wilt, leaf spots, and the worst disease, canker. Spreads easily by seed.

Attracts butterflies and birds.

Habitat: Sun



Redbud in winter
© *Mark H. Brand*



Redbud flowers
© *Julie Makin*



Redbud in flower, spring
© *Albert F.W. Vick*

River Birch

Betula nigra

River birch is fast growing and long-lived and is probably our the most trouble-free birch. Do not prune until summer when the sap has stopped flowing. The tree's selling point is its satiny, silver bark that peels to reveala cinnamon-brown trunk beneath. Fall foliage is yellow but seldom effective.

Attracts birds.

Habitat: Sun



River Birch in winter ©
Mark H. Brand



River Birch bark
© *Mark H. Brand*



River Birch, mid-summer
© *Mark H. Brand*

Sassafras
Sassafras albidum

The aromatic sassafras is a deciduous tree with horizontal branching in cloud-like tiers. Sassafras can sucker into a small grove, but is easily controlled as a single tree. Large taproot makes transplanting of established trees difficult. If root suckers are not removed, tree will spread and begin to take on the appearance of a large multi-stemmed shrub. It is an appropriate tree to introduce into disturbed sites with infertile soil. Fall foliage is yellow, purple and red.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Sassafras fruit
© *Missouri Botanical Garden*



Sassafras in winter
© *Missouri Botanical Garden*



Sassafras with fall color
© *Missouri Botanical Garden*

Shagbark Hickory
Carya ovata

This is the hickory with bark that peels in longcurls off the straight trunk. Tough to transplant, because of a large taproot, and slow to grow. Sensitive to disturbance once established. Undisturbed trees are fairly disease resistant. Leaves turn yellow to golden brown in fall.

Attracts birds. Squirrels harvest nuts.

Habitat: Shade



Shagbark Hickory leaves
© *Missouri Botanical Garden*



Shagbark Hickory bark
© *Albert F.W.Vick*



Shagbark Hickory, mid-summer
© *Mark H. Brand*

Shellbark Hickory

Carya laciniosa

Can be difficult to transplant because of its deep taproot. Cross-pollination generally produces a more abundant crop of better quality nuts. Shellbark nuts are the largest in size of the hickories.

Attracts birds and butterflies. Squirrels harvest nuts.

Habitat: Sun



Shellbark Hickory, leaves
© *Vern Wilkens*



Shellbark Hickory, mid-summer
© *Vern Wilkens*



Shellbark Hickory, bark
© *Vern Wilkens*

Shrubby St. John's Wort

Hypericum prolificum

Blooms on new growth. Prune in early spring. Bark of older branches exfoliates and reveals an orange inner bark in fall. A dry, dehiscent, three-valved capsule persists all winter. Very drought tolerant and disease resistant.

Attracts bees and other insects. Food source for caterpillars.

Habitat: Sun



Shrubby St. John's Wort in winter
© *Dropseed Nursery*



Shrubby St. John's Wort flower
© *Stefan Bloodworth*



Shrubby St. John's Wort in flower, summer
© *George H. Bruso*

Shumard Oak

Quercus shumardii

Shumard Oak is a fast-growing, pyramidal tree, growing 50-90 ft. and becoming more open at maturity. This species is quite drought resistant and also withstands short-term flooding. Can be difficult to transplant and establish. Fall foliage is scarlet.

Attracts butterflies, birds and other wildlife. Food source for caterpillars.

Habitat: Sun



Shumard Oak leaves
© *Chris Evans*



Shumard Oak and acorns
© *Sally & Andy Wasowski*



Shumard Oak with fall color
© *Sally & Andy Wasowski*

Silky Dogwood

Cornus amomum

Branches that touch the ground may root at the nodes. When left alone, this shrub may spread to form thickets. Good plant for colonizing and stabilizing stream banks. Twigs are purplish brown in spring.

Attracts birds.

Habitat: Shade



Silky Dogwood flower
© *Missouri Botanical Garden*



Silky Dogwood fruit
© *Mark H. Brand*



Silky Dogwood with fruit
© *Sally & Andy Wasowski*

Smooth Alder
Alnus serrulata

A multiple-trunked, suckering shrub or small tree, 12-20 ft. tall, with a picturesque habit and shiny gray-brown bark. Yellow and red fall colors. The wood is weak and breakage is common. Very flood tolerant. Alders fix nitrogen and thus serve as nutrient-giving pioneers in reclamation projects.

Attracts birds.

Habitat: Sun



Smooth Alder in summer
© *Karen A. Rawlins*



Smooth Alder male flowers
© *Sally & Andy Wasowski*



Smooth Alder in winter
© *John Ruter*

Sourwood
Oxydendrum arboreum

Tree with conical or rounded crown of spreading branches, clusters of flowers recalling Lily-of-the-valley. Open-grown sourwood is pyramidal and branched to the ground. If grown in shadier situations, the deciduous tree develops a taller, more columnar crown on a limbless trunk. Sourwood leaves turn a brilliant, deep-red in early fall. This species is not typically susceptible to insects or diseases.

Attracts bees and birds.



Sourwood flowers
© *Sally & Andy Wasowski*



Sourwood with fall color
© *Sally & Andy Wasowski*



Sourwood in flower, mid-July
© *Sally & Andy Wasowski*

Southern Blackhaw

Viburnum rufidulum

Slow-growing. With its waxy leaves, Southern Blackhaw presents excellent fall hues of red, lavender, pink, and orange. More than one plant should be used in order to facilitate proper pollination necessary for abundant fruit production. Promptly remove root suckers to prevent colonial spread unless naturalization is desired.

Attracts butterflies and birds.

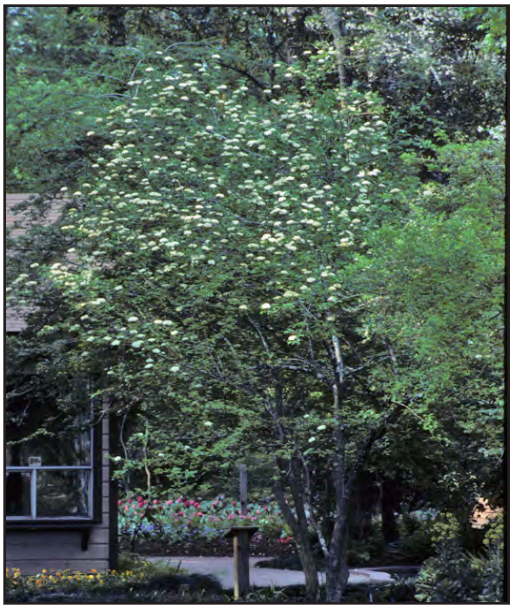
Habitat: Sun



Southern Blackhaw with fall color
© *Stefan Bloodworth*



Southern Blackhaw flowers
© *Lee Page*



Southern Blackhaw in flower, spring
© *Sally & Andy Wasowski*

Spicebush

Lindera benzoin

In fall, foliage turns yellow with female plants developing attractive but sometimes hidden red berry-like drupes. Hardy, fast-growing bush. Yellow leaf color in the fallLeaves are aromatic when crushed.

Attracts bees, butterflies, and birds. Food source for a large variety of caterpillars. Will tolerate clay soil. Not attractive to deer.

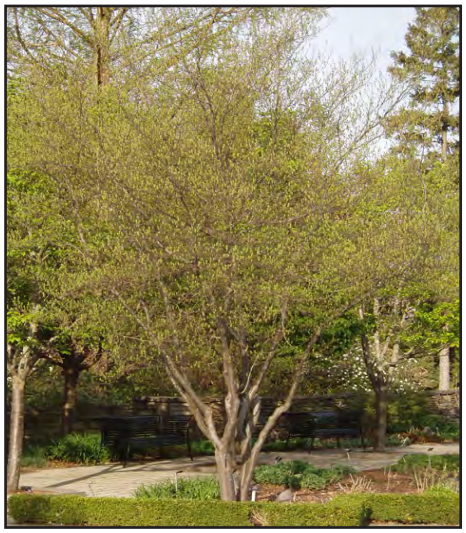
Habitat: Shade



Spicebush with fall color
© *Mark H. Brand*



Spicebush berries
© *Mark H. Brand*



Spicebush in early spring
© *Julie Makin*

Staghorn Sumac
Rhus typhina

Staghorn Sumac reaches tree size more often than related species and commonly forms thickets. This shrub is most effective when drifts or colonies, typical of natural settings, are allowed to establish. Can be used for erosion control. Colonies can be rejuvenated every few years by cutting them to the ground in mid-winter. Only female plants produce flowers and berries. Berries persist through winter. Attractive fall colors of red, orange and yellow.

Attracts bees and birds. Berries are a food source for a large variety of birds.

Habitat: Sun



Staghorn Sumac with fall color
© *Mark H. Brand*



Staghorn Sumac with fruit
© *John Hixson*



Staghorn Sumac, mid-summer
© *Albert F.W.Vick*

Steeplebush
Spiraea tomentosa

Dense, erect, plumes of pink to rose-purple flowers occur at the tips of the stems. The orange to reddish-brown bark has a peeling texture; the fall foliage is yellow. This species forms flowers on new wood, so prune in late winter to early spring if needed. Spreads by suckers to form colonies. Keep suckers cut back if single-stemmed form is desired. Susceptible to many of the diseases that attack other rose family members, including leaf spot, fire blight and powdery mildew.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun



Steeplebush in flower, summer
© *George H. Bruso*



Steeplebush in flower, summer
© *Stefan Bloodworth*

Strawberry Bush
Euonymus americanus

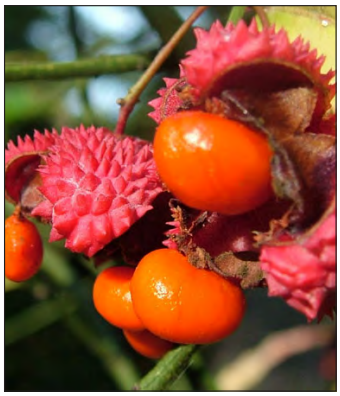
Its ridged twigs become purplish when exposed to the sun. Bright green, oval leaves become dark red in fall when bright red fruits open to reveal orange seeds. Strawberry Bush will spread by underground runners forming small thickets. The stems are relatively weak and taller plants often lean against other shrubs or trees for support.

Attracts birds and other wildlife.

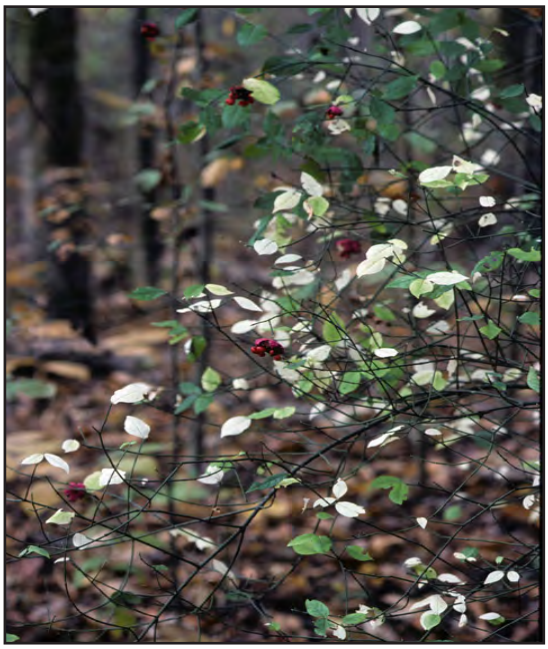
Habitat: Shade



Strawberry Bush flower
© *Chris Evans*



Strawberry Bush fruit
© *Stefan Bloodworth*



Strawberry Bush in fruit
© *Sally & Andy Wasowski*

Sugar Maple
Acer saccharum

Large tree with rounded, dense crown and striking, multicolored foliage in autumn. The dense shade and shallow roots of sugar maple may preclude growing lush grass under its canopy. Has been frequently used as a street tree, but is generally intolerant of road salt, soil compaction and pollution.

Attracts birds.

Habitat: Shade



Sugar Maple, winter
© *Mark H. Brand*



Sugar Maple, mid-summer
© *Mark H. Brand*



Sugar Maple, fall
© *Mark H. Brand*

Sugarberry

Celtis laevigata

This tree tolerates wind, many urban pollutants and a wide range of soil conditions, including poor soils and is often planted along sidewalks and parking lots. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun



Sugarberry fruit
© *Franklin Bonner*



Sugarberry leaves
© *Melody Lytle*



Sugarberry mid-summer
© *Sally & Andy Wasowski*

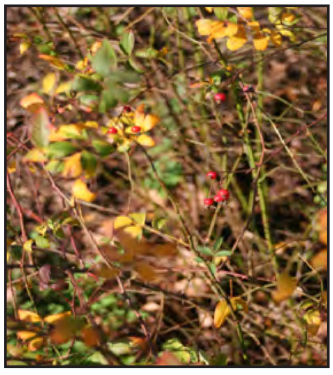
Swamp Rose

Rosa palustris

Swamp rose is an upright deciduous shrub with arching branches. Prune as needed in late winter. Plants slowly spread by suckers. Leaves often turn attractive shades red in fall. Forms attractive red fruits in the fall

Attracts bees, butterflies and birds.

Habitat: Sun



Swamp Rose in winter
© *Dropseed Nursery*



Swamp Rose with fall fruits
© *Missouri Botanical Garden*



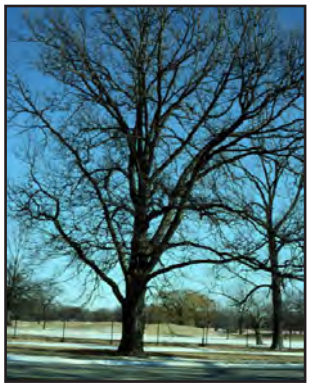
Swamp Rose, summer flowers
© *Sally and Andy Wasowski*

Swamp White Oak
Quercus bicolor

This is one of the faster growing oaks and appears to be more tolerant than similar oaks to landscape use. Swamp white is susceptible to iron chlorosis and prefers somewhat acidic soils. Leaves turn yellow to reddish purple in fall. Mature trees have distinctive, scaly-ridged, gray-brown bark.

Attracts birds and butterflies.

Habitat: Sun



Swamp White Oak in winter
© *Mark H. Brand*



Swamp White Oak male flowers
© *Mark H. Brand*



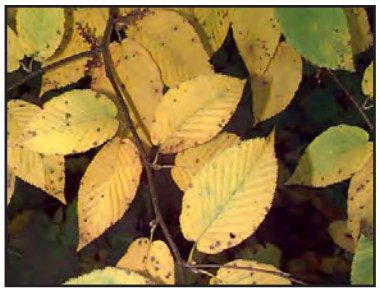
Swamp White Oak, mid-summer
© *Mark H. Brand*

Sweet Birch
Betula lenta

Conical in youth, the deciduous tree becomes ovoid to globular in maturity. Aromatic tree with rounded crown of spreading branches and odor of wintergreen in crushed twigs and foliage. Fall color is golden-yellow and the flower is a catkin that appears before leaf emergence. Do not prune until summer when the sap has stopped flowing.

Attracts birds.

Habitat: Shade



Sweet Birch, leaves with fall color
© *Mark H. Brand*



Sweet Birch in winter
© *Mark H. Brand*

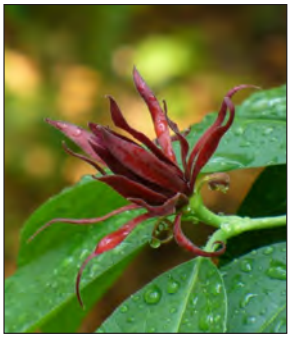


Sweet Birch mid-summer
© *Mark H. Brand*

Sweet Shrub
Calycanthus floridus

Prune immediately after flowering to shape or maintain compactness. Tends to sucker and often forms colonies in the wild. Remove root suckers promptly if naturalization is not desired. Fragrant flowers and aromatic leaves when crushed. Golden yellow fall color.

Habitat: Shade



Sweet Shrub flower
© *Jeff McMillian*



Sweet Shrub in summer
© *Mark H. Brand*



Sweet Shrub fall color
© *Mark H. Brand*

Sweetgum
Liquidambar styraciflua

Can become aggressive in moist, sandy soils. It is not drought-tolerant and does not do well in polluted areas or small areas which limit root development. It grows rapidly and is long-lived, adapting to a variety of sites. It is susceptible to iron chlorosis in soil which is too basic. Plant only in spring as roots, they take 3-4 months to recover from the shock of transplanting. Fall foliage is yellow, orange, purple and red, and will become colorful even without cold temperatures. Gum balls mature to dark brown and usually remain on the tree through the winter, but can create clean-up problems during the general period of December through April as the clusters fall to the ground and do not decompose. Because of this, "Fruitless" cultivars such as Liquidamber styracifula "Rotundiloba" are recommended for urban applications.

Attracts birds.

Habitat: Sun



Sweetgum, mid-summer
© *Sally & Andy Wasowski*



Sweetgum, fall color
© *Benny Simpson*

Sycamore
Platanus occidentalis

The bark of large, old trunks sloughs off in scales or plates leaving a smooth, whitish inner bark. Globular fruits often persist through December. Large, medium- to dark-green, maple-shaped leaves turn brown in fall. Sycamore anthracnose is a significant disease that can severely damage the foliage and twigs, often precipitating premature leaf drop. Canker, leaf spot and powdery mildew may also occur.

Attracts birds and other wildlife.

Habitat: Sun



Sycamore fruit
© *Steven Schwartzman*



Sycamore bark
© *Mark H. Brand*



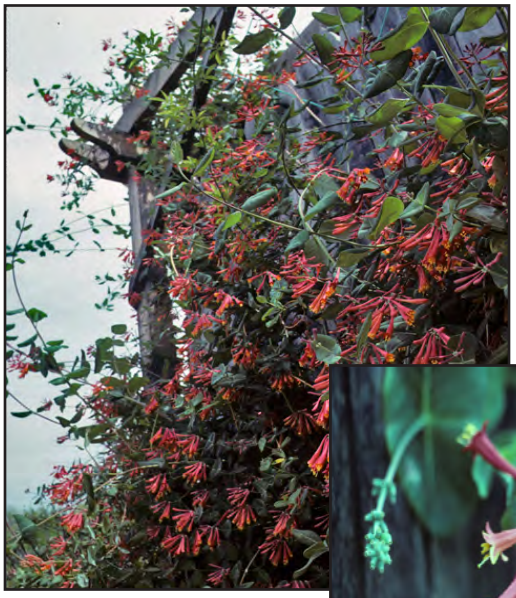
Sycamore, mid-summer
© *Mark H. Brand*

Trumpet Honeysuckle
Lonicera sempervirens

This vine can be a good climber or ground cover. Blooms are followed by bright red berries. Blooms primarily on previous year's stems, so prune to shape after flowering. Trumpet honeysuckle requires light, good air circulation, and adequate drainage to prevent powdery mildew. Some structural assistance may be necessary to help it begin climbing

Attracts bees, birds, hummingbirds and butterflies.

Habitat: Shade



Trumpet Honeysuckle in flower
© *Sally & Andy Wasowski*



Trumpet Honeysuckle flowers
© *Sally & Andy Wasowski*

Tulip Poplar
Liriodendron tulipifera

Tulip Poplar has a medium to narrow crown. Showy, yellow-orange, tulip-like flowers are often missed because they are found 50 ft. or higher in the tops of trees. Cone-shaped seed heads remain after leaves have fallen. Golden fall foliage. Tulip Poplar is insect and disease free. It is intolerant of compacted soil and should not be placed in confined beds or planters near pavement.

Attracts bees, butterflies, hummingbirds and birds. Food source for caterpillars.

Habitat: Sun



Tulip Poplar, mid-summer
© *Mark H. Brand*



Tulip Poplar in winter
© *Mark H. Brand*



Tulip Poplar flower
© *Mark H. Brand*

Virgin's Bower
Clematis virginiana

Virgin's Bower is a vigorous, deciduous, twining vine with a rampant growth habit. Lacking tendrils, the vine supports itself by means of twisted stems, or petioles, that wrap around other plants. Branches may be pruned at any time during the growing season. To encourage bushiness, prune stems in the spring to within a few feet off the ground. Climbs well on narrow supports such as twigs or wire fences. Can spread aggressively by self-seeding and suckering.

Attracts bees, hummingbirds and butterflies.

Habitat: Shade



Virgin's Bower in flower
© *W.D. and Dolphia Bradsford*



Virgin's Bower with open seed pods
© *Albert F.W.Vick*

Virginia Sweetspire

Itea virginica

Can form dense colonies by root suckering. Fragrant tiny white flowers and strong red and purple fall colors that persist into winter make this plant a desirable ornamental.

Attracts bees, butterflies, hummingbirds and birds.

Habitat: Shade



Virginia Sweetspire, fall color
© *Mark H. Brand*



Virginia Sweetspire flowers
© *Mark H. Brand*



Virginia Sweetspire in flower
© *Mark H. Brand*

Wahoo

Euonymus atropurpureus

Wahoo is a deciduous, shrub or small tree which is most often grown for its attractive red berries and fall color. Susceptible to scale.

Attracts bees, birds and other wildlife. Food source for caterpillars.

Habitat: Sun



Wahoo in winter
© *Julie Makin*



Wahoo fall color
© *Missouri Botanical Garden*



Wahoo fruit
© *Missouri Botanical Garden*

White Oak
Quercus alba

White Oak has wide spreading branches and a rounded crown, the trunk irregularly divided into spreading, often horizontal, stout branches. The round-lobed leaves turn burgundy in fall. Dried leaves remain into winter. Old trees are sensitive to construction disturbance in their root zone and to planting turf around the tree

Attracts birds and butterflies.

Habitat: Sun



White Oak, mid-summer
© *Mark H. Brand*



White Oak in winter
© *Mark H. Brand*



White Oak leaves, fall color
© *Mark H. Brand*

White Pine
Pinus strobus

The largest northeastern conifer, a magnificent evergreen tree with straight trunk and crown of horizontal branches, becoming broad and irregular. Rapid-growing and long lived. Landscape size and shape can be controlled through pruning to the extent that white pine may be sheared and grown as a hedge.

Attracts birds and other wildlife.

Habitat: Shade



White Pine, an evergreen
© *Albert F.W. Vick*



White Pine cones
© *Albert F.W. Vick*

Wild Hydrangea

Hydrangea arborescens

Wild hydrangea suckers freely, creeping over large areas. It is susceptible to sunscald, chlorosis in alkaline soils, and winter dieback. Many weak, brittle canes are easily broken in wind and ice. Fast-growing and short-lived, this hydrangea is often treated as an herbaceous perennial and cut to the ground every winter. If the canes are allowed to grow, the naturally peeling bark is attractive. Blooms on new season growth. Fall foliage is insignificant.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Shade



Wild Hydrangea leaves
© *Mark H. Brand*



Wild Hydrangea flowers
© *Mark H. Brand*



Wild Hydrangea in flower
© *Mark H. Brand*

Willow Oak

Quercus phellos

Readily transplanted because of shallow roots. A popular street and shade tree with fine-textured foliage that turns yellow to red in the fall.

Attracts birds, butterflies, and other wildlife. Food source for caterpillars.

Habitat: Sun



Willow Oak, mid-summer
© *Mark H. Brand*



Willow Oak leaves
© *Sally & Andy Wasowski*

Winterberry
Ilex verticillata

The leaves of Common winterberry are not shaped with sharp teeth like other hollies and are not evergreen. The purplish green foliage turns black, in fact, with the first frost. Winterberry has separate male and female plants; only females will produce the attractive red berries that persist through the winter. Generally one male winterberry will be sufficient for pollinating 9-10 female plants. Prune to shape in early spring just before new growth appears.

Attracts bees, birds and other mammals. Food source for caterpillars.

Habitat: Shade



Winterberry, mid-summer
© *Mark H. Brand*



Winterberry in winter
© *Mark H. Brand*



Winterberry fruits
© *Stefan Bloodworth*

Witch Hazel
Hamamelis virginiana

This small tree or tall shrub is often multi-trunked and usually grows 10-15 ft. tall but can reach 35 ft. in height. The large, crooked, spreading branches form an irregular, open crown. Promptly remove suckers to prevent colonial spread. Little pruning is required. Prune in early spring if necessary. Fragrant yellow flowers appear in the fall and persist after leaf drop. Fall foliage is gold.

Attracts birds.

Habitat: Sun



Witch Hazel in summer
© *Mark H. Brand*



Witch Hazel with winter flowers
© *Mark H. Brand*



Witch Hazel with fall color
© *Mark H. Brand*

Yellowwood

Cladrastis kentukea

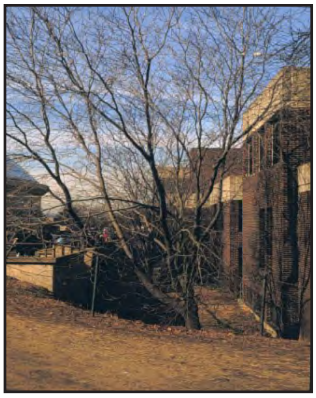
Showy, pendent, foot-long spikes of cream-colored flowers appear in quantity only two or three times a decade. Fall color is a delicate orange or yellow. Yellowwood has deep roots which make transplanting difficult but allows for other species to thrive underneath. Corrective pruning is often necessary to eliminate weak branch forks. Do not prune in the spring or immediately after transplanting. Summer is best for pruning.

Attracts birds and butterflies.

Habitat: Sun



Yellowwood, fall color
© *Mark H. Brand*



Yellowwood in winter
© *Mark H. Brand*



Yellowwood in spring with flowers
© *Mark H. Brand*



Japanese Sedge colony in spring

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Grasses											
Autumn Moor Grass	Sesleria autumnalis	E	-	GR	-	0.75-1	green	y	Sept-Oct		
Big Bluestem	Andropogon gerardii	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	1.6	
Blue Fescue	Festuca amethystina "Superba"	E	-	GR	-	0.5	white	y	May-June		
Blue Fescue	Festuca glauca "Elijah Blue"	E	-	GR	-	.75-1	green	n	June-July		
Blue Fescue	Festuca ovina "glauca"	E	-	GR	-	1	green	y	June-July		
Blue-joint Grass	Calamagrostis canadensis	N	UPL	UR, B	low	2-4	green	n	June-July	1.25	
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Broomsedge	Andropogon virginicus	N	FACU	UR, U, B	high	2-3	yellow	y	Aug-Sept	1.2	
Indian Grass	Sorghastrum nutans	N	UPL	UR, B, U, R	medium	1-3	yellow	y	Aug-Sept	2	
Japanese Sedge	Carex morrowii "Ice Dance"	E	-	GR	-	.5-1	green	n	June-July		
June Grass	Koeleria macrantha	N	UPL	UR, U, GR	low	1-2	yellow	n	May-June	1.6	
Lilttle Bluestem	Schizachyrium scoparium "The Blues"	C	FACU-	B, U, GR	medium	2-4	purple	y	Aug-Oct	1	
Little Bluestem	Schizachyrium scoparium	N	FACU-	UR, B, U, GR	medium	2-3	yellow	y	Aug-Sept	1	
Oval-headed Sedge	Carex cephalophora	N	FACU	UR, B	medium	1	green	n	May	0.75	
Poverty Grass	Danthonia spicata	N	UPL	UR, GR	high	1	green	n	June		
Prairie Dropseed	Sporobolus heterolepis	N	UPL	GR, U, B, UR	low	1-3	green	y	July-Sept	1	
Prairie Dropseed	Sporobolus heterolepis "Tara	C		GR, U		1-3	brown	y	July-Sept	1	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Shortbeak Sedge	Carex brevior	N	UPL	UR, U	medium	1-2	yellow	n	May-June		



Ladybells bloom in Summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Grasses *(continued)*											
Side-oats Grama	Bouteloua curtipendula	N	UPL	UR, GR, U	low	1.5-2.5	yellow	y	July-Aug	0.66	
Silky Wild Rye	Elymus villosus	N	FACU-	UR, B	medium	1-2	yellow	n	June		
Silver Sedge	Carex morrowii "Silver Sceptre"	E	-	GR	-	1	green	n	June-July		
Switchgrass	Panicum virgatum	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	1	
Sun — Dry Site — Forbs/Flowers											
Alpine Thrift	Armeria juniperifolia	E	-	GR	-	.5-1	pink	y	May-July		
Ashy Sunflower	Helianthus mollis	N	NI	B, U, UR	low	2-4	yellow	n	Aug-Sept		
Balloon Flower	Playtcodon grandiflorus "Sentimental Blue"	E	-	GR	-	0.5-1	blue	n	July-Aug		
Basal Balm	Monarda clinopodia	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		
Beardtongue	Penstemon digitalis "Husker Red"	C	-	GR	-	2-3	white	n	April-June		
Beardtongue	Penstemon hirsutus "pygmaeus"	C	-	GR	-	.5	violet	n	June-July		
Bee Balm	Monarda fistulosa	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	
Bellflower	Campanula trachelium	E	-	GR	-	1.5	blue	n	June-Aug		
Bitter Root	Lewisia longipetala "Little Plum"	E	-	GR	-	0.5	pink	n	May-Sept		
Black-eyed Susan	Rudbeckia hirta	N	FACU-	B, U, UR	medium	2-3	yellow	n	June-Sept	0.8	
Blue-Stemmed Goldenrod	Solidago caesia	N	FACU	U, B, UR	medium	1-2	yellow	n	Sept-Oct		
Bundleflower	Desmanthus illinoensis	N	FAC	R, B	high	2-3	white	n	July	1	
Butterfly Milkweed	Asclepias tuberosa	N	NI	U, B, UR	medium	1-2.5	orange	n	June-Aug		
Catmint	Nepeta faassenii "Blue Wonder"	E	-	GR	-	.5-1	blue	n	May-Sept		



Purple Coneflower colony in bloom

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
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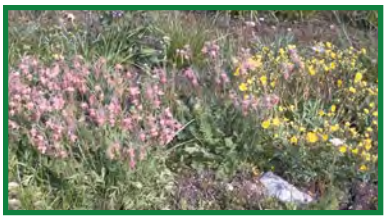
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Catmint	Nepeta faassenii "Walker's"	E	-	GR	-	1-3	blue	n	May-Sept		
Cheddar Pinks	Dianthus subacaulis "Gary Eichhorn"	E	-	GR	-	1	pink	n	May-July		
Chives	Allium schoenoprasum	E	-	GR	-	1-1.5	purple	n	April-May		
Cinquefoil	Potentilla neumanniana "Nana"	E	-	GR	-	0.25-0.5	yellow	n	April-June		
Compass Plant	Silphium laciniatum	N	NI	B, U, UR	low	5-8	yellow	n	July-Sept	15	
Cranesbill	Geranium cantabrigiense "Biokovo"	E	-	GR	-	.5-1	pink	n	May-June		
Cranesbill	Geranium cantabrigiense "Karmina"	E	-	GR	-	.5-1	red	n	May-June		
Cranesbill grandiflorus	Geranium sanguineum "Max Frei"	E	-	GR	-	.5-.75	purple	n	May-June		
Creeping Baby's Breath	Gypsophila repens "Alba"	E	-	GR	-	0.5	white	n	June-July		
Creeping Baby's Breath	Gypsophila repens "Rosea"	E	-	GR	-	0.5	pink	n	June-July		
Creeping Thyme	Thymus praecox	E	-	GR	-	0.25-0.5	purple	y	June-Sept		
Culver's Root	Veronicastrum virginicum	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		
Cushion Spurge	Euphorbia polychroma	E	-	GR	-	1.5	yellow	y	May		
Cylindrical Blazing Star	Liatris cylindracea	N	UPL	U, UR	low	1-2	purple	n	July-Oct		
Cypress Spurge	Euphorbia cyparissias "Fen's Ruby"	E	-	GR	-	1-1.5	yellow	n	April-June		
Downy Alum Root	Heuchera americana	N	FACU-	UR, U	medium	1-2	white	n	June-Aug		
Downy Alum Root	Heuchera americana "Dale's Strain"	C	-	GR	-	1-2	pink	n	June-Aug		
Dwarf Balloon Flower	Platycodon	E	-	GR	-	1-2.5	blue	n	June-Aug		
Dwarf Bearded Iris	Iris pumila "Baby Blessed-yellow"	E	-	GR	-	1	yellow	n	June		



Geum in bloom in Summer

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Dwarf Bearded Iris	Iris pumila "Sarah Taylor"	E	-	GR	-	1	blue and	n	June		
Early Goldenrod	Solidago juncea	N	UPL	U, UR	medium	2-4	yellow	y	June-Sept		
Elm-leaved Goldenrod	Solidago ulmifolia	N	UPL	UR, U	medium	3	yellow	y	July-Nov		
False Aloe	Manfreda virginica	N	UPL	UR, GR	medium	4	yellow	n	July		
False Blue Indigo	Baptisia australis	N	NI	B, U, UR	low	3-4	blue	n	May-June		
False Sunflower	Heliopsis helianthoides	N	NI	B, U, UR	medium	4-6	yellow	n	June-Oct		
Frost Aster	Symphyotrichum pilosum (Aster pilosus)	N	UPL	U, B, UR	o	2-5	white	n	Sept-Oct	0.8	
Fumitory	Corydalis lutea	E	-	GR	-	1-1,5	yellow	n	May-Sept		
Geum	Geum triflorum	E	-	GR	-	.5-1.5	pink	n	May-July		
Goat's Rue	Tephrosia virginiana	N	UPL	UR, U	medium	1-3	pink	n	May-June		
Golden Alexanders	Zizia aurea	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Golden Stonecrop	Sedum acre "Aureum"	E	-	GR	-	.25-.5	yellow	y	June-July		
Grass-leaved Goldenrod	Euthamia graminifolia	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		
Gray Goldenrod	Solidago nemoralis	N	NI	U, GR, UR	high	2-4	yellow	y	Sept-Oct	1	
Gray-headed Coneflower	Ratibida pinnata	N	NI	B, U, UR	medium	3-5	yellow	n	July-Aug	1.2	
Hairy Alum Root	Heuchera villosa	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		
Hairy Beardtongue	Penstemon hirsutus	N	NI	B, U, UR	medium	1-2	pink	n	May-June		
Hardy Ice Plant	Delosperma congestum	E	-	GR	-	0.1-0.2	yellow	n	June-Sept		
Harebell	Campanula rotundifolia	E	-	GR	-	.5-1.5	blue	n	June-Sept		



Dwarf Balloon Flower in bloom

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Hens and Chicks	Sempervivum montanum "Braunii"	E	-	GR	-	0.5	ma-genta	y	June-July		
Hens and Chicks	Sempervivum tectorum "Hart"	E	-	GR	-	0.5-1	purple	y	June-July		
Ironweed	Vernonia gigantea	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		
Knautia	Knautia macedonica	E	-	GR	-	1.5-2	bur-gandy	n	July-Sept		
Ladybells	Adenophora confusa	E	-	GR	-	2-3	blue	n	May-July		
Lamb's Ears	Stachys byzantina "Big Ears"	E	-	GR	-	0.5-1	Purple	n	rarely flow-ers		
Lamb's Ears	Stachys byzantina "Silver Carpet"	E	-	GR	-	0.25-0.5	none	n	rarely flow-ers		
Late Boneset	Eupatorium serotinum	N	FAC-	UR, U	high	2-4	white	n	July-Oct		
Lyre-leaved Sage	Salvia lyrata	N	UPL	B, U, UR	high	1-2	blue	n	April-June		
Meadow Blazing Star	Liatris ligulistylis	E	-	GR	-	1-3	purple	n	July-Sept		
Mexican Sedum	Sedum hispanicum "Diploid"	E	-	GR	-	0.3'	white	n	July-Aug		
Nodding Wild Onion	Allium cernuum	N	NI	UR, U, GR	low	1-2	white	n	July		
Ornamental Onion	Allium tanguticum "Summer Beauty"	E	-	GR	-	1-1.5	purple	n	July		
Ornamental Onion	Allium thunbergii "Ozawa"	E	-	GR	-	.5-1	purple	n	August		
Ornamental Oregano	Origanum laevigatum	E	-	GR	-	1-2	purple	n	July-Sept		
Pale Indian Plantain	Arnoglossum atriplicifolium	N	NI	UR	medium	3-6	white	n	July-Aug		
Pasque Flower	Pulsatilla vulgaris	E	-	GR	-	0.75-1	violet	n	April-May		
Phlox	Phlox paniculata	N	FACU	UR, B	medium	3-5	pink	n	July-Sept		
Pinks	Dianthus carthusianorum	E	-	GR	-	1.5	pink	n	May-June		



Black-eyed Susan colony in bloom

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Prairie Dock	Silphium terebinthinaceum	N	UPL	B, U, UR	low	5-10	yellow	n	July-Sept		
Prairie Onion	Allium stellatum	E	-	GR	-	1-1.5	pink	n	July-Sept		
Purple Coneflower	Echinacea purpurea	N	NI	GR, U, B, UR	low	3-5	purple	n	June-Aug	2	
Purple Prairie Clover	Dalea purpurea	N	UPL	GR, U, UR	low	1	purple	n	June-Sept	1.25	
Pussytoes	Antennaria dioica	E	-	GR	-	.1-.2	white	n	May-July		
Rattlesnake Master	Eryngium yuccifolium	N	FAC	B, U	low	3-4	white	y	July-Sept		
Rose Wine Sage	Salvia nemorosa "Rosenwein"	E	-	GR	-	1-1.5	rose	n	June-Sept		
Rough Blazing Star	Liatris aspera	N	NI	U, UR	low	1-3	purple	n	Aug-Sept		
Round-headed Lespedeza	Lespedeza capitata	N	FACU-	U, B, UR	low	1-2	purple	n	Aug-Sept	1.5	
Russian Stonecrop	Sedum kamtschaticum "Akibono"	E	-	GR	-	0.5	yellow	n	July		
Salvia	Salvia nemorosa "Marcus"	E	-	GR	-	0.5-1	violet	n	June-Sept		
Sea Thrift	Armeria maritima	E	-	GR	-	.5-1	pink	n	April-May		
Sedum	Sedum acre Oktoberfest	E	-	GR	-	.25-.5	white	y	July-Aug		
Showy Goldenrod	Solidago speciosa	N	UPL	UR, U	medium	1-3	yellow	y	Sept-Oct		
Small Yellow Onion	Allium flavum	E	-	GR	-	1	yellow	n	July		
Smooth Blue Aster	Symphyotrichum laeve (Aster laevis)	N	UPL	U, B, UR	medium	2-4	blue	y	Sept-Oct	0.8	
Snow-In-Summer	Cerastium tomentosum "Silver Carpet"	E	-	GR	-	.5-1	white	n	May-June		
Soapwort	Saponaria lempergii "Max Frei"	E	-	GR	-	0.75-1.5	pink	n	March-April		



Hens and Chicks in bloom in early Summer

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Spiderwort	Tradescantia bracteata	E	-	GR	-	1-1.5	purple	n	May-July		
Spotted Dead Nettle	Lamium maculatum "Aureum"	E	-	GR	-	1	purple	y	May-Sept		
Spotted Dead Nettle	Lamium maculatum "Chequers"	E	-	GR	-	1	purple	y	May-Sept		
St. John's Wort	Hypericum sphaerocarpum	N	FAC	U, UR, B	medium	1-2	yellow	n	June-Sept		
Stonecrop	Sedum album "Coral Carpet"	E	-	GR	-	0.25-0.5	pink	y	May-June		
Stonecrop	Sedum dasyphyllum "Blue Ridge"	E	-	GR	-	0.5-1	white	n	June-July		
Stonecrop	Sedum hybridum "Immergrunchen"	E	-	GR	-	0.3'	yellow	y	July-Aug		
Stonecrop	Sedum middendorffianum "Striatum"	E	-	GR	-	0.5	yellow	y	June-July		
Stonecrop	Sedum ochroleucum	E	-	GR	-	0.5	yellow	n	July		
Stonecrop	Sedum reflexum	E	-	GR	-	0.5	yellow	n	June-July		
Stonecrop	Sedum rupestre "Sandy's Silver Crest"	E	-	GR	-	0.5	yellow	n	July		
Stonecrop	Sedum sarmentosum	E	-	GR	-	0.5	yellow	n	May-June		
Stonecrop	Sedum sexangulare	E	-	GR	-	0.3	yellow	y	June-July		
Stonecrop	Sedum sichotense	E	-	GR	-	0.5	yellow	y	July		
Stout Blue-Eyed Grass	Sisyrinchium angustifolium "Lucerne"	N	FACW-	U, UR	medium	1	blue	n	May-June	0.3	
Sweet Violet	Viola sororia "Freckles"	C	-	GR	-	0.6	violet	n	April-May		
Tall Coreopsis	Coreopsis tripteris	N	FAC	U	medium	6-8	yellow	n	Aug-Sept		
Threadleaf Coreopsis	Coreopsis verticillata "Zagreb"	E	-	GR	-	1-1.5	yellow	n	May-June		



Ironweed in bloom in late summer

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Tickseed	Coreopsis lanceolata	E	-	GR	-	1-2	yellow	n	May-July		
Tunic Flower	Petrorhagia saxifraga "Lady Marie"	E	-	GR	-	0.5	pink	n	June-Oct		
Two Row Stonecrop	Sedum spurium "Eco Mt. Emei"	E	-	GR	-	0.5	yellow	n	July		
Wall Germander	Teucrium chamaedrys "Summer Sunshine"	E	-	GR	-	0.75-1	purple	n	May		
Whorled Rosinweed	Silphium trifoliatum	N	NI	B, U, UR	medium	4-6	yellow	n	July-Aug		
Wild Geranium	Geranium maculatum	N	FACU	UR, R	medium	1	violet	n	April-May		
Wild Quinine	Parthenium integrifolium	N	UPL	U, UR	medium	2-3	white	n	July-Aug		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Sun — Dry Site — Trees, Shrubs, and Vines											
American Beech	Fagus grandifolia	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	slow
American Bittersweet	Celastrus scandens	N	FACU-	U, UR	high	15-20	white	y	May-June		
American Smoketree	Cotinus obovatus	E	-	U	-	20-30	pale green	y	April-May		
American Plum	Prunus americana	N	FACU-	U, UR	high	15-25	white	n	March	2	moderate
Bitternut Hickory	Carya cordiformis	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	slow
Black Cherry	Prunus serotina	N	FACU	U, UR	high	50-80	white	n	April-May	3	rapid
Black Walnut	Juglans nigra	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	rapid
Blackhaw Viburnum	Viburnum prunifolium	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	



Persimmon, early fall

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Trees, Shrubs, and Vines *(continued)*											
Blackjack Oak	Quercus marilandica	N	UPL	U, UR	medium	20-40	yellow	y	May	2	slow
Bur Oak	Quercus macrocarpa	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	slow
Chestnut Oak	Quercus prinus	N	UPL	U, UR	medium	50-70	yellow	y	April	3	slow
Chinese Dogwood	Cornus kousa	E	-	U	-	20-30	white	y	May-June		slow
Cockspur Hawthorn	Crataegus crus-galli	N	FACU	UR	high	25-35	white	y	May	2	moderate
Cornelian Cherry Dogwood	Cornus mas	E	-	U	-	15-25	yellow	y	March		slow
Crossvine	Bignonia capreolata	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		
Eastern Hophornbeam	Ostrya virginiana	N	FACU-	U, UR	medium	25-40	yellow	n	April	1.3	slow
Eastern Red Cedar	Juniperus virginiana	N	FACU	U, UR	high	30-40	n/a	n	n/a		slow
Fragrant Sumac	Rhus aromatica	N	NI	B, U, UR	high	2-6	yellow	y	April		forms thickets
Hackberry	Celtis occidentalis	N	FACU	UR	high	40-60	green	y	April-May	3	rapid
Higan Cherry	Prunus subhirtella	E	-	U	-	25-35	pink	n	March-April		rapid
Honey Locust	Gleditsia triacanthos	N	FAC-	R, UR	high	100	yellow	y	May-June	4	rapid
Kentucky Coffeetree	Gymnocladus dioicus	N	UPL	B, U, UR	medium	75-100	white	n	June	3	slow
Ohio Buckeye	Aesculus glabra	N	FACU+	U, UR	high	20-40	green	y	April-May	3	
Pasture Rose	Rosa carolina	N	UPL	U, UR	high	1-3	white	y	June-Sept	1	
Persimmon	Diospyros virginiana	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	slow - messy
Red Oak	Quercus rubra	N	FACU-	U, UR	medium	50-75	yellow	y	May	3	moderate
Redbud	Cercis canadensis	N	FACU-	U, R, B, UR	high	20-30	purple	n	April	2	



Sassafras with fall color

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Trees, Shrubs, and Vines *(continued)*											
Sassafras	Sassafras albidum	N	FACU-	U, UR	high	30-60	yellow	y	April-May	1.5	moderate
Shrubby St. John's Wort	Hypericum prolificum	N	FACU	U, B, UR	medium	3	yellow	n	June-Aug	0.8	
Southern Blackhaw	Viburnum rufidulum	N	UPL	U, UR	medium	10-20	white	y	April-May		
Staghorn Sumac	Rhus typhina	N	UPL	UR	high	15-25	red	y	June-July	1.6	
Sugar Maple	Acer saccharum	N	FACU-	UR	medium	40-80	green	y	April	3.3	slow
Sweet Shrub	Calycanthus floridus	N	UPL	U, UR	low	6-10	red	n	April-July		
Trumpet Honeysuckle	Lonicera sempervirens	N	FACU	U, B, UR	medium	3-20	orange	n	Mar-Aug	0.8	
Tulip Poplar	Liriodendron tulipifera	N	FACU	U, UR	high	60-90	yellow	y	May-June	3	rapid
Wahoo	Euonymus atropurpureus	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	
White Oak	Quercus alba	N	FACU	B, UR	medium	50-80	yellow	y	May	4	slow
Witch Hazel	Hamamelis virginiana	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	slow
Yellowwood	Cladrastis kentukea	N	NI	U, UR	low	30-50	white	y	May	2	moderate



Pale Indian Plantain colony in bloom in summer

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Grasses											
Beak Grass	Diarrhena americana	N	NI	U, B, UR	medium	1-2	green	n	August		
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Lance-fruited Oval Sedge	Carex radiata	N	UPL	UR	medium	1	green	n	April-May		
Oval-headed Sedge	Carex cephalophora	N	FACU	UR, B	medium	1	green	n	May	0.75	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Silky Wild Rye	Elymus villosus	N	FACU-	UR, B	medium	1-2	yellow	n	June		
Spreading Oval Sedge	Carex normalis	N	FACU	UR	medium	1-3	green	n	May-June	1	
Woodland Brome	Bromus pubescens	N	NI	UR	medium	2-4	green	n	May-June		
Shade — Dry Site — Forbs/Flowers											
Basal Balm	Monarda clinopodia	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		
Bee Balm	Monarda fistulosa	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	
Bellflower	Campanulastrum americanum	N	FACU	B, UR	high	2-6	blue	n	June-July	0.75	
Blue-Stemmed Goldenrod	Solidago caesia	N	FACU	U, B, UR	medium	1-2	yellow	y	Sept-Oct	0.6	
Celandine Poppy	Stylophorum diphyllum	N	NI	B, UR, U	medium	1-2	yellow	n	April-May		
Culver's Root	Veronicastrum virginicum	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		
Downy Alum Root	Heuchera americana	N	FACU-	U, UR	medium	1-2	white	n	June-Aug		
Downy Wood Mint	Blephilia ciliata	N	NI	B, U, UR	medium	1-2.5	blue	n	May-Aug		
Early Goldenrod	Solidago juncea	N	UPL	U, UR	medium	2-4	yellow	n	June-Sept		
Goat's Rue	Tephrosia virginiana	N	UPL	UR, U	medium	1-3	pink	n	May-June		



Lyre-leaved Sage colony in spring

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Forbs/Flowers *(continued)*											
Hairy Alum Root	Heuchera villosa	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		
Hairy Wood Mint	Blephilia hirsuta	N	FACU	U, UR	medium	1-3	blue	n	July-Aug		
Jacob's Ladder	Polemonium reptans	N	FACU	R, B, UR	medium	1-1.5	blue	n	April-June		
Late Boneset	Eupatorium serotinum	N	FAC-	U, UR	high	2-4	white	n	July-Oct		
Lyre-leaved Sage	Salvia lyrata	N	UPL	B, U, UR	high	1-2	blue	n	April-June		
Pale Indian Plantain	Arnoglossum atriplicifolium	N	NI	UR	medium	3-6	white	n	July-Aug		
Short's Aster	Symphyotrichum shortii (Aster shortii)	N	UPL	B, UR, U	medium	2-3	blue	n	Sept-Oct		
Solomon's Seal	Polygonatum biflorum	N	FACU	R, B, UR	medium	1-3	white	n	April-May		
White Wood Aster	Aster divaricatus	N	UPL	U, UR	low	1-2.5	white	n	Aug-Sept		
Wild Geranium	Geranium maculatum	N	FACU	R, UR	medium	1	violet	n	April-May		
Wild Ginger	Asarum canadense	N	FACU-	B, UR	medium	1	ma-roon	n	April-May		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Wood Aster	Aster cordifolius	N	UPL	U, UR	medium	1-3	purple	y	Sept-Oct	0.8	
Woodland Sunflower	Helianthus divaricatus	N	NI	U, UR	medium	2-5	yellow	n	Sept-Oct		
Zig-Zag Goldenrod	Solidago flexicaulis	N	FACU	B, R, UR	medium	1-2	yellow	y	Sept-Oct	0.6	



Crossvine

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Wetland Indicator					
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Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Trees, Shrubs, and Vines											
American Beech	Fagus grandifolia	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	slow
Americum Plum	Prunus americana	N	FACU-	U, UR	high	15-25	white	n	March	2	moderate
Bitternut Hickory	Carya cordiformis	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	slow
Black Cherry	Prunus serotina	N	FACU	U, UR	high	50-80	white	n	April-May	3	rapid
Black Walnut	Juglans nigra	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	rapid
Blackhaw Viburnum	Viburnum prunifolium	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	
Coralberry	Symphoricarpos orbiculatus	N	UPL	B, U, UR	high	2-5	white	y	June-July	1.5	
Crossvine	Bignonia capreolata	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		
Fragrant Sumac	Rhus aromatica	N	NI	B, U, UR	high	2-6	yellow	y	April		forms thickets
Hackberry	Celtis occidentalis	N	FACU	UR	high	40-60	green	y	April-May	3	rapid
Kentucky Coffeetree	Gymnocladus dioicus	N	UPL	B, U, UR	medium	75-100	white	n	June	3	slow
New Jersey Tea	Ceanothus americanus	N	UPL	U, UR	medium	3	blue	n	Mar-Apr	1.2	
Ohio Buckeye	Aesculus glabra	N	FACU+	U, UR	high	20-40	green	y	April-May	3	
Persimmon	Diospyros virginiana	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	slow - messy
Shagbark Hickory	Carya ovata	N	FACU	U, UR	medium	70-90	yellow	y	April-May	4	slow
Southern Blackhaw	Viburnum rufidulum	N	UPL	U, UR	medium	10-20	white	y	April-May		
Staghorn Sumac	Rhus typhina	N	UPL	UR	high	15-25	red	y	June-July	1.6	
Strawberry Bush	Euonymus americanus	N	UPL	U, UR	medium	6-12	green	y	May-June	0.6	
Sugar Maple	Acer saccharum	N	FACU-	UR	medium	40-80	green	y	April	3.3	slow



Fragrant Sumac in the fall.

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Trees, Shrubs, and Vines *(continued)*											
Sweet Birch	Betula lenta	N	FACU	U, UR	medium	72-100	yellow	n	April-May	2.25	
Sweet Shrub	Calycanthus floridus	N	UPL	U, UR	low	6-10	red	n	April-July		
Trumpet Honeysuckle	Lonicera sempervirens	N	FACU	U, B, UR	medium	3-20	coral	n	Mar-Aug	0.8	
Wahoo	Euonymus atropurpureus	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	
White Pine	Pinus strobus	N	FACU	U, UR	medium	75-100	n/a	n	n/a	3.3	rapid
Wild Hydrangea	Hydrangea arborescens	N	FACU	B, UR, U	medium	3-6	cream	y	June-Sept		
Witch Hazel	Hamamelis virginiana	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	slow
Sun — Moist to Wet Site — Grasses, Sedges and Rushes											
Awl-fruited Sedge	Carex stipata	N	OBL	W	medium	2-3	green	n	May	0.75	
Big Bluestem	Andropogon gerardii	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	9	
Brome-like Sedge	Carex bromoides	N	FACW+	W, R, B	low	1-2	green	n	May		
Crested Sedge	Carex cristatella	N	FACW	W, B	medium	2-3	green	n	May-June	0.75	
Eastern Gamma Grass	Tripsacum dactyloides	N	FACW	U, B	medium	4-8	yellow	n	May-Sept	1.6	
Fowl Manna Grass	Glyceria striata	N	OBL	W, B, R	medium	2-4	green	n	May-June	0.3	
Fox Sedge	Carex vulpinoidea	N	OBL	W, B. R	high	2-3	green	n	May-June	1.3	
Frank's Sedge	Carex frankii	N	OBL	W, B, R	high	1-2	green	n	June-July	0.75	
Fringed Sedge	Carex crinita	N	OBL	W	medium	2-4	green	n	May-June	1.5	
Gray's Sedge	Carex grayi	N	FACW+	W	medium	1-2	green	n	May-June	0.75	
Green Bulrush	Scirpus atrovirens	N	OBL	W	high	3-5	brown	n	May-June	1	



Dwarf Bluestar in bloom

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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N = Native to Kentucky
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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Grasses, Sedges and Rushes *(continued)*											
Hop Sedge	Carex lupulina	N	OBL	W	medium	1-2	green	n	May-June	1.5	
Large-Fruited Oval Sedge	Carex scoparia	N	FACW	W	medium	2-3	green	n	May	0.75	
Lurid Sedge	Carex lurida	N	OBL	W	medium	1-2	green	n	May-June	1.3	
Meadow Sedge	Carex granularis	N	FACW+	W, B	medium	1-2	green	n	May-June	0.75	
Prairie Cordgrass	Spartina pectinata	N	OBL	B, W	medium	4-7	yellow	n	July-Aug	1.5	
Rice Cutgrass	Leersia oryzoides	N	OBL	W, B	high	2-4	green	n	Aug-Sept	1.2	
River Cane	Arundinaria gigantea	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	
Riverbank Wild Rye	Elymus riparius	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	
Soft Rush	Juncus effusus	N	FACW+	W, B, R	medium	2-4	green	n	May-June	1	
Softstem Bulrush	Scirpus validus	N	OBL	W	high	4-8	red	n	May-June		
Switchgrass	Panicum virgatum	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	11	
Woolgrass	Scirpus cyperinus	N	FACW+	W	medium	3-5	green	n	July-Aug	1	
Yellow Fox Sedge	Carex annectens	N	FACW	B, W	high	2-3	yellow	n	May-June		
Sun — Moist to Wet Site — Forbs/Flowers											
Arrow Arum	Peltandra virginica	N	OBL	W, R	medium	2-3	white	n	June-July	1.3	
Bishop's Wort	Stachys officinalis	E	-	B	-	1.5-2	blue	n	May-June		
Blue Flag Iris	Iris virginica	N	-	W, B	medium	2-3	blue	n	May-June	0.5	
Blue Vervain	Verbena hastata	N	FACW+	B, W	high	3-5	blue	n	July-Sept		
Boneset	Eupatorium perfoliatum	N	FACW+	R, U	high	3-5	white	n	Aug-Sept		



Tickseed Sunflower in bloom in Fall

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Broad-leaf Arrow-head	Sagittaria latifolia	N	OBL	R, W	medium	1-3	white	n	July-Sept	1.5	
Common Mountain Mint	Pycnanthemum virginianum	N	FAC	W, B	medium	1-2	white	n	July-Aug		
Coral Bells	Heuchera "Rave On"	E	-	B	-	1-2	pink/ white	n	July-Aug		
Cranesbill	Geranium Gerwat Rizanne	E	-	B	-	1-1.5	yellow	n	May-July		
Dense Blazing Star	Liatris spicata	N	FAC+	W, B	low	3-5	purple	n	July-Aug	1.2	
Dwarf Bluestar	Amsonia tabernaemontana "Short Stack"	C	-	R	-	0.75-1	pale blue	y	April-May		
Flat-topped Aster	Doellingeria umbellata (Aster umbellatus)	N	FACW	B, R	medium	3-5	white	n	Sept-Oct		
Foxglove Beardtongue	Penstemon digitalis	N	FAC	W, R	high	2-3	white	n	June	0.6	
Gaura	Gaura lindheimeri "Siskiyou Pink"	E	-	B	-	2.5-3	yellow	n	May-Aug		
Germander	Teucrium canadense	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	
Giant Bur-reed	Sparganium eurycarpum	N	OBL	W	low	3-6	green	n	June-July	1	
Golden Alexanders	Zizia aurea	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Golden Ragwort	Packera aureus	N	FACW	B, R	medium	1	pink	n	May		
Grass-leaved Goldenrod	Euthamia graminifolia	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		
Green-headed Coneflower	Rudbeckia laciniata	N	FACW	U, W, B	medium	5-8	yellow	n	July-Aug	1	
Hardy Hibiscus	Hibiscus "Fantasia"	E	-	B	-	2-3	pink/ white	n	July-Sept		
Ironweed	Vernonia gigantea	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		
Joe-Pye Weed	Eupatorium fistulosum	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		
Lizard's Tail	Saururus cernuus	N	OBL	W	medium	1-2	yellow	n	June-Sept		



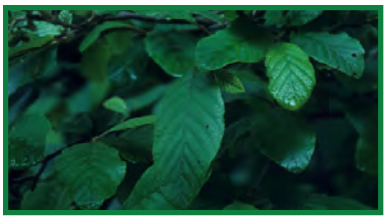
Hardy Hibiscus in bloom in late summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Long-leaved Pondweed	Potamogeton nodosus	N	OBL	W	medium	1-3	green	n	June-Sept		
Many-flowered Agrimony	Agrimonia parviflora	N	FACW	B, W	medium	6	yellow	n	July	0.5	
Mistflower	Conoclinium coelestinum	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	
Monkey Flower	Mimulus ringens	N	OBL	W, B	medium	2-4	blue	n	July-Sept		
Narrow-leaved Sunflower	Helianthus angustifolius	N	FACW	B, U	low	4-6	blue	n	Sept-Oct	0.5	
Nepeta	Nepeta subsessilis "Candy Cat"	E	-	B	-	2-2.5	pink	n	May-Sept		
New England Aster	Symphyotrichum novae-angliae (Aster novae-angliae)	N	FACW-	W, B, U, R	medium	3-6	purple	n	Aug-Sept		
Nodding Bur Marigold	Bidens cernua	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	
Obedient Plant	Physostegia virginiana "Miss Manners"	C	-	R	-	2-2.5	white	n	June-Sept		
Orange Coneflower	Rudbeckia fulgida	N	FAC	B, U, UR	medium	2-3	yellow	n	Aug-Sept	0.6	
Phlox	Phlox paniculata "Robert Poore"	C	-	B	-	3-5	pink	n	July-Sept		
Pickerelweed	Pontederia cordata	N	OBL	R, W	low	2-3	blue	n	July-Sept	0.8	
Purple Coneflower	Echinacea purpurea "Vintage Wine"	C	-	R	-	2-3	white	n	June-Aug	2	
Purple Joe-Pye Weed	Eupatorium purpureum	N	FAC	W, B	medium	4-6	violet	n	July-Aug		
Purple-stemmed Aster	Symphyotrichum puniceum (Aster puniceus)	N	OBL	W	low	6-8	blue	n	Aug-Sept		
Rattlesnake Master	Eryngium yuccifolium	N	FAC	B, U	low	3-4	white	y	July-Sept		
Sage	Salvia nemorosa "Sensation Rose"	E	-	B	-	0.75-1	white	n	June-Sept		
Slender Mountain Mint	Pycnanthemum tenuifolium	N	FACW	B, U, R	high	1-2	white	n	July-Aug		
Smooth Rose-mallow	Hibiscus laevis	N	OBL	W, B, R	medium	2	pink	y	July-Aug	1	



Smooth Alder leaves

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Sneezeweed	Helenium autumnale	N	FACW+	W, B	medium	3-5	pink	n	Sept-Oct	0.5	
Spiderwort	Tradescantia ohiensis	N	FAC	B, U	medium	2-3	Purple	n	June-July	0.3	
Spotted Joe-Pye Weed	Eupatorium maculatum	N	FACW	R, W	low	4-6	violet	n	Aug-Sept		
Swamp Hibiscus	Hibiscus moscheutos	N	OBL	W, B, R	high	3-5	pink	n	July	0.8	
Swamp Milkweed	Asclepias incarnata	N	OBL	W, B, R	medium	4-5	pink	n	July-Aug	1.5	
Sweet Flag	Acorus calamus	N	OBL	W	high	2-2.5	yellow	n	April	1	
Tickseed	Coreopsis "Jethro Tull"	E	-	B	-	1-1.5	yellow	n	June-Aug		
Tickseed Sunflower	Bidens aristosa	N	FACW	W	o	2-3	yellow	n	Sept-Oct	0.75	
Water Horehound	Lycopus americanus	N	OBL	W, B	medium	1-2	white	n	July-Aug		
Water Plantain	Alisma subcordatum	N	OBL	W	high	1-2	white	n	June	0.66	
White Turtlehead	Chelone glabra	N	OBL	R, W, B	medium	2-4	white	n	Aug-Sept		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Sun — Moist to Wet Site — Trees, Shrubs, and Vines											
Allegheny Serviceberry	Amelanchier laevis	N	NI	B, U, R	low	14-40	white	y	April	2.5	moderate
Arrow-wood	Viburnum dentatum	N	FAC	R, B	medium	6-10	white	y	May-June		
Bald Cypress	Taxodium distichum	N	OBL	W, U, R	medium	50-70	n/a	y	n/a	3.3	rapid
Black Chokeberry	Aronia melanocarpa	N	NI	R, U	medium	3-6	white	y	May	2	
Black Gum	Nyssa sylvatica	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	1.5	moderate



Possumhaw Holly berries

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Black Willow	Salix nigra	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	rapid
Bur Oak	Quercus macrocarpa	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	slow
Buttonbush	Cephalanthus occidentalis	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	
Common Elderberry	Sambucus canadensis	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		
Common Ninebark	Physocarpus opulifolius	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	slow
Cornelian Cherry Dogwood	Cornus mas	E	-	U	-	15-25	yellow	y	March		slow
Devil's Walkingstick	Aralia spinosa	N	FAC	U	medium	20	white	n	June-Aug	2.5	moderate
European Hornbeam	Carpinus betulus "Globosa"	E	-	U	-	15-20	green	n	April		slow
Fringe Tree	Chionanthus virginicus	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	slow
Green Hawthorn	Crataegus viridis	N	FACW	U	medium	20-35	white	y	May	1.6	moderate
Leadplant	Amorpha fruticosa	N	FACW	R, B	medium	1-3	purple	n	June-July	2	
Meadowsweet	Spiraea alba	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	
Peach-leaf Willow	Salix amygdaloides	N	FACW	R, W	low	60	white	n	Apr-May	2.5	rapid
Pin Oak	Quercus palustris	N	FACW	W, B, U	medium	50-70	yellow	y	April	2.5	rapid
Possumhaw Holly	Ilex decidua	N	FACW	R, B, U	medium	15-30	yellow	n	March-May	1	
Pussy-Willow	Salix discolor	N	FACW	W	low	25	white	n	Feb-Mar	1.6	rapid
Red Chokeberry	Aronia arbutifolia	N	NI	R, U	medium	3-6	white	y	May	1.6	
River Birch	Betula nigra	N	FACW	B, U, R	medium	40-70	brown	n	April-May	1.6	rapid
Sandbar Willow	Salix exigua	N	OBL	W, R	high	15	white	n	Mar-Apr		rapid



Meadowsweet in flower mid-summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Shellbark Hickory	**Carya laciniosa**	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	slow
Shumard Oak	**Quercus shumardii**	N	FAC+	U	medium	40-60	yellow	y	April	3.3	moderate
Smooth Alder	**Alnus serrulata**	N	OBL	W, R	medium	15	yellow	n	March-April	2	rapid
Steeplebush	**Spiraea tomentosa**	N	FACW-	B, W	medium	2-5	purple	y	July-Sept	1.2	
Sugarberry	**Celtis laevigata**	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	moderate
Swamp Rose	**Rosa palustris**	N	OBL	B, W, R	medium	2-7	pink	y	June-July	1.5	
Swamp White Oak	**Quercus bicolor**	N	FACW+	W, U, R	low	50-60	yellow	y	April	3.3	rapid
Sweetgum	**Liquidambar styraciflua**	N	FAC	R, U	high	60-80	green	y	April-May	3	rapid
Sycamore	**Platanus occidentalis**	N	FACW-	R, U	high	75-100	red	y	April	2.5	rapid
Virginia Sweetspire	**Itea virginica**	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	
Willow Oak	**Quercus phellos**	N	FAC+	R, W, U	low	40-75	yellow	y	April	1	rapid
Winterberry	**Ilex verticillata**	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	



Virginia Wild Rye in Summer

Project Uses		
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GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Grasses, Sedges and Rushes											
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Brome-like Sedge	Carex bromoides	N	FACW+	W, R, B	low	1-2	green	n	May		
Deertongue Panic Grass	Dichanthelium clandestinum	N	FAC+	R, B	high	2	green	n	June-July		
River Cane	Arundinaria gigantea	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Riverbank Wild Rye	Elymus riparius	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	
Virginia Wild Rye	Elymus virginicus	N	FACW-	UR, B	medium	2-3	yellow	n	June-July		
Shade — Moist to Wet Site — Forbs/Flowers											
Blue Lobelia	Lobelia siphilitica	N	FACW+	W, B, R	medium	1-3	pink	y	Aug-Sept		
Calico Aster	Symphyotrichum lateriflorum (Aster lateriflorus)	N	FACW-	R, U	high	1-3	purple	y	Sept-Oct	0.8	
Cardinal Flower	Lobelia cardinalis	N	FACW+	W, B, R	medium	1-3	blue	n	Aug-Sept	1	
Cinnamon Fern	Osmunda cinnamomea	N	FACW	R, B	low	2-3	pink	n	n/a	1	
Coral Bells	Heuchera "Rave On"	E	-	B	-	1-2	red	n	July-Aug		
Foxglove Beardtongue	Penstemon digitalis	N	FAC	W, B	high	2-3	white	n	June	0.6	
Germander	Teucrium canadense	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	
Jack-In-The-Pulpit	Arisaema triphyllum	N	FACW-	R, B	medium	1-2	ma-roon	y	April-May		
Joe-Pye Weed	Eupatorium fistulosum	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		
Lady Fern	Athyrium filix-femina	N	FAC	B, R	medium	1-3	n/a	n	n/a		
Many-flowered Agrimony	Agrimonia parviflora	N	FACW	B, W	medium	6	yellow	n	July	0.5	



Allegheny Serviceberry, fall color

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Forbs/Flowers *(continued)*											
Mistflower	Conoclinium coelestinum	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	
Nepeta	Nepeta subsessilis "Candy Cat"	E	-	B	-	2-2.5	n/a	n	May-Sept		
Nodding Bur Marigold	Bidens cernua	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	
Panicled Aster	Symphyotrichum lanceolatum (Aster lanceolatus)	N	OBL	R, W	medium	5	white	n	Sept-Oct		
Purple Joe-Pye Weed	Eupatorium purpureum	N	FAC	W, B	medium	4-6	violet	n	July-Aug		
Royal Fern	Osmunda regalis	N	OBL	R, B	low	2-3	n/a	n	n/a	1.3	
Sensitive Fern	Onoclea sensibilis	N	FACW	R, B	medium	3-4	n/a	n	n/a		
Stout Blue-Eyed Grass	Sisyrinchium angustifolium	N	FACW-	U, B	medium	1	blue	n	May-Aug		
Wild Columbine	Aquilegia canadensis	N	FAC	R, U, B	medium	2-3	red	n	April-May		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Shade — Moist to Wet Site — Trees, Shrubs, and Vines											
Allegheny Serviceberry	Amelanchier laevis	N	NI	B, U, R	low	14-40	white	y	April	2.5	moderate
American Hornbeam	Carpinus caroliniana	N	FAC	W, B, U, R, UR	medium	20-35	orange	y	Feb	1.6	
Arrow-wood	Viburnum dentatum	N	FAC	R, B	medium	6-10	white	y	May-June		
Black Chokeberry	Aronia melanocarpa	N	NI	R, U	medium	3-6	white	y	May		
Black Gum	Nyssa sylvatica	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	2.5	moderate
Black Willow	Salix nigra	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	rapid
Buttonbush	Cephalanthus occidentalis	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	
Common Elderberry	Sambucus canadensis	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		



Virginia Sweetspire fall color

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Common Ninebark	**Physocarpus opulifolius**	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	slow
Devil's Walkingstick	**Aralia spinosa**	N	FAC	U	medium	20	white	n	June-Aug	2.5	moderate
Fringe Tree	**Chionanthus virginicus**	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	slow
Fullmoon Maple	**Acer japonicum "Taki No Gawa"**	E	-	U	-	10-15	red	y	May		slow
Meadowsweet	**Spiraea alba**	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	
Oak-leaf Hydrangea	**Hydrangea quercifolia**	E	-	B	-	6-8	yellow	n	May-July		
Possumhaw Holly	**Ilex decidua**	N	FACW	R, B, U	medium	15-30	white	y	March-May	1	
Red Chokeberry	**Aronia arbutifolia**	N	NI	R, U	medium	3-6	white	y	May	1.6	
Sandbar Willow	**Salix exigua**	N	OBL	W, R	high	15	white	y	Mar-Apr		
Shellbark Hickory	**Carya laciniosa**	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	slow
Silky Dogwood	**Cornus amomum**	N	FACW	W, B, U, R	medium	6-10	white	n	April	1.3	
Smooth Alder	**Alnus serrulata**	N	OBL	W, R	medium	15	yellow	n	March-April	2	rapid
Spicebush	**Lindera benzoin**	N	FACW-	R, W, B	medium	4-8	white	y	April	1.5	
Steeplebush	**Spiraea tomentosa**	N	FACW-	B, W	medium	2-5	purple	n	July-Sept	1.2	
Sugarberry	**Celtis laevigata**	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	moderate
Virginia Sweetspire	**Itea virginica**	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	
Virgin's Bower	**Clematis virginiana**	N	FAC	U, R, B	medium	4-8	white	n	Aug-Sept	1.2	
Winterberry	**Ilex verticillata**	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Appendix II: Invasive Species



Kudzu infestation (Photo: Kentucky Energy and Environment Cabinet, Division of Forestry).

Introduction

This appendix contains non-native plants that have been identified by the *Kentucky Exotic Pest Plant Council* as having the ability to spread aggressively into native plant communities. Many of these plants are still available for purchase at some nurseries or over the internet and their use in gardens over time has caused them to spread and infest natural areas and parks. Outside of their indigenous habitat, these plants can easily overtake ecosystems and threaten biodiversity. **All of these plants should be avoided when making your planting list.** If any of these plants become established in your revegetated areas, remove them immediately using one of the recommended control methods.

Note: Herbicides in this appendix are listed by their chemical, not commercial, names. Read labels carefully for the active chemical, its strength, precautionary statements, recommended personal protective equipment, environmental hazards and directions. When applying herbicide near or around water, be sure to use a product that is advertised as water-safe. Always keep the label available when using the herbicide and heed all safety warnings. If you are applying herbicide for commercial purposes, please refer to the *University of Kentucky Pesticide Safety Education Program* at http://pest.ca.uky.edu/PSEP/welcome.html. This website contains information about categories of various commercial pesticide applicator licenses and will help you determine if you need a license, which one and how to apply.

For additional information about invasive plant species, please refer to the *Kentucky Exotic Pest Plant Council* website at http://www.se-eppc.org/ky. In addition to reference information about invasive plants, there is information about how to support KY-EPPC's efforts in combating invasive exotic species.

Do NOT Use
Invasive Species List

- **Akebia** *(Akebia quinata)*
- **Autumn Olive** *(Elaeagnus umbellata)*
- **Bicolor Lespedeza** (*Lespedeza bicolor)*
- **Burning Bush** (*Euonymus alatus)*
- **Bush Honeysuckles** (*Lonicera maackii , L. morrowii , L. tatarica , L. x bella)*
- **Canada Thistle** (*Cirsium arvense)*
- **Chinese Silver Grass** *(Miscanthus sinensis)*
- **Chinese Yam** (*Dioscorea batatas, D. oppositifolia, D. bulbifera)*
- **Common Burdock** *(Arctium minus)*
- **Common Chickweed** (*Stellaria media)*
- **Common Reed** *(Phragmites australis)*
- **Common Teasel** *(Dipsacus sylvestris)*
- **Crown Vetch** (*Coronilla varia)*
- **English Ivy** (*Hedera helix)*
- **Fescue** (*Festuca arundinacea)*
- **Garlic Mustard** *(Alliaria petiolata)*
- **Goose Grass** *(Eleusine indica)*
- **Ground Ivy** *(Glechoma hederacea)*
- **Ivy-leafed/ Purple Morning Glory** *(Ipomoea hederacea, I. purpurea)*
- **Japanese Honeysuckle** *(Lonicera japonica)*
- **Japanese Barberry** *(Berberis thunbergii)*
- **Japanese Knotweed** *(Polygonum cuspidatum)*
- **Japanese Spiraea** *(Spiraea japonica)*
- **Japanese Stilt Grass** *(Microstegium vimineum)*
- **Johnson Grass** *(Sorghum halepense)*
- **Jointhead Grass** *(Arthraxon hispidus)*
- **Kentucky Bluegrass** *(Poa pratensis)*
- **Korean Lespedeza, Kobe Lespedeza** *(Lespedeza stipulacea, L. striata)*
- **Kudzu** *(Pueraria lobata)*
- **Lesser Periwinkle** *(Vinca minor)*
- **Mimosa** *(Albizia julibrissin)*
- **Multiflora Rose** *(Rosa multiflora)*
- **Musk Thistle** *(Carduus nutans)*
- **Oriental Bittersweet** *(Celastrus orbiculata)*
- **Ox-Eye Daisy** *(Chrysanthemum leucanthemum)*
- **Poison Hemlock** *(Conium maculatum)*
- **Princess Tree** *(Paulownia tomentosa)*
- **Privet** *(Ligustrum sinense, L. vulgare)*
- **Purple Loosestrife** *(Lythrum salicaria)*
- **Queen Anne's Lace** *(Daucus carota)*
- **Sericea Lespedeza** *(Lespedeza cuneata)*
- **Smooth Brome Grass** *(Bromus inermis)*
- **Spotted Knapweed** *(Centaurea biebersteinii)*
- **Star of Bethlehem** *(Ornithogalum umbellatum)*
- **Tree of Heaven** *(Ailanthus altissima)*
- **White Mulberry** *(Morus alba)*
- **White Poplar** *(Populus alba)*
- **White Watercress** *Roripa nasturtium-aquaticum*
- **Winter Creeper** *Euonymus fortunei*
- **Yellow and White Sweet Clover** *Melilotus officinalis, M. alba*

Akebia, Chocolate Vine

Akebia quinata



James H. Miller, USDA Forest Service, Bugwood.org



Nancy Fraley, USDI National Park Service, Bugwood.org

Description

- Twining vine or vigorous ground cover, typically deciduous in Kentucky.
- Slender rounded stems are green when young and brown when mature.
- Leaflets are green, oval and slightly purple when they emerge.
- Leaflets are 1½ to 3 inches long and arranged in groups of five whose stems meet from a center point.
- Flowers are chocolate-colored and have flattened sausage-like pods that appear in late March or early April.

Distribution

Found in five mid-Atlantic and southeastern states, including Kentucky.

Establishment method

Spreads primarily through vegetative growth. Is capable of growing twenty to forty feet in a season.

Threat

Grows quickly and produces a dense mat that can overpower understory trees, shrubs and even canopy trees by overtopping and smothering them.

Control

Vines that are growing as ground cover may be pulled and removed with follow-up pulling to exhaust the plants. Climbing vines should be cut low to the ground and the stump treated with a 25% glyphosate application. Repeated treatment will most likely be necessary.

Origin

Central China, Japan, Korea. Was introduced to the U.S. in 1845 as an ornamental

Resources

The Pennsylvania DCNR, the Plant Conservation Alliance's Alien Plant Working Group and www.invasive.org.

Autumn Olive

Elaeagnus umbellata



James H. Miller, USDA Forest Service, Bugwood.org



Pennsylvania Dept. of Conservation and Natural Resources - Forestry Archive,, Bugwood.org

Description

- Shrub that grows to 20 feet with a bushy and spreading crown.
- Leaves grow alternately on the stem, are short-stemmed, hairless, dark green above and silvery underneath.
- Twigs are silvery or golden brown, often with prominent spines.
- Abundant berries turn red as they mature in the fall and are speckled with brown to silvery scales.
- Small clusters of fragrant tube-shaped yellowish flowers bloom May-June.

Distribution

Autumn Olive was actively promoted for wildlife habitat, hedge rows, strip mine reclamation and ornamental uses. Found throughout the eastern and midwestern U.S.

Establishment method

An individual plant can produce up to 8 pounds of fruit that is eaten and spread by birds and small mammals. Plants develop fruits annually after 3 years of age.

Threat

Rapid growth enables this shrub to out-compete native species. Prolific fruit production ensures ready distribution. Fire stimulates re-sprouts, making grassland management in infested areas more difficult.

Control

For large thickets where the threat to non-target species is minimal, apply a foliar spray of 2-4% triclopyr or glyphosate. For individual trees, cut the trunk close to the ground and apply a 25-40% concentration of triclopyr or glyphosate.

Origin

Native to China, Korea and Japan.

Resources

Kentucky Exotic Pest Plant Council

Bicolor Lespedeza

Lespedeza bicolor




James H. Miller, USDA Forest Service, Bugwood.org

Description

- Upright, semi-woody, perennial forb, 3 to 10 feet tall with many grey-to-green slender stems and arching branches.
- Leaves are oval, 3-part, numerous and alternate along the stems.
- Flowers are less than ½ inches long, purple and pea-like, grow in clusters and appear in the summer.

Distribution

Found throughout the eastern half of the U.S.

Establishment method

Spreads through its seeds.

Threat

An aggressive invader of open areas forming dense thickets that can displace native plants.

Control

Dig individual plants before they develop seed heads or apply a foliar application of 5% glyphosate with a surfactant in late summer. For larger infestations, mow or weed-eat the plants 1 to 3 months before applying the foliar herbicide application. If glyphosate is not effective, try similar rates of triclopyr.

Origin

Native to Asia, introduced to the U.S. in the late 1800s for wildlife food and habitat.

Resources

NC State University, www.invasive.org, USDA Plant Database, Indiana Cooperative Agricultural Pest Survey Program.

Burning Bush

(Winged Euonymus, Winged Wahoo)
Euonymus alatus



© 2009 Barry Rice



Invasive.org

Description

- Deciduous shrub with gray stems and corky wing-like ridges.
- Opposite leaves, elliptic with a tapered tip, have fine serrations on the margins.
- Leaves turn bright red color in fall.
- Flowers are small, yellowish green in color and inconspicuous in pairs at the tips of y-shaped stems.
- Smooth, purplish fruit are a half-inch long and are present from September through October. Each fruit contains approximately four red-to-orange seeds.

Distribution

Found in most states in the eastern U.S. and the upper midwest.

Establishment method

Spreads quickly by root suckers and from birds dispersing seeds.

Threat

Can form dense thickets in natural woods and shade out native plants. It is also an adaptive plant, growing well in a wide range of soil types and pH levels.

Control

Hand-pull small plants. Larger plants can be cut and the stump surface painted with 25% glyphosate. Foliar spray is also an option but most effective during early summer months.

Origin

Introduced from northeast Asia and promoted as an ornamental.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA .

Bush Honeysuckles

Lonicera maackii , L. morrowii , L. tatarica , L. x bella

Lonicera mackii



© 1999 Nick Kurzenko

Lonicera morrowii



© 2003 Joseph Dougherty/ecology.org

Lonicera tatarica



Chris Evans, River to River CWMA, Bugwood.org

Description

- Shrubs, ranging from 6 to 15 feet in height.
- Egg-shaped to oblong opposite leaves are 1 to 2 ½ inches long with pointed tips, leafing out first in spring and persisting into late fall.
- Pairs of fragrant, tubular white-to-pink flowers appear in late spring.
- Fruits are red or orange berries containing many seeds.

Distribution

Introduced for use as ornamentals and for wildlife food and cover. Bush Honeysuckles are found in a wide variety of habitats from the Central Great Plains to southern New England and south to Tennessee and North Carolina.

Establishment method

Plants fruit prolifically and are highly attractive to birds who distribute the fruits and seed. In established populations, vegetative sprouting also aids in their reproduction.

Threat

Aggressively forms dense shrub layer that crowds out native plant species. Can reduce tree regeneration and eliminate understory species due to deep shade cast by dense thickets. Fruits are rich in carbohydrates but do not offer migrating birds the high-fat, nutrient-rich food sources needed for long flights. Increased predation of nests built in Honeysuckle Bushes has been attributed to its branching structure and lack of thorns which enable predators easy access.

Control

Hand removal of seedlings or small plants may be useful for small populations; however any portion of root remaining can resprout. Apply 2% glyphosate or triclopyr foliar spray where risk to non-target species is minimal. Air temperature should be above 65 degrees F. As an alternative, cut stems low to ground and immediately treat cut stump surface with a 25% solution of glyphosate or triclopyr.

Origin

China, Asia and Russia. *L. x bella* is a hybrid of *L. morrowii* and *L. tatarica*. These shrubs were introduced to the U.S. as ornamental plants and for wildlife cover.

Resources

Kentucky Exotic Pest Plant Council

Canada Thistle

Cirsium arvense



www.missouriplants.com

Description

- Perennial herbaceous plant, grows up to 4 feet tall.
- Leaves are lance-shaped with irregular lobes and prickly spines. Leaves alternate along the stem.
- Stems are ridged and hairy.
- Flowers are purple to white, ½ inches in diameter and typically flower late June to August.

Distribution

Found throughout the continental U.S. except in the deep south.

Establishment methods

Plants spread through sprouting from an extensive root system and from the distribution of numerous seeds per plant.

Threat

Dense thistle patches may form from a single plant. Seeds can be blown up to ½ mile. Once established it spreads rapidly and is difficult to remove.

Control

Hand-pulling can stimulate the plants to send up more sprouts from the roots. However, repeated pulling will eventually starve underground stems in areas where other dense vegetation compete. Mowing can be effective if plants are cut in the early bud stage. Repeated mowing over successive years will be necessary. Foliar application of 2% glyphosate or glufosinate-ammonium can be effective when sprayed early in the season before the plants have flowered.

Origin

Brought to the U.S., most likely accidentally, from Europe in the 1600s.

Resources

Wildflowers and Weeds Info, Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org, USDA Plant National Database.

Chinese Silver Grass

Miscanthus sinensis



James H. Miller, USDA Forest Service, Bugwood.org



© 2001 CDFA

Description

- Loose plume-like heads of pale pink-to-red flowers that turn silver in fall.
- Produces tall stalks that persist through winter.
- Leaves grow from the base and arise from a large central clump.
- Individual leaves taper to a point and are 3 to 4 feet long.
- Margins are sharp and slightly serrated.
- Seeds are rough with a twisted bristle tip.
- Spreads primarily by underground roots or rhizomes.

Distribution

Can invade roadsides, old fields, shores of reservoirs and forest openings following fires. Has spread throughout the eastern U.S. to Colorado and California.

Establishment method

Spreads through airborne seed as well as through its roots, forming colonies. May also resprout from a piece of underground sprouting stem.

Threat

Aggressive. Highly flammable and poses a fire hazard as burning plants can have flame lengths of 30 feet.

Control

Small patches may be grubbed, but all roots must be removed. Plant must be actively growing for herbicidal control. Use a 2% glyphosate foliar spray in fall or late spring. Cover the leaves to the point of runoff, but be careful not to spray desirable vegetation.

Origin

Originated in Asia. Introduced to the U.S. as an ornamental.

Resources

Kentucky Exotic Pest Plant Council

Chinese Yam

(Cinnamon Vine, Air Potato)
Dioscorea batatas, D. oppositifolia, D. bulbifera

Dioscorea opppsitifolia



Troy Evans, Great Smoky Mountains National Park, Bugwood.org

Description

- Chinese Yam is a long-climbing vine with 2- to 3-inch wide shiny heart-shaped leaves having arc-shaped veins.
- Leaves may vary in shape to arrowhead-like with lobes at the leaf base.
- Pea- to marble-sized bulbils that look like small potatoes occur at leaf nodes in late summer. These may become potato-sized in other regions.
- Ripe bulbils drop readily at slightest touch. New plants sprout from bulbils.

Distribution

Found increasingly along stream corridors, forest openings, roadsides and around old home sites.

Establishment method

Reproduces prolifically starting in late June and can spread rapidly along forest edges and openings.

Threat

The vine is fast-growing (up to 1 inch per day at peak). It covers trees, shrubs, ground vegetation and structures.

Control

Shading not recommended for long-term control. Mechanical control includes clipping, pulling or burning plants before bulbils form in mid-June. Follow with foliar herbicide control of sprouts with 25% glyphosate in June to August as bulbils are just forming.

Origin

Native to China; it was introduced to the United States as a food crop in the early 1800s.

Resources

The Nature Conservancy, the National Park Service and the Universities of Tennessee, Florida and Connecticut.

Common Burdock

Arctium minus



Richard Old, XID Services, Inc.

Description

- Biennial in the Aster family; forms a rosette in the first year and grows to 6 feet tall in the second year.
- The large, heart-shaped leaves are smooth above and wooly-hairy beneath.
- The flowers range from white to purple and somewhat resemble a thistle, flowering from July to October.
- Flowers dry to a bur with hooked bract.

Distribution

Grows in full or partial shade along roadsides, on stream banks and in old fields. It is found throughout North America.

Establishment method

Spreads by seed, one plant typically produces 15,000 seeds.

Threat

Crowds out native vegetation in natural areas. Host for powdery mildew and root rot. Can taint milk products if grazed in large quantities.

Control

Mowing or cutting the plant when in flower is an effective control. Application of a 2% solution of glyphosate herbicide to the leaves is also an effective control method.

Origin

Europe. Burdock was brought to the U.S. by early settlers for its medicinal properties.

Resources - USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants; Virginia Tech Weed Identification Guide http://www.ppws.vt.edu/scott/weed_id/arfmi.htm.

Common Chickweed

Stellaria media



John D. Byrd, Mississippi State University, Bugwood.org

Description

- Winter annual that often forms dense mats 2 to 6 inches high.
- Leaves are opposite and oval with pointed tips and there is a characteristic line of hairs along one side of the stem.
- Flowers have 5 deeply cut white petals, giving the appearance of 10 petals.

Distribution

This species is found on disturbed sites, in cultivated fields, along roadsides, in forest communities and in gardens throughout the U.S.

Establishment method

Spreads by seeds (each plant produces between 600-15,000 seeds) and reproduces vegetatively through a fibrous root system.

Threat

Crowds out native vegetation and forms a monoculture.

Control

Spray leaves with a 2% glyphosate solution. Application of herbicide in the very early spring can catch this species in growth but before many other native species are active.

Origin

The Common Chickweed is originally from Europe.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants, www.invasive.org.

Common Reed

Phragmites australis



© 2005 Luigi Rignanese



© 2009 Steve Matson

Description

- Perennial grass with hollow stout stems that can grow up to 15 feet tall.
- Leaves are narrow, long and tapered at the ends; they can grow up to 2 feet long.
- Large feathery plumes of flowers develop by mid-summer.
- Purple/brown flowers turn tan or gray and seeds set through fall and winter.

Distribution

Thrives in sunny wetland habitats. Occurs throughout the U.S.

Establishment method

Spreads rapidly by underground sprouting stems, which may extend 30 feet in one year. Produces large quantities of wind-borne seeds.

Threat

Crowds out native vegetation and forms a monoculture. Monocultures as large as 7000 acres have been documented.

Control

Apply a 2% solution of water-safe glyphosate herbicide to the leaves when plants are tasseling. Re-treatments are often needed due to denseness of foliage and inability of spray to reach all plants at one time. Cutting with hedge trimmers just before seeds set can reduce vigor. Treatment will be needed for several years.

Origin

The origin is uncertain. *Phragmites australis* is found on every continent except Antarctica.

Resources

Kentucky Exotic Pest Plant Council

Common Teasel

Dipsacus sylvestris



R.A. Howard. ©Smithsonian Institution. Courtesy of Smithsonian Institution, Richard A. Howard Photograph Collection.

Description

- Herbaceous plant up to 6 feet tall with stout straight stems that branch at the top.
- Leaves are paired along the stem, are long and narrow and have prickles on the underside midrib.
- Flowers are tiny, pink and clustered on a head with straight prickles sticking out like a pin cushion.

Distribution

Found throughout the continental U.S.

Establishment method

Propagated by seeds. A single teasel plant can produce over 2,000 seeds; 30-80% of these seeds may germinate.

Threat

The plant is easily spread and difficult to exterminate.

Control

Stems of teasel can be cut just below the ground surface just before flowering. (The stems will resprout if they are cut prior to flowering). If the flowers have opened, the plant material should be removed from the site to prevent formation of additional seed. Glyposate can be applied to the leaves at a 2% concentration before the plant starts to bolt.

Origin

Europe. This species is thought to have been introduced accidentally to the U.S. with other seed.

Resources

www.invasive.org, www.missouriplants.com, USDA Plant National Database, http://dnr.wi.gov/invasives.

Crown Vetch

Coronilla varia



© 2005 Louis-M. Landry



© 2008 Louis-M. Landry

Description

- Creeping stem reaches 1 ½ feet in length
- Compound leaves (multiple tiny "leaflets" on each leaf stem) range from 2 to 4 inches in length and have nine to twenty-five oblong leaflets.
- Five to twenty pea-like flowers that vary from pink, rose or lilac appear in late May-August

Distribution

Widely distributed as an ornamental ground cover and for erosion control on banks and mine reclamation throughout the continental U.S.

Establishment method

Spreads vegetatively by underground roots or rhizomes and by seed. Seeds remain viable in the soil for several years requiring consistent post-treatment monitoring.

Threat

Crown Vetch's rapid growth allows it to cover and out-compete native vegetation. May form single-species stands that can dominate treeless natural areas that receive full sun, such as grasslands.

Control

Hand-pulling of mature plants may be effective for small initial infestations. Mowing in the flower bud stage for two to three consecutive years may reduce vigor and control further spread. Cut plants as low to the ground as possible before they seed. Mowing or burning and then applying an herbicide such as 2% triclopyr or 2% glyphosate to the leaves while the plants are actively growing has been effective for control. Repeated treatments are often needed due to the dense growth of plants and the inability to adequately cover all stem surfaces with herbicide in one application.

Origin

Native to Europe, southwest Asia and northern Africa.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's-Alien Plant Working Group, The Nature Conservancy and the USDA .

English Ivy

Hedera helix





Chris Evans, River to River CWMA, Bugwood.org

Description

- Evergreen vine that can grow up to 100 feet.
- Leaves are dark green and waxy; leaf shape is variable but typically has three lobes with a heart-shaped base.
- Flowers are triggered by sunlight and are yellowish-green, occurring at the ends of the stems.
- Fruits are black and round.

Distribution

Found throughout the eastern U.S. and along the west coast.

Establishment method

Spreads primarily along the ground by runners. Fruit can be eaten by birds, spreading seed. Broken pieces of stem are able to root in the soil.

Threat

Forms a thick ground cover that displaces native understory species. English ivy can climb into trees, covering branches and slowly killing trees.

Control

Hand-pulling can be an effective control method if all of the above-ground stems are pulled. Foliar application of 2 to 4% glyphosate solution with 0.5-1% non-ionic surfactant can be effective, but repeated treatments will be necessary. Herbicide will be most effective in the summer and fall; however, in order to avoid native annuals, treatment could be applied in the winter.

Origin

Europe, introduced to the U.S. as an ornamental plant

Resources

www.invasive.org, USDA Plant Database, Plant Conservation Alliance's Alien Plant Working Group.

Fescue, Kentucky 31 Fescue

Festuca arundinacea





Ted Bodner, Southern Weed Science Society, Bugwood.org

Description

- Cool season perennial grass, grows up to six feet tall and remains green in the winter and spring.
- Moderately stout stems are unbranched with 1 to 3 swollen, light green nodes at the base.
- Leaves grow mostly from the base, are flat, 4 to 18 inches long with whitish to yellow-green flared collars.
- Flowers grow in loose, diversely branching clusters that are 4 to 12 inches tall and have a slightly purplish cast.

Distribution

Found in almost every state in the U.S.

Establishment method

It spreads mainly through sprouting underground stems and can form extensive colonies.

Threat

Extensive colonies compete with and displace native plants. It is frequently infected with a fungus that can cause illness in livestock and some wild animals.

Control

Growth can be reduced by competition from other species, especially legumes. A controlled burn in the spring before native warm season grasses have germinated can also be effective. A better option may be a spring burn followed by a foliar application of 2.5% glyphosate, chlorsulfuron or metsulfuron to new sprouts before warm season grasses appear.

Origin

Native to Europe; planted as livestock forage in the mid-1800s.

Resources

The Nature Conservancy, www.invasive.org and the USDA .

Garlic Mustard

Alliaria petiolata



Tom Heutte, USDA Forest Service, Bugwood.org

Description

- Biennial herb, over winters as a rosette, 2 to 3 feet tall at maturity.
- Leaves are broadly heart-shaped with scalloped edges; new leaves have a garlic odor when crushed.
- Flowers are small and white and produced in April-May; seed pods are long and narrow.

Distribution

Thrives in forested communities and edge habitats. Garlic Mustard is most widespread in the midwestern and northeastern U.S. and in southern Ontario.

Establishment method

Spreads only by seeds, which are transported by wind, water and animals. Seeds may remain viable in the soil for up to seven years.

Threat

Crowds out native vegetation and forms a monoculture in the understory of forest communities. Studies indicate that Garlic Mustard can harm certain butterfly species and alter the composition of soil fungi at a site, reducing regeneration of tree species.

Control

The most effective method of control is to cut and remove Garlic Mustard plants when they are in flower and before they set seed. Seeds can continue to mature when the Garlic Mustard is cut; therefore, it is essential to remove the cut plant material from the site.

Late fall or early spring application of a 2% solution of glyphosate herbicide to the leaves is also effective. Management must be repeated annually until the seed bank has become depleted

Origin

Originally from Europe, Garlic Mustard was introduced to the United States as a garden herb.

Resources - http://wiki.bugwood.org/Invasipedia

Goose Grass

Eleusine indica



Hitchcock, A.S. (rev. A. Chase). 1950. Manual of the grasses of the United States. USDA Miscellaneous Publication No. 200. Washington, DC. 1950.



John D. Byrd, Mississippi State University, Bugwood.org.

Description

- Summer annual with stems radiating outward from a distinctive white center.
- Forms a green mat-like clump with flattened stems that grow in a low rosette.
- Leaves are 2 to 14 inches long and folded along the midvein.
- Flowers cluster along stiff spikes; usually two to six spikes radiate out from a single stem.

Distribution

Found throughout most of the continental U.S., with the exception of the Pacific Northwest.

Establishment methods

Reproduces by seed.

Threat

Each plant can radiate out 2 ½ feet and tolerates a wide range of conditions.

Control

Hand-pull individual plants or mow plants before they go to seed. Repeat this treatment until initial seed source has been exhausted.

Origin

Goose Grass originated in Africa.

Resources - University of California Agriculture and Natural Resources, Virginia Tech Weed Identification Guide, USDA Plants National Database.

Ground Ivy

Glechoma hederacea



Leslie J. Mehrhoff, University of Connecticut

Description

- Perennial herb in the Mint family.
- The stems lie along the ground and the plants form a dense mat.
- The leaves are kidney-shaped with scalloped edges and have a minty odor when crushed.
- The pale violet flowers are tubular and open from March-May.

Distribution

This species is found on disturbed sites, open woods, forest edges, lawns, gardens and pastures throughout most of the U.S.

Establishment method

Spreads by seeds and by creeping stems.

Threat

Ground Ivy can form dense mats that displace native plant species. The plant is toxic to many vertebrates.

Control

Spray leaves with a 2% glyphosate herbicide solution.

Origin

Originally from Eurasia; introduced into North America in the 1800s as an ornamental and medicinal plant.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants, www.invasive.org

Ivy-leafed Morning Glory, Purple Morning Glory

Ipomoea hederacea, Ipomoea purpurea

Ivy-leafed Morning Glory



Purple Morning Glory



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Description

- Annual vines, can grow up to six feet long, branching occasionally.
- Round stems are light green to dull red and mostly covered in hairs.
- Leaves of Ivy-leafed Morning Glory are deeply 3-lobed and indented at the base; up to 4 inches wide in the middle.
- Leaves of Purple Morning Glory are heart-shaped and have hairs that lie flat against the leaf.
- Flowers of Ivy-leafed Morning Glory are blue to purplish-pink, up to 2 inches wide, in the form of a funnel and bloom primarily in the morning on sunny days.
- Flowers of Purple Morning Glory occur in clusters of three or more and range in color from purple to white.

Distribution

Ivy-leafed Morning Glory is found throughout the eastern and midwestern U.S.; Purple Morning Glory is found in all U.S. states except Idaho and Wyoming.

Establishment method

The vines grow vegetatively. Birds sometimes eat the plants' large seeds, dispersing them elsewhere. Rain, wind and gravity may also disperse the seeds.

Threat

Plants are especially aggressive in disturbed areas. They are capable of climbing native vegetation and easily out-compete native plants for resources.

Control

Small infestations can be hand-pulled, being sure to get the entire root. For more mature plants, a cut-stem treatment can be successful. After cutting the stem low to the ground, apply a 30% solution of glyphosate to the cut stem within 15 to 20 seconds. Successful control has also been achieved with repeated foliar applications of 2-4% glyphosate.

Origin

Central and South America; was introduced to the United States by early settlers in 1700 and sold as an ornamental.

Resources - WCRC-4 research, USDA Agricultural Research Service, www.illinoiswildflowers.info/weeds/, www.missouriplants.com, USGS Weeds in the West Project.

Japanese Honeysuckle

Lonicera japonica



Chuck Bargeron, University of Georgia, Bugwood.org

Description

- Evergreen to semi-evergreen vine that can grow to over 80 feet in length.
- Leaves grow in opposite pairs on the stem, are oval-shaped, 1 to 2 ½ inches long and cling to the vine without a leaf stem.
- Flowers are white-pink to yellow and look like those of the bush honeysuckles.
- Fruits develop in the fall and are shiny, small and black.

Distribution

Found throughout the northeast, southeast, midwest and southwestern U.S.

Establishment method

Spreads by seeds, underground rhizomes and above-ground runners.

Threat

The vine can girdle young saplings and form dense vegetative mats, shading everything underneath. The vine may also engulf small trees, pulling them down under their weight.

Control

Control of this plant is very difficult, so vigilance to identify and eliminate the plant before it establishes is crucial. Pull out any young stems, attempting to remove the entire root. Late fall burns when native plants are dormant followed by a foliar herbicide application of 2% glyphosate to resprouts can be effective. Foliar herbicide applications, whether following a burn or not, are best applied within two days of the first killing frost.

Origin

Eastern Asia, originally planted in the 1800s for erosion control, landscaping and wildlife habitat.

Resources

The Nature Conservancy, www.invasive.org and the USDA .

Japanese Barberry

Berberis thunbergii



Plant Conservation Alliance's Alien Plant Working Group

Description

- Dense deciduous shiny shrub that grows two to eight feet tall.
- Branches are brown, deeply grooved and grow in a zig-zag form.
- Leaves are ½ inch to 1 ½ inches long, oval to spatula-shaped and green or bluish green.

Distribution

Found throughout the southeast, southwest and parts of the midwest. Scattered across Kentucky. Grows in native grasslands, fields, road cuts and in forest edges.

Establishment method

Spreads into new area via seed and resprouts vigorously from cut stumps.

Threat

Strong competitor in open areas, disturbed forests and forest edges. Crowds out native trees and shrubs. Can grow in a variety of soils. Can be a problem along streams.

Control

Hand-pulling of young seedlings is recommended where feasible. Treat trees by girdling, basal trunk spraying or cutting to eliminate seed production. Freshly cut stumps should be treated with 25% solution of glyphosate or triclopyr with water or Garlon 4 with an oil-based surfactant. Root or stump sprouting is likely as well as seedlings, so follow-up foliar spraying with 2% glyphosate or triclopyr is recommended.

Origin

Originated in Japan. Was introduced to the U.S. in 1875 as an ornamental shrub.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

Japanese Knotweed

Polygonum cuspidatum



©Elaine Haug. Provided by Smithsonian Institution, Department of Systematic Biology-Botany. United States, VA, Woodbridge, Occoquan National Wildlife Refuge.

Description

- Forms dense stands that reach 10 feet tall.
- Leaves are 2 to 6 inches long and heart-shaped.
- Stems are bamboo-like (hollow), light green to purplish-red, smooth and swollen at joints where leaves are attached.
- Small flowers are white to greenish white in small sprays along smallest branches.

Distribution

Found throughout much of the U.S. and scattered across KY. Grows along streams, home sites, low-lying areas and rights of way.

Establishment method

Spreads primarily vegetatively through its long, stout underground stems that will root and send up shoots. Stems are sometimes transported through fill dirt or, occasionally, carried by water.

Threat

Dense thickets crowd native vegetation. Tolerates adverse growing conditions. Quickly expands in natural areas from cultivated sources. Threatens riparian areas where it is rapidly colonizing scoured shorelines.

Control

Hand-pull small plants. Grub larger plants removing roots (rhizomes) and other plant parts. Foliar spray with glyphosate or triclopyr (2%) during growing season. Treat cut plants with 25% solution to knock down plants for easier foliar spraying when new sprouts and leaves emerge.

Origin

Originated in Japan. This species was introduced to the U.S. as an ornamental landscape plant.

Resources

Southeast Exotic Pest Plant Council

Japanese Spiraea

Spiraea japonica



Great Smoky Mountains National Park Resource Management Archive, USDI National Park Service, Bugwood.org

Description

- Deciduous shrub four to six feet tall with slender, brownish, erect stems.
- Leaves alternate along the stem, are 1 to 3 inches long, oval to lance-shaped and have toothed edges.
- Rosy-pink flowers grow in a cluster at the tips of the branches.
- Lustrous seed pods contain seeds $^{1}/_{10}$ inch long.

Distribution

Found throughout the eastern part of the U.S.

Establishment methods

Spreads via seed carried by water and soil that may be transported from one site to another.

Threat

Each plant produces hundreds of seeds. Once established, plants can form dense stands which displace natives and close open areas. The plant vigorously resprouts from cuts, so repeated control treatments are necessary.

Control

For small infestations, hand-pulling seedlings or cutting larger plants may be effective with repeated treatment. For larger infestations or dense stands, apply a foliar application of 2% glyphosate before the plant has gone to seed. If the infestation is intermingled with native understory plants, employ a cut-stem treatment with an application of 25 to 40% glyphosate immediately after cutting.

Origin

Eastern Asia. Japanese Spiraea was introduced into the United States as an ornamental landscape plant around 1870.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org, USDA Plant National Database.

Japanese Stilt Grass

(Asian Stilt Grass, Nepal Grass)
Microstegium vimineum



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Description

- Pale green lance-like thin leaves up to 3 inches long on thin stems. Silvery strip of reflective hairs at center of upper side of leaf is a distinctive mark.
- Size varies: can be up to 3 feet tall, but often ½ to 2 feet. Sometimes seen as a nearly mat-like cover where mowed.
- Plants are shallow-rooted and are easily pulled up.

Distribution

Observed along road sides, stream banks, gravel beds and trails, but also found deep in forests. Found throughout Kentucky.

Establishment method

Seeds remain viable for up to seven years and are easily spread by hay, soil on shoes, tires and water.

Threat

Adapted to shade, invades forests and forms dense patches that crowd out native plants in open and shaded sites. Spreads easily and can take over fields and forests quickly, especially moist, rich soils and wetlands.

Control

Repeated hand-pulling, especially when plants are in full bloom (late summer). Larger populations may be weed-whacked in late summer just before plants produce seeds. Important to control small populations quickly. Chemical controls include foliar application of 2% glyphosate. In wet areas, wetland herbicide formulations are needed.

Origin

Japan, Korea, China, Malaysia, India. Japanese Stilt Grass was introduced accidentally to the U.S. – the seeds were carried in with packing material.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Southern Appalachian Man and the Biosphere Program (samab.org), TVA, the University of Tennessee, U.S. Fish & Wildlife Service, the Nature Conservancy, Plant Conservation Alliance and others.

Johnson Grass

Sorghum halepense



©James H. Miller. James H. Miller and Karl V. Miller. 2005. Forest plants of the southeast and their wildlife uses. University of Georgia Press., Athens. Courtesy of University of Georgia Press.

Description

- Perennial grass, grows in large clumps that can grow 7 to 8 feet tall.
- Flowers are in a purple-colored branched cluster at the end of the stem.
- Leaves are 6 to 20 inches long with a white mid vein.
- Stems are pink to red near the base.

Distribution

Found throughout the continental U.S.

Establishment methods

Propagates through large underground stems and massive seed production.

Threat

By the 20th century, Johnson Grass was recognized as one of the six most damaging weeds in the U.S. Forms dense stands and has the capability of producing large numbers of seeds that remain viable in the soil for 25 years. Nutritional value as fodder is very low as compared to native species. Out-competes native plants for water.

Control

Hand-pulling is usually not effective because underground stems are left behind; however this method, when repeated, may reduce vigor. If implemented, hand-pulling is best done in early spring. Mechanical cutting and use of 2% glyphosate as a foliar spray are acceptable when used repetitively.

Origin- Introduced from the Mediterranean region as a forage crop.

Resources- Kentucky Exotic Pest Plant Council

Jointhead Grass

Arthraxon hispidus





Leslie J. Mehrhoff, University of Connecticut

Description

- Creeping annual grass that grows to a height of 1 ½ feet.
- Leaves are short and wide and have an oval shape with a pointed tip; the edges of the leaves are hairy.
- Flowers are composed of many spikelets that resemble fingers and open from September to October.

Distribution

This species prefers sunny moist sites and is found primarily in the eastern half of the U.S.

Establishment method

Spreads by water-dispersed seeds.

Threat

Jointhead Grass can form dense stands that displace native plant species, particularly along shorelines.

Control

The species can be controlled by hand-pulling or mowing prior to seed production. May also be treated with a foliar application of 2-4% glyphosate solution.

Origin

Eastern Asia: China, Japan and Korea.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants; Virginia Tech Weed Identification Guide http://www.ppws.vt.edu/scott/weed_id/arahi.htm.

Kentucky Bluegrass

Poa pratensis



Robert H. Mohlenbrock. USDA SCS. 1989. Midwest wetland flora: Field office illustrated guide to plant species. Midwest National Technical Center, Lincoln. Courtesy of USDA

Description

- Shallow-rooted perennial grass.
- Distinguished by its flat leaf blade and boat-shaped leaf tip.
- Flowers are in clusters of two to six on a loosely branched form at the end of the stem that can grow as tall as 4 ½ feet.

Distribution

Found in all of continental U.S., although more common in the north than in the south.

Establishment method

Spreads via sprouts from its roots, aerial sprouts from leaves that form their own roots, as well as by seed.

Threat

Kentucky Bluegrass is especially a problem in tallgrass and mixed grass prairies. It can penetrate between native plants, competing for resources.

Control

In small stands where Kentucky Bluegrass has intermingled with other native species, herbicide treatment is not recommended and hand-pulling may be effective. However, in areas where Bluegrass dominates or is a monoculture, a foliar application of 2% glyphosate in the early spring when native warm season plants are dormant can be effective.

Origin

There is some debate as to whether Kentucky Bluegrass is native to the northern U.S. and Canada or whether it was introduced here and has naturalized. It is thought that Kentucky Bluegrass is native to Europe and Eurasia and was spread extensively throughout North American for use as a pasture and turf grass starting in the early 1600s.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.missouriplants.com.

Korean Lespedeza, Kobe Lespedeza

Lespedeza stipulacea, Lespedeza striata



www.missouriplants.com



www.weedalert.com

Description

- Summer annual that grows primarily along the ground forming mats 15 to 18 inches in diameter.
- Leaves consist of three leaflets 1/2 inch to 3/4 inch long and with obvious venation.
- Flowers are pinkish purple and are found on the leaf axils.

Distribution

Found throughout the eastern and midwestern U.S.

Establishment method

Spreads via seed.

Threat

Spreads rapidly in open areas, road sides and disturbed areas; can outcompete native vegetation.

Control

Foliar application of herbicide containing 5% fluroxypyr, metsulfuron or triclopyr when the plant is actively growing and in the seedling or flowering stage.

Origin

Native to Asia. Both plants were brought to the U.S. as cover crops and fodder for cattle and horses.

Resources

www.missouriplants.com, Virginia Tech Weed Identification Guide, www.weedalert.com.

Kudzu

Pueraria lobata



James H. Miller, USDA Forest Service, Bugwood.org



Forest & Kim Starr, U.S. Geological Survey, Bugwood.org

Description

- Fast-growing perennial, semi-woody vine, usually with three leaflets resembling pea leaves.
- Leaflets 2 to 4 inches wide and hairy on edges.
- Light purple/pink flowers with a fragrant, sweet grape smell in late summer.
- Roots are fleshy with massive tap roots.

Distribution

Major infestations in eastern and western Kentucky with scattered populations statewide.

Establishment method

Spreads primarily vegetatively through runners and rooting underground stems. Vine nodes may also root to form new plants.

Threat

Kudzu kills or degrades other plants by shading them under a blanket of leaves, by girdling stems and tree trunks and by breaking branches or uprooting trees by its weight.

Control

Seedlings can be sprayed with herbicide or pulled. The root system must be killed. Mow or cut monthly over two or more growing seasons. Sever vines and treat roots to get foliar levels manageable for more direct treatments. Late season cutting of vines at root tops followed by immediate stump treatment with 25% glyphosate works best. Foliar application of 2% glyphosate to small plants repeatedly in a season may keep plants in check. No biological controls are available.

Origin

Asia (China, Japan). Was introduced as a ground cover for erosion-prone sites.

Resources

Plant Conservation Alliance's Alien Plant Working Group

Lesser Periwinkle

Vinca minor



Dan Tenaglia, Missouriplants.com, Bugwood.org

Description

- Evergreen to semi-evergreen trailing vine and groundcover that reaches almost seven feet long.
- Stems are slender, somewhat woody and green in color.
- Leaves are glossy, 1 inch long and grow in pairs along the stem.
- Flowers are periwinkle in color, 1 inch wide, five-petaled and flower in the spring.

Distribution

Found throughout most of the U.S.

Establishment method

Spreads vegetatively.

Threat

Periwinkle forms dense and extensive mats along open areas and forest floors that exclude native vegetation.

Control

Can be removed by digging, raising the runners from the soil with a rake and mowing the plants. For most effective removal and in dense stands, spray the cut area with a 3% solution of glyphosate immediately after cutting the stems. Follow-up spot treatment will be necessary. Mix glyphosate and water with a surfactant for plants with waxy cuticles. Apply in early spring when the plant is vigorously growing and the cuticle is not yet thick.

Origin

Introduced from Europe as a horticultural plant.

Resources

DCNR Invasive Exotic Plant Tutorial for Natural Land Managers, Plant Invaders of Mid-Atlantic Natural Areas, www.invasive.org.

Mimosa, Silk Tree

Albizia julibrissin



James H. Miller, USDA Forest Service, Bugwood.org

Description

- Small to medium-sized tree with multiple trunks and spreading crown.
- Leaves finely divided and fern-like, bark light brown.
- Flowers a delicate white and pink in clusters like pom-poms in mid-summer.
- Bean pods six inches long and conspicuous through early winter.

Distribution

Found throughout the southeast, southwest and parts of the midwest. Scattered across Kentucky. Grows in native grasslands, fields, road cuts and in forest edges.

Establishment method

Spreads into new area via seed and resprouts vigorously from cut stumps.

Threat

Strong competitor in open areas, disturbed forests and forest edges. Crowds out native trees and shrubs. Can grow in a variety of soils. Can be a problem along streams.

Control

Hand-pulling of young seedlings is recommended where feasible. Treat trees by girdling, basal trunk spraying or cutting to eliminate seed production. Freshly cut stumps should be treated with 25% solution of glyphosate or triclopyr with water or Garlon 4 with horticultural oil. Root or stump sprouting is likely as well as seedlings, so follow-up foliar spray with 2% glyphosate or triclopyr is recommended.

Origin - Iran to Japan. Was introduced to the U.S. as an ornamental in 1745.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

Multiflora Rose

Rosa multiflora



Leslie J. Mehrhoff, University of Connecticut, Bugwood.org



James H. Miller, USDA Forest Service, Bugwood.org

Description

- Thorny, round-shaped, medium to large shrub.
- Leaves have 7 to 9 leaflets arranged in pairs and with one at the end of the stem.
- Leaves have a characteristic fringe along the base of the leaf stem.
- Flowers are small and white to pinkish white, appearing in May or June.
- Fruit turn from green to red to brown through winter.

Distribution

Widely distributed in Kentucky along roadsides, fence rows, stream sides, forest edges and into the interior of forests and unmaintained fields.

Establishment method

Reproduces by seeds that are spread by birds and other animals and vegetatively when arching canes touch the ground and root from the tip

Threat

Forms single-species thickets crowding out native plants, especially at stream sides.

Control

Mowing can keep invasions in check. Pulling up small plants can be effective if repeated to control root sprouts and seedling germination. Chemical control involves foliar sprays of glyphosate or triclopyr at 2% to 3% or cut-stump treatment of the same chemicals at 25% concentrations.

Origin

Japan, Korea, eastern China. Multiflora Rose was originally introduced to the U.S. as a rootstock for ornamental Roses. In the 1930s, it was promoted by the U.S. Soil Conservation Service for erosion control and as a "living fence" to contain livestock.

Resources

Southeast Exotic Pest Plant Council, Plant Conservation Alliance's Alien Plant Working Group and www.invasive.org.

Musk Thistle, Nodding Thistle

Carduus nutans



James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Usually a biennial, a seedling emerges in mid- to late July and develops into a rosette the first year; the second year it bolts in mid-March.
- Mature plants range from 1½ to 6 feet tall with multi-branched spiny stems.
- Spiny leaves are dark green and coarsely lobed with a smooth waxy surface.
- Large, showy, pink-purple disk-shaped flower heads contain hundreds of tiny individual flowers which emerge in May to August and occur at the tips of stems. The flower heads will droop at a 90- degree angle from the stem when mature.

Distribution

Found throughout the continental U.S. except for Maine, Vermont and Florida.

Establishment method

Spreads via seed. Each plant can produce thousands of straw-colored seeds with plume-like hairs.

Threat

Invades native grasslands and pastures. Can out-compete natives as grazing animals will not eat it.

Control

Hand-pulling or cutting of small populations can be done after the stems have bolted but should be done before seed production. Flowers and seed heads should be bagged and taken to landfill to minimize seed dispersal. Foliar spraying of 3% glyphosate or triclopyr applied during rosette stage prior to stem development is also effective.

Origin

Nodding Thistle was accidentally introduced to the U.S. from Europe and Asia.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.invasive.org.

Oriental Bittersweet

Celastrus orbiculata



James H. Miller, USDA Forest Service, Bugwood.org



James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Twining vine with round, glossy to semi-glossy, finely toothed leaves the size of a quarter to half-dollar.
- Flowers and fruit occur at base of leaf stems.
- Greenish-yellow flowers bloom in May with 5 petals.
- Greenish-yellow fruits split open to reveal three red-orange fleshy seeds.

Distribution

Scattered in Kentucky with populations spreading. Alluvial woods, road sides, thickets and old home sites.

Establishment method

Seeds spread by birds and small mammals.

Threat

Aggressively covers, shades and chokes native vegetation including ground layer, shrubs and canopy trees. Believed to readily hybridize with native bittersweet. Tolerates shade.

Control

Hand-pull small infestations, but requires 100% removal, which is difficult. For dense infestations, cut vines and paint cut stems with 25% glyphosate herbicide. Apply herbicides before spring wildflowers emerge or after killing frost. Follow-up and late season treatments necessary.

Origin

Eastern Asia - introduced to the U.S. in the 1860s as an ornamental plant.

Resources

TN Exotic Plant Management Manual; Plant Conservation Alliance's Alien Plant Working Group; Exotic Pest Plants of Southeastern Forests.

Ox-Eye Daisy

Chrysanthemum leucanthemum



Description

- Perennial plant with flower stems 1 to 3 feet tall.
- Small tuft of leaves develop at base with other leaves alternating up the stem.
- Flowers grow one per stem and have a typical daisy-like appearance.

Distribution

Found throughout the U.S.

Establishment method

Livestock and animals feed on the plants and pass the still-viable seeds through their systems to other areas.

Threat

Has the potential to form dense colonies, replacing up to 50% of the native grass species in pastures. Heavy infestations increase the potential for soil erosion because its shallow roots displace deeper-rooted native grasses. Typical plants can produce up to 500 seeds.

Control

Hand-pull all plants before the flowers form seed heads. Seeds remain viable for two to three years, so repeated monitoring and pulling is necessary.

Origin

Introduced from Eurasia as an ornamental plant.

Resources

www.invasive.org, www.illinoiswildflowers.info/weeds/, USFS Weed of the Week.

Poison Hemlock

Conium maculatum



William & Wilma Follette. USDA NRCS. 1992. Western wetland flora: Field office guide to plant species. West Region,Sacramento.

Description

- Annual plant whose hollow stems are purple mottled, erect, smooth and from 2 to 10 feet tall.
- Small white flowers grouped in large clusters that are 1 ½ to 2 ½ inches wide.
- Fern-like leaves are alternate and basal, upper leaves progressively smaller.
- Leaves are sub-divided 3 to 4 times; the enlarged leaf base sheaths the stem.

Distribution

Invades riparian areas, ditches, old fields, roadsides throughout most of North America.

Establishment method

Plant spreads by seed alone, which can be carried by water, somewhat by wind or through mud on vehicles or gardening equipment.

Threat

All parts of the plant are toxic to humans and animals when eaten. Prolific seed production, aggressive growth habits and tolerance of shade allow rapid spread which overwhelms native vegetative cover. Not valuable to wildlife as food or shelter.

Control

The suggested method for small infestations is to dig up the plants or cut them back before flowering. It is not necessary to remove the entire root since the plant is an annual. Do not compost flowers as they can go to seed.

Origin

Eurasia. Introduced to the U.S. as a garden plant.

Resources

The Nature Conservancy's Element Stewardship Abstract, U.S. Forest Service Weed of the Week.

Princess Tree

Paulownia tomentosa



James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Deciduous tree that grows up to 60 feet tall.
- Leaves are arranged in pairs along the stem, 6 to 12 inches long and heart-shaped and hairy on the underside.
- Stems are markedly flattened at the "nodes" where stems and branches meet.
- Flowers are showy, appearing in clusters in the spring. Long, tubular, pale-violet flowers develop in upright clusters.
- Fruit resemble pecan nuts and split to release thousands of seeds.

Distribution

Found throughout the eastern U.S. and Texas

Establishment method

Reproduces via seed and root sprouts, the latter growing up to 15 feet in a season.

Threat

This tree is a prolific reproducer. Individual trees are capable of producing up to twenty million seeds, each easily transportable via water and wind. Trees vigorously resprout from either stem or root after being cut, burned or even bulldozed. Its aggressive growth allows it to out-compete native plants for resources.

