MID-AMERICA REGIONAL COUNCIL

AND

AMERICAN PUBLIC WORKS ASSOCIATION

Manual of Best Management Practices For Stormwater Quality

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EXECUTIVE SUMMARY

The Kansas City Mid-America Regional Council (MARC) has developed this manual as a guide for applying stormwater Best Management Practices (BMP) to land development within the Kansas City Metropolitan Area and the MARC planning region. The manual addresses the need for developers, engineers, and planners to control volumes and quality of stormwater discharges—crucial requirements for protecting human life and property, maintaining overall water quality, and for creating more environmentally sensitive site designs. The authors envision use of this manual alone or in conjunction with the guidelines in Division V of American Public Works Association (APWA) Section 5600 stormwater design criteria. Communities participating in the program can use state-of-the-art stormwater management practices to meet new water quality regulations such as the NPDES Phase II requirements, reduce flooding, conserve water, protect wildlife habitat, and create community amenities.

This manual furnishes clear understandable guidance for planning and implementing BMPs. It describes how to determine potential water quality impacts and how to select BMPs most appropriate for mitigating those impacts. This manual is based on widely-accepted water quality protection, BMP design, and BMP application guidance from sources throughout the U.S. It adapts this information for use in the Kansas City region. The information includes:

- Definitions for BMPs and water quality treatment concepts
- Stormwater management goals and concepts
- A regionally based procedure for selecting and applying BMPs for a development
- A recommended program of minimum BMPs for all municipalities
- Methods of performing hydrologic calculations for design of water quality treatment
- General BMP descriptions and design guidance
- Complete design specifications and standard details for several widely applicable BMPs.

APWA has established a basic goal for all developments to maintain predevelopment peak flows, runoff volumes, and water quality. In other words, development should maintain the velocity or quantity of runoff and the amount of pollutants leaving the site, unless the effects are fully considered and documented in the design or unless site conditions apply that require more stringent measures.

Stormwater management proceeds from thorough site analysis to planning and to site design, and is unique for each site and development project. The first step in water quality management is to maintain or reduce the amount of runoff generated within a watershed by maintaining watershed hydrology and cover. Treatment is then applied to the remaining runoff to remove some of the pollutant load. BMPs are the key to both approaches – they may be non-structural (preserved soils; preserved or established open space and native vegetation; stream buffers) or structural (infiltration, filtration, and detention practices designed specifically for water quality treatment).

This manual provides a "Level of Service Method" for selecting and applying BMPs for site development. This method was developed specifically for the MARC region:

- **STEP 1** – Calculate weighted curve number (CN) for predevelopment conditions using Technical Reference No. 55 (TR-55) from the Natural Resources Conservation Service.
- **STEP 2** – Calculate weighted CN for the proposed development.
- **STEP 3** – Determine the water quality measures, or Level of Service (LS), that compensates for the difference in predevelopment and postdevelopment CN.
- **STEP 4** – Calculate the LS rating provided by the proposed development, including impervious surfaces, vegetative cover, preserved and created vegetation.
- **STEP 5** – Select a Mitigation Package of BMP(s) applied specific areas of the site (analogous to TR-55). BMPs may be non-structural or structural.
- **STEP 6** – Calculate the Mitigation Package LS based on assigned value ratings (VR). A VR is a combination of (1) physical runoff retention and (2) mechanical and biological water quality treatment efficiency documented in nationally published research. If the proposed Mitigation Package does not meet the LS, apply different BMPs or apply multiple BMPs in a "treatment train" approach.
- **STEP 7** – Size and design BMPs for optimum water quality treatment.

BMPs are sited and designed using the hydrology and design guidelines provided in Sections 6 through 9 and Appendix A.

This manual is written as voluntary guidance and a reference for BMP application and design. However, communities may choose to mandate some or all of its provisions and adopt design criteria and specifications. Jurisdictions are encouraged to adopt this manual in its entirety for maximum benefit and consistency. Those that adopt part of this manual may consider adopting the Initial Measures and Minimum Practices (Section 5), along with the hydrologic calculations, design criteria, and specifications for minimum BMPs from Sections 6 through 9 and Appendix A. Jurisdictions that use this document as a design manual should consider adopting the implementation portion (Sections 6 to 9 and Appendix A).

1.0 INTRODUCTION

This manual is a guide to use stormwater Best Management Practices (BMP) in land development within the Kansas City Metropolitan Area and the Mid-America Regional Council (MARC) planning region. It provides developers, engineers, and planners flexible tools to control the volumes and quality of stormwater discharges—important for maintaining water quality. Use of this manual alone or in conjunction with the guidelines in Division V of American Public Works Association (APWA) Section 5600 stormwater design criteria can lead developers to a unified up-to-date strategy for managing stormwater quantity and quality. This stormwater management can protect life, property, and the environment, and can improve quality of life for the citizens of the Kansas City region.

This BMP manual is the first attempt to describe state-of-the-art water quality protection practices for the MARC region, based on current (though occasionally limited) knowledge. Therefore, the BMP manual is a "living document" to be updated periodically with advances in water quality protection practices. Indeed, future versions probably will reflect lessons learned from implementing the methods and practices currently recommended in this manual– particularly those involving water quality monitoring data and performance assessments.

1.1 BACKGROUND

MARC and the Metropolitan Kansas City chapter of APWA developed a proactive, integrated, watershed-based approach to stormwater management to (1) balance future development with environmental health and quality of life, and (2) comply with new water quality regulations such as the National Pollution Discharge Elimination System (NPDES) Phase II requirements. By implementing new policies and practices, MARC and APWA seek to reduce flooding, conserve water, improve water quality, protect wildlife habitat, and create community amenities. To that end, MARC and APWA provide this document to assist efforts of developers and engineers to create more environmentally sensitive site designs. Use of stormwater BMPs is one way MARC and APWA hope to achieve the goals of environmentally sound development and resource conservation.

The term "BMP" originated in the agriculture industry as a reference to practices that reduce farmland erosion and improve crop yield. In the broadest sense, a stormwater BMP is any action or practice aimed at reducing flow rates and pollution concentrations in urban runoff; examples include site planning practices, public education efforts, open space preservation, pollution prevention practices, and engineered natural treatment systems. This manual describes two classes of BMPs: non-structural and structural. Non-structural controls minimize contact of pollutants with rainfall and runoff. Structural controls are facilities constructed for treating stormwater runoff (Texas Chapter, APWA [Texas APWA] 1998).

1.2 GOALS AND OBJECTIVES

This manual is an important component of a regionally based program dedicated to combine community planning, engineering design, and environmental management for conserving, protecting, and enhancing water and natural resources. The guiding philosophy of this program is to "Manage Stormwater Quantity, Protect Water Quality." Flood control and water quality are linked inextricably.

The overall goal of the program is to mitigate and reduce the environmental impact of increased stormwater runoff due to development—to control large water quantities produced by developing watersheds and to minimize quality impairment of runoff from impacted areas. Peak flows and overall quantity of stormwater can be maintained after development, perhaps reduced where conditions allow. BMPs can improve stormwater quality by mitigating extreme pH values and assisting removal of sediment, petroleum-based materials, biochemical oxygen demand (BOD), metals, bacteria, nutrients, toxic organic compounds, and other substances that may be present in harmful concentrations. Communities participating in the program can use state-of-the-art stormwater management practices to meet new water quality regulations such as the NPDES Phase II requirements.

1.3 BRIEF DESCRIPTION OF MANUAL

This manual furnishes clear understandable guidance for planning and implementing BMPs. It describes how to determine potential water quality impacts and how to select BMPs most appropriate for mitigating those impacts. It also describes uses, effective placements, and likely effects of BMPs. Developers of entire communities, individual homeowners, and businesses can use these BMPs. This manual compiles guidance on water quality protection, BMP design, and BMP application from sources throughout the U.S. It adapts this information for use in the Kansas City region. The information includes:

- Definitions for BMPs and water quality treatment concepts
- Performance goals for applying BMPs
- A regionally based procedure for selecting and applying BMPs for a development
- A recommended program of minimum BMPs for all municipalities

- Methods of performing hydrologic calculations for design of water quality treatment
- General BMP descriptions and design guidance
- Complete design specifications and standard details for several widely applicable BMPs.

The first half of the manual provides general information:

- Section 2 lists definitions of BMPs and other stormwater management terms.
- Section 3 discusses stormwater management goals and concepts, and the "treatment train" approach for placing BMPs in series for additional water quality improvements. As well, this section cites additional BMP application and design guidance documents pertinent to the Kansas City region.
- Section 4 identifies developments that should meet stormwater management goals. Section 4 also provides the recommended procedure for quantifying postdevelopment impacts on a site and selecting a stormwater management system to mitigate those impacts.
- Section 5 describes the first measures for treating water quality that should be considered as part of a minimum program.

The second half of the manual includes "nuts and bolts" information on BMP selection and design:

- Section 6 describes the method for modeling hydrology for water quality improvement and BMPs design.
- Sections 7 and 8 provide general selection and design criteria for non-structural and structural BMPs.
- Section 9 includes more detailed design guidance for several widely applicable BMPs.
- Section 10 describes how to tie sediment controls, erosion control, and other regulatory programs into the stormwater management system.
- Section 11 provides a detailed list of references used in the preparation of this document.

1.4 FORMAL ADOPTION OF THIS MANUAL

This manual is written as voluntary guidance and a reference for BMP application and design. However, communities may choose to mandate some or all of its provisions and adopt design criteria and specifications. Recommended practices or procedures described in this document should be considered mandatory if specified by the governing jurisdiction. Jurisdictions are encouraged to adopt this manual in its entirety for maximum benefit and consistency. Those that adopt part of this manual may consider adopting the Initial Measures and Minimum Practices (Section 5), along with the hydrologic calculations, design criteria, and specifications for minimum BMPs from Sections 6 through 9 and Appendix A. Jurisdictions that adopt this document as a design manual should consider adopting the implementation portion (Sections 6 to 9 and Appendix A).

2.0 DEFINITIONS

Best Management Practice (BMP): Stormwater management practice used to prevent or control the discharge of pollutants to waters of the U.S. BMPs may include structural or non-structural solutions, a schedule of activities, prohibition of practices, maintenance procedures, or other management practices.

Bioengineered Channel: A drainage channel stabilized with geosynthetic or other structural materials. A bioengineered channel embodies biological, ecological, and engineering concepts to convey stormwater runoff, prevent soil erosion, control sedimentation, and provide wildlife habitat.

Bioretention: Soil and plant-based stormwater management practices designed to filter runoff from developed communities by mimicking vegetated systems that naturally control hydrology through detention, filtration, infiltration, and evapotranspiration.

Bottomlands: Low-lying lands along a watercourse subject to frequent flooding.

Controlled Area: That part of the surface area where peak discharges are controlled by a detention facility.

Curve Number (CN): A runoff coefficient developed in the U.S. Natural Resource Conservation Service (NRCS) family of hydrologic models by combining land use and one of four hydrologic soil types on a parcel of land.

Detention Storage: The volume occupied by water below the level of the principal spillway crest during operation of a stormwater detention facility.

Dry Detention Facility: Any detention facility designed to permit no permanent impoundment of water.

Dry Swale: An open, vegetated, drainage channel or depression with an engineered soil matrix and underdrains designed to filter stormwater runoff.

Emergency Spillway: A device or devices for discharging water when inflow exceeds designed outflow from a detention facility. The emergency spillway can prevent damage to the detention facility from sudden release of impounded water.

Engineered Swale: An open drainage channel designed to convey and infiltrate the entire runoff volume from a Water Quality Storm.

Extended Detention Wetland: A land area that is permanently wet or periodically flooded by surface or groundwater, and has developed hydric soil properties that support vegetation growth under saturated soil conditions. It may have been engineered with adequate capacity to detain large storm flows.

Filter Strip: A grassed area that accepts sheet flow runoff from adjacent surfaces. It slows runoff velocities and filters out sediment and other pollutants. Filter strips may be used to treat shallow, concentrated, and evenly distributed storm flows.

First Flush: The quantity of initial runoff from a storm or snowmelt event that commonly contains elevated pollutant concentrations. Often the first flush contains most of the pollutants in drainage waters produced by the event.

Floodplain: A relatively level surface that is submerged during times of flooding. Located at either side of a watercourse, it is composed of stratified alluvial soils built up by silt and sand carried out of the main channel.

Grassed Channel: A broad, mildly sloped, open channel designed to convey stormwater runoff to a downstream point and to filter pollutants while doing so.

Hydrologic Soil Group (HSG): NRCS soil grouping according to runoff producing characteristics. The chief criterion is capacity of soil (absent vegetation) to permit infiltration. Soils are grouped from HSG A (greatest infiltration and least runoff) to D (least infiltration and greatest runoff).

Impact Stilling Basin: A pool placed below an outlet spillway and designed for reducing discharge energies in order to minimize downstream erosive effects.

Impervious Surface: A surface that prevents infiltration of water.

Infiltration: Percolation of water into the ground.

Infiltration System: A system allowing percolation of water into the subsurface of the soil. This may recharge shallow or deep groundwater.

Level of Service (LS): The level of water quality protection recommended for a development or provided by a postdevelopment stormwater management system. The LS requirement for the development is determined by the change in runoff from the predevelopment condition. The LS provided by the stormwater management system is determined by a combination of detention and water quality treatment.

Native Species: Plant and animal species that exist in the region where they have evolved.

Natural Channel: Any river, creek, channel, or drainageway that has an alignment, bed and bank materials, profile, bed configuration, and channel shape predominately formed by the action of moving water, sediment migration, and biological activity. The natural channel's form results from regional geology, geography, ecology, and climate.

National Pollutant Discharge Elimination System (NPDES): Defined in Section 402 of the Clean Water Act, this provides for the permit system that is key for enforcing the effluent limitations and water quality standards of the Act. The Phase II Final Rule**—**published in the Federal Register on December 8, 1999**—**requires NPDES permit coverage for stormwater discharges from certain regulated, small, municipal, separate storm sewer systems (MS4s) and from land areas between 1 and 5 acres disturbed by construction.

Pervious Pavement: A special type of pavement that allows water to infiltrate the surface layer and enter into a high-void, aggregate, sub-base layer. The captured water is stored in the reservoir layer until it either infiltrates the underlying soil strata or is routed through an underdrain system to a conventional stormwater conveyance system.

Predevelopment: The time period prior to a proposed or actual development activity at a site. Predevelopment may refer an undeveloped site or a developed site that will be redeveloped or expanded.

Principal Spillway: A device such as an inlet, pipe, or weir used to discharge water during operation of the facility under conditions of the design storm.

Rain Garden: A small residential depression planted with native wetland and prairie vegetation, rather than a turfgrass lawn, where runoff collects and infiltrates.

Riparian Zone: The vegetated strip along the fringe of a stream or other water body.

Riparian Buffers: Strips of herbaceous and woody vegetation along perennial and intermittent streams and open bodies of water. Riparian Buffers capture sediment and other pollutants in surface runoff water before these enter the adjoining surface waterbody.

Sand Filter: A self-contained bed of sand used to treat wastewater or diverted stormwater runoff; the water subsequently is collected in underground pipes for additional treatment or discharge.

Stormwater Detention Facility: Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.

Treatment Train: The series of BMPs (or other treatments) used to achieve biological and physical treatment efficiencies necessary for removing pollutants from stormwater (or other wastewater flows).

Treatment Rating (TR): A relative ranking of a BMP's stormwater treatment based on actual or assumed water quality benefits.

Tree Preservation: Maintenance of existing trees and shrubs.

Total Suspended Solids (TSS): Matter suspended in stormwater excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter.

Uplands: Lands elevated above the floodplain that are seldom or never inundated.

Value Rating (VR): The assumed water quality improvement value of a cover type or BMP, based on its water quality treatment efficiency and ability to retain stormwater.

Water Quality: The chemical, physical, and biological characteristics of water. This term also can refer to regulatory concerns about water's suitability for swimming, fishing, drinking, agriculture, industrial activity, and healthy aquatic ecosystems.

Water Quality Storm: The storm event that produces less than or equal to 90 percent stormwater runoff volume of all 24-hour storms on an annual basis.

Water Quality Volume (WQv): The storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. It is calculated by multiplying the Water Quality Storm times the volumetric runoff coefficient and site area.

Watershed: All the land area that drains to a given body of water (also described as a basin, catchment, and drainage area).

Wet Pond: A constructed system with sufficient capacity to detain flood volumes and to store the WQv in a permanent pool.

Wetland Treatment System: A stormwater or wastewater treatment system consisting of shallow ponds and channels vegetated with aquatic or emergent plants. This system relies on natural microbial, biological, physical, and chemical processes to treat stormwater or wastewater.

3.0 PRINCIPLES OF STORMWATER QUALITY

This BMP manual suggests regional water quality goals and provides tools for meeting these goals. The water quality goals and tools are based on several basic water quality concepts. Stormwater management proceeds from thorough site analysis to planning and to site design, and is unique for each site and development project. Proposed design in a stormwater management system is sensitive to site characteristics including slopes, soils and cover types, infiltration capacity, and detention. These characteristics can be adjusted to improve both site drainage and water quality. Additional water quality BMPs may be applied for further reduction of pollutants in runoff where water quality goals cannot be achieved through site design alone.

Section 3.1 recommends stormwater management goals for the MARC region. Municipalities should start with these goals as a basis for their stormwater management programs, whether or not they formally adopt APWA Section 5600 and this manual. The goals cover both quantity and quality management, and provide options for various watershed conditions and levels of stringency. Sections 3.2 and 3.3 discuss water quality concepts used to develop this BMP manual and how they apply to water quality BMPs that are applied to meet water quality goals. This section is not comprehensive – more detailed water quality information may be obtained from the following resources:

- Chapter 1 of the *2000 Maryland Stormwater Design Manual, Volume I* from the Maryland Department of Environment includes a good discussion of basic stormwater management concepts.

- *The Stormwater Manager's Resource Center* (www.stormwatercenter.net) is directed to practitioners, local government officials, and others who need technical assistance on stormwater management issues.

Section 3.4 provides references and a brief description for several other BMP manuals.

3.1 STORMWATER MANAGEMENT GOALS

The basic goal of stormwater management is to ally water quantity and quality management to maintain current conditions and prevent further deterioration of our watersheds. However, special management goals may apply on a case-by-case basis. It may be necessary to exceed the basic goal and reduce storm water impacts—including peak flows and surface water pollutants—in watersheds with serious flooding and water quality problems. For this reason, APWA has developed water quality criteria that allow more stringent goals. Some or all of these goals may apply to specific circumstances, as explained below.

3.1.1 Maintain Existing Conditions

Regional discussions point toward the attainment of a basic goal for all developments to maintain predevelopment peak flows, runoff volumes, and water quality. In other words, development should not increase the velocity or quantity of runoff, or the amount of pollutants leaving the site. This is not a blanket rule, however. Some increases in either volume or discharge velocity may be acceptable if the effects are fully considered in the design, based on a watershed study or other site-specific analysis. Conversely, additional conditions may apply that increase the requirements beyond the basic goal. The following sections discuss circumstances under which deviations from the basic goal would be apt.

3.1.2 Decreased Peak Flow

The Decreased Peak Flow goal applies to watersheds with specified flood control requirements. It is defined as a net reduction in the postdevelopment peak discharge velocity and quantity from predevelopment conditions. Local regulations or officials would determine additional flood control requirements using the results of a watershed study, master plan, or Preliminary Engineering Study.

3.1.3 Improved Water Quality

Improved Water Quality is defined as a net reduction in pollutant discharges from a site. This goal is to produce a qualitative improvement in water quality as a result of development (beyond the “do no harm” approach of maintaining existing conditions). It applies where local stormwater design standards are superseded by a state or federal water quality requirement such as a Total Maximum Daily Load (TMDL) or similar state discharge limit for pollutant or water quality indicator. This goal also may be applied where local authorities require water quality improvement. The governing municipality may set more than one tier of improved water quality using the Level of Service Method described in Section 4.2.4.

3.1.4 Special Management Goals

Special Management Goals are developed on a case-by-case basis, considering the unique characteristics of a watershed or stormwater project. Municipal regulations or the city engineer establishes the water quality or flood control requirements using results of a watershed study, master plan, or Preliminary Engineering Study. Special management goals may apply where an engineering study indicates a unique flooding risk, where local stormwater design standards are superseded by a state or federal water quality requirement (such as a TMDL or similar state discharge limit for pollutant[s] or water quality indicator[s]), or where local regulations require additional water quality improvement.

3.2 WATER QUALITY CONCEPTS

Studies have shown that atmospheric deposition distributes most stormwater pollutants. A full range of pollutants is present in virtually all runoff—whether from yards, roads, or rooftops—because of this atmospheric redistribution. The pollutants are mobilized and impact surface water quality when rainfall produces runoff that carries the contaminants into surface waters. For this reason, impervious surfaces are the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996). Runoff volumes and peak velocities are determined primarily by the site's cover type and soils, and other factors such as slope, distance, and existing drainage features (USDA 1986). Runoff quantity and water quality are linked, and this linkage forms the basis for this BMP manual.

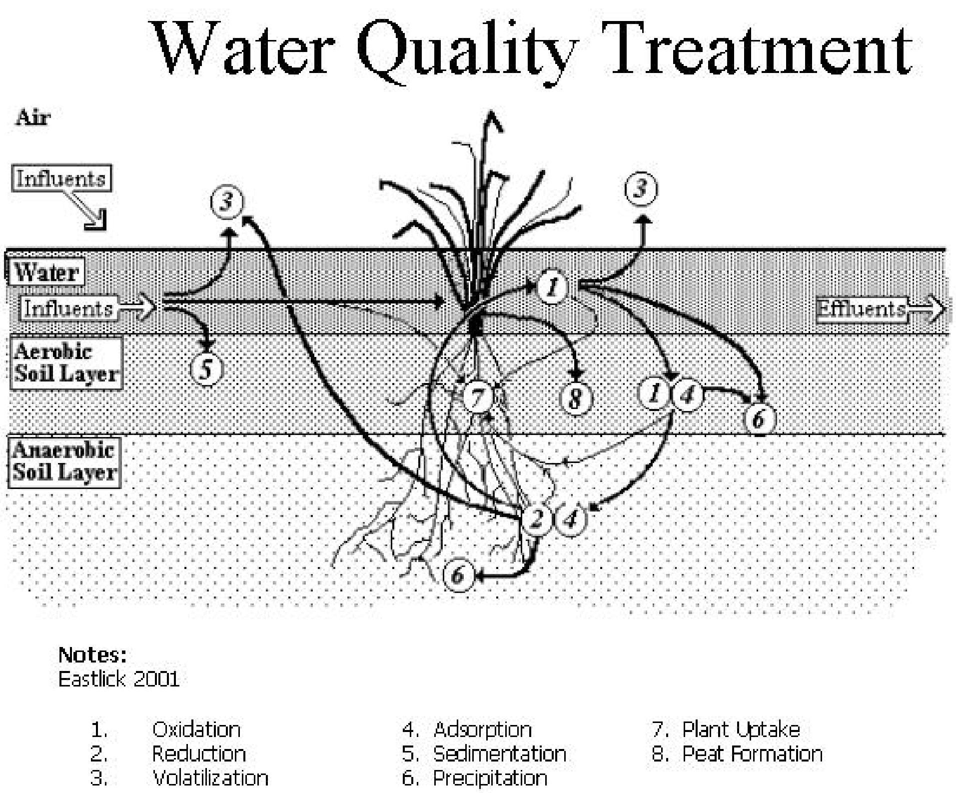
The first step in water quality management is to maintain or reduce the amount of runoff generated within a watershed. Treatment is then applied to the remaining runoff to remove some of the pollutant load. BMPs are the key to both approaches, described below.

Preserving a site's infiltration capacity is a relatively inexpensive non-structural measure to reduce runoff rates, volumes, and pollutant loads. Stormwater runoff rates and volumes and water quality are influenced heavily by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Urbanization shortens a watershed's response to precipitation mainly by reducing infiltration and decreasing travel time. An impervious surface decreases travel time by preventing infiltration and speeding runoff. Furthermore, faster runoff velocities reduce the opportunity for pollutants to settle out or be removed by natural processes.

Most urban areas are only partially covered by impervious surfaces, however, and natural infiltration rates to underlying soils are influenced primarily by soil type and by plant cover. Any disturbance of a soil profile and cover type can change infiltration characteristics significantly (USDA 1986). Site designs can preserve existing pervious surfaces (open space and vegetation, especially native species), incorporate pervious landscaping and vegetated cover, and reduce and disconnect impervious cover. Pervious cover, and especially vegetation, allows water infiltration that minimizes runoff, erosion, and potential for downstream pollution. Vegetation helps reduce erosion and filters sediment and other pollutants from stormwater runoff by creating a natural buffer to reduce velocity of surface water. Native vegetation and open space provide aesthetic and habitat benefits. Site development practices also can protect soils from compaction and restore high-quality native soil characteristics. Section 7 discusses non-structural BMPs in considerable detail.

Communities can improve their water quality significantly by treating the remaining runoff volumes with structural BMPs. Structural BMPs are designed to infiltrate and reduce the amount of runoff, or to filter and detain runoff to reduce discharge velocities and remove pollutants. Infiltration galleries represent an example of the former, while bioretention areas (vegetated depressions designed to collect and treat runoff through an engineered matrix of soils and plant roots) represent an example of a filtration practice. As shown below, filtration and detention BMPs remove pollutants by several processes, including physical settling and filtering by plants and soil media, aeration, adsorption onto soils, and biological processes in the root zone.

Figure 1: Natural Treatment Processes



Some practices can also be designed to serve both functions, such as by removing the underdrain from a bioretention cell. Section 8 includes descriptions and design criteria for several structural BMPs.

Not all runoff contains high concentrations of pollutants, however. The initial rainfall mobilizes pollutants that have built up on pervious and impervious surfaces. The pollutants are more concentrated in this “first flush,” and concentrations gradually diminish as rainfall continues. To be efficient and cost-effective, water quality BMPs must be sized and designed to treat this more concentrated runoff rather than the extreme flood events that are managed by conventional stormwater systems. The design storm for water quality BMPs is the water quality volume (WQv). The WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is a function of the Water Quality Storm, which is the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis.

The following section discusses application of non-structural and structural BMPs.

3.3 TREATMENT TRAIN

A single BMP may not suffice to meet the stormwater management and design objectives for a development. The preferred approach for water quality improvement is a combination or series of stormwater BMPs called a “treatment train.” This set of biological and physical treatments successively removes pollutants from stormwater flows. A treatment train also can reduce the physical volume of runoff, thus reducing stormwater management costs while improving water quality (Texas APWA 1998).

While many practitioners focus on engineered structural BMPs, a treatment train combines site development strategies, management and housekeeping practices, and engineered solutions. What is not imposed on a site or development can be more important than the applied engineered BMPs. Avoidance is the best strategy to deal with most problems – the most cost-effective practice is to limit the generation of runoff by preserving or creating natural areas and vegetation that soak up precipitation, slow runoff, and filter sediment. Engineered solutions then deal with the remaining runoff volume most effectively at the source. Infiltration and filtration BMPs placed at the source also reduce runoff volumes and peak flows from smaller, more frequent storms (see Section 6 for a discussion of water quality and hydrology). Finally, what cannot be absorbed or treated at the source must be routed through larger BMPs for detention and treatment prior to discharge from the site. Pollution prevention is also applied so that contaminants are not released from a site where they can be picked up by runoff and carried into surface water bodies. Selection of treatment train components is based on a combination of local and state stormwater requirements, site characteristics, development needs, runoff sources, financial resources, and BMP characteristics (such as space requirements, design capacities, and construction and maintenance costs).

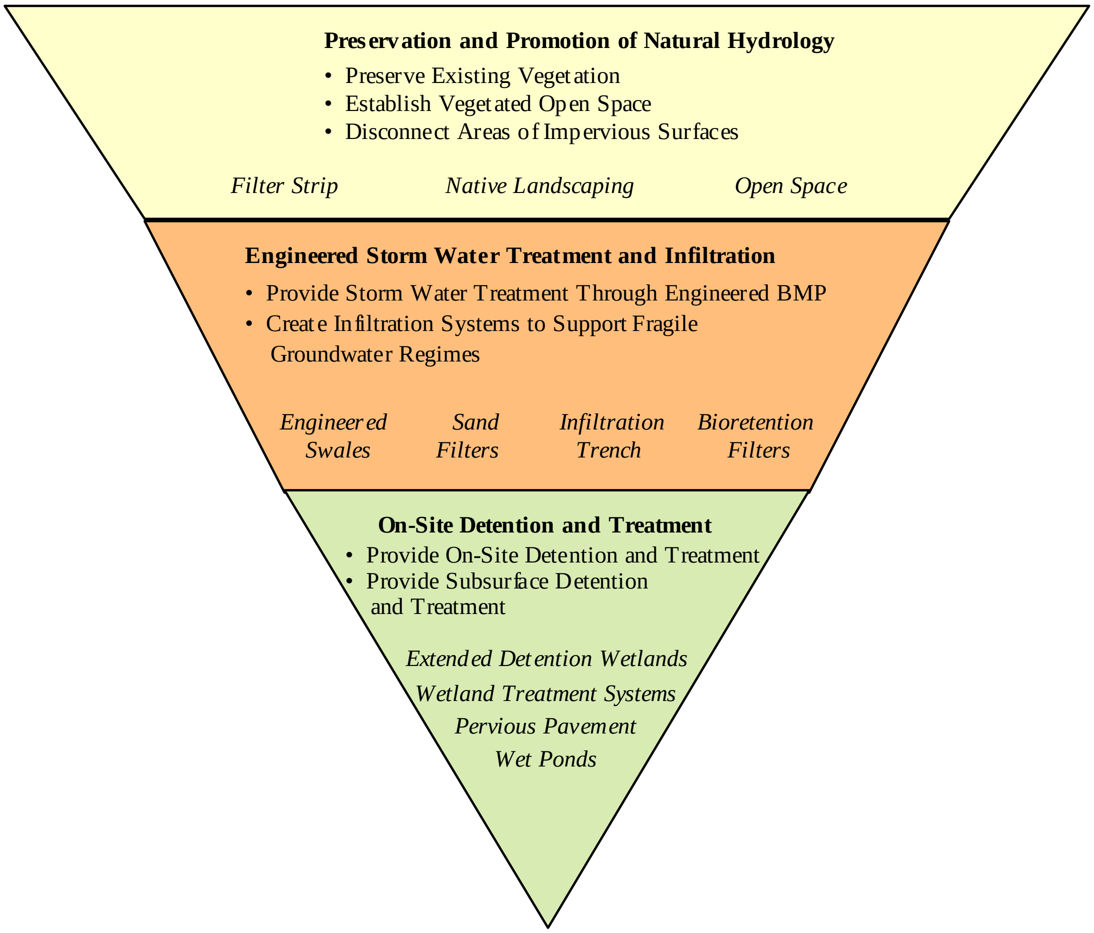
Before choosing a sequence of treatment practices, a planner must understand the site conditions and hydrological characteristics of the site's drainage area, and the requirements for water quality treatment. Most developments are required to manage stormwater quantity from the site according to Section 5600 or other local regulations; developments also should provide water quality management described in this BMP manual or other local regulations. This BMP manual includes guidelines for determining a development's approximate water quality impact and selecting an appropriate BMP package for the site and development. At a minimum, the predevelopment quality of the site must be maintained if possible. The procedure for ranking the predevelopment condition of the site and for selecting a BMP package that will maintain that condition is in Section 4. This procedure includes a method for determining how much treatment a development should include. Methods for determining site hydrology and for calculating the WQv are described in Section 6.

Selecting a combination of practices that meet basic requirements is up to the developer and the site design team. The "right" treatment train best satisfies stormwater management requirements and the project goals, and it offers the most overall value for the development. Treatment train practices that generally follow the Hierarchy of Stormwater Best Management Practices (see Figure 2) usually provide the most benefit at the least cost and the greatest flexibility in addressing needs of the site design. The treatment train may include the following components, in order of preference:

- Preserved open space and natural vegetation
- Created open space with native vegetation
- Infiltration practices at the source of runoff—including infiltration trenches, pervious paving or rain gardens
- Filtration systems at the source of runoff—such as vegetated filter strips, sand filters, or bioretention basins
- Engineered swales for capture at the source or conveyance between BMPs
- Detention structures such as wetlands, extended detention wetlands, and wet ponds.

FIGURE 2

HIERARCHY OF STORM WATER BEST MANAGEMENT PRACTICES



The following examples illustrate hypothetical treatment trains for three types of sites:

Residential subdivision: (1) preserve native prairie remnant as common open space; (2) landscape with native vegetation; and (3) use dry swales to convey and treat runoff from landscaped streets and yards.

Commercial development: (1) establish native landscaping in and around buildings and parking areas to break up impervious areas; (2) use bioretention cells in parking lots.

Office park: (1) place filter strips around building downspouts and parking lots, leading to (2) infiltration basins; (3) use dry swales to treat runoff from streets and convey it to (4) a wet pond.

Three useful references for conservation development strategies are:

- Growing Greener Booklet from the National Lands Trust (http://www.natlands.org/planning/growgreen.html)
- Better Site Design: A Handbook for Changing Development Rules in Your Community (http://www.cwp.org/)
- Low-Impact Development Design Strategies – An Integrated Approach (http://lowimpactdesign.org/)

The following paragraphs discuss each stage of the treatment train in more detail. Sections 8 and 9 discuss how to select and design BMPs.

Preserving and incorporating native areas into the design of the site or establishing open space with native vegetation is commonly the first stage of a treatment train. The more land left in an undisturbed state or returned to a natural state through native landscaping, the greater the water infiltration that minimizes runoff, erosion, and potential for downstream pollution.

The proposed land use or site design may not allow for sufficient open space to manage all runoff from precipitation that falls on or runs onto a site. Runoff that contacts pollutants (from rooftops, sidewalks, driveways, parking lots, roadways and so on), is most efficiently managed close to its origin. Often, the second stage of the treatment train controls runoff at its sources. Examples include pervious vegetated areas (such as lawns or specially designed filter strips around parking lots and buildings), infiltration trenches and basins, pervious pavement parking lots, and residential rain gardens (Texas APWA 1998). Source controls can maximally infiltrate and substantially reduce runoff that contains pollutants (for example, runoff from the smaller storms such as the Water Quality Storm). In addition, reducing peak runoff rate—even from smaller rain events—decreases stress on downstream control facilities that consequently can be smaller. Peak reduction from reducing impervious surfaces or detaining these smaller events is a function of site and BMP design; it should be calculated and applied by the site engineer or stormwater planner as part of the design process.

Open space and infiltration practices alone may not suffice to manage all runoff from a site because of inadequate space, soils and geology, slopes, or other factors. Engineering filtration systems at or near the source of runoff is the next stage of the treatment train. Filtration systems route the most contaminated "first flush" of rainfall (the WQv) through an engineered natural filter. Examples of filtration systems include sand filters, bioretention, dry swales, and grassed channels (Center for Watershed Protection

2000b, Claytor and Schueler 1996). Note that by omitting underdrains, planners may use bioretention and sand filters for infiltration (see Section 8). These practices also detain smaller rain events, as they are designed to treat the Water Quality Storm. The stormwater engineer or planner should estimate the maximum volume of detention available and required.

Devising stormwater detention practices is the last stage of the treatment train. Detention generally applies to large developments; it provides solutions for sites where space inadequacy precludes stormwater treatment closer to the source. Detention may be the preferred option where predevelopment site conditions are of low quality. “Wet” detention detains and manages releases from larger rainfall events—usually up to and including the 100-year return interval event — and includes a treatment component sized for the WQv. Many examples and designs are discussed in Sections 8 and 9.

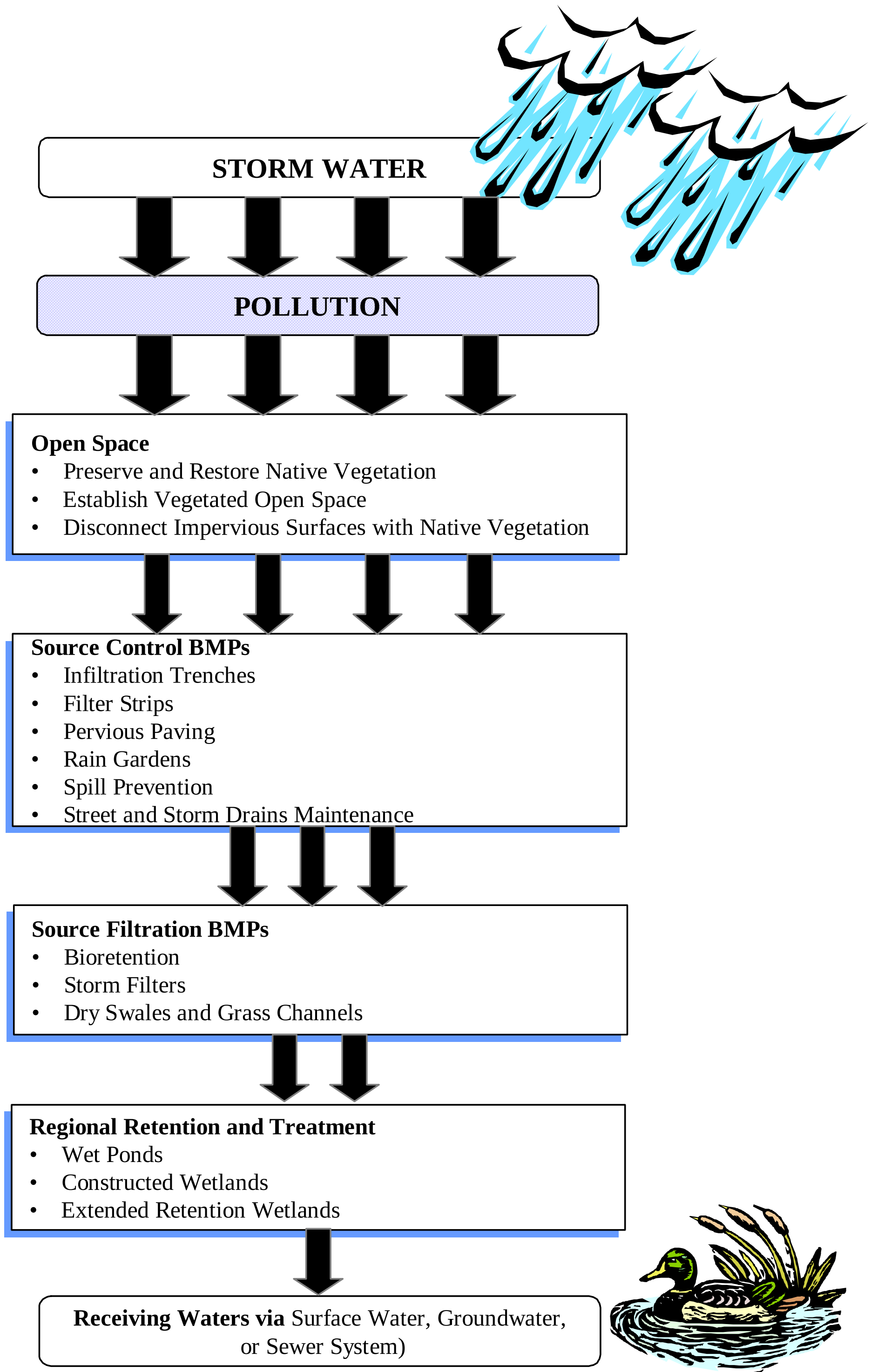
Finally, proper maintenance and pollution prevention practices can limit stormwater runoff pollution further. Routinely cleaning and periodically refurbishing BMPs helps them function as designed. Maintenance practices (such as sweeping streets and parking lots) remove pollutants before rainfall can mobilize them. Surely many pollutants result from airborne emissions and deposits, but some chemicals enter surface water from spills and leakage from equipment (Claytor and Schueler 1996). Pollution prevention strategies can contain common sense practices not included in most treatment trains—containment barriers around chemical storage areas to confine potential spills, berms around fueling stations to prevent stormwater run-on, or vehicle and equipment maintenance to prevent leakage (Texas APWA 1998). Appendix D includes information on such practices. Figure 3 illustrates an elementary treatment train concept.

3.4 SUMMARY OF BMP SELECTION METHODS

Section 4 presents the “Level of Service Method,” a BMP selection method designed for the greater Kansas City region based on nationally recognized research and practices. This is not the only BMP application procedure, however. A number of jurisdictions through the U.S. have adopted their own methods for implementing water quality principles into workable development ordinances and design criteria.

FIGURE 3

STAGES OF A TREATMENT TRAIN



Water quality planners, engineers, and developers may want to consult other manuals and guidance on a case-by-case basis. A number of the better-known methods are described below:

- *2000 Maryland Stormwater Design Manual, Volumes I & II*. Maryland Department of Environment, Water Management Administration. October 2000.

  This State of Maryland publication specifies 14 mandatory performance standards that apply to any construction activity disturbing 5,000 or more square feet of earth. The manual provides selection guidance for pretreatment, non-structural BMPs, and structural BMPs designed to remove 80 percent of the average annual post-development total suspended solids load and 40 percent of the average annual post-development total phosphorous load. The redevelopment policy specifies a 20 percent reduction in impervious surface area below existing conditions. Where impractical due to site constraints, this manual requires the use of BMPs to meet the equivalent in water quality control of a 20% decrease in impervious surface area. Additional BMPs are provided for stormwater "hot spots" or highly polluting land uses. This text also includes a good discussion of basic stormwater management concepts.

- Minnesota Urban Small Sites BMP Manual. Metropolitan Council. July 2001.

  This manual provides voluntary BMP application and design guidance for small sites (less than 5 acres). The manual furnishes general siting and selection criteria, design guidance, and operation and maintenance recommendations for 40 BMPs—along with relative rankings of each based on treatment suitability, physical feasibility, and community acceptance.

- *Stormwater Management Manual, Revision #2*. The City of Portland, Oregon, Environmental Services Department. September 2002.

  The City of Portland requires that all development projects with over 500 square feet of impervious development footprint area, and all redevelopment projects redeveloping over 500 square feet of impervious surface, treat runoff from the additional impervious areas. Portland requires treatment and removal of 70 percent of total suspended solids (TSS) from runoff generated by a design storm up to and including 0.83 inches of rainfall over a 24-hour period. The manual provides a list of acceptable BMPs and simplified sizing and design guidance for each based on the impervious area treated. It also includes a performance-based BMP selection method for designing and customizing BMPs.

- *Texas Nonpoint Source Book*. Texas APWA. 1998. On-Line Address: www.txnpsbook.org.

  This web site provides general guidance for various aspects of stormwater management, including water quality concepts, stormwater programs and utilities, and links to other resources. The site also furnishes general planning criteria, design guidance, and operation and maintenance recommendations for a number of BMPs—and relative rankings of each based on treatment suitability, physical feasibility, and community acceptance.

- *Urban Best Management Practices for Nonpoint Source Pollution*. Wyoming Department of Environmental Quality, Water Quality Division. February 1999.

  This text is a general reference for water quality principles, and for selecting and applying BMPs geared toward semi-arid climates.

- *Urban Storm Drainage Criteria Manual Vol. 3 – Best Management Practices*. Urban Drainage and Flood Control District, Denver, Colorado. September 1999.

  Denver's Urban Storm Drainage Criteria Manual provides water quality management guidance for local jurisdictions, developers, contractors, and commercial and industrial operations. This manual includes discussions of water quality principles and hydrology; in-depth selection and design criteria for a number of BMPs; standard engineering details; operations and maintenance guidelines; and BMP design worksheets. The manual is geared toward semi-arid climates.

4.0 WATER QUALITY GOALS AND BMP SELECTION CRITERIA

Communities may need to go beyond their current practices to satisfy NPDES Phase II requirements. The central question is how to design site developments for water quality. MARC and APWA have recommended stormwater management goals for the Kansas City region. APWA Section 5600 and this BMP manual provide a package of technical tools to achieve these goals.

This section presents the Level of Service (LS) Method for BMP selection. This procedure has been developed specifically for the Eastern Kansas-Western Missouri region; it is based on widely accepted research and applied hydrology from the NRCS, as well as water quality studies compiled from a number of sources (USDA 1986; Claytor and Schueler 1996; CWP 2000a). Municipalities that adopt the LS Method as local design criteria for water quality protection will use the procedure to assess predevelopment and proposed postdevelopment site conditions, and to create a package of BMPs that achieves stormwater design goals for that site. Other municipalities and developers are encouraged to follow this method when making stormwater management decisions.

Section 4.1 outlines the conditions that determine stormwater design goals for a specific development or stormwater improvement project. Section 4.2 discusses how to use the LS Method to design a water quality protection package to meet those goals.

4.1 DEVELOPMENT CONDITIONS

Stormwater management goals described in Section 3.1 are based on a combination of the following development conditions: (1) size of development; (2) type of development (or public improvement project); (3) any local exemptions that may apply to specified projects; (4) specific watershed conditions such as flood control needs, water quality impairments (for example, specified TMDLs), or sensitive habitats (for instance, high-quality stream segments); (5) any additional stormwater goals that a municipality may impose beyond the minimum requirements of maintaining existing conditions.

The Maintaining Existing Conditions goal suits all developments that increase the percent impervious cover, except for a specific exemption. Decreased Peak Flow and Improved Water Quality may apply where the municipality actively seeks to improve water quality and reduce flooding as development occurs. Decreased Peak Flow and Improved Water Quality may apply together or independently.

The following flow chart will help determine water quality goals and requirements appropriate for development conditions. It describes levels of water quality protection the governing municipality may require and when special watershed conditions apply.

If the development or flood improvement project does not rate an exclusion based on the conditions described in the flowchart, the owner or developer would then determine the postdevelopment level of service (LS) to maintain water quality according to the selection procedure provided in the following section.

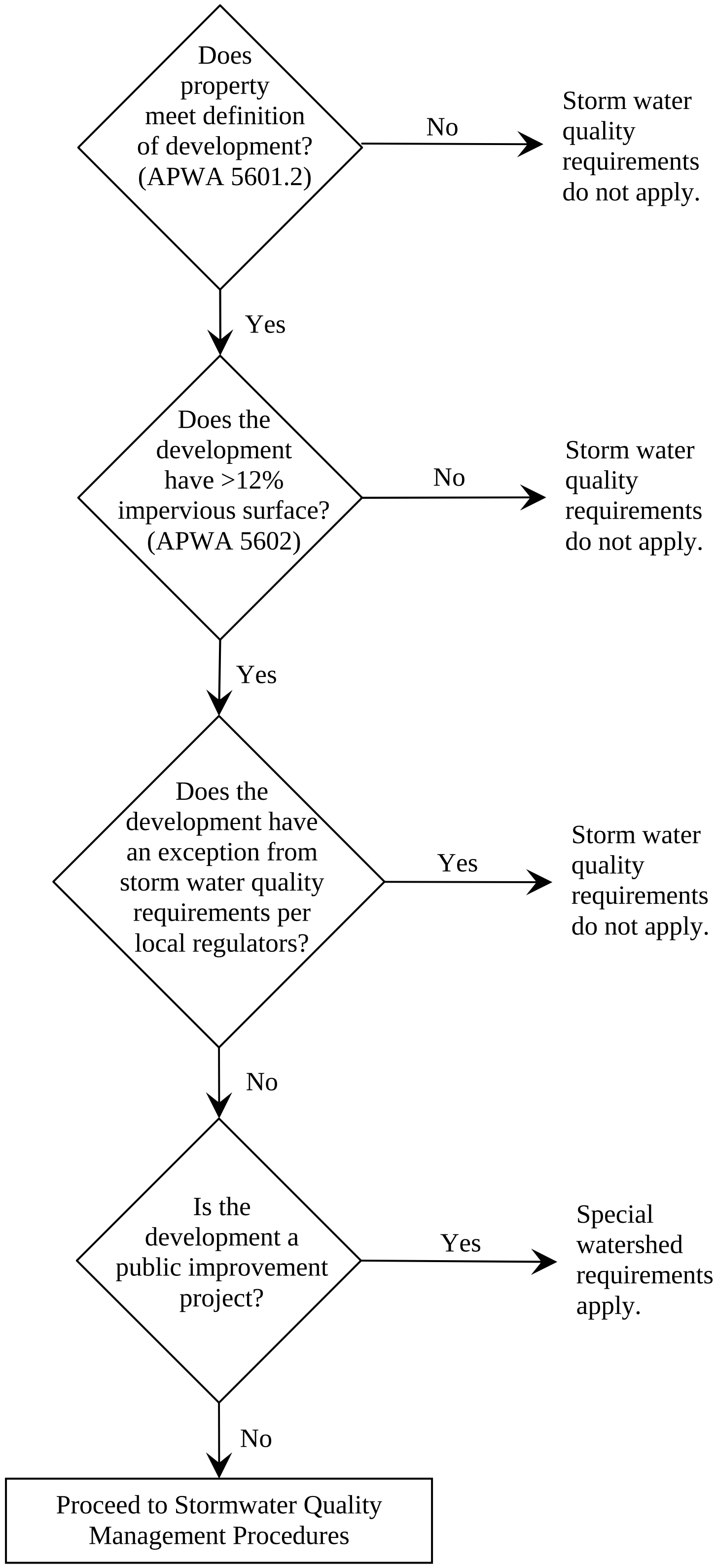
4.2 THE LEVEL OF SERVICE METHOD

The LS refers to the level of water quality protection recommended for a development or provided by a postdevelopment stormwater management system. The LS requirement for the development is determined by the change in runoff from the predevelopment condition. The LS provided by the stormwater management system is determined by a combination of detention and water quality treatment. If the development or project is excluded, BMPs are still recommended.

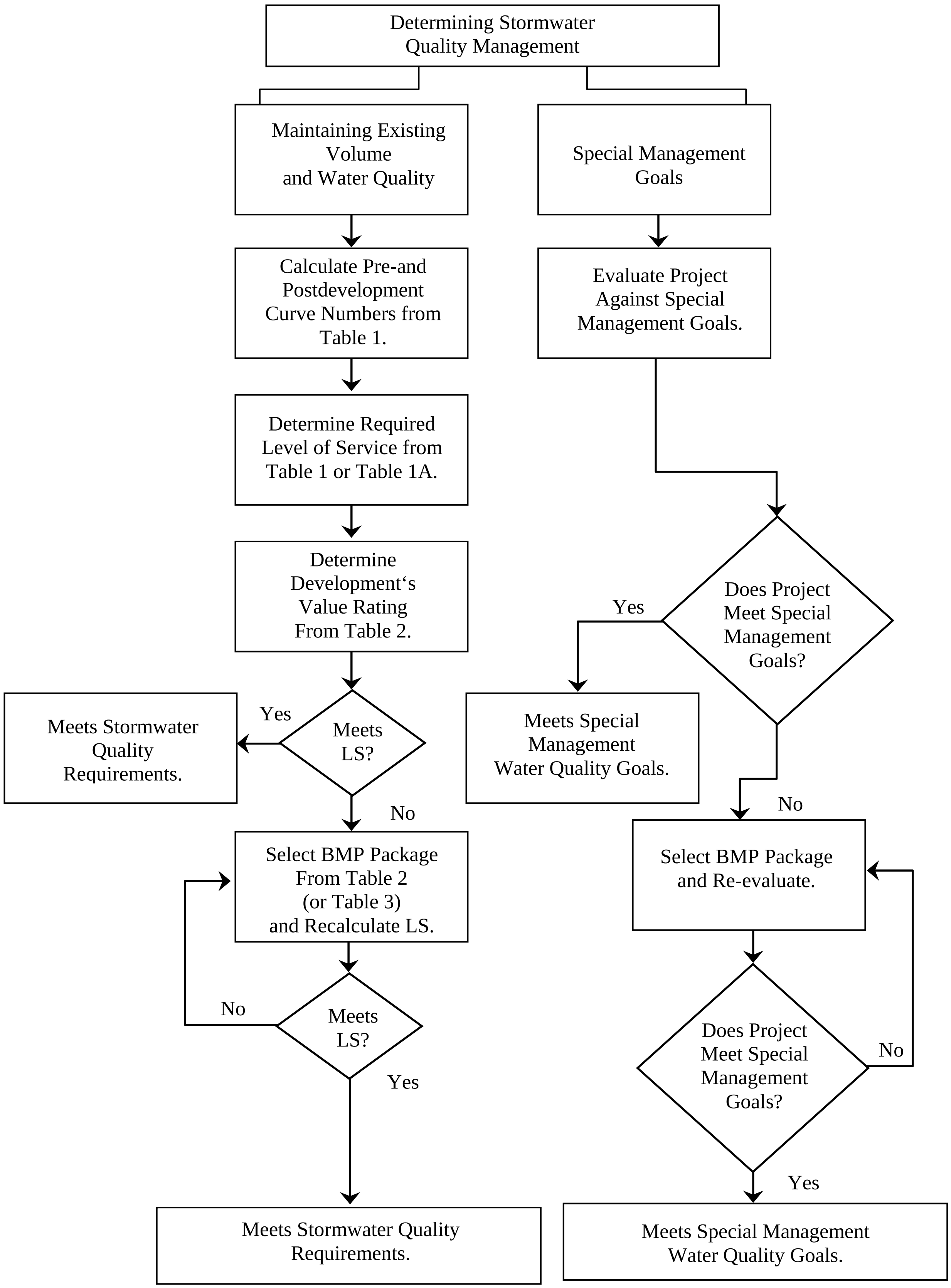
The intent of setting LS is to create a stormwater management system equivalent or superior to that which existed in the site's predevelopment condition through site design and BMPs. Predevelopment condition depends on whether the site is in a developed or developing area and whether the development is new or an incremental improvement to a previously developed site. The selection procedure adjusts for these factors.