Control

Young sprouts may be hand-pulled. It is best to pull them after a rain in order to get the entire root since broken root fragments may resprout. For more mature trees, cut the stump close to the ground after the tree has flowered but before it has gone to seed and immediately apply a mixture of 50% glyphosate or triclopyr to the outer 20% of the stump. The stump should be monitored for resprouts which should be cut and painted with herbicide.

Origin

East Asia, China. Princess Tree was introduced to the U.S. as an ornamental around 1840.

Resources

U.S. Forest Service Weed of the Week, Plant Conservation Alliance's Weed Working Group, www.invasives.org.

Privet

Ligustrum sinense, L. vulgare



Description

- Semi-evergreen shrub that grows to 20 feet tall.
- Trunks usually occur as multiple stems with many long, leafy branches.
- Leaves grow in pairs on the stem, are oval, with hair on the underside midvein and are less than 2 inches long.
- Flowering occurs in late spring, when small, white flowers develop at the ends of branches in 2 to 3 inch-long clusters.
- Fruit are oval, fleshy, less than ½ inch long, ripen to a dark purple to black color and persist into winter.

Distribution

Found in cultivated landscapes, wildlands and disturbed areas throughout the southeastern U.S., particularly in wet to moist habitats and along fence rows.

Establishment method

Grows readily from seed or resprouting stumps. Seeds may be spread by wildlife, particularly birds.

Threat

Can form dense thickets that out-compete native vegetation.

Control

Young seedlings may be pulled when they are tall enough to grasp but have not yet produced seed. They are best pulled after a rain when the ground is moist. For large homogenous stands, a foliar herbicide spray may be used; suggested is 2% glyphosate, metsulfuron or triclopyr mixed with a 0.5% ionic surfactant to ensure that the herbicide will cling to the leaves. For individual plants, cut the stem and paint the stump with a 25% glyphosate mixture.

Origin

It originated in China and was introduced to the U.S. as an ornamental shrub.

Resources

The Nature Conservancy, the Missouri Dept. of Conservation, www.invasive.org and the USDA.

Purple Loosestrife

Lythrum salicaria



© 2005 Louis-M. Landry

Description

- Erect perennial herb with leaves growing in opposite pairs or in a circular arrangement around the stem, with heart-shaped bases.
- Showy spikes of purple-magenta flowers during the summer months.
- Grows four to eight feet tall and can have 30 to 50 stalks per root mass.
- Strong tap root, stems become woody, persisting for up to two years.

Distribution

Found in every state except Florida.

Establishment method

A prolific seed producer; seeds that germinate in the spring will produce a flowering stem that year. Seeds remain viable for several years.

Threat

Quickly adapts to natural and disturbed wetlands; overtakes native aquatic plants and forms large dense stands. Displacement of native aquatic species impacts waterfowl dependent upon them for food and cover. Research suggests that Loosestrife plants can alter the pH of wetlands, inhibiting success of amphibian populations.

Control

Small infestations and young plants can be pulled by hand, preferably before seed sets in late summer, early fall. Plant parts should be bagged and removed from the site as any plant fragment that remains could resprout. Cutting and mowing increase vegetative spreading. Older plants can be treated by a foliar application with a 2-4% glyphosate formulation for use over water.

Origin

Introduced from Eurasia as an ornamental.

Resources

Kentucky Exotic Pest Plant Council

Queen Anne's Lace, Wild Carrot

Daucus carota



Chris Evans, River to River CWMA, Bugwood.org

Description

- Biennial plant that may grow 3 feet tall.
- Leaves are deeply divided and look similar to carrot leaves.
- Stems are coarse and hairy.
- Flowers are white and grow in a flat-topped round cluster.

Distribution

Found throughout the U.S.

Establishment method

Seeds have barbs that allow dispersal by animals and wind.

Threat

One plant can produce 1,000 to 40,000 seeds. Queen Anne's Lace invades disturbed open areas and, because of a deep taproot and rapid maturation, may out-compete native plants for water.

Control

Hand-pull individual plants from low on the stem before plants set seed.

Origin

Native to Europe and southwest Asia and introduced to the U.S. as an ornamental.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.invasive.org, USFS Weed of the Week .

Sericea Lespedeza, Chinese Lespedeza

Lespedeza cuneata



James H. Miller, USDA Forest Service, Bugwood.org

Description

- Perennial herb in the Pea family.
- Grows erect from 3 to 5 ½ feet in height with leaves that grow alternately on the stem.
- Each leaf is divided into three smaller leaflets about ½ to 1 inch long with awl-shaped spines.
- Leaflets are covered with densely flattened hairs making them appear grayish green or silver.
- Flowers are pea-like, white with purple markings and emerge singly or in clusters of 2 to 4 in the upper axils.
- Older stems are woody and fibrous.

Distribution

Found in open areas throughout the eastern United States.

Establishment method

Mature seeds may remain viable for up to 20 years. Seedlings may represent only 1% of the seeds actually available in the soil. Fruits are eaten and dispersed by animals. Haying of infested fields can also disperse seed.

Threat

Invades bottomlands and burned grasslands, crowding out native plants and forming pure stands. High tannin content makes it undesirable to wildlife.

Control

Hand-pulling is impractical, but mowing plants in the flower bud state for two or three consecutive years may reduce vigor and control further spread. Cut as low to the ground as possible. Foliar herbicide treatment in early to mid-summer with a 2% solution of triclopyr is effective. On wet sites, a 2% solution of glyphosate is effective from late June until seed set.

Origin

Introduced from eastern Asia for erosion control, wildlife food and as a forage crop.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA .

Smooth Brome Grass

Bromus inermis




Ohio State Weed Lab Archive, Ohio State University, Bugwood.org

Description

- Perennial grass 1 to 3 ½ feet tall.
- Leaves are narrow and 6 to 15 inches long, hairless and flat.
- Flower heads bloom at top of plant and are purplish, growing in drooping branching clusters of 7 to 10 flowers.
- Characteristic "W" shape wrinkle near the leaf tip.

Distribution

Found throughout the U.S.

Establishment method

Spreads via seed and from spreading roots that sprout new plants.

Threat

Roots form a thick sod that can out-compete native grasses and wildflowers. Seeds are tenacious, staying viable in the soil for up to ten years.

Control

Cut or hand-pull the plants when the seed head is just beginning to form but is not yet hard. Monitoring and repeated pulling will be necessary.

Origin

Introduced from Europe for use as forage and pasture grass.

Resources

Plant National Database, www.invasive.org, www.illinoiswildflowers.info/weeds/, The Nature Conservancy's Element Stewardship Abstract.

Spotted Knapweed

Centaurea biebersteinii



USDA Plant National Database

Description

- Biennial or short-lived perennial herbaceous plant, 2 to 3 feet tall.
- First year's leaves grow from the base and form a rosette from which grow 1 to 20 wiry, white-haired, branched stems during the second year.
- Leaves are alternate, grayish and divided into lance-shaped lobes decreasing in size at the top.
- Flowers are purple to pink in color, appear in early summer and have black tips on the petal-like underside fringe.

Distribution

Found throughout most of the continental U.S.

Establishment methods

Spreads through seed distribution and new plants sprouting from lateral roots

Threat

Especially threatening to dry prairies, oak and pine barrens and sandy ridges. Spotted Knapweed thrives especially well in these conditions and out-competes native vegetation.

Control

Hand-pull first-year rosettes and second year plants before they go to seed. Repeated mowing may be effective to prevent second-year plants from flowering. Foliar application of 0.5% clopyralid during bud growth can be effective.

Origin

Europe and western Asia. It was accidentally introduced in contaminated alfalfa and clover seed in the late 1800s.

Resources

Minnesota Department of Natural Resources, www.invasive.org, USDA Plant National Database.

Star of Bethlehem

Ornithogalum umbellatum



R.A. Howard. ©Smithsonian Institution. Courtesy of Smithsonian Institution, Richard A. Howard Photograph Collection. United States, MA, Weston.

Description

- Perennial plant with 6 inch to 12 inch-long leaves sprouting from base and spanning one-foot across.
- There is often a white stripe down the center of leaves.
- Flowers are white and six-petaled, resembling a star and sprout from individual stems from the base of the plant.
- Blooms occur in late spring and last about two weeks.

Distribution

Throughout eastern, midwestern U.S. and along the west coast.

Establishment method

Most plants develop from bulbs. Smaller "bulblets" form around the parent bulb and these are what form new plants each year.

Threat

Aggressive in full sun to light-shade. Because it germinates and flowers in the spring, it has the potential to displace some native spring wildflowers.

Control

Herbicide has limited effect on this plant due to the energy reserves in the bulbs. The most effective, although time-consuming, method is to sift through the soil and remove every bulb and bulblet. Annual monitoring may be necessary to ensure all bulbs are removed.

Origin

Eastern Europe and parts of the Middle East; it was introduced to the U.S. as an ornamental plant.

Resources

Virginia Tech Weed Identification Guide, www.illinoiswildflowers.info.

Tree of Heaven

Ailanthus altissima



James H. Miller, USDA Forest Service, Bugwood.org



Jan Samanek, State Phytosanitary Administration, Bugwood.org

Description

- Rapidly growing deciduous tree; grows up to 80 feet tall.
- Leaves are 1 to 4 feet long, each having 10 to 41 spear-shaped and smooth-edged leaflets.
- Small lobes at leaflet base are a key identifier, each lobe having a small hard bump (gland).
- Crushed leaves, broken twigs and cut bark have acrid burnt peanut butter odor.
- Yellow-green flowers cluster at end of limbs in July, turn to gray seed clusters in winter.

Distribution

Widespread in the U.S.; scattered throughout Kentucky.

Establishment method

Reproduces by seed and by sprouting from its roots.

Threat

Grows thickly, excluding native species. Roots exude chemicals that push out native plants. Infests closed woodlands but is most common along open areas and forest edges. Each female tree can produce as many as 325,000 seeds per year.

Control

Hand-pull young seedlings, removing entire root. For more mature trees, cut down before they go to seed and immediately spray stump with 25% glyphosate solution.

Origin

Central China. Introduced to the U.S. as an ornamental tree around 1840.

References

TN Exotic Plant Management Manual, Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

White Mulberry

Morus alba



Ohio State Weed Lab Archive, The Ohio State University, Bugwood.org

Description

- Deciduous shrub or tree, can grow up to 30 to 50 feet tall.
- Young bark, bark along the roots and inner bark have an orange color.
- Glossy green leaves are 3 to 6 inches long, grow alternately along the stem, have blunt teeth, heart-shaped bases and are variable in shape.
- Fruits resemble long blackberries, growing 1 to 1 ¼ inches long and ripening in July.

Distribution

Found throughout the U.S. except Nevada, Alaska and Arizona.

Establishment method

Seeds are spread by wildlife that feed on the tasty fruits. Locally, new trees can sprout from existing tree roots.

Threat

Capable of hybridizing with and replacing native mulberry. It can transfer a harmful root disease to native mulberry.

Control

Trees should be cut close to the ground and the outer rim of the stump treated with 25-40% glyphosate or triclopyr. Stump should be monitored for resprouts which should be cut and treated with herbicide.

Origin

Asia; this species was introduced to the U.S. during colonial times in an effort to promote a silkworm industry in the US.

Resources

California Rare Fruit Growers, U.S. Forest Service Weed of the Week, www.invasive.org.

White Poplar

Populus alba



Herman, D.E., et al. 1996. North Dakota tree handbook. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck. Courtesy of ND State Soil Conservation Committee.

Description

- Deciduous tree, can grow to be 40 to 80 feet tall.
- The bark on young trees is smooth and greenish white becoming gray and wrinkled as trees mature.
- Leaves resemble those of maples except the top is shiny and dark green and the underside is bright white and hairy.
- Young green or brown twigs are covered with dense woolly hair.
- Fruits are small hairy seed pods that are wind-dispersed.

Distribution

Found throughout the continental U.S. except Arizona.

Establishment method

Seeds are spread by the wind; this species also spreads by sprouting from the roots.

Threat

This tree produces large seed crops and is a vigorous resprouter. Will escape original planting site and out-compete native trees and shrubs for resources.

Control

Hand-pull seedlings and young plants, making sure to remove the entire root system to prevent resprouts. Manual removal is best after a rain or when the soil has been loosened. Mature trees may be cut and the stumps treated with a 25-40% glyphosate or triclopyr solution painted on the outer 20% of the stump rim.

Origin

Eurasia; White Poplar was introduced to the U.S. in 1748 as an ornamental tree.

Resources

U.S. Forest Service Weed of the Week, www.invasive.org, Univ. of Wisconsin Green Bay Herbarium, USDA Plant National Database.

White Watercress

Rorippa nasturtium-aquaticum



Robert H. Mohlenbrock. USDA NRCS. 1995. Northeast wetland flora: Field office guide to plant species. Northeast National Technical Center, Chester. Courtesy of USDA NRCS Wetland Science Institute.

Description

- Leafy green perennial that grows in water or on wet soil.
- Leaves alternate along hollow stems; each leaf contains three to nine oval-shaped "leaflets"; the terminal leaflet is larger than the side ones.
- Flowers are less than 1/4 inch wide, white and four-petaled, blooming from April through September on relatively long stems.
- Seed pods are slender and no more than 1/2 inch long.

Distribution

Found throughout the continental U.S. but is native in some of those states.

Establishment method

Nodes on the stems can send forth roots and spread the plant vegetatively.

Threat

Watercress rapidly forms dense stands that exclude native plants.

Control

Hand-pulling is recommended.

Origin

Europe. Introduced in 1831.

Resources

Central Jersey Invasive Species Strike Team, USDA Plant Database.

Winter Creeper

Euonymus fortunei



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Description

- Evergreen vine that forms a dense ground cover. Can also grow as a shrub up to 3 feet in height or climb 40- to 70-foot vertical surfaces with the aid of aerial roots.
- 1 to 2 ½ inch-long paired leaves are dark green, shiny and egg-shaped with finely-toothed margins and whitish veins.
- Inconspicuous green-white 5-petaled flowers bloom June to July.
- Fruits are pinkish to red capsules that split open to expose seeds adorned with a fleshy orange seed coat in fall.

Distribution

Scattered throughout the eastern United States.

Establishment method

Spreads vegetatively from lateral shoots off its branches and by new plants produced from shoots at the stem. Stems that break off may be carried via water and establish elsewhere. Vines produce fruits that are eaten by birds and wildlife that disperse the seed and establish new plants.

Threat

Forms dense ground cover that eliminates native species from the understory and inhibits establishment of tree seedlings. Impedes recruitment of canopy species. Can overtop trees and cause decreased vigor.

Control

Hand-pull young infestations and sensitive areas where herbicide is not suitable; however, any plant stem left can resprout. For larger vines, immediately apply a 25% solution of glyphosate or triclopyr to cut stems. Foliar spray with a surfactant can be effective on large populations.

Origin

Introduced from China as an ornamental ground cover.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA.

Yellow and White Sweet Clover

Melilotus officinalis and Melilotus alba

Melilotus alba



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Melilotus officionalis



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Description

- Primarily a biennial, first year's growth is vegetative. Second year plants have a taproot that may exceed 50 inches and flowering stems that ascend 1-10 feet upward.
- Fruit is a small one- to two-seeded pod.
- Flowers are pea-like, either yellow or white.
- Both species flower in June and July, yellow usually a few weeks earlier than white.
- Leaves are alternate and divided into three serrated leaflets; the middle leaflet is on a distinct stalk.

Distribution

Its use in agriculture and for soil stabilization has helped it to spread across N. America. It is now found in every state.

Establishment method

A plant can produce 14,000 to 350,000 seeds. Seeds may remain viable in the soil for more than 20 years.

Threat

Invades grasslands and out-competes native plants for space and resources. Infested areas managed with prescribed fire can actually enhance germination rates and seedling establishment.

Control

For small infestations, hand-pulling of first year stems in late summer/early fall may be effective. Mowing in late spring/early summer may reduce but not prevent seed set as flowering shoots can re-sprout. Foliar application of 2,4-D on young seedlings at two to three tablespoons per gallon with a surfactant has been effective.

Origin

Europe and Western Asia. Introduced as a forage crop and for nitrogen fixing to rebuild depleted soils.

Resources

Kentucky Exotic Pest Plant Council

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CHAPTER 14
TREE PRESERVATION

14.1 PURPOSE

MSD's objective is to preserve as many trees as possible during design and construction of facilities. Trees are beneficial to a community and provide an aesthetically pleasing environment. Trees reduce noise, purify the air, modify the climate, in most cases increase property values and provide wildlife habitats.

To meet these objectives, during the planning and design stages, the proposed routing of the facility must be carefully reviewed. The routing should avoid trees when possible and stay outside of the tree's dripline.

The Louisville and Jefferson County Planning Commission is further developing the following guidelines. The contents of this chapter are intended to be interim guidelines pending completion of the final document.

14.2 GUIDELINES AND GENERAL INFORMATION

14.2.1 General

Generally, cutting the root of a tree within the dripline will reduce the tree's life support system by as much as 25%, outside the dripline only 5%. These percentages can vary with different species of trees.

Exhibit 14-1 shows the common root structure of trees. Exhibit 14-2 shows the dripline and root zones for trees.

14.2.2 Survey Information Needed

a. Species of Tree (Use the Audubon Society Field Guide to North American Trees, Eastern Region).

b. Size (DBH - Diameter at Breast Height). **DBH is measured at approximately 4.5 feet above ground.**

c. Value of the Tree ("Valuation of Trees in Kentucky" - **Kentucky** Arborist **Association**, Inc.).

d. Dripline (Diameter).

e. Encroachment Allowed within the Dripline.

f. Location

1. All trees, **4**-inches in diameter or greater, shall be located and the species given within 30-feet of the centerline of the pipe or 14-feet outside the top of slope of ditches.
2. All trees less than **4**-inches in diameter shall be located and species given, when within an existing or proposed sewer and drainage easement.
3. When trees are grouped together, at a very close interval, locate the approximate center of the grouping and list the most dominant species of the group.

g. Condition (healthy, dead or dying).

14.2.3 Alignment

Pipelines and ditches shall be designed to meander around trees when possible, but necessary measures shall be taken to reinforce ditches in these meandering bends to prevent erosion. The use of the "Green Approach" to reinforce these bends is preferred. The "Green Approach" refers to the use of vegetative solutions to erosion rather than hard liners such as concrete, riprap or gabion, and **revetment** mattresses.

14.2.4 Tunneling or Boring

a. When within a dripline of a tree, consider boring or tunneling. A minimum of 2 feet to the top of the bore or tunnel is recommended. A distance of 3 feet to the top of the tunnel or bore for trees under 12 inches in diameter and 4 feet to the top of the tunnel or bore for trees 12 inches in diameter or more is preferred.

b. For trees 6 inches in diameter and smaller at the DBH, the work pits wall for tunneling or boring should come no closer than the dripline of the tree or as shown on Exhibit 14-3.

c. The side of the tunnel or bore shall be at least 2 feet from the outside of the tree.

d. Most roots live in the top 18 inches of soil. However, root patterns vary depending on the species, size of the tree and the kind of soil. A test pit should be dug to determine if the tunnel or bore should be lowered or could be raised.

14.2.5 Selection & Location

For the answer to "What tree to plant and where to plant it?" contact the City of Louisville's Arborist or Forester or another qualified Arborist.

14.2.6 Arborist

A qualified Arborist shall review all plans, where construction is to take place in a treed area. This plan review and a site visit should determine the effect of the project on the trees that are present. The Arborist should make recommendations on how to prevent or minimize tree damage.

14.2.7 Utility Easements

Do not replant trees within the utility or sewer and drainage easement without written permission from the utility for which the easement was granted.

14.2.8 Root Barrier

Use a root barrier device where necessary to prevent roots from causing damage to pavement or structures.

14.2.9 Replacement

Where removing a tree of significant size and if the property owner agrees, a note shall be placed on the plans stating that a replacement tree, 3-inch caliper, will be planted within the same property and outside the permanent easement. **The replacement tree will be selected from the general guidelines of Chapter 13 of this manual.**

14.2.10 Relocation

Where it is not possible to leave a tree in a permanent easement undisturbed, investigate the possibility of moving the tree outside the permanent easement upon agreement of the property owner.

14.2.11 Construction

a. Protection of the bark of trees shall be prescribed by specifying a method of protection in the specifications or the special provisions.

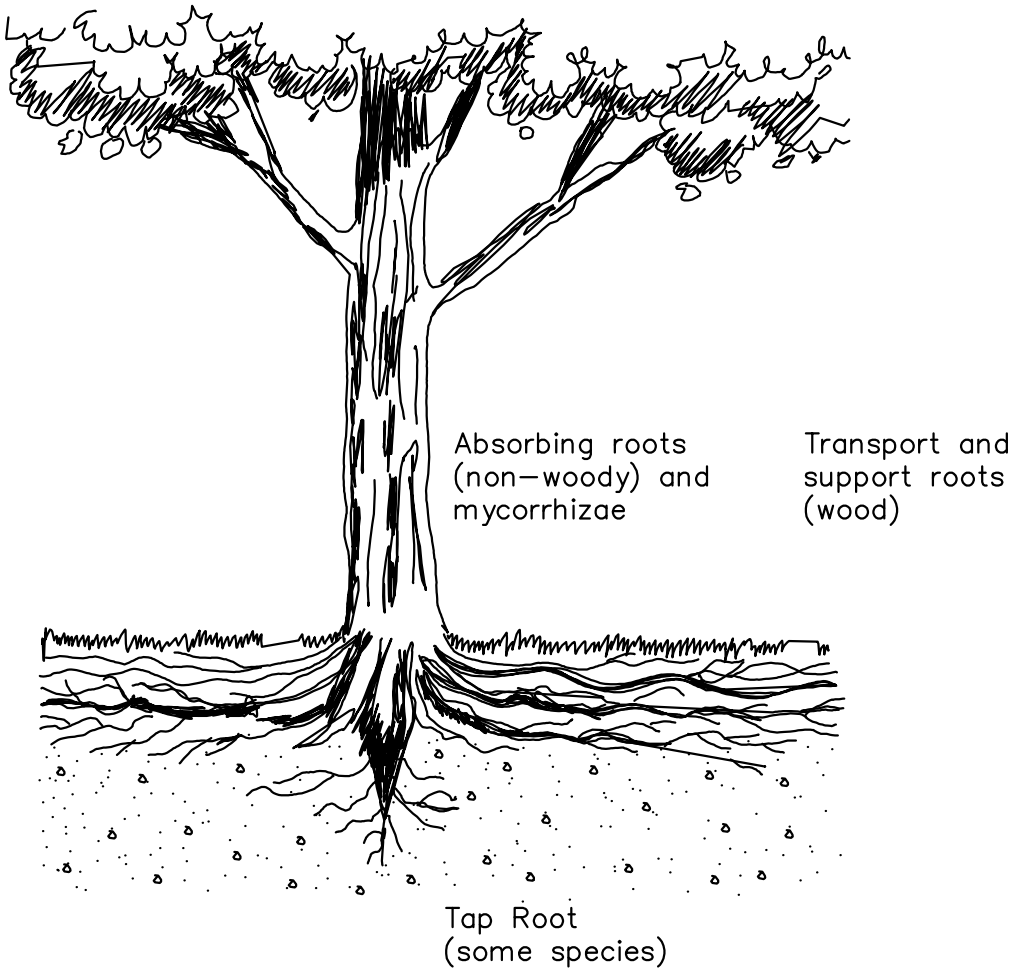
b. Protection of the tree's root system from compaction by construction equipment, vehicular parking, or excessive foot traffic shall be specified in the specifications or the special provisions.

c. Design facilities to reduce the operating of vehicles, equipment, or parking within the dripline of all trees.

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 14-1
COMMON ROOT STRUCTURE

EFFECTIVE DATE: JUNE 30, 2009



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700 W. Liberty Street
Louisville, Kentucky
40203-1913
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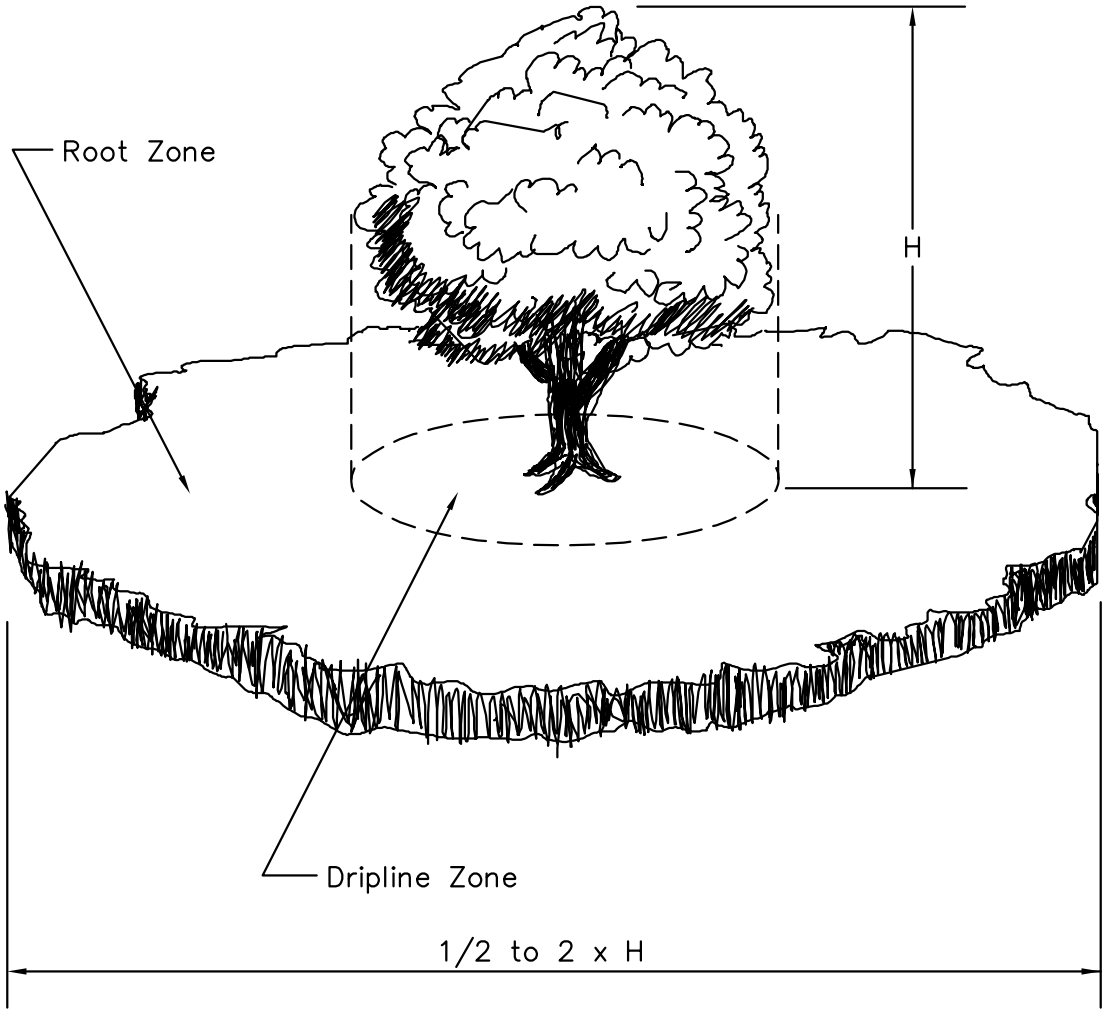
EXHIBIT 14-2
DRIPLINE

EFFECTIVE DATE: JUNE 30, 2009



MSD
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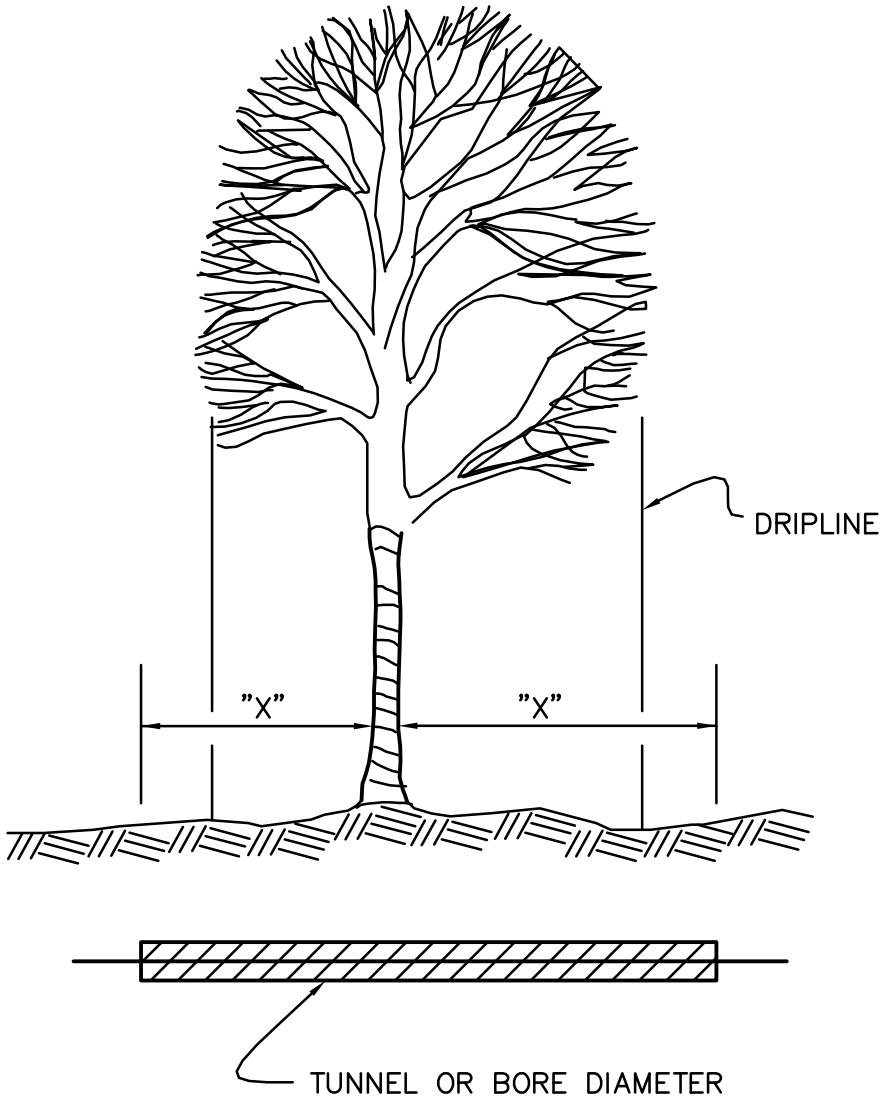
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 14-3
TUNNEL OR BORE LENGTHS FOR TREE PROTECTION

EFFECTIVE DATE: JUNE 30, 2009

Diameter	Distance "X"
6"–9"	5–Feet
10"–14"	10–Feet
15"–19"	12–Feet
over 19"	15–Feet



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CHAPTER 15
SMALL PUMP STATIONS

15.1 PURPOSE

This chapter:

a. Identifies the planning and design approach to be used for small pump stations.

b. Defines specific criteria for the design of small, sanitary pump stations **and their associated force mains**.

c. Delineates submittal requirements required by MSD for review and approval of small pump stations.

d. Delineates requirements for opinions of construction and operating costs.

e. Pump stations must satisfy the regulations of agencies having jurisdiction. Pump stations, at a minimum, shall conform to this document, MSD's Miscellaneous Electrical, Instrumentation & Control Design Standards, and to the Recommended Standards for Wastewater Facilities, 2004 Edition (Ten State Standards).

15.2 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit the Concept Plan and Final Design submittals to MSD for review and approval. Approval by MSD will be required prior to authorization of any succeeding design phase.

15.2.1 Concept Plan Submittals

The purpose of a Concept Plan is to provide MSD with preliminary design data for proposed facilities (sanitary sewers, pump stations, force main sewers). The Concept Plan is used to determine the compatibility of proposed facilities with the approved countywide 201 Plan and Area Action Plans and to justify alternatives recommended for providing sanitary sewer service.

Developers and engineers submitting Concept Plans should reference previous Area Action Plans and the countywide 201 Plan for information on the existing environment and collection system and on estimated future conditions. Concept Plan submittals relating to pump stations shall include the following elements.

a. Project Background

1. Narrative description of the proposed service and drainage areas that can be served by the proposed facility.
2. Description and reference to any Action Plan requirements that relate to the proposed service area (on-site area to which service will be provided) and drainage areas (off-site areas that can be served with the proposed facilities).
3. Topographic map showing the boundaries of the proposed service and drainage areas.

b. Existing Environment

1. Existing land use for the proposed service area, adjacent areas, and drainage areas, delineating project area or development site.
2. Existing hydrology, land features, floodplains, geological characteristics, surface conditions, subsoil conditions, and water table details.

c. Existing Collection System

1. Current sanitary sewer and stormwater collection system maps for the proposed service area, drainage area, and surrounding area.
2. Details of existing system to which a proposed sewer or force main may connect. Capacity of existing sewer system to receive flow from force main or future gravity sewer if temporary pump station is installed.
3. Locations of streets, alleys, unusual obstructions, required rights-of-ways, and all similar data that may help to define the physical features of a proposed sewer project.

d. Future Conditions

1. Designated land use for the proposed service area, drainage area, and surrounding area.
2. Population and flow projections for the proposed service area and drainage areas as called out in the Area Action Plans.
3. Types of development, i.e., residential, commercial, or industrial.
4. Area Action Plan forecasts for the proposed service area, drainage area, and surrounding area.
5. Location of future roads, parks, industrial areas, etc., which may affect the routing and location of sewers and force mains.
6. Construction phasing to accommodate proposed development.

e. Pump Station Justification

In many cases, pump stations are unavoidable and necessary to provide service to a new area. The need for a sanitary pump station must be justified according to one or more of the following criteria. Compliance with one or more of the following criteria does not relieve the designer from the requirement to evaluate alternatives if portions of the service area do not satisfy these conditions:

1. The pump station is recommended in an approved Area Action Plan; or
2. The elevation of a proposed service area is too low to be served by existing or future on-site or off-site gravity sewers; or
3. Interceptor sewers, planned by MSD, are not in place; or
4. The proposed sanitary pump station has been determined to be a cost-effective alternative to an on-site or off-site gravity sewer. To justify a pump station using these criteria, alternatives must be developed and evaluated as described in the following two sections.

f. Development of Alternatives

The following are minimum alternatives to be considered when a cost-effectiveness study is required as part of the pump station justification.

1. Gravity Sewer to Existing Collection System:
   Provide description and preliminary drawings to illustrate existing facilities, proposed facilities, and connection.
2. Interim Solutions:
   Temporary pump stations that provide service until permanent interceptors or other facilities are constructed.
3. Other Possible Solutions:
   a. Consolidation with other pump stations.
   b. Address sewer connections that are not cost-effective due to site conditions or not possible due to elevation differences, individually.
   c. Grinder pumps for individual homes or small clusters of homes.
4. Pump Station Construction:
   Provide description and preliminary drawings to illustrate existing facilities, proposed facilities, and connection.

g. Evaluation of Alternatives

The alternatives shall be evaluated based on a cost-effectiveness analysis outlined in Section 15.3.4. The analysis shall be performed on each alternative and include both economic and non-economic factors.

15.2.2 Final Design Submittals

Design submittals relating to pump stations shall include the following elements:

a. MSD plans and standard specifications modified to specific project needs with additional diagrams and technical data as necessary to construct the proposed installation.

b. Population and flow projections and calculations.

c. Wetwell calculations.

d. Force main calculations.

e. Pump curve/system curves in feet of total dynamic head versus flow in gallons per minute with the following labels: Pump Curve; Single Pump Operation Curve; Two-Pump Operation Curve; Three-Pump Operation Curve (if applicable); Design Point(s); and Operating Point(s) and Operating Envelope. Shut-off head should be included where it will be a controlling point.

f. Total hydraulic efficiency at operating point(s).

g. Pump cycle time.

h. Valve configuration.

i. Float setting calculations.

j. Buoyancy calculations.

k. Force main pressure and water hammer calculations.

l. Determinations for air release, air/vacuum, and/or sewage combination air valves.

m. Odor control calculations and/or assumptions.

n. Electrical calculations and/or power requirements (refer to Section 15.5.5.1 for specific requirements).

o. Opinions of capital and operation and maintenance costs. **Energy efficiency is to be considered in the design.**

p. Site plans showing details of site access, landscaping (if applicable), and electrical utility pole or service rack location.

15.3 DESIGN APPROACH

15.3.1 Compliance with Area Sanitary Plans

Proposed construction or expansion of small sanitary pump stations shall be in compliance with the approved countywide wastewater 201 Plan and approved Area Action Plans.

15.3.2 Approvals

Prior to construction or expansion of a small sanitary pump station, the design documents must receive the approval of the following agencies and be signed and sealed by a Professional Engineer currently registered in the Commonwealth of Kentucky:

a. MSD

b. Kentucky Division of Water

c. Jefferson County Health Department

15.3.3 Service Level

Guidelines presented in this Design Manual govern the planning and design of small pump stations defined as follows:

a. Range in size up to 700 gallons per minute (peak flow) and/or up to 80 feet of total dynamic head.

b. Proposed construction or expansion of sanitary pump stations exceeding the stated ranges will be considered by MSD on an individual basis.

15.3.4 Cost-Effectiveness Analysis

The cost-effectiveness comparison analysis between a pump station and gravity sewer shall include both economic and non-economic factors.

a. Economic Factors

The economic portion of the cost-effectiveness analysis shall use a present worth calculation that considers capital costs, operation and maintenance costs, and salvage values.

Capital costs shall include opinions of construction cost as outlined in Section 15.6, engineering costs based on recognized fee curves and costs for acquisition of properties, easements and rights-of-way, including legal costs. Operation and maintenance costs shall include opinions of cost for labor, utilities, maintenance and repair of facilities. Salvage values shall be developed on straight-line depreciation.

Life cycle costs should be considered over a 20-year period. Unless otherwise directed by MSD, a discount rate equal to that required by the Division of Water should be used to calculate the present worth value of each alternative.

b. Non-Economic Factors

Non-economic factors to be addressed in narrative form, as a part of the cost-effectiveness analysis, should include:

1. Environmental Impact: The short-term and long-term impacts of the alternative on the environment.
2. Reliability: A measure of how dependable the alternative performs over time.
3. Operability: The ease with which the alternative operates over time.
4. Constructability: The ease with which an alternative can be constructed and phased into operation.
5. Resistance to vandalism.
6. Aesthetics and comments on neighborhood/property owner acceptance.

15.4 DESIGN CRITERIA

15.4.1 Definitions

a. Residential Equivalent Population: Refer to Exhibits 8-2 and 8-3.

b. **Design** Average Daily Flow: Residential equivalent population x 100 gallons per capita per day (gpcd). **This term is also referred to as Average Flow.**

c. Peak Flow: **Design** Average **Daily** Flow x peaking factor.

Peaking factor = $\frac{18 + (P)^{1/2}}{4 + (P)^{1/2}}$; Where P = population in thousands

d. Initial Average Flow: Initial residential equivalent population x 100 gpcd.

e. Initial Peak Flow: Initial average flow x peaking factor.

f. 20-Yr. Average Flow: 20-yr. residential equivalent population x 100 gpcd.

g. 20-Yr. Peak Flow: 20-yr. average flow x peaking factor.

h. Ultimate Average Flow: Ultimate residential equivalent population x 100 gpcd.

Ultimate residential equivalent population is defined as the population halfway between 20-year population and watershed saturation population.

i. Ultimate Peak Flow: Ultimate average flow x peaking factor.

j. Watershed Saturation Population: The maximum projected population for the watershed based on present zoning that is equated to equivalent residential units.

k. Emergency Response Storage Volume: Ultimate average flow x 120 min.

15.4.2 General

Population and flow projections for developed and undeveloped areas that are used to design pump stations shall be as defined in Chapter 8. Saturation and 20-year population projections shall be those as used in approved Area Action Plans.

For instances where an Action Plan is unavailable, population projections should be prepared by the Design Engineer and be submitted to MSD for approval.

When designing a new pump station to serve an existing collection system, an infiltration and inflow (I&I) study which considers the effects of wet weather flow shall be performed. The I&I study shall be based on peak flow data

provided by MSD based upon available computer model simulations for the area.

Pump station peaking factors should be the same as sanitary sewer peaking factor, which includes anticipated wet-weather flows.

Pump stations shall be of the wetwell type utilizing submersible pumps. They shall operate automatically under normal conditions but be capable of manual control. Pump stations shall be planned and designed to include provisions for ease of future elimination. Precast concrete or cast-in place concrete wetwells are acceptable.

The pump station top shall be designed to an elevation at least 2 feet above the 100-year flood elevation or the pump station shall be flood proofed to provide maximum protection against flooding while still permitting operation.

Pumps shall be sized such that the pumping capacity, with the largest pump out of service, will handle the peak design flow condition.

All gate and check valves shall be installed horizontally in shallow concrete valve vaults next to the wetwells. The arrangement shall provide for easy access to the equipment to facilitate maintenance. Valve vaults are confined spaces; therefore, they require adequate means for ingress and egress, including OSHA approved ladders and access hatches of sufficient size.

If the pump station is provided with potable water service, the service line shall have a backflow preventer and/or a pressure vacuum breaker ASSE #1020 or a reduced pressure zone ASSE #1013 installed to prevent possible cross connections to the potable water supply. The service line shall be installed in compliance with Louisville Water Company regulations.

Each pump station shall be accessible via an access road with a minimum width of 12 feet and a turn-around to accommodate an AASHTO SU design vehicle at the pump station site. The access road shall be paved with bituminous concrete with a pavement design appropriate to the vehicle and shall be designed to an elevation at least 2 feet above the 100-year flood elevation and maximum grade of 7 percent.

Fencing of the pump station site shall be reviewed on a case-by-case basis by MSD. Landscaping shall comply with buffer requirements of the Louisville and Jefferson County Planning Commission. Any deviations from the above criteria shall be submitted to MSD for review and approval.

To ensure uniformity and MSD system compatibility, MSD has prepared Standard Drawings and Specifications for a typical duplex pump station and its electrical system (see Exhibits 15-1 **through 15-4**). **The DWG files can be found on MSD's web site.** The Design Engineer should use the information that is provided herein to customize these documents in order for the installation to meet the specific project needs. The Design Engineer shall be responsible for the design of the system.

15.4.3 Process

15.4.3.1 Wetwell

Wetwells shall be designed for the ultimate peak flow. The cycle of operation for each pump shall not be less than 15 minutes and the maximum detention time in the wetwell shall average no more than 30 minutes.

The wetwell volume for optimum operation shall be computed as follows:

$$V = (\phi q)/4 \ ;$$

Where:

V = Required operating capacity in gallons

ϕ = Minimum time of one pumping cycle in minutes, from start to start. Ideally ϕ = 15 minutes (maximum 30 minutes; minimum 12 minutes)

q = Pump capacity in gallons per minute (use ultimate peak flow)

Detention times for both initial average flow and ultimate average flow conditions shall be computed.

Wetwell volume shall be based on a maximum draw down depth of 4 feet between the lead pump on elevation and the pumps off elevation.

The design of the pump station shall incorporate a minimum two-hour emergency response storage volume based on ultimate average flow conditions as stipulated under Section 15.4.1. The required volume must be provided in the wetwell and/or a separate, self-draining surge tank between the high wetwell alarm elevation and the invert elevation of the lowest influent gravity sewer. The two-hour emergency response storage volume may be waived by MSD if two sources of electric service are provided or there is an

emergency generator permanently installed at the pump station. Unless specifically prevented by site conditions, the Design Engineer shall layout the collection system and pump station such that the top of the wetwell or nearest upstream manhole is at least two feet below the lowest building floor elevation receiving sewer service. In the event that emergency response measures are overburdened, this will provide a point of relief to prevent backups into homes and the adverse impacts on public health and property damage. The Design Engineer shall identify the location and characteristics of the overflow relief point on the Drawings.

Avoid dropping influent flows into wetwells **by installing a drop pipe connection on the wetwell interior or exterior** to eliminate air entrainment. **The wetwell shall be considered as a Class 1, Division 1 hazardous location. Rail packages shall be non-sparking.** Further wetwell sizing constraints are detailed in Section 15.5.3, Pump Control.

15.4.3.2 Force Main

Force mains shall be designed for ultimate peak flow conditions and checked for initial and ultimate peak flow conditions to insure the velocity ranges.

Sewage combination air valves shall be provided at all high points in the force main. Long horizontal runs and increases in slope may require air/vacuum and/or air release valves, realizing that air release valves are for pockets of air accumulated during operation and air/vacuum valves are to exhaust or admit air during filling or draining the force main. Cleanouts shall be provided at all low points and at additional critical locations. The Design Engineer shall consider and review with MSD the location of all air release valves, air/vacuum valves, sewage combination air valves and cleanouts.

The Engineer shall provide an economic analysis comparing the installation of air release and air/vacuum release valves against the installation of deeper force main piping. The economic analysis shall take into account the installation and maintenance costs associate with the air release and air/vacuum release valves. Air release and air/vacuum release valves shall be specifically designed for wastewater service and be sized per the manufacturer's recommendations.

The air and vacuum release valves will be contained in a vault and vented above ground. A manually controlled isolation valve shall be installed between the force main and the air release or air/vacuum release valves.

Joint restraints **or concrete thrust** blocks shall be **installed** at bends**. An analysis must be made to determine if a joint restraint is required either upstream or downstream of the bend.**. For slopes of 20 percent and greater, anchors shall be provided at each joint (at a minimum). A flexible through-wall connector shall be used at pipe penetrations through structures to allow for differential settlement.

Force main design criteria shall be as follows:

a. Minimum Pipe Size

1. 4-inch I.D. for wastewater pumps
2. 2-inch I.D. for grinder pumps

b. Design Pipe Roughness Coefficient (C)

1.	PVC	C = 120 **and 150**
2.	Polyethylene	C = 120
3.	Lined Ductile Iron	C = 120
4.	Steel or Unlined Iron	C = 100

c. Velocity (V) Range

1. V = 2.0 to 5.0 feet per second (fps) for wastewater pumps
2. V = 3.0 to 5.0 fps for grinder pumps

Note: A maximum velocity of 6.0 fps is allowable with a present worth economic calculation that considers capital and operating costs in order to justify any increase above 5.0 fps.

15.4.3.3 System Head Curve

The pump/system curve calculation may be performed utilizing any acceptable hydraulic equation.

The system head curve is a plot of the discharge through a pipe system given the size against the head losses as a result of friction

in that pipe system. Selection of pump size shall be based on static head and total dynamic head. The design operating point is at the intersection of the pump curve and the system curve. Also, the pump should have an impeller size such that the shut-off head exceeds the pumping head at peak Q.

Static head or static pressure (h_S) shall be based on the average elevation of lead pump on/off:

h_S = (Elevation of highest point in force main) - (Average elevation of lead pump on/off)

Fittings and valves **can** be converted to an equivalent length of force main to compute station losses.

Friction losses (h_f) in the force main **can** be computed according to the Hazen-Williams formula as follows:

$$H_f = (10.44)\,(L)\,\frac{(q)^{1.85}}{(C)^{1.85}\,(d)^{4.8655}}\;;$$

Where:

L = Length of pipe (feet)
q = Flow rate (gallons per minute)
C = Hazen-Williams friction loss coefficient
d = Pipe diameter (inches)

Compute total dynamic head as follows:

TDH = Static Lift + Friction Loss
$= h_S + h_f$

The TDH shall be calculated for the design roughness coefficient as stated in Section 15.4.3.2 and per the pipe manufacturer's **and pump supplier** recommended roughness coefficient. **All applicable** system curves shall be plotted on the pump curve submitted.

The operating point for the selected pump shall be in the range of initial peak flow to ultimate peak flow as determined by MSD. The pump efficiency at the operating point should be within the acceptable operating range of 60 to 120% of the capacity at the best efficiency point. The selected pump must be approved by MSD.

The pump efficiency shall be included in the final design submittal. Grinder pump efficiencies may be obtained from the manufacturer. Following pump selection, the system should be checked for low static head conditions (i.e., full wetwell condition). The minimum head curve shall be plotted on the pump curve. This check is performed to insure that in no case will the pump be required to operate outside its normal operating range. Such an occurrence could result in overloading of the motor and eventual pump failure. **The motors shall be sized to be non-overloading over the entire pump curve.**

When pump stations are proposed to discharge into gravity sewers, the capacity of the gravity sewer receiving the discharge shall be checked to determine the impact on the sewer capacity.

When pump stations are proposed to discharge into force main sewers, an analysis of the existing pump station shall be performed to evaluate the impact of the additional flow in the existing force main and its effect on the existing pump(s) performance. The Design Engineer should check initial and ultimate flow conditions to see if the existing pump capacity is compromised. Conditions should be verified when the existing pump station is pumping and when it is not pumping (on and off). An analysis of the potential for reverse flow through the existing pumps shall be included. If the capacity is reduced, a recommended upgrade to this station should also be presented in conjunction with the proposed pump station design. Approval of systems that discharge into force mains will be evaluated on a case-by-case basis.

15.4.3.4 Buoyancy

Buoyancy shall be analyzed on the wetwell to determine whether additional methods of restraint are necessary. Mechanical equipment, water weight, and other temporary loads shall not be included in the analysis. A safety factor of 1.5 (minimum) is required.

Buoyancy Force shall be computed as follows:

Buoyancy Force = (Displaced Volume) x (Unit Weight of Water)

Opposing Force shall be computed as follows:

Opposing Force = Weight of Barrel + Weight of Bottom Slab + Weight of Top Slab + Net Weight of Saturated Soil over Bottom Slab Extension + Any Additional Restraints (Do not include electrical/mechanical components).

Factor of Safety is computed as follows:

$$\text{Factor of Safety} = \frac{\text{Opposing Force}}{\text{Buoyant Force}} \geq 1.5$$

15.4.3.5 Force Main Pressure and Water Hammer Calculations

From the Uni-Bell Handbook of PVC Pipe, Design and Construction, 1986, water hammer is an increase in pressure in a pipe caused by a sudden change in velocity. The velocity change usually results from the closing of a valve. The maximum surge pressure encountered is a function of wave velocity (a) as follows:

$$a = 4660/(1 + (kd/Et))^{1/2};$$

Where:

- a = Wave velocity
- k = Fluid bulk modulus, 300,000 pounds per square inch (psi) for water
- d = Pipe ID, (inches)
- E = Modulus of elasticity of pipe
  - 400,000 psi for PVC pipe
  - 24,000,000 psi for ductile iron pipe
  - 110,000 psi for polyethylene
- t = Wall thickness (inches)

OR

$$a = 4660/((1 + (k/E)\,(DR-2))^{1/2};$$

Where:

- DR = (O.D. (inches)) ÷ (wall thickness (inches))
- DR = Dimension Ratio

The maximum surge pressure (P) is computed as follows:

$$P = \frac{aV}{2.31\,g};$$

Where:

- V = Maximum change in velocity (velocity goes to 0 feet per second)

g = Acceleration due to gravity (32.2 feet per second-squared)
P = Pressure surge (pounds per square inch)

Total pressure is computed as:

Total Pressure = Maximum Surge Pressure + Static Pressure = $P + h_S$

Total pressure must be less than the rated pressure of the pipe (rated pressure including surge allowance).

Cyclic Surge (Fatigue) Analysis is determined (for PVC force mains only) as follows:

a. Estimate the number of pump cycles for the proposed system using a design life of 80 years (use 4 cycles per hour and a safety factor of 2.5).

b. Calculate the peak hoop stress (S) using Vinson's formula.

$$C = (5.05 \times 10^{21}) S^{-4.906};$$

Where:
C = Average number of cycles to failure
S = Peak hoop stress (pounds per square inch)

c. Determine Total System Pressure (P_T)

P_T = Maximum Surge Pressure + Static Pressure

d. Use International Standards Organization (ISO) formula to determine minimum dimension ratio.

$$DR_{required} = (2S/P_T) + 1 ;$$

Where:
DR = Dimension Ratio
S = Peak Hoop Stress
P_T = Total System Pressure

The calculated DR value must be greater than the DR of the selected pipe.

Force main pressure and water hammer calculations for ductile iron pipe shall be based upon AWWA Standards

C150/A21.15-91, "American National Standard for the Thickness Design of Ductile Iron Pipe." Calculations for polyethylene pipe shall be based upon AWWA Standards C906-90 "Standard for Polyethylene (PE) Pressure Pipe and Fittings."

15.4.3.6 Odor Control

The Design Engineer shall consider the need for odor control if detention time in either the wetwell or the force main, based on the average flow, exceeds 30 minutes.

Refer to Chapter 17, Odor Control, for specific requirements.

15.5 ELECTRICAL

15.5.1 General

This section provides guidelines for the design and preparation of plans and specifications as related to small sanitary pump station power, control, and telemetry. All electrical documents must be signed and sealed by a Professional Electrical Engineer currently registered in the Commonwealth of Kentucky.

All concepts and designs are to strike a balance between function, initial cost, operational cost, and ease of maintenance. Generally accepted designs, materials, and methods are to be used throughout the project. **MSD provides sample design documents that balance these issues. Drawings and specifications for full-voltage started 3-phase and single-phase, and soft started 3-phase, duplex pump stations are available for downloading from MSD's website. The Design Engineer shall utilize these as a template for completing design.** If, however, the Design Engineer identifies an opportunity to take advantage of an innovative design approach, the Design Engineer is to present the proposal in writing to MSD for evaluation.

15.5.2 Applicable Standards or Codes

All systems, designs and procedures are to meet or exceed the requirements of the latest issue of the following codes or standards:

- Kentucky Building Code: KBC
- National Electrical Code: NEC
- Underwriters Laboratories, Inc.: UL
- Factory Mutual: FM
- National Fire Protection Association: NFPA

- National Electrical Manufacturers Association: NEMA
- Occupational Safety and Health Administration: OSHA
- Kentucky Occupational Safety and Health Administration: KYOSHA

Designs should relate to the following specific requirements:

- NFPA 37 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
- NFPA 110 Standard for Emergency and Standby Power Systems
  NFPA 820 Recommended Practice for Fire Protection in Wastewater Treatment and Collection Facilities

15.5.3 Pump Control

15.5.3.1 Automatic Operational Sequence

Programmable logic controller (PLC) based primary controls shall operate the pumps and shall perform automatic alternation and duplexing for two pumps or triplexing for three pumps. The **PLC** shall alternate the lead pump once the wetwell level has been pumped down to the stop elevation. The **PLC** shall also provide for energizing the other pump as a backup or lag pump if needed. Provisions shall also be made for overriding the alternator by manually selecting the pump sequence.

A float switch-based back up control system shall be included that will sequentially start and stop all pumps via time delay relay(s). The back up control system shall function independently of the PLC controls. Upon actuation of a backup float switch, both pumps will be started sequentially with the use of time delay relays. As the level in the pump station falls below the backup stop float switch, the pumps will be stopped in sequential fashion with time delay relays.

A step control or variable level scheme shall be used for the pump control. These schemes shall establish the following sequence of operations:

a. Constant Speed Pumps - The lead pump shall start when the wetwell volume from the pumps "off elevation" to the lead pump "start elevation" is equal to the volume derived in Section 15.4.3.1. The minimum separation between these elevations shall be 12 inches.

If the influent sewage flow into the wetwell is greater than the capacity of one pump, the second and, if applicable, third pumps shall start at ascending, separate levels (start elevations). They then continue to run until the liquid level in the wetwell is pumped down to a predetermined level (stop elevation) for all pumps.

b. Variable speed pumps will be considered on a case-by-case basis.

A PLC program shall be provided and downloaded by MSD based on the sample pump station designs identified earlier. Elevations (in feet above the wet well floor) shall be provided by the Design Engineer to MSD for pump controls. Deviation from the sample pump station designs may render incompatible the associated PLC program developed by MSD for the Developer's use. At MSD's discretion, responsibility for PLC program development for non-standard pump stations may be transferred to the Developer.

15.5.3.2 Control Settings

PLC-based primary controls shall stop all pumps at the wetwell level equal to the minimum level recommended by the manufacturer of the proposed pumps **plus 24 inches and a minimum of 12 inches below the PLC controls lead start elevation**. The increment in levels between the **PLC control** multi-pump start points shall be a minimum of 12 inches.

The elevation for actuation of the back up stop float switch shall be 12 inches below the PLC controls stop elevation. The back up start float switch shall be 12 inches above the last lag pump PLC controls start elevation.

The **SCADA** high water alarm level shall be at or lower than the invert of the influent pipe and at least 12 inches above the **back up start float switch** elevation. **The local high water alarm level shall be a minimum of 12 inches above the high water SCADA alarm.**

15.5.3.3 Level Detection

A hydrostatic level transmitter shall be the preferred method of level detection and shall be incorporated into the pumping station

operation. **Float switches shall provide back up pump control and high level alarm signaling. The level transmitter shall be installed in a stainless steel stilling well**. The float switches shall be **free hanging and** suspended by weighted cables, which contain the wiring. The cables shall be of sufficient length to be installed without splicing. Level detection systems that require maintenance personnel to enter the wetwell to repair or replace components are unacceptable. Intrinsically safe relays must be used in conjunction with float switches**, and intrinsically-safe signal repeater used with the level transmitter,** in order to meet the requirements of Class 1, Division I, Group D hazardous locations.

15.5.3.4 Operator Interface

A graphic touch screen "human-machine interface" terminal (HMI) shall be provided for indicating status and alarms, and for input from the operator for various control functions. Two exceptions are the inclusion of a hardwired Hand-Off-Auto switch and a reset pushbutton for each pump to allow manual operation of pumps and resetting of motor starter faults without the HMI or PLC. MSD shall provide and download graphics programming for the operator interface for the sample duplex pump stations designs identified earlier. Deviation from the sample pump station designs may render incompatible the associated HMI graphics developed by MSD for the Developer's use. At MSD's discretion, responsibility for HMI program development for non-standard pump stations may be transferred to the Developer.

15.5.3.5 Pump Interlock

Sensors and control hardware shall be provided to monitor the following conditions:

a. Motor stator over-temperature.
b. Seal leakage.
c. Loss-of-phase, phase reversal, or under voltage.
d. Electrical overload (solid-state, temperature compensated **overload relay for full-voltage started pumps**).
e. **Starter fault (from reduced voltage solid-state starter on soft started pumps).**
f. Short circuit.

All of these conditions shall de-energize the appropriate pump(s). Seal leakage **and over-temperature** shall be **latched in the PLC program until** manually reset **via either "soft buttons" on the** the **HMI on the** control panel inner door **or remotely via the MSD SCADA system**. **When the back up level control mode is engaged,** motor stator over-temperature **and seal failure** shall de-energize the pump**, however, the pump will be re-enabled upon if either interlock self-resets e.g. the motor cools down**. **Electrical overload relays and soft starters shall be provided with a reset pushbutton on the inner door of the control panel, independent of PLC or HMI controls.**

Loss-of-phase, phase reversal or under voltage condition shall de-energize all pumps **in any mode of control**. The monitor for these conditions shall reset automatically once the problem parameter falls within its appropriate range. If, **upon** reset **of the monitor**, the control system calls for more than one pump, the additional pump(s) shall be energized after a time delay(s) **in both the PLC logic or the backup control system to reduce motor inrush current on the electrical service or the generator.**

15.5.4 Alarm System

15.5.4.1 Station Local Alarms

The station shall be provided with a local alarm system **powered from the main control panel and powered via an uninterruptible power supply (UPS). The following shall initiate the local alarm.**

a. High wetwell level.
b. Power failure.

These alarms should annunciate locally via a red flashing light and a horn. The horn shall have a silence button accessible to the general public. The light shall remain on during alarm condition. The horn and light will de-energize automatically **once** the listed alarm conditions **have reset**.

15.5.4.2 Telemetry

The following alarm signals shall be provided **as inputs to the PLC for transmission via MSDs county-wide SCADA system:**

a. Power failure.
b. High wetwell level.
c. Pump on (1 per pump).
d. Pump overload **or starter fault** (1 per pump).
e. Pump seal leak **(1 per pump)**
f. **Pump high** temperature **(1 per pump)**
g. Pump circuit **breaker tripped** (1 per pump).
h. Pump **circuit breaker off** (1 per pump).
i. Pump in Hand (1 per pump)
j. Pump in Auto (1 per pump)
k. Pump in Off (1 per pump)
l. Failure of UPS or DC power supply
m. Main circuit breaker tripped.
n. Transfer switch in normal position.
o. Transfer switch in emergency position.
p. Normal source available.
q. Emergency source available.
r. Generator failure.
s. Generator running.
t. **Generator control in Auto.**

All alarms shall be implemented via 120 VAC dry contacts.

The control panel shall include a blank space on the subpanel for mounting of a modem. MSD shall provide and field install the modem upon notification of control panel installation. MSD shall also provide cabling and antenna as necessary to deliver the SCADA signal from the PLC modem port to its host SCADA site.

15.5.5 Pump Station Electrical Criteria

15.5.5.1 General

All pumping stations shall be wired in strict accordance with the latest edition of the National Electric Code. Pumps and equipment shall normally be designed to operate from a 230/460 volt, three-phase power source. No single-phase to three-phase converters will be allowed. Single-phase service will be considered by MSD on a case-by-case basis. Single-phase pump stations shall have capacitor start motors. A control power transformer will not be required to facilitate auxiliary equipment when **240/**120 volts are available

from the utility. All motor starters and controls shall be located in a shop-assembled control cabinet, located above ground level.

All conductors shall be insulated, stranded, copper wire, rated at 600 volts.

An enclosed circuit breaker shall be provided and rated for use as service entrance equipment and shall be housed in a stainless steel, NEMA 4X enclosure. **It shall include an auxiliary contact for indicating a tripped condition to the PLC.**

Pump control cabinets shall be stainless steel, NEMA 3R enclosures suitable for outdoor installation. Each cabinet shall be equipped with a hasp, staple, and three-point latching handle to provide watertight and tamper-proof service and shall be mounted on **a wet well electrical rack.** Each cabinet shall have a hinged inner door, containing all operator control devices, and must be appropriately sized for the application.

Motor starters shall be enclosed in separate enclosures with interface wiring to pumps and control panel as indicated on the sample duplex pump station drawings. Reduced-voltage starting, if required, shall utilize solid-state motor starters with bypass contactors. The solid-state starters shall be used to start and stop the pumps with the bypass contactor utilized for full speed operation. Consult with LG&E for motor starting requirements.

Separate pedestal mounted stainless steel enclosures shall be provided to facilitate the junction of cords from Class I, Division 1 wet well components with permanent wiring to non-hazardous starters and control panel. Cable hangers shall be used to suspend wet well component cables and facilitate easy access for component removal from the wet well top slab. Conduit seal-offs shall be provided between the cord junction box and the respective starter or control panel to isolate them from hazardous and corrosive wet well gases.

At a minimum, the following key issues must be addressed in the design with calculations and/or NEC references to verify such:

a. Service size
b. Feeder/service conductor size
c. Ground conductor size
d. Feeder/service disconnect size

e. Branch circuit conductor size
f. Branch circuit type of protection
g. Branch circuit over-current protection rating
h. Motor controllers size and overload protection rating
i. Pump control system transformer over-current protection
j. Available fault current
k. Feeder/service over-current protection
l. Ground fault protection if required

The sample electrical design drawings available on MSD's website identify conduit and conductor connections with "fill-in-the-blank" provisions for number and size of wires, and conduit sizes.

The **service conductors,** main **circuit breaker, transfer switch, and starter** branch **circuit conductors**, must be sized so that the full capacity of the motor starters may be utilized in the future.

15.5.5.2 Emergency Power

An on-site internal combustion engine-powered generator shall be provided. MSD prefers the use of natural gas. However, MSD will consider economic factors presented by the Engineer regarding generator and gas service costs vs. the use of diesel generators. These stations shall be totally automatic and shall include all necessary transfer switches and other components. The electrical generators shall be housed in weatherproof enclosures. A critical silencer must be provided to minimize noise from the engine-powered generator.

For those generators with a control panel higher than 6 feet above finished grade, an aluminum or stainless steel platform shall be provided around the perimeter of the generator to facilitate access to the control panel as well as routine maintenance points on the generator.

Generator output circuit breakers shall be equipped with an auxiliary contact to indicate the breaker is tripped. This signal contact shall be combined with other signals in the generation of a common failure alarm SCADA signal. Other SCADA signals as identified above shall be provided.

Transfer switches shall be provided with a time-delayed neutral position and shall be mounted in a stainless steel, NEMA 3R enclosure with three-point latching handle **on an deadfront outer**

door. An inner door shall be provided behind the deadfront door for the mounting of operator interface devices. Accessories shall be provided to meet the SCADA requirements mentioned above.

When two independent public electrical utility sources are available, the requirements for in-place generators may be waived by MSD in favor of the dual utility feed.

15.6 OPINIONS OF COST

Opinions of probable cost shall be based on the best professional opinions of the Design Engineer. The Design Engineer should use recent bid tabulations, and information from suppliers and contractors in formulating the opinions of cost.

15.6.1 Opinions of Capital Cost

Opinions of capital cost shall be in Construction Specification Institute (CSI) formatting and shall be grouped by category.

Opinions of capital cost shall include a construction contingency of 3% and should include a cost for necessary land, easement, or right-of-way acquisition.

15.6.2 Opinions of Operation and Maintenance Cost

Opinions of operation and maintenance cost shall include costs for labor, utilities, maintenance and repair. **Energy efficiency is to be considered in the design.**

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EXHIBIT 15-1 PAGE 1
STANDARD DUPLEX PUMP STATION DETAILS

EFFECTIVE DATE: JUNE 30, 2009

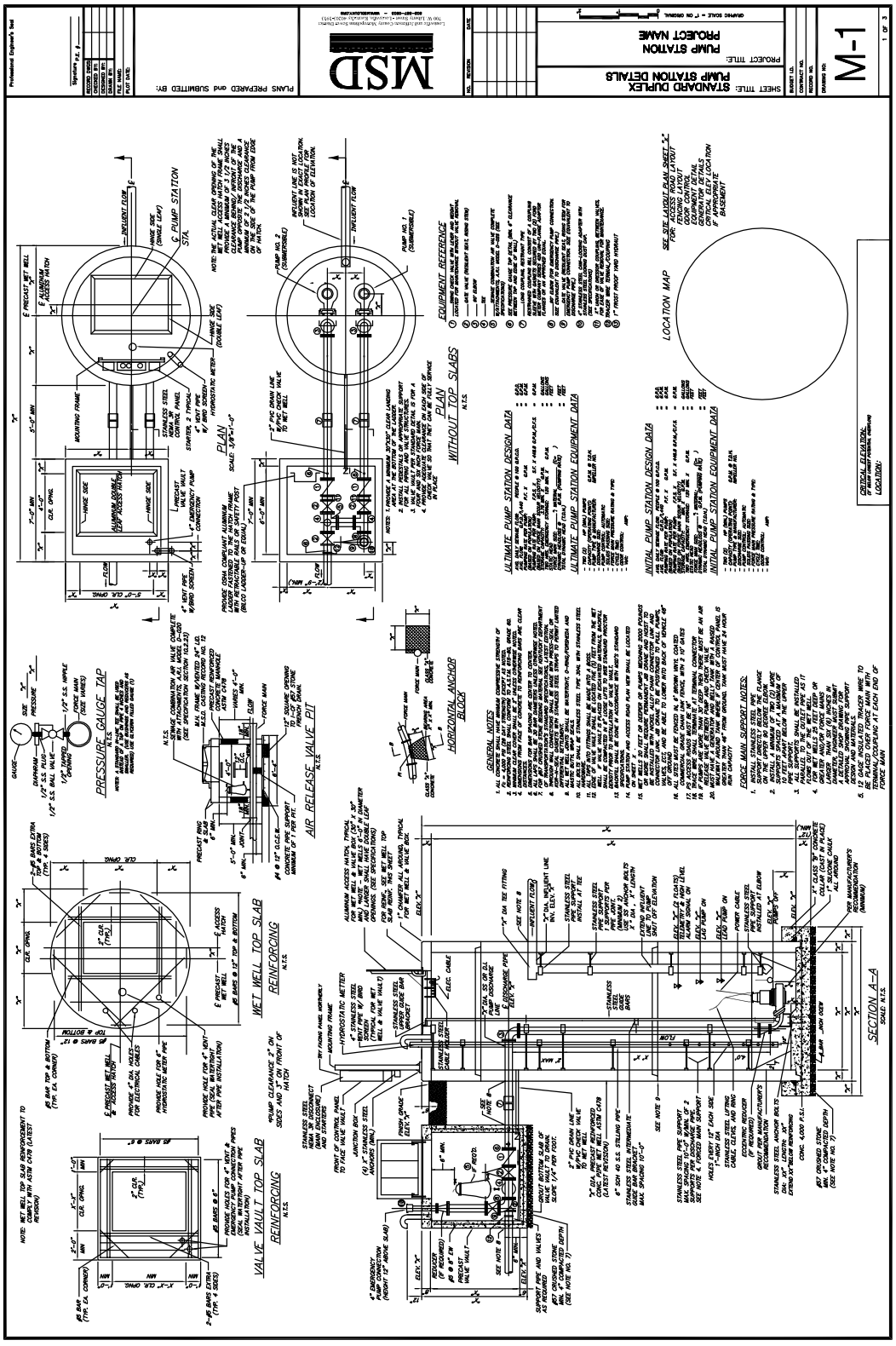

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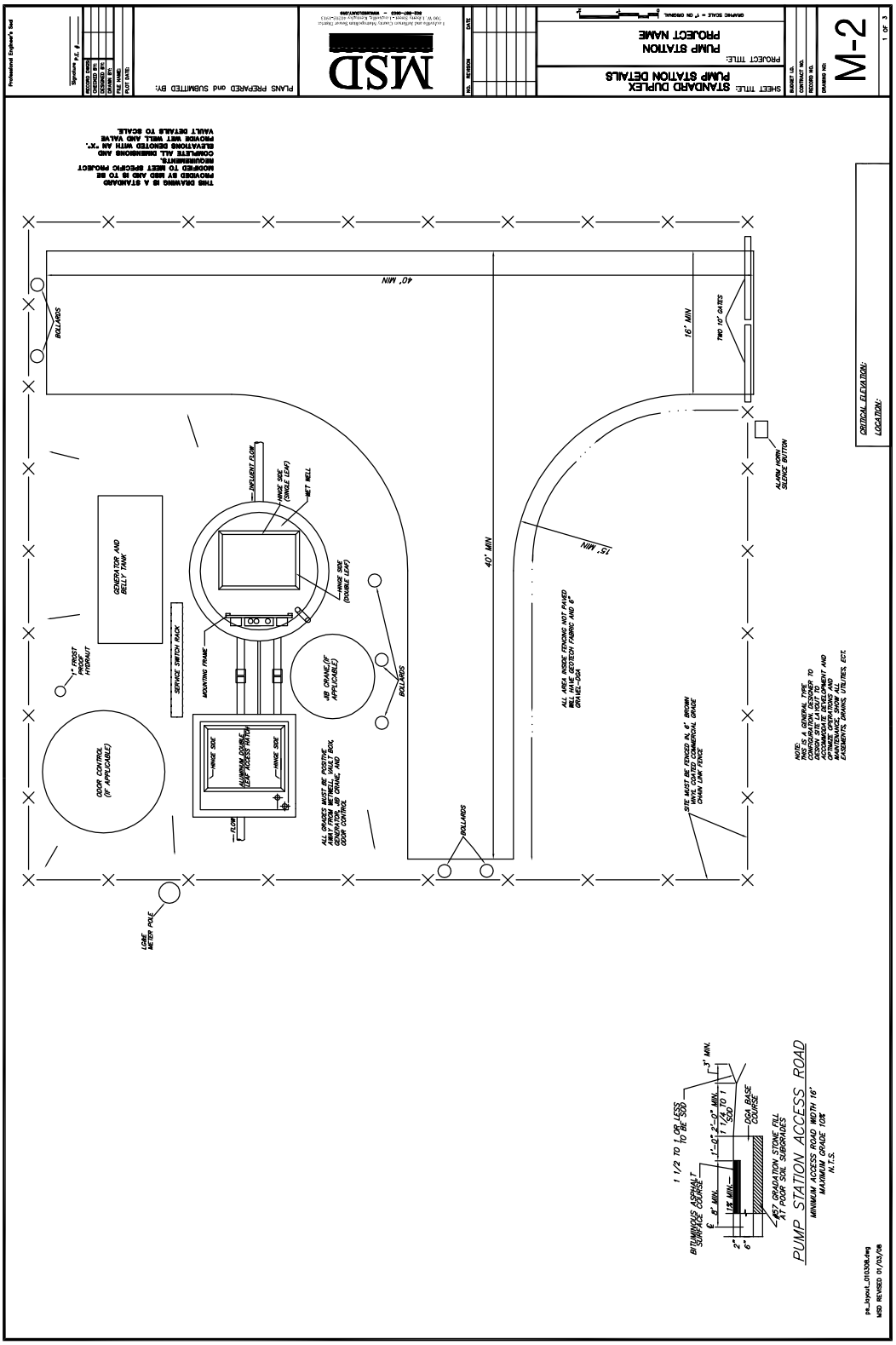
EXHIBIT 15-1 PAGE 2
STANDARD DUPLEX PUMP STATION DETAILS

EFFECTIVE DATE: JUNE 30, 2009



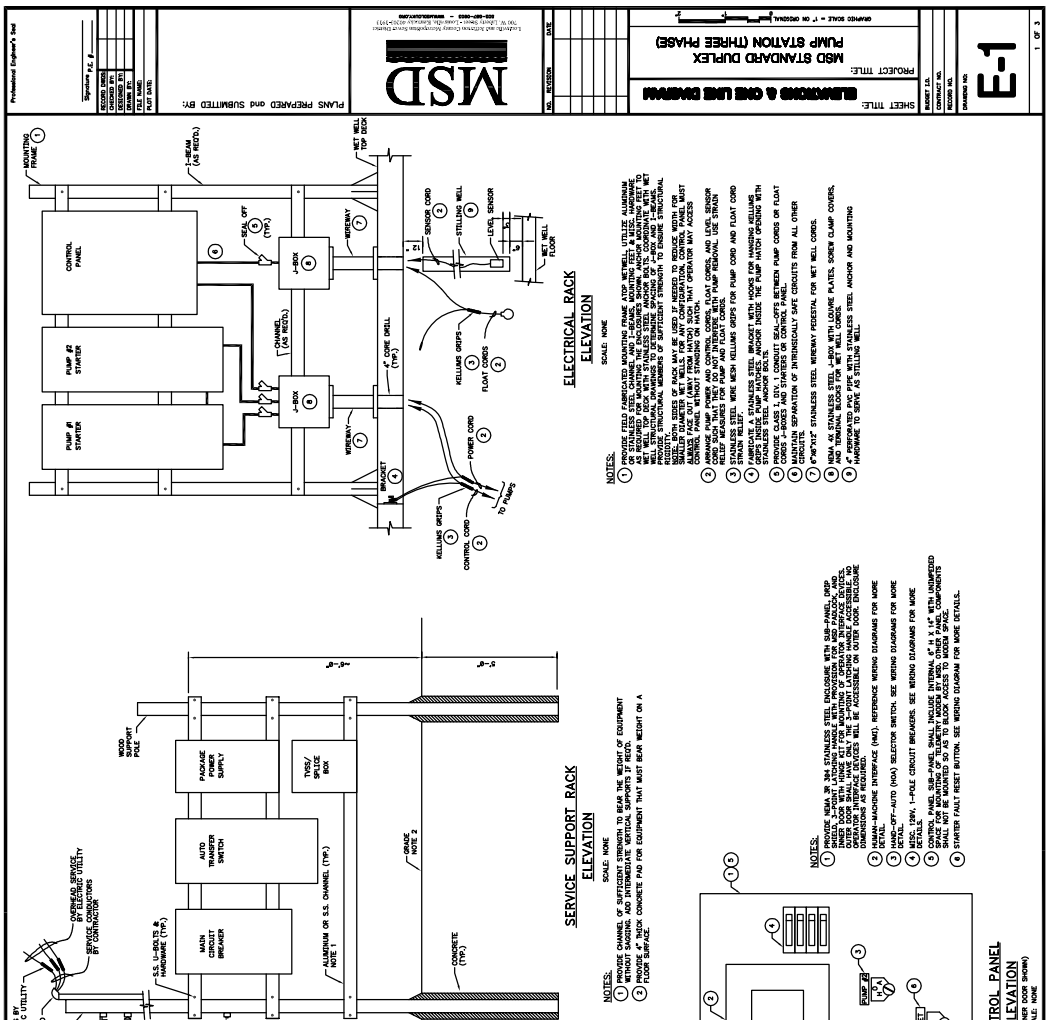

ELECTRICAL & ONE LINE DIAGRAM
MSD STANDARD DUPLEX
PUMP STATION (THREE PHASE)
E-1
ELECTRICAL RACK ELEVATION
SERVICE SUPPORT RACK ELEVATION
CONTROL PANEL ELEVATION
ONE LINE DIAGRAM
CIRCUIT LIST

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EXHIBIT 15-2
STANDARD DUPLEX PUMP STATION
(THREE PHASE)

EFFECTIVE DATE: JUNE 30, 2009

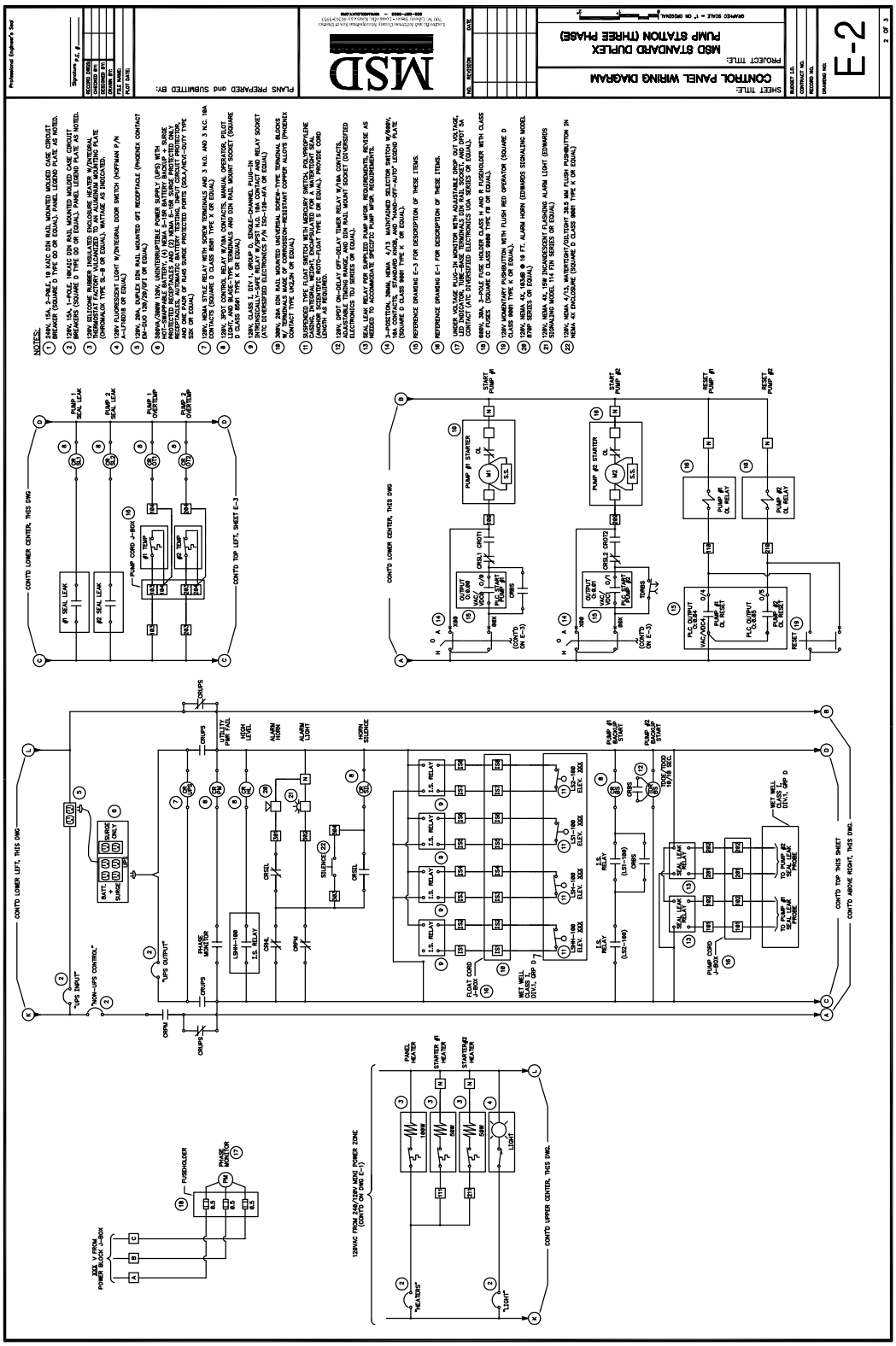

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EXHIBIT 15-2
STANDARD DUPLEX PUMP STATION
(THREE PHASE)

EFFECTIVE DATE: JUNE 30, 2009

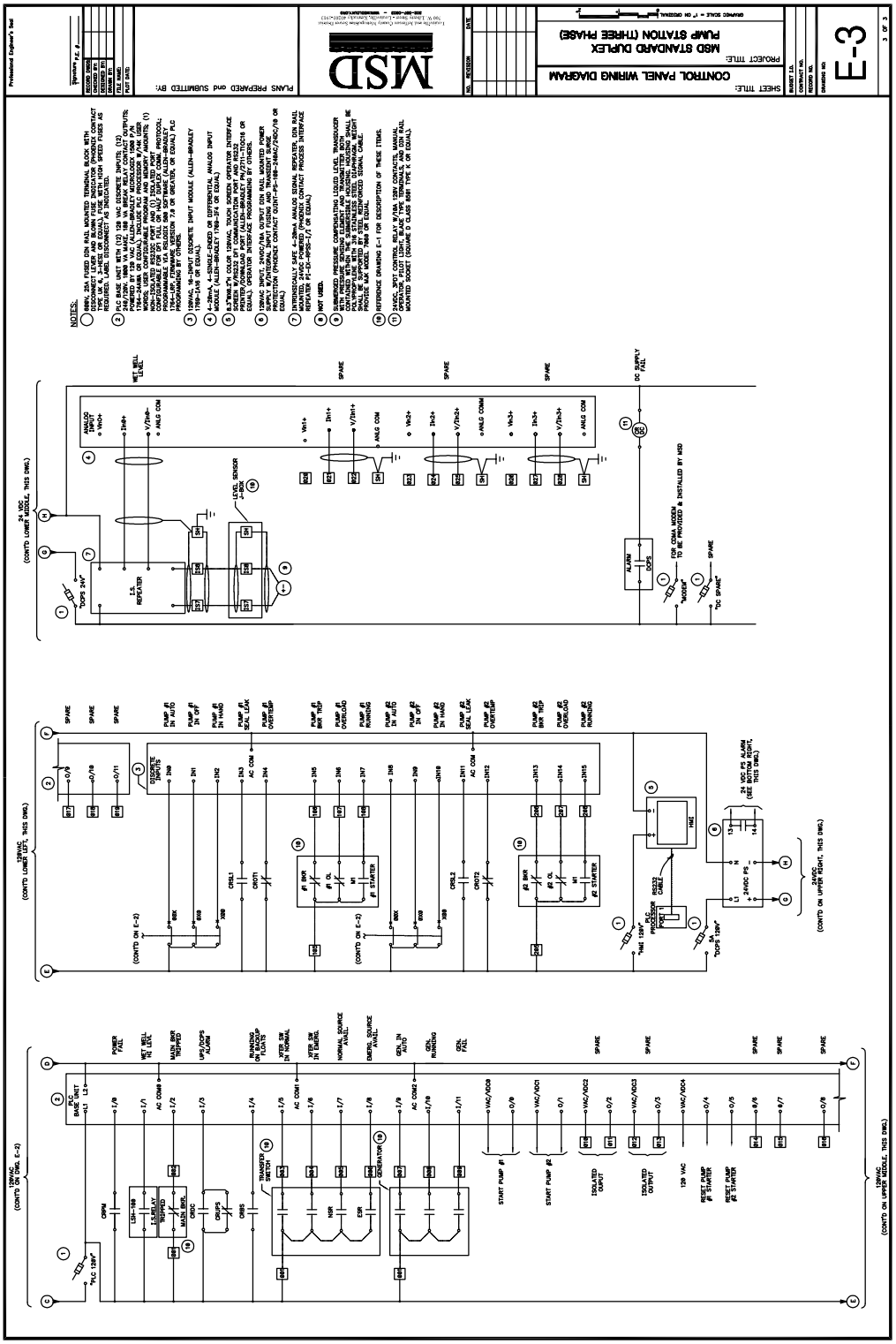

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EXHIBIT 15-3
STANDARD DUPLEX PUMP STATION
(SINGLE PHASE)

EFFECTIVE DATE: JUNE 30, 2009

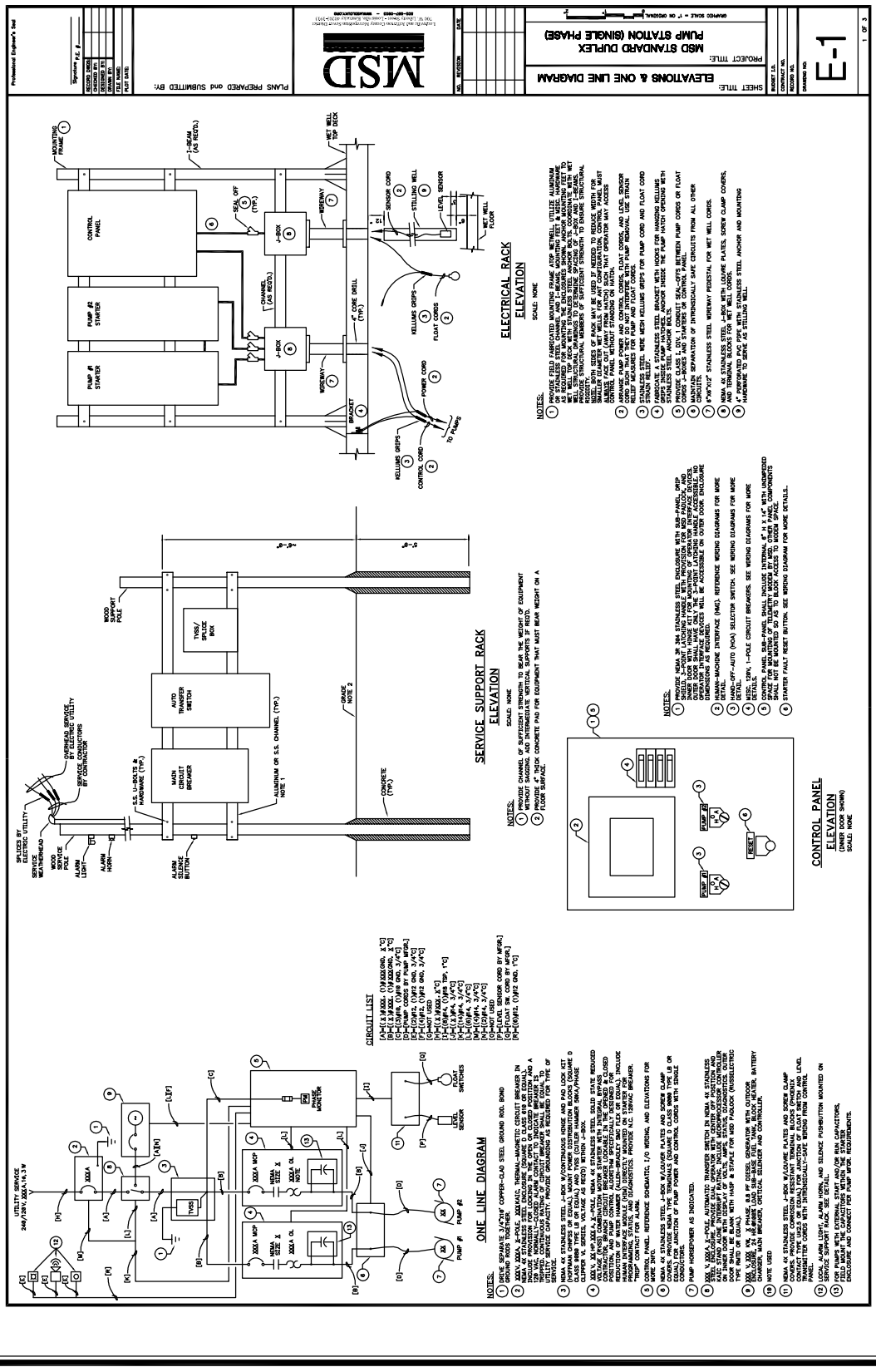

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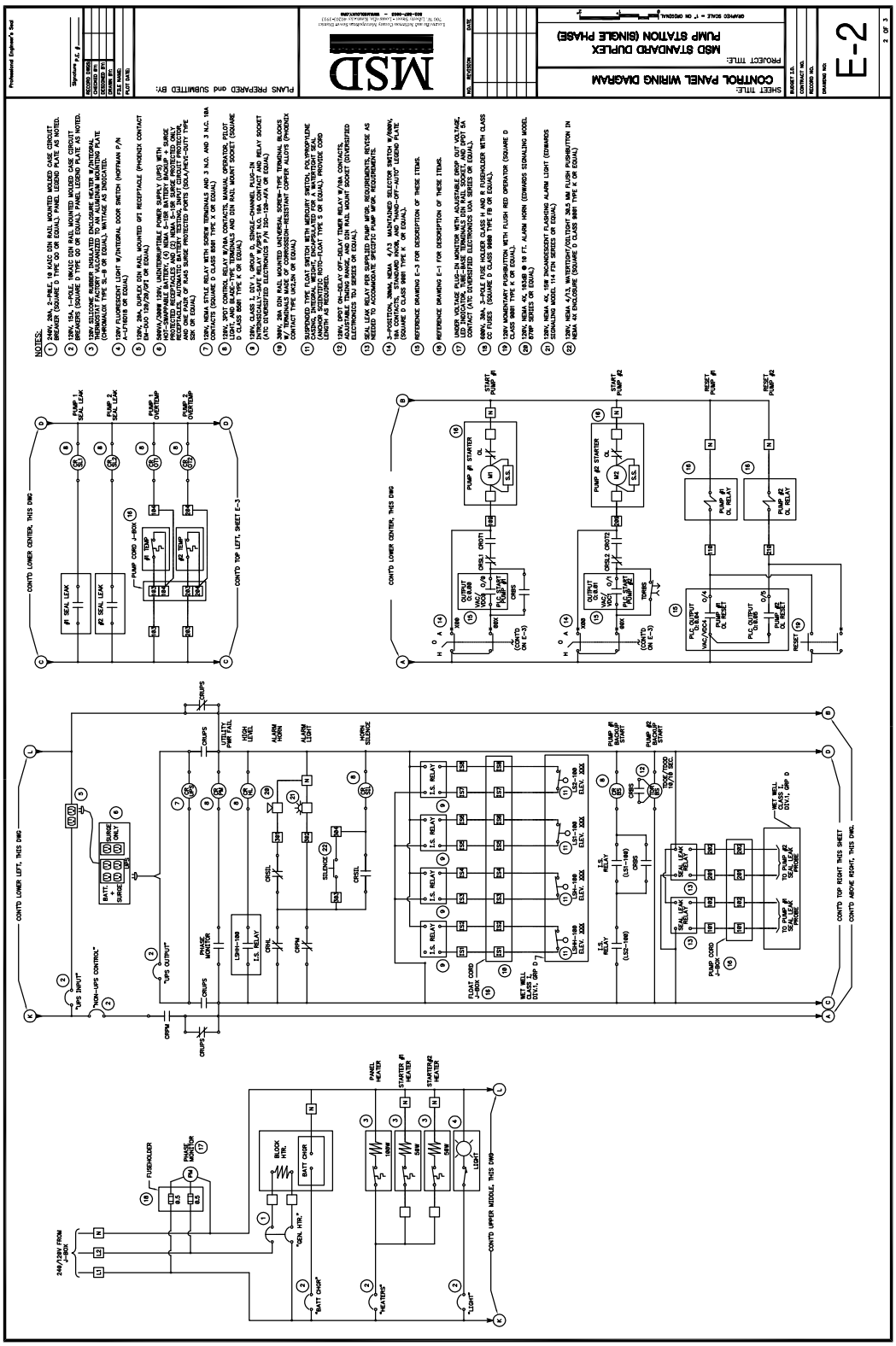
EXHIBIT 15-3
STANDARD DUPLEX PUMP STATION
(SINGLE PHASE)

EFFECTIVE DATE: JUNE 30, 2009



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Metropolitan Sewer District
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Louisville, Kentucky
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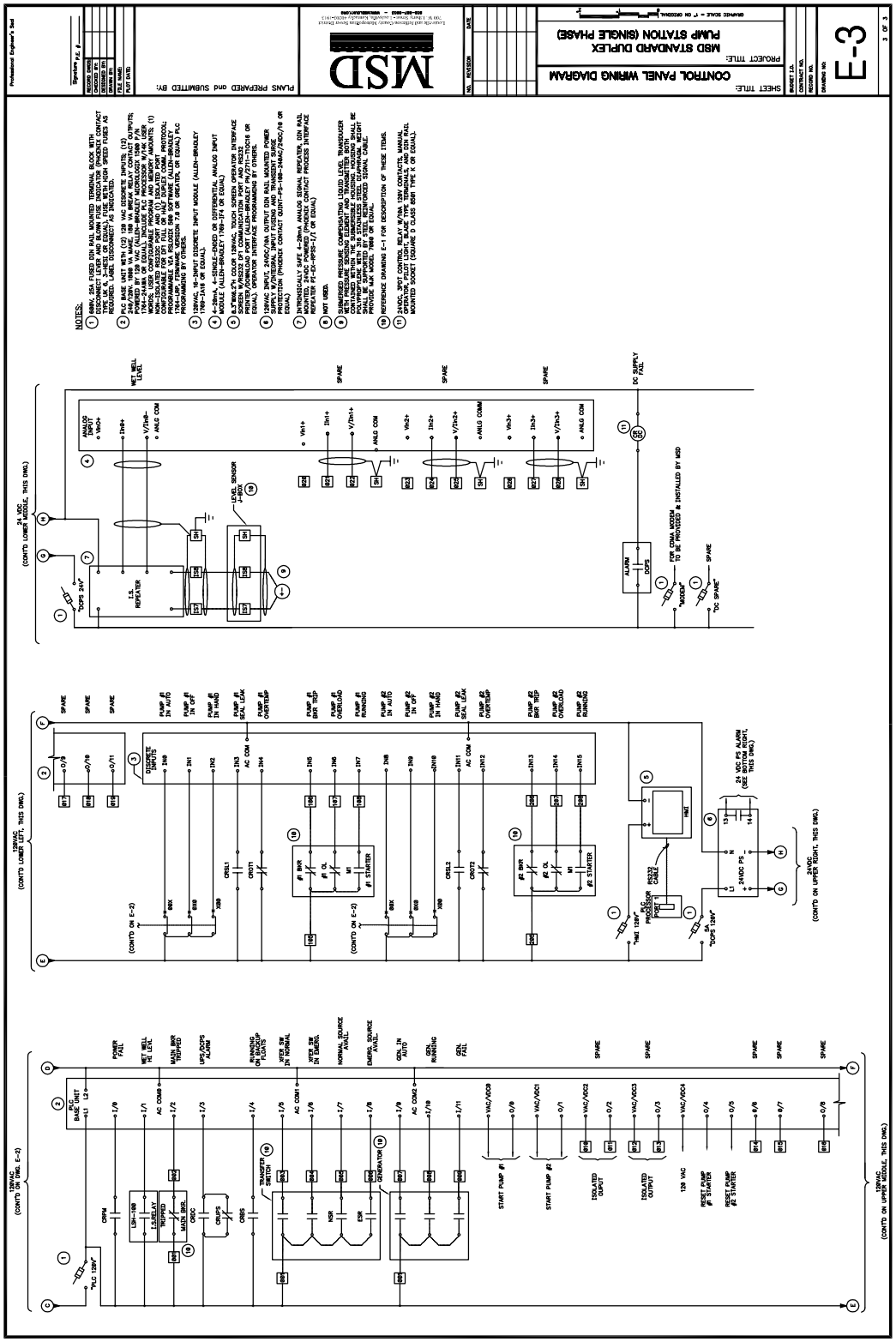

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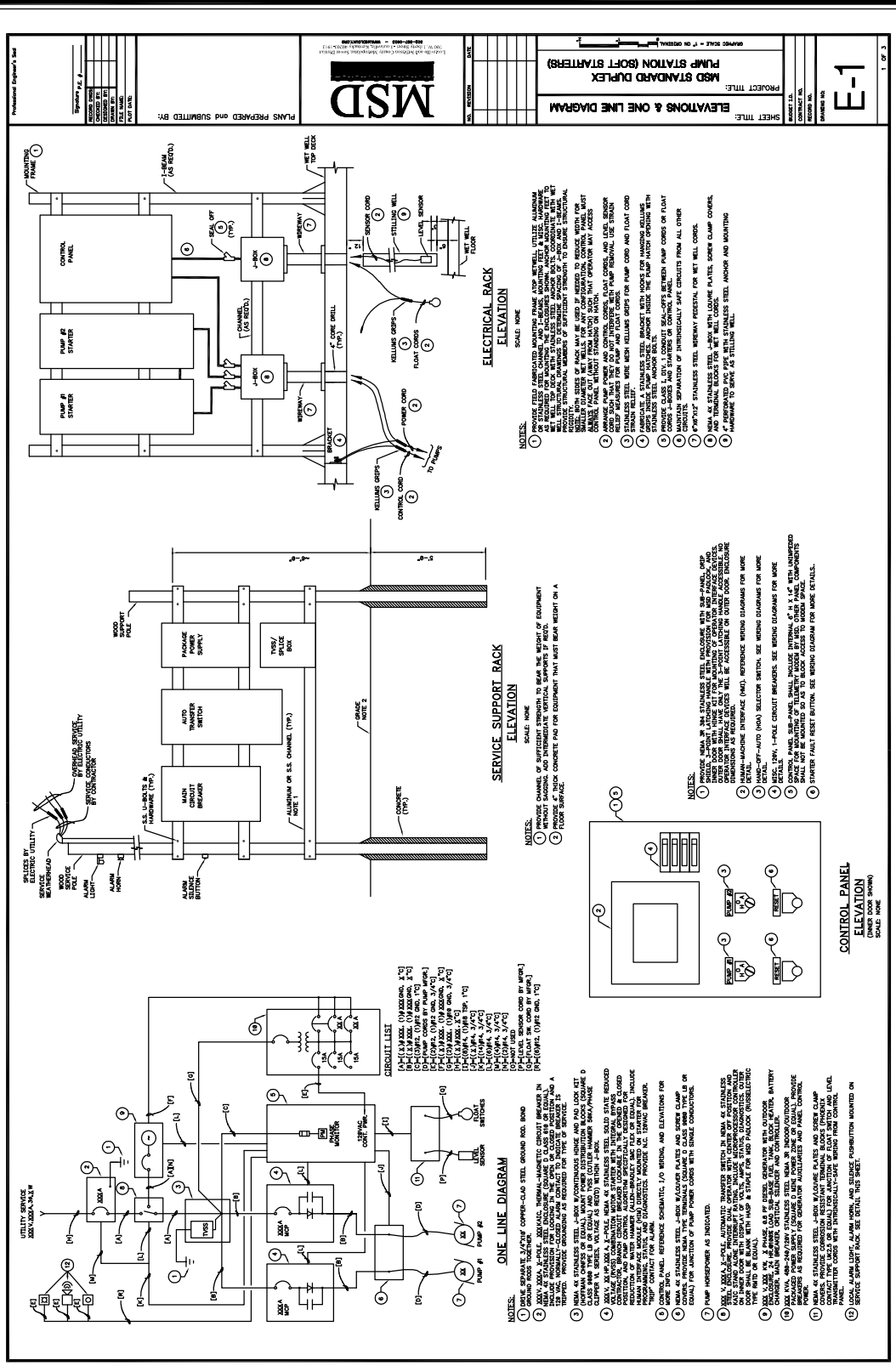
EXHIBIT 15-4
STANDARD DUPLEX PUMP STATION
(SOFT STARTERS)

EFFECTIVE DATE: JUNE 30, 2009



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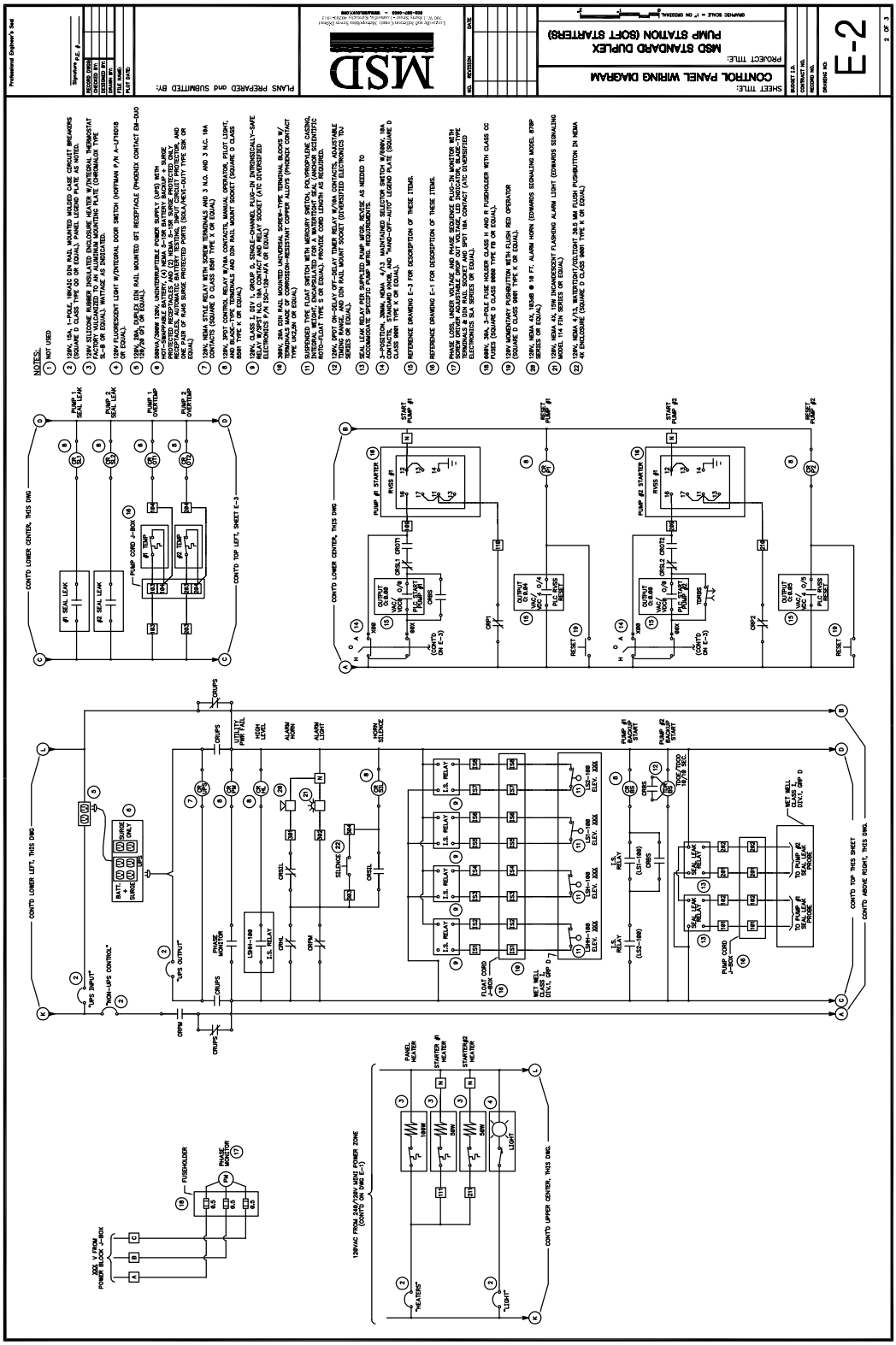

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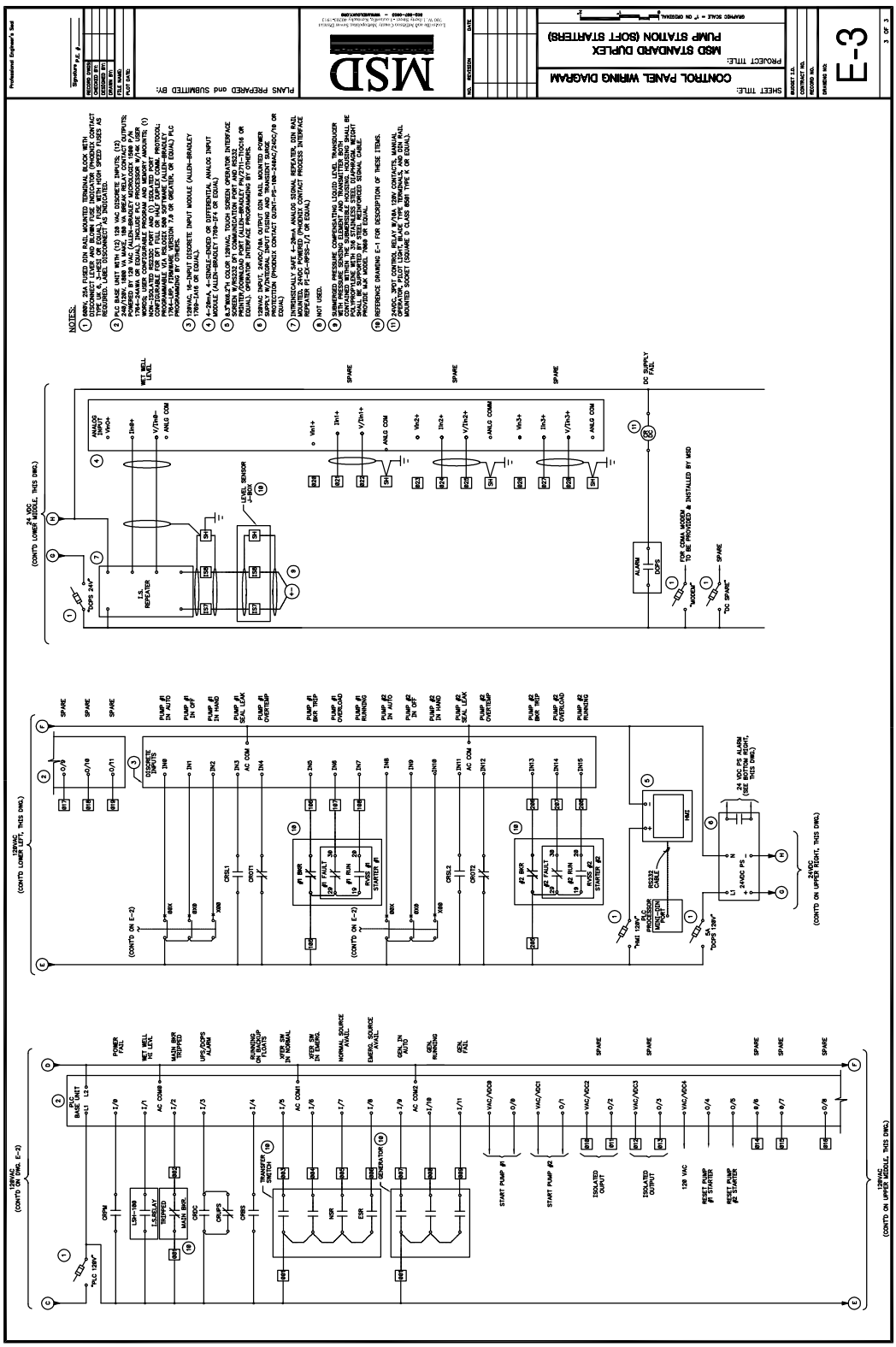

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ODOR CONTROL
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CHAPTER 16
ODOR CONTROL

16.1 PURPOSE

The purpose of this chapter is to:

a. Identify the planning and design approach to be used for controlling odors from pumping stations, force mains, sanitary sewers and small wastewater treatment plants.

b. Define specific criteria by which odor control systems will be designed.

c. Identify submittal requirements required by MSD for review and approval of odor control systems.

d. Outline the requirements for opinions of construction and operating costs.

16.2 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit to MSD for review and approval, the Concept Plan, Preliminary Design and Final Design. If the odor control systems are being designed as part of a larger project then the odor control submittals shall be made a part of the submittals for the larger project. Approval by MSD will be required prior to authorization of any succeeding design phase.

Submittals shall be prepared in report format (8.5-inch x 11-inch) and shall be spiral bound, three-ring bound or bound in some other permanent manner. Appended to or included in the bound submittal shall be maps, figures, and drawings as necessary. Sections are to be organized and tabbed according to the requirements of this section.

16.2.1 Concept Plan Submittal

The purpose of a Concept Plan is to provide MSD with preliminary design data for proposed odor control facilities to determine the compatibility of proposed facilities with the design manual and to justify recommended alternatives.

Concept Plan submittals relating to odor control shall be submitted in accordance with Chapter 2, Section 2.3 and include the following elements:

a. A narrative description of the proposed system.

b. Justification of the need for the system and of the type of system proposed. Identification of potential odor producing conditions.

c. Odor control system design criteria form. (Exhibit 16-1).

d. Location of the facility for which odor control is being provided and proximity to potentially sensitive odor receptors.

e. Description of the potential odor control alternatives and rationale used to select the proposed system.

f. Discussion on availability of utilities required to service system.

g. Identification of duties required of operating and maintaining personnel and listing of potential hazards of handling proposed chemicals (if applicable).

h. Cost effective analysis as described in Section 16.3.4.

16.2.2 Preliminary Design and Final Design Submittals

Preliminary Design and Final Design submittals relating to odor control facilities shall be prepared in accordance with Chapter 4 – Drafting Standards and include the following elements:

a. Design Documentation - Preliminary and Final Design submittal shall include all design requirements, assumptions, background data, design calculations and references. Submittals shall include, but not be limited to, those elements outlined in Section 16.4.1.

b. Plans - Show the project name, sheet title and submittal date on all sheets. Plans must be legible and uncluttered. Final documents shall include Professional Engineer stamp and signature on each sheet.

c. Specifications - Prepare specifications consistent with the MSD Contract Documents Manual.

16.3 DESIGN APPROACH

16.3.1 Approvals

Prior to construction or enhancement of odor control facilities, the design documents must receive the written approval of MSD. The Design Engineer shall consult the **Louisville Metro** Air Pollution Control District (**LM**APCD) to determine if a permit to construct and/or operate an air treatment system is required for the project.

16.3.2 Service Level

Guidelines presented in this Design Manual govern the planning and design of odor control systems defined as follows:

a. Chemical feed systems designed to control the formation and release of odorous compounds from wastewater pumping stations, force mains, sanitary sewers and small treatment plants.

b. Air treatment systems for pump stations, force mains and small treatment plants, which capture the odorous air and treat it by means of absorption, adsorption, oxidation or chemical biological stabilization.

16.3.3 Justification

MSD will determine the need for odor control system(s), based on information provided by the design engineer, on a case-by-case basis according to the following criteria:

a. The history of odor complaints in the vicinity. If the MSD has received odor complaints from residents within 100 yards of the proposed facility within the previous year, odor control will be required.

b. The potential that the facility has to create an off-site odor nuisance. If the facility is fed by upstream pumping stations, if it has collection sewers that have low velocities (<2 ft/sec) and/or long detention times (>6 hours) or if it is expected to receive heavy industrial flow, odor control will be required. On-site odor control will also be required if the wetwell has an average detention time in excess of 45 minutes and may be required with lesser detention times if other conditions warrant it.

c. The proximity of proposed facilities to existing and future homes, businesses and roads. If a home or business is located within 150 feet of the facility, or is expected to be within this distance, odor control facilities will be required.

d. Design calculations provided by the design engineer. Refer to Exhibit 16.1.

16.3.4 Cost Effective Analysis

The cost effective comparison analysis between odor control alternatives shall include both economic and non-economic factors.

The economic portion of the cost-effectiveness analysis shall use a present worth calculation that considers capital costs, operation and maintenance costs, and salvage values.

Capital costs shall include opinions of construction cost as outlined in Section 16.5, engineering costs based on recognized fee curves and costs for acquisition of properties, easements and rights-of-way, including legal costs. Operation and maintenance costs shall include opinions of cost for labor, utilities, maintenance and repair of facilities. Salvage values shall be developed on straight-line depreciation.

Life cycle costs should be considered over a 20-year period. Unless otherwise directed by MSD, a discount rate equal to that required by the Division of Water should be used to calculate the present worth value of each alternative.

Non-economic factors to be addressed in narrative form, as a part of the cost-effectiveness analysis, should include:

1.	**Environmental Impact:**	**The short-term and long-term impacts of the alternative on the environment.**
2.	**Reliability:**	**A measure of how dependable the alternative performs over time.**
3.	**Operability:**	**The ease with which the alternative operates over time.**

16.4 DESIGN CRITERIA

16.4.1 General

Design requirements, assumptions, background data, design calculations and references must be documented and submitted to MSD. If it is determined that an odor control system is required based on the preliminary information and the design calculations submitted on Exhibit 16-1, the following information shall be submitted to MSD for review, as a minimum:

a. Air Treatment Systems

   1. Description of source
   2. Air flow rate
   3. Actual or anticipated odorous compounds and projected concentrations. Include mass loadings data and calculations to support projections.
   4. Number of air changes per hour

5. Headloss calculations and duct sizes
6. Exhaust fan sizing
7. Treatment system description, size, dimensions and space requirements
8. Media replacement projections

b. Chemical Addition Systems

1. Pump cycle times
2. Force main velocities and flow rates
3. Chemical feed dosages
4. Bench scale and/or demonstration test results
5. Air relief valve and force main discharge locations and their relationship to nearby homes and businesses.
6. Chemical storage tank sizing and safety requirements
7. Actual or anticipated sulfide levels in wastewater
8. Chemical feed equipment

16.4.2 Odor Production

Odor complaints from collection systems, pump stations, force mains and small wastewater treatment plants are generally caused by the release of hydrogen sulfide (H_2S) gas. Therefore, the chemical feed and air treatment systems described herein are primarily designed to control H_2S. The following is a description of the sulfide generation process in wastewater systems:

- A slime layer will develop on the submerged walls of gravity sewers and force mains if the velocity of the wastewater through the pipe is too low to scour the sides.

- In aquatic environments lacking dissolved oxygen only anaerobic bacteria attach to the slime layer. These bacteria reduce sulfate (SO_4^{2-}), one of the most common anions in water and wastewater to sulfide (S^{2-}).

- The sulfide ions combine with hydrogen ions in the wastewater to form hydrogen sulfide. Depending on pH, the hydrogen sulfide dissociates to dissolved hydrogen sulfide gas (H_2S), hydrosulfide ion (HS^{1-}), and sulfide ion (S^{2-}). At neutral pH of 7, the distribution is approximately 50% H_2S and 50% HS^{1-}. At pH 6, the distribution is approximately 90% dissolved hydrogen sulfide gas and 10% hydrosulfide ion.

- Dissolved hydrogen sulfide gas is the only form of dissolved sulfide which can be released from wastewater to the atmosphere. H_2S produces the "rotten egg" odor characteristic of septic sewage. The release of H_2S from solution is accelerated under turbulent conditions.

Gravity sewers are generally designed to accommodate population growth well into the future. Often, designers will utilize larger pipe at shallower slopes to allow for future flows, minimize the sewer depth, and reduce construction cost. This practice often results in lower wastewater velocities during the initial years when the sewer carries substantially lesser volumes.

Wastewater velocity directly impacts wastewater detention time within the sewer, the amount of grit and organic solids deposition (both of which tend to further reduce wastewater velocity and increase depth of flow), and the extent of slime layer buildup within the submerged portion of the sewer. Velocity thus affects formation of dissolved sulfide and also the release of hydrogen sulfide gas into the sewer atmosphere.

As with sewers, pump station wet wells are normally designed for future flows. While this practice makes economic sense, it does allow for excessive detention times during the initial years of operation. The longer the detention time, the greater the likelihood that the wastewater will become septic. Unless the pump suction pipes and wetwell geometry are appropriately designed, the accumulation of organic matter will promote the generation of dissolved sulfide and hydrogen sulfide gas.

Force mains, inverted siphons and other surcharged pipes are normally completely full of wastewater, and because this condition does not allow reaeration from the sewer atmosphere, dissolved oxygen levels in the wastewater become depleted, and significant quantities of dissolved sulfide can be generated. These conditions should be avoided when possible.

16.4.3 Odor Control Design Guidelines

16.4.3.1 Pipeline Design

Good design and maintenance practices will reduce sulfide problems in collection systems without the use of chemical addition or air treatment. In general, pipeline design should adhere to the following;

a. Limit the use of closed conduit systems (force mains, siphons, and surcharged sewers). If a closed conduit system must be used, limit its length and provide adequate velocity to scour the pipe. Limiting the use and length of force mains in raw wastewater

conveyance systems is probably the single most important factor in minimizing sulfide release from collection systems.

b. Wastewater velocities in both gravity and pressure pipes must be adequate to prevent deposition and accumulation of solids, especially during periods of low flow.

c. Maintain gravity trunk sewer and interceptor velocities to the point where wastewater surface reaeration is adequate to prevent sulfide build-up. Maintain dissolved oxygen levels above 0.5 mg/L.

The minimum acceptable velocity for small sewers (less than 18 in. diameter) is two (2.0) feet per second (fps) at initial peak flow conditions as defined in Chapter 8 Section 8.9**.3 and 8.9.4**. Velocities as low as 1.0 fps may be acceptable during low-flow periods and during the early years of development of an area if it is adequately justified. Otherwise, the minimum design velocity shall never be less than 2.0 fps and may need to be higher if a significant sediment load is anticipated. Further information on the design of large diameter systems with regard to sulfide control can be found in ASCE-Manuals and Reports on Engineering Practice-No. 69- "Sulfide in Wastewater Collection and Treatment Systems."

The minimum allowable slopes for sanitary sewer systems are shown on Exhibit 8-5 Chapter 8 – Sanitary Sewer Systems.

The oxygen content of the sewer atmosphere should be maintained close to the 21% found in clean air. Suppression of oxygen content occurs where there are few, if any, connections to an interceptor and/or there is a siphon, pumping station or surcharged section which is blocking the movement of air through the interceptor.

16.4.3.2 Pump Station and Force Main Design

The primary means of minimizing sulfide formation in force mains is maintenance of scouring velocities. It is recommended in Chapter 15 that force mains be designed with a velocity between 2 and 5 fps. A velocity of 2 fps is acceptable with regard to odor control on short force mains (less than 1,000 ft.), but on longer force mains the minimum velocity should be as follows:

MINIMUM SCOUR VELOCITY FOR FORCE MAINS		
Force Main Size (in.)	**Minimum Velocity (fps)**	
	Typical (1)	**Heavy Grit Load (2)**
≤10	3.2	3.9
12-30	3.5	4.3
32-60	4.1	5.0
(1) Average or typical wastewater where scour velocity is achieved frequently. (2) Heavy grit load or substantial time between scouring velocity events.		

The wastewater discharged from the force main should enter the receiving manhole at the invert or below the water level to reduce turbulence. Interior drop pipes shall be used to lower forcemain discharge elevation to manhole invert.
Pump station wet wells should be designed to limit detention time and prevent the deposition of solids in order to minimize sulfide production. New pump station and force main designs shall be modeled to predict H_2S production and release. If the station and force main has the potential to be an odor source, then the designer should take the appropriate actions which may include reducing the pump cycle times using dual force mains, using variable speed pumps or decreasing detention time by adjusting the pump level switches.

The bottom of the wet well shall be sloped to match the requirements of the pumps being installed based on pump/wet well modeling. Pump suction should generate enough velocity at its floor to move solids and eliminate dead spots. Influent drop pipes should be used to bring wastewater in below the wet well water level to reduce turbulence.

All wetwells shall have a 6-inch diameter corrosion resistant fiberglass, aluminum or stainless steel vent pipe with two flanged 90º elbows, which will allow connection to odor control device.

16.4.3.3 Chemical Feed Systems

Chemicals may be added to the wastewater to prevent the formation of sulfides through oxidation or precipitation of sulfides that are already in solution. Certain chemicals, such as calcium nitrate (Bioxide) prevent the formation of sulfides because bacteria use nitrates, if no dissolved oxygen (DO) is present, preferentially over sulfates, which prevents the sulfates from being reduced to sulfides. Hydrogen peroxide, potassium permanganate, hypochlorite and chlorine will oxidize sulfides after their formation in the wastewater. Iron salts, such as ferrous chloride, react with the sulfides to produce an insoluble precipitate and prevent the

release of H_2S. In addition, caustic (sodium hydroxide) has been used in slug doses to inactivate slime layers in pipes.

MSD currently uses calcium nitrate for purposes of odor control through chemical addition. Hydrogen peroxide, ferrous chloride, potassium permanganate, hypochlorite and chlorine are not used at pumping stations due to poor performance, excessive cost and/or safety concerns.

MSD has found calcium nitrate and ferrous chloride to be effective in controlling H_2S. Calcium nitrate is also easy to handle by operating personnel. An important difference between these two chemicals is that nitrate solutions are less effective at preventing the release of H_2S if sulfides are already in solution. $FeCl_2$, on the other hand, will precipitate the sulfides after they are formed and prevent further formation. This means nitrates should be added upstream of sulfide formation where possible.

Another product used by MSD is a mixture of calcium nitrate and anthraquinone (marketed as Bioxide AQ). This product is often used in situations where existing sulfides have to be removed and where the formation of dissolved sulfides (DS) need to be prevented. This product is non-hazardous and is handled like calcium nitrate except a mixer is required in the storage tank to prevent settling.

The first step in designing a chemical feed system is to conduct laboratory tests on the wastewater to determine sulfide levels under various conditions. For existing pump stations, these tests should be performed on the wastewater as it exits the force main because the sulfide levels will be highest at this point.

The following design criteria shall be used as a guide in designing systems to feed nitrates at pump stations.

CHEMICAL FEED SYSTEM DESIGN CRITERIA	
Criterium	Nitrates
Method of Delivery	Bulk Liquid
Design Dosage Range (1)	1.5 gallons/lb DS
Minimum Reaction Time (mins.)	30
Maximum Allowable DS at Discharge (mg/l)	0.3-0.5
Storage Tank Capacity (days)	90
Storage Tank Material	See Note (2)
Secondary Containment	Secondary containment berm may be required depending on threat to nearby water supplies
Number of Chemical Feed Pumps	2
Chemical Feed Point (Discharge point must be visible from above)	Entrance to P.S. Wetwell above High Water Level

Notes:

1. Design dosages shall be used to size equipment on systems where field tests cannot be performed. Actual dosages will be determined via field tests when system is on-line.
2. Cross-linked High Density Polyethylene or Fiberglass Reinforced Plastic (FRP).

The liquid chemical feed system equipment shall consist of a chemical storage tank (or drums), chemical metering pump(s), pump calibration tube and control panel. Nitrate storage tanks shall be enclosed unless a variance is allowed by MSD and the tank shall include flanges for a fill pipe, pump suction line and vent.

If the chemical is being stored in drums as shown on Exhibit 16-2 the pumping system shall consist of a single diaphragm-type electronic metering pump with spare parts, a calibration cylinder and a pump stand. Pump materials shall be compatible with the chemical being pumped.

The pump and control unit that shall be used with the tank shown in Exhibit 16-3 shall include two metering pumps (with spare parts), pump calibration tube, pump timer, heaters, thermostat, on/off/auto switches, GFI outlet, in a stainless steel NEMA 3R enclosure suitable for outdoor installation. Refer to Exhibit 16-4.

16.4.3.4 Air Treatment Systems

Unlike chemical feed systems, which are designed to prevent the formation of odorous compounds, air treatment systems are designed to capture and treat the odors after they are produced.

Air treatment systems may include the air collection ductwork, an exhaust fan and a means of removing the odorous compounds from the air. System components shall be designed using the following criteria:

a. Ductwork

- Ductwork shall be designed based on the following criteria:

  Materials of Construction — Below Grade:

  - SCH40 or SDR35 PVC Pipe
  - DR 32.5 high density polyethylene

  Above Grade:

  - Fiberglass reinforced plastic coated for UV protection
  - 304 stainless steel

- Air Velocity in Duct — 1500 - 2500 ft/min

- Duct size shall be computed using the following equations:

  $Q = (V)(AC/hr)(1\ hr/60\ min)$
  $A = Q/v$
  $D = (4A/\pi)^{0.5}$

  Where:

  A = Duct cross-sectional area (ft^2)
  D = Duct diameter (ft)
  V = Volume of structure from which air is to be drawn (ft^3)
  v = Velocity of air through duct (ft/min) - (2500 ft/min)
  AC/hr = Air changes per hour from area being ventilated
  Q = Air flow rate (ft^3/min)

The ventilation rate (air changes per hour) shall be based on NFPA 820-Fire Protection in Wastewater Treatment Plants (latest edition) issued by the National Fire Protection Association.

b. Exhaust Fan

Exhaust fans shall be corrosion resistant and constructed of fiberglass reinforced plastic or 304L stainless steel materials with sliding motor mounts to allow sheave replacement.

Fans shall be located indoors if possible and if not then noise suppression devices may be required. Constant speed motors will be acceptable in most applications and timers should be considered if intermittent operation may be required. Flexible connectors shall be mounted on the inlet and outlet flanges of the fan and the volute of the fan shall be equipped with a drain to remove condensate.

c. Air Treatment

1. Modular Biofilters

Biofiltration uses naturally occurring microbes to biologically break down odors in waste air streams into carbon dioxide and water. Typically, air is drawn through a humidification chamber through a media bed, which provides a surface on which the microbes can flourish and then discharged through a stack after treatment. The biofilters shall be a modular design which are essentially fully assembled in the factory and delivered to the site ready for connection of ducts and utilities.

Use the following criteria when designing biofilters. Note these design criteria are applicable for installations with H_2S concentrations of 50 parts per million (ppm) or less. Installations with higher expected H_2S concentrations will require lower loading rates and special design considerations.

TYPICAL BIOFILTER DESIGN CRITERIA	
Media Type	Inorganic Media
Air Plenum Depth (inches)	12-18
Media Depth (feet)	4-6
Loading Rate (cfm/ft^2)	12-18
Empty Bed Residence Time (EBRT) (seconds)	20-30
Maximum H_2S concentration (ppm)	50
Maximum Pressure Drop through Media (inches w.c./ft media depth)	0.25-0.33
Initial Media pH Range	7-8.5
Media Moisture Content (% by weight)	40-60
Media Porosity %	40-50

Water Usage (gallons/ 100,000 ft^3 of air)	10
Maximum Air Temperature (°F)	105
Anticipated Media Life (years)	10-12

There are two primary types of biofilter media. Organic media consists of wood chips, bark nuggets, compost and other organic materials or a combination of these locally available materials. It typically has a lower initial cost than inorganic media but it has to be replaced every 2-3 years and has a higher pressure drop resulting in higher power costs.

Inorganic media is typically a nutrient rich mixture of organic and inorganic material that has an expected life of 10 years or more, has lower pressure drop and power costs and is less susceptible to compaction and drying out. Inorganic media shall be used in MSD biofilters.

2. Carbon Canisters

Activated carbon is an effective method of treating a variety of organic contaminants and odor causing compounds. Carbon canisters are vessels, which allow the odorous air to pass through a bed of odor adsorbing carbon-based media. Carbon canisters are available in many shapes and sizes including preassembled, skid-mounted units. Integrally mounted fans are also available. Refer to Exhibit 16-5 for a detail of a typical skid-mounted carbon canister. The size of the canister will be based on the air flow rate, the estimated contaminant loadings and the type of carbon used. The typical velocity through the bed is 50 - 75 feet per minute.

Small carbon canisters are also available for installation on the vent pipes of wetwells. These vent canisters are passive (no fan) and are bolted to a standard 6" diameter vent flange as shown on Exhibit 16-6.

Carbon adsorbs and captures volatile organics and will adsorb hydrogen sulfide if the carbon is impregnated with caustic or if specifically formulated for H_2S removal. MSD will not regenerate carbon on-site therefore the carbon must be replaced as its adsorption capacity is reached. Carbon is not suitable for high concentrations of H_2S (i.e. greater then 5 ppm) due to its limited adsorption capacity. Carbon must be periodically replaced. Most adsorbers located at pumping stations and

wastewater treatment plants should use caustic impregnated carbon.

3. Packed Bed Scrubbers

Scrubbers are used to absorb and oxidize H_2S and other organic compounds in a packed bed of randomly dumped media. Water is recirculated to the top of the media from a collection sump. Caustic chemicals are added to adjust the pH to about 9.5-10, and hypochlorite or potassium hydroxide is dosed to oxidize the absorbed odorants. Typical design criteria are as follows:

Media height -	6 - 10 ft.
Velocity -	350 - 450 ft/min
Recirculation flow rates -	12 - 14 gpm/1,000 cfm
Water blowdown rate -	1 – 3 gpm
Headloss -	2 - 4 inches w.c.

Other requirements for a scrubber installation shall include a demister, automatic control of pH and oxidation reduction potential (ORP), freeze protection and sump high and low level switches. Scrubbers are well suited for high H_2S loadings, and should be installed where close monitoring and control is available from operating personnel. Scrubbers typically are not used at MSD pumping stations and other small facilities due to the chemical storage and handling requirements and their need for operator attention.

4. Odor Counteractants

Odor counteractants, or odor neutralizers, can reduce odor intensity by interacting two specific compounds in certain proportions. In most cases, the odor counteractant is sprayed into the foul air stream using an atomizer. The atomizer divides the counteractant into tiny particles, which improves surface contact between the odorous compounds and the counteractant.

MSD will not accept odor counteractants as a permanent odor control system but may consider it as a temporary solution while a permanent system is installed.

16.4.4 Applications

Selecting the best means of controlling odors requires an understanding of the cause of the odors, the compounds present, the duration and frequency of the odor, site conditions, utilities available and ultimately the overall cost effectiveness. MSD will evaluate each situation and determine the level of odor control required at each site on a case-by-case basis but the following guidelines may be used to predict odor control requirements.

Summary of MSD Collection System Odor Control Guidelines

1. Pipeline Design

a. Minimize use of force mains and siphons

b. Maintain dissolved oxygen levels above 0.5 mg/L

c. Minimum allowable velocity for gravity sewers 2 feet per second unless waiver is received

d. Minimum allowable velocity for force mains is 2 feet per second for force mains less than 1000 feet long. Refer to 16.4.3.2 for minimum velocities on longer mains.

e. Minimize use of air release valves on force mains

f. Air release valves shall be PVC coated for corrosion protection

g. Force mains shall discharge to receiving manhole at manhole invert via internal drop pipes if necessary. Internal drop pipes shall have open tee connection for clean out purposes.

h. Chemical feed system shall be designed in basic conformance with Exhibit 16-2.

i. Calcium nitrate shall be used in the chemical feed systems unless conditions favor using a different chemical.

j. The need for a chemical feed system at the pump station will be based on:

- Predicted total sulfide production in the force main (Exhibit 16-1)
- History of odor complaints in area
- Density of population along force main route
- Number of air release valves

- Potential for downstream corrosion

2. Pump Station Wetwell Design

a. Gravity sewers discharging to a wetwell shall discharge below low water level to minimize turbulence. Interior drop pipes shall be used.

b. The wetwell bottom shall be designed to prevent the deposition of solids.

c. Wetwell detention times shall be less than 45 minutes whenever possible.

d. All wetwells shall be equipped with a 6-inch diameter flanged corrosion-resistant vent pipe and a carbon canister (Exhibit 16-5) shall be attached to the vent to treat the air prior to exhausting. A larger carbon canister with exhaust fan (Exhibit 16-4) may be required if deemed necessary by MSD.

e. Access hatches to wetwells shall be sealed with weather stripping to prevent fugitive emissions.

f. Drain lines from valve vaults to the wetwell shall be trapped to prevent odor emissions from valve vault vent.

g. Packed bed scrubbers, biofilters and other air treatment systems will only be used at pump station sites when abnormal situations exist and when specifically requested by MSD.

Design engineer shall review potential need for odor control, evaluate odor control options and make recommendations in the Concept Plan submittal. Submittal shall include the information outlined in Section 16.2.1. MSD will review the information and determine need for odor control.

16.5 OPINIONS OF COST

Opinions of probable cost shall be prepared in accordance with Chapter 2, Section 2.6.

16.6 REFERENCES

(1) Bowker, R.P.G., J.M. Smith, N.A. Webster, Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants, Design Manual, U.S. Environmental Protection Agency, Center for Environmental Research, Cincinnati, Ohio, 1985.

(2) Sulfide in Wastewater Collection and Treatment Systems, American Society of Civil Engineers, New York, NY, 1982.

(3) Bowker, R.P.G., N.A. Webster, Detection, Control, and Correction of Hydrogen Sulfide Corrosion in Existing Wastewater Systems, U.S. EPA, Office of Wastewater Enforcement and Compliance, Washington, D.C., 1992.

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EXHIBIT 16-1
ODOR CONTROL SYSTEM
DESIGN CRITERIA FORM

EFFECTIVE DATE: JUNE 30, 2009

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT
RESIDENTIAL AND LIGHT COMMERCIAL DEVELOPMENT PUMP STATIONS
WETWELL DETENTION TIMES AND PROJECTED SULFIDES

Development: _____
Developer: _____
Engineer: _____

Pump Station:			
(a)	Initial Average Daily Flow Rate (gpm)		Data Input
(b)	Wetwell Diameter (ft):		Data Input
(c)	Depth from All Pumps Off to Lead Pump On (ft):		Data Input
(d)	Will Pumps Have VFDs:	Yes/No	Data Input
(e)	One Pump Flow Rate (gpm):		Data Input
(f)	Number of Pumps:		Data Input
(g)	Distance from Wetwell to Nearest Current or Future Residence (ft):		Data Input
(h)	Distance from Wetwell to Nearest Body of Water (ft):		Data Input
(i)	Does Station Receive Flow from Any Other Pump Station?	Yes/No	Data Input
(j)	Name of Upstream Station:		Data Input
(k)	Volume in Wetwell with Pumps Off (gallons): $V = [3.14*(b)^2/4]*(c)*7.48\ gal/ft^3$	0	Formula
(l)	Wetwell Detention Time(DT) (min): DT = (k)/(a)	#DIV/0!	Formula
Force Main:			
(m)	Force Main Length (ft):		Data Input
(n)	Force Main Inside Diameter (ft):		Data Input
(o)	Number of Air Release Valves (ARV):		Data Input
(p)	Closest Distance from ARV to Residence (ft):		Data Input
(q)	Distance from Discharge Manhole to Nearest Residence (ft):		Data Input
(r)	Force Main Cross Sectional Area (ft^2): $A = 3.14*(n)^2/4$	0.00	Formula
(s)	Force Main Velocity With One Pump Running (ft/s): V = (e)/(r)/7.48/60	#DIV/0!	Formula
(t)	Force Main Volume (Ft^3): V = (m)*(r)	0.00	Formula
(u)	Force Main Detention Time at Avg.Daily Flow (min): DT = (t)*7.48/(a)	#DIV/0!	Formula
(v)	Sulfide Flux Coefficient (ft/hr):	0.001	Given
(w)	Effective Biological Oxygen Demand of Wastewater (mg/L):	280	Given
(x)	Hydraulic Radius of Full Pipe (ft): HR = (n)/4	0	Formula
(y)	**Predicted Total Sulfide Production (mg/L): $S_c = [3.28*(v)*(w)*[(1+0.48*(x)](x)^{-1}]*(u)/60$**	**#DIV/0!**	Formula
(z)	Predicted Total Sulfide Mass (lbs/day): S_m =(y)*(a)*60*24/1000000*8.34	#DIV/0!	Formula
	Predicted Bioxide Usage (gals/day): B = (z)*1.0	**#DIV/0!**	Formula

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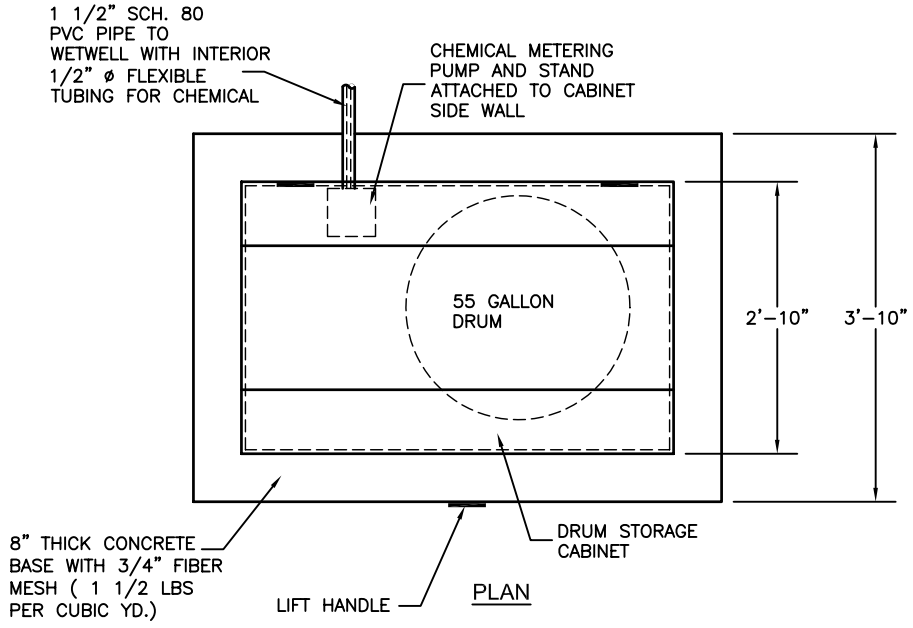
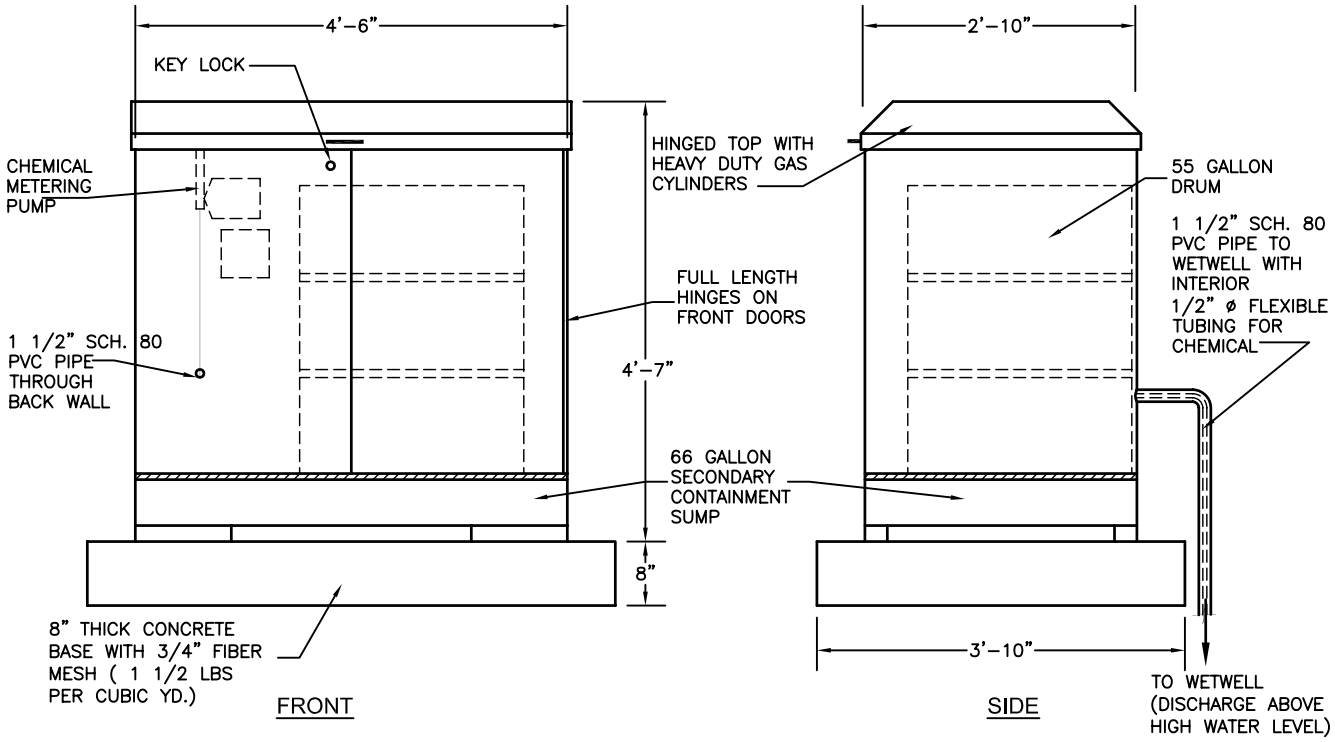
EXHIBIT 16-2
ODOR CONTROL CHEMICAL DRUM STORAGE CABINET DETAIL

EFFECTIVE DATE: JUNE 30, 2009





NOTE:
DRUM STORAGE CABINET SHALL BE DENIOS ENCLOSED 2-DRUM HAZMAT STATION OR EQUAL. CABINET SHALL BE CONSTRUCTED OF WELDED STEEL WITH CORROSION AND WEATHER RESISTANT FINISH.

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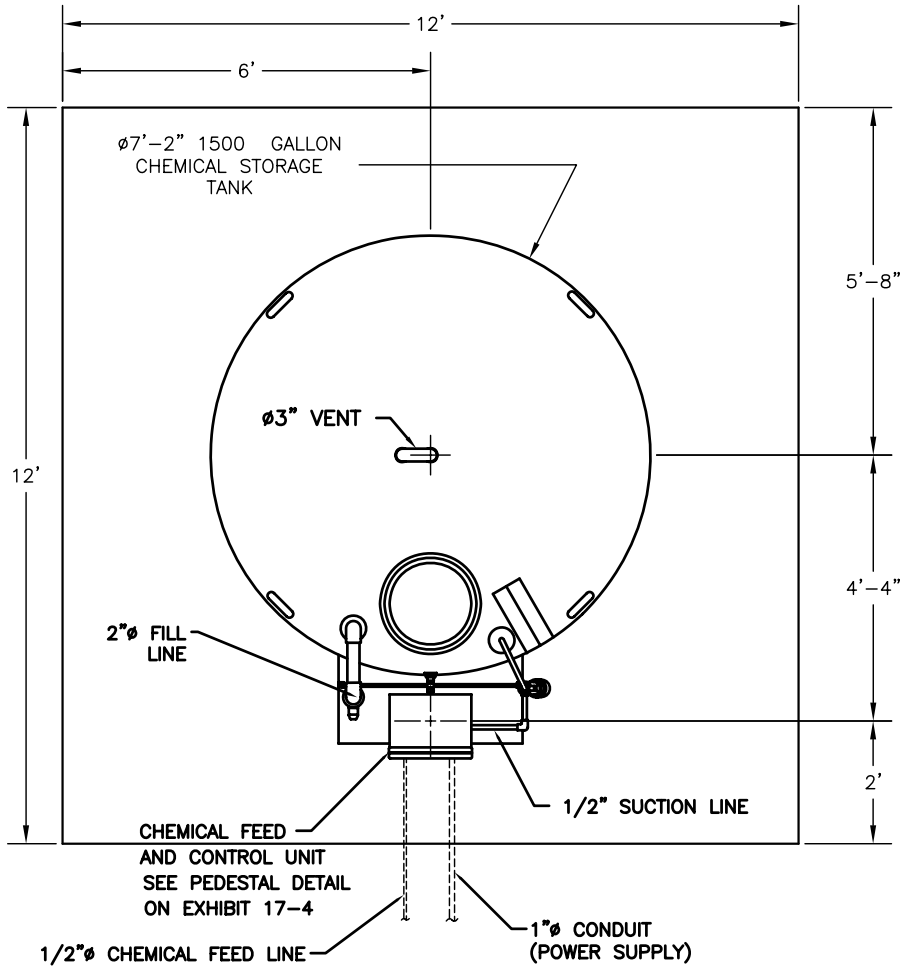
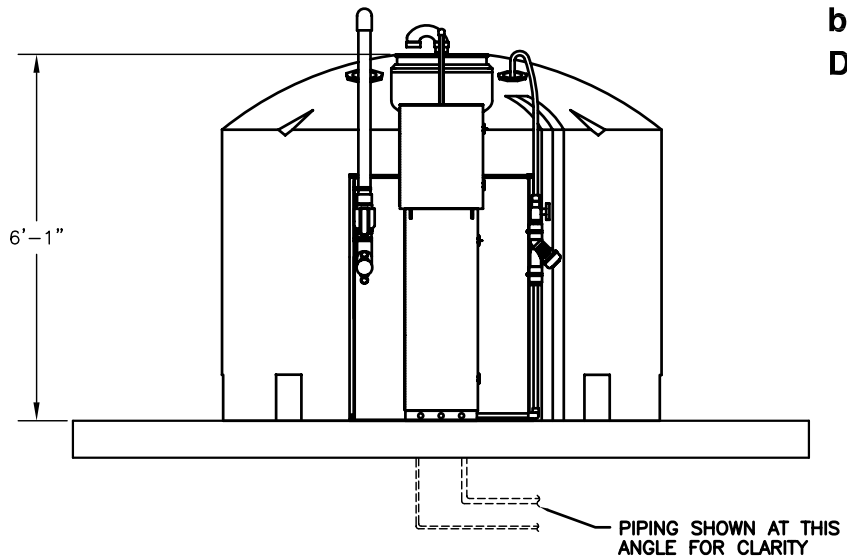
EXHIBIT 16-3
CHEMICAL FEED SYSTEM WITH 1500 GALLON ICT TANK

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW



ELEVATION VIEW

Drawing prepared by US Filter / Davis Process.

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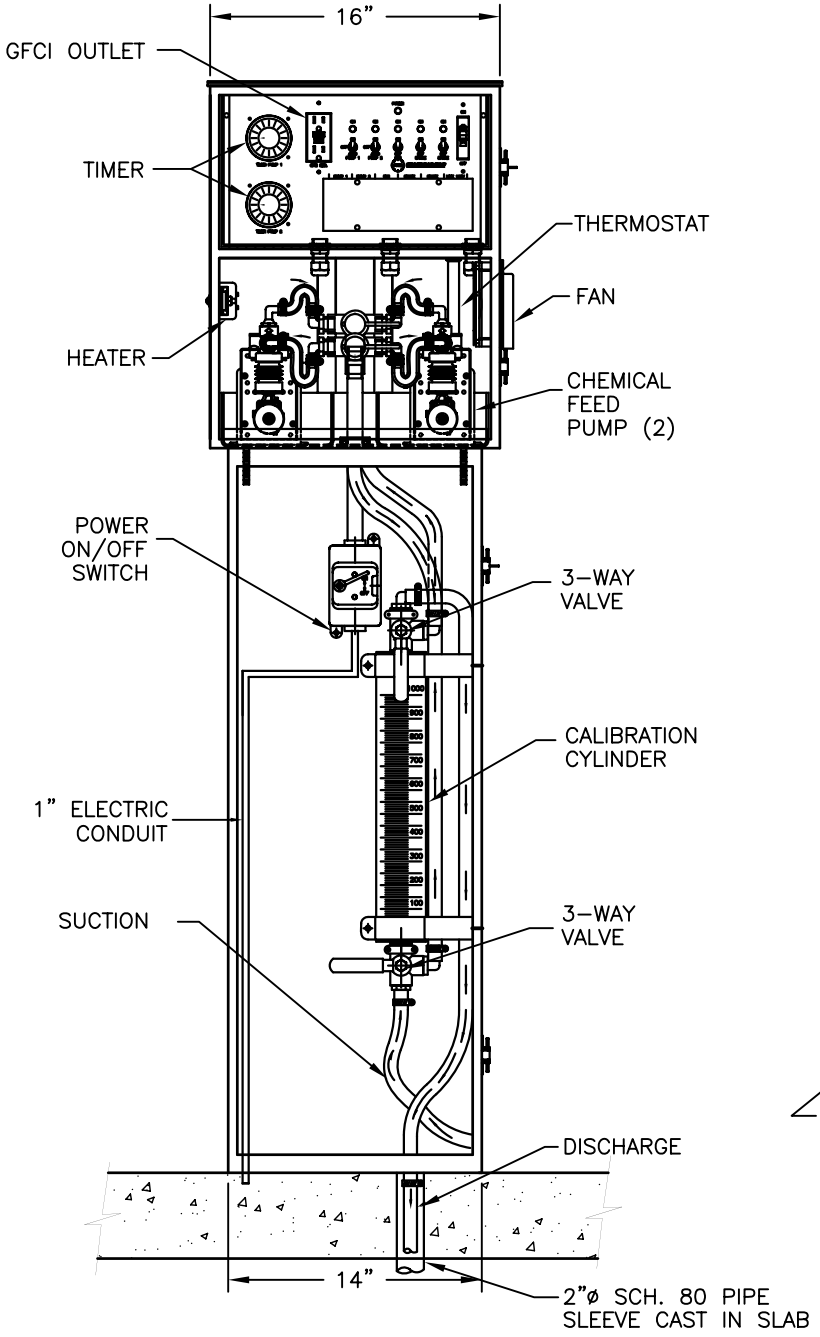
EXHIBIT 16-4
CHEMICAL FEED SYSTEM
CONTROL PANEL DETAIL

EFFECTIVE DATE: JUNE 30, 2009

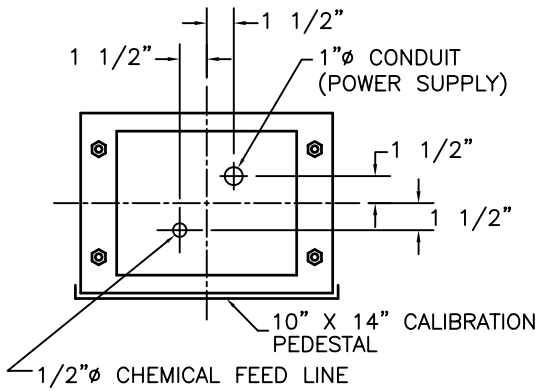
NOTES

1. ALL PIPING AND APPURTENANCES , SCH 80 PVC
2. ALL HARDWARE REQUIRED FOR INSTALLATION SHALL BE STAINLESS STEEL.



CHEMICAL FEED AND CONTROL UNIT

Drawing prepared by US Filter / Davis Process.



PEDESTAL DETAIL

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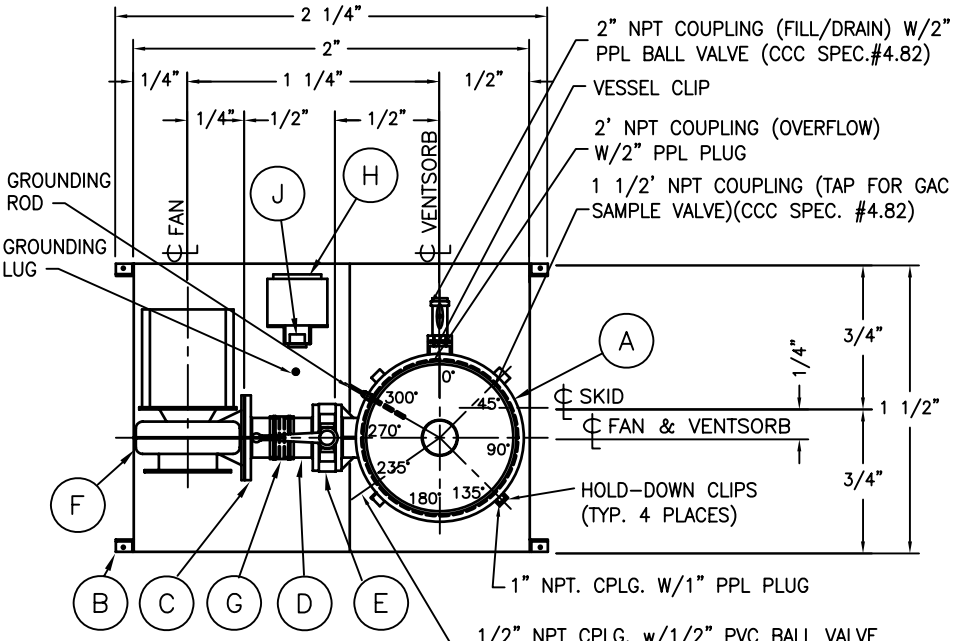
EXHIBIT 16-5
TYPICAL SKID MOUNTED CARBON ADSORBER DETAIL

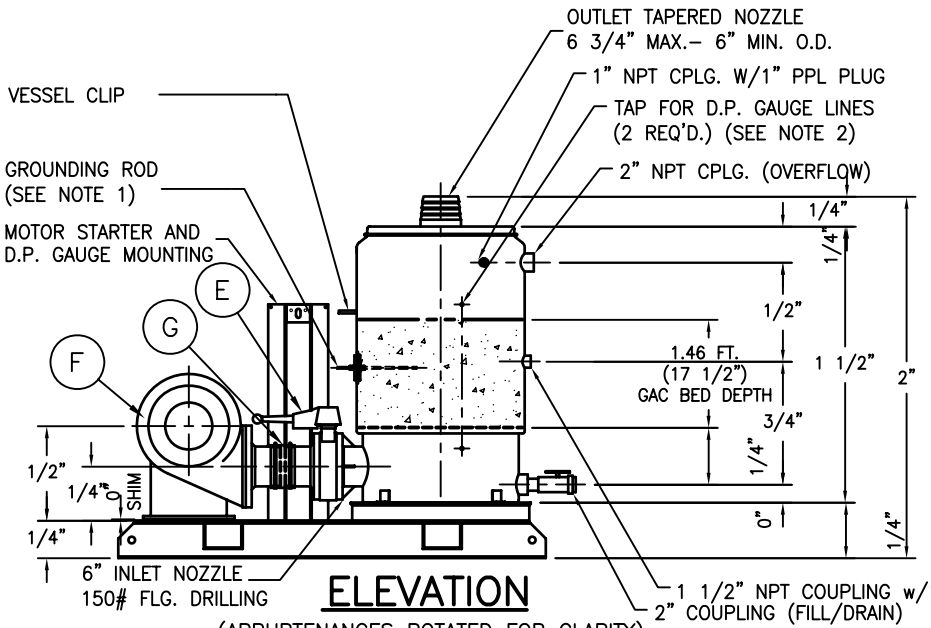
EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

1. 3/8" THK. x 4 1/4" O.D. WALL REINFORCEMENT BOSS (1) INSIDE & (1) OUTSIDE. HOLE THRU VESSEL TO BE DRILLED CLOSE TO THE MIDDLE OF THE GAC BED. ROD TO EXTEND APPROX. 10" INTO GAC BED. GROUNDING ROD (316 STN STL.)

2. INSTALL 1/2" HALF-COUPLING OUTSIDE. THREAD 1/2" NPT PIPE NIPPLE INTO COUPLING. ATTACH 1/2" PVC ISOLATION VALVE. (CCC SPEC. #4.50) ATTACH 1/2" NPT X 1/4" TUBE SWAGELOCK S.S. MALE ELBOW. ATTACH LINES FROM DP GAUGE. (2 REQD-(1)ABOVE THE GAC BED AND (1)BELOW GAC BED)



ELEVATION

(APPURTENANCES ROTATED FOR CLARITY)
(SEE PLAN VIEW FOR PROPER ORIENTATION)

Drawing prepared by Calgon Carbon Corporation

BILL OF MATERIAL

MK#	REQD.	MAT'L.	DESCRIPTION
A	1	PE.	CANNISTER, 28" DIA. x 51" HIGH W/ 6" NOZZLES
B	1	C. STL.	MOUNTING SKID, 48" x 71 1/4" x 6 1/4" THK.
C	1	PPL.	FLANGED SPOOL (BLOWER SIDE)
D	1	PPL.	FLANGED SPOOL (VESSEL SIDE)
E	1	PVC	6" BUTTERFLY VALVE W/LEVER OPERATOR (3.16)
F	1	FRP	FRP FAN (SEE FAN DATA)(RFE-200)
G	1	SILICONE	6" FLEX BOOT W/2- STN. STL. CLAMPS
H	1	FRP	COMBINATION MOTOR STARTER
J	1	–	D.P. GAUGE (DWYER MINIHELIC – MODEL #5020)

ESTIMATED ASSEMBLED WEIGHTS:
EMPTY: 1,163#
OPERATING: 1,388#
FLOODED: 2,303#
CARBON CAPACITY: 225#

FAN DATA

CAPACITY:400 CFM@4553 RPM	RPM: 3600
PRESSURE: 10" SP	TYPE: TEXP
ARRG'T: 10	
ROTATION: CW-BH	S.F.: 1.15
ISOLATORS: YES	REMARKS: GRAPHITE
WEATHER GUARD: YES	IMPREGNATED

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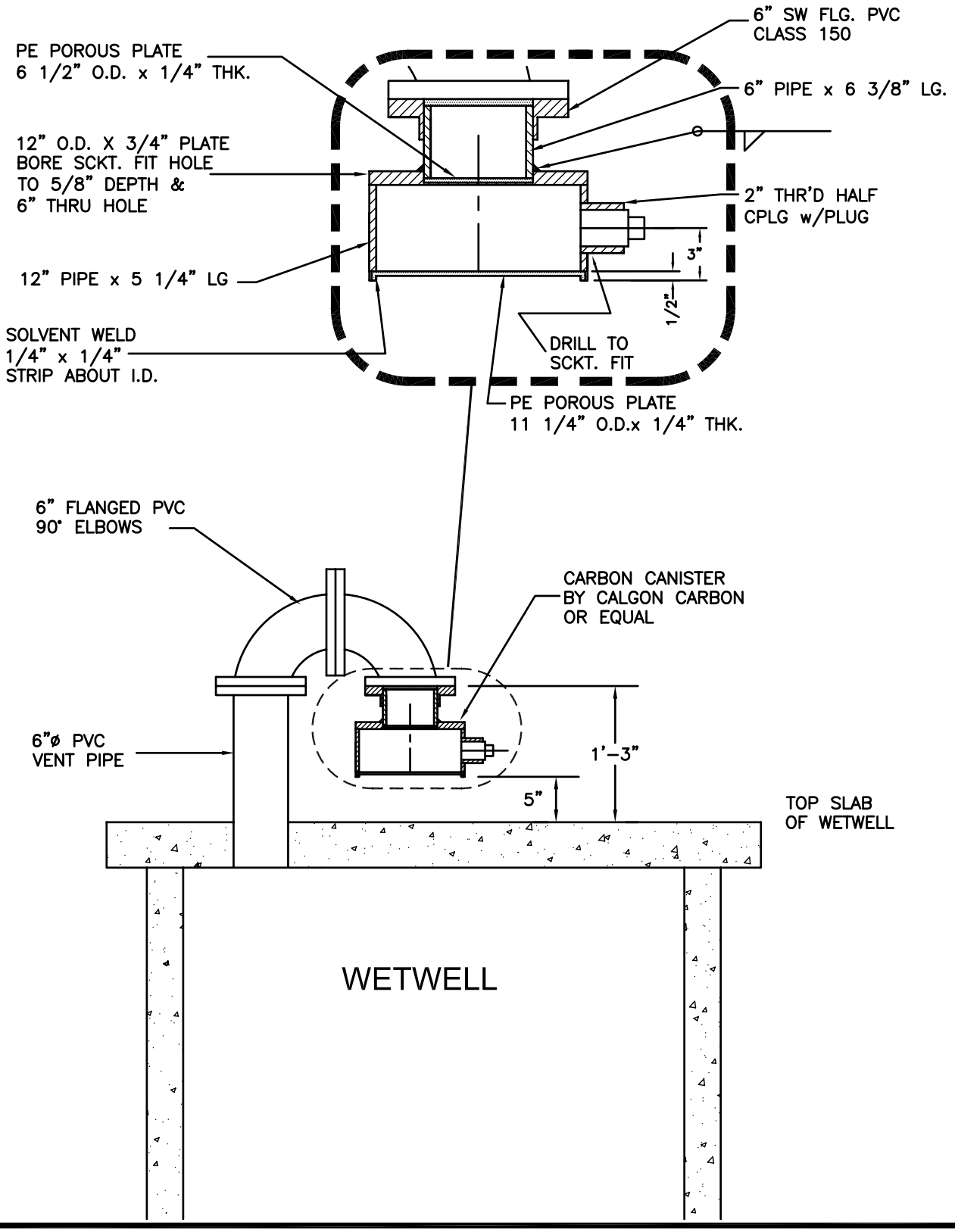
EXHIBIT 16-6
WETWELL VENT CARBON CANISTER DETAIL

EFFECTIVE DATE: JUNE 30, 2009



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GEOTECHNICAL

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CHAPTER 17
GEOTECHNICAL
EXHIBITS

EXHIBIT	TITLE	PAGE
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CHAPTER 17
GEOTECHNICAL

17.1 PURPOSE

This section establishes the minimum standards for performing geotechnical explorations on MSD projects. Geotechnical explorations are required on all MSD projects, unless otherwise directed by MSD. Reasons for performing geotechnical explorations include, but are not limited to, the following:

a. To establish the bedrock depth along the alignment of proposed sewers or at the location of proposed structures.

b. To determine the subsurface profile and properties (texture, moisture content, density, shear strength, compressibility, etc.) of soil and bedrock materials. This information is needed for the design of below grade structures, (wetwells, junction structures, tanks, etc.) building foundations, sheeting and bracing systems, retaining walls, stable channel slopes, pavements, and embankments. Additionally, this information is necessary when unsuitable foundation conditions are at the trench subgrade level or when unstable trench wall conditions are anticipated.

c. To investigate the subsurface conditions at tunnel or boring and jacking sites. The composition and nature of materials at underground crossings is needed to establish the conditions to be encountered (soft ground, hard ground, or mixed face tunneling) and the appropriate construction method.

d. To provide information regarding groundwater so that the contractor can plan for an adequate dewatering system.

e. To determine pavement section makeup, layer thickness and condition.

17.2 GENERAL

17.2.1 Right of Entry

When the geotechnical exploration work will require entry onto private property, the property owner shall be contacted, the work described, and permission to enter obtained. Efforts to contact property owners shall include telephone calls and the leaving of letters for those who are not at home. In some instances, MSD may deem it necessary to issue a letter of introduction and identification (on MSD's letterhead), which the geotechnical field party will provide to the owner. In the event that the owner does not grant permission, and it is evident that the

geotechnical work will be delayed, MSD should be notified, in writing, immediately. It is the responsibility of MSD to take whatever course of action is deemed necessary to obtain the legal right of entry in accordance with state statutes.

17.2.2 Protection of Underground Structures and Utilities

Prior to drilling and sampling in public rights-of-way and easements, the Kentucky Underground Utility Protection Center (BUD) shall be called at 1-800-752-6007 and requested to mark the locations of existing underground facilities. At least 2-business days notice is required for service. BUD confirmation numbers should be documented so that a record for the request is available. Drilling should not begin until clearance has been provided or notification that all underground utility lines are marked has been received.

On private property, the BUD does not normally maintain records. It then becomes necessary to employ the property owner's assistance and knowledge of service lines, underground storage tanks, septic tank facilities and/or use visible surface features, such as meter vaults, shut-off valves, etc., to estimate the locations of underground facilities. Borings should be offset accordingly, if necessary, to avoid any conflicting utilities.

If there is any reason to believe that an underground facility exists in an area to be drilled, and its location cannot be determined with reasonable accuracy, then that boring should not be advanced.

17.2.3 Erosion Prevention and Sediment Control/Ground Restoration

All efforts should be extended to avoid rutting, especially in residential areas. Ruts should be repaired with leveling the area with topsoil and seeding or sodding as required by MSD or as agreed upon with the property owner.

When using a truck-mounted drill rig, efforts should be made to access boring locations without crossing streams. In the event that crossing a stream is necessary to access a critical boring location, a ford in the stream, which is regularly used by the property owner, should be used after receiving approval from the property owner and MSD. Any rutting should be repaired with seeding and sodding as described above.

Dozer roads cut to permit access to boring and sounding locations should be leveled and seeded and strawed immediately following completion of the work.

Upon completion, borings should be completely backfilled from the bottom to the ground surface, using excavated cuttings. Reversed auger rotation or down

pressure on the drill tools should be used to achieve compaction. In sodded areas, the sod should first be carefully cut, lifted from the boring site, and set aside. After backfilling, the sod should be replaced over the boring and tamped. Asphalt cold patch or concrete should be used to repair borings in pavements.

When drilling around sinkholes or at a site with the potential to drain storm water directly into a water feature (including streams, lakes or impoundments, or along steep slopes), special care should be taken to place all auger cuttings back into the hole. If excess cuttings remain, they should be removed from the site.

17.3 DRILLING AND SAMPLING

17.3.1 Methods and Equipment

Unless otherwise authorized by MSD, power equipment shall be utilized to obtain geotechnical data. In most cases, this will involve a truck or skid-mounted soils drilling rig equipped with continuous flight mechanical augers. In some instances it may be advantageous to use an air track rock drill if only rock soundings are being performed. In areas where drilling rig access is restricted with steep slopes, heavy woods, soft ground, or where the rock surface is known to be shallow with reasonable assurance (for example, next to a rock bottom stream), MSD may permit the use of manually driven sounding rods or hand augers.

In general, all soil test borings shall be performed in accordance with ASTM D 1586 "Standard Method for Penetration Test and Split Barrel Sampling of Soils". Split-barrel samples shall be taken at five-foot depth intervals and at changes in strata. When undisturbed samples in clay soils are required (for example, when shear strength determinations are needed), samples should be obtained in accordance with ASTM D 1587 "Standard Practice for Thin-Walled Tube Sampling of Soils".

Observation wells should be installed in completed soil borings whenever groundwater is encountered during the drilling process. Casing should be of 1-inch diameter field slotted PVC pipe. Water table readings should be obtained from observation wells no sooner than seven days from completion of the boring.

Rock core drilling shall be performed in accordance with ASTM D 2113 "Standard Practice for Diamond Core Drilling for Site Investigation", except when wire line drilling is permitted. The diameter of the rock core shall not be less than 2-1/8 inches.

Limestone formations are prevalent across much of Jefferson County. Rock remnants and hard clay soils are sometimes encountered above the top of rock in these formations. Accordingly, when performing rock line soundings with

mechanical augers, the field crew should note the depth intervals of any rock remnants or hard clay soils encountered above the top of rock.

17.3.2 Location, Frequency and Depth Requirements for Soundings and Borings

When required, rock soundings should be performed at intervals of 50 feet where rock is encountered and 100 feet where rock is not encountered along the proposed alignment of collector and interceptor sewers, manholes, pump stations, and underground structures. The soundings should be advanced to a maximum depth, which corresponds to one foot below the invert elevation or to auger refusal, whichever occurs first. The requirements for rock soundings may be waived by MSD in areas of the Jefferson County where the bedrock surface is known to be deeper than excavation depths.

The requirements for soil test borings will be evaluated by MSD on a project-by-project basis. In general, soil test borings will be required for sewers located in areas with deep, potentially unstable soils or where high groundwater may be expected. When required, soil test borings should be drilled at approximate intervals of 500 feet and should be terminated 4 feet below the invert elevation or at auger refusal, whichever occurs first. If bedrock occurs higher than the invert elevation, then rock core drilling should extend the boring to 2 feet below the invert elevation.

Whenever possible, the boring plan should be developed to position test borings at locations of special interest. For example, test borings should be sited at the deepest excavation or where the open trench may affect existing buildings or major utilities. Borings should be drilled at the access pits or shafts of tunnels. If access is available, intermediate borings along the tunnel alignment should be advanced at 100-foot intervals. For large pump station and wastewater treatment plants, the number of borings needed may vary based on the number and layout of the individual facilities.

17.4 LABORATORY ANALYSES

Representative split-barrel samples should be analyzed for Atterberg limits, (ASTM D 4318) particle size distribution (ASTM D 422), specific gravity (ASTM D 854) and moisture content (ASTM D 2216). The samples should then be classified in accordance with ASTM D 2487 "Test Method for Classification of Soils for Engineering Purposes". Representative samples of soil materials, which are to be placed and compacted to controlled moisture-density conditions, should be subjected to Standard Proctor moisture-density tests (ASTM D 698) to determine the maximum dry density and optimum moisture content. Additionally, for any projects requiring pavement design, representative samples of proposed subgrade soils should be subjected to laboratory California Bearing Ratio tests (ASTM D 1883) to provide design CBR values.

When shear strength parameters are required for geotechnical analyses, these parameters should be determined as follows. The shear strength for non-cohesive materials (sand and sand-gravel mixtures) should be measured in accordance with ASTM D 3080 "Standard Test Method for Direct Shear Test of Soils under Consolidated-Drained Conditions". The undrained shear strength for cohesive soils (clays) should be measured in accordance with ASTM D 2166 "Standard Test Method for Unconfined Compressive Strength of Cohesive Soil". The drained shear strength for cohesive soils should be measured in accordance with ASTM D 4767 "Standard Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils."

17.5 REPORT DEVELOPMENT AND DRAFTING

Reports of geotechnical explorations should include discussions on the project, general site conditions, site geology, scope of work, results of the exploration, and conclusions and recommendations relative to the proposed design and construction. More specifically, the site description should include discussions of the site topography, site drainage characteristics, any existing improvements, etc. Descriptions of the site geology should include underlying soil types and rock formations. Other geologic features such as faults or susceptibility to sinkholes should also be included. A description of the scope of work should also be provided and should include a complete description of the drilling, sampling, and laboratory analysis programs. The results of the exploration should include descriptions of soil types, depths, the presence of any groundwater, etc. Descriptions of rock cores should note the presence of joints, voids, mudseams, recovery ratios and rock quality designation values. References to site locations should also be included. In addition, any engineering analysis performed (slope stability, settlement, etc.) should be discussed. Finally, the conclusions and recommendations relative to design and construction from a geotechnical standpoint should be included.

When submitting the results of rock line soundings, the depth intervals of any rock remnants or hard clay soils encountered above the top of rock should be reported.

Geotechnical exploration data, including boring locations, graphical boring logs, sounding symbols, penetration test blowcounts, unconfined compressive strengths, natural moisture contents, groundwater elevations, top of rock elevations, etc., should be placed on the plan and profile drawings by the Design Engineer. The drawings should reflect the difference between soundings performed with mechanical augers and soundings performed with manually driven sounding rods. For intervals that have been sounded by mechanical augers and by manually driven soundings rods, report both sets of data. The elevations of any rock remnants or hard clay soils encountered above the top of rock should also be noted on the drawings. Refer to the MSD Geotechnical Legend Sheet, Exhibit 17-1, for the appropriate symbols. MSD's drafting standards as outlined before should be followed.

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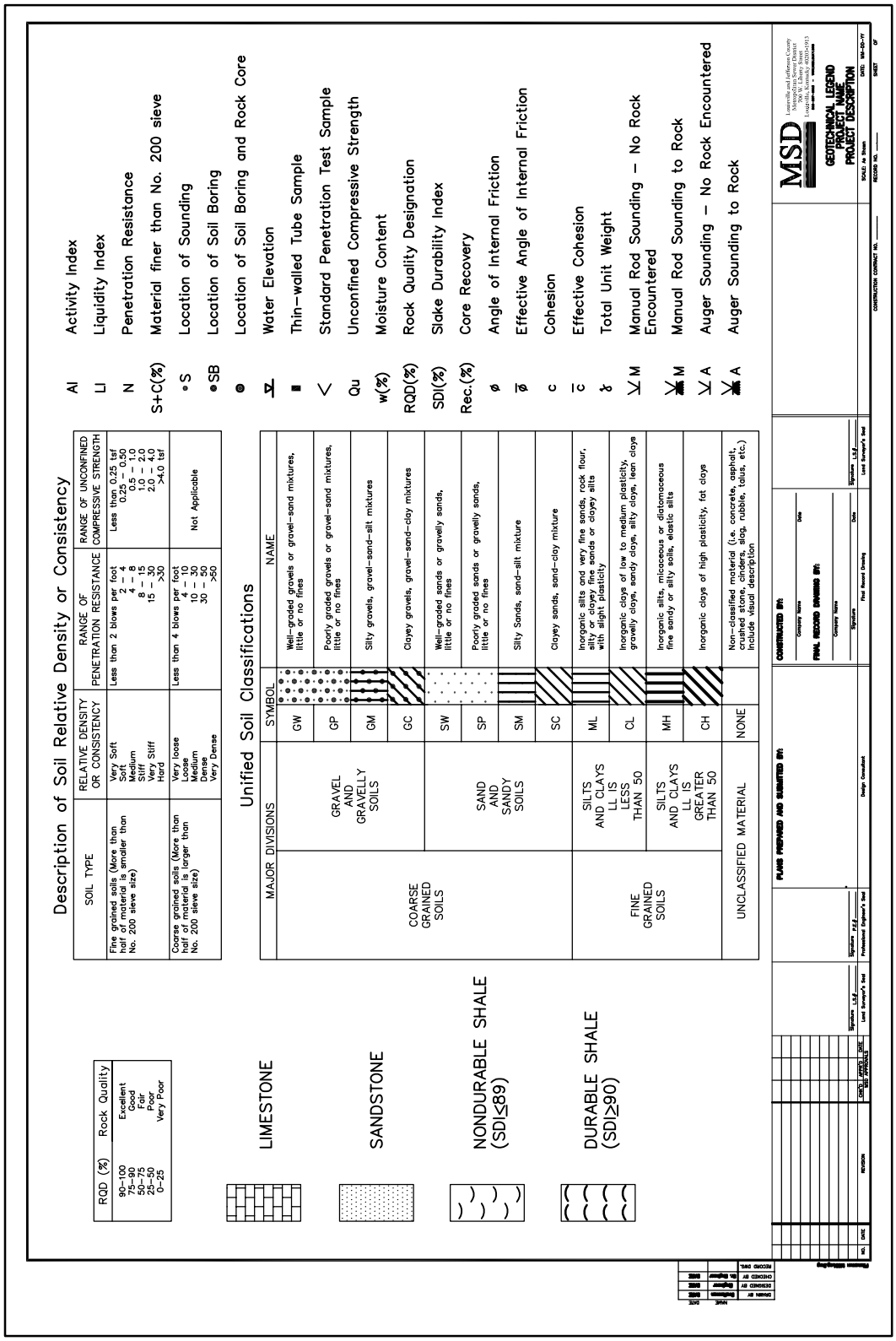
EXHIBIT 17-1
GEOTECHNICAL LEGEND SHEET

EFFECTIVE DATE: JUNE 30, 2009



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18.4.2	Green Intersection
18.4.3	Stormwater Curb Extensions
18.4.4	Green Alleys
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- Calculation Sheets
- Green Infrastructure Construction Inspection Forms
- Green Infrastructure Operation & Maintenance Inspection Forms

18.7 Operation & Maintenance
18.8 Infiltration Testing Specifications
18.9 Financial Incentive Program—Section Held in Reserve

- Memorandum of Agreement—Stipend
- Memorandum of Agreement—Credit

18.10 Fee In Lieu Program—Section Held in Reserve
18.11 Miscellaneous Forms and Checklists

- Stormwater Quality Maintenance Agreement
- Soil Characterization and Infiltration Testing Form

Acronyms & Definitions
References

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.1 Purpose of this Chapter



Louisville skyline (Photo: Louisville & Jefferson County MSD)

Louisville Metro is promoting Green Management Practices (GMPs) to supplement traditional development methods to encourage environmental sustainability and economic growth. Benefits of GMPs include aesthetics, improvements to quality of life, cleaner water and air, increased property values, and increased potential for recreation. Green infrastructure is a method to manage stormwater in a manner that promotes stormwater reduction, reduces sewer treatment costs, reduces gray infrastructure sizing, improves water quality, increases public awareness, and economic benefits. The green infrastructure goals for Louisville and Jefferson County MSD are as follows:

- Comply with the Consent Decree
- Eliminate Sanitary Sewer Overflows (SSOs)
- Reduce Combined Sewer Overflows (CSOs)
- Manage stormwater
- Improve water quality
- Beautify the community
- Improve air quality
- Reduce the heat island effect

The purpose of this chapter is to outline the design, development, implementation and maintenance of green infrastructure for the community and to assist with the planning and design of green management practices, referred to in this chapter "GMPs". This chapter is divided into six subsections, which includes a summary of regulations and ordinances that should be considered for the implementation of GMPs, the process for selecting GMPs for a site, examples demonstrating the GMP selection process, design strategies, fact sheets, guidance for operation and maintenance, and definitions. The design strategies demonstrate various approaches and uses for the GMPs. The fact sheets provide design guidance for GMPs. Chapter 18.7, Operation & Maintenance (O & M), provides guidance for ongoing operation and maintenance activities that are required to maintain GMP functionality.

Chapter Components

The following design strategies are explained in this chapter:

- Green Streets
- Green Intersections
- Stormwater Curb Extensions
- Green Alleys
- Green Parking
- Downspout Disconnection
- Roofs
- Rainwater Harvesting
- Urban Forestry
- No Mow Buffer Zones
- Stream Buffers
- Retrofits for Detention Basins
- Small Parks & Multi-Use Areas
- Residential Neighborhoods

The following series of GMP fact sheets are included in this chapter:

- Bioswales
- Rain Gardens
- Constructed Wetlands
- Green Wet Basins
- Green Dry Basins
- Extensive Green Roofs
- Intensive Green Roofs
- Blue Roofs
- Permeable Pavers
- Pervious Concrete
- Porous Asphalt
- Planters
- Tree Boxes
- Rainwater Harvesting
- Vegetated Buffers
- Vegetated Swales
- Underground Storage
- Catch Basin Inserts
- Proprietary Water Quality Units
- Infiltration Drains

The goal of each GMP fact sheet is to provide the following information:

- Typical Implementation Areas
- Key Considerations for Purpose and Location
- Relative Cost
- Maintenance Level
- Stormwater Management Benefits
- Advantages/Benefits
- Disadvantages/Limitations
- Application and Site Feasibility
- Physical Requirements
- Design Criteria
- Treatment Trains—Combination and Location in Series with other GMPs
- Education Awareness
- Application and Site Feasibility Criteria Chart
- Step By Step Design Procedures
- Operation and Maintenance

The application of sound engineering and judgment, along with thorough planning and the use of the information in this chapter, are necessary for planning, design, construction, and maintenance of GMPs. This chapter is not intended to be a detailed design methodology, nor can this chapter address every variable and site-specific design challenge that may arise.

Defining Green Infrastructure

The definition for green infrastructure can vary in use and meaning. Green infrastructure has been used to refer to anything from trees in an urban setting to planned, engineered infrastructure in a community. For purposes of this chapter, green infrastructure refers to an adaptable term used to describe an array of materials, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate and/or recycle stormwater runoff. The Environmental Protection Agency (EPA) defines green infrastructure similarly and recognizes green infrastructure as a means to manage stormwater runoff. Examples of green infrastructure include green roofs, porous pavement, rain gardens, and vegetated swales.

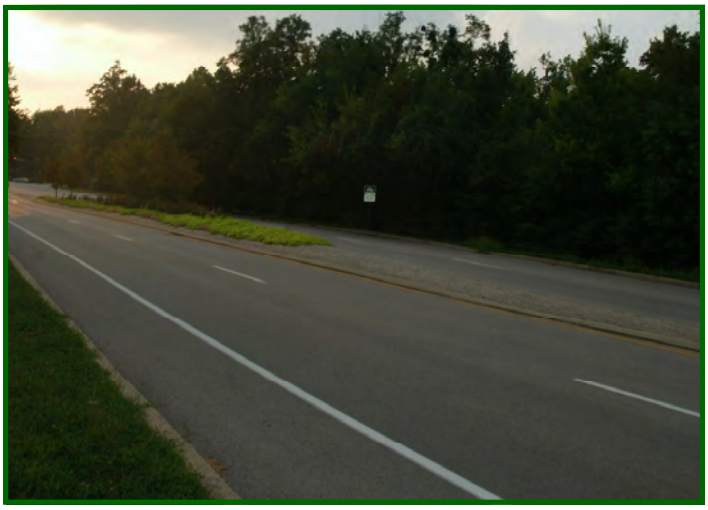


Green roof (Photo: Louisville & Jefferson County MSD)

Defining Green infrastructure Cont.

These systems are planned, designed, and managed to mimic natural systems. Green infrastructure can be implemented on scales ranging from statewide, to the local level, including local governments, and parcel-specific green management strategies.

When used as components of a stormwater management system, green infrastructure practices can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits.



Planted median and grass swale at Lexington Road in Louisville (Photo: Erin Wagoner, URS Corporation)



Pervious driveway leading to CSO 108 (Photo: Louisville & Jefferson County MSD)



Rain barrel (Photo: Louisville & Jefferson County MSD)



Bashford Manor detention basin (Photo: Louisville & Jefferson County MSD)

Green Management Practices (GMPs)

Green infrastructure is a term commonly applied to stormwater Best Management Practices (BMPs) such as pervious pavement, rain gardens, and bioswales. These BMPs are designed to infiltrate rain water into the ground rather than it running off into MSD's combined sewers or the community's waterways.

BMPs and GMPs can be further categorized as structural and non-structural. Structural GMPs vary from the use of dams and risers, to grading a site to create grass channels or rain gardens. Non-structural GMPs are generally design practices that reduce the amount of impervious area and the impact of impervious cover on the site. Non-structural practices also can include education or public outreach regarding the GMPs on the site.

Impacts of Green Infrastructure on Water Quality and Water Quantity

The water quality of many local streams is degraded from pollutants in stormwater runoff that commonly result from large amounts of impervious area in a watershed. Green infrastructure has been demonstrated to reduce the impact of impervious areas by providing a point to infiltrate stormwater runoff. In addition, while green infrastructure cannot in itself serve as a flood control practice, the severity and extent of flood events, including flash flooding, is reduced by green infrastructure.

Natural systems like riparian areas and wetlands provide benefits due to stormwater management, flood control, and the filtration of pollutants. These natural systems are free and highly valuable to local waterways. The loss of these mechanisms can result in increased costs for mitigation efforts, disaster relief, and recovery after a natural disaster. Detailed benefits for Louisville Metro and local waterways include:

- Aesthetically pleasing environment
- Savings for property owners
- Increased property values
- Reduced flooding
- Improvements to water quality
- Reduced costs and discounted stormwater fees
- Increased land values
- Maximized developable property
- Money savings on heating and cooling
- Attractive areas for customers
- Reduced sewer overflows and flooding
- Improved air quality and human health
- Pleasant workplace for employees



This sign along banks of the Ohio River informs the public of the location of a potential combined sewer overflow (Photo: Louisville & Jefferson County MSD)



Artist's rendering of a roadway median with green infrastructure, including native plants to assist with drainage and water quality (Concept rendering: Shea Powell, Dropseed Nursery)

The following page contains a map demonstrating some of the projects with GMPs that are implemented, or are under design throughout Louisville Metro. Not only are there site specific projects, regional GMPs are also demonstrated where the Metro area is expanding park land, creating riparian corridors along Floyds Fork, and improving connectivity with existing parks.

Local Examples of Green Infrastructure: Ranging from Site Specific to Regional GMPs

The photos below demonstrate local examples of GMPs, ranging from site specific to regional implementation of green practices.



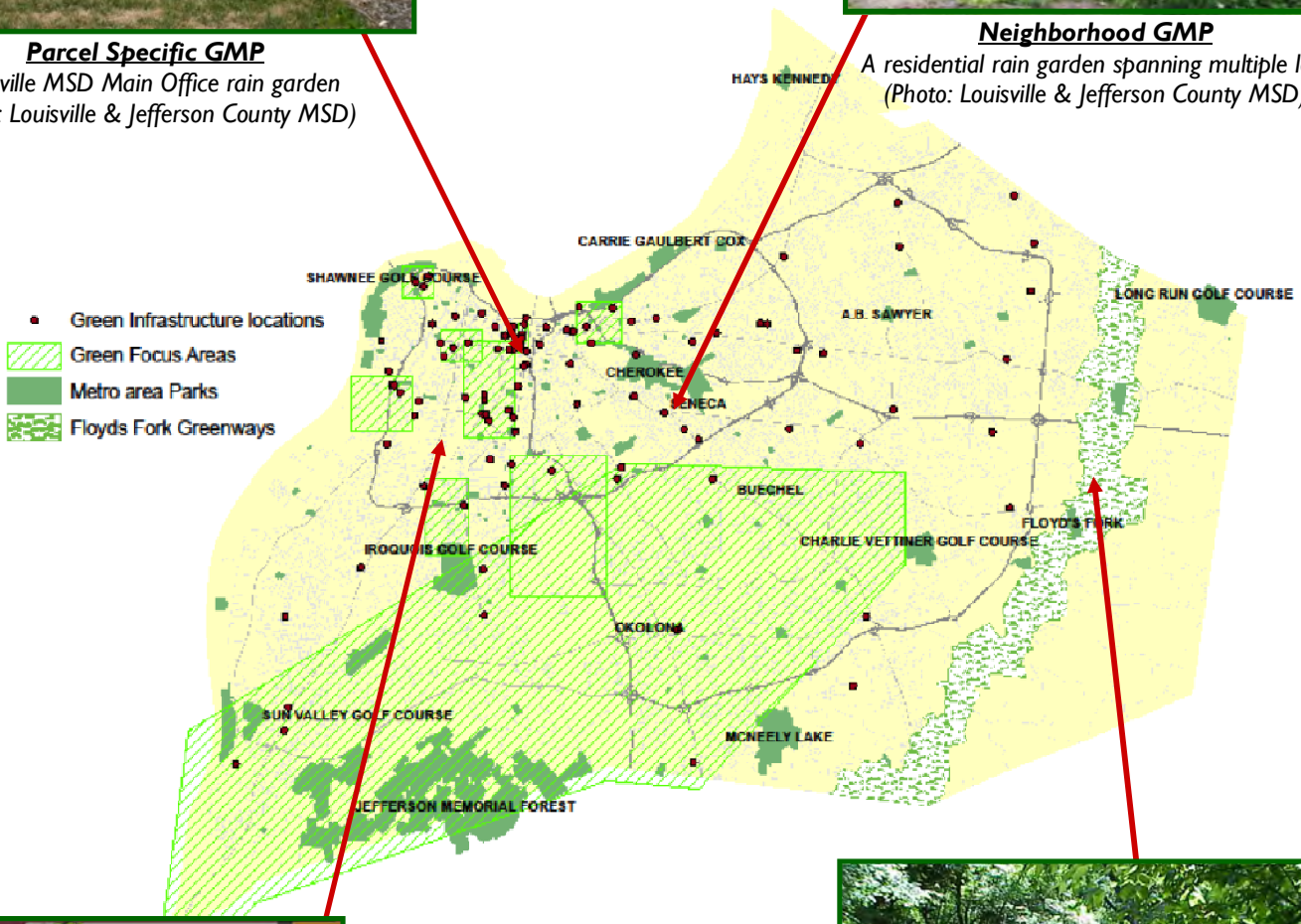
Parcel Specific GMP

Louisville MSD Main Office rain garden (Photo: Louisville & Jefferson County MSD)



Neighborhood GMP

A residential rain garden spanning multiple lots (Photo: Louisville & Jefferson County MSD)





Multiple GMPs

Pervious pavers and planter boxes spanning multiple lots (Concept plan: Louisville & Jefferson County MSD)



Regional GMP

Floyds Fork Greenway (Photo: Louisville & Jefferson County MSD)

Gray infrastructure

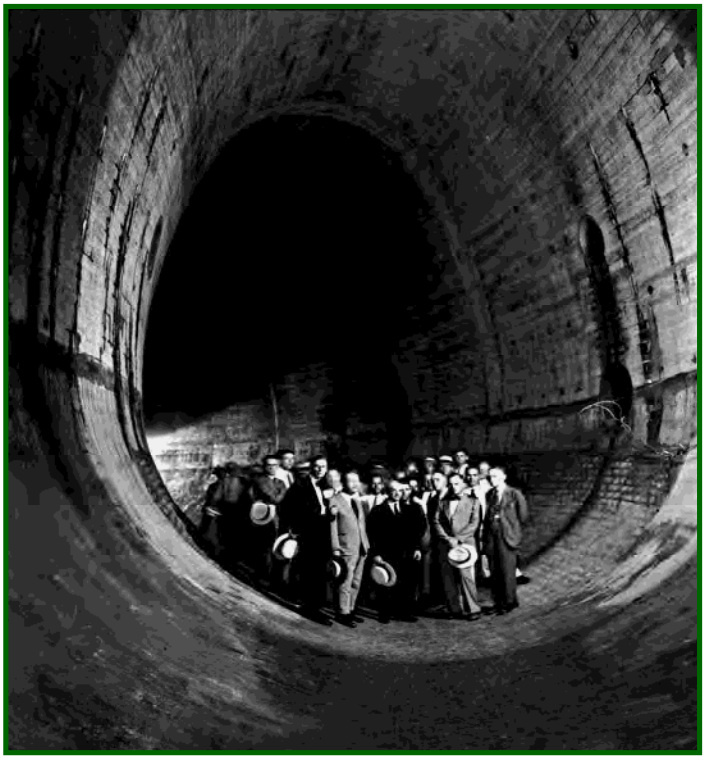
Gray infrastructure is the means of moving stormwater and sewage water through a series of pipes, tunnels, cement ditches and wastewater treatment plants. This practice has evolved over the last 100 plus years. Before there was a complete understanding of both environmental issues and public health practices, the goal was to move wastewater directly into local creeks, streams, and ultimately the river. As technology improved, and environmental and health awareness grew, wastewater began to be treated at wastewater treatment plants instead of being sent directly to the Ohio River. As more development occurred, stormwater combined sewer infrastructure was separated from wastewater infrastructure. Researchers also began to understand the implications of increased impervious area (including stormwater flooding) and started to develop better practices for drainage and water quality. These practices include the use of better planning and the implementation of GMPs in developed areas. The pictures on this page are local examples of gray infrastructure.



River Road drainage improvements
(Photo: Louisville & Jefferson County MSD)



Beechwood Village drainage improvements
(Photo: Louisville & Jefferson County MSD)



Combined sewer
(Photo: Louisville & Jefferson County MSD Archives)



Concrete lined drainage way in Louisville Metro
(Photo: Louisville & Jefferson County MSD)

Why is MSD doing this?

MSD believes the use of GMPs in urban watersheds will reduce the downstream peak flow rates through urban stream corridors during periods of wet weather and more closely mimic natural, pre-development conditions. GMPs are techniques that store, infiltrate or otherwise manage runoff from impervious areas. These GMP improvements will: reduce stream bank erosion, reduce sediment transport through critical flood control structures, reduce nutrient transport and improve the potential for riparian and aquatic habitat.

If stormwater runoff is managed pursuant to the process outlined in Chapter 18.3, the volume of runoff entering traditional gray infrastructure, drainageways and streams will be reduced during storm events, because the GMPs in this manual promote retaining and infiltrating stormwater runoff on site; and slowing and/or reducing runoff. The base flow of streams can be increased, depending on the GMP selected, and the infiltration capacity of in situ soils and connectivity to the water table. Incorporation of GMPs is recognized by MSD as a critical component in reducing CSOs, the MS4 program compliance, and meeting flood control objectives in both the CSO and separate sewer systems.

When strategically selected and sited in both CSS and separate sewer storm system sewersheds, the appropriate combination of GMPs and traditional (gray) wastewater engineering solutions will improve the sustainability of urban watersheds by embracing social values, reducing costs to rate payers and the community and improving urban environmental quality. Likewise, GMPs placed in the MS4 watersheds will provide long-lasting benefits to the community. To encourage these opportunities on private property, MSD may offer credits and incentives for the use of GMPs, as funding is available.

By keeping rain water from entering the sewer system, pipes become less full and are less likely to overflow. The green infrastructure techniques presented in this chapter help capture rain water and keep it from overwhelming Louisville's Combined Sewer System (CSS) in compliance with the Environmental Protection Agency (EPA) consent decree requirements and Louisville's Municipal Separate Storm Sewer System (MS4). Additionally, green infrastructure techniques can replace gray infrastructure and help to lower wastewater treatment costs through infiltration into the groundwater system.

MSD takes pride in our commitments to water quality and quantity measures. For more information on programs and ordinances from MSD see the following website http://msdlouky.org/.



MSD rain garden at 700 West Liberty Street immediately after installation (Photo: Louisville and Jefferson County MSD)



MSD rain garden at 700 West Liberty Street (Photo: Carolyn Cromer, Dropseed Nursery)



Installation of a new drainage system along Reynolds Avenue (Photo: Louisville & Jefferson County MSD)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.2 Overview of Wastewater/ Stormwater Discharge Regulations and Other Requirements



Louisville Metro City Hall (Photo: Kristen Dunaway, URS)

Introduction

Federal and local regulatory programs can impact water quality and quantity. This chapter provides an overview of the basic regulatory programs. The regulatory programs outlined in Chapter 18.2 should not be considered static, as requirements of regulatory programs frequently change over time. Therefore, the designer should always consult pertinent statutes and ordinances when developing a green infrastructure project. This chapter provides an overview of the Municipal Separate Storm Sewer Program (MS4), including construction and post-construction requirements, water quantity permits, local permits, and KYTC permits.

Municipal Separate Storm Sewer System (MS4)

Louisville Metro is regulated by the MS4 Program, as required by the Clean Water Act, through the Kentucky Pollutant Discharge Elimination System (KPDES), which is administered by Kentucky Division of Water (KDOW). The MS4 permit program mandates that MS4 communities enforce stormwater management ordinances, regulations, and/or policies. MSD, the City of Anchorage, the City of St. Matthews, the City of Jeffersontown, the City of Shively and Louisville Metro are MS4 co-permittees and collaborate to meet permit requirements. As a result of this co-permittee relationship, Louisville MSD leads, implements and enforces designated permit activities.

The MS4 related ordinances, regulations and policies must be considered when designing, constructing and implementing GMPs. Three ordinances are pursuant to the MS4 permit: an erosion prevention and sediment control ordinance (EPSC), a post-construction ordinance, and an illicit discharge detection and elimination ordinance. For purposes of this chapter and to aid designers with the implementation of GMPs, the following sections will be explained in more detail: the City of Louisville/Jefferson County Erosion Prevention and Sediment Control Ordinance and Article Six Stormwater Post-Construction Best Management Practices in the Wastewater/Stormwater Discharge Regulation. MSD implements the Illicit

Discharge Detection and Elimination and Post-construction requirements through the MSD Wastewater/Stormater Discharge Regulations.

MSD Wastewater/Stormwater Discharge Regulations

Effective August 1, 2013, MSD adopted Article Six of the MSD WDRs that includes MS4 post-construction minimum control measures and green infrastructure to be implemented in Louisville Metro. The post-construction requirements apply to all development with a disturbed area equal to or greater than one (1) acre, including projects less than one acre that are part of a larger common plan of development or a common scheme of development equal to or greater than one acre (disturbed area does not include utility installation), located in the City of Louisville, Jefferson County, and the incorporated cities of Jefferson County. The purpose of the regulations is to prohibit non-stormwater discharges to the MS4, prevent improper disposal of chemicals and other materials into the MS4 that degrade water quality and to provide the necessary enforcement mechanisms. Pursuant to the WDRs, MSD has the authority to:

- Review and approve post-construction plans
- Perform pre-construction site meetings, inspections and negotiated compliance efforts in the enforcement of these regulations
- Provide education and training program for contractors
- Develop, implement, and administer a post-construction Best Management Practice (BMP) Long-Term Maintenance Program
- Administer and manage a fee in lieu program

Permit Application Submittal

Application submittal forms are available for permittees to complete, acknowledging their status as the person responsible for the post-construction BMPs. Application submittal plans require the stamp of a professional engineer licensed in the Commonwealth of Kentucky. A schedule of submittal requirements for each type of application and plan required pursuant to the WDRs can be found on MSD's website and in the MSD Design Manual, Standard Specifications, and Standard Drawings.

Stormwater Quality Maintenance Agreement

A Stormwater Quality Maintenance Agreement is required to be submitted with a permit application. The Stormwater Quality Maintenance Agreement includes a maintenance plan for all post-construction BMPs and GMPs that require more than general maintenance and periodic mowing. The land disturbance permit approval can be withheld until responsible parties sign the agreement. The plan must ensure that post-construction BMPs are kept functional and provide the minimum operation and maintenance requirements. The submitted plan should include schedules for inspections and techniques for operation and maintenance requirements.

Long-term self-inspections are required for post-construction BMPs and GMPs. Long-term self-inspections are the responsibility of the property owner or the person defined in the Stormwater Quality Maintenance Agreement to ensure that the BMPs are functioning according to the permit and subsequent Stormwater Quality Maintenance and post-construction BMP Maintenance Plan requirements. A Qualified post-construction Inspector (QPCI) must perform the inspections. A QPCI is a person who is qualified by MSD; qualification includes passing a training course sponsored or approved by MSD. The QPCI will perform on-site post-construction BMP/GMP inspections consistent with the WDRs. A QPCI must be experienced and knowledgeable with operation standards for post-construction BMPs and GMPs; causes and failures of post-construction BMPs and GMPs; maintenance practices for post-construction BMPs and GMPs; and successful completion of MSD training courses. QPCI registration will be valid for up to three years. MSD has the authority to revoke registrations for repeated violations or activities that result in significant adverse impact, off-site degradation, or for disregard of the programs. MSD plan reviewers are required to attend MSD-sponsored or approved training courses.

Following the release or acceptance of a project (and termination of the site disturbance permit), the property owner will be responsible for maintaining the project site in a manner that will prevent soil erosion, sedimentation, and other long-term water quality issues in compliance with the Wastewater Discharge Regulations and the Stormwater Quality Maintenance Agreement. The permittee or a designee is required to conduct continuing inspections of all post-construction BMP measures and conduct repairs or modifications within 30 days of the initial discovery of a control failure or violation.

Alternative Practices for Post-Construction BMPs and GMPs

To encourage the development and testing of alternative Post-Construction BMPs and GMPs, MSD adopted policies to enable alternative practices. Alternative management practices that are not included in the MSD Design Manual, Standard Specifications, and Standard Drawings, may be allowed upon review and approval MSD. The alternative management practice must be supported by evidence that it will perform at least equivalently to a currently approved control contained in the MSD Design Manual, Standard Specifications, Standard Drawings and conforms to current American Society for Testing and Materials (ASTM) Standards. However, if the control or practice fails, or is inadequate to contain the target pollutants onsite or meet long-term post-construction stormwater management objectives, the permittee will be required to remove and replace it with a control approved by MSD and in accordance with the MSD Design Manual Standard Specifications and Standard Drawings.

Final Approval or Permit Revocation

MSD has the authority to revoke any permit based on the following conditions:

- The post-construction BMP or GMP is in violation of the WDRs;
- The post-construction BMP or GMP is in violation of approved plans, permits, specifications, or conditions of approval;
- The post-construction BMP or GMP is being undertaken in a way as to be a public nuisance; or
- The post-construction BMP or GMP was obtained by false representations or it was issued by mistake.

Fee in Lieu Program

For sites where GMPs are not practicable, developers can contribute to MSD's Fee in Lieu Program. A developer will pay into the Fee in Lieu Program so post-construction BMPs or GMPs are incorporated at another site. See Section 18.10 for details.

Erosion Prevention and Sediment Control Ordinances

The City of Louisville/Jefferson County EPSC, § 159, defines land disturbing requirements at active construction sites. The purpose of the ordinance is to comply with the Clean Water Act by preserving and conserving soils, water, vegetation and wildlife in Louisville Metro. Those involved in qualifying land disturbing activities are required to have an approved EPSC plan and a duly-issued site disturbance permit or an authorized general permit. Land disturbance activities do not include the following:

- Minor land disturbance activities such as home landscaping, repairs and maintenance work
- Installation, maintenance, or repair of any underground public utility lines that occurs on a hard surfaced road, street or sidewalk, provided that the land disturbing activity is limited to the area of the road, street or sidewalk
- Septic tank lines or lateral fields unless included in an overall plan for land disturbing activities related to the building to be served by the septic tank system
- Tilling, planting or harvesting of agricultural, horticultural, forest crops or livestock feedlot operations; including soil conservation operations related to agriculture as follows: construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds, ditches, strip cropping, lister furrowing, contour cultivating, contour furrowing, land drainage and irrigation which does not cause an increase in stormwater runoff and does not exacerbate erosion and sedimentation
- Clearing and grading activities that disturb less than 2,000 square feet and are situated no closer than 50 feet to a solid or intermittent blue line stream, and which are not governed under a general permit or site disturbance permit
- Emergency work to ensure health, safety, property and emergency repairs. However, if land disturbance activities would have required an approved EPSC plan, and if the activities were not conducted under emergency circumstances, then the land area will be shaped and stabilized consistent with the Louisville/ Jefferson County EPSC ordinance

The following land disturbance activities are exempt from the requirements of the Louisville/Jefferson County EPSC ordinance, provided that all exempt activities are undertaken in a manner that presents no significant erosion or sedimentation potential:

- Agriculture operations required to adopt and implement an individual agriculture water quality plan pursuant to the requirements set forth in the Kentucky Agriculture Water Quality Act (KRS 224.71-100 et seq.)

- Usual and customary site investigation and surveying activities that include soil testing, rock coring, test pits, boundary and topographic surveying, monitoring wells and archeological excavations that are conducted prior to the submittal of an application for a preliminary subdivision or development approval, so that the land disturbance is incidental to necessary equipment access and performance of investigation and surveying activities
- Following preliminary subdivision or development approval but prior to site disturbance permit approval and issuance, clearing necessary to provide access for survey work, rock surroundings or other usual and customary site investigations provided that the preliminary site investigations are planned to minimize the amount of the clearing required, clearing will follow the proposed roadway centerlines and will not result in a clear access way of more than 20 feet in width, cleared access ways beyond proposed roadways to assess individual lots will not exceed 12 feet in width, and no trees eight inches or greater in diameter measures at breast height (dbh) will be removed without prior approval by the Louisville Metro Division of Planning and Design Services
- Minor land disturbing activities that disturb 2,000 square feet or less of land area and not within 50 feet of a drainageway. This will not apply to land disturbance activities subject to the general permit provisions by utilities or in connection with family home construction.

There are two types of permits granted by MSD for land disturbing activities; the Site Disturbance Permit and the General Permit. These permits are distinguished by the land disturbing activity at issue. There are three types of review: Type I, Type II and General Permit. Table 18.2-A, located on the following page, originates from the City of Louisville/Jefferson County EPSC Ordinance and summarizes the review requirements. For a detailed explanation of these ordinances refer to Chapter 12 of the MSD Design Manual.

Permit Requirements for Land-Disturbing Activities in Louisville Metro

Table 18.2-A.

Type of Land-Disturbing Activity	Type of Permit Required See § 159.02(c)(3)		Type of Review Procedure Required See § 159.02(c)(2)			Type of EPSC Required See § 159.02(c)(4)	
	Site Disturbance Permit	General Permit	Type I	Type II	General Permit	Concept EPSC Plan	Detailed EPSC Plan
1. Requires Land Use Approval	**X**		**X**			**X**	**X**
2. Requires Building Permit Only (Non-Discretionary)	**X**			**X**			**X**
3. Undertaken by Public Utility		**X**			**X**	**N/A**	**N/A**
4. Single-Lot Residential Construction in an Approved Subdivision		**X**			**X**	**N/A**	**N/A**
4a. Reserved							
4b. Single-Lot Residential Construction on a "Red-Flagged" Lot	**X**			**X**			**X** (At MSD's Discretion)
5. Excavation, Site Clearing, or Filling of Land (No Building Permit Required)	**X**			**X**		**X** (Only if Type I Review Required)	

Numbers 1-5 below provide additional description regarding the type of land disturbing activities in Table 18.2-A, column 1.

1. Includes all land disturbing activities association with specific development proposal subject to discretionary land use or development approvals (e.g. subdivisions, conditional uses, development plan reviews etc.).

2. Includes all land disturbing activities associated with a specific development proposal not subject to discretionary land use or development approvals (e.g., development requiring building permit approval only).
3. Includes land disturbing activities undertaken by a private contractor hired by a utility, includes utility related land disturbing activities such as small trench work service hook-ups to individual structures, general and emergency maintenance and repair work and the like.
4. This category includes only construction of a residence, and/or accessory residential structures on a single lot that is part of a subdivision subject to an EPSC plan approved pursuant to this ordinance. Please see category 4.B in the table for important variations on this general provision.
5. "Red Flagging" refers to a notation on the approved subdivision plan that a particular individual lot shall be subject to additional restrictions or scrutiny prior to construction.

The permittee should consult the Louisville/Jefferson County EPSC Ordinance for specific permitting requirements.

Inspections, Permits, and Licenses

Louisville Metro Building Division oversees the implementation, inspection, and enforcement of the Kentucky Building Code KRS Section 105.1. A permit may be required when a property owner or authorized agent intends to construct, enlarge, remodel, or change the occupancy of a building or to erect, convert, or replace any electrical, gas, mechanical, or plumbing system. Before any work is to begin, the owner shall first submit an application to a Louisville Metro Building Division building official and obtain the required permit.

Kentucky Transportation Cabinet Encroachment Permits

Any firm, individual, or governmental agency that wants access to a road on the state highway system or wants to conduct any type of work activity on the right-of-way, must obtain a permit.

Water Quantity

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP). Louisville Metro is a participant in the NFIP and is required to comply with programmatic requirements, including the enforcement of a floodplain management ordinance. MSD is the administrator of Louisville Metro's Floodplain Management Ordinance. This ordinance must be consulted when developing in or near a floodplain. Specifics regarding the floodplain ordinance can be found in Chapter 3.6 of the MSD Design Manual titled Floodplain Ordinance and in Chapter 10.4 titled Local Regulatory Floodplain and Conveyance Zone, or on the MSD website. Floodplain permits are required from both the state and local community. MSD is the local administor and the Kentucky Division Of Water (KDOW) issues a state permit. A permit, issued by MSD, is required for any disturbance in the floodplain including construction, filling, dredging, or any development in the Local Regulatory Floodplain. If a permit is not issued pursuant to local or state ordinances, development in the floodplain is prohibited and the property owner will be issued a Stop Work Order as well as fines. No development is permitted in the conveyance zone. This ordinance also has requirements for buffers along blue line streams.

An Application for Permit to Construct Across or Along a Stream from the (KDOW), Floodplain Management Section, is also required. KDOW should be contacted for more information regarding this permit.

Water Quality

The Clean Water Act is the federal legislation that governs water quality and there are several components of it that should be considered when designing a site. See Table 18.2-A.

Section 404– Nationwide Permits from the United States Army Corps of Engineers (USACE) may be required if the project crosses or is in close proximity to waters of the United States (U.S.). The purpose of the 404 program is to regulate the discharge of dredged and fill material into waters of the U.S., which includes streams and wetlands. The Section 404 permitting program is shared by the EPA and the USACE. The EPA develops and defines the criteria used for permit applications, identifies the activities that are exempt from the permit, enforces Section 404 provisions, and has the authority to veto USACE permit decisions. The USACE administers the program and approves permit applications. Design engineers must inquire from the USACE whether a project requires a 404 permit.

Section 401– Application for a Water Quality Certificate (WQC) from KDOW, Water Quality Branch may be required if the activities related to a project result in physical disturbance to streams or wetlands.

Total Maximum Daily Loads

Total Maximum Daily Load (TMDL) is the computed pollutant load that a waterbody can receive and still meet water quality standards. TMDLs are allocated to point and nonpoint sources in a watershed. The most common sources of pollutants are sediment, pathogens, nutrients, and metals. As updated TMDLs are developed and approved by KDOW, MSD is required to respond with additional regulatory requirements for site development for the respective pollutants of concern.

Summary of Potential Permitting Requirements for Drainage and Green Infrastructure Projects

The following table provides a summary of permits that are typically required for stormwater drainage and Green Infrastructure projects.

Potential Permits Required for Green Infrastructure Projects

Table 18.2-B.

Permit	*Typical Submittals	Agency	When Required
Construction Along a Stream	Application, HEC2 analysis or floodplain verification	KDOW	For any construction along or across a blueline stream, in a floodplain, or when impounding water
MSD Application for Permit to Develop/ Repair in a Floodplain or in a Regulatory Conveyance Zone	Application; consult MSD website for step by step requirements	MSD	For construction in the Regulatory Floodplain or Regulatory Conveyance Zone
Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	USACE	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow ≥ 5 cfs. May require DOW Water Quality Certification
Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	KDOW	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Consult with the USACE and KDOW
Stormwater Discharge Permit	Application/ NOI (Notice of Intent)	KDOW	For all projects disturbing ≥ 1 acre
Water Withdrawal Permit	Application/ Letter	KDOW	When necessary to withdraw more than 10,000 gpd of water from a blueline stream
MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects
Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and USACE	When encroaching on the floodwall right-of-way
Encroachment Permit	Application	KYTC	When encroaching on state right-of-way: to be submitted at 80% design stage
Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: to be submitted at 80% design stage
Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way
Building Permit	Site Plan	Louisville Metro – Code Enforcement or City of Louisville Public Works	Any building
Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic
Planning Commission Approval	Site Plan(s)	Louisville Metro – Planning Commission	For all projects
Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept. of Public Works	For any project which requires obstruction of a roadway

*Always consult regulations, ordinances and state and federal laws when assessing permit requirements, as requirements change over time. This list is not meant to be comprehensive of the potential permitting requirements.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.3 Green Infrastructure Plan Development Standards and Selection Process



Traditional Stormwater Design



Green Infrastructure Design

The sketches above demonstrate the different design approaches for a traditional stormwater drainage design and a green infrastructure design. The green infrastructure design promotes infiltration into pervious areas on the site.
(Adapted from Brad Lancaster www.rainwaterharvesting.com)

Introduction

The purpose of this chapter is to provide guidance for managing the water quality requirements on a project site and updated in 2013 since the 2011 printing to include additional detailed information. The primary goals of a Green Management Practice (GMP) is to provide both water quantity reduction and water quality improvements before runoff leaves a site. Although the process for selecting GMPs is the same, the GMP selections will vary from site to site. There are many factors that contribute to the effectiveness of a specific GMP. It is important for a design professional to consider and assess numerous factors, including but not limited to: site characteristics, the water quality volume (WQv) required to be managed on a site, site design, constructability of GMP, and long-term operation and maintenance of GMPs. This section provides the process for selecting green infrastructure design components for a site, but is not intended to address every site planning or design variable that a designer may encounter. The application of sound engineering, planning, and surveying principles and judgment apply. Approval of plans pursuant to this process does not relieve the designer from required compliance with the other sections of the MSD Design Manual and applicable standards, outlined in Section 18.2.

The GMPs in the MSD Design Manual should be considered as a list of tools and implemented based on the site conditions and stormwater management needs to comply with the Clean Water Act and post-construction stormwater water quality and quantity requirements. Furthermore, appropriate site planning will allow for GMPs that are potentially less expensive and more effective for the intended purpose, and will play a role in enhancing new development and urban spaces in Louisville Metro.

This Section provides a summary of the general considerations for design and steps that can also be referenced in the GMP Summary Process flow chart, Figure 18.3-A. This Section provides more specific guidelines for the design of each GMP. At the end of the section there are various GMP examples to demonstrate the process for selecting GMPs.

In general, the following steps should be followed to incorporate green infrastructure design components:

1. Implement Site Planning Recommendations, including conserving natural areas and reducing impervious cover
2. Determine Required Water Quality Rain Event (RE_{WQV})—0.6 inches
3. Calculate Required WQ_V
4. Select GMPs with Runoff Reduction Abilities
5. Determine Managed Water Quality Volume (MWQ_V)
6. Calculate Remaining Water Quality Volume (RWQ_V), as needed
7. Select Alternative GMPs to Treat the RWQ_V
8. Provide Operation and Maintenance (O&M) Documentation

The Impacts of Stormwater Management

The purpose of stormwater management is to mitigate the impact on the hydrologic cycle resulting from alterations to land surfaces. As land is developed, the hydrologic cycle is impacted through a reduction in the natural storage and infiltration capabilities of natural pervious areas, including grasslands and forests. By reducing natural vegetation and increasing impervious areas, the quantity of runoff entering drainage systems and streams increases significantly. Even green areas in older developments often contain compacted soils, which can increase stormwater runoff.

With urbanization, naturally occurring pervious areas can be reduced and replaced with impervious surfaces. Urbanization also increases the types and amounts of pollutants that enter local streams and drainage ways. Some of the increased pollutant runoff is due to the increased stormwater runoff volume. Research indicates that small frequently occurring rain events account for a significant amount of the pollutants generated from stormwater runoff. Therefore, designing GMPs that treat the runoff volumes generated by smaller rain events is the approach utilized in this manual. Pollutants typically found in stormwater runoff include the following:

- Nutrients
- Bacteria and pathogens
- Petrochemical products
- Heavy metals
- Pesticides and herbicides
- Thermal pollution
- Sediments
- Deicers
- Floatables

Nutrients Naturally occurring nutrients, such as phosphorous and nitrogen, are commonly found in manmade fertilizers which are typically used on lawns, golf courses, parks, and construction sites to promote vegetative growth. These chemicals can disrupt the aquatic ecosystem through increased vegetative and algae growth, which can result in lower dissolved oxygen (DO) levels, as well as taste and odor problems. Lower DO levels are caused by the decomposition of organic materials in waterways and algae respiration. The resulting lower DO levels can lead to fish kills and the loss of sensitive aquatic species.

Bacteria and Pathogens Bacteria and pathogens can impact human health when they enter the body through ingestion or open wounds. Coliform bacteria originate from human and animal waste, including wildlife and domestic animals. Leaking sewer systems, failing septic systems, sanitary sewer overflows (SSOs) and combined sewer overflow (CSOs) are also potential sources of these pollutants.

Heavy Metals Heavy metals originate from such sources as preserved wood, paint, and metals from automobile tires and brake liners. These enter the waterways through corrosion, flaking, dissolving, decaying or leaching. Heavy metals are toxic to aquatic animals, can be bioaccumulative, and can contaminate drinking water supplies.

Pesticides and Herbicides Pesticides and herbicides have the potential to be used improperly or excessively for residential and commercial purposes and as a result, have the potential to runoff into water sources. Both can be toxic to aquatic life as well as the general public.

Thermal Pollution The change of ambient water temperature can affect the level of DO in the water and the life cycle of some aquatic species. Water temperature can be increased by cooling waters used by power plants, as well as urban runoff. With an increase in temperature, a decrease of DO levels occurs in the water, which is harmful to aquatic animals.

Sediments The amount of particulate matter in water is usually measured by total suspended solids, which is the amount of solids suspended in a water column, or turbidity. Turbidity is the discoloration of water. The impacts from excessive sediment include: stream warming, transportation of pollutants during rain events, destruction of stream habitats, declines in mussels and darters, and decreased flow capacity of pipes and channels, which can lead to localized flooding. Water that is too turbid does not allow sunlight to penetrate the water and grow phytoplankton, which are the foundation for the aquatic food chain.

Deicers Deicers are used to melt snow and ice from roadways and walkways. Deicers can harm aquatic life by increasing salt levels and conductivity within stormwater runoff.

Floatables Floatables include trash and organic materials such as leaves, grass, and other yard waste that float on the surface of the water. Floatables are unsightly and can damage aquatic habitats. As organic floatables decompose, they deplete the level of DO needed by fish and other organisms.

A summary of the potential pollutants including pollutant sources and pollutant impacts is provided in the following paragraphs.

GMP Benefits to Water Quantity and Quality

Pollutant loadings to local waterways can be decreased by treating and reducing stormwater runoff. Table 18.3-A contains a summary of the relative pollutant treatment and stormwater management benefits that can be provided by well-maintained GMPs. Table 18.3-A was derived from the stormwater benefits that are identified on each of the GMP fact sheets located in Chapter 18.5. The intent of this table is to provide a brief summary of the potential benefits of the recommended GMPs including: Pollutant reduction, hydrologic characteristics, and a reduction in potential runoff volumes.

Green Management Practices Summary

Table 18.3-A

■ Significant Benefit
◩ Partial Benefit
□ Low or Unknown Benefit

		Pollution Reduction								Hydrologic Charateristics					Runoff Volume Reduction		
		Sediment	Phosphorous	Nitrogen	Metals	Pathogens	Floatables	Oil and Grease	Dissolved Pollutants	Surface Flow Reduction	Infiltration	Stormwater Conveyance	Stream Channel Protection	Peak Flow Control	Runoff Capture	Maintenance	Cost
18.5.1	Bioswales	■	◩	◩	◩	□	◩	◩	◩	◩	◩	◩	◩	□	◩	Low	Low
18.5.2	Rain Gardens	■	◩	◩	◩	◩	◩	◩	◩	◩	◩	□	◩	◩	■	Low	Low
18.5.3	Constructed Wetlands	■	◩	◩	◩	◩	◩	◩	◩	◩	□	□	◩	◩	◩	Medium	Medium
18.5.4	Green Wet Basin	■	◩	◩	◩	◩	◩	◩	◩	◩	□	□	◩	◩	◩	Low	Medium
18.5.5	Green Dry Basin	■	◩	◩	◩	□	◩	◩	□	◩	□	□	◩	◩	◩	Low-Medium	Low-Medium
18.5.6	Extensive Green Roof	□	□	□	□	□	□	□	□	■	□	□	◩	■	■	Low	High
18.5.7	Intensive Green Roof	□	□	□	□	□	□	□	□	■	□	□	◩	■	■	Medium	High
18.5.8	Blue Roofs	□	□	□	□	□	□	□	□	□	□	□	◩	◩	■	Low	Medium
18.5.9	Permeable Pavers	◩	□	□	◩	□	□	□	□	■	■	□	◩	□	■	High	High
18.5.10	Pervious Concrete	◩	□	□	◩	□	□	□	□	■	■	□	◩	□	■	Medium	Medium
18.5.11	Porous Asphalt	◩	□	□	◩	□	□	□	□	■	■	□	◩	□	■	Medium	Medium
18.5.12	Planters	■	◩	◩	◩	□	◩	◩	◩	◩	◩	◩	□	□	◩	Low	Medium
18.5.13	Tree Boxes	■	◩	◩	◩	□	◩	◩	◩	◩	◩	◩	□	□	◩	Low	Medium
18.5.14	Rainwater Harvesting Cisterns	□	□	□	□	□	□	□	□	■	□	□	◩	□	■	Medium-High	Medium-High
18.5.15	Vegetative Buffers	◩	◩	◩	◩	□	◩	□	□	◩	◩	◩	□	□	◩	Low	Low-Medium
18.5.16	Vegetated Swales	◩	□	□	□	□	◩	□	□	□	◩	■	□	□	◩	Low	Low
18.5.17	Underground Storage	◩	□	□	□	□	◩	□	□	□	□	□	◩	□	■	Medium	Medium-High
18.5.18	Catch Basin Inserts	◩	□	□	◩	□	◩	◩	□	□	□	□	□	□	◩	Medium-High	Low-Medium
18.5.19	Proprietary Water Quality Units	*varies by technology*								□	□	◩	□	□	◩	Medium	Medium-High
18.5.20	Infiltration Drains	■	■	■	■	◩	◩	◩	◩	■	■	■	◩	◩	■	Medium-High	Medium

Green Management Practice Selection Process

Developing a green infrastructure project involves incorporating GMPs throughout the life of the project, from the concept stage through the final design and subsequent operation and maintenance. Figure 18.3-A is a flow chart that depicts the steps in developing a green infrastructure project. Each of these steps are discussed in more detail in this section.

Steps 1 through 5 of the flow chart below outline the steps to design a GMP based on water volume. If however the entire volume cannot be captured, a practice that focuses on the water quality can be implemented. Steps 6 and 7 outline that process.

See 18.2, Section : MSD Wastewater/Stormwater Discharge regulations for exclusions.

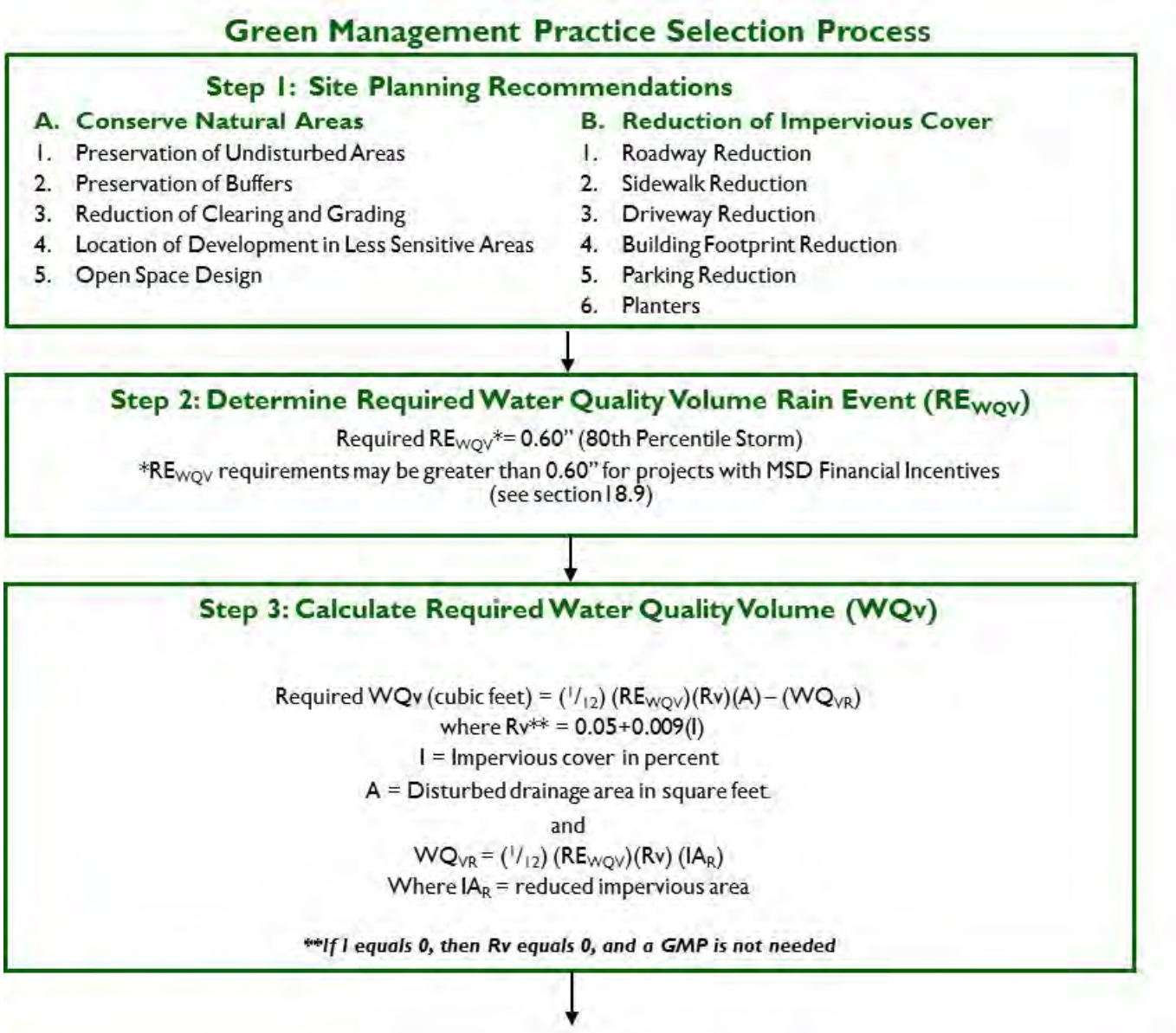


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Figure 18.3-A. Green Management Practice Selection Process

Green Management Practice Selection Process (Continued)

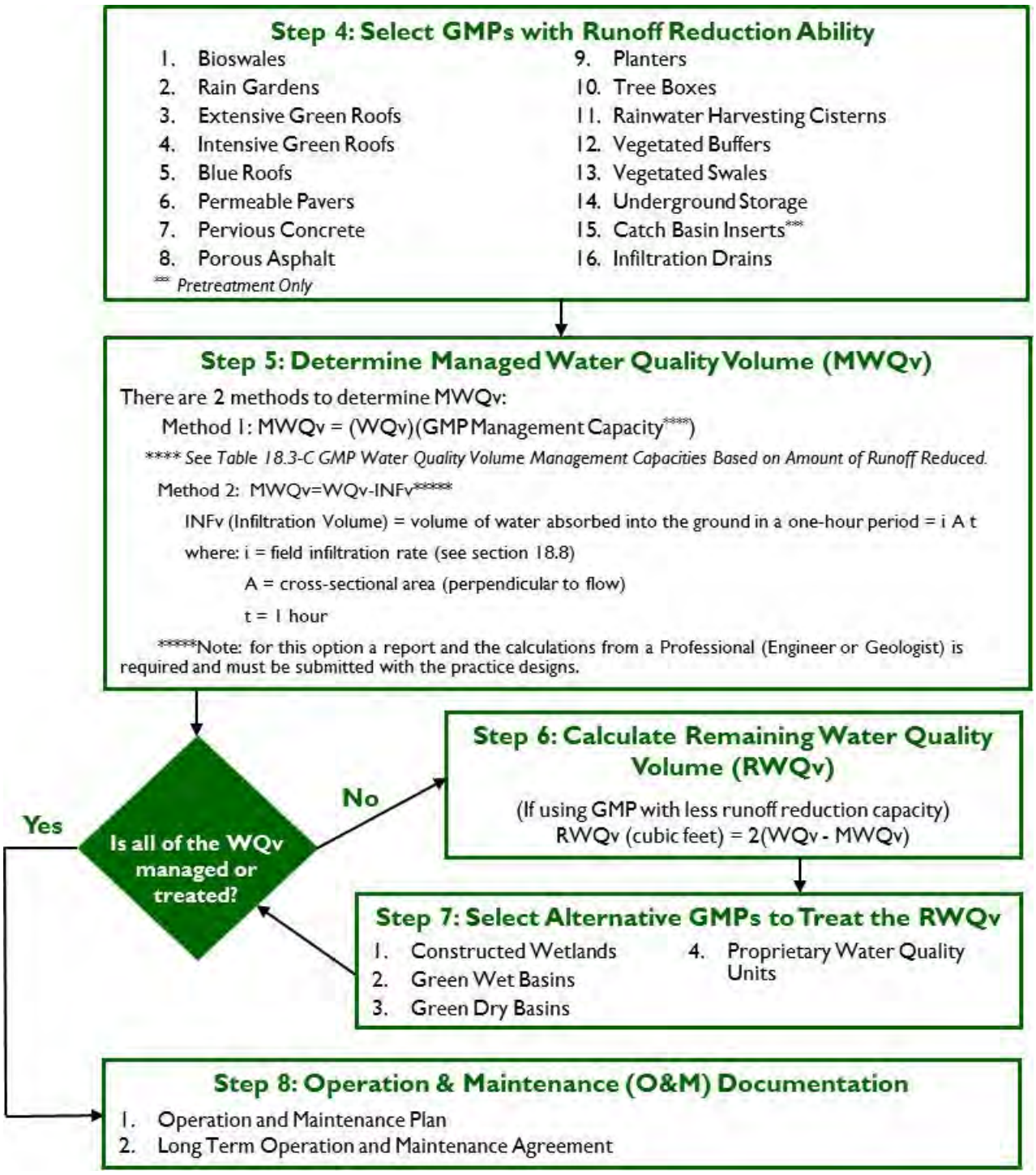


Figure 18.3 A (continued) Green Management Practice Selection Process

Following is a Step-by-Step explanation for the GMP process.

Step 1: Site Planning Recommendations

During the first step of selecting GMPs for a project, consideration should be given to preserving the natural features of a project site, (conservation design). As discussed in Chapter 18.1 green infrastructure can range from natural features on a property that treat runoff, to manmade structures that treat stormwater before it enters the drainage system. Research indicates that it is more effective to treat stormwater at its source. Therefore, preserving the natural features on a site can be a cost effective means for stormwater management. The first step of the selection process is to observe and evaluate the site characteristics, including the following:

Development Features Development features include both the natural and manmade features of the site, including utilities, park areas, waterfront areas, landscaping, conservation areas, roads, and sidewalks. Development features should be considered during the site assessment and planning phase.

Natural Features Natural features are grasslands, wooded areas and streams or ponds on a site. Special attention should be given to the preservation of existing drainage features and the conservation of natural areas, which reduces the amount of stormwater runoff leaving a site.

Manmade Features Manmade features include existing structures, roads, sidewalks and utilities on a site.

Watershed Factors Watershed factors to consider include pollutants, water quality, sources of water pollution and location of the property within the watershed.

Aesthetic and Habitat Related Issues Aesthetic and habitat related issues can include a site's proximity to impaired waters or sensitive areas, and if there are threatened and/or endangered species identified on the site.

Topography A site's topography will impact the location and types of GMPs that can be used. It is important to try to utilize the natural topography to the best extent possible.

Karst Area Karst areas consist of limestone terrain with caverns, sinkholes and underground streams. GMPs that impound water can be problematic in karst areas if they cause these underground caverns and sinkholes to expand and open at the surface. Liners may be a solution to this design impediment; however, the conveyance to the GMP and from the GMP to the downstream location must be considered because of the increased runoff volume and its potential migration to areas that may not have received runoff previously. Furthermore, in karst topographies, there is a risk that stormwater runoff may enter the water table with little to no pollutant treatment. This is why appropriate GMP selection is critical in these areas. Infiltration GMPs should not be used in karst topographies.

High Water Tables High water tables can impact the efficiency of a GMP. High infiltration GMPs are prohibited in these areas since high water tables can prevent the percolation of stormwater into the subsoils. In addition, special geotechnical considerations may be necessary in these areas, especially for embankment or impoundment facilities.

Wind Exposure Exposure to wind may impact the planting selections for green roofs and other GMPs that require landscaping.

Vegetation Vegetation on a site can both enhance and impede the effectiveness of a GMP. For example, deciduous trees near pervious pavement can clog the GMP with leaves, but reduce stormwater runoff by rainfall interception and evapotranspiration. In spite of these challenges, appropriately selected vegetation in GMPs can improve performance.

Existing Development and Steep Slopes

One goal of stormwater management is to allow for the natural recharge of groundwater. This process also has the potential to impact adjacent ground during and after storm events. Saturating the soils on steep slopes (6 to 10 percent or greater) can cause the failure of the slope and adjacent structures.

Costs

GMP costs may be incurred in the planning, design, construction, and Operations and Maintenance stages of a project.

Credits

Credits are reductions applied to the stormwater user fees in exchange for the implementation of GMPs on a site. The requirements for these credits vary and as a result, the designer should consult MSD policy as to the availability of credits.

Local Planning and Regulatory Requirements

Federal, state and/or local regulatory requirements may prohibit or require certain GMPs to meet specific standards. The designer should consult all applicable ordinances and regulatory requirements, as that may impact the design process, selection criteria, operation and maintenance and the cost of the GMPs. Some of the planning and regulatory aspects to consider when planning GMPs for a site are; CSO mitigation, TMDL requirements, MS4 permitting, 401/404 permitting, floodplain permitting, and MSD credits/incentives. Review local ordinances and zoning codes to verify that potential GMPs comply with these requirements and that there are not any regulatory impediments to the GMPs proposed for the site. Regulatory programs and local ordinances are discussed in more detail in Sections 18.2, 2.5 and Chapter 10 of Design Manual.

Operation and Maintenance

The operation and maintenance schedule and costs may impact the decision to use a GMP. Some GMPs require more maintenance than others. Information regarding operation and maintenance is in Section 18.7.

Designated Land Use

The designated land use is a factor to consider since some GMPs are better suited for specific land uses than others. A summary of the most applicable land uses can be found on the first page of each GMP fact sheet shown in Section 18.5.

Contributing Drainage Area Size

The applicability of some GMPs will be limited due to the size of the contributing drainage area and the functionality of GMPs. The maximum and minimum contributing drainage area sizes are shown on the GMP fact sheet guidelines. However, when incorporating proprietary water quality units into a site design, design criteria should be modified only by the manufacturer.

Hotspots

Hotspots are a land use or activity that generate higher concentrations of pollutants, including but not limited to; hydrocarbons, sediments and trace metals that are found in stormwater near the land use. Due to the potential for groundwater contamination, the use of some GMPs near hotspots is prohibited. Separation from the groundwater table or an impermeable liner for impoundment structures should be considered for hotspots.

Hotspot locations include:

- Gas/fueling stations
- Vehicle washing /steam cleaning
- Auto salvage yards/auto recycling facilities
- Outdoor material storage areas
- Outdoor loading and transfer areas
- Landfills
- Construction sites
- Facilities that store or generate hazardous materials
- Industrial sites
- Industrial rooftops

Treatment Trains

A treatment train is the use of multiple GMPs in series on a site to meet the WQv requirement for stormwater management. Treatment trains can include structural and non-structural GMPs. When assessed and planned, a treatment train consists of all of the design concepts and GMPs that work to accomplish the revised reductions in runoff volume. The general approach for treatment trains should consider:

1. Avoiding additional stormwater runoff volume.
2. Managing stormwater runoff as close to the source as possible.
3. As appropriate, infiltrating as much of the stormwater runoff as possible.

Two examples of treatment trains for residential and commercial developments are provided in Figures 18.3-B and 18.3-C.

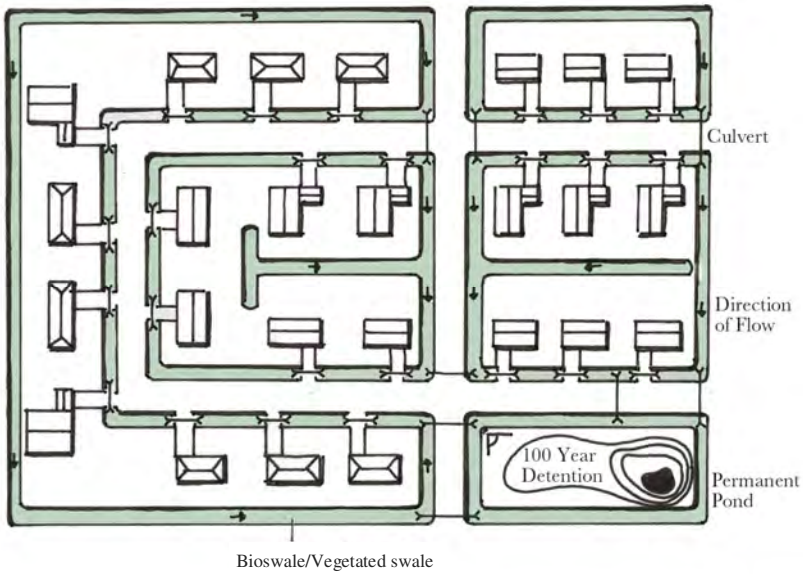


Figure 18.3-B. Multiple GMPs are used in a residential setting. The use of vegetated swales and a green detention basin are used in combination to manage the stormwater runoff. (Sketch: Shea Powell, Dropseed Nursery; Source: Atlanta Regional Council and Georgia Stormwater Design Manual)

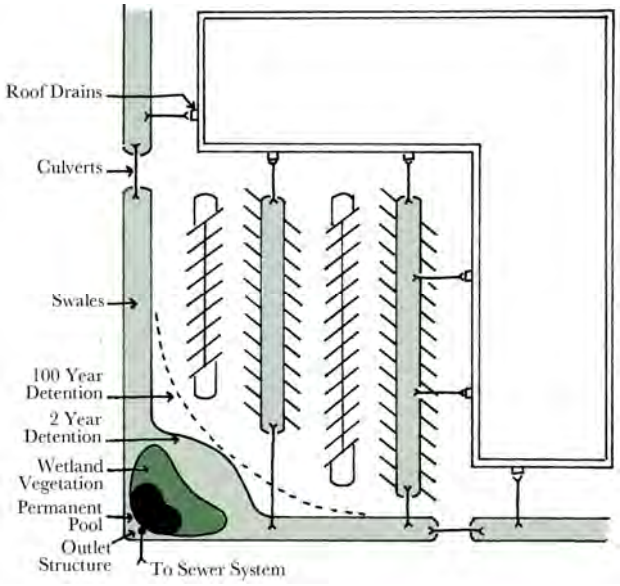


Figure 18.3-C. Multiple GMPs used in a commercial development, including directing roof drains to vegetated swales to a wetland system. (Sketch: Shea Powell, Dropseed Nursery; Source: Atlanta Regional Council, 2001)

Questions to consider when developing a treatment train include the following:

- Do management GMPs cost effectively help manage stormwater runoff?
- Can existing GMPs be retrofitted to increase their effectiveness?
- Does one structural GMP cost effectively help manage stormwater runoff?
- Do multiple structural GMPs cost effectively help manage stormwater runoff?

Evaluate Site Conditions

By evaluating the site characteristics and identifying the opportunities and limitations of the site, the designer can select the most cost effective GMP to reduce stormwater runoff for a site..

Opportunities on a site may include:

- Utilizing existing utility easements for GMP areas.
- Open spaces and preservation areas that can serve as GMPs while also providing multi-use areas such as parks, playgrounds, walking and hiking areas, and water recreational areas.

Limitations on a site may include:

- Regulatory restrictions
- Soil types
- High water table
- Land use
- Existing utilities
- Local acceptance of particular GMPs

Consideration should be given to preserving the natural features of a site. Conservation design is a means of development to preserve the natural features of a site that can protect water resources, natural habitats, and sensitive areas. These practices provide significant benefit for reducing imperviousness and as a result, the amount of stormwater leaving the site. Table 18.3-B contains recommended conservation design practices.

Conservation Design Practices

Table 18.3-B.

Practice	Description
Minimization of Disturbed Areas	Minimization of disturbed areas includes maintaining undisturbed forests, native vegetative areas, riparian corridors, wetlands, and natural terrains to preserve natural drainage characteristics of the area.
Preservation of Buffer Areas	The preservation of riparian buffers along streams, rivers, and wetland areas provides water quality benefits by allowing pollutants to filter from the stormwater runoff before entering these aquatic areas. Buffers also protect stream channels, wetlands, existing vegetation and habitats.
Reduction of Clearing and Grading	Reducing planned grading and clearing to the minimum area needed for structures, roads, driveways and utilities can minimize the amount of impervious cover on the site and as a result, reduce the required WQv.
Minimization of Development Impacts to the Site	Preserve the natural drainage patterns and topography of the land by incorporating natural features into a site design. This can result in lower costs for stormwater management.
Identification of Less Sensitive Areas for Development	Identifying less sensitive areas for development can reduce the impacts on water quality. Sensitive areas include highly erosive soil, steep topography, streams, wetlands, and buffers. The designer should also reference federal, state, and local laws for floodplain development and permitting regulated by the Clean Water Act in these areas.