The procedure is outlined in the second flow chart and is described in the following paragraphs. Supporting information for selecting site design strategies and BMPs are included as Tables 1 through 4 at the end of the section. Table 3 may be used where Special Management Goals apply to a specific pollutant or class of pollutants. Table 4 furnishes vegetation suggestions for BMPs. Appendix B includes detailed, step-by-step instructions along with worksheets and examples.

Determining If Development Requires Stormwater Quality Management



Stormwater Quality Management Procedures



4.2.1 Predevelopment and Postdevelopment Conditions

Calculate the predevelopment condition by determining the development site's curve number (CN) or weighted CN using Table 1. The CN is a factor used to estimate stormwater infiltration and runoff for various combinations of soils and cover types; it is determined using the NRCS CN method described in Technical Release 55 (TR-55) (USDA 1986). The predevelopment site condition is determined from: (1) the original cover type(s) and site quality; (2) the hydrologic soil group (HSG) or groups of underlying soils on site as documented in the NRCS soil survey for the county where development is occurring. Soils on sites developed since publication of the soil survey is assigned an HSG one higher than listed in the soil survey (for example, assign HSG C for listed HSG B). For sites with more than one cover type or HSG, determine a CN for each combination of cover type and HSG, and an area-weighted CN for the entire site.

Use the same method to calculate the postdevelopment condition CN, and then determine the net change in CN from predevelopment to proposed postdevelopment condition. A range of LS scores has been assigned to changes in CN as shown below and on Table 1. The LS rating is based on: (1) documented water quality impacts on watersheds with various levels of imperviousness; (2) assumed percent-impervious surface for various developments contained in TR-55 (CWP 2000b, USDA 1986). Determine the LS that the postdevelopment stormwater management system must provide—find the LS that corresponds to the net change in CN on the following scale and in Table 1.

Change in CN	Impact	LS
17+	High water quality impact	8
7 to 16	Moderate water quality impact	7
4 to 6	Low water quality impact	6
1 to 3	Minimal water quality impact	5
0	No change	4
-7 to –1	Minimal water quality improvement	3
-8 to –17	Low water quality improvement	2
-18 to –21	Moderate water quality improvement	1
-22 +	High water quality improvement	0

LS of 4 signifies no change in CN and corresponds to the maintaining existing conditions design goal described previously. The larger the LS, the greater the impact of development. The smaller the LS below 4, the greater the benefit of development—the proposed development will decrease runoff and improve water quality, thus lowering the development's need to provide "water quality service."

Examples of this include a predevelopment poor cover type that is stabilized by the postdevelopment cover, and a retrofit of a previously developed urban site to a new land use with a lower percentage of impervious cover.

The goal after thoroughly analyzing the site and development requirements is to design the site for the lowest possible LS. Developers, stormwater engineers, and planners are encouraged to incorporate site improvements to reduce postdevelopment CNs over all or a portion of a proposed development site. Section 4.2.2 explains how to do this.

Important: A reduction of the CN over part of a site reduces the weighted CN for the overall project. Recalculate the postdevelopment CN and change in CN any time the proposed site design changes so the project's LS is reduced correspondingly.

Incremental improvements to a previously developed site will cumulatively increase runoff and pollutant discharge. In this case, determine the water quality impact by measuring the change in the range of imperviousness. Developed sites are grouped into four ranges of imperviousness: (1) less than 12 percent, (2) 12 to 25 percent, (3) 25 to 65 percent, and (4) greater than 65 percent. The range assigned to a site may be determined in either of two ways: calculating actual predevelopment and postdevelopment percent imperviousness of the site or estimating the range of impervious surface based on CN and cover type using Table 1A. Values in Table 1A are based on the assumed percent impervious surface from TR-55 (USDA 1986). A cumulative water quality impact from an increase of one or more ranges of percent impervious cover must be mitigated. The LS ratings corresponding to these increases in range are as follows:

Increase in range of % imperviousness	Impact	LS
None	Negligible water quality impact	4
1	Low water quality impact	5
2	Moderate water quality impact	6
3	High water quality impact	7

4.2.2 Postdevelopment BMP Determination

This section describes the procedure to create a stormwater management plan that meets the required LS. Water quality protection strategies include site design choices such as BMPs. Site design options include minimizing and disconnecting impervious cover using low-impact design. BMPs include both non-structural approaches (such as preserving existing vegetative buffers or establishing native landscaping) and structural approaches (such as installing a wet detention pond or engineered swale). In some cases, a site design feature can be a BMP, such as preserving sufficient existing vegetation to reduce the site's postdevelopment CN and corresponding LS.

Determine the value rating (VR) for each proposed cover type and BMP from the menu of choices in Table 2. A VR is the assumed water quality improvement value of a cover type or BMP, based on its water quality treatment efficiency and ability to retain stormwater. A higher VR represents increasing water quality improvement value. Traditional cover types and stormwater management practices, such as pavement, turf grass landscaping, and dry detention basins, are included in Table 2 along with their respective VRs.

The VR of several BMPs is the sum of their stormwater retention qualities (as measured by the S function from TR-55) and a mechanical and biological treatment rating (TR), which is a relative ranking of BMP treatment efficiency based on the best available pollutant removal data (USDA 1986, CWP 2000a). Where pollutant removal data were available, TRs were developed by ranking treatment practices on a scale of 0 (no treatment value) to 4 (best treatment value) based on their median percent pollutant removal.

The TR for a given pollutant generally follows the following ordinal scale:

Median Removal (percent)	TR
0	0
Less than 25	1
26 to 50	2
51 to 75	3
Greater than 76	4

Some minor adjustments were made in the rankings where natural groupings occurred. Table 2 shows overall TRs for various BMPs that are composites based on each BMP's average ranking across all measured pollutants. Table 3 lists the median pollutant removal percentages and TRs for individual pollutants—it may be used in lieu of Table 2 to meet pollutant-specific Special Management Goals, such as where TMDLs are in effect. Appendix C provides the original, published, water-quality performance data used to develop the TRs for some BMPs.

The VRs of other practices, such as filter strips and preserving or creating native vegetation, vary with proposed cover type and soils.

BMPs required to achieve the appropriate LS, must be selected carefully by considering their suitability to the site's unique conditions. Table 2 lists land use, treatment suitability, physical feasibility, cost, and community and environmental benefits; however, consult the more detailed guidance and specifications provided in Sections 8 and 9 before making a final selection.

If a selected site design feature or BMP will decrease the proposed development's CN, recalculate the weighted CN using Table 1, and recalculate the LS using Table 1 or Table 1A. Just changing the proposed site design may reduce the change in CN sufficiently to meet the required LS—for example, from a 7 to a 6. Changing the proportions of a site design may also change the weighted CN and LS.

Next, calculate weighted values by multiplying all VR scores of proposed BMPs or cover types by the percent of the site each treats. Then sum the weighted values to produce an area-weighted value. This step is analogous to the weighted CN that is calculated following TR-55. The resulting total is the overall LS for the proposed stormwater management system. The LS of the proposed development must meet or exceed the required LS. For example, if the required LS for the proposed development is 6, the LS of the proposed stormwater management plan must meet or exceed 6.00.

A treatment train may help remove additional pollutants or maximize available space on the site by successively removing pollutants from the stormwater flow. Just as the first BMP removes a percentage of pollutants from the flow, each additional BMP placed in series will remove a percentage of the remaining pollutants. For this reason, the effective value of the secondary practice is a function of the effectiveness of the primary practice as follows:

Example:

Contributing area -- parking lot = 5 acres

BMP 1 -- Engineered swale, VR 8.08
8.08 x 5 acres = weighted value of 40.4

BMP 2 -- Bioretention cell fed by the engineered swale, VR = 8.38
Effective VR = [(8.38+8.08)/8.08] = 2.04
2.04 x 5 acres = weighted value of 10.2; 10.2 + 40.4 (BMP 1) = cumulative VR of 50.6 for the parking lot

Multiple combinations of site design and BMPs may be tested using this procedure until the optimum water quality protection package is attained. Changes in the proposed site design or stormwater management practices may reduce the postdevelopment CN. For this reason, the weighted CN and LS should be recalculated for any water quality protection packages that change site cover.

Table 4 provides guidance on appropriate native vegetation for BMPs.

Detailed step-by-step instructions and worksheets for selecting water quality protection packages are provided in Appendix B, along with examples.

4.2.3 Additional Practices for Stormwater "Hot Spots"

Some land uses contribute greater concentrations of hydrocarbons, metals, and other pollutants. They are called "hot spots" and may require additional measures to manage the quality of their runoff (Claytor and Schueler 1996). The final step in creating a water quality protection package is to determine whether the development is a hot spot, and, if so, to specify additional management practices. Appendix D includes management practices for the following land uses (adapted from the City of Portland, Oregon [2002]):

- Fuel Dispensing Facilities
- Aboveground Storage of Liquid Materials
- Solid Waste Storage Areas, Containers, and Trash Compactors
- Exterior Storage of Bulk Materials
- Material Transfer Areas and Loading Docks
- Equipment and/or Vehicle Washing Facilities
- Covered Vehicle Parking Areas
- High-Use Vehicle and Equipment Traffic Areas, Parking, and Vehicle Storage.

4.2.4 Level of Service Adjustment for Increased Water Quality

Communities may require developments to meet more stringent water quality standards than the previous procedure achieves. Among a number of ways to accomplish this is to stipulate that the LS provided by the BMP package exceed the base LS by a given amount. Testing this system on both hypothetical and actual site development plans indicates that an LS increase of 0.50 or 1.00 is achievable and would increase water quality treatment significantly over the basic model. A community can adopt these thresholds (LS + 0.50 and LS + 1.00) to create a two- or three-tiered hierarchy of water quality standards based on development size or type, or other criteria appropriate to the community’s water quality goals. This system could also be used to calculate and assign “water quality credits” that apply to other areas or phases of the project or to other developments.

Meeting a more stringent standard requiring the LS to rise may need extensive use of “treatment trains” to increase the VR of selected BMPs. Section 3 describes treatment train concepts. Section 4.2.2 provides the equation for effective VRs for treatment trains.

TABLE 1
REQUIRED LEVEL OF SERVICE

STEP 1 - Calculate weighted Curve Number (CN) for predevelopment condition:
A. Determine the acreage of the site in various uses as a percentage of the total.
B. Assign a curve number for each area of the site based on the type of land use, below; use either undeveloped or developed land use values as appropriate.
C. Calculate an area-weighted curve number for the entire site based on the curve numbers of the sub areas.

STEP 2 - Calculate weighted CN for postdevelopment condition:
A. Determine the acreages of proposed uses as a percentage of the total.
B. Assign a Curve Number for each area from the previously developed side of the table, as appropriate.
C. Calculate an area-weighted Curve Number for the site based on the Curve Numbers of the sub areas.

UNDEVELOPED					**DEVELOPED**			
Cover Type	**Condition**	**CN by Hydrologic Soil Group (HSG)**			**Cover Type**	**CN by HSG**		
		B	C	D		B	C	D
Straight row crops	Good	78	85	89	Parking lots, roofs, streets with sewer, etc.	98	98	98
Contoured crops	Good	75	82	86	Commercial, business	92	94	95
Contoured and terraced crops	Good	71	78	81	Streets: paved, open ditch	89	92	93
Pasture	Good	61	74	80	Streets: gravel	85	89	91
Pasture	Fair	69	79	84	Streets: dirt	82	87	89
Woods-grass	Poor	67	77	83	Newly graded areas	86	91	94
Woods-grass	Fair	65	76	82	Residential, 1/8-acre	85	90	92
Woods-grass	Good	55	70	77	Residential, 1/4-acre	75	83	87
Woods	Poor	66	77	83	Residential, 1/3-acre	72	81	86
Woods	Fair	60	73	79	Residential, 1/2-acre	70	80	85
Woods	Good	55	70	77	Residential, 1-acre	68	79	84
Meadow		58	71	78	Residential, 2-acre	65	77	82
Brush-weeds-grass	Poor	67	77	83	Open space, poor	79	86	89
Brush-weeds-grass	Fair	56	70	77	Open space, fair	69	79	84
Brush-weeds-grass	Good	48	65	73	Open space, good	61	74	80

Notes:
Postdevelopment HSG is assumed to be one group higher in runoff than predevelopment, unless soil treatment plan is provided to document otherwise.

STEP 3 - Calculate the net change in CN: Postdevelopment CN - Predevelopment CN = Net Change in CN

STEP 4 - Determine required Level of Service (LS) from net change in CN:

Change in CN		**Level of Service**
17+	High water quality impact	8
7 to 16	Moderate water quality impact	7
4 to 6	Low water quality impact	6
1 to 3	Minimal water quality impact	5
0	No change	4
-7 to -1	Minimal water quality improvement	3
-8 to -17	Low improvement	2
-18 to -21	Moderate improvement	1
-22 +	High improvement	0

Source: U.S. Department of Agriculture, Natural Resource Conservation Service Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55; 1986)

TABLE 1A
REQUIRED LEVEL OF SERVICE FOR CUMULATIVE WATER QUALITY IMPACTS

Calculate composite CN for postdevelopment condition if improvements are made to an already developed site:

Step 1 - Calculate the pre and postdevelopment change in CN as you would for a new development using Table 1, Steps 1 and 2.
Step 2 - Determine the CN range and/or impervious percent of the pre and postdevelopment conditions based on the table below.
Step 3 - Determine whether the site improvements will increase the site's range of imperviousness (for example from 12 to 25% to 25 to 65%).
Step 3 (alt) - Calculate the actual percent of impervious surface for the site and determine whether the improvement will increase the total into a higher range.

PREVIOUSLY DEVELOPED

Cover Type	CN by HSG			% Impervious
	B	C	D	(range)
Parking lots, roofs, streets with sewer, etc.	98	98	98	> 65
Commercial, business	92	94	95	↑
Streets: paved, open ditch	89	92	93	
Newly graded areas	86	91	94	
Residential, 1/8-acre	85	90	92	25 to 65
Streets: gravel	85	89	91	↑
Streets: dirt	82	87	89	
Residential, 1/4-acre	75	83	87	
Residential, 1/3-acre	72	81	86	
Residential, 1/2-acre	70	80	85	12 to 25
Residential, 1-acre	68	79	84	↑
Residential, 2-acre	65	77	82	< 12
Undeveloped	< 65	< 77	< 82	↑

Step 4 - If the site improvement increases the site's range of imperviousness, determine the water quality impact from the following range of increases in percent imperviousness:

Increase in range of % Imperviousness		Level of Service Rating
None	Negligible water quality impact	4
1	Low water quality impact	5
2	Moderate water quality impact	6
3	High water quality impact	7

TABLE 2
STORMWATER BMP APPLICABILITY MATRIX

Cover Type or BMP	Water Quality Value Rating			Land Use			Treatment Suitability					Physical Feasibility					Community and Environmental Benefits				Cost
	Retention (S)	Water Quality Treatment Rating (TR)[a,b]	Value Rating (VR)	Residential	Commercial	Industrial/ Hotspots	Ground Water Recharge	Channel Protection	Flood Control	Reduce Pollutants	Habitat	Size of Watershed Area (Acres)	Space Required for BMP	Slope (%)	Hydraulic Head (ft)	Requires Irrigation in Dry Areas	Aesthetics	Habitat	Safety	Maintenance	Relative Cost
Native Vegetation, preserved or established[c]	Actual	4.25[d]	Sum of S and TR	Y	Y	Y	Y	Y	Y	Y	Y	NA	High	NA	NA	N	H	H	H	H	H
Turf Grass	NA	NA	3.00[d]	S	S	S	N	N	N	D	N	Any	Low to High	NA	NA	Y	L	L	H	H	L
Swales and Channels	4.08	4.00	8.08	Y	Y	N	D	Y	D	Y	Y	<5	Medium	<2	1	Y	M	M	H	H	M
Bioretention/Rain Gardens	5.38	3.00	8.38	Y	S	N	Y	N	N	Y	Y	<5	Medium	<6	<5	Y	H	H	H	L	M
Grass Filter Strips[c]	Actual	2.00	Sum of S and TR	S	Y	N	D	D	D	Y	D	<2	Medium	<6	<1	Y	M	M	H	M	M
Wet Ponds	4.00[e]	3.00	7.00	S	S	L	D	D	D	Y	Y	>25	High	<10	3 to 5	Y	H	H	M	L	L
Wetlands	4.00[e]	3.00	7.00	S	S	L	D	D	D	Y	Y	>10	High	<10	3 to 5	Y	H	H	M	L	L
Pervious Pavement	4.71	4.00	8.71	S	Y	N	Y	Y	Y	Y	D	Any	None	<6	<1	N	M	M	H	M	H
Surface Sand Filters	4.00[e]	3.00	7.00	S	Y	Y	N	N	N	Y	N	<10	Low	<10	>3	N	M	L	H	M	L
Perimeter Sand Filters	4.00[e]	3.00	8.00	S	Y	Y	N	N	N	Y	N	<10	Low	<10	>3	N	M	L	H	M	L
Infiltration Basins	4.71	4.00	8.71	Y	Y	N	Y	D	D	Y	D	>25	High	NA	1 to 15	N	M	M	H	M	M
Infiltration Trenches	4.71	4.00	8.71	Y	Y	N	Y	D	D	Y	N	5 to 25	Medium	NA	1 to 10	N	M	L	H	M	M
Dry Detention Basins	2.50	1.00	3.50	S	S	N	N	Y	Y	N	D	>5	Medium	<10	3 to 5	N	L	L	M	L	M
Parking Lot Detention	0.20	1.00	1.20	N	S	N	N	N	N	N	N	<10	Low	<5	Any	N	L	L	H	M	L
				Y: Yes S: Sometimes N: No L: Only use with an impermeable liner			Y: Yes N: No D: Depends					Y: Yes N: No					H: High M: Moderate L: Low				H: High M: Mod. L: Low

*This table was modified from its original format located on the Texas Nonpoint Source Book Website http://www.txnpsbook.org/BMPs/urbmps-3.htm

Notes:

The applicability criteria provided above are for preliminary selection only. Consult the design criteria for each practice for more detailed information.

ED Extended detention
Mod Moderate
NA Not applicable
a Composite ranking based on National Pollutant Removal Performance Data, 2nd. Ed. (Center for Watershed Protection 2000)
b For rankings based on specific pollutants, refer to Table 3
c Considered equivalent to preserved if the soil is restored and the vegetation planted according to the specifications in Section 9.3 and Appendix A.
d Determined by percent impervious surface using TR-55 methodology
e Default value for BMPs with no S value

TABLE 3
WATER QUALITY TREATMENT RATINGS BY POLLUTANT CATEGORY

	TSS		Total Phosphorus		Soluble Phosphorus		Total Nitrogen		NOx		Copper		Zinc		Bacteria[b]		Hydrocarbons	
	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]	Median removal efficiency (%)	Treatment Rating[a]
Infiltration Practices	95	4.00	70	3.00	85	4.00	51	3.00	82	4.00	ND	2.00	99	4.00	ND	2.00	99	4.00
Filtering Practices	86	4.00	59	3.00	3	1.00	38	2.00	-14	0.00	49	2.00	88	4.00	49	2.00	88	4.00
Swales and Channels	81	3.00	34	2.00	38	2.00	84	4.00	51	3.00	51	3.00	71	3.00	51	3.00	71	3.00
Wet Ponds	80	3.00	51	3.00	66	3.00	33	2.00	43	2.00	57	3.00	66	3.00	57	3.00	66	3.00
Wetlands	76	3.00	49	2.00	35	2.00	30	2.00	67	3.00	40	3.00	44	2.00	40	2.00	44	2.00
Filter Strip	ND	2.00	ND	2.00	ND	2.00	ND	2.00	ND	2.00	ND	2.00	ND	2.00	ND	2.00	ND	2.00
Dry Ponds	47	2.00	19	1.00	-6	0.00	25	1.00	4	1.00	26	1.00	26	1.00	26	1.00	26	1.00

Note:
a Source: Based on National Pollutant Removal Performance Database, 2nd. Ed. (Center for Watershed Protection 2000)
b Bacteria data include fecal streptococci, enterococci, fecal coliform, E. coli., and total coliform
TSS Total suspended solids
NOx Soluble Nitrogen
ND No data (default to 2.00 value rating)

TABLE 4

RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
GRASSES																	
Prairie Cordgrass (Spartina pectinata)	P	W	T	G/BG	M/S	X		X	X	X	X			X	X	X	
Switchgrass (Panicum virgatum)	P	W	T	G	M/S	X	X	X	X	X	X			X	X	X	X
Western Wheatgrass (Pascopyrum smithii)	P	C	M	G/YG	M/S	X	X		X					X			X
Indian Grass (Sorghatrum nutans)	P	W	T	G	D/M	X	X	X	X	X	X	X		X		X	X
Big Bluestem (Andropogon gerardii)	P	W	T	G	M	X	X	X	X	X	X			X	X	X	X
Little Bluestem (Schizachyrium scoparium)	P	W	M	BG/G	D/M	X	X	X	X	X	X	X		X		X	X
Side Oats Grama (Bouteloua curtipendula)	P	W	M	P/G	D/M	X	X	X	X	X	X	X		X			
Canada Wildrye (Elymus canadensis)	P	C	T	G	D/M	X	X		X	X	X	X					
Virginia Wildrye (Elymus virginicus)	P	C	M	G	M	X	X	X	X	X	X			X	X	X	
Buffalograss (Buchloe dactyloides)	P	W	S	BG/G	D/M/S	X	X		X	X	X	X	X	X			
Redtop (Agrostis gigantea)	P	C	T	R/G	D/M/S	X	X		X	X	X	X					
Bermuda (Cynodon dactylon)	P	W	S	G	D/M/S		X		X	X	X	X	X	X			X
Blue Grama (Bouteloua gracilis)	P	W	S	BG	D	X	X		X	X	X	X	X	X			
Hairy Grama (Bouteloua hirsuta)	P	W	S	BG	D	X	X		X	X	X	X	X	X			
Alta or Kentucky 31 Fescue (Festuca elatior var. arund.)	P	C	M	G	D/M/S	X	X		X	X	X	X		X			X
Kentucky Bluegrass (Poa pratensis)	P	C	S	BG	D/M	X	X		X	X	X	X		X			X
Perennial Ryegrass (Lolium perenne var. derby)	P	C	M	G	D/M	X	X		X	X	X	X		X			X

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RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Red Creeping Fescue (Festuca rubra)	P	C	S	G/R	D/M	X	X		X	X	X	X		X			X
Prairie Dropseed (Sporobolus heterolepsis)	P	W	M	G	D/M	X	X		X	X	X	X		X			
Saltgrass (Distichlis stricta)	P	W	S	G	M/S		X	X	X	X	X	X	X	X		X	
Vine Mesquite (Panicum obtusum)	P	P	S	G	M/S		X	X	X	X	X	X	X	X		X	
Timothy (Phleum pratense)	P	C	M	G	M	X	X		X	X	X						X
Bottlebrush Grass Hystrix patula (Elymus hystrix)	P	C	M	G	M		X		X	X	X			X			
Woodland Brome Bromus pubescens	P	C	M	G	M		X		X	X	X			X			X
Seed Oats (Avena sativa)	A	C	T	G/BG	D/M	X			X								X
Annual Rye (Lolium multiflorum)	A	C	M	G	D/M	X			X								X
Winter Rye (Secale cereale)	A	C	T	G	D/M	X			X								X
FORBS AND LEGUMES																	
Illinois Bundleflower (Desmanthus illinoensis)	P	W	M	G/BR	M	X	X		X					X			
Purple Coneflower (Echinacea purpurea)	P	W	M	P	M	X	X		X					X	X	X	
Leadplant (Amorpha canescens)	P	W	M	B	M	X	X		X					X	X	X	
Showy Goldenrod (Solidago speciosa)	P	W	T	Y	M	X	X		X	X				X	X	X	
Maximillian Sunflower (Helianthus maximillianii)	P	W	T	Y	M	X	X		X	X				X	X	X	
Prairie Blazingstar (Liatris pycnostachya)	P	W	M	P/R	M	X	X		X	X				X	X	X	
Black-eyed Susan (Rudbekia hirta)	A/P	W	M	Y	M	X	X		X	X				X	X	X	

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Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Purple Prairie Clover (Dalea purpurea)	P	W	M	P	M	X	X		X	X				X	X	X	
Common Dayflower (Commelina communis)	P	W	S	B	M	X	X		X	X				X	X	X	
Cut-leaf Coneflower (Rudbeckia laciniata)	P	W	T	Y	D/M	X	X		X	X				X	X	X	
Shrubby Cinquefoil (Potentilla fruticosa)	P	W	S	Y	M	X	X		X	X				X	X	X	
Wild False Indigo (Baptisia alba var. macrophylla)	P	W	M/T	W/Y	M	X	X		X	X				X	X	X	
Showy Tick Trefoil (Desmodium canadense)	P	W	S/M	P	M/D	X	X		X	X				X	X	X	
Showy Sunflower (Helianthus lateriflorus)	A/P	W	T	Y	D/M	X	X		X	X				X	X	X	
False Sunflower (Heliopsis helianthoides)	P	W	M	Y	D/M	X	X		X					X	X	X	
Rough Blazing Star (Liatris aspera)	P	W	M	P/R	D/M	X	X		X					X	X	X	
Joe Pyeweed (Eupatorium maculatum)	P	W	M	P	M/W	X	X	X	X					X	X	X	
Boneset (Eupatorium perfoliatum)	P	W	T	W	W			X						X	X	X	
Sneezeweed (Helenium autumnale)	P	W	S	Y	M/W	X	X	X	X					X	X	X	
Prairie Cinquefoil (Potentilla arguta)	P	W	S	Y	D/M	X	X		X					X	X	X	
Heart-leaved Alexander (Zizia aptera)	P	W	S	Y	D/M	X	X		X					X	X	X	
Swamp Milkweed (Asclepias incarnata)	P	W	T	P/PK	M/W	X	X	X	X					X	X	X	
Marsh Aster (Aster puniceus)	P	W	M/T	W/Y	W			X						X	X	X	
Great Blue Lobelia (Lobelia siphilitica)	P	W	M	B	M/W	X	X	X	X					X	X	X	

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RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Common Water Horehound (Lycopus americanus)	P	W	S	W	W		X	X						X	X	X	
Common Mountain Mint (Pycnanthemum virginianum)	P	W	M	W	M/W	X	X	X	X					X	X	X	
Cup Plant (Silphium perfoliatum)	P	W	T	Y	M/W	X	X	X	X					X	X	X	
Purple Meadow Rue (Thalictrum dasycarpum)	P	W	M	P	M/W	X	X	X	X					X	X	X	
Blue Vervain (Verbena hastata)	P	W	S	P/B	M/W	X	X	X	X					X	X	X	
Canada Anemone (Anemone canadensis)	P	W	S	W	M/W	X	X	X	X					X	X	X	
Cream Gentian (Gentiana alba)	P	W	M	W	D/M	X	X		X					X	X	X	
Showy Evening Primrose (Oenothera speciosa)	P	W	S	W	D/M	X	X		X					X	X	X	
Indian Blanket (Gaillardia pulchella)	A	W	S	R/Y	D/M	X	X		X					X	X	X	
Nodding Onion (Allium cernuum)	P	C	S	PK	D/M	X	X		X					X	X	X	
Cream False Indigo (Baptisia bracteata)	P	W	S	W	D/M	X	X		X					X	X	X	
White Prairie Clover (Dalea candida)	P	C	S	W	D/M	X	X		X					X	X	X	
Golden Alexanders (Zizia aurea)	P	W	M	Y	M/W	X	X	X	X					X	X	X	
Sky Blue Aster (Aster azureus)	P	W	M	B	D/M	X	X		X					X	X	X	
Blue Wild Indigo (Baptisia australis)	P	W	M	B	D/M	X	X	X	X					X	X	X	
Wild Bergamot (Monarda fistulosa)	P	W	M/T	P/B	D/M	X	X		X					X	X	X	
Smooth Penstemon (Penstemon digitalis)	P	W	M	W	M/W	X	X	X	X					X	X	X	

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RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Ohio Spiderwort (Tradescantia ohiensis)	P	W	M	B	D/M/W	X	X	X	X					X	X	X	
Slender Mountain Mint (Pycanthemum tenuifolium)	P	W	S	W	D/M	X	X		X					X	X	X	
Wild Columbine (Aquilegia canadensis)	P	W	M	R	D/M	X	X		X					X	X	X	
False Solomon's Seal (Smilacina racemosa)	P	W	S/M	W	D/M	X	X		X					X	X	X	
Hoary Vervain (Verbena stricta)	P	W	M	P/PK	D/M	X	X		X					X	X	X	
Common Milkweed (Asclepias syriaca)	P	W	M	PK	M	X	X	X	X					X	X	X	
Partridge Pea (Cassia fasciculata)	A	W	S	Y	D/M	X	X		X					X	X	X	
Bush Clover (Lespedeza capitata)	P	W	M	B	D/M	X	X		X					X	X	X	
Compass Plant (Silphium laciniatum)	P	W	T	Y	D/M	X	X		X					X	X	X	
Stiff Goldenrod (Solidago rigida)	P	W	M/T	Y	D/M	X	X		X	X				X	X	X	
Buttererfly Milkweed (Asclepias tuberosa)	P	W	M	OR	D/M	X	X		X	X				X	X	X	
Whorled Milkweed (Asclepias verticillata)	P	W	S	W	D/M	X	X		X	X				X	X	X	
Smooth Blue Aster (Aster laevis)	P	W	M	P/B	D/M	X	X		X	X				X	X	X	
Western Sunflower (Helianthus occidentalis)	P	W	M	Y	D/M	X	X		X	X				X	X	X	
Spotted Berfgamot (Monarda punctata)	P	W	M	Y/P	D	X	X		X	X							
Yellow Coneflower (Ratibida pinnata)	P	W	M	Y	D/M	X	X		X	X				X	X	X	
New England Aster (Aster novae-angliae)	P	W	M/T	B	M/W	X	X		X	X				X	X	X	

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Thimbleweed (Anemone cylindrica)	P	W	S	G	D/M	X	X		X	X				X	X	X	
Heath Aster (Aster ericoides)	P	W	S/M	W	D/M	X	X		X	X				X	X	X	
Silky Aster (Aster sericeus)	P	W	S	P/B	D	X	X		X	X							
New Jersey Tea (Ceanothus americanus)	P	W	S/M	G/BR	D/M	X	X		X	X				X	X	X	
Alum Root (Heuchera richardsonii)	P	W	S	GR	D/M	X	X		X	X				X	X	X	
Prairie Smoke (Geum triflorum)	P	W	S	R	D/M	X	X		X	X				X	X	X	
Wild Lupine (Lupinus perennis)	P	W	S	B	D	X	X		X	X							
Large Flowered Beard Tongue (Penstemon grandiflorus)	P	W	M	P/B	D	X	X		X	X							
Downy Phlox (Phlox pilosa)	P	W	S	PK	D/M	X	X		X	X				X	X	X	
Blue-eyed Grass (Sisyrinchium campestre)	P	W	S	B	D	X	X		X	X							
Old Field Goldenrod (Solidago nemoralis)	P	W	S	Y	D	X	X		X	X							
Riddell's Goldenrod (Solidago riddellii)	P	W	S/M	Y	M/W	X	X	X	X	X				X	X	X	
Flowering Spurge (Euphorbia corollata)	P	W	S	W	D/M	X	X		X	X				X	X	X	
Prairie Spiderwort (Tradescantia bracteata)	P	W	S	B	D/M	X	X		X	X				X	X	X	
WETLAND SPECIES																	
Blueflag (Iris virginica)	P	W	S/M	B	M/W			X						X	X	X	
Arrowhead (Sagitaria fasciculate & latifolia)	P	W	S/M	W	M/W									X	X	X	
Needle Spikerush (Eleocharis acicularis)	P	W	S	BR	M/W			X						X	X	X	

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Rice Cutgrass (Leersia oryzoides)	P	W	S	GR	M/W			X						X	X	X	
Bulrush var. Olney's (Scirpus americanus)	P	W	T	GR	M/W			X						X	X	X	
Common Spikerush (Eleocharis acicularis)	P	W	S	BR	M/W			X						X	X	X	
Cardinal Flower (Lobelia cardinalis)	P	W	M	R	M/W			X						X	X	X	
White Water Lilly (Nymphaea odorata)	P	W	S	W	W									X		X	
Wild Calamus (Acorus calamus)	P	W	M	W	W			X						X	X	X	
Bottlebrush Sedge (Carex hystricina)	P	W	M	BR	M/W			X						X	X	X	
Pointed Broom Sedge (Carex scoparia)	P	W	M	BR	M/W			X						X	X	X	
Dark Green Rush (Scirpus atrovirens)	P	W	M	GR	M/R			X						X	X	X	
Wool Grass (Scirpus cyperinus)	P	W	M	GR	M/W			X						X	X	X	
Great Bulrush (Scirpus validus creber)	P	W	T	GR	M/W			X						X	X	X	
Common Spike Rush (Juncus effusus)	P	W	S	BR	M/W			X						X	X	X	
Wood Sedge (Carex rosea)	P	W	S	GR	M/W	X								X		X	
Smartweed (Polygonum spp.)	P	W	S/T	BR	M/W			X						X	X	X	
Angelica (Angelica atropurpurea)	P	W	M	GR/W	M/W			X						X	X	X	
Water Hemlock (Cicuta maculata)	P	W	T	Y	W									X	X	X	
Barnyard Grass (Echinochloa crusgalli)	P	W	M	GR	M/W			X						X	X	X	X

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Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Fowl Manna Grass (Glyceria striata)	P	W	M/T	GR	W			X						X	X	X	
Germander, Wood Sage (Teucrium canadense)	P	W	M	W/P	M	X										X	
Woodland Sedge (Carex blanda)	P	W	S/M	GR	M	X										X	
Pen Sedge (Carex pensylvanica)	P	W	S/M	GR	M			X						X	X	X	
Woodland Sedge (Carex sparganioides)	P	W	S/M	GR	M			X						X	X	X	
Winged Loosestrife (Lythrum alatum)	P	W	S	B/P	W			X						X	X	X	
Common Bur Reed (Sparganium eurycarpum)	P	W	M/T	BR	W			X						X	X	X	
Iron Weed (Vernonia fasciculata)	P	W	M	R/PK	M/W									X	X	X	
Culver's Root (Veronicastrum virginicum)	P	W	M/T	W	M/W			X						X	X	X	
Blue Joint Grass (Calamagrostis canadensis)	P	W	M/T	GR/Y	M/W			X						X	X	X	
TREES																	
Sycamore (Platanus occidentalis)					M/W	X								X		X	
Hackberry (Celtis occidentalis)					D/M	X								X		X	
Shagbark Hickory (Carya ovata)					D/M	X											
Red bud (Cercis canadensis)					D/M	X								X		X	
Black Cherry (Prunus serotina)					D/M	X								X		X	
White Oak (Quercus alta)					D	X										X	
Black Walnut (Juglans nigra)					D/M	X										X	

TABLE 4

RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Eastern Red Cedar (Juniperus virginiana)					D/M/S	X								X		X	
Red Maple (Acer rubrum)					M/W/S	X								X		X	
Bur Oak (Quercus macrocarpa)					M/S	X								X		X	
Eastern Cottonwood (Populus deltoides)					D/M/S	X		X						X		X	
River Birch (Betula nigra)					M/W	X		X						X	X	X	
Hazelnut (Corylus americana)					D/M	X								X		X	
Pin Oak (Quercus palustris)					M/W/S	X		X						X		X	
Red Elm (Ulmus rubra)					D/M	X								X		X	
Green Ash (Fraxinus pennsylvanica subintegerrima)					M/W	X								X	X	X	
Red Oak (Quercus rubra)					D/M	X								X		X	
Basswood (Tilia americana)					D/M	X								X		X	
Boxelder (Acer negundo)					M/S	X		X						X		X	
SHRUBS AND VINES																	
Streamco Willow (Salix purpurea)				GR/Y	M/W	X		X						X	X	X	
Sandbar Willow (Salix exigua)				GR/Y	M/X	X		X						X	X	X	
Rough-leaved Dogwood (Cornus drumondii)				W	D/M	X	X		X	X				X	X	X	
Coralberry (Symphocarpus orbiculatus)				PK	D/M	X	X		X	X				X	X	X	
Wild Plum (Prunus americana)				W	D/M	X	X		X	X				X		X	

TABLE 4

RECOMMENDED PLANT MATERIALS FOR BMPs

Plant Species	Annual/Perennial	Cool/Warm	Short/Medium/Tall	Leaf/Stem/Flower Color	Moist/Wet/Salt Tolerant	Riparian Buffer	Dry Swale	Wet Swale	Filter Strip	Infiltration Basin	Infiltration Trench	Sand Filter	Pervious Pavement	Bioretention	Rain Garden	ED Wetland	Phased Const.
Elderberry (Sambucus canadensis)				W	M	X	X	X	X	X				X		X	
Flame-leaf Sumac (Rhus glabra)				R	D/M	X	X		X	X				X		X	
Red-osier Dogwood (Cornus stolonifera)				W	D/M	X	X	X	X	X				X		X	
Chokecherry (Prunus virginiana)				W	D	X	X		X					X			
Common Buckthorn (Rhamnus cathartica)				Y	D	X	X		X	X				X		X	
Button Bush (Cephalanthus occidentalis)				w	M/W			X						X	X	X	
Gray Dogwood (Cornus racemosa)				W	D/M	X	X		X	X				X		X	

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
GRASSES											
Prairie Cordgrass (Spartina pectinata)	P	W	T	G/BG	Sl	Sun	M/W			M/S	
Switchgrass (Panicum virgatum)	P	W	T	G	Di, Dr	Sun	D-M	5+	10	M/S	Dense habitat cover, stands up through winter, soil tolerent
Western Wheatgrass (Pascopyrum smithii)	P	C	M	G/YG	Dr, Sl, Alkaline	Sun	M-D		8-10	M/S	Best in fine-grained soils that collect runoff.
Indian Grass (Sorghatrum nutans)	P	W	T	G	Dr	Sun	M-W		6-10 #/Ac	D/M	Deep, moist soils
Big Bluestem (Andropogon gerardii)	P	W	T	G	Dr	Sun	D-W	5.4-6.2	10-12	M	
Little Bluestem (Schizachyrium scoparium)	P	W	M	BG/G	Dr	Sun	D-M	5.4-6.2	Wildlife:6-10 10-12	D/M	Not for clay/damp soils Turns crimson in fall.
Side Oats Grama (Bouteloua curtipendula)	P	W	M	P/G		Sun	D-M		6-10	D/M	
Canada Wildrye (Elymus canadensis)	P	C	M/T	G	Mod-Dr	Sun	D-M		15	D/M	Does not do well in sandy soil Good soil erosion control
Virginia Wildrye (Elymus virginicus)	P	C	M	G	Dr	p-Sh	M		10-12	M	Grows on moist, woodland soils Not as dr tol as Canada Wildrye
Buffalograss (Buchloe dactyloides)	P	W	S	BG/G	Dr	Sun to p-Sh	D-M		5#/1000 SF	D/M/S	clays and loams, rarely sands tends to establish dominance
Redtop * (Agrostis gigantea)	P	C	T	R/G			W-M		15	D/M/S	Acidic or clayey, not for limestone areas; allergen
Bermuda * (Cynodon dactylon)	P	W	S	G	Dr, Sl, acidic	Sun	M-D	5-8	35	D/M/S	Tropical: some varieties developed for cooler temperatures
Blue Grama (Bouteloua gracilis)	P	W	S	BG	Dr	Sun	D		10	D	Cannot tolerate shade from taller plants

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Hairy Grama (Bouteloua hirsuta)	P	W	S	BG	Dr	Sun to p-Sh	D			D	Well drained rocky soils, particularly limestone and granite
Alta or Kentucky 31 Fescue * (Festuca elatior var. arund.)	P	C	S	G	Dr, Mod-Di	Sun to p-Sh	D-M		7-10#/1000SF	D/M/S	
Kentucky Bluegrass * (Poa pratensis)	P	C	S	BG		Sun	M		2#/1000 SF	D/M	
Perennial Ryegrass * (Lolium perenne var. derby)	P	C	M	G		Sun to p-Sh	M			D/M	Lawn varieties not suitable for forage; needs irrigation.
Red Creeping Fescue * (Festuca rubra)	P	C	S	G/R	Dr, mod-Sl	Sun to p-Sh				D/M	Generally hardy, soil tolerant
Prairie Dropseed (Sporobolus heterolepis)	P	W	M	G	Dr	Sun	D-M			D/M	Establish by sodding; well drained soil; fragrant seedhead
Saltgrass (Distichlis stricta)	P	W	S	G	Sl	Sun	M	alkaline		M/S	Brackish marshes, saline, alkaline soils that are poorly drained.
Vine Mesquite (Panicum obtusum)	P	W	S	G		Sun to p-Sh	M	4.8-7.0	6	M/S	Moist areas in arid environments with short, mild winters.
Timothy * (Phleum pratense)	P	C	M	G					8-10	M	Allergen
Bottlebrush Grass Hystrix patula (Elymus hystrix)	P	C	M	G		p-Sh	D-M		7-10	M	Prefers well drained soils light to medium shade
Woodland Brome Bromus pubescens	P	C	M	G		p-Sh				M	
Seed Oats (Avena sativa)	A	C	T	G/BG	wet/heavy soil	Sun	D-M		cover: 30	D/M	Seed rate for crop: 90-100 #/Ac Cold sensitive

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Annual Rye (Lolium multiflorum)	A	C	M	G		Sun to p-Sh	M		Spring: 5 Fall: 15	D/M	Better with p-Sh in hot south; not heat/drought tolerant
Winter Rye (Secale cereale)	A	C	T	G	cold tolerant to -40F	Sun to p-Sh	M		3 #/ 1000 SF	D/M	Better with p-Sh in hot south; not heat/drought tolerant
FORBS AND LEGUMES											
Illinois Bundleflower (Desmanthus illinoensis)	P	W	M	G/BR	Dr, Cold	Sun	D-M		13	M	Prefers clay soils
Purple Coneflower (Echinacea purpurea)	P	W	M	P	Dr, Cold to 10F	Sun	M		12	M	Herb
Leadplant (Amorpha canescens)	P	W	M	B		Sun to p-Sh	D-M			M	Well drained sandy/gravelly soils South and East slopes
Showy Goldenrod (Solidago speciosa)	P	W	T	Y		Sun	D-M			M	Prefers sandy loam
Maximillian Sunflower (Helianthus maximillianii)	P	W	T	Y		Sun	M		5	M	
Prairie Blazingstar (Liatris pycnostachya)	P	W	M	P/R		Sun	M		2	M	
Black-eyed Susan (Rudbekia hirta)	A/P	W	M	Y		Sun	M		2	M	
Purple Prairie Clover (Dalea purpurea)	P	W	M	P	Dr, heat	Sun	D-M		3-8	M	slopes, roadsides, meadows well drained soils
Common Dayflower * (Commelina communis)	P	W	S	B		Sh	W			M	Considered invasive plant in KY and VI. Flowers for only 1 day
Cut-leaf Coneflower (Rudbeckia laciniata)	P	W	T	Y	Dr	Sun to p-Sh	M-W	4.5-7.0		D/M	well drained soil
Shrubby Cinquefoil (Potentilla fruticosa)	P	W	S/M	Y	Dr, cold	Sun	M-W			M	Well-drained; pond/marsh edges and calcareous fens
Wild False Indigo (Baptisia alba var. macrophylla)	P	W	M/T	W/Y		Sun	D-M			M	Toxic alkaloids cause cattle poisoning

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Showy Tick Trefoil (Desmodium canadense)	P	W	S/M	P		Sun	D-M			M/D	Prefers clay or loam
Showy Sunflower (Helianthus lateriflorus)	A/P	W	T	Y		Sun to p-Sh	D-M			D/M	Sandy loam
False Sunflower (Heliopsis helianthoides)	P	W	M	Y	Dr	Sun to p-Sh	D-M			D/M	Best in well drained moist soils near woods. Long blooming
Rough Blazing Star (Liatris aspera)	P	W	M	P/R		Sun to p-Sh	D-M	acidic		D/M	Sandy loams
Joe Pyeweed (Eupatorium maculatum)	P	W	M	P		Sun to p-Sh	M			M/W	Moist meadows, ditches, water or swamp edges
Boneset (Eupatorium perfoliatum)	P	W	T	W		Sun to p-Sh	W-M			W	Damp to wet streams, low meadows. Herb
Sneezeweed (Helenium autumnale)	P	W	S/M	Y		Sun to p-Sh	M-W			M/W	Misnamed, not an allergen
Prairie Cinquefoil (Potentilla arguta)	P	W	S/M	Y	Dr	Sun to p-Sh	D-M			D/M	well-drained, sandy loam to open rocky areas
Heart-leaved Alexander (Zizia aptera)	P	W	S/M	Y		Sun to p-Sh	M			D/M	Grows in well drained soils in woods, thickets, glades, and prairies.
Swamp Milkweed (Asclepias incarnata)	P	W	T	P/PK		Sun to p-Sh	W-M			M/W	Wet, marshy areas with clayey, peaty soils
Marsh Aster (Aster puniceus)	P	W	M/T	W/Y		Sun to p-Sh	W			W	
Great Blue Lobelia (Lobelia siphilitica)	P	W	M	B		Sun to p-Sh	M-W			M/W	
Common Water Horehound (Lycopus americanus)	P	W	S	W		Sun	M-W			W	
Common Mountain Mint (Pycnanthemum virginianum)	P	W	M	W		Sun to p-Sh	W-M			M/W	Misnomer, not mountainous

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Cup Plant (Silphium perfoliatum)	P	W	T	Y		Sun to p-Sh	M-W			M/W	Prefers clay or loam
Purple Meadow Rue (Thalictrum dasycarpum)	P	W	M	P		Sun	M-W			M/W	
Blue Vervain (Verbena hastata)	P	W	S	P/B		Sun	M-W			M/W	Moist stream/pond edges
Canada Anemone (Anemone canadensis)	P	W	S	W		Sun to p-Sh	M-W	to slt. acidic		M/W	Damp roadside ditches
Cream Gentian (Gentiana alba)	P	W	M	W		Sun to p-Sh	D-M			D/M	mesic black soils; rare plant
Showy Evening Primrose (Oenothera speciosa)	P	W	S	W		Sun	D		1	D/M	Rocky soils and waste areas
Indian Blanket (Gaillardia pulchella)	A	W	S	R/Y	Dr	Sun	D		10	D/M	Thrives in hot, sunny, dry conditions
Nodding Onion (Allium cernuum)	P	C	S	PK		Sun to p-Sh	M			D/M	
Cream False Indigo (Baptisia bracteata)	P	W	S	W		Sun to p-Sh	D-M			D/M	Prefers sand and loam slow growing/long lived
White Prairie Clover (Dalea candida)	P	C	S	W		Sun to p-Sh	D-M			D/M	sandy loam
Golden Alexanders (Zizia aurea)	P	W	M	Y		Sun to p-Sh	M-W			M/W	
Sky Blue Aster (Aster azureus)	P	W	M	B	Dr	Sun to p-Sh	D-M			D/M	sandy loam
Blue Wild Indigo (Baptisia australis)	P	W	M	B		Sun	D-M			D/M	Prefers rocky soil that isn't too alkaline.
Wild Bergamot (Monarda fistulosa)	P	W	M/T	P/B		Sun to p-Sh	D-M	Neutral		D/M	Well drained, sandy loam

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Smooth Penstemon (Penstemon digitalis)	P	W	M	W		Sun to p-Sh	M			M/W	loves clay
Ohio Spiderwort (Tradescantia ohiensis)	P	W	M	B		Sun to p-Sh	D-M			D/M/W	Dormant in summer
Slender Mountain Mint (Pycanthemum tenuifolium)	P	W	S	W		Sun	D-M			D/M	
Wild Columbine (Aquilegia canadensis)	P	W	M	R		Sun to Shade	D-M			D/M	Sandy loam
False Solomon's Seal (Smilacina racemosa)	P	W	S/M	W		Shade	M			D/M	Moist, shady forest floor
Hoary Vervain (Verbena stricta)	P	W	M	P/PK	Dr	Sun	D-M			D/M	Dry, sandy soils and well drained loamy soils
Common Milkweed (Asclepias syriaca)	P	W	M	PK		Sun to p-Sh	M			M	Host for Monarch Butterfly Poisonous to animals
Partridge Pea (Cassia fasciculata)	A	W	S	Y		Sun	D-M		13	D/M	Soil stabilization/reclamation Sandy loam
Bush Clover (Lespedeza capitata)	P	W	M	B	Dr	Sun	D-M			D/M	Middle to dry prairie Sandy loam
Compass Plant (Silphium laciniatum)	P	W	T	Y	Dr	Sun	M-D			D/M	Leaves point North/South
Stiff Goldenrod (Solidago rigida)	P	W	M/T	Y	Dr	Sun	M-D			D/M	Not an allergen
Butterfly Milkweed (Asclepias tuberosa)	P	W	M	OR		Sun	M-D	acidic		D/M	Host for Monarch Butterfly; toxic to animals; dry, sandy/rocky soils
Whorled Milkweed (Asclepias verticillata)	P	W	S	W		Sun	D-M			D/M	Dry, calcareous soils and rocky hillsides
Smooth Blue Aster (Aster laevis)	P	W	M	P/B	Dr	Sun to p-Sh	M-D			D/M	Sandy loams

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Western Sunflower (Helianthus occidentalis)	P	W	M	Y		Sun	D-M			D/M	Poor, dry, sandy soils Not recommended for clay
Spotted Berfgamot (Monarda punctata)	P	W	M	Y/P	Dr	Sun to p-Sh	M			D	Sandy soil
Yellow Coneflower (Ratibida pinnata)	P	W	M	Y	Dr, flood, heat, cold	Sun to p-Sh	D-M			D/M	Thrives in dry sandy soils and in raw clay
New England Aster (Aster novae-angliae)	P	W	M/T	B		Sun	M		2	M/W	
Thimbleweed (Anemone cylindrica)	P	W	S	G		Sun to p-Sh	M-D			D/M	Sandy, loamy, gritty soils Foliage is toxic
Heath Aster (Aster ericoides)	P	W	S/M	W	Dr	Sun	D-M			D/M	Dry or well drained soils
Silky Aster (Aster sericeus)	P	W	S	P/B	Dr	Sun	D-M			D	Dry, open uplands Associate with limestone soils
New Jersey Tea (Ceanothus americanus)	P	W	S/M	G/BR		Sun to p-Sh	D-M			D/M	Sand/loam. Used as a tea.
Alum Root (Heuchera richardsonii)	P	W	S	GR		Sun to p-Sh	D-M			D/M	Prefers full sun in northern range but partial sun further south.
Prairie Smoke (Geum triflorum)	P	W	S	R		Sun	D-M			D/M	Found in pine forests at 6,000 to 9,500 foot elevations
Wild Lupine (Lupinus perennis)	P	W	S	B		Sun to p-Sh	Dry			D	Endangered Karner Blue Butterfly (Great Lakes area) depends on plant.
Large Flowered Beard Tongue (Penstemon grandiflorus)	P	W	M	P/B		Sun	Dry			D	Very sandy soils
Downy Phlox (Phlox pilosa)	P	W	S	PK		Sun to p-Sh	M-W			D/M	Woods and meadows
Blue-eyed Grass (Sisyrinchium campestre)	P	W	S	B		Sun	M-D			D	
Old Field Goldenrod (Solidago nemoralis)	P	W	S	Y		Sun to p-Sh	M-D			D	

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Riddell's Goldenrod (Solidago riddellii)	P	W	S/M	Y		Sun	W-M			M/W	Wet seeps on prairies
Flowering Spurge (Euphorbia corollata)	P	W	S/M	W	Dr	Sun	M-D			D/M	
Prairie Spiderwort (Tradescantia bracteata)	P	W	S	B		Sun	M-D			D/M	Sandy, rocky prairie soils
WETLAND SPECIES											
Blueflag (Iris virginica)	P	W	S/M	B		Sun to p-Sh	M-W	acidic boggy		M/W	Light shade in south part of range, marshes
Arrowhead (Sagitaria latifolia)	P	W	S/M	W		Sun to p-Sh	M-W			M/W	Water edges, shallow water
Needle Spikerush (Eleocharis acicularis)	P	W	S/M	BR		Sun	M-W			M/W	Erosion control Water edges, shallow water
Rice Cutgrass (Leersia oryzoides)	P	W	S	GR		Sun	Wet			M/W	
Bulrush var. Olney's (Scirpus americanus)	P	W	T	GR		Sun	Wet			M/W	Calcareous fens water edges, wet meadows
Common Spikerush (Eleocharis palustris)	P	W	S	BR		Sun to p-Sh	M-W			M/W	Shallow water and marshes
Cardinal Flower (Lobelia cardinalis)	P	W	M	R		Sun to p-Sh	M	to slt. acidic		M/W	Attracts hummingbirds Moist but not saturated soils
White Water Lilly (Nymphaea odorata)	P	W	S	W		Sun	Aquatic			W	Forms dense patches; can cause problems if not controlled
Wild Calamus (Acorus calamus)	P	W	M	W		Sun to p-Sh	Aquatic			W	Around edges of stream. Herb: stimulant, psychadelic
Bottlebrush Sedge (Carex hystricina)	P	W	M	BR		Sun	Wet to Aquatic			M/W	Shallow marshes, bogs, peat soil
Pointed Broom Sedge (Carex scoparia)	P	W	M	BR		Sun	Wet to Aquatic			M/W	Peat soil
Dark Green Rush (Scirpus atrovirens)	P	W	M	GR		Sun	Wet to Aquatic			M/R	Marshes, wet meadows, peats, mucks, clay, sand
Wool Grass (Scirpus cyperinus)	P	W	M/T	GR		Sun to p-Sh	Wet			M/W	peat, sand
Great Bulrush (Scirpus validus creber)	P	W	T	GR	Dr	p-Sh	Wet to Aquatic			M/W	Shallow water or saturated soils

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Common Rush (Juncus effusus)	P	W	S	BR	Dr	Sun	M-W			M/W	Very hardy, withstands flloding
Wood Sedge (Carex rosea)	P	W	S	GR		Sun to p-Sh	M-W			M/W	forests
Smartweed (Polygonum spp.)	P	W	S/T	BR		Sun	Aquatic			M/W	Wetland varities around water edges and marshes
Angelica (Angelica atropurpurea)	P	W	M	GR/W		Sun	M-W			M/W	Moist, swampy woodlands
Water Hemlock (Cicuta maculata)	P	W	T	Y		Sun	Wet			W	Most violently poisonous plant in N.Amer. Resembles edible plants.
Barnyard Grass * (Echinochloa crusgalli)	P	W	M	GR		Sun	W-D			M/W	Removes 80% soil nitrogen causes crop failure, poisons cattle
Fowl Manna Grass (Glyceria striata)	P	W	M/T	GR		Sun	M-W			W	
Germander, Wood Sage (Teucrium canadense)	P	W	M	W/P		Sun to p-Sh	M			M	Thickets and moist sites along water bodies
Woodland Sedge (Carex blanda)	P	W	S/M	GR		Sun to p-Sh	D-M-W			M	Swamps to dry woodlands Wet woods along streams
Pennsylvania Sedge (Carex pensylvanica)	P	W	S/M	GR		Shade to Sun	D-M			M	Forests and open meadows, well drained dry soils
Woodland Sedge (Carex sparganioides)	P	W	S/M	GR		Shade	D-M			M	Soil stabilization on shady slopes
Winged Loosestrife (Lythrum alatum)	P	W	S	B/P		Sun	W-M			W	Swamps and wet meadows, poorly drained soils
Common Bur Reed (Sparganium eurycarpum)	P	W	M/T	BR		Sun	W-A			W	Marshes, wetlands, muddy ditches, pools of shallow water
Iron Weed (Vernonia fasciculata)	P	W	M	R/PK		Sun to	M-W			M/W	Damp soils, wet prairies
Culver's Root (Veronicastrum virginicum)	P	W	M/T	W		Sun to p-Sh	M			M/W	Thickets, prairies, moist, well drained soils
Blue Joint Grass (Calamagrostis canadensis)	P	W	M/T	GR/Y	mod-Sl	Sun	W	as low as 3.5		M/W	Very common, widespread. Moist, moderately well drained soils

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
TREES											
Sycamore (Platanus occidentalis)	P		90'	R	Dr, wet	Sun	M			M/W	Urban uses, soil tolerant
Hackberry (Celtis occidentalis)	P		45-80'	G	Dr, Sl	Sun to p-Sh	M			D/M	Bark easily damaged, ice damage Urban uses, soil tolerant
Shagbark Hickory (Carya ovata)	P		60-80'	G		Sun to p-Sh	M			D/M	Ornamental not general use; Nut-fall problem. Well drained soil
Red bud (Cercis canadensis)	P		30	Pk/P		Sun to p-Sh	M			D/M	Fast growth/short lived. Soil tolerant. Partial sun in hot areas.
Black Cherry (Prunus serotina)	P		60-90'	W	Dr	Sun to p-Sh	M	acidic to alkaline		D/M	Staining and pits cause problems on walks/pavement.
White Oak (Quercus alta)	P		60-100'	Br	Mod-Dr	Sun to p-Sh	M	acidic		D	Slow growth. Not adapted to dry fairly soil tolerant, well drained
Black Walnut (Juglans nigra)	P		70' +	-	Dr	Sun	M			D/M	Open, sunny area with moist, rich soil Nut-fall problem. Well drained soil
Eastern Red Cedar (Juniperus virginiana)	P		50'	G/Y	Dr, mod-Sl	Sun to p-Sh	M-D			D/M/S	Urban uses, windbreaks, screens Doesn't like continuous moisture
Red Maple (Acer rubrum)	P		40-75'	R		Sun to p-Sh	W			M/W/S	Use local seed source. Tree shorter in south. Avoid alkaline soil
Bur Oak (Quercus macrocarpa)	P		70-90'	Br	Dr, Sl	Sun	M			M/S	Soil tolerant
Eastern Cottonwood (Populus deltoides)	P		70-90'	-	Dr	Sun	M			D/M/S	Fast growth, floodplains, soft wood separate male/female trees
River Birch (Betula nigra)	P		50' +	Br	Flood, low soil Oxygen	Sun to p-Sh	M	Requires acidic		M/W	Short lived (30-40 years)
Hazelnut (Corylus americana)	P		10-15'	Br		Sun to p-Sh	M			D/M	Fast growth; best in rich, moist, well drained soils
Pin Oak (Quercus palustris)	P		50-75'	Br	wet, urban	Sun	M	acidic		M/W/S	Not recommended for limestone (alkaline conditions)
Red Elm (Ulmus rubra)	P		80'	G	Dutch Elm disease	Sun to p-Sh	M-W			D/M	Fast growth, less flood tolerant than Amer. Elm., Drier sites if limestone
Green Ash (Fraxinus pennsylvanica subintegerrima)	P		60'	G	mod-Sl	Sun	D-M-W			M/W	Prefers moist but is adaptable. Urban uses, fast growth.
Red Oak (Quercus rubra)	P		70'	Br	Dr	Sun	D-M	below 7.5		D/M	Common to north and east slopes Well drained soils

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks
Basswood (Tilia americana)	P		50'	Y	mod-Dr	Sun to p-Sh	M	acidic to slt. Alkaline		D/M	Attracts honey bees; low branches may require pruning.
Boxelder (Acer negundo)	P		50'	W	Dr, mod-Sl	Sun to p-Sh	M			M/S	Fast growth/short lived, weak wood, disease/decay, stream banks.
SHRUBS AND VINES											
Streamco Willow * (Salix purpurea)	P		15'	GR/Y		Sun	W			M/W	Fast rooting, erosion control Doesn't like shade
Sandbar Willow (Salix exigua)	P	C	18'	GR/Y	Dr	Sun	W			M/X	Sandbars, mud flats, stream banks. thickets, soil stabilization
Rough-leaved Dogwood (Cornus drumondii)	P	C	20'	W	Dr	Sun to p-Sh	M			D/M	Well drained, moist soils
Coralberry (Symphocarpus orbiculatus)	P	W	6'	PK			D			D/M	Dry sand along streams, in woods field edges, and prairies.
Wild Plum (Prunus americana)	P	C	20-30'	W	Dr	Sun	D-M			D/M	Short lived found in thickets, old fields
Elderberry (Sambucus canadensis)	P	W	12'	W			M			M	Rich bottom/upland soils on steams
Flame-leaf Sumac (Rhus glabra)	P	C	15'	R						D/M	Open uplands, sandy soils
Red-osier Dogwood (Cornus stolonifera)	P		3-19'	W	flood, cold	Sun to p-Sh	W-M	5.5-7.0		D/M	Good screen, windbreak (generally a northern plant)
Chokecherry (Prunus virginiana)	P		6-10'	W	Dr		M			D	Bank stabilization, windbreaks Moist, well drained soils
Common Buckthorn * (Rhamnus cathartica)	P		22'	Y		Sun to p-Sh	D-W			D	Aggressive invasive, crowds out native plants. Soil tolerant
Button Bush (Cephalanthus occidentalis)	P	W	15'	w		Sun to p-Sh	M			M/W	Swamps, water edges
Gray Dogwood (Cornus racemosa)	P		15'	W		Sun to p-Sh	M-W			D/M	Prairie and stream bed invasive May need to control spread

TABLE 4A

PLANT RECOMMENDATIONS

Plant Species	Life Cycle	Season	Growth Height	Color of Flower	Resistance or Tolerance	Light	Moisture	pH	Rate (Pounds/Acre unless specifed)	Site Tolerance	Remarks

Life Cycle: A – Annual; B – Biennial; or P – Perennial

Season: C – Cool; or W – Warm

Growth Height: S – Short, < 2 ft.; M – Medium, 2-4 ft.; T – Tall, >4 ft. Tree and shrub heights are given.

Color of Flower: B – Blue; BG – Blue Green; Br - Brown; G – Green; OR – Orange; P – Purple; PK – Pink; R – Red; W – White; or Y – Yellow

Site Tolerance: D – Dry; M – Moist; S – Salt; or W - Wet

Planting Rates - Pounds of Seeds per Acre:
Certified Seed for Grasses, Sedges and Forbs: Pounds of PLS (Pure Live Seed) per Acre
Non-Certified Seed for Grasses, Sedges and Forbs: Pounds of BS (Bulk Seed) per Acre
Planting Rate - Number of Live Plants:
Wetland Species: Maximum number of stems per Acre – 2 X 2 ft. = 10,890/Ac
Shrubs: Maximum spacing per Acre – 6 X 6 ft. = 1210/Ac
Trees: Maximum spacing per Acre – 10 X 10 ft. = 436/Ac
Mixture of Trees and Shrubs: Maximum spacing per Acre – 6 X 10 ft. = 726/Ac

* Introduced plant, not native to North America

5.0 INITIAL MEASURES AND MINIMUM PRACTICES

The LS Method described in Section 4.0 is detailed and flexible enough for a wide variety of sites and developments. Communities may start with a simplified water quality management program that incorporates a few widely accepted BMPs, however. The minimum program includes:

- Introducing community-wide stream buffer systems through enactment of stream setback ordinances
- Applying soil protection and reconstruction to residential developments
- Capturing runoff from all impervious surfaces in non-residential developments using bioretention areas
- Discouraging or eliminating direct connections of impervious areas to storm drains.
- Regulating commercial and industrial “hot spots.”

Descriptions of these minimum practices follow. (General siting and design guidance are discussed in Sections 7 and 8, and detailed design specifications for each of these measures are included in Section 9. Standard specifications and plans are provided in Appendix A.)

Stream Buffers: Creating a system of stream buffers is an important first step. The “riparian zone” (the heavily vegetated strip along the fringe of a stream) is an integral part of the stream system. For example, preservation of a 100-foot riparian buffer—only about 5 percent of the land in a typical watershed—can yield disproportionate benefits. This buffer limits development in the floodplain and controls streambank erosion; it removes pollutants from adjacent properties; and it can serve as a greenway park (Haag, Mazzeo, and Schulte 2001). Buffers also provide financial returns to communities—research indicates that a comprehensive system of stream buffers that typically takes up about 5 percent of a community’s developable land may increase adjacent property values by as much as 33 percent (Chesapeake Bay Foundation 1996).

A comprehensive stream setback ordinance restricts use in the streamside zone over a given distance, usually in two to three zones that increase use flexibility farther from the stream. A number of models for setbacks and buffers are in several setback ordinances enacted in the Kansas City region. The U.S. Environmental Protection Agency (EPA) and Johnson County, Kansas, have developed a standard ordinance that cities throughout the region may adopt (Johnson County, Kansas 2001). Stream setbacks and buffers can be based on a set of generic assumptions about streams and developments or (preferably) on actual stream conditions documented through a natural resource inventory; clear and cost-effective stream assessment protocols have been developed and used throughout the MARC region (City of Lenexa, Kansas 2001; Patti Banks Associates). Sections 7 and 9 provide more information and design guidance for riparian buffer design.

Soil Preservation: The second measure to protect water quality is a development regulation requiring soil protection and restoration on all residential developments. Both stormwater runoff volumes and water quality are heavily influenced by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Preserving the soil's capacity to infiltrate precipitation is a relatively inexpensive non-structural measure that can be implemented as part of a development's sediment and erosion control program.

Urbanization shortens a watershed's response to precipitation mainly by reducing infiltration and decreasing travel time. An impervious surface decreases travel time by preventing infiltration and speeding runoff, and should be limited as much as is practical. However, most urban areas are only partially covered by impervious surfaces, and the soil remains an important factor in producing runoff. Natural infiltration rates to underlying soils are primarily influenced by soil type and by plant cover. Any disturbance of a soil profile by mixing native soil profiles, introducing off-site fill materials, and increasing soil compaction can significantly change infiltration characteristics (USDA 1986).

Restoring infiltration characteristics of the entire soil profile in residential areas (and other developments) after disturbance will also benefit water quality. These requirements can help residential developments maximally infiltrate stormwater for given vegetation and cover types without structural treatment measures. Communities could include this requirement in residential development codes or as part of sediment and erosion control specifications. The requirements can be applied easily to other developments as well. A detailed soil protection and restoration specification is in Section 9.

Bioretention: Stormwater runoff from impervious surfaces in non-residential land uses (commercial, office, and manufacturing) should be treated. These land uses generate more impervious surface than residential developments and this significantly impacts a community's water quality. Impervious area for residential land uses typically ranges from 12 to 65 percent, while industrial and commercial areas may include 72 to 85+ percent impervious area (USDA 1986). Because most pollutants originate from atmospheric deposition, impervious surfaces are the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996).

Communities can significantly impact their water quality by treating runoff from non-residential impervious surfaces such as rooftops and parking lots. MARC and APWA recommend that as part of their development code, communities require treatment of runoff from all new impervious surfaces by using bioretention areas (vegetated depressions designed to collect and treat runoff from the Water Quality Storm through an engineered matrix of soils and plant roots). Effective bioretention cells typically require only about 5 percent of the total impervious area. They are easily designed and planned as part of the site's required open space. In practice, these units are maintained in the same manner as decorative landscaped beds—minimizing maintenance costs and increasing value-added benefits. Implementing this one standardized practice in all developments can minimize design, inspection, and maintenance costs. Replacement of the systems may be needed every few years (initially at least).

Detailed construction guidance for bioretention is in Section 9, and standard specifications and plans are in Appendix A.

Eliminate Direct Connections: Direct connections include downspouts and sump pumps that flow directly onto pavement or that are piped into stormwater inlets. If this water is allowed to flow over pervious surfaces, some of the water will infiltrate. This measure requires close attention to site drainage patterns to minimize associated problems such as soggy yards.

Regulate "Hot Spots": Land uses that contribute greater concentrations of hydrocarbons, metals, and other pollutants are called "hot spots" and may require additional measures to manage the quality of their runoff (Claytor and Schueler 1996). Communities should require commercial and industrial hot spots to adopt industry-specific BMPs or should impose local regulations. Appendix D includes management practices for various land uses (adapted from the City of Portland, Oregon [2002]).

6.0 HYDROLOGY METHODS

Sizing BMPs properly is critical to their success. Design detention and retention BMPs to capture and treat the WQv. Design conveyance BMPs to handle peak discharge of the WQv. WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is based on the Water Quality Storm and volumetric runoff coefficient and site area. The Water Quality Storm is defined as the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis. The Water Quality Storm for the Kansas City Metropolitan Area is 1.37 inches (Young and McEnroe 2002).

Two methods can be used to estimate the WQv for a proposed development—the Short-Cut Method and the Small-Storm Hydrology Method. Use the Short-Cut Method (Claytor and Schueler 1996) only for sites with one predominant type of cover and a drainage area less than 10 acres:

$$WQv = P * Rv$$

where

WQv	=	Water Quality Volume
P	=	Rainfall event in inches (the Water Quality Storm or other appropriate amount, with the approval of the city engineer)
Rv	=	Volumetric runoff coefficient 0.05 + 0.009(I)
I	=	Percent site imperviousness

The Small Storm Hydrology Method (Claytor and Schueler 1996) is based on the volumetric runoff coefficient (Rv), which accounts for specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method may be used for all drainage areas. Rv's used to compute the volume of runoff are identified in Table 5. The Small Storm Hydrology Method is:

$$WQv = P * \text{Weighted } Rv$$

where

Weighted Rv	=	$\sum(Rv1*Ac1)+(Rv2*Ac2)+\ldots(Rv_i*Ac_i)$/Total Acreage
Rv_i	=	Volumetric runoff coefficient for impervious cover type *i*
Ac_i	=	Acreage of impervious cover type *i*
Total Acreage	=	Total acreage of the drainage area

A reduction factor may be applied to the Rv values for drainage areas with disconnected impervious surfaces. The pervious surface flow path below an impervious area must be at least twice the impervious flow path. The reduction factors are provided in Table 6.

TABLE 5

VOLUMETRIC COEFFICIENTS FOR URBAN RUNOFF FOR DIRECTLY CONNECTED IMPERVIOUS AREAS (CLAYTOR AND SCHUELER 1996)

Rainfall (inches)	Flat roofs and large unpaved parking lots	Pitched roofs and large impervious areas (large parking lots)	Small impervious areas and narrow streets	Silty soils HSG-B	Clayey soils HSG-C and D
0.75	0.82	0.97	0.66	0.11	0.20
1.00	0.84	0.97	0.70	0.11	0.21
1.25	0.86	0.98	0.74	0.13	0.22
1.50	0.88	0.99	0.77	0.15	0.24

TABLE 6

REDUCTION FACTORS TO VOLUMETRIC RUNOFF COEFFICIENTS FOR DISCONNECTED IMPERVIOUS SURFACES (CLAYTOR AND SCHUELER 1996)

Rainfall (inches)	Strip commercial and shopping center	Medium-to-high-density residential with paved alleys	Medium-to-high-density residential without alleys	Low-density residential
0.75	0.99	0.27	0.21	0.20
1.00	0.99	0.38	0.22	0.21
1.25	0.99	0.48	0.22	0.22
1.50	0.99	0.59	0.24	0.24

Note:

To use the reduction factors for disconnected impervious surfaces listed above, the impervious area uphill from a pervious area (a cover type that allows stormwater to infiltrate) should be less than one-half the area of the pervious surface, and the flow path through the pervious area should be at least twice the impervious surface flow path. For example, a 10-foot wide sidewalk would be a “disconnected impervious surface” if separated from the conveyance system by a 20-foot grassed strip or other pervious cover.

To size a conveyance BMP correctly, calculate the peak discharge for the Water Quality Storm. Use the following procedure for estimating the peak discharge for the Water Quality Storm (Claytor and Schueler 1996):

1. Calculate a Curve Number (CN) based on the previously calculated WQv:

$$CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25\ QP)^{1/2}]$$

where

P = Water Quality Storm rainfall (inches)
Q = Runoff volume (inches)—equal to WQv

2. Determine Time of Concentration (Tc):

$$Tc = (L^{0.8}[(1000/CN)-9]^{0.7})/(1140 * Y^{0.5})$$

where

Tc = Time of concentration (hours)
L = Flow length (feet)
CN = Runoff Curve Number
Y = Average watershed slope (percent)

Use a minimum of 0.01 hours for Tc.

3. Use Table 7 or TR-55 to determine Initial Abstraction (Ia).

TABLE 7

Ia VALUES FOR VARIOUS CURVE NUMBERS

Curve Number	Ia (in.)	Curve Number	Ia (in.)
61	1.279	78	0.564
62	1.226	79	0.532
63	1.175	80	0.500
64	1.125	81	0.469
65	1.077	82	0.439
66	1.030	83	0.410
67	0.985	84	0.381
68	0.941	85	0.353
69	0.899	86	0.326
70	0.857	87	0.299
71	0.817	88	0.273
72	0.778	89	0.247
73	0.740	90	0.222
74	0.703	91	0.198
75	0.667	92	0.174
76	0.632	93	0.151
77	0.597	94	0.128

4. Compute Ia/P and use Exhibit 4-II in TR-55 to determine the unit peak discharge (qu) for the appropriate Tc.

5. Calculate the peak discharge:

$$Qp = qu * A * WQv$$

where

Qp	=	Peak discharge (cubic feet per second [cfs])
qu	=	Unit peak discharge (cfs/ac/in)
A	=	Drainage area (acres)
WQv	=	Water Quality Volume (watershed inches)

For computing runoff volume and peak rate for storms larger than the Water Quality Storm, use the published CN's from TR-55, and follow the prescribed procedures in TR-55 or other approved methods.

7.0 GENERAL GUIDANCE FOR NON STRUCTURAL BMPS

Section 6 generally describes nonstructural and structural solutions preferred for stormwater management. These BMPs are recommended for use in conjunction with APWA Section 5600 or local regulations. The following paragraphs discuss in more detail nonstructural BMPs and how to apply them to site design and development. Subsections that ensue discuss how to use nonstructural BMPs to conserve various types of undisturbed areas and establish native landscaping in specific environments.

To preserve and promote native areas should be the main goal of a site development. During development, paved areas should be minimized. The more land kept in an undisturbed state or returned to a natural state through soil restoration and native landscaping, the more water will infiltrate—and thus minimize runoff, erosion, and potential for downstream pollution. Vegetation slows surface runoff; filters out sediment and sediment-bound pollutants; and encourages infiltration. Vegetation therefore reduces peak flows. Though preservation of existing vegetation is preferable in all circumstances, establishing native vegetation is considered equivalent if the site developer carefully restores the predevelopment soil profile, then selects and plants vegetation according to specifications in Section 9.

"Native species" exist where they have evolved. Their traits uniquely adapt them to local conditions. A site developer establishing or restoring native plant communities must maintain the relationship between plant species and their required site characteristics. Critical are plant species associations, slope, microclimate, hydrological regime, soil conditions, and available light. Identifying native plant species and understanding their complex community associations can be difficult enough to merit assistance from a professional horticulturist or botanist.

As developed areas expand, regions previously undisturbed come to need vegetation management and on-site soil protection to maintain or improve water quality. The site landscaping plan should reflect the local ecoregion (impacted or not) as a vital aspect of the site planning process. Vegetation conservation and stream buffers are two effective strategies to reduce surface runoff, improve water quality, and preserve current site conditions.

Vegetation conservation maintains predevelopment ground cover to minimize construction-site soil erosion in two ways. The more successful way is to use construction site phasing—disturbing only a portion of the site at any time. If phased site construction is not feasible, construction sites should remain void of vegetation after the grubbing process for a period longer than 14 days, during which the site is temporarily seeded. Both practices are detailed in Section 10.

7.1 UPLANDS

"Uplands" are lands elevated above bottomlands and floodplains that are neither deepwater aquatic habitats nor special aquatic sites; they are seldom or never inundated. Prairie grasses and a few tree species typically dominate undisturbed and native landscaped uplands. The prairie grasses can include, but are not limited to, Big Bluestem, Little Bluestem, and Canada wild rye. Tree species include, but are not limited to, Hickory, Oak, and Black Locust. See Section 9.3 for more information on native vegetation.

Undisturbed or native landscaped uplands can serve many BMP functions. They can help reduce erosion by protecting the underlying soil from splash erosion and slowing velocity of runoff. They can reduce off-site runoff by providing infiltration. They can filter sediment and other pollutants from stormwater runoff. They can also provide wildlife habitat and aesthetic values for the public.

Native prairie planting requires less maintenance than "tame" or domestic turf grass planting, reducing operations and maintenance costs. Native vegetation is also better suited than turf grasses for poor soils. Native grasses have deeper roots and can access more nutrients and water. Mowing and fertilizer application are not required to maintain a healthy stand of native vegetation. If controlled burning is not an option, mowing can control deciduous growth that may encroach on prairie plantings. See Table 4 for a list of native vegetation recommended for upland landscaping.

Design Criteria:

To establish native uplands, choose plant species suited to the location. Consider moisture regimes, soils, light levels, runoff properties (pollutants, concentrated flow, and sheet flow), intended land use, and level of maintenance. Determine seeding rates considering the intended purpose of the site. Decide how to apply the seed (for example, broadcasting, drilling, or hydroseeding). Determine correct fertilization rates, if required, by soil testing. Submit soil samples to a qualified laboratory or to the local county extension service for nutrient testing. Seedbed preparation is critical to success of plantings—so do not over compact the soil.

Maintenance:

Preserving existing upland native vegetation demands less maintenance than turf grass plantings or other landscaping, reducing operations and maintenance costs. Minimal mowing and herbicide application is needed to maintain a healthy stand of native vegetation. Some mechanical means may be necessary to control invasive species and preserve the health of the system. Minimal fertilization is required. Establishing native uplands necessitates that seeded areas be kept moist during the first weeks of establishment; mulch also may be needed. Reseeding may be necessary when the first seeding does not produce a vigorous stand.

Advantages of native upland cover:

- Preserves predevelopment hydrology effectively—especially streams, ponds and lakes
- Slows surface flows, promotes infiltration, and reduces erosion
- Traps sediment and sediment-bound pollutants
- Improves soil structure
- Transforms nutrients into usable forms and breaks down many pollutants (as do microorganisms)
- Typically requires less maintenance than non-native landscaping
- Preserves wildlife habitat and provides aesthetic and recreational benefits
- Requires significantly less expense
- May increase property values.

Limitations of native upland cover:

- Reduces the area of land available for development
- Limits construction to locations around open space
- May require a cover crop
- Cannot be established during winter.

7.2 STREAM BUFFERS

Stream buffers are important BMPs to be included when determining the proper package of BMPs (as directed in Section 4). They are defined as strips of heavy herbaceous and woody vegetation along streams (perennial and intermittent) and open bodies of water. They help reduce the impact of runoff by trapping sediment and sediment-bound pollutants; encouraging infiltration; and slowing and dispersing stormwater flows over a wide area. They help preserve streambank stability by reinforcing the soil with root systems. In addition, they provide detritus and biomass for aquatic and terrestrial habitat, shade cover to manage stream temperatures, and wildlife corridors (USDA 1999).

APWA Section 5605.3 specifies stream buffers for all drainage areas greater than 40 acres, and recommends that cities adopt comprehensive stream preservation and buffer zone requirements as part of their master plan. Stream buffer creation and maintenance also may be required and enforced by development codes and city ordinance.

APWA Section 5605.3 does not specify multiple zones. From a design perspective, stream buffers consist of minimally two zones; however, they are more effective if they have three zones. Zone 1 typically extends from the water's edge or top of bank for a set distance to protect the immediate streamside area, and is planted with fast growing tree and shrub species suited for the site. Activities and structures are most restricted in this zone. Zone 2 extends from the edge of zone 1 and includes slower growing tree species and shrubs. The width of zone 2 may be set or variable. No permanent structures are permitted in this zone, but more intensive activities may be permitted, such as hiking and biking trails. Where appropriate, zone 3 is upgradient of zone 2 and provides a buffer to protect zones 1 and 2. This zone may include more intensive activities such as residential landscaping, but no permanent structures. Design criteria from NRCS and Johnson County, Kansas are provided below. Table 4 shows recommended vegetation for stream buffers.

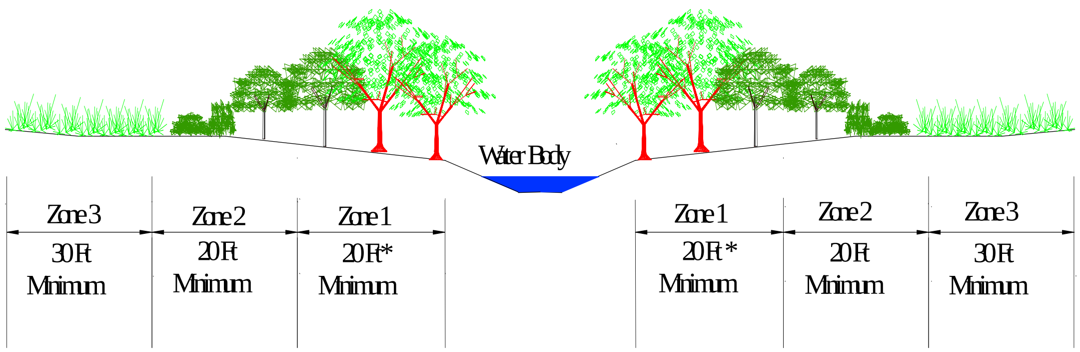
Design Criteria:

According to Section 5605.3, buffer widths as measured from the ordinary high water mark (OHM) outward in each direction shall exceed the following:

Contributing drainage basin size (acres)	Buffer width, from OHM outwards, measured separately in each direction
Less than 40	40 feet
40 acres to 160	60 feet
160 acres to 5,000	100 feet
Greater than 5,000	120 feet

Design criteria should be adapted to incorporate these minimum widths. According to NRCS design standards for Kansas, zone 1 shall begin at the waterline or top of bank and extend for a minimum of 15 feet. Where an active floodplain is connected to the water body, the combined widths of zones 1 and 2 should be the smaller of 30 percent of the floodplain or 100 feet. Runoff entering zone 3 of the buffer must be sheet flow. A flow spreader may be required to ensure that concentrated flows do not develop. The width of zone 3 must be 33 percent of the contributing area length with a minimum of 30 feet and a maximum of 120 feet. Zone 3 vegetation should include permanent herbaceous vegetation consisting of grasses, legumes, and forbs. NRCS specifies a minimum buffer width of 35 feet; however, the minimum width should be increased in keeping with Section 5600. When establishing a stream buffer, select appropriate methods of planting and seeding (USDA 1999). See Figure 4 for a stream buffer zone schematic.

Figure 4: Stream Buffer Zone Placement Example



Source: USDA 1999;
* modified in accordance with APWA Section 5605.3

The Stream Protection Guidelines for Johnson County, Kansas (2001) is somewhat more conservative by requiring a 25-foot minimum zone 1 and 25-foot minimum zone three, with a variable zone 2 based on actual site conditions. This model is an acceptable alternative to NRCS design guidance, provided that minimum buffer widths specified in Section 5605.3 are observed.

Maintenance:

During establishment of stream buffers, it may be necessary to replant or reseed areas that did not establish with the initial planting and/or seeding. Stream buffers should be inspected to guard against excessive damage from pedestrian and vehicular traffic, pest infestations, pesticides, herbicides, and wildlife. Replace dead trees and shrubs to improve vegetative health and prevent overpopulation of invasive species. Consider leaving debris from dead trees and shrubs for the benefit of wildlife habitat. Selectively harvest trees and shrubs in a manner that serves the intended purpose of the buffer. Mechanical means or prescribed burning may be necessary to manage zone 3 of the stream buffer.

Advantages of stream buffers:

- Most effectively preserve predevelopment hydrology—especially streams, ponds, and lakes
- Slow surface flows, which promotes infiltration and reduces erosion
- Trap sediment and sediment-bound pollutants
- Improve soil structure
- Transform nutrients into usable forms and break down pollutants via actions of microorganisms and plants
- Preserve wildlife habitat and provide aesthetic and recreational benefits
- May lower water temperature
- Provide floodplain protection from erosion.

Limitations of stream buffers:

- Reduce amount of developable land
- Limit construction to locations around open spaces
- May require a cover crop in zone 3
- Cannot be established during winter.

7.3 BOTTOMLANDS AND FLOODPLAINS

Bottomlands are defined as low-lying lands along a watercourse that floods frequently. The floodplain is a level surface of stratified alluvial soils on either side of a watercourse; it is typically built up by silt and sand, carried out of the main channel, and submerged during times of flood. Undisturbed bottomlands and floodplains typically host a diverse collection of vegetative species.

Preserving bottomland and floodplain vegetation during development maintains a natural buffer that can: (1) filter out sediment from runoff before it enters the watercourse; and (2) reduce the velocity of surface water runoff, thus decreasing the potential for erosion.

Typically, soils near a watercourse in the floodplain have high water tables and low bearing strength. Along with the prospect of frequent flooding, this limits construction feasibility and encourages preservation of bottomlands and floodplains.

The habitat of bottomlands and floodplains often provides a desirable environment for aquatic and terrestrial wildlife, giving the public an opportunity for recreations such as fishing or observing wildlife.

Maintenance:

It may be necessary to replant or reseed areas damaged by excessive pedestrian or vehicular traffic, pest infestations, pesticides, herbicides, or wildlife. Replace dead trees and shrubs to prevent overpopulation of undesirable species. Consider leaving debris from dead trees and shrubs for the benefit of wildlife habitat. Selectively harvest trees and shrubs in a manner that serves the intended purpose. Mechanical means or prescribed burning may be necessary to manage the area.

Advantages of bottomlands and floodplains:

- Most effectively preserve predevelopment hydrology
- Slow surface flows, which promotes infiltration and reduces erosion
- Trap sediment and sediment-bound pollutants
- Improve soil structure
- Host microorganisms and plants that transform nutrients into usable forms and can break down pollutants
- Preserve wildlife habitat and provide aesthetic and recreational benefits.

Limitations of bottomlands and floodplains:

- Reduce amount of developable land
- Limit construction to locations around open space.

8.0 GENERAL GUIDANCE FOR STRUCTURAL BMPS: ENGINEERED SYSTEMS

If minimizing site disturbance and introducing native landscaping practices are not feasible during site development, select engineered practices to promote infiltration and water treatment. Structural BMPs differ from nonstructural practices in that they are engineered to manage stormwater for water quality treatment. Many structural BMPs ally native vegetation with man-made materials and engineered subgrades to help control runoff.

As described in Section 5, structural BMPs may promote infiltration, filtration, and detention. BMPs that promote infiltration include, but are not limited to, bioretention, infiltration trenches, pervious pavement, rain gardens, and sand filters. Structural BMPs that provide on-site filtration include bioretention, engineered swales, and sand filters. On-site stormwater detention is storage of excess runoff before its entry into a principal drainage system. Wet ponds, wetlands, dry basins, and parking lots are examples of detention practices. Incorporate them into the site design to preserve native landscaping when infiltration practices are not feasible.

The following design guidance is prepared using information from a variety of sources and the authors' professional experience. Unless otherwise noted, one or several of the following references were consulted for each of the BMPs included in this section:

- Claytor, Richard A. and Thomas R. Schueler. 1996. *Design of Stormwater Filtering Systems*. Center for Watershed Protection. December.
- Urban Drainage and Flood Control District, Denver, Colorado. 1999. U*rban Storm Drainage Criteria Manual Vol. 3 – Best Management Practices*. September.
- U. S. Department of Interior. 1963. *Hydraulic Design of Stilling Basins and Energy Dissipaters*. Bureau of Reclamation. July.
- U. S. Department of Transportation. 1983. *Hydraulic Engineering Circular No. 14 – Hydraulic Design of Energy Dissipaters for Culverts and Channels*. Federal Highway Administration. September.
- U.S. Department of Agriculture (USDA). 1999. *Kansas Field Office Technical Guide*. Natural Resources Conservation Service. July.
- U.S. Department of Agriculture (USDA). 1997. *National Engineering Handbook, Part 650 – Engineering Field Handbook, 210-VI-Amendment KS1*. Natural Resources Conservation Service. June 25.
- USDA. 1986. *Urban Hydrology for Small Watersheds, Technical Release 55*. Natural Resources Conservation Service. June.

- USDA. 1972. *National Engineering Handbook, Part 630 – Hydrology*. Natural Resources Conservation Service.
- USDA. 1966. *Handbook of Channel Design for Soil and Water Conservation*. Natural Resources Conservation Service.

8.1 VEGETATED SWALES

Vegetated swales are broad shallow channels with a dense stand of vegetation covering the side slopes and channel bottom. Design them to store temporarily the WQv and slowly convey excess stormwater runoff—and in the process trap pollutants, promote infiltration, and reduce flow velocities. Vegetated swales can be either wet or dry. Use dry swales in areas where standing water is undesirable, such as residential areas. Dry swales typically have underdrain systems installed under the soil bed to convey the treated stormwater back into the stormwater drainage system. Unlike dry swales, wet swales do not have an underlying filtering system. Use swales where standing water does not create a nuisance and where the groundwater level is close enough to the surface to maintain the permanent pool in inter-event periods.

Rather than routing stormwater runoff into a lined channel or into a curb or gutter system, consider a natural conveyance channel such as a swale. Vegetated swales promote infiltration and also help filter and settle out many particulate contaminants. Do not use swales as a BMP component to convey deep concentrated flow; swales are only effective when conveying shallow concentrated flow. Take care to identify the proper location for a swale. Minimizing the amount of disturbance to the area greatly enhances the swale's ability to remove contaminants. Select grass and plant species that tolerate low maintenance, can survive without significant human influence, and survive periods of inundation (see Table 4). Figure 5 illustrates a typical dry swale. Figure 6 illustrates a typical wet swale.

Design Criteria:

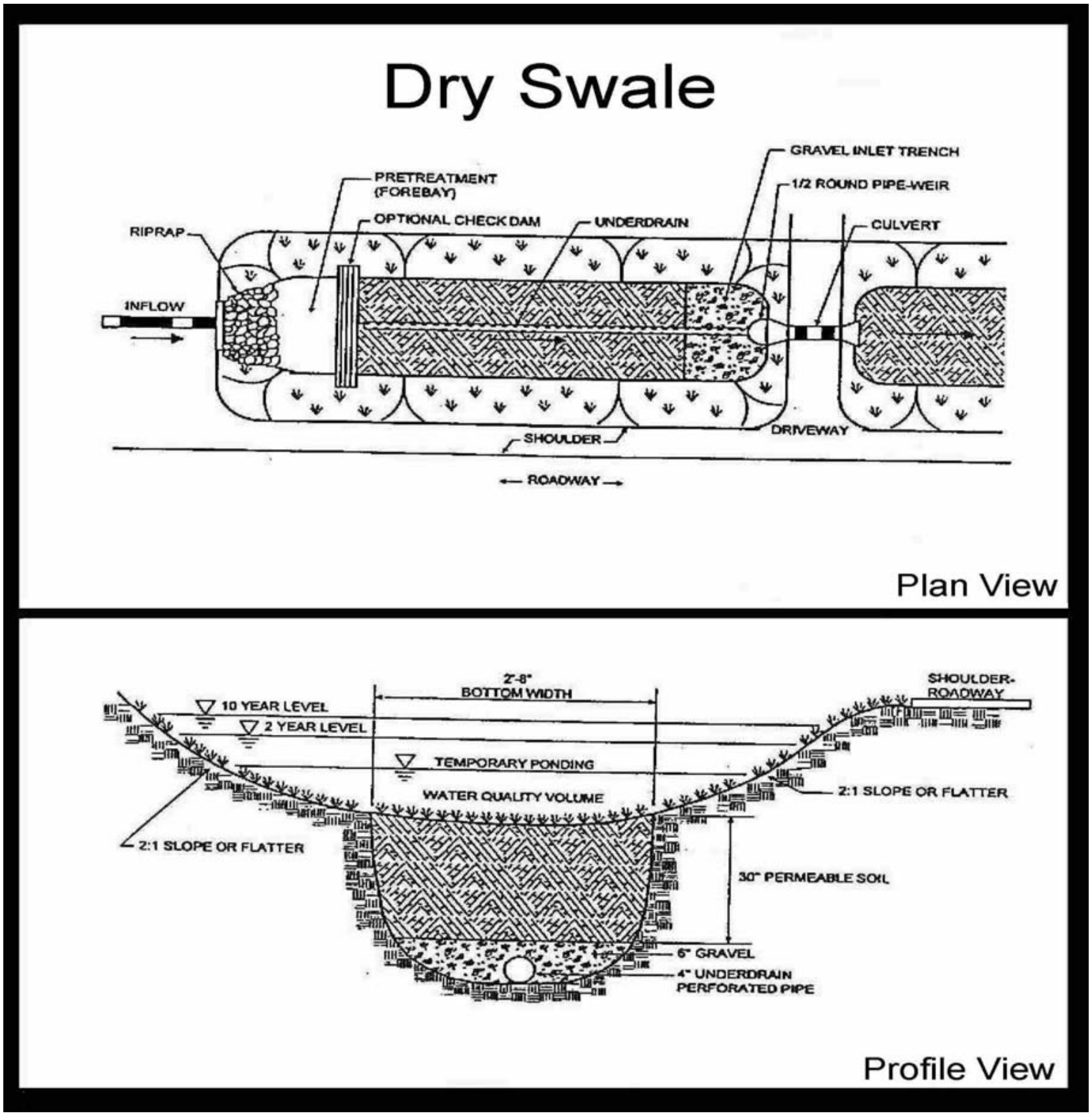
The swale shape may be parabolic or trapezoidal. The bottom width of trapezoidal swale should support infiltration and adequate contact without causing braiding. Bottom widths should not exceed 2 feet. Swales must have adequate capacity for the WQv with a maximum ponding of 18 inches. Design outlet structures in the swale so that the WQv is released within 24 hours. Maximum permissible velocities of flow for the 2-year, 24-hour event depend on channel vegetation and soils, and should not exceed 3 feet per second; flows for the 10-year storm event generally should not exceed the values shown in Table 6. Swale vegetation can be classified into five general retardance curves, A through E (NRCS 1987).

Vegetative retardance A represents thick tall (over 18 inches) vegetation. Vegetative retardance E represents short vegetation such as a lawn. Calculate velocities in the channel using short grass conditions—vegetative retardance E or equivalent n value. Calculate capacity in the channel for the 10-year storm using vegetative retardance B or equivalent n value. Provide a minimum of 1 foot of freeboard in addition to the capacity of the 10-year, 24-hour storm. Longitudinal slope of the swale should not exceed 2 percent with the side slopes not exceeding 3 to 1 (horizontal to vertical), although flatter side slopes are preferred. If the longitudinal slopes exceed 2 percent, install check dams. A sediment forebay should be installed at the inlet of the swale if significant sediment loadings from up-gradient sources are projected. Design swale outlets to avoid scour erosion. The soil for a dry swale should consist of moderate-to well-drained material a minimum of 30 inches deep with an underdrain. Soils in a wet swale should be in-situ. Select vegetation in a dry swale by its ability to withstand periods of inundation and drought. Select wet swale vegetation based on periods of long-term inundation (see Table 4).

Maintenance:

The following is a partial list of maintenance procedures to upkeep swales properly:

- Control vegetation by mowing or grubbing techniques (not by chemicals). Remove any clippings.
- After major rain events, check the swale for any developing erosion problems.
- If heavy sediment loading occurs, remove excess particulates from the swale.



Source: CWP 1996

Figure 5 – Dry Swale Plan and Profile Example (For Informational Purposes Only)

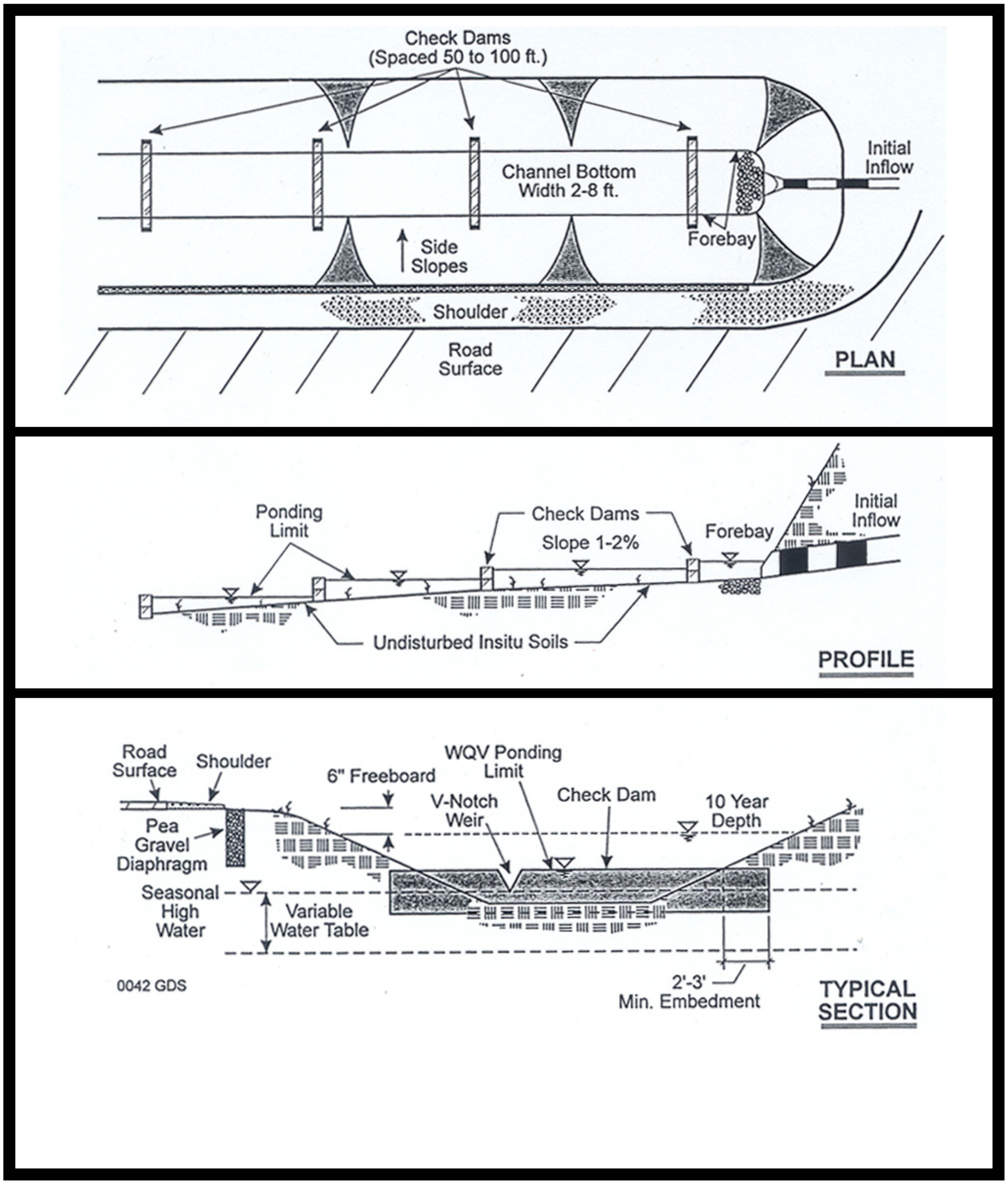


Figure 6 – Wet Swale Plan and Profile Example (For Informational Purposes Only)

TABLE 8

PERMISSIBLE VELOCITIES IN VEGETATED SWALES

Vegetation Type	Slope Range (%)	Permissible Velocity (feet per second)	
		Erosion Resistant Soils	Easily Eroded Soils
Bermuda Grass	<5 5 – 10 Over 10	7 6 4	5 4 3
Buffalo Grass Kentucky Blue Grass Smooth Brome Blue Grama Tall Fescue	<5 5 – 10 Over 10	5 5 5	5 4 3
Grass Mixture Reed Canarygrass	<5 5 – 10	5 4	4 3
Redtop Alfalfa Red Fescue Small Grains	<5	3.5	2.5
Other native grasses not listed above			

Notes:

1. Erosion resistant soils are defined as cohesive (clayey) fine-grain soils and coarse grain soils with cohesive fines with a plasticity index of 10 to 40 (CL, CH, SC, and CG).
2. Use small grains only for temporary seeding.

Advantages of vegetated swales:

- Constructed less expensively and maintained more easily than underground pipes
- Improve water quality by settling out particulate contaminates and increasing infiltration
- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing conveyance of water.

Limitations of vegetated swales:

- May require irrigation to ensure proper ground cover for controlling erosion and reducing pollution in the swale
- May not be feasible to implement after development has occurred

- Require relatively large areas, proper sloping, and connection to other conveyance components
- Not the fastest conveyance method—carefully design and place swales to minimize risk of flooding.

8.2 VEGETATED CHANNELS

Vegetated channels are broad, shallow, natural, or constructed channels with a dense stand of vegetation covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Vegetated channels can have either parabolic or trapezoidal cross sections. Channels are well suited for roadside applications. Unlike a dry swale, a vegetated channel does not include a prepared soil filter bed.

Rather than routing stormwater runoff into a lined channel or into a curb-gutter system, consider using a natural conveyance channel. Vegetated channels promote infiltration and also help settle many particulate contaminants. Do not use channels as a BMP component to convey deep concentrated flow; channels are only effective conveying shallow concentrated flow. Take care to identify the proper location for a vegetated channel. Minimizing disturbance to the area (for example, avoiding application of pesticides and herbicides) maintains the channel's ability to remove contaminants. Select grass and plant species that tolerate low maintenance and can survive without significant human influence. Figure 7 illustrates a typical vegetated channel.