Table 18.3-B **Conservation Design Practices (Cont.)**

Practice	Description
Promotion of Open Space Design	Open space design includes the use of stormwater controls in areas that are set aside as open space for the development. Inclusion of these practices in areas that were already set aside as open space or landscaping areas can improve drainage and reduce development and management costs.
Minimization of Impacts to Soil Permeability	Unaltered soils that contain high levels of organic material allow for the infiltration and storage of large quantities of rainfall, when compared to altered and compacted soils. When top soils are removed during development and compacted subsoils with a high clay content and little organic material remain, stormwater is more likely to flow to streams and wetlands with little natural water quality treatment. Many GMPs in the MSD Green Infrastructure Design Manual have specific soil permeability requirements.
Reduction of Impervious Cover	The reduction of impervious cover includes the following practices: roadway reduction, sidewalk reduction, driveway reduction, building footprint reduction, parking reduction, and the installation of planter boxes. By implementing these practices, impervious area can be reduced on a site and thus the associated WQv that must be treated on-site.
Additional Aspects to Consider	• Managing stormwater as a resource instead of a waste product • Managing stormwater at its source

Figure 18.3-D below is an example of a conceptual green site plan. As demonstrated in Figures 18.3-E & F on the next page, the designer has preserved conservation areas on the property including ponds and forested areas.



Figure 18.3-D. Conceptual Green Site Plan (Sabak, Wilson and Lingo, Inc.)



Figure 18.3-E. Conservation design is used to preserve open space and natural site characteristics. This approach can reduce the WQv that must be managed on a site.



Figure 18.3-F. This residential street in a development using conservation and open space design uses narrower streets than traditional practices. (Photo Sabak, Wilson and Lingo Inc.)

Step 2: Determine the Required Water Quality Volume Rain Event

The Required Water Quality Volume Rain Event (RE_{WQV}) is

0.60 inches (80th Percentile Storm)-Event Capture
Higher RE_{WQV} maybe selected for participation in financial incentive programs see Section 18.9 for further details.

Step 3: Calculate Required Water Quality Volume (WQv)

The third step of the process to select GMPs for a project site requires calculating the WQv. The WQv for a site is the volume of runoff from the site for the Required RE_{WQV}.

The equation for the Required WQv is as follows: Required WQv (ft^3) = $(RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

- RE_{WQV} is the required water quality volume rain event, determined in Step 2
- R_V is the volumetric runoff coefficient, $R_V = 0.05 + 0.009(I)$, where I is the impervious area of the site as a percent
- A is the site area in square feet
- $WQ_{VR} = (1/12)\ (RE_{WQV})(Rv)\ (IA_R)$, where IA_R = reduced impervious area

Step 4: Select the GMPs with Runoff Reduction Abilities

During the fourth step, consideration should be given to selecting GMPs with Runoff Reduction abilities. The designer should experiment with various GMPs or a combination of GMPs with runoff reduction abilities on the site until the required WQv is managed and/or treated. In each scenario, the designer estimates the drainage area contributing to each GMP, calculates the size of the GMP needed to manage the Required WQv, and attempts to footprint the GMP in the design. Runoff from at least 90% of the sites disturbed impervious area is required to be managed or treated. This allows for flow from discharges at property lines or locations with little to no setback to be accommodated. In these instances other site GMPs must be oversized to capture additional WQ_V to make up the difference for the total site water quality volume. The maximum oversizing of one GMP to account for bypassing site area shall be 10%.

The GMP Water Quality Volume Management (Capacities for each GMP are listed in Table 18.3-C labeled "GMP Management Capacity". By applying a combination of GMPs with water quality volume reduction abilities, the designer should manage 100% of the WQv calculated in Step 3. If the Managed Water Quality Volume (MWQv) provided by the designed GMPs calculated in this step is greater than or equal to the WQv calculated in Step 3, the designer has met the requirements. When compliance cannot be achieved on the first try, the designer should return to prior steps to see if different GMPs, GMP sizes, or a combination of GMPs can be applied or whether the site can be redesigned to minimize the impervious area to achieve compliance with the sizing criteria in Step 4.

Step 5: Determine Managed Water Quality Volume (MWQ_V)

The fifth step requires calculating the managed portion of the WQv. Each GMP has a management capacity shown in Table 18.3-C, on the following page. The MWQ_V for a GMP is the WQv provided by multiplying the WQv of a GMP by the management capacity of the GMP (See Table 18.3-C for management capacity values). The sum of the MWQ_V provided by the GMPs is then compared to the Required WQv. If the MWQ_V is greater than or equal to the Required WQv, then the designer can move to Step 8.

An alternative method to determine the MWQv is to take the difference between the WQv and the Infiltration Volume (INFv), or the volume of water absorbed into the ground over a one hour period. Infiltration rates must be in situ soil infiltration rates as determined in section 18.8. This method may be preferred when in situ soils provide sufficient infiltration capacity. A Professional Engineer or Geologist must verify the calculations of the infiltration volume and submit to MSD.

Due to the terrain of certain pieces of property, not all site developed stormwater runoff will be able to be directed into a GMP. If no more than 10% of the site has site generated stormwater runoff not managed by GMPs, then the calculated MWQv remains the same for the site. If more than 10% of the site has stormwater runoff that is not directed into a green management practice, the site needs to be redesigned so that 10% or less of the site developed stormwater runoff is not directed at a GMP. See section 18.10 Fee In Lieu Program as an alternative.

Step 6 & 7: Calculate Remaining Water Quality Volume and Select Alternatives

GMP Water Quality Volume Management
Capacities Based on Amount of Runoff Reduced

Table 18.3-C.

GMP	GMP Management Capacity as a % of the WQv
Bioswales	• 100%, if entire WQv is stored within practice, including forebay, check dams and soils, and no underdrain is provided or underdrain is above the water level of the WQv stored in the stone or soil media • 50%, if entire WQv is stored within practice, including forebay, check dams and soils, and underdrain is provided
Rain Gardens/Bioretention Areas	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the stone or soil media • 60%, if underdrain is below the water level of the WQv stored in the stone or soil media and drains in 24 to 48 hours • 30%, if underdrain is below the water level of the WQv stored in the stone or soil media and drains in less than 24 hours
Constructed Wetlands	• 100%, if stores 76%-100% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 75%, if stores 51%-75% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 50%, if stores 25%-50% of RWQ_v over and above the normal water level for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone.
Green Wet Basin	• 100%, if stores 76%-100% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 75%, if stores 51%-75% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 50%, if stores 25%-50% of RWQ_v over and above the normal water level for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone.
Green Dry Basin	• 100%, if stores 76%-100% of RWQ_v for at least 24 hrs and drains within 36 hrs. • 75%, if stores 51%-75% of RWQ_v for at least 24 hrs and drains within 36 hrs. • 50%, if stores 25%-50% of RWQ_v for at least 24 hrs and drains within 36 hrs.
Extensive Green Roof	80%
Intensive Green Roof	95%
Blue Roof	• 100%, if rainfall is stored and beneficially used later (i.e. rain water collected can be used to water plants, etc.) • 80%, if rainfall is only temporarily detained
Permeable Pavers	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate
Pervious Concrete	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate

GMP Water Quality Volume Management
Capacities Based on Amount of Runoff Reduced (Cont.)

Table 18.3-C.

GMP	GMP Management Capacity as a % of the WQv
Porous Asphalt	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate
Planters	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the planter media • 60%, if underdrain is below the water level of the WQv stored in the planter media and it drains in 24 to 48 hours • 30%, if underdrain is below the water level of the WQv stored in the planter media and it drains in less than 24 hours
Tree Boxes	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the tree box media • 60%, if underdrain is below the water level of the WQv stored in the tree box media and drains in 24-48 hours • 30%, if underdrain is below the water level of the WQv stored in the tree box media and it drains in less than 24 hours
Rainwater Harvesting - Cisterns	• 100%, if the rainfall is stored and beneficially used later (i.e. rain water collected can be used to water plants, etc.) • 50%, if the rainfall is only temporarily detained in the cistern less than 36 hours
Vegetated Swale	• 40%, if residence time is nine minutes or greater for the WQ_v rain event • 20%, if the residence time is greater than or equal to five minutes and less than nine minutes for the WQ_v rain event
Vegetated Buffer	• 100%, if residence time is 10 minutes or greater for the WQ_v rain event • 30%, if time is between 1 and 10 minutes for the WQ_v rain event • 15%, if time is less than 1 minute for the WQ_v rain event
Infiltration Drains	• 100% , if no underdrain or *underdrain is above the water level of the WQv stored in the media in the infiltration drain • 60%, if *underdrain is below the water level of the WQv stored in the media in the infiltration drain and it drains in 24 to 48 hours • 30%, if *underdrain is below the water level of the WQv stored in the media in the infiltration drain and it drains in less than 24 hours
Underground Storage	• 100%, if the collected rainfall runoff is infiltrated • 60%, if the collected rainfall runoff is only temporarily detained for 24-48 hours
Catch Basin Inserts	• 0%, pretreatment only, runoff reduction is not provided
Proprietary Water Quality Units	100%, if the flow rate of the proprietary water quality unit is equal to or more than the peak flow rate calculated from the following: $Q_p = C*I*A$ where • Q_p = the peak flow rate through the proprietary water quality unit in cfs. • C = runoff coefficient for the area draining to the proprietary water quality unit. • I = rainfall intensity for a 15 minute, 1-year return frequency storm, 2.82 inches/ hour for Louisville MSD. • A = drainage area to the proprietary water quality unit in acres.

* Please reference 18.5.20 for Class V Injection Wells definition and requirements.

If the MWQ_V is not greater than or equal to the Required WQv, then the designer should revisit the site planning recommendations to reduce the impervious area, consider alternatives, and/or include additional GMPs with runoff reduction ability. If the designer cannot manage the WQv for the site with these options, then the designer must provide justification in the plan that evaluates each of the GMP calculations, limitations to reducing the impervious area, and any additional site limitations that make application of the technique(s) infeasible.

Step 8: Operation and Maintenance Documentation

During step 8 of the selection process for GMPs, consideration should be given to operation and maintenance of GMPs, including documentation requirements (see Section 18.6 for operation and maintenance-specific inspection Forms and 18.7 for details on operation and maintenance needs). Maintenance is a critical aspect of a proper functioning GMP. Pursuant to the Wastewater/Stormwater Discharge Regulations, sites with GMPs the required to enter into long-term O&M agreements with MSD regarding the inspection and maintenance requirements for the GMPs. Additional reporting requirements may be necessary for properties receiving credits and/or stipends as part of the Green Infrastructure Financial Incentives Program. For more information regarding the level of service, MSD access to the GMPs, maintenance requirements, maintenance schedules, inspections, and compliance mechanisms, owners should consult the long-term O&M agreement and MSD policy, Section 18.7.

Routine inspections are an important element of GMP O&M. The inspection results should be documented and reviewed at least annually, to assess the effectiveness of the GMP (See Section 18.6).

After Plan Submittal

After the GMPs are designed the following aspects should be considered: GMP construction, long-term O&M agreements, inspection requirements, enforcement and education awareness.

GMP Construction

GMPs require care during construction and installation for optimal performance. Special care shall be given not to compact native soils with construction equipment during instillation. Knowledgeable personnel should provide construction oversight of the GMPs.

Long-Term Operation and Maintenance Agreements

The terms and conditions regarding the long-term operation and maintenance of each GMP are be defined by the agreement between the GMP owner and MSD. Operation includes, but is not limited to, the following: start up, validation that the device is meeting its intended purpose, and record keeping for the life of the GMP. Maintenance includes, but is not limited to, the following: cleaning, pumping, disposing of waste, pruning, mowing, weeding, and record keeping.

Inspection Requirements

The GMP owner is required to make routine inspections to ensure that the GMP is operating properly and that maintenance is being conducted as needed to maintain proper function of the GMP. The GMP owner is required to maintain records of installation and maintenance activities. These records will be made available to MSD or Louisville Metro government upon request. An annual report shall to be submitted to MSD.

Enforcement

Enforcement is vital to public health and safety. Enforcement measures shall be consistent with local ordinances and MSD regulations and policies.

Education Awareness

Outreach opportunities are an important aspect of GMPs. Education and outreach is key to the success of the GMP and can compliment the GMP through behavior changes. Educational programs are a means to promote proper operation and maintenance of GMPs. Employees or residents that benefit from a GMP at their place of employment or near their homes should be informed of the benefits of the GMP and actions that can impact the functionality of the GMP. Behaviors such as mowing and landscaping, pesticide and herbicide use, improper disposal of motor oil, and litter can impact the effectiveness of a GMP. Therefore, making information available as to how the GMP functions and behaviors that can promote the effectiveness of the GMP are encouraged. For example, employees can be given reoccurring training, including ready access

to the MSD Green Infrastructure Design Manual, regarding best management practices (BMPs) for operation and maintenance of a GMP. Another example of an outreach opportunity includes providing education and outreach information to residents living near a no mow buffer zone that surrounds a detention basin explaining the benefits of the "No Mow Buffer" as well as information encouraging residents to help preserve the "No Mow Buffer". This includes the appropriate signage. For more information, see Chapter 18.7.

GREEN MANAGEMENT PRACTICE (GMP) SELECTION PROCESS EXAMPLES

Following are three examples to demonstrate the process for selecting GMPs.

They are:

- Example 1- Bioretention Area Site Confirmation
- Example 2 - Size an Infiltration Planter
- Example 3 - Expanded Office Building
- Example 4 - Size an Infiltration Trench

Example 1 – Bioretention Area Site Confirmation

An area in the combined sewer system is being developed (see illustration below). In this example, the developer wants to use bioretention to manage the stormwater runoff from 34,600 square feet that is 85% impervious. The proposed bioretention area is 600 square feet, has 18 inches of soil media that has a porosity of 0.4, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 6 inches. Will this bioretention area provide the required Runoff Reduction Volume (RRv) in accordance with the GMP Manual? The following examples outlines a step-by-step process for how to use the selection process to determine the GMP RRv.

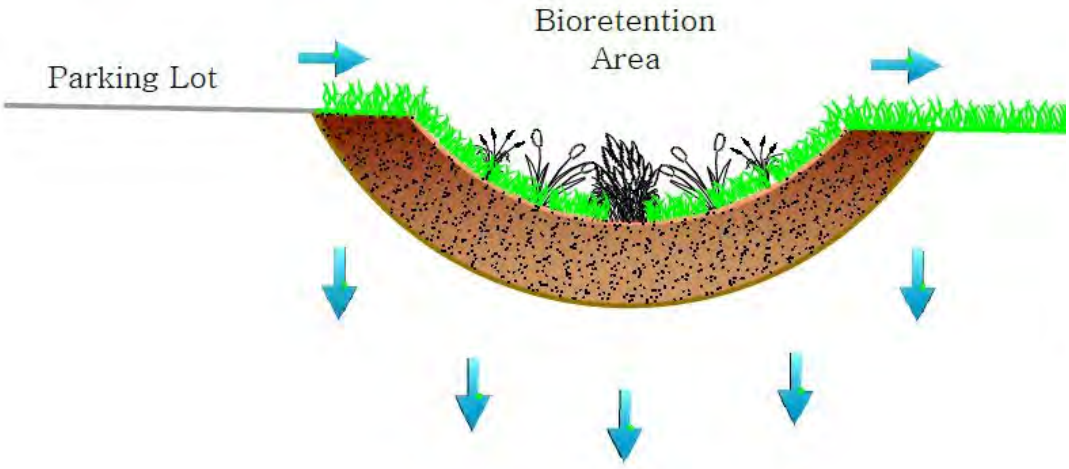


Figure 18.3-G Bioretention Area & Parking Lot.

Example 1 – Bioretention Area Site Confirmation *(Continued)*

Step 1: Site Planning Recommendation

The developer wants to minimize impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (RE_{WQV})

The required WQv rain event (RE_{WQV}) is 0.60 inches.

Step 3: Calculate the Required Water Quality Volume (WQv)

$WQv = (1/12)(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 85%. Adding the values to the equation yields the following:

$WQv = (1/12)(0.60)[0.05 + 0.009(85\%)]34{,}600 = 1410$ cubic feet

Step 4: Select GMPs with Runoff Reduction ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(600)(1.5)(0.4) + (600)(0.5)] = 660 cubic feet

Step 5: Determine Managed Water Quality Volume (MWQv)

Since the bioretention area has an underdrain below the water level of the WQv stored in the media, the management capacity is only 60%. Therefore, the MWQv is:

660(0.6) = 396 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 396 cubic feet, while the required WQv is 1410 cubic feet, so this GMP does not manage all of the WQv.

(Proceed to Step 6, next page.)

Example 1 – Bioretention Area Site Confirmation *(Continued)*

Suppose the developer cannot provide any other GMPs to manage the WQv. What is the required remaining WQv that he will need to treat?

Step 6: Calculate the Required Remaining Water Quality Volume (RWQv)

Required RWQv = 2(WQv – MWQv)

Adding the values into the equation yields the following:

Required RWQv = 2(1410-396) = 2028 cubic feet, which must be treated by an alternate GMP.

Step 7: Select Alternate GMPs to Treat RWQv

While any of the GMPs mentioned in Section 18.5 are an option for a treatment train the developer chooses to use a **green wet basin** (which has less runoff reduction capacity) to treat the required RWQv (see sketch below). The developer must modify the site plan, while still maintaining the percent impervious, to allow for the green wet basin. The green wet basin must be designed to treat a WQv of 2028 cubic feet.

Is all of the WQv managed or treated?

Yes

Step 8: O&M Documentation

Complete O&M documentation.

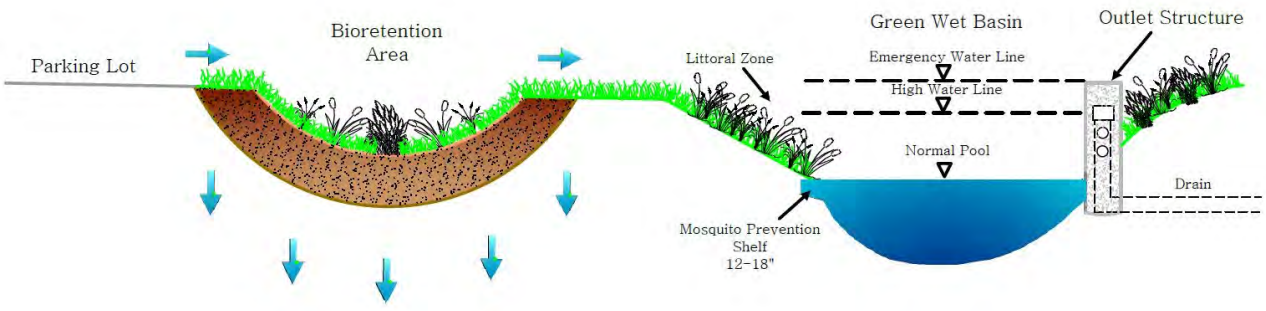


Figure 18.3-H Final Design of Bioretention Area and

Example 2 – Size an Infiltration Planter

A new development is proposed in the MS4 area (see illustration below). The developer wants to use an infiltration planter with no underdrain to manage the stormwater runoff from 3,000 square feet of rooftop that is 100% impervious. The proposed infiltration planter has 18 inches of soil media, a porosity of the soil media of 0.4 and has a ponding depth of 6 inches. What is the area of planter needed to manage the WQv in accordance with the Green Infrastructure Design Manual? The following steps show how to use the selection process to determine the GMP RRv.

*Note: for example 2, because the infiltration point must be at least 10-feet from a building footer, a planter without an underdrain was chosen. For illustration purposes, the planter shown is wider than the one in the example.

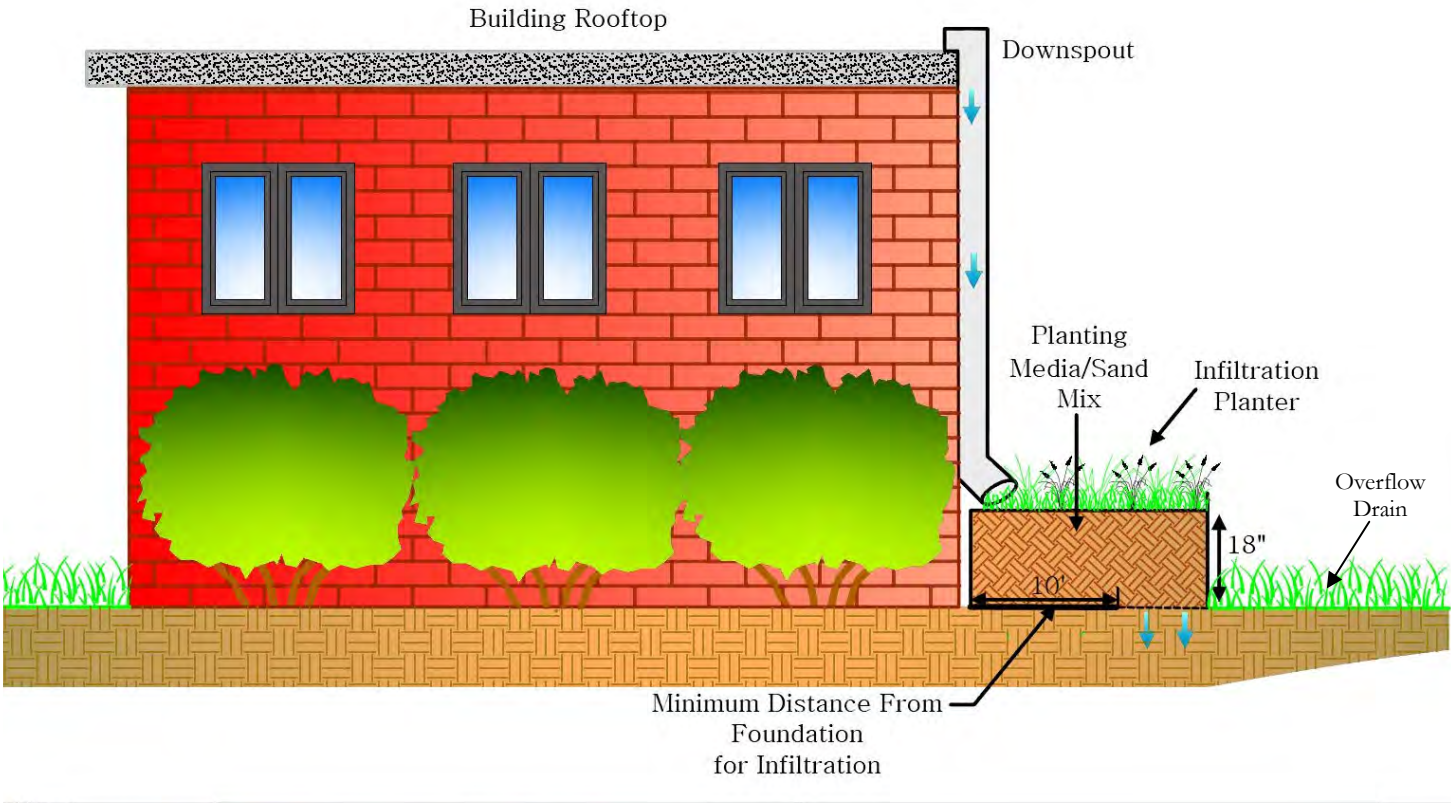


Figure 18.3-I Proposed Infiltration Planter site

Example 2 – Size an Infiltration Planter (*Continued*)

Step 1: Site Planning Recommendation

The developer has conserved as much natural areas as possible and minimized impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (RE_{WQV})

The required WQv rain event (RE_{WQV}) is 0.60 inches.

Step 3: Calculate the Required Water Quality Volume (WQv)

$WQv = (^{1}/_{12})(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 100%. Adding the values to the equation yields the following:

$WQv = (^{1}/_{12})(0.60)[0.05 + 0.009(100\%)]3{,}000 = 142$ cubic feet

Step 4: Select GMPs with Runoff Reduction Ability

The developer selected an infiltration planter box.

Step 5: Determine Managed Water Quality Volume (MWQv)

From the GMP Management Capacity Table (Table18.3-C), an infiltration planter with no underdrain (Figure 18.3-I) has a management capacity equal to 100% of the WQv provided.

A required = WQv/[d(p) + h] *Adding the values to the equation yields the following:*

A required = 143/[1.5(0.4) + (0.5)] = 130 square feet

Use an infiltration planter that is 3 feet wide by 45 feet long.

WQv = (3 x 45)[1.5(0.4) + 0.5)] = 148.5 cubic feet

Is all of the WQv managed or treated? **Yes**

The MWQv (148.5 cubic feet) is greater than the required WQv (142 cubic feet), so **YES**

Step 6: O&M Documentation

Complete O&M documentation.

Example 3 – Expanded Office Building

A developer is expanding his office building and adding parking in the MS4 area. While a number of GMP options were available, the developer decided to do the following:

- a new 2,000 square foot office building will manage stormwater runoff with a vegetated swale and two rain gardens.
- The new parking area will be pervious concrete with a vegetated buffer around the downhill side of the parking area.

Green project specifics are as follows:

- Project Disturbed Area: 5,000 square feet
- Rain Garden #1: The proposed Rain Garden #1 has a contributing area of 1,000 square feet (500 square feet from the old office building) that is 95% impervious. The rain garden is 45 square feet, has 30 inches of soil media that has a porosity of 0.4, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 6 inches. The rain garden drains in 18 hours.
- Vegetated Swale: The vegetated swale is 90 feet long, has a 2% slope, 2 foot wide bottom slope width with 3:1 side slopes, has a peak flow rate at the WQv rain event of 3 cfs and n = 0.03.
- Rain Garden #2: The proposed Rain Garden #2 has a contributing area 2,500 square feet (500 square feet from an old office building) that is 90% impervious. The rain garden is 125 square feet, has 24 inches of soil media that has a porosity of 0.4, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 12 inches. The rain garden drains in 24 hours.
- Pervious Concrete: The proposed pervious concrete has a contributing area of 4,500 square feet that is 98% impervious with a ground water level that is 2.5 feet below ground elevation. The pervious concrete is 2,000 square feet and consists of a gravel layer with a porosity of 0.4, a concrete layer with a porosity of 0.18, depth of gravel layer of 1 foot, depth of concrete layer of 6 inches and an underdrain below the water level of the WQv stored in the gravel.
- Vegetative Buffer: The vegetated buffer varies between 10 feet to 50 feet wide at a 2% slope and is located downgrade of the pervious concrete.

Rain garden #1, vegetated swale and rain garden #2 are discharged to the same point, while the pervious concrete and vegetative buffer share a discharge point. All GMPs used on-site are part of the same stream or tributary network.

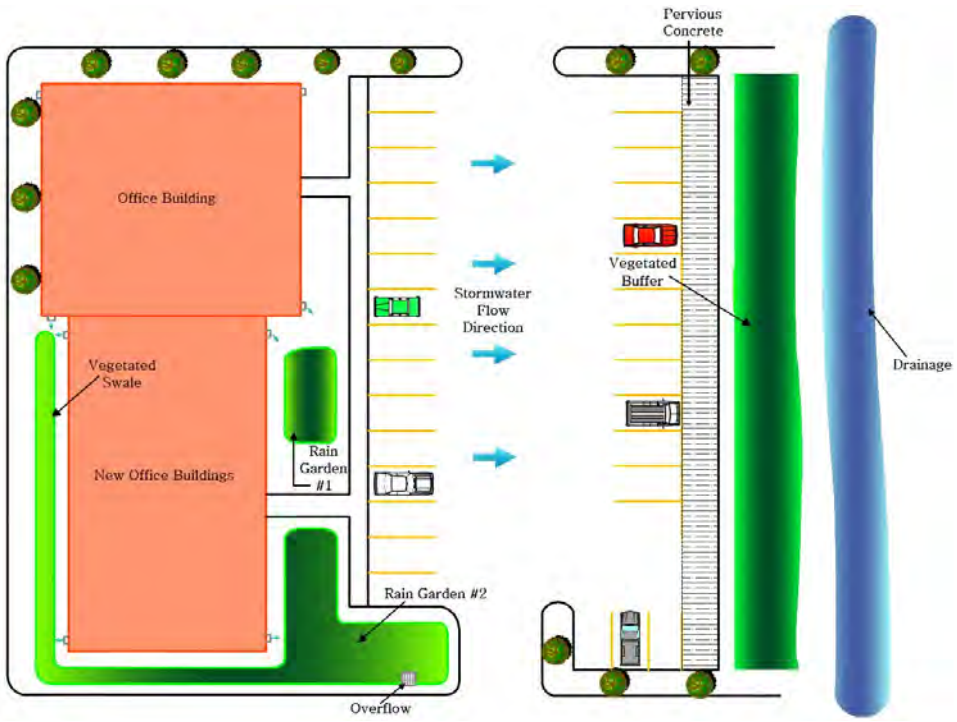


Figure 18.3-J Proposed Office Building Expansion

Example 3 – Expanded Office Building *(Continued)*

Step 1: Site Planning Recommendation

The developer has tried to conserve natural areas and limit impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (WQv)

The RE_{WQV} is 0.60 inches.

Step 3 (Rain Garden #1): Calculate the Required Water Quality Volume (WQv)

$WQv = (^{I}/_{12})(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 95%. The WQv requirements only apply to the newly disturbed portion of the site so A = 500 square feet. Adding the values to the equation yields the following:

$WQv = (^{I}/_{12})(0.60)[0.05 + 0.009(95\%)]500 = 23$ cubic feet

Step 4 (Rain Garden #1): Select GMPs with Runoff Reduction Ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(45)(2.5)(0.4) + (45)(0.5)] = 67.5 cubic feet

Step 5 (Rain Garden #1): Determine Managed Water Quality Volume (MWQv)

Since rain garden #1 has an underdrain and drains in less than 24 hours, the management capacity is only 30%. Therefore, the MWQv is:

67.5(0.3) = 20.25 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 20.25 cubic feet, while the required WQv is 23 cubic feet, so this GMP does <u>not</u> manage all of the WQv. There is a deficit of 2.75 cubic feet. *(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)*

Example 3 – Expanded Office Building *(Continued)*

Step 4 (Vegetated Swale) Select GMPs with Runoff Reduction Ability

Calculate the flow depth during the peak flow rate.

$D = \{n(Q)/[1.49W(s)^{1/2}]\}^{3/5}$

Adding the values to the equation yields the following:

$D = \{0.3(3)/[1.49W(s)^{1/2}]\}^{3/5} = 0.40$ feet

Calculate the velocity, $v = Q/[W(D)]$ Adding the values to the equation yields the following:

$V = 3/[2(0.40)] = 3.8$ fps

Calculate the residence time, $R = L/[60(v)]$. Adding the values to the equation yields the following:

$R = 90/[60(3.8)] = 0.4$ minutes

Step 5 (Vegetated Buffer): Determine Managed Water Quality Volume (MWQv)

Does the vegetated buffer meet the minimum requirements?

R is < 1 minute for the WQv Rain Event

Is all of the WQv managed or treated?

No

The vegetated swale does not meet the minimum requirements so additional or different treatment is needed.
(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)

Example 3 – Expanded Office Building *(Continued)*

Step 3 (Rain Garden #2): Calculate the Required Water Quality Volume (WQv)

$WQv = (^{1}/_{12})(RE_{WQv})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 90%. Adding the values to the equation yields the following:

$WQv = (^{1}/_{12})(0.60)[0.05 + 0.009(90\%)]2{,}500 = 108$ cubic feet

Step 4 (Rain Garden #2): Select GMPs with Runoff Reduction Ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(125)(2)(0.4) + (125)(1)] = 225 cubic feet

Step 5 (Rain Garden #2): Determine Managed Water Quality Volume (MWQv)

Since rain garden #1 has an underdrain below the water level of the WQv stored in the media and it drains in greater than 24 hours the management capacity is only 60%. Therefore, the MWQv is:

225(0.6) = 135 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 135 cubic feet, so the required WQv is 108 cubic feet. This GMP manages all of the WQv. *(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)*

Example 3 – Expanded Office Building *(Continued)*

Step 3 (Pervious Concrete): Calculate the Required Water Quality Volume (WQv)

WQv = $(^{1}/_{12})(RE_{WQV})(Rv)$ (A) where Rv = 0.05 + 0.009(I).

From the project information I, imperviousness, is 98%. Adding the values to the equation yields the following:

WQv = $(^{1}/_{12})(0.60)[0.05 + 0.009(98\%)]4{,}500$ = 210 cubic feet

Step 4 (Pervious Concrete): Select GMPs with Runoff Reduction ability

WQv provided = (A) [(Porosity of Aggregate Layer)(Depth of Aggregate Layer)]

Adding the values to the equation yields the following:

WQv provided = 2000[(0.4)(1)] = 800 cubic feet

Step 5 (Pervious Concrete): Determine Managed Water Quality Volume (MWQv)

Since the pervious concrete has an underdrain below the water level of the WQv stored in the media, the management capacity is only 60%. Therefore, the MWQv is:

800(0.6) = 480 cubic feet

Is all of the WQv managed or treated? **Yes**

The MWQv is 480 cubic feet, which is in excess of the required WQv of 210 cubic feet (effectively oversized, could be reduced). Up to 10% of the additional capacity maybe used to offset other areas on site that could not be captured/treated.

So the WQ_V for the GMP is 10% of 210 is 21. So the overall MWQv is 210+21=231.

Thus MWQv is 231 cubic feet which is still greater than the WQv of 210 cubic feet.

So this GMP does manage all of the WQv.
(Proceed to step 6, next page.)

Example 3 – Expanded Office Building *(Continued)*

Will these multiple GMPs manage all of the required WQv in accordance with the GMP Manual?

Step 6 (Total) : Determine the Managed Water Quality Volume (MWQv)

Is MWQv total ≥ WQv total?

20.25 + 0 + 135 + 231 > 23 + 0 + 108 + 210

386.25 cubic feet > 341 cubic feet

Yes

Is all of the WQv managed or treated?

Yes

Proceed to step 8 since the MWQ_v is > WQ_v. Reference the GMP Selection Process.

Step 8: O&M Documentation

Complete O&M documentation.

Example 4 – Infiltration Drain Parking Lot Design

A store and parking lot (see illustration below) is being retrofitted with an infiltration drain. In this example, the developer wants to use an infiltration trench to manage the stormwater runoff from 0.75 acres (32,670 square feet) that is 76% impervious. The proposed infiltration drain is 420 square feet, has 6 feet of #3 stone with a porosity of 0.4, and a ponding depth of 6 inches. Will this infiltration drain provide the required Runoff Reduction Volume (RRV) in accordance with the GMP manual?

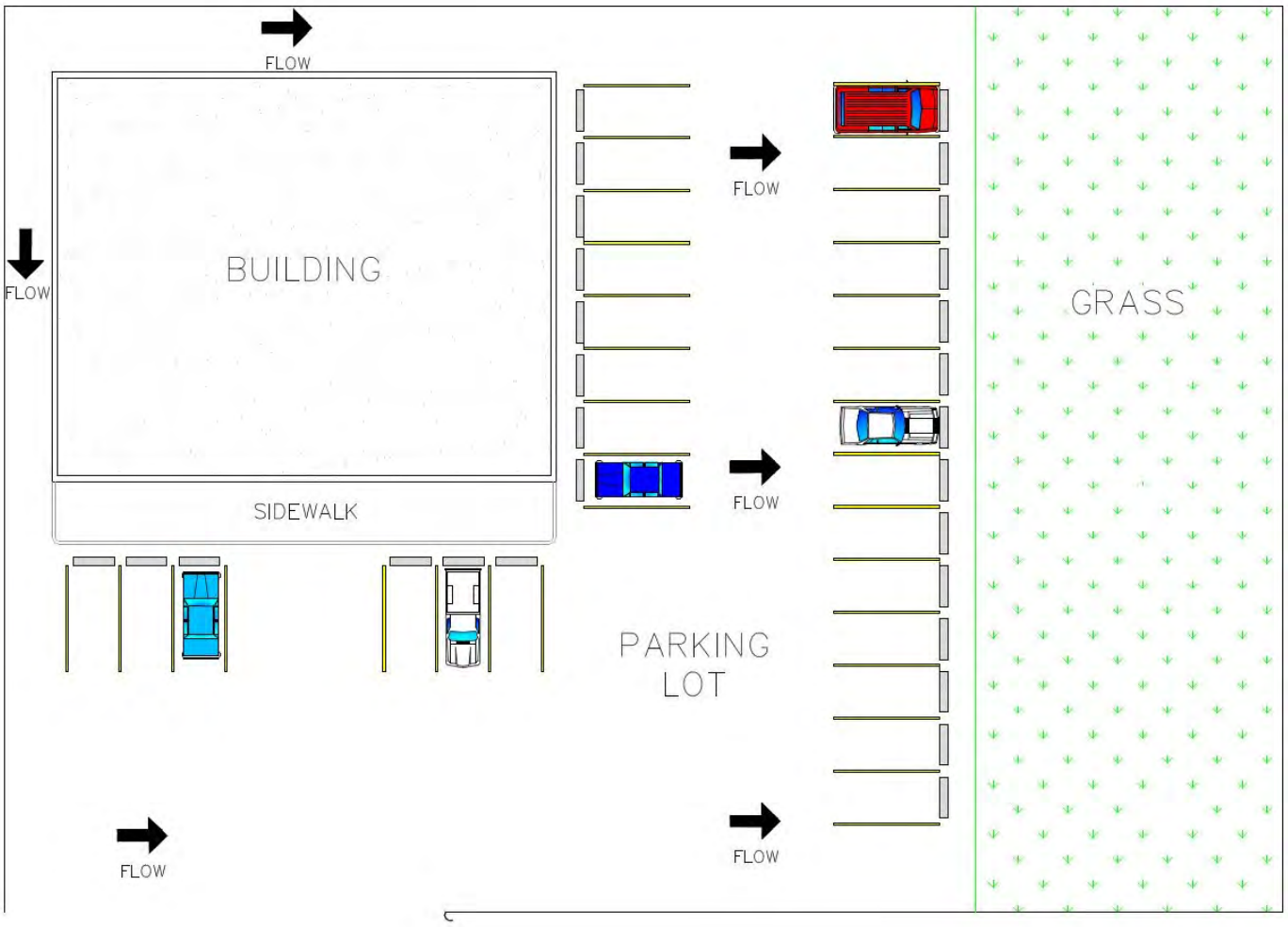


Figure 18.3-K Existing Conditions.

Example 4 – Infiltration Drain Example *(Continued)*

Step 1: Site Planning Recommendation

The developer has tried to conserve natural areas and limit impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (WQv)

The RE_{WQV} is 0.60 inches.

Step 3: Calculate the Required Water Quality Volume (WQv)

$WQv = (1/12)(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 76%. The WQv requirements only apply to the newly disturbed portion of the site so A = 32,670 square feet. Adding the values to the equation yields the following:

$WQv = (1/12)(0.60)[0.05 + 0.009(76\%)]32{,}670 = 1{,}199$ cubic feet

Step 5: Calculate the Provided Water Quality Volume (WQv Provided), or storage capacity of Infiltration Trench

WQv Provided= (A)[(Porosity of Media)(Depth of Media) + (height of water above in situ soils)]

Adding the values to the equation yields the following:

WQv Provided= (420)[(0.4)(6) + (0.5)] = 1,218 cubic feet

Example 4 – Infiltration Drain Example *(Continued)*

Step 5: Determine Managed Water Quality Volume (MWQv)

Since infiltration trench does not have an underdrain the management capacity is 100%. Therefore, the MWQv is:

1,218(1.0) = 1,218 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv is 1,218 cubic feet, which is in excess of the required WQv of 1,199 cubic feet. This GMP manages all of the WQv. Therefore, the proposed infiltration drain of 420 square feet is adequate for this site.

Step 6: O&M Documentation

Complete O&M documentation.

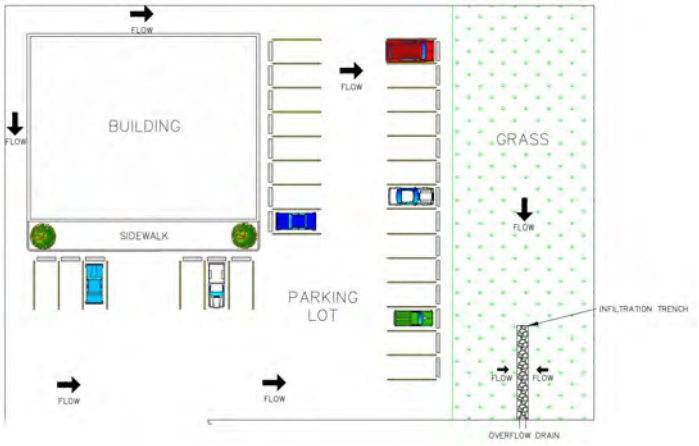


Figure 18.3-L Final design of Infiltration Drain

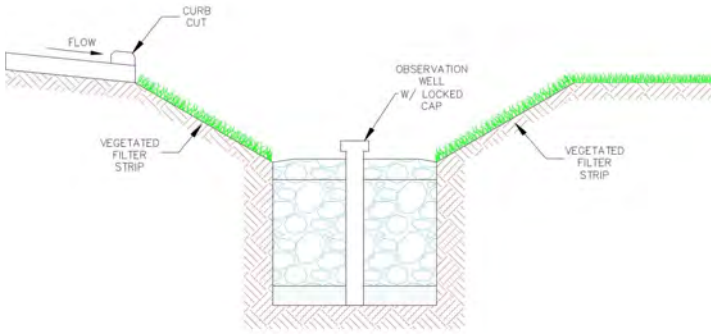


Figure 18.3-M Cross section view of Infiltration Drain

Design Strategies Key

Louisville and Jefferson County MSD logo and address

MSD
Metropolitan Sewer District

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Infrastructure Design Strategies

18.4.1 Green Streets

Chapter and section number and the design strategy name

Bulletted items list potential GMPs that can be used as part of this design strategy; several of these options are outlined in photos and descriptions on subsequent pages of each design strategy

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Infiltration Planters
- ☑ Rain Gardens
- ☑ Bioswales



Conceptual Green Streetscape
(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Photo/illustration of a typical implementation or schematic of the design strategy

General description of the design strategy

Description:

Green streets use linear landscape and hardscape GMPs to capture and reduce runoff from the street and adjacent properties. Green streets provide multiple benefits that are not limited to stormwater management including: reducing stormwater volume, replenishing ground water, improving air quality, encouraging economic development and improving the overall aesthetics in a community. There are several GMP options to use as a component of green street design including: pervious pavement, tree boxes, infiltration planters, rain gardens and bioswales.

Typical areas to implement a design strategy

Suitable Applications:

Green streets are suitable for a wide variety of land uses ranging from mid densities to high densities, including residential and commercial areas as well as parkways.

Items to consider before implementing a design strategy

Special Considerations:

- Design consistency with local and state ordinances/regulations
- Minimum widths for service trucks and emergency response vehicles
- Curb extension compatibility with narrow street widths
- Soil permeability
- Use of curb extensions for rain gardens, tree boxes and bioswales
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)

Effective date

Page number

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.1 Green Streets

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Planters
- ☑ Rain Gardens
- ☑ Bioswales



Conceptual Green Streetscape (Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Green streets use linear landscape and hardscape GMPs to capture and reduce runoff from the street and adjacent properties. Green streets provide multiple benefits that are not limited to stormwater management including: reducing stormwater volume, replenishing ground water, improving air quality, encouraging economic development, and improving the overall aesthetics in a community. There are several GMP options to use as a component of green street design including: pervious pavement, tree boxes, infiltration planters, rain gardens, and bioswales.

Suitable Applications:

Green streets are suitable for a wide variety of land uses ranging from mid to high densities, including residential and commercial areas as well as parkways.

Special Considerations:

- Design consistency with local and state ordinances/regulations (see Table 18.2-B)
- Any construction in a roadway will require Louisville Metro right-of-way (ROW) and/or Kentucky Transportation Cabinet ROW encroachment approvals
- Minimum widths for service trucks and emergency response vehicles
- Curb extension compatibility with narrow street widths
- Soil permeability
- Use of curb extensions for rain gardens, tree boxes and bioswales
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)

Concept Neighborhood and Parkway Uses

Multiple GMPs can be used as part of the design strategy for green streets as demonstrated in the following pictures.

Existing: Traditional Curb and Gutter with Catch Basins in a Residential Development →

A traditional street with catch basins and curbing is shown in the picture to the right.



Existing: Traditional Curb and Gutter Parkway with Island →

An arterial road with traditional curb and gutter drainage and a center island provides aesthetic benefits.





← Green Option: Rain Garden, Pervious Pavers and Trees are Used in Residential Neighborhood

In residential neighborhoods existing catch basins can be incorporated into curb cuts that capture street runoff and direct it to rain gardens (demonstrated in the picture to the left), bioswales and filter strips. The use of pervious pavers reduces the runoff from the street. These GMPs provide environmental benefits, as well as aesthetic and economic benefits.



← Green Option: Parkway with Center Bioswale Incorporating Urban Forestry and Rain Garden

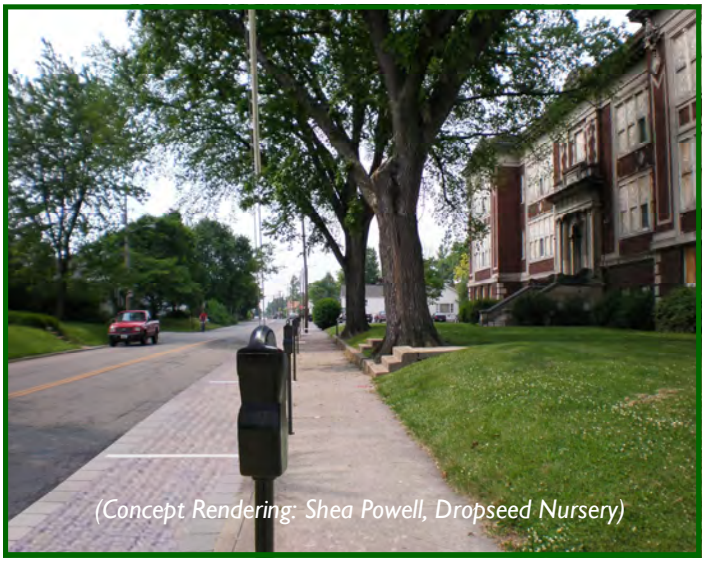
A rain garden with curb cuts has replaced the traditional curb and gutter along the side of the street, allowing stormwater runoff to drain to the rain garden. A bioswale has been added to the center island. These practices add aesthetic and stormwater management benefits.

Concept Residential and Urban Uses

Green streets can utilize various GMPs to manage drainage and improve water quality. These practices can be used in residential and non-residential areas.

Existing: Street Parking with Traditional Curb and Gutter ➔

Traditional gray infrastructure, with curb and gutter stormwater management is a common practice.



(Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Traditional Curb and Gutter Used Along an Urban Street ➔

Existing conditions contain the use of curb and gutter in an ultra-urban area.



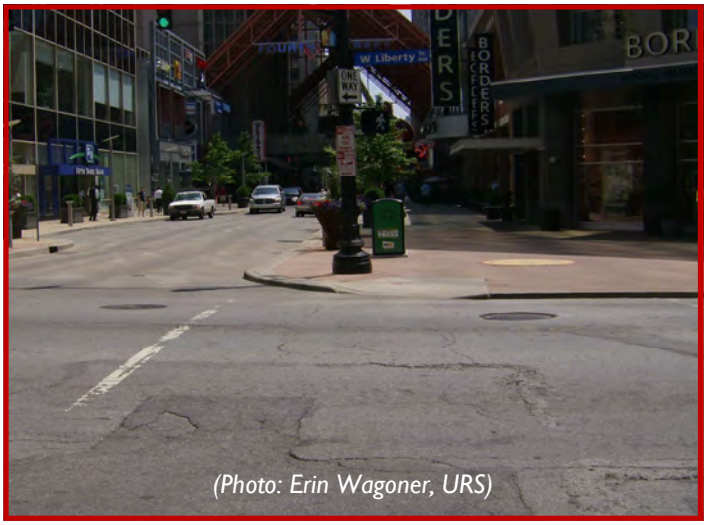
(Concept Rendering: Shea Powell, Dropseed Nursery)



(Photo Erin Wagoner, Concept Rendering: Shea Powell, Dropseed Nursery)

➔ Green Option: Pervious Pavers Used in a Parking Area

In this concept rendering, on-street parking has been converted from impervious pavement to permeable pavers.



(Photo: Erin Wagoner, URS)

➔ Green Option: Tree Box with Curb Cuts

The design strategy to the right demonstrates the use of curb cuts with tree boxes to treat stormwater. Permeable pavers are incorporated into this design, adding both stormwater management and aesthetic benefits.

Concept Residential and Urban Uses (Cont.)

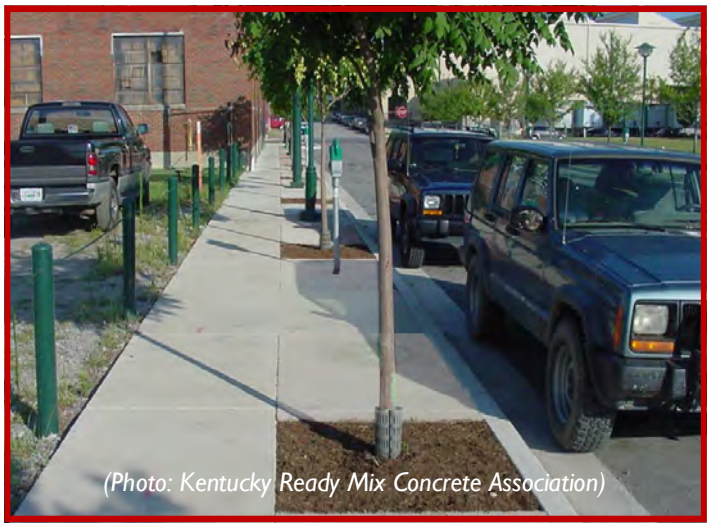
Green streets can utilize various GMPs to manage drainage and improve water quality. These practices can be used in residential and non-residential areas.

Existing: Traditional Tree Box with Impervious Concrete ➔

Surrounding a tree box with impervious concrete is a common practice.



(Concept Rendering: Shea Powell, Dropseed Nursery)



(Photo: Kentucky Ready Mix Concrete Association)

➔ Green Option: Pervious Concrete Surrounding Tree Boxes

In this concept rendering, pervious concrete has been added adjacent to existing trees.

Flow-Through Planter Box Along Downtown Storefront ➔

These photos along 4th Street show a small flow-through planter with flowering annual plants. The downspout is routed from inside the building to the planter box.



(Photos: Erin Wagoner, URS)

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18.4.2 Green Intersections

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Porous Asphalt
- ☑ Permeable Pavers
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales



Green Intersection Concept
(Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Green intersections use landscape and hardscape GMPs to capture and treat stormwater. GMPs vary depending on the area and goals for the intersection. In some circumstances, it could be beneficial to use rain gardens.

Suitable Applications:

Green intersections are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Location and size of the intersection
- Minimum widths for service or emergency response vehicles
- Soil permeability
- Curb breaks can be retrofitted to route stormwater to GMPs prior to draining to catch basins
- Design consistency with local and state ordinances/regulations
- Surrounding land uses
- Pedestrian walking area, lighting and trash receptacles locations
- Permeable pavers, pervious concrete and porous asphalt maintenance and structural issues should be considered if used in a driving or heavy load areas (such as a drive lane in contrast to parking stalls)
- Permeable pavers, pervious concrete and porous asphalt placed in areas with trees will require additional maintenance to keep clean and functional

Concept Corner Beautification

Green intersection GMPs can vary depending on the location of the intersection and the type of development near the intersection as demonstrated in the following pictures.

Existing: Traditional Asphalt Paving ➔

Traditional asphalt paving used for a park entrance near high traffic intersection.



(Photo: Erin Wagoner, URS)



(Concept Rendering Shea Powell, Dropseed Nursery)

➔ Green Option #1: Rain Garden is Incorporated into Park Access Entrance

This green intersection was designed with porous asphalt that spans the full width of the walkway and includes a rain garden and bioswale near the street. Stormwater from adjacent sidewalks and residential developments is intercepted by these facilities.

Green Option #2: Pervious Pavers are Used ➔

Permeable pavers are installed along the alley centerline and rain gardens and bioswales are installed along the street in this design. Stormwater from adjacent sidewalks and residential developments is intercepted by these facilities.



(URS Concept Rendering: Shea Powell ,Dropseed Nursery)

Concept Pervious Crosswalks

Green intersection GMPs can vary depending on the location of the intersection and the type of development near the intersection as demonstrated in the following pictures.

Existing: Intersection in Urban Area with Traditional Infrastructure →

An urban intersection is shown with a large amount of impervious area.



(Photo: Erin Wagoner, URS)



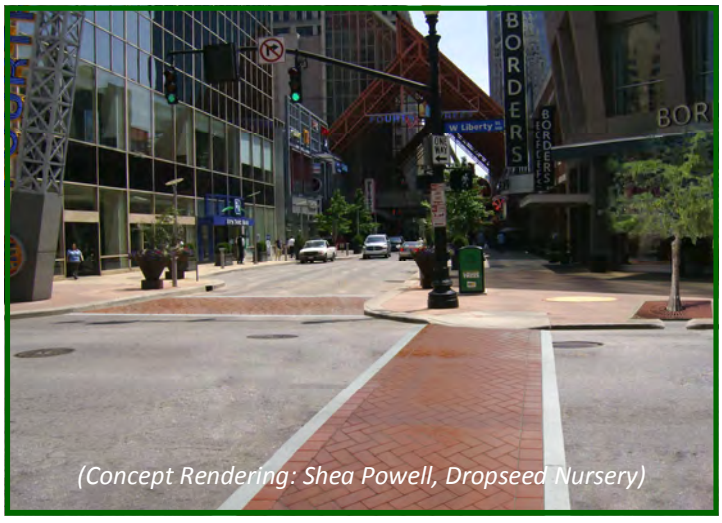
(Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option #1: Tree Boxes and Pavers Add Stormwater as well as Aesthetic Benefits

Pavers replace traditional asphalt along the street crosswalk. Tree boxes capture runoff from the street. Pervious concrete and porous asphalt can be substituted for pavers where appropriate.

Green Option: #2: Use of Multiple GMPs →

This intersection includes the use of a curb cuts to collect stormwater from the street and direct it to a tree box, where it can filter though the soil medium. In this design, overflow and underdrain pipes prevent stormwater from collecting in the street.



(Concept Rendering: Shea Powell, Dropseed Nursery)

Concept Intersection Green Planning

Green intersection GMPs can vary depending on the location of the intersection and the type of development as demonstrated in the following green intersection design.



Example of a green intersection design in San Francisco (Courtesy of http://sf.streetsblog.org)

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18.4.3 Stormwater Curb Extensions

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales



Stormwater Curb Extension Concept (Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Stormwater curb extensions, like traditional curb extensions, are traffic calming measures that can extend the length of the sidewalk and reduce the crossing distance for pedestrians. Stormwater curb extensions utilize breaks in the curb and the space created inside the curb for infiltration GMPs including rain gardens, tree boxes or bioswales. Stormwater curb extensions capture, infiltrate and treat stormwater runoff through various GMPs.

Suitable Applications:

Stormwater curb extensions are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Curb extension compatibility with narrow street widths
- Minimum widths for service trucks and emergency response vehicles
- Soil permeability
- Curb break location (route stormwater to GMPs prior to draining to catch basins)
- Landscaping curb extensions with deep rooted native plants and trees
- Use of permeable pavers, pervious concrete or porous asphalt for on-street parking
- Use of a concrete edge on permeable pavers, pervious concrete or porous asphalt to limit clogging and facilitate street cleaning
- Existing utility locations and any conflict with curbing, soil depths, or other design improvements

Residential Implementation

Stormwater curb extensions can be located in urban or residential settings. The following pictures demonstrate the use of stormwater curb extensions in a residential setting.

Existing: Curb and Gutter Infrastructure ➔

This photo shows a traditional curb and gutter used in a residential neighborhood with grass and landscaped swales.



(Photo: Erin Wagoner, URS)



(Concept Rendering: Shea Powell, Dropseed Nursery)

➔ Green Option: Multiple GMPs

In this rendering, stormwater curb extensions create space for a bioretention cell and permeable pavers that are used to define on-street parking lanes. These practices capture stormwater runoff while enhancing the streetscape of the neighborhood.

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18.4.4 Green Alleys

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales



Green Alley Concept (Concept Rendering: Katherine Holmok, URS)

Description:

Green alleys use linear landscape and hardscape GMPs to capture and reduce runoff from the alley and adjacent properties. Green alleys capture, infiltrate and treat stormwater runoff through various GMPs.

Suitable Applications:

Green alleys are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Alley width compatability with various GMPs
- Minimum widths for service trucks and emergency response vehicles
- Soil permeability
- Crowned alleys require primary GMPs along right-of-way edges
- Inverse crowned alleys require primary GMPs along the alley centerline
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)
- Existing utility locations

Green Alley Illustrations

Green alleys utilize centerline strips as infiltration areas or incorporate GMPs along the full width of the alley as demonstrated in the following pictures.

Existing: Traditional Alley →

Traditional inverse crowned alley with runoff from multi-family and single-family residences.



(Photo: Chad McCormick, URS)



(Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option #1: Permeable Pavers Combined with a Rain Garden

In this concept rendering, permeable pavers span the full width of the street with rain gardens and bioswales along the right-of-way. Rain gardens capture the parking lot runoff prior to draining to the alley. Tree boxes with curb cuts can be used in place of rain gardens.



(Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #2: Permeable Paver Strip with a Rain Garden →

Permeable paver strip located along the alley centerline with rain gardens and bioswales along the right-of-way.



(Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option #3 Pervious Concrete Strip with Multiple GMPs

In this design, a porous asphalt strip along the alley centerline with rain gardens and bioswales along the right-of

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18.4.5 Green Parking

Potential Green Management Practices Included:

- ☑ Permeable Pavers
- ☑ Pervious Concrete
- ☑ Porous Asphalt
- ☑ Tree Boxes and Planter Boxes



Grass Grid Pavers (Photo: Erin Wagoner, URS)

Description:

Traditional parking lots generate stormwater runoff that typically enters the storm sewer system though inlets at various points around the parking lot. Green parking incorporates various GMPs to capture, filter and infiltrate stormwater.

Suitable Applications:

GMPs include permeable pavers, pervious concrete, porous asphalt, pervious catch basin rings, infiltration planters and tree/planter boxes that are suitable for both new construction and to retrofit projects involving parking lots.

Special Considerations:

- Minimize the footprint of the parking lot, shared parking or create overflow parking green spaces
- Soil permeability and stability
- GMP locations relative to impervious areas
- Permeable catch basin rings, infiltration planters, tree boxes or permeable parking spaces can be used for retrofit applications
- Permeable pavers can be used to designate traffic lines, parking spaces or cross walks

Concept Parking Lots

Green parking can utilize various GMPs to reduce or offset the amount of impervious area of a parking lot as demonstrated in the following pictures.

Green Option #1: Permeable Catch Basin Rings ➔

Parking lot retrofit added a ring of permeable concrete and an aggregate sub base to infiltrate stormwater prior to entering the storm sewer system.



(Photo: Erin Wagoner, URS)

Green Option #3: Permeable Concrete/Asphalt ➔

Traditional pavement is paired down gradient with pervious concrete parking spaces to capture and filter stormwater runoff prior to entering the adjacent creek.



(Photo: David Dods, URS)



(Photo: Erin Wagoner, URS)

➔ Green Option #2: Permeable Grass Grid Pavers

Permeable grass grid pavers provide parking for low traffic areas at this park entrance. The permeable parking lot allows the opportunity for stormwater to infiltrate into the soil rather than running off into the adjacent creek.



(Photo: Erin Wagoner, URS)

➔ Green Option #4: Parking Drains to Bioswale

Through the use of a curb cut, this parking lot drains to a bioswale to treat stormwater.

Concept Commercial Parking Lots

Green parking can utilize various GMPs to reduce or offset the amount of impervious area of a parking lot as demonstrated in the following pictures.

Green Option #5: Parking Drains to Bioswale ➔

As an alternative to raised landscape and tree beds lining the entrance to this business, a tree bioswale accepts runoff from the parking lot and sidewalk.



(Photo: Erin Wagoner, URS)

Green Option #7: Internal Bioswale ➔

This parking lot at the Office of Employment in Louisville was designed with an internal bioswale to treat stormwater runoff from the parking lot, rather than using traditional raised beds.



(Photo: Erin Wagoner, URS)



(Photo: Lara Kurtz, URS)

➔ Green Option #6: Parking Drains to Tree Lined Swale

Stormwater from the parking lot of this shopping center drains off into a grass swale lined with trees. In addition, the catch basin is raised to allow temporary storage of stormwater.



(Photo: Erin Wagoner, URS)

➔ Green Option #8: Parking Drains to Corner Bioretention Cell

The parking lot of the Office of Employment in Louisville drains to a corner bioretention cell. Curbs with curb cuts allow stormwater to enter the bioretention cell while also keeping cars out.

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18.4.6 Downspout Disconnection

Potential Green Management Practices Included:

- ☑ Cisterns
- ☑ Rain Barrels
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Planters



Downspout Disconnection (Photo: Louisville & Jefferson County MSD)

Description:

Downspouts convey rooftop runoff, prevent basement flooding and reduce sewer system overflows when they are disconnected from the sewer system. Connected downspouts are most common in older neighborhoods. As part of the Plumbing Modification Program (PMP), MSD encourages property owners to disconnect downspouts, conveying stormwater to lawns, or to a GMP. Contact MSD Customer Relations at (502) 587-0603 for more information on the downspout disconnection program and the PMP.

Suitable Applications:

Downspout disconnection should be considered for any structure with improper downspout connections to the sewer system. For new construction or redevelopment, it is prohibited to connect downspouts to the sewer system.

Special Considerations:

- Proximity of adjacent buildings
- Direction of downspout conveyance prior to disconnection
- Routing disconnected downspouts to other GMPs, including rain barrels or rain gardens

Downspout Disconnections Illustrations

Downspout disconnection reduces sewer system overflows and can be paired with various GMPs to infiltrate and treat stormwater as demonstrated in the following photos.

Green Option #1: Disconnected Downspouts Flow Through Cisterns to a Bioswale →

In these two photos, tall cisterns store and release rooftop runoff to irrigate adjacent bioswales and rain gardens.





← Green Option #2: Disconnected Downspout Flows to a Rain Barrel

The rain barrel at this office building has a low profile and color that blends with the building. The rain barrell captures rooftop runoff released onto the lawn.

Green Option #3: Disconnected Downspout Flows to a Rain Garden →

The interior roof drains at this office building were disconnected from the sewer system and plumbed to discharge to a rain garden.



Downspout Disconnections Illustrations (Cont.)

Downspout disconnection reduces sewer system overflows and can be paired with various GMPs to infiltrate and treat stormwater as demonstrated in the following photos.

Green Option #4: Disconnected Downspout Flows to a Rain Garden ➔

Downspouts on this building are routed to discharge to a rain garden.



(Photo: Louisville & Jefferson County MSD)



(Photo: Erin Wagoner, URS)

➔ Green Option #5: Disconnected Downspout Flows to a Flow-Through Planter

The interior roof drains at this storefront on 4th Street are disconnected from the combined sewer system and routed to a small planter box with flowering annual plants.

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18.4.7 Green Roofs

Potential Green Management Practices Included:

- ☑ Extensive Green Roof
- ☑ Intensive Green Roof



Extensive Green Roof Bed and Patio (Photo: Chad McCormick, URS)

Description:

Green roofs are roofs of buildings that are planted over a waterproof membrane with vegetation including plants, shrubs or trees. Green roofs capture and absorb rainwater, resulting in decreased stormwater runoff. Green roofs provide more than a stormwater benefit, such as reducing rooftop temperatures, creating urban habitats and enhancing outdoor gathering spaces. Green roofs include two types of GMPs: extensive and intensive green roofs.

Suitable Applications:

Green roofs are typically used in urban areas. All buildings must have the structural capacity to hold a green roof. Extensive green roofs use less than six inches of planting media, whereas intensive green roofs use greater than six inches of planting media. Rooftop applications will vary based on structural capacity of the building.

Special Considerations:

- Structural capacity of building
- Maintenance requirements
- Leak detection systems or tray systems
- Replacement of the green roof layers
- Green roofs can be used as a rooftop garden or gathering space
- Planting plans (choose plants with minimal irrigation requirements)

Concept Green Roofs

Green roofs absorb rainwater and can be constructed as elaborate rooftop gardens, gathering spaces or simply a low-maintenance and energy efficient building option.

Green Option #1: Extensive Green Roof Vegetable Garden ➔

This apartment building green roof is a rooftop garden for residents to gather. The garden includes beds for shrubs and vegetables.


(Photo: Ted Wathen)


(Photo: Maggie Huber)

Green Option #3: Combination Extensive and Intensive Green Roof ➔

This green roof combines shallow extensive beds with deeper intensive beds planted with trees.


(Photo Erin Wagoner, URS)


(Photo: Chad McCormick, URS)

➔ Green Option #2: Extensive Green Roof with Sedums

This extensive green roof was planted with sedums in a landscaped pattern that can be viewed from the office spaces. Excess stormwater that is not absorbed by the planting media is collected by cisterns and then conveyed to a bioswale and rain garden.


(Photo: Lousiville & Jefferson County MSD)


(Photo: Louisville & Jefferson County MSD)

➔ Green Option #4: Green Wall

For added plant space and reuse of water collected from rooftops, green walls utilize similar concepts of a green roof, only they are planted vertically.

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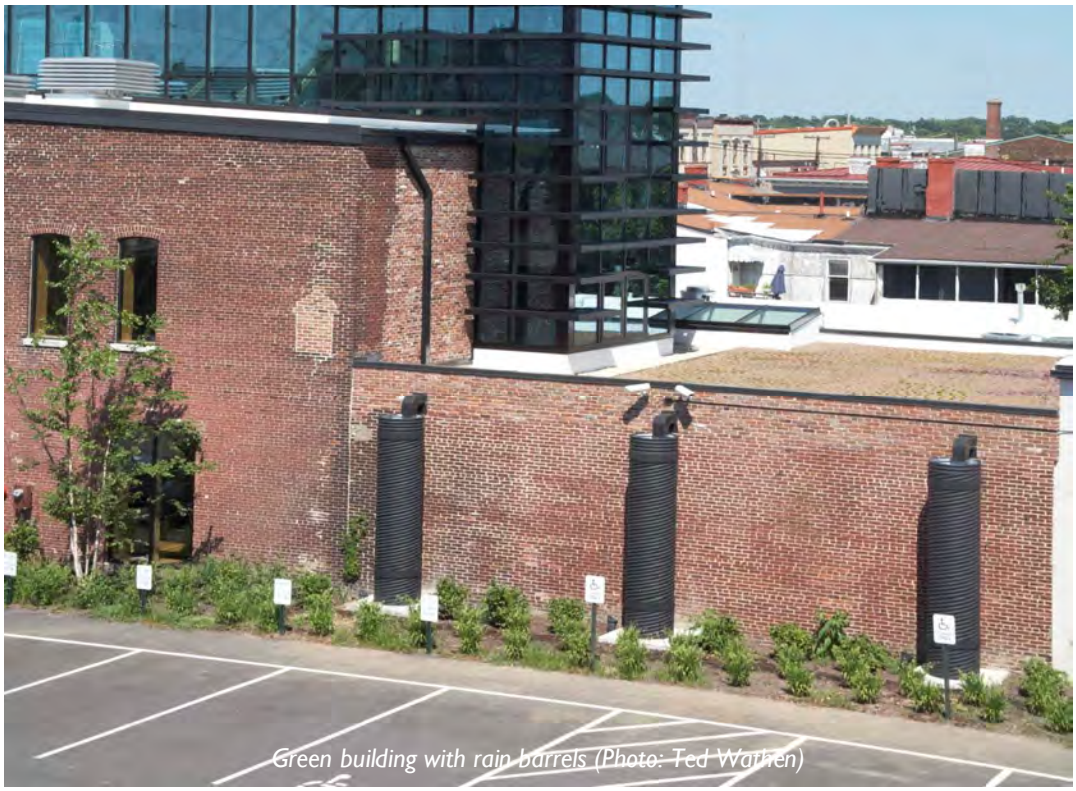
18.4.8 Rainwater Harvesting—Cisterns

Potential Green Management Practices Included:

- ☑ Cisterns
- ☑ Rain Barrels



Green building with rain barrels (Photo: Ted Wathen)

Description:

Rainwater harvesting is the practice of capturing and temporarily storing rainwater, typically from rooftops, in a cistern or rain barrel for beneficial use. The beneficial use often includes landscape watering, but may include water for flushing toilets (contact Louisville Metro Public Health & Wellness for regulations regarding reuse of rainwater), make-up water for HVAC units and boilers, and water for vehicle washing.

Suitable Applications:

Rainwater harvesting can be used in most land use practices including: high-density residential, commercial, institutional and industrial areas. Rainwater in a cistern or rain barrel can be used before the next rain event.

Special Considerations:

- Distance of the harvested rainwater from its intended use
- Water treatment requirements may limit use of harvested rainwater
- Storage of harvested rainwater below ground vs. above ground
- Contact Louisville Metro Public Health & Wellness for regulations regarding reuse of rainwater
- Use of harvested rainwater prior to the next rain event allows for continued harvesting

Commercial Rainwater Harvesting

The type of container used for rainwater harvesting, and its location below ground or above ground, can vary to match the needs of the site.

Existing: Downspout at Garden Center →

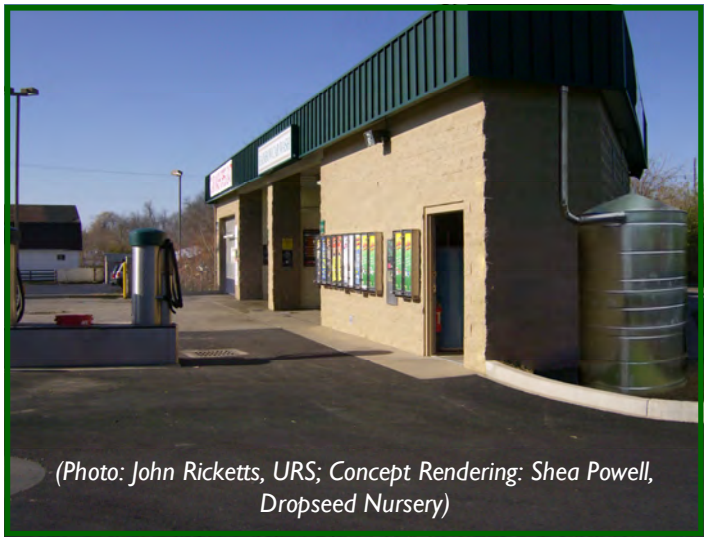
Typical downspout at the garden center of local box store.



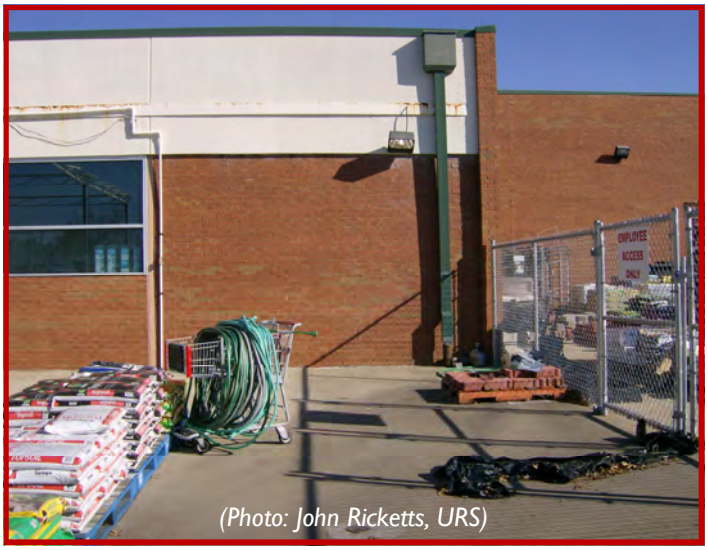
(Photo: John Ricketts, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Car Wash with Traditional Design →

Typical car washing facility.



(Photo: John Ricketts, URS; Concept Rendering: Shea Powell, Dropseed Nursery)



(Photo: John Ricketts, URS)

← Green Option: Cistern Utilized to Collect Stormwater

In this concept rendering, a cistern has been added and collects rainwater that can be used to irrigate plants in the



(Photo: John Ricketts, URS)

← Green Option: Cistern Utilized to Collect Stormwater

In this rendering, a cistern has been added to collect rainwater that can be used to supplement water for car washing.

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18.4.9 Urban Forestry

Potential Green Management Practices Included:

- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Constructed Wetland
- ☑ Wet Basins
- ☑ Dry Basins



Urban Forestry (Photo: Kory Johnson Photography)

Description:

Urban forestry is defined by the care and management of trees in urban settings. Urban forestry can vary from planting trees boxes in a sidewalk to preserving large acreages of trees in a city. The benefits of urban forestry include: reduction of the heat island effect, reduction of soil erosion, reduction of stream temperatures and reduced stormwater run-off. Trees direct precipitation towards the ground through their trunks and absorb stormwater through their roots. Trees can also provide bank stabilization in riparian buffers.

Suitable Applications:

Urban forestry practices can be used in residential neighborhoods, along urban streets, in street islands, in urban parks and multi-use facilities among others.

Special Considerations:

- Soil types and conditions (compaction, root volume, elevated pH, etc.)
- Combination of urban forestry with the disconnection of impervious areas
- Use of urban forestry as a visual buffer or part of a filter strip
- Types of tree species should be suitable for site conditions and aesthetics
- Location of the tree(s)
- Irrigation
- Location of other GMPs

Concept Uses of Urban Forestry

These pictures demonstrate some of the options for implementation of urban forestry into green site planning.

Green Option #1: Tree Boxes Used in Ultra-urban Area →

The picture to the right demonstrates the use of tree boxes along the street in an urban setting, adjacent to large impervious areas. These GMPs not only provide stormwater benefits, but also beautify the community.



(Photo: David Dods, URS)



(Photo: Lara Kurtz, URS)

← Green Option #2: Trees Planted in a Bioswale

The picture to the left demonstrates the use of trees as part of a bioswale, serving both an aesthetic purpose and providing additional water quantity and quality benefits.

Green Option #3: Tree Boxes in an Island →

The picture to the right demonstrates the use of urban forestry in a center island. This island not only provides stormwater benefits, but also provides a safety benefit by slowing traffic.


(Photo: Meg Babani, Taliaferro & Browne, Inc.)

Concept Uses of Urban Forestry

These pictures demonstrate some of the options for implementation of urban forestry into newly developed and re-developed areas and the versatility of urban forestry.

Green Option #1: Tree Boxes in an Urban Area →

The picture to the right demonstrates the use of urban forestry in a commercial development with a large amount of impervious area. The tree boxes provide both a water quality benefit and are aesthetically pleasing.



(Photo: Meg Babani, Taliaferro & Browne, Inc.)



(Photo: David Dods, URS)

← Green Option #2: Tree Boxes with a Bioswale Curb Extension

The picture to the left demonstrates the use of urban forestry with tree boxes between a green space and street.

Green Option #3: Tree Boxes Used in a Metropolitan Multi-use Area →

The picture to the right demonstrates the use of urban forestry in an urban center with significant impervious area.



(Photo: Erin Wagoner, URS)

Concept Uses of Urban Forestry

These pictures demonstrate the wide variety of applications of urban forests designed in combination with other GMPs.

Green Option #1: Urban Forestry in a Constructed Wetland →

The picture to the right demonstrates the combination of a constructed wetland and urban forestry.



(Photo: David Dods, URS)



(Photo: David Dods, URS).

← Green Option #2: Urban Forestry Used with a Wet Basin

The picture to the right demonstrates the use of a mowed buffer surrounding a wet basin, combined with urban forestry.

Green Option #3: Urban Forestry Used in a Dry Basin →

In this photo, young trees are planted in a green dry basin along the highway. These trees serve a stormwater benefit, provide aesthetic benefits, as well as noise reduction.



(Photo: David Dods, URS. Concept Rendering: Shea Powell, Dropseed Nursery)

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18.4.10 No Mow Buffer Zones

Potential Green Management Practices Included:

- ☑ Bioswales
- ☑ Rain Gardens
- ☑ Basins



Bioretention cell at Willow Pond at Lexington Road and Grinstead Drive (Photo: Erin Wagoner, URS)

Description:

No mow buffer zones are natural undisturbed areas that treat and control stormwater before entering a stream or wetland. These areas remove pollutants through filtration and infiltration. There are many benefits from the use of no mow buffer zones, including: groundwater recharge, enhancing water quality through shading to lower water temperature in channels, valuable corridor protection for streams and wetlands by decreasing bank erosion and minimizing risk of flooding by stabilizing soil, furnishing wildlife habitat and the reduction of pollutant loads to local waterways and wetlands.

Suitable Applications:

No mow buffer zones can be used in residential, commercial and industrial developments. They can also be used in combination with GMPs on nearby properties to manage stormwater quantity and quality.

Special Considerations:

- Natural depressions utilized for runoff storage
- Buffers must be fully vegetated
- Local ordinances and minimum buffer requirements (check local MS4 and floodplain management ordinances)
- Public outreach and education of citizens regarding the purpose of no mow buffer zones
- Reduced mowing costs
- No mow signage
- More information on no mow and low mow options can be found on the Louisville Metro Air Pollution Control District's (APCD) website at http://www.louisvilleky.gov/

No Mow Buffers Concepts

No Mow Buffers can be used with various land uses. The pictures below demonstrate No Mow Buffers in residential and park settings.

Green Option # 1: Residential No Mow Buffer ➔

The picture to the right demonstrates the use of a no mow buffer in a residential area. Education and outreach is a key component for obtaining community acceptance of no mow buffers.



(Photo: Sabak, Wilson and Lingo, Inc.)



(Photo: Sabak, Wilson and Lingo, Inc.)

➔ Green Option #2: Walking Trail with a No Mow Buffer

No mow buffers can be used in multi-use areas and parks.

Green Option # 3: No Mow Buffer in a Park ➔

No mow buffers preserve habitat for wildlife and provide stormwater benefits.



(Photo: Kristen Dunaway, URS)

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18.4.11 Stream Buffers

Potential Green Management Practices Included:

N/A



(Photo: Lousiville & Jefferson County MSD)

Description:

Stream buffers are vegetated filter strips or undisturbed natural areas that treat and control stormwater before entering the stream. These areas remove pollutants through filtration and infiltration. There are many benefits from the use of stream buffers, including: groundwater recharge, valuable corridor protection for streams and wetlands, and the reduction of pollutant loads to local waterways and wetlands.

Suitable Applications:

Stream buffers can be used in residential, commercial and industrial developments. They can also be used in combination with GMPs on nearby properties to manage stormwater quantity and quality. When planned, designed and maintained correctly stream buffers can protect streams from polluted stormwater discharges, manage stormwater quantity, especially during rain events, and play an important role in protecting habitats.

Special Considerations:

- Width and planned vegetation (buffers must be fully vegetated)
- Legal mechanism to preserve the buffer into perpetuity
- Protection of the native vegetation
- Local ordinance (Land Development Code) requirements
- Natural depressions utilized for runoff storage

Stream Buffers Illustrations

Stream Buffers are an important part of floodplain management. The following pictures demonstrate different stream buffers and their application in various types of land uses.

Green Option #1: Stream Buffer →

The stream buffer to the right demonstrates the use of urban forestry and a stream buffer.



(Photo: Erin Wagoner, URS)

Green Option #3: Stream Buffer Used in a Residential Development →

This picture demonstrates a stream buffer that would be common as part of a residential development. The use of the buffer will help to prevent streambank erosion in this neighborhood.



(Photo: Louisville & Jefferson County MSD)



(Photo: Erin Wagoner, URS)

← Green Option #2: Stream Buffer Used as a Filtration Practice for a Parking Lot

This parking lot drains to a stream buffer before entering the local stream. The use of the buffer will slow the stormwater runoff, filter pollutants and reduce the temperature of the stormwater before entering the stream. Pervious concrete, asphalt, or pavers can be used in combination with the stream buffer.



(Photo: Kristen Dunaway, URS)

← Green Option #4: No Mow Stream Buffer

This stream buffer demonstrates a riparian buffer, under high water conditions, that is not mowed.

Stream Buffer Illustrations

Stream buffers can be used to protect structures and in combination with GMPs.

Green Option #1: Stream Buffer Used to Protect Residential Land Use →

This picture demonstrates the benefit of a stream buffer after a rain event. Water overflows stream banks and does not flood the lower level of a structure on the adjacent property.



Green Option #3: Use of Pervious Pavers Near a Stream Buffer →

The picture to the right demonstrates the use of pervious pavers near a stream buffer in a parking lot.





← Green Option #2: Stream Buffer in an Urban Forest

This picture demonstrates the use of stream buffers and urban forestry through the preservation of regional GMPs.



← Green Option #4: Multi-use Stream Buffer in a Local Park

During dry weather the buffer areas in this park are used for recreation, including areas for picnic tables.

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Green Infrastructure Design Strategies

18.4.12 Green Detention Basins

Potential Green Management Practices Included:

- ☑ Green Wet Basins
- ☑ Green Dry Basins



Cedar Pond Park Lake (Photo: Rusty Schmidt, URS)

Description:

Retrofitting a wet detention basin involves the addition of native, deep-rooted plantings along the perimeter of the basin, just below the normal pool level and along the banks in the extended detention portion of the basin. A new wet basin should be designed to include these plantings. Retrofitting a dry detention basin or installing a new dry detention basin involves the addition of native, deep-rooted plantings along the entire bottom of the basin, a sediment forebay to collect the heavier sediment, a multi-stage outlet to temporarily detain runoff from smaller, more frequent rain events, and the removal of any low flow channels to promote sheet flow across the basin floor. All of these options provide water quality benefits not afforded by the traditional wet and dry basins.

Suitable Applications:

Newly designed basins or any wet or dry basin that was not designed with native, deep-rooted plantings to provide water quality treatment through the vegetation up taking and filtering pollutants and that does not include a multi-stage outlet to temporarily detain the smaller, more frequent rain events.

Special Considerations:

- Proper slope to accommodate a vegetated bench, prevent ponding water, etc.
- Reconfiguration of outlet structures to properly detain smaller storms

Retrofit Illustrations

Traditional wet and dry basins are modified to add native, deep-rooted plantings and multi-port outlets that allow temporary detention of runoff from smaller, more frequent rain events.

Existing: Traditional Wet Basin →

This picture illustrates a traditional wet basin in a business park.



(Photo: David Dods, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Dry Basin with a Low Flow Channel →

A traditional dry basin is shown here, with a concrete-lined, low flow channel near an interstate.



(Photo: David Dods, URS; Concept Rendering: Shea Powell, Dropseed Nursery)



(Photo: David Dods, URS)

← Green Option: Retrofit with a Vegetated Beach

This concept rendering shows a vegetated bench around the perimeter of this green wet basin provides water quality benefits.



(Photo: David Dods, URS)

← Green Option: Retrofit with Native Vegetation

In this concept rendering, native vegetation and the promotion of sheet flow along the bottom of the green dry basin provides water quality benefits.

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18.4.13 Parks and Multi-Use Areas

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Wet Basins
- ☑ Dry Basins
- ☑ Constructed Wetland



Arthur K. Draut Park, St. Matthews (Photo: Kristen Dunaway, URS)

Description:

Parks and multi-use areas are an opportunity for communities to provide water quality and quantity benefits. These green spaces can be used to collect and treat water during storm events. During dry weather, these areas can be used for public facilities, including parks, sports, hiking, walking and biking paths.

Suitable Applications:

If the conditions are appropriate all of the GMPs in this manual can be implemented into parks and multi-use areas.

Special Considerations:

- Goals for the area
- Existing infrastructure and surrounding development
- Local ordinance requirements (check MS4 ordinances and Land Development Code)
- Fencing around some GMPs for safety

Multi-use Illustrations

These pictures demonstrate some of the options for GMPs in multi-use areas.

Green Option #1: Wetland Area with Walking Paths ➔

A wetland in an urban area that includes walking paths.



(Photo: Kristen Dunaway, URS)



(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

➔ Green Option #2: Baseball Field Used in a Dry Basin

This picture demonstrates a sports field located in a detention basin. Multi-use areas can be included in large detention basin areas for larger storms.

Green Option #3: Play Ground and Picnic Area in a Dry Basin ➔

Multi-use areas are an efficient land use in urban or built out areas where land for detention is limited.



(Photo: Erin Wagoner, URS)

Multi-use examples:

These pictures demonstrates the variety of uses for multi-use areas ranging from business offices to detention areas.

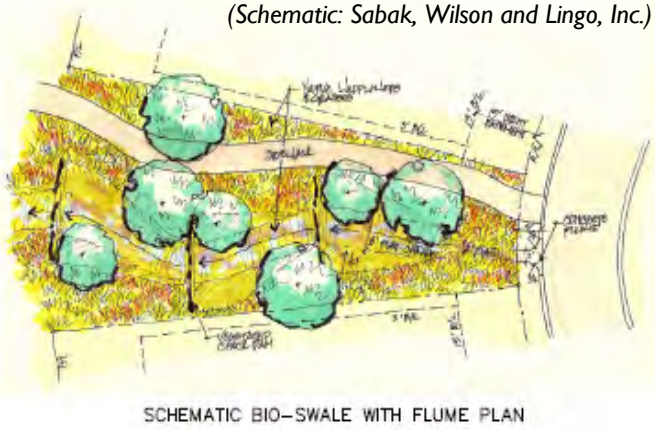
Green Option #1: Rain Garden Used in an Open Space Near an Office Complex →

This project demonstrates the use of an open space area with a rain garden. This area not only serves stormwater management needs but is also an area for employees to enjoy. Native plants and multi-cultivars are options for plantings.



(Photo: Lara Kurtz, URS)

(Schematic: Sabak, Wilson and Lingo, Inc.)



SCHEMATIC BIO–SWALE WITH FLUME PLAN

← Green Option #2: Traditional Gray Infrastructure Used in Combination with Green Infrastructure

This schematic demonstrates the use of gray infrastructure with a bioswale.



(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #3: Swale in a Residential Green Space →

This picture demonstrates an open space in a residential area that also serves as drainage during storm events.

Local Park and Multi-use Areas

These pictures demonstrate some of the options for multi-use areas with stormwater benefits.

Green Option #1: Park Space and Urban Forestry➔

This picture demonstrates a combination of green infrastructure design strategies, including urban forestry and multi-use concepts. The picture also shows the use of elevation for permanent structures.



(Photo: Kristen Dunaway, URS)



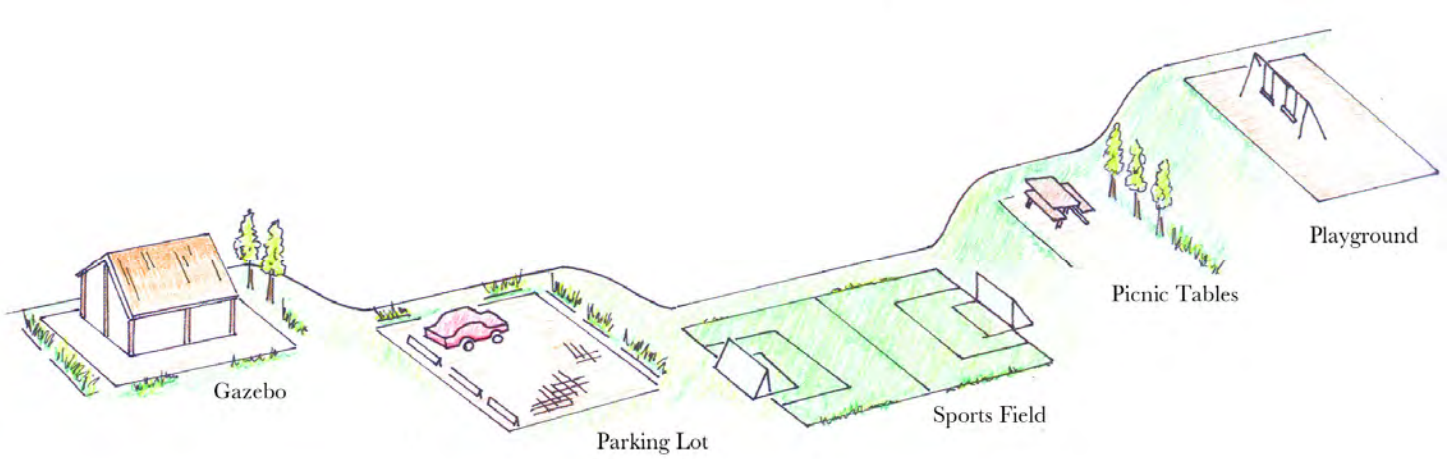
(Photo: Kristen Dunaway, URS)

← Green Option #2, Walkways, Urban Forestry, Stream Buffers, and Use of Retention Areas

This picture demonstrates the use of stream buffers and the use of retention areas in an urban park.

Local Park and Multi-use Areas

These pictures demonstrate some of the options for multi-use areas with stormwater benefits.



(Sketch: Shea Powell, Dropseed Nursery)

The sketch demonstrates the concept of a multi-use area that can serve recreational purposes as well as stormwater benefits. The sports field is located where it is more likely to have standing water for longer periods of time, when compared to the higher elevations. As the elevation increases, so do the structures, since flooding of these areas is less likely to occur.

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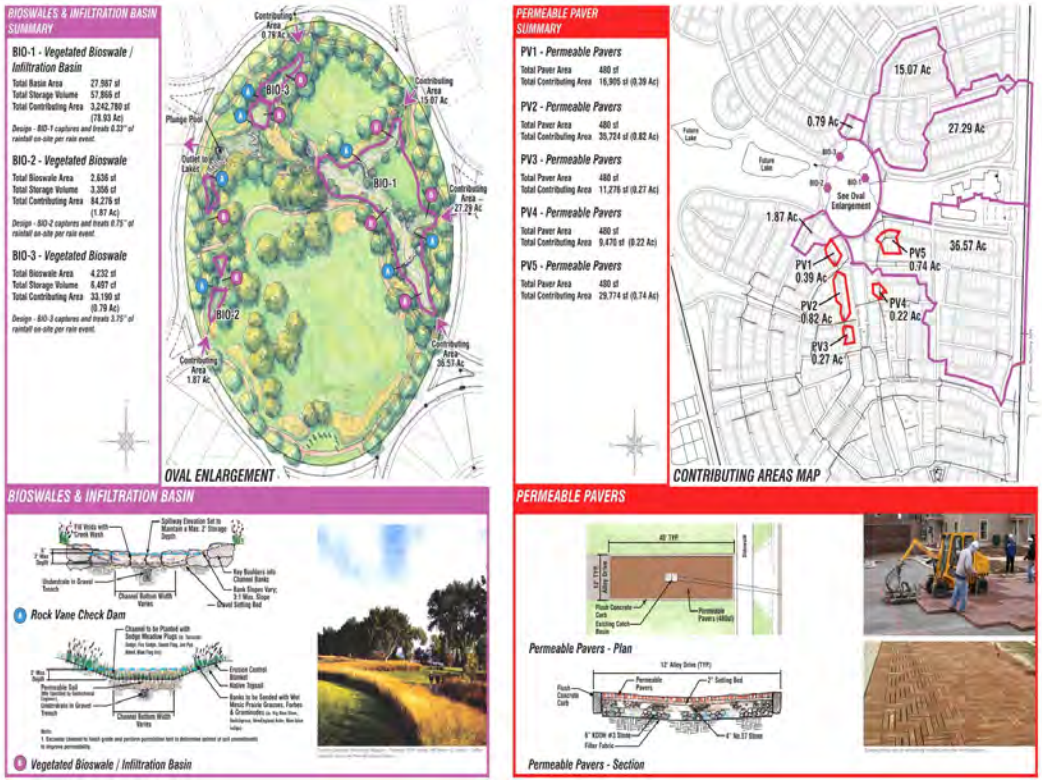
18.4.14 Residential Neighborhoods

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Planter Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Rainwater Harvesting
- ☑ Pervious Pavers
- ☑ Catch Basin Inserts
- ☑ Detention Basins
- ☑ Downspout Disconnections



Residential Neighborhood Concept Plan (Sabak, Wilson and Lingo)

Description:

GMPs can be used in new and existing residential neighborhoods. A variety of green infrastructure approaches can be used in a residential setting. There are many benefits resulting from the implementation of GMPs that include but are not limited to: increased greenspace, reduced paving if clustering is used, encouraged recreational use, preservation of historical features, forests, streams and agricultural areas, stormwater runoff reduction, improved water quality, and increased property values.

Suitable Applications:

Applications of GMPs in residential neighborhoods is dependent on site specifics and community acceptance of aesthetics. For example, a cistern may not be as accepted from an aesthetics perspective as a well maintained detention pond.

Special Considerations:

- Local planning and land development codes
- Future resident acceptance of GMPs
- Narrow street widths and their compatibility with GMPs
- Minimum widths requirements for service trucks and emergency response vehicles
- Narrow sidewalks on one side of the street only
- Driveway length and width, or shared driveways
- Use of permeable pavement in parking areas, sidewalks and driveways
- Use of bioswales or other GMPs in right of ways
- Retrofitted curb breaks used to route stormwater to GMPs
- Green roofs for multi-family residential sites
- Use of planter boxes for stormwater treatment

GMPs in Residential Neighborhoods

The following pictures demonstrate implementation of GMPs in residential neighborhoods.

Green Option #1: Plan for a Low Impact Development ➔

This plan demonstrates practices for reducing impervious cover and conserving natural site features, including tree cover.



(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #3: Bioswales Used for Drainage in Apartment Complex ➔

This picture demonstrates the use of a bioswale in a residential area.



(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)



(Concept Plan: Sabak, Wilson and Lingo, Inc.)

➔ Green Option #2: Pervious Pavers and Curb Cuts

Pervious pavers and curb cuts can be used in combination with rain gardens and bioswales, as demonstrated in this picture. This rain garden captures the street runoff and replaces the catch basin.



(Photo: David Dods, URS)

➔ Green Option #4: Pervious Pavers Used Between Street and Sidewalk

The photo rendering to the left demonstrates the use of pervious pavers. The pervious pavers are depicted where cars park along the road, as opposed to high traffic areas.

Rain Garden and Bioswales Illustrations

These pictures provide examples of GMPs in residential neighborhoods.

Green Option #1: Rain Garden in an Existing Development ➔

This picture shows a rain garden in an existing development. A modification has been made to the traditional curb and gutter to direct stormwater to the rain garden.



(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #3: Rain Garden for Drainage Between Two Homes ➔

The use of a rain garden between two homes is used to manage stormwater for two properties. This rain garden has aesthetic benefits while providing stormwater benefits.





(Photo: David Dods, URS)

➔ Green Option #2: Rain Garden Used along a Parkway

This GMP design replaced a traditional curb and gutter so that stormwater run-off drains to the rain garden.



(Photo Courtesy of Louisville & Jefferson County MSD)

➔ Green Option #4: Treebox Bioswale

This design can be used along streets in neighborhoods. Not only does it have aesthetic benefits, it also provides storm water benefits as well.

Planning Illustrations

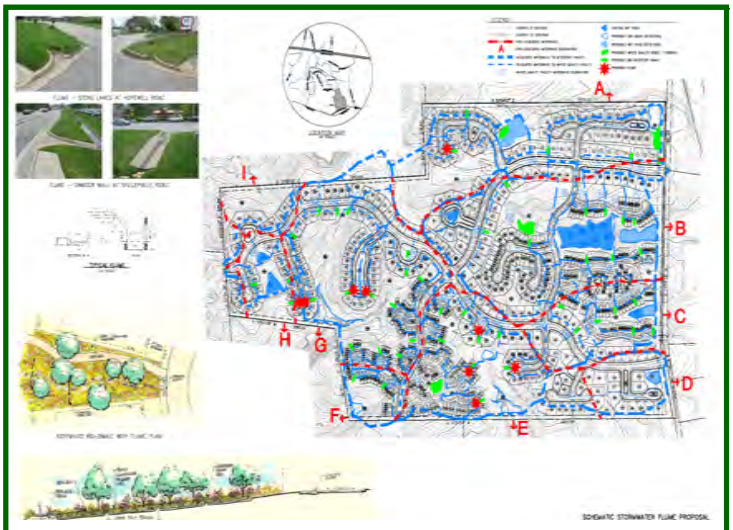
The following demonstrate the implementation of GMPs during the planning phase.

Green Option #1: Concept Plan for Conservation Subdivision ➔

GMP practices are proposed in the concept plan to the right. This concept plan promotes stormwater infiltration rather than conveyance and concentration to reduce erosion and enhance stormwater quality. Infiltration and grass swales are used as GMPs in place of piping, culverts and paved ditches to reduce runoff, promote infiltration and improve water quality. The plan for this conservation subdivision also preserves tree canopies.



(Concept Plan: Sabak, Wilson & Lingo, Inc.)



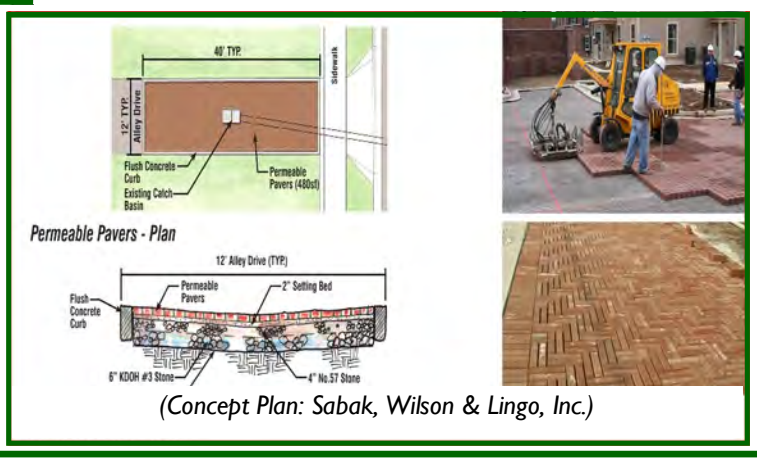
(Concept Plan: Sabak, Wilson & Lingo, Inc.)

➔ Green Option #2: Design Demonstrates the Use of Traditional Gray Infrastructure with GMPs

The plan to the left demonstrates the use of a bioswale containing an energy dissipating flume to direct the runoff from the street to the bioswale.

Green Option #3: Use of Permeable Pavers in Residential Development ➔

The picture to the right demonstrates the use of pervious pavers in a residential area.



(Concept Plan: Sabak, Wilson & Lingo, Inc.)

Planning Illustrations

The following demonstrate the implementation of GMPs during the planning phase.

Green Option #1: Aerial Photo of Narrow Streets ➔

This residential neighborhood used narrow streets to reduce impervious area and to enhance preservation of open spaces.



(Photo: Sabak, Wilson and Lingo, Inc.; Concept Rendering: Shea Powell, Dropseed Nursery)



(Concept Plan: Sabak, Wilson and Lingo, Inc.)

➔ Green Option #2: Open Space Preservation

This development demonstrates the implementation of open space preservation in a residential development.



(Concept Plan: Sabak, Wilson and Lingo, Inc.)

Green Option #3: Preservation of Natural Areas ➔

In this residential neighborhood, sinkholes were preserved as natural areas.

GMP Illustrations

The following demonstrates the various GMPs that can be used in residential areas.

Green Option #1: Detention Basin in a Residential Area ➔

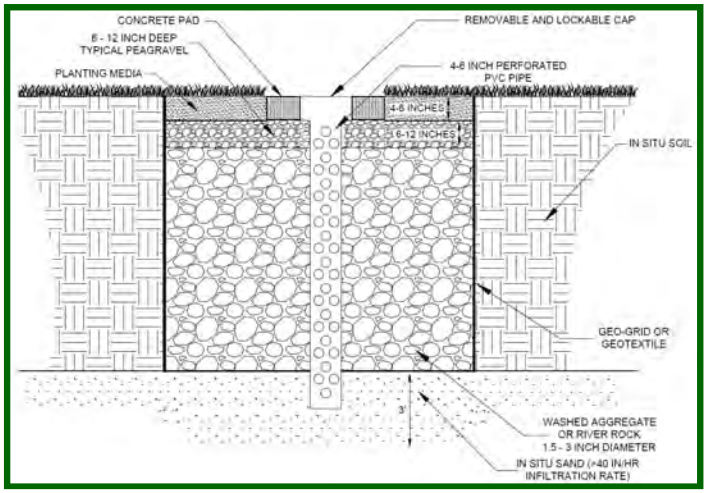
This picture demonstrates the use of a detention basin in a residential neighborhood.



(Photo: Louisville & Jefferson County MSD)

Green Option #3: Catch Basin Inserts Can Be Used in Residential Neighborhoods ➔

Catch basin inserts can be used for construction and post-construction purposes.



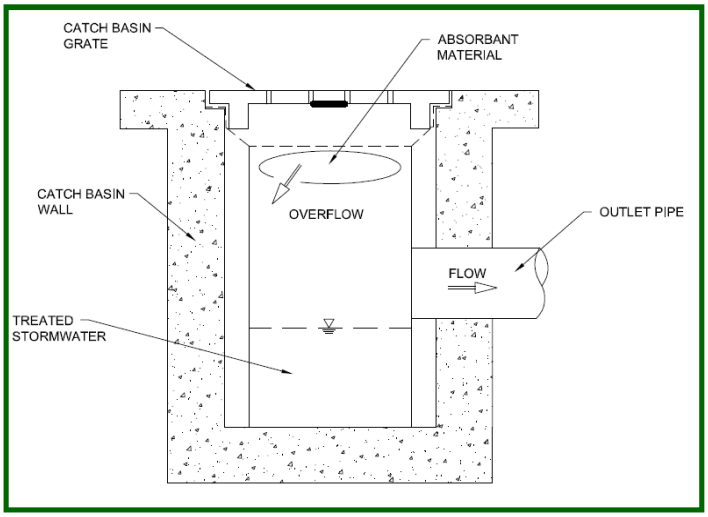
(Sketch: URS)



(Photo: Rusty Schmidt, URS)

➔ Green Option #2: Downspout Disconnection on a Residential Home

Downspouts can be disconnected in a residential neighborhood to capture rooftop run off and store it in a rain barrel, or to discharge and infiltrate into a rain garden.



(Sketch: URS)

➔ Green Option #4: Infiltration Drains

Infiltration practices can be used to catch and store water. Water can then drain back into the filter media.

Fact Sheet Key

Louisville and Jefferson County MSD logo and address

Louisville and Jefferson County Metropolitan Sewer District

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Green Management Practice (GMP) Fact Sheet

18.5.1 Bioswales

Chapter and section number and the GMP type.

Examples of areas that the GMP is typically installed or examples of the most applicable site for installation.

Typical Implementation Areas:

- Multi-use areas (commercial courtyards, entranceways)
- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/ median
- Downspout conveyance
- Drainage areas up to 5 acres

Areas of interest or special considerations required for installation of the given GMP.

Key Considerations:

- Use native vegetation
- Overflow structure

Typical relative capital cost and maintenance efforts for each GMP are categorized as Low, Low-Medium, Medium, Medium-High, and High.

Cost: Low
Maintenance: Low



Photo/illustration of a typical implementation or schematic of the GMP.

Landscaped bioswale shown adjacent to sidewalk (Photo: David Dods, URS)

General description of the GMP with bulleted items that highlight the GMPs ability to improve water quality.

Bioswales are stormwater conveyance features that mimic the ecological function of a landscape, often as replacements to open ditches or underground pipes. Bioswales are generally shallow, wide, and gently sloped, and contain deep rooted native vegetation that helps slow and filter stormwater. In some cases they also promote infiltration or contain underdrains. Bioswales improve water quality through:

- ☑ Reduction of runoff velocities passing through dense vegetation
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater (dependent upon design)
- ☑ Biological uptake through native plants

Stormwater Management Benefits

Typical pollutant removal benefits of the GMP.

Pollutant Reduction

Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪

Typical hydrologic capabilities of the GMP.

Hydrologic Characteristics

Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	◪
Peak Flow Control	□

Typical ability of the GMP to capture the volume of runoff from the drainage area.

Runoff Volume Reduction

Runoff Capture	◪

Key: ■ Significant Benefit ◪ Partial Benefit □ Low or Unknown Benefit

Signifies the amount of benefit the GMP will provide.

Potential design limitations and benefits with installation of the GMP.

Advantages/Benefits

- Conveys runoff while improving water quality
- Reduces volume of stormwater runoff
- Infiltration and groundwater recharge
- Fits in narrow spaces
- Increases biodiversity by providing urban habitats for wildlife
- Reduces channel/stream bank erosion
- Lowers curb and pipe costs

Disadvantages/Limitations

- Increased maintenance over traditional curb and gutter drainage systems
- Potential for erosion if not installed and maintained properly
- Increased maintenance during and following large storm events
- Property ownership and long-term maintenance agreements
- Not recommended for steep slopes (>4%)

Effective:

Effective date

18.5.1 - 1

Page number

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Green Management Practice (GMP) Fact Sheet

18.5.1 Bioswales

Typical Implementation Areas:

- Multi-use areas (commercial courtyards, entranceways)
- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/ median
- Downspout conveyance
- Drainage areas up to 5 acres

Key Considerations:

- Use native vegetation
- Overflow structure

Cost: Low
Maintenance: Low



Landscaped bioswale shown adjacent to sidewalk (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	◪
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Bioswales are stormwater conveyance features that mimic the ecological function of a landscape, often as replacements to open ditches or underground pipes. Bioswales are generally shallow, wide, and gently sloped, and contain deep rooted native vegetation that helps slow and filter stormwater. In some cases they also promote infiltration or contain underdrains. Bioswales improve water quality through:

- ☑ Reduction of runoff velocities passing through dense vegetation
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater (dependent upon design)
- ☑ Biological uptake through native plants

Advantages/Benefits

- Conveys runoff while improving water quality
- Reduces volume of stormwater runoff
- Infiltration and groundwater recharge
- Fits in narrow spaces
- Increases biodiversity by providing urban habitats for wildlife
- Reduces channel/stream bank erosion
- Lowers curb and pipe costs

Disadvantages/Limitations

- Increased maintenance over traditional curb and gutter drainage systems
- Potential for erosion if not installed and maintained properly
- Increased maintenance during and following large storm events
- Property ownership and long-term maintenance agreements
- Not recommended for steep slopes (>4%)

Application and Site Feasibility

Bioswales are linear features that are used to convey stormwater runoff at a slower rate to promote filtration and infiltration. They may also be designed in non-linear or meandering shapes to match site characteristics, or to create a naturalized appearance. Bioswales are appropriate for use in a wide variety of land use applications such as commercial, industrial or medium to high density residential areas.

Physical Site Considerations

Key physical considerations are:

- Space available—Sufficient space is required to convey peak flow rates without overtopping the swale
- Slopes—Slopes affect flow rates, swale capacities, infiltration rates, and erosion
- Soil types—Soil types affect infiltration and erosion; sandy permeable soils promote infiltration but are also susceptible to erosion

Design Criteria

The design of a bioswale includes several elements to manage stormwater infiltration, as well as stormwater conveyance, to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.1-A. Note that bioswale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Design criteria to consider includes:

- Flow capacity, velocity and freeboard
- Erosion prevention



Bioswale with naturalized, established native plantings
(Photo: David Dods, URS)



Stepping stones allow accessibility across this bioswale
(Photo: Rusty Schmidt, URS)

- Slopes
- Inlet and pretreatment
- Soil composition
- Plant selection
- Outlet design
- Mosquito Control
- Maintenance

Flow Capacity, Velocity and Freeboard

Since swales are conveyance features, they are designed to slow and detain small storm events while also safely passing large storms with adequate freeboard. Flow velocity calculations for evaluating erosion protection needs are typically done assuming new or short vegetation. Flow conveyance and freeboard calculations for large storms typically assume taller, denser vegetation when the plants are fully grown.

Bioswales along the roadway should have adequate flow conveyance and maintain adequate freeboard to avoid flooding or overtopping the pavement. When bioswales are in close proximity to the pavement structure, they should have enough flow capacity to provide positive subgrade drainage.

Erosion Prevention

Bioswales should be lined with biodegradable erosion control matting for erosion prevention and sediment control during the plant establishment period. Turf



Bioswale with rustic log check dam and new plantings (Photo: David Dods, URS)

reinforcement mats, or other enhanced erosion protection may be necessary in locations of concentrated flow or to protect against high stormwater velocities produced by large storm events. Mat selection should be based upon anticipated flow velocities, vegetation planting requirements, and longevity needs. When bioswales are used in conjunction with underdrains or storm sewer systems along roadways, make sure that drainage inlets are not blocked or obstructed by bioswale features.

Slopes

Site topography should be considered in bioswale design, including slope and cross-sectional area to maintain non-erosive velocities. Typically, slopes should be 1 to 2%. Where there are poor soils or slopes less than 1%, an underdrain system should be used. In areas with slopes greater than 4%, check dams or weirs should be placed perpendicular to the flow to increase detention and extend time for infiltration. Placement of check dams or weirs should include scour protection to limit erosion. See Figures 18.5.1-F, G, H, & K for check dam placement and bioswale design layouts.

Inlet and Pretreatment

Pretreatment should be used for most applications to ease maintenance, especially in land use areas with high sediment loads. The use of a forebay, weir or check dam at the inlet facilitates maintenance and removal of accumulated sediment.

Soil Composition

Consider soil types when selecting erosion control materials. Soil type affects erosion potential and infiltration rates. Heavier clay soils are less prone to erosion but have lower infiltration rates. Sandy, permeable soils promote infiltration, but are more prone to erosion. Infiltration rates in tighter soils will improve over time as plants grow and their root systems penetrate into the soil.

Check dams can be used temporarily to pond water within swales to slow flows, prevent erosion and promote infiltration. Consider whether you want them to be impermeable and pool water behind them for prolonged periods, or allow water to slowly drain through them after storm events pass. Typical construction materials are earth, stone, river rock, and rot resistant timbers.

Evaluate in situ soil conditions and consider the following options when designing the soil composition for a bioswale:

1. In Situ Soils Option 1: If the primary purpose is to convey drainage while filtering, consider a bioswale design with in situ soils. Topsoil should be stripped and stockpiled for reuse or after final grading, 2 to 3 inches of compost should be tilled to support plant growth. This is the least expensive option, but allows minimal infiltration. See Figure 18.5.1-A.

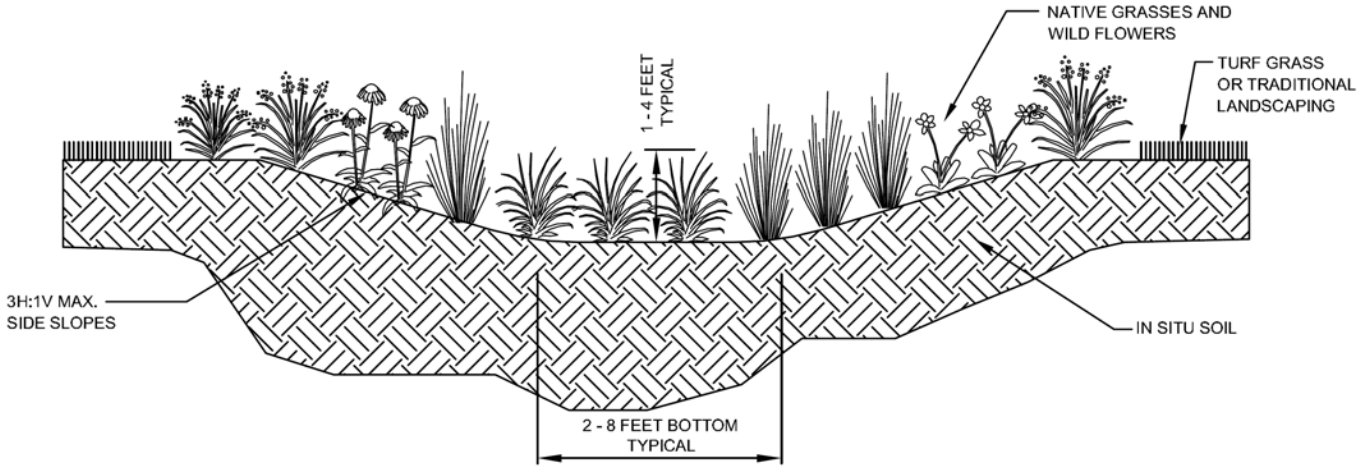

Figure 18.5.1-A. Soil Composition Option 1—In Situ Soils: Bioswale typical section

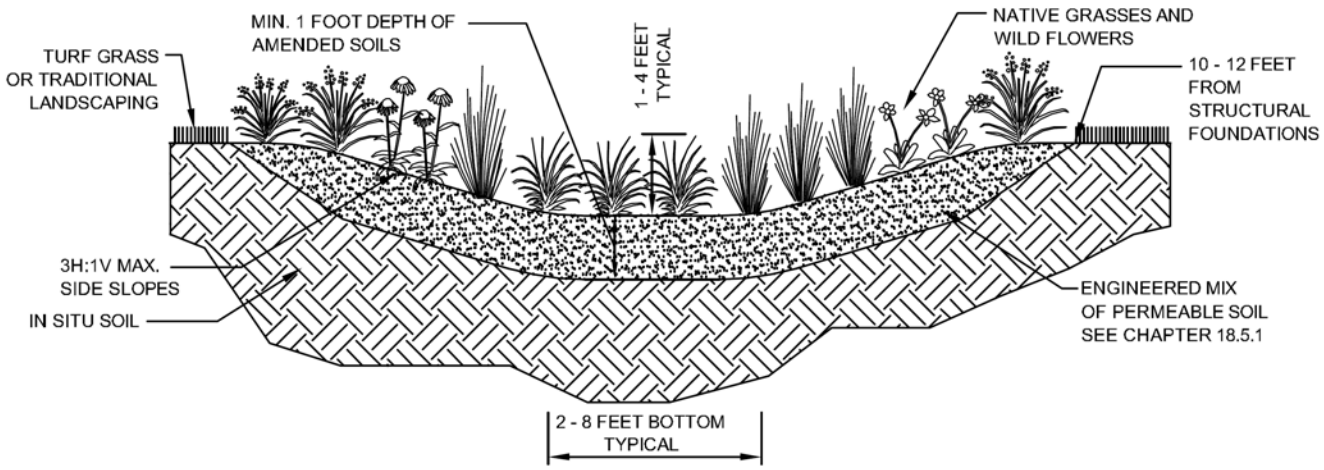

Figure 18.5.1-B. Soil Composition Option 2—Engineered Soils: Bioswale typical section

2. Engineered Soils Option 2: If the primary purpose is to promote infiltration and improve water quality, amend in situ soils with an engineered soil mix and add check dams. Erosion control design options must be considered when using engineered soils, however they provide increased pollutant filtering capacity and pore space. See Figure 18.5.1-B.
3. Engineered Soils with Underdrain Option 3: If the primary purpose is to promote infiltration and improve water quality while limiting standing water, amend in situ soils with an engineered soil mix and add check dams and an underdrain system. This option is more expensive and requires careful consideration of erosion control design options, but has increased filtering capacity and void space. See Figures 18.5.1 C & D.

For soil composition Option 2 and 3, the soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum for Option 1, but higher infiltration rates are recommended for the Engineered Soils Options.

For all options, the soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5%, by weight. The following soil mix is recommended, but other soil mixtures may be used based on site characteristics and proposed plantings. To enhance infiltration rates and prevent soil consolidation over time, a soil mix with a high sand content is recommended. The typical soil mix to enhance infiltration rates and prevent soil consolidation over time consists of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

For plants that need a higher organic content and less well-drained soils to support growth and development, a soil mix with a higher content of compost may be appropriate. However, testing of infiltration rates and soil aeration may be needed over time to maintain the functionality of the bioswale. Where appropriate for site conditions and plantings, consider this soil mix consisting of the following materials, by volume:

- 60% organic compost
- 30% construction sand
- 10% topsoil

When grading and soil mix placement are performed, care should be taken that soil is not compacted, resulting in diminished infiltration capacity. For soil composition Option 3, underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in

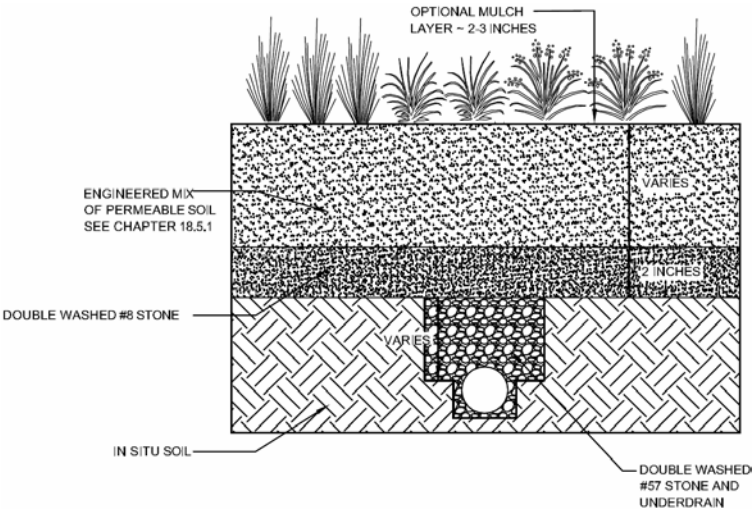

Figure 18.5.1-C. Soil Composition Option 3a—Engineered Soils with Underdrain: Schematic

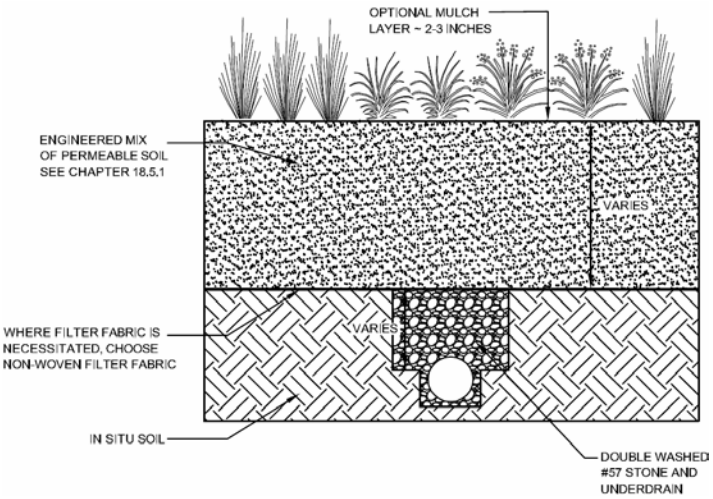

Figure 18.5.1-D. Soil Composition Option 3b—Engineered Soils with Underdrain: Schematic
Note: Filter fabric should be avoided due to its propensity for clogging.

double washed KY #57 stone. Filter fabric should be avoided due to its propensity for clogging. To minimize the migration of soil particles into the stone layer and underdrain, layer double washed KY #8 stone over the double washedKY #57 stone layer (Option 3a). Where filter fabric is necessitated, choose non-woven filter fabric (Option 3b). Cross-sections of soil composition options and underdrain schematics are provided. See Figures 18.5.1 -A through 18.5.1-E.

A primary function of bioswales, like traditional swales, is the conveyance of stormwater. For this reason, the use of a herbaceous layer of ground cover is recommended over mulching to prevent erosion of mulch and soil layers. As the herbaceous ground cover is established, it will stabilize the soil layers beneath during significant flow events. However, if mulch is used, fresh shredded bark mulch is preferred to maximize nitrogen retention. The slope of the bioswale should be designed to minimize erosion. Mulch should be applied as an even 2 to 3 inch layer avoiding mounding around trees and shrubbery.