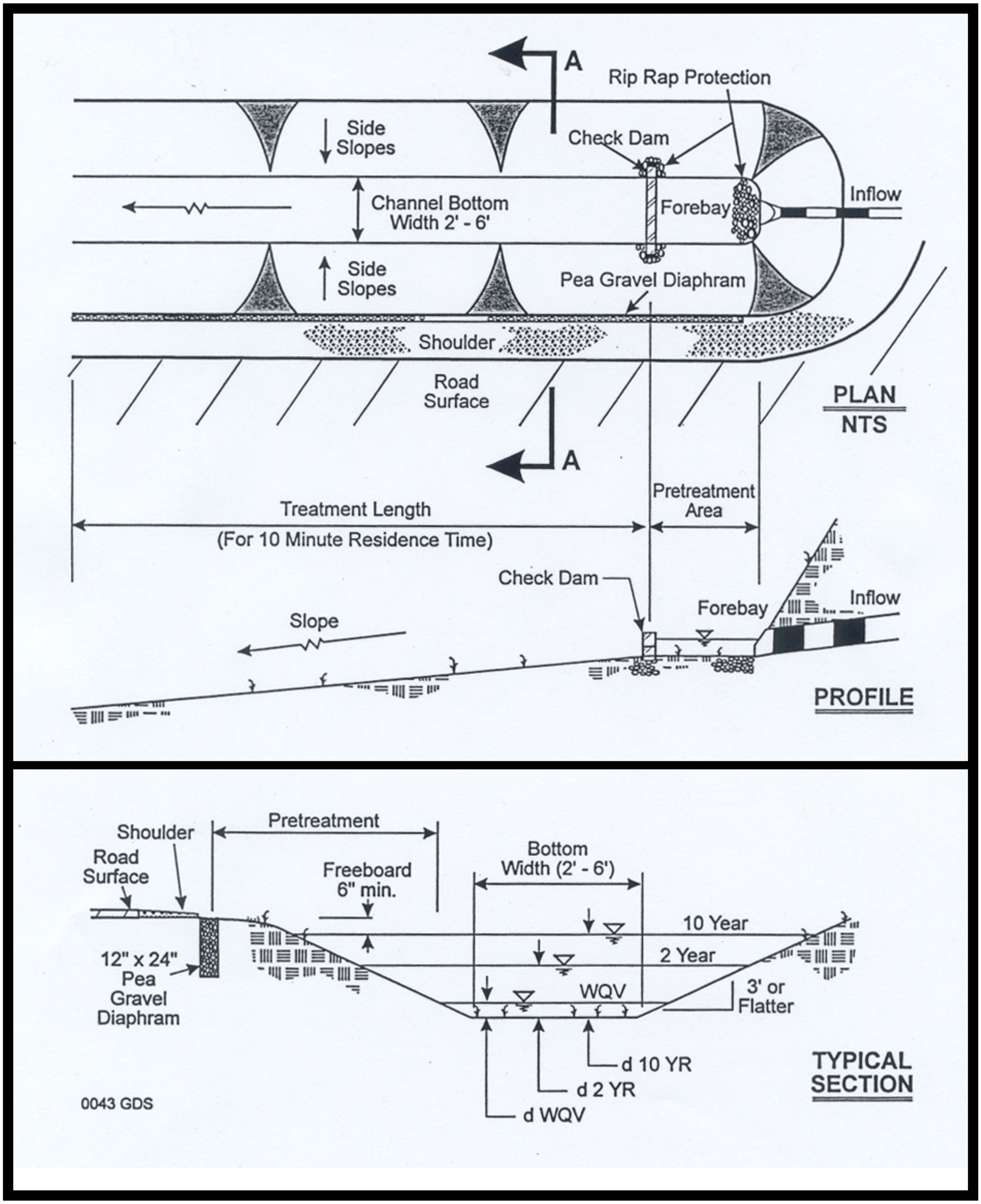
Design Criteria:

Vegetated channel shape may be parabolic or trapezoidal. Vegetated channels should carry the peak runoff from the water quality storm. The water quality storm shall move no faster than 1 foot per second at a maximum flow depth of 4 inches though a channel length sufficient to provide a minimum contact time of 10 minutes. Maximum permissible velocities of flow for the 2-year, 24-hour event are the same as for vegetated swales. Maximum velocities depend on channel vegetation and soils; they should not exceed 3 feet per second. Flows for the 10-year storm event generally should not exceed the values shown in Table 8. Channel vegetation can be classified into five general retardance curves, A through E (USDA 1997). Vegetative retardance A represents thick, tall (over 18 inches) vegetation. Vegetative retardance E represents short vegetation such as a lawn. If multiple reaches are designed in the channel, velocities should increase in each downstream reach. If reduction of the velocity is required, it should not exceed 25 percent. Calculate velocities in the channel using short grass conditions, vegetative retardance E, or equivalent n value. Calculate capacity in the channel for the 10-year storm using vegetative retardance B or equivalent n value. Provide a minimum of 1 foot of freeboard in addition to the capacity of the 10-year, 24-hour storm. Longitudinal slope of the channel should not exceed 5 percent with the side slopes not exceeding 3 horizontal to 1 vertical, although flatter side slopes are preferred. If the longitudinal slopes exceed 5 percent, install check dams. Install a sediment forebay at the inlet of the channel. Design channel outlets to avoid scour erosion. Select vegetation in a channel by its ability to withstand periods of inundation and drought (see Table 4).

Maintenance:

The following is a partial list of actions to upkeep channels properly.

- During establishment of vegetation, inspect the channel for erosion after every rainfall event and repair as necessary.
- Control vegetation by mowing or grubbing techniques (not by chemicals).
- After major rain events, check the channel condition to identify any developing erosion problems.
- If heavy sediment loading occurs, clean the channel to remove excess particulates.



Source: CWP 1996

Figure 7 – Vegetated Channel Plan and Profile Example (For Informational Purposes Only)

Advantages of vegetated channels:

- Constructed less expensively and maintained more easily than underground pipes
- Improve water quality by settling out particulate contaminates and increasing infiltration
- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing the conveyance of water.

Limitations of vegetated channels:

- May require irrigation to maintain proper vegetative cover for controlling erosion and reducing pollution in the channel
- May not be feasible to implement after development has occurred
- Require relatively large areas, proper sloping, and connection with other conveyance components
- Not designed to be the fastest conveyance method and, therefore, require exact placement and design to minimize risk of flooding.

8.3 FILTER STRIPS

Filter Strips are grassed practices that accept sheet flow runoff from adjacent surfaces. They slow runoff; filter out sediment and other pollutants; and enhance infiltration of surface water runoff. Use filter strips to treat shallow sheet flows and evenly distribute storm flows over very short contributing distance areas. Filter strips are well suited to areas adjacent to parking lots and other impervious surfaces where runoff can be conveyed and filtered before it is discharged into swales, storm sewers, or surface water bodies. Filter strips are also appropriate for construction sites and developing land to filter sediment from overland sheet flow.

A common design for a filter strip includes several components. Runoff from an impervious surface is collected into a sediment forebay or a stone trench and enters the vegetated filter strip over a flow spreader device to ensure sheet flow. The WQv is stored temporarily within a shallow ponding area. Figure 8 illustrates a typical filter strip.

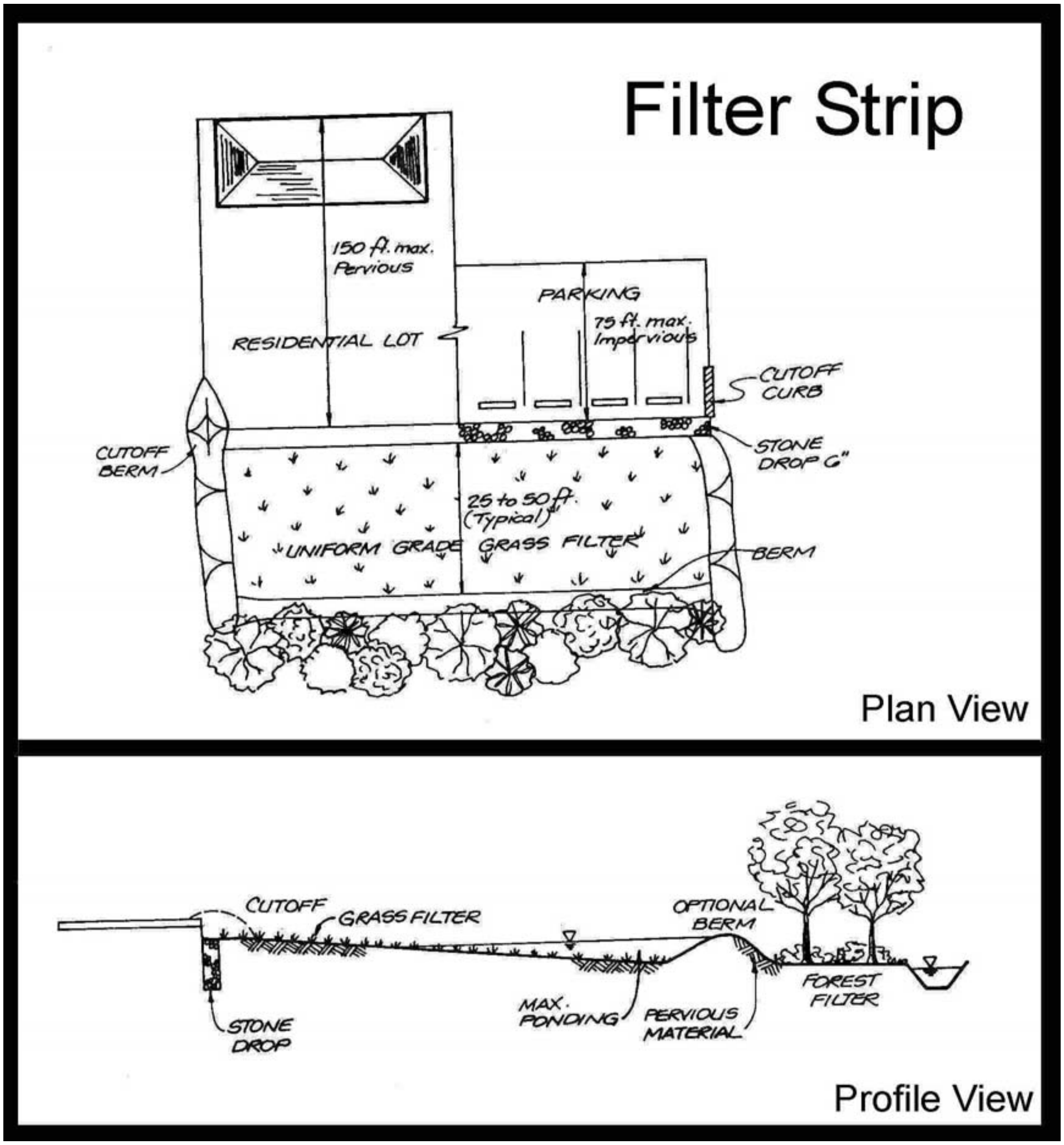
Design Criteria:

The maximum drainage area into the filter strip should be 5 acres. The filter strip width (dimension perpendicular to the flow path) shall be as close to the width of the impervious area flowing into the filter strip as practical. The filter strip length (dimension parallel to flow) depends on the filter strip width and drainage area. The filter strip length should be at least half the unit area length. Calculate unit area length dividing the drainage area (in square feet) by the filter strip width. Generally, the minimum filter strip length shall be 5 feet except on construction sites, where the minimum length shall be 25 feet (see APWA, Section 5100). The maximum slope of a filter strip should be 6 percent, unless additional flow spreader devices are installed every 100 feet to maintain sheet flow. Provide sufficient slope for temporary storage of the WQv. Design outlets to release the WQv in less than 24 hours. Furnish overflow or bypass systems for storms larger than the WQv. Maximum flow velocities on the filter strip for the 10-year, 24-hour storm should not exceed the velocities shown in Table 9 using vegetative retardance D or equivalent n value. Be sure filter strip vegetation is fully established before directing surface runoff onto the filter strip. Select vegetation for the filter strip by its ability to withstand high velocities and short periods of ponding (see Table 4). Do not construct vegetated filter strips within the floodplain of a natural channel.

Maintenance:

The following is a partial list of actions to upkeep filter strips:

- During establishment of vegetation, inspect the filter strip for erosion after every rainfall event and repair as necessary.
- To maximize nutrient uptake, harvest vegetation by mowing or grubbing techniques, or by burning (not by chemicals). Remove clippings from the filter area.
- Protect filter strips from heavy foot or vehicular traffic during construction to prevent overcompaction and loss of infiltration capacity.
- If heavy sediment loading occurs, clean the forebay to remove excess particulates.
- Aeration may be necessary if the underlying soils have high clay content.



Source: CWP 1996

Figure 8 – Vegetated Filter Strip Plan and Profile Example (For Informational Purposes Only)

TABLE 9

PERMISSIBLE VELOCITIES IN VEGETATED FILTER STRIPS

Vegetation Type	Slope Range (Percent)	Permissible Velocity (Feet per second)	
		Erosion Resistant Soils	**Easily Eroded Soils**
Bermuda Grass	<5 5 – 10 Over 10	7 6 4	5 4 3
Buffalo Grass Kentucky Blue Grass Smooth Brome Blue Grama Tall Fescue	<5 5 – 10 Over 10	5 5 5	5 4 3
Grass Mixture Reed Canarygrass	<5 5 – 10	5 4	4 3
Redtop Alfalfa Red Fescue Small Grains	<5	3.5	2.5

Notes:

1. Erosion resistant soils are defined as cohesive (clayey) fine-grain soils and coarse-grain soils with cohesive fines with a plasticity index of 10 to 40 (CL, CH, SC, and CG).
2. Use small grains only for temporary seeding.

Advantages of filter strips:

- Improve water quality by settling out particulate contaminates and increasing infiltration
- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing the conveyance of water
- May help maintain temperature norm of receiving water.

Limitations of filter strips:

- Need to maintain vegetative cover for controlling erosion and reducing particulates in the runoff
- May not be feasible to implement after development has occurred
- Not appropriate for hilly or highly impervious terrain
- Need to maintain sheet flow in the filter strip
- Best implemented as part of a treatment train.

8.4 INFILTRATION PRACTICES

Infiltration practices include infiltration basins, pervious pavement, bioretention areas, rain gardens, and infiltration trenches or wells. An infiltration BMP captures a volume of stormwater runoff, retains it, and infiltrates that volume into the ground. Infiltrating stormwater has advantages and disadvantages. The advantages include water quantity control and water quality control. Water quantity control can occur by infiltrating surface runoff into the underlying soil. This reduces the volume of water discharged to receiving streams, thereby reducing some harmful impacts of excess flow and increased pollutant concentrations in the receiving stream. Design infiltration systems to capture and infiltrate water into the ground over a period of several hours or even days, thereby maximizing infiltrative capacity of the BMP. Infiltration BMPs can also provide water quality treatment. Pollutant removal can occur as water percolates through the various soil layers. As the water moves through the soil, particles can be filtered out. In addition, microorganisms in the soil can degrade organic pollutants contained in the infiltrated stormwater.

Infiltration of stormwater also has some drawbacks. It may not be appropriate in areas where groundwater is a primary source of drinking water because of potential for contaminant migration. This is especially apt if the runoff is from a commercial or industrial area with potential for contamination by organics or metals. Also, performance of infiltration BMPs is limited in areas with poorly permeable soils. In addition, infiltration BMPs can undergo reduced infiltrative capacity and even clogging due to excessive sediment accumulation. Frequent maintenance may be required to restore the infiltrative capacity of the system. Care should be taken during construction to limit compaction of the soil layers underlying the BMP. Excessive compaction due to construction equipment may reduce infiltrative capacity. Excessive sediment generation during construction, site grading, and stabilization may cause premature clogging of the system. Do not place infiltration systems into service until dense vegetation or grasses have stabilized disturbed areas in the tributary area.

8.5 INFILTRATION BASINS

Infiltration basins are earthen structures that capture a stormwater runoff volume, hold this volume, and infiltrate it into the ground over a period of days. Infiltration basins are almost always placed off-line, and are designed only to intercept a certain volume of runoff. Any excess volume is bypassed. Vegetated infiltration systems help to prevent migration of pollutants; the roots of the vegetation can increase the permeability of the soils, thereby increasing the basin's efficiency. Infiltration basins typically are not designed to retain a permanent pool volume. Their main purposes are to transform a surface water flow into a groundwater flow and to remove pollutants through mechanisms such as filtration, adsorption, and biological conversion as the water percolates through the underlying soil. Design infiltration basins to drain within 72 hours to prevent mosquito breeding and potential odors from standing water, and to prepare the basin to receive runoff from the next storm (US EPA 1993a). Infiltration basins are also useful to help restore or maintain predevelopment hydrology in a watershed. Infiltration can increase the water table, increase baseflow, and reduce the frequency of bank-full flooding events. Infiltration basins are not well suited for drainage areas that deliver high concentrations of sediments. They are best used as a BMP toward the end of the treatment train. If groundwater is close to the surface, do not use an infiltration basin.

Typical components of an infiltration basin include an inlet, sediment forebay, level spreader, principal spillway, a backup underdrain, emergency spillway, and a stilling basin. Figure 9 illustrates a typical infiltration basin.

Design Criteria:

Restrict the contributing drainage area to any infiltration basin to 2 acres or less. Locate basins at least 150 feet away from drinking water wells to limit the possibility of groundwater contamination, and at least 10 feet downgradient and 100 feet upgradient from building foundations to avoid potential seepage problems. The length-to-width ratio for an infiltration basin should be 3:1 or greater. Grade the basin as flat as possible to provide uniform ponding and infiltration of the runoff across the floor. Be sure the side slopes of the basin are no steeper than 3 horizontal to 1 vertical (flatter slopes are preferred) to allow for proper vegetative stabilization, easier mowing, easier access, and better public safety. Select vegetation for the infiltration basin by its ability to withstand wet weather, drought, and short periods of ponding (see Table 4). Design the infiltration basin to store temporarily and infiltrate the WQv. The maximum depth of 2 feet and ponding time of the infiltration area should promote the survival of vegetation. Determine the ponding time by plant inundation tolerances—it must be no greater than 72 hours. Conservative estimates of soil infiltration rates are in county soil surveys published by the U.S. Department of Agriculture or are obtainable by field testing methods. After determining the infiltration rate of the soil, calculate the maximum depth of the infiltration basin using the following equation:

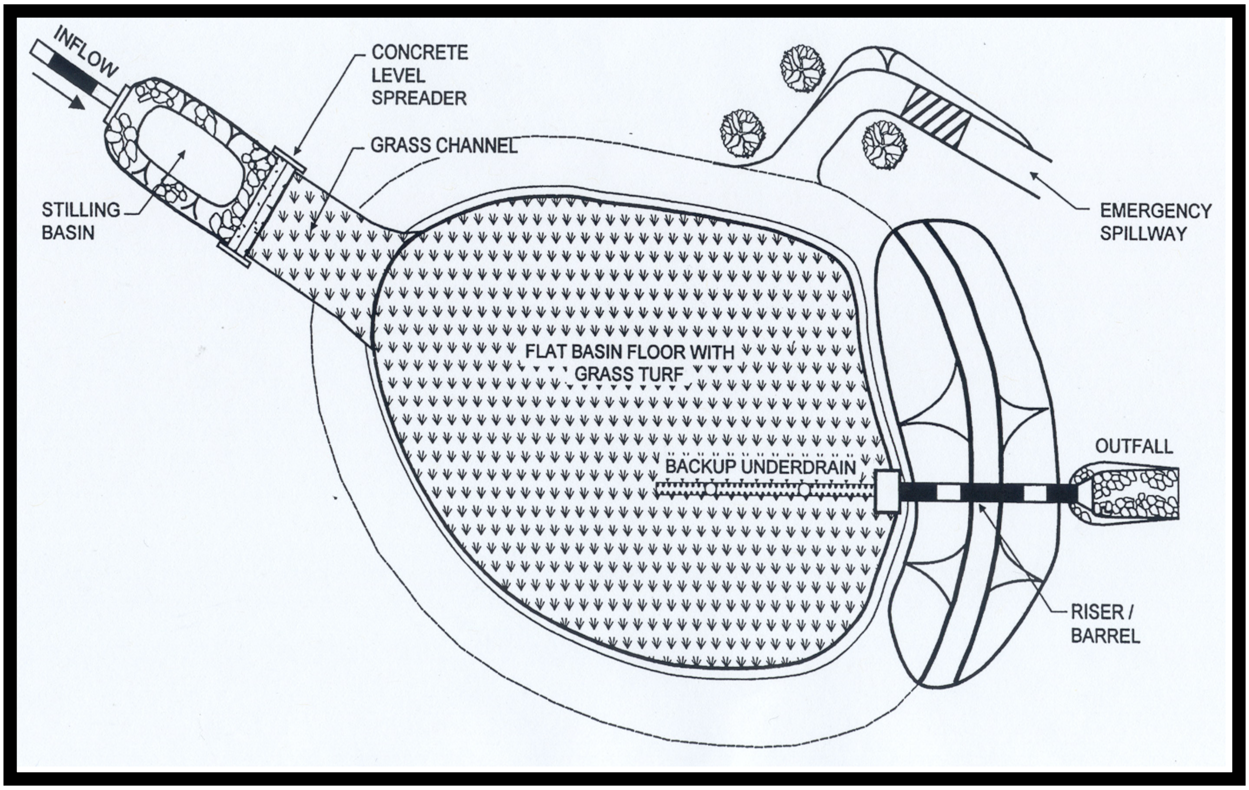
$$d_{\max} = (f)(T_p)$$

where:

$d_{\max}$ = maximum design depth (inches)
f = soil infiltration rate (inches/hour)
T_p = design ponding time (hours)

Since infiltration basins are susceptible to high failure rates due to clogging from sediments, pretreating stormwater is necessary to remove as many suspended solids from the runoff as possible before the runoff enters the basin. The design of infiltration basins should include an appropriate combination of grit chambers (for pretreating), swales with check dams, filter strips, or sediment forebays and traps. Figure 9 shows an infiltration basin with pretreatment via a stilling basin.

If runoff is delivered by a storm drainpipe or along the main conveyance system, design the infiltration practice as an off-line practice. To prevent incoming flow velocities from reaching erosive levels, stabilize inlet channels to the basin with rip rap or other suitable methods, and design inlet channels to terminate in a broad apron (spreads the runoff more evenly over the basin surface to promote better infiltration). Incorporate a bypass flow path or pipe in the design to convey high flows—from storms larger than the water quality storm—around the basin. All basins must have an emergency spillway capable of passing runoff from the 25-year, 24-hour storm without damage to the impounding structure.



Source: CWP 1996

Figure 9 – Typical Infiltration Basin (For Informational Purposes Only)

Maintenance:

The following is a partial list of actions for proper upkeep of infiltration basins:

- Inspect and clean pretreatment devices associated with basins at least twice a year, and ideally every other month.
- Following every major storm for the first few months after the basin has gone on-line, perform inspections to maintain proper stabilization and function. Pay attention to how long water remains standing in the basin after a storm; standing water within the basin more than 72 hours after a storm indicates the infiltration capacity may have been overestimated. Repair factors responsible for clogging (such as upland sediment erosion and excessive compaction of soils) immediately. Inspect newly established vegetation several times to determine if any remedial actions (reseeding, irrigation, and so on) are necessary.
- Thereafter, inspect the infiltration basin at least twice per year for differential accumulation of sediment, erosion of the basin floor, condition of riprap, and the health of the vegetation.
- Replant eroded or barren spots immediately after inspection to prevent additional erosion and accumulation of sediment.
- Remove sediment within the basin when the sediment is dry enough to crack and readily separates from the basin floor.

- To remove the top layer of sediment, use light equipment that will not compact the underlying soil.

- Control weed growth to maintain vegetation.

Advantages of infiltration basins:

- Reduce the volume of runoff from a drainage area

- Effectively remove fine sediment, trace metals, nutrients, bacteria, and oxygen-demanding substances (organics)

- Reduce downstream flooding and protect streambank integrity

- Reduce the size and cost of downstream stormwater control facilities and storm drain systems by infiltrating stormwater in upland areas

- Provide groundwater recharge and baseflow in nearby streams

- Reduce local flooding.

Limitations of infiltration basins:

- Have potentially high failure rates due to improper siting, design, and lack of maintenance—especially if pretreatment is not incorporated into the design

- Carry a risk of groundwater contamination, depending on soil conditions and groundwater depth.

- Have potential for clogging—not appropriate for treating significant loads of sediment and other pollutants

- Are not appropriate for industrial or commercial sites where release of large amounts or high concentrations of pollutants are possible

- Require flat continuous area

- Require frequent inspection and maintenance

- Have effectiveness limited to small sites (2 acres or less).

8.6 INFILTRATION TRENCHES

Infiltration trenches are defined as excavated trenches filled with coarse granular material; they collect stormwater runoff for temporary storage and infiltration. Typically, infiltration trenches and wells can capture only a small amount of runoff and therefore may be designed to capture the first flush of a runoff event rather than the full WQv. For this reason, they frequently are combined with another BMP such as a detention basin to control peak hydraulic flows. Infiltration trenches and wells can remove suspended solids, particulates, bacteria, organics, soluble metals, and nutrients through mechanisms of filtration, absorption, and microbial decomposition.

Infiltration trenches promote groundwater recharge. But, as with all infiltration practices, the possibility for groundwater contamination must be considered where groundwater is a source of drinking water. Infiltration trenches also do not filter coarse sediments.

Infiltration trenches should have approximate depth of 3 to 8 feet. Design the volume of the trench to accommodate the water quality storm runoff per tributary acre within the depth of 3 to 8 feet. A standard length-to-width ratio is not recommended, since the infiltration rate of the soil dictates the dimensions of the trench.

Typical applications of infiltration trenches include runoff treatments for residential lots and small commercial lots. In densely populated areas where undeveloped land area is scarce, infiltration basins may not be practical or effective. For these areas, infiltration trenches should become part of a developer’s initial master plan of future development.

Locate infiltration trenches where the contributing drainage area is 5 acres or less; slopes are 5 percent or less; and surrounding soils have less than 40 percent clay and permeability rates of 0.5 to 2.0-inches per hour. The surrounding soil should also have a high, available, water-holding capacity.

A typical cross section for an infiltration trench includes filter fabric lined trench, optional underdrain, and coarse granular material topped with clean compacted soil or gravel that can be planted with various species of vegetation. The clean stones’ diameters should be 1.5 to 2.5-inches. Install the optional underdrain to convey excess stormwater to the storm drain system. Install an observation well in conjunction with an infiltration trench. Install overflow devices so that storm events can bypass the infiltration trench to a safe point downstream.

Do not use limestone or shale as backfill material of the infiltration trench, because they may cement over time. The filter fabric should be permeable enough for the trench to drain the design storm within 72 hours.

Stabilize the contributing drainage area for erosion control before installing an infiltration trench. Use multiple pretreatment techniques together with infiltration trenches to eliminate potential clogging and to increase the lifespan of the trench. Install a 20-foot-minimum wide grass filter upslope of the infiltration trench to help remove coarse sediments from the stormwater. Figure 10 illustrates a typical infiltration trench.

Estimates indicate that infiltration trenches can remove 95 percent of suspended solids, 42 percent of phosphorous, and 42 percent of nitrogen in the stormwater (Claytor and Schueler 1996). Do not use them to treat highly contaminated runoff.

Design Criteria:

Restrict the contributing drainage area to any infiltration trenches to 5 acres or less. Design trenches to provide a detention time of 6 to 72 hours for the water quality storm. Provide a minimum drainage time of 6 hours for satisfactory pollutant removal in the infiltration trench. Adjust the depth of the trench so that maximum drain time based on soil permeability is 72 hours for the total design infiltration volume.

Accommodate the volume and surface area of an infiltration trench to the water quality storm volume of runoff entering the trench from the contributing watershed and the permeability of the soil below the trench. Conservative estimates of soil infiltration rates are obtainable in the county soil surveys published by the U.S. Department of Agriculture or through field testing methods in accordance with NRCS guidance. If stormwater is conveyed to the trench as uniform sheet flow, maximize the length of the trench perpendicular to the flow direction. If stormwater is conveyed as channel flow, maximize the length of the trench parallel to the direction of flow. Calculate the appropriate bottom area of the trench using the following equation:

$$A = \frac{12(V)}{(P)(n)(t)}$$

where:

A	=	bottom area of the trench (square feet)
V	=	runoff volume to be infiltrated (cubic feet)
P	=	percolation rate of surrounding native soil (inches per hour)
n	=	void space fraction in the storage media (0.4 for clear stone)
t	=	retention time (maximum of 72 hours)

Create trench depths between 3 and 8 feet. Calculate a site-specific, maximally effective trench depth based on the soil percolation rate, aggregate soil space, and the trench storage time using the following equation:

$$D = \frac{(P)(t)}{(n)(12)}$$

where:

D	=	depth of the trench in feet
P	=	percolation rate of surrounding existing soil (inches per hour)
t	=	retention time (maximum of 72 hours)
n	=	void space fraction in the storage media (0.4 for clear stone)

Line the sides and bottom of the infiltration trench with geotextile fabric (filter fabric). Place a layer of nonwoven filter fabric 6 to 12 inches below the ground surface to prevent suspended solids from clogging the majority of the storage media. The filter fabric material must be compatible with the surrounding soil textures and application purposes. The cut width of the filter fabric must have sufficient material for a minimum 12-inch overlap. When overlaps are required between rolls, the upstream roll must lap a minimum of 2 feet over the downstream roll to provide a shingled effect. In place of filter fabric, cover the bottom of the infiltration trench with a 6-inch to 12-inch layer of clean sand.

The basic infiltration trench design uses stone aggregate in the top of the trench to provide storage. Fill the trench with clean washed stone (diameter of 1.5 to 2.5 inches) to provide a void space of 40 percent. Pea gravel or soil may be substituted for stone aggregate in the top 0.3 meter (1 foot) of the trench to improve sediment filtering and maximize pollutant removal at the top of the trench. Plant the infiltration trench with vegetation that can withstand periods of saturation and drought. Review and implement alternative storage media solutions case by case until adequate research and experience indicate how they perform.

An observation well located at the center of the trench to monitor water drainage from the system is required. The well should be 4-inch to 6-inch diameter PVC pipe anchored vertically to a footplate at the bottom of the trench. The well should have a lockable aboveground cap.

To remove as many suspended solids from the runoff as possible before they enter the trench, incorporate pretreatment (such as grit chambers, swales with check dams, filter strips, or sediment forebays and traps) as a component of infiltration trench design. Pretreatment helps maintain the infiltrating facility and extends periods between maintenance. Incorporate a bypass flow path in the design to convey high flows (storms larger than the water quality storm) around the trench. To preclude erosive concentrated flows, manage the overland flow path of the surface runoff that exceeds the capacity of the infiltration trench.

Maintenance:

The following is a partial list of actions to upkeep infiltration trenches:

- Once the trench enters operation, inspect it after every major storm for the first few months to maintain proper stabilization and function. Record water levels in the observation well for several days to check trench drainage.
- Inspect for ponding after storm events to make sure the trench is not clogged.
- Frequently remove sediment from pretreatment facilities.
- When ponding occurs at the surface or in the trench, undertake corrective maintenance immediately.
- Remove grass clippings, leaves, and accumulated sediment routinely from the surface of the trench.
- Ponded water inside the trench (visible from the observation well) after 24 hours or several days following a storm event indicates the bottom of the trench is clogged. Remove and replace all of the stone aggregate and filter fabric or media.

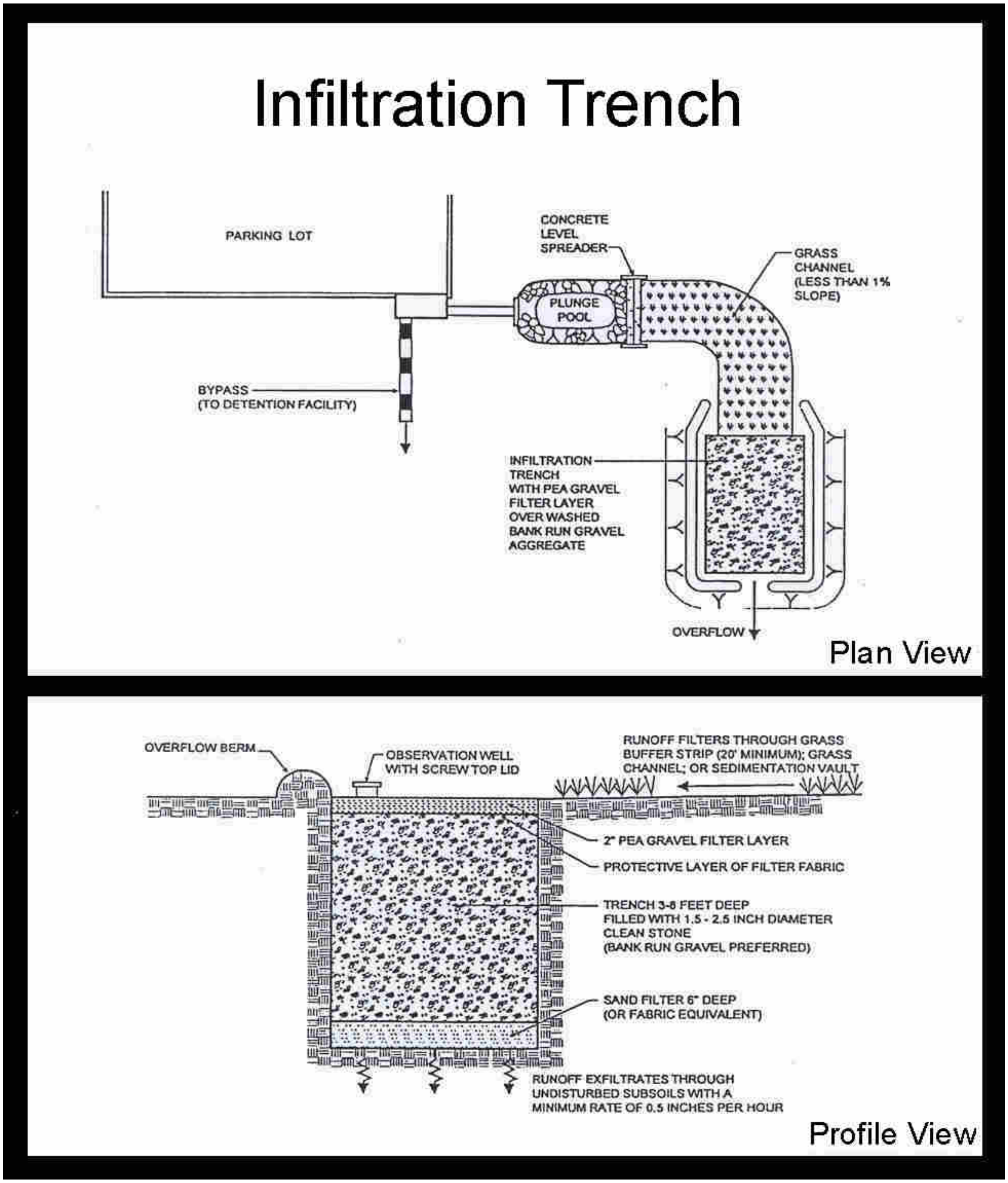
Advantages of infiltration trenches:

- Reduce the volume of runoff from a drainage area
- Remove fine sediment, trace metals, nutrients, bacteria, and oxygen-demanding substances (organics)
- Reduce the size and cost of downstream stormwater control facilities and storm drain systems by infiltrating stormwater in upland areas
- Provide groundwater recharge and baseflow in nearby streams

- Reduce local flooding
- Useful where space is limited because of their narrow dimensions.

Limitations of infiltration trenches:

- Should not be installed until the entire contributing drainage area has been stabilized
- Risk failure because of improper siting, design, and lack of maintenance—especially if pretreatment is not incorporated into the design
- Risk contaminating groundwater depending on soil conditions, land use in the watershed, and groundwater depth
- Not appropriate for industrial or commercial sites where release of large amount or high concentrations of pollutants is possible
- Susceptible to clogging by sediment, necessitating frequent maintenance
- Inappropriate where surrounding soils have low permeability rates
- Effectively limited to small sites (2 acres or less).



Source: CWP 1996

Figure 10 – Infiltration Trench Plan and Profile Example (For Informational Purposes Only)

8.7 SAND FILTERS

Sand filters are defined as stormwater quality treatment practices in which runoff is diverted to a self-contained bed of sand, collected in underground pipes, and discharged into a stream, channel, or sewer system. A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatable and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber. The treated filtrate normally is discharged through an underdrain system either to a storm drainage system or directly to surface waters. Sand filters take up little space and can be used on highly developed sites and sites with steep slopes. They can be added to retrofit existing sites. Sand filters can achieve high removal efficiencies for sediment, biological oxygen demand (BOD), and fecal coliform bacteria. Their ability to remove metals is moderate, and their ability to remove nutrients is often low.

Sand filters are intended primarily for water quality enhancement. In general, they are preferred over infiltration practices (such as infiltration trenches) when contamination of groundwater with conventional pollutants—BOD, suspended solids, and fecal coliform—is a concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately or where groundwater tables are high. Most sand filters can be constructed with impermeable basins or chamber bottoms, which help to collect, treat, and release runoff either to a storm drainage system or directly to surface water; this avoids contact between contaminated runoff and groundwater.

Sand filters are only feasible for highly impervious stabilized areas such as parking lots and rooftops. Sand for the filters should conform to AASHTO M-6 or ASTM C-33 ranging in size from 0.02 to 0.04 inch. Different configurations of sand filters are suitable for different types of sites depending on site conditions such as available space and type of development. The basic principles of all configurations are similar. Sand filter configurations include surface, underground, perimeter, and pocket. Each configuration is described in more detail below.

Surface sand filters (sometimes referred to as Austin sand filters) use an off-line sediment chamber to collect the first flush of stormwater; larger flows are diverted around the sedimentation chamber. Stormwater that is diverted into the sediment chamber is freed of coarse sediments. The water then flows from the sedimentation chamber into a depressional sand filter. The depressional area typically contains 18 inches of sand. The surface may be sand or preferably vegetation. Ponded water in the depressional area infiltrates through the sand and is collected in an underdrain that conveys the treated water to the stream or channel at a downstream point. Calculate sizing of a surface sand filter assuming a porosity of 40 percent for the sand and gravel, a coefficient of permeability of 3.5 feet per day for the sand, and an appropriate sediment basin to reduce the chances of clogging. Size the sedimentation basin based on the fall velocity of the smallest particle that the basin should capture (usually sand). The fall velocities for various sized particles are in ASCE, *Manuals and Reports on Engineering Practice*, No. 54, Sedimentation Engineering. If the surface of the sand filter is vegetated, be sure to specify a species that will not impede infiltration. Surface sand filters are best suited for treating parking-lot and roof runoff where space is not limited. Typically, the surface sand filter system is designed to handle runoff from drainage areas up to 50 acres. Pretreatment is essential to the success of a surface sand filter. Figure 11 illustrates a typical surface sand filter.

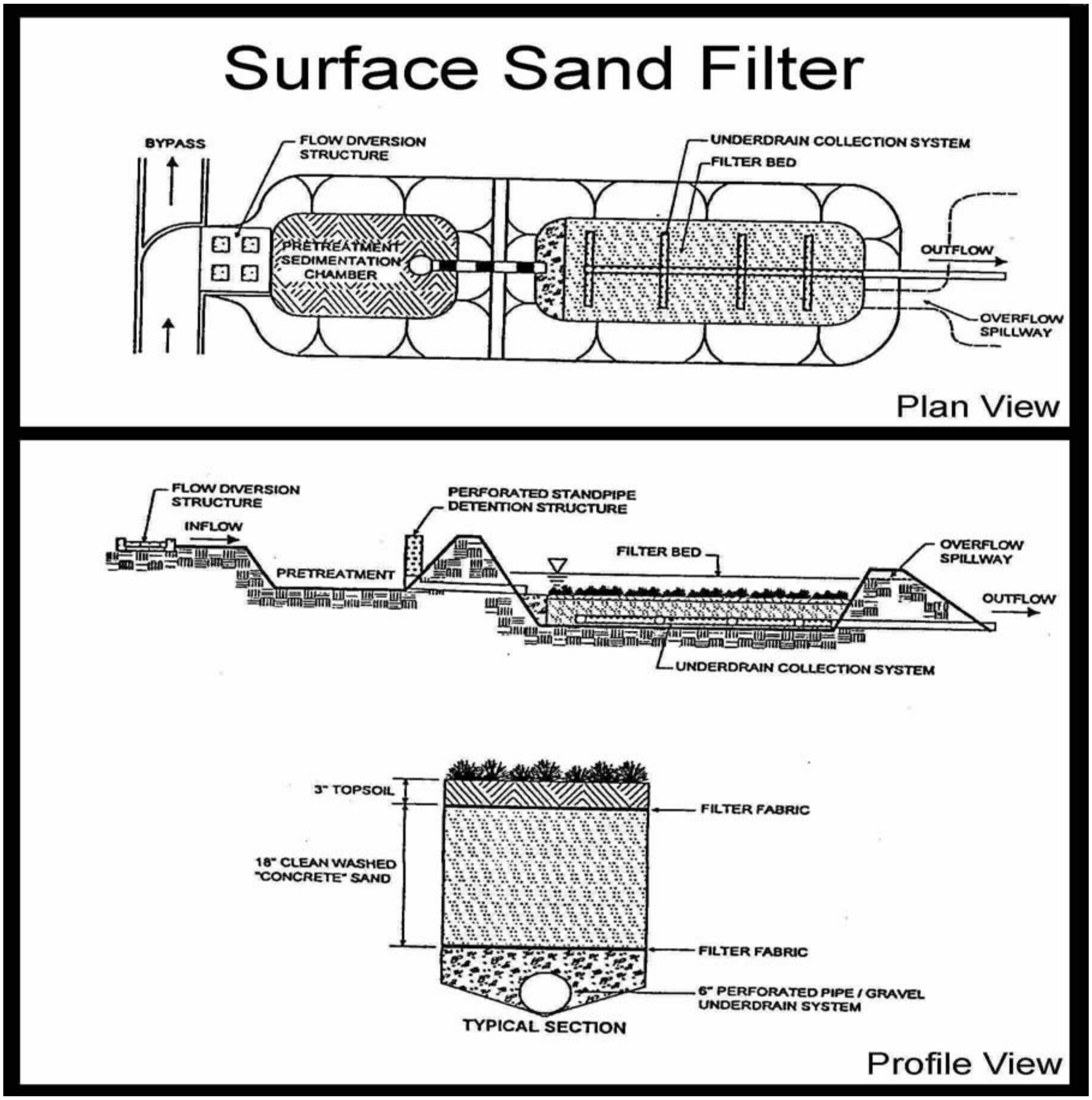
Underground sand filters (also called Washington D.C. sand filters) use a three-chamber concrete vault placed at or beneath grade with the existing ground surface. The first chamber of the vault is used for pretreatment. It serves to settle coarse sediments and skim oil and floatable debris. The second chamber contains 18 inches of sand. Gravel, a protective screen, or permeable geotextile prevents clogging of the sand filter. Flow from the sand filter is collected in an underdrain and conveyed to the third chamber. The third chamber acts as a collection point for the stormwater. It fills and conveys the filtered stormwater through pipes to the stream or channel downstream. Provide access manholes of 30-inch minimum diameter for each chamber of the vault to allow cleaning. Typically, the underground sand filter system can handle runoff from completely impervious drainage areas of 1 acre or less. The sand filter system can accept the first 0.5 inch of runoff. Underground sand filters are ideal for retrofit situations where surface area is limited. Figure 12 illustrates a typical underground sand filter.

Perimeter sand filters use a two-chamber concrete vault. A typical application is along the perimeter of a parking lot. The first chamber of the vault is used for pretreatment that settles out coarse sediments. Stormwater flows over a weir into the second chamber that contains an 18-inch layer of sand. An underdrain system collects the filtered stormwater and conveys it to the stream or channel downstream. Provide access manholes for each chamber of the vault. Perimeter sand filters are best suited for parking lots and rooftops where surface area is limited. Figure 13 illustrates a typical perimeter sand filter.

Pocket sand filters (also called Delaware sand filters) are simplified surface sand filters only applicable to small sites. Stormwater must be pretreated before entering a pocket sand filter by a sediment basin, filter strip, or other means. The pocket sand filter consists of an excavated, shallow, depressional area. The depressional area contains the 18-inch layer of sand covered by a 3- to 4-inch soil layer that is vegetated.

Typically, pocket sand filters are constructed where surrounding soils have a permeability of 0.5 to 2 inches per hour to allow the filtered water to infiltrate into surrounding soils. Be sure to specify a species of vegetation for pocket filters that will survive frequent periods of ponding and drought but will not impede infiltration. Typical pocket sand filter systems can handle runoff from drainage areas of 5 acres or less. A major advantage of the pocket sand filter is its shallow structure depth of only 30 inches, which reduces construction and maintenance costs. Figure 14 illustrates a typical pocket sand filter.

According to estimates, surface (Austin) sand filters, underground (Washington D.C.) sand filters, and pocket (Delaware) sand filters have the potential to remove 85 percent of suspended solids; 55 percent of phosphorous; 35 percent of nitrogen; and between 35 and 90 percent of metals from the stormwater (Claytor and Schueler 1996). Perimeter sand filters are estimated to remove 80 percent of suspended solids, 65 percent of phosphorous, and 45 percent of nitrogen.



Source: CWP 1996

Figure 11 – Surface Sand Filter Plan and Profile Example (For Informational Purposes Only)

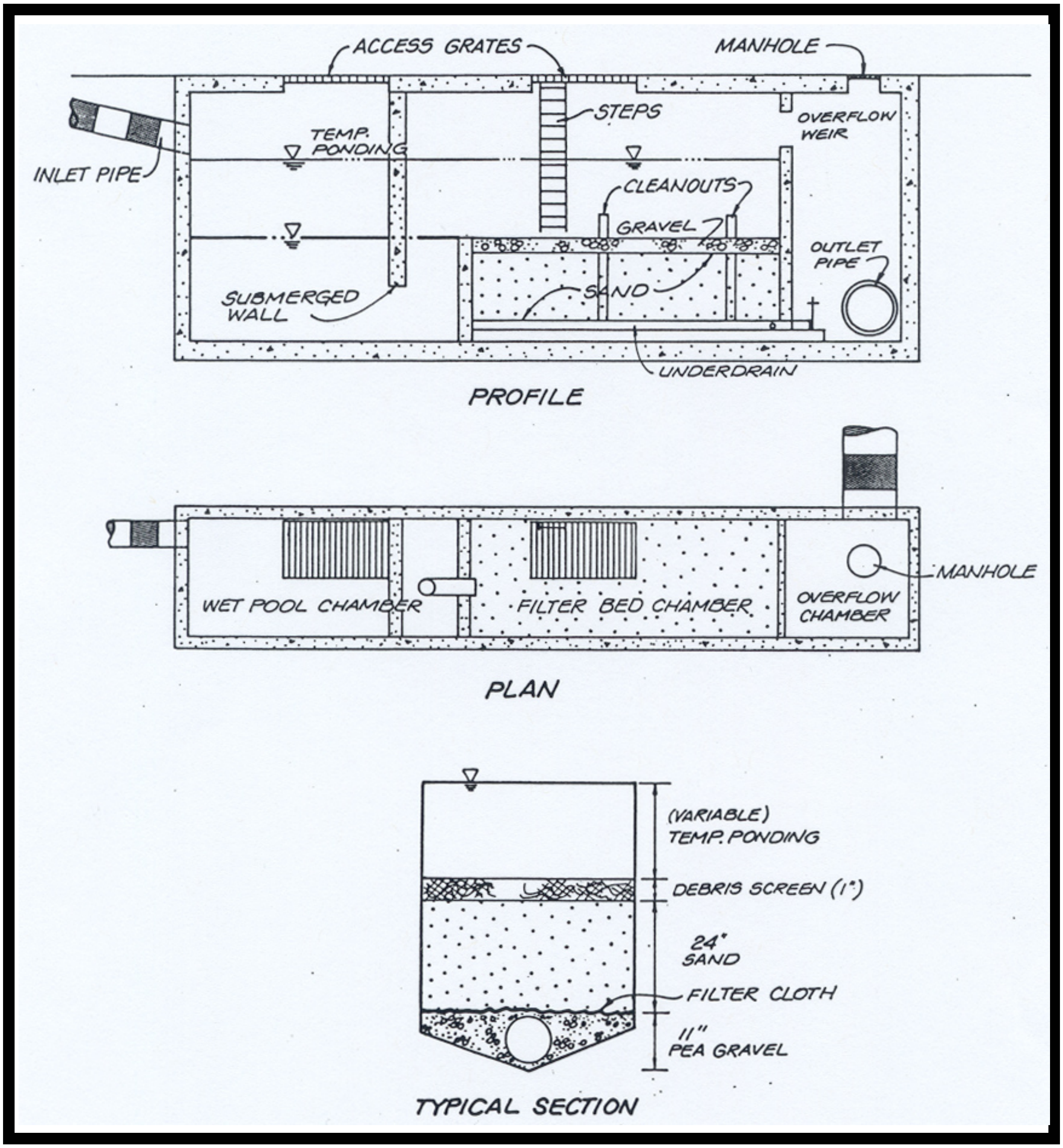
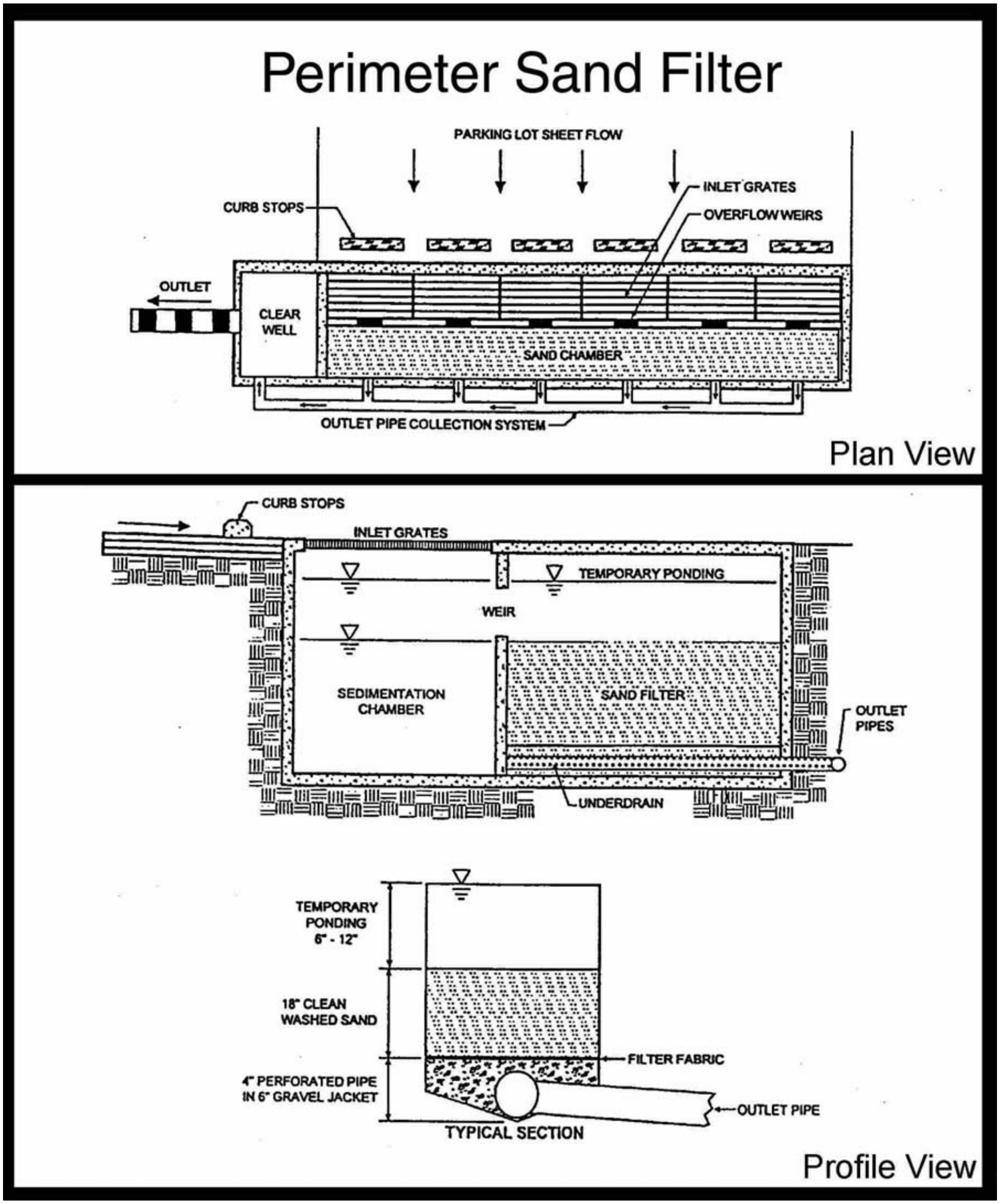


Figure 12 – Underground Sand Filter Plan and Profile Example (For Informational Purposes Only)



Source: CWP 1996

Figure 13 – Perimeter Sand Filter Plan and Profile Example (For Informational Purposes Only)

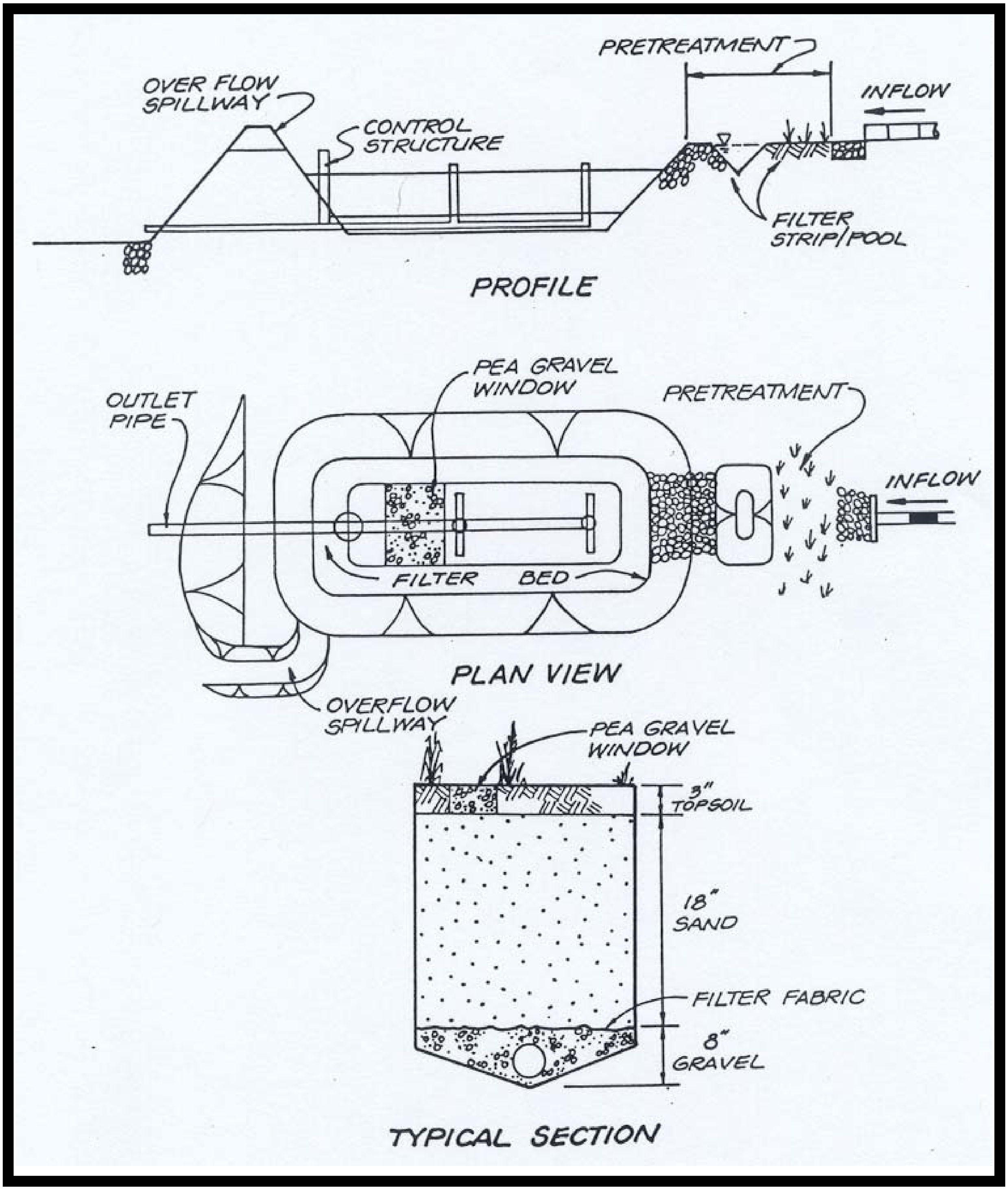


Figure 14 – Pocket Sand Filter Plan and Profile Example (For Informational Purposes Only)

Design Criteria:

Restrict the contributing drainage to any sand filter to 5 acres or less. Design sand filters as off-line practices to capture and treat only the water quality storm and bypass all other storms. A flow regulation structure or flow splitter may be required along with the sand filter. Design a sedimentation basin in conjunction with all sand filters. Porosity (n) for sand and gravel should be 0.4 for sizing sand filters.