Plant Selection

Bioswales are typically planted with deep rooted native grasses, sedges, and forbes. They are also planted with shrubs and trees avoiding inflow entrance areas or other areas where they may block flow. In selecting plants, consider whether the swales are designed to dry out between storm events, or retain water for prolonged periods behind check dams. Also consider the different planting zones in the swales because the bioswale bottom may be moist while the sides will dry out quickly. Select various plants accordingly.

Whether to plant with seed or plugs is often an economic concern. Seeding is less expensive initially, but requires a longer establishment period. Plugs are more expensive than seed, but grow in quicker.

A list of native species is provided in Chapter 13 of the MSD Design Manual. Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Cultivar species are provided in Chapter 13 of the MSD Design Manual.

Outlet Design

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. See Figure 18.5.1-E.

Mosquito Control

By their design, bioswales are not in danger of becoming a breeding ground for mosquitoes. See Table 18.5.1-A for bioswale residence time and drawdown time. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining bioswale, the chances of providing mosquito habitat are virtually eliminated. If the bioswale holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

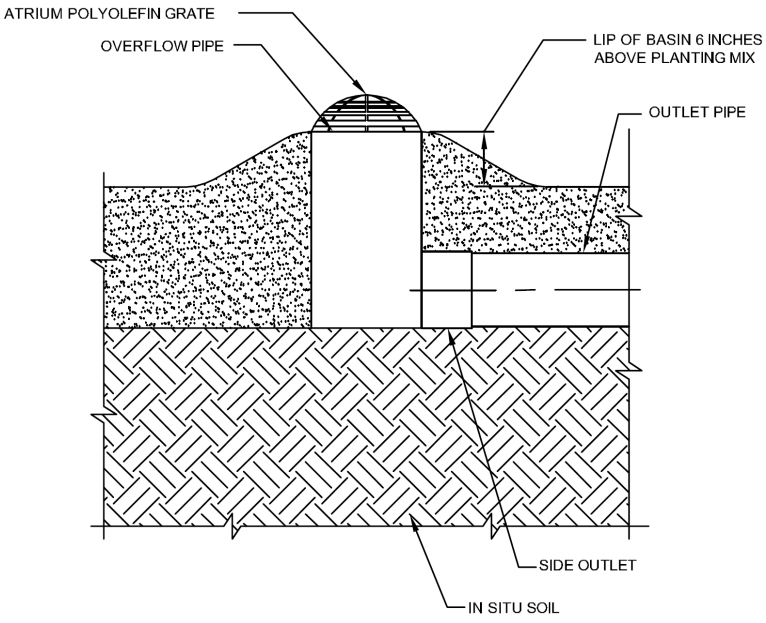

Figure 18.5.1-E. Overflow drain detail

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Bioswales are typically linear practices, but can be located in series with other GMPs such as rain gardens or bioretention to supplement infiltration and volume control.

Educational Awareness

The difference between bioswales and traditional landscaped areas may not be visible to the maintenance staff or the general public. It is important that those maintaining it as well as the public including customers, visitors or staff can understand that its features move beyond aesthetic landscaping to manage and treat stormwater. At a minimum, signage should include a message for maintenance staff that the bioswale is a "no mow" zone for purposes of carrying and treating stormwater runoff. For information on educational credits, call MSD Customer relations at (502) 587-0603.

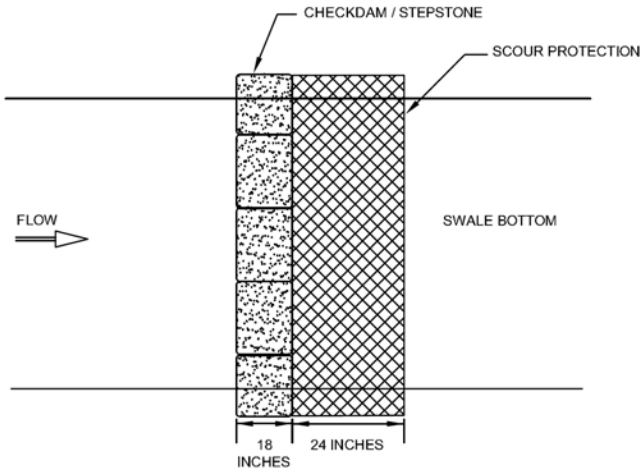

Figure 18.5.1-G. Stone check dam—typical plan view

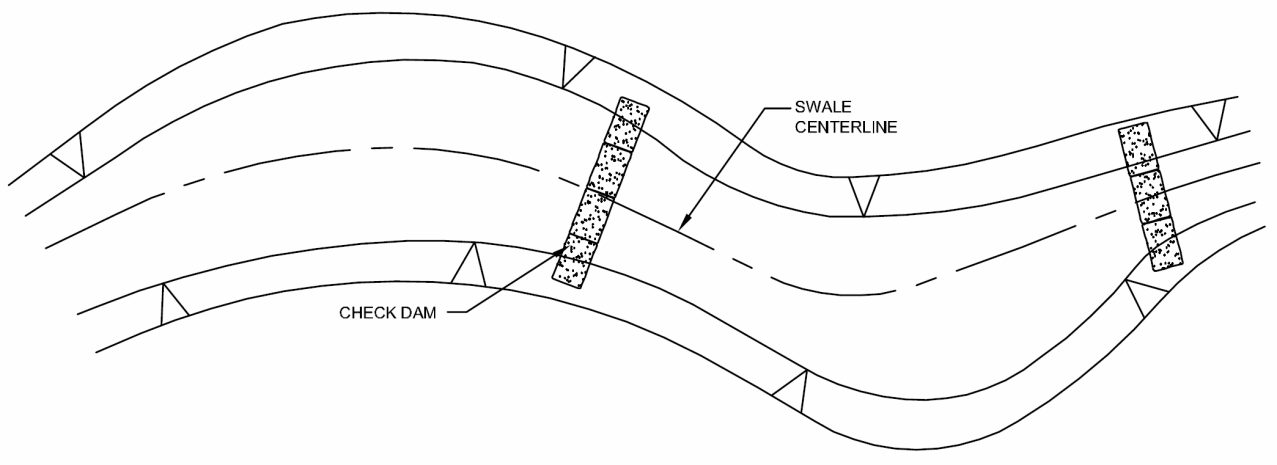

Figure 8.5.1-F. Alternate bioswale layout concept—typical plan view

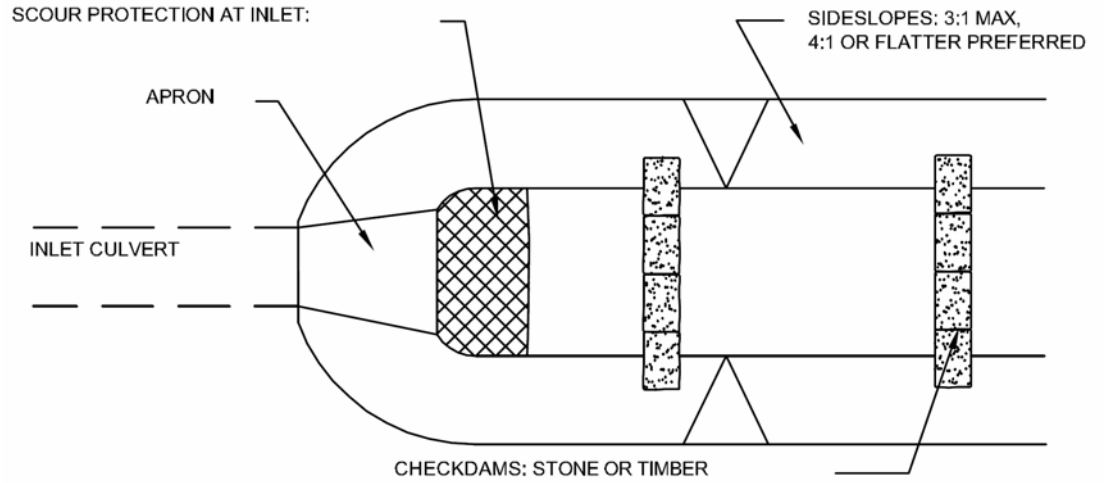

Figure 18.5.1-H. Typical bioswale features—typical plan view

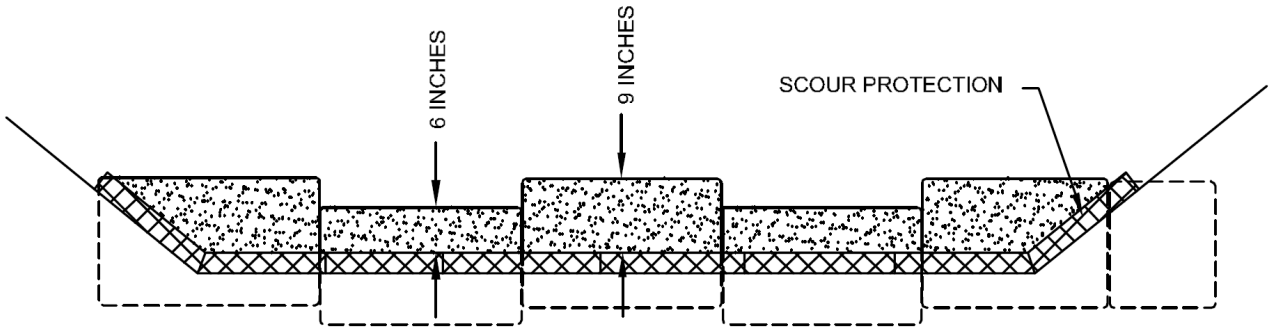

Figure 18.5.1-J. Stone check dam—typical section

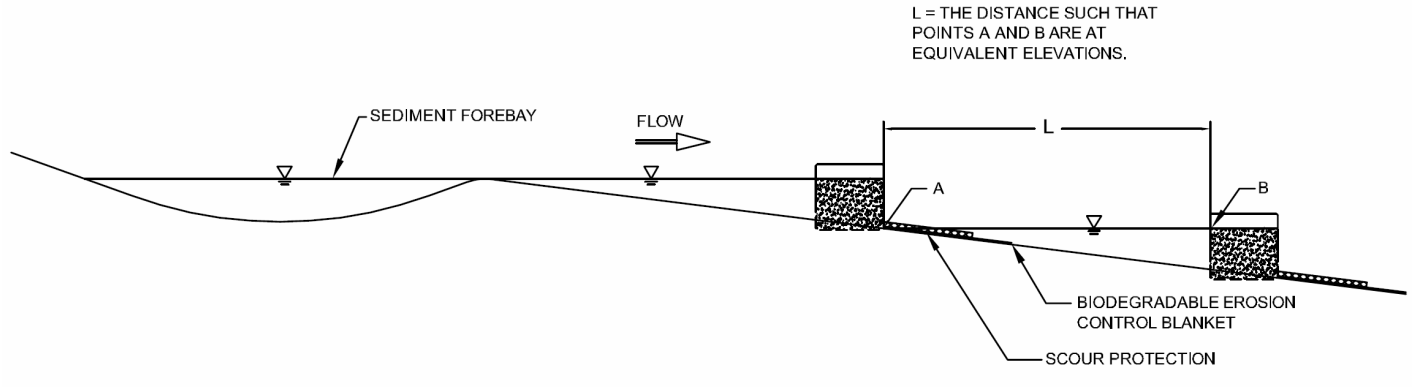

Figure 18.5.1-K. Check dam spacing—typical profile view

Bioswales Application and Site Feasibility Criteria

Table 18.5.1-A.

Design Parameter	Criteria
Longitudinal Slope	Typically less than 4% 1 - 2% preferred If greater than 4%, use check dams to achieve slopes as needed
Bottom Width	2 - 8 feet typical
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Maximum Permissible Velocity	• 1 fps for water quality storm peak flow • 4.5 fps for the 100-year, 24-hour storm peak flow
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm
Soils	Engineered soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate for the In Situ Soils Option, however higher infiltration rates are recommended for the Engineered Soils Options. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5% by weight. The soil mix will consist of the following materials, by volume: • 60% construction sand • 30% organic compost • 10% topsoil
Residence Time for WQv Storm Event	• Optimal greater than 9 minutes (to achieve >80% TSS removal) Minimum = 5 minutes (to achieve~60% TSS removal) • Maximum ponding time typically about 24 hours • Installation of check dams to provide adequate residence time
Pretreatment	Size pretreatment forebay to hold 10% to 15% of the WQv
Outlet Protection	Scour protection required at discharge point
Drawdown Time	Check dams and underdrains should dewater within 24 hours. Underdrains are required for in-situ soils if infiltration rate is less than 0.5 inches/hour.
Storage Capacity	Bioswale total volume should be equivalent to the required WQv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A) - (WQ_{VR})$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the bioswale (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area The design volume provided by the bioswale is V (ft^3) = (A)(d)(P) + (A)(h), where • A = area of the bioswale (ft^2) • d = depth of the media (ft) • P = media porosity (% void) • h = average height of water above the media during the WQv rain event in feet

* Note that bioswale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Step by Step Design Procedures

Step 1: Define goals/primary function of the bioswale

Define the goals/primary function of the bioswale. Consider whether the bioswale is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide conveyance or fix a drainage problem
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. To design an appropriate bioswale, determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the bioswale. In conjunction with in situ topographic and soil conditions, this criteria will determine the elements of the bioswale (check dams, engineered soils, underdrain, etc).

Step 2: Determine the residence time, peak flow rate, and total runoff volume

Swales should achieve the residence time shown in Table 18.5.1-A. Swales must be designed to safely convey flow rates produced by larger storm events with adequate freeboard and minimum erosion.

Where space allows and check dams are used, bioswales should be sized to capture and detain the WQv in the volume behind check dams, as provided in Chapter 18.3 Green Infrastructure Plan Development Standards and Selection Process. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.1-A can be used in this form: $WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following storm events:

- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a bioswale area. Utilize Table 18.5.1-A. Create a rough layout of swale dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

Pretreat with forebay, weir or check dam, and scour protection. Size the forebay per Table 18.5.1-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Step 5: Determine bioswale dimensions

Size bottom width, depth, length and slope necessary to achieve the residence time and/or store the WQv per Table 18.5.1-A.

Step 6: Determine check dam needs

Lay out preliminary check dam locations based on the grade of the swale. Consider adding/adjusting check dam locations where crossing access is needed. Calculate the number of check dams required to detain the WQv. Check that the velocity for the Water Quality storm is within 1 fps to reduce erosion potential.

Step 7: Check velocities for water quality storm

Based on the average bioswale cross-section and slope, check flow velocities and water surface elevations for the WQv Rain Event. Check that the velocity for the WQv Rain Event is within 1 fps to promote sediment drop out and filtration as well as reduce erosion potential.

Step 8: Check velocities and freeboard for larger storms

Based on the average bioswale cross-section and slope, check flow velocities and water surface elevations for the 2-, 10- and 100-year, 24-hour storm events for the bioswale to pass safely. This includes meeting freeboard requirements per Table 18.5.1-A and determining the need for erosion prevention measures. Modify design as appropriate. Assess energy dissipation options at outlets points.

Step 9: Select erosion control measures

Compare peak flow velocities calculated for the 2-, 10- and 100-year, 24-hour storm events to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and determine the need for biodegradable erosion control materials. For most bioswales, a biodegradable erosion control mat will be needed to limit soil erosion while the vegetation is becoming established. Choose biodegradable erosion control mat based on the manufacturer's specifications that meet the peak flow velocities.

Step 10: Prepare vegetation and landscaping plan

Choose deep rooted native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones within the bioswale. In general, the sides of the bioswale will be well drained and the plants on the sides will need to tolerate dry conditions as well as occasional wet conditions. The bottom of the bioswale will have more moist conditions, so plants located in the bottom of the bioswale will need to tolerate longer periods of saturation. If check dams are not used, the bottom of the bioswale may be well drained. If check dams are used, water will be held behind the check dams for a longer period of time. Choose plants appropriate for the conditions that will be created in the bioswale.

Native and cultivar species are provided in Chapter 13 of the MSD Design Manual. Although native, deep rooted species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Invasive species should not be used. A list and description of Louisville and Kentucky invasive species are provided in Chapter 13, Appendix II of the MSD Design Manual.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.2 Rain Gardens

Typical Implementation Areas:

- Commercial & residential landscaping
- Multi-use areas (courtyards, entranceways)
- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/median

Key Considerations:

- Use of native vegetation
- Overflow structure
- Infiltration

Cost: Low
Maintenance: Low



Residential landscaped rain garden with native and cultivar plants (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	◪
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	□
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Rain gardens, also referred to as bioretention cells, biofiltration cells or bioinfiltration cells, are shallow stormwater basins (typically 4 to 12 inches deep) that mimic the ecological functions of a natural landscape. Rain gardens contain deep rooted native vegetation or cultivar species to filter stormwater, promote infiltration and provide wildlife habitat. Rain gardens improve water quality through:

- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater
- ☑ Natural evapotranspiration
- ☑ Biological uptake

Advantages/Benefits

- Good retrofit capability
- Reduces volume of stormwater runoff
- Provides infiltration and groundwater recharge, filtering pollutants and reducing runoff volume
- Suitable for runoff from highly impervious areas
- Increases biodiversity by providing urban habitats for wildlife

Disadvantages/Limitations

- Location constraints (utilities, shallow groundwater, bedrock, sinkholes, downgradient from buildings/ basements, overflow pathway, etc.)
- Maintenance commitment (basic gardening/landscape maintenance)
- Available space for capture of target volume
- Not recommended for slopes >15%.

Application and Site Feasibility

Rain gardens are shallow basins landscaped with deep rooted, native or non-invasive cultivar plants to capture, filter and infiltrate stormwater runoff. They can be flexible in design to accommodate landscape requirements. Rain gardens are appropriate in a wide variety of land use applications such as commercial, industrial, or residential areas and they are often located adjacent to parking lots or roof downspouts. This fact sheet includes guidance for rain gardens in non-residential applications, such as commercial or industrial properties. MSD's *A How-To Guide for Building Your Own Rain Garden* was developed specifically for homeowners. A copy can be downloaded from the MSD website at www.msdlouky.org.



This photo is an example of a residential rain garden using MSD's How-To Guide as a resource for homeowners (Photo: Louisville & Jefferson County MSD)

Physical Requirements

Key physical considerations are:

- Soil type and infiltration—Rain gardens should drain within 24 hours. Infiltration rates for native soils with clay content may improve over time with installation of deep rooted plants as they have the potential to penetrate and loosen the soils. Soils shall have an infiltration rate of 0.5 inches per hour or greater.
- Deep rooted plants—Native plants are preferred and non-invasive cultivars/hardy plants can be used to landscape the rain garden. Native, hardy plants with deeper root systems and tolerance for drought to wet conditions are suitable for the varying wet and dry conditions of rain gardens.

Design Criteria

The design of a rain garden includes several elements to manage stormwater ponding and infiltration as well as to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.2-A.

Design criteria to consider includes:

- Location
- Inlet and pretreatment
- Sizing and ponding area
- Soil composition
- Plant selection
- Outlet design
- Mosquito control
- Maintenance

Location

Since rain gardens are retention structures, they are designed to effectively capture stormwater runoff. When finding the most appropriate location for the rain garden, it is best to find a site with a small drainage area. For larger drainage areas, it is recommended that more than one rain garden be established.

Rain gardens should be built where the groundwater table is significantly lower than the lowest point of the rain garden to promote affective infiltration. Areas with heavy sediment flow are not suitable locations for rain gardens because the structures or soil may become clogged. In addition, rain gardens should be placed at least 10 feet from building foundations and underground utilities. See Figure 18.5.2-D for a rain garden typical cross-section.

Inlet and Pretreatment:

Pretreatment is a key feature that can ease maintenance, especially in land use areas with high sediment loads. The use of a forebay, or other energy dissipating device, such as a strip of vegetative or gravel filter to spread the flow at the inlet, facilitates maintenance and removal of accumulated sediment while preventing erosion.

Sizing and Ponding Area

The surface storage parameter should be designed to retain/ capture the volume produce by the rainfall events specified in Table 18.5.2-A. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. Ponding depth should be limited to 6 inches or less. An overflow drain also should be installed to move excess water during a large storm event or due to clogging.

Sizing of a rain garden is based on the volume provided by the porosity of any amended soils and in the ponding above any amended or in situ soils. This volume should at least be equal to the Water Quality Volume (WQv).

See Table 18.5.2-A for the minimum surface area of the rain garden.

Soil Composition

The composition of media used within a rain garden is vital because it will either promote or hinder the ability for runoff to infiltrate through the structure. Consider soil types when selecting erosion control materials. Soil affects erosion potential and infiltration rates. Heavier clay soils are less prone to erosion but have lower infiltration rates. Sandy, permeable soils promote infiltration, but are more prone to erosion. Soils used should not have excessive levels of phosphorus due to treatment because this can affect water quality. Infiltration rates in tighter soils will improve over time as plants grow and their root systems penetrate into the soil.

It is important to evaluate in situ soil conditions and determine the need for an underdrain and engineered soils:

1. Engineered Soils Option 1: If the primary purpose is to promote infiltration and improve water quality, amend in situ soils with an engineered soil mix. This option works best with well draining soils.
2. Engineered Soils with Underdrain Option 2: If the primary purpose is to promote infiltration and improve water quality while limiting standing water, amend in situ soils with an engineered soil mix and add an underdrain system. This option is more expensive, but has increased filtering capacity, increased void space, and will prevent permanent standing water where clay prevents total infiltration.

In situ soils should have an infiltration rate of 0.5 inches per hour or greater and higher infiltration rates are recommended for the Engineered Soils Options 1 & 2. If the infiltration rate is less than 0.5 inches per hour an underdrain is required. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5%, by weight. The following soil mix is recommended, but other soil mixtures may be used based on site characteristics and proposed plantings. To enhance infiltration rates and prevent soil consolidation over time, a soil mix with a high sand content is recommended. The typical soil mix to enhance infiltration rates and prevent soil consolidation over time consists of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

For plants that need a higher organic content and less well-drained soils to support growth and development, a soil mix



Rain garden at Louisville & Jefferson County MSD main office with naturalized native plantings. (Photo: Carolyn Cromer, Dropseed Nursery)



Native plants suitable for rain gardens (Photo: Louisville & Jefferson County MSD)

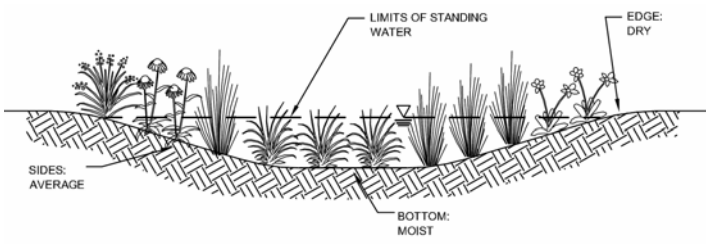

Figure 18.5.2-A. Rain garden (no underdrain) planting considerations for wet/dry tolerant plants

with a higher content of compost may be appropriate. However, testing of infiltration rates and soil aeration may be needed over time to maintain the functionality of the bioswale. Where appropriate for site conditions and plantings, consider this soil mix consisting of the following materials, by volume:

- 60% organic compost
- 30% construction sand
- 10% topsoil

At inflow and outflow areas of the rain garden, the use of a herbaceous layer of ground cover is recommended over mulching to prevent erosion of mulch and soil layers. Ground covers also act as a weed control by providing a thick cover that inhibits the growth of unwanted plants. However, if mulch is used fresh shredded bark mulch is preferred to maximize nitrogen retention. The slope of the rain garden should be designed to minimize erosion. Mulch should be applied as an even 2 to 3 inch layer avoiding mounding around trees, shrubbery and plants.

For soil composition Option 2 (Engineered Soils with Underdrain), underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed KY #57 stone. Filter fabric should be avoided due to its propensity for clogging. To minimize the migration of soil particles into the stone layer and underdrain, layer double washed KY #8 stone over the double washed KY #57 stone layer (Option 2a). Where filter fabric is necessitated, choose non-woven filter fabric (Option 2b). Cross-sections of soil composition options



Rain garden with native and cultivar plants (Photo: Lara Kurtz, URS)

and underdrain schematics are shown in Figures 18.5.2-B through 18.5.2-C.

Plant Selection

Rain gardens are typically planted with deep rooted native grasses, sedges, and forbes. In selecting plants, consider the favorable conditions where plants can thrive. The conditions for plants used should be able to survive droughts as well as inundated scenarios.

Whether to plant with seed, plugs or container plants is often an economic and maintenance decision. Seeding is less expensive initially, but requires a longer establishment period, and makes maintenance and weeding more intense.

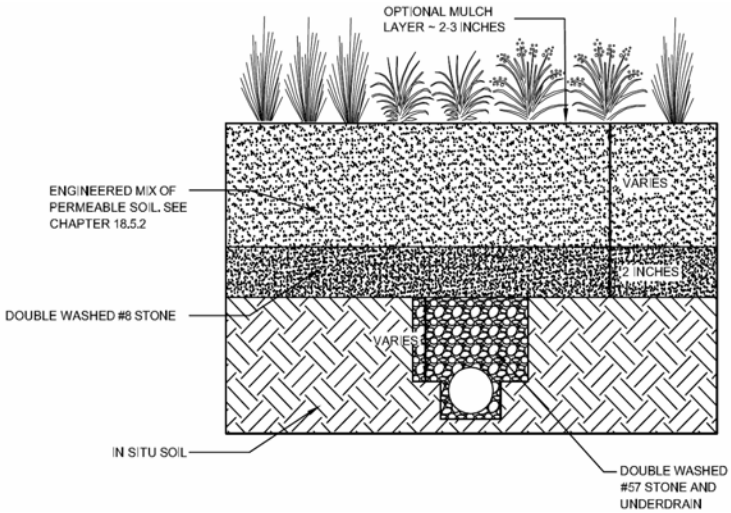

Figure 18.5.2-B. Soil Composition Option 2a—Engineered Soils with Optional Underdrain: Schematic

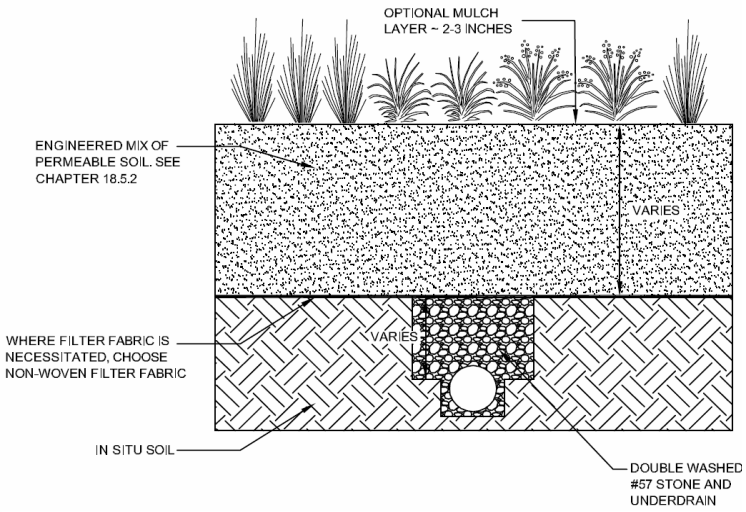

Figure 18.5.2-C. Soil Composition Option 2b—Engineered Soils with Optional Underdrain: Schematic
Note: Filter fabric should be avoided due to its propensity for clogging.

Plugs and container plants are more expensive than seed, but plants will grow and establish quicker and less weeding will be required.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Native species and non-invasive cultivar/hardy species are provided in Chapter 13 of the MSD Design Manual.

Outlet Design

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. If an underdrain is used, this may also help expedite the infiltration process when there is an excess amount of water retained within the structure after ground saturation has occurred.

Mosquito Control

By design, rain gardens should not be in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By designing a properly functioning and draining rain garden, the chances of providing mosquito habitat are virtually eliminated. If the rain garden holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for rain garden maintenance activities and schedules.

Treatment Trains—Combination and Location in Series With Other GMPs

Rain gardens can be located in series with other GMPs such as forebays and bioswales to supplement erosion prevention sediment control and infiltration. Energy dissapators or other erosion prevention sediment control features can be used inside the rain gardens to prevent excessive erosion during heavy rainfall.

Educational Awareness

The difference between rain gardens and traditional landscaped areas may not be visible to the general public. It is important that those maintaining it, as well as the public, including customers, visitors or staff, understand that its features move beyond aesthetic landscaping to manage and treat stormwater. Educational signage varies from an interpretive sign that explains how the rain garden functions



No mowing sign for Metro Parks promotes maintenance awareness at a rain garden (Photo: Erin Wagoner, URS)



Interpretive signage explains how a rain garden and other GMPs work in this regional watershed demonstration project (Photo: Erin Wagoner, URS)

to a simple "no mow" sign. Signage and edging should be used to delineate the rain garden from adjacent landscaped or lawn areas. Signage may include awareness information that the rain garden is a "no mow" zone and used for purposes of carrying and treating stormwater runoff. Stone or raised edging will help to delineate the rain garden from surrounding landscape, however care should be taken to ensure edging does not inhibit the flow of drainage into the rain garden. For information on educational credits, call MSD Customer relations at (502) 587-0603.

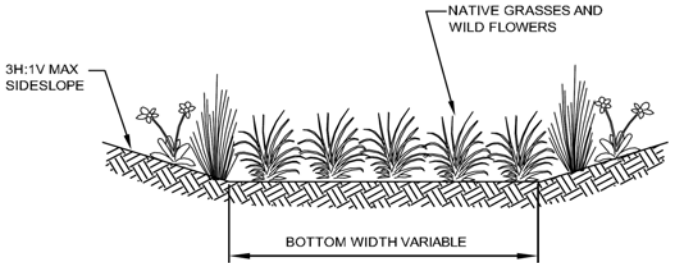

Figure 18.5.2-D. Rain garden typical cross-section

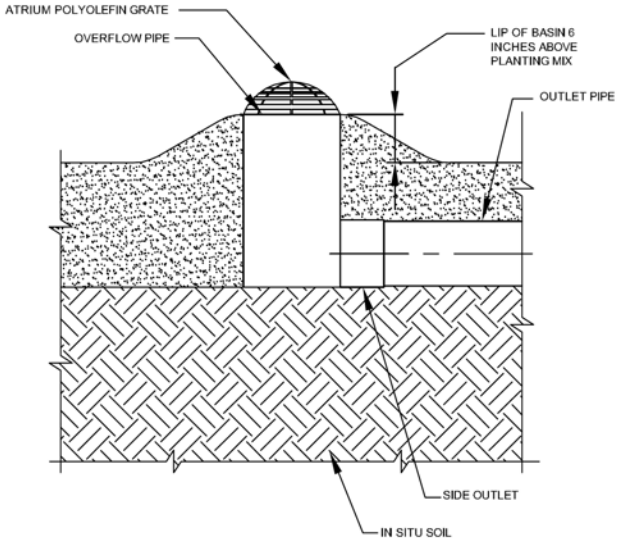

Figure 18.5.2-E. Overflow drain detail

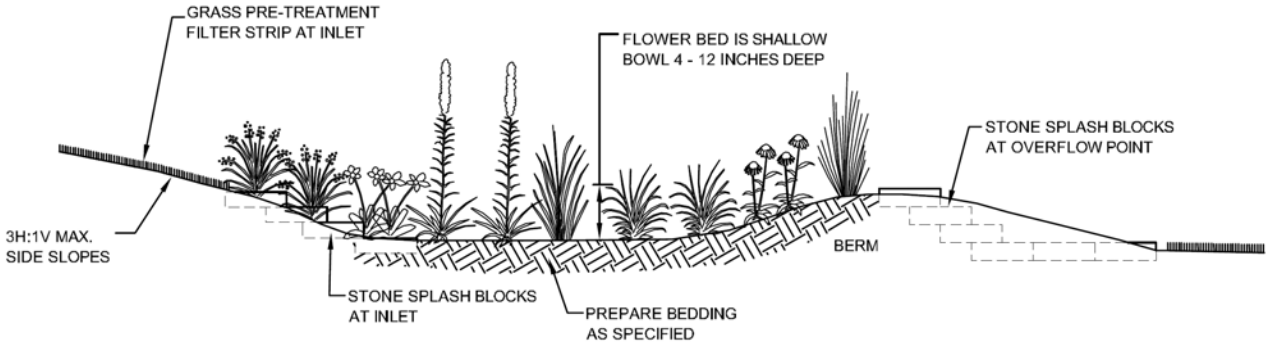

Figure 18.5.2-F. Rain garden typical cross-section with overflow splash blocks

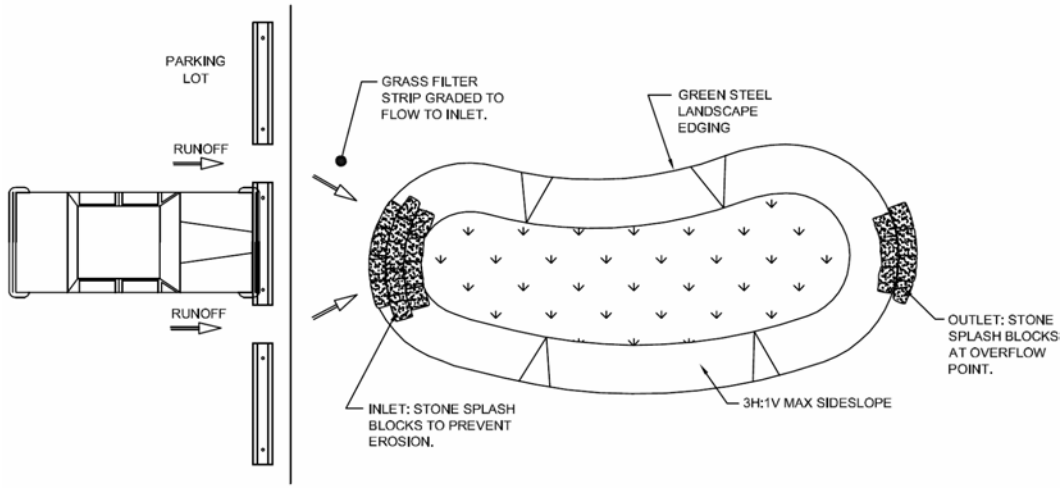

Figure 18.5.2-G. Rain garden typical plan view with splash blocks

Rain Garden Application and Site Feasibility Criteria

Table 18.5.2-A.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: $A = (WQv)/[(d)(P)+h]$, where • A = surface area of the ponding area of the rain garden (ft^2) • WQv = required water quality volume (ft^3) • d = depth of any amended soils (ft) • P = porosity of any amended soils (% void) • h = average height of water above the amended/in situ soils during WQv rain event (ft)
Longitudinal Slope	No greater than 15%.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm with 6" of freeboard
Soils	Engineered soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate for the In Situ Soils Option, however higher infiltration rates are recommended for the Engineered Soils Options. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5% by weight. For many projects, the mix will consist of the following materials, by volume: • 60% construction sand • 30% organic compost • 10% topsoil
Pretreatment (optional)	Size pretreatment forebay to hold 10% to 15% of the WQv.
Inlet/Outlet protection	Scour protection required at inlet and discharge point.
Drawdown Time	Dewatering of the rain garden should occur within 24 hours.
Storage Capacity	Rain garden total volume should be equivalent to the Required Water Quality Volume. Required WQv (cubic feet) = $(1/12)(REWQ_v)(Rv)(A) - (WQ_{VR})$, where • $REWQ_v$ = required water quality volume rain event (refer to chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the rain garden (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

Rain Garden Step by Step Design Procedures

Step 1: Define goals/primary function of the rain garden

Define the goals/primary function of the rain garden. Consider whether the rain garden is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide a fix to an excess drainage problem
- Enhance landscape aesthetic qualities

Consider whether the rain garden requires any special site-specific design conditions/criteria. Inventory any site restrictions and/or surface water or watershed requirements that may apply or effect the design.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the rain garden. In conjunction with in situ topographic and soil conditions, this information will determine the elements and design of the rain garden (engineered soils, underdrain, outlet/overflow, etc).

Step 2: Determine the total runoff volume and rain garden footprint

Rain gardens should be sized to capture and retain the water quality volume (WQv). To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.2-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

To determine he minimum surface area of the rain garden use the following formula:

$A = (WQv)/[d(P)+h]$ (see table 18.5.2-A).

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Water Quality
- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a rain garden area. Consider Table 18.5.2-A. Create a rough layout of the rain garden dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

It may be desired to use pretreatment to reduce flow velocities or facilitate sediment removal and maintenance of the rain garden. Pretreatment with a forebay, weir or check dams are optional for rain gardens. Size the forebay per Table 18.5.2-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations. Splash blocks or level spreaders should be considered to dissipate the concentration of stormwater runoff at the inlet and to prevent scour.

Step 5: Determine rain garden parameters

Size any engineered soils depth to achieve the WQv per Table 18.5.2-A.

Step 6: Prepare native vegetation and landscaping plan

Choose deep rooted native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones for a high functioning rain garden. In general, the sides of the rain garden will be well drained and the plants on the sides will need to tolerate both dry and wet conditions. The bottoms of the rain garden will have more moist conditions, so plants here may need to tolerate longer periods of saturation. Choose plants that are appropriate for the conditions that will be created in the rain garden.



Rain garden with newly installed native plants (Photo: Erin Wagoner, URS)

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Green Management Practice (GMP) Fact Sheet

18.5.3 Constructed Wetlands

Typical Implementation Areas:
- Parks and greenways
- Commercial, residential and institutional developments

Key Considerations:
- Used to both retain and treat stormwater
- Use native vegetation
- Enhances local ecosystem with new, connected habitat
- Proper design needed to avoid mosquito concerns

Cost: Medium
Maintenance: Medium



Constructed wetland (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	◪
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	□
Stormwater Conveyance	□
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Constructed wetlands incorporate marsh and pool areas to temporarily store stormwater runoff, treat pollutants and create habitat. Constructed wetlands are generally shallow, except for the pool areas, and contain dense native aquatic vegetation, typically covering 50% of the surface area that helps treat the stormwater. Wetland systems can store additional runoff, provide extended detention, or incorporate the benefits of a pond in a pond/wetland system. Constructed wetlands improve water quality through:

- ☑ Biological uptake through native plants and biodegradation by microorganisms
- ☑ Sediment settling
- ☑ Adsorption and other chemical/physical processes

Advantages/Benefits

- One of the most effective GMPs for pollutant removal because it does not infiltrate
- Increases biodiversity by providing habitat for wildlife
- Reduces channel/stream bank erosion by reducing number of downstream bankfull events
- Opportunity for multiple uses, including passive recreation

Disadvantages/Limitations

- Typically requires larger tracts of land
- Needs regular flow of water, so stormwater runoff may need to be supplemented during dry conditions
- Needs to be properly designed and managed to reduce potential to breed mosquitoes
- Water quality of discharge can change with seasonal growth of plantings

Application and Site Feasibility

Constructed wetlands are a basin feature, similar to stormwater ponds in scale, that are used to treat and temporarily store stormwater runoff. Generally, to help sustain wetlands during dry periods, design should incorporate a drainage area of 25 acres, 10 acres for pocket wetlands. The permeability of the soils around the constructed wetlands should be less than 0.14 inches per hour to prevent drainage. In addition, wetlands should have an aerial extent of 2-5% of the watershed they drain and a minimum elevation difference between the inlet and outlet of about 2-5 feet. Constructed wetlands are appropriate for use in a wide variety of land use applications such as commercial, industrial, or residential areas.

There are three basic types of constructed wetlands, which are depicted in Figure 18.5.3-A: shallow wetlands, pond/ wetland systems, and extended detention wetlands. Shallow wetlands consist of a combination of shallow water areas, 6 to 18 inches deep in combination with deeper pools. Extended detention shallow wetlands are similar, except they incorporate additional storage above the normal pool elevation. Pond/wetland systems utilize detention ponds and shallow wetlands in series.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to treat and temporarily store the stormwater runoff
- Drainage area—Have an adequately large drainage area to provide base flow during drier weather
- Soil conditions—Soils need to have a low permeability to allow ponding of the water; constructed wetlands typically do not infiltrate stormwater runoff

Design Criteria

The design of constructed wetlands includes several elements to facilitate water quality improvement and routing and detention of stormwater runoff. For a summary of design parameters, see Table 18.5.3-A.

Design criteria to consider includes:

- Configuration and layout
- Soils
- Conveyance
- Forebay (pretreatment)
- Treatment
- Outlet
- Landscaping/plant selection
- Safety
- Maintenance



Pocket wetland (Photo: David Dods, URS)

Configuration and Layout

Common constructed wetlands components include the following:

- Inlet(s)
- Sediment forebay
- Shallow water zones
- Outlet and overflow structures
- Deeper pool zones, including a micropool near the outlet to allow for final settling and prevent and re-suspension of settled matter prior to discharge

These components are shown in Figures 18.5.3-B and 18.5.3 -C. The configuration and layout of these components will be dictated by the site topography, flow paths and access.

Soils

Constructed wetlands are intended to stay wet, so the soils need to be relatively impermeable and limit infiltration; however, they should be above the local high water table. If the underlying soils have a permeability of 0.14 inches per hour or less, then they will not typically require the use of an impermeable or low permeability liner. Soils with

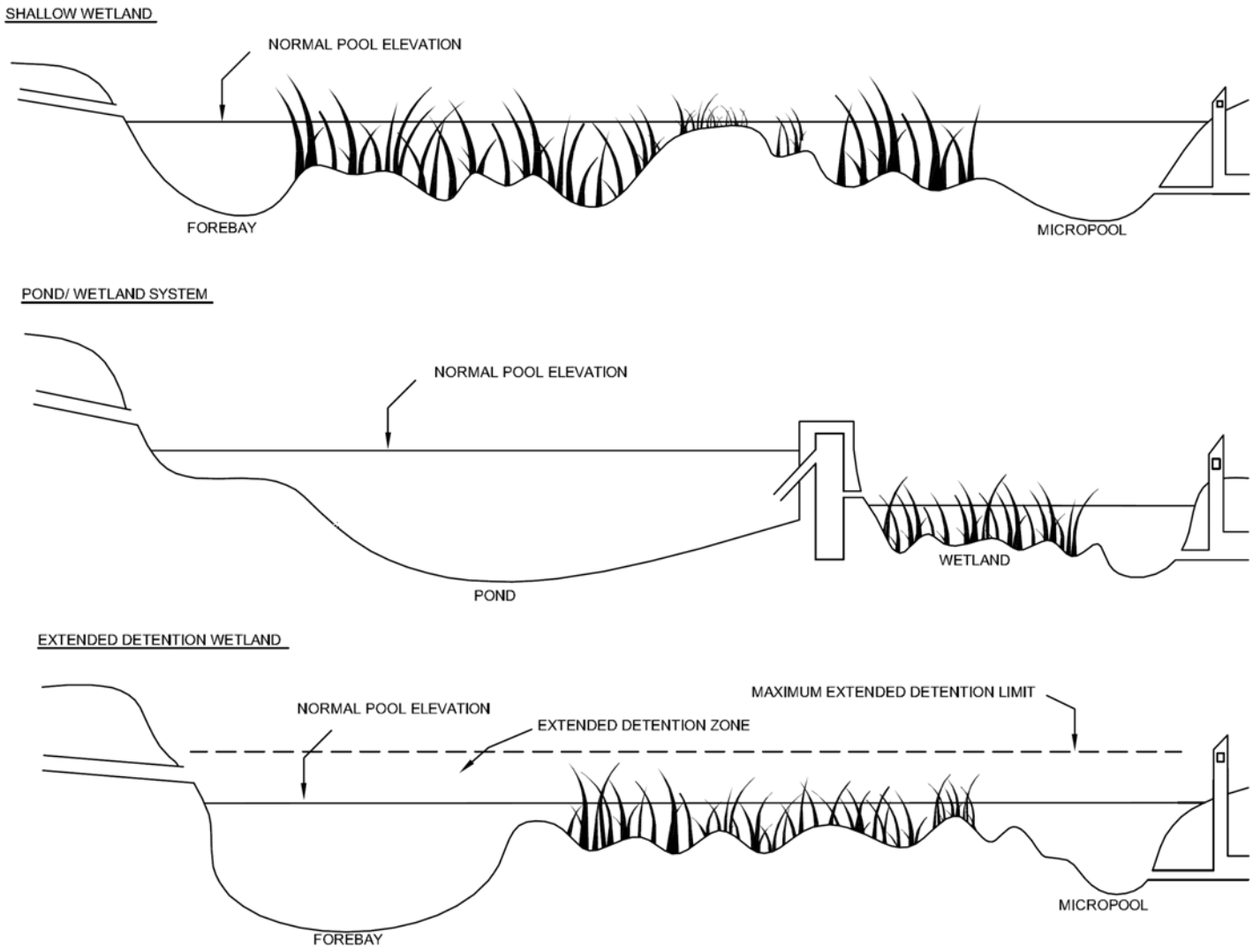

Figure 18.5.3-A. Three Typical Types of Constructed Wetlands

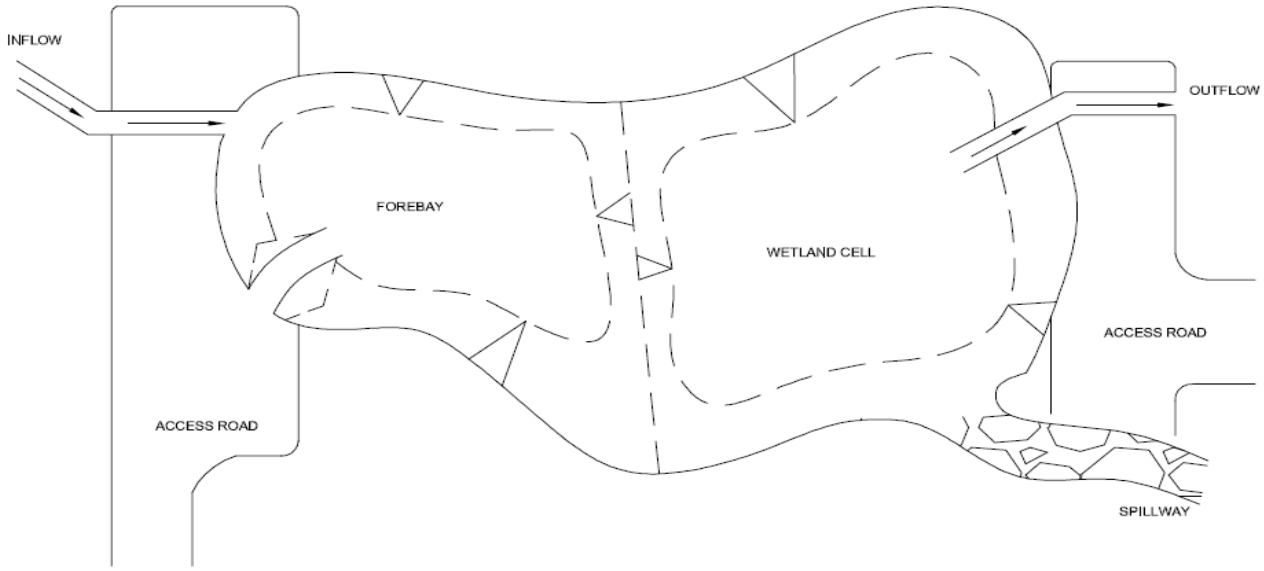

Figure 18.5.3-B. Typical Shallow Wetland (Plan View)

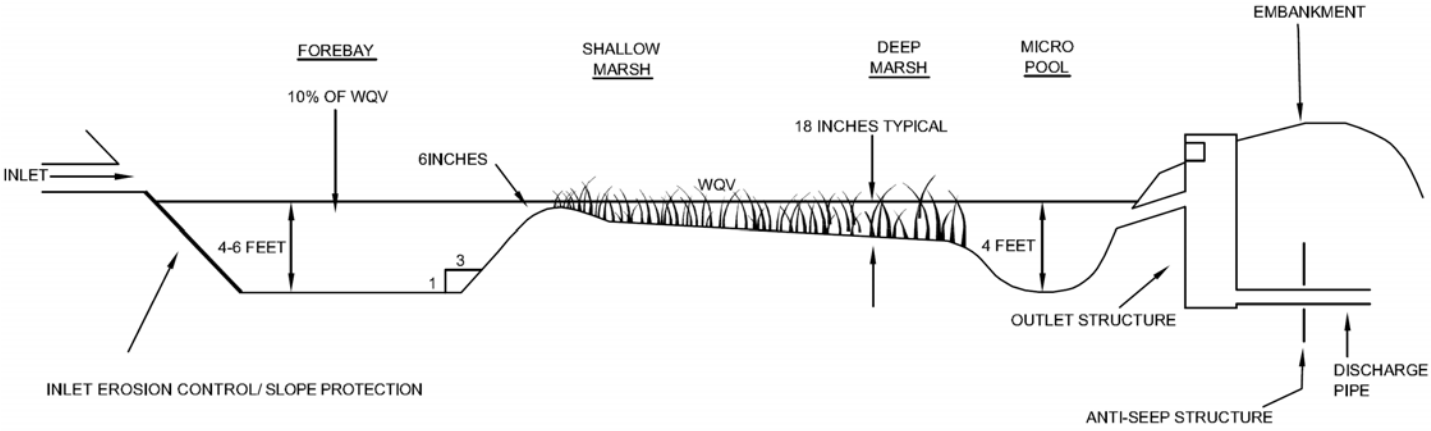

Figure 18.5.3-C. Typical Constructed Shallow Wetland (Profile View)

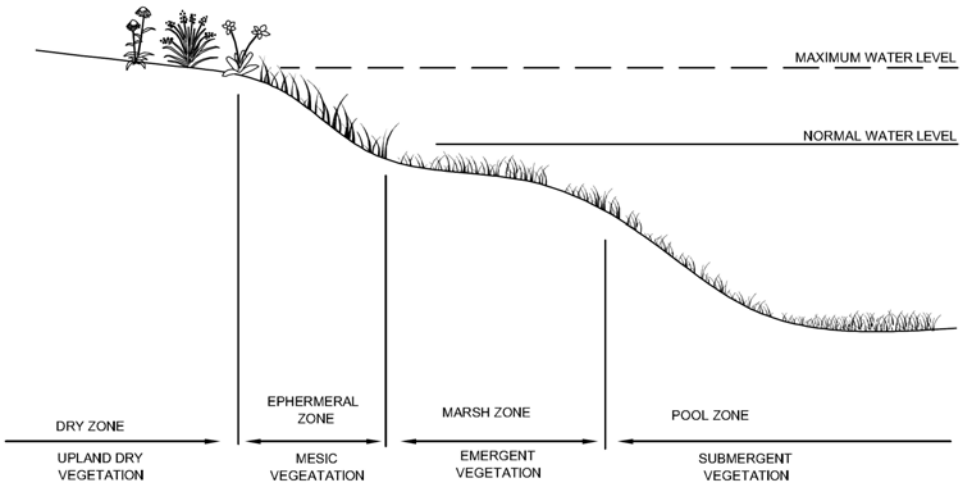

Figure 18.5.3-D. Typical Plant Selection Zones

permeability rates greater than 0.14 inches per hour will require the use of an impermeable or low permeability liner.

Conveyance

Though the constructed wetlands primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because the pooled water in the wetlands allows opportunity for solid particles in the stormwater to settle, the flow path should be diffuse and as long as possible. To provide a long flow path, the wetlands need to have a length to width ratio of at least 2:1, with 3:1 preferred, or internal dikes that provide a winding path for the stormwater runoff.

Constructed wetlands need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the wetlands will help to reduce velocities during larger flows, reducing the potential for erosion. An emergency spillway is also needed to safely convey high flow out of the wetlands. The area downstream of the emergency spillway needs to be protected to prevent scour.

Pretreatment—Forebay

Excessive sediment accumulation in a wetland can reduce hydraulic capacity, block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the wetlands. The forebay should be sized to provide approximately 10% of the WQv and prevent the resuspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 4-6 feet, which will also prevent the growth of unwanted vegetation and allow for the survival of mosquito eating fish. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the wetlands system and reduce velocities to prevent erosion. The forebay should also be designed to allow for ready access to perform maintenance, including removal of accumulated sediment.

Treatment

The primary pollutant removal mechanism in wetlands is sedimentation, since many pollutants are affiliated with sediment particles in stormwater. Consequently, proper design, construction and maintenance of the sediment forebays are critical to the wetlands' performance.

The shallow water zones in the wetlands promote numerous treatment processes. Slowing flows over these zones promotes additional particle settling and biological activity degrades some of the organic pollutants while exposure to sun and air promotes other degradation processes.

A micropool near the outlet helps keep vegetation from encroaching on and clogging the outlet and helps prevent re



Constructed wetland with native plantings (Photo: David Dods, URS)

-suspension of sediment into the discharge. Fish in the micropool can also help manage mosquito larvae production within the wetlands.

Shallow wetlands should be sized to have a permanent pool volume equal to the required WQv. The distribution of the volume amongst the forebay, shallow water zone, deep water zone, and micropool should be as follows:

- 10-15% for forebay
- 10-15% for micropool
- 30-35% for shallow water zones
- 35-40% for deeper water zones

Extended detention shallow wetlands and pond/wetland systems should be designed to store above the normal pool level the stormwater runoff from storms greater than the WQv storm event. In addition, the wetland or pond should drain to the normal pool level within 36 hours following the rain event.



Constructed wetland with soft rush (Photo: David Dods, URS)

Because keeping the wetlands wet is critical for their viability, a water balance should be performed. Estimate the seasonal inflows, such as rainfall, stormwater runoff and groundwater contribution, and outflows. Evaporation, transpiration and any infiltration should be included in the estimate. Size the wetlands to be able to sustain the wetland vegetation should there be minimal rainfall and runoff in a thirty day time period. If seasonal drying is anticipated, compensate in the plant selection process, but the effectiveness of the wetlands may be reduced.

Outlet

The design and configuration of the outlet structure will depend on whether storage is provided over and above the WQv. Typical outlet structures include reverse-sloped pipes, weirs or risers connected to a discharge pipe that discharges to the downstream receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars around the discharge pipe to prevent seepage.

A high flow bypass either separate from, or in conjunction with, the outlet structure should be included to safely convey high flows from storm events greater than the WQv rain event. A minimum of one foot of freeboard should be provided during the 100-year rain event. The discharge from the outlet structure should be equipped with armoring, plunge pool, energy dissipater or similar best management practices to prevent scour.

Landscaping/Plant Selection

A landscaping plan is recommended for planting constructed wetlands. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Identify deep pools, deep and shallow water zones, ephemeral zones that will be subject to wet and dry periods, and dry zones (see Figure 18.5.3-D). Select plants appropriate for each zone.

Choices available for planting the wetlands include seed, rhizomes, bare root stock, potted plants and transplanting vegetation from an established site. Planting rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species an cultivar species are provided in Chapter 13 of the MSD Design Manual.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 4:1 or flatter and relatively flat safety benches should be provided in the water just above the permanent pool level of the deep pool zones. In addition, a vegetated buffer around the wetlands can be provided to minimize undesired access or direct desired access and enhance wildlife habitat.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed wetlands are typically basin-scale practices that can be located in series with other GMPs such as wet ponds to supplement runoff volume control.

Educational Awareness

It is important that those maintaining constructed wetlands, as well as the public, including customers, visitors or staff understand that wetlands and their associated buffers are stormwater management features that also provide aesthetic beauty and ecosystem benefit. At a minimum, signage should include awareness information that the constructed wetlands and their associated buffer are a "no mow" zone for purposes of carrying and treating stormwater runoff.



Wetland at Buechel Basin (Photo: Erin Wagoner, URS)

Constructed Wetlands Application and Site Feasibility Criteria

Table 18.5.3-A.

Design Parameter	Criteria
Drainage Area	At least 25 acres of upstream drainage area, 10 acres for pocket wetlands, to maintain adequately wet conditions during dry weather
Sizing	Footprint of constructed wetland should be 2-5% of the area draining to it
Side Slopes	No greater than 4:1 (H:V), flatter is recommended
Soil Permeability	Soil permeability should be ≤ 0.14 inches/hour
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred
Design Flows and Conveyance Capacity	Pass the 2-, 10- and 100-year storms with one foot of freeboard
Pretreatment	Size pretreatment forebay to hold 10% to 15% of the WQv with a depth of 4-6 feet
Outlet Protection	Scour protection required at discharge point
Soils	Low permeability soils, typically in the hydrologic groups "C" and "D". Hydric soil designations should be used.
Sizing	Wetland total volume should be equivalent to the Required WOv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A) - (WQ_{VR})$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the wetland (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

Constructed Wetlands Step by Step Design Procedures

Step 1: Define goals/primary function of the constructed wetlands

To define the goals/primary function and location of the constructed wetlands by considering whether the wetlands is intended to:

- Treat the WQv
- Provide temporary storage of larger stormwater flows

If the wetlands is to be primarily a water quality feature, define the primary pollutant(s) of concern and design the wetlands to address the pollutant(s). For example, if suspended sediment is the primary concern, extra attention should be given to the sediment forebay design. If nitrogen is a priority, then detention times become important.

Also, define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements. In addition site access should be a major consideration.

Step 2: Calculate the peak flow rate and total runoff volume

At a minimum, the constructed wetland should be sized to store the required WQv. To find the WQv in cubic feet, the Storage Capacity equation from the Table 18.5.3-A can be used in this form: WQv (ft^3) = (RE_{WQV})(Rv)(A/12)- (WQ_{VR}). If possible, extended detention should be provided to capture and temporarily store the 2-year storm event runoff. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- WQv rain event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a constructed wetland. Consider Table 18.5.1-A. Create a rough layout of constructed wetland dimensions including existing trees, utility lines, and other site obstructions, as well as soil types.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per Table 18.5.3-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Step 5: Determine constructed wetland configuration

The wetland cell portion of the constructed wetland should be designed with a micropool at the outlet and shallow and deep water zones to provide the WQv, less the portion of the WQv provided in the forebay. The allocation of the remaining WQv should be about 10-20% for the micropool, 35-40% for the shallow water zone and 40-45% for the deep water zone.

Extended detention should be provided above the water quality level. Benches should be provided just above the WQv level and within the water just above the deep pools for safety and to provide planting surfaces. The wetland configuration should be irregularly shaped aerially and have uneven surfaces within the wetland to provide for long flow paths and microhabitats. Provide the length to width ratio and side slopes per Table 18.5.3-A. Maintenance access needs to be provided, especially for the forebay and micropool.

Step 6: Determine inlet and outlet design

Based on the constructed wetland configuration, check water surface elevations for all design storm events (shown in Step 2) so the constructed wetland can pass these flows safely. This includes meeting freeboard requirements of one foot and determining the need for erosion prevention measures at inlets, outlets, overflow points and slopes. Modify design as appropriate. Assess energy dissipation options at inlets, overflow and outlet points.

Step 7: Select erosion control measures

Compare peak flow velocities and water levels calculated for the design flow storm events (see Table 18.5.3-A) to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and assess the need for erosion control materials. A biodegradable erosion control mat may be needed on slopes and embankments to limit soil erosion while the vegetation is becoming established. Choose erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements. Hard armoring may be required for scour protection at inlets, outlets and overflow points within the wetlands.

Step 8: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated water depth zones within the constructed wetland. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

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Green Management Practice (GMP) Fact Sheet

18.5.4 Green Wet Basins

Typical Implementation Areas:

- Parks, greenways and common areas
- Retrofit of exiting wet retention basin
- Commercial, residential and institutional developments
- Retrofit of existing retention basins

Key Considerations:

- Provides water quality treatment for traditional wet basin
- Need low permeability soils
- Use native vegetation throughout perimeter

Cost: Medium
Maintenance: Low



Wet basin with native vegetation along the perimeter (Photo: Rusty Schmidt, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	◪
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	□
Stormwater Conveyance	□
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Green wet basins are similar to standard wet basins, except they contain an aquatic bench along the perimeter of the pond just below the normal pool level and possibly other plantings above the normal pool elevation (safety bench) in the extended detention portion of the basin that provide water quality benefits and they retain the stormwater runoff for at least 24 hours. The vegetation helps provide water quality benefits. Green wet basins improve water quality by:

- ☑ Biological uptake and filtering of native plants
- ☑ Sediment settling, including attached pollutants
- ☑ Temporary retention of stormwater

Advantages/Benefits

- Relatively high removal rate for many pollutants
- Increases biodiversity by providing habitats for wildlife and aquatic life
- Reduces channel/stream bank erosion by reducing number of bankfull events
- Opportunity for multiple use, including active and passive recreation

Disadvantages/Limitations

- Projects may require complying with KDOW dam regulations
- Large space requirement
- Possible safety concerns with a pool of water, fence may be required
- Not to be used in high groundwater areas

Application and Site Feasibility

Green wet basins are similar to a standard wet basin, except for the addition of vegetation and detention of the stormwater runoff. In addition, features may need to be included in the basin to minimize short circuiting between the inlet and outlet. Green wet basins can be constructed new or can be the result of retrofitted standard wet basins. Green wet basins are appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or residential areas. See the last page for Step by Step Green Wet Basins Design Procedures.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to treat and temporarily store the stormwater runoff
- Drainage area—Have adequately large drainage area to provide base flow during drier weather
- Plantings—Robust aquatic planting around the perimeter of the green wet basin to provide water quality treatment
- Outlet Structure—outlet structure designed to provide retention for the 2, 10, and 100-yr storms; note additional storm events must be considered if participating in the financial incentives program (Section 18.9).

Design Criteria

Generally, green wet basins need to have a drainage area of 25 acres to help sustain them during dry periods and keep the aquatic bench wet. The size of green wet basins should be determined using the design requirements for detention basins as described in Chapter 10.3.8 of MSD's Design Manual. The following additional criteria should also be included in the design of green wet basins. For a summary of design parameters and site feasibility criteria, see Table 18.5.1-A on page 5.

Design criteria to consider for green wet basins include:

- Conveyance
- Soils
- Landscaping/plant selection
- Slopes
- Outlet Structures
- Safety
- Maintenance

Conveyance

Although green wet basins' primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because the pooled water in the basins allow opportunity for solid particles in the stormwater to settle, the flow path needs to be diffused and as long as possible. To provide a long flow path, basins need to have a length to width ratio of at least 2:1, with 3:1 preferred. Internal dikes can be added, especially in retrofit situations, to provide a winding path for the stormwater runoff and the necessary length to width ratio.

Green wet basins need to be capable of passing the 100-year storm without damaging the vegetation or the surrounding embankments. The basin should be a minimum of 3 feet deep. A wide flow path through green wet basins will help to spread out and slow down larger flows, reducing the potential for erosion. An emergency spillway to safely convey the flow out of the green wet basin is also needed. The area downstream of the emergency spillway should be protected to prevent any scour. See Figure 18.5.4-A for a typical plan and section of a green wet basin.

Soils

Green wet basins are intended to hold water; therefore the underlying soils need to be relatively impermeable. Soils should have a permeability ≤ 0.14 inches/hour.

Landscaping/Plant Selection/Side Slopes

A bench around the perimeter of green wet basins provides the opportunity for aquatic plantings. This bench may be 10-15 feet wide with a slope of 4:1 or flatter and a depth of no more than 18 inches. The bench should cover approximately 25% of the total pond surface area.

In addition, plantings may be made in the basin slope just above the normal pool level that will be inundated during rain events due to the storage characteristics of the basins. These plantings need to be located such that they do not impact access for maintenance activities.



Buechel Basin has a naturalized buffer (Photo: Erin Wagoner, URS)

A landscaping plan is recommended for planting green wet basins. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. In addition, the plan should identify wet zones, ephemeral zones that will be subject to wet and dry periods and dry zones in order to select plants appropriate for each zone. Plants should be placed so that their roots do not impact any piping or other structures.

Choices available for planting the green wet basins include seed, rhizomes, bare root stock and potted plants. Planting rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but grow in and provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Outlet Structure

The outlet structure should include orifices or weirs (or a combination there of) to provide at least 24 hours of detention of the 2, 10, and 100 year storms. Considerations should be given to protecting the orifices from getting clogged with debris.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 4:1 or flatter and relatively flat safety benches should be provided just above the permanent pool level. In addition, a buffer around the green wet basins can direct public access and enhance wildlife habitat.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Train - Combination and Location in Series With Other GMPs

Green wet basins, if used in series with other GMPs, are typically near the end of the treatment train. Upstream GMPs may include vegetated swales, rain gardens and bioretention basins. One exception to being placed at the end of a treatment train is when it is used in a pond/ constructed wetland system. If used alone, a forebay (pretreatment) is required. If other GMPs are used upstream then a forebay may not be necessary.

Educational Awareness

It is important that those maintaining green wet basins, as well as the public, including customers, visitors or staff understand that the basins and their associated plantings and buffers are a stormwater management feature that also provides aesthetic beauty and ecosystem benefits. Signage should be provided at green wet basins to include awareness information that green wet basin perimeters and their associated buffers are a "no mow" zone, that no swimming is allowed and that the basin is for managing stormwater runoff.



Wet basin with buffer (Photo: David Dods, URS)



Wet basin with small buffer (Photo: David Dods, URS)

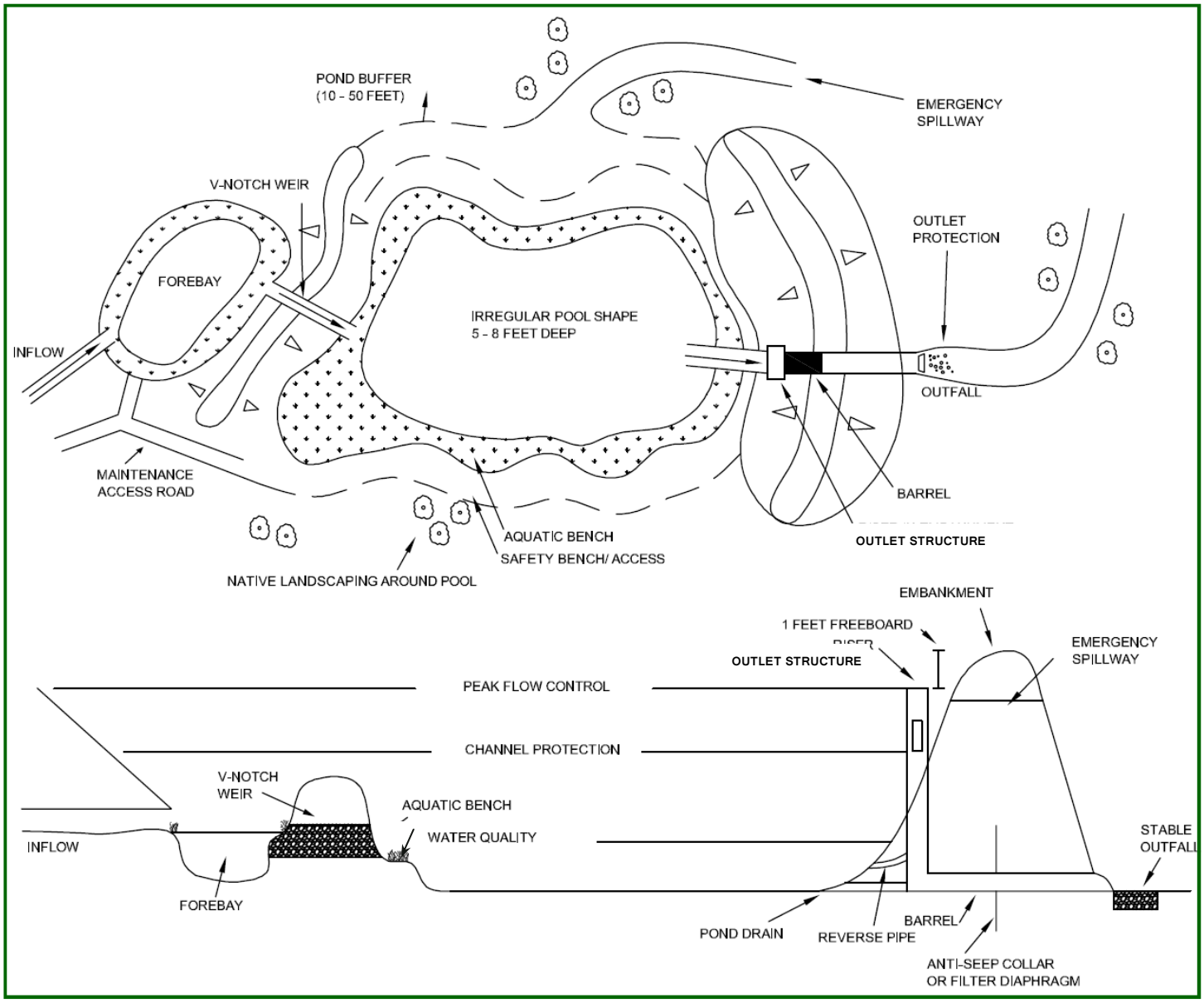

Figure 18.5.4-A. Plan and section of typical green wet basin

Green Wet Basins Application and Site Feasibility Criteria

Table 18.5.4-A.

Design Parameter	Criteria
Drainage Area	At least 25 acres of upstream drainage area to maintain water levels during dry weather; capable of passing the 100 year storm and a minimum of 3 feet deep
Side Slopes	No greater than 3:1 (H:V), flatter is recommended. Aquatic bench should be no greater than 4:1 and safety bench should be relatively flat and cover approximately 25% of total pond surface
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred and emergency spillway
Soil Permeability	Soil permeability should be ≤ 0.14 inches/hour
Pretreatment—Forebay	~ 10-15% of WQ_v
Design Flows and Conveyance Capacity	Detain for at least 24 hours and pass the 2-, 10- and 100-year storms with at least one foot of freeboard. Detention basins shall be fully discharged within 36-hours after the storm event per MSD Design Manual. Note: additional storm events must be considered if participating in the financial incentive program (Section 18.9).

Green Wet Basins Step by Step Design Procedures

Step 1: Define goals/primary function of the green wet basin

Begin by defining the goals/primary function of the green wet basin, especially the extended detention of stormwater runoff. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations. The design should be based on detention basin requirements stipulated in the MSD Design Manual.

Step 2: Determine the peak flow rate and total runoff volume

The green wet basin should be sized to capture and temporarily store for at least 24 hours the runoff volume required by the MSD Design Manual. If MSD's Design Manual requirements are met, the required WQv is presumed to be met as well. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows per MSD's Design Manual. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Note: additional storm events must be considered if participating in the financial incentive program (Section 18.9).

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a green wet basin, including topography, impermeable soils and a groundwater table below the bottom of the pond. Consider Table 18.5.4-A. Create a rough layout of green wet basin dimensions including existing trees, utility lines, topography and other obstructions.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per MSD's Design Manual.

Step 5: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2, 10, and 100-year storm events to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the basin is filling and vegetation is established. Choose erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Step 6: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated water depth zones within the green wet basin. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

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Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.5 Green Dry Basins

Typical Implementation Areas:

- Parks, greenways and common areas
- Detention basin retrofits
- Commercial, multi-family residential and institutional developments

Key Considerations:

- Provides water quality treatment for traditional dry basin
- Used to both detain and treat stormwater
- Use deep rooted, native vegetation along bottom of basin

Cost: Low-Medium
Maintenance: Low-Medium



Green dry basin rendering
(Photo: David Dods, URS, Concept rendering: Shea Powell, Dropseed)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	□
Stormwater Conveyance	□
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Green dry basins are similar to standard dry basins. The exceptions are that a green dry basin contains a forebay for capturing the heavier sediment and floatables, non-turf grass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm events and no low flow channel so sheet flow can be promoted instead. By design green dry basinssw allow for extended detention, about 48 hours. Green dry basins improve water quality through:

- ☑ Biological uptake and filtering through deep rooted, native plants
- ☑ Sediment settling, including attached pollutants
- ☑ Temporary detention of stormwater
- ☑ A slower rate of release that reduces downstream bank erosion

Advantages/Benefits

- Effective at removing sediment
- Increases biodiversity by providing urban habitats for wildlife
- Reduces channel/stream bank erosion by reducing number of bankfull events downstream
- Well accepted by community

Disadvantages/Limitations

- Relatively large space requirement
- Tends not to drain well, leading to maintenance challenges
- Can pose a safety hazard due to water pooling during rain events
- Not to be used in high groundwater areas

Application and Site Feasibility

Green dry basins are similar to standard dry basins, except for the addition of native vegetation, a forebay and a multi-stage outlet. Features may need to be included in basins to minimize short circuiting between the inlet and outlet. Generally, dry ponds need to have a drainage area of at least 10 acres to keep the vegetation watered during the dry periods and to not have too small of a low flow orifice that would likely become plugged with debris. Green dry basins can be constructed new or can be the result of retrofitting standard dry basins. Green dry basins are appropriate for use in a wide variety of land use applications such as commercial, industrial or multi-family residential areas.

Physical Requirements

Key physical considerations are:

- Space available—Sufficient space is required to temporarily store the stormwater runoff
- Drainage area—Have adequately large drainage area to provide some flow during drier weather and maintain larger low flow orifices.
- Plantings—Robust plantings along the bottom of green dry basins provide water quality treatment; plantings need to be able to survive the dry to submerged conditions that they will experience

Design Criteria

The size of green dry basins should be determined using the design requirements for detention basins as described in Chapter 10.3.8 of MSD's Design Manual. The following additional criteria should also be included in the design of green dry basins. For a summary of design parameters, see Table 18.5.5-A on page 7.

Design criteria to consider for green dry basins include:

- Pretreatment—Forebay
- Conveyance
- Outlet
- Landscaping/plant selection
- Safety
- Maintenance

Pretreatment—Forebay

Excessive sediment accumulation in green dry basins can block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the basin. The forebay should be sized to meet the requirements of Chapter 10.3.8 of MSD's Design Manual and prevent the resuspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 4-6 feet, which will also prevent the growth of unwanted vegetation and allow for the survival of mosquito eating fish. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the green dry basin and reduce velocities to prevent erosion. The forebay should also be designed to allow for ready access to perform maintenance, including removal of accumulated sediment and floatables.

Conveyance

Though green dry basins' primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because pooled water in the basins allows opportunities for the solid particles in the stormwater to settle, the flow path needs to be diffuse and as long as possible. To provide a long flow path, basins need to have a length to width ratio of at least 2:1, with 3:1 preferred.

Green dry basins need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the green dry basins will help to spread out and slow down larger flows, reducing the potential for erosion. An emergency spillway is also needed to safely convey the flow out of the green dry basins. The area downstream of the emergency spillway needs to be protected to prevent scour.

Outlet

The design and configuration of the outlet structure should allow for extended detention of the stormwater runoff from the required WQv, 2-year, 10-year and 25-year rain events. The outlet structure will likely consist of a riser connected to a discharge pipe that discharges to the downstream receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars around the discharge pipe to prevent seepage.

A high flow bypass either separate from or in conjunction with the outlet structure should be included to safely convey high flows from large storm events. A minimum of one foot of freeboard should be provided during the 100-year rain event. The discharge from the outlet structure should be equipped with armoring, plunge pool, energy dissipater or similar best management practices to prevent scour.

Landscaping/Plant Selection

A landscaping plan is recommended for planting green dry basins. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Identify ephemeral zones that will be subject to wet and dry periods and dry zones and select plants appropriate for each zone. Choices available for planting the green dry basins include seed, rhizomes, bare root stock and potted plants. Planting

rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 3:1 or flatter and relatively flat safety benches should be provided in the water just above the permanent pool level of the forebay. The maximum depth of the basin should be 10 feet to provide an additional factor of safety.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Green dry basins, if used in series with other GMPs, are typically installed near the outlet structure or the end of the series. Upstream GMPs may include rain gardens and bioretention basins.

Educational Awareness

To maintain the integrity of green dry basins, those maintaining them need to understand that the basins and their associated plantings are a stormwater management feature that also provides aesthetic beauty and ecosystem benefit. Signage should be provided at green dry basins to include awareness information that they are a "no mow" zone and for managing stormwater runoff.



Green dry basin rendering
(Photo: Erin Wagoner, URS, Concept rendering: Shea Powell, Dropseed)

Green Dry Basins Application and Site Feasibility Criteria

Table 18.5.5-A.

Design Parameter	Criteria
Drainage Area	At least 10 acres of upstream drainage area to provide watering of vegetation during dry weather
Side Slopes	No greater than 3:1 (H:V), flatter is recommended. Safety bench around forebay just below the permanent water level should be relatively flat.
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred
Pretreatment—Forebay	Size pretreatment forebay per MSD Design Manual requirements
Design Flows and Conveyance Capacity	Pass the 2-, 10- and 100-year storms with at least one foot of freeboard. Detention basins shall be fully discharged within 36 hours after the storm event per MSD Design Manual.
Sizing Storage Capacity	MSD Design Manual detention basin requirements

Green Dry Basins Step by Step Design Procedures

Step 1: Define goals/primary function of the green dry basin

Begin by defining the goals/primary function of the green dry basin, especially the extended detention of stormwater runoff. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations. The design should be based on MSD's detention basin requirements stipulated in the MSD Design Manual.

Step 2: Determine the peak flow rate and total runoff volume

The green dry basin should be sized to capture and temporarily store the runoff volume required by the MSD Design Manual. If the Design Manual requirements are met, the required WQv is presumed to be met as well. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows per MSD's Design Manual. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a green dry basin. Consider Table 18.5.5-A. Create a rough layout of green dry basin dimensions including existing trees, utility lines, topography and other obstructions.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per the Chapter 10.3.8 of MSD's Design Manual.

Step 5: Determine outlet design

Based on the green dry basin configuration, check water surface elevations for all storm events (shown in Step 2) so the basin can pass these flows safely and drain empty within 36 hours. This includes meeting the 1 foot freeboard requirement for the 100-year storm event and determining the need for erosion prevention and energy dissipation measures at the outlet. Modify design as appropriate.

Step 6: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2-year to 100-year storm events to maximum permissible velocities for the soil types present at the site and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the basin is filling and vegetation is becoming established. Choose an erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Step 7: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances and the anticipated water depth zones within the green dry basin. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

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Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.6 Extensive Green Roof

Typical Implementation Areas:

- Rooftops including urban commercial and residential use
- Urban public space

Key Considerations:

- Structural capacity of building
- Slope of roof
- Use of drought tolerant native vegetation or cultivars

Cost: High
Maintenance: Low



Extensive green roof planted with vegetables (foreground) and sedum (background) (Photo: Chad McCormick, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	☐
Phosphorus	☐
Nitrogen	☐
Metals	☐
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	☐
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	■
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

An extensive green roof is a roofing system made up of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive green roofs are classified as green roofs with a soil depth of six inches or less. This shallow soil layer is designed to support dense, low growing, drought tolerant vegetation. Green roofs may also be called vegetated roofs or eco-roofs. Green roofs improve water quality through:

- ☑ Significant reduction of roof runoff volume
- ☑ Reduction of runoff pollutant loads compared to traditional roof applications
- ☑ Reduction of impervious area
- ☑ Biological uptake through drought tolerant plants

Advantages/Benefits

- Reduces energy costs
- Provides additional roof insulation
- Reduces urban heat island effect
- Improves air quality
- Extends life of roof
- Adds landscaping value to outdoor rooftop gathering spaces
- Provides wildlife habitat
- Allows for retrofit opportunities

Disadvantages/Limitations

- Roof strength/structure may limit retrofit application
- Extreme sun and wind conditions can challenge plant survival
- Potential for roof leaks
- Irrigation often necessary to establish plants
- Planting on a sloped roof requires erosion control structures

Application and Site Feasibility

An extensive green roof can be placed on high density residential, commercial, or industrial buildings that have the structural stability to support the increased loads of the green roof system. Passive outdoor amenity/recreational spaces may benefit or compliment a green roof with paths and patio areas adjacent to planting beds. Rooftops may be flat or sloped as steep as 25%, given consideration for structural stability and erosion control of the system. An extensive green roof may be constructed on a new roof, or a remodeled roof that has the waterproofing and structural stability to hold the system in saturated, wet weather conditions. Especially in ultra urban areas, green roofs can be used as passive recreational spaces including roof garden patios or functioning vegetable and herb gardens.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof must be structurally capable of supporting saturated soil media, vegetation and other structural loads. Substrate depths for extensive green roofs may vary from 2 to 6 inches. Shallower planting depths can reduce costs and structural loads.
- Roof waterproofing and drainage—The drainage layer is a key component to convey excess moisture through saturated soils and off the roof deck. The roof must be waterproofed to prevent leaking and damage of the structure below. Leak detection systems may be installed to identify and locate leaks.
- Plant selection—Plant selection is limited due to extreme rooftop weather conditions including wind, sun, drought and cold winter temperatures. Plants selected should be able to withstand these extreme conditions.
- Slope of rooftop—Extensive green roofs are suitable for both flat or sloped rooftops, but are much easier to design and install for flat rooftops (with a pitch of up to 1.5 %). Rooftops with steep slopes require additional structural components to hold the soil and drainage layers in place and prevent erosion. Rooftops with slopes greater than 25% are not suitable for extensive green roofs.

Design Criteria

Green roofs should be designed to manage the WQv of runoff. Extensive green roofs have several elements to manage stormwater including eliminating impervious area, stormwater retention and plant absorption and reduction of stormwater runoff volumes. There are proprietary applications on the market that design green roof systems, in addition to utilizing the guidance provided here. See Figure 18.5.6-A for a typical exstensive green roof cross-section. For a summary of design parameters, see Table 18.5.6-A on page 6.

Design criteria to consider includes:

- Location of the green roof bed
- Structural integrity
- Waterproofing
- Drainage
- Soil and plants
- Maintenance



Newly planted sedum on extensive green roof (Photo: Erin Wagoner, URS)



Established sedum plants on extensive green roof (Photo: Chad McCormick, URS)

Location of Green Roof Bed

Consider the purpose of the green roof. If the roof is intended for access by building occupants or patrons, beds must be separated by walking paths and patio areas. Beds should be clearly delineated and separated to minimize damage to plants and compression of soils due to walking or standing.

Wind and uplift pressures tend to be higher around the roof perimeter, and therefore should have a vegetation-free buffer between the green roof bed and the edge of the roof. Any rooftop openings should also have a vegetation-free buffer.

Structural Integrity of Roof

The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an extensive green roof. Both the dead load, including the total weight of green roof materials; saturated soil and snow loads, and other live loads must be considered.

Waterproofing

Since water is being retained on the rooftop, it is essential to have adequate waterproofing to minimize leaks that can damage the building interior. Waterproofing may be accomplished through the use of a waterproofing membrane or other waterproofing roofing systems. See Figure 18.5.6-A. Coordinate with the roofing system manufacturer for application and comply with their specifications for installation.

A protective layer or root barrier should be used to prevent roots from damaging the waterproof membrane. Electronic leak detection systems may also be considered to notify and locate leaks when they occur.

Drainage

The drainage layer often consists of a manufactured material or a shallow gravel layer to store stormwater for plant uptake and routing of stormwater. Rooftops should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.

Downspouts should not be directly connected to the sewer system, and should be routed to another green management practice, such as a cistern, rain garden, bioswale or pervious pavement.



Roof garden patio includes a green house and extensive green roof planted with vegetables and herbs (Photo: Chad McCormick, URS)



Installation of plants on an extensive green roof (Photo: Louisville & Jefferson County MSD)

Soil and Plants

Soils for extensive green roofs should be between 2 and 6 inches thick. The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical extensive green roof soil mix may consist of the following materials, by volume:

- 50% pumice perlite
- 25% organic compost
- 25% topsoil

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. Although perennial, self-sustaining, native plant varieties are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities or function. Native and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Green roofs, if used with other GMPs, are typically the first in the series or treatment train, collecting stormwater at the source. Excess runoff from saturated soils or from the roof perimeter can be routed from downspouts to a treatment train of cisterns, pervious pavement, rain gardens or planters.

Educational Awareness

To maintain a green roof and the structure beneath it, those maintaining it need to understand that the roof is a stormwater management feature that needs to be maintained.



Extensive green roof showing drainage slots and non-vegetated buffer along roof perimeter (Photo: Erin Wagoner, URS)



Extensive green roof with non-vegetated access path and buffers around vents (Photo: Erin Wagoner, URS)



Excess drainage from extensive green roof flows from drainage layer slots over non-vegetated buffer to roof downspouts, which discharge into a rain garden (Photo: Erin Wagoner, URS)

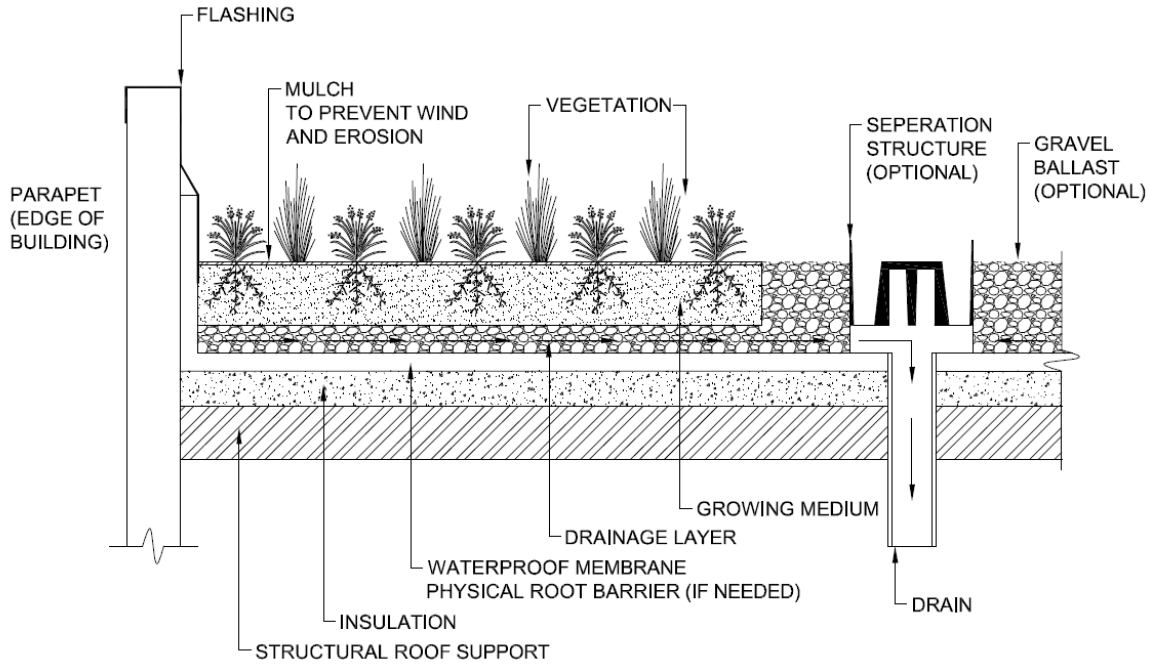


Stormwater treatment train flows from green roof to cisterns to a bioswale (Photo: Ted Wathen The Green Building)

Extensive Green Roof Application and Site Feasibility Criteria

Table 18.5.6-A.

Design Parameter	Criteria
Waterproofing Roof	Roof must contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Soil Mix	The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical green roof soil mix may consist of the following materials, by volume: • 50% pumice perlite • 25% organic compost • 25% topsoil
Storage Capacity	Green roof total volume should be equivalent to the Required WQv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A)$- (WQ_{VR}), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009(I)$, where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the green roof (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
Structural Integrity of Roof	The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an extensive green roof.



ECOROOF WITH DRAINAGE LAYER

Figure 18.5.6-A. Typical extensive green roof (soil depth of 6 inches or less)

Extensive Green Roof Step by Step Design Procedures

Step 1: Define goals/primary function of the green roof

Define the goals/primary function of the green roof. Consider whether the roof is intended to:

- Provide passive recreational space
- Support loads in addition to the green roof system
- Treat excess stormwater by routing through a series of GMPs

Consider any special site-specific design conditions/criteria. Where traditional rooftops may be proposed, consider using a green roof as an alternative if the structure will support additional loads. Locate roof downspouts and check potential locations/available space incorporating a series of GMPs down gradient of the green roof. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions, requirements, goals and primary function(s) of the green roof. Manufactured systems may be used and could include modular, tray or rolled systems.

Step 2: Determine if structure is appropriate

Based on the defined goals for the green roof, determine if the structure is appropriate and can support additional loads. Use Table 18.5.6-A.

Step 3: Determine the total runoff volume and drainage

The green roof system should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.6-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

Green roofs must be designed to safely convey excess runoff produced by larger storm events through a drainage layer. Sloped rooftops should consider erosion protection and stabilization.

Step 4: Determine green roof dimensions

Calculate the required volume of the green roof based on the void space of the planting media and storage of the drainage layer so that it can store the WQv per Table 18.5.6-A. Locate non-vegetated buffers along the roof perimeter and around the base of any openings in the roof.

Step 5: Prepare vegetation plan

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Invasive species must not be used.

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18.5.7 Intensive Green Roof



Intensive (deep) and extensive (shallow) green roof beds
(Photo: Louisville & Jefferson County MSD)

Typical Implementation Areas:

- Rooftops including urban commercial and residential use
- Urban public space

Key Considerations:

- Structural capacity of building
- Use of drought tolerant native vegetation or cultivars
- Slope of roof

Cost: High
Maintenance: Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	☐
Phosphorus	☐
Nitrogen	☐
Metals	☐
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	☐
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	■
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

An intensive green roof is a roofing system made up of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Intensive green roofs have soil depths greater than six inches to support the root growth of larger plants, shrubs and trees. The soil layer is designed to support trees or elaborate rooftop gardens. Green roofs may also be called vegetated roofs or eco-roofs. Green roofs improve water quality through:

- ☑ Significant reduction of roof runoff volume
- ☑ Reduction of runoff pollutant loads compared to traditional roof applications
- ☑ Reduction of impervious area to closely mimic pre-developed hydrology
- ☑ Biological uptake through drought tolerant plants

Advantages/Benefits

- Reduces energy costs
- Provides additional roof insulation
- Reduces urban heat island effect
- Improves air quality
- Extends life of roof
- Adds landscaping value to outdoor rooftop gathering spaces
- Provides wildlife habitat
- Allows for retrofit opportunities

Disadvantages/Limitations

- Roof strength/structure may limit retrofit application
- Extreme sun and wind conditions can challenge plant survival
- Potential for roof leaks
- Irrigation often necessary to establish and maintain plants
- Not recommended for sloped rooftops

Application and Site Feasibility

An intensive green roof can be placed on high density residential, commercial or industrial buildings that have the structural stability to support the increased loads of the green roof system. Passive outdoor amenity/recreational spaces may benefit or compliment a green roof with paths and patio areas adjacent to planting beds. Rooftops for intensive green roofs must be flat or slightly sloped. Although an intensive green roof may be constructed on an existing structure, they are more often designed for new construction due to the increased loads. Intensive green roof beds can be combined with shallower, extensive beds to supplement the roof with larger shrubs or trees at less cost than designing the entire roof as an intensive green roof.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof must be structurally capable of supporting saturated soil media, vegetation and other structural loads. Substrate depths for intensive green roofs are greater than 6 inches and less than 24 inches, to accommodate tree and shrub root systems.
- Roof waterproofing and drainage—The drainage layer is a key component to convey excess moisture through saturated soils and off the roof deck. The roof must be waterproofed to prevent leaking and damage of the structure below. The waterproofing layer should be protected to prevent roots from damaging it. Leak detection systems may be installed to identify and locate leaks.
- Plant selection—Plant selection is limited due to extreme rooftop weather conditions including wind, sun, drought and cold winter temperatures. Plants selected should be able to withstand these extreme conditions. Intensive green roofs require increased maintenance or irrigation during extreme conditions
- Slope of rooftop—Intensive green roofs are suitable for both flat or slightly sloped rooftops, up to 10%.

Design Criteria

Green roofs should be designed to manage the WQv of runoff. Intensive green roofs have several elements to manage stormwater including eliminating impervious area, stormwater retention and plant absorption to facilitate water and air quality improvement and reduction of stormwater runoff volumes into the sewer system. There are manufacturers and proprietary applications on the market that design green roof systems, in addition to utilizing the guidance provided here. See Figure 18.5.7-A for a typical cross-section of an intensive green roof planting. For a summary of design parameters, see Table 18.5.7-A.



Intensive green roof beds, planted with evergreen shrubs (Photo: Chad McCormick, URS)

Design criteria to consider includes:

- Location of the green roof bed
- Structural integrity
- Waterproofing
- Drainage
- Soil and plants
- Maintenance

Location of Green Roof Bed

Consider the purpose of the green roof. Most intensive green roofs are intended for use by building occupants, patrons or the general public. Green roof beds must be separate from walking paths and patio areas. Beds should be clearly delineated and separated to minimize damage to plants and compression of soils due to walking or standing.

Wind and uplift pressures tend to be higher around the roof perimeter, and therefore should have a vegetation-free buffer between the green roof bed and the edge of the roof. Any rooftop openings should also have a vegetation-free buffer.

Structural Integrity of Roof

The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an intensive green roof. The dead load, including the total weight of green roof materials; saturated soil and snow loads; and other live loads must be considered. The placement of large trees or shrubs should be located over columns or main beams to support the heavy weight of the soil and plant.

Waterproofing

Since water is being retained on the rooftop, it is essential to have adequate waterproofing to minimize leaks that can damage the building interior. Waterproofing may be accomplished through the use of a waterproofing membrane or other waterproofing roofing system. Coordinate with the roofing system manufacturer for application and comply with their specifications for installation.

A protective layer or root barrier should be used to prevent roots from damaging the waterproof membrane. The root balls of large trees and shrubs should also be anchored to avoid piercing the waterproof membrane. Electronic leak detection systems may also be considered to notify and locate leaks when they occur.

Drainage

The drainage layer often consists of a manufactured material or a shallow gravel layer to store stormwater for plant uptake and routing of stormwater. Rooftops should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.

Downspouts should not be directly connected to the sewer system, and should be routed to another green management practice, such as a cistern, rain garden, bioswale or pervious pavement.

Soil and Plants

Soils for intensive green roofs should be greater than 6 inches thick. The soil mix may be determined by the designer or product manufacturer and can vary based on selected plant species. A typical extensive green roof soil mix may consist of the following materials, by volume:

- 50% pumice perlite
- 25% organic compost
- 25% topsoil

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Intensive green roof plants require more maintenance such as irrigation and pruning compared to extensive green roof plants. To reduce maintenance, plants



Extensive green roof beds (foreground) are paired with intensive green roof beds (background), planted with evergreen shrubs (Photo: Chad McCormick, URS)

should be selected with the goal of reducing the need for irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Although perennial, self-sustaining, native plant varieties are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities or function. Native and cultivar species are provided in Chapter 13 of the MSD Design Manual. Especially in ultra urban areas, extensive green roofs can be used as passive recreational spaces including elaborate roof garden patios or functioning vegetable and herb gardens.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Train—Combination and Location in Series With Other GMPs

Green roofs, if used with other GMPs, are typically the first in the series or treatment train, collecting stormwater at the source. Excess runoff from saturated soils or from the roof perimeter can be routed from downspouts to a treatment train of cisterns, pervious pavement, rain gardens or planters.

Educational Awareness

To maintain a green roof and the structure beneath it, maintenance of this stormwater management feature is critical. It is especially important to check for leaks in the waterproofing, weed periodically to pull out any plant growth over one foot tall (typically from tree seeds), limit irrigation and keep gutters and downspouts clear of leaves and debris.

Application and Site Feasibility Criteria

Table 18.5.7-A.

Design Parameter	Criteria
Waterproofing Roof	Roof must contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Soil Mix	The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical green roof soil mix may consist of the following materials, by volume: • 50% pumice perlite • 25% organic compost • 25% topsoil
Storage Capacity	Green roof total volume should be equivalent to the Required WQv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A)$ - (WQ_{VR}), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the green roof (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
Structural Integrity of Roof	The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an intensive green roof.

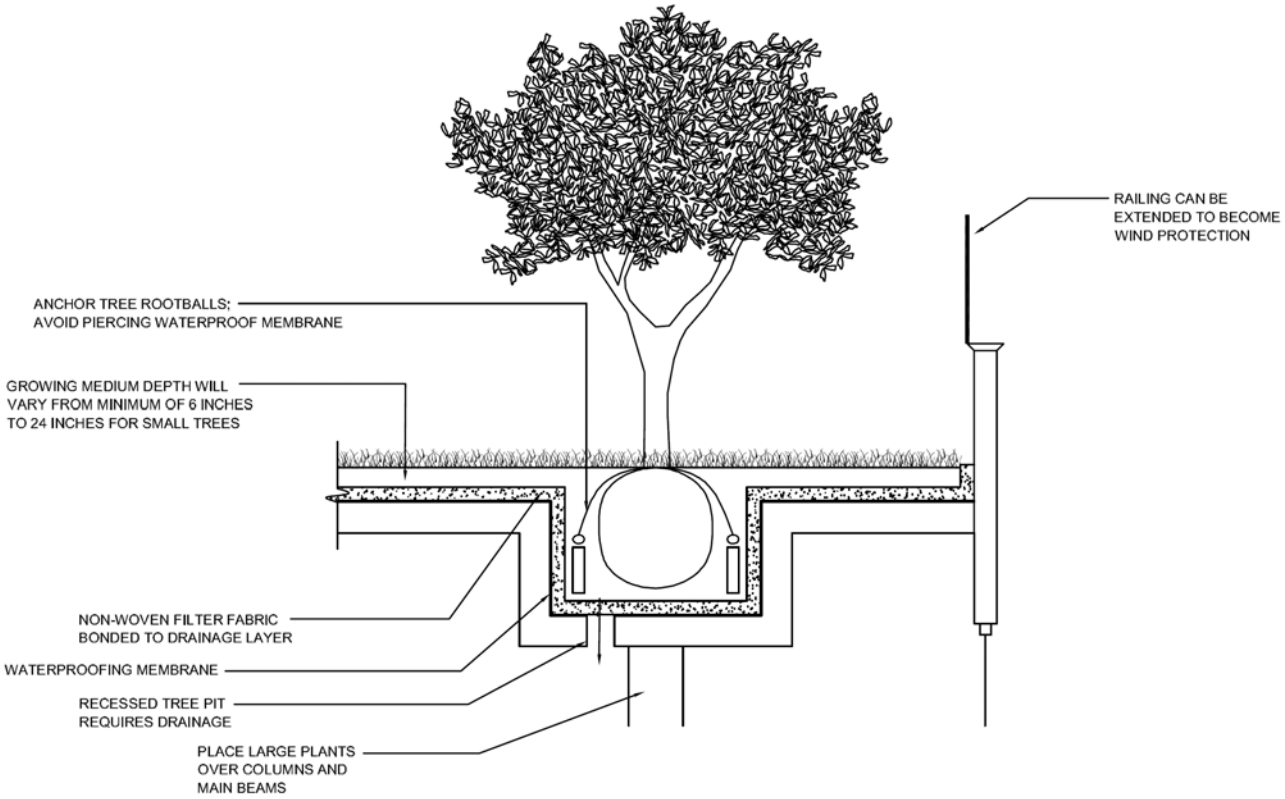

Figure 18.5.7-A. Cross-sectional View

Step by Step Design Procedures

Step 1: Define goals/primary function of the green roof

Define the goals/primary function of the green roof. Consider whether the roof is intended to:

- Provide passive recreational space
- Support loads in addition to the green roof system
- Treat excess stormwater by routing through a series of GMPs

Consider any special site-specific design conditions/criteria. Where traditional rooftops may be proposed, and where the structure will support additional loads consider using a green roof as an alternative. Locate roof downspouts and check potential locations/available space incorporating a series of GMPs down gradient of the green roof. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply. The design should be based on the restrictions/requirements, goals and primary function(s) of the green roof.

Step 2: Determine if structure is appropriate

Based on the defined goals for the green roof, determine if the structure is appropriate and can support additional loads. When designing intensive green roofs, the placement of large trees or shrubs should be located over columns or main beams to support the heavy weight of the soil and plant. Use Table 18.5.7-A.

Step 3: Determine the total runoff volume and drainage

The green roof system should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.7-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

Green roofs must be designed to safely convey excess runoff produced by larger storm events through a drainage layer. Sloped rooftops should consider erosion protection and stabilization.

Step 4: Determine green roof dimensions

Calculate the required volume of the green roof based on the void space of the planting media and storage of the drainage layer so that it can store the WQv per Table 18.5.7-A. Locate non-vegetated buffers along the roof perimeter and around the base of any openings in the roof.

Step 5: Prepare vegetation plan

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Invasive species must not be used.

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18.5.8 Blue Roof



Blue roof adjacent to green roof (Photo: New York City Blue Roof and Green Roof Comparison Study)

Typical Implementation Areas:

- Commercial, industrial, multi-family residential and institutional developments
- Highly urbanized areas

Key Considerations:

- Waterproof and structurally sufficient roof
- Used to detain stormwater
- Slope of roof

Cost: Medium
Maintenance: Low

Stormwater Management Benefits

Pollutant Reduction	
Sediment	☐
Phosphorus	☐
Nitrogen	☐
Metals	☐
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	☐
Infiltration	☐
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

A blue roof, also referred to as rooftop detention, is the practice of storing 1 to 4 inches of rainfall on the roof and slowly releasing it into the storm sewer system over a period of time, typically 24 hours. Some blue roofs also incorporate passive recreation, such as sun-bathing and water play areas, as an added bonus. To accomplish the rooftop detention, outlet devices consisting of weirs or orifice plates are placed around the roof drains, allowing some rainfall to discharge down the roof drain while the rest is temporarily stored. Should rainfall exceed the design detention depth and volume, the collected rainfall would flow over the weir or orifice plate and into the roof drain. A blue roof improves water quality through:

☑ Temporary detention of stormwater and reduction of peak flows

Advantages/Benefits

- Reduces channel/stream bank erosion by reducing number of downstream bankfull events
- Opportunity for multiple uses, including passive recreation
- Ability to store water around the perimeter of roofs if designed correctly
- Cost-effective way to capture rainfall volume

Disadvantages/Limitations

- Possible roof reinforcing requirements
- Potential for roof leaks
- Can only be applied to a relatively flat roof

Application and Site Feasibility

A blue roof is similar to a standard flat roof, except for the addition of a waterproofing system and the necessary structural stability to support the detained rainwater. The roof needs to be relatively flat to store the required rainwater without exceeding the ponding levels and load limits of the roof. A blue roof can be constructed on a new roof, or a remodeled roof that has the waterproofing and structural stability to store the desired rainfall depth. A blue roof is appropriate for use in a wide variety of land use applications such as commercial, industrial or multi-family residential highly urbanized areas.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof has to be structurally capable of supporting the stored rainwater
- Roof waterproofing—Roof has to be waterproof to prevent leakage and damage of the structure below
- Slope of roof—Roof slope should be relatively flat

Design Criteria

A blue roof should be able to collect and temporarily detain the required WQv rainfall event over a 24 hour period following the rain event. Detainage of the rainfall can be accomplished through the use of weirs and orifice plates on the roof drains or valving. For a summary of design parameters, see Table 18.5.8-A on the next page.

Design Criteria to consider for a blue roof includes:

- Water Storage Depth
- Structural Integrity
- Waterproofing
- Outlets
- Maintenance

Water Storage Depth

The water storage depth is typically between 1-4 inches, based on the storage volume needed, the slope of the roof and the structural integrity of the roof.

Structural Integrity

The structural integrity of the roof should be evaluated by a licensed structural engineer. The engineer should determine the loading limits of the roofing system to determine the depth and volume of rainwater that the roof can detain.

Waterproofing

For a roof to detain rainfall, it has to be waterproof. This may be accomplished through the use of a waterproofing membrane or a fluid applied waterproofing roofing system. Coordinate with the roofing system manufacturer for application and comply with their installation specifications .

Outlets

Weirs or orifice plates are needed around the roof drains/ outlets to restrict runoff from the roof and temporarily detain the rainfall. Valving can also be used to serve the same purpose. The roofing system needs to include overflows and an adequate number of roof drains/outlets to pass the larger rain events, even if 35% of the drains/ outlets are clogged with leaves and debris. Typically a minimum of two roof drains/outlets are required for a smaller roof (10,000 square feet and less) and four or more are required for a larger roof.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A blue roof, if used in series with other GMPs to provide stormwater management, is typically at the beginning of the treatment train because it collects water at the source.

Educational Awareness

To maintain the integrity of a blue roof and the structure under it, those maintaining should be aware that the roof is a stormwater management feature that needs to be maintained.

Blue Roof Application and Site Feasibility Criteria

Table 18.5.8-A.

Design Parameter	Criteria
Water Storage Depth	Determine the structural integrity of the roof. Typical water storage depth is 1-4 inches.
Waterproofing Roof	Roof has to contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Detention	Stormwater should be slowly released over the 24 hours following the storm event.
Storage Capacity	Blue roof total volume of detained water should be equivalent to the Required WQv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A) - (WQ_{VR})$, where • RE_{WQV} = Required WQv Rain Event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009\ (I)$ ♦ I = impervious cover in percent • A = the drainage area to the blue roof (ft^2). • $WQ_{VR} = (1/12)(RE_{WQV})(Rv)(IA_R)$ ♦ Where IA_R = reduced impervious area

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18.5.9 Permeable Pavers

Typical Implementation Areas:

- Parking lot stalls and overflow parking
- Crosswalks, sidewalks, multi-use paths

Key Considerations:

- Soil type and stability
- Grade
- Traffic volume
- Type of desired drainage
- Storage retention/infiltration
- Ratio of drainage area to area of pavers

Cost: High
Maintenance: High



Installation of permeable interlocking concrete pavers
(Photo: Louisville & Jefferson County MSD)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	◪
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefits
☐ Low or Unknown Benefits

Permeable pavers are pavement surfaces that promote infiltration of stormwater. Pavers can be used in numerous locations, are aesthetically pleasing and are Americans with Disabilities Act (ADA) compliant. Permeable pavers consist of individual concrete or stone shapes that are placed adjacent to one another over a specially designed sub-base. Permeable Pavers improve water quality through:

- ☑ Effective removal of light sediment and pollutants
- ☑ Possible reduction of stormwater runoff through infiltration to surrounding soils
- ☑ Surface flow reduction of peak flows

Advantages/Benefits

- Reduces volume of stormwater runoff
- Reduces impermeable areas
- Reduces need for drain pipe
- Longer life than traditional pavement
- Reusable product
- Reduces need for detention space
- Attractive/aesthetic pavement options

Disadvantages/Limitations

- Higher cost of pavers versus traditional concrete or asphalt pavement
- Geotechnical exploration required
- Maintenance requirements
- Specialized knowledge required for proper installation
- Not recommended for use in roadway
- Not recommended under tree canopy

Application and Site Feasibility

Permeable pavers are an alternative to traditional asphalt and concrete paving methods, and allow stormwater to infiltrate into the soil below. A Professional (Geologist or Engineer) with geotechnical experience shall evaluate the soil to determine the proper design for the site being considered for permeable pavers. The Engineer shall determine the capacity, permeability and the soil type of the selected site. It is recommended that samples be taken of the site prior to construction to be used as a reference to ensure proper material is being used. This will help contractors be consistent in providing the specified aggregate during construction. To minimize the frequency and amount of needed maintenance, it is recommended that strict silt control measures be used. By keeping the site clean during construction and keeping vegetation along the application will reduce clogging on the practice once the construction is complete. See section 10.5.20 for the aggregate specifications. Testing of the site shall be done in accordance with the recommendations of the Interlocking Concrete Pavement Institute (ICPI). More information on ICPI can be found at www.icpi.org. Permeable paver design procedures assume a subsoil California Bearing Ratio (CBR) strength of at least 4% to 5% to qualify for use under vehicular traffic. Table 18.5.9-A below summarizes typical CBR ranges based on soil classification.

Table 18.5.9-A. Suitability of Soils and Typical CBR Ranges (Unified Soil Classification System)

USCS Soil Classification	Typical Ranges for Coefficient of Permeability, k, in/hour	Relative Permeability when Compacted and Saturated	Shearing Strength when Compacted	Compressibility	Typical CBR Range (%)
GW– well graded gravels	1.3 to 137	Permeable	Excellent	Negligible	30-80
GP– poorly graded gravels	6.8 to 137	Very Permeable	Good	Negligible	20-60
GM– silty gravels	$1.3x10^{-4}$ to 13.5	Semi-Permeable to impermeable	Good	Negligible	20-60
GC– clayey gravel	$1.3x10^{-4}$ to $1.3x10^{-2}$	Impermeable	Good to Fair	Very Low	20-40
SW– well graded sands	0.7 to 68	Permeable	Excellent	Negligible	10-40
SP– poorly graded sands	0.07 to 0.7	Permeable to semi-permeable	Good	Very Low	10-40
SM– silty sands	$1.3x10^{-4}$ to 0.7	Semi-permeable to impermeable	Good	Low	10-40
SC– clayey sands	$1.3x10^{-5}$ to 0.7	Impermeable	Good to Fair	Low	5-20
ML– inorganic silts/low plasticity	$1.3x10^{-5}$ to 0.07	Impermeable	Fair	Medium	2-15
CL– inorganic clays/ low plasticity	$1.3x10^{-5}$ to $1.3x10^{-3}$	Impermeable	Fair	Medium	2-5
OL– organic silts/ low plasticity	$1.3x10^{-5}$ to $1.3x10^{-2}$	Impermeable	Poor	Medium	2-5
MH– inorganic silts/high plasticity	$1.3x10^{-6}$ to $1.3x10^{-5}$	Very Impermeable	Fair to Poor	High	2-10
CH– inorganic clays/high plasticity	$1.3x10^{-7}$ to $1.3x10^{-5}$	Very Impermeable	Poor	High	2-5

Physical Site Considerations

Minimum site requirements:

- The natural water table should be a minimum of three feet below the subsoil surface
- Surrounding topography should have a maximum slope of 20%
- There should be a minimum separation of fifteen feet from buildings
- The site should have a low volume of traffic and not support construction vehicles
- Proper soil inspection

Design Criteria

The base layer under the permeable pavers is key to their performance. The design of this layer is based on vehicle equivalent single axle loads (ESALS), soil subgrade (geotechnical review), frost heave, design vehicle, pedestrian usage and the paver manufacturer's instructions. While the actual paver is designed to last much longer, most pavement/base designs are based upon a 20 year pavement life. The design and installation of permeable pavers shall be performed by qualified professionals. See Figures 18.5.9-A through 18.5.9-C for permeable pavers typical sections. For a summary of design parameters, see Table 18.5.9-B. Consider the following criteria when using permeable pavers for a green management practice:

- Intended Use
- Storage Capacity
- Slopes (Subsoil and Pavement)
- Soil Stabilization
- Edge Restraint
- Base Design
- Choker Course
- Permeable Paver Selection
- Frost Heave Consideration
- Outlet Design
- Maintenance

Intended Use

Intended use is a key consideration when selecting the type of permeable paver. This fact sheet addresses brick, concrete, concrete/grass grid, gravel and articulated concrete block paver types. Intended use will drive the selection of paver type, for example grass pavers would be suitable for overflow parking, but not for heavily traveled surface roads. Site specific considerations should be evaluated per this fact sheet and discussed with the product manufacturer.

Storage Capacity

The base layers of the permeable paver system are designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The base layers provide a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The engineer will design the base layers, or the appropriate outlet system, to provide a depth that will accommodate required water WQv (refer to Chapter 18.3).



These permeable pavers in a parking lot at Cherokee Park are concrete grid permeable pavers, consisting of a grid filled with topsoil and planted with grass. Concrete grid permeable pavers should be used for light traffic use, such as this overflow parking lot. (Photos: Erin Wagoner, URS)

The WQv provided by the designed permeable paver system can be calculated using the equation in Table 18.5.9-B. The WQv provided should meet or exceed the required WQv.

Slopes (Subsoil and Pavement)

If a large slope is applied to either the pavement surface or subsoil the depth of the base and/or the effective subsoil must be increased to account for the loss of capacity. If the base depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that

the surface and subsoil have a 0% slope and the surface have a 0.5% slope if it is at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with permeable pavers as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns, geogrid shall be placed on the subsoil surface before any of the aggregate layers are placed. If the aggregate layer is greater than twelve inches it is recommended to place a second layer of geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads, the deformation/failure of the soil and pavement are greatly decreased, resulting in less failure in the pavement system over time. Any geogrid used in conjunction with the permeable pavers shall include the following geogrid specifications, at a minimum:

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Edge Restraint

An edge restraint is a concrete barrier around the perimeter of the permeable pavers not placed adjacent to another paved surface. It is typically made of concrete and can be made to look like a curb. This feature can be placed flush with the top of the pavers so that it can be driven over or if overflow is desired. The concrete edge restraint should extend to the lesser of: the bottom of the base layer or 18 inches below the surface of the permeable pavers. The edge restraint is used to keep the pavers from shifting after a load is placed on them. Edge restraints are only required for articulated concrete blocks.

Base Design

The base of the permeable paver system will act as the storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The base should be made up of 2 layers of washed aggregate. The first layer is placed directly on the geogrid and consists of double washed No. 3 stone. This



Mechanical installation of permeable interlocking concrete pavers (Photo: Erin Wagoner, URS)



Installation of permeable interlocking concrete pavers (Photo: Louisville & Jefferson County MSD)

first layer should be a minimum thickness of 12 inches (18.5 inches where frost heave is a concern). Due to the thickness of the first layer, a second layer of geogrid is recommended to be placed between the two layers of stone in the base layer. The second layer of stone consists of double washed No. 57 stone and should be placed directly upon the geogrid covering the No. 3 stone. This second layer of base should be a minimum of 4 inches thick. The entire base layer (including both the No. 3 and No. 57 layers should be a minimum of 16 inches thick (21.5 inches thick where frost heave is a concern). See section 18.5.21, Aggregate Specifications, for additional guidelines on the aggregate used for this practice. This minimum thickness will be structurally sufficient for the design ESAL of permeable pavers. The base thickness may be increased based on storage capacity. The base layer should completely drain after a design storm event if properly maintained.

Choker Course

The choker course is placed on top of the base layer and should be comprised of washed No. 8 aggregate. The minimum thickness of the choker course is 1.5 inches. This course serves as a leveling surface for the pavers. The aggregate in the base is too large to produce an even surface suitable for the pavers to achieve a smooth surface. Choker Course should be used for brick, concrete, and articulated concrete block pavers.

Permeable Paver Selection

Permeable Paver selection for the surface layer is dependent primarily on aesthetics and functionality. Types of permeable pavers include:

Brick

- Made of natural materials
- Suitable for road and paths
- Available in a variety of colors

Concrete

- Made of natural materials
- Suitable for roads and paths

Concrete Grid/Grass Grid

- Made of natural materials
- Suitable for overflow parking, paths, and utility access
- Emergency access lanes

Gravel (Course Graded-Well Draining)

- Made of natural materials
- Suitable for trails, parking and storage
- Emergency access lanes



A snow plow removing snow from pavers (Photo: Advanced Pavement Technologies)



Installation of articulated concrete block mats (Photo: Site Supply, Inc)

Articulated Concrete Block

- No.8 stone required between pavers
- Due to settlement and torquing, blocks with arches are not permitted.
- Made of natural materials
- Suitable for roads, walking paths and parking lots

Frost Heave Considerations

As with any type of pavement surface, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the base layer should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average of a 3 feet frost depth).

Outlet Design

If the site prevents the surface and subsoil of the permeable pavers from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the use of an underdrain system or overflow must be implemented.

Underdrain System

If the recommended CBR value for the subsoil does not yield the desired porosity for the water to percolate, or if it is desired to capture and reuse the runoff, then an underdrain system should be used. Underdrain systems are a series of pipes that run longitudinal with the pavers. The pipes used in an underdrain system are perforated pipes that tie into a non-perforated outlet. The size of the pipe is determined by the calculated stormwater capacity drained onto the permeable pavers. Perched or elbowed underdrains (Figure 18.5.9-B) are encouraged to allow for temporary storage and groundwater infiltration. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

Overflow Design

An alternative to the underdrain system, if the soil has been determined unable to adequately infiltrate stormwater, is an overflow. An overflow directs water that cannot infiltrate into the subsoil to a specific location like a bioswale, rain garden or storm sewer where it can be stored, infiltrated or conveyed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed permeable pavers can easily be located in series with other GMPs such as bioswales or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a permeable pavers and traditional pavers may not be visible to everyone. To maintain the integrity of the permeable pavers, it is important that those maintaining it, as well as the general public, understand that the permeable pavers are stormwater management features that also provide aesthetic beauty. Training of maintenance staff may be required.