Determine the size of the sand filter bed surface area using Darcy's law:

$$A_f = WQv * d_f / [k * t_f (h_f + d_f)]$$

where

A_f = Surface area of the sand filter (square feet)
d_f = Sand filter depth (feet)
k = Coefficient of permeability for sand bed (feet per day)
h_f = Average height of water above the sand bed (feet; hf = ½ * h_{max}, not to exceed 6 feet)
t_f = Time required for the WQv to filter through the sand bed (days; 40 hours is recommended)

Compute the minimum required storage within the sand filter as follows:

$$V_{min} = ¾ * WQv$$

Compute the water volume within the filter bed using the following equation:

$$V_f = A_f * d_f * n$$

where

n = porosity

For surface sand filters, compute the temporary water storage volume above the filter bed, $V_{f\text{-}temp}$.

Calculate the remaining volume required for the settling basin, V_s. V_s should be approximately 50 percent of $V_{min;}$ adjustments of h_f may be required to meet this criterion. V_s can be calculated as follows:

$$V_s = V_{min} – (V_f + V_{f\text{-}temp})$$

where

$V_{f\text{-}temp}$ = Temporary storage volume in the filter media

Calculate the height in the settling basin, $h_{s:}$

$$h_s = V_s / A_s$$

where

A_s = Surface area of the BMP

Verify that $h_s > 2 * h_f$, and h_s equals or exceeds 3 feet. If not, adjust h_f and repeat the sizing procedure.

For underground sand filters, compute the minimum wet pool volume in the settling basin, V_w. As a minimum, $V_w = A_s * 3$.

Calculate the temporary storage volume required in both chambers:

$$V_{temp} = V_{min} – (V_f + V_w)$$

Compute the total surface area of both chambers, $A_{t:}$

$$A_t = A_f + A_s$$

Calculate the additional temporary storage height, h_{add}, using the following equation:

$$h_{add} = V_{temp} / A_t$$

Ensure that h_{add} equals or exceeds $2 * h_f$. Adjustments to h_f may be necessary to meet this requirement.

For perimeter sand filters, compute the minimum wet pool volume in the settling basin, V_w. As a minimum, $V_w = A_s * 2$.

Calculate the temporary storage volume required in both chambers:

$$V_{temp} = V_{min} – (V_f + V_w)$$

Compute the total surface area of both chambers, $A_{t:}$

$$A_t = A_s + A_f$$

Calculate the additional temporary storage height, H_{temp}, using the following equation:

$$h_{temp} = V_{temp} / A_t$$

Ensure that h_{temp} equals or exceeds $2 * h_f$. Adjustments to h_f may be necessary to meet this requirement.

For pocket sand filters, compute the temporary water storage volume above the filter bed, V_{temp}:

$$V_{temp} = V_{min} - V_f$$

Calculate the temporary storage height in the settling basin, h_{temp}:

$H_{temp} = V_{temp} / A_{avg}$, where A_{avg} is the average area of the pocket sand filter.

Set the emergency spillway elevation of the pocket sand filter at h_{temp}.

Maintenance:

The following is a partial list of maintenance issues related to sand filters:

- Inspect for erosion of pretreatment surface and pocket sand filters bi-annually.
- Monitor the water level in underground sand filters quarterly.
- Frequently inspect the overflow systems.
- Frequently remove organic material from the site.
- Frequently inspect and mow vegetation (keep less than 18-inches).
- Frequently remove sediment in the sediment basin or chamber.
- Inspect structural components for degradation regularly.

Advantages of sand filters:

- Can effectively treat hot spot runoff
- Cosume small amounts of land (underground and perimeter sand filters)
- Improve water quality.

Limitations of sand filters:

- OSHA-confined space for underground and perimeter sand filters
- Do not add aesthetic value.

8.8 PERVIOUS PAVEMENT SYSTEMS

Pervious pavement infiltrates stormwater runoff into the ground through a permeable layer of pavement or other stabilized permeable surface. These systems can include porous asphalt, porous concrete, cobble pavers with porous joints or gaps, or reinforced turf (Choi and Engel No Date). However, modular perforated concrete or equivalent surfacing that provides large voids with sufficient volume for establishing vegetation may be used. Pervious pavement used in parking lots, roads, and other paved areas can greatly reduce runoff and associated pollutants leaving the area—especially when vegetated. Pervious pavement systems are suitable for a limited number of applications in areas not exposed to high volumes of traffic or heavy equipment. They are particularly useful for driveways, streets, residential areas, and overflow parking areas. Pervious pavement is not effective in areas that receive runoff with high amounts of sediment because the pores clog (Urban Drainage and Flood Control District, Denver, Colorado 1999).

Design Criteria:

Design pervious pavement to infiltrate the water quality storm; provide for runoff from larger storms. Several systems may be used as pervious pavement:

- **Cast-in-place concrete slabs:** Reinforced concrete slabs covering large areas formed in place on the ground to cover. The slab is suitable for heavy loads and has maximum resistance to movement caused by frost heave or settling.

- **Pre-cast concrete grids:** Concrete paving units incorporating void areas, usually pre-cast at a concrete products plant and trucked to a job site for placement. These units have a higher percentage of permeable surfaces such as grass.

- **Modular unit pavers:** Smaller pavers that may be clay bricks, granite sets, or pre-cast concrete of various shapes. These are monolithic units that do not have void areas incorporated in the blocks. They are installed on the base layer with pervious material placed in the gaps between the units.

- **Geowebs:** Primarily designed for soil reinforcement. But they may serve as permeable pavement.

- **Porous Pavement:** Porous concrete and asphalt surfaces have been used across the U.S. with mixed results. Recent performance data indicate that materials and design guidance have improved and porous surfaces may be viable solutions. See http://www.fcpa.org/publications.html and http://www.odot.state.or.us/ for design and maintenance information.

The base coarse should contain an AASHTO No. 8 coarse aggregate with all fractured surfaces. Assume a 30-percent open pore space.

The design area ratio (contributing impervious area divided by pervious pavement area) should not exceed 3.0.

Provide a storage volume (Design Volume) equal to the WQv (watershed inches of runoff) assuming a 12-hour drain time. To calculate the Design Volume in cubic feet, first determine the required WQv, assuming a 12-hour drain time and imperviousness of 100 percent for the area; then apply the formula:

Design Volume = (WQv/12)* Area

where

Area = The watershed area tributary to the pervious pavement (square feet)

Calculate minimum required surface area as follows:

Minimum surface area (square feet) = Design Volume (cubic feet)/ 0.17 feet

If expansive soils are a concern or the tributary catchment has chemical petroleum products handled or stored, install an impermeable membrane and place the base course on top of the membrane. Otherwise, install a non-woven geo-textile membrane to encourage infiltration.

If the pavement is in low permeability soils such as clayey silt, sandy clays, clays or others, design a subdrain with a permanent restrictor outlet to drain the available pore space volume in the base course within 12 hours.

Maintenance:

- Maintain the turf included in these installations as the permeable surface medium. Limit fertilizers and deicing chemicals because they adversely affect concrete products.
- Cast-in-place installations can be snowplowed, provided the blade is set high enough to prevent damage to grass cover. Additional care is needed when plowing paving blocks or grids.

Advantages of pervious pavement systems:

- Reduce flooding potential by infiltrating or slowing down runoff
- Can remove particles
- Can furnish functional and aesthetic advantages via modular block patterns, colors, and materials.

Limitations of pervious pavement systems:

- Can cost more than traditional paving
- Present uneven driving surface and potential traps for high heels of shoes
- Can require high cost for restorative maintenance when the system seals with sediment and no longer functions as pervious pavement.

8.9 BIORETENTION

Bioretention areas are soil-based and plant-based stormwater management practices that filter runoff from developed sites by mimicking natural vegetated systems; these naturally control hydrology through infiltration and evapotranspiration. A typical application for a bioretention area is to infiltrate and treat surface runoff from parking lots. Bioretention areas are small vegetated depressions into which surface water is diverted. Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Pollutants are removed by processes that include adsorption, filtration, volatilization, ion exchange, and decomposition (Prince George's County, MD 1999). Treated water is allowed to infiltrate into the surrounding soil, or is collected by an underdrain system and discharged to the storm sewer system or directly to receiving waters. If a bioretention system allows water to infiltrate into the surrounding soil, it can be an excellent source of groundwater recharge.

The components of a bioretention system include:

Grass Filter Strips: Runoff enters the bioretention area as sheet flow through the grass buffer strips. Refer to the filter strip section for guidance.

Ponding Area: This provides surface storage of stormwater runoff before it filters through the soil bed. It also allows evaporation of ponded water and sediment settling in the runoff.

Organic Mulch Layer: This protects the soil bed from erosion; retains moisture in the plant root zone; provides a medium for biological growth and decomposition of organic matter; and filters pollutants.

Planting Soil Bed: This furnishes water and nutrients to support plant life in the bioretention system. Stormwater filters through the planting soil bed where pollutants are removed by filtration, plant uptake, adsorption, and biological degradation.

Sand Bed: This underlies the planting soil bed and allows water to drain from the planting soil bed into the surrounding soil. It provides additional filtration and allows aeration of the planting soil bed.

Plants: These are important components of a bioretention system. They remove water though evapotranspiration, and remove pollutants and nutrients through uptake. Plant species are selected to replicate a forested ecosystem and to survive stresses such as frequent periods of inundation during runoff events and drying during interevent periods.

Water Level Control Structure: This shall consist of a structure for draining the basin when the designed ponding depth has been achieved. The structure shall be a 6-inch diameter perforated riser with 2-inch holes at 24 holes per foot, with a 6-inch metal intake trash guard, Agridrain brand, or its equivalent.

A pretreatment component is necessary to reduce inflow velocity and to reduce the load of coarse sediment entering the bioretention area. Pretreatment creates a miniature treatment train; it may proceed via a filter strip, sediment basin, or other technique.

A typical cross section of a bioretention area consists of approximately 9 inches of ponding depth, 3 inches of organic or shredded hardwood mulch planted with various species of plants, approximately 4 feet of planting soil, and an underdrain beneath filter fabric to convey filtered stormwater to an appropriate outlet. Stormwater runoff collects in the ponding area. The ponding depth temporarily stores the water quality volume. The ponding area also allows sediment to settle out of the stormwater. Stormwater runoff stored in the bioretention area filters through the mulch and planting soil. The underdrain returns the filtered stormwater to the storm drain system. Runoff events larger than the water quality volume pass through the bioretention areas through standard drop inlets and into the storm drain system.

Pine mulch and wood chips are not acceptable in the mulch layer because they are displaced during storm events. Provide clean-out pipes on the underdrain to facilitate cleaning.

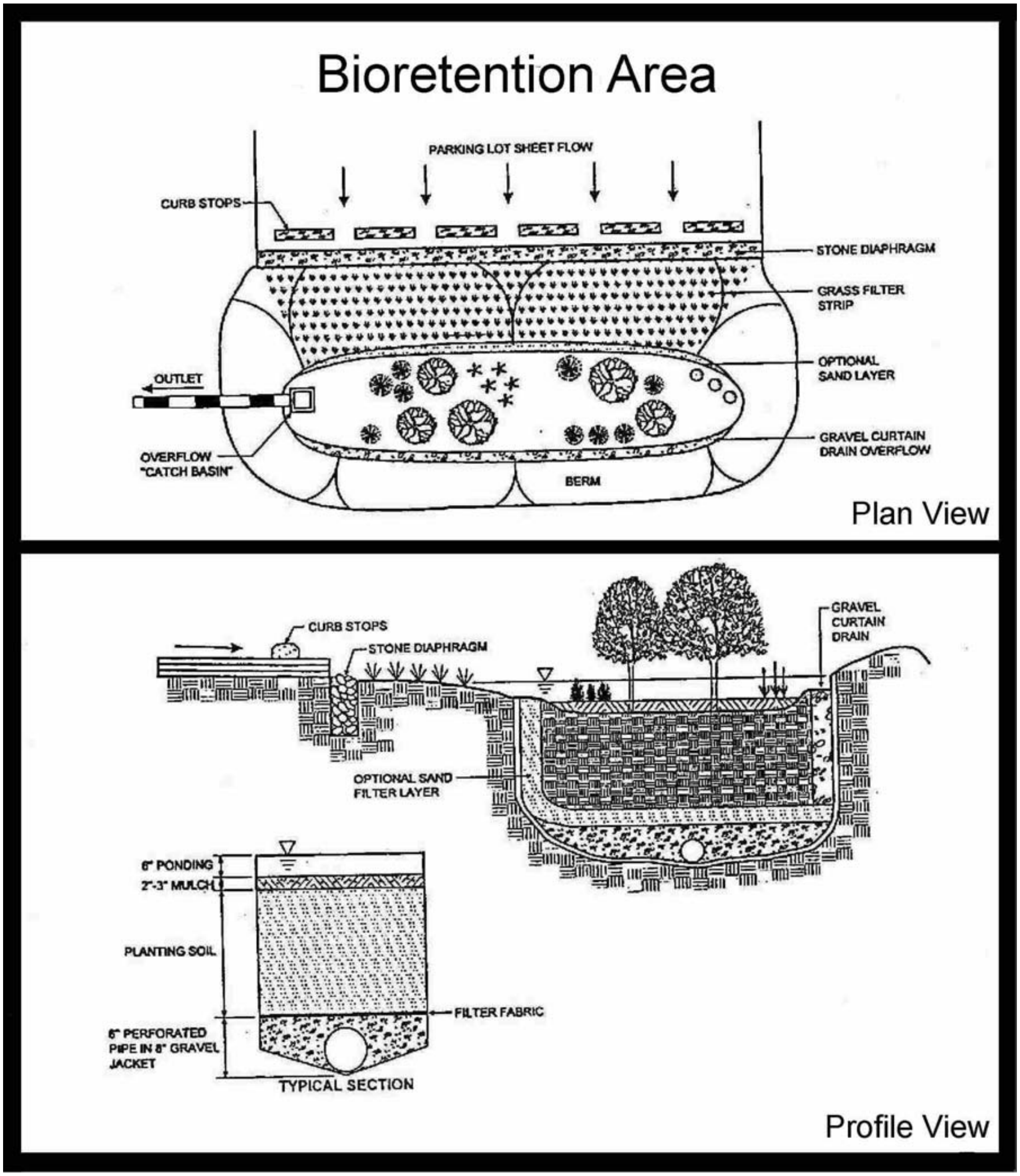
Incorporate a uniform mix of the planting soil during construction so that stormwater infiltrates evenly and does not create preferential pathways. Minimize compaction of the base and planting soil—compaction results in design failure because it reduces infiltration.

Vegetation for the bioretention area should consist of native plant species with hydric tolerances. Do not place wood vegetation near the stormwater inflow location. Plant trees primarily along the perimeter of the bioretention area. Figure 15 illustrates a typical bioretention area.

According to estimates, bioretention areas have the potential to remove 90 percent of suspended solids, 65 percent of phosphorous, 50 percent of nitrogen, and 80 percent of metals from the stormwater (Claytor and Schueler 1996).

Properly maintained bioretention facilities can be aesthetically pleasing in parking lot islands, landscaped areas around buildings, parking lot perimeters, and in other open spaces.

Bioretention-facility layout can be very flexible, and the selection of plant species can provide for a wide variety of landscape designs. Before construction, consult a landscape architect with proper experience designing bioretention areas to select plants that tolerate growing conditions in bioretention facilities.



Source: CWP 1996

Figure 15 – Plan and Profile of a Bioretention Area Example (For Informational Purposes Only)

Design Criteria:

Pretreatment: A grass filter strip or grass channel is the primary pretreatment unit for bioretention facilities. At sites where runoff enters the bioretention system through sheet flow, a grass filter strip with a pea gravel diaphragm (ASTM D 448 size no. 6) is the preferred pretreatment method. Several factors determine the length of the filter strip—size of the drainage area, imperviousness, and filter strip slope. The following table provides guidelines for sizing the filter strip based on approach length, land use, and slope. A minimum filter length should be 10 feet.

Pretreatment Filter Strip Sizing Guidance

Parameter	Impervious Parking Lots				Residential Lawns				Notes
Maximum inflow approach length (feet)	35		75		75		150		
Filter strip slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum Slope = 6%
Filter strip minimum length (feet)	10	15	20	25	10	12	15	18	

For sites where concentrated or channelized runoff enters the bioretention system (such as through a slotted curb opening) a grass channel with a pea gravel diaphragm is the preferred pretreatment method. The length of the grass channel depends on the drainage area, land use, and channel slope. The following table provides guidance for the grass channels leading to a bioretention facility; the minimum grass channel length should be 25 feet.

Pretreatment Grass Channel Sizing Guidance for a 1.0-Acre Drainage Area

Parameter	≤33 % Impervious		Between 34% and 66% Impervious		≥67% Impervious		Notes
Channel slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum Slope = 6%
Grass channel minimum length (feet)	25	40	30	45	35	50	Assumes a 2 foot wide bottom width

Filter Media: The correct sizing of the bioretention facility depends on the filter bed surface area, water balance, and planting soil bed characteristics.

Determine filter Bed Surface Area using the following equation:

$$A_f = WQv * d_f/k* t_f (h+ d_f)$$

where

A_f = Surface area of the bioretention planting bed (square feet)
WQv = Water quality treatment volume (cubic feet)
d_f = Planting soil bed depth (assumed to be 4 feet)
k = Coefficient of permeability for planting soil bed (feet/day)
h = Average height of water above the bioretention bed (feet); h_{avg} = ½ h_{max}
t_f = Time in days required for the WQv to filter through the planting soil bed (3 days is recommended)

Planting Soil Bed Characteristics: The soil characteristics are critical for the proper operation of the bioretention facility. The soil must be sufficiently permeable to allow runoff to filter through the media and also able to host a robust vegetative cover. To enhance nutrient uptake, the soil must have a combination of chemical and physical properties to support a diverse microbial community.

The planting soil should be a sandy loam, loamy sand, loam, or loam and sand mix; clay content should be less than 25 % by volume. Soils should fall within the SM, ML, or SC classifications or the Unified Soil Classification System (USCS). A permeability of at least 1.0 foot per day is required. Soils should be free of stones, stumps, roots, or other weedy material over 1 inch in diameter. Brush or seeds from noxious weeds (such as Johnson Grass, Mugwort, Nutsedge, and Canadian Thistle) should not be present in the soils. Specific characteristics are shown in the following table:

Planting Soil Characteristics

Parameter	Value
pH range	5.2 to 7.00
Organic matter	1.5 to 4.0 %
Magnesium	35 pounds per acre, minimum
Phosphorous (P_2O_5)	75 pounds per acre, minimum
Potassium (K_2O)	85 pounds per acre, minimum
Soluble salts	≤ 500 parts per million
Clay	10 to 25 %
Silt	30 to 55%
Sand	35 to 60 %

Mulch Layer: The mulch layer should be standard landscape style, single or double, shredded hardwood mulch, or chips. The mulch layer should be well aged (stockpiled for at least 12 months), uniform in color, and free of other materials (such as weed seed, soil, and roots). Apply the mulch to a maximum depth of 3 inches. Do not use grass clippings.

Planting Plan Guidance: Direct plant material selection to create a terrestrial forested community comprised of native species. The goal of the bioretention system is to re-create an upland-oriented ecosystem dominated by trees, shrubs, and herbaceous materials. This system should contain a diverse dense plant cover to treat stormwater runoff and withstand urban stress.

Proper selection and installation of plant material is key to the success of this system. See Table 4 for the recommended plant materials.

Overflow: The overflow component of the bioretention system consists of the gravel underdrain system, pea gravel overflow curtain drain, and a high-flow overflow structure. Design the underdrain system with the following components: a 6-inch minimum perforated pipe system (AASHTO M-278, Rigid Schedule 40) with an 8-inch gravel bed (AASHTO M-43, 0.5 to 2 inch, clean, bankrun, river pea gravel). The pipe should have 0.375-inch perforations, spaced at 6-inch centers, with a minimum of 4 holes per row. Space the pipe at a maximum of 10-foot on-center, and maintain a minimum grade of 0.5 percent. Provide at least one cleanout per run. Connect the underdrain system to the conventional drainage system, or daylight it to a suitable non-erosive outfall.

The high flow overflow system is usually a yard drain catch basin; but any number of conventional drainage practices may be used, including an open vegetated or stabilized channel. If the system is off line, design it to convey peak discharge of the WQv, and set it above the shallow ponding limit. If the facility is on line, design the high flow overflow as a conventional storm drainage structure or channel. Connect the overflow structure to the site drainage system, or outfall to a suitable non-erosive location.

Maintenance:

Bioretention maintenance resembles that of any maintained landscaping area. The following is a partial list of maintenance actions to upkeep bioretention:

- Inspect bi-annually for erosion of pretreatment and bioretention.
- Mulch bi-annually.

- Annually test soil for nutrients and pH.
- Annually inspect vegetation and pruning.
- Mildly control vegetation (non-chemically) so the area does not become a nuisance.
- Annually inspect overflow devices.
- Remove trash and sediment as necessary.
- Aerate periodically.

Advantages of bioretention:

- Minimally consumes land
- Improves water quality
- Reduces site runoff
- Provides aesthetic enhancement
- Increases groundwater recharge.

Limitation of bioretention:

- Should not be installed until the entire contributing drainage area has been stabilized
- Requires proper plant selection and maintenance
- Does not provide flood control
- Treats small drainage area.

8.10 RAIN GARDENS

A rain garden is a small residential depression planted with native wetland and prairie vegetation (rather than a turfgrass lawn) where sheet flow runoff collects and infiltrates. Rain gardens function similar to larger-scale bioretention areas. Typical sites for rain gardens include residential yards and community common areas.

Design Criteria:

The maximum drainage area for a rain garden is 1 acre. The ponding depth of a rain garden is typically 4 to 6 inches. Limit ponding in the depressional area to 4 days or less to avoid nuisance insects. Line the depressional area with a mulch and organic layer in which vegetation is planted. The mulch holds moisture and aids removal of metals. Underneath the mulch and organic layer is the planting soil. The planting soil should be a mixture of sand, loam, and clay to provide water and nutrients to the plants.

Place rain gardens a minimum of 10 feet away from building foundations. Placement of the rain garden should not interfere with adjoining property drainage patterns.

Pine mulch and wood chips are not acceptable for the mulch layer, because they are displaced during storm events. The mulch should be shredded hardwood. During construction of the rain garden, do not compact the surrounding soils or planting soil.

Plant selection for rain gardens should include species that tolerate extremes of drought and flooding. Typical stream species do well in rain gardens. Base plant selection ultimately on the planting soil composition. Perennials, shrubs, and trees should all be in the planting plan.

According to estimates, rain gardens have approximately the same potential as bioretention to remove 95 percent of suspended solids, 42 percent of phosphorous, 42 percent of nitrogen, and approximately 80 percent of metals from the stormwater (Claytor and Schueler 1996).

Maintenance:

The following is a partial list of actions to upkeep rain gardens:

- Inspect bi-annually for erosion.
- Mulch bi-annually.
- Annually test soil for nutrients.
- Annually inspect spillway systems.
- Annually inspect vegetation and pruning.
- Remove trash and sediment as necessary.
- Aerate periodically.

Advantages of rain gardens:

- Please aesthetically
- Minimally consume land
- Improve water quality
- Reduce site runoff.

Limitations of rain gardens:

- Should not be installed until the entire contributing drainage area has been stabilized
- Take up smaller drainage area than does bioretention.

8.11 WETLANDS

Constructed (engineered) wetlands exploit natural processes involving wetland vegetation, soils, and associated microbial assemblages to treat an effluent or other water source. Stormwater wetlands are passive systems not engineered to meet specific pollutant discharge limits. In general, these systems should be engineered and constructed in uplands, outside waters of the United States. Configurations of constructed wetlands can include extended detention wetlands that provide extra detention above the wetland pool (with some loss of treatment efficiency). These configurations also can use submerged gravel wetlands with a gravel chamber or basin into which wetland plants are rooted and through which stormwater flows. Figure 16 illustrates a typical extended detention wetland.

Slowing the flow in a wetland allows debris to settle. Efficiency of a BMP to remove suspended matter by sedimentation depends on the time available for particles to settle. As water moves slowly through a marsh, sediment and other pollutants settle to the substrate or floor, thereby improving overall water quality. Preferably, a sediment forebay is included in the design.

In addition, growths of marsh vegetation and microorganisms take up excess nutrients (such as nitrogen and phosphorus from fertilizer) that otherwise can pollute surface water. Constructed wetlands remove 15 to 45 percent of the phosphorus, less than 30 percent of both nitrogen and pathogens, and 50 to 80 percent of the metals.

A wetland channel develops dense wetland vegetation and conveys runoff slowly (Choi and Engel No Date). Generally, this rate is less than 2 feet per second at the 2-year peak flow. Because they slow the flow of water through the system, constructed wetlands typically remove between 50 and 80 percent of the suspended solids in stormwater.

Wetlands configurations include: shallow wetland, extended detention wetland, pocket wetland, and submerged gravel wetland. Shallow wetlands are designed with high surface to volume ratio and therefore consume a large amount of land. Shallow wetlands maximize wildlife habitat and have a diverse topography. In extended detention wetlands, additional storage volume is accomplished in the 0 to 2 feet above the permanent pool. Shallow wetlands and extended detention wetlands are designed for drainage areas greater than 10 acres. Pocket wetlands are designed for small drainage areas (less than 5 acres), are excavated to groundwater, and have higher maintenance requirements. Submerged gravel wetlands are designed for stormwater to flow through gravel to filter the pollutants.

Shallow wetlands, extended detention wetlands, and pocket wetlands may be designed with or without an open water (permanent pool) component. Wetland basins with open water are similar to retention ponds, except that a significant portion (usually 50 percent or more) of the permanent pool volume is covered by emergent wetland vegetation. Wetland basins without open water are inundated with water during runoff events but do not maintain a significant permanent pool; also known as "wetland meadows," they support a variety of wetland plants adapted to saturated soil conditions and tolerant of periodic inundation by runoff.

Submerged gravel wetlands support hydrophytic vegetation without an aboveground permanent pool, minimizing potential problems such as odors or insects, or contact with highly polluted runoff.

The number of active, constructed, treatment, wetland projects receiving wastewater from municipal sources (including stormwater sources) has increased to more than 600 across the United States. If planned properly, these treatment wetlands offer opportunities to regain some natural functions of wetlands and offset some significant losses in wetland acreage while they provide flood detention and improve water quality. With appropriate siting, design, preapplication treatment, operation, maintenance, monitoring, and management, these manmade systems often can emulate natural wetlands by furnishing integrated ecological functions within the watershed and landscape.

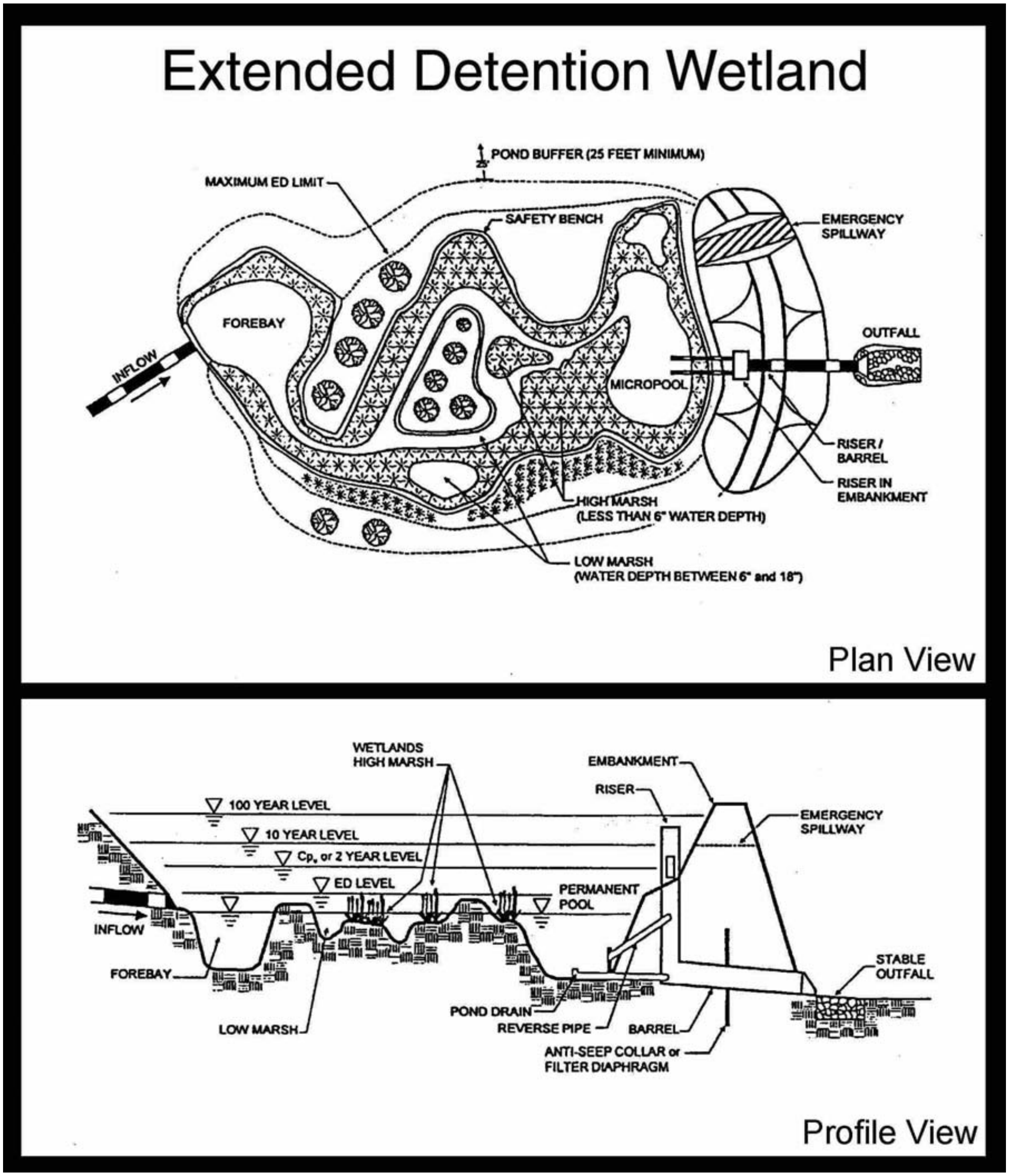


Figure 16 – Extended Detention Plan and Profile Example (For Informational Purposes Only)

The goal of all wetland configurations is removing pollutants to improve water quality. Pollutant removal in wetlands can occur through a number of mechanisms that include sedimentation, filtration, volatilization, adsorption, absorption, microbial decomposition, and planting.

Design Criteria:

Sediment forebays are required to decrease velocity and sediment loading to the wetland. The forebay should contain at least 5 years of sediment expected from the watershed and should be 4 to 6 feet deep—separated from the wetland by gabions, gravel and riprap, or an earthen berm.

The design should include a buffer to separate the wetland from surrounding land. A buffer of 25 feet is required as the minimum, plus an additional 25 feet if wildlife is a concern. Leaving trees undisturbed in the buffer zone minimizes the disruption of wildlife and reduces opportunity for nuisance vegetation to invade.

Design the wetland to treat the WQv. The minimum drainage area for shallow wetlands and extended detention wetlands should be 10 acres and for pocket wetlands should be 5 acres. The ratio of drainage area to permanent pool typically is about 5:1 in the MARC region (USDA 1984). Allocations of surface area and storage for different configurations of wetlands are shown in Tables 10 and 11:

TABLE 10

SURFACE AREA ALLOCATIONS IN EXTENDED DETENTION WETLANDS

Percent of Surface Area	Shallow Wetland	Extended Detention Wetland	Pocket Wetland
Forebay	5	5	0
Micropool	5	5	0
1 to 6’ below permanent pool	5	0	5
6 to 18” below permanent pool	40	40	50
0 to 6” below permanent pool	40	40	40
0 to 2’ above permanent pool	5	10	5

TABLE 11

VOLUME ALLOCATIONS IN EXTENDED DETENTION WETLANDS

Percent of Volume	Shallow Wetland	Extended Detention Wetland	Pocket Wetland
Forebay	10	10	0
Micropool	10	10	0
1 to 6’ below permanent pool	10	0	20
6 to 18” below permanent pool	45	20	55
0 to 6” below permanent pool	25	10	25
0 to 2’ above permanent pool	0	50	0

Place aboveground berms or high marsh wedges at approximately 50-foot intervals and at right angles to the direction of the flow to increase the dry-weather flow path within the wetland. The flow path should have a minimum length-to-width ratio of 2:1.

Incorporate a 4-foot to 6-foot deep micropool (a capacity at least 10 percent of total treatment volume) before the outlet to prevent outlet clogging. A reverse slope pipe or a hooded, broad-crested weir is the recommended outlet control. Locate the outlet from the micro pool at least 1 foot below the normal pool surface. To prevent clogging, install trash racks or hoods on the riser. To facilitate access for maintenance, install the riser within the embankment.

A bottom drain pipe with an inverted elbow is required to prevent sediment clogging, so the wetland can be drained completely in an emergency or for routine maintenance. Fit the outlet pipe and bottom drainpipe with adjustable valves at the outlet ends to regulate flows.

Surround all deep-water cells with a safety bench of minimum width 10 feet and a depth of 0 to 18 inches below the pool’s normal water level.

For recommended wetland vegetation, see Table 4.

Maintenance:

The following is a partial list of actions to upkeep stormwater wetlands:

- Clean and remove debris after major storm events.
- Harvest excess vegetation.
- Repair embankment and side slopes.
- Repair control structure (annually or as needed).
- Remove accumulated sediment from forebays or sediment storage areas (5-year cycle or as needed).
- Remove accumulated sediment from main cells of pond once the original volume has been significantly reduced (20-year cycle, or as needed).

Advantages of wetlands:

- Improve water quality and runoff control
- Create wildlife habitat corridors, greenways, and open space
- Stimulate community involvement and participation
- Protect downstream water bodies
- Please aesthetically
- May provide groundwater recharge—a particular advantage during periods of drought
- Work well with other BMPs in treatment trains.

Limitations of wetlands:

- May require large land area
- May be limited to a gentle slope
- May or may not require supplemental water to support vegetation—depending on vegetation type or permanent pools in dry periods.

8.12 PONDS AND LAKES

Streams are natural watercourses with well-defined beds and banks; they flow continuously or intermittently. Legal definitions of streams are in the latest revision of the Missouri Code of State Regulations, Division 20, and the State of Kansas Rules and Regulations, KSA 82a-301 through 305a.

Lakes and ponds are standing bodies of water defined in terms of capacity, effective height, and effective storage. Based on Missouri and Kansas regulations, total storage for a pond is less than 50 acre-feet of water, and the product of the effective height (in feet) and effective storage (in acre-feet) is less than 1,250. Lakes are larger than ponds. Lakes are inland bodies of water with total storage greater than 50 acre-feet, and the product of the effective height (in feet) and effective storage (in acre-feet) greater than 1,250. Legal definitions and regulations for dams and reservoirs can be found in the Missouri Code of State Regulations, Division 22, and the State of Kansas Rules and Regulations, KSA 82a-301 through 305a. All developments involving lake and pond construction must conform to local, state, and federal regulations.

Preserve undisturbed ponds and lakes during development according to federal and state laws and regulations. Preserving the natural drainage system, instead of replacing it with storm sewers or concrete channels, reduces the potential for downstream degradation because of increased runoff. Ponds can be modified to increase their storage capacity and enhanced with vegetation to increase their water-quality treatment effectiveness.

Maintenance:

The following is a partial list of actions to upkeep ponds and lakes:

- Harvest certain vegetation from the dams.
- Control animals to maintain safe structure.
- Clean and remove debris after major storm events.
- Repair embankment and side slopes.
- Remove accumulated sediment.
- Repair and unclog the principal spillway and trash rack.
- Repair excessive erosion in the emergency spillway.

Advantages of ponds and lakes:

- Improve runoff control
- Create wildlife habitat
- Encourage community recreation facilities

- Please aesthetically
- May provide groundwater recharge
- May increase property values.

Limitations of ponds and lakes:

- Reduce the amount of developable land
- Limit site plans to build around open space
- Reduce the amount of developable land.

9.0 ADDITIONAL DESIGN GUIDANCE

MARC and APWA recommend several minimum practices for all communities and other practices applicable to a variety of situations. This Section 9.0 describes how to design, plant, and maintain these practices. Following are detailed design guidance for five practices: (1) Stream Buffers, (2) Soil Protection, (3) Bioretention, (4) Engineered Swales, and (5) Wet Pond and Extended Detention Wetland. Standard specifications and plans are in Appendix A.

9.1 STREAM BUFFER

Section 7.0 provides planning guidance for stream buffers. The ensuing sections furnish more detailed guidance for designing stream buffers. See Appendix A for specifications and plans. For preserving an existing stream buffer according to local ordinances, see Sections 9.2 and 9.3, and Appendix A.

Plant Materials:

Table 4 (Recommended Plant Materials for BMPs), recommends plant materials for stream buffers. Calculate effective tree height from the normal flow line to the top of mature trees heights in zone 1. The effective height is great enough to provide sufficient shadow lengths to moderate water temperatures. Consider the function of the stream buffer when selecting vegetation. For example, if a trail is nearby, avoid shrubs that block the view of other vital aspects and avoid tree species with low hanging branches.

Planting Densities:

The location, layout, and density of the stream buffer should complement natural features within and adjacent to the buffer. As a general rule of thumb, use the following densities:

Plant Types/Heights	Plant Spacing
Small Shrubs (<10 feet)	3 to 6 feet
Large Shrubs / Small Trees (10 to 25 feet)	6 to 8 feet
Large Trees	8 to 16 feet

Maintenance:

Inspect the stream buffer periodically to monitor plant survival and protect the buffer from excessive vehicular and pedestrian traffic, pest infestations, and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation, and periodically control undesirable vegetative competition. Remove excessive storm debris and trash. Leaving some dead snags improves wildlife habitat. Natural biomass production is necessary throughout the life of the stream buffer to maintain its full functionality.

9.2 NATIVE SOIL AND VEGETATION PRESERVATION

Section 7.0 describes how to preserve and restore existing soil and vegetation that promote and preserve natural hydrology across the site. The following sections provide more information about this. See Appendix A for detailed specifications and plans.

Soil and Vegetation Surveys:

Conduct soil and vegetation surveys in accord with the latest survey methods approved by state and federal agencies. Qualified individuals that perform them should include a professional soil scientist, practicing NRCS soil scientist, professional wetland scientist, certified wildlife biologist, horticulturist, and person(s) trained in mapping soils and vegetation as botanists or other biological or geoscience professionals.

Most counties publish soil surveys prepared by the NRCS, formerly Soil Conservation Service (SCS). These surveys describe general soil associations and series found in each county, including: soil associations and series delineations on aerial photos; descriptions of soil profiles; suitability for various land uses; wildlife habitats; crops and vegetation production yields; and various engineering and chemical properties.

Site development activities within areas previously disturbed by urban developments (such as site grading, road construction, and other soil disturbance activities) may require additional soil and vegetation investigations to determine the limits of remaining undisturbed native soils and vegetation. Additional site investigations may be needed in areas of minimal disturbance to determine the limits of native soils and vegetation planned for preservation.

Generally, soils are identified through field investigations and mapping to the first or second order survey. Investigations include installing hand borings or test pits to a maximum depth of 60 inches or to parent material. Vegetation surveys can be performed either by general field reconnaissance or detailed measures such as transects or sample plots. Accurately locate soil and vegetation investigation borings, test pits, transects, and sample plots according to horizontal coordinates and vertical elevations; then plot them on site development drawings. Also identify the size and species of individual trees and preservation zones on site plans and construction drawings.

Soil and Vegetation Protection Standards:

Standards for soil protection and restoration are published in two primary sources:

NRCS. 1994. *NRCS Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater*.

Office of Surface Mining. 1983. 30 CFR Sec. 816.22. "Topsoil and Subsoil Performance Standards". May 16.

The primary native soil and vegetation preservation goals of these standards are to: protect native soils from compaction and erosion; and protect vegetation, especially trees, from damage by equipment and construction activities. Permanent native or naturalized vegetation established on native soil can be incorporated into other BMPs such as stream buffers, engineered swales, and low impact developments.

Maintenance:

Inspect preserved areas periodically to: (1) monitor plant survival and erosion problems, and (2) protect soil and vegetation from excessive vehicular and pedestrian traffic, pest infestations, and other potential damage caused by weather events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation; periodically interplant desirable native species; control undesirable vegetative species; and remove excessive debris buildup from storms. Biomass may be required throughout the life of the preserved area to maintain full functionality.

9.3 NATIVE SOIL RESTORATION

Section 7.0 discusses how to restore and protect existing native soil to promote and preserve natural hydrology across the site. The following sections furnish more detail about designing native soil restoration. See Appendix A for detailed specifications and details.

Soil Surveys:

Most counties publish soil surveys prepared by the NRCS, formerly Soil Conservation Service (SCS). These surveys provide information about general soil associations and series found within each county—soil associations and series delineations on aerial photos; descriptions of soil profiles; suitability for various land uses; wildlife habitats; crops and vegetation production yields; and various engineering and chemical properties. Site development activities within areas previously disturbed by urban developments (such as site grading, road construction, and other soil disturbance activities) may require additional soil investigations to determine limits of the remaining, undisturbed, native soils types and limits. Where native soils are to be restored, additional soil investigations of native soil may be needed.

Qualified individuals such as professional soil scientists, practicing NRCS soil scientists, or other geoscience professionals trained in mapping soils should prepare soil surveys according to the latest soil survey methods approved by the NRCS. Generally, soils are identified through field investigations and mapping to the first or second order survey. Sink hand borings or test pits to a maximum depth of 60 inches or to parent material; accurately locate them according to horizontal coordinates and vertical elevations, and plot them on site development drawings.

Native Soil Restoration and Protection Standards:

Standards for native soil restoration and protection are published in two primary sources:

NRCS. 1994. *NRCS Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater*.

Office of Surface Mining. 1983. 30 CFR Sec. 816.22. "Topsoil and Subsoil Performance Standards". May 16.

These standards promote the following primary soil restoration and protection goals: (1) to salvage, stockpile, and restore natural soil profile(s) properly, and (2) to protect restored soils from compaction and erosion where permanent native or naturalized vegetation is to be planted and maintained. Permanent native or naturalized vegetation established on restored native soil can also benefit other BMPs such as stream buffers, engineered swales, and open space areas.

Maintenance:

Inspect restored areas periodically to monitor plant survival and erosion problems. Protect these areas from excessive vehicular and pedestrian traffic; pest infestations; and other potential damage caused by weather events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically interplant appropriate native species; control undesirable vegetative species; and remove excessive storm debris. Biomass production may be required perpetually in the restored area to maintain fully functional condition.

9.4 BIORETENTION BASIN

Section 8.0 provides general guidance for bioretention basins or cells. The following sections furnish more detail about designing bioretention basins. See Appendix A for specifications and plans.

Plant Materials:

Table 4 (Recommended Plant Materials for BMPs) recommends plant materials for bioretention basins. Consider location of bioretention basin (for example, parking lot, street scape, or yard) and the types of vegetation most appropriate for that location. Consider effective height of vegetation and general appearance of landscaping features. Select vegetation considering slope; aspect; drought and water tolerance; and (if relevant) salt tolerance. Mix small trees, shrubs, grasses, sedges, and forbs to achieve maximum diversity.

Planting Densities:

Complement natural features within and adjacent to the site with suitable location, layout, and density of the bioretention basin. As a general rule of thumb, use the following densities for trees and shrubs:

Plant Types/Heights	Plant Spacing
Small Shrubs (<10 feet)	3 to 6 feet
Large Shrubs / Small Trees (10 to 25 feet)	6 to 8 feet
Large Trees	8 to 16 feet

Maintenance:

Inspect the bioretention basin periodically to monitor plant survival. Protect it from excessive pedestrian traffic; pest infestations; and other potential damage caused by storm events, wildlife and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive storm debris and trash. Biomass production will be required perpetually in the bioretention basin to maintain a fully functional condition.

9.5 ENGINEERED SWALE

Section 8.0 provides general guidance for engineered swales. The following sections furnish more detail about designing engineered swales. See Appendix A for specifications and plans.

Plant Materials:

Table 4 (Recommended Plant Materials for BMPs) suggests plant materials for engineered swales. Most engineered swales host predominantly herbaceous vegetation. However, consider adding trees and shrubs (as in bioretention basins). But avoid shrubs that block the view of other vital aspects. Do not introduce tree species with low hanging branches if a trail is nearby.

Planting Densities:

Complement natural features within and adjacent to the swale with suitable location, layout, and density of the swale. As a general rule of thumb, use the following densities for trees and shrubs species:

Plant Types/Heights	Plant Spacing
Small Shrubs (<10 feet)	3 to 6 feet
Large Shrubs / Small Trees (10 to 25 feet)	6 to 8 feet
Large Trees	8 to 16 feet

Maintenance:

Inspect the engineered swale periodically to monitor plant survival. Protect it from excessive vehicular and pedestrian traffic; pest infestations; and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive storm debris and trash. Biomass production will be required perpetually in the swale to maintain a fully functional condition.

9.6 WET POND/EXTENDED DETENTION

Section 8.0 provides general guidance for wet ponds and extended detention wetlands. The following sections furnish more detail about designing wet ponds. See Appendix A for specifications and plans. When designing a wet pond as part of detention, assume the detention is required by local ordinances. Water quality treatment using wet ponds and associated wetland vegetation usually does not require major modification of the detention facility.

Plant Materials:

Table 4 (Recommended Plant Materials for BMPs) suggests plant materials for wet ponds, including aquatic species. Consider depths of detention and permanent water regimes when selecting vegetation.

Avoid shrubs that block the view of other vital aspects. Do not introduce tree species with low hanging branches if a trail is nearby.

Planting Densities:

Complement natural features within and adjacent to the detention facility with suitable location, layout, and density of the wet pond. As a general rule of thumb, use the following densities:

Plant Types	Plant Spacing
Small Shrubs (<10 feet)	3 to 6 feet
Large Shrubs / Small Trees (10 to 25 feet)	6 to 8 feet
Large Trees (<24 feet)	8 to 16 feet
Wetland and Aquatic Species (12 to 36 feet)	1 to 2 feet

Maintenance:

Inspect the wet pond periodically to monitor plant survival. Protect it from excessive sedimentation; pest infestations; and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive buildup of sediment, storm debris, and trash. Biomass production will be required perpetually to maintain a fully functional condition. Leave some dead snags to improve wildlife habitat.

10.0 LINKS TO OTHER PROGRAM REQUIREMENTS

This manual complements and complies with local stormwater management programs and guidelines. The ensuing sections provide additional guidance for applying construction practices and controlling sediment and erosion to protect water quality. The following information is not a substitute for reviewing and implementing APWA Section 5100, but a complement to it.

10.1 PHASED CONSTRUCTION

Perform development of sites in phases. Phasing should include construction operation timelines and timelines for land disturbance and stabilization that minimize degradation of surrounding water bodies. Effective phased construction minimizes disturbed areas during the stages of a development. Consider phased construction as a BMP to include in the proper package of BMPs discussed in Section II.