Construction of a green parking lot
(Photo: Louisville & Jefferson County MSD)

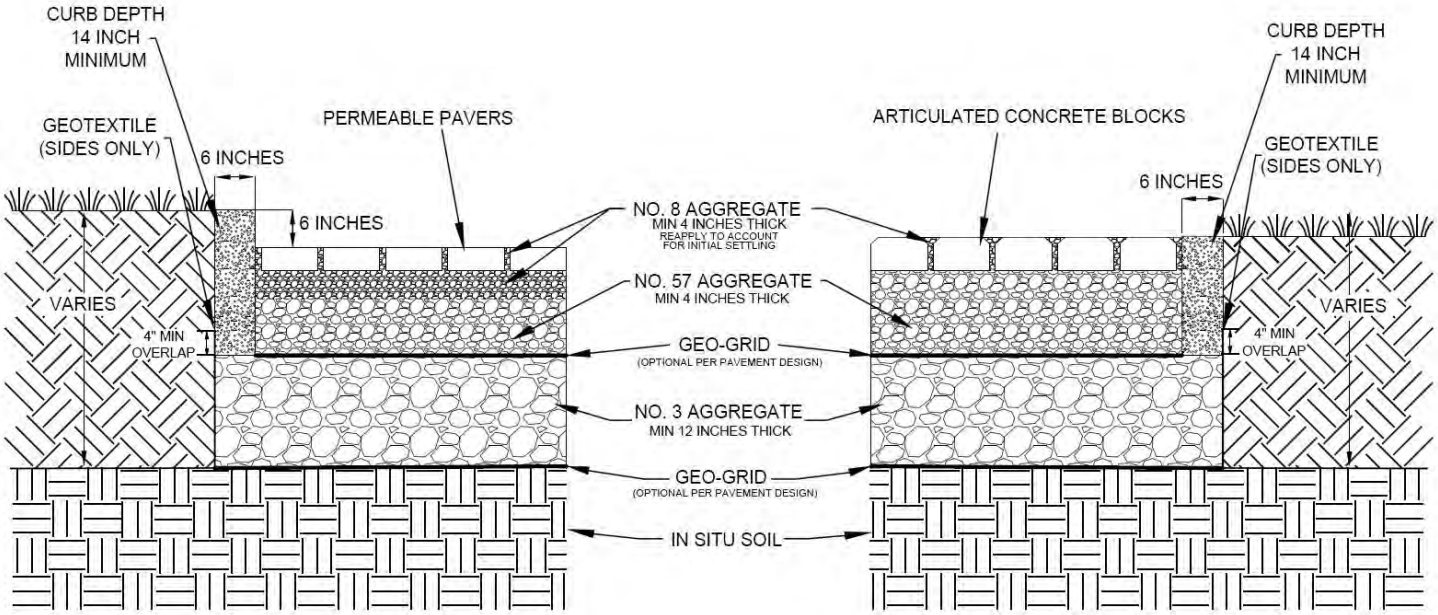

Figure 18.5.9-A. Permeable Pavers Typical Installation (in area of well draining soils class A or B)

NOTES

- ALL AGGREGATE WILL BE DOUBLE WASHED
- RAISED HEADER CURB IS OPTIONAL. IT MAY BE CONSTRUCTED AS SHOWN WITH DRAIN SLOTS OR FLUSH. THE USE OF HEADER CURB IS SITE SPECIFIC.
- PAVER THICKNESS SHALL BE AT A MINIMUM 2-3/8 INCHES FOR PEDESTRIAN USE AND 3-1/2 INCHES FOR VEHICULAR USE
- ALL CONCRETE SHALL B CLASS "A" CONCRETE

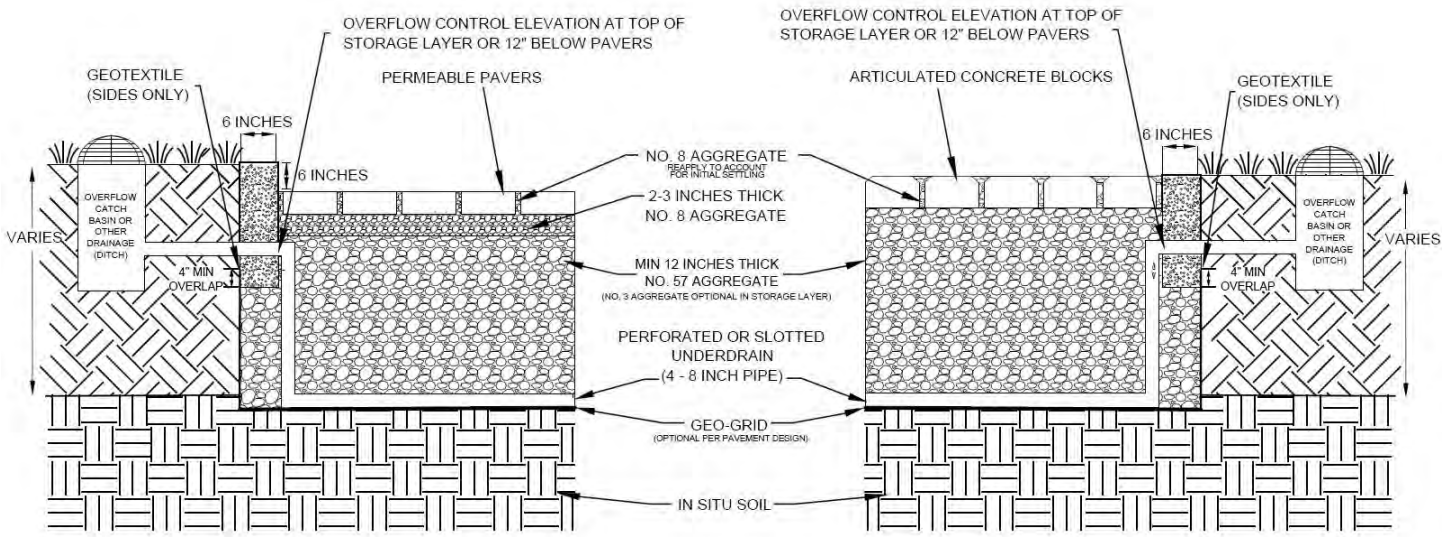

Figure 18.5.9-B. Permeable Pavers with Perched Underdrain System (in area with poor draining soil class C or D)

NOTES

- ALL AGGREGATE WILL BE DOUBLE WASHED
- RAISED HEADER CURB IS OPTIONAL. IT MAY BE CONSTRUCTED AS SHOWN WITH DRAIN SLOTS OR FLUSH. THE USE OF HEADER CURB IS SITE SPECIFIC.
- PAVER THICKNESS SHALL BE AT A MINIMUM 2-3/8 INCHES FOR PEDESTRIAN USE AND 3-1/2 INCHES FOR VEHICULAR USE
- ALL CONCRETE SHALL B CLASS "A" CONCRETE

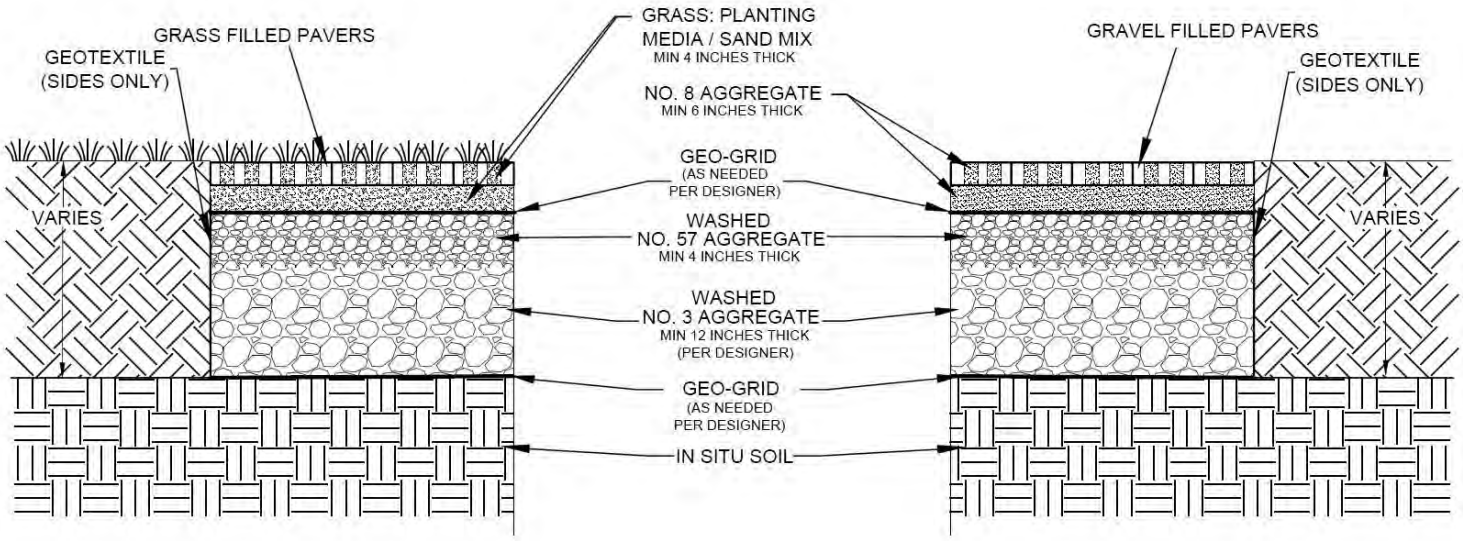

Figure 18.5.9-C. Grass and Gravel Pavers

NOTES

- ALL AGGREGATE WILL BE DOUBLE WASHED
- RAISED HEADER CURB IS OPTIONAL. IT MAY BE CONSTRUCTED AS SHOWN WITH DRAIN SLOTS OR FLUSH. THE USE OF HEADER CURB IS SITE SPECIFIC.
- PAVER THICKNESS SHALL BE AT A MINIMUM 2-3/8 INCHES FOR PEDESTRIAN USE AND 3-1/2 INCHES FOR VEHICULAR USE
- ALL CONCRETE SHALL B CLASS "A" CONCRETE

Permeable Pavers Application and Site Feasibility Criteria

Table 18.5.9-B.

Design Parameter	Criteria
Size (Area & Depth)	The ratio of drainage area to area of pavers should be small (10:1). Based upon the design storage capacity and the following equation: WQv (ft^3) provided=(A) [(p1)(d1)] *Note: this formula only applies if the paver surface and sub soil have a 0% slope. • A = area of permeable pavers (ft^2) • p1 = porosity of base layer (% void) • d1 =depth of base layer (ft)
Location	• The natural water table should be a minimum of 3 feet below the subsoil surface • There should be a minimum separation of 15 feet from buildings
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	• The site should be inspected by an Engineer with geotechnical experience • Geogrid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the permeable paver system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.
Storage Capacity	The storage capacity of the base layers should produce a WQv provided that is equivalent to the required WQv. WQv required(cubic feet) = $(1/12)(RE_{WQV})(R_V)(A)-(WQ_{VR})$, where • WQv required = Required WQv (ft3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3) • R_V = 0.05+0.009 (I) where ♦ I = Impervious cover of the contribution drainage area in percent • A = Contributing drainage area to the permeable pavers (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

Permeable Pavers Step By Step Design Procedures

Step 1: Determine Storage Capacity

The base layers of the permeable paver system which provide storage capacity should be sized to store the WQv. To find the WQv in ft³, the storage capacity equation from Table 18.5.9-B can be used in this form:

$$WQv\ (ft^3)=REWQV\ (RV)\ (A/12)-\ (WQ_{VR}),$$

The WQv provided by the designed permeable paver system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

$$WQv\ (ft^3)\ provided=(A)\ [(p1)(d1)]$$

*Note: this formula only applies if the paver surface and sub soil have a 0% slope.

Step 2: Determine Slopes

Permeable paver sites should have a subsoil slope of zero and a surface slope 0.5%, if possible. If underdrain systems are installed, permeable paver sites may have a slope up to 5%.

Step 3: Layout the Site

Mark the area of the site where permeable pavers will be placed, to minimize soil disturbance and compaction.

Step 4: Erosion Control/Base Protection

Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that stormwater runoff does not enter the construction site during construction of the aggregate bases.

Step 5: Excavate the Subsoil

Excavate the site to the depth shown in the design. Extra care should be taken not to compact the subsoil.

Step 6: Soil Stabilization

Geogrid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and shall be placed on the aggregate as a second layer if the aggregate depth exceeds twelve inches in depth. Geotextile fabric may be used in conjunction with the geogrid if recommended by the engineer for soils separation between the aggregate and subsoil but shall not be used as a soil stabilization device.

Step 7: Edge Restraint (for Articulated Concrete Blocks only)

The edge restraint should be placed around the perimeter of the permeable pavers if they are not placed adjacent to another paved surface; this serves as a lateral load confining barrier. This restraint provides lateral stability to the pavers. The restraint prevents the pavers from shifting due to settlement and increases amounts of stormwater runoff during large storms.The concrete edge restraint should extend to the lesser of: the bottom of the base layer or 18 inches below the surface of the permeable pavers.

Step 8: Base Design

The base layer is made up of two layers. The bottom layer is made of washed No. 3 aggregate that is a minimum thickness of 12 inches (18.5 inches where frost heave is a concern). The top layer is made of washed No. 57 aggregate that is a minimum thickness of 4 inches. The entire base layer will be a minimum of 16 inches thick (22.5 inches where frost heave is a concern) and will be placed on the soil stabilization device.

Step 9: Choker Course

The choker course is placed on top of the base layer and serves as a leveling surface to place pavers on. It is made of washed No. 8 aggregate that is a minimum thickness of 1.5 inches and will be placed on the base layer.

Step 10: Selection of Paver Type

The permeable paver will be chosen based on the specific site conditions and the pavers will be placed on top of the choker course.

Step 11: Outlet Design

There are two types of outlet designs used with permeable pavers in areas that complete infiltration is not possible:

Underdrain Systems

- Series of perforated pipes that run longitudinal with the pavers to remove stormwater runoff. Perforated pipes may either be at the base of the aggregate or at some intermediary level to allow for temporary storage.

Overflow Systems

- Direct water that cannot be infiltrated into the subsoil to an appropriate location to be captured and removed from the pavers (bioswales, storm sewer systems, etc.)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.10 Pervious Concrete



Installation of Pervious Concrete (Photo: Louisville & Jefferson County MSD)

Typical Implementation Areas:
- Parking lot parking stalls
- Sidewalks
- Multi-use paths

Key Considerations:
- Soil type and stability
- Traffic volume
- Type of desired drainage

Cost: Medium
Maintenance: Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	◪
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefits
☐ Low or Unknown Benefits

Pervious concrete is a permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and base layers. Pervious concrete is designed without any "fine" material resulting in a gap-graded mixture with high void space. It is recommended to contact the Kentucky Ready Mix Concrete Association to identify resources to oversee proper installation (www.nrmca.org). The drainage of the stormwater through the pavement reduces the volume of stormwater entering the storm sewer system. Pervious Concrete improves water quality through:

- ☑ Removal of light sediment and pollutants
- ☑ Reduction of stormwater runoff through infiltration to surrounding soils
- ☑ Surface flow reduction of peak flows

Advantages/Benefits:

- Reduces volume of stormwater runoff
- Reduces impervious areas
- Reduces amount of catch basins and cross pipes
- Easily installed
- May eliminate the need for detention ponds on site

Disadvantages/Limitations:

- Geotechnical exploration required
- Increased maintenance requirements
- Not recommended for use in roadway
- Not recommended under tree canopy
- Not desirable for small jobs that may have to be done by hand
- Not safe for skateboards
- More costly than traditional asphalt or concrete

Application and Site Feasability

Pervious concrete is an alternative to traditional concrete and asphalt that allows stormwater to infiltrate into the soil below. A Professional Engineer (Engineer) with geotechnical experience shall evaluate the soil in the site being considered for pervious concrete. The Engineer shall determine what type of soil is present and the percolation rate of the soil. Soils shall be tested at a depth of four feet below the base subsoil surface. Soils having a permeability of at least 0.05 in/hr are suitable for subsoil material.

Physical Site Considerations

Minimum feasibility requirements:

- Areas should have permeable soils (minimum 0.05 in/hr permeability)
- The natural water table should be a minimum of three feet below the subsoil surface
- Maximum slope of surrounding topography should be 20%
- Minimum separation of fifteen feet from buildings
- Site should have a low volume of traffic and not support construction vehicles

Design Criteria

The design of pervious concrete includes several elements to ensure proper drainage and infiltration of the stormwater by the system. For a summary of the design parameters, see Table 18.5.10-A on page 6.

Design Criteria to consider includes:

- Storage Capacity
- Slopes (Subsoil and Pavement)
- Soil Stabilization
- Base Design
- Frost Heave Considerations
- Pavement Design
- Outlet Design (Complete Infiltration, Over Flow Design or Underdrain System)
- Maintenance

Storage Capacity

The base layer of the pervious concrete system should be designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The base layer provides a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The Engineer will design the base layer, or the appropriate outlet system, to provide a depth that will accommodate required WQv (refer to Chapter 18.3).

The WQv provided by the designed pervious concrete system can be calculated using the equation in Table 18.5.10



Installation of pervious concrete (Photo: Louisville & Jefferson County MSD)

-A. The WQv provided should meet or exceed the required WQv.

Slopes

If a large slope is applied to either the pavement surface or subsoil, the depth of the base and/or the effective subsoil must be increased to account for the loss of capacity. If the base depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the subsoil have a 0% slope and the surface have a 0.5% slope or less if at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with pervious concrete as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns geogrid

shall be placed on the subsoil surface before any of the aggregate layers are placed. If the aggregate layer is greater than twelve inches it is recommended to place a second layer of geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads the deformation/failure of the soil and pavement are greatly decreased resulting in less failure to the pavement system over time. Any geogrid used in conjunction with the permeable pavers shall include the following specifications, at a minimum:

Geogrid Specifications

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Base Design

The base of the pervious concrete pavement system will act as the storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The base is made up of double washed No. 57 aggregate (producing 40% void space) that is uniformly graded and washed. The entire subbase should have a thickness of 12 inches (22 inches if frost heave is a concern) at a minimum, which will be structurally sufficient for the design ESAL of the pervious concrete. The base thickness may be increased based on storage capacity as discussed in the previous sections. If maintained properly, the base layer should drain completely after a design storm event.

Frost Heave Considerations

As with any type of pavement, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the subsoil layer should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average of 3 feet frost depth). Also, as will be discussed later, air-entrained admixtures can be added to the concrete to reduce freeze-thaw concerns.

Pavement Design

The pavement design is the design of the surface layer of concrete that will be exposed to the elements. The pavement is made up of aggregate, water and cement that bonds together to create a durable surface having 18%-21% voids. See Figures 18.5.10-A through 18.5.10-D on page 5 for typical sections of pervious concrete pavement.



Pervious Concrete Parking Spaces at Dixie Highway Kroger in Louisville KY. (Photo: Erin Wagoner, URS)

Aggregate

No. 8 and/or No. 9 washed stone are typically used in aggregate for pervious concrete. Gravel and crushed stone are both acceptable forms of aggregate. All aggregate used should conform to ASTM D 448 and ASTM C 33.

Water Content

Water content with pervious concrete differs from the water content used with typical concrete. Typical water/cement ratios of 0.29-0.32 are used with chemical admixtures. Unlike impervious concrete, it is not desired to produce the paste-like bond between the cement and water that gives concrete its dense, smooth finish. Water content in pervious concrete should be closely monitored. As a general rule, the water should give the concrete a sheen but not flow off of the aggregate.

Admixtures

Due to the lessened amount of water and increased void space, pervious concrete has a lower workability and an increased setting time. As a result, retarders or hydration-stabilizing admixtures are used. As mentioned previously, air -entrained admixtures are also commonly used in areas where freeze-thaw is a concern to reduce the effects of frost heave. ASTM C 494 and ASTM C 260 should be used when adding admixtures to the cement.

Outlet Design

If the site prevents the subsoil of the pervious concrete from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the use of trenches or an underdrain system must be implemented.

Trenches

Trenches may be dug across the slope (perpendicular) at intervals determined from the stormwater capacity analysis being drained into the pervious concrete. The trenches shall be filled with rock that will guide water from the subsoil to pipes that will empty into a retention area or a storm sewer system. Filter fabric is recommended in these instances to prevent the washing out of the subsoil. See Figure 18.5.10-C for a typical section of pervious concrete with a trench outlet design.

Underdrain Systems

If the recommended CBR value for the subsoil does not yield the desired porosity for the water to percolate or to capture and reuse the runoff, then an underdrain system should be used. Underdrain systems are a series of pipes that run longitudinal with the pavement. The pipes used in the underdrain system are perforated pipes that tie into a non-perforated outlet. The size of the pipe is determined by the storm sewer capacity analysis. See Figure 18.5.10-D for a typical section of pervious concrete with an underdrain system. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Combination and Location in Series With Other GMPs: Treatment Trains

Constructed pervious concrete can easily be located in series with other GMPs such as bioswales, bio-retention areas or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a pervious concrete and traditional concrete pavement may not be visible to everyone. To maintain the integrity of the pervious concrete, it is important that those maintaining it, as well as the general public, understand that the pervious concrete pavement is a stormwater management feature. Training of maintenance staff may be required.



Pervious concrete surface (Photo: Kentucky Concrete Pavement Association)



Pervious concrete at Louisville Fire Station (Photo: Kentucky Concrete Pavement Association)



Green striping is a public education tool at this "green" parking lot (Photo: Kentucky Concrete Pavement Association)

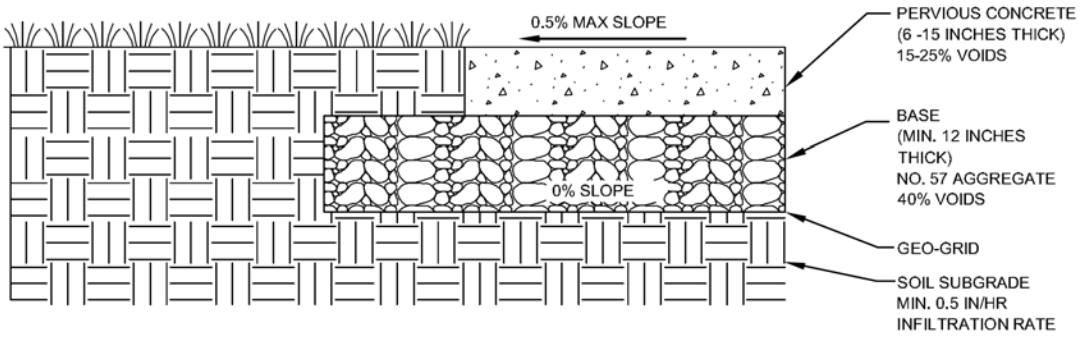

Figure 18.5.10-A. Pervious Concrete Typical Installation

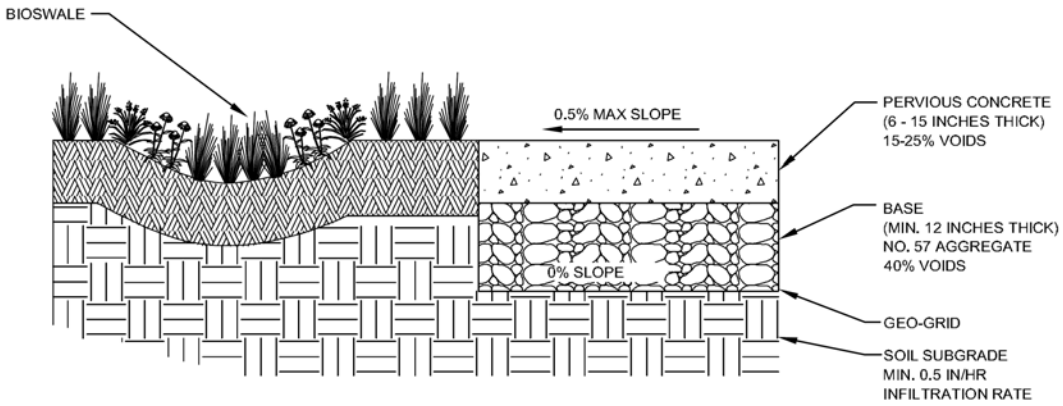

Figure 18.5.10-B. Pervious Concrete with Bioswale Outlet

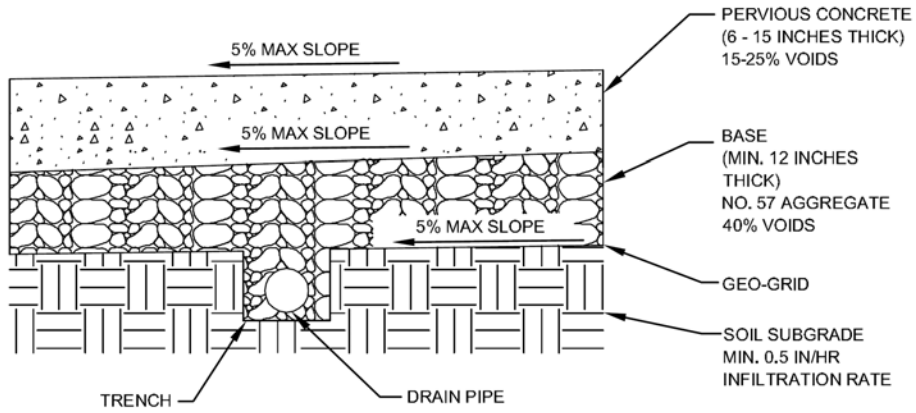

Figure 18.5.10-C. Pervious Concrete with Trench Outlet

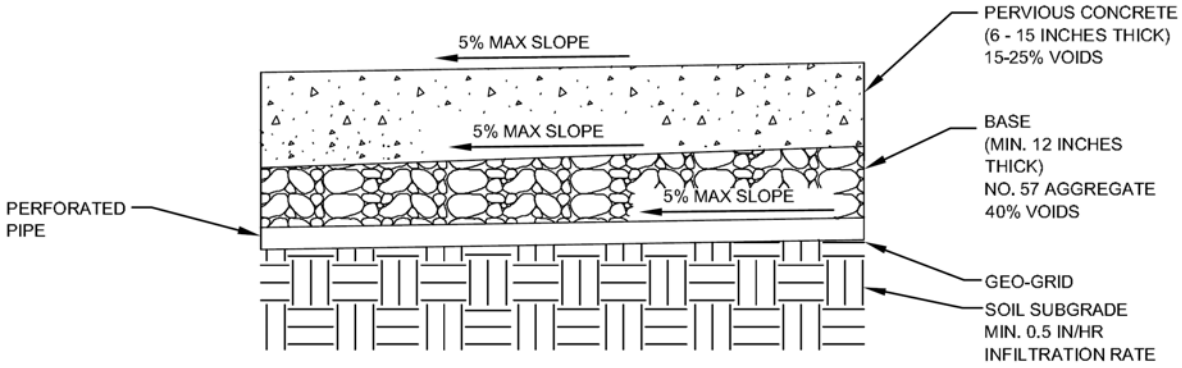

Figure 18.5.10-D. Pervious Concrete with Underdrain System

Pervious Concrete Application and Site Feasibility Criteria

Table 18.5.10-A.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: WQv (ft^3) provided = (A) [(p1)(d1)] *Note: this formula only applies if the concrete surface and sub soil have a 0% slope. • A = area of pervious concrete (ft^2) • p1 = porosity of base layer (% void) • d1 = depth of base layer (ft)
Location	The natural water table should be a minimum of 3 feet below the subsoil surface. There should be a minimum separation of 15 feet from buildings
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	The site should have permeable soils (minimum 0.05 in/hr permeability) The site should be inspected by a Civil Engineer with geotechnical experience Geogrid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the pervious concrete system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.
Storage Capacity	The storage capacity of the base layer should produce a WQv provided that is equivalent to the required WQv. • WQv required = $(1/12)$ (RE_{WQV}) (R_V) (A)- (WQ_{VR}), where • WQv required = Required WQv (ft^3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3) • R_V = 0.05+0.009 (I) ♦ I = Impervious cover of the contribution drainage area given as percent • A = Contributing drainage area to the pervious concrete (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

Pervious Concrete Steps to Construct Pervious Concrete

Table 18.5.10-B.

Step No.	Description
Step 1: Layout the Site	Mark the area of the site where pervious concrete will be placed to minimize soil disturbance and compaction.
Step 2: Erosion Control	Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that no stormwater runoff will enter the construction site during construction of the aggregate base.
Step 3: Subsoil Preparation	Excavate the site to the depth shown in the design that was determined by: storage capacity, the engineer and frost-heave concerns. Make any modifications to the subsoil that have been recommended by the engineer for use of unsatisfactory subsoil.
Step 4: Soil Stabilization	Geogrid will be placed on the subsoil as a soil stabilization device. Only approved geogrid that meets the minimum specifications may be used. Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.
Step 5: Outlet Design (If required)	If the design requires an underdrain or trenching system to be used with the pervious concrete, the outlet pipes or trenches shall be placed on the soil stabilization device and connected to the appropriate outlet.
Step 6: Install Base	Install the base made up of No. 57 double washed aggregate. The base layer is at a minimum 12 inches thick (22 inches if frost heave is a concern). The actual thickness will vary from site to site, and will be specified in the design. The base layer will be kept moist to minimize water loss from the pervious concrete during installation and the curing process.
Step 7: Install Concrete	After the soil stabilization device and base layer are installed, the pervious concrete can be placed. Special attention should be given to the hauling of the pervious concrete. The concrete mixture should be completely used within one hour after initial mixing. Another issue with the installation of pervious concrete is the fact that it cannot be pumped, therefore the site must be able to equip the concrete trucks. When testing the concrete on site, the slump test should not be used since the concrete is designed to be stiff. A unit weight test should be used to determine the quality of the mix. When the concrete is placed, it is consolidated with steel rollers, the consolidation process should be completed within 15 minutes after placement.
Step 8: Joint Placement	Joints are not required to be placed in pervious concrete since random cracking does not reduce the structural integrity of the pavement. However, for aesthetic purposes joints may be placed in pervious concrete to control cracking. When joints are placed, they should be placed at 20 ft spacing and be at a depth equal to 1/4 of the surface layer thickness.
Step 9: Curing	As stated previously, the base layer should be moist when the surface layer is placed. Because of the low water content of the pervious concrete, the moist base layer will keep the base from drawing moisture out of the concrete. After the concrete is placed, it will be lightly sprayed with a mist. Plastic sheets secured with lumber or stakes should be placed over the concrete for a minimum of 7 days.

Pervious Concrete Step By Step Design Procedures

Step 1: Determine Storage Capacity

The base layers of the pervious concrete system which provide storage capacity should be sized to store the WQv. To find the WQv in ft^3, the storage capacity equation from Table 18.5.10-A can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (Rv)\ (A/12) - (WQ_{VR})$$

The WQv provided by the designed pervious concrete system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

$$WQv\ (ft^3)\ provided = (A)\ [(p1)(d1)]$$

*Note: this formula only applies if the concrete surface and sub soil have a 0% slope.



Construction of a pervious concrete sidewalk (Photo: David Dods, URS)

Step 2: Determine Slopes

Pervious concrete sites should have a subsoil slope of 0% and a surface slope of 0.5%, if possible. If an underdrain or trench is installed, pervious concrete sites may have a slope up to 5%.

Step 3: Soil Stabilization

Geogrid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and shall be placed on the aggregate as a second layer if the depth exceeds twelve inches. Geotextile fabric may be used in conjunction with the geogrid if recommended by the Engineer.

Step 4: Base Design

The base design consists of No. 57 double washed aggregate. The base layer will be a minimum of 12 inches thick (22 inches if frost heave is a concern), additional thickness may be based on storage capacity and the base design will be placed on the soil stabilization device.

Step 5: Pavement (Surface) Design

Consider the following:

- Load transfer coefficient
- Drainage coefficient
- ESALs (Equivalent Single Axle Loads)

Step 7: Outlet design

There are two types of outlet designs used with pervious concrete in areas that complete soil infiltration is not possible:

Trenches

- Placed perpendicular to pervious pavement
- Lined with rock that will guide water away from the pavement base and subsoil to pipes

Underdrain Systems

- Series of perforated pipes that run longitudinal with the pavement to remove stormwater runoff

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
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Green Management Practice (GMP) Fact Sheet

18.5.11 Porous Asphalt



Iroquois Amphitheater (Photo: Plantmix Asphalt Industry of Kentucky)

Typical Implementation Areas:
- Parking lot stalls
- Sidwalks
- Bicycle paths and multi-use paths

Key Considerations:
- Soil type and stability
- Traffic volume
- Type of desired drainage

Cost: Medium
Maintenance: Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	◪
Pathogens	☐
Floatables	☐
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefits

Porous asphalt is a permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and stone reservoir. Porous asphalt is different from conventional asphalt mixtures because they primarily utilize one aggregate size which results in a gap-graded mixture and high void space. The drainage of the stormwater through the pavement helps to reduce the volume of stormwater entering the storm sewer system. Porous Asphalt improve water quality through:

- ☑ Removal of light sediment and pollutants
- ☑ Possible reduction of stormwater runoff through infiltration to surrounding soils
- ☑ Surface flow reduction of peak flows

Advantages/Benefits:

- Reduces volume of stormwater runoff
- Reduces impervious areas
- Reduces amount of catch basins and cross pipes
- Ready to use upon completion
- Easily installed

Disadvantages/Limitations:

- Geotechnical exploration required
- Increased maintenance requirements
- Not recommended for use in roadway
- Not recommended under tree canopy

Application and Site Feasibility

Porous asphalt is an alternative to traditional asphalt pavement that allows water to infiltrate into the soil below. A Professional Engineer (Engineer) with geotechnical experience shall evaluate the soil in the site being considered for porous asphalt. The Engineer shall determine what type of soil is present and the percolation rate of the soil. Soils having a permeability that allow proper drainage in a 72 hour period are suitable for subsoil material.

Physical Site Considerations

When selecting a site as a candidate for porous asphalt pavement, there are many conditions that must be met for the pavement to produce the desired result. The following list contains some of the minimum requirements that must be met to ensure the porous asphalt will work properly:

- Areas should have permeable soils or implement the use of drainage systems (soils should drain completely in a 72 hour period)
- The natural water table, at a seasonal high, should be a minimum of three feet below the subsoil surface
- Surrounding topography should have a maximum slope of 20%
- There should be a minimum separation of fifteen feet from buildings



KY Horse Park, Lexington KY (Photo: Plantmix Asphalt Industry of Kentucky)



KY Horse Park, Lexington KY (Photo: Plantmix Asphalt Industry of Kentucky)

Design Criteria:

The design of porous asphalt includes several elements to ensure proper drainage and infiltration of the stormwater. See Figures 18.5.11-A through 18.5.11-D for asphalt pavement typical section designs. For a summary of design parameters, see Table 18.5.11-B on page 7.

Design Criteria to consider includes:

- Storage Capacity
- Slopes
- Soil Stabilization
- Stone Reservoir
- Frost Heave Considerations
- Pavement Design
- Outlet Design
- Maintenance

Storage Capacity

The stone reservoir of the porous asphalt system is designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The stone reservoir provides a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The Engineer should design the stone reservoir to provide a depth that will accommodate required WQv (refer to Chapter 18.3). The WQv provided by the designed porous asphalt system can be calculated using the equation provided in Table 18.5.11-B on page 7.

Slopes

If a large slope is applied to the pavement surface, the depth of the stone reservoir and/or the effective subsoil must be increased to account for the loss of capacity from the slope. If the stone reservoir depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the surface have a 0.5% slope or less and the subsoil have a 0% slope, if at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with porous asphalt as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns geogrid shall be placed on the subsoil surface before the stone reservoir is placed. If the stone reservoir is greater than twelve inches it is recommended to place a second layer of geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the stone reservoir. The geogrid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads the deformation/failure of the soil and pavement are greatly decreased resulting in less failure to the pavement system over time. Any geogrid used in conjunction with the porous asphalt shall include the following specifications, at a minimum:



Park & Ride, Covington KY (Photo: Plantmix Asphalt Industry of Kentucky)

Geogrid Specifications

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Stone Reservoir

The stone reservoir layer of the porous asphalt pavement system will act as the main storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The stone reservoir is made up of double washed No. 2 or No. 3 aggregate that is uniformly graded and washed. The entire stone reservoir should have a minimum thickness of 12 inches, (22 inches if frost heave is a concern) which shall be structurally sufficient for the design ESAL of the porous asphalt. The stone reservoir thickness may be increased, based on storage capacity as discussed in the previous sections. The stone reservoir layer should drain completely

in 72 hours after a design storm event, if maintained properly.

Frost Heave Considerations

As with any type of pavement, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the stone reservoir should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average 3ft frost depth).

Pavement Design

The pavement design is the design of the surface course of asphalt that will be exposed to elements. The pavement is made up of aggregate and liquid asphalt that bond together and create a durable surface.

Aggregate

Fine aggregates are screened and reduced in porous asphalt to increase the void space. This increased void space allows stormwater to percolate through the asphalt. The porous bituminous surface shall be laid with a bituminous mix of 5.75% to 6% by dry weight aggregate. Aggregate in the asphalt will meet the gradation criteria listed in Table 18.5.11-A below. Total drain down of the binder shall be less than 0.3% in accordance with ASTM D6390.

Liquid Asphalt

Liquid Asphalt is used in all types of asphalt pavement whether it is porous or non-porous. Binders are classified by their PG-performance grade (average high and low temperatures they can withstand). A PG 76-22 binder is recommended for porous asphalt.

Table 18.5.11-A. KYTC Standard Specifications

Porous Bituminous Aggregate Gradation	
U.S. Standard Sieve Size	**Percent Passing**
1/2 inch	100
3/8 inch	90-100
No. 4	25-50
No. 8	5-15
No. 16	-
No. 200	2-5



Drainage Pipes (Photo: CH2M Hill)



Stone Reservoir with Drainage Pipes (Photo: CH2M Hill)

Outlet Design

If the site prevents the surface and subsoil of the porous asphalt from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the use of trenches or an underdrain system must be implemented.

Trenches

Trenches may be dug perpendicular across the slope at intervals determined from the stormwater capacity analysis being drained into the porous asphalt. The trenches will be filled with rock that will guide water from the subsoil to pipes that will empty into a retention area or a storm sewer system. Filter fabric is recommended in these instances to prevent the washing out of the subsoil.

Underdrain Systems

If the recommended CBR value for the subgrade doesn't yield desired porosity for the water to percolate, then underdrains should be considered. Underdrain systems are a series of pipes that run longitudinal with the pavement. The pipes used in the underdrain system are perforated pipes. The size of the pipe is determined by the stormwater capacity draining into the porous asphalt. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed porous asphalt can easily be located in series with other GMPs such as bioswales, bio-retention areas or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a porous asphalt and traditional asphalt pavement may not be visible to everyone. To maintain the integrity of the porous asphalt, it is important that those maintaining it, as well as the general public, understand that the porous asphalt pavement is a stormwater management feature. Training of maintenance staff may be required.



University of New Hampshire
(Photo: National Asphalt Pavement Association)

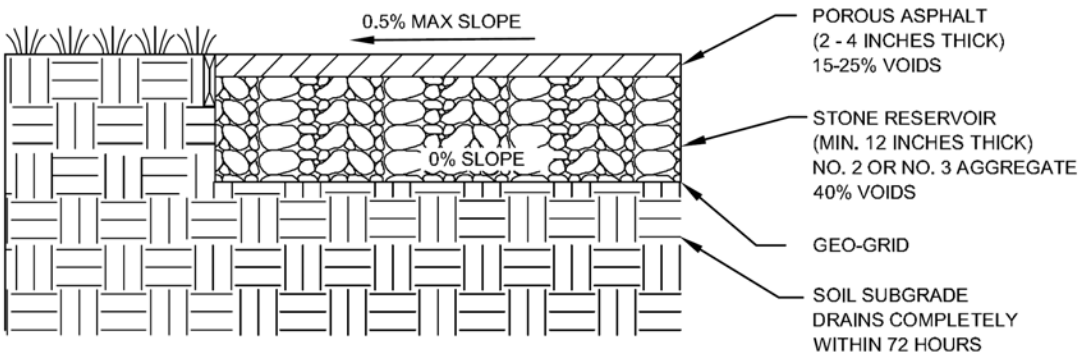

Figure 18.5.11-A. Porous Asphalt Typical Installation

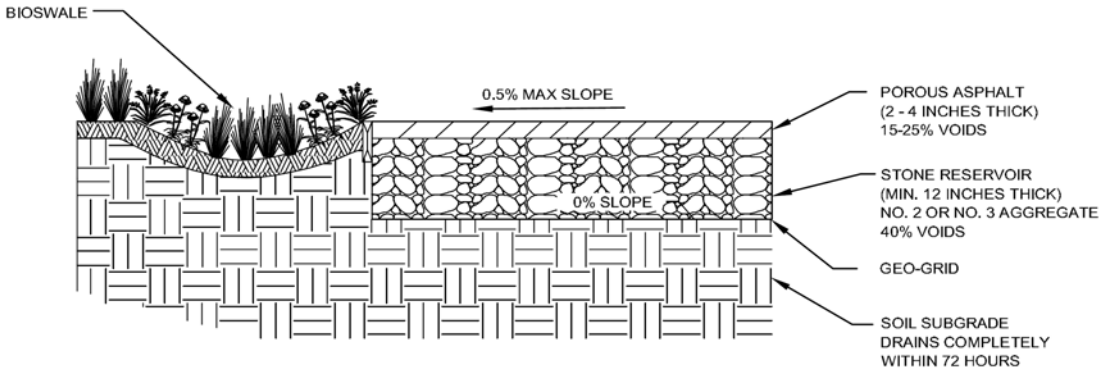

Figure 18.5.11-B. Porous Asphalt with Bioswale Outlet

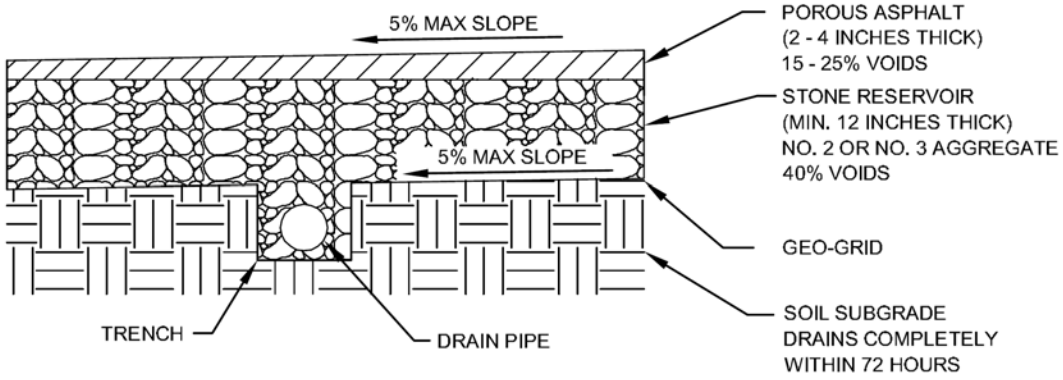

Figure 18.5.11-C. Porous Asphalt Trench Outlet

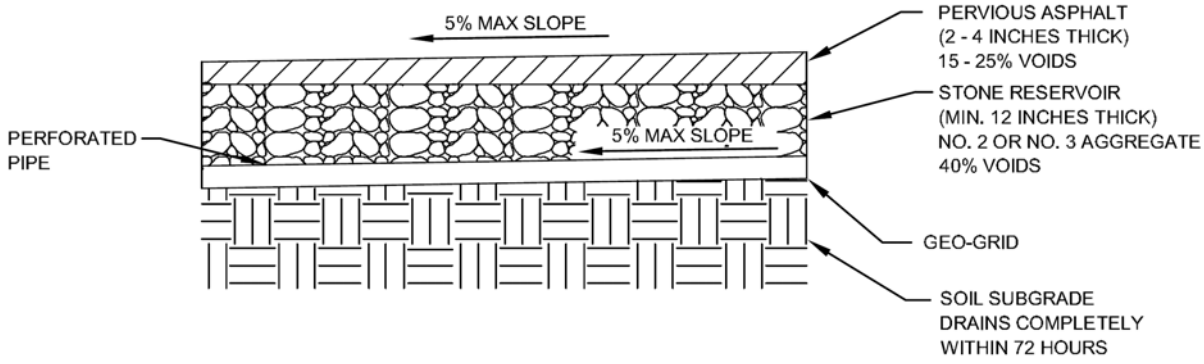

Figure 18.5.11-D. Porous Asphalt with Underdrain System

Porous Asphalt Application and Site Feasibility Criteria

Table 18.5.11-B.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: WQv (ft^3) provided = (A) [(p1)(d1)] *Note: this formula only applies if the asphalt sub soil has a 0% slope and the surface has a 0.5% slope or less. • A = area of porous asphalt (ft^2) • p1 = porosity of base layer (% void) • d1 = depth of base layer (ft)
Location	The natural water table should be a minimum of 3 feet below the subsoil surface and there should be a minimum separation of 15 feet from buildings.
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	• The site should have permeable soils (minimum 0.5 in/hr permeability) • The site should be inspected by an Engineer with geotechnical experience • Geogrid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the porous asphalt system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.

Storage Capacity	The storage capacity of the stone reservoir should produce a WQv provided that is equivalent to the required WQv.
	
	WQv required = $(1/12)$ (RE_{WQV}) (R_V) (A)- (WQ_{VR}), where
	• WQv required = Required WQv (ft^3)
	• RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3)
	• R_V = 0.05+0.009 (I)
	  ♦ I = Impervious cover of the contribution drainage area given as percent
	• A = Contributing drainage area to the porous asphalt (ft^2)
	• WQ_{VR} = $(1/12)(RE_{WQV})(R_V)(IA_R)$
	  ♦ Where IA_R = reduced impervious area

Steps to Construct Porous Asphalt

Table 18.5.11-C.

Step No.	Description
Step 1: Site Layout	Mark the area of the site where porous asphalt will be placed to minimize soil disturbance and compaction.
Step 2: Erosion Control	Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that no stormwater runoff will enter the construction site during construction of the stone reservoir.
Step 3: Subsoil Preparation	Excavate the site to the depth shown in the design that was determined by the storage capacity requirements for the site and by the Engineer.
Step 4: Soil Stabilization	Geogrid will be placed on the subsoil as a soil stabilization device. Only approved geogrid that meets the minimum specifications may be used. Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.
Step 5: Outlet Design (if required)	If the design requires an underdrain system or trenching system to be used with the porous asphalt, the outlet pipes or trenches shall be placed on the soil stabilization device and connected to the appropriate outlet (storm sewer, retention area, bioswale, etc.)
Step 6: Install Stone Reservoir	Install the stone reservoir made up of No. 2 or No. 3 washed aggregate. The stone reservoir should be placed at a minimum of 12 inches thick (22 inches if frost heave is a concern). The actual thickness will vary from site to site and will be specified in the design.
Step 7: Install Asphalt	After the stone reservoir is installed, the porous asphalt can be placed. The porous bituminous asphalt surface shall be laid in 3½ inches lifts and rolled to a finish depth of 2½ inches. The exact thickness of the asphalt surface will be determined by the Engineer and will be site specific. Compaction of the surface course shall take place when the surface is cool enough to resist a 10-ton roller. One or two passes by the roller are all that is required for proper compaction.

Porous Asphalt Step By Step Design Procedures

Step 1: Determine storage capacity

The stone reservoir of the porous asphalt system which provides storage capacity should be sized to store the WQv. To find the WQv in ft³, the storage capacity equation from Table 18.5.11-B can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12) - (WQ_{VR})$$

The WQv provided by the designed porous asphalt system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

WQv (ft3) provided = (A) [(p)(d)]
*Note: this formula only applies if the asphalt surface and sub soil have a 0% slope.

Step 2: Determine slopes

Porous asphalt sites should have a soil subgrade slope of 0% and a surface slope of 0.5%, if possible. If underdrains or trenches are installed, porous asphalt sites may have a slope up to 5%.

Step 3: Soil stabilization

Geogrid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and geotextile fabric may be used in conjunction with the geogrid if recommended by the engineer.

Step 4: Stone reservoir design

Before placing the stone reservoir, the non-woven geotextile fabric should be placed on the subsoil for separation between the two layers. The stone reservoir will have a minimum thickness of 12 inches (22 inches if frost heave is a concern), additional thickness may be added based on storage capacity and consists of No. 2 or No. 3 washed aggregated with 40% voids. The stone reservoir should drain completely in 72 hours.

Step 6: Pavement (surface) design

The Engineer will use the following criteria to determine the appropriate surface design:

- CBR
- ESALs
- Structural Number

Step 7: Outlet design

There are two types of outlet design used with porous asphalt in areas that complete soil infiltration is not possible:

Trenches

- Trenches dug perpendicular to the porous pavement
- Lined with rock that will guide water away from the pavement stone reservoir and subsoil to pipes

Underdrain System

- Series of perforated pipes that run longitudinal with the pavement to carry stormwater away from the pavement

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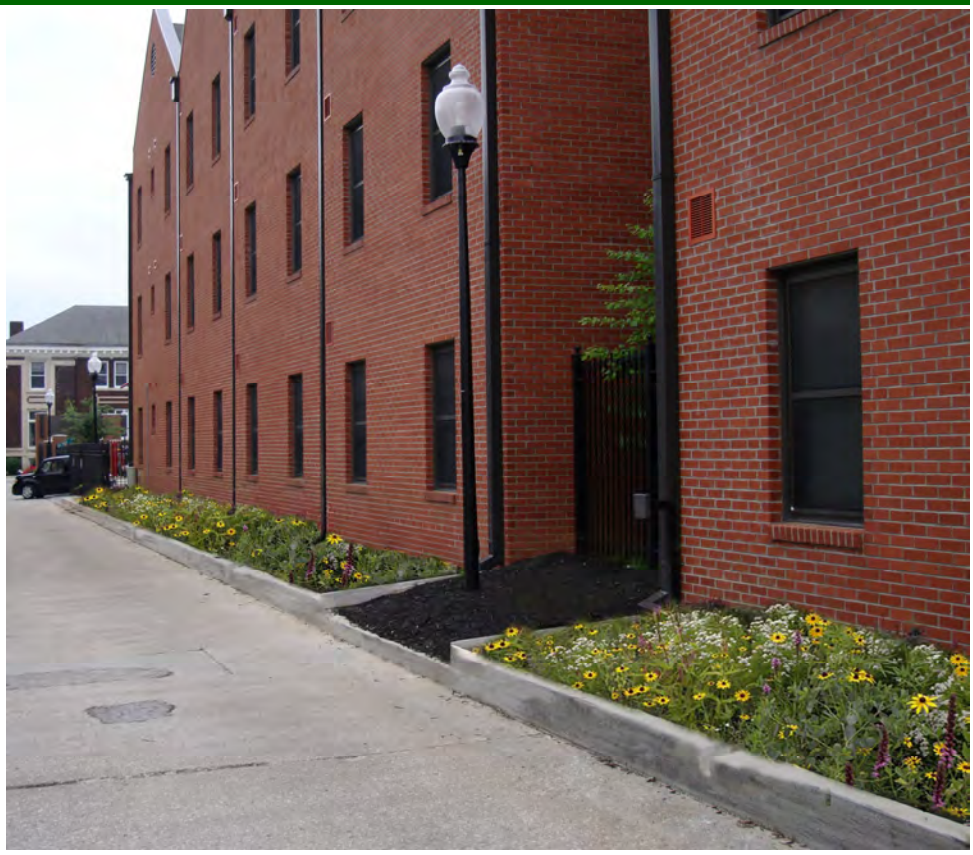
Green Management Practice (GMP) Fact Sheet

18.5.12 Planters



Concept flow-through planter (Photo: Chad McCormick, URS)

Typical Implementation Areas:

- Adjacent to buildings
- Sidewalks, courtyards, plazas and entrance bays
- Connected with rooftop downspouts.
- Redevelopment and retrofit

Key Considerations:

- Proximity of building foundations
- Infiltration rates of soil/media
- Use of deep rooted native vegetation

Cost: Medium
Maintenance: Low

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	◪
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit ◪ Partial Benefit □ Low or Unknown Benefit

Planters, like tree boxes, are very similar to rain gardens and bioretention basins in their design purpose and stormwater management benefits to detain, filter and infiltrate stormwater and ability to utilize plants ranging from native flowers or shrubs to small trees. Planters provide temporary detention and infiltration as stormwater flows through the planter bed and are most often used to promote infiltration of stormwater runoff from rooftop downspouts. Planters improve water quality through:

- ☑ Reduction of runoff volume
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater
- ☑ Biological uptake through deep rooted, native plants

Advantages/Benefits

- Visually appealing
- Can be used to address landscaping requirements
- Can provide infiltration and groundwater recharge, reducing runoff volume
- Increases biodiversity by providing urban habitats for wildlife
- Reduces heat island effects

Disadvantages/Limitations

- Building foundations may limit application
- Soil conditions may limit application
- Limited to small drainage areas
- Not recommended for high groundwater level areas
- Erosion potential at downspout inlets

Application and Site Feasibility

Planters are typically applied to manage runoff from rooftop or they can also be submerged at parking lot or street level to manage flow to treat, detain and infiltrate stormwater runoff. Similar to traditional landscapes or hardscapes, the designer can adjust the shape, wall type and plantings used in the planter to fit the character of the site. Planters can be used in urban areas, and are appropriate for use in a wide variety of land use applications including commercial, industrial or residential areas.

Physical Requirements

Key physical considerations are:

- Building foundations—Sufficient space is required from building foundations. Where a gravel infiltration trench is used (in open box design, or infiltration planter), the gravel infiltration trench of the planter must be set back from building foundations. For all applications, buildings and building foundations must be waterproofed with foundation drains to limit seepage into basements or lower levels.
- Space available—Sufficient space is required to plant herbaceous plants, shrubs or trees and allow space for foliage growth above ground and root growth below ground. Plant type and species vary by preferred landscape and aesthetic qualities.
- Soil types—Native soil types affect infiltration and the ability for plant roots to grow and spread. Soils under existing infrastructure around the planter need to be evaluated to determine their ability to allow the plant roots to spread.
- Planting media—The infiltration rate of the media in the planter will dictate how large an area will be required for managing the stormwater runoff.

Design Criteria

The design of an planter includes several elements to manage stormwater infiltration, retention and conveyance to facilitate water quality improvement and reduction of stormwater runoff volumes into the sewer system. Generally, infiltration planters follow the same design approach as a rain garden/bioretention pond. There are some proprietary applications that perform these design calculations or the guidance provided below can be utilitized. For a summary of design parameters, see Table 18.5.12-A on page 4.

Design criteria to consider includes:

- Selection of planter type and size
- Soil composition
- Plant selection
- Maintenance

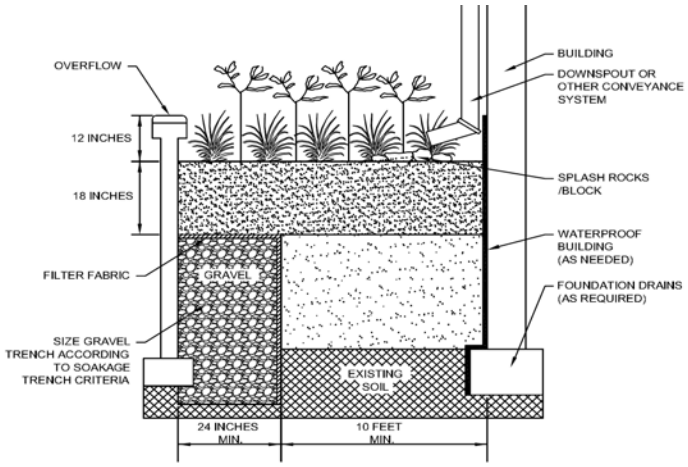


Figure 18.5.12-A. Typical infiltration planter with open box design.

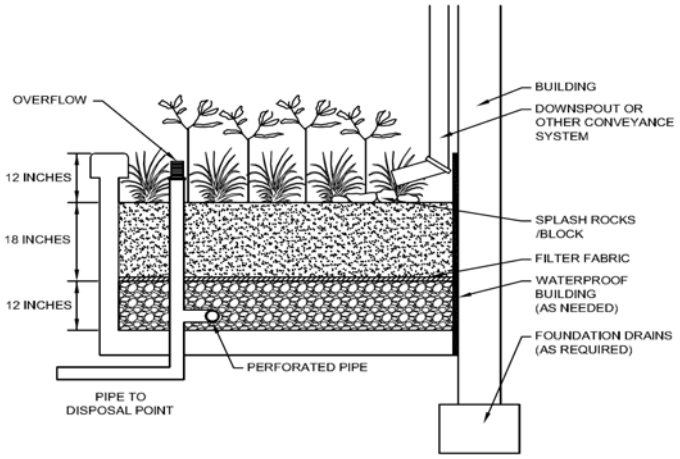


Figure 18.5.12-B. Typical flow-through planter with flow-through closed box design.

Selection of Planter Type and Size

Infiltration planters are designed to capture and infiltrate stormwater runoff through an open box design. If infiltration into native soils is not desired, planters may be designed to capture and retain stormwater runoff with a flow-through closed box design, also called flow-through planters. Flow-through planters include an overflow pipe and underdrain system connected to the storm sewer system. Typical sections of open and closed box designs are shown in Figures 18.5.12-A and 18.5.12-B. If the in-situ soil infiltration rate is less than 0.5 inches per hour, then an underdrain is required.

The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil composition in the box and surrounding soils. If an underdrain is needed, storage space can be provided beneath an underdrain system to allow more time for infiltration to occur. In general, a planter should not accept drainage from more than 0.25 acres of impervious area.

This is the maximum acreage, but a smaller drainage area is encouraged for better performance.

Sizing of the planter will depend on the infiltration rate of the native soils, the planting media and the drainage volume it receives. The infiltration planter should be sized to capture the WQv. See Table 18.5.12-A for WQv formulas.

Soil Composition

Planters should be designed to drain within 24 hours. Evaluate in situ soil conditions to determine if they meet this criteria for use in the planter. If they do not, consider amending in situ soils with an engineered soil mix, such as a mixture consisting of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

If the primary purpose is infiltration (open box design), it is important that soils are not compacted. If the primary purpose is temporary detention with subsequent drainage to the storm sewer system (flow-through closed box design), then an underdrain system is required. An underdrain system may also be required for open box designs that do not have adequate infiltration rates in the surrounding soils. Underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed No. 57 stone. When grading and soil mix is placed, care should be taken that the soil is not compacted, resulting in a diminished infiltration capacity.

Plant Selection

Planters are typically planted with deep rooted, native trees, shrubs and herbaceous plants. Plants selected should be tolerant of highly variable hydrologic conditions. In selecting trees and shrubs, consider the box and soil depth, space for roots to grow and if the box will retain water for extended periods of time and select species accordingly.

Although deep rooted, native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.



Flow-through planter application (Photo: Erin Wagoner, URS)

Treatment Trains—Combination and Location in Series With Other GMPs

Planters are typically local practices, but can be located in a series with each other through a highly permeable trench. This series allows greater area for infiltration and root growth and for conveyance of stormwater. Pervious areas above the series also promotes additional stormwater drainage and aeration of the plant roots. Planters may also be preceded in series by a cistern or rain barrel connected to roof downspouts. Planters can also be located as the first GMP in a series with other GMPs, such as rain gardens or bioretention areas to supplement infiltration and volume control.

Educational Awareness

The difference between planters and traditionally landscaped areas may not be visible to everyone. It is important that those maintaining the planters, as well as the general public, understand that its features move beyond aesthetic landscaping to manage and treat stormwater.

Planters Application and Site Feasibility Criteria

Table 18.5.12-A.

Design Parameter	Criteria
Size (Area & Depth)	The minimum surface area of the planter should be determine based upon the design storage capacity and the following equation: $A = (WQv)/[(d)(P)+h]$, where • A = surface area of the ponding area of the planter bed (ft^2) • WQv = required WQv (ft^3) • d = depth of any amended soils (ft) • P = porosity of any amended soils (% void) • h = average height of water above the amended/in situ soils during WQv rain event (ft)
Surrounding Soils	Ideal soils should be sandy loam, loamy sand, or loam texture. If infiltration is desired, soil infiltration should be > 0.5 inches per hour.
Planting Media	Ideal media will contain adequate content for plant growth while maintaining infiltration rates greater then several feet per hour.
Drawdown Time	Infiltration planters should dewater within 24 hours. If necessary, an underdrain system can be added.
Storage Capacity	Planter bed total volume should be equivalent to the Required WQv. Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A)- (WQ_{VR})$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the planter (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

Planters Step by Step Design Procedures

Step 1: Define goals/primary function of the planter

Define the goals/primary function of the planter. Consider whether the planter is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Provide conveyance
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. Where landscaped beds or foundation plantings are proposed at the site, consider using infiltration planters as a substitute for traditional raised landscape beds. Locate roof downspouts and check potential locations/available space for planters. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions, requirements, goals and primary function(s) of the planter. In conjunction with in situ topographic and soil conditions, this will determine the elements of the planter (engineered soils, underdrain, etc).

Step 2: Determine the peak flow rate and total runoff volume

Planters should be sized to capture and detain or infiltrate the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.12-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

Planters also must be designed to safely convey or bypass flow rates produced by larger storm events with adequate freeboard and minimum erosion. Larger storms (2-, 10-, and 100-year) should be checked to size overflow or underdrain structures to convey the flow.

Step 3: Determine if site is appropriate

Based on the defined goals for the planter, determine if the site conditions and drainage area are appropriate for use of an planter. If so, determine whether an open box design or a flow-through closed box design is appropriate. Use Table 18.5.12 -A, especially for the infiltration rate of the surrounding soils.

Step 4: Determine planter dimensions

Calculate the minimum surface area of the planter, assuming a desired depth of filter media and water over the filter bed, using the equation provided in Table 18.5.12-A:

$A = (WQv)/[d(P)+h]$

Based on the required volume, minimum surface area and the site restrictions, including existing trees, utility lines, and other obstructions, calculate the dimensions of the planter. Create a rough layout of the planter.

Step 5: Check freeboard and bypass capability for larger storms

Based on the average infiltration rate of the planter system and projected water surface elevations for all other storm events (shown in Step 2), determine the need for bypass or underdrain systems. This includes allowing a 0.5 foot freeboard between the inlet elevation and water level during the WQv event and determining the need for erosion prevention measures. Modify design as appropriate.

Step 6: Prepare native vegetation

Choose native trees, bushes and/or herbaceous plants based on aesthetic preferences, root depths, plant heights, sun/shade tolerances and the anticipated moisture within the planter.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP)

18.5.13 Tree Boxes

Typical Implementation Areas:

- Sidewalks, courtyards and entrance bays
- Parking lot islands, edges
- Roadway island/median and right-of-ways
- Redevelopment and retrofit

Key Considerations:

- Detain/treat and possibly infiltrate and convey stormwater
- Infiltration rates of soils/ media
- Use deep rooted vegetation
- Drainage area to tree box
- Metro Planning Approval

Cost: Medium
Maintenance: Low



Tree boxes (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	□
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

A tree box is very similar to a rain garden/bioretention basin in its design purpose and stormwater management benefits, except it exclusively uses trees and tall bushes. At a minimum, a tree box temporarily detains the stormwater runoff as it flows through the box prior to discharge into the sewer system. If surrounding soils have adequate permeability, a tree box can also be designed to promote infiltration of the stormwater runoff. A tree box can be used as a single GMP or connected in series through trenches. A tree box improves water quality through:

- ☑ Reduction of runoff volume through infiltration
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Temporary detention of stormwater runoff
- ☑ Biological uptake through deep rooted, native plants

Advantages/Benefits

- Visually appealing
- Can be used to address landscaping requirements
- Provides infiltration, reducing runoff volume
- Increases biodiversity by providing urban habitats for wildlife
- Reduces heat island effects

Disadvantages/Limitations

- Increased maintenance over traditional curb and gutter drainage systems
- Soil conditions may limit application
- Limited to small drainage areas
- Not recommended for high groundwater level areas

Application and Site Feasibility

A tree box is a local feature that is used to treat and detain, and possibly infiltrate stormwater runoff. It may be connected in a series to provide opportunities for enhanced treatment of the stormwater and promote better tree viability. A tree box is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to plant the tree and allow space for its growth both aboveground and belowground.
- Soil types—Soil types affect infiltration and the ability for the tree roots to grow and spread. In addition, soils under existing infrastructure around the tree box need to be evaluated to determine their ability to allow the tree roots to spread.
- Tree box media—The infiltration rate of the media in the tree box will dictate how large a box area will be required for the WQv.
- Location—Construction in a Louisville Metro right-of-way (ROW) or Kentucky Transportation Cabinet ROW will require conformance to applicable standards

Design Criteria

The design of a tree box includes several elements to manage stormwater; detention and conveyance to facilitate water quality improvement and infiltration to reduce stormwater runoff volumes into the sewer system. Generally, a tree box follows the same design approach as a rain garden/bioretention pond. There are proprietary tree boxes with standard sizes form the manufacturer. If a proprietary tree box is not chosen, the following guidance can be used to size a tree box. For a summary of design parameters, see Table 18.5.13-A on page 5.

Design criteria to consider includes:

- Selection of tree box type and size
- Soil composition
- Plant selection
- Maintenance

Selection of Tree Box Type and Size

A tree box can be designed to capture and infiltrate the stormwater runoff through an open box design (see Figure 18.5.13-A). If infiltration is not desired, temporary detention of the stormwater runoff can be accomplished using a flow-through sealed box design (see Figure 18.5.13-B). The sealed box design will include an underdrain system connected to the storm sewer system, while the need

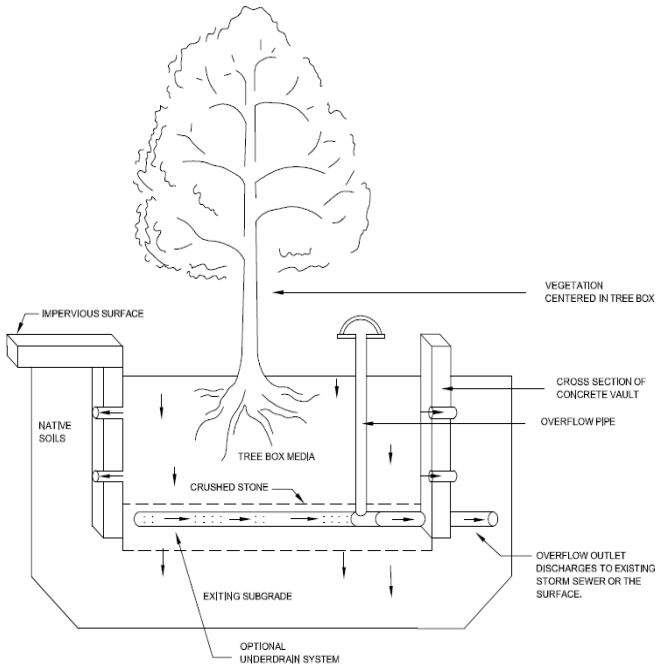


Figure 18.5.13-A: Typical Open Box Design (Rendering: Shea Powell, Dropseed)

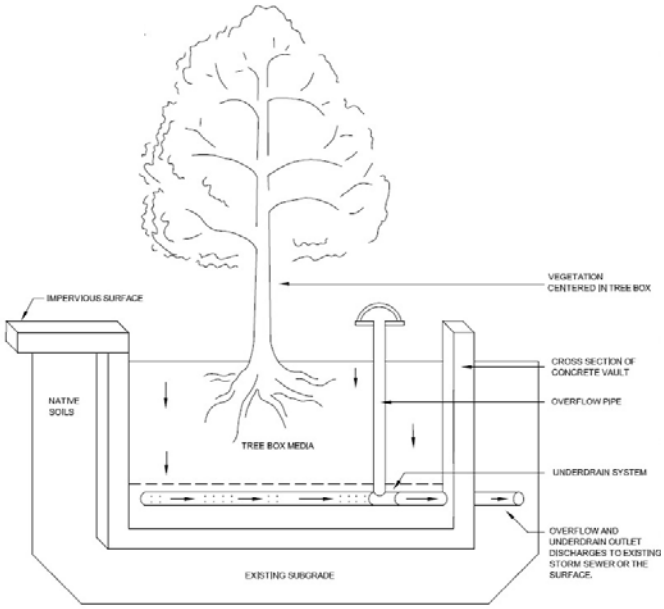


Figure 18.5.13-B: Typical Closed Box Design (Rendering: Shea Powell, Dropseed)

for an underdrain system in the open box design will depend on the infiltration rate of the surrounding soil. The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil composition in the box and surrounding soils. Storage space can be provided under an underdrain system to allow more time for infiltration to occur. As a general guidance, the tree box should not accept drainage from more than 0.25 acres of impervious area. This is the maximum acreage, but a smaller drainage area is encouraged for better performance.

Sizing of a tree box is based on the volume provided by the porosity of the tree box media and in the ponding above the tree box media. The volume should at least be equal to the WQv. See Table 18.5.13-A for WQv formulas.

Evaluate in situ soil conditions to determine if they have the needed infiltration for the tree box. If they do not, consider amending in situ soils with an engineered soil mix, such as a mixture consisting of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

Soil Composition

The soils around the tree box are extremely important, especially in an open box design where the tree roots are allowed to expand out past the tree box. If tree roots are allowed to spread, they will typically extend at least as far as the branches. However, if the surrounding soils are too compacted, the tree roots may not be able to penetrate the soil, thus limiting its viability.

The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

If the primary purpose of the tree box is temporary detention with subsequent drainage to the storm sewer system (sealed box design), then an underdrain system is required. An underdrain system may also be required for open box designs that do not have the needed infiltration rates in the surrounding soils. Underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed No. 57 stone. Topsoil should be stripped and stockpiled for reuse. When grading and soil mix is placed, care should be taken that the soil is not compacted, resulting in a diminished infiltration capacity.

Plant Selection

A tree box is typically planted with a deep rooted, native tree or shrub. In selecting a tree or shrub, consider the box and soil depth, space for roots to grow, if the box will retain water for extended periods of time and select species accordingly.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.



Flow through tree box
(Photo: Meg Babani, Taliaferro & Browne, Inc.)

Maintenance

Maintenance is a key component to the long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A tree box is typically a local practice, but it can be located in series with others through a highly permeable trench between the boxes. The series allows greater area for infiltration and root growth and for conveyance of the stormwater. Pervious areas above the series also promote additional stormwater drainage and aeration of the tree roots. Tree boxes can also be located as the first GMP in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

It is important that those maintaining the tree boxes, as well as the general public, understand that its features move beyond aesthetic landscaping to manage and treat stormwater. Training of maintenance staff may be required.

Tree Box Application and Site Feasibility Criteria Chart

Table 18.5.13-A.

Design Parameter	Criteria
Surrounding Soils	Ideal soils are sandy loam, loamy sand, or loam texture. If infiltration is desired, soil infiltration should be > 2.0 inches per hour.
Tree Box Media	Ideal media will contain adequate content for plant growth while maintaining infiltration rates greater than 1 foot per hour.
Drawdown Time	A tree box should dewater within 24 hours. If necessary, an underdrain system can be added.
Storage Capacity	Tree box volume should be equivalent to the Required WQv. Required WQv (cubic feet) = $(1/12)[(RE_{WQV})(Rv)(A)]- (WQ_{VR})$, where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009 (I)$ ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the tree box (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
Surface Area	$A = (WQv)/[(d)(P)+h]$, where • A is the surface area of the tree box (ft^2) • WQv = required WQv (ft^3) • d = depth of tree box (ft) • P = porosity of the soil mix in the tree box (% void) • h = average height of water over tree box bed during required WQv storm event (ft)

Tree Box Step by Step Design Procedures

Step 1: Define goals/primary function of the tree box

Define the goals/primary function of the tree box. Consider whether the tree box is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Provide conveyance
- Enhance landscape aesthetic qualities

Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations.

The design should be based on the restrictions, requirements, goals, and primary function(s) of the tree box. In conjunction with in situ topographic and soil conditions, this will determine the elements of the tree box (engineered soils, underdrain, etc).

Step 2: Determine the peak flow rate and total runoff volume

A tree box should be sized to capture and detain or infiltrate the required WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.13-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

A tree box also must be designed to safely convey or bypass flow rates produced by larger storm events with adequate freeboard and minimum erosion. Larger storms (2-, 10-, and 100-year) should be checked to size overflow or underdrain structures to convey the flow.

Step 3: Determine if site is appropriate

Based on the defined goals for the tree box, which sets the type of tree box to use (open or closed); determine whether the site conditions and drainage area are appropriate for use of a tree box. Consider Table 18.5.13-A, especially the infiltration rate of the surrounding soils.

Step 4: Determine tree box dimensions

Calculate the required area of the tree box based on the void space of the tree box media so that it can store the WQv using the following equation: $A = (WQv)/[d(P)+h]$.

Based on the required volume, minimum surface area and the site restrictions, including existing trees, utility lines, and other obstructions, calculate the dimensions of the tree box. Create a rough layout of the tree box.

Step 5: Check freeboard and bypass capability for larger storms

Based on the infiltration rate of the soils around the tree box system and projected water surface elevations for all other storm events (shown in Step 2), determine the need for bypass or underdrain systems. This includes allowing a 0.5 foot freeboard between the inlet elevation and water level during the WQv event and determining the need for erosion prevention measures. Modify design as appropriate.

Step 6: Prepare native vegetation

Choose native trees and bushes based on aesthetic preferences, root depths, plant heights, sun/shade tolerances and the anticipated moisture within the tree box.

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Metropolitan Sewer District

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Green Management Practice (GMP)

18.5.14 Rainwater Harvesting—Cisterns

Typical Implementation Areas:

- Downspout conveyance
- Exterior reuse—irrigation
- Storage for gray water use
- Interior reuse—non-potable

Key Considerations:

- Beneficial reuse opportunities
- Treatment of stored water
- Storage size and location
- Plumbing codes for using rainwater inside a building
- Supply of water versus demand for usage

Cost: Medium
Maintenance: Medium—High



Cisterns drain to a bioswale at the Green Building in Louisville (Photo: Erin Wagoner, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	■
Floatables	■
Oil and Grease	■
Dissolved Pollutants	■
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	■
Stream Channel Protection	◪
Peak Flow Control	■
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit ◪ Partial Benefit ■ Low or Unknown Benefit

Rainwater harvesting is the practice of collecting and temporarily storing rainwater. Typically this is limited to rainwater runoff from roofs with the intent for the captured roof runoff to be used following the rain event. Beneficial uses for commercial and industrial applications may include watering nearby landscaping, washing vehicles, toilet flushing water and HVAC or boiler make-up water. Due to the size needed for such applications, a cistern is typically used instead of multiple rain barrels. A cistern is a more permanent structure than rain barrels, typically having a volume over 100 gallons and can be placed aboveground or belowground. Rainwater harvesting improves stormwater management through:

- ☑ Beneficial use and reduction of stormwater runoff volume
- ☑ The harvested rainwater needs to be used prior to the next rain event to allow for continued harvesting.

Advantages/Benefits

- May reduce water bill
- Reduces channel/stream bank erosion by reducing number of bankfull events
- Allows beneficial reuse of stormwater

Disadvantages/Limitations

- Need to drain or use captured roof runoff between rain events
- Water may need to be pumped if cistern is belowground
- Not to be used with tar and gravel and asbestos shingled roofs
- May not be aesthetically pleasing
- Plumbing codes for using rainwater inside a building

Application and Site Feasibility

Rain harvesting generally relies on the ability of the rainwater to flow by gravity from the rooftop to the cistern and to the beneficial reuse area. If the cistern is located belowground, pumping will be required. In addition, the overflow needs to discharge to a location that is stable and pervious. Rainwater harvesting is appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/high density residential areas. It should be noted that rainwater harvesting is more beneficial when the demand is great enough to balance water supply.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space, whether aboveground or belowground is required to locate the required volume of storage.
- Construction of the cistern—The cistern needs to include an inlet for the downspout, overflow port and outlet.
- Slopes—The cistern needs to be located on stable and flat surface to prevent accidental tipping.
- Beneficial reuse area—The cistern needs to be drained or the water used regularly to be able to receive the next roof rainfall runoff. Consideration needs to be given to whether the beneficial reuse can receive/utilize the water volume on a regular basis.
- Interior reuse—Additional plumbing that requires approval pursuant to local building codes and from health departments, as well as a pumping system are required to use cistern water for interior uses such as toilet flush water and HVAC make-up water.

Design Criteria

The design of a cistern includes several elements to properly reduce stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.1-A on page 5.

Design criteria to consider includes:

- Roof runoff discharge locations
- Roof drainage area to each discharge location
- Select number and type of cisterns
- Location of cistern
- Inlet and pretreatment
- Drain or outlet
- Overflow
- Maintenance

Roof Runoff Discharge Locations



Cistern under construction at Americana (Photo: Louisville & Jefferson County MSD)

Review the building to determine where the roof runoff discharges. Identify the downspouts and determine where these downspouts discharge.

Roof Drainage Area to Each Discharge Location

Review the location of the gutter system, the slope of the gutter system and consider the location of the downspouts to determine the roof area that drains to each downspout. When determining the roof area, the aerial extent of the roof should be considered. The slope and pitch of the roof are not critical for determining the area.

Select Number and Type of Cisterns

Calculate the area of the roof draining to each downspout, multiply by the required WQv rain event and convert to gallons to determine the storage volume required for rainwater harvesting. Based on the required number of gallons, space available, water reuse needs and budget limitations, select an appropriate sized and shaped cistern for each downspout. Routing multiple downspouts to one larger cistern should also be considered.

Rainwater harvesting cisterns are available in a variety of different materials and should be selected based on their

application. Underground cisterns should have the structural capability to support applicable weight bearing loads.

Location of Cistern

A cistern needs to be located on a firm, level surface to prevent tipping which could cause damage to the cistern and surrounding structures and landscaping. Consideration should be given to strapping the cistern to nearby structures to help prevent tipping and to resist any wind gusts.

Because harvested rainwater is typically used to water vegetation following the rain event, the cistern needs to be located close to the area identified for watering and at an elevation that will allow the harvested rainwater to flow by gravity, unless pumping is provided.

Inlet and Pretreatment

The downspout should form a tight fit with the cistern inlet to prevent harvested rainwater leakage and mosquito access. Using a grated inlet helps prevent leaves and other debris washed from the rooftop from entering the cistern. A fine mesh screen placed over the bottom of the grated inlet is also recommended to prevent mosquito access.

Drain or Outlet

Each aboveground cistern should be equipped with a drain or outlet nozzle located near the bottom, to allow it to be drained or used after the rain event and prior to the next rain event, or if the cistern has to be taken off line for the winter. Belowground cisterns should also be equipped with outlet piping near the bottom to allow for full use of the cistern volume.

Overflow

A cistern needs to be equipped with an overflow port to manage the roof rainwater runoff that is greater than the required WQv rain event. The port opening should be sized to handle the peak runoff from the 100 year, 24-hour rain event. The port on an aboveground cistern should be located to allow about one foot of head space between it and the top of the cistern. The discharge from the outlet should be directed to a pervious, stabilized area that will not be eroded from this concentrated flow.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs



Rainwater harvesting cisterns at the Green Building
(Photo: Erin Wagoner, URS)

A cistern is intended to only temporarily store harvested rainwater. Following the rain event, the stored rainwater needs to be drained or used to prepare for the next rain event. Therefore, this GMP should be in series with other GMPs such as rain gardens or bioretention areas to provide infiltration and volume control or some other beneficial reuse.

Educational Awareness

Signage should be provided at the cistern indicating that the water is not safe for human consumption.

Rainwater Harvesting-Cisterns Application and Site Feasibility Criteria

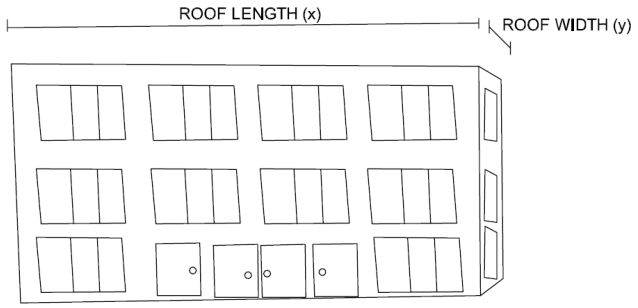
Table 18.5.14-A.

Design Parameter	Criteria
Design Volume and Conveyance Capacity	Store the runoff volume from the Required WQv Rain Event. Calculate runoff to pass the 2-, 10- and 100-year storms.
Pretreatment	Provide grate and fine mesh screen to prevent leaves and debris from entering the cistern.
Overflow Protection	Provide scour protection at the overflow discharge point. The overflow needs to sized to pass the 100-year storm event.
Volume	Cistern volume should be at least equivalent to the Required WQv. WQv (cubic feet) = $(1/12)[(RE_{WQV})(Rv)(A)]$- (WQ_{VR}) where • RE_{WQV} = Required WQv Rain Event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009$ (I) ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the cistern (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
Drawdown Time	Cistern should be emptied prior to the next rain event or continuous simulation model must demonstrate regular use and drainage of captured water.

Rainwater Harvesting-Cisterns Step by Step Design Procedures

Step 1: Determine the roof drainage area and runoff volume

When measuring the area of the roof, the footprint of the roof is required, not the area of each section of the pitched roof. An easy way to measure the roof footprint is to measure the outside of the building at ground level to determine the length and width of the building and then to add the length of any roof overhang, which is the distance that the roof extends past the building. Therefore, the area of the roof can be calculated as follows:



Roof Area (square ft) = x*y, where

x = length of the roof footprint (ft)
y = width of the roof footprint (ft)

A cistern should be sized to capture the required WQv, which is as follows:

$WQv\ (ft^3) = (1/12)[(RE_{WQV})(Rv)(A)]- (WQ_{VR})$, where

RE_{WQV} = Required WQv Rain Event
$Rv = 0.05 + 0.009\ (I)$;
I = impervious cover in percent;
A = drainage area to the cistern (ft^2); and
$WQ_{VR} = (1/12)[(RE_{WQV})(Rv)(IA_R)]$
Where IA_R = reduced impervious area
0.623 is a conversion factor

Step 2: Determine the roof drainage area and required WQv to each downspout

Evaluate the roof to determine the percentage of the entire roof or the specific area of the roof that drains to each downspout. Use this area along with the WQv calculation in Step 1 to determine the required WQv for each downspout.

Step 3: Determine number and size of cisterns

Based on the required WQv for each downspout calculated in Step 2, site constraints, and cistern costs, determine whether one larger cistern has adequate volume or whether multiple cisterns are needed. Select the combination of cistern(s) that provides the required WQv.

Step 4: Check stormwater reuse opportunities at each downspout

Evaluate the stormwater reuse opportunities at each downspout so that the stored stormwater can be used prior to the next rain event. Consider combining downspouts, as necessary. Follow applicable plumbing codes for using rainwater inside a building.

Step 5: Determine size of overflow

Calculate the peak stormwater roof runoff rate to each downspout for the 2-, 10- and 100-year storm events. Size and locate the overflow port for each cistern so that it can pass these larger storm events. The discharge from the overflow should be stabilized to prevent any scour and erosion.

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Metropolitan Sewer District

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Green Management Practice (GMP) Fact Sheet

18.5.15 Vegetated Buffers

Typical Implementation Areas:

- Commercial, industrial, multi-family residential and institutional developments

Key Considerations:

- Provide sheet flow into and across entire vegetated buffer
- Use to treat/infiltrate stormwater
- Applicable with gentle slopes (<6%)

Cost: Low-Medium
Maintenance: Low



Vegetated buffer strip along a bike path (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	☐
Floatables	◪
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	☐
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

A vegetated buffer, or filter strip, is a uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff. The vegetation in the buffer works to slow down the stormwater runoff, settling and filtering some pollutants and uptaking others. The stormwater runoff volume can also be reduced by infiltration into the pervious soil, if available, and by absorption and evapotranspiration of the vegetation. For a vegetated buffer to be effective, the stormwater has to enter and flow through the buffer in sheet flow. As a result, a flow spreader is often needed. The slope needs to be between 2 and 6%. The vegetation should consist of native, deep rooted grasses, shrubs and trees. A vegetated buffer can be managed or unmanaged depending on the desired aesthetics. A vegetated buffer improves water quality through:

- ☑ Settling and filtering pollutants
- ☑ Reducing stormwater peak flows due to infiltration of stormwater runoff

Advantages/Benefits

- Reduces stormwater runoff volume through infiltration and groundwater recharge
- Can be used as part of conveyance system and provides pretreatment for other GMPs

Disadvantages/Limitations

- Need to provide sheet flow to and throughout the buffer
- Limited applications (i.e. adjacent to trails and sidewalks)
- Not recommended for steep slopes or "hot spot" areas

Application and Site Feasibility:

A vegetated buffer usually receives stormwater runoff from an upstream impervious area and through sheet flow is able to treat the runoff and if the soils allow, infiltrate some of the stormwater runoff volume. For the buffer to be effective, the runoff needs to enter and flow through the entire buffer length in sheet flow. A flow spreader or similar device is typically required to produce sheet flow into the buffer; uniform grading within the buffer is required to maintain the sheet flow throughout the buffer. In addition, the buffer slope needs to be less than 6% to allow the flow to move slow enough for the vegetation to filter and settle out the pollutants and for the runoff to infiltrate. If the slope is less than 2%, then ponding water may be produced, which can lead to mosquito concerns. Often a vegetated buffer is used as preliminary treatment of the stormwater prior to entering another GMP. A vegetated buffer is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space to provide the buffer width and length is required
- Slope—The slope of the vegetated buffer should be between 2 and 6%
- Soil types—Soil types affect the amount of infiltration and the ability for the vegetation to thrive
- Sheet flow—Sheet flow needs to be provided at the beginning and throughout the vegetated buffer

Design Criteria

The design of a vegetated buffer includes several elements to manage stormwater treatment and infiltration. For a schematic of a typical vegetated buffer design see Figure 18.5.15-A. For a summary of design parameters, see Table 18.5.15-A.

Design criteria to consider include:

- Buffer slope and length
- Buffer width
- Soil composition
- Drainage area
- Inlet
- Landscaping plan
- Maintenance

Buffer Slope and Length

The vegetated buffer slope in the direction of flow should be between 2 and 6%, which prevents ponding of the runoff, but does not promote the formation of concentrated flow. The length of the buffer (parallel to flow) should be a minimum of 25 feet and should be determined using the formula given in Table 18.5.15-A.



Typical vegetated buffer (Photo: David Dods, URS)

Buffer Width

Stormwater runoff must enter the vegetated buffer as sheet flow across its entire width (perpendicular to flow) at a depth no greater than one inch for the required WQv rain event. The buffer width should be determined using the formulas in Table 18.5.15-A.

Soil Composition

A vegetated buffer should be used on soils that have minimal clays and an infiltration rate greater than two inches/hour. The objective is to use soils that are able to sustain a dense vegetative growth.

Drainage Area

The vegetated buffer is intended to treat runoff from a small contributing drainage area, typically not to exceed three acres.

Inlet

Stormwater runoff must enter the vegetated buffer in sheet flow across its entire width for it to be effective. A flow spreader or similar device is required to convert the upstream concentrated or overland flow to sheet flow across the entire buffer. The inlet design should also accommodate the passing or diversion of flows greater than the runoff from the required WQv rain event, without damaging the flow spreader and eroding the buffer.

Landscaping Plan

A landscaping plan is recommended for planting the vegetated buffer. The plan should include bedding preparation, identification of the various planting zones and

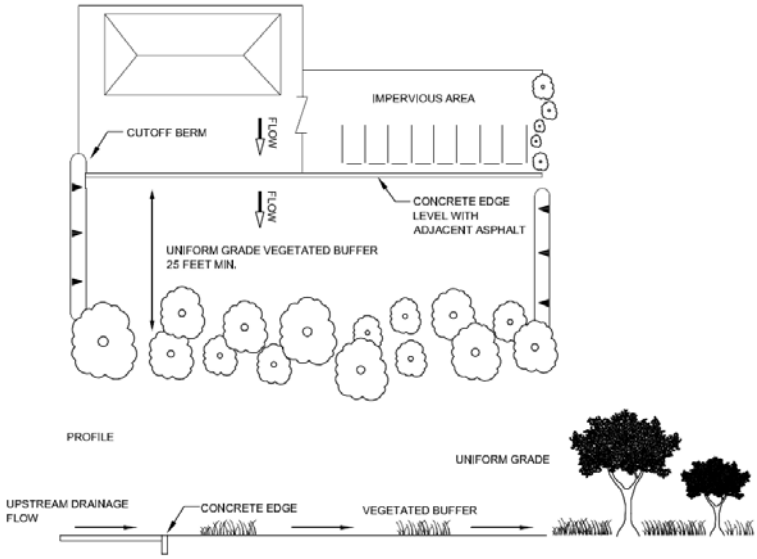

Figure 18.5.15-A. Vegetated Buffer Schematic (Rendering: Shea Powell, Dropseed)

recommended plants for each planting zone. Be sure to select plants appropriate for each zone.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Vegetated buffers are typically one of the first in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

The difference between a vegetated buffer and a traditionally landscaped area may not be visible to everyone. It is important that those maintaining it, as well as the general public, understand that its features extend beyond aesthetic landscaping to manage and treat stormwater runoff. Signs indicating "No Mow" areas serve to inform the public and may be required.

Vegetated Buffers Application and Site Feasibility Criteria

Table 18.5.15-A.

Design Parameter	Criteria
Buffer Slope and Length	• Slope in the direction of flow should be between 2 and 6% • Buffer length (parallel to the flow) should be a minimum of 25 feet and be calculated using the following equation: $L=[(T)^{1.25}(P)^{0.625}(S)^{0.5}]/3.34n$, where L = length of the buffer parallel to the flow path (ft) T = travel time through the filter strip (minutes), has to be 10 minutes at a minimum P = required WQv rain event (refer to Chapter 18.3) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient
Buffer Width	• The maximum discharge loading per linear foot of buffer width (perpendicular to flow) should be calculated using the following equation: $q = 0.0237(S)^{0.5}/n$, where q = discharge per foot of width of the filter strip (cfs/ft) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient The minimum width of the buffer should be calculated using the following equation: $W = Q/q$, where W = minimum width of the filter strip (perpendicular to the flow (ft) Q = peak discharge to the buffer from the required WQv rain event (cfs) • Calculate the velocity of the stormwater runoff across the buffer to be sure that it is less than 2.0 fps using the following equation: $V = Q/d*W$, where d = the depth of flow (ft)
Soil Composition	The infiltration rate within the vegetated buffer needs to be at least two inches/hr.
Drainage Area	The area draining to the vegetated buffer needs to be less than three acres.
Inlet	The vegetated buffer needs to have a flow spreader to provide uniform sheet flow across the entire width of the buffer.
Travel Time	Select a buffer length of at least 25 ft, use the following equation to calculate travel time: $T=[2.624*(n*L)^{0.8}]/(P^{0.5}*S^{0.4})$ Adjust the buffer length as necessary to determine the appropriate travel time.

Vegetated Buffers Step by Step Design Procedures

Step 1: Determine if site is appropriate

Determine if the site conditions and drainage area are appropriate for use of a vegetated buffer. Consider Table 18.5.15-A, especially the infiltration rate of the underlying soils.

Step 2: Determine the maximum discharge loading per foot of vegetated buffer width

Use the following equation to calculate the maximum discharge loading per foot of vegetated buffer width.

$$q = 0.0237(S)^{0.5}/n$$

Step 3: Determine the peak flow rate

Use modeling to calculate the peak runoff from the required WQv rain event (Q). The vegetated buffer also must be designed to safely convey or bypass flow rates produced by larger storm events with minimum erosion. Larger storms (2-,10-, and 100-year) should be modeled to size overflow or bypass structures to safely convey the flow.

Step 4: Determine minimum buffer width (perpendicular to the flow)

Calculate the minimum buffer width (perpendicular to the flow) using the following equation:

$$W_{min} = Q/q$$

Step 5: Determine the depth of flow in the buffer strip:

$$Q=q*W=V*A=V*W*d$$

Where d is the depth of flow in the buffer strip or V=q/d.
V can also be calculated from the Manning's Equation, which is:

$$V=(1.49/n)*R^{2/3}*S^{1/2}$$

Where R is the hydraulic radius. The hydraulic radius is the area of flow divided by the wetted perimeter. Since the width of the buffer strip is significantly larger than the depth of flow the wetted perimeter is practically 2W. Combining these two equations and inputting the wetted perimeter simplification the equation becomes

$$d=(1.04*q^{0.6}*n^{0.6})/S^{0.3}$$

Confirm that d is less than 1 inch.

Step 6: Check velocity through vegetated buffer

Check to make sure that the velocity through the vegetated buffer is less than two fps using the following equation:

$$V = Q/d*W$$

Should the velocity be too high, consider decreasing the slope or increasing the buffer width.

Step 7: Determine the Travel Time Through the Filter Strip

Select your buffer length to be at least 25 feet wide and calculate the travel time using the following equation:

$$T=[2.624*(n*L)^{0.8}]/(P^{0.5}*S^{0.4})$$

If T is too small, consider increasing the buffer length.

Step 8: Inlet design and bypass capability for larger storms

For the vegetated buffer to be effective, it needs to have uniform sheet flow into it and all along its length. A flow spreader should be designed at the entrance to the vegetated buffer to provide sheet flow. Consideration should be given for minimizing erosion at the beginning of the buffer once the flow leaves the flow spreader. In addition, the flow spreader and vegetated buffer should be designed to bypass or pass runoff from the larger storm events (2-, 10-, and 100-year) without causing erosion within the vegetated buffer.

Vegetated Buffers Step by Step Design Procedures (Continued)

Step 9: Prepare landscaping plan

Choose native plants to incorporate into the vegetated buffer based on aesthetic preferences, plant heights and sun/shade tolerances. The plan should include the following information:

- Different planting zones
- The species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.16 Vegetated Swales

Typical Implementation Areas:

- Natural or manmade shallow drainage ways in commercial, industrial, multi-family residential and institutional developments

Key Considerations:

- Drain within 24 hours after a rain event
- Large storm velocity <4.5 fps
- Only applicable with gentle slopes (preferably <2%)

Cost: Low
Maintenance: Low



Vegetated swale (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	☐
Pathogens	☐
Floatables	◪
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	☐
Infiltration	◪
Stormwater Conveyance	■
Stream Channel Protection	☐
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

A vegetated swale is a shallow, open-channel concentrated flow feature that contains a dense growth of vegetation, typically tall grass, that partially treats and can infiltrate stormwater runoff. The vegetation in the swale slows down the stormwater runoff, settling and filtering out some pollutants and uptaking others. The stormwater runoff volume can also be reduced by infiltration into the pervious soil, if available. A vegetated swale can enhance the local landscaping and be used as a good pre-treatment for other GMPs. A vegetated swale improves water quality through:

☑ Settling and filtering pollutants
☑ Reducing stormwater peak flows due to infiltration of stormwater runoff

Advantages/Benefits

- Can provide infiltration of runoff from smaller rain events (provided underlying soils allow)
- Can be used as part of conveyance system and provides pretreatment for other GMPs
- Can reduce cost of typical curb/gutter and storm sewer pipe infrastructure

Disadvantages/Limitations

- Low pollutant removal ability
- Need to be at lower slopes (<2%)
- May contain wet spots leading to maintenance and mosquito concerns
- Potential for erosion in bottom of swale while vegetation is becoming established

Application and Site Feasibility

A vegetated swale typically receives stormwater runoff from an area less than 20 acres. The vegetated swale slope needs to be less than 5%, and preferably in the 1-2% range to allow the flow to move slow enough for the vegetation to filter and settle out the pollutants and for the runoff to infiltrate, should the soils allow. With slopes less than 2%, ponding water may occur, which can lead to mosquito and maintenance concerns. In addition, the bottom of the swale should be at least 1 foot above the seasonal high water table to promote drainage of the swale. An underdrain system can be added to help remove ponding water.

The flatter swale slope is also important to prevent scouring of the swale bottom and sides and to allow time for the soil particles to be filtered out and any infiltration to occur. The runoff velocity within the swale should be kept to less than 4.5 foot per second (fps) during large rain events and 1.0 fps during the required WQv rain event. The swale length should be at least 100 feet long and provide a minimum of 5 minutes of residence time.

A vegetated swale is appropriate for stormwater conveyance in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space to provide the swale width and length required
- Slope—Should be between 1 and 2%, and not to exceed 5%
- Channel length—Provide at least five minutes of residence time
- Soil types—affect the amount of infiltration and the ability for the vegetation to thrive
- Conveyance—Able to convey the required flows at acceptable velocities

A schematic of a vegetated swale is provided in Figure 18.5.16-A below.

Design Criteria

The design of a vegetated swale includes several elements to manage stormwater treatment and infiltration. For a summary of design parameters, see Table 18.5.1-A. Note that vegetated swale design requirements differ from conventional conveyance requirements, as provided in

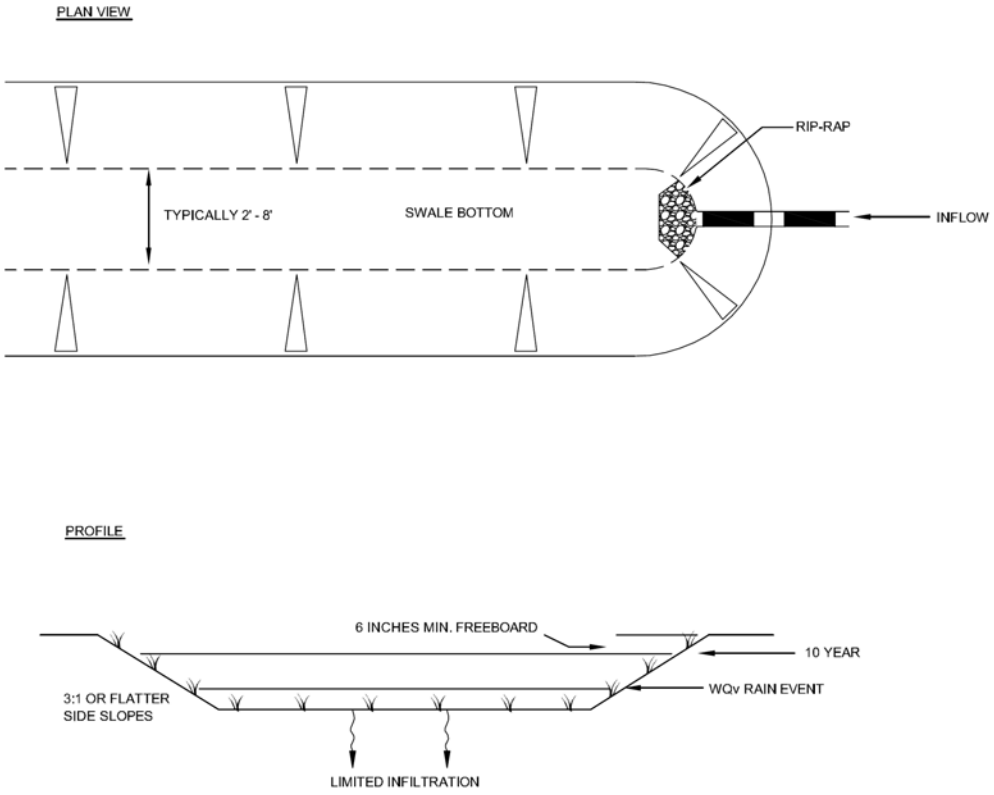

Figure 18.5.16-A. Schematic of vegetated swale

Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Design criteria to consider include:

- Flow capacity, velocity and freeboard
- Erosion prevention
- Slopes
- Swale length
- Soil composition
- Landscaping Plan
- Maintenance

Flow Capacity, Velocity, and Freeboard

Since swales are conveyance features, they are designed to slow and detain small storm events while also safely passing large storms with adequate freeboard. Flow velocity calculations for evaluating erosion protection needs are typically done assuming new or short vegetation. Flow conveyance and freeboard calculations for large storms typically assume taller, denser vegetation. The flow velocity for the peak runoff from the required WQv rain event should not exceed 1.0 fps, while that for the 100-year rain event should not exceed 4.5 fps or the limit for the vegetation to be used, whichever is lower.

A minimum of 6 inches of freeboard should be provided in the swale for runoff from the 100-year, 24-hour rain event. The maximum flow depth for the peak runoff from the required WQv rain event should be four inches.

The swale should be sized to have a bottom swale width of between two and eight feet. The width can be calculated using the formula in Table 18.5.16-A. Vegetated swales along the roadway should have adequate flow conveyance and maintain adequate freeboard to avoid flooding or overtopping the pavement. When swales are in close proximity to pavement structure, they should have enough flow capacity to provide positive subgrade drainage.

Erosion Prevention

Vegetated swales should be lined with biodegradable erosion control matting for erosion prevention during the vegetation establishment period. Selection should be based on shear stress of flowing water. In addition, velocities should be maintained within the limits noted in the previous section.

Slopes

Site topography should be considered in the vegetated swale design, including main channel slope and side slope to maintain non-erosive velocities. Typically, main channel slopes (parallel to the flow) should be 1 to 2%. Where there are poor soils, an underdrain should be used, to prevent ponding water. In areas with slopes between 2 and 5%, check dams or weirs should be placed perpendicular to the flow to extend time for infiltration and filtration and reduce the effective slope of the swale. Placement of check dams or weirs should include scour protection to limit erosion.

The side slopes of the swale should be a minimum of 3:1, with 4:1 preferred. These flatter slopes prevent scour from runoff entering the channel from the sides and from the concentrated flow in the swale.



Vegetated swale installation using turf reinforcement mats
(Photo: David Dods, URS)

Swale Length

The vegetated swale length should be sized to provide a minimum of 5 minutes of residence time and should be a minimum of 100 feet. The swale length can be calculated using the equations provided in Table 18.5.16-A.

Soil Composition

A vegetated swale should be used on soils that have minimal clays and an infiltration rate greater than 0.5 inches/hr. The soils should be able to sustain a dense vegetative growth.

Landscaping Plan

A landscaping plan is recommended for planting the vegetated swale. The plan should include bedding preparation, identification of the various planting zones and recommended grasses for each planting zone considering flow velocity and wet and dry fluctuations. Select grasses appropriate for each zone.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A minimum of three different types of grasses are recommended. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A vegetated swale is typically one of the first in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

The difference between a vegetated swale and a traditionally landscaped area may not be visible to everyone. To maintain the integrity and effectiveness of the vegetated swale, it is important that those maintaining it understand that its features move beyond aesthetic landscaping to manage and treat stormwater runoff. Signs indicating that the vegetated swale is a stormwater management feature will provide outreach to the general public and may be required.



MSD staff re-grade a vegetated roadside swale (Photo: Louisville & Jefferson County MSD)

Vegetated Swales Application and Site Feasibility Criteria Chart*

Table 18.5.16-A.

Design Parameter	Criteria
Longitudinal Slope	• Less than 5% • 1 - 2 % preferred • Use check dams to achieve slopes as needed
Bottom Width	• 2 - 8 feet typical • The width can be calculated using the following equation: $W = (n*Q)/(1.49*D^{5/3}*S^{1/2})$, where W = minimum bottom swale width (ft) n = Manning's roughness coefficient Q = peak runoff (cfs) D = flow depth (ft) S = slope (%)
Swale Length	• The swale length can be calculated using the following equations: $V = Q/(W*D)$ $L = 60*V*R$, where V = velocity (fps) L = swale length (ft) R = residence time (minutes)
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended
Maximum Permissible Velocity	• 1.0 fps for peak flow from required WQv rain event • 4.5 fps for peak flow from the 100-year, 24-hour rain event
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm
Soils	Underlying soils should have an infiltration rate of 0.5 inches per hour or greater
Residence Time for the Required WQv Rain Event	• Minimum of 5 minutes • Preferably greater than 9 minutes
Drawdown Time	Vegetated swale should dewater within 24 hours
WQv	Calculate WQv (cubic feet) $=(1/12)[(RE_{WQV})(Rv)(A)]- (WQ_{VR})$, where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009\ (I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the swale (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

* Note that vegetated swale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Vegetated Swales Step by Step Design Procedures

Step 1: Determine if site is appropriate

Determine if the site conditions and drainage area are appropriate for use of a vegetated swale. Consider Table 18.5.16-A.

Step 2: Determine the peak flow rate

Swales should achieve the residence time shown in Table 18.5.16-A for the runoff from the required WQv rain event. Swales must be designed to safely convey flow rates produced by larger storm events with adequate freeboard and minimum erosion.

Larger storms (2–, 10– and 100-year) should be checked to size the swale to carry them. For each culvert/drainage area, model or calculate the peak flow rate for the following storm events:

- Required WQv rain event
- 2-year, 24-hour
- 10-year, 24-hour

Step 3: Determine the depth of flow and the bottom width of the vegetated swale

Select either a desired flow depth (D), which should be 4 inches or less, or bottom width (W) of the vegetated swale and solve for the other using the following equation:

$$W=(n*Q)/(1.49*D^{5/3}*S^{1/2})$$

Confirm that D is 4 inches or less.

Step 4: Determine the velocity of the peak flow from the WQv rain event

Calculate the velocity in the vegetated swale using the following equation:

$$V=Q/(W*D)$$

Confirm the velocity is less than or equal to 1.0 fps.

Step 5: Determine the length of the vegetated swale and the residence time

Select either a desired residence time (R) or length (L) and solve for the other using the following equation:

$$L=60*V*R$$

Should the residence time be less than desired, consider increasing the vegetated swale length or bottom width or decrease the swale slope.

Step 6: Check velocities and freeboard for larger storms

Based on the average swale cross-section and slope, check flow velocities and water surface elevations for the 2- , 10- and 100- year, 24-hour storm events for the swale to pass safely. Check that the velocity is 4.5 fps or less to promote sediment drop out and filtration as well as reduce erosion potential. Check that the water depth provides 6 inches of freeboard. Modify design as appropriate.

Step 7: Select erosion control measures

Compare peak flow velocities calculated for the required WQv rain event, 2-, 10– and 100-year, 24-hour storm events to maximum permissible velocities for the soil types present at the site and determine the need for biodegradable erosion control materials. For most swales, a biodegradable erosion control mat will be needed to limit soil erosion while the vegetation is becoming established. Choose biodegradable erosion control mat based on the manufacturer's specifications that meet the peak flow velocities.

Step 8: Prepare vegetation and landscaping plan

Choose deep rooted, native grasses based on aesthetic preferences, grass heights, and the anticipated moisture zones within the swale. In general, the sides of the swale will be well drained and the vegetation on the sides will need to tolerate dry conditions as well as occasional wet conditions. The bottom of the swale will have more moist conditions, so vegetation will need to tolerate longer periods of saturation. Choose grasses appropriate for the conditions that will be created in the swale.

The plan should include the following information:

- Different planting zones
- Species to be planted within each planting zone and planting plan
- Planting density for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the vegetation

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP)

18.5.17 Underground Storage

Typical Implementation Areas:

- Underneath paved areas in commercial, industrial, multi-family residential and institutional developments
- Highly urbanized areas where land is expensive or limited

Key Considerations:

- Temporarily detains stormwater
- Access for maintenance

Cost: High
Maintenance: Medium

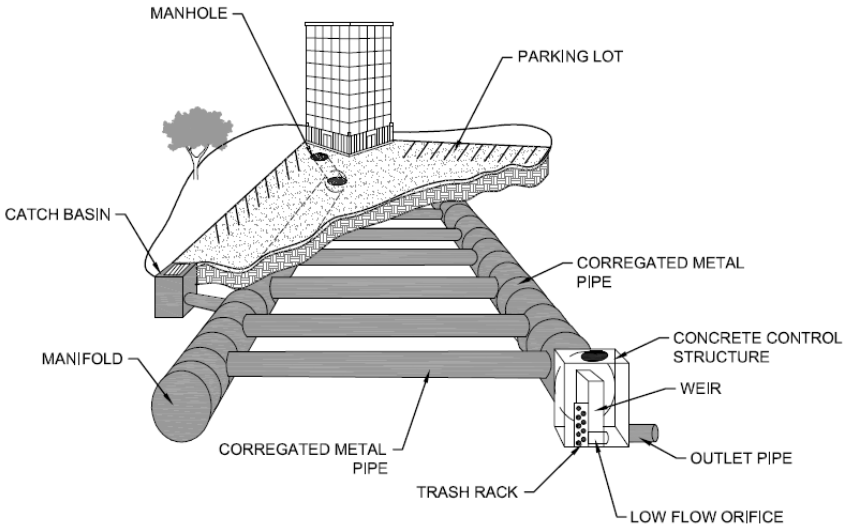

Figure 18.5.17-A. Typical underground stormwater storage system (Source: Montgomery County, MD)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	☐
Pathogens	☐
Floatables	◪
Oil and Grease	☐
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	☐
Infiltration	☐
Stormwater Conveyance	☐
Stream Channel Protection	◪
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

Underground storage is the practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures. The collected stormwater runoff is intended to be released back to the surface drainage system or storm sewer system at a reduced rate and completely drained prior to the next rain event, similar to a green dry detention pond. Some underground storage systems may also infiltrate the stormwater into the underlying soils, provided the surrounding soils have the necessary permeability. An underground storage system may be constructed of concrete, steel or plastic with many proprietary products in the market. These systems provide very little water quality benefit, so additional GMPs or pretreatment devices are required where water quality improvements are needed. Underground storage improves stormwater management through:

- ☑ Detention of stormwater runoff, reducing peak flows
- ☑ Possible reduction of stormwater runoff volume through infiltration to surrounding soils

Advantages/Benefits

- Reduces channel/stream bank erosion by reducing the number of bankfull events
- Less installation time than other GMPs
- Adapts to unusual shaped property
- Increased public safety compared to surface GMPs

Disadvantages/Limitations

- Not intended for water quality benefit
- Requires pretreatment to reduce maintenance efforts or to infiltrate
- Not to be used in areas with high groundwater table

Application and Site Feasibility

Underground storage is applicable in areas where water quantity control is desired and land is not available or is too expensive for aboveground GMPs. Underground storage needs to be located such that the stormwater runoff gravity feeds into and out of the storage system. Underground storage should be located in areas that can be excavated in the future, should the need arise. Underground storage is appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/ high density residential areas, typically in ultra-urban areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to locate the required storage volume and provide access for maintenance vehicles.
- Material selection—Select the material of construction for the underground storage system based on desired useful life, earthwork requirements, overburden support and potential for the system to float.
- Access—Several manholes/access ports need to be provided to allow for maintenance and inspection of the system.
- Slopes—The bottom of the underground storage system should be sloped no more than 2% to allow for complete draining.

Design Criteria

The design of underground storage includes several elements to properly reduce stormwater runoff volumes and reduce peak flow rates into the sewer system. See Figure 18.5.17-A for a schematic drawing of a typical underground storage system. For a summary of design parameters, see Table 18.5.1-A on page 3.

Design criteria to consider includes:

- EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)
- Inlet and pretreatment
- Outlet
- Overflow and bypass
- Infiltration
- Overburden support
- Drain time
- Maintenance

EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)

Infiltration drains are generally long, narrow stormwater quality features that capture stormwater. However, an infiltration drain can be classified as a Class V Injection well by the EPA if it meets the following criteria (see the Class V wells page at www.epa.gov):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system."

If the infiltration drain designed meets any of the criteria listed above, the EPA form 7520-16 should be filled out and all other additional EPA regulations should be followed. Other terms including well, injection well, improved sinkhole or drywell will trigger requirements by the EPA.

Inlet and Pretreatment

Inlets need to be provided in the quantity and size needed for the desired stormwater runoff to enter the underground storage system. Pretreatment, focused on the removal of floatables and sediment, should be provided at the inlets to reduce maintenance efforts and prevent any groundwater contamination, if infiltration is provided. Pretreatment may include catch basin inserts or proprietary water quality units.

Outlet

The outlet orifices need to be sized to prevent clogging, typically no smaller than 8 inches, but provide the required retention of the stormwater runoff.

Overflow and Bypass

The underground storage system needs to have an emergency overflow to allow for safe passage of the larger storm events. In addition, a bypass system should be provided to allow the underground system to be taken out of service should it become inoperable.

Infiltration

Should the underground storage system intend to infiltrate the stormwater runoff into the surrounding soils, the soils need to have a permeability rate of at least 0.5 inches/hr. Pretreatment of the stormwater runoff should be provided to prevent groundwater contamination.

Overburden Support

When selecting the underground storage system material, consider the loading coming from above. The loading will include backfill, pavement, and possibly vehicular traffic.

Drain Time

The stormwater runoff WQv collected in underground storage should drain out to a surface drainage or sewer system or infiltrate into the surrounding soils within 48 hours.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. Provide an adequate number of access points, a minimum of two, to allow for maintenance activities. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Underground storage mostly provides water quantity benefits and not water quality benefits. Therefore, this GMP will typically be in series with other GMPs. It may follow proprietary water quality units or catch basin inserts or may precede other GMPs such as bioswales or green detention ponds to provide infiltration and additional volume control.

Educational Awareness

Underground storage is confined space, so special precautions, protective equipment and training are required for personnel entering the storage system.

Underground Storage Application and Site Feasibility Criteria

Table 18.5.17-A.

Design Parameter	Criteria
Pretreatment	Provide BMPs to prevent leaves, trash and sediment from entering the underground storage system.
Overflow Protection	The overflow needs to be sized to pass runoff from storms greater than the 100 -year, 24-hour event.
Conveyance	Pass the runoff from the 2-, 10- and 100-year, 24-hour storms.
Volume	Underground storage volume should be at least equivalent to the Required WQv. WQv (cubic feet) = $(1/12)[(RE_{WQV})(Rv)(A)]$- (WQ_{VR}) where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.3) • $Rv = 0.05 + 0.009$ (I) where ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the underground storage system (ft^2) • $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
Infiltration Rate	For underground storage to infiltrate the stormwater runoff into the surrounding soils, the soils need to have a permeability of at least 0.5 inches/ hour.
Drawdown Time	Underground storage should be drained within 48 hours of the end of the required water quality rain event.

Underground Storage Step by Step Design Procedures

Step 1: Define goals/primary function of underground storage

Define the goals/primary function of the underground storage system, especially whether it will provide infiltration into the surrounding soils. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), and site access considerations.

Step 2: Determine the peak flow rate and total runoff volume

Underground storage should be sized to capture and temporarily store the required WQv created from the runoff from the required WQv rain event. The underground storage system should drain in no more than 48 hours. Larger storms (2-, 10- and 100-year) should be checked to size outlet, bypass and overflow structures to convey these flows. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of underground storage. Consider Table 18.5.17-A. Create a rough layout of the underground storage system including existing utilities, topography and other obstructions.

Step 4: Determine outlet, bypass and overflow design

Based on the underground storage system configuration, check water surface elevations for all storm events (shown in Step 2) so the system can pass these flows safely and drain within 48 hours. Determine the need for erosion prevention and energy dissipation measures at the outlet. Modify design as appropriate.

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Green Management Practice (GMP)

18.5.18 Catch Basin Inserts

Typical Implementation Areas:
- Retrofit areas
- Pretreatment upstream of other GMPs
- Inlet protection

Key Considerations:
- Media type/manufacturer
- Size of drainage area

Cost: Low-Medium
Maintenance: High

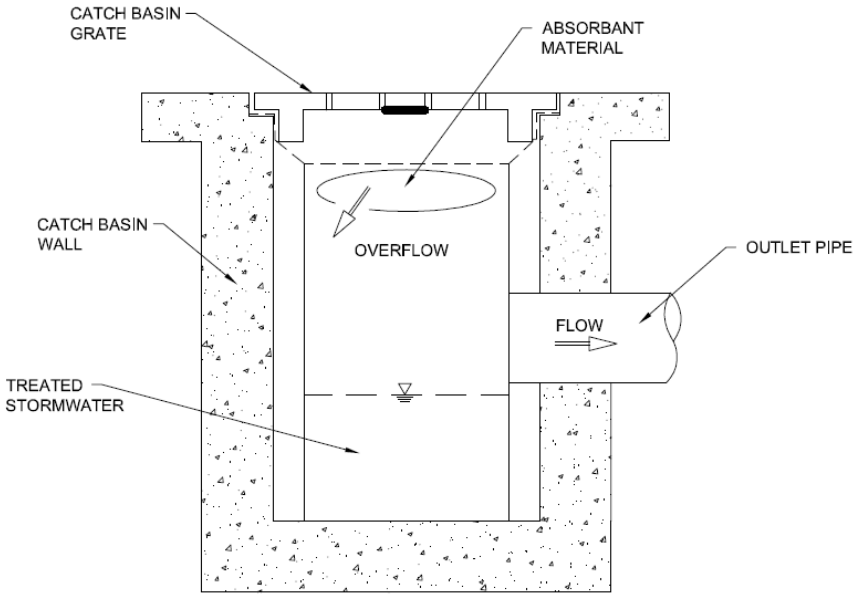


Figure 18.5.18-A. Catch basin insert schematic

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◪
Phosphorus	☐
Nitrogen	☐
Metals	◪
Pathogens	☐
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	☐
Hydrologic Characteristics	
Surface Flow Reduction	☐
Infiltration	☐
Stormwater Conveyance	☐
Stream Channel Protection	☐
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

Catch basin inserts are space saving devices installed underneath the grate of an inlet to remove sediment, debris, oils or metals from stormwater inflow. This can be achieved through filtering, settling or absorbing pollutants. Catch basin inserts are beneficial because they install easily in retrofit systems and work well in a treatment train as they minimize clogging in downstream water quality features. Catch basin inserts improve water quality through:

- ☑ Filtering sediment, debris and oils
- ☑ Effective form of pretreatment

Advantages/Benefits:

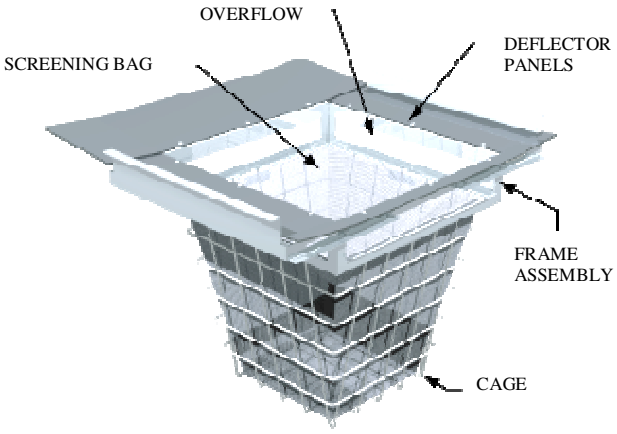
- Typically easy installation
- Appropriate for sites with space limitations and where infiltration is not an option
- Appropriate for retrofit applications
- No aboveground or underground storage is needed beyond the typical storm sewer system

Disadvantages/Limitations:

- Not effective as a stand-alone water quality treatment source
- Susceptible to clogging and not suitable for accepting runoff from areas with heavy sediment flow
- May require more frequent maintenance or could become a source of pollutant depending on volume of flow received
- Does not effectively capture dissolved pollutants and fine particles

Application and Site Feasibility:

Catch basin inserts are an effective way of filtering stormwater before it enters a rain garden, dry basin or some other form of GMP. Since the inserts trap sediment and debris, they minimize the potential of clogging for downstream water quality features. They can also be installed as an additional source of water quality improvement and receive filtered water from a GMP. However, they are not suitable for receiving runoff from areas with heavy sediment flow because of their minimal storage capacity for captured sediment. Catch basin inserts are suitable for use in unpaved areas with minimal erosion or in parking lots with a small drainage area. Catch basin inserts are also beneficial for retrofit areas because of their ability to be installed easily into existing systems.



Catch basin insert with a metal screen to catch sediment and debris (Source: Enviropod, Stormwater 360)

Physical Requirements:

Catch basin inserts performance ability and size vary based on the manufacturer and/or project need. Inserts should be designed and installed based on the manufacturer's recommendations. Recycled and reusable products are available for some types of insert media. The following types of material are generally used in combination with the catch basin inserts:

- Metal/Plastic Screens—typically effective in the removal of sediment and other debris (See schematic to the right)
- Fabric—typically effective in the removal of oil and grease (See photo to the right)
- Filter inserts—designed to remove metals or other types of pollutants (See graphic page 3)



Catch basin insert with an oil-absorbent fabric (Source: Enpac)

Design Criteria:

The design of catch basin inserts should be based on manufacturer's recommendations. Some typical design considerations for choosing the type and manufacturer include:

- Location of Catch Basin
- Overflow (Bypass)
- Location of Filter Media
- Pollutant Removal
- Installation
- Maintenance

Location of Catch Basin

The catch basin should be located in an area that is accessible for maintenance at any time. Special consideration should be given during the design phase to ensure that the basin will not be blocked for maintenance by vehicles or other obstructions.

Overflow (Bypass)

Catch basin inserts should be designed to bypass stormwater flow in excess of the water quality design volume into another system or inlet. This prevents overflow of the catch basin if it becomes clogged or when there is excessive rainfall.

Location of Filter Media

The bottom of the filter media should be located above the crown of the outlet pipe (See Figure 18.5.18-A on page 1). This will ensure that the water quality design volume is filtered through the media.

Pollutant Removal

Catch basin inserts can be designed to remove various types of pollutants based on the media inserts discussed under physical requirements. Care should be taken to ensure that the insert type chosen has the necessary performance capabilities based on the manufacturer's recommendations.

Installation

Inserts should be installed based on manufacturer's recommendations. Generally, the construction site should be stabilized before the insert in installed into the basin to prevent clogging from excess sediment.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

As stated previously, catch basin inserts are not stand-alone features because of their small storage capacity and are recommended to be located in series with other GMPs.

Educational Awareness:

Some catch basin inserts collect pollutants that could be harmful to human health, so appropriate personal protective equipment is recommended.