In phased construction, soil is disturbed as little as possible during all construction phases to minimize erosion and prevent sediment from migrating off site. It is also imperative to limit the time of subsurface-soil exposure. For example, denude only the part of the site applicable to immediate work. Stabilize that portion of the project before continuing to the next phase. Detail construction phasing in the erosion and sediment control plan.

More preferably on large sites, develop the tract of land in sections. For example, leave bottomland and watercourses undisturbed until uplands have been developed and stabilized. This provides a natural buffer for stormwater to slow and filter stormwater runoff from the site. After stabilizing uplands, continue development on lower lying lands. This type of phasing generates the greatest number of credits. On tracts of land over 80 acres, disturb only one-quarter of the site at a time until other sections have been stabilized.

10.2 SEDIMENT AND EROSION CONTROL PLANS

An erosion and sediment control plan defines and schedules control measures to minimize erosion and prevent sediment-laden stormwater from leaving the project site. Erosion and Sediment plans are required by the NPDES permitting program for construction activities. The Kansas Department of Health and Environment (KDHE), Bureau of Water, Industrial Programs Section administers the program referred to as a Stormwater Pollution Prevention Plan (SWP3). The Missouri Department of Natural Resources (MDNR), Water Protection and Soil Conservation Division administers the program in Missouri. Each state's process is described briefly below.

In Kansas, owners or operators of any project that will disturb one or more acres must apply for authorization. Apply for the permit by completing a Notice of Intent (NOI) form at least 60 days before start of construction. A qualified professional must seal the SWP3. The plan should include the location, installation, and maintenance of the practices foreseen to minimize erosion and prevent sediment from leaving the site.

Begin the permitting process by filing a NOI and paying a filing fee of $60 to KDHE 60 days before starting construction. Submit the SWP3, sealed by a qualified stormwater professional. The contractor is also responsible for submitting a contractor certification form. After the project is stabilized, submit a notice of termination.

In Missouri, contact the Corps to determine if the project is in jurisdictional waters and is regulated. A project may be regulated if it involves placing materials in a lake, river, stream,- or wetland (including dry streams or wetlands). If the project is regulated, complete a 401 Certification Application Checklist. If also applying to the Corps for a 404 permit, attach the 404 permit application form (ENG Form 4345) and provide any additional information needed (and a mitigation plan when impacting a jurisdictional stream and/or wetland). Note that a 401 Certification Application is required even if the project is authorized under a nationwide permit. MDNR has a list of general conditions for certain nationwide permits. Submit the application to MDNR. The 401 Certification Application fee is $75. Upon receipt of the fee, a copy of the certification will be mailed to the appropriate office of the Corps of Engineers to inform them the certification is now in effect and final.

More information and forms required for permitting are on KDHE's web site at URL www.kdhe.state.ks.us.stormwater and MDNR's web site at URL http://www.dnr.state.mo.us/wpscd/wpcp/homewpcp.htm.

Refer to APWA 5100 for detailed guidance on preparing sediment and erosion control plans.

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APPENDIX A

STANDARD SPECIFICATIONS AND PLANS

APPENDIX A
BEST MANAGEMENT PRACTICES
MODEL SPECIFICATION

Mid-America Regional Council

Kansas City Metropolitan Chapter
American Public Works Association

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SECTION 1 BEST MANAGEMENT PRACTICES

1.0 SCOPE: This section governs the furnishing of all labor, equipment, tools, material, and the performance of all work necessary to construct the following Best Management Practices for stormwater management:

A. Stream Buffer

B. Native Soil and Vegetation Preservation

C. Native Soil Restoration

D. Bioretention Basin

E. Engineered Swale

F. Wet Pond/Extended Detention Wetland

1.1 REFERENCED STANDARDS: The following standards are referenced directly in this section. The latest version of these standards shall be used.

AASHTO

M-43 – Standard Specification for Gravel
M-190 – Standard Specification for Bituminous coated corrugated metal pipe
M-245 – Standard Specification for the Procedure For The Quality Assurance Of Corrugated Metal Pipe
M-246 – Standard Specification for the Certification Procedure For Corrugated Metal Pipe
M-252 – Standard Specification for Plastic And Polyethylene Corrugated Drainage Pipe Or Tubing
M-274 – Standard Specification for Aluminized Steel Type 2 Material
M-278 – Standard Specification for PVC Pipe
M-294 – Standard Specification for Corrugated Polyethylene Plastic Pipe
T-99 – Standard Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in) Drop

ASTM

C361 – Standard Specification for Reinforced Concrete Low-Head Pressure Pipe
D448 – Standard Classification for Sizes of Aggregate for Road and Bridge Construction
D1785 – Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
D2241 – Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated (SDR-Series)
D3786– Standard Test Method for Hydraulic Bursting Strength of Textile Fabrics-Diaphragm Bursting Strength Tester Method
D4632 – Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
D4355 – Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture, and Heat in a Xenon Arc Type Apparatus
D4751 – Standard Test Method for Determining Apparent Opening Size of a Geotextile
D4833 – Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

ANSI

Z60.1 – Standard Specification for Nursery Stock

1.2 DEFINITIONS:

A. **Best Management Practice (BMP):** Stormwater management practice used to prevent or control the discharge of pollutants to waters of the U.S. BMPs may include structural or non-structural solutions, a schedule of activities, prohibition of practices, maintenance procedures, or other management practices.

B. **Bioretention:** Soil and plant-based stormwater management practices designed to filter runoff from developed communities by mimicking vegetated systems that naturally control hydrology through detention, filtration, infiltration, and evapotranspiration.

C. **Contractor:** The individual, firm, partnership, joint venture, or corporation contracting with the Owner for performance of the work described in these specifications and plans.

D. **Engineered Swale:** An open drainage channel designed to convey and infiltrate the entire runoff volume from a Water Quality Storm.

E. **Extended Detention Wetland:** A land area that is permanently wet or periodically flooded by surface or groundwater and has developed hydric soil properties which support vegetation growth under saturated soil conditions. It may have been engineered with adequate capacity to detain large storm flows.

F. **Native Soils:** A soil profile and associated undisturbed landscape that exists in the environment in which they have been formed. Native soils consist of earthy materials containing living matter supporting or capable of supporting plant life.

G. **Native Vegetation:** Plant species that exist in the region where they have evolved.

H. **Owner/Engineer:** The individual, firm, partnership, joint venture, or corporation employing the contractor for performance of the work described in these specifications and plans. The term may also refer to the Owner’s authorized representative (Engineer).

I. **Plans:** The approved plan drawings, profiles, typical cross-sections, working drawings, etc., and exact reproductions thereof, which show the location, character, dimensions, and details of the work to be done.

J. **Riparian Buffers:** Strips of herbaceous and woody vegetation along perennial and intermittent streams and open bodies of water. Riparian Buffers capture sediment and other pollutants in surface runoff water before these enter the adjoining surface water body.

K. **Stream Buffer:** A strip of preserved land adjacent to a stream that physically protects the stream channel from future disturbance or encroachment. A stream buffer includes the riparian buffer adjacent to the stream, and may include one or two additional outer zones in which development and activities are progressively less restricted.

L. **Topsoil:** Fertile, friable soil of uniform quality and consisting of the soil series A horizon, without a mixture of subsoil materials or soil series B horizon, and shall be reasonably free from materials such as hard clods, stiff clay, hardpan, partially disintegrated stone, large stone or any other impurities. Topsoil shall be reasonably free from grass, roots, or debris, which are considered to be harmful to plant establishment and growth.

M. **Wet Pond:** A constructed system with sufficient capacity to detain flood volumes and to store the Water Quality Volume in a permanent pool.

N. **Work:** Work shall mean the furnishing of all labor, materials, equipment, and other incidentals necessary or convenient to the successful completion of the project.

1.3 MATERIALS:

1.3.1 Plant Materials: Refer to Section 2 – Best Management Practice Planting for all Best Management Practices.

1.3.2 Earthfill: The material placed in the fill shall be free of sod, roots, frozen soil, stones over 6 inches (.15 m) in diameter, and other objectionable material. Fill material for the center of the embankment, and core trench must have at least 30 percent passing the number 200 sieve. To the extent they are suitable and approved by the Engineer, excavated materials are to be used as fill materials.

It shall be the responsibility of the Contractor to advise the Engineer when, in his opinion, rock excavation is encountered. It shall be the responsibility of the Engineer, when so notified, to rule on proper classification of the excavation and final determination of the excavation as "earth" or "rock" excavation shall be made by the Engineer as the work is performed. Excavation shall be classified as follows:

A. Earth excavation will include all material not classified as rock excavation and shall include clay, silt, sand, gravel, hard pan, loose shale, loose stone in masses, and boulders measuring less than ½ cubic yard in volume.

B. Rock excavation shall include all boulders measuring ½ cubic yard or more in volume, rock material in ledges, bedded deposits, and unstratified masses, conglomerate deposits so firmly cemented that they possess the characteristics of solid rock, which cannot be removed without systematic drilling; and concrete or masonry structures.

1.3.3 Corrugated Metal Pipe: All of the following criteria shall apply for corrugated metal pipe.

A. Polymer-Coated Steel Pipe: Steel pipes with polymeric coatings shall have a minimum coating thickness of 0.01 inch (10 mil) on both sides of the pipe. This pipe and its appurtenances shall conform to the requirements of AASHTO Specifications M-245 and M-246 with watertight bands or flanges.

B. Aluminum-Coated Steel Pipe. This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Aluminum-coated Steel Pipe, when used with flowable fill or when soil and water conditions warrant the need for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Any aluminum coating damaged or otherwise removed shall be replaced with cold applied bituminous coating compound. Aluminum surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt. Hot dip galvanized bolts may be used for connections. The pH of the surrounding soils shall be between 4 and 9.

C. Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.

D. Connections: All connections with pipes must be completely watertight. The drainpipe or barrel connection to the rise shall be welded all around when the pipe and riser are metal. Anti-seep collars shall be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.

E. All connections shall use a rubber or neoprene gasket when joining pipe sections. The end of each pipe shall be re-rolled an adequate number of corrugations to accommodate the bandwidth. The following type connections are acceptable for pipes less than 24 inches in diameter: flanges on both ends of the pipe with a circular 3/8-inch closed cell neoprene gasket, pre-punched to the flange bolt circle, sandwiched between adjacent flanges; a 12-inch-wide standard lap-type band with 12-inch-wide by 3/8-inch-thick closed cell circular neoprene gasket; and a 12-in-wide hugger type band with o-ring gaskets having a minimum diameter of 0.5 inch greater than the corrugation depth. Pipes 24 inches in diameter and larger shall be connected by a 24-inch-long annular corrugated band using a minimum of four rods and lugs, two on each connecting pipe end. A 24-inch-wide by 3/8-inch-thick closed cell circular neoprene gasket will be installed with 12 inches on the end of each pipe. Flanged joints with 3/8-inch closed cell gaskets the full width of the flange is also acceptable.

F. Helically corrugated pipe shall have either continuously welded seams or have lock seams with internal caulking or a neoprene bead.

1.3.4 Reinforced Concrete Pipe: Reinforced concrete pipe shall have bell and spigot joints with rubber gaskets and shall equal or exceed ASTM C-361.

1.3.5 Plastic Pipe: The following criteria shall apply for plastic pipe.

A. PVC pipe shall be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241. Corrugated High Density Polyethylene (HDPE) pipe, couplings and fittings shall conform to the following: 4- by 10-inch pipe shall meet the requirements of AASHTO M252 Type S, and 12 inch through 24 inch shall meet the requirements of AASHTO M294 Type S.

B. Joints and connections to anti-seep collars shall be completely watertight.

1.3.6 Concrete: The following criteria shall apply for concrete when required.

A. Concrete, when required in the drawings, shall be Class 3000M with a maximum net water content of 6 1/2 gallons/bag and a minimum cement content of 6 bags/cubic yard.

B. Portland cement shall be Type I or II. Air entraining admixture shall be used to provide an air content of 5 to 8 percent of the volume of concrete.

C. Coarse aggregate shall be hard, free from dirt and organic materials, and shall consist of gravel, crushed stone, or other suitable materials larger than 1/4 inch (6.4 mm). Maximum size shall be 1 1/2 inches (38.1 mm).

D. Fine aggregate shall consist of natural or manufactured sand with particle gradation ranging from coarse (1/4 inch (6.4 mm)) to fine (#200 sieve).

E. Mixing water shall be clean and free from oil, alkali, or acid.

F. The proportions of aggregates shall be such to produce a concrete mixture that will work readily into the corners and angles of the forms and around steel reinforcement when consolidated. The slump at the time of placing shall be 2 to 4 inches (51 to 102 mm).

G. Forms shall be wood, plywood, steel, or other approved materials and shall be mortar tight. The forms shall be unyielding and shall be constructed so the finished concrete conforms to the specified dimensions and contours. Prior to placement of concrete, the forms and subgrade shall be free of chips, sawdust, debris, water, ice, snow, extraneous oil, mortar, or other harmful substances or coatings.

1.3.7 Rock Riprap: Rock riprap, when required, shall meet the requirements of the local Department of Transportation or State Materials Testing Agency. Geotextile should be placed under all riprap and shall meet the requirements of the local Department of Transportation or State Materials Testing Agency.

1.3.8 Sand and Gravel: Sand, when required, shall be washed and meet AASHTO M-43, Size No. 9 or No. 10. The Engineer must approve any alternative sand gradation. Gravel shall be washed and meet AASHTO M-43, Size No. 2 or No. 3. Rounded "Bank Run" gravel is preferred.

1.3.9 Under Drains: Underdrains, when required, shall be constructed of polyvinyl chloride or high-density polyethylene piping conforming to AASHTO M-278. Underdrains shall be constructed of 6-inch Rigid Schedule 40 piping with 3/8-inch perforations spaced 6 inches on center, with four holes per row.

1.3.10 Filter Fabric: Geotextiles shall be manufactured from randomly oriented synthetic long chain or continuous polymeric filaments or yarns (such as polypropylene, polyethylene, polyester, polyamide, or polyvinylidene-chloride) bonded together by the needle-punched process. In addition, one side may be slightly heat-bonded. The geotextile shall be formed into a stable network of filaments or yarns that retain their relative position to each other; are inert to commonly encountered chemicals; and are resistant to ultraviolet light, heat, hydrocarbons, mildew, rodents and insects. The geotextile shall be free of any chemical treatment or coating that might significantly reduce its permeability and shall have no flaws or defects that significantly alter its physical properties.

A. The filter fabric shall meet the following minimum requirements:

Property	Test Method	Minimum Value
Tensile Strength	ASTM D 4632	120 lbs
Bursting Strength	ASTM D 3786	210 psi
Elongation	ASTM D 4632	> 50%
Puncture	ASTM D 4833	60 lbs
UV Resistance @ 150 hours	ASTM D 4355	70%
Apparent Opening Size	ASTM D 4751	No. 70 (max)

Notes: lbs – pounds; psi – pounds per square inch; % - percent

B. Installation of Filter Fabric:

1. The Contractor shall install filter fabric as shown on the drawings. Filter fabric shall be installed in a directional manner as recommended by the manufacturer.

2. The Contractor shall assume a 20% scrap factor (overlap and burial loss) for filter fabric. Material will be trenched at the top and bottom of the slopes and shall be installed to match the final graded contour of the riprap. A minimum lap of 24 inches is required if the fabric is installed in more than one piece. The Contractor shall account for all scrap and trench-secured quantities in his/her quotation. Such quantities are considered incidental and non-payable for the project.

3. Place filter fabric over entire bedding material. The filter fabric shall be loosely laid (not stretched) such that it will conform to any minor surface irregularities. No cuts or punctures in the fabric will be permitted.

4. The filter fabric shall be anchored to a minimum depth of 12 inches into the trench.

5. The filter fabric shall not be left exposed for more than 48 hours.

6. Installation of Staples and Fasteners: Staples, fasteners, pins, etc. shall be installed as per the recommendations of the manufacturer.

1.3.11 Bioretention: The allowable materials to be used in bioretention areas are detailed below:

Parameter	Specification	Size	Notes
Mulch minimum	Shredded hardwood	N/A	Aged 2 to 12 months
Pea Gravel Diaphragm and Curtain Drain	ASTM D-448 size no. 6	Varies (approx. $^{1}/_{8}$” to ¼”)	Use clean river pea gravel
Underdrain Gravel	AASHTO M-43	½” to 2”	Use clean river pea gravel
PVC Piping	AASHTO M-278	6” Rigid Schedule 40	$^{3}/_{8}$” perf. @ 6” C-C, 4 holes per row

1.3.12 Topsoil Materials: Soil backfill for trees, shrubs, and herbaceous plantings shall meet the following conditions specified for topsoil.

A. Topsoil shall be stripped from designated areas up to a depth of four (4) inches. Imported topsoil shall be fertile, friable soil of uniform quality, with minimal mixture of subsoil material, and shall be reasonably free from materials such as hard clods, stiff clay, hardpan, partially disintegrated stone, large stone or any other impurities. Topsoil shall be reasonably free from grass, roots, or debris, which are undesirable or harmful to plant life.

B. Stockpiling and Spreading: The topsoil shall be stockpiled in convenient non-construction areas before shaping of areas to be planted. When shaping is completed and approved by the Engineer, the topsoil shall be spread over all areas to be planted. Minimum depth of topsoil shall be four (4) inches on all areas to be planted.

1.3.13 Engineered Swale:

A. Permeable soil mixture (20 to 30 inches deep) should meet the definition of Topsoil in Section 1.12

B. The underlying soil bed shall be moderately permeable soils, 30" deep with gravel/pipe underdrain system.

1.4 PLANTING: See Section 2 – Best Management Practice Planting.

1.5 CONSTRUCTION DETAILS: The following sections provide construction specifications for the following Best Management Practices:

A. Native Soil and Vegetation Preservation

B. Native Soil Restoration

C. Bioretention Basin

D. Engineered Swale

E. Wet Pond/Extended Detention Wetland

Refer to Section 2 – Best Management Practice Planting for construction specifications for Stream Buffers as well as planting for the following BMPs.

1.5.1 Native Soil and Vegetation Preservation:

1.5.1.1 Construction Requirements:

A. Selective clearing is removal of undesirable trees and underbrush around specimen trees and brush as designated on the drawings and/or instructed by the Engineer.

B. Soil and specimen trees as shown on the drawings and/or instructed by the Engineer to save, shall be protected from damage incident to clearing, grubbing, and construction operations, by the erection of timber barriers or by such other means as the circumstances require. Such barriers must be placed and be approved by the Engineer before construction operations can proceed.

C. Plant Preservation: All plant materials on the site to be saved and/or relocated shall be marked specifically by the Engineer. No plant material may be removed from the site prior to the Engineer's inspection. All plant material to be saved/or relocated will be protected from injury to the roots and to the branches, to a distance five feet beyond the drip-line. No grading, trenching, pruning, or storage of materials may go in this area, except as approved by the Engineer.

D. Trees and Plants to be Relocated: Any tree or plants moved shall be done in a timely manner so as not to delay construction progress. The Contractor shall take extra measures to protect the tree during the relocation by erecting barricades, staking, trimming, etc. as required. All trees to be relocated shall be performed by certified arborists. Tree relocation shall be performed between October 15th, and April 15th. Tree relocation shall be measured per each tree relocated, in place and accepted.

1.5.1.2 Construction Specifications:

A. Silt, snow, board, plastic fence, or other approved methods of restricting access shall be installed 5 feet outside of the dripline of trees and plant materials marked to be preserved.

B. No construction activity is allowed inside these barriers.

C. Avoid movement and parking of vehicles over the root zones where no grading is proposed.

D. Do not store materials in restricted access areas within the dripline of trees and plant materials marked to be preserved.

E. Avoid placing fill within the dripline of trees marked to be saved.

F. Where necessary, up to 20 percent of the area within the dripline of trees to be preserved may be disturbed when approved by the Engineer. Tree roots within the limits of disturbance shall be cleanly severed using a chainsaw or other approved mechanical method.

1.5.1.3 Inspection and Maintenance:

A. The Contractor and Engineer shall inspect trees for damage, stress and disease, and will bring any occurrences to the attention of the Engineer.

B. The Engineer will mark trees that require repairs.

C. Repairs, to include pruning, applying wound dressings, etc., shall be made by the Contractor within 7 days of occurrence.

D. The Contractor shall replace trees that have been damaged beyond saving after construction is complete at no additional cost to the Owner.

E. Remove the protective measures when construction is complete.

1.5.2 Native Soil Restoration:

A. Materials: Prior to delivery of any materials to the site, submit to the Engineer a complete list of all materials to be used during this portion of the work. Include complete data on source, amount and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Engineer.

B. The full depth of topsoil shall be stripped from all grading areas, using a phased approach where appropriate. Topsoil up to a minimum depth of six (6) inches or the entire A horizon of the applicable soil series being disturbed as published in the Published County Soil Survey or other detailed soil survey, shall be stripped and stockpiled from all areas to be excavated or filled.

C. Removal:

1. All “A horizon” and topsoil shall be removed and segregated as a separate layer from the area to be disturbed. Where the Engineer determines that the topsoil is of insufficient quantity or poor quality for sustaining vegetation, other materials may be substituted with approval by the Engineer in accordance with paragraph D of this section. Selected overburden materials

to be substituted shall be removed as a separate layer from the area to be disturbed, and segregated.

2. If topsoil is less than 6 inches thick, the operator may remove the topsoil and the unconsolidated materials immediately below the topsoil to a total depth of 6 inches and treat the mixture as topsoil.

3. Timing: All material to be removed under this section shall be removed after the vegetative cover that would interfere with its salvage is cleared from the area to be disturbed, but before any drilling, blasting, excavating, or other surface disturbance takes place.

D. Substitutes and Supplements: Selected overburden materials may be substituted for, or used as a supplement to topsoil pursuant to a detailed soil survey and restoration plan that demonstrates to the Engineer that the resulting soil medium is equal to, or more suitable for sustaining vegetation than, the existing topsoil, and the resulting soil medium is the best available in the area where native soil is to be disturbed and restored. Topsoil substitutes and supplements shall consist of approximately thirty percent (30%) clay, thirty-five percent (35%) silt, thirty percent (30%) sand and five percent (5%) organic matter. Organic matter shall be Dakota Peat, biosolids, composted biomass, or other materials that are approved by the Engineer. All mixing of materials must be by a soil-blending machine and may be done either on- or off-site. The Engineer must approve the end product. After the topsoil mixture has been thoroughly blended, it shall be transported to the area of spreading and dumped at various points within the area. The material can then be moved more easily by a small crawler-type tractor suitably equipped with a blade to push the mixture onto the prepared surface. After the mixture has been spread uniformly over the surface, it must be firmed into place by light compaction with the crawler tractor. Any soft spots existing after the firming process, must be raked, floated and lightly compacted to obtain a uniform depth of placement.

E. Storage:

1. Materials removed under paragraph C and D of this section shall be segregated and stockpiled when it is impractical to redistribute such materials promptly on regraded areas.

2. Stockpiled materials shall –

   a. Be selectively placed on a stable site within the construction area;

   b. Be protected from contaminants and unnecessary compaction that would interfere with revegetation;

   c. Be protected from wind and water erosion through prompt establishment and maintenance of an effective, quick growing vegetative cover or through other measures provided in the approved water pollution control plan; and

   d. Not be moved until required for redistribution unless approved by the Engineer.

3. Where long-term stockpiling of materials removed under paragraph C(1) and D of this section is required, and where such stockpiling would be detrimental to the quality or quantity of those materials, the Engineer may approve the temporary distribution of the soil materials to an approved site within the construction area.

a. Such action will not permanently diminish the capability of the topsoil of the host site.

b. The material will be distributed in a condition more suitable for redistribution than if stockpiled.

F. Redistribution:

1. Topsoil materials removed under paragraph A and B of this section shall be redistributed in a manner that--

   a. Achieves an approximately uniform, stable thickness consistent with the approved restoration plan, finished grading, and surface-water drainage systems;

   b. Prevents excess compaction of the materials; and

   c. Protects the materials from wind and water erosion before and after seeding and planting.

2. Before redistribution of the material removed under paragraph C and D of this section the regraded land shall be scarified to reduce potential slippage of the redistributed material and to promote root penetration. Such treatment may be conducted after the material is replaced if no harm will be caused to the redistributed material and reestablished vegetation.

3. The Engineer may choose not to require the redistribution of topsoil or topsoil substitutes on the final embankments if it determines that--

   a. Placement of topsoil or topsoil substitutes on such embankments will result in greater sedimentation than would otherwise occur, or

   b. Such embankments will be stabilized by other approved means.

G. Vegetation: Vegetation shall be established on all exposed surfaces. Plantings shall be as shown in the plans and as specified in Section 2 – Best Management Practice Planting.

1.5.3 Bioretention Basin:

A. Compaction: Minimize compaction of both the base of the bioretention area and the required backfill to ensure proper function of the system using the following procedures.

1. When possible, use excavation hoes to remove original soil. If bioretention areas are excavated using a loader, the contractor will use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and storage volumes and is not acceptable.

2. Using a primary tilling operation such as a chisel plow, ripper, or subsoiler to remedy compaction at the base of the bioretention facility. Till and refracture the soil profile through the 12-inch compaction zone. The Engineer must approve substitute methods. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment and are not acceptable.

B. Rototill 2 to 3 inches of sand into the base of the bioretention facility before back filling the required sand layer. Pump any ponded water before preparing (rototilling) base.

C. When backfilling the topsoil over the sand layer, first place 3 to 4 inches of topsoil over the sand, then rototill the sand/topsoil to create a gradation zone. Backfill the remainder of the topsoil to final grade.

D. When back filling the bioretention facility, place soil in lifts 12 inches or greater. Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

E. Water Level Control Structure: This work shall consist of providing the structure and all associated hardware and installing the structure in accordance with the manufactures recommendations at the locations shown on the plans. The structure shall be a 6-inch diameter perforated riser with 2-inch holes at 24 holes per foot, with a 6-inch metal intake trash guard, Agridrain brand or its equivalent. A standard yard or area inlet may be installed for larger units. Inlets shall be as specified by the governing jurisdiction.

F. Under Drains: Under drains are to be placed on a 3-foot-wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of under drainpipes not terminating in an observation well shall be capped.

   The main collector pipe for under drain systems shall be constructed at a minimum slope of 0.5 percent. Observation wells and clean-out pipes should be provided (one minimum per every 1,000 square feet of surface area).

G. The bioretention facility shall not be constructed until all contributing drainage area has been stabilized.

H. Vegetation: Vegetation shall be established on all exposed surfaces. Plantings shall be as shown in the plans and as specified in Section 2 – Best Management Practice Planting.

1.5.4 Engineered Swale:

A. Rototill the soil/gravel interface to 6 inches to avoid a sharp soil/gravel interface.

B. Check dams, if required, shall be placed as specified on the plans.

C. Finished grading will provide 1 foot of freeboard above the outlet structure, at a minimum.

D. Side slopes shall be constructed at 3 horizontal to 1 vertical (3:1) minimum. 4:1 side slopes or greater are recommended.

E. No gravel or perforated pipe is to be placed under driveways.

F. Dry Swale: The bottom of the facility shall be above the seasonal high water table.

G. The longitudinal slope shall be 1 to 2 percent, maximum (up to 5 percent with check dams).

H. Bottom width to be 6 feet maximum to avoid braiding; larger widths may be used if proper berming is supplied. The minimum bottom width shall be 2 feet.

I. Under Drains (Dry Swale only): Under drains are to be place on a 3-foot-wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of under drainpipes not terminating in an observation well shall be capped.

   The main collector pipe for under drain systems shall be constructed at a minimum slope of 0.5 percent. Observation wells and clean-out pipes should be provided (one minimum per every 1,000 square feet of surface area).

J. Vegetation: Vegetation shall be established on all exposed surfaces. Plantings shall be as shown in the plans and as specified in Section 2 – Best Management Practice Planting.

1.5.5 Wet Pond/Extended Detention Wetland:

1.5.5.1 Site Preparation:

A. The foundation area shall be cleared of all trees, logs, stumps, roots, boulders, sod, and rubbish. Channel banks and breaks shall be sloped no steeper than 1 1/2 horizontal to 1 vertical (1 ½:1). Topsoil containing substantial amounts of organic matter shall be stockpiled for later placement on the dam, spillway, and borrow areas located outside the pool area.

B. Stream channels in the foundation area shall be deepened and widened as necessary to remove stones, gravel, sand, stumps, roots, mud, or other objectionable material and to accommodate compaction equipment.

C. The foundation area will be thoroughly scarified to a minimum depth of 4 inches (.10 m) before placement of the fill material and moisture added, if necessary, so the first layer of fill material can be bonded to the foundation.

D. Waste material from the construction operation such as rocks, frozen soil, mud, stumps, trees, logs, roots, or rubbish shall be disposed of by piling, burying, or burning at locations outside the dam area or as directed by the Engineer. Burning shall comply with Kansas State Department of Health and Environment Regulation No. 28-19-45 through 28-19-47 (Open Burning Policy), Missouri Department of Natural Resources, and appropriate local ordinance.

1.5.5.2 Excavation:

A. Cutoff and Principal Spillway Trenches: These trenches shall be excavated to the lines, grades, and widths shown on the drawings or as directed by the Engineer for depth adjustment during excavation. The trenches shall be kept free of standing water during back fill operations. Back fill shall be made with selected impervious material approved by the Engineer and be placed in the same manner as specified for earth fill.

B. Emergency Spillway and Outlet Channel: These excavations shall conform to the lines, grades, bottom width, and side slopes shown on the drawings or as staked in the field.

C. Borrow: The location, extent, and depth of the borrow area shall be as shown on the drawings. The borrow pits shall be stripped of all vegetation and topsoil containing substantial amounts of organic matter. This stripped material will be stockpiled for use to topsoil areas disturbed by the construction, embankment slopes, emergency spillway, and other required topsoil areas.

Borrow pits will be excavated and dressed in a manner to eliminate steep or unstable side slopes or other hazardous conditions. Side slopes shall not be steeper than 3 horizontal to 1 vertical (3:1). Surfaces of the borrow pits not covered by permanent water shall be graded and shaped to prevent the ponding of water.

1.5.5.3 Earthfill:

A. The placing and spreading of fill material shall be started at the lowest point of the foundation and the fill brought up in horizontal layers of such thickness that the required compaction can be obtained. The fill shall be constructed in continuous horizontal layers except where openings or sectionalized fills are called for. In those cases the slope of the bonding surfaces between embankment in place and embankment to be placed will not be steeper than 3 horizontal to 1 vertical (3:1). The bonding surface is to be treated the same as that specified for the foundation so as to insure a good bond with the new fill.

B. The distribution and gradation of materials shall be such that there will be no lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material. Where it is necessary to use materials of varying texture and gradation, the impervious material shall be placed in the center and upstream portions of the fill. Where zoned fills are specified of substantially differing materials, the zones shall be placed according to lines and grades shown on the drawings.

C. Backfill adjacent to pipes or structures shall be of the type and quality conforming to that specified for the adjoining fill material. The fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material needs to fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Under no circumstances shall equipment be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.

   Structure backfill may be flowable fill meeting the requirements of the local Department of Transportation or State Materials Testing Agency. The mixture shall have a 100 to 200 psi; 280day unconfined compressive strength. The flowable fill shall have a minimum pH of 4.0 and a minimum resistivity of 2,000 ohm-cm. Material shall be placed such that a minimum of 6 inches (measured perpendicular to the outside of the pipe) of flowable fill shall be under (bedding), over, and on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill shall be 7 inches to assure flowability of the material. Adequate measures shall be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill, all metal pipe shall be bituminous coated. Any adjoining soil fill shall be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material shall completely fill all voids adjacent to the flowable fill zone. At no time during the backfilling operation shall driven equipment be allowed to operate closer than 4 feet, measured horizontally to any part of a structure. Under no circumstances shall equipment be driven over any part of a structure or pipe unless there is a compacted fill of 24 inches or greater over the structure or pipe. Backfill material outside the structural backfill (flowable fill) zone shall be of the type and quality conforming to that specified for the core of the embankment or other embankment materials.

D. The completed work shall conform to the lines, grades, and elevations shown on the drawings or as staked in the field.

E. Stockpiled topsoil strippings will be placed on the outer portion of the embankment as a part of each lift. Topsoil shall not be less than 6 inches (.15m) nor more than 2 feet (.61 m) thick measured vertically and shall be compacted concurrently with the earth fill.

1.5.5.4 Compaction: The movement of the hauling and spreading equipment over the fill shall be controlled so that the entire surface of each lift shall be traversed by not less than one tread track of heavy equipment or compaction shall be achieved by a minimum of four complete passes of a sheepsfoot, rubber tired or vibratory roller. Fill material shall contain sufficient moisture such that the required degree of compaction will be obtained with the equipment used. The fill material shall contain sufficient moisture so that if formed into a ball it will not crumble, yet not be so wet that water can be squeezed out.

When required by the reviewing agency, the minimum required density should not be less than 95 percent of maximum dry density with a moisture content within 2 percent of the optimum. Each layer of fill shall be compacted as necessary to obtain that density, and is to be certified by the Engineer at the time of construction. All compaction is to be determined by AASHTO Method T-99 (Standard Proctor).

1.5.5.5 Moisture Control: The moisture content of the fill material shall be such that the required compaction can be obtained. Material that is too wet shall be dried to meet this requirement, and material that is too dry shall have water added and mixed until the requirement is met. Moisture requirements will be as shown on the drawings or in the Construction Detail section of this specification.

1.5.5.6 Principal Spillway:

A. The materials and manufacture of the pipe, anti-seep collars, coupling bands, coatings, and other appurtenances shall be as shown on the drawings and shall conform to the appropriate federal, AASHTO, or ASTM specifications suitable for the intended purpose.

B. The pipe shall be laid to the lines and grades shown on the drawings, be placed in original earth or properly compacted earth fill, and be uniformly bedded to the depth and in the manner specified. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support. Gravel bedding is not permitted.

C. Selected, impervious back fill material shall be placed around the conduit and appurtenances in layers not more than 4 inches (.10 m) thick before compaction and each layer shall be thoroughly compacted by hand tamping, manually directed power tampers, or plate vibrators to the density of the surrounding material. The height of fill shall be increased at approximately the same rate on all sides of the structure. Heavy equipment shall not be operated within 2 feet (.61 m) of any structure.

D. Bell and spigot pipe shall be placed with the bell end upstream. Joints shall be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding shall be placed so that all spaces under the pipe are filled. Care shall be exercised to prevent any deviation from the original line and grade of the pipe. The first joint must be located within 4 feet from the rise.

E. Other details (water level control structures, anti-seep collars, valves, etc.) shall be as shown on the drawings.

1.5.5.7 Foundation and Embankment Drains: Foundation and embankment drains, when required, will be placed to the lines and grades as shown on the drawings. Drain fill shall be kept from being contaminated by adjacent soil materials during placement by either placing it in a cleanly excavated trench or by keeping the drain at least one foot above the adjacent earth fill. Gradation requirements for drain fill and filter material and material requirements for pipe will be shown on the drawings or as specified in the Construction Detail section of this specification.

1.5.5.8 Concrete:

A. Concrete shall be conveyed from the mixer to the forms as rapidly as practical by methods that will prevent segregation of the aggregates and loss of mortar. Concrete shall not be dropped more than 5 feet (1.5 m) vertically except where suitable equipment is used to prevent segregation.

B. Immediately after the concrete is placed in the forms, it shall be consolidated by spading, hand tamping, or vibration as necessary to insure smooth surfaces and dense concrete.

C. Forms shall be removed in such a way to prevent damage to the concrete.

D. All exposed surfaces of the concrete shall be accurately screeded to grade and then wood floated.

E. Concrete shall be prevented from drying for a curing period of at least 7 days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period or until curing compound is applied.

F. Concrete shall not be mixed nor placed when the atmospheric temperature is less than 40 F (4 C) or more than 90 F (32 C) unless facilities are provided to prevent freezing or for cooling as required.

1.5.5.9 Vegetation: A protective cover of vegetation shall be established on all exposed surfaces of the embankment, spillway, outlet channel, and borrow area. Plantings shall be as shown in the plans and as specified in Section 2 – Best Management Practice Planting.

1.5.5.10 Inspection:

A. In addition to normal progress inspections, schedule and conduct the following formal inspections, giving the Engineer at least 24 hours prior notice of readiness for inspection:

    1. Inspection of the core trench during excavation and backfill.

    2. Inspection of principal spillway and appurtenances.

    3. Inspection of plants prior to planting.

    4. Inspection of plant locations, to verify compliance with the Drawings.

5. Final inspection after completion of seeding and planting; schedule this inspection sufficiently in advance, and in cooperation with the Engineer, so that final inspection may be conducted within 24 hours after completion of planting.

6. Final inspection at the end of the maintenance period, provided that all previous deficiencies have been corrected.

1.6 Measurement:

1.6.1 Wet Pond/Extended Detention Wetland:

A. Earth Fill in Dam: The volume of earth fill completed as specified will be determined from the design dimensions as staked in the field.

   The design dimensions shall be the measured surface of the foundation prior to stripping and the specified neat lines of the settled fill surface. Volume will be computed to the nearest cubic yard. No reduction in volume will be made for embedded conduits and appurtenances.

B. Earth Fill in Cutoff Trench: The volume of earth fill will be computed from the measured surface of the foundation prior to stripping and the bottom of the excavated cutoff trench.

C. Emergency Spillway and Outlet Channel: No volume measurement will be made for these excavations.

D. Other Component Parts: Unless otherwise specified in the Construction Detail of this specification, measurement shall be to the units shown in the bid schedule and/or drawings.

1.6.1 Engineered Swale: By the linear foot.

1.6.2 General Best Management Practices: Best Management Practices other than those listed in the previous sections shall be measured as a single unit.

1.7 Basis of Payment: Each Best Management Practice will be paid for as follows:

A. Wet Pond/Extended Detention Wetland: Payment shall be by unit price as shown in the bid schedule and/or drawings for the units listed in 1.6.1.

B. Engineered Swale: Payment shall be by the linear foot.

C. General Best Management Practices: Payment shall be a lump sum per Best Management Practice.

SECTION 2 SPECIFICATIONS FOR PLANTING AND MANAGING NATURAL VEGETATION FOR BMPs

Section 2.0 SUMMARY: The work described herein consists of furnishing, transporting, and installing all trees, shrubs, roots, seeds, and other materials as required for the restoration and establishment of Mesic Forests, Savannas, Stream (riparian) Course Forests, Wet Prairies, Emergent Wetlands, Drainage Conveyance Swales, Ephemeral Wetlands, Mesic Prairies, and Dry Prairies and management of planting areas after final acceptance. The Contractor shall perform all planting, soil preparation, management, and such additional, extra and incidental work as may be necessary to complete the work in accordance with the specifications and plans. The Contractor shall furnish all required materials, equipment, tools, labor, and incidentals, unless otherwise provided in the specifications or plans.

A. Legal Responsibilities: The Contractor shall at all times observe and comply with all Federal and State laws, local laws, ordinances, and regulations which in any manner affect the conduct of the work, and all such orders or enactments as exist at the present and which may be enacted later, of legislative bodies or tribunals having legal jurisdiction or which may have affect over the work.

B. Familiarity With Job Site: The Contractor shall familiarize himself with conditions at the job site prior to the commencement of work. The Contractor shall notify the Engineer immediately if site conditions are such that inhibit progress of the work.

   The Contractor shall be responsible for having all underground utilities located by servicing agency. The Contractor shall take all necessary precautions for the protection of utility facilities. The Contractor shall be responsible for any damage or destruction of utility facilities resulting from negligence or misconduct in the Contractor’s manner or method of execution of the work, or caused by defective work or the use of unsatisfactory materials. Whenever any damage or destruction of a utility facility occurs as a result of work performed by the Contractor, the Utility company, Owner, and Engineer will be immediately notified.

C. Quality Assurance

   1. Qualifications of Workmen: Provide at least one person who shall be present at all times during execution of this portion of the work, who shall be thoroughly familiar with this type of work and the type of materials being used. Said person shall be competent at identification of plant materials to be cut, preserved, and planted during the season (summer, winter) work is to be completed. Said person shall also direct all work performed under this section.

   2. Standards: All materials used during this portion of the work shall meet or exceed applicable federal, state, county and local laws and regulations. The use of any herbicide shall follow directions given on the herbicide label. In the case of a discrepancy between these specifications and the herbicide label, the label shall prevail.

D. Submittals

   1. Materials: Prior to delivery of any materials to the site, submit to the Engineer a complete list of all materials to be used during this portion of the work. Include complete data on source, amount, and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Engineer.
   2. Licenses: Prior to any herbicide use, the Contractor shall submit to the owner a current copy of the commercial pesticide applicator’s license, with certification in the Forestry or other

appropriate category, for each person who will be applying herbicide at the project site. A copy of each commercial pesticide applicator's license must be maintained on site at all times during completion of the work.

3. Equipment: Prior to commencement of any work, submit to the Owner a written description of all mechanical equipment and its intended use during the execution of the work.

4. After the work is complete, submit to the Owner "as-built" plans including a listing of all species installed, and quantities installed. Mark in red ink on the original planting plan any field changes or deviations from the original plans.

E. RELATED SECTIONS: Section 1 Best Management Practices

Section 2.1 REFERENCED STANDARDS: The following standards and specifications are referenced directly in this section. The latest version of these standards and specifications shall be used.

1. Draft Standard Specifications for Ecological Stewardship Programs, City of Lenexa, Kansas, August 2001
2. ANSI Z60.1 – Standard Specification for Nursery Stock

Section 2.2 DEFINITIONS: Wherever in these specification and plans the following terms are used, the intent and meaning shall be interpreted as follows:

A. **Contractor:** The individual, firm, partnership, joint venture, or corporation contracting with the Owner for performance of the work described in these specifications and plans.

B. **Owner:** The individual, firm, partnership, joint venture, or corporation employing the contractor for performance of the work described in these specifications and plans. The term may also refer to the Owner's authorized representative (Engineer).

C. **Engineer:**

1. **Plans**. The approved plan drawings, profiles, typical cross-sections, working drawings, etc., and exact reproductions thereof, which show the location, character, dimensions, and details of the work to be done.

2. **Work**. Work shall mean the furnishing of all labor, materials, equipment, and other incidentals necessary or convenient to the successful completion of the project.

2.3 MATERIALS

2.3.1 Herbicides:

A. Herbicide to be used for woody basal applications shall be triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl ester, trade name Garlon 4 or equivalent as approved in writing by the Engineer.

B. Herbicide to be used for woody foliar applications shall be triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl ester, trade name Garlon 3 or equivalent as approved in writing by Engineer.

C. Herbaceous species to be removed in areas without standing water or saturated soils shall be treated with Glyphosate, N-(phosphonomethyl) glycine, trade name Roundup or equivalent as approved in writing by Engineer.

D. Herbaceous species to be removed in areas with standing water or saturated soils shall be treated with Glyphosate, N-(phosphonomethyl) glycine in a form approved for aquatic applications such as Rodeo or equivalent as approved in writing by Engineer.

E. Selective grass herbicides and other specialty herbicides may also be used in appropriate locations.

2.3.2 Plant Materials:

A. General: Plant materials shall consist of the species, quantity, and size as shown on the plans or as selected from Table 1 in these specifications and generally meet the following requirements:

1. Conform to American Standard for Nursery Stock – ANS1 Z60.1.

2. Furnish plants and seed that are true to name and type, sound, healthy specimens representative of the species or variety with well-formed tops and healthy root systems.

3. Plant material with injured bark or roots, broken branches, objectionable disfigurements, shriveled dry roots, broken pots, insect pests, diseases or other compliance deficiencies are unacceptable.

4. Plant materials that experience excessive growth during storage period are unacceptable.

5. Bare root plant materials that have broken dormancy are unacceptable.

6. Plant materials shall be nursery grown, winter hardy stock.

7. Meet or exceed specifications of Federal, State and County laws requiring inspection for plant disease and insect control and shall be labeled in accordance with U.S. Department of Agriculture Rules and Regulations under the Federal Seed Act.

8. All plants shall be true be true to name and one of each bundle or lot shall be tagged with the name and size of the plants in accordance with the standards of practice of the American Association of Nurserymen. In all cases, botanical names shall take precedence over common names.

B. Delivery, Storage, and Handling:

1. Pick up plant materials in accordance with any special handling instructions and deliver to project site in good condition.

2. Use all means necessary to protect plant materials before during, and after installation and to protect the installed work and materials of all other trades.

3. Rootstock of the plant material shall be kept moist during transport and on-site storage.

4. Provide adequate protection of root systems from drying winds and sun while plant materials are being stored. All plant materials that cannot be planted within 1 week after delivery to the project storage area shall be “heeled-in” at a site approved by the Engineer or placed in an approved cold storage site.

5. Do not end or bind-tie in such a manner as to damage bark, break branches, or destroy natural shape.

6. Deliver plant materials to planting sites after preparations for planting have been completed and plant immediately. If planting is delayed more than 6 hours after delivery to planting sites, set materials in shade, protect from weather and mechanical damage, and keep roots moist. Heel-in bare rootstock that cannot be planted within one day at the planting site. Soak roots in water for two hours if dried out.

C. Replacements: In the event of damage during storage or planting, immediately make all repairs and replacements necessary to the approval of the Engineer and at no additional cost to the Owner.

D. Cover Crop Seeding: All grass species shall be supplied as pure live seed. Submit to the Engineer lab germination test results. Straw or hay for erosion control shall be clean, seed-free hay or threshed straw of wheat, rye, oats, or barley.

1. Prairie Cover Crop Species List

Scientific Name	Common Name	Pounds/Acre
Avena sativa (Spring)	Oats	30.00
Lolium multiflorum (Spring)	Annual rye	30.00
Secale cereale (Fall)	Winter rye	20.00

2. Wetland Cover Crop Species List

Scientific Name	Common Name	Pounds/Acre
Echinochloa crusgalli	Barnyard grass	5.00
Lolium multiflorum	Annual rye	5.00
Polygonum spp.	Smartweed	2.00

3. Swales Cover Crop/Bioengineering

Scientific Name	Common Name	Pounds/Acre
Echinochloa crusgalli (Spring)	Barnyard grass	5.00
Lolium multiflorum (Spring)	Annual rye	60.00
Secale cereale (Fall)	Winter rye	60.00

4. Tree Planting Zone Cover Crop

Scientific Name	Common Name	Pounds/Acre
Lolium multiflorum	Annual rye	30.00
Phleum pratense	Timothy	2.00

E. Herbaceous Perennial Planting: Live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be from within a 150-mile radius of the project site and native to Kansas and Missouri. Species shall be true to their scientific name as specified.

1. Dry Prairie Species List

Scientific Name	**Common Name**	**Plants/ Acre**	**Flower drift Species**
Amorpha canescens	Lead plant	25	
Anemone cylindrica	Thimbleweed	25	
Aster azureus (A. oolentangiensis)	Sky blue aster	50	X
Aster ericoides	Heath aster	50	X
Aster laevis	Smooth blue aster	50	
Aster (Solidago) ptarmicoides	Stiff aster	50	
Aster sericeus	Silky aster	50	
Ceanothus americanus	New Jersey tea	25	
Euphorbia corollata	Flowering spurge	25	
Geum triflorum	Prairie smoke	25	
Helianthus occidentalis	Western sunflower	50	
Heuchera richardsonii	Alum root	25	
Liatris aspera	Rough blazing star	50	
Lupinus perennis	Wild lupine	50	
Monarda fistulosa	Bergamot	50	X
Penstemon grandiflorus	Large flowered beard tongue	50	
Phlox pilosa	Downy phlox	25	
Ratibida pinnata	Yellow coneflower	50	
Silphium laciniatum	Compass plant	50	
Sisyrinchium campestre	Blue-eyed grass	50	
Solidago nemoralis	Old field goldenrod	25	X
Solidago speciosa	Showy goldenrod	50	
Zizia aptera	Heart-leaved Alexander	50	

2. Mesic Prairie Species List

Scientific Name	Common Name	Plants/ Acre	Flower Drift Species
Aster azureus	Sky blue aster	50	
Aster laevis	Smooth blue aster	50	
Aster novae-angliae	New England aster	50	
Baptisia alba var. macrophylla	Wild false indigo	50	
Desmodium canadense	Showy tick trefoil	50	
Echinacea angustifolia	Purple coneflower	50	X
Helianthus lateriflorus (H. rigidus)	Showy sunflower	50	
Heliopsis helianthoides	False sunflower	50	X
Lespedeza capitata	Bush clover	50	
Liatris aspera	Rough blazing star	50	
Monarda fistulosa	Bergamot	50	X
Petalostemum purpureum	Purple prairie clover	50	
Potentilla arguta	Prairie cinquefoil	25	
Ratibida pinnata	Yellow coneflower	50	X
Silphium laciniatum	Compass plant	50	
Solidago rigida	Stiff goldenrod	50	X
Tradescantia bracteata	Spiderwort	50	

3. Wetlands Species List

Scientific Name	Common Name	Plants/Acre
Acorus calamus	Wild calamus	75
Asclepias incarnata	Swamp milkweed	75
Eupatorium maculatum	Joe pye weed	50
Eupatorium perfoliatum	Boneset	50
Helenium autumnale	Sneezeweed	75
Iris virginica	Blue flag	75
Lobelia siphilitica	Great blue lobelia	75
Lycopus americanus	Water horehound	50
Lythrum alatum	Winged loosestrife	50
Mimulus ringens	Monkey flower	50
Penthorum sedoides	Ditch stone crop	50
Pycnanthemum virginianum	Mountain mint	50
Sagittaria latifolia	Common arrowhead	75
Silphium perfoliatum	Cup plant	50
Sparganium eurycarpum	Common bur reed	75
Thalictrum dasycarpum	Meadow rue	50
Verbena hastata	Blue vervain	50
Vernonia fasciculata	Iron weed	75
Veronicastrum virginicum	Culvers root	75
Zizia aurea	Golden Alexander	75

F. Prairie and Wetland Species (Seed): All grass species shall be supplied as pure live seed. Submit to the Engineer lab germination test results. Seed of all species native to Eastern Kansas or Western Missouri shall be from within a 150-mile radius of the project site. Straw or hay for erosion control shall be clean, seed-free hay or threshed straw of wheat, rye, oats, or barley.

1. Dry Prairie Species List

Scientific Name	**Common Name**	**Ounces/ Acre**	**Flower Drift Species**
Andropogon scoparius	Little bluestem grass	120.00	
Asclepias syriaca	Common milkweed	0.50	
Asclepias tuberosa	Butterfly milkweed	1.00	
Asclepias verticillata	Whorled milkweed	1.00	
Aster azureus	Sky blue aster	1.00	
Aster laevis	Smooth blue aster	1.00	
Avena sativa	Seed oats	800.00	
Bouteloua curtipendula	Side oats gramma	120.00	
Cassia fasciculata	Partridge pea	4.00	
Desmodium canadense	Showy tick trefoil	2.00	
Helianthus occidentalis	Western sunflower	1.00	X
Heliopsis helianthoides	False sunflower	1.00	X
Monarda fistulosa	Wild bergamot	2.00	X
Monarda punctata	Spotted bergamot	2.00	
Oenothera biennis	Common evening primrose	1.00	X
Ratibida pinnata	Yellow coneflower	4.00	X
Rudbeckia hirta	Black-eyed Susan	8.00	X
Silphium laciniatum	Compass plant	2.00	
Solidago rigida	Stiff goldenrod	2.00	
Tradescantia bracteata	Spiderwort	1.00	
Verbena stricta	Hoary vervain	2.00	X

2. Mesic Prairie Species List

Scientific Name	Common Name	Ounces/ Acre	Flower Drift Species
Andropogon gerardii	Big bluestem grass	80.00	
Asclepias syriaca	Common milkweed	0.50	
Aster novae-angliae	New England aster	1.50	X
Avena sativa	Seed Oats	800.00	
Cassia fasciculata	Partridge pea	2.00	X
Desmodium canadense	Showy tick trefoil	2.00	X
Echinacea angustifolia	Purple coneflower	2.00	
Elymus canadensis	Canada wild rye	48.00	
Elymus virginicus	Virginia Wild Rye	6.00	
Heliopsis helianthoides	False sunflower	1.00	X
Lespedeza capitata	Bush clover	2.00	
Liatris aspera	Rough blazing star	1.00	
Monarda fistulosa	Wild bergamot	2.00	X
Oenothera biennis	Common evening primrose	1.00	X
Panicum virgatum	Switch grass	16.00	X
Petalostemum purpureum	Purple prairie clover	1.00	
Potentilla arguta	Prairie cinquefoil	1.00	
Ratibida pinnata	Yellow coneflower	4.00	X
Rudbeckia hirta	Black-eyed susan	8.00	X
Silphium laciniatum	Compass plant	2.00	
Solidago rigida	Stiff goldenrod	2.00	X
Sorghastrum nutans	Indian grass	24.00	
Tradescantia bracteata	Spiderwort	1.00	
Verbena stricta	Hoary vervain	1.00	
Zizia aptera	Heart-leaved Alexander	1.00	

3. Wetland Species List (Emergent and Wet Prairie and Stream Buffer Edge)

Scientific Name	**Common Name**	**Ounces/ Acre**	**Zone**
Alisma subcordatum	Water plantain	2.00	E
Angelica atropurpurea	Angelica	2.00	WP, BE
Asclepias incarnata	Swamp milkweed	2.00	WP, BE
Aster novae-angliae	New England aster	1.00	WP, BE
Aster puniceus	Marsh aster	0.50	WP, BE
Avena sativa	Oats	640.00	WP, BE
Calamagrostis canadensis	Blue joint grass	4.00	WP, BE
Carex hystricina	Bottlebrush sedge	4.00	BE
Carex scoparia	Pointed broom sedge	32.00	WP, BE
Cicuta maculata	Water hemlock	0.10	WP
Echinochloa crusgalli	Barnyard grass	6.00	WP, BE
Elymus canadensis	Canada wild rye	16.00	BE
Elymus virginicus	Virginia Wild rye	24.00	WP, BE
Glyceria striata	Fowl manna grass	1.00	WP, BE
Helenium autumnale	Sneezeweed	1.00	WP
Juncus effusus	Common spike rush	1.00	WP, BE
Liatris pycnostachya	Prairie blazing star	0.50	WP
Lobelia siphilitica	Great blue lobelia	1.00	WP, BE
Lycopus americanus	Common water horehound	0.05	WP, BE
Mimulus ringens	Monkey flower	1.00	WP, BE
Panicum virgatum	Switch grass	2.00	WP, BE
Pycnanthemum virginianum	Common mountain mint	0.25	WP, BE
Rudbeckia laciniata	Wild golden glow	1.00	WP, BE
Scirpus atrovirens	Dark green rush	1.00	WP, BE
Scirpus cyperinus	Wool grass	2.00	WP, BE
Scirpus validus creber	Great bulrush	1.00	WP, BE
Silphium perfoliatum	Cup plant	2.00	WP, BE
Spartina pectinata	Prairie cord grass	2.00	WP, BE
Teucrium canadense	Germander, Wood sage	0.10	WP, BE
Thalictrum dasycarpum	Purple meadow rue	1.00	WP
Verbena hastata	Blue vervain	2.00	WP, BE

4. Savanna Species List

Scientific Name	Common Name	Ounces/Acre
Aquilegia canadensis	Wild columbine	0.50
Bromus pubescens	Woodland brome	2.00
Carex blanda	Woodland sedge	.50
Carex pensylvanica	Pen sedge	1.00
Carex sparganioides	Woodland sedge	.50
Carex rosea	Wood sedge	1.00
Carex sprengelii	Sprengel's sedge	2.00
Corylus americana	Hazelnut	16.00
Elymus virginicus	Virginia wild rye	12.00
Hystrix patula (Elymus hystrix)	Bottlebrush grass	2.00
Smilacina racemosa	False Solomon's seal	2.00
Solidago flexicaulis	Zig zag goldenrod	1.00

G. Tree and Shrub Species: Seedling protection tubes shall be 4" diameter, 24" tall, photodegradable plastic, with a 2-year life span, such as Pro/Gro tubes manufactured by Protex, or equivalent with written approval by the Engineer. Trees shall be from within a 150-mile radius of the project site. All trees shall be 1 to 2" caliber bare root nursery grown stock unless approved in writing by the Engineer.

1. Savanna Species List

Scientific Name	Common Name	Plants/Acre
Quercus alba	White oak	25
Quercus macrocarpa	Bur oak	25
Quercus rubra	Red oak	25
Tilia americana	Basswood	25

2.4 Selective Woody Brush Removal

A. Description: This section includes the selective cutting and disposal of woody brush including trees and shrubs.

1. Method

a. The Contractor will cut all woody species designated for removal in up to approximately 12.5 acres of woods with hand tools including, but not necessarily limited to, gas powered chain saws, gas powered clearing saws, bow saws, and loppers.

b. All stumps shall be cut flat with no sharp points, and to within two inches of surrounding grade.

c. Removal of undesirable woody species shall preferentially occur when the ground is frozen.

d. Stumps shall be left in the ground and not removed. All stumps shall be treated with an approved herbicide mixed with a marking dye.

e. Girdling may also be used in combination with cutting and stump herbicide treatment if approved in writing by the owner. Trees to be girdled shall have a one inch deep notch cut completely around the trunk approximately 36" above surrounding grade. A basal application of an approved herbicide shall also be used following label directions.

f. Stack cut brush in piles not to exceed eight (8) feet in height by twelve (12) foot in diameter. Piles shall be spaced as necessary to minimize dragging of cut material over long distances. Piles shall be located in open areas without canopy branches of preserved trees overhanging the piles. Piles shall be burned on site. Ensure no debris (rubble, plastic, etc.) other than the cut brush is placed in the burn piles.

g. A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the owner within 24 hours.

h. The Contractor shall maintain copies at the project site of all current pesticide applicator's licenses, herbicide labels, and MSDS's (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

i. Species designated for removal shall be determined for a specific site and may include some or all of the following species:

Common Name	**Scientific Name**	**Disposition**
Boxelder	*Acer negundo*	Remove all
Common buckthorn	*Rhamnus cathartica*	Remove all
Tartarian Honeysuckle Amur Honeysuckle Showy fly honeysuckle	*Lonicera tatarica* *Lonicera maackii* *Lonicera x bella*	Remove all Remove all Remove all
Prickly ash	*Xanthoxylum americanum*	Reduce by 50%
Red elm	*Ulmus rubra*	Reduce by 50%
Green ash	*Fraxinus pennsylvanica subintegerrima*	Reduce by 50%
Gray dogwood	*Cornus racemosa*	Reduce by 50%

2. Clean-Up, Removal and Repair

a. Clean up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths and paved areas shall be kept free of mud and dirt.

b. Removal: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor.

c. Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. In the event any vegetation designated to be preserved is damaged, notify the owner within 24 hours. The Contractor shall be liable for remedying said damages to plant materials.

3. Inspection

   a. After completion of selective woody brush removal, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

   b. After provisional acceptance of selective woody brush removal, the Contractor shall conduct a year-end inspection of work areas. Within five business days of the inspection, the Contractor shall notify the owner in writing of the results of the inspection, and noting any stumps that have re-sprouted.

4. Acceptances and Guarantee

   a. Provisional Acceptance: The work shall be provisionally accepted by the Owner after initial selective woody brush removal is completed per the given plans and specifications, and the Contractor has completed all clean up, removal, and repair as described in this section. Selective woody brush removal shall be considered 75% complete at the time of provisional acceptance.

   b. Final Acceptance: Selective woody brush removal shall be considered 100% complete after the Contractor has complied with all provisions of the Guarantee described in this section.

   c. Guarantee: The Contractor guarantees not more than 10% of the cut stumps shall be re-sprouting at any time. The Contractor shall guarantee the work until one full year after brushing.

2.5 Herbaceous Species Removal

A. Description: This section includes the eradication of herbaceous species, including grasses and forbs. This work will occur in the areas to be restored to prairies, areas to be restored to wetlands and areas to receive native landscaping treatments.

1. Method

   a. The Contractor will treat all vegetation within targeted areas with an approved herbicide, applied by a certified application, in accordance with applicable laws. Herbicide application instructions given on the label shall be followed at all times.

   b. Targeted areas may be shown on plans or located in the field by the Engineer.

   c. Care shall be taken not to affect vegetation outside of target areas.

   d. A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the Engineer within 24 hours.

   e. The Contractor shall maintain copies at the project site of all current pesticide applicator's licenses, herbicide labels, and MSDS's (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

f. Herbicide may be applied using a backpack sprayer, a hand-held wick applicator, or a vehicle mounted high-pressure spray unit, as specified by the chemical label, in accordance with applicable laws.

1. Clean-Up, Removal and Repair

a. Clean-Up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths and paved areas shall be kept free of mud and dirt.

b. Removal: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor, in accordance with the chemical label and applicable laws.

c. Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. In the event any vegetation outside of targeted areas is damaged, notify the Owner within 24 hours. The Contractor shall be liable for remedying said damages to plant materials.

3. Inspection

a. After completion of herbaceous species removal, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

b. After provisional acceptance of herbaceous species removal, the Contractor shall conduct monthly inspections of work areas until the end of the current growing season. Within five business days of the inspection, the Contractor shall notify the Engineer by telephone of the results of the inspection.

4. Acceptance and Guarantee

a. Provisional Acceptance: The work shall be provisionally accepted by the Owner after initial herbaceous species removal is completed per the given plans and specifications, and the Contractor has completed all clean up, removal, and repair as described in 3.2 of this section. Herbaceous species removal shall be considered 90% complete at the time of provisional acceptance.

b. Final Acceptance: Herbaceous species removal shall be considered 100% complete after the Contractor has complied with all provisions of the Guarantee described in 3.4C of this section.

c. Guarantee: The Contractor guarantees not more than 10% vegetative cover within the treated area at any time. The Contractor shall guarantee the work until provisional acceptance of Seeding, Herbaceous perennial planting, and/or tree and shrub planting in the targeted area.

2.6 Soil Preparation

A. Description: This section includes preparation of soil prior to seeding and/or planting for areas to be restored to prairies, wetlands and native landscaping in areas currently dominated by agricultural or weedy vegetation, old fields, etc. All herbaceous species removal will be done prior to soil preparation.

1. Method

   a. Prior to seeding and planting, rotovate soils to produce a fine seedbed.

   b. Soils shall not have a measured compaction greater five pounds per square inch, based on Lang or Cone penetrometer measurements, at the time of seeding or planting unless otherwise stated on the plans or in the specifications. If ten percent or more of penetrometer readings are greater than five pounds per square inch, disc, rotovate, and/or chisel plow said areas as necessary to reduce compaction.

   c. Re-check soil compaction as described above after tillage. Repeat treatment until ninety percent or more of penetrometer readings are less than five pounds per square inch.

   d. Remove all foreign matter larger than one inch in any dimension from the areas to be seeded and/or planted.

2. Clean-Up, Removal and Repair

   a. Clean-Up: After soil preparation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over the area to minimize additional compaction.

   b. Repair: Repair any damages caused by the Contractor during completion of the work described in this Section.

2. Inspection: After completion of soil preparation, the Contractor shall schedule with the Owner a final acceptance inspection of soil preparation.

3. Acceptance and Guarantee: Final acceptance: this portion of the work shall be considered 100% complete after the Contractor has completed soil preparation, and completed all required clean up as described in this section.

2.7 Cover Crop Seeding

A. Description: This section includes installation of cover crop seed in any area of disturbed soil that may or may not be final planted to native, plantings and species.

1. Method

   a. Seeds shall have proper stratification and/or scarification to break seed dormancy for spring planting.

   b. Seeding shall be preferentially conducted as a late fall dormant seeding (after November 1) or in early spring (as soon as the soil is free of frost and in a workable condition but no later than July 15).

c. All seed shall be preferentially installed with a rangeland type grain drill or no-till planter, such as by Truax, or equivalent as approved in writing by the Owner.

d. If soil is too wet to install seed as described above, a mechanical broadcast seeder, such as by Cyclone, shall be used. Hand broadcasting of seed may also be employed. Within 24 hours, or as soon as site conditions permit, broadcast seeded areas shall be rolled or dragged perpendicular to the slope.

e. Within seven days of seeding, crimp 2,000 pounds per acre of straw or hay for erosion control onto slopes greater than one foot horizontal to five foot vertical (1:5).

f. If area to be seeded was treated with herbicide, seeding shall occur no less than 14 days after herbicide application.

2. Clean-Up, Removal and Repair

a. Clean-Up: The work area shall be kept free of debris by the Contractor. After seed installation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over seeded areas to minimize disturbance

b. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

c. Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

3. Inspection: After completion of seeding, the Contractor shall schedule with Owner a provisional acceptance inspection of the work.

4. Acceptance and Guarantee

a. Provisional Acceptance: The work shall be considered 90% complete after all seed has been installed and the Contractor has completed all required clean up, removal, and repair as described in this section.

b. Final Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and completed all required clean up, removal, and repair as described in this section.

c. The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 70% plant cover.

2.8 Herbaceous Perennial Planting

A. Description: This section includes installation of live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants.

1. Method

a. Planting of all live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be completed after May 15 but no later than July 15.

b. All live herbaceous plants shall be potted, two year old nursery grown stock unless approved in writing by the Owner.

c. All live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be approved by the Owner prior to installation.

d. Provide healthy, vigorous live herbaceous perennial plants; provide freshly dug tubers, bulbs, and dormant rootstocks of herbaceous perennial plants. Do not use materials that have been in cold storage for longer than 45 days.

e. Deliver live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants to project site after preparations for planting have been completed.

f. Live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks shall be packed in such a manner as to insure adequate protection against wind damage, desiccation, and other physical damage while in transit.

g. If planting is delayed more than four hours after delivery, keep plants in refrigerated container or set plants in shade protected from weather and mechanical damage, and keep moist and cool.

h. Live herbaceous emergent perennial plants, tubers, bulbs, and dormant rootstocks shall be installed in 0-6” depth of water.

i. Emergent live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be clustered into groups of 25-50 individuals of the same species.

j. Dry prairie, mesic prairie, and wetlands live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be clustered into groups of 75-125 individuals of randomly mixed species from the species lists given in this section.

k. All live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be adequately healed in to prevent desiccation.

l. All groupings of live herbaceous emergent perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be protected from wildlife herbivory, if necessary, on all four sides by 36-48” high fencing attached to wooden stakes. The Contractor shall submit shop drawings, including a materials list, to the Owner for approval prior to installation. Said fencing shall be removed by the Contractor one full growing season after installation or as otherwise directed by the Owner.

m. If planting into an area treated with herbicide, plant materials shall be installed not less than 14 days after herbicide treatment.

2. Clean-Up, Removal and Repair

   a. Clean-Up: The work area shall be kept free of debris by the Contractor. After the work is complete, clean up any remaining materials, plant containers, debris, trash, etc. Avoid driving or walking over planted areas to minimize disturbance.

   b. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

   c. Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

3. Inspection: After completion of planting and fencing, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

4. Acceptance and Guarantee

   a. Provisional Acceptance: the work shall be considered 90% complete after initial planting and construction of fencing, and after the Contractor has completed all required clean up, removal, and repair as described in this section.

   b. Final Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, completed all required clean up, removal, and repair as described in this section, and removed fencing as described in this section.

   c. The Contractor shall guarantee planted areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 10% survivorship of all planted species

2.9 Seeding

A. Description: This section includes installation of seed.

1. Method

   a. Seeds shall have proper stratification and/or scarification to break seed dormancy for spring planting.

   b. All legumes shall be inoculated with proper rhizobia at the appropriate time prior to planting.

   c. Seeding shall be preferentially conducted as a late fall dormant seeding (after November 1) or in early spring (as soon as the soil is free of frost and in a workable condition but no later than July 15).

d. All seed on drivable slopes shall be preferentially installed with a rangeland type grain drill or no-till planter, such as by Truax, or equivalent as approved in writing by the Owner.

e. If soil is too wet to install seed as described in 3.1D. above, a mechanical broadcast seeder, such as by Cyclone, shall be used. Hand broadcasting of seed may also be employed. Within 24 hours, or as soon as site conditions permit, broadcast seeded areas shall be rolled or dragged perpendicular to the slope. Hydro seeding and mulching onto a lightly disked soil surface is also an acceptable method. Contractor shall provide specifications on the nature of the equipment, mulching system, and tackifier that would be used if hydro seeding/mulching is the chosen procedure.

f. Within seven days of seeding, crimp 2,000 pounds per acre of clean weed free straw or hay for erosion control onto slopes greater than one foot horizontal to five foot vertical (1:5).

g. If area to be seeded was treated with herbicide, seeding shall occur no less than 14 days after herbicide application.

2. Clean-Up, Removal and Repair

   a. Clean-Up: The work area shall be kept free of debris by the Contractor. After seed installation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over seeded areas to minimize disturbance.

   b. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

   c. Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

3. Inspection: After completion of seeding, the Contractor shall schedule with Owner a provisional acceptance inspection of the work.

4. Acceptance and Guarantee

   a. Provisional Acceptance: The work shall be considered 90% complete after all seed has been installed and the Contractor has completed all required clean up, removal, and repair as described in this section.

   b. Final Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and completed all required clean up, removal, and repair as described in this section.

   c. The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 70% plant cover, seedlings of three planted grass/sedge species found, and seedlings of three planted forb species found.

d. The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria two full growing seasons after provisional acceptance: 80% plant cover, 5% cover by planted native grass/sedge species, 10% cover by planted forb species, and 20% of planted species are found.

2.10 Tree and Shrub Planting

A. Description: This section includes planting of trees and shrubs.

1. Method

a. Planting of trees shall be completed as soon as the soil is free of frost and in a workable condition but no later than July 15.

b. All trees shall be approved by the Engineer prior to installation.

c. Provide healthy, vigorous, freshly dug plant materials. Do not use materials that have been dug more than 30 days in advance.

d. Deliver trees to project site after preparations for planting have been completed.

e. Trees shall be packed in such a manner as to insure adequate protection against wind damage, desiccation, and other physical damage while in transit.

f. If planting is delayed more than four hours after delivery, keep plants in refrigerated container or set plants in shade protected from weather and mechanical damage, and keep moist and cool.

g. Trees shall be randomly planted from the species lists given in this section.

h. A seedling protection tube shall be installed around every tree and shrub within seven days of planting. Seedling protection tubes shall be secured to the ground with a 3/8”x36” bamboo stake and plastic cable tie. Seedling protection tubes shall not be removed by the Contractor unless directed by the Engineer.

i. If planting into an area treated with herbicide, plant materials shall be installed not less than 14 days after herbicide treatment.

2. Clean-Up, Removal and Repair

a. Clean-Up: The work area shall be kept free of debris by the Contractor. After the work is complete, clean up any remaining materials, plant containers, debris, trash, etc. Avoid driving or walking over planted areas to minimize disturbance.

b. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

c. Repair: Repair any damages caused by the Contractor during completion of the work described in this Section.

3. Inspection: After completion of the work, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

4. Acceptance and Guarantee

   a. Provisional Acceptance: The work shall be considered 90% complete after initial planting and installation of seedling protection tubes, and after the Contractor has completed all required clean up, removal, and repair as described in this section.

   b. Final Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and has completed all required clean up, removal, and repair as described in this section.

   c. The Contractor shall guarantee planted areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 50% survivorship of all planted species.

2.11 Management

A. Description: Seeding, herbaceous perennial planting, tree and shrub planting, woody brush removal.

B. Execution

   1. Herbicide Application

      a. The Contractor will treat all undesirable species with an approved herbicide. Herbicide application instructions given on the label shall be followed at all times.

      b. Undesirable species include plant species not native to Kansas or Missouri.

      c. Care shall be taken not to affect surrounding vegetation. The Contractor may be required to replant any vegetation affected by herbicide outside of targeted species.

      d. A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the Owner within 24 hours.

      e. The Contractor shall maintain copies at the project site of all current pesticide applicator’s licenses, herbicide labels, and MSDS’s (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

      f. Herbicide may be applied using a backpack sprayer, a hand-held wick applicator, or a vehicle mounted high-pressure spray unit.

      g. For bidding purposes, Contractor shall provide costs for three herbicide control treatments over an Owner-specified number of acres.

2. Mowing

   a. The Contractor shall mow all seeded areas to a height of 8-12” after vegetation in said areas reach a height of 30” and before non-native species go to seed during the first two growing seasons after planting.

   b. For bidding purposes, Contractor shall provide costs for providing three mowings over an Owner-specified number of acres.

3. Prescribed Burning

   a. Prescribed burning shall be the primary method of long-term ecological management and weed control of planting areas at the project site. Burning shall be conducted annually after the second full growing season or as directed by the Owner.

   b. Prior to the commencement of prescribed burning, the Contractor shall compile a burn plan that outlines a plan of action, identifies contingencies, and lists the names and phone numbers of emergency agencies (fire department, police department, etc.). Proper notice of intent to burn shall be given.

   c. The Contractor shall apply for and receive all required permits prior to the commencement of prescribed burning.

   d. For bidding purposes, contractor shall provide costs for two burns over an Owner-specified number of acres.

4. Clean-Up, Removal and Repair

   a. Clean-Up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths, and paved areas shall be kept free of mud and dirt.

   b. Removal: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor.

   c. Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. The Contractor shall be liable for remedying damages to plant materials and property at no cost to the Owner caused by Contractor negligence during completion of the work.

5. Inspection: At the request of the Engineer, the Contractor shall schedule an inspection with the Owner to review the work completed by the Contractor pursuant to this section.

6. Acceptance and Guarantee: Final acceptance: Management shall be considered 100% complete after the Contractor has complied with all parts of this section.

2.12 Method of Measurement: Natural vegetation planting and management will be measured by one of the following:

Per acre or tenth part thereof.

2.13 Basis of Payment: Natural vegetation planting and management will be paid by the contract unit bid price.

2.14 Odds & Ends

A. Maintenance:

1. General: Maintain all components of the structure, starting with the clearing operations and continuing for 30 calendar days after all planting is complete and approved by the Engineer.

2. Work Included:

   a. Maintenance shall include erosion and sediment control. Construction operations will be carried out in such a manner that erosion will be controlled and water and air pollution minimized. State and local laws concerning pollution abatement will be followed.

   b. Maintenance shall include grading all borrow areas to provide proper drainage and left in a slightly better condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms shall be stabilized by seeding, limin, fertilizing, and mulching.

   c. Maintenance shall include all watering, weeding, cultivating, spraying, and pruning necessary to keep the plant materials in a healthy growing condition and to keep the planted areas neat and attractive throughout the maintenance period.

   d. Provide all equipment and means for proper application of water to planted areas.

   e. Protect all planted areas against damage, including erosion and trespassing, by providing and maintaining proper safeguards.

3. Replacements:

   a. At the end of the maintenance period, all plant material shall be in a healthy growing condition.

   b. During the maintenance period, should the appearance of any plant indicate weakness and probability of dying, immediately replace that plant with a new and healthy plant of the same type and size without additional cost to the Engineer.

4. Extension Oo Maintenance Period: Continue the maintenance period at no additional cost to the Owner until all previously noted deficiencies have been corrected, at which time the final inspection shall be made.

B. Acceptance:

1. The Contractor shall guarantee 80% survival of tree and shrub planting stock and 95% herbaceous.

2. Ninety days after planting, after “leaf-out”, a final inspection shall be made by the Contractor and the Engineer.

3. The Contractor shall satisfactorily replace any seedlings or shrubs up to 80% of the total number specified herein and up to 95% of the total area of herbaceous planting. With this replacement, as approved by the Engineer, the Contractor shall be issued a letter of acceptance for work covered by this Section of the Specifications in accordance with applicable provisions stated in the Special Provisions.

4. Clean-Up: General: During the progress of this work, and upon completion, thoroughly clean the project area and remove and properly dispose of all resultant dirt, debris and other waste materials.

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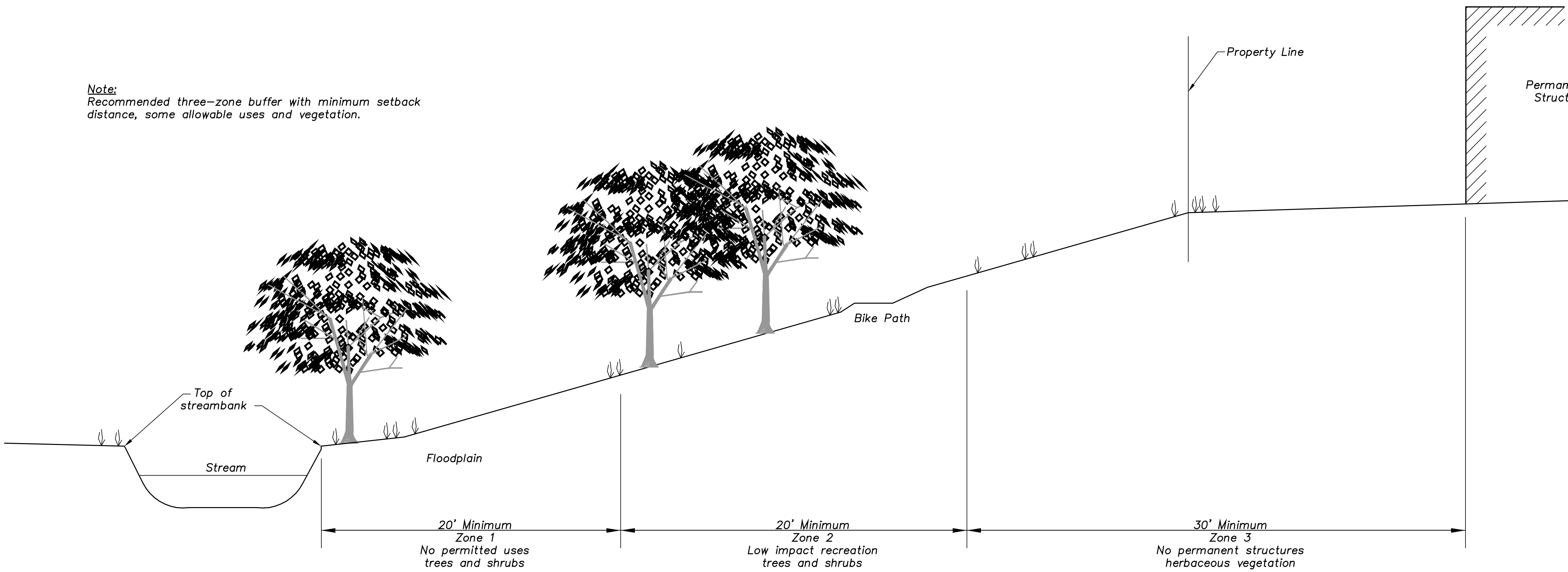
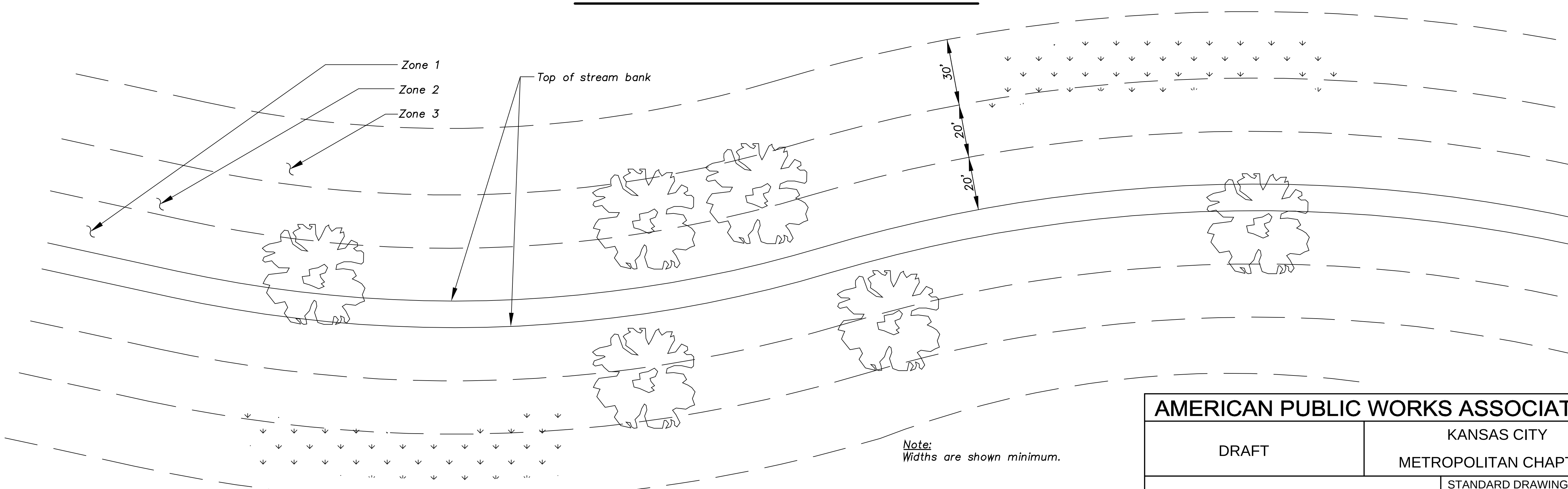


Section View of Three Zone Stream Buffer



Plan View of Three-Zone Stream Buffer

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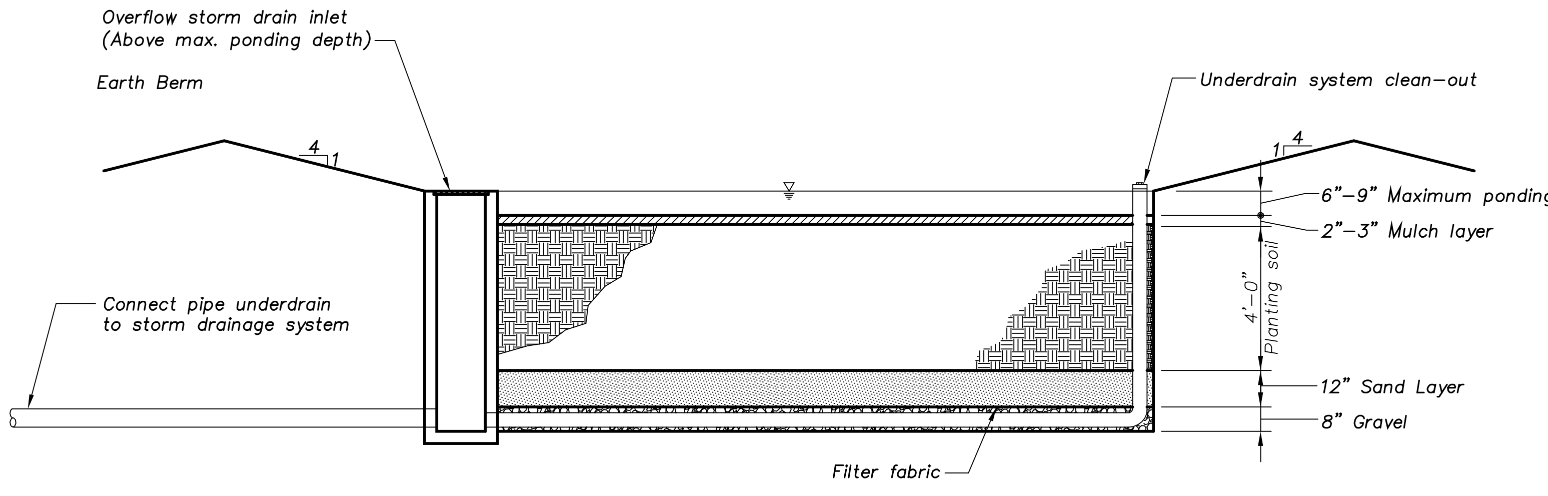
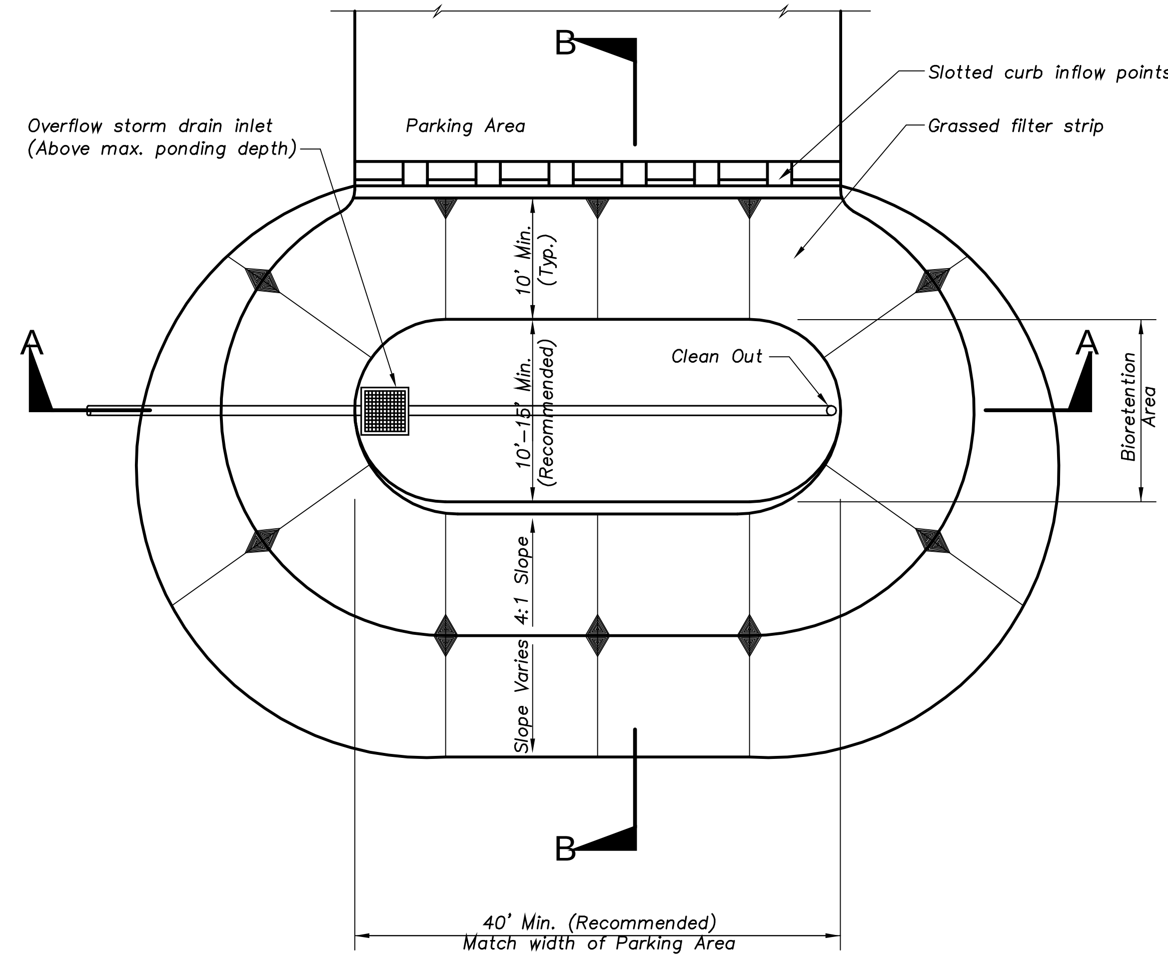
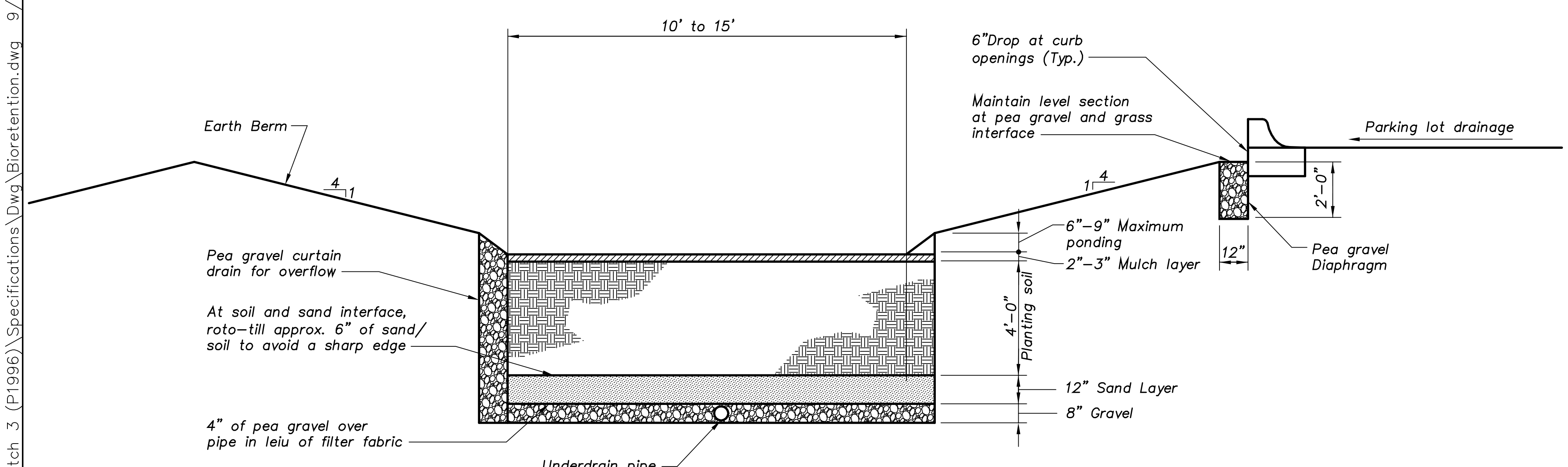
STREAM BUFFER	STANDARD DRAWING NUMBER BF-1 ADOPTED:



SECTION A-A



PLAN VIEW



SECTION B-B

Notes:

1) Ponding area is designed to store the water quality volume.

2) Organic mulch layer should be a hardwood mulch, pine mulch and wood chips are not acceptable materials.

3) Grass filter strip width is equal to 1/2 the unit area length. The minimum width is 60 inches.

4) A 48 inch depth of planting soil is to be used unless calculations are performed to base soil depth on the soil capacity.

5) Energy dissipaters including filter strips and sediment basins may be used as pretreatment of water into the bioretention cell to reduce inflow velocities.

6) 3-6 inch diameter clean crushed stone shall be used to construct gravel envelopes. ASTM C-33 sand shall be used for the sand filter layer. 1/2 in. clean crushed stone shall be used for gravel curtains.

7) Overflow catch basin shall be an Agridrain drawdown structure or approved equal

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BIORETENTION DETAILS	STANDARD DRAWING NUMBER BR-1 ADOPTED:

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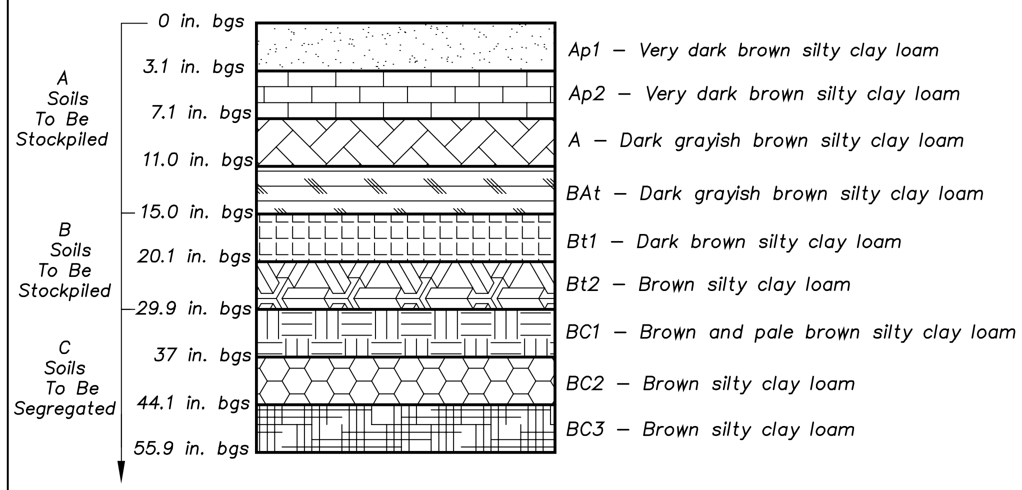
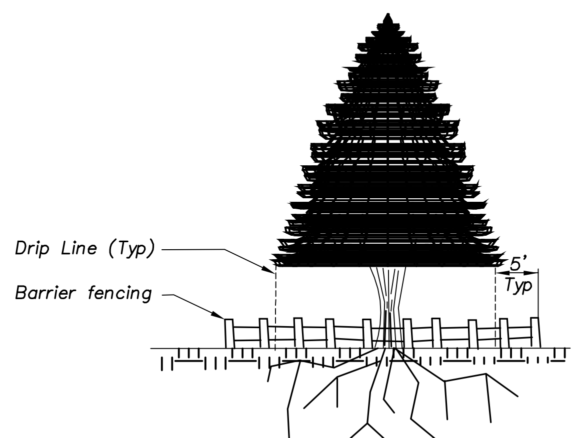
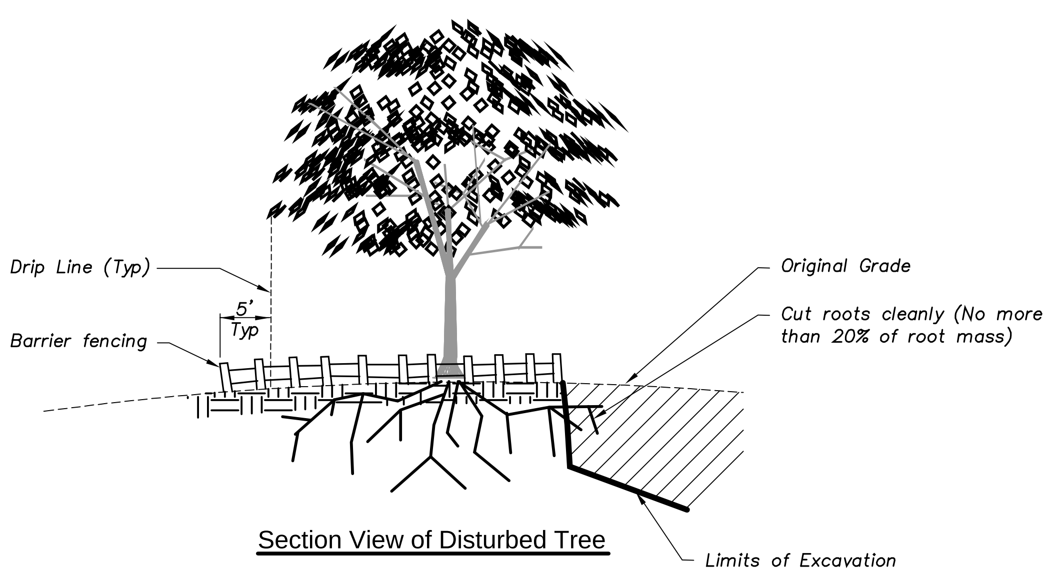


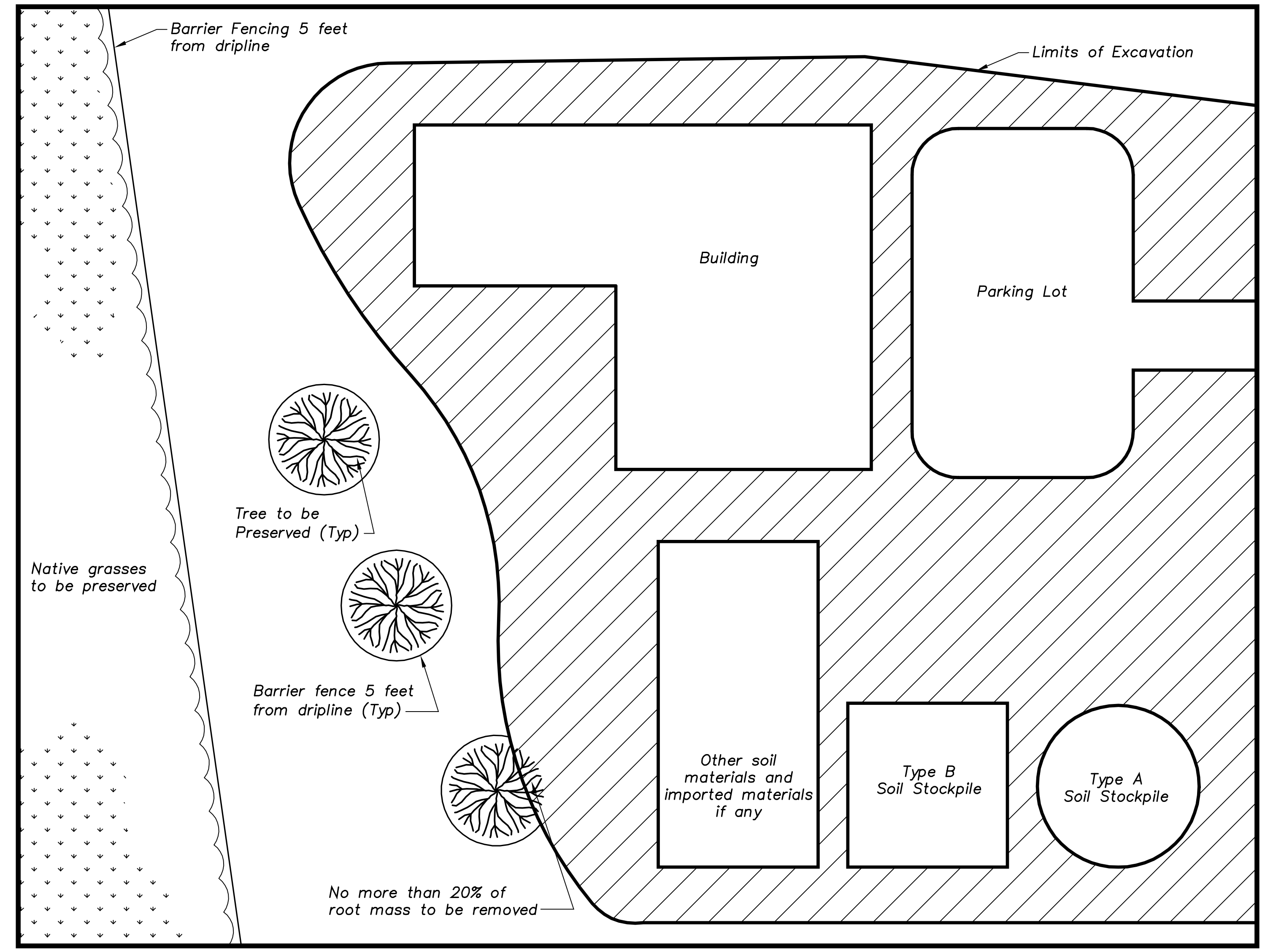
Typical Soil Profile (Sharpsburg Series)



Section View of Preserved Tree



Section View of Disturbed Tree



Example Site Layout

NOTES:

1. No vehicular access or storage of materials is allowed within the dripline of vegetation to be preserved.
2. Approximate horizontal limits of protection are shown on the site grading, clearing and demolition plans.
3. Install protective barriers and erosion/sediment control structure prior to clearing and around stock piles as required.

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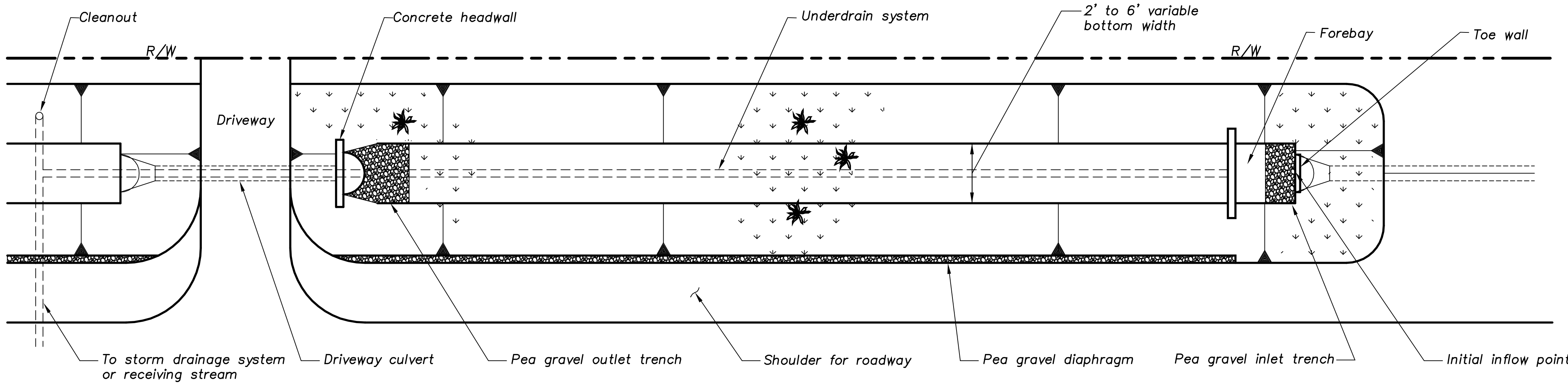
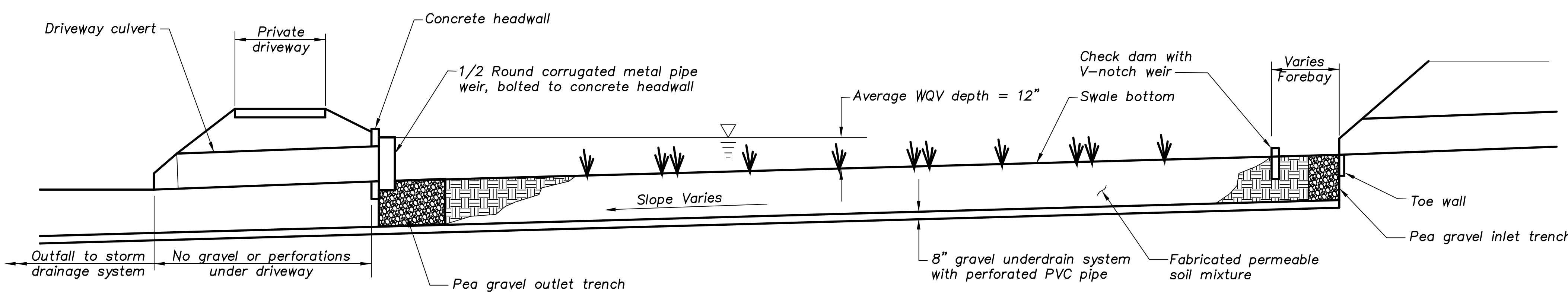
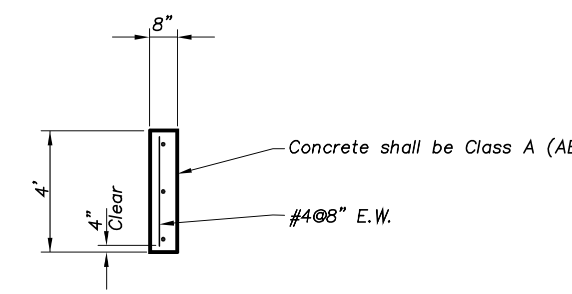
NATIVE SOIL AND VEGETATION PRESERVATION	STANDARD DRAWING NUMBER SV-1 ADOPTED:



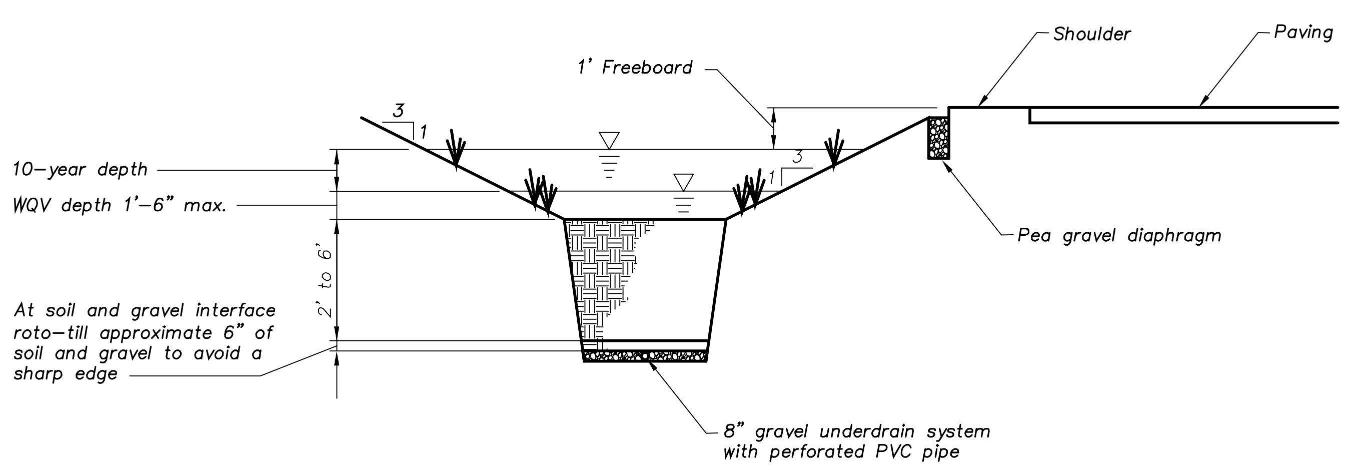
Plan View



Profile of Swale



Typical Section of Check Dam and Toe Wall



Typical Section of Swale

Dry Swale

Notes:

1) 1/2-inch diameter clean crushed stone shall be used to construct gravel envelopes.