Catch basin insert incorporates a specialized filtration fabric and a mesh lining to remove various types of pollutants (Source: CleanwayUSA)

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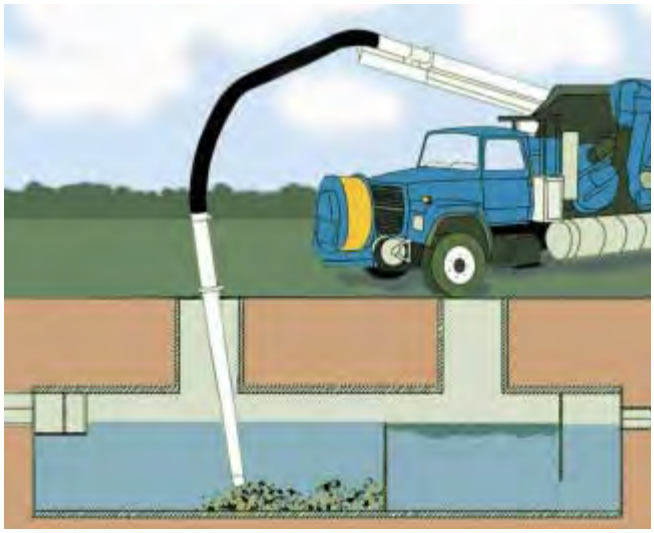
Green Management Practice (GMP)

18.5.19 Proprietary Water Quality Units

Typical Implementation Areas:
- Parking lots and roadways
- Hazardous substance facilities
- Curb and inlet runoff
- Retrofit areas

Key Considerations:
- Unit type

Cost: Medium-High
Maintenance: Medium



Water quality units are typically equipped with access risers for easier inspection and maintenance. (Graphic: Advanced Drainage Systems)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	varies
Phosphorus	varies
Nitrogen	varies
Metals	varies
Pathogens	varies
Floatables	varies
Oil and Grease	varies
Dissolved Pollutants	varies
Hydrologic Characteristics	
Surface Flow Reduction	☐
Infiltration	☐
Stormwater Conveyance	◪
Stream Channel Protection	☐
Peak Flow Control	☐
Runoff Volume Reduction	
Runoff Capture	◪

Key : ■ Significant Benefit
◪ Partial Benefit
☐ Low or Unknown Benefit

Proprietary water quality units vary based on manufacturer, but are typically underground treatment systems installed at inlet structures. These systems are a space effective design that creates a swirling vortex or contains multiple chambers to separate sediments and floatables, such as oil/grease, from stormwater inflow. Proprietary water quality units improve water quality through:

- ☑ Effective removal of heavy sediment
- ☑ Effective removal of oil/grease
- ☑ Removal of hazardous substances before they have a chance to infiltrate into the soil
- ☑ Works well in a treatment train

Advantages/Benefits

- Typically easy installation
- Appropriate for sites with space limitations and where infiltration is not an option
- Appropriate for retrofit applications
- Good for impervious area runoff that may clog other types of GMP's
- Can be designed to be suitable for hazardous substance runoff

Disadvantages/Limitations

- Not effective as a stand-alone water quality treatment source
- May require more frequent maintenance depending on size of structure and quantity of flow and pollutants
- Cannot effectively remove dissolved pollutants and fine particles
- Potential source of pollutants if maintenance is neglected

Application and Site Feasibility

Proprietary water quality units can provide water quality benefits for sites with limited area for infiltration opportunities. The units typically will need to be used in conjunction with other GMPs as they do not provide removal of fine or soluble particles. Some systems are suitable for areas with impervious runoff or hazardous materials because they provide treatment of water before it is infiltrated into the soil. The water quality units are also implemented in retrofit areas because of their ability to meet space requirements.

Physical Requirements

Key physical considerations:

- Unit Type—Proprietary water quality units vary based on the manufacturer, however there are two main types of units: hydrodynamic and chambered

Hydrodynamic Devices

Hydrodynamic designed units allow flow to enter the system where the water will move in a swirling motion inside the unit to allow particles of sediment and debris to separate and fall to the bottom. There may also be a separate filter inside the water quality unit to absorb oil and grease. Hydrodynamic devices are generally effective in treating smaller storms and are typically designed to pass flow from larger storm events to prevent re-suspension of captured sediment and debris. Additional GMP's used in conjunction with the units could be effective in meeting water quality requirements for larger storms. A schematic section of a hydrodynamic water quality unit is shown on Figure 18.5.19 -A below.

Chambered Devices

Chambered devices allow water to flow into a sump-like structure with weir or baffle plate walls located vertically, thus dividing the structure into separate chambers. (See schematic below). These chambers allow sediment and debris to settle and oil and grease to be separated from the outflow. As with hydrodynamic units, these structures are typically designed to pass larger storms so additional GMP's are recommended in conjunction with the chambered device. A schematic section of a chambered device is shown on Figure 18.5.19-B on page 3.

Design Criteria

Design for water quality units should be based on manufacturer's recommendations. Some typical design criteria to consider when choosing a type and manufacturer are:

- Location
- Sizing
- Installation
- Pollutant Removal
- Maintenance

Location

Water quality units should be installed upstream of additional GMPs as pretreatment devices. Refer to manufacturer's recommendations for maximum drainage area for each type of device.

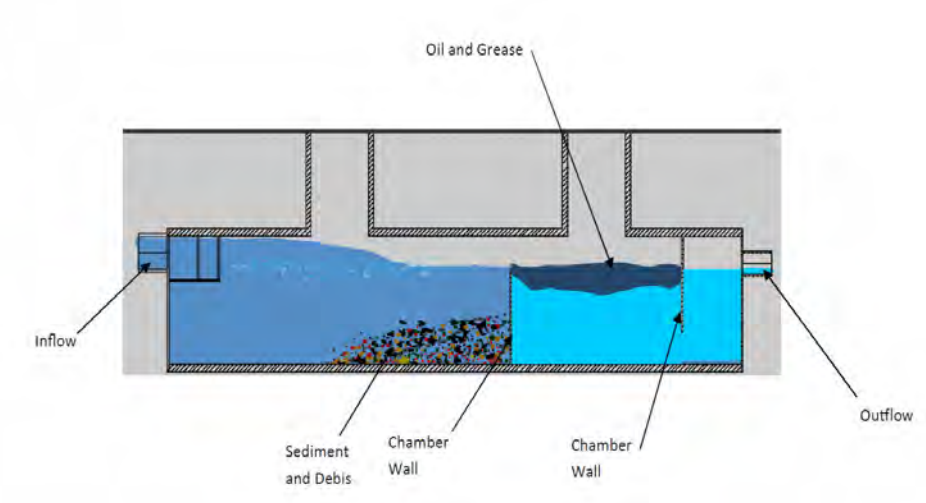


Figure 18.5.19-A. Schematic section of a chamber device (Graphic: Advanced Drainage Systems)

Sizing
At a minimum, the water quality unit should be sized to treat the peak flow associated with the WQv in order to be an effective pretreatment device.

Installation
Installation should always occur per manufacturer's recommendations. A manufacturer's representative should be present on-site during the installation of the water quality unit to ensure that it is installed properly. Based on the water quality unit chosen, screens may also need to be installed to prevent mosquitos and rodents from entering the unit.

Pollutant Removal
Pollutant removal varies based on the individual design of the water quality unit and can be customized per manufacturers' recommendations. If the unit will be accepting flow from a hazardous substance facility or has any other special pollutant removal requirements, care should be taken to ensure that the unit chosen has the necessary performance capabilities.

Maintenance
Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs
As stated previously, water quality units are not typically stand-alone treatment sources because of their inability to remove dissolved sediment and fine particles and are thus most effective located in series with other GMPs.

Educational Awareness
Some proprietary water quality units are confined space, so special precautions, personal protective equipment and training are required for personnel entering the unit.

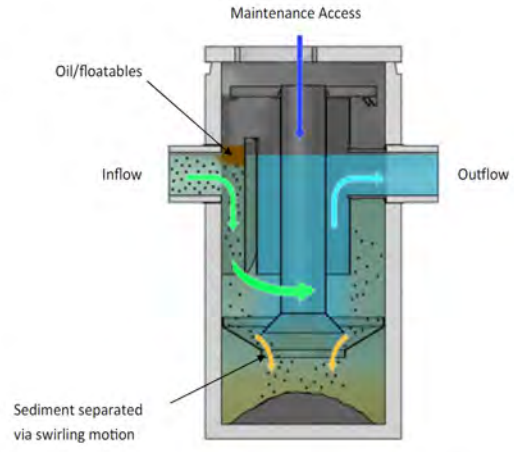


Figure 18.5.19-B. Schematic section of a hydrodynamic device
(Graphic: Hydro International)

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Green Management Practice (GMP) Fact Sheet

18.5.20 Infiltration Drains

(a.k.a. sumps galleries, trenches, and infiltration practices)

Typical Implementation Areas:

- Parking lot perimeters
- Small sites
- Medians between drive lanes

Key Considerations:

- Surface dimension vs. depth
- Requires pretreatment
- Infiltration
- Proximity to building foundations
- Slopes

Cost: Medium
Maintenance: Medium-High



Construction of the U of L Speed Art Museum Infiltration Trench
(Photo: Louisville & Jefferson County MSD)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	◪
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	■
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	■

Key : ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Infiltration drains are shallow, excavated areas that receive stormwater. Overland flow or a perforated inlet pipe allows stormwater to infiltrate through the aggregate and into the underlying soil, promoting groundwater recharge. Three important factors to consider when designing an infiltration drain are: the size of the drainage area, the capacity of the storage, and the exfiltration of the water out to the soil. Infiltration drains improve water quality through:

- ☑ Treatment of stormwater percolating through soil
- ☑ Groundwater recharge
- ☑ Effective removal of light sediment and pollutants

Avantages/Benefits

- Provides WQv for sites with limited space available
- Reduces volume of stormwater runoff and provides peak flow control
- Typically appropriate for small sites (< 5 acres) unless large infiltration area is available.
- Provides infiltration, groundwater recharge and pollutant filtration
- Works well with other GMPs in series

Disadvantages/Limitations

- May not be suitable for locations impacting utilities, shallow groundwater, bedrock, sinkholes, buildings/basements, etc.
- Not suitable for steep slopes (>15%)
- Requires pretreatment to prevent clogging
- Potential for groundwater contamination
- Additional EPA permitting requirements if designed as an underground injection well

Application and Site Feasibility

Infiltration drains are appropriate for use in series with other GMPs. They are typically filled with aggregate and contain no outlet structure. For these drains, a pretreatment device is required to filter large sediment and debris before entering the drain to prevent clogging. These infiltration drains are applicable for a wide variety of uses such as the perimeter of parking areas or medians between drive lanes. They can also be applicable for sites with limited space available for water quality features. In addition, there are a variety of ways these structures can be designed. One possibility is the drain receives overland flow through gravel or grass. Another possibility is the structure receives point flow from a sump that then drains to the filter media.

Physical Requirements

Key physical considerations are:

- Surface dimension vs. depth—if an infiltration drain is designed so that it is deeper than it is wide, then it meets the EPA definition of a Class V Injection Well. See the Design Criteria on this page for more information.
- Infiltration—Drains should drain in 24 to 48 hours. Native soils shall have an infiltration rate of 0.5 inches per hour or greater.
- Slopes—Slopes affect flow rates, infiltration rates, and erosion.

Design Criteria

The design of an infiltration drain includes several elements to manage stormwater infiltration as well as stormwater conveyance to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.20-A.

Design criteria to consider include:

- EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)
- Location
- Cover Types
- Sizing
- Storage Capacity
- Slopes
- Pretreatment
- Native Soils
- Storage Media
- Overflow
- Observation well
- Erosion Prevention
- Mosquito Control
- Maintenance

EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)

Infiltration drains are generally long, narrow stormwater quality features that capture stormwater. However, an infiltration drain can be classified as a Class V Injection well by the EPA if it meets the following criteria (see the Class V wells page at www.epa.gov):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system."

If the infiltration drain designed meets any of the criteria listed above, the EPA form 7520-16 should be filled out and all other additional EPA regulations should be followed. Other terms including well, injection well, improved sinkhole or drywell will trigger requirements by the EPA.

Location

Since infiltration drains are retention structures, they are designed to effectively capture stormwater runoff. When finding the most appropriate location for the drain, it is best to find a location with a small drainage area (approximately less than 5 acres). For larger drainage areas, it is recommended that a comparable area be used for infiltration, more than one infiltration drain is installed, or another GMP be established in series.

This drain should be used where the groundwater table is at least 4 feet lower than the lowest point of the infiltration structure to promote effective infiltration. Areas with heavy sediment flow or a significant pollutant load are not suitable locations because the aggregate may become clogged or the



An improved sinkhole can be considered a Class V Injection Well by the EPA (Photo: Sabak, Wilson and Lingo)

groundwater contaminated. In addition, this drain should be placed at least 10 feet from building foundations and underground utilities. See Figures 18.5.20-A through E for typical design layouts/profiles for this structure.

Cover Types

- Grass
- Pea gravel
- Pervious pavers
- Permeable Concrete/Concrete
- Porous Asphalt/Asphalt
- Pervious pedestrian mats (playground surfacing)

Sizing

The surface storage parameter should be designed to retain/capture the volume produced by the rainfall events specified in Table 18.5.20-A. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. Ponding depth should be limited to 6 inches or less. An overflow feature should be installed to move excess water during a large storm event or in case of clogging.

Sizing of the infiltration drains is based on the volume provided by the porosity of the media in the drain and in the ponding above the drain media. The volume should at least be equal to the WQv. See Table 18.5.20-A for the WQv formulas.

Storage Capacity

Infiltration drains are designed to detain small storm events while also safely passing large storms with adequate freeboard. Infiltration drains in the medians between roadways, for example, should have an adequate overflow system and maintain adequate freeboard to avoid flooding or overtopping the pavement.

Slopes

Site topography should be considered in an infiltration drain design. Typically, natural slopes of areas providing stormwater drainage flow to the drain should be less than 15%. This prevents excessive scouring of the vegetated area due to high velocities from stormwater inflow. See Figure 18.5.20-C through E for a typical profile of an infiltration drain.

Pretreatment

Pretreatment should be used for all applications to prevent clogging and ease maintenance, especially in land use areas with high sediment loads. Figure 18.5.20-E shows the cross section of a pretreatment device. The following list provides some examples for pretreatment methods:

- Forebay—Ideal for areas with large amounts of sediment
- Level Spreader—Applicable for areas with high-velocity storm water, this device can also be used this to reduce water pollution
- Vegetated Strip—Suitable for areas with large amounts of sediment and other pollutants as well as high velocity
- Proprietary Water Quality Unit—Applicable for areas with stormwater runoff that includes both sediment and floatables (oil/grease), such as parking lots and roadways. See Section 18.5.19 for design specifications.

Native Soils

Infiltration drains typically contain no outlet structure. The native soils underneath the drain should have an infiltration rate of 0.5 inches per hour or greater and should be designed to drain in 24 to 48 hours. Should the drain have in situ soils that are Hydrologic Soils Group A or field determined to be equivalent, then the infiltration capability of the soils can be factored into the sizing of the infiltration trench. Modeling and analysis showing how a smaller infiltration drain can manage the required WQv can be prepared by the design professional and submitted to MSD for review and concurrence.

Storage Media

Infiltration drains should be installed using washed aggregate, pea gravel, sand, and filter fabric. River rock may be used in trenches with non-load-bearing applications. A 6 to 12 inch layer of sand should be installed on the bottom of the trench to promote infiltration and to prevent compaction of the native soils. Filter fabric should also be installed on the sides only of the drain to prevent migration of the native soils into the storage media. A 6 inch to 12 inch layer of pea gravel as the top layer of the drain will help to filter large sediment and debris before it enters the storage layer. See Figure 18.5.20-C.

Overflow

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. This may be achieved by installing a vegetated berm around the perimeter of the drain or by designing the drain so the overflow flows downhill. The planning and installation of the high flow bypass or diversion structure will be largely based on each site design.

Observation Well

An observation well should be installed in the center of the drain to monitor the water level of the drain and check for

clogging. The observation well should be a 6-inch perforated PVC pipe with a removable and lockable cap.

Erosion Prevention

Infiltration drains receiving stormwater by means of sheet flow through a vegetated area may require the use of level spreaders, turf reinforcement mats, or other enhanced erosion protection. This may be necessary in locations of concentrated flow or to protect against high stormwater velocities produced by large storm events. Mat selection should be based upon anticipated flow velocities, vegetation planting requirements, and longevity needs.

Mosquito Control

By their design, infiltration drains are not in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining structure, the chances of providing mosquito habitat are virtually eliminated. If the drain holds enough water for mosquitoes to successfully breed, there is a problem with the aggregate or overflow structure that should be addressed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Infiltration drains can be located in series with other GMPs such as green roofs, forebays, or vegetated swales to prevent clogging as well as supplement erosion prevention, sediment control, and infiltration.

Educational Awareness

The difference between infiltration drains and traditional areas with landscaped stone may not be visible to the general public. It is important that those maintaining the infiltration drains, as well as the public, including customers, visitors or staff understand that its features move beyond aesthetic landscaping to manage and treat stormwater. At a minimum, signage and edging should be used to delineate the infiltration drain and its pretreatment features. Signage should include awareness information that the infiltration drain and its surrounding pretreatment is for purposes of carrying and treating stormwater runoff. Raised edging can help to delineate the infiltration drain from surrounding landscape, however care should be taken to ensure edging does not inhibit the flow of drainage into the infiltration drain. For information on educational credits, call MSD Customer Relations at (502) 587-0603).



Construction of the U of L Speed Art Museum Infiltration Trench (Photo: Louisville & Jefferson County MSD)



Construction of the U of L Speed Art Museum Infiltration Trench (Photo: Louisville & Jefferson County MSD)

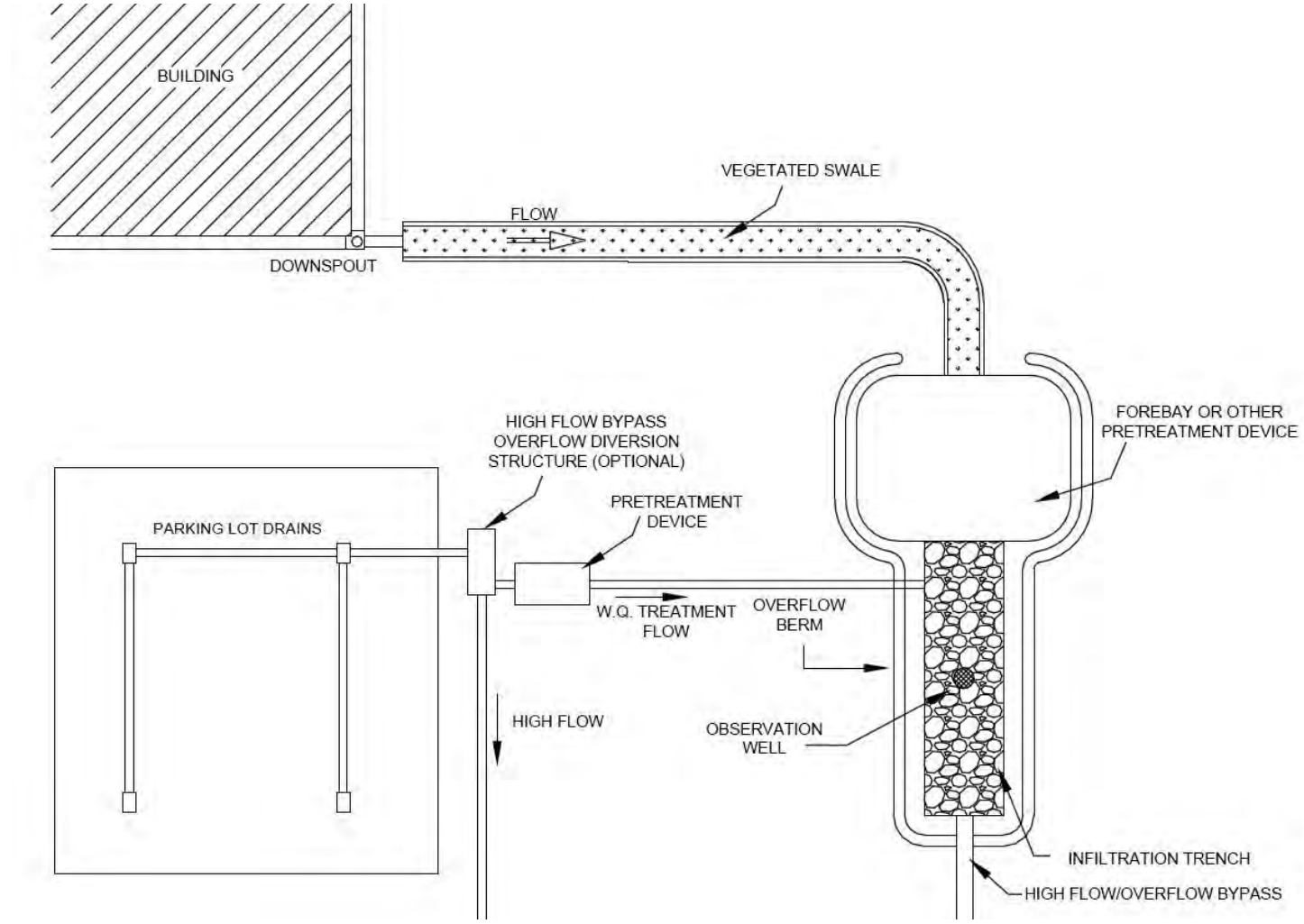


Figure 18.5.20-A. Schematics of a typical implementation of an infiltration drain accepting rooftop drainage

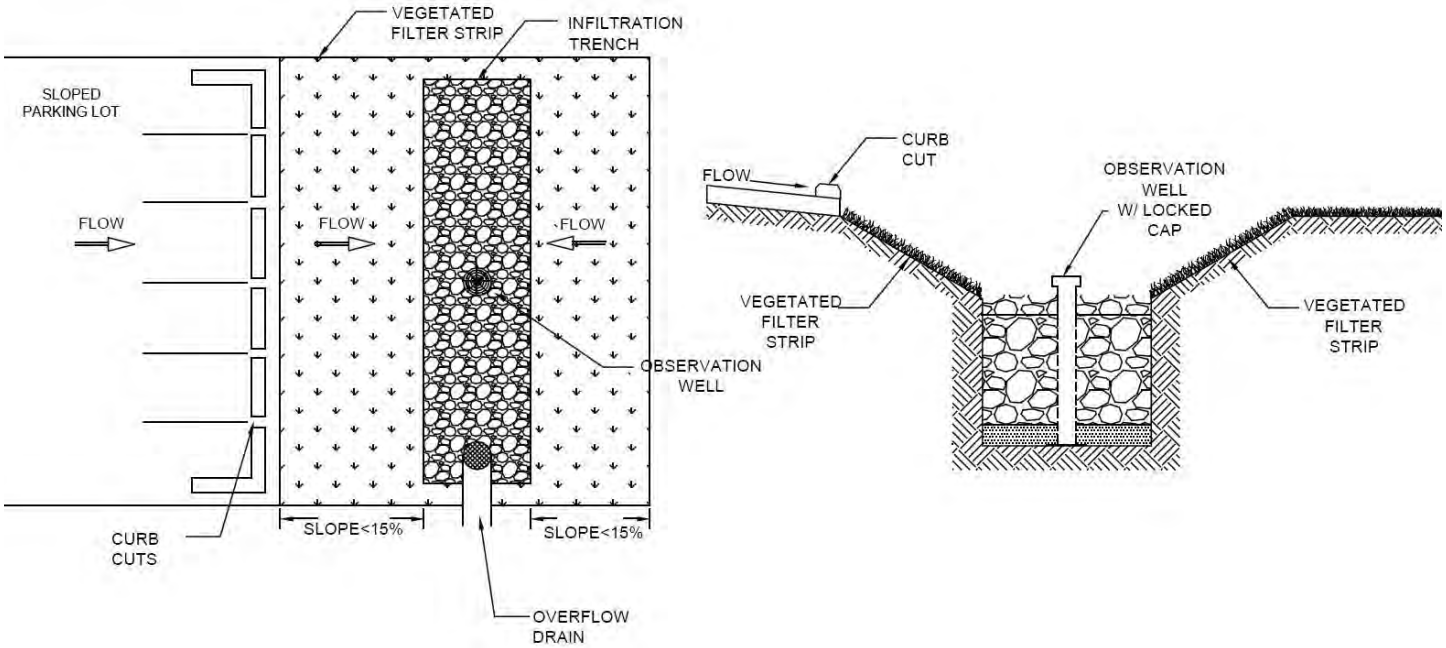


Figure 18.5.20-B. Plan and cross-sectional view schematic of typical implementation of an infiltration drain accepting parking lot runoff

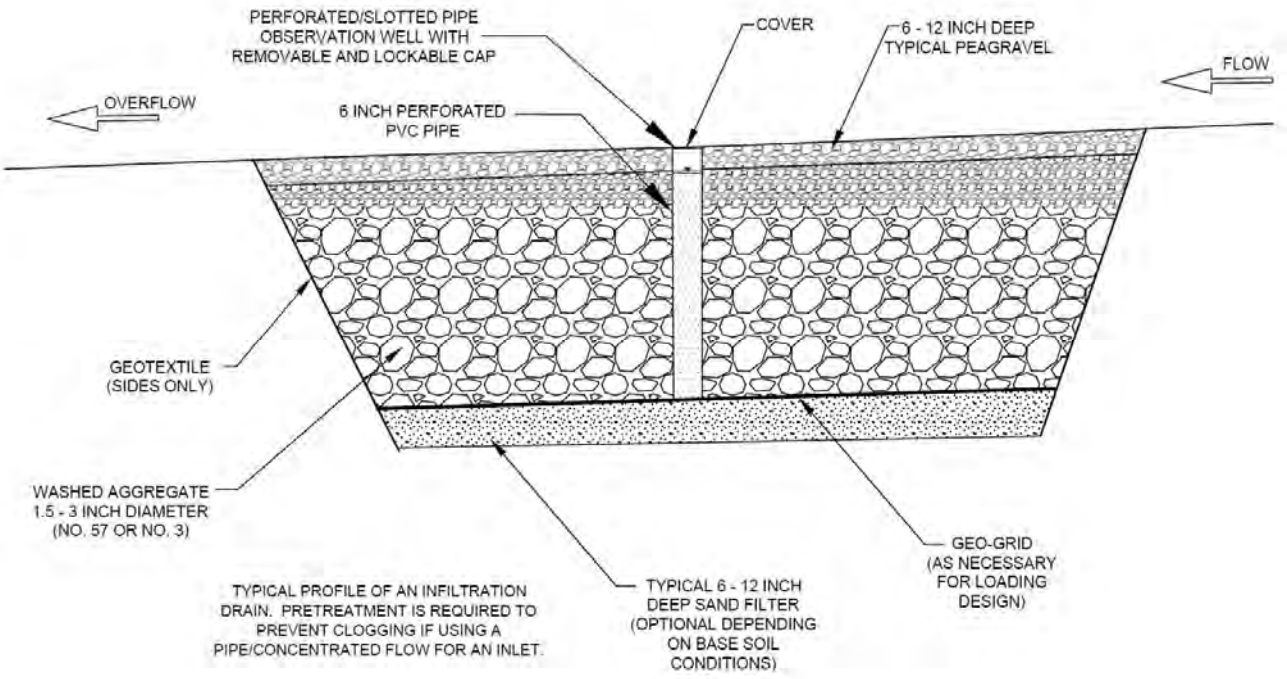


Figure 18.5.20-C. Typical cross section for an Infiltration Drain

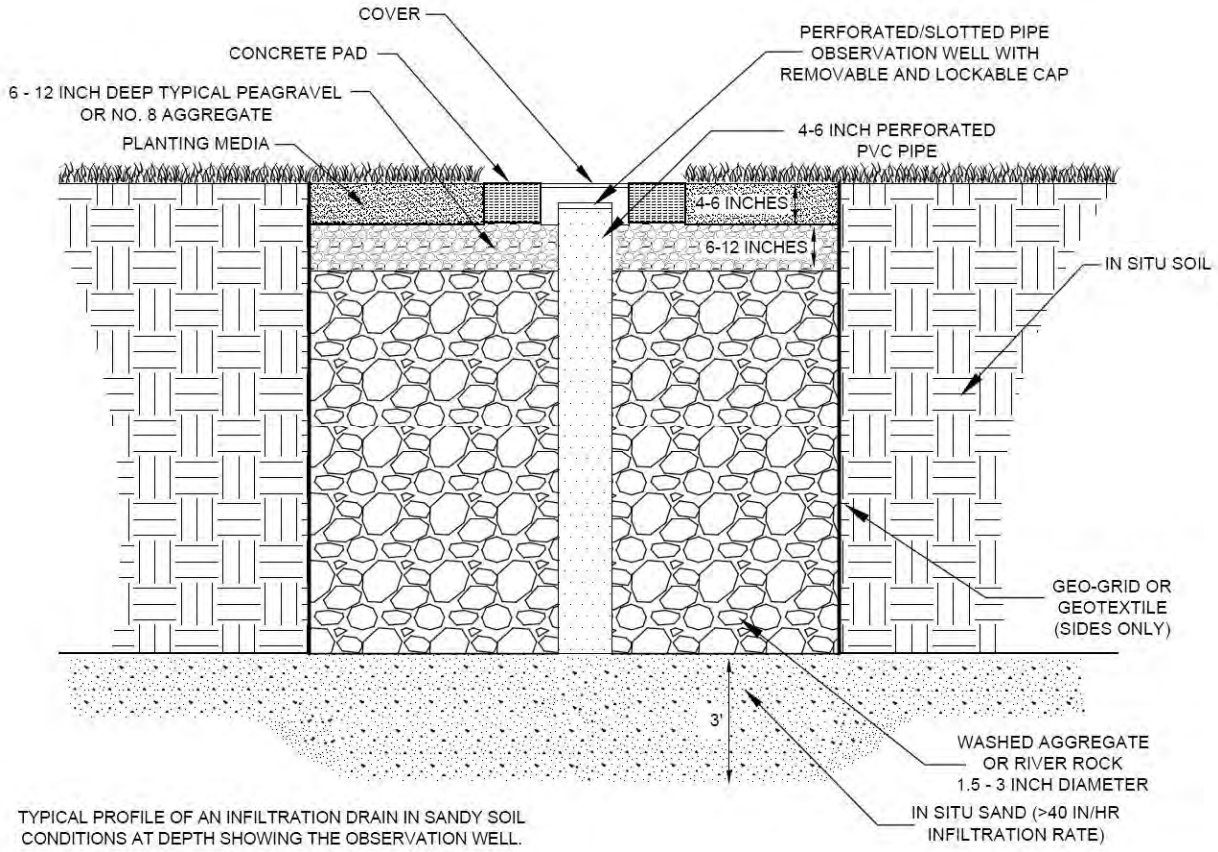


Figure 18.5.20-D. Typical cross section for an Infiltration Drain

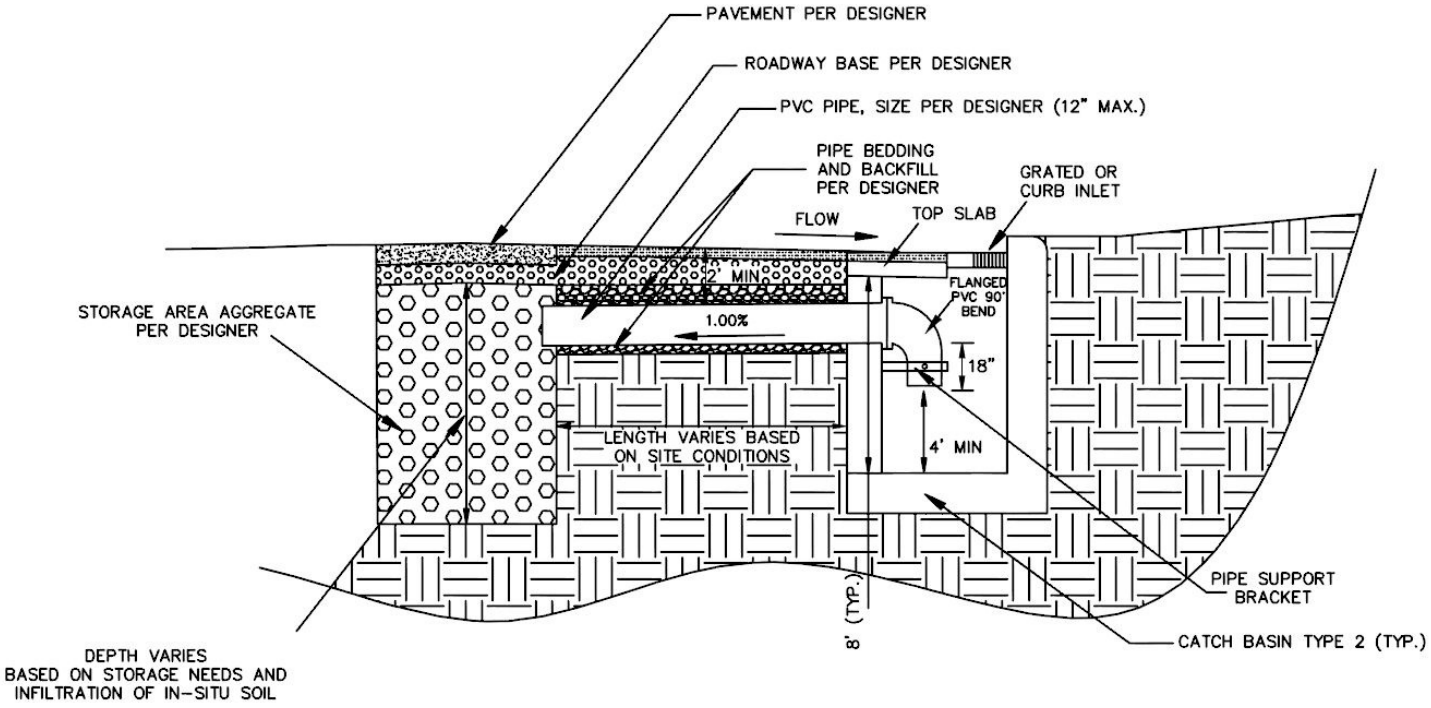


Figure 18.5.20-E. Typical profile of an infiltration drain that includes a sump

Infiltration Drain Application and Site Feasibility Criteria Chart

Table 18.5.20-A.

Design Parameter	Criteria
Size (Area & Depth)	The minimum surface area of the infiltration drain should be determined based upon the design storage capacity and the following equation: A = (WQv)/[d(P)+h], where A = surface area of the ponding area of the infiltration drain (ft^2) WQv = required WQv (ft^3) d = depth of infiltration drain (ft) P = porosity of the media in the infiltration drain (% void) h = the average height of water above the infiltration drain during the WQv rain event (ft) If the infiltration drain is deeper than it is wide, then it will fall under the EPA classification of a Class V Injection Well. All applicable EPA regulations should be followed.
Longitudinal Slope	No greater than 15%
Side Slopes	Dependent on integration of soils and OSHA safety requirements
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm • Meet 6 inches freeboard
Native Soils	Native soils should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate, however higher infiltration rates are recommended.
Pretreatment (required)	Size pretreatment forebay to hold 10% to 15% of the WQv
Inlet/Outlet protection	Scour protection required at inlet and discharge point, dependent upon individual designs
Maximum Drainage Area	Contributing drainage area should be no larger than 5 acres
Drawdown Time	Dewatering of the drain should occur within 24-48 hours

Storage Capacity	Total volume should be equivalent to the required WQv.
	
	Required WQv (cubic feet) = $(1/12)(RE_{WQV})(Rv)(A)$- (WQ_{VR}) where
	• RE_{WQV} = required WQv rain event (refer to Section 18.3)
	• Rv = 0.05 + 0.009(I) where
	  ♦ I = impervious cover of the contributing drainage area in percent
	• A = contributing drainage area to the infiltration drain (ft^2)
	• $WQ_{VR} = (1/12)(RE_{WQV})(R_V)(IA_R)$
	  ♦ Where IA_R = reduced impervious area

Infiltration Drain Step by Step Design Procedures

Step 1: Define goals/primary function of the drain

Define the goals/primary function of the drain. Consider whether the drain is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide a fix to an excess drainage problem
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply. Determine if the drain will be an improved sinkhole or a subsurface fluid distribution system. If the drain meets this criteria, then all applicable EPA regulations will need to be followed for a Class V Injection Well.

Consider the surface type of maintenance preferred. Compact, urban sites may benefit from using an infiltration drain that includes a sump and can be cleaned out with a vacuum truck. Infiltration drains with grass or pea gravel surface treatments require surface infiltration area.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the drain.

Step 2: Determine the total runoff volume and infiltration drain footprint

Infiltration drains should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from the Table 18.5.20-A can be used in this form: WQv (ft3) = $(RE_{WQV})(Rv)(A/12)$- (WQ_{VR}). The minimum surface area of the infiltration drain should be determined using the following formula:
A = (WQv)/[d(P)+h] (see Table 18.5.20-A).

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes per Chapter 10 of the MSD Design Manual. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following rain events:

- Water Quality
- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of the drain. Consider Table 18.5.20-A. Create a rough layout of the dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

It may be desired to use pretreatement to reduce flow velocities or facilitate sediment removal, maintenance and clogging of the drain. A forebay, sump, or other pretreatment system is recommended. Size the forebay per Table 18.5.20-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations. Splash blocks or level spreaders should be considered to dissipate the concentration of stormwater runoff at the inlet and overflow to prevent scour.

Step 5: Determine infiltration drain parameters

Size bottom width, depth, and length necessary to achieve the WQv per Table 18.5.20-A.

Step 6: Determine overflow location

Consider site specific design considerations when determining the type of overflow system installed. The site topography may dictate the best option for each application.

Step 7: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2-year to 100-year storm events to maximum permissible velocities for the soil types present at the site and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the vegetation surrounding the drain is becoming established. Choose an erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.5.21 Aggregate Specifications



Stone used as a base layer for Green Infrastructure (Photo: Louisville & Jefferson County MSD)

Introduction

This fact sheet includes the specifications for the aggregates used for Green Infrastructure GMPs shown in this manual.

Clean Aggregates Specification

There are fundamentally different aggregate specifications for green infrastructure and traditional practices. Green infrastructure requires water flow and infiltration through media and aggregate, whereas traditional projects combine aggregate with binding agents, creating impermeable surfaces. For aggregate used in green infrastructure projects, this is especially important to minimize fines coating the surface of the aggregate stone by double washing. Aggregate that is not double washed is not suitable for green infrastructure practices.

Coarse Aggregates

Furnish crushed aggregate meeting the quality of section 805 of the Kentucky transportation construction standards with the following exception: a shale content of 5% will be allowed, providing the combined shale, friable particles, and minus No. 200 content does not exceed 5%.

Compaction and Settlement

The aggregate of green infrastructure should be compacted to minimize the compaction of existing in situ soils and to allow as much exfiltration as possible. Compact the aggregate utilized for storage volume or load-bearing to minimize any settlement that may occur at the surface. Compaction of the aggregate needs to be determined by the designer based on the anticipated loads at the surface. Typically vibratory plate compactors are used to obtain about 95% compaction of the aggregate.

At the aggregate/in-situ soil interface, the intermixing of these two materials should be minimized. Two typical approaches for minimizing this intermixing is the use of geotextile fabric (sides only) and geogrids. Geogrids are effective at the bottom and the sides of a practice. Geogrids provide structural stability and keep the different layers of aggregate separated (i.e. the No. 3 aggregate layer should be kept separate from the No. 57 aggregate layer). This separation will help reduce settling due to the smaller particles filling in the void space provided by the larger aggregate. The aperture size of the geogrids is important in keeping the aggregate layers seperated.

Geotextile fabric is effective on the sides of a practice to keep the aggregate from intermixing with the in situ soil. Do not use geotextile fabric on the bottom of the practice. Geotextile fabrics should be a nonwoven fabric.

River Rock—Non-Structure Application

For some applications river rock can be substituted for crushed limestone as the coarse aggregate. River rock is considered an acceptable substitute because there is less grit on the rock. However, River Rock is not recommended for practices with a loading (i.e. roads, parking lots pavers and sidewalks); due to reconsolidating and shifting. An example of an acceptable substitution would be for rain gardens and bioswales. River rock is available in the following sizes: 1/2" and down, 3/8"—5/8", 3/4"—2".

Dense Grade Aggregate (DGA)

Dense Grade Aggregate (DGA) is aggregate that includes a wide variety of stone sizes. As water can not pass through DGA as readily as course grades, it is not acceptable for use in green infrastructure.



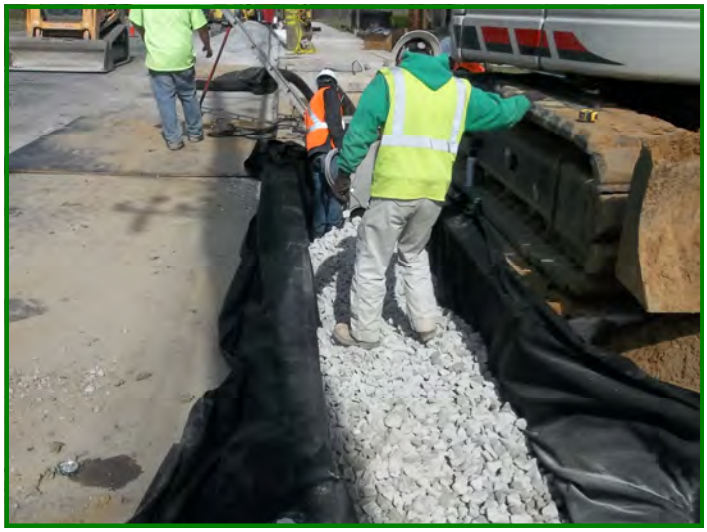
Aggregate plate compacted prior to placement of pavers
(Photo: Louisville & Jefferson County MSD)



Close up of a practice settling
(Photo: Louisville & Jefferson County MSD)



Geogrids to provide stability and separate aggregate
(Photo: Louisville & Jefferson County MSD)



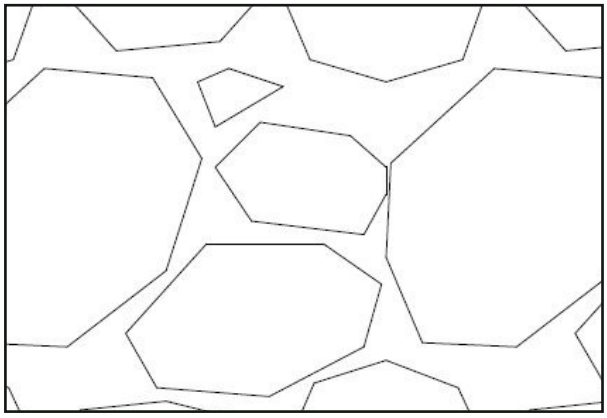
Geotextile fabric on the sides of a green practice
(Photo: Louisville & Jefferson County MSD)

No. 3 Stone

No. 3 stone is placed at the very bottom of the structure and is used as a storage area. The stones must be double washed to keep as much sludge out of the storage area as possible.

Table 18.5.21-A: Gradation Sizes of No. 3 Aggregate

Sieve Size-Percent Passing				
2 ½ inch	2 inch	1½ inch	1 inch	½ inch
100	90-100	35-70	0-15	0-2



Number 3 Stone used in legends



Number 3 Stone (Photo: Daniel Sturdevant, URS)



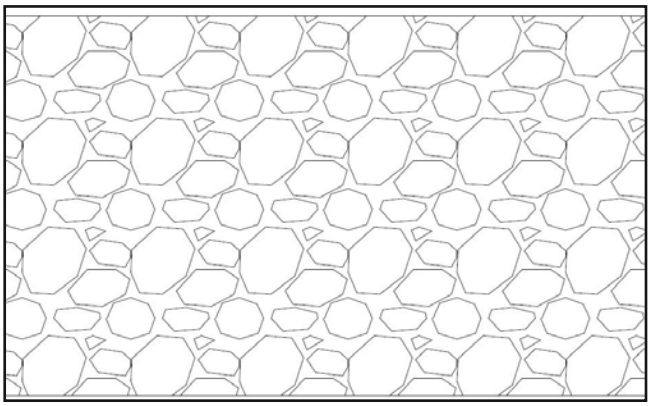
Number 3 Stone (Photo: Daniel Sturdevant, URS)

No. 57 Stone

No. 57 stone should be used as a base for a structure with loadings. An example of this would be sidewalks and roadways. In addition, it is generally placed on top of No. 3 stone. For practices that include pervious pavers, the No. 57 rock should be placed directly below the bricks. Most practices require double washed No. 57 stone. This 'washing' allows for dirt to be removed from the rocks, reducing the amount of clogging in the structure.

Table 18.5.21-B: Gradation sizes of No. 57 Stone

Sieve Size-Percent Passing				
1 ½ inch	1 inch	½ inch	No. 4	No. 8
100	95-100	25-60	0-10	0-2



Number 57 Stone used in legends



Number 57 Stone (Photo: Daniel Sturdevant, URS)



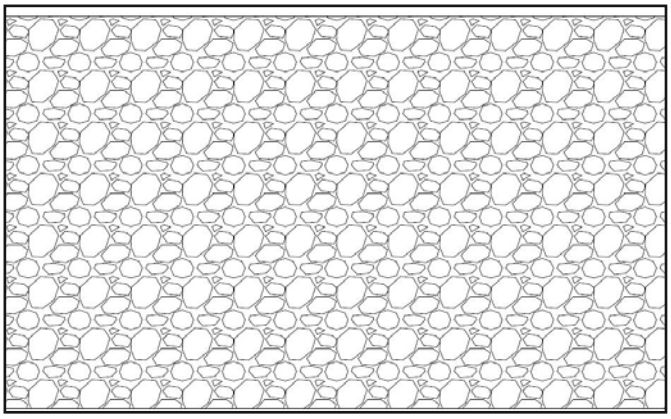
Number 57 Stone (Photo: Daniel Sturdevant, URS)

No. 8 Stone

No. 8 stone should be placed between the brick, concrete, or articulate concrete pavers. The stone should be washed, to keep dirt out of the storage areas and reduce clogging.

Table 18.5.21-C: Gradation Sizes of No. 8 Stone

Sieve Size-Percent Passing				
½ inch	3/8 inch	No. 4	No. 8	No. 16
100	85-100	10-30	0-10	0-5



Number 8 Stone used in legends



Number 8 Stone (Photo: Daniel Sturdevant, URS)



Number 8 Stone (Photo: Daniel Sturdevant, URS)

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Project Name_____
Date Submitted:_____
Property Address:_____
Development/Property Name:_____
Design Firm:_____
Design Engineer:_____Telephone:_____Email:_____
KY PE No.:_____

MSD Reviewer: _____
WM No._____
_____

This checklist gives the minimum requirements needed for MSD's review. All items shall be checked as included or marked N/A. The omission of required items is cause for rejection of the submittal without review.

Required Items on GMP Plan Sheet

_____ Green BMPs (type, location, limits)
_____ Drainage area defined for each GMP
_____ Storage volume of each GMP
_____ Infiltration rate of GMP
_____ Infiltration rate of existing soil
_____ Pretreatment for GMPs
_____ Existing and proposed easements
_____ Plant types (if applicable)
_____ Soil composition
_____ Edge restraint for pervious pavers (if applicable)
_____ Observation sump (if applicable)
_____ Proposed contours
_____ Drainage arrows
_____ Pipe length, size, slope, type, and number
_____ Inlet grate and invert elevations
_____ Existing & proposed drainage structures
_____ Sanitary sewers
_____ Other

Additional Information (If Applicable)

_____ Easement Plat
_____ Long Term Maintenance Agreement
_____ Geotechnical Report
_____ GMP water quality calculations
_____ Operation and maintenance plan
_____ Other: _____

Water Quality Volume/ Attachments—Calculation Sheets (Indicate Number of Each GMP Included on Plans)

#	Provided WQ_V		#	Provided WQ_V	
__	_____	Bioswales	__	_____	Porous Asphalt
__	_____	Rain Gardens	__	_____	Planters
__	_____	Constructed Wetlands	__	_____	Tree Boxes
__	_____	Green Wet Basins	__	_____	Rainwater Harvesting
__	_____	Green Dry Basins	__	_____	Vegetated Buffers
__	_____	Extensive Green Roofs	__	_____	Vegetated Swales
__	_____	Intensive Green Roofs	__	_____	Underground Storage
__	_____	Blue Roofs	__	_____	Catch Basin Inserts
__	_____	Permeable Pavers	__	_____	Proprietary Water Quality Units
__	_____	Pervious Concrete	__	_____	Infiltration Drains

Required Water Quality Volume: _____Total Water Quality Volume Managed: _____
Total Number of Practices: _____ Total Water Quality Volume (for Fee-in-Lieu Program): _____

Note: The Professional Engineer Licensed in Kentucky that stamped the submitted plans must sign the checklist and is responsible for obtaining applicable permits, including, but not limited to, those identified in Section 18.2.

_____ _____
Printed Name KY PE No.

_____ _____
Signature Date

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Practice(s) as labeled on the plans		
2	Impervious drainage area delineated to each GMP		
3	Pervious drainage area delineated to each GMP		
4	Percolation test or infiltration test is provided		
5	Required water quality volume per drainage area		
6	Footprint area at overflow elevation		
7	Footprint area at bottom of excavation		
8	Storage depth below overflow		
9	Side slopes: <3:1 (H:V) for rain gardens, <4:1 (H:V) for wetlands		
10	Longitude slope <15%		
11	Footprint area at top of excavation		
12	Storage zone at least 10-ft from nearest building footer		
13	Storage media specified to have less than 2% fines		
14	Each inlet pipe/channel has erosion protection		
15	Pretreatment provided with appropriate settling velocities and cleanout		
16	Easement or inspection/maintenance access provided		
17	Planting plan included (with phasing/seasonal installation issues)		
18	Forebays (if applicable) ~ 10-15% of WQ_V		
19	# of check dams meet/exceed slope/length requirements		
20	Proper length to width ratio		
21	Inlets and outlets set to limit short circuiting		
22	Underdrain (if in poor soils)		
23	Observation wells provided (if applicable)		
24	Calculation sheet(s) included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Practice(s) as labeled on the plans		
2	Impervious drainage area delineated to each basin		
3	Pervious drainage area delineated to each basin		
4	Percolation test or infiltration test is provided		
5	Required volume		
6	Footprint area at overflow elevation		
7	Footprint area at bottom of excavation		
8	Storage depth below overflow		
9	Porosity of the storage media		
10	Volume below overflow		
11	Footprint area at top of excavation		
12	Storage depth above overflow		
13	Pretreatment provided with appropriate settling velocities and cleanout		
14	Forebay ~ 10 –15% of total WQ_v		
15	Proper length to width ratios		
16	Inlets and outlets set to limit short circuiting		
17	Wet: aquatic shelf > 12" deep (mosquito preventer)		
18	Wet: safety bench included		
19	Planting plan included (with phasing for seasonal installation)		
20	Forebay overflow large enough to limit scour or sediment resuspension		
21	Easement or inspection/maintenance access provided		
22	Calculation sheet(s) included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Practice(s) as labeled on the plans		
2	Impervious drainage area delineated to each GMP		
3	Pervious drainage area delineated to each GMP		
4	Percolation test or infiltration test is provided		
5	Required water quality volume		
6	Footprint area at overflow elevation		
7	Footprint area at bottom of excavation		
8	Storage depth below overflow		
9	Porosity of the storage media		
10	Volume below overflow		
11	Footprint area at top of excavation		
12	Storage depth above overflow		
13	Aggregate specified to have less than 2% fines; washed; coarse graded		
14	Underdrain needed (soil conditions)—draining elevation set to top of storage zone		
15	Geogrid in areas of regular drive loading		
16	Topping material (paver, block, concrete, asphalt) suitable to loading: driving use/ pedestrian use		
17	Paver top chip stone placed two applications (after settling to fill surface flush)		
18	Adequate side restraints/edge transitions to other materials		
19	Impermeable barrier shown on side walls next to traditional KYTC pavement designs		
20	Filter fabric only on sides		
21	Easement or inspection/maintenance access provided		
22	Calculation sheet(s) included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Letter indicating that Structural Professional Engineer licensed in Kentucky has evaluated roof and deemed acceptable		
2	Practice(s) as labeled on the plans		
3	Roof area delineated		
4	Water proofing layers included		
5	Required (open media or media trays or blue open trays) volume		
6	Sufficient drains/drain spouts		
7	Storage depth below overflow		
8	Easement or inspection/maintenance access provided		
9	Storage media specified to have less than 2% fines		
10	Calculation sheets included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Practice(s) as labeled on the plans		
2	Roof drainage area delineated to each storage unit		
3	Required water quality volume < storage volume (event based projection calculations)		
4	Overflow path set		
5	Storage is freeze proof		
6	Storage drawdown projection calculations		
7	Pretreatment screening (simple screen if from roof; W.Q. unit if from surface drainage)		
8	Plumbing set with air gap (if applicable)		
9	Pumping/disinfection unit (if use for internal plumbing)		
10	Underground storage: Multiple sediment removal access points/manholes for sediment removal (especially at pre-treatment inlets and at discharge/outfall)		
11	Easement or inspection/maintenance access provided		
12	Calculation sheet(s) included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Practice(s) as labeled on the plans		
2	Impervious drainage area delineated to each unit/insert		
3	Pervious drainage area delineated to each unit/insert		
4	Required water quality volume		
5	Manufacturer/sizing data provided		
6	Maintenance hatches or manholes in easement/access points for vactor truck		
7	Diversion or pass through capacity stormwater for high flows		
8	Easement or inspection/maintenance access provided		
9	Calculation sheet(s) included		

MSD Reviewer: _____
WM No._____
_____

Practice # or location on site: _____		Plan Submitter	MSD Plan Reviewer
1	Underground Injection Control—USEPA permit application included, or approved permit		
2	Practice(s) as labeled on the plans		
3	Impervious drainage area delineated to each drain		
4	Pervious drainage area delineated to each drain		
5	Percolation test or infiltration test is provided		
6	Required water quality volume		
7	Footprint area at overflow elevation		
8	Footprint area at bottom of excavation		
9	Storage depth below overflow/bypass drains at top of storage layer		
10	Underdrain location/layout/sizes		
11	Underdrain overflow is at elevation of top of storage layer		
12	Observation wells provided (if applicable)		
13	Porosity of the storage media		
14	Volume below overflow		
15	Footprint area at top of excavation		
16	Storage depth above overflow		
17	Storage aggregate specified to have less than 2% fines		
18	Pretreatment provided with appropriate settling velocities and cleanout		
19	Overflow of high flow bypass provided		
20	Filter fabric only on sides only		
21	Geogrid (optional per loading design)		
22	Easement or inspection/maintenance access provided		
23	Calculation sheet(s) included		

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Site Preparation/General Setup							
1	Drainage area(s) appear to match plans						
2	Erosion prevention measures in place						
3	GMP area is not staging area for heavy equipment or other item causing compaction						
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
4	Excavation depth and footprint match plans						
5	Inlet pipes/channels						
6	Subgrade material/aggregate						
7	Engineered soil						
8	Overflow structure and pipe						
9	Side slopes <3:1 (H:V)						
10	Pretreatment weirs/forebays						
11	Outlet structure						
12	Check dams level and sides buried						
13	Scour and erosion protection						
14	Observation wells/overflow drains						
Finishing (Per plans for plants, trees, bushes, mulch, etc.)							
15	Plants						
16	Mulching						
17	Watering system in place (as needed seasonally)						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Site Preparation/General Setup							
1	Drainage area(s) appear to match plans						
2	Erosion prevention measures in place						
3	GMP area is not staging area for heavy equipment or other item causing compaction						
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
4	Excavation depth and footprint match plans						
5	Inlet pipes/channels						
6	Overflow structure and pipe						
7	Side slopes						
8	Pretreatment weirs/forebays						
9	Outlet structure: pipe headwall, pads, blocks, etc						
10	Grading safety features (benches and buffers)						
11	Scour and erosion protection						
Finishing (Per plans for plants, trees, bushes, mulch, etc.)							
12	Plants						
13	Seed/mulching/stabilization						
14	Watering system in place (as needed seasonally)						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

	GMP labeled in plans:_____ (Type and Location)	Condition (1) S	M	U	NA	Photo No.	Comment
Installation (Constructed according to plans—dimensions, measurements, etc.)							
	Waterproofing measures						
	Drainage layer is consistent with specifications						
	Overflow structure and pipe						
	Engineered media compositional depth						
	Trays or storage containers with drains or overflows						
	Downspouts						
Finishing (Per plans for plants, trees, bushes, mulch, etc.)							
	Plants						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Site Preparation/General Setup							
1	Drainage area(s) appear to match plans						
2	Soil stabilization methods are consistent with plans						
3	Excavation depth and footprint match the plans						
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
4	Excavation depth and footprint match plans						
5	Subgrade material/aggregate layer depth(s)						
6	Observation wells						
7	Aggregate placed in lifts and compacted (last with vibratory plate—if articulated blocks)						
8	Aggregate match grading shown in Section 18.5.21						
9	Underdrains—overflow at correct layer/elevation						
10	Underdrains—locations/length/depth						
11	Side slopes						
12	Filter fabric on sides only						
13	Geogrid (at appropriate layers)						
14	Outlet curb cuts or area drains						
15	Scour and erosion protection						
16	Edge restraint						
Finishing/Topping							
17	Pavers: chip stone applied to joints						
18	Pavers: chip stone allowed to settle						
19	Pavers: chip stone fill joints to even with surface						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Site Preparation/General Setup							
1	Excavation depth and footprint match the plans						
2	Drainage Area matches plans						
3	Erosion prevention measures in place according to the plans						
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
4	Inlet						
5	Subgrade aggregate						
6	Overflow structure and pipe						
7	Side slopes						
8	Pretreatment screening						
9	Outlets						
10	Pumping/disinfection unit						
11	Underground storage: Manhole/hatches at pretreatment and sump prior to outfall						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
1	Inlet pipes						
2	Overflow bypass or pass through						
3	Outlet pipes						
4	Manhole/hatch or other access						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

Inspector: _____
Property Address: _____
Contractor: _____
Contractor Site Representative: _____
Telephone: _____Email: _____

MSD Reviewer: _____
WM No._____
_____

Plans/Exhibit A of Agreement available? (Check one) _____ Yes _____ No

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Site Preparation/General Setup							
1	Drainage area(s) appear to match plans						
2	Erosion prevention measures in place						
3	GMP area is not staging area for heavy equipment or other item causing compaction						
Installation/Structural (Constructed according to plans—dimensions, measurements, etc.)							
4	Excavation depth and footprint match plans						
5	Inlet pipes plans (if included)						
6	Aggregate layer depth						
7	Aggregate match grading shown in Section 18.5.21						
8	Aggregate placed in lifts and compacted (optional if topped with grass or non-loaded area)						
9	Underdrains—overflow at correct layer/elevation						
10	Underdrains—locations/length/depth						
11	Side slopes						
12	Overflow/bypass drain: size and depth/layer						
13	Pretreatment unit or sump (see separate checklist as necessary)						
14	Filter fabric on sides only						
15	Geogrid (at appropriate layers)						
16	Observation wells						
Finishing/Topping (Per plans for grass, sidewalk, pavers, etc.)							
17	See Permeable Paver, Pervious Concrete, or Porous Asphalt checklist (as needed)						
18	If topped with grass or sidewalk—filter fabric on top layer or aggregate						

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

MSD WM No.: _____ Date / Time: _____

GMP Installation Date (Month/ Year):_____ Property Address: _____

Inspector Name: _____ _____

_____

Inspector Telephone: _____ Site Description/Name: _____

Inspector Email: _____ Site Contact: _____

Site Contact Telephone: _____

LTMOA* Reviewed	Yes	No	N/A
Plan Sheets Reviewed	Yes	No	N/A
Landscaping Plan Reviewed	Yes	No	N/A
Section 18.7 Fact Sheets Reviewed	Yes	No	N/A

Site Contact Mailing Address: _____

_____

_____

Date and amount of last rain event: _____

Date of Last Inspection: _____

Check one: Regular Inspection: ❑ Follow-up Inspection: ❑

Type of GMP(s) Onsite	Check Practice	# of Practices	Site Picture*	Comments / Description
Bioswale	❑		❑	
Rain Garden	❑		❑	
Constructed Wetland	❑		❑	
Wet Basin	❑		❑	
Dry Basin	❑		❑	
Extensive Green Roof	❑		❑	
Intensive Green Roof	❑		❑	
Blue Roof	❑		❑	
Permeable Pavers	❑		❑	
Pervious Concrete	❑		❑	
Porous Asphalt	❑		❑	
Planters	❑		❑	
Tree Boxes	❑		❑	
Rainwater Harvesting	❑		❑	
Underground Storage	❑		❑	
Vegetated Buffer	❑		❑	
Vegetated Swale	❑		❑	
Catch Basin Insert	❑		❑	
Proprietary Water Quality Unit	❑		❑	
Infiltration Trench	❑		❑	

* For larger sites, multiple photos may be used.

Corrective Actions Needed: _____

_____

Inspector Certification:

I certify that this inspection was performed consistent with the Memorandum of Agreement(s) regarding Long Term Operation and Maintenance including attached construction plans/details and the intent MSD's local Wastewater /Stormwater Discharge Regulations controlling the discharge of stormwater from this property. I am aware that there are significant penalties for submitting false or inaccurate information, including the possibility of revocation of Qualified Post Construction Inspector (QPCI) registration, fines, or imprisonment for known violations.

Signature: _____ Date: _____ QCPI Registration No. _____

*LOTMA-Long-term Operational Maintenance Agreements, may include any or all of the following: STIPEND, CREDITS, and/or Stormwater quality Memorandum of Agreements.

GMP labeled in plans:_____ (Location; Biowale or Rain Garden)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around the structure						
3	No evidence of erosion at the pretreatment structure						
4	Forebay (pretreatment) free from trash, debris, sediment (2)						
5	Weir (pretreatment) free from trash, debris, sediment (no deeper than 25% total depth) (2)						
6	Check dam(s) free from trash, debris, sediment (2)						
7	Erosion protection present and intact						
8	No evidence of ponding or standing water on or near the outlet structure, i.e. stains, odors, water logged vegetation or mosquito larvae						
9	No evidence of check dams or outlet structure settling or other structural deficiencies						
10	No evidence of erosion on sides of check dams or formation of plunge pools						
11	High flow bypass or diversion structures clear and obstruction free						
12	Overflow/drain(s) intact and free from obstructions						
13	No evidence of erosion, scour or flooding downstream of the overflow structure						
14	Signage present and intact if required (2)						
Plantings							
15	Vegetation appears to be maintained, clippings removed (3)						
16	Weeds and invasive, non-native plant species are not present						
17	Mulch is approximately 3-4" total depth						
18	Dead/ stressed plants replaced						
19	No indicators of excessive fertilizer use						
Overall Conditions							
20	Consistent with Maintenance Agreement(s)						
21	Overall condition						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Location; Wet or Dry)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around the structure						
3	No evidence of erosion at pretreatment structure						
4	Forebay(s) (pretreatment) free from trash, debris, sediment (2)						
5	Accumulated sediment in forebay is less than 25% of total depth - note approx. sediment depth in comments						
6	Erosion protection present and intact						
7	All inflow points (pipes and channels) are free from trash, vegetation debris, other obstructions.						
8	Wetland embankments are intact and free from erosion, rills or gullies						
9	Embankments intact and free from woody roots and animal holes						
10	Embankment freeboard is maintained per Maintenance Agreement —Note freeboard height in comments						
11	No evidence of settling or other structural deficiencies						
12	Overflow structure and emergency spillway are intact and free from trash, vegetation debris or other obstructions						
13	No evidence of seepage (eg, staining, dampness) around discharge pipe						
14	No evidence of erosion, scour or flooding downstream of the overflow structure and emergency spillway						
15	Signage present and intact if required Agreement (2)						
Plantings Inspection							
16	Attach vegetation monitoring report if required by USACE permit.						
17	Vegetation appears to be maintained and clippings are removed (3)						
18	Weeds and invasive plant species are not present						
19	No indications of excessive fertilizer use						
20	Rooted aquatic vegetation or sediment islands have not formed within the open water pool						

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Overall Condition							
21	Standing water is clear, with no oily sheen, excessive algal growth or odors						
22	Overall condition						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around the structure						
3	No evidence of erosion at pretreatment structure						
4	Forebay (pretreatment) free from trash, debris, sediment (2)						
5	Accumulated sediment in forebay(s) is less than 25% of total depth - note approx. sediment depth in comments						
6	No significant sediment accumulation in main basin area						
7	Erosion protection present and intact						
8	Inlet pipes, headwalls, splash blocks, pads, etc. intact						
9	All inflow points (pipes and channels) are free from trash, vegetation debris, other obstructions						
10	Embankments are intact, no woody roots, animal holes						
11	No evidence of settling or other structural deficiencies						
12	Overflow structure and emergency spillway are intact and free from trash, vegetation debris or other obstructions						
13	No seepage (e.g., staining, dampness) around outlet pipe						
14	No evidence of erosion, scour or flooding downstream of the overflow structure or emergency spillway						
15	Outlet pipe, headwall, splash block, pads, etc. are intact						
16	Signage present and intact (2)						
Plantings							
17	Vegetation appears to be maintained and clippings are removed (3)						
18	Weeds and invasive plant species are not present						
19	Rooted aquatic vegetation or sediment islands have not formed within the open water pool (wet only)						
20	No indications of excessive fertilizer use						
Overall Condition							
21	Standing water is clear, with no oily sheen, excessive algal growth or odors						
22	Overall condition						
Additional Comments							

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Roof type: ____Green Intensive ____ Green Extensive						
2	Access is adequately maintained						
3	No evidence of settling or other structural deficiencies						
4	No evidence of trash, sediment or debris						
5	Drainage routes are clear of obstructions						
6	Trays or storage containers intact with drains or overflows clear of obstructions						
Plantings							
7	Vegetation appears to be maintained and clippings are removed (2)						
8	Media depth is maintained per the Plan- note mulch depth in comments (2)						
9	Weeds and invasive plant species are not present						
10	No indications of excessive fertilizer use						
Overall Conditions							
11	No evidence of ponding or standing water, i.e. stains, odors, water logged vegetation or mosquito larvae						
12	Consistent with Maintenance Agreement(s)						
13	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, the power area						
3	No evidence of ponding or standing water, sediment, stains or settling						
4	Pavers are intact, not cracked or broken						
5	No evidence of settling or other structural deficiencies						
6	Edge restraint is intact, with no cracking or settling						
7	Overflow is intact and free of obstructions (2)						
Toppings							
8	Chip stone fills area between pavers and is even with surface						
9	Trash, vegetation debris and sediment are not present						
10	Grass Permeable Pavers: grass appears to be maintained and in generally good condition per the Plan (3)						
Overall Condition							
11	Consistent with Maintenance Agreement(s)						
12	Overall condition						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, porous concrete areas						
3	No evidence of ponding or standing water, sediment, stains or settling						
4	Concrete is intact, not cracked or broken						
5	Less than 10% of repairs to potholes and cracks are patched with traditional concrete methods						
6	Trash, vegetation debris and sediment are not present						
7	No evidence of settling or other structural deficiencies						
8	No evidence of use for heavy traffic or large vehicles						
9	Overflow is intact and free of obstructions (2)						
Overall Condition							
10	Consistent with Maintenance Agreement(s)						
11	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).
(2) If not present, check NA.

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, porous asphalt areas						
3	No evidence of ponding or standing water, sediment, stains or settling						
4	Asphalt is intact, not cracked or broken						
5	Less than 10% of repairs to potholes and cracks are patched with traditional asphalt or concrete methods						
6	Trash, vegetation debris and sediment are not present						
7	No evidence of settling or other structural deficiencies						
8	No evidence of use for heavy traffic or large vehicles						
9	Overflow is intact and free of obstructions (2)						
Overall Condition							
10	Consistent with Maintenance Agreement(s)						
11	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).
(2) If not present, check NA.

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, the structure						
3	Inflow structure is free from trash, vegetative debris, sediment or other obstructions (2)						
4	No evidence of ponding or standing water on or near the structure, ie stains, odors, water logged vegetation or mosquito larvae						
5	No evidence of settling or other structural deficiencies						
6	Overflow structure is intact and free of obstructions (2)						
Plantings							
7	Plantings appear to be maintained and clippings are removed per the Plan (3)						
8	Plantings appear healthy and appropriately sized for area						
9	Weeds and invasive plant species are not present						
10	No indications of excessive fertilizer use						
Overall Condition							
10	Consistent with Maintenance Agreement(s)						
11	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, the structure						
3	Inflow structure is free from trash, vegetative debris, sediment or other obstructions (2)						
4	No evidence of ponding or standing water on or near the structure, ie stains, odors, water logged vegetation or mosquito larvae						
5	No evidence of settling or other structural deficiencies						
6	Overflow structure is intact and free of obstructions (2)						
Plantings							
7	Plantings appear to be maintained and clippings are removed per the Plan (3)						
8	Plantings appear healthy and appropriately sized for area						
9	Weeds and invasive plant species are not present						
10	No indications of excessive fertilizer use						
Overall Condition							
11	Consistent with Maintenance Agreement(s)						
12	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed).
(2) If not present, check NA.

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	Downspout fits tightly to cistern inlet						
3	Inlet is grated to prevent clogging with leaves or other debris and has a fine mesh for mosquito control						
4	Gutters and downspouts are clean and do not show evidence of leaking						
5	Cistern appears to be structurally sound, with no evidence of cracking or leaking						
6	Overflow valve appears intact with no evidence of leaking (eg, stains, dampness)						
7	Drain valve appears intact with no evidence of leaking (eg, stains, dampness)						
Operation							
8	Actual pumping performance appears to match pumping details in maintenance agreement						
Overall Condition							
9	Consistent with Maintenance Agreement(s)						
10	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access is adequately maintained						
2	No evidence that water is going around, rather than into, the buffer/swale						
3	No evidence of erosion, rill, gullies or channel						
4	No evidence of concentrated flow (eg, gullies, erosion) delivered to the structure						
5	Turf reinforcement mats or other permanent erosion protection are in working condition						
6	No evidence of ponding or standing water, stains, odors, water logged vegetation or mosquito larvae						
7	Signage, such as "No-Mowing", is present and intact (2)						
Planting Inspection							
8	Vegetation appears to be maintained and clippings are removed, except grass clippings, per the Plan (3)						
9	Weeds and invasive plant species are not present						
10	No indications of excessive fertilizer use						
Overall Condition							
11	Consistent with Maintenance Agreement(s)						
12	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Type and Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	Access manholes / hatches are clear for inspection and maintenance						
2	Site access is adequately maintained for inspection and maintenance (3)						
3	Trash, sediment bags/vaults (replace, cleaned out or emptied) (2)						
4	Inlet structure is intact and free from trash, vegetative debris, sediment accumulation or other obstructions						
5	No evidence of settling or other structural deficiencies						
6	Overflow structure is intact and free of obstructions						
7	Inspection criteria specified by manufacturer: (3) _____ _____						
Overall Condition							
8	Consistent with Maintenance Agreement(s)						
9	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Structural							
1	If Underground Injection Control, review USEPA approved permit. If not required, check NA						
2	Access is adequately maintained						
3	No evidence that water is going around the structure						
4	No evidence of erosion at pretreatment structure (2)						
5	Unit or sumped manhole clear of sediment, trash and debris (2)						
6	Forebay (pretreatment) is free from trash, debris, sediment (2)						
7	Level spreader (pretreatment) is free from trash, debris, sediment (2)						
8	Vegetated strip (pretreatment) is free from trash, debris, sediment (2)						
9	Proprietary water quality unit (pretreatment) is present? If yes, separate complete Inspection Sheet (2)						
10	Erosion protection present (e.g. turf reinforcement mats, stone, etc.) and intact						
11	No evidence of ponding or standing water on or near the outlet structure, i.e. stains, odors, water logged vegetation or mosquito larvae						
12	If topped with aggregate - clean, not clogged sediment (2)						
13	Observation well cap is removable, locked, intact and accessible, well casing is intact						
14	Six (6) inches or less of water is present in the observation well - note water depth in comments field						
15	No evidence of settling or other structural deficiencies						
16	Overflow structure intact and free of obstructions/sediment						
17	No evidence of erosion or flooding downstream of the overflow structure						
18	Signage is present and intact						

GMP labeled in plans:_____ (Location)		Condition (1)				Photo No.	Comment
		S	M	U	NA		
Plantings							
19	Plantings appear to be maintained and clippings are removed per the Plan (3)						
20	Weeds and invasive plant species are not present						
21	No indications of excessive fertilizer use						
Overall Condition							
22	Consistent with Maintenance Agreement(s)						
23	Overall condition:						
Additional Comments							

_____

_____

Notes: (1) S: Satisfactory (in compliance); M: Marginal (in compliance, needs maintenance); U: Unsatisfactory (needs immediate attention or repair to achieve compliance); NA: Not Applicable (not present or can't be observed)
(2) If not present, check NA
(3) If Landscaping Plan not available, check NA

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.7 Operation & Maintenance






Clockwise from top left: number 8 Stone into permeable pavers, cutting back old growth on native plants, mulching a rain garden, sweeper removes dust and debris from pervious pavers.
(Photos: Louisville & Jefferson County MSD, DropSeed Nursery)

Overview of Maintenance Procedures

Routine inspections will help to maintain function of the GMP systems and prevent problems from arising. As most GMP systems are largely affected by the seasonal changes and storms, inspections should typically be conducted at the beginning of each season as well as after large rain events.

In general, the inspection and maintenance of GMP systems includes:

- Removal of sediment buildup
- Removal of debris from any inflow and outflow points
- Local erosion prevention and sediment control
- Routine inspection of the structural integrity of the GMP to ensure function
- Replacement of filter media (if needed)

In general vegetation maintenance includes:

- Irrigation and weeding during the first few months of planting to ensure species establishment
- Maintenance of the health and abundance of native species and plantings
- Annual mowing, trimming or pruning to prevent woody species growth
- Removal of any invasive species

This section provides detailed operation and maintenance (O&M) procedures for each GMP.

Bioswales

Maintenance of the bioswale will primarily consist of inspections of the drainage surface to remove debris, obstructions, or sediment buildup. Maintenance includes:

- Repairing erosion or other surface damage
- Replacement and care of plant materials
- Removal of invasive non-native plants
- Regular irrigation during dry periods

Inspections and repairs should be scheduled prior to the first seasonal rains as well as during and after each major storm to insure proper function of the bioswale and prevent possible flooding, sediment buildup, and erosion.

In addition to these general maintenance procedures, the bioswale should be trimmed every year or two to prevent woody species from establishing. Mowing or cutting the vegetation usually reduces evapotranspiration and therefore reduces the amount of pollutant uptake. If the bioswale is built in an area that receives heavy stormwater runoff consisting of chemical fertilizers, chemical pesticides, and/ or oil and grease from cars, plant clippings may need to be disposed of at a landfill rather than composted.

For the Bioswales Maintenance Schedule, see Table 18.7-A on the next page.

Rain Gardens

Maintenance should be periodically conducted to ensure that the rain garden area is functioning properly. Initially, the landscape will require more intensive maintenance to ensure proper species establishment and function. Maintenance of the system will primarily consist of:

- Monthly inspections of the soil
- Removal of accumulated debris or sediment buildup
- Erosion repair
- Watering of the garden during periods with no rain
- Replacement of dead or diseased vegetation
- Weeding of non-native invasive species.

Plant material should be cut back and removed from the garden during the winter months when plants are dormant. Mulch should be added to the garden every 1-2 years; shredded hardwood mulch is preferred. Care should be given when mulching not to allow mulch to pile up on the stems of plants (woody or herbaceous.)

After rainstorms, it is important to inspect the rain garden cell and make sure that drainage paths are clear and that the pooling water dissipates over 4-6 hours; note that water may pool for longer times during the winter and early spring.



Trash removal (Photo: DropSeed Nursery)



"No Mow" maintenance signs installed at a bioretention cell in Louisville Metro Parks (Photo: Louisville & Jefferson County MSD)

If the rain garden/bioretention pond is not functioning properly, repairs to the under-drain as well as inflow and outflow structures may be needed.

By their design, rain gardens and bioswales are not in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining rain garden or bioswale, the chances of providing mosquito habitat are virtually eliminated. If the rain garden or bioswale holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

For the Rain Garden Maintenance Schedule, see Table 18.7-A on the next page.

Table 18.7-A. Bioswales & Rain Gardens Maintenance Schedule

Schedule	Activity
At least 4 times during growing season	• Prune and control weeds • Remove and replace dead or damaged plants • Mow perimeter areas as needed
Semi-annually in spring and fall	• Remove sediment, trash and debris from inlets/forebays • Inspect inflow points for clogging and remove any sediment • Inspect for erosion, rills or gullies and repair • Herbaceous trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from rain garden to prevent clogging and replace dead plants • Develop/adjust plant maintenance plan for trimming and dividing perennials to prevent overcrowding and stress and to achieve desired aesthetic qualities; remove any non-native, invasive species • Inspect plants for health and signs of stress; if plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe infiltration rates after rain events; rain gardens should drain within 24-48 hours of a storm event • A mulching depth of about 3-4 inches should be inspected and obtained, and additional mulch should be added if necessary • Evaluate areas containing low flow stone or gravel; replace if necessary
2-3 years	• Replace/repair inlets, outlets, scour protection or other structures as needed • Implement plant maintenance plan to trim and divide perennials to prevent overcrowding and stress • If the rain garden is not meeting desired infiltration rates or over time soil has compacted, check soil infiltration rates by performing a percolation test • Re-aerate or replace soil and mulch layers as needed to achieve infiltration rate of 0.5 inches per hour • When removing soil for replacement, take to landfill or soil recycling center



A MSD worker cleans out the inlet structure for a rain garden (Photo: Louisville & Jefferson County MSD)

Constructed Wetland

Constructed wetlands should be visited every two to three weeks and following major storms during the first year after construction. Inspections should evaluate:

- The success of the native plantings
- Establishment of invasive non-native plants
- Inlet/outlet conditions
- Sediment/debris accumulation

Repairs, replacements, and maintenance should be conducted as problems arise to maintain the functionality of the wetland. Maintenance will consist of:

- Repairs to the structural integrity of the outlet and containment edges.
- Erosion and burrow repair
- Monitoring and removal of debris and sediment buildup with special not to their effect on water storage capacity.
- Invasive nonnative species control
- Replacement of native plant material as needed.

Visits to the site can be reduced to 4 times per year in the second and third years after establishment

A high level of quantitative monitoring should occur during the first five years after the wetland is installed to insure proper function and establishment of the constructed wetland. Monitoring should focus on successful establishment of native wetland plants, water storage capacity, and pollutant removal. Sediment markers may be used in the wetland to determine how frequently sediment/ debris should be removed. Over time, large wetlands that are heavily loaded will require more frequent monitoring than smaller less loaded wetlands.

Vegetation assessment should be conducted utilizing transect plots that bisect the wetland. Randomly spaced quadrants (square plots, usually 3 ft x 3 ft) should be selected within the wetland and monitored seasonally to determine species composition and concentration. Changes of concern include an increase in the numbers of aggressive non-native species, a decrease in the density of the vegetative cover, and signs of disease.

If near a populated area, monitor the wetland regularly for mosquito populations and develop and implement a control plan as needed.

For the Constructed Wetland Maintenance Schedule, See Table 18.7-B below:



No mow buffer surrounding wetland at Buechel basin (Photo: Erin Wagoner, URS)

Table 18.7-B. Constructed Wetland Maintenance Schedule

Schedule	Activity
Monthly during the first year after construction	• Remove and replace dead, severely diseased vegetation, or damaged plants • Remove or control weeds and invasive species • Monitor wetland after major storm events to ensure structures are functioning properly and inspect for erosion
Semi-annually in spring and fall	• Inspect inflow points for clogging • Inspect for erosion, rills or gullies along the embankments and repair • Remove fallen, clipped or trimmed plant material from wetland to prevent outlet clogging • Harvesting of seasonally dead plant material in the fall may be needed if high nutrient level treatment is desired • Inspect vegetation for health and signs of stress; if plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe water levels to confirm that they are as designed • Mow maintenance access areas around wetland • Maintain signs in "no mow" areas
5 years or as needed	• Remove sediment, trash and debris from inlets/forebays when one-quarter of the forebay volume has been lost
10 plus years	• Monitor sediment accumulation in the wetland cell and remove when one-quarter of the wetland volume has been lost

Green Wet Basin

A wet basin should be inspected at the beginning and end of the rainy season as well as after any storm or heavy rain event. The basin should be maintained for structural stability and proper inflow and outflow discharge. Accumulated sediment and debris should be removed from the basin as well as the inflow area to prevent future clogging during rain events. Overall health and abundance of the native vegetation should be maintained, replacing dead or diseased plants as necessary. In addition, seasonal or yearly management should be conducted to remove or control invasive non-native vegetation from the site as well as to remove woody vegetation from all embankment areas.

Inspection of the buffer zone, downstream of the outflow point, should be conducted regularly to make sure that the wet basin is functioning properly and the outflow is not negatively impacting downstream habitats. This includes inspection for any erosion along the embankment of the basin.

For the Green Wet Basin Maintenance Schedule, see Table 18.7-C below.



Wet basin with small buffer; trash and debris needs to be removed from the practice to prevent clogging at the inflow and outflow. (Photo: David Dods, URS)

Green Dry Basin

The seasonal maintenance of a dry basin consists primarily of the inspection of the inlet and outlet pipes for structural integrity; the clearing of sediment and debris from the inlet and outlet pipes as well as the basin; and the removal of debris from upstream areas to prevent it from washing into the basin. It is important to note that improperly maintained basins can reduce the storage volume of the pond as well as create breeding areas for mosquitoes.

Native vegetation should be maintained seasonally and after large rain events. Maintenance consists of replacement of dead or diseased plants, replanting of eroded areas, and invasive species control. The basin should also be trimmed annually to prevent the growth of woody species.

For the Green Dry Basin Maintenance Schedule, see Table 18.7-C.



Dead or damaged plants as well as weeds or other invasive species should be removed from the practice as necessary. (Photo: Erin Wagoner, URS, Concept rendering: Shea Powell, Dropseed Nursery)

Table 18.7-C. Green Wet & Green Dry Basin Maintenance Schedule

Schedule	Activity
Monthly during the first growing season	• Remove and replace dead or damaged plants • Remove or control weeds and invasive species • Inspect for erosion • Water as needed to keep plants alive
Semi-annually in spring and fall	• Inspect inflow/outflow points for clogging • Remove any trash and debris from forebay • Inspect for erosion, rills or gullies along the embankments and repair • Vegetation should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from basin to prevent outlet clogging • If plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Inspect for plant root damage to piping and mammal burrows; remove/repair when discovered • Mow maintenance access areas around green wet/dry basins; for green wet basins, do not mow close the to the water's edge which will discourage the habitation • Observe infiltration rates of the basin to ensure storage volume is being maintained • Clean pond of debris and trash • For dry basins, remove any sediment accumulation
5-10 years	• Remove sediment from inlets/forebays when one-quarter of the forebay volume has been lost
10 plus years	• Monitor sediment accumulation in green wet basins and remove when one-quarter of the green wet basins volume has been lost



Wet basin with native vegetation along the perimeter. Trash and debris should be removed from practice (Photo: Rusty Schmidt, URS)

Extensive Green Roof

Extensive green roofs will require irrigation, or natural precipitation, at least once a week until the plants have fully established. Once the plants have matured, extensive green roofs no longer need to be irrigated except in cases of extreme drought. Weeding the rooftop will follow the same natural pattern- the roof will require regular weeding during the establishment phase and only seasonal weeding thereafter. Vegetation should be monitored seasonally to maintain overall health and plants should be replaced or re-sown as needed. Plants should be fertilized annually or as recommended by the source nursery.

The severe consequences of drainage backups, root punctures, and leaks in the waterproofing membrane system make seasonal inspections crucial. Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil. Debris and dead vegetation should be removed along with any woody vegetation.

For the Extensive Green Roof Maintenance Schedule, see Table 18.7-D below.

Intensive Green Roof

The increased weight and the addition of more intensive plantings tend to increase the maintenance requirements of intensive green roofs. The same overall maintenance noted for an Extensive Green Roof should be followed, but on a more frequent basis. Plantings will need additional care and maintenance due the increased soil depth and the likelihood of additional invasive exotic plants becoming established.

For the Green Dry Basin Maintenance Schedule, see Table 18.7-D below.



Remove sediment, trash, weeds and debris
(Photo: Louisville & Jefferson County MSD; Concept Rendering: Shea Powell, Dropseed Nursery)

Table 18.7-D. Extensive Green Roof & Intensive Green Roof Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
4-8 times during growing season	• Remove sediment, trash, weeds and debris • Implement landscaping maintenance plan for trimming to achieve desired aesthetic qualities • Mulch as needed • Inspect landscaping for health and signs of stress • If vegetation begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect underneath roof system • Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil • Observe infiltration rates after rain events; green roof should drain within 24 hours of a storm event
10-25 years	• Remove trees/shrubs and replace with smaller specimen

Blue Roofs

Blue roofs require repair and replacement of piping and other structural features. Piping and weirs around the roof drain should be periodically checked for clogging attributed to sediment build-up and debris or obstructions. It is also important to ensure that the captured water is filtering through the system as designed and that the waterproofing membrane is still functioning properly.

For the Blue Roof Maintenance Schedule, see Table 18.7-E below.



Blue roof adjacent to green roof (Photo: New York City Blue Roof and Green Roof Comparison Study)

Table 18.7-E. Blue Roof Maintenance Schedule

Schedule	Activity
Monthly	• Inspect weirs around roof drains/outlets and any valving for proper operation and remove debris and leaves from the rooftop, especially from around the roof drains, weirs and valving
Semi-annually in spring and fall	• Inspect under roof system for any potential leaks • Check weirs around roof drains and valving for proper operation, including ponding depth and detained water drain time; repair as needed
7 plus years	• Inspect weirs, roof drains and valving for failure; replace as needed

Permeable Pavers

Block permeable pavers (brick, concrete, articulated concrete block) require that the surface be kept clean of organic materials and debris through periodic vacuuming and low-pressure washing. Cleaning should be conducted seasonally with certain sites requiring additional maintenance due to the local conditions and the frequency of storm events. Such cleaning will help to maintain the pavement's flow capacity and restore permeability. After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damages and repaired as needed.

Areas should be routinely inspected for settling and loss of water flow through the system and maintenance should be conducted as problems arise. Regular maintenance should help prevent these issues.

Vegetation surrounding the pavers will initially require irrigation and weeding until the plants have become established. Once the plants have matured, maintenance can be conducted spring and fall with additional irrigation during periods of extreme drought.

Grass grid permeable pavers can be irrigated and fed as a normal lawn. It is important that they are not aerated. As a general rule of thumb, if a golf course nearby irrigates their lawn, you will need to irrigate grass pavers.

Gravel grid permeable pavers require little maintenance when installed correctly. Areas that experience traffic require the most attention as gravel will work it's way out of the rings. A broom can be used to get the gravel back into place or, if necessary, adding stones to the area. Generally the practice should only require attention once or twice a year.

In times of winter snow, pervious pavers can be plowed similarly to any other unpaved road, requiring the blade to be lifted about a half inch above the turf. Please note, the use of sand, ash, salt, or other deicing products should be avoided, as they will adversely affect all concrete and turf materials. However, organic deicers are recommended.

For the Permeable Pavers Maintenance Schedule, see Table 18.7-F.



Permeable pavers should be inspected for trash, debris and dirt and cleaned several times per year, as needed
(Photo: Bethany Shain, URS)



Permeable pavers should be kept free of dirt and debris
(Photo: David Dods, URS)



Cleaning of permeable pavers
(Photo: Louisville & Jefferson County MSD)

Table 18.7-F. Permeable Pavers Maintenance Schedule

Schedule	Activity
2-5 times per year as needed for low traffic areas with little or no tree coverage	• High pressure broom vacuum • Replace aggregate between pavers as necessary
6-10 times per year as needed for high traffic areas with trees or other dust or grit sources	• High pressure broom vacuum • Replace aggregate between pavers as necessary
Monthly during the growing season	• Inspect the pavers for trash, debris and dirt • Keep weeds and grass out of the paved area (unless concrete grid pavers are being used) • Mow/trim adjacent vegetation and remove clippings from the area • Visually inspect the pavers after large storms to ensure the overflow drainage system is working • After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damage and repaired as needed
Semi-annually in spring and fall	• Sweep or vacuum the pavers with a street sweeper or street vacuum • If the pavers are installed in an area that is subject to higher than normal amounts of sediment (i.e. an area with large trucks traveling on it daily) it may need to be cleaned more often • Replace any joint material that may have eroded • Observe the system during a rain event • Areas should be routinely inspected for settling and loss of water flow through the system
As needed in winter	• Organic deicers may be used to melt ice and snow • Snow plows may be used when necessary under the following conditions: ♦ The edges of the plow are beveled ♦ The blade of the snow plow is raised 1 to 2 inches ♦ The snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces

Pervious Concrete and Porous Asphalt

Pervious pavement should be maintained monthly and between storms to ensure the success of the system. This involves regular vacuuming and jet washing of the pavement surface to remove debris and sediment. Upland and adjacent areas should be kept vegetated to reduce erosion and sediment flow onto the pavement area. The surface should be inspected annually for deterioration; areas with pavement failure should be resurfaced. Pervious pavement is intended for areas of low traffic; heavy traffic use and large vehicles should be prohibited.

In winter months, the use of sanding materials and deicing products should be limited. Potholes in porous asphalt are not common, however small damaged areas can be patched with either a porous or a standard asphalt mix. If the damaged area is greater than 10% of the total area, a repair patch type must be approved by the Engineer.

For the Pervious Concrete and Porous Asphalt Maintenance Schedule, see Table 18.7-G below.



Pervious Pavements should be kept free of dirt and debris to keep the practice draining effectively
(Photo: David Dods, URS)



When pervious pavements get clogged, it will be necessary to clean the pavement
(Photo: Kentucky Concrete Pavement Association)

Table 18.7-G. Pervious Concrete and Porous Asphalt Maintenance Schedule

Schedule	Maintenance Activities
Preventative measures	• Keep trucks carrying dirt, mulch or sand off the pavement • Route drainage of surrounding landscaping away from the pervious pavements
As needed	• Potholes and cracks may be patched with traditional methods as long as no more than 10% of the total area is effected
Monthly during the growing season	• Keep the asphalt pavement clear of trash, debris and dirt • Keep weeds and grass out of the paved area • Mow/trim adjacent vegetation and always remove any clippings from the area • Monitor infiltration after large storms to ensure the drainage system is working
Semi-annually in spring and fall	• Sweep or vacuum pavement with a street sweeper or street vacuum • Pavement washing systems and compress units are not recommended for **asphalt pavements**, however clogged pores/voids in **concrete pavements** can be pressure washed • If the pavement is located in an area that is subject to higher than normal amounts of sediment, it may need to be cleaned more often
As needed in winter	• Organic deicers may be used to melt ice and snow (sand and gravel are not permitted for the use of deicing) • Snow plows may be used when necessary if the snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces

Tree Boxes & Planters

Tree boxes and planter boxes should be kept free of debris and trash, and periodic cleaning should be conducted to clear the inflow and outflow mechanisms. The vegetation in the boxes will require more intensive maintenance over the first several months after installation, but this demand will decrease as the plants become established. Boxes should be kept free of invasive species and the overall health of the plants should be maintained. The soil and mulch in the boxes should be tested periodically to avoid the build-up of pollutants that may harm the vegetation. Any mulch used should be replaced biannually.

Tree boxes require regular irrigation during dry periods. If an under-drain system is used, maintenance of inflow and outflow structures will require periodic inspection and removal of sediment and debris, if necessary. In addition to general maintenance procedures, the tree/shrub should be trimmed or pruned according to an established maintenance plan.

For the Tree Boxes and Planters Maintenance Schedule, see Table 18.7-H below.



Series of tree and planter boxes accept stormwater runoff from a roadway and should drain within 24 hours after the rain event (Photo: David Dods, URS)

Table 18.7-H. Tree Boxes and Planters Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
Semi-annually in spring and fall	• Remove sediment, trash, weeds and debris • Implement vegetation maintenance plan for trimming to achieve desired aesthetic qualities • Inspect vegetation for health and signs of stress • If tree/shrub begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Observe infiltration rates after rain events. The tree box or planter should drain within 24 hours of a storm event • Replace mulching
10-25 years	• Remove tree/shrub and replace with smaller specimen

Rainwater Harvesting

Rainwater harvesting cisterns will require routine maintenance in the spring and fall. Roof downspouts should be disconnected before the first significant freeze and the cistern will need to be drained. Rain barrels should be drained and removed or kept at half capacity with the spigot open during the winter months to prevent ice damage.

Overall maintenance consists of regular inspection of the unit with replacements and repairs being conducted as needed. In addition, gutters and downspouts should be kept clean and free of leaks. Vegetation receiving the rainwater should be inspected for health and signs of stress and replaced if necessary.

For the Rainwater Harvesting Maintenance Schedule, see Table 18.7-J below.



Three cisterns capture and store excess runoff from rooftop surfaces at the Green Building and are drained between rain events to water the bioswale and rain garden. (Photo: Ted Wathen)

Table 18.7-J. Rainwater Harvesting Maintenance Schedule

Schedule	Activity
Before first significant freeze (late fall)	• Disconnect aboveground cistern from the roof downspouts and direct downspouts to a stabilized, pervious surface • Drain and clean out aboveground cistern
After last significant freeze (early spring)	• Connect cistern to roof downspout
Regularly during the rainwater harvesting season	• Drain harvested rainwater to vegetated, pervious area or utilize beneficially • Inspect health of vegetation receiving harvested rainwater to determine watering needs
Semi-annually in spring and fall	• Remove leaves and debris from grated and screened inlet • Inspect aboveground cistern for tight connections at the inlet and drain valve • Inspect for erosion around the overflow discharge and repair as necessary • Check for algae growth inside the cistern; if found, treat the water to remove the algae and then paint cistern so sunlight can not penetrate system • Check pumping systems to ensure it is working properly • Flush piping as necessary and consult the owner's manual or a professional for further troubleshooting
Annually	• Check accumulated sediment and remove when it is more than 5% of the volume of the cistern

Vegetated Buffer & Vegetated Swale

Initially, vegetated buffers and swales should be inspected after rain events to ensure proper draining. The vegetated buffer should maintain desired slope, length and width. Bare spots or eroded areas should be repaired to ensure they are functioning according to design specifications. Vegetation should be mowed regularly according to maintenance plans and "No Mow" areas should be clearly defined. Inspections should consist of replacement and care of plant materials and irrigation during dry periods. Accumulated sediment or other trash and debris should be removed and the buffer should be checked for erosion.

For the Vegetated Buffer and Vegetated Swale Maintenance Schedule, see Table 18.7-K below.



Inspect vegetation for health and signs of stress
(Photo: Louisville & Jefferson County MSD)

Table 18.7-K. Vegetated Buffer and Swale Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions • Mow or trim vegetation in accordance with nursery recommendations
Semi-annually in spring and fall during first year and annually thereafter	• Inspect grading of vegetative buffer to ensure sheet flow across the entire buffer length and width • Inspect vegetation for health and signs of stress; if tree/shrub/grass begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect buffer for erosion and bare spots and repair
Following significant rain events (>10 yrs)	• Inspect and repair eroded or damaged areas to maintain sheet flow to and across the vegetative buffer

Catch Basin Inserts

Catch basin inserts will require very frequent sediment removal as their volume is very limited in comparison to the volume of the catch basin sump. It is necessary to routinely remove sediment, trash and debris and to replace the inserts if they are damaged. Inspections of catch basin inserts should be scheduled, at a minimum, prior to the first seasonal rains as well as during and after each major storm event.

The site should also be checked for excessive erosion or sediment flow upstream of the catch basin. It may also be necessary to periodically check the catch basin to ensure stormwater is flowing through the filter system. In addition to general maintenance procedures, the catch basin inserts should be replaced annually.

For the Catch Basin Insert Maintenance Schedule, see Table 18.7-L below.



Catch basins should be kept free of sediment, trash and debris and cleaned as needed
(Photo: Dauphin County Conservation District, Pennsylvania)



Catch basin inserts should be cleaned regularly to ensure water can flow through the practice and replaced annually
(Photo: David Dods, URS)

Table 18.7-L. Catch Basin Inserts Maintenance Schedule

Schedule	Activity
Preventative Measures	• Inflow should flow through the filter system
Regularly	• Inspect catch basin inserts for clogging and remove sediment, trash or debris
Semi-annually in spring and fall	• Visit site to ensure there is not excessive erosion or sediment flow upstream of the catch basin insert
Annually	• Replace catch basin inserts

Proprietary Water Quality Units & Underground Storage

Proprietary water quality units and underground detention should be inspected seasonally and after major storm events or per manufacturer's recommendations to ensure proper function. Manufacturer's guidelines should be followed and an individual maintenance plan should be developed for all systems based on routine inspections. In general, maintenance will include pumping and pressure washing the unit and cleaning blockage or sediment buildup with use of vacuum trucks or boom trucks. Drainage areas should be regularly maintained to prevent the flow of trash, sediment and debris into the system. Note that the system may need additional cleaning in the event that a spill of a foreign substance enters the unit. Drainage areas should be regularly maintained to prevent the flow of trash, sediment and debris into the system.

Inspections should be conducted after the first rain event and also after major storms. Repairs to inlets, outlets, control valves or other structures should be performed periodically. Safety and maintenance practices for confined spaces should be followed when appropriate.

For the Proprietary Water Quality Units and Underground Storage Maintenance Schedule, see Table 18.7-M below.



MSD employees use a vacuum truck to cleanout existing structures (Photo: Louisville & Jefferson County MSD)

Table 18.7-M. Proprietary Water Quality Units & Underground Storage Maintenance Schedule

Schedule	Activity
As needed	• Inspect drainage areas for trash, erosion and debris • Perform cleanout if hazardous or foreign substances are spilled in the drainage areas • Repair inlets, outlets, control valves or other structural features as needed • Inspect system after major rain events to ensure it is draining properly
Quarterly	• Inspect system for blockage or sediment buildup and perform cleanout if necessary • Follow manufacturer's guidelines and develop/adjust maintenance plan for the system
Annually	• Perform cleanout of the system with vacuum or boom trucks • Clean any sediment or oil chambers • Inspect inlets, outlets and other structural features; repair as needed

Infiltration Drains

Infiltration drains are characterized as having a surface dimension (length or width) greater than their depth and do not have a subsurface fluid distribution system (i.e. below-grade perforated piping to enhance infiltration).

Infiltration drains will require maintenance inspections at least semi-annually, and more frequently if pre-treatment is not used. It is necessary to check the observation well for clogging on an as needed basis. All pretreatment systems and other structures installed should be routinely checked for clogging. If the pea gravel layer becomes clogged with sediment and debris, it may be necessary to remove the layer and replace it with new pea gravel. It may also be necessary to check the observation well after large storm events to ensure the trench is draining properly. The top of the trench and all pretreatment devices should be cleared of leaves and other debris routinely. It is necessary to mow the area around the pretreatment devices, as well as the perimeter of the trench to clear access for maintenance. If the entire system appears to be clogged with sediment and is no longer functioning properly, this may trigger the removal of the GMP and replacement of unwanted material.

For the Infiltration Drains Maintenance Schedule, see Table 18.7-O below.



MSD employees use a vacuum truck to cleanout the sump of an Infiltration Drain (Photo: Louisville & Jefferson County MSD)



Infiltration Drains should be cleaned and kept free of dirt, trash, and debris (Photo: Louisville & Jefferson County MSD)

Table 18.7-O. Infiltration Drains Maintenance Schedule

Schedule	Activity
2-3 times per year, as needed	• Monitor the drain observation well after large rain events and check for any ponding water • Mow or trim the perimeter of the practice and any pretreatment devices; grass clippings should be removed to prevent clogging • Check observation well for clogging
Semi-annually in spring and fall during first year and annually thereafter	• Check pretreatment systems and other structures for clogging; remove sediment and debris as necessary • Inspect the top layer of the trench for ponding water, leaves, grass clippings or other debris • Inspect any piping or other structural devices for damage and replace as necessary
Upon Failure	• If the entire system becomes clogged, remove and install clean, washed trench aggregate • It may also be necessary to replace piping, filter fabric, etc.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.8 Infiltration Testing Specifications

Key Considerations:

- Different approaches for:
  - Feasibility
  - Conceptual design
  - Financial Incentives Projects
- May involve field work with safety concerns
  - Excavation safety
  - Shoring of deep test pits



The purpose of green management practices is to store, treat and infiltrate stormwater into the soil, mimicking natural systems. Subsurface conditions are key in assessing the feasibility of infiltration in the design of green management practices (GMPs). Infiltration capacity testing and design of GMPs that rely on infiltration to treat the stormwater quality volume shall follow the specifications summarized in this chapter. While National Resources Conservation Service (NRCS) soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits. The following infiltration testing options are addressed in this fact sheet:

- ☑ Single-Ring Infiltrometer
- ☑ Test Pit
- ☑ Other Infiltration Testing and Verification Methods

Infiltration Testing Requirements

The following outlines infiltration testing requirements for all GMPs in Jefferson County in order to take credit for infiltration volume as part of the stormwater quality volume (see Chapter 18.3 Development Standards and Selection Process). The minimum infiltration rate for all practices is 0.5 inches/hour. Where the minimum infiltration rate is not achieved, design cannot account for infiltration and an underdrain is required. Perched or elbowed underdrains are recommended to increase exfiltration through increased contact time with native soils. Infiltration tests shall not be conducted in the rain or within 24 hours of significant rainfall events (greater than 0.5 inches), or when the temperature is below freezing.

Infiltration testing performed, including testing procedures followed, shall be documented and submitted as part of the plan approval process to MSD.

Portions of this Section present testing methods at the bottom of an excavation. It is the testing personnel's responsibility to be aware of and take proper health and safety precautions for activities in an excavation. See the U.S. Occupational Health and Safety Administration (OSHA) for guidelines and requirements (www.osha.gov).

Tiered Testing Approach

MSD's tiered approach to infiltration testing recognizes the importance of accurate in situ conditions while screening out sites unsuitable for infiltration practices and thereby reducing soil investigation and testing costs. The following tiers include:

1) Feasibility Analysis
2) Conceptual Design Testing

Minimum testing requirements for each tier are summarized in Table 18.8-A.

Financial Incentive Program Projects

For projects that are supported financially by MSD or as part of the Green Infrastructure Financial Incentive Program (Section 18.9), more stringent infiltration testing requirements apply. Test pits are required to confirm infiltration rates and soil profiles for each practice, and a minimum of two infiltration tests per test pit is required to confirm infiltration rates.

Qualified Professionals

Infiltration testing shall be conducted by a qualified professional and plans including infiltration testing results must be certified by a professional engineer or professional geologist.

Minimum Infiltration Rates

Minimum infiltration rates for design are specified in GMP fact sheets provided in Section 18.5 of this chapter.

High Water Table

Where a high water table occurs (vertically) within three feet of the plane of infiltration (bottom of GMP), infiltration shall not be considered as part of the water quality volume. Data may be acquired by the NRCS methods or other field methods.

Shallow Soils/Depth to Bedrock

Thin soil zones and shallow bedrock limit the capacity of GMPs to exfiltrate into native soils. Where shallow soils and depth to bedrock occurs (vertically) within three feet of the plane of infiltration, infiltration shall not be considered as part of the water quality volume. Data may be acquired by NRCS or field methods.

Karst Topography

Sinkholes and karst topography limit options for GMPs, and additional infiltration may cause sinkholes to develop. Where sinkholes or karst features are present onsite, infiltration shall not be considered as part of the water quality volume.

Table 18.8-A. Tiered Infiltration Testing Requirements

Green Management Practice Type	Tier 1: Feasibility Analysis	Tier 2: Conceptual Design Testing		Financial Incentive Program Projects (per Section 18.9)
		For initial yields greater than 0.5"/hr	For initial yields less than 0.5"/hr	
Linear practices (i.e. bioswales, interconnected tree boxes, infiltration trenches, etc.)	1 single-ring infiltrometer test per site	1 single-ring infiltrometer test and 1 test pit per 400 linear feet (minimum 1 infiltration test per test pit) of GMP practice	Underdrain required	1 single-ring infiltrometer test* and 1 test pit per 400 linear feet (minimum 2 infiltration tests per test pit) of GMP practice
Non-linear practices (rain gardens, basins, etc.)	1 single-ring infiltrometer test per site	1 single-ring infiltration test and 1 test pit per 400 square feet of practice area (minimum 1 infiltration test per test pit)	Underdrain required	1 single-ring infiltrometer test* and 1 test pit per 200 square feet of practice area (minimum 2 infiltration tests per test pit)

*Includes Conceptual Design testing.

Construction Equipment and Minimizing Compaction

For green management practices designed to infiltrate stormwater runoff, it is essential that soils are not compromised by compaction from construction equipment. Care should be taken to minimize soil compaction throughout the GMP and especially at the plane of infiltration so that infiltration rates of native soils are not impacted. Acceptable excavation methods at infiltration practices include hand labor with shovels or the use of an excavator such as a backhoe or trackhoe (located outside the perimeter or footprint of the practice). Heavy equipment should never be used over existing or the footprint of planned infiltration practices. Prior to site disturbance, the perimeter of the practice should be partitioned off with temporary fencing/tape to keep heavy equipment from crossing the perimeter throughout time of active construction. In cases where the GMP is sufficiently large that equipment must enter it, methods proposed to limit and restore compacted soil must be approved in advance.

Long-term Infiltration Rates

Infiltration rates may decrease over time due to settlement of filter media, compaction, or accumulation of sediment in the practice. To sustain infiltration rates long-term, it is important that a maintenance plan is in place. Regular maintenance should be conducted to optimize operating infiltration rates.

Background and Desktop Analysis

A desktop analysis of soils data, topography, the location of streams, waterbodies, existing/previous land uses, and structures is encouraged to identify potential GMP locations and types. Existing or previous soil investigation or lab data may also be used to support preliminary siting of GMPs and infiltration testing. While NRCS soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits.

Tier 1: Feasibility Analysis

A minimum of one single-ring infiltrometer test must initially be performed on site.

Single-Ring Infiltrometer Infiltration Test

This test method utilizes perforated 200 mm to 250 mm (8-inch to 10-inch) plastic or metal canisters with bottom, set in coarse drainage sand, to minimize disturbance to in-place soils and to prevent siltation of the test hole during testing.

1) Holes in the test canister should be 3 mm (1/8 inch) diameter and spaced on 25 mm (1 inch) centers.
2) Excavate a test hole to the depth of the infiltration plane, or the bottom of the GMP and approximately 25 mm (1 inch) larger diameter and approximately 25 mm (1 inch) deeper than the dimensions of a test canister. If the depth of testing is greater than 18", it may be necessary to excavate a shallow test pit to conduct testing.
3) Check that the sides of the test hole are not smooth, but scarified.
4) Place coarse drainage sand in the bottom of the hole and place the canister firmly into the hole. The bottom of the hole should be uncompacted.
5) Backfill the space around the canister with soil and tamp the soil into place.
6) Fill canister with water and allow to drain completely or to soak the surrounding soils for a minimum of one hour, whichever occurs first.
7) Re-fill the canister and measure the rate at which the water level drops.
8) Record the infiltration rate as the decrease in depth of water per hour (inches/hour).

Where the feasibility analysis does not meet minimum infiltration criteria, the designer may prefer to the use of an underdrain rather than continue with further testing.

Where the feasibility analysis meets minimum infiltration criteria, the test pits are necessary for conducting infiltration testing per table 18.8-A to further verify site information characteristics.

Tier 2: Conceptual Design Testing

Test Pit Infiltration Test

This test method consists of a trench or pit that allows visual observation of the soil horizons and overall soil conditions at a particular location on the site. Multiple test pit observations can be made for a relatively low cost and in a short time period. The use of soil borings shall not be substituted for test pits. Test pits allows in-situ visual observation of soil conditions, where soil borings do not. Soil borings are encouraged to supplement data collection, but cannot be substituted for infiltrometer or test pits.

1) Dig a backhoe-excavated trench/pit, 2-1/2 to 3 feet wide, to the proposed depth of the infiltration plane of the practice, or until bedrock or fully saturated conditions are encountered.
2) Safe test pit entry should always be observed. A test pit should never be accessed if it is not safe to do so. OSHA regulations should always be observed.
3) Document soil profile (soil horizons, soil texture and color and depth below ground surface, depth to water table, depth to bedrock, etc).

4) Based on observed field conditions, the qualified professional should consider modifying the proposed infiltration plane of the practice and adjust infiltration testing locations as necessary.
5) Perform Single-Ring Infiltrometer test (above) at depth of infiltration plane of the proposed practice.
6) Soil samples may be collected at various horizons for additional analysis at the designer's discretion.
7) After testing is complete, re-fill test pit with original native soils and stake the location of the test pit.

For Financial Incentive Projects (Section 18.9) and where multiple infiltration tests are conducted, the highest result should be discarded, and remaining results averaged for design purposes (inches/hour).

Other Infiltration Testing and Verification Methods

Other infiltration testing standards that are acceptable include ASTM D3385—09 Standard Test Method for Infiltration Rate of Soils in Filed Using Double Ring Infiltrometer.

Verification methods such as soil borings may be used to verify site conditions where final locations of GMPs are adjusted and do not fall within the original testing location. Test results must verify that the soil conditions are the same as those from the original test results.

Designers should also consider construction access and staging during the design process. Activities that could compact soils where GMPs are sited should be avoided. Where site constraints make this unavoidable, the designer shall compensate accordingly in the design of the GMP.

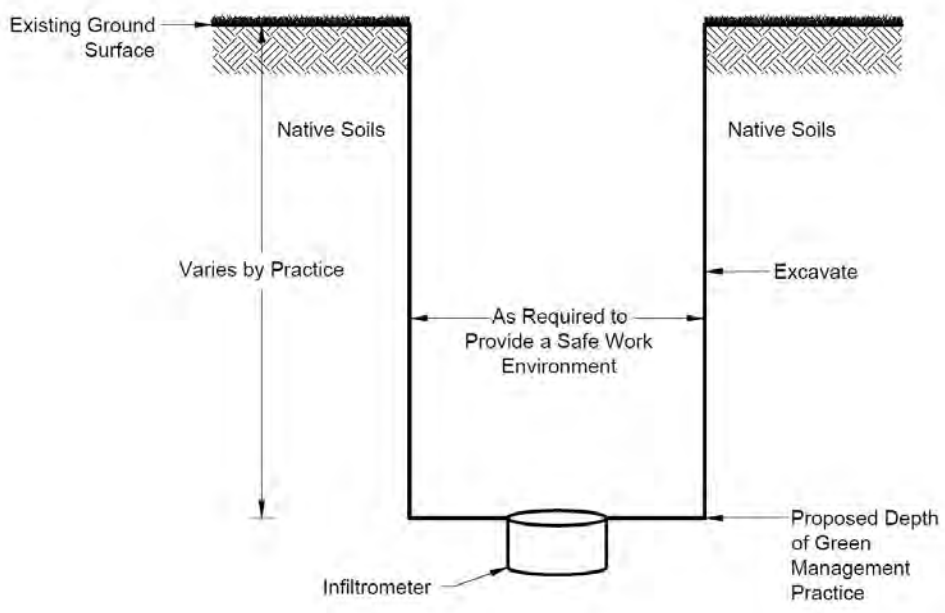

Figure 18.8-A. Test Pit

~Section Held In Reserve~

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Chapter 18.9: Financial Incentive Program

Number	Section
18.9—3	Memorandum of Agreement (Stipend)
18.9—10	Memorandum of Agreement (Credit)

MEMORANDUM OF AGREEMENT
(STIPEND)

BETWEEN THE

LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT

AND

_____

(Company/Facility Name)

PERTAINING TO:
GREEN INFRASTRUCTURE PROJECT

_____

THIS *COVENANT* made and entered into this _____ day of _____, 20_____ by and between, _____ **(*"PROPERTY OWNER"*)** whose mailing address is _____, and who is the owner of property located at _____ with a recorded deed on said property, filed in the Office of the Clerk of Jefferson County, Kentucky in Deed Book _____ Page _____ which is the property restricted by this Maintenance Agreement and the **LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (*"MSD"*)**, public body corporate subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statues, 700 West Liberty Street, Louisville, Kentucky 40203.

WITNESSETH:
Whereas, MSD is a public body corporate and political subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statutes whose primary responsibility is the operation, maintenance, and regulation of public and private sewers and drains, and the discharge of waste and waters into the sewer system; and

WHEREAS, MSD has statutory and regulatory authority to undertake projects to improve the public sewer and drainage system, which includes the development and implementation of a green infrastructure best management practices (as defined in MSD's Schedule of Rates, Rentals, and Charges) incentive program the purpose of which is to minimize the inflow of storm water runoff into the Combined Sewer System (CSS) and Municipal Separate Storm Sewer System (MS4); and

WHEREAS, the incentive program is designed to promote and encourage public and private use of green infrastructure on existing multi-family, commercial, industrial, and institutional properties, new development, and redevelopment; and

WHEREAS, the Property Owner is a _____(Organization Type) in the business of _____ (What you Do) and desires to participate in MSD's green infrastructure best management practices incentive program by developing green infrastructure best management practices at, _____ (Address Of), Louisville, Kentucky ("the Property"); and

WHEREAS, the Property Owner's proposed green infrastructure practices are intended to and will have the potential to reduce the high amount of runoff into the public CSS and MS4 which will provide a significant environmental benefit to the Metro Louisville community and will be ideally suited to showcase green infrastructure.

NOW THEREFORE, in consideration of the promises and mutual covenants contained herein, and other good and valuable consideration, the Parties hereto agree as follows:

(1) **PROJECT SCOPE OWNER AND LOCATION**: The Property is owned by _____. The property herein is described as follows (list legal description of the property that this agreement pertains

to):_____
_____, and, is required to implement green infrastructure best management practices at its property located at _____, Louisville, Kentucky ("the Property"); the Property Owner agrees to and shall construct and install green infrastructure at the Property consisting of the Green Management Practices (GMPs/BMPs) set forth in Exhibit "A" attached hereto, which Exhibit is hereby incorporated into and made a part of this Agreement ("the Project") as if fully set forth herein. The GMPs/BMPs shall be constructed in accordance with plans prepared by a qualified professional in accordance with the MSD Design Manual and in accordance with the construction methodology described within Exhibit "A."

(2) **TERM OF AGREEMENT**: The term of this MOA shall be for a period of ten (10) years from the Effective Date unless earlier terminated in accordance with Section (7) herein below.

(3) **COST AND COST RECOVERY**: The Property Owner shall be solely responsible for the cost of design, construction, installation, maintenance, and operation of the GMPs/BMPs except that MSD agrees to and shall pay Property Owner a stipend per the terms of its Schedule of Rates, Rentals, and Charges in the amount of _____Dollars ($) to enable recovery of a portion of the Property Owner's capital construction costs ("Capital Recovery Stipend"). The Capital Recovery Stipend shall be paid by MSD in accordance with the payment schedule set forth in Exhibit "B" attached hereto and incorporated herein, which is connected with completion by Property Owner and approval by MSD of certain defined milestones.

(4) **DRAINAGE SERVICE CHARGE DISCOUNT**: Contingent upon approved credit application, MSD also agrees to and shall apply up to a twenty-five percent (25%) discount to the Drainage Service Charge levied by MSD upon that part of the Property (defined by Equivalent Service Units) serviced by the green infrastructure GMPs/BMPs. The discount, which shall become effective the first billing cycle after approval, shall be applied throughout the term of this Agreement.

(5) **OPERATION AND MAINTENANCE**: The Property Owner agrees to and shall, to the extent practicable, maintain and operate the GMPs/BMPs during the Term for the purpose of achieving MSD's defined infiltration and other water quality benefits, which maintenance and operation activities shall include, at a minimum, the following (as noted applicable):

Checked as:		
Applicable	Not Applicable	
❑	❑	Consistent and routine observations of infiltration rates of surfaces for infiltration chambers and other hardscape pervious systems. This is for all GMPs/BMPd with surfaces that infiltrate and can be found in Chapter 18 of the MSD Design Manual
❑	❑	Annual maintenance of GMPs/BMPs to remove excess sediment, leaf or other vegetative debris, etc. to keep inflow points free of clogging and to confirm infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.
❑	❑	Annual inspections of vegetated areas of GMPs/BMPs for trimming, pruning, and dividing perennials to prevent overcrowding and to address stress indicators.
❑	❑	Monthly inspections in spring (April – June) and fall (September – October) of vegetated areas of GMPs/BMPs to determine the need for and maintain removal of excess sediment, debris, etc. to keep inflow points free of clogging, as well as consistent and routine pruning, trimming, and weeding, removal of fallen, clipped, and trimmed plant material, removal and replacement of dead or damaged plants, and removal of trash and debris.

❑	❑	Inspect media, soil and/or mulch every 2 to 3 years to determine necessity to re-aerate or replace media, soil and/or mulch layers to achieve infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.
❑	❑	Quarterly inspections of pre-treatment and post- treatment systems including, but not limited to: filters, swirl separators, oil-water separators, grit controllers, absorbents, adsorbents, etc. to determine the need for media replacement and/or maintain removal of sediment, trash, leaf or other vegetative debris, etc. to keep inflow and emergency overflow points free of clogging or re-suspension of collected materials.
❑	❑	The Property Owner or third party entity, such as a Management Group or Homeowners Association, is responsible for notifying MSD when potential structural maintenance is required at the outlet structure, overflow bypasses, culverts, pipes, observation well, and/or other structural elements. The responsible entity will be responsible for the following activities for GMPs/ BMPs: mowing; debris, sediment, and trash removal; and vegetation replacement and maintenance.
❑	❑	Operation, inspection, and maintenance requirements for pre-treatment or post-treatment water quality treatment devices as provided in "Exhibit B".
❑	❑	Operation, inspection, and maintenance requirements for harvesting, storage or blue roof technologies as provided in "Exhibit B".
❑	❑	Preparing and submitting to MSD an "Annual Inspection Checklist" as provided in the MSD Design Manual (Chapter 18), which shall be due on each anniversary of the Effective Date of this Agreement. If requested, MSD agrees to and shall assist the Property Owner in preparing the first inspection report to be submitted during the first year of this Agreement.
❑	❑	The "Annual Inspection Checklist" shall be prepared under the direction of and signature of a Qualified Post-Construction Inspector (QPCI) currently registered with the MSD.
❑	❑	Operation, inspection, and maintenance requirements for outlet of GMPs/ BMPs.
❑	❑	Other: _____

(6) **ACCESS AND USE**: Property Owner agrees to provide site access to MSD personnel for the purposes of green infrastructure inspection, observation, testing, and demonstration to third parties. Property Owner agrees to allow MSD to collect data, review records, and take photographs for the purpose of demonstrating green infrastructure feasibility and effectiveness in technical studies, promotional materials, etc. MSD agrees to provide reasonable notice for access and to seek Property Owner's consent if MSD intends to be accompanied by third parties.

(7) **TERMINATION**: If, within the term of this agreement, the Property Owner chooses to remove the green infrastructure GMPs/BMPs, make modifications that negate the intended purpose of the GMPs/BMPs and or the Project, or fails to operate, maintain, or repair the green infrastructure GMPs/BMPs as required by this Agreement, then the Property Owner shall be deemed to be in default of this Agreement and shall be obligated to reimburse MSD the greater of: 25% of

the Capital Recovery Stipend; or, a straight line 10 year depreciation of the stipend amount.

In the event of the occurrence of default, MSD shall provide the Property Owner written notice (by certified, first class, or overnight mail) of default setting forth the nature of the default, and Property Owner shall have sixty days (60) days after receipt of such notice to cure such default. If the Property fails or refuses to cure said default within this time period, the reimbursement shall become immediately due and payable and this Agreement shall terminate. The Parties also agree that performance of reimbursement shall be enforceable notwithstanding termination.

(8) **SUCCESSORS AND ASSIGNS:** This Agreement shall inure to the benefit of and shall be binding on the Parties hereto and their successors, grantees, and assigns.

(9) **ENTIRE AGREEMENT:** This Agreement contains the entire agreement and understanding of the Parties with respect to the subject matter herein, and may only be amended or modified in writing signed by the Parties hereto.

(10) **GOVERNING LAW/ENFORCEABILITY:** This Agreement shall be governed by and construed in accordance with the laws of the Commonwealth of Kentucky. In the event any provision is determined to be invalid or unenforceable, the same shall not impair the validity or enforceability of the remainder of the Agreement.

IN TESTIMONY WHEREOF, witness the signatures of the Parties hereto, each by its proper officer duly authorized.

LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT	COMPANY/ENTITY
_____	_____
(Printed Name)	(Printed Name)
_____	_____
MSD Executive Director	Signature
	_____
	Title

COMMONWEALTH OF KENTUCKY)

) SS.

COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by _____, (name) who, being by me first duly sworn, did acknowledge and declare that he/she signed the foregoing instrument as _____ (title) of _____, by authority and direction of its _____(members/directors/partners) as his/her free and authorized act and deed.

Witness my hand this _____ day of _____ 20____.

My Commission expires: _____

_____

NOTARY PUBLIC

COMMONWEALTH OF KENTUCKY)

) SS.

COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by Greg Heitzman, PE., who, being by me first duly sworn, did acknowledge and declare that he signed the foregoing instrument as Executive Director of the LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT, by authority and direction of its Board of Directors, as his free and authorized act and deed.

Witness my hand this _____ day of _____, 20____.

My Commission Expires: _____.

_____

NOTARY PUBLIC

This Instrument prepared by:

_____

Legal Counsel

Louisville and Jefferson County

Metropolitan Sewer District

700 West Liberty Street

Louisville, Kentucky 40203-1911

(502) 540-6000

(502) 540-6565 (Fax)

EXHIBIT B

Option One

MOA between MSD and _____

Re: Green Infrastructure Project

Milestone Schedule

The Property Owner shall request inspection(s) at key milestones of the Project, providing at least fourteen (14) days notice. Key milestones, applicable to the various types of green infrastructure GMPs/BMPs, shall include:

Full depth excavation of subsurface green infrastructure - This may include excavation to the bottom of an infiltration trench, bioswale, rain garden, etc.;

Installation of engineered soil or other infiltration material;

Installation of vegetative materials;

Installation of pervious pavers/concrete/asphalt;

Installation of diversion drains or other source water conveyances; and,

Installation of subsurface/surface tanks, pumps and piping systems (for water harvesting systems).

When the Property Owner believes the Project is finally complete and is ready for a final inspection, the Property Owner shall notify MSD in writing and shall submit a written pay request for the Capital Recovery Stipend. Thereupon MSD will perform a final inspection. If MSD confirms that the Project is complete and that all work performed by the Contractor or Property Owner has been completed in accordance with the Agreement, MSD will tender a written approval certifying completion and that the Property Owner is entitled to payment which shall be tendered within thirty (30) days of the request. If MSD does not confirm that the Project is complete and/or that all work performed by the Contractor or Property Owner has been completed in accordance with the Agreement, written approval shall be withheld until acceptable completion.

Exhibit B: Option Two

MOA between MSD and _____

Re: Green Infrastructure Project

Milestone Schedule

Prior to commencement of work to be performed under the Agreement, the Property Owner shall submit a schedule apportioning the Capital Recovery Stipend among the various elements of the Project for purposes of periodic and final payment. Requests for periodic payments of the Capital Recovery Stipend shall be submitted to MSD from the Property Owner on the first day of each month following work performed through the duration of the Project, and each request shall include a written summary of work integral to the construction of the green infrastructure GMPs/BMPs completed as of that date. The Property Owner's request for payment shall also be backed-up by a detailed pay application from the Property Owner's Contractor, signed by the Contractor and documenting the work completed to include unit prices applicable to each element. A copy of the Contractor's pay application to the Property Owner will be required to initiate an MSD milestone inspection.

Milestone inspections, which shall be conducted following receipt of a pay request, shall include an inspection of the work at the Property (Project site) to determine whether the quantity of work performed has been properly performed and/or installed as required and has reached the level for which payment is being requested. MSD shall approve in writing the amount which, in the opinion of MSD, is properly owing to the Property Owner and shall make payment within thirty (30) days following written approval of each such request. When payment is received by the Property Owner, the Property Owner shall immediately pay the Contractor(s) for any unpaid work included in the pay request.

MSD shall have the right to refuse to make payment and may demand the return of a portion or all of the amount previously paid the Property Owner in the event (i) the quantity or quality of the Contractor's work is not as represented in the Property Owner's written summary, the Contractor's pay request, and/or the Agreement and the Property Owner has failed to reconcile or correct deficiencies, (ii) the Project has been inexcusably delayed such that it has jeopardized completion and/or the Property Owner's ability to fulfill the terms of the Agreement, or (iii) the Property Owner has failed to use the Capital Recovery Stipend payments to pay its Contractor as required.

When the Property Owner believes the Project is finally complete and is ready for a final inspection, the Property Owner shall notify MSD in writing. Thereupon MSD will perform a final inspection. If MSD confirms that the Project is complete and that all work performed by the Contractor per its final pay request has been completed in accordance with the Agreement, MSD will tender a written approval certifying completion and that the Property Owner is entitled to the remainder of the unpaid Capital Recovery Stipend, which shall be paid within thirty (30) days following written approval of the final pay request

MEMORANDUM OF AGREEMENT
(CREDIT)

BETWEEN THE

LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT

AND

_____

(Company/Facility Name)

PERTAINING TO:
GREEN INFRASTRUCTURE PROJECT

_____

THIS *COVENANT* made and entered into this _____ day of _____, 20_____ by and between, _____ **(*"PROPERTY OWNER"*)** whose mailing address is _____, and who is the owner of property located at _____ with a recorded deed on said property, filed in the Office of the Clerk of Jefferson, County Kentucky in Deed Book _____ Page _____ which is the property restricted by this maintenance agreement and the **LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (*"MSD"*)**, public body corporate subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statues, 700 West Liberty Street, Louisville, Kentucky 40203.

WITNESSETH:
Whereas, MSD is a public body corporate and political subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statutes whose primary responsibility is the operation, maintenance, and regulation of public and private sewers and drains, and the discharge of waste and waters into the sewer system; and

WHEREAS, MSD has statutory and regulatory authority to undertake projects to improve the public sewer and drainage system, which includes the development and implementation of a green infrastructure best management practices (as defined in MSD's Schedule of Rates, Rentals, and Charges) incentive program the purpose of which is to minimize the inflow of storm water runoff into the Combined Sewer System (CSS) and Municipal Separate Storm Sewer System (MS4); and

WHEREAS, the incentive program is designed to promote and encourage public and private use of green infrastructure on existing multi-family, commercial, industrial, and institutional properties, new development, and redevelopment; and

WHEREAS, the Property Owner is a _____(Organization Type) in the business of _____ (What you Do) and desires to participate in MSD's green infrastructure best management practices incentive program by developing green infrastructure best management practices at, _____ (Address Of), Louisville, Kentucky ("the Property"); and

WHEREAS, the Property Owner's proposed green infrastructure practices are intended to and will have the potential to reduce the high amount of runoff into the public CSS and MS4 areas which will provide a significant environmental benefit to the Metro Louisville community and will be ideally suited to showcase green infrastructure.

NOW THEREFORE, in consideration of the promises and mutual covenants contained herein, and other good and valuable consideration, the Parties hereto agree as follows:

(1) **PROJECT SCOPE OWNER AND LOCATION**: The Property is owned by _____. The

property herein is described as follows (list legal description of the property that this agreement pertains to):_____
_____, and, is required to implement green infrastructure best management practices at its property located at _____, Louisville, Kentucky ("the Property"); the Property Owner agrees to and shall operate green infrastructure at the Property consisting of the Green Management Practices (GMPs/BMPs) set forth in Exhibit "A" attached hereto, which Exhibit is hereby incorporated into and made a part of this Agreement ("the Project") as if fully set forth herein. The GMPs/BMPs shall be constructed in accordance with plans prepared by a qualified professional in accordance with the MSD Design Manual and in accordance with the construction methodology described within Exhibit "A."

(2) **TERM OF AGREEMENT**: The term of this MOA shall be for a period of ten (10) years from the Effective Date unless earlier terminated in accordance with Section (6) herein below.

(3) **DRAINAGE SERVICE CHARGE CREDIT**: The Property Owner shall be solely responsible for the cost of design, construction, installation, maintenance, and operation of the GMPs/BMPs except that MSD agrees to reduce drainage service charges and shall per the terms of its Schedule of Rates, Rentals, and Charges in the amount of _____ Equivalent Service Units (ESUs) to facilitate operation and maintenance; reducing the property's billable ESUs to _____. The discount, which shall become effective the first billing cycle after approval, shall be applied throughout the term of this Agreement.

(4) **OPERATION AND MAINTENANCE**: The Property Owner agrees to and shall, to the extent practicable, maintain and operate the GMPs/BMPs during the Term for the purpose of achieving MSD's defined infiltration and other water quality benefits, which maintenance and operation activities shall include, at a minimum, the following (as noted applicable):

Checked as:

Applicable	Not Applicable	
❑	❑	Consistent and routine observations of infiltration rates of surfaces for infiltration chambers and other hardscape pervious systems. This is for all GMPs/BMPs with surfaces that infiltrate and can be found in Chapter 18 of the MSD Design Manual
❑	❑	Annual maintenance of GMPs/BMPs to remove excess sediment, leaf or other vegetative debris, etc. to keep inflow points free of clogging and to confirm infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.
❑	❑	Annual inspections of vegetated areas of GMPs/BMPs for trimming, pruning, and dividing perennials to prevent overcrowding and to address stress indicators.
❑	❑	Monthly inspections in spring (April – June) and fall (September – October) of vegetated areas of GMPs/BMPs to determine the need for and maintain removal of excess sediment, debris, etc. to keep inflow points free of clogging, as well as consistent and routine pruning, trimming, and weeding, removal of fallen, clipped, and trimmed plant material, removal and replacement of dead or damaged plants, and removal of trash and debris.
❑	❑	Inspect media, soil, and/or mulch every 2 to 3 years to determine necessity to re-aerate or replace media, soil and/or mulch layers to achieve infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.

❑	❑	Quarterly inspections of pre-treatment and post- treatment systems including, but not limited to: filters, swirl separators, oil-water separators, grit controllers, absorbents, adsorbents, etc. to determine the need for media replacement and/or maintain removal of sediment, trash, leaf or other vegetative debris, etc. to keep inflow and emergency overflow points free of clogging or re-suspension of collected materials.
❑	❑	The Property Owner or third party entity, such as a Management Group or Homeowners Association, is responsible for notifying MSD when potential structural maintenance is required at the outlet structure, overflow bypasses, culverts, pipes, observation well, and/or other structural elements. The responsible entity will be responsible for the following activities for GMPs/ BMPs: mowing; debris, sediment, and trash removal; and vegetation replacement and maintenance.
❑	❑	Operation, inspection, and maintenance requirements for pre-treatment or post-treatment water quality treatment devices as provided in "Exhibit B".
❑	❑	Operation, inspection, and maintenance requirements for harvesting, storage or blue roof technologies as provided in "Exhibit B".
❑	❑	Preparing and submitting to MSD an "Annual Inspection Checklist" as provided in the MSD Design Manual (Chapter 18), which shall be due on each anniversary of the Effective Date of this Agreement. If requested, MSD agrees to and shall assist the Property Owner in preparing the first inspection report to be submitted during the first year of this Agreement.
❑	❑	The "Annual Inspection Checklist" shall be prepared under the direction of and signature of a Qualified Post-Construction Inspector (QPCI) currently registered with the MSD.
❑	❑	Operation, inspection, and maintenance requirements for outlet of GMPs/ BMP.
❑	❑	Other:_____ _____ _____

(5) **ACCESS AND USE**: Property Owner agrees to provide site access to MSD personnel for the purposes of green infrastructure inspection, observation, testing, and demonstration to third parties. Property Owner agrees to allow MSD to collect data, review records, and take photographs for the purpose of demonstrating green infrastructure feasibility and effectiveness in technical studies, promotional materials, etc. MSD agrees to provide reasonable notice for access and to seek Property Owner's consent if MSD intends to be accompanied by third parties.

(6) **TERMINATION**: If, within the term of this agreement, the Property Owner chooses to remove the green infrastructure GMPs/BMPs, make modifications that negate the intended purpose of the GMPs/BMPs and or the Project, or fails to operate, maintain, or repair the green infrastructure GMPs/BMPs as required by this Agreement, then the Property Owner shall be deemed to be in default of this Agreement and shall result in termination of the associated credit and shall be obligated to reimburse MSD for past credits.

In the event of the occurrence of default, MSD shall provide the Property Owner written notice (by certified, first class, or overnight mail) of default setting forth the nature of the default, and Property Owner shall have sixty days (60) days after receipt of such notice to cure such default. If the Property fails or refuses to cure said default within this time period,

the reimbursement shall become immediately due and payable and this Agreement shall terminate. The Parties also agree that performance of reimbursement shall be enforceable notwithstanding termination.

(7) **SUCCESSORS AND ASSIGNS:** This Agreement shall inure to the benefit of and shall be binding on the Parties hereto and their successors, grantees, and assigns.

(8) **ENTIRE AGREEMENT:** This Agreement contains the entire agreement and understanding of the Parties with respect to the subject matter herein, and may only be amended or modified in writing signed by the Parties hereto.

(9) **GOVERNING LAW/ENFORCEABILITY:** This Agreement shall be governed by and construed in accordance with the laws of the Commonwealth of Kentucky. In the event any provision is determined to be invalid or unenforceable, the same shall not impair the validity or enforceability of the remainder of the Agreement.

IN TESTIMONY WHEREOF, witness the signatures of the Parties hereto, each by its proper officer duly authorized.

LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT	COMPANY/ENTITY
_____	_____
(Printed Name)	(Printed Name)
_____	_____
MSD Executive Director	Signature
	_____
	Title

COMMONWEALTH OF KENTUCKY)

) SS.

COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by _____, (name) who, being by me first duly sworn, did acknowledge and declare that he/she signed the foregoing instrument as _____ (title) of _____, by authority and direction of its _____(members/directors/partners) as his/her free and authorized act and deed.

Witness my hand this _____ day of _____ 20____.

My Commission expires: _____

_____

NOTARY PUBLIC

COMMONWEALTH OF KENTUCKY)

) SS.

COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by Greg Heitzman, PE., who, being by me first duly sworn, did acknowledge and declare that he signed the foregoing instrument as Executive Director of the LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT, by authority and direction of its Board of Directors, as his free and authorized act and deed.

Witness my hand this _____ day of _____, 20____.

My Commission Expires: _____.

_____

NOTARY PUBLIC

This Instrument prepared by:

_____

Legal Counsel

Louisville and Jefferson County

Metropolitan Sewer District

700 West Liberty Street

Louisville, Kentucky 40203-1911

(502) 540-6000

(502) 540-6565 (Fax)

~Section Held In Reserve~

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.10 Fee In Lieu Program

Purpose

The purpose of this policy is to provide an alternate for sites which cannot meet MSD's requirements (Section 18.3) for green infrastructure to be installed on site for projects disturbing one acre or more. Site limitations, such as steep slopes, poorly draining soils or other potential reasons may preclude the use of green infrastructure on some sites. MSD understands that green infrastructure may not be feasible on all sites, where regional facilities supported by a fee in lieu program are appropriate. Regional facilities in some cases may also be more cost effective or provide better stormwater quality treatment than smaller onsite facilities. For sites that the developer or designer determines that it is not feasible to construct green infrastructure, a waiver and payment through the Fee In Lieu Program maybe available.

Applicability

The waiver and subsequent fee in lieu payment are available in areas where MSD has constructed or has a master plan for regional stormwater quality control facilities. If the designer cannot manage the water quality volume onsite, the designer must fill out the waiver request application form and submit along with a justification and calculations evaluating green management practice (GMP) alternatives and site limitations that make the GMPs infeasible.

Process

The Post-Construction Stormwater Quality Fee In Lieu Waiver Application will be reviewed by MSD staff and a final determination of whether the payment of the fee or another mitigation measure is appropriate for each development will be made on a case by case basis. The applicant shall allow sufficient time for MSD to review the application, submittal calculations and justification.

Costs

The costs to be included in the fee are the costs for MSD to acquire land, prepare designs, construction costs as well as operation and maintenance costs for the regional stormwater quality facilities. In areas where MSD has already constructed facilities, the fee may be tied directly to the actual cost of the facility. In areas where facilities are still in the planning process, MSD will develop a cost curve based on previously constructed projects or other appropriate information. The fee will be based on the amount of water quality volume (WQv) in cubic feet generated by the site based on the requirement of providing control for 0.6" of runoff for the site or the portion of the site which is infeasible.

Post-Construction Stormwater Quality Fee In Lieu Waiver Application

- *This form may be downloaded from MSD's website at www.louisvillemsd.org*
- *Refer to the "Stormwater Guidelines" section of the design manual located on MSD's website at www.msdlouky.org for guidance.*

General Information

MSD Reviewer: _____
WM No._____
_____

Project Name: _____

Project Address: _____

Tax Block: ____Lot: ____ Deed Book: _____Pg: _____

Project Total Site Area: _____ (Acres)

Site Impervious Area: _____ (Acres)

Applicant's Name: _____

Address: _____

Telephone: _____ Mobile: _____

Email: _____

Engineer Contact Information (Example: Engineer Representative)

Name: _____ Telephone: _____

Email: _____ KY PE No.: _____

Reason for Waiver Request:

_____

_____

_____

_____

_____

_____

_____

(Add Checklist for submittal information required with the application)

(ADD calculation formula for determining the amount of the fee if the waiver is approved)

Certification Statement

"I hereby certify under penalty of law that by signing as the Representative the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are penalties and fines for submitting false information."

Signature: _____ Date:_____

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Chapter 18.11: Miscellaneous Forms and Checklists

Number	Section
18.11-2	Stormwater Quality Maintenance Agreement
18.11-8	Soil Characterization and Infiltration Testing Form

STORMWATER QUALITY MAINTENANCE AGREEMENT

BETWEEN THE

LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT

AND

_____

PERTAINING TO:

LONG-TERM OPERATION AND MAINTENANCE RESPONSIBILITIES

THIS *COVENANT* made and entered into this _____ day of _____, 20_____ by and between, _____ **(*"PROPERTY OWNER"*)** whose mailing address is _____, and who is the owner of property located at _____ with a recorded deed on said property, filed in the Office of the Clerk of Jefferson County, Kentucky in Deed Book _____ Page _____ which is the property restricted by this Maintenance Agreement and the **LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (*"MSD"*)**, public body corporate subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statues, 700 West Liberty Street, Louisville, Kentucky 40203.

WITNESSETH:

WHEREAS, MSD is a public body corporate and political subdivision organized pursuant to Chapter 76 of the Kentucky Revised Statutes whose primary responsibilities are the operation, maintenance, and regulation of public and private sewers and drains, and the discharge of waste and waters into the sewer system; and

WHEREAS, MSD has statutory and regulatory authority to undertake projects to improve the public sewer and drainage system, which includes green infrastructure best management practices (also known as Green Management Practices (GMPs/ BMPs) or long-term stormwater quality controls) for the purpose of managing the inflow of storm water runoff pollutants into the Combined Sewer System (CSS) and/or Municipal Separate Storm Sewer System (MS4) as is required of Louisville, MSD and its co-permittees through Kentucky Pollutant Discharge Elimination System Permit KYS000001; and

WHEREAS, the Property Owner's proposed green infrastructure practices are required to operate over the long-term use of the property in order to reduce runoff into the public CSS and/or runoff pollutants into the public MS4.

NOW THEREFORE, in consideration of the promises and mutual covenants contained herein, and other good and valuable consideration, the Parties hereto agree as follows:

(1) **PROJECT SCOPE OWNER AND LOCATION**: The Property is owned by _____. The property herein is described as follows (list legal description of the property that this agreement pertains to):_____

_____,
and, is required to implement green infrastructure best management practices at its property located at _____, Louisville, Kentucky ("the Property"); and the Property Owner agrees to and shall construct and install green infrastructure at the Property set forth in "Exhibit A" attached hereto, which Exhibit is hereby incorporated into and made a part of this Agreement ("the Project") as if fully set forth herein. The GMPs/ BMPs shall be constructed in accordance with plans prepared by a qualified professional in accordance with the MSD Design Manual and in accordance with the construction methodology described within "Exhibit A."

(2) **TERM OF AGREEMENT**: The term of this Agreement shall continue in perpetuity unless terminated in accordance with Section (8) herein below.

(3) **COSTS**: The Property Owner shall be solely responsible for the cost of design, construction, installation, maintenance, self-inspection, and operation of the GMPs/BMPs. MSD shall be responsible for costs associated with compliance inspections needed to confirm implementation of this Agreement.

(4) **DRAINAGE SERVICE CHARGE INCENTIVES ELIGIBLITY**: This Agreement does not preclude eligibility of the Property or Property Owner's participation in incentives programs as defined by the MSD Policies. However, MSD may restrict the Property or Property Owner's participation in the policies for other properties for failure to implement the terms of this agreement.

(5) **OPERATION, MAINTENANCE, AND INSPECTION**: The Property Owner agrees to and shall, to the extent practicable, maintain and operate the GMPs/BMPs for the purpose of achieving MSD's defined infiltration and other water quality benefits, which maintenance and operation activities shall include, at a minimum, the following (as noted applicable):

Checked as:

Applicable	Not Applicable	
❑		❑ Consistent and routine observations of infiltration rates. This is for all GMPs/ BMPs that infiltrate and can be found in Chapter 18 of the MSD Design Manual or alternative GMPs/BMPs that MSD approved.
❑		❑ Annual maintenance of GMPs/BMPs to remove excess sediment, leaf or other vegetative debris, etc. to keep inflow points free of clogging and to confirm infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.
❑		❑ Annual inspections of vegetated areas of GMPs/BMPs for trimming, pruning, and dividing perennials to prevent overcrowding and to address stress indicators.
❑		❑ Monthly inspections in spring (April – June) and fall (September – October) of vegetated areas of GMPs/BMPs to determine the need for and maintain removal of excess sediment, debris, etc. to keep inflow points free of clogging, as well as consistent and routine pruning, trimming, and weeding, removal of fallen, clipped, and trimmed plant material, removal and replacement of dead or damaged plants, and removal of trash and debris.
❑		❑ Inspect media, soil, and/or mulch every 2 to 3 years to determine necessity to re-aerate or replace media, soil, and/or mulch layers to achieve infiltration rates of approximately 0.5 inches per hour as estimated through observation or basic on-site testing.

❑ ❑ Quarterly inspections of pre-treatment and post- treatment systems including, but not limited to: filters, swirl separators, oil-water separators, grit controllers, absorbents, adsorbents, etc. to determine the need for media replacement and/or maintain removal of sediment, trash, leaf or other vegetative debris, etc. to keep inflow and emergency overflow points free of clogging or re-suspension of collected materials.

❑ ❑ The Property Owner or third party entity, such as a Management Group or Homeowners Association, is responsible for notifying MSD when potential structural maintenance is required at the outlet structure, overflow bypasses, culverts, pipes, observation well, and/or other structural elements. The responsible entity will be responsible for the following activities for GMPs/ BMPs: mowing; debris, sediment, and trash removal; and vegetation replacement and maintenance.

❑ ❑ Operation, inspection, and maintenance requirements for pre-treatment or post-treatment water quality treatment devices as provided in "Exhibit B".

❑ ❑ Operation, inspection, and maintenance requirements for harvesting, storage or blue roof technologies as provided in "Exhibit B".

❑ ❑ Preparing and submitting to MSD an "Annual Inspection Checklist" as provided in the MSD Design Manual (Chapter 18), which shall be due on each anniversary of the Effective Date of this Agreement. If requested, MSD agrees to and shall assist the Property Owner in preparing the first inspection report to be submitted during the first year of this Agreement.

❑ ❑ The "Annual Inspection Checklist" shall be prepared under the direction of and signature of a Qualified Post-Construction Inspector (QPCI) currently registered with the MSD.

❑ ❑ Operation, inspection, and maintenance requirements for outlet of GMPs/BMPs.

❑ ❑ Other:
_____
_____
_____

(6) **ACCESS AND USE**: Property Owner agrees to provide site access to MSD personnel for the purposes of green infrastructure inspection, observation, testing, maintenance, and repairs. Property Owner agrees to allow MSD to collect data, review records, collect samples, and take photographs.

(7) **INDEMNIFICATION**: Property Owner agrees to hold harmless and indemnify MSD from any and all claims or damages, to the fullest extent permitted by law, which may arise as a result of the implementation, planning, design, construction, installation, operation or maintenance of the GMPs/BMPs and does release MSD fully, finally and completely from any and all claims, liabilities, obligations, and warranties associated herewith and any and all damages which may result from any work performed in connection with this agreement.

(8) **TERMINATION and ENFORCEMENT**: The removal of, or failure to maintain _____ may subject property to an enforcement action which may include notices of violation and fines. In the event of the occurrence of default, MSD shall provide the Property Owner written notice (by certified, first class, or overnight mail) of default setting forth the nature of the default, and the Property Owner shall have sixty days (60) days after receipt of such notice to cure such default. If the Property Owner fails or refuses

to cure said default within this time period, MSD may institute enforcement procedures provided in the Wastewater / Stormwater Discharge Regulations.

(9) **SUCCESSORS AND ASSIGNS:** This Agreement shall inure to the benefit of and shall be binding on the Parties hereto and their successors, grantees, and assigns.

(10) **ENTIRE AGREEMENT**: This Agreement contains the entire agreement and understanding of the Parties with respect to the subject matter herein, and may only be amended or modified in writing signed by the Parties hereto.

(11) **GOVERNING LAW/ENFORCEABILITY**: This Agreement shall be governed by and construed in accordance with the laws of the Commonwealth of Kentucky. In the event any provision is determined to be invalid or unenforceable, the same shall not impair the validity or enforceability of the remainder of the Agreement.

IN TESTIMONY WHEREOF, witness the signatures of the Parties hereto, each by its proper officer duly authorized.

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT

_____
_____ (name)
_____ (MSD Executive Director)

_____
_____ (name)
_____ (title)

COMMONWEALTH OF KENTUCKY)
) SS.
COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by _____, (name) who, being by me first duly sworn, did acknowledge and declare that he/she signed the foregoing instrument as _____ (title) of _____, by authority and direction of its _____(members/ directors/partners) as his/her free and authorized act and deed.

Witness my hand this _____ day of _____ 20____

My Commission expires: _____.

_____
NOTARY PUBLIC

COMMONWEALTH OF KENTUCKY)
) SS.
COUNTY OF JEFFERSON)

I, the undersigned, a Notary Public within and for the State and County aforesaid, do hereby certify that the foregoing instrument was this day produced before me by _____, (name) who, being by me first duly sworn, did acknowledge and declare that he signed the foregoing instrument as Executive Director of the LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT, by authority and direction of its Board of Directors, as his free and authorized act and deed.

Witness my hand this _____ day of _____, 20___

My Commission Expires: _____.

_____ NOTARY PUBLIC

This Instrument prepared by:

_____

Legal Counsel
Louisville and Jefferson County
Metropolitan Sewer District
700 West Liberty Street
Louisville, Kentucky 40203-1911
(502) 540-6000
(502) 540-6565 (Fax)

Project Name _____

Date_____ Infiltration Test No. _____of_____ MSD WM/Sub. No._____

Depth to Bottom _____ Diameter of Canister _____ Financial Incentive Project (Yes/No) _____

The purpose of this form is to facilitate the review process for GMP infiltration capacity. The omission of required items may be cause for rejection of the submittal without review.

Attachments

__ Site map identifying infiltration test location

__ Boring logs

__ Other (specify) _____

_____

Testing Methodology

__ Standard MSD Infiltrometer Test

__ ASTM D3385-09 Double Ring Infiltrometer

Soil Profile Description (Test Pits)

Depth (feet)	Soil Texture

Infiltration Testing Log

Time	Time Interval (minutes)	Depth to Water Surface (feet)	Drop in Water Level (feet)	Infiltration Rate (inches/hour)	Comments

Results

Infiltration rate: _____ inches per hour

The undersigned acknowledges by signature that these documents meet or exceed the design standards of the Louisville and Jefferson County Metropolitan Sewer District and that they were prepared under my supervision. I, the undersigned, further acknowledge that to the best of my knowledge and belief, the products resulting from these documents will function as intended.

_____

Name

_____ _____

Signature Date

Acronyms

ASTM	American Society of Testing and Materials
BMP	Best Management Practice
CBR	California Bearing Ratio
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EPSC	Erosion Prevention & Sediment Control
ESAL	Equivalent Single Axle Load
FEMA	Federal Emergency Management Agency
Fps	Feet per second
GMP	Green Management Practice
H:V	Horizontal: Vertical
I/I	Inflow and Infiltration
IOAP	Integrated Overflow Abatement Plan
KAR	Kentucky Administrative Regulations
KDEP	Kentucky Department of Environmental Protection
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
KRS	Kentucky Revised Statutes
KYTC	Kentucky Transportation Cabinet
LEED	Leadership in Energy and Environmental Design
LF	Linear Feet
LOJIC	Louisville Jefferson County Information Consortium
MEP	Maximum Extent Practicable
mg/L	Milligrams per Liter
MOA	Memorandum of Agreement
MS4	Municipal Separate Storm Sewer System
MSD	Metropolitan Sewer District
MWQv	Managed Water Quality Volume
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
O&M	Operation & Maintenance
PE	Professional Engineer
PIO	Public Information and Outreach
PLS	Pure Live Seed
PVC	Polyvinyl Chloride
RE_{WQV}	Required Water Quality Volume Rain Event
ROW	Right-of-way
RRV Capacity	Runoff Reduction Volume Capacity
RWQv	Remaining Water Quality Volume
SDP	Site Disturbance Permit
SSO	Sanitary Sewer Overflow
SSS	Sanitary Sewer System
SWPPP	Stormwater Pollution Prevention Plan
SWQMP	Stormwater Quality Management Plan
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
WQv	Water Quality Volume

Definitions

Aquatic bench	Shallow areas around the edge of a wet basin that sustains vegetation and that provide water quality benefits.
Beneficially Used	Utilizing stormwater runoff for vegetative irrigation or non-potable uses; not allowing stormwater runoff to directly discharge onto impervious surfaces and into pipes and culverts.
Best Management Practice (BMP)	Schedules of activities, prohibitions of practices, treatment requirements, operating procedures, and other various protocols used to prevent or reduce the discharge of pollutants to the waters of the United States.
Bioaccumulation	The uptake of toxic substances, including pesticides and absorbs the toxic substance at a rate greater than it is lost.
Bioswale	Stormwater conveyance features that mimic ecological function of a landscape, often serving as replacements to open ditches or underground pipes.
Blue Roof	A stormwater management practice that detains 1 to 4 inches of rainfall in the roof and slowly releasing the water to a storm sewer system generally over a 24 hour period.
Buffer Strip	Undisturbed natural areas that treat stormwater runoff.
Catch Basin Inserts	Space saving devices installed underneath the grate of an inlet to remove sediment, debris, oils or metal from stormwater inflow.
Channel Stabilization	Erosion prevention and stabilization of velocity distribution in a channel using drops, revetments, vegetation and other measures.
Check Dams	Small dam built across minor channels, swales, bioswales, or drainage ditches; used to reduce erosion and allow pollutants/sediments to settle.
Choker Course	Aggregate layer placed above the base layer in permeable pavement design for leveling of the surface material.
Cisterns	A permanent structure typically having a volume over 100 gallons and can be placed aboveground or belowground.
Class V Injection Well	Defined by EPA as a bored, drilled or driven shaft or a dug hole that is deeper than it is wide, an improved sinkhole or a subsurface fluid distribution system.
Clean Water Act	An act by which congress mandated that the EPA address non-point source pollution in stormwater runoff.
Combined Sewer Overflow	An outfall which MSD is authorized to discharge during wet weather, as defined by MSD's KPDES permit for the Morris Forman WWTP.
Combined Sewer System	The portion of MSD's Sewer System designed to convey municipal sewage (domestic, commercial, and industrial wastewaters) and stormwater runoff through a single-pipe system to MSD's Morris Forman WWTP or CSOs.
Compost	Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.
Consent Decree	Judicial decree expressing a voluntary agreement between parties to a suit; often an agreement by a defendant to cease illegal activities in exchange for an end to criminal charges.
Conservation Subdivision	An alternative to conventional subdivision adopted by the Louisville Metro Planning Commission and Louisville Metro Council, to balance residential development open space conservation and natural resource protection.
Constructed Wetland	Stormwater management practices that are generally shallow, except for pool areas and contain dense native aquatic vegetation. Constructed wetlands temporarily store storm-

	water runoff, treat pollutants and create habitat.
Credit	A credit is a long-term financial incentive. Every MSD customer is charged a monthly fee for drainage.
CSS Sewersheds	Drainage area of man-made sewers and storm drains.
Cultivars	A plant cultivated for its desirable characteristics and often used in ornamental or landscaped gardens.
Design Life	The period of time for which a facility is expected to perform its intended function.
Detention	Managing stormwater runoff or sewer flows through a temporary holding and controlled release.
Dry Well	See Class V Injection Well.
Emergency Spillway	Gates or structures that regulate the passage of flood flows around the dam or containment structure.
Energy Dissipater	A mechanism to break up and slow the flow of water.
Erosion	Detachment and movement of soil or rock fragments by water, wind, ice or gravity.
Evapotranspiration	The combined loss of water from a given area and during a specific period of time, by evaporation from the soil and by transpiration from plants.
Excess Rainfall	Direct runoff at the place where it originates.
Extensive Green Roof	A stormwater management practice comprised of a roofing system consisting of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive roofs have soil depths of six inches or less that is designed to support dense, low growing, drought tolerant vegetation.
Filter Fabric	A woven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.
Filter Strip	See Vegetated Buffer.
First flush	The first portion of runoff generated by rainfall event and containing the main portion of the pollutant load resulting from the storm.
Floatable	A type of litter pollution that floats on the surface of stormwater, typically bottles, cans, styrofoam containers or other trash.
Flood Peak	The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.
Forebay	A manmade pool of water in front of a larger body of water, often used for flood control.
Foundation Drain	A pipe or series of pipes which collects groundwater from the foundation or footing of structures and discharges this water into sewers or other points of disposal.
Freeboard	A vertical distance between the elevation of the design high water and the top of a dam, levee or diversion ridge.
Frost Heave	Uplift of soil or pavement surface due to expansion of groundwater upon freezing.
Geogrid	Manufactured soil reinforcement products that stabilize subsurface conditions through a multi-directional load distribution grid.
Gray Infrastructure	Constructed structures such as treatment facilities, sewer systems, stormwater systems, or storage basins. The term "gray" refers to the fact that such structures are typically made of, or involve the use of concrete.

Gray Infrastructure	Constructed structures such as treatment facilities, stormwater systems, storage basins, sewer systems, etc. "Gray" referencing that most of these structures are made from concrete.
Green Dry Basin	Stormwater management practices that are similar to standard dry basins, except that they contain a forebay for capturing the heavier sedient and floatables, non-turf frass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm evetns and no low flow channel so sheet flow can be promoted. Water quality benefits include uptake and filtering through deep rooted, native plants; sediment settling; temporary stormwater detention; and a slower rate of release.
Green Infrastructure	An adaptable term used to describe an array of materials, technologies, and practices that use natural systems—or engineered systems that mimic natural processes— to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. Examples of green infrastructure include green roofs, porous pavement, rain gardens, and vegetated swales.
Green Management Practice (GMP)	Term used to describe best management practices within green infrastructure.
Green Wet Basins	Stormwater management practices that are similar to standard wet basins, except that they contain an aquatic bench along the perimeter of the pond just below the normal pool level and possibly other plantings above the normal pool elevation in the extended portion of the basin. The aquatice benches provide water quality benefits.
Greenway Trails	Multi-use paths or trails constructed for pedestrian and/or bicycle traffic and recreational use often through scenic natural areas or along waterways and connect neighborhoods with parks, schools and recreational areas.
Hardscape	Areas where the upper soil profile is no longer exposed to the actual surface of the Earth (e.g., paved areas, business complexes and housing developments, industrial areas).
Heat Island Effect	Causes an area to be consistently warmer than its surrounding rural area, often due to urban development. Affects communities by increasing energy demand, air pollution, and water quality.
Hotspots	A land use or activity that generates higher concentrations of pollutants including but not limited to hydrocarbons, sediments, and trace metals that are found in stormwater near the land use.
Impaired Waters	Surface water that is negatively impacted by pollution, resulting in decreased water quality. Kentucky Division of Water publishes impaired waters in its 303(d) list.
Impervious surface	Surfaces that do not allow water to permeate or infiltrate through the material, such as paved roadways, sidewalks, rooftops, etc.
Incentives Policy	Louisville & Jefferson County's Rates, Rentals and Charges Policy, also refered to as the Stormwater User Fee Credits Program, includes financial incentives to encourage commercial, industrial and institutional property owners to implement green infrastruture as a way to manage the stormwater runoff generated by impervious surfaces on their property.
Infiltration	Groundwater that enters a wastewater system through such means as defects in pipes, pipe joints, connections, or manholes.
Infiltration Rate	A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions including the presence of an excess of water.
Infiltration Trenches	Shallow, excavated areas that receive stormwater that are typically filled with aggregate and contain no outlet structure.

Inlet	Narrow body of water between islands or leading inland from a larger body of water, often leading to an enclosed body of water.
Intensive Green Roof	A stormwater management practice comprised of a waterproof layer, drainage system, engineered soils and vegetation. Intensive green roofs have soil depths greater that six inches to support the root growth of larger vegetation, including: plants, shrubs and trees.
Invasive Species	A non-native species that adversely affect the habitats that they invade by disrupting the natural balance of the habitat either by dominating resources, habitat or native species.
KAR	Administrative regulations published by the Kentucky Legislative Commission. An unofficial posting of the KAR is available via the Commission's website at www.lrc.ky.gov.
Kentucky Pollutant Discharge Elimination System Permit	Any National Pollutant Discharge Elimination System permit issued to MSD by the Cabinet pursuant to the authority of the Clean Water Act and Kentucky Revised Statues (KRS) Chapter 224 and the regulations promulgated thereunder..
Leadership in Energy and Environmental Design (LEED)	A rating system that is administered by the US Green Building Council (USGBC) and is currently the most accepted benchmark for the design, construction, and operation of high performance green buildings and neighborhood developments in the U.S. The five key areas include sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.
Louisville and Jefferson County Metropolitan Sewer District	The agency responsible for providing wastewater, stormwater, and flood protection services in Jefferson County. MSD is also responsible for response, mitigation, notification, and reporting of overflows, including unauthorized discharges.
MS4 Program	Municipal Separate Storm Sewer System; operated by MSD in Anchorage, Jeffersontown, St. Matthews and Shively, as well as operated by the Kentucky Transportation Cabinet.
Mulch	A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover and minimizes temperature fluctuations.
National Pollutant Discharge Elimination System	A national program under the Clean Water Act that regulates discharges of pollutants from point sources to Waters of the United States. Discharges are illegal unless authorized by an NPDES permit.
Nonpoint Source Pollution	The EPA defines this term as any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground and carrying with it pollutants that are eventually deposited in lakes, rivers, wetlands, coastal waters and ground water.
Nutrients	A type of water contamination including nitrogen and phosphorous that degrades waterways. Excess nitrogen and phosphorous lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that make people sick.
Outfall	The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.
Outlet	The mouth of a waterway, where water flows into a larger body of water.
Overflow	Any release of wastewater from MSD's sanitary or combined sewer system at locations not specified in any KPDES permit. This includes any Unauthorized Discharge and releases to public or private property that do not reach Waters of the United States, such as basement backups. However, wastewater backups into buildings caused by blockages, flow conditions, or malfunctions in a building lateral, other piping or conveyance system that is not owned or operationally controlled by MSD are not overflows for the purposes of the

	IOAP.
Overland Flow	Surface runoff that occurs when soil is saturated and excess water from rain or snowmelt flows over the land.
Pathogen	An organism capable of causing disease, including disease-causing bacteria, protozoa, and viruses.
Peak Flow	The maximum flow that occurs over a specific length of time (e.g., daily, hourly, instantaneous).
Permeable Pavers	Pavement surfaces that promote infiltration of stormwater that consist of individual concrete or stone shapes that are placed adjacent to one another over a sub-base.
Permeable/Pervious/Porous	Allows water to pass through.
Pervious Concrete	A permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and base layers.
Phosphorus	Phosphorous pollution is a type of nutrient pollution that causes degradation of waterways. See Nutrients.
Planters	Are similar to rain gardens and bioretention basins in that they detain, filter and infiltrate stormwater; nad are suitable for plants ranging from native flowers to shrubs or small trees. They are most commonly used as infiltration of stormwater runoff from rooftop downspouts.
Pollutants of Concern	Pollutants that are identified as current and/or future problems for local waterways. This list will be re-evaluated as monitoring data becomes available and conditions change. Factors to consider when listing a pollutant of concern include potential violation NPDES permit violation, pollutants that pose a threat to local waterways, potential pollutant impact on human health. Any pollutant that has been documented via analytical data as a cause of impairment in any waterbody.
Porous Asphalt	A permeable pavement that allowes the water to infiltrate into the subsoil through the pavement surface and stone reservoir.
Pretreatment	The process of wastewater traveling through municipal wastewater treatment plants before exiting into waterways or water bodies, reducing water pollutants.
Proprietary Water Quality Units	Space effective stormwater management structures that typically underground treatment systems installed at inlet structures.
Rain Garden	A stormwater management practice, sometimes referred to as bioretention cells, bioinfiltration cells, or biofiltration cells which are shallow stormwater basins that mimic the ecological funtions of a natural landscape. Rain gardens contain deep rooted vegetation or cultivar species to filter and infiltrate stormwater.
Rainwater Harvesting	the practice of collecting and temporarily storing rainwater.
Reasonable Engineering	As a legal term of art, this is the statutory and regulatory standard for judgment evaluating engineering practices.
Recharge	Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.
Required Water Quality Volume	This is the third step in the GMP selection process. During this step, the volume for treating the water quality rain event is calculated.
Required Water Quality Volume Rain Event	This is the second step in the GMP selection process. During this step, the rain event for calculating the water quality volume for the site is selected. RE_{WQV} depends on the location of the project site. If the project site is in the Combined Sewers System, then the 92 percentile storm (1.00") is used. If the project site is in the MS4 area, then

	the 80 percentile storm (0.60") is used.
Retrofit	Refers to the addition of new technology or features to older systems.
Riparian Areas	Ecosystems that occur along waterways or bodies of water.
Sanitary Sewer	A pipe or conduit (sewer) intended to carry wastewater or water-borne wastes. from homes, businesses, and industries to the publicly owned treatment works.
Sanitary Sewer Overflow	Any discharge of wastewater to waters of the United States from MSD's Sewer System through a point source not authorized by a KPDES permit, as well as any release of wastewater from MSD's Sewer System to public or private property that does not reach Waters of the United States, such as a release to a land surface or structure that does not reach Waters of the United States; provided, however, that releases or wastewater backups into buildings that are caused by blockages, flow conditions, or malfunctions in a building lateral, or in other piping or conveyance system that is not owned or operationally controlled by MSD are not SSOs.
Sanitary System	The portion of MSD's sewer system designed to convey only municipal sewage (domestic, commercial, and industrial wastewaters) to MSD's WWTPs.
Sensitive Areas	Areas of particular environmental significance or sensitivity as determined by the KPDES permitting authority in coordination with State and Federal agencies, that include Outstanding National Resources Waters, waters with threatened or endangered species and their habitats, waters with primary contract recreation, public drinking water intakes or their designated protection areas.
Sewer System	The wastewater collection, retention, and transmission system that MSD owns or operates, that are designed to collect, retain and convey municipal sewage (domestic, commercial and industrial wastewaters) to MSD's WWTPs or CSOs which is comprised of the CSS and the SSS.
Slope	Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plan with a 90 degree slope being vertical (maximum) and a 45 degree being a 1:1 or 100 percent slope.
Spillway	See Emergency Spillway.
Stipend	A stipend is a short-term financial incentive for green infrastructure construction cost recovery.
Stormwater	Water runoff that is a result of natural precipitation.
Stormwater Pollution Prevention Plan	A plan for stormwater discharge that when implemented will decrease stormwater discharge.
Stormwater Quality Management Program	All activities undertaken that improve the quality of stormwater runoff into the waters of Louisville Metro.
Stream	Surface water channel having well-defined banks and bed, either constantly or intermittently flowing. "Ephemeral stream" means a watercourse which only flows in direct response to precipitation in the immediate watershed, or in response to the melting of a cover of snow and ice, and which has a channel bottom that is above the local water table. An ephemeral stream is a water of the United States, provided it has an OHWM. "Intermittent stream" means a steam or part of a stream that does not flow continuously throughout the calendar year; but that has a bed below the local water table for at least one (1) month of the calendar year during which it obtains its flow from both surface water and ground water discharge. The term does not include an ephemeral stream. "Perennial stream" means a stream or part of a stream that flows continuously during all of the calendar year as a result

	of ground-water discharge or surface runoff. The term does not include "intermittent stream" or "ephemeral stream".
Surface Waters	Those waters having well-defined banks and beds, either constantly or intermittently flowing; lakes and impounded waters; marshes and wetlands; and any subterranean waters flowing in well-defined channels and having a demonstrable hydrologic connection with the surface.
Total Dissolved Solids	The fine particles that are suspended in water as measured by a laboratory analysis. TDS are typically small enough to pass through a sieve size of two micrometers.
Total Maximum Daily Load	A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.
Treatment Train	The use of multiple GMPs in series on a site to meet the water quality volume requirement for stormwater management.
Tree Box	provides similar benefits as a rain garden/bioretention basin in its design purpose and stormwater benefits by infiltrating, treatment, temporary detention, and biological uptake using trees and tall bushes.
Turbidity	The cloudiness of a fluid caused by microscopic particles suspended in the fluid.
Underdrain Surface	A series of pipes that run longitudinal with pavers that can be used to capture and reuse storwmater runoff; or to reach the desired porosity.
Underground Storage	The practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures with the intent of releasing the stormwater runoff to the surface drainage system at a reduced rate and completely drained prior to the next rain event, similar to a green dry detention pond.
United States Army Corps of Engineers	A branch of the US Government, made up of civilians and military members with a wide diversity of disciplines. From biologists, engineers, geologists, hydrologists, natural resource managers, to other professionals needed within this entity. The Corps plans, designs, builds, operates, and regulates water resources projects that are crucial to the citizens of the United States.
United States Environmental Protection Agency	The federal agency responsible for enforcing the Clean Water Act, Safe Drinking Water Act and other federal environmental regulations.
United States Geological Survey	A division of the United States Government, Department of Interior. USGS is the sole science agency for the Department of Interior.
Urbanization	The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.
Vegetated Buffer	Uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff, generally consisting of native, deep rooted grasses, shrubs and trees.
Vegetated Swale	a shallow, open-channel concentrated flow feature that contains a dense growth of vegetation, generally tall grass, that partially treats and infiltrates stormwater runoff.
Water	From KRS 224.01 (33) "Water" or "waters of the Commonwealth" means and includes any and all rivers, streams, creeks, lakes, ponds, impounding reservoirs, springs, wells, marshes, and all other bodies of surface or underground water, natural or artificial, situated wholly or partly within or bordering upon the Commonwealth or within its jurisdiction; Effluent ditches and lagoons used for waste treatment which are situated on property owned, leased, or under valid easement by a KPDES-permitted discharger are not considered to be waters of the Commonwealth.
Water Quality	A term used to describe the chemical, physical and biological characteristics of water, usu-

	ally in respect to its suitability for a particular purpose.
Water Quality Standards	Standards that set the goals, pollution limits, and protection requirements for each waterbody. These standards are composed of designated (beneficial) uses, numeric and narrative criteria, and antidegradation policies and procedures.
Water table	The upper surface of the free groundwater in a zone of saturation; locus of points in subsurface water at which hydraulic pressure is equal to atmospheric pressure.
Waters of the United States	As defined in 40 CFR I22.2: (a) All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide; (b) All interstate waters, including interstate "wetlands," (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, "wetlands," sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters: (1) Which are or could be used by interstate or foreign travelers for recreational or other purposes; or (2) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (3) Which are used or could be used for industrial purposes by industries in interstate commerce; (d) All impoundments of waters otherwise defined as waters of the United States under this definition; (e) Tributaries of waters identified in paragraphs (a) through (d) of this definition; (f) The territorial sea; and (g) "Wetlands" adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (a) through ('1) of this definition.
Watershed	Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.
Watershed Approach	A flexible framework used for managing water resources within a specified drainage area, or watershed. This approach includes stakeholder involvement and management actions supported by sound science and appropriate technology.
Weir	Device of measuring or regulating the flow of water.
Wet Weather Flow	A combination of dry weather flows and infiltration, inflow and/or runoff, which occurs as a result of rainstorms.
Wetlands	A region of land whose soil is saturated with moister permanently or seasonally.

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APPENDIX A
SELECTED DEFINITIONS

AASHTO - American Association of State Highway Transportation Officials.

ASTM - An abbreviation for American Society for Testing and Materials.

Abandoned - To remove from service for all functional use.

Activated Sludge Process - The process of using biologically active sewage sludge to hasten breakdown of organic matter in sewage during secondary waste treatment.

Acute Toxicity - Any poisonous effect produced within a short period of time, usually within 24-96 hours, resulting in severe biological harm and often death of test organisms.

Aeration - The process of being supplied or impregnated with air. Aeration is used in wastewater treatment to foster biological and chemical oxidation.

Aerobic - This refers to life or processes that can occur only in the presence of oxygen.

Ammonia - One of the seven forms that nitrogen can exist in nature (NH_3-N). It is used as an indicator of water quality because nitrogen is one of the fertilizing elements necessary for algal growth.

Anaerobic - Refers to life or processes that occur in the absence of oxygen.

Arch - The curved top of a structure, usually referred to as being from the springline to the top.

Assimilation - Conversion or incorporation of absorbed nutrients into protoplasm. Also refers to the ability of a body of water to purify itself of organic pollution.

Auger - A boring instrument used for subsurface exploration.

Available Chlorine - A measure of total oxidizing power.

Available Oxygen - The quantity of dissolved oxygen available for oxidation of organic matter in a body of water.

Average Daily Flow - That flow occurring in the sewers as a 24-hour dry weather average, including a nominal amount of infiltration, otherwise described as the total quantity of flow tributary to a point divided by the number of days of flow measurement.

Backfill - (a) The refilling of an excavation after a structure has been placed therein.

(b) The material placed in an excavation in process of backfilling.

Bacteria - Single-celled microorganisms that lack chlorophyll. Some bacteria are capable of causing human, animal, or plant diseases; others are essential in pollution control because they break down organic matter in the air and in the water.

Baffle - Any deflecting device used to change the direction of flow or the velocity of water.

Bar Screen - A preliminary treatment process that removes oversize solids in order to protect downstream treatment processes. Bar screens normally consist of vertical or inclined steel bars spaced at equal intervals across a channel of wastewater.

Barrel, Manhole - The vertical portion of a manhole used to gain access to a sewer or sewer structure.

Base, Manhole - The bottom or supporting structure on which the manhole barrel rests.

Bedding - The earth or other materials on which a sewer or other structure is supported.

Bell - The recessed, over enlarged, female end of a pipe into which the male or spigot end fits.

Biodegradable - The process of decomposing quickly as a result of the action of microorganisms.

Biological Oxidation - The process by which bacterial and other microorganisms feed on complex organic materials and decompose them. Self-purifications of waterways and activated sludge wastewater treatment processes depend on this process. The process is also called biochemical oxidation.

Biosolids - Settleable solids separated from the water during processing of wastewater.

Blazed - The act of removing a portion of bark from a tree for surveying purposes.

Blow Off - A waste gate or device for discharging accumulated solids or for emptying a depressed sewer.

Blueline Stream - Natural surface drainage structure shown on USGS topographic maps as a solid blueline. Also, classified by Kentucky Division of Water as a natural drainage structure having continuous flow during normal weather conditions.

Borings - Subsurface investigations performed to classify the types of soils.

Branch, Y (Wye) - A pipe joined to another pipe (usually at 60 degrees with alignment of the other) molded together and manufactured as a whole unit.

Bulkhead - A partition closing off an opening, usually constructed of timber, brick, or concrete.

Five-Day Carbonaceous Biochemical Oxygen Demand (CBOD5) - A measure of the amount of oxygen consumed in five days by the biological processes that break down organic carbonaceous matter in water. Large amounts of organic waste use up large amounts of dissolved oxygen; thus the greater the degree of pollution, the greater the BOD.

Capacity - The amount of flow in terms of cubic feet per second that a conduit can or will discharge. Capacity depends on factors such as velocity, coefficient of roughness, size, shape, and slope of conduit.

Carbon Dioxide - A colorless gas heavier than air, which is poisonous if inhaled. Its presence can be detected with proper equipment. Common in sewers that are not properly ventilated.

Castings - Metallic objects (normally cast iron) formed in a mold. Examples are: manhole lids; manhole rims; catch basin grates; and frames; etc.

cfs - Cubic feet per second - A unit of measure of the volume of liquid flow past a given point in one second.

Chamber, Chlorine Contract - A structure in which water and chlorine is mixed and then detained in order to achieve disinfection.

Chamber, Diversion - A chamber which contains a device for drawing off all or part of the flow.

Chamber, Junction - A converging section of a conduit used to facilitate the flow from one or more conduits into the main conduit.

Chamber - A general term applied to a space enclosed by walls or to a compartment often prefixed by a descriptive word, such as "junction chamber", "grit chamber", etc.

Chamfer - A flat surface created by slicing off a square edge or corner.

Chemical Oxygen Demand (COD) - A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the biochemical oxygen demand test, is used to determine the degree of pollution in an effluent.

Chlorination - The application of chlorine to drinking water or sewage for disinfection or the oxidation of undesirable compounds or micro-organisms.

Chlorinator - A device for adding a chlorine in the form of a gas or liquid to water.

Chlorine - An element ordinarily existing as a greenish-yellow gas about 2.5 times as heavy as air. At atmospheric pressure and a temperature of -30.1 degrees Fahrenheit, the gas becomes an amber liquid about 1.5 times as heavy as water. The chemical symbol of chlorine is Cl, its atomic weight is 35.457, and its molecular weight is 70.914.

Clarification - The removal of suspended solids by means of gravity settling, which can be aided by chemically-induced coagulation.

Clarifier - A settling tank which allows solids to separate out by gravity and contains a method to mechanically remove solids from the bottom of the tank.

Coagulant Agent - Chemical(s) that cause very fine particles to clump together into larger particles.

Coagulation - The clumping of very fine particles into larger particles induced by chemicals such as lime or alum. The larger particles allow separation of the solids from the water by settling, skimming, draining or filtering.

Coefficient - A numerical quantity interposed in a formula which expresses the relationship between two or more variables, which may be derived by theoretical or experimental methods.

Coefficient, Roughness - A factor, "n", in the Kutter, Manning, Hazen-Williams, and other formulae, which represents the effect of roughness of the confining channel or conduit material upon the energy losses in the flowing water.

Collar - (a) A cylindrical ring of either brick or precast concrete, secured upon the cone or barrel of a manhole upon which the frame will rest.

(b) A cylindrical monolithic concrete encasement for securing a joint and preventing shear by movement.

Collector System - A network of lateral and branch sewers in a defined area, which collects and transports sewage to a larger sewer.

Comminutor - A device that shreds solids in the wastewater in order to make them easier to treat and transport.

Composite Sample - A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of individual samples. Periodic samples may have equal volume or may be roughly proportioned to the flow at the time each sample is taken.

Conduit - A continuous piping or passage system for transporting water or sewage underground. Also, used for containing wires and cables of other utilities.

Connection, House - See Property Service Connection.

Contract Documents - The Agreement, Addenda (which pertain to the Contract Documents), Bid Proposal (including documentation accompanying the bid and any post-bid documentation submitted prior to the Notice of Award) when attached as an exhibit the Agreement, the Bonds, the General Conditions, the Special Provisions, the Specifications and the Drawings as the same or more specifically identified in the Agreement, together with all amendments, modifications and supplements issued on or after the effective date of the Agreement.

Cradle - Type of bedding, usually of gravel or concrete, being laid upwards from the trench bottom to the springline of the pipe.

Crown - The highest inside part of a conduit; the inner top of a conduit.

Cubic Feet per Second - (Abbreviated c.f.s.) A unit of measure of the volume of liquid flow past a given point in one second.

Cul-de-sac - An alley or street having no outlet at one end, usually having an area at its dead end for turning around.

Culvert - A closed conduit typically of precast or monolithic structure of sufficient length for the passage of water.

Datum - An agreed standard point or plane of stated elevation. Any position or element in relation to which others are determined, for example, the horizontal control system used in map making.

Dead Man - A post put in solid ground for furnishing and fastening or anchoring guy wires.

Dechlorination - Removal of residual chlorine in water by a chemical or physical processes.

Delta - Used as a symbol, this indicates the angle of deflection from the forward tangent either left or right to the centerline of the sewer.

Detention Tank - A tank used to provide adequate storage time for chemical or physical reactions to occur.

Digestion - The biochemical decomposition of organic matter. Digestion of biosolids takes place in tanks where the biosolids decompose, resulting in partial gasification, liquefaction, and mineralization of pollutants.

Discharge - (a) As applied to a sewer or stream; the rate of flow, or volume of water flowing therein at a given place and within a given period of time.

(b) The act, in water or other liquid, of passing through an opening or along a conduit or channel.

(c) The water or other liquid which emerges from an opening or passes along a conduit or channel.

Disinfection - Effective killing by chemical or physical processes of organisms capable of causing infectious disease. Chlorination is currently the most common method in wastewater treatment processes.

Diversion - An arrangement of pipes, conduits, gates and/or valves that allows flow to be passed around a hydraulic structure or appurtenance.

Double System - Usually two conduits laid in parallel -- one conduit laid in the trench being used for a drain, and the other as a sewer or sewers laid on either side of a street.

Drainage Area - A tributary area which is generally limited by a topographic area, but may be also limited by political boundary or economic factors.

Drop Inlet - A contrivance of pipe fittings which is utilized when an incoming sewer is considerably higher than the outgoing sewer.

Dynamic Head - In pumping water, a head usually expressed in pounds per square inch (p.s.i.) representing both the pressure due to the elevation to which the water is pumped and that due to friction of the water in the pipe; the head against which a pump works.

Effluent - The water or wastewater that flows from a basin, treatment process or treatment plant.

Encasement - Usually monolithic concrete that is used to enclose the periphery of a conduit.

Engineer - A consultant or in-house designer who is in responsible design and who is a registered Professional Engineer in the Commonwealth of Kentucky.

Equivalent - Being equal in measure.

Extended Aeration - Treatment process similar to conventional activated sludge with the exception that the wastewater is retained in the aeration tank longer (18-24 hours).

Fascines - A long bundle of sticks of wood bound together and used for such purposes as filling ditches and making revetments for riverbanks.

Fecal Coliform Bacteria - A group of organisms indigenous to the intestinal tracts of humans and other mammals. The presence of fecal coliform in water is an indicator of pollution and of potentially dangerous bacterial contamination.

Filtration - The process of passing water through material such as a bed of sand, coal or other granular substance to remove impurities such as suspended particles and bacteria.

Final Effluent - The effluent from the final treatment unit of a wastewater treatment plant.

Flap Gate - A gate that opens and closes by rotation around a hinge or hinges at the top of the gate, permitting the fluid to pass only in one direction.

Floc - A clump of solids formed in sewage by biological or chemical action.

Flocculation - The process of gathering fine particles to form larger particles after coagulation by the use of gentle mixing.

Flood Level - The stage of a stream at the time of a flood.

Flood Plain - The land contained within the perimeter of the probable limiting flood.

Flood Frequency - The frequency with which the maximum flood may be expected to occur at a site in any average interval of years. Frequency analysis defines the "N-year flood" as being the flood which will, over a long period of time, be equaled or exceeded on the average once every N years.

Flow, Dry-Weather (Sanitary) - The flow of wastewater in a sewer during dry weather. Such flow consists mainly of sewage and wastes with no stormwater or groundwater included.

Flow Meter - A device that measures the rate at which water is flowing through the conduit or channel.

Force Main - A pipe under internal pressure created by being on the discharge side of a pump station.

fps - Feet per second.

Gate, Sluice - A gate constructed to slide vertically, or nearly so, and fasten into or against a permanent structure.

Grade - (a) The inclination or slope of a stream channel, conduit or natural ground surface, usually expressed in terms of the ratio or percentage of vertical rise or fall per 100 feet of horizontal distance. See Slope.

(b) The elevation of the invert of the bottom of a pipe line, canal, culvert, sewer, etc.

Grade, Hydraulic - In a closed conduit under pressure, a line joining the elevations to which water would rise in pipes freely vented and under atmospheric pressure. See Gradient, Hydraulic; also, Line, Hydraulic Grade.

Gradient - The rate of change of any characteristic per unit of length, or slope. The term is usually applied to such things as elevation, velocity, pressure, etc. See Slope.

Gradient, Hydraulic - The slope of the hydraulic grade line, the rate of change of pressure head, the ratio of the loss in the sum of the pressure head, and positive head to the flow distance.

Grit - The heavy material present in wastewater, such as sand, gravel, and cinders.

Groundwater - Subsurface water occupying the zone of saturation. In a strict sense, the term applies only to water below the water table.

Head - The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid.

Head, Friction - The head lost by water flowing in a conduit as the result of intermolecular friction or disturbances setup by the contract between the moving water and its containing conduit.

Head, Loss of - The vertical distance or height through which a body must fall freely under the force of gravity to acquire the velocity which it possesses. It is equal to the square of the velocity divided by twice the acceleration of gravity.

Heavy Metals - Metallic elements with high molecular weights, generally toxic in low concentrations to plant and animal life. Such metals often reside in the environment and accumulate biologically. Examples include mercury, chromium, cadmium, arsenic, and lead.

Hydraulic Grade Line - A hydraulic profile of the piezometric level of water at all points along the line. The term is usually applied to water moving in a conduit, open channel, stream, etc. In an open channel it is the free water surface.

Hydrogen Sulfide (H_2S) - A malodorous gas made up of hydrogen and sulfur with the characteristic odor of rotten eggs. It can be emitted in the natural decomposition of organic matter if it becomes anaerobic. In heavy concentrations, it can cause illness or death.

I/I - Refers to infiltration and/or inflow.

Increment, Area - A precise part of an area or one of a series of areas.

Industrial Waste - That waste from the processes of manufacturing discharge in water, as distinguished from the normal sanitary waste contributed by employees.

Infiltration - Refers to groundwater that enters a sewer system through such sources as defective pipes, pipe joints, connections, or manholes.

Infiltration, Groundwater - That part of sanitary sewage flow derived from groundwater sources and passing into public sewers through defects or faulty construction.

Inflow - Refers to water discharged into service connections and sewer pipes from foundations and roof drains, paved surfaces and sump pumps.

Inorganic Matter - Chemical substances of mineral origin, or more correctly not of basic carbon structure.

Interceptor - See Sewer Interceptor.

Interceptor Sewer - A sewer which receives flow from a number of collector sewers or outlets and, frequently, additional predetermined quantities of stormwater (if from a combined system), and transports such water to a point for treatment or disposal.

Invert - The floor, bottom or lowest portion of the internal cross-section of a sewer or other conduit.

Joint, Bell-and-Spigot - A form of joint used on pipes which have an enlarged diameter or bell at one end, and a spigot at the other which fits into and is laid in the bell. The joint is then made tight by cement, lead, a rubber "O" ring, or other jointing compounds or materials.

Lamp Hole - 8" diameter cleanout on the end of a long 8" sanitary stub.

Lathes - Wooden 1" x 2" survey stakes.

Local Drainage System - A drainage system that does not receive or transport runoff from an adjoining property.

Manhole - An opening by which a man may enter or leave a sewer, conduit, or other closed structure for inspection, cleaning, and other maintenance operations, closed by a removable cover.

MGD - Millions of gallons per day.

Microbes - Minute life form or micro-organisms, especially one that causes disease.

Milligrams per liter (mg/L) - A measure of the concentration by weight of a substance per unit volume. One mg/L is equivalent to one part per million (ppm).

Monolithic - Cast-in-place, rather than precast.

MSD - Louisville and Jefferson County Metropolitan Sewer District.

Neutralization - Addition of an acid or alkali to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

Nutrients - Elements or compounds essential as raw materials for organism growth and development. Common nutrients are carbon, oxygen, hydrogen, nitrogen, sulfur and phosphorus.

Organism - Living organisms common to the intestinal tract of man and other mammals whose presence in wastewater is an indicator of pollution and of potentially dangerous bacterial contamination.

Outcrop, Rock - The appearance at the earth surface of a rock strata.

Outfall - The conduit leading to the discharge stream through which the effluent flows.

Oxygen Demand - The quantity of oxygen utilized in the biochemical oxidation of organic matter.

Package Wastewater Treatment Plant - A prefabricated wastewater treatment plant that is hauled to the plant site and installed as the only facility.

Peak - A maximum quantity which occurs over a relatively short period of time, such as an hour or day.

Peak Demand - The maximum, momentary load placed on a wastewater plant or pumping station.

Peak, Instantaneous - The maximum rate which ever occurs, possibly for only a moment.

pH - A measure of the acidity or alkalinity of a material, liquid, or solid. pH is represented on a scale of 0 to 14, with 7 representing a neutral state, 0 representing the most acid, and 14 representing the most alkaline.

Pipe, Vitrified Clay - A pipe made of clay burned in a kiln with surfaces glazed for water tightness. It is used for carrying sewage and sometimes for carrying water. It is seldom used under pressure.

Pollutant - Any gas, liquid, or solid that makes a resource unfit for a specific purpose.

Population, Equivalent - A hypothetical number of persons representing flow. The equivalent population of an existing industry or a school, for example, is determined from the normal flow of sewage divided by the average contribution of wastewater per person.

Population, Saturation - The actual or equivalent population of a given area that exists or would occur when the area is completely developed according to its present use for developed areas, and its present zoning for undeveloped areas.

Population, Total Equivalent - The sum of the residential population in a given area, and its equivalent population.

Potable Water - Water suitable for drinking or cooking purposes from health and aesthetic considerations.

ppm - Part per million. A measure of the concentration by weight of a substance per unit volume. One ppm is equal to one mg/L.

Precast - That which is formed in a mold or form and distributed by the manufacturer as a complete unit.

Precipitate –

(a) Noun: An insoluble, finely-divided substance which is a product of a chemical reaction within a liquid.

(b) Verb: Separation from solution of an insoluble substance.

Pretreatment - Any process used to reduce pollution before the wastewater is introduced into a sewer system for further treatment.

Primary Treatment - An early stage process in wastewater treatment in which floating and settleable solids are mechanically separated from the water being treated.

Private Drainage System - See Local Drainage System

Property Service Connection - That portion of a sewer system located within an easement or right-of-way which transports sewage from private property to the main sewer.

Proposed - That which is to have immediate consideration for construction.

Pump Station - A station at which sewage is pumped to a higher elevation.

Receiving Waters - A stream, river, lake, ocean, or other surface or groundwaters into which treated or untreated wastewater is discharged.

Sanitary Sewers - Sewers intended to carry wastewater from residences, businesses and industries. Stormwater runoff is carried in a separate system.

Screen - A device with openings used to retain or remove suspended or floating solids in flowing water or sewage.

Secondary Treatment - Wastewater treatment process used to convert dissolved or suspended materials into a form more easily separated from the water being treated. The most common form of secondary treatment is a biological treatment process that is followed by secondary clarifiers.

Sedimentation Tanks - Tanks where the solids are allowed to settle or to float. Settled solids are pumped to thickeners or digesters. Scum that floats in a sedimentation tank is either skimmed off or recycled through the wastewater treatment plant.

Sedimentation - The separation of solids by means of gravity.

Service Area - A geographic area serviced by a public utility or served by a sewage collection system.

Settleable Solids - Bits of debris and fine matter heavy enough to settle out of wastewater.

Sewage - Largely, the water supply of a community after it has been fouled by various uses. From the standpoint of source, it may be a combination of the liquid or water carried wastes from residences, businesses and institutions, together with those from industrial establishments, and with such groundwater, surface water, and stormwater as may be present.

Sewage, Combined - Sewage containing both sanitary sewage and surface or stormwater.

Sewage, Domestic - Sewage derived principally from dwellings, businesses, institutions, and the like. It may or may not contain groundwater, surface water, or stormwater.

Sewage, Industrial - Sewage in which industrial wastes pre-dominates.

Sewage, Sanitary -

(a) Domestic sewage with storm and surface water excluded.

(b) Sewage discharging from the sanitary conveniences of dwellings (including apartment complexes and hotels), office buildings, factories, or institutions.

(c) The water supply of a community after it has been used and discharged into a sewer.

Sewer - A pipe or conduit that carries waste, storm or surface water.

Sewer, Branch - A sewer which receives sewage from lateral sewers and discharges into a larger sewer.

Sewer, Collector - A sewer which receives flow directly from property service connections. Collector sewers are tributaries to interceptor sewers.

Sewer, Combined - A sewer intended to receive both wastewater and storm or surface water.

Sewer, Interceptor - A sewer which receives flow from a number of collector sewers or outlets and, frequently, additional predetermined quantities of stormwater (if from a combined system), and transports such water to a point for treatment or disposal.

Sewer, Inverted Siphon - A section of sewer constructed lower than adjacent sections to pass beneath a watercourse or other obstruction. It runs full or at greater than atmospheric pressure because its crown is depressed below the hydraulic grade line.

Sewer, Lateral - A sewer which receives sewage from a relatively small area which discharges into a branch or other sewer and has few others sewers tributary to it.

Sewer, Main - The principal sewer to which branch sewers and submains are tributary, also called trunk sewer.

Sewer, Outfall - A sewer that receives wastewater and/or stormwater and carries it to a point of final discharge.

Sewer, Relief - A sewer built to carry the flows in excess of the capacity of an existing sewer.

Sewer, Sanitary - A sewer which primarily carries sewage, and to which storm surface, and ground waters are not intentionally admitted.

Sewer, Submain - An arbitrary term used for relatively large branch sewers.

Slope - The inclination of the invert of a conduit expressed as a decimal or as feet per stated length measured horizontally in feet.

Soundings - Method used to ascertain the depth of rock strata.

Springline - The inner edge of the inclined or horizontal base where the arch begins.

Stabilization - The process of converting active organic matter into inert, harmless material.

Stacks – A vertical connection to a collector sewer. Used when more economical than a typical property service connection.

Storm Sewer - A separate sewer that carries runoff from storms, surface drainage and street, and does not include domestic or industrial wastes.

Subgrade - The bottom of a trench or other excavation that is somewhat below the predetermined elevation of the bottom of the final excavation or structure, the intervening space being backfilled with some special material such as sand, gravel, broken stone, or tamped earth, or impervious lining. The term is also applied to the elevation of such bottom.

Submain - See Sewer, Submain.

Sump - A depression that serves as a receptacle for liquids to be pumped.

Surcharge - A condition where a sewer is inadequate to discharge the total amount of flow when it is just filled or flowing at the planned depth or head. The amount of surcharge is measured by the volume or rate of excess flow or by the excess height of the hydraulic grade line.

Surface Water - Water on the earth's surface open to the atmosphere, such as rivers, streams, and oceans.

Swale - A shallow ditch which does not exceed 6" in depth from the top of bank.

"Ten-States Standards" - "Recommended Standards for Wastewater Facilities of the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers." 1990 Edition.

Through Drainage System – A drainage system that collects or transports runoff from more than one property.

Topography - The configuration of a surface area including its relief, or relative elevations, and the location of its natural and constructed features.

Total Dissolved Solids (TDS) - The total amount of dissolved materials, organic and inorganic, contained in water and wastes. Excessive dissolved solids make water unpalatable for drinking water and unsuitable for some industrial uses.

Transition - A short section of a conduit used as a conversion section to unite two conduits having different hydraulic elements.

Trunk - See Trunk Sewer.

Trunk Sewer - A sewer which receives many tributary branches and which serves a large area.

USGS - Abbreviation for United States Geological Survey.

Velocity, Self-Cleaning - The minimum velocity in sewers necessary to keep solids in suspension and prevent their deposition and the subsequent nuisances from stoppages and odors on decomposition.

Wastewater - See Sewage.

Water Quality Criteria - The maximum levels of pollutants that can be reached prior to impacting the suitability of water for a given water use classification. Generally, water use classification includes: public water supply; recreation; propagation of fish and other aquatic life; agricultural use and industrial use.

Water Quality Standard - A plan for water quality management containing four major elements: the use (recreation, drinking water, fish and wildlife propagation, industrial or agricultural) to be made of the water; criteria to protect those uses; implementation plans (for needed industrial municipal waste treatment improvements) and enforcement plans; and an anti-degradation station to protect existing high quality waters.

Watershed - The area drained by a given stream or segment of a stream.

APPENDIX B
SYSTEMS INTERNATIONAL CONVERSIONS

Alphabetical List of Units

To Convert From	To	Multiply By
acre-foot	meter^3 (m^3)	1.233 482 E+03
acre	meter^2 (m^2)	4.046 856 E+03
astronomical unit	meter (m)	1.495 98 E+11
atmosphere (normal)	pascal (Pa)	1.013.25 E+05
bar	pascal (Pa)	1.000 000 E-05
barrel (for petroleum, 42 gal)	meter^3 (m^3)	1.589 873 E-01
British thermal unit (International Table)	joule (J)	1.055 056 E+03
bushel (U.S.)	meter (m^3)	3.523 907 E-02
caliber (inch)	meter (m)	2.540 000 E-02
calorie (International Table)	joule (J)	4.186 800 E+00
cal/g	joule/kilogram (J/kg)	4.186 800 E+03
calorie (thermochemical)/minute	watt (W)	6.973 333 E-02
carat (metric)	kilogram (kg)	2.000 000 E-04
centimeter of mercury (0°)	pascal (Pa)	1.333 22 E+03
centimeter of water (4°C)	pascal (Pa)	9.806 38 E+01
circular mil	meter^2 (m^2)	5.067 075 E-10
cup	meter^3 (m^3)	2.365 882 E-04
day (mean solar)	second (s)	8.640 000 E+04
degree (angle)	radian (rad)	1.745 329 E-02
degree Celsius	Kelvin (K)	$t_K = t°_C + 273.15$
degree Fahrenheit	degree Celsius	$t_C = (t_F - 32)/1.8$
degree Fahrenheit	Kelvin (K)	$t_K = (t_F + 459.67)/1.8$
degree Rankine	Kelvin (K)	$t_K = t_R/1.8$
dyne	newton (N)	1.000 000 E-05
dyne-centimeter	newton-meter (Nm)	1.000 000 E-07
dyne/centimeter	pascal (Pa)	1.000 000 E-01
electron volt	joule (J)	1.602 19 E-19
erg	joule (J)	1.000 000 E-07
faraday (chemical)	coulomb ©	9.649 57 E+04
fluid ounce (U.S.)	meter^3 (m^3)	2.957 353 E-05
foot	meter (m)	3.048 000 E-01
foot^3/minute	meter^3/second)m^3/s)	4.719 474 E-04
foot/second	meter^3/second (m^3/s)	2.831 685 E-02
foot^3	meter^3 (m^3)	2.831 685 E-02
foot^3	gallons (gal)	7.48052 E+00
foot^2	meter^2 (m^2)	9.290 304 E-02
foot/hour	meter/second (m/s)	8.466 667 E-05
foot/minute	meter/second (m/s)	5.080 000 E-03
foot/second	meter/second (m/s)	3.048 000 E-01
foot^2/second	meter^2/second (m^2/s)	9.290 304 E-02
foot of water (39.2°F)	pascal (Pa)	2.988 98 E+03
footcandle	lumen/meter^2 (lm/m^2)	1.076 391 E+01
footcandle	lux (lx)	1.076 391 E+01
foot-pound-force	joule (J)	1.355 818 E+00

To Convert From	To	Multiply By
foot-pound-force/hour	watt (W)	3.766 161 E-04
foot-pound-force/minute	watt (W)	2.259 697 E-02
foot-pound-force/second	watt (W)	1.355 818 E+00
foot-second^2	meter/second^2 (m/s^2)	3.048 000 E-01
gallon (U.S. dry)	meter^3 (m^3)	4.404 884 E-03
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 E-03
gallon (U.S. liquid)/day	meter^3/second (m^3/s)	4.381 264 E-08
gallon (U.S. liquid)/minute	meter^3/second (m^3/s)	6.309 020 E-05
gallon/minute	foot^3/hr	8.020800 E+00
gamma	tesla (T)	1.000 000 E-09
gill (U.S.)	meter^3 (m^3)	1.182 941 E-04
grad	degree (angular)	9.000 000 E-01
grad	radian (rad)	1.570 796 E-02
gram	kilogram (kg)	1.000 000 E-03
gram/centimeter^3	kilogram/meter^3 (kg/m^3)	1.000 000 E+03
gram-force/centimeter^2	pascal (Pa)	9.806 650 E+01
horsepower (electric)	watt (W)	7.460 000 E+01
horsepower (metric)	watt (W)	7.354 99 E+02
inch	meter (m)	2.540 000 E-02
inch^2	meter^2 (m^2)	6.451 600 E-04
inch^3	meter^3 (m^3)	1.638 706 E-05
inch^3/minute	meter^3/second (m^3/s)	2.731 177 E-07
inch of mercury (32°F)	pascal (Pa)	3.386 389 E+03
inch of water (39.2° F)	pascal (Pa)	2.490 82 E+02
kilocalorie (International Table)	joule (J)	4.186 800 E+03
kilocalorie (thermochemical)	joule (J)	4.184 000 E+03
kilocalorie (thermochemical)/minute	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/second	watt (W)	4.184 000 E+03
kilogram-force (kgf)	newton (N)	9.806 650 E+00
kilogram-force-meter	Newton-meter (N m)	9.806 650 E+00
kilogram-force-second^2/meter (mass)	kilogram (kg)	9.806 650 E+00
kilogram-force/centimeter^2	pascal (Pa)	9.806 650 E+04
kilogram-force/meter^2	pascal (Pa)	9.806 650 E+00
kilogram-force/millimeter^2	pascal (Pa)	9.806 650 E+06
kilogram-mass	kilogram (kg)	1.000 000 E+00
kilometer/hour	meter/second (m/s)	2.777 778 E_01
kilowatt-hour	joule (J)	3.600 000 E+06
kip (1000 lbf)	newton	4.448 222 E+03
kip/inch^2 (ksi)	pascal (Pa)	6.894 757 E+06
knot (International)	meter/second (m/s)	5.144 444 E-01
liter (L)	feet^3 (ft^3)	3.53000 E+02
liter (L)	gallons(gal)	0.264000 E+00
liter (L)	meter^3 (m^3)	1.000 000 E-03
lux	lumen/meter^2 (lm/m^2)	1.000 000 E+00
maxwell	weber (Wb)	1.000 000 E-08
mil	meter (m)	2.540 000 E-08
mile (International Nautical)	meter (m)	1.852 000 E+03
mile (U.S. nautical)	meter (m)	1.852 000 E+03
mile (U.S. statue)	meter (m)	1.609 344 E+03

To Convert From	To	Multiply By
mile^2 (U.S. statue)	meter^2 (m^2)	2.589 988 E+06
mile/hour (U.S. statue)	meter/second (m/s)	4.470 400 E-01
mile/hour (U.S. statue)	kilometer/hour	1.609 344 E+00
minute (angle)	radian (rad)	2.908 882 E-04
moment of inertia (lbm·ft^2)	kilogram-meter^2 (kg·m^2)	4.214 011 E-02
moment of inertia (lbm·in^2)	kilogram-meter^2 (kg m^2)	2.926 397 E-04
ounce (U.S. fluid)	meter^3 (m^3)	2.957 353 E-05
peck (U.S)	meter^3 (m^3)	8.809 768 E-03
pennyweight	kilogram (kg)	1.555 174 E-03
pint (U.S. dry)	meter^3 (m^3)	5.506 105 E-04
pint (U.S. liquid)	meter^3 (m^3)	4.731 765 E-04
poise (absolute viscosity)	pascal-second (Pa·s)	1.000 000 E-01
pound-force-foot/inch	newton-meter/meter (N·m/m)	5.337 866 E+01
pound-force-foot/inch	newton-meter/meter (N·m/m)	4.448 222 E+00
pound-force/inch	newton/meter (N/m)	1.751 268 E+02
pound-force/foot	newton/meter (N/m)	1.459 390 E+01
pound-force/foot^2	pascal (Pa)	4.788 026 E+01
pound-force/inch^2 (psi)	pascal (Pa)	6.894 757 E+03
pound-force-second/foot^2	pascal-second (Pa·s)	4.788 026 E+01
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 E-01
pound-mass (troy or apothecary)	kilogram (kg)	3.732 417 E-01
pound-mass/foot^2	kilogram/meter^2 (kg/m^2)	4.882 428 E+00
pound-mass/second	kilogram/second (kg/s)	4.535 924 E-01
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 E+01
pound-mass/inch^3	kilogram/meter^3 (kg/m^3)	2.767 990 E+04
pound-mass/gallon (U.S. liquid)	kilogram/meter^3 (kg/m^3)	1.198 264 E+02
pound-mass/foot – second	pascal – second (Pa·s)	1.488 164 E+00
quart (U.S. dry)	meter^3 (m) ^{3}	1.101 221 E-03
quart (U.S. liquid)	kilogram/meter^3 (kg/m^3)	9.463 529 E-04
rod	meter (m)	1.101 221 E-03
roentgen	coulomb/kilogram (C/kg)	2.579 760 E-04
second (angle)	radian (rad)	4.848 137 E-06
slug	kilogram (kg)	1.459 390 E+01
slug/foot^2	kilogram/meter^3 (kg/m^3)	5.153 788 E+02
slug/foot-second	pascal-second (Pa·s)	4.788 026 E+01
statute mile (U.S.)	meter (m)	1.609 344 E+03
stere	meter^3 (m^3)	1.000 000 E+00
tablespoon	meter^3 (m^3)	1.478 676 E-05
teaspoon	meter^3 (m^3)	4.928 922 E-06
tex	kilogram/meter (kg/m)	1.000 000 E-06
ton (assay)	kilogram (kg)	2.916 667 E-02
ton (long, 2240 ibm)	kilogram (kg)	1.016 047 E+03
ton (metric)	kilogram (kg)	1.000 000 E+03
ton (nuclear equivalent of TNT)	joule (J)	4.200000 E+09
ton (register)	meter^3 (m^3)	2.831 685 E+00
ton (short, 2000 ibm)	kilogram (kg)	9.071 847 E+02
ton (short, mass)/hour	kilogram (kg)	2.519 958 E-01
ton (long, mass)/yard^3	kilogram/meter^3 (kg/m^3)	1.328 939 E+03
watt-hour	joule (J)	3.600 000 E+03

To Convert From	To	Multiply By
watt-second	joule (J)	1.000 000 E+00
yard	meter (m)	9.144 000 E-01
$yard^2$	$meter^2$ (m^2)	8.361 274 E-01
$yard^3$	$meter^3$ (m^3)	7.645 549 E-01
$yard^3$/minute	$meter^3$/second (m^3/s)	1.274 258 E-02
year (calendar)	second (s)	3.153 600 E+07

APPENDIX C
FLEXIBLE PIPE
UTILIZATION IN MSD SYSTEM

For many years pipe materials installed into MSD's gravity sewer system were rigid pipe products comprised predominantly of two types. These were vitrified clay pipe (VCP), which was installed for small and intermediate size sewers, and reinforced concrete pipe (RCP) which was typically laid for larger diameter sewers. While each of these traditional products has some limitations, in general they have proven to b very durable and strong and they have served well in the MSD system.

In the early 1980's, solid wall polyvinyl chloride pipe (PVC) was introduced into MSD's sanitary system. PVC pipe has now replaced clay pipe as the preferred product for small to intermediate size sanitary sewers. Since PVC pipe diameters were limited to 18 inches and below, and these pipe materials exhibit relatively high stiffness values, MSD's standard crushed stone encasement (based on the industry standard ASTM D2321) has proven to be adequate for the necessary structural support.

In recent years, manufacturers have developed a number of new flexible pipe products with increasing diameters and some with lower stiffness values. These have included corrugated polyethylene (PE) pipe, high-density polyethylene (HDPE) profile-wall pipe, corrugated PVC pipe, PVC profile wall pipe, and steel spiral rib pipe. Many of these products have been reviewed and approved for use, because MSD recognizes that in certain situations the benefits of lighter weights and fewer joints may be greater than the structural disadvantages associated with flexible pipe.

However, MSD also recognizes that the use of flexible pipe products may not be appropriate in every situation. Accordingly, MSD's Director of Engineering has issued Guidelines for Use of Flexible Pipe for Drainage Facilities. These guidelines were developed after evaluating flexible pipe materials and seeking input from local engineers, developers and contractors. A copy of the guidelines, which have been in effect since February, 1991, is attached.

MSD considers the use of flexible pipe in drainage applications more critical than in sanitary facilities for several reasons. First, drainage facilities often include pipes installed at shallow depths. This makes the pipe more susceptible to damage caused by construction equipment, traffic loads, utility cuts, etc. Second, the flexible pipes products that are approved for sanitary applications tend to exhibit high stiffness values compared with flexible pipe products approved for drainage applications. Last, drainage pipes are typically of larger diameter. This means that larger loads must be supported by the pipe/soil structure. Consequently, more care must be exercised during installation to ensure that the crushed stone is properly worked into the haunching and initial backfill zones to provide the required lateral support.

It is for these reasons that rigid pipes are the preferred product in MSD's drainage system. MSD's policy requires that the Engineer justify the use of flexible pipe on drainage projects. The following is an application form and checklist which should be completed when an Engineer decides to use flexible pipe in the MSD drainage system.

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APPLICATION FOR USE OF FLEXIBLE PIPE IN DRAINAGE FACILITIES WITHIN MSD DRAINAGE SERVICE AREA

General Data

Date:_____

Project Name:_____

Owner/Developer:_____

Engineer:_____

MSD Reviewer:_____

Decision: _____ Accepted _____ Rejected

_____ Revise and Resubmit

Flexible Pipe Data

Type of Pipe Proposed:_____

Manufacturer/Trade Name:_____

Diameter:_____ in. Min./Max. Cover:_____ ft./ _____ ft.

Justification Data

It is the responsibility of the Engineer submitting plans for approval to request and justify the use of flexible pipe materials. As a minimum, the Engineer must address the following items. Attach written responses to this application and reference MSD's Design Manual whenever applicable. Include responses as notes on plans when response requires Contractor's attention.

Item 1. Outline procedures to protect flexible pipe from excessive construction loadings (both equipment and backfill material). If conditions are outside of those used in the Min./Max. Burial Depths Chart for Flexible Pipe, (for example, if backfill weights or construction loads are greater) provide design calculations in accordance with 1) AASHTO Design Procedures Section 12 or Section 18 (as appropriate) and 2) the Modified Iowa Equations to demonstrate a maximum deflection of 5 percent. Design calculations must also show maximum allowable loads, maximum construction loads and maximum in-service loads.

Item 2. Provide information which demonstrates the proposed flexible pipe has adequate hydraulic capacity (If "n" value is higher than a previously approved product).

Item 3. Provide geotechnical data to support design assumptions concerning soil stiffness in haunching and initial backfill zones. Refer to MSD's trench Details for trench widths and crushed stone encasement dimensions, and reference the required trench width and encasement information on plans.

Item 4. Does the groundwater condition or provisions where long runs of concrete encasement indicate that the pipe will be subjected floatation? If yes, discuss measures to prevent occurrence and reference on plans.

Item 5. Discuss the potential for post-installation damage by subsequent construction of other utilities, service connections, fence posts, structure excavation, etc. Flexible pipe shall not be allowed within road right of ways and other locations where potential for damage exists.

Item 6. If steep slopes exist, discuss methods to be employed that will prevent creep or downslope slippage.

Item 7. Discuss the need to provide end treatments to protect inlet/outlet end of flexible pipes from damage.

Item 8. Flexible pipe generally requires more inspection to ensure proper bedding, haunching, backfilling, etc. Outline a plan for the owner/developer to provide the construction inspection of flexible pipe, if MSD inspection forces are not available for full-time inspection during pipe installation. The plan should include the inspector's qualifications and procedures that will be followed to provide complete inspection of installation procedures. Note that supervision must be provided by a registered professional engineer.

MSD Review Comments: _____

_____

_____

_____

_____

APPENDIX D
MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

The attached table outlines minimum and maximum burial depths for the flexible pipe products that are currently approved for use on MSD projects. It was developed using the design procedures contained in the AASHTO Standard Specifications – Division I, Section 12 for aluminized steel pipe and Section 18 for thermoplastic pipe. It also considers a limiting deflection of 5 percent, using the Modified Iowa Method. This table should be used as a reference when standard conditions apply.

Standard conditions assume that the pipe is installed in a trench conforming with the details shown in Appendix F. Backfill is assumed to be 120 pounds per cubic foot. This corresponds to normal soil receiving moderate compaction, or sand which has been flushed and jetted. If the backfill is expected to contain significant quantities of rock fragments, then a higher unit weight should be used and project specific calculations should be performed when unusual (greater than AASHTO H-20) live loadings are expected or the loading does not represent a true negative projecting installation. This could occur in situations containing fill embankments.

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MSD

Louisville and Jefferson County
Metropolitan Sewer District

EXHIBIT D-1
MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

EFFECTIVE DATE: APRIL 1, 1995

MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

Pipe Type	Applicable Standard	Diameter (inches)	Stiffness (psi)	Minimum / Maximum Burial Depth (feet)
ETI Ultra-Rib Pipe	ASTM D-794	8" through18"	60 PSI	1.0 / 25.0'
Ribbed PVC Sewer Pipe		21" through 30"	46 PSI	1.0 / 25.0'
Perma-Loc Corrugated PVC Sewer Pipe	ASTM F-794	18" - 36"	46 PSI	1.0 / 25.0'
Contech A 2000 PVC Sewer Pipe	ASTM F-949	4" - 18"	55 PSI	1.0 / 25.0'
Carlon Vylon H. C. Profile PVC Sewer Pipe	ASTM F-794	21" - 48"	46 PSI	1.0 / 25.0'
ADS - N12 HDPE Corrugated Pipe	AASHTO M252	4" - 8"	50 PSI	1.0 / 20.0'
	AASHTO M252	10"	50 PSI	1.0 / 17.0'
	AASHTO M294	12"	50 PSI	1.0 / 17.0'
	AASHTO M294	15"	42 PSI	1.0 / 17.0'
	AASHTO M294	18"	40 PSI	1.0 / 17.0'
	AASHTO M294	24"	34 PSI	1.0 / 17.0'
	AASHTO M294	30"	28 PSI	1.0 / 14.0'
	AASHTO M294	36"	22 PSI	1.0 / 12.0'
Hancor Hi-Q HDPE Corrugated Pipe	AASHTO M252	4" - 6"	50 PSI	1.0 / 23.0'
	AASHTO M252	8"	50 PSI	1.0 / 20.0'
	AASHTO M252	10" - 12"	50 PSI	1.0 / 16.0'
	AASHTO M294	15"	42 PSI	1.0 / 16.0'
	AASHTO M294	18"	40 PSI	1.0 / 16.0'
	AASHTO M294	24"	34 PSI	1.0 / 16.0'
	AASHTO M294	30"	28 PSI	1.0 / 15.0'
	AASHTO M294	36"	22 PSI	1.0 / 12.0'
Driscopipe Permacore HDPE Profile Pipe	ASTM F-894	18" through 48"	RSC 160	1.0 / 25.0'
Solid Wall PVC Pipe				
SDR 35	ASTM D-3034	4" through 27"	46 PSI	1.0 / 25.0'
SDR 26	ASTM D-2241	1-1/2" through 12"	115 PSI	1.0 / 25.0'
SDR 21	ASTM D-2241	1-1/2" through 12"	234 PSI	1.0 / 25.0'
CONTECH Aluminized Steel ULTRA-FLO	AASHTO M36	18" through 48"	16 gauge	1.0 / 25.0'
	AASHTO M36	54"	16 gauge	1.25 / 22.0'
	AASHTO M36	60"	16 gauge	1.25 / 20.0'
	AASHTO M36	18" through 48"	14 gauge	1.0 / 25.0'
	AASHTO M36	54" through 60"	14 gauge	1.25 / 25.0'
	AASHTO M36	66"	14 gauge	1.5 / 25.0'
	AASHTO M36	72"	14 gauge	1.5 / 24.0'
	AASHTO M36	78"	14 gauge	1.75 / 22.0'
	AASHTO M36	18" through 60"	12 gauge	1.0 / 25.0'
	AASHTO M36	66" through 72"	12 gauge	1.25 / 25.0'
	AASHTO M36	78"	12 gauge	1.5 / 25.0'
	AASHTO M36	84"	12 gauge	1.75 / 25.0'
	AASHTO M36	90" through 96"	12 gauge	2.0 / 25.0'
	AASHTO M36	102"	12 gauge	2.5/ 25.0'

NOTE: Based on H-20 loading, 100% pavement transference, AASHTO impact factors, prism load with soil unit weight of 120 pcf, and soil modulus of 1000 psi. Refer to installation details for trench width and installation specifications.

APPENDIX E
REQUIRED PIPE CLASS FOR REINFORCED CONCRETE PIPE

The attached chart contains the required pipe class for reinforced concrete pipe. It was developed using the revised bedding factors outlined in ACPA publication Design Data 40. This chart should be used as a reference when standard conditions apply.

Standard conditions assume that the pipe is installed in a trench conforming with the details shown in Appendix F. Backfill is assumed to be 120 pounds per cubic foot. This corresponds to normal soil receiving moderate compaction, or sand which has been flushed and jetted. If the backfill is expected to contain significant quantities of rock fragments, then a higher unit weight should be used and project specific calculations should be performed. Furthermore, project specific calculations should be preformed when unusual (greater than AASHTO H-20) live loadings are expected or the loading does not represent a true negative projecting installation. This could occur in situations containing fill embankments.

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REQUIRED PIPE CLASS FOR CIRCULAR REINFORCED CONCRETE PIPE
IN TRENCH INSTALLATION WITH #57 CRUSHED STONE PIPE CRADLE

Height of Cover (feet)

Pipe Inner Diameter (in)	0.5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
12	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
15	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
18	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
21	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
24	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
27	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
30	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
33	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
36	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
39	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
42	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
48	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
54	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
60	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
66	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
72	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
78	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
84	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
90	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
96	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
102	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
108	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
114	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
120	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
126	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
132	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
138	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
144	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4

Notes: (1) Based on H - 20 loading, 100% pavement transference, AASHTO impact factors, soil unit weight of 120 pcf with Marston Equation, maximum allowable MSD trench widths, and bedding factor = 2.4. Refer to installation details for trench width and installation specifications.

(2) For pipe sizes 12-inch through 24-inch diameter, non-reinforced concrete pipe meeting ASTM C14 Class III, can be used where reinforced concrete pipe Class III is allowed.

MSD
Louisville and Jefferson County
Metropolitan Sewer District

EXHIBIT E-1
CIRCULAR RCP CLASS AND DEPTH CHART

EFFECTIVE DATE: JANUARY 1, 2001

APPENDIX F
TRENCH DETAILS

An evaluation of standard installation procedures and specifications which are referenced by pipe product manufacturers has resulted in revisions to MSD's trench details. Installation specifications which were reviewed in developing the revised details include manufacturer's specific recommended trench width and the following ASTM specifications.

1.) ASTM D 2321: Standard Practice for Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.

2.) ASTM A 798: Standard Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications.

The revised details are illustrated in the following exhibits. In certain installations conformance with manufacturers recommended procedures will result in wider trench widths and more crushed stone encasement than MSD has previously required. This is especially the case for large diameter flexible pipes, and in situations where flexible pipe is used and poor soil conditions exist.

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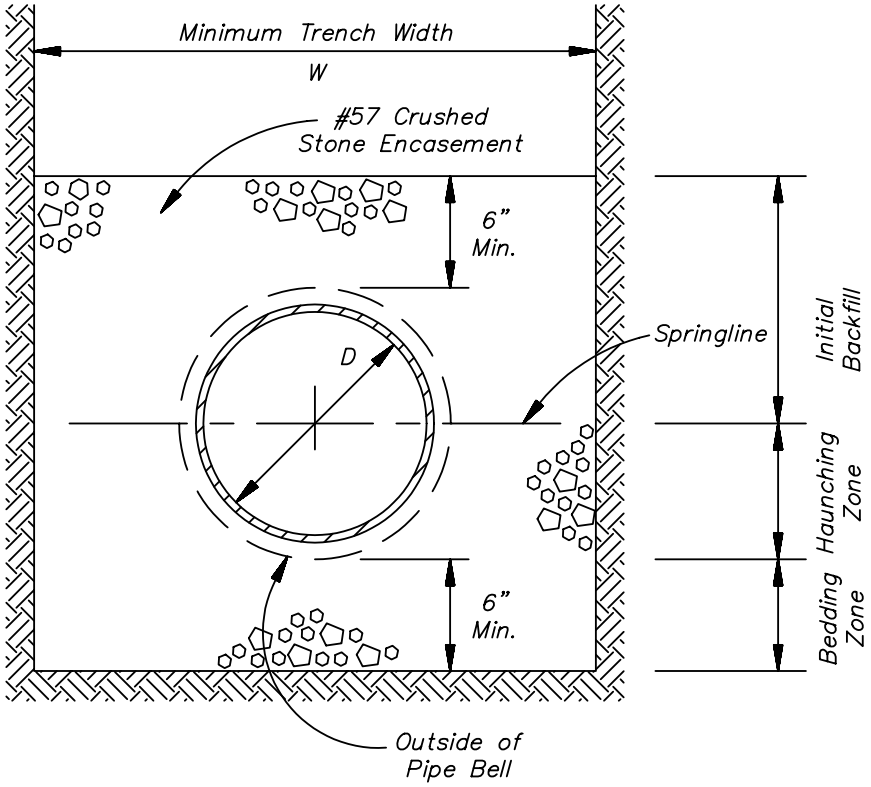
EXHIBIT F-1
CRUSHED STONE ENCASEMENT FOR THERMOPLASTIC PIPE 4" - 12" DIA.

EFFECTIVE DATE: JANUARY 1, 2001



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
4"	1'-9"	2'-0"
6"	1'-11"	3'-0"
8"	2'-1"	4'-0"
10"	2'-3"	5'-0"
12"	2'-6"	6'-0"

*See Note 6

NOTES

1. Place #57 crushed stone in 6" maximum layers and work in around pipe by hand within the haunching zone.
2. Provide bell holes in pipe bedding, no larger than necessary, to ensure uniform pipe support. Fill all voids under bell by hand with bedding material.
3. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.
4. Any trench bracing used below the top of pipe shall be left in place.
5. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.
6. For installations in poor native soils where in-situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N-values less than 10, the minimum trench width shall be expanded by increasing the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 2.5 pipe diameters (2.5 x D).
7. Deflection tests shall be performed as per MSD specifications.
8. For installations where the trench bottom consists of soft clay or very loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.
9. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

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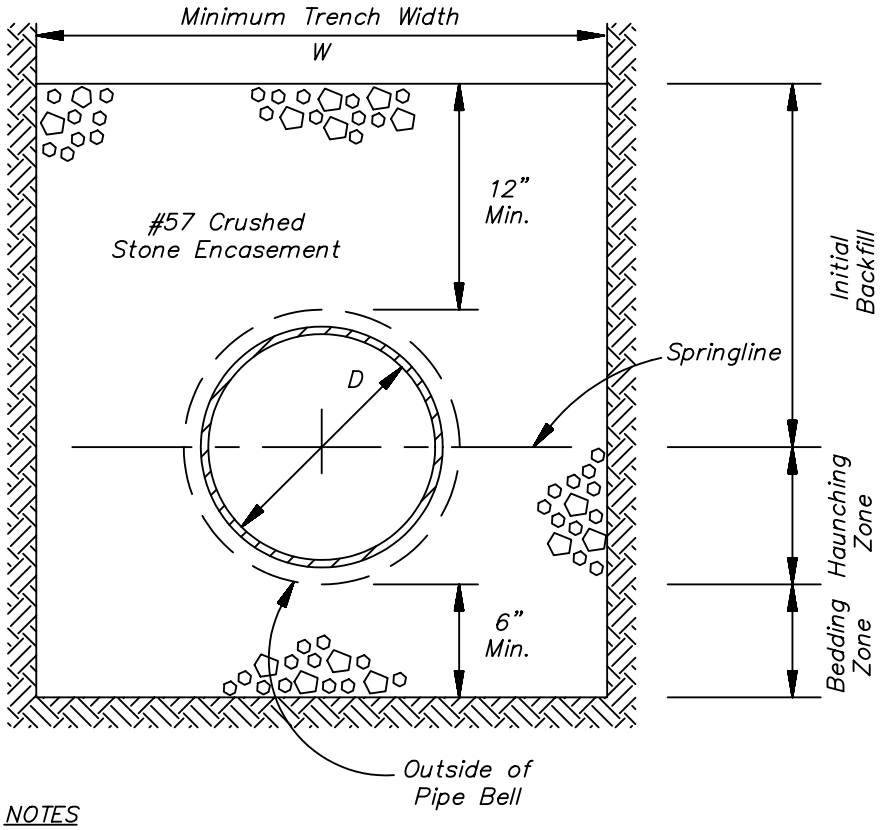
Louisville and Jefferson County
Metropolitan Sewer District

EXHIBIT F-2
CRUSHED STONE ENCASEMENT FOR THERMOPLASTIC PIPE 15" - 48" DIA.

EFFECTIVE DATE JANUARY 1, 2001



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
15"	2'–10"	6'–3"
18"	3'–3"	6'–6"
24"	4'–4"	7'–0"
30"	5'–6"	7'–6"
36"	6'–6"	9'–0"
42"	7'–11"	10'–6"
48"	8'–4"	12'–0"

*See Note 6

NOTES

1. Place #57 crushed stone in 6" maximum layers and work in around pipe by hand within the haunching zone.
2. Provide bell holes in pipe bedding, no larger than necessary to ensure uniform pipe support. Fill all voids under bell by hand with bedding material.
3. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.
4. Any trench bracing used below the top of pipe shall be left in place.
5. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.
6. For installations in poor native soils where in–situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N–values less than 10, the minimum trench width shall be expanded by increasing the the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 30" or one pipe diameter (D) whichever is greater.
7. Deflection tests shall be performed as per MSD specifications.
8. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.
9. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

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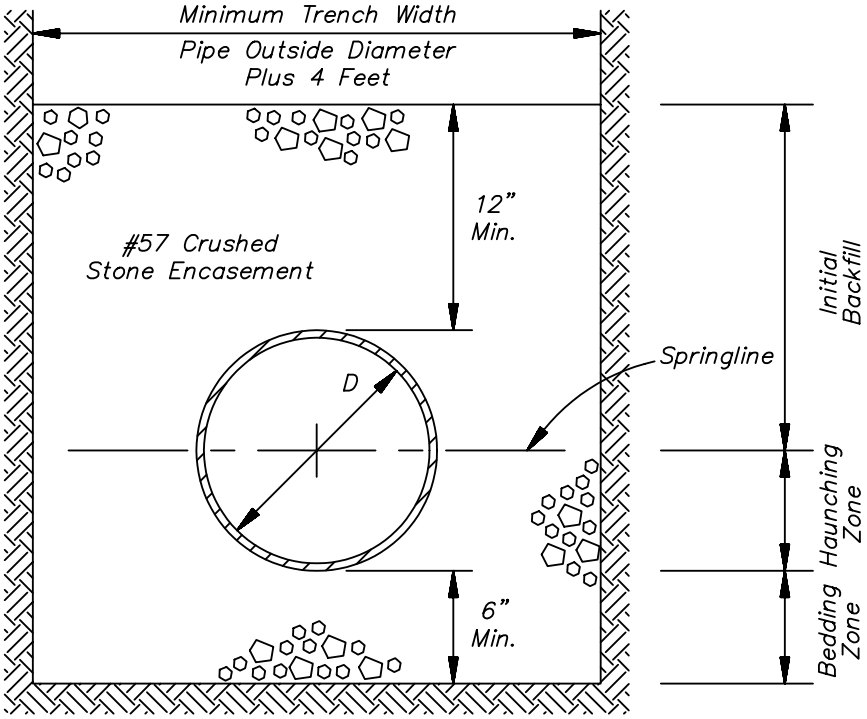
Metropolitan Sewer District

EXHIBIT F-3
CRUSHED STONE ENCASEMENT FOR CORRUGATED/SPIRAL RIB METAL PIPE

EFFECTIVE DATE: JANUARY 1, 2001



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
18"	3'–3"	6'–6"
21"	3'–10"	6'–9"
24"	4'–4"	7'–0"
30"	5'–6"	7'–6"
36"	6'–6"	9'–0"
Larger Than 42"	Pipe O.D. Plus 48"	

*See Note 6

NOTES

1. Place #57 crushed stone in 6" maximum layers and work in around pipe by hand within the haunching zone.
2. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.
3. Any trench bracing used below the top of pipe shall be left in place.
4. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater, the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.
5. For installations in poor native soils where in–situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N–values less than 10, the minimum trench width shall be expanded by increasing the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 30" or one pipe diameter (D) whichever is greater.
6. Deflection tests shall be performed as per MSD specifications.
7. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.
8. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

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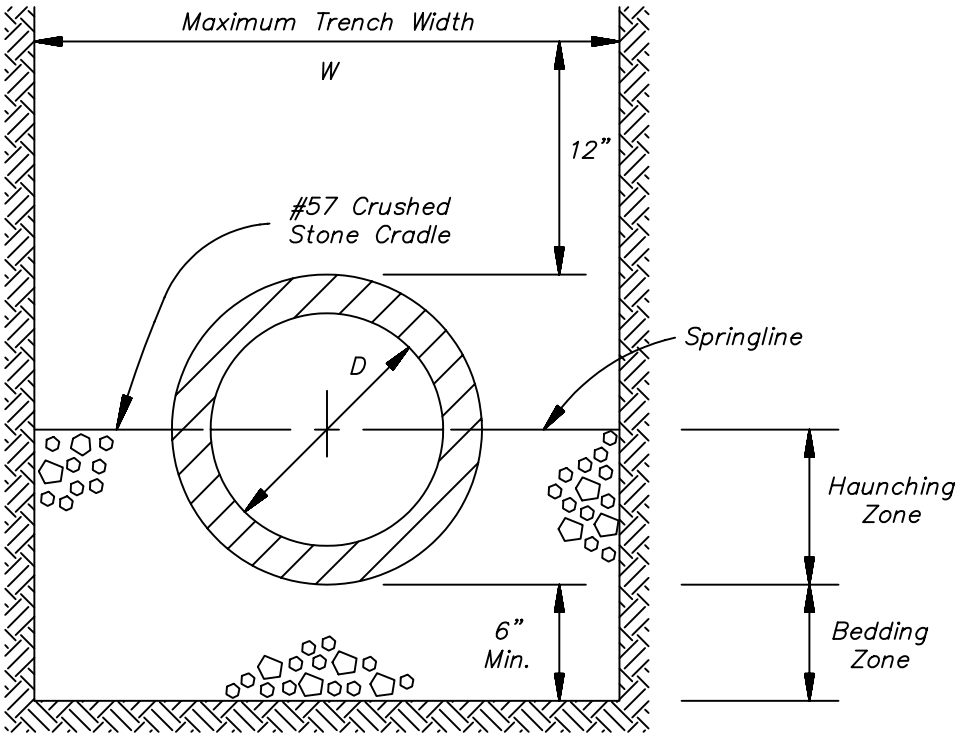
Metropolitan Sewer District

EXHIBIT F-4
CRUSHED STONE CRADLE FOR REINFORCED CONCRETE PIPE

EFFECTIVE DATE: JANUARY 1, 2001



NOTES

1. Place #57 crushed stone in 6" maximum layers and work under pipe by hand within the haunching zone.
2. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.
3. Any trench bracing used below the top of pipe shall be left in place.
4. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.
5. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.
6. The maximum allowable trench width shall apply to a height of 12" above the outside top of the pipe.

Nominal Pipe Dia. (D)	W
12"	3'–5"
15"	3'–9"
18"	4'–1"
21"	4'–4"
24"	4'–8"
27"	5'–1"
30"	5'–5"
33"	5'–10"
36"	6'–2"
39"	6'–8"
42"	6'–11"
48"	7'–6"
Larger Than 48"	Pipe O.D. Plus 2'–8"

APPENDIX G

MSD CRITERIA FOR PRECAST STRUCTURES

Effective October 1, 1990

1. Any use of precast structures must be so noted on the plans, including a typical detail for each type of structure for the project.

2. Structures which require specially designed footings, cut-off walls, etc., will not be allowed as precast.

3. Openings in precast structures for pipes shall be the outside diameter of the pipe plus maximum of 6 inches. In order to use non-shrink grout, the opening shall be the outside diameter of pipe plus 3 inches. (Outside diameter of pipe plus 4 ½ inches is permissible when tapered hole forms are utilized.)

4. For precast structures (other than those with knockout panels), the opening around the pipe shall either be filled with non-shrink grout for the wall thickness of the structure or the pipe shall be encased with a minimum 6-inch collar of concrete from the inside face of the wall to 1'-0" outside the outer face of the wall. The pipe shall be adequately supported to prevent settling while the grout or the concrete encasement is setting up. The inside face of the structure walls shall be finished with a trowel and wet brush finish.

5. For circular structures, the following applies as to the maximum inside diameter (or horizontal dimension) of pipe to be used with a given size of manhole.

Diameter of Structure	Maximum Size of Pipe*
4'-0"	24 inches
5'-0"	36 inches
6'-0"	48 inches

*Outside diameter may be considered on a case-by-case basis for flexible pipe.

6. For circular structures, the minimum distance allowed between precast holes for the pipes shall be 12 inches.

7. For circular structures and rectangular structures (other than those with knockout panels), the minimum vertical distance from the holes for the pipes to the top of the structure wall shall be 4 inches. If this vertical distance is less than 12 inches, then additional reinforcing steel shall be furnished for this section. The top slab must be designed for HS-20 loading.

8. For precast structures with knockout panels, holes for the pipe shall not be cut into the structural members (i.e., top beams and corner columns) and non-shrink grout shall not be allowed to be placed around the pipes. The pipes shall be encased with concrete a minimum 6-inch collar around the outside of pipe or a minimum of 3 inches beyond the hole knocked in the wall, whichever is greater. Also, the concrete encasement shall extend from the inside face of the wall to 1'-0" outside the outer face of the wall.

9. Precast structures with knockout panels shall not be used with more than 2 feet of earth cover unless load calculations are supplied.

10. For rectangular structures where pipe will be installed in adjacent walls (other than those with knockout panels), at least 6 inches of wall (measured from the interior corner)is required on each side of the pipe beyond the precast opening for the pipe. This rule is not applicable for structures which have pipe installed in opposite walls or where one outlet pipe is utilized.

11. A wash is required in the bottom of catch basins to provide positive drainage (sloped toward outlet).

APPENDIX H

POLICY ON DESIGN OF STORMWATER CAPITAL PROJECTS
ADOPTED BY MSD BOARD JULY 11, 1994

Policy Statements

a. General

Flood reduction solution alternatives shall be evaluated primarily based upon relative cost. MSD shall implement the most cost-effective solution whenever feasible. In addition to standard and traditional alternatives, such as modifying or replacing downstream structures and improving stream conveyance, floodproofing of affected structures shall be routinely considered in evaluating solution alternatives. If acquisition and relocation of demolition of affected structures is identified as the most cost-effective solution alternative for a drainage problem, then the Board shall consider the specific situation and decide on the alternative to be used.

Solution alternatives should be evaluated secondarily on the opportunity to use Best Management Practice (BMPs) to improve water quality and maintain natural habitat. Of alternatives with similar estimated costs, the alternative with the highest potential to improve water quality and maintain habitat shall be chosen.

b. Priorities for Project Evaluation

Projects should address drainage requests in the following order of priority:

1. Eliminate or reduce flowing with risk of personal injury.
2. Eliminate first floor flooding.
3. Eliminate or reduce basement flooding.
4. Provide an outlet for drainage from a critical upstream project or area.
5. Eliminate or reduce flooding which interferes with transportation of priority access roads to neighborhoods.
6. Control erosion in situations where structures or property are being damaged or erosion is occurring outside of defined easements.
7. Eliminate long-term standing water of “yard flooding” which occurs outside a defined easement.
8. Control erosion within a defined easement.
9. Eliminate long-term standing water due to the lack of an outlet within an easement.

The final solution to the problems within a project area should address as many as possible of the above-listed items that exist, while remaining cost-effective.

c. Definition of Project Scope

Improvement projects fall into the three categories, depending upon the numbers and locations of affected buildings and residents and the scope of construction effort required: mini-project, neighborhood project, and regional project.

Mini-projects shall meet the following criteria. If one or more of the listed criteria are not met, the project is beyond the scope of a mini-project and is either a neighborhood or regional project.

1. Project addresses a problem located within a single defined subdivision or group of structures.

2. Project does not involve construction of, or improvement to, a regional detention facility.

3. Project does not involve improvement of conveyance within a defined blueline stream.

Neighborhood projects shall meet the following criteria. If one or both of the listed criteria are not met, the project is beyond the scope of a neighborhood project and is a regional project.

1. Project addresses a problem located in one or more subdivisions or groups of structures in a centralized area.

2. Project does not involve construction of a regional detention facility.

Regional projects shall meet the following criteria:

1. Project addresses problems of multiple subdivision, developments, or groups of structures; at least some of the problems are independent and could be solved by separate neighborhood projects.

2. Project influences extend downstream and upstream in the watershed, beyond the typical reach of a neighborhood project.

3. Project involves construction or modification of a regional detention facility or improvement to conveyance of a blueline stream.

d. Design Criteria and Guidelines

Specific design criteria for drainage projects are found in this Design Manual. General guidance for all drainage design and particular guidance of various project categories follows.

For all projects, the guidelines of the Stream Corridors/Greenways Multi-Objective Plan shall be followed. The disturbance of natural stream corridors should be minimized, the preservation of natural streams and habitat should be emphasized, and the use of the piped systems and lined channels should be discouraged. In addition, designs should incorporate BMP's for water quality control.

Structural improvements, such as downstream culvert replacements or upstream detention ponds, shall be designed to mitigate existing flooding problems and provide one foot of freeboard for the 100-year event. If improvements require phasing of funding and/or construction, phasing should be done beginning from the downstream improvements and proceeding upstream. An exception to this general phasing rule is a detention facility, which should be constructed in the early phases of overall project construction. All projects shall be constructed in conformance with the Soil Erosion and Sediment Control Ordinance.

Mini-projects will be designed to establish adequate conveyance capacity of improve the conveyance capacity of the existing drainage system to control frequent storm events. Drainage systems shall be designed so that no flooding of habitable structures occurs during a 100-year event. Neighborhood projects shall be designed similarly so that drainage systems do not allow flooding of habitable structures for the 100-year event. Regional projects shall be designed to reduce or eliminate flooding of habitable structures and property. Regional facilities should also be evaluated for their impacts on base flow, since maintenance of adequate base flow in receiving waters is essential to watershed-wide water quantity and quality management.

e. Non-structural Solution Alternative Design Criteria

e.1. Floodproofing

Floodproofing is the term for procedure which eliminate or reduce flood damage by protecting or modifying buildings instead of preventing flood waters from reaching them. Dry floodproofing seals the exterior of the home and protects the interior. Wet floodproofing involves designing or retrofitting a building's electrical systems, utilities, and valuable items so that they are located above the predicted flood stage and allowing flood water to pass into or through the structure. Both types of floodproofing shall be routinely considered among possible alternatives for solving drainage and flooding problems. If floodproofing alone, or in combination with other measures, provides the lease expensive solution to a problem, it should be utilized.

Floodproofing has limitations; it protects to a specific elevation and does not guarantee a structure will not be damaged by flood waters. Floods exceeding the design event could still damage the structure. Also, some means of floodproofing requires human intervention (e.g., blocking openings and entryways). Education of the owners or residents of floodproofed structures, in terms of their responsibilities and expectations, is essential to the success of floodproofing operations.

Floodproofing designs shall be based upon the 100-year storm event and provide one foot of freeboard. Designs should conform to the guidelines listed in the Kentucky Flood Protection Manual and/or the appropriate Federal Emergency Management Agency (FEMA) Publication.

FEMA 15 – Design Guidelines for Flood Damage Reduction
FEMA 54 – Elevated Residential Structures
FEMA 85 – Manufactured Home Installation in Flood Hazard Areas
FEMA 102 – Floodproofing Non-residential Structures
FEMA 114 – Retrofitting Flood-prone Residential Structures

e.2 Acquisition and Relocation

The cost of acquiring flood-prone properties for relocation or demolition as a solution alternative for flooding problems shall be determined routinely and compared to the costs of other alternatives. For such a property, the total acquisition cost will include the following component costs: for demolition candidates, buying the property, razing the building, disposing of waste materials, and restoring the site; for relocation candidates, buying the old property, buying and preparing the new site, moving and installing the building on the new site, and restoring the old site.

In a case where acquisition appears to be the lowest cost alternative, the MSD Board will receive a summary of alternatives, costs, and supporting arguments. The Board will then decide whether to select acquisition of another alternative to address the specific case. For any property from which a flood-prone building is moved or demolished, redevelopment shall meet the criteria of the floodplain management ordinance.

f. Conformance with Watershed Master Plans

Projects shall be designed and constructed in a manner consistent with the Watershed Master Plan for the area. If a project is proposed that does not conform to the Watershed Master Plan, the impact of the project on the entire drainage basin shall be evaluated prior to final design and construction. The completed project shall be represented in future updates of the Watershed Master Plan model.

g. Public Involvement

g.1. Public Meetings

Public involvement shall be mandatory for all drainage projects. Complaint files and resident interviews shall be the basis for assessing the need for a project and developing its scope. Public meetings will be held for at least three stages of each project: pre-design, presentation of alternatives, and pre-construction. Additional public meetings may be scheduled as needed to inform residents further and to build support for a project.

g.2. Consensus Building

Through the public involvement process, MSD will describe the goals, approach, and anticipated benefits of a proposed project to the affected parties and will evaluate their level of support. A strong majority of affected individuals must support a project for it to proceed. If support is weak, there will be not project. If support is moderate, MSD will approach the local elected official to explain the need for strong support and to enlist the official's help in increasing the local approval. If a strong majority support the project, it will go forward, utilizing condemnation if necessary to assure the project's progress.

h. Easements

Residents who will benefit from a project are expected to provide easements needed for the project at no cost to the project. Residents whose property is affected but not benefited by a project may be asked to donate easements. Easement acquisition must be timely; attempts to obtain easements at no cost must not slow a project's schedule. If a project has strong consensus support and benefits but necessary easements cannot be obtained rapidly, MSD will pursue condemnation after obtaining specific Board approval.

i. Project Funding

In general, MSD will fund the assessment of problems related to public drainage facilities and the design and construction of projects to solve the problems. Projects which provide greater benefits should receive higher priority in the process of scheduling work. During project planning, issues outside MSD's responsibility may be added into a project if the requesting owner or owners are willing to fund the difference in project costs.

Flooding due to existing, approved development shall be addressed by MSD. Alternative solutions shall be evaluated and presented to the affected parties. MSD will fund the most cost-effective feasible solution. If the parties involved prefer an alternative solution and are willing to fund the difference in cost, MSD may consider implementing the alternative.

Flooding resulting from the unapproved actions or development by a citizen, group or company shall be mitigated by that individual. Solution alternatives developed by the responsible party will be subject to review and comment by MSD and the public.

Inter-agency projects for infrastructure improvement are encouraged. MSD will coordinate with other government agencies to review planned projects in areas for which mini-projects are planned. Lead agency approaches, with a single contractor performing all proposed improvements, are encouraged. Costs of the drainage improvements will be prorated to the costs of the other improvements.