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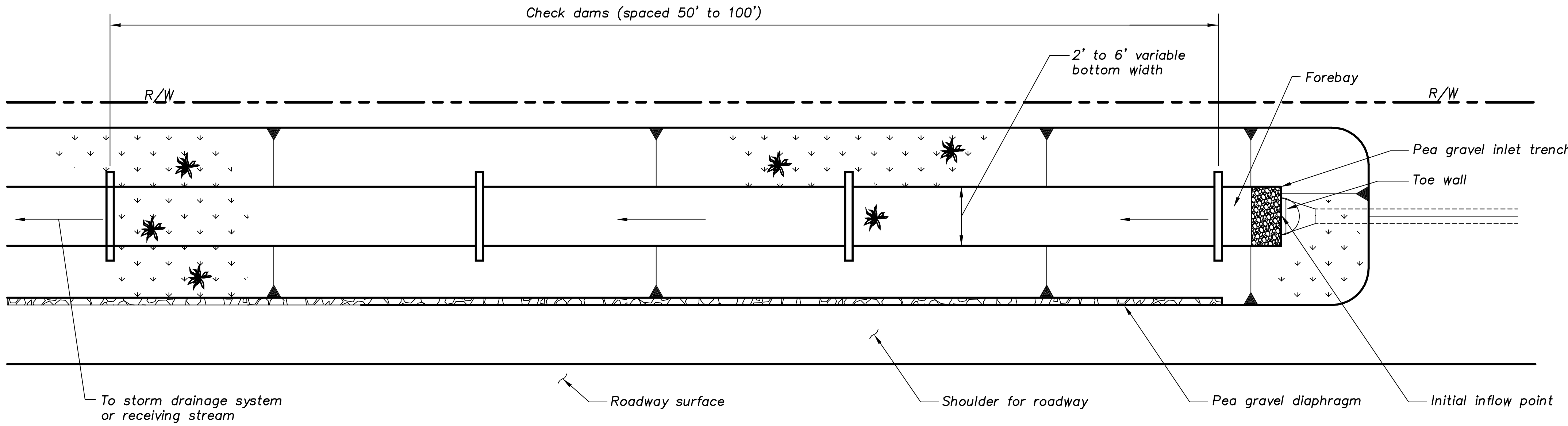
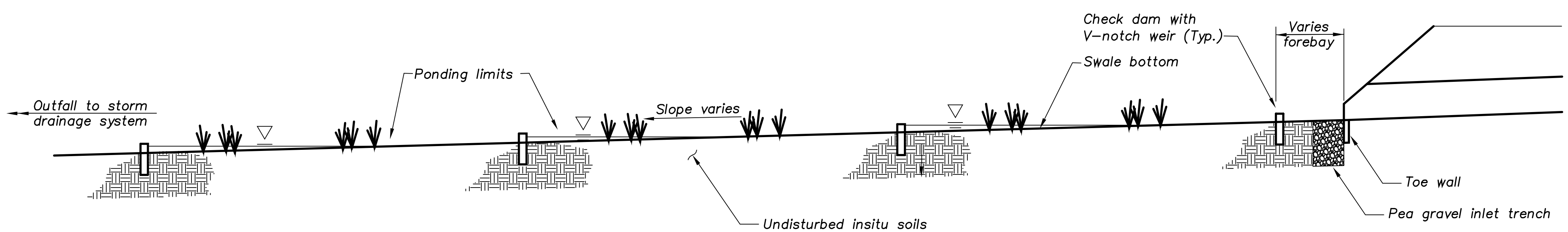
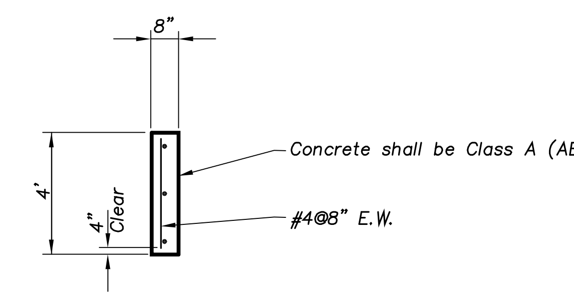
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
DRY SWALE DETAIL	STANDARD DRAWING NUMBER SW-1 ADOPTED:



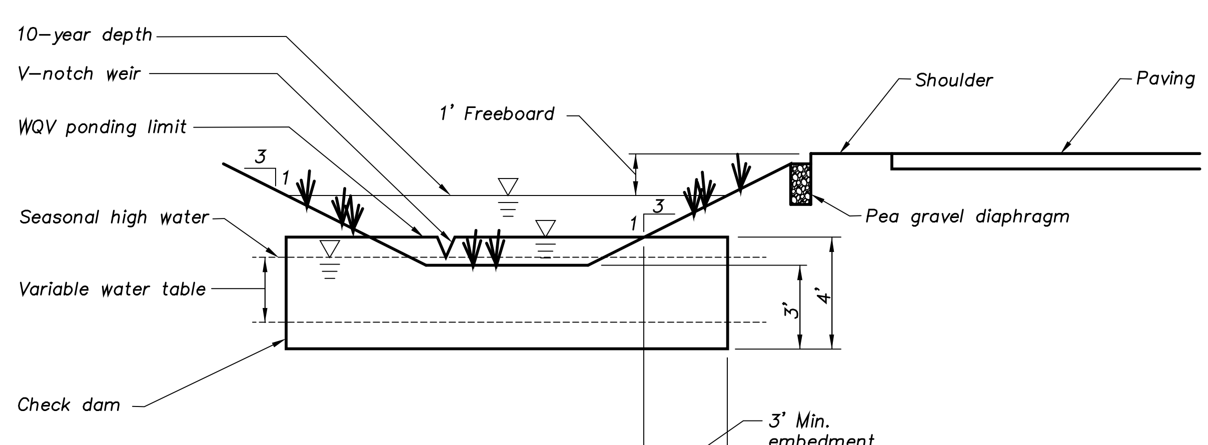
Plan View



Profile of Swale



Typical Section of Check Dam and Toe Wall



Typical Section of Swale

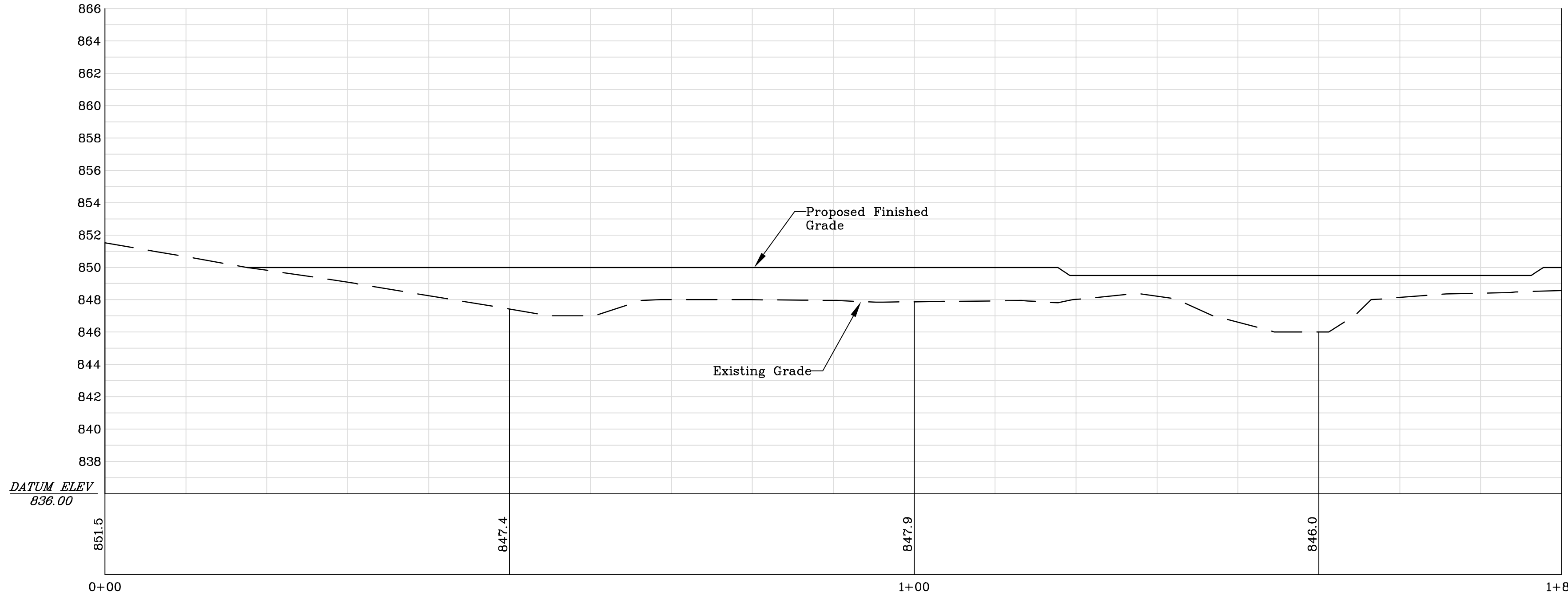
Wet Swale

Notes:

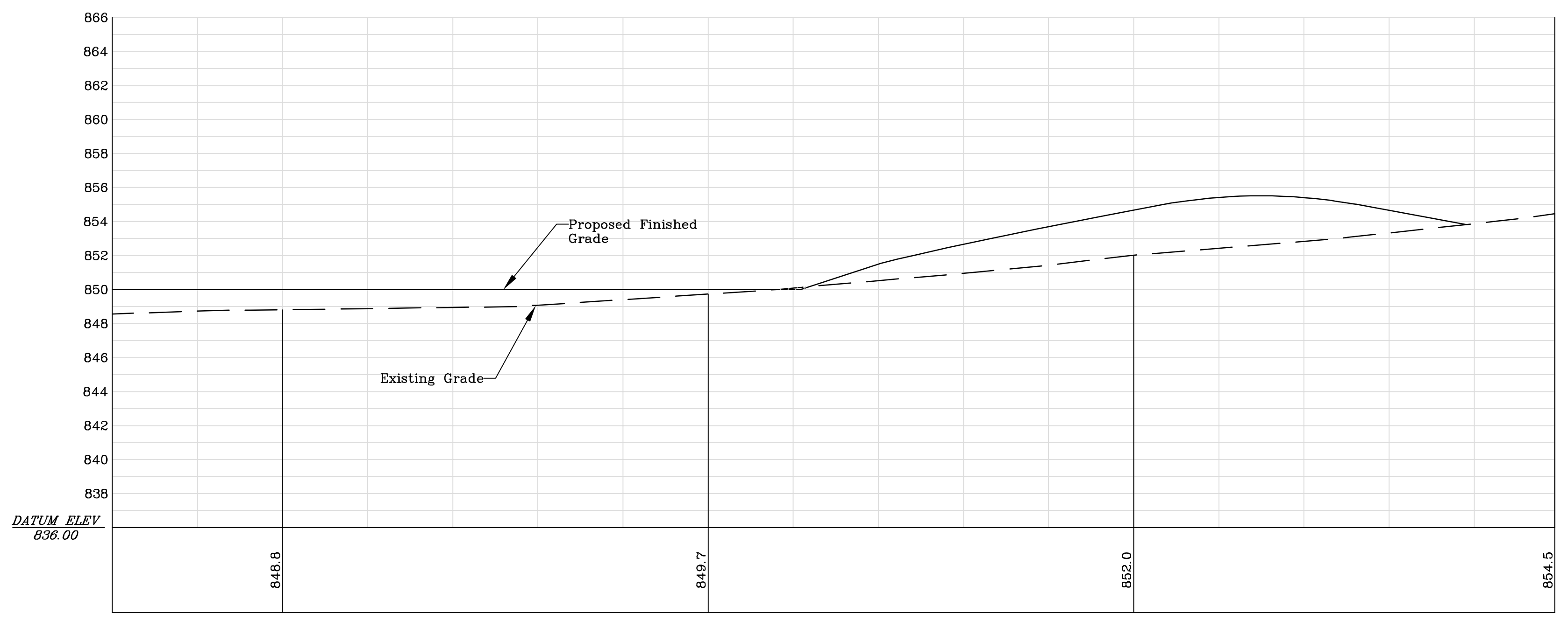
1) 1/2–inch diameter clean crushed stone shall be used to construct gravel envelopes.

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
WET SWALE DETAIL	STANDARD DRAWING NUMBER SW-2 ADOPTED:

S:\PROJECTS\Black & Veatch 3 (P1996)\Specifications\Dwg\Wet Swale.dwg 9/10/2003 8:15:19 AM CDT



Cross Section 3+05.26
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



Cross Section 3+05.26
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

Legend

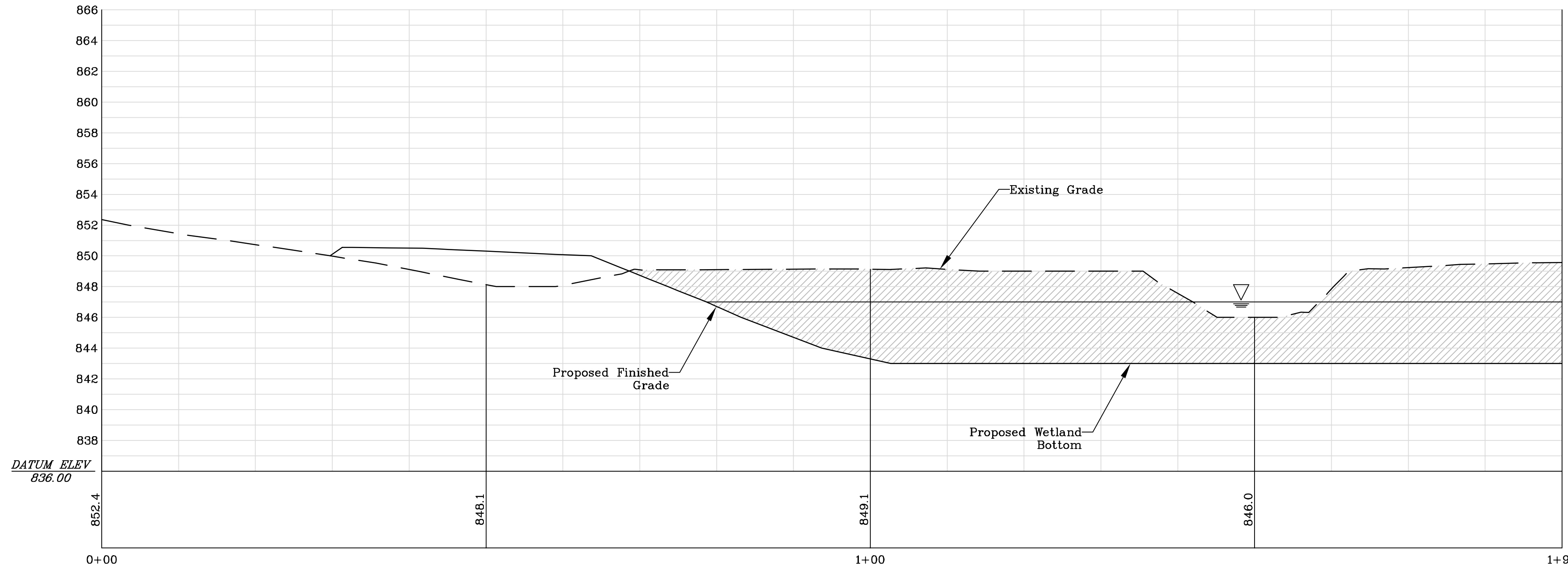
Area of Excavation

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskelDesign2.dwg

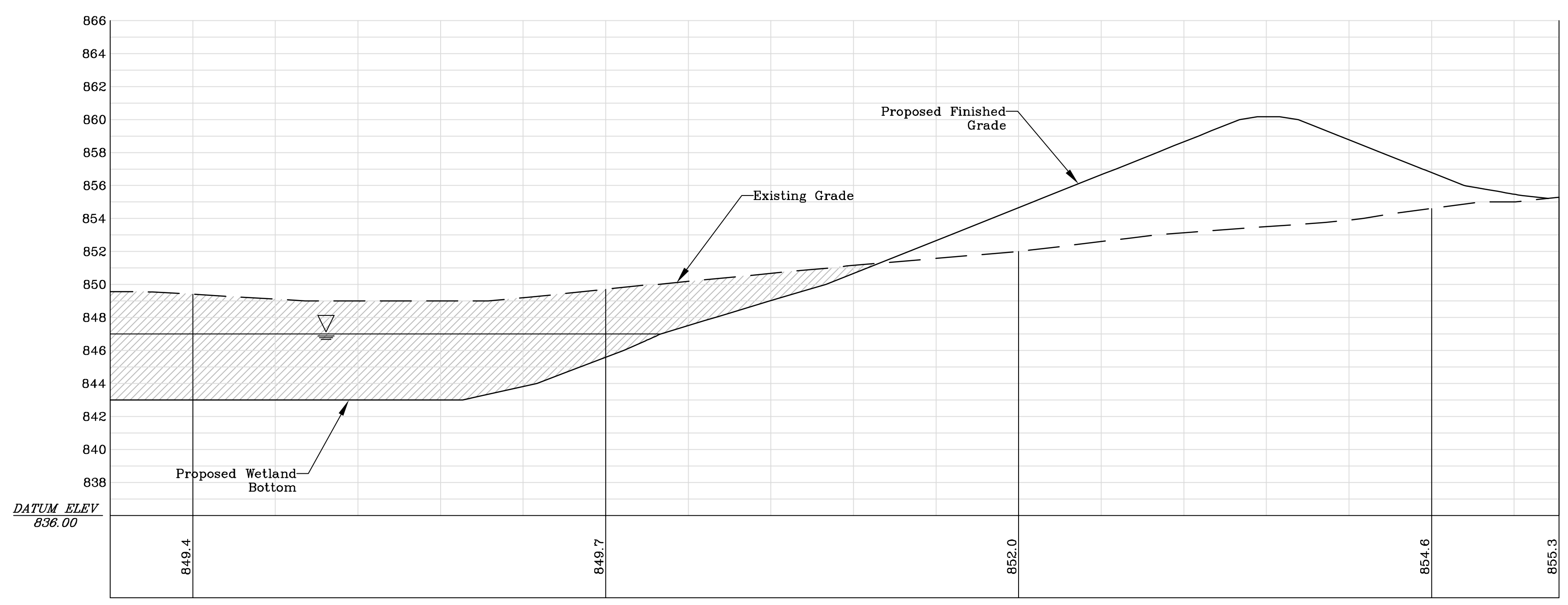
SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION

DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-9 ADOPTED:



Cross Section 2+55.41 Sta. 0+00 to 1+90
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



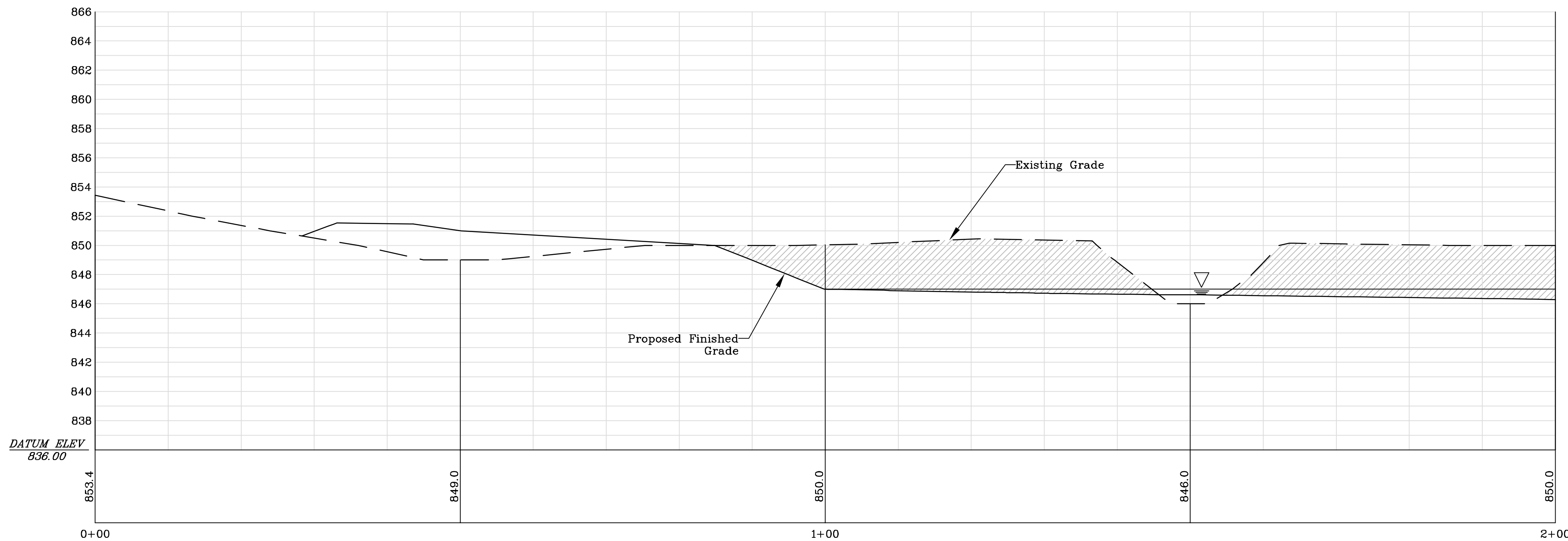
Cross Section 2+55.41 Sta. 1+90 to 3+65.42
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

Legend
Area of Excavation

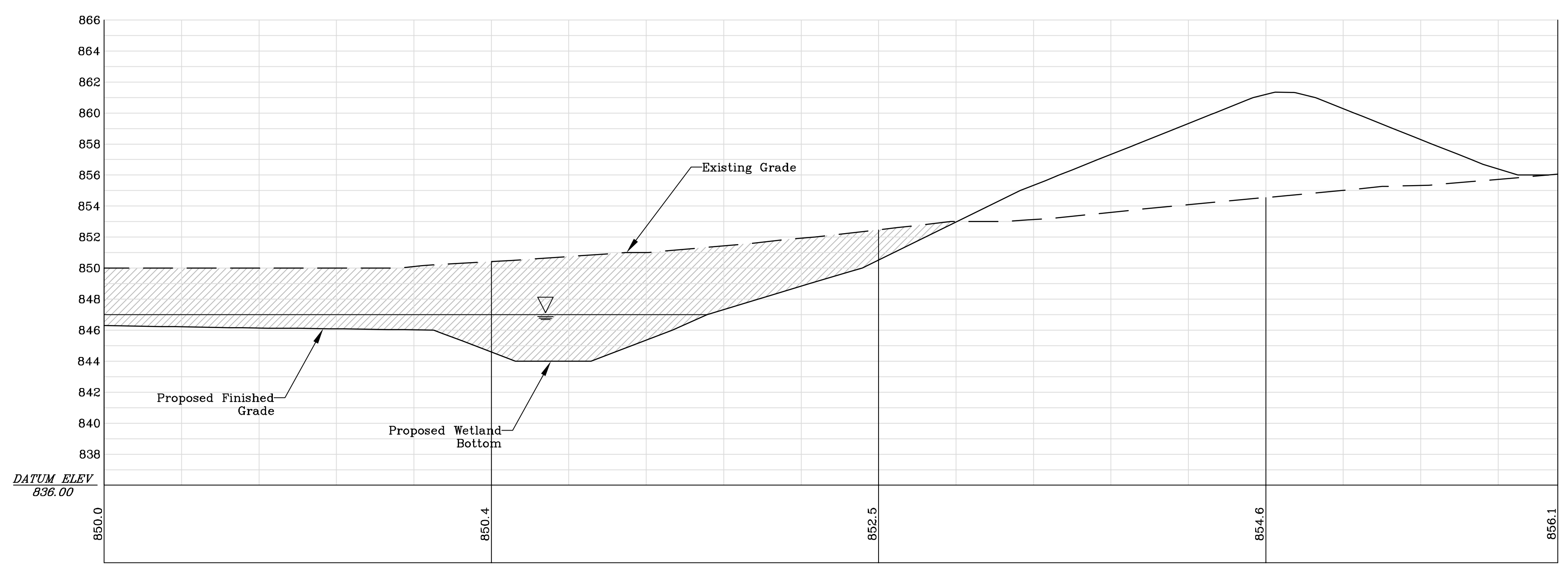
S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg

SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-8 ADOPTED:



Cross Section 1+88.10 Sta. 0+00 to 2+00
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



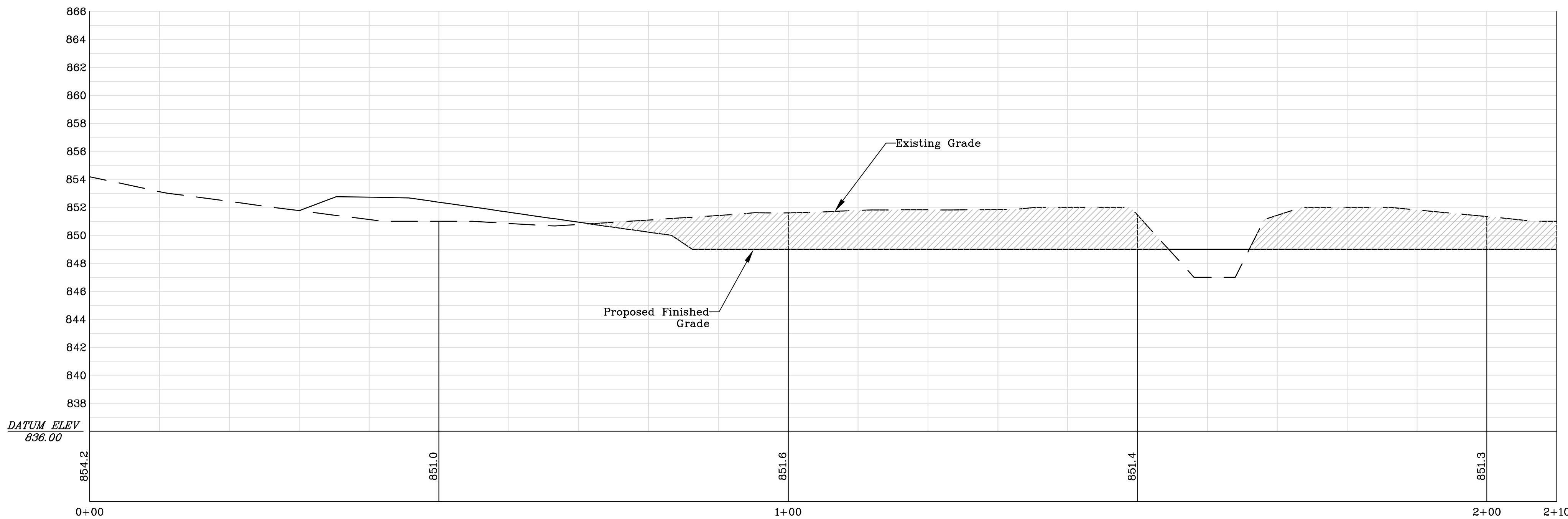
Cross Section 1+88.10 Sta. 2+00 to 3+87.71
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

Legend
Area of Excavation

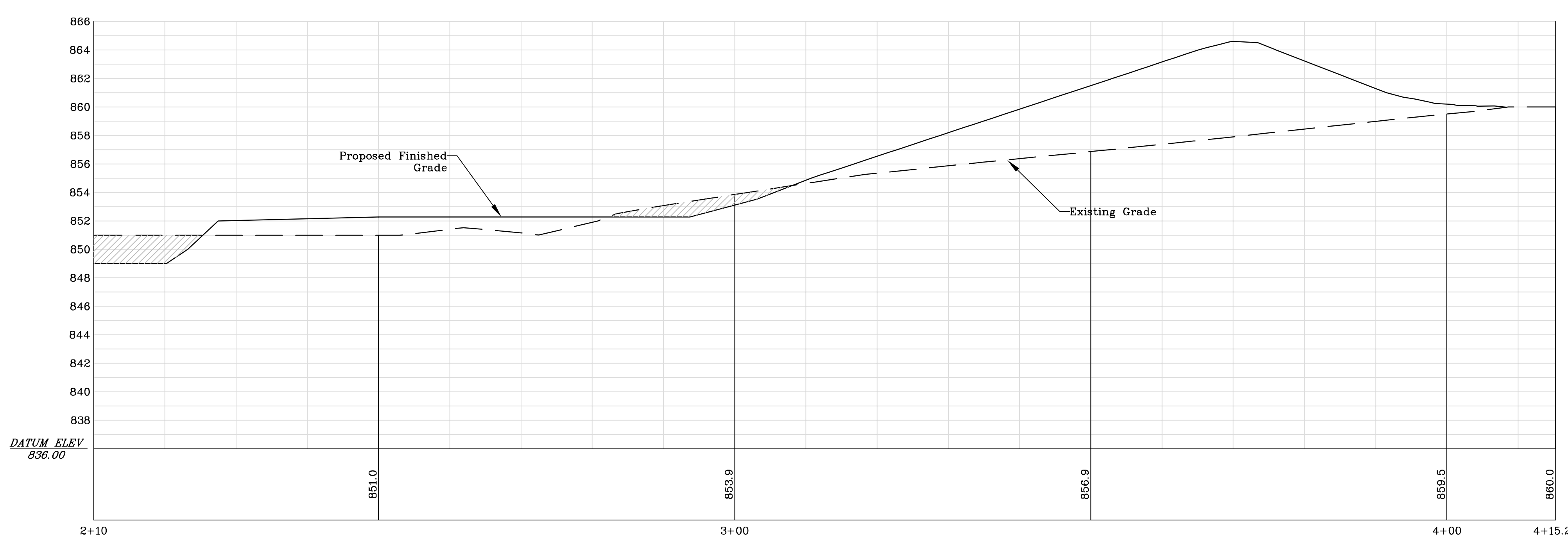
S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg

SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-7 ADOPTED:



Cross Section 1+06.29 Sta. 0+00 to 2+10
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



Cross Section 1+06.29 Sta. 2+10 to 4+15.25
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

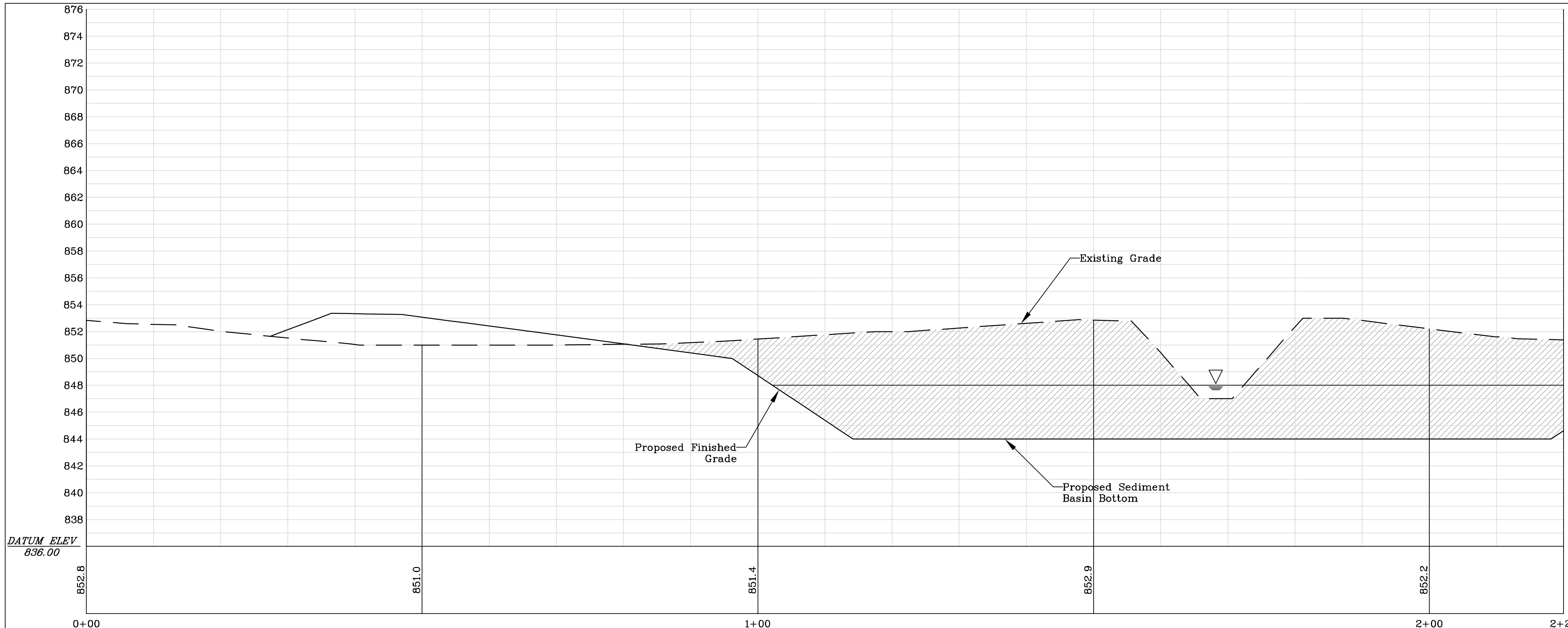
Legend

Area of Excavation

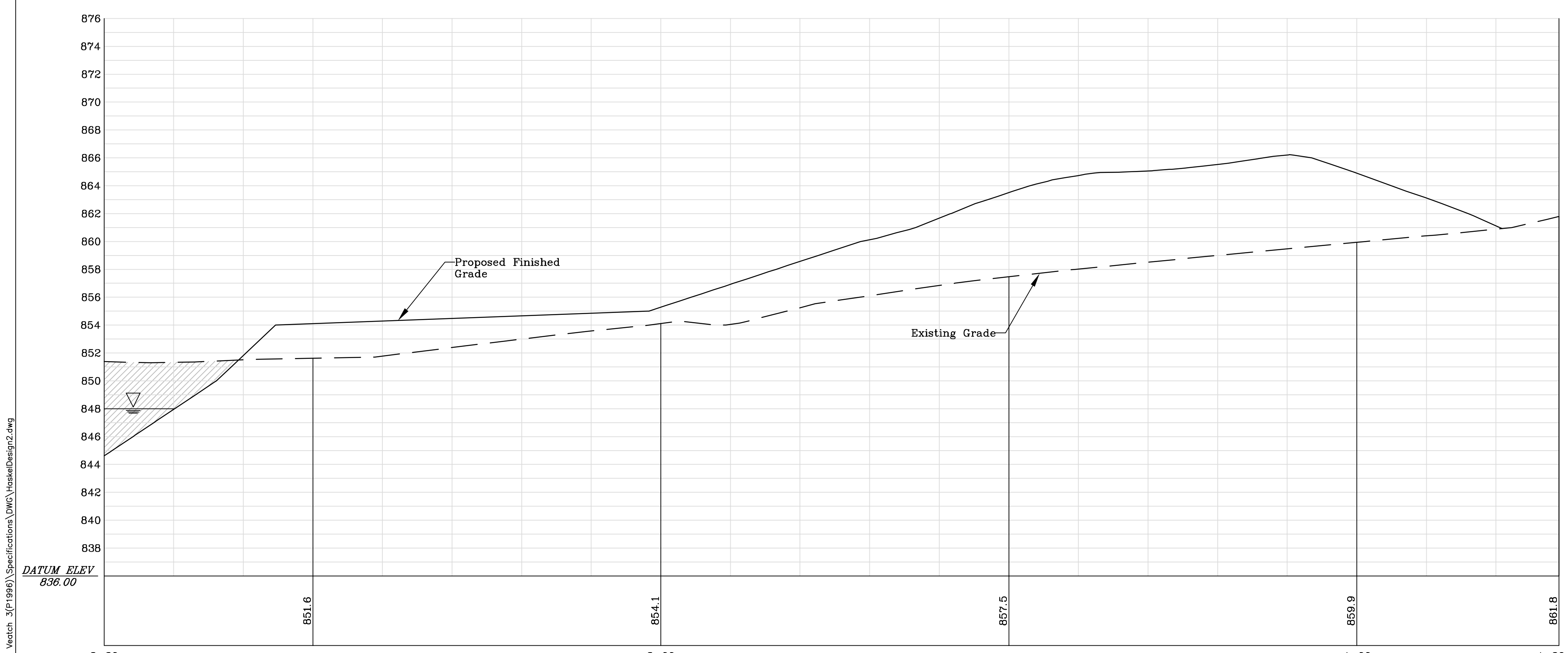
SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-6 ADOPTED:

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg



Cross Section 0+67.53 Sta. 0+00 to 2+20
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



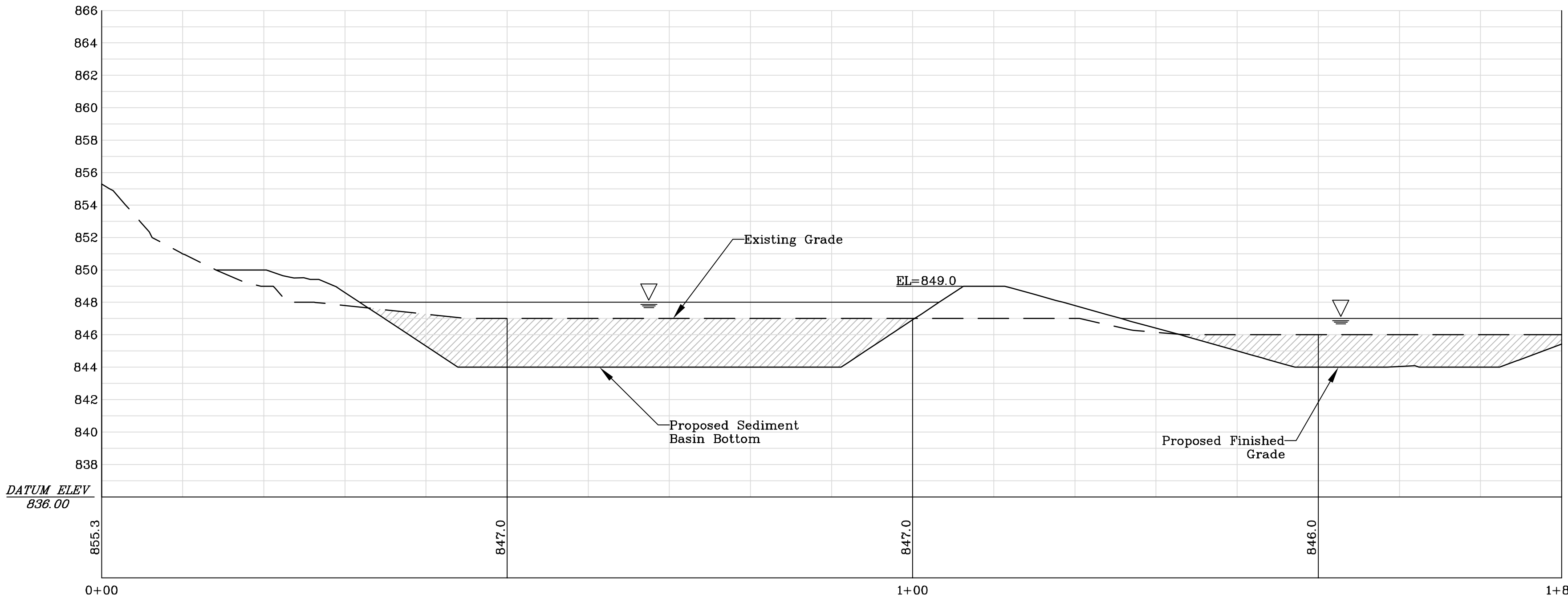
Cross Section 0+67.53 Sta. 2+20 to 4+29.05
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

Legend
Area of Excavation

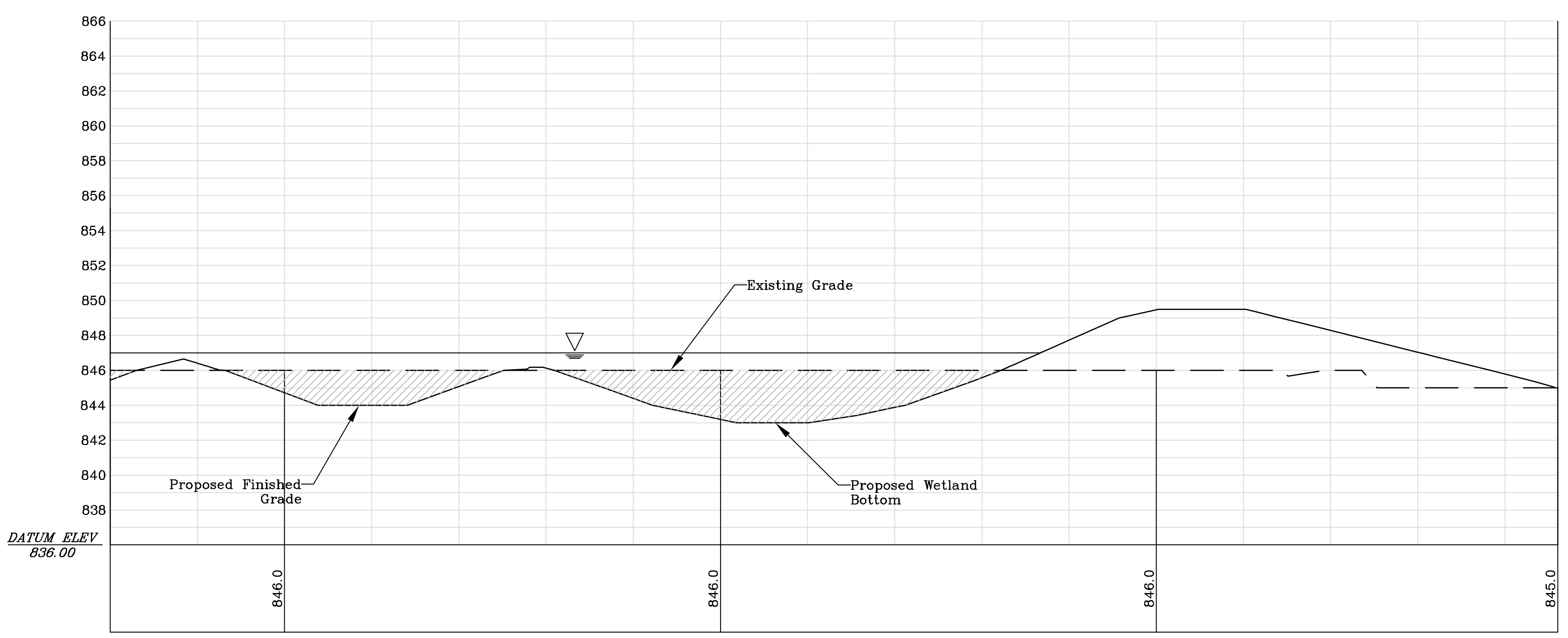
SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-5 ADOPTED:

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskelDesign2.dwg



Profile Along ℄ of Existing Channel Sta. 0+00 to 1+80
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



Profile Along ℄ of Existing Channel Sta. 1+80 to 3+46.04
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

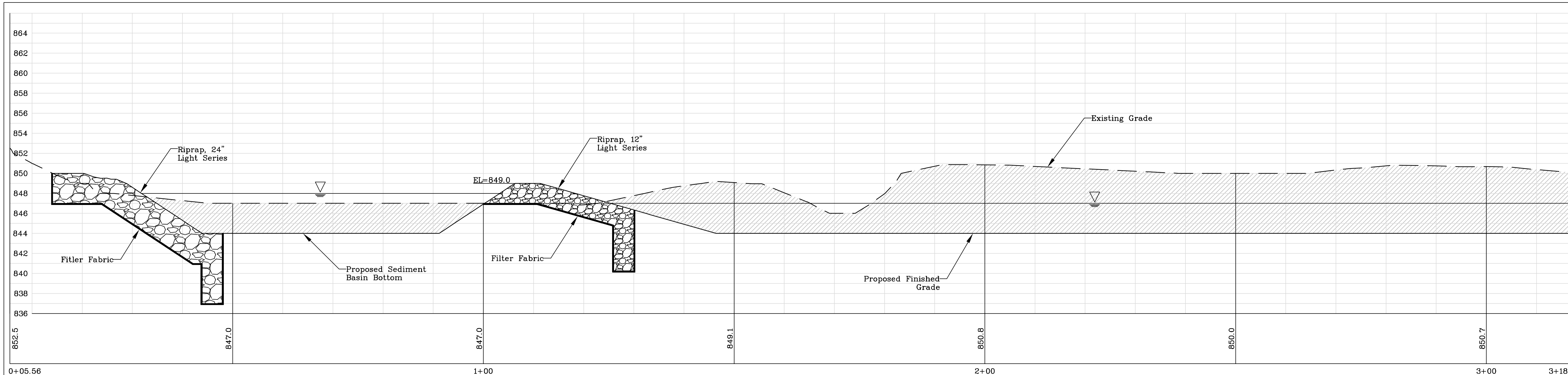
Legend

Area of Excavation

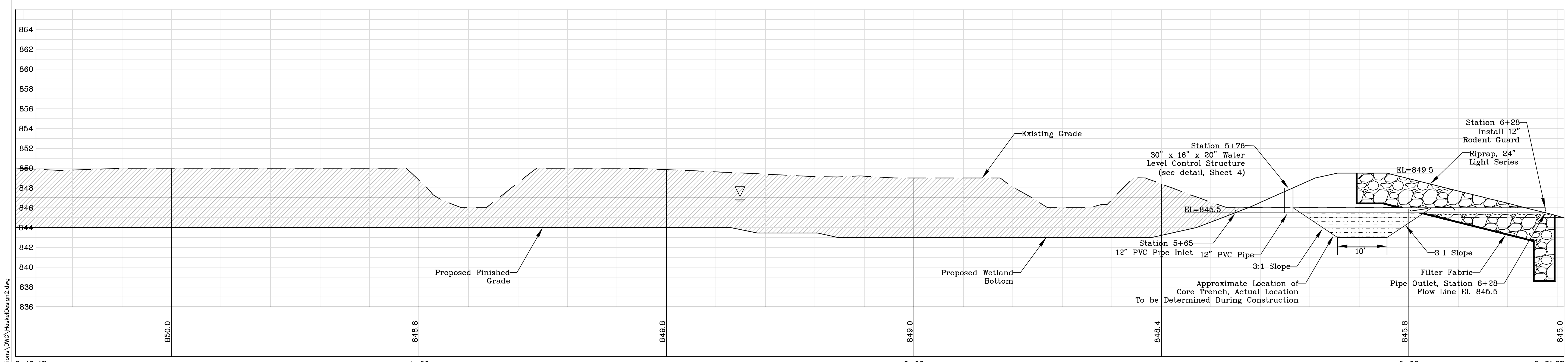
S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg

SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-4 ADOPTED:



Profile Along ℄ of Proposed Channel Sta. 0+05.56 to 3+18.47
Scale: Horizontal 1" = 10'
Vertical 1" = 5'



SOURCE: CITY OF LAWRENCE, KANSAS 2003

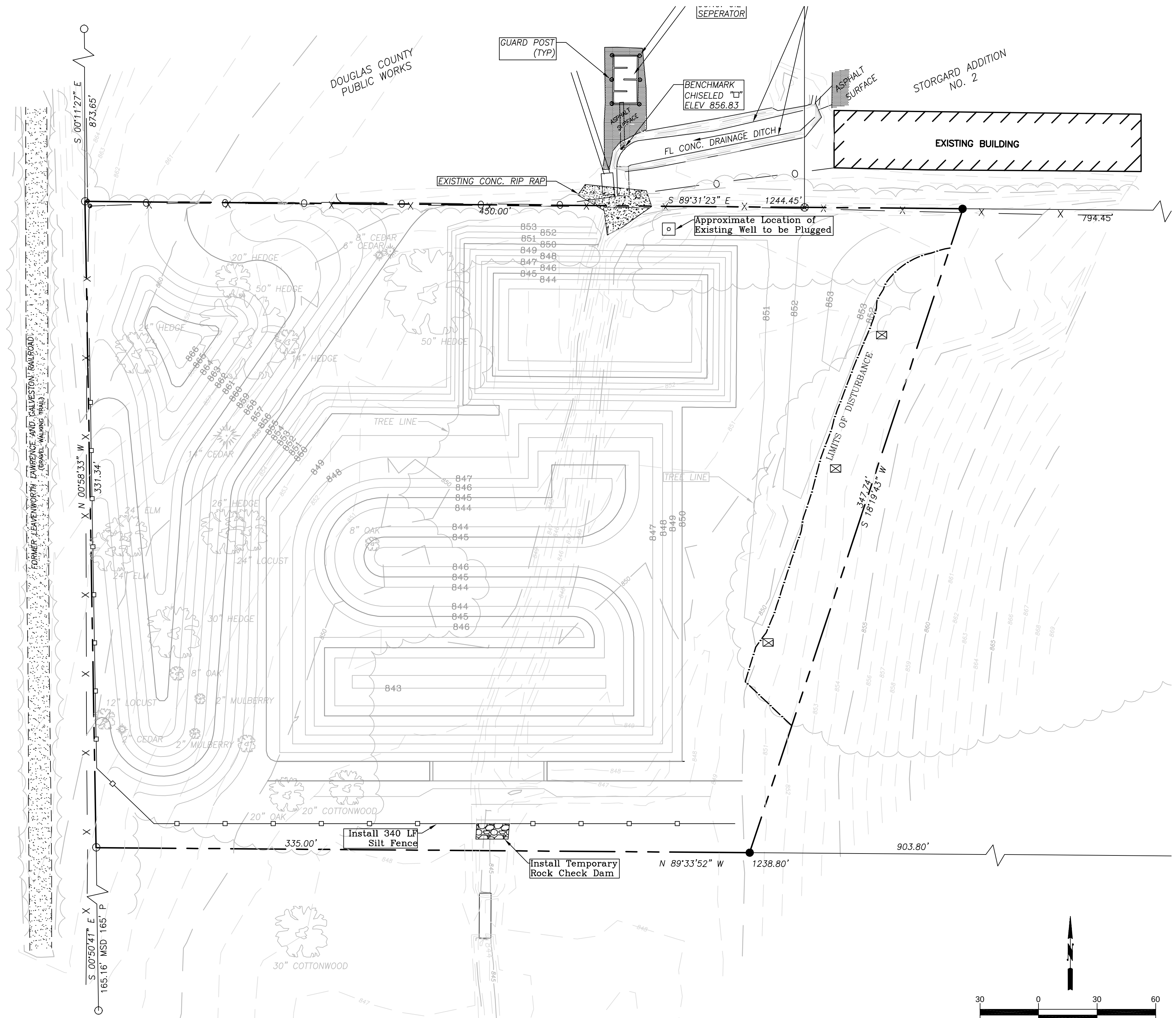
Profile Along ℄ of Proposed Channel Sta. 3+18.47 to 6+31.37
Scale: Horizontal 1" = 10'
Vertical 1" = 5'

Legend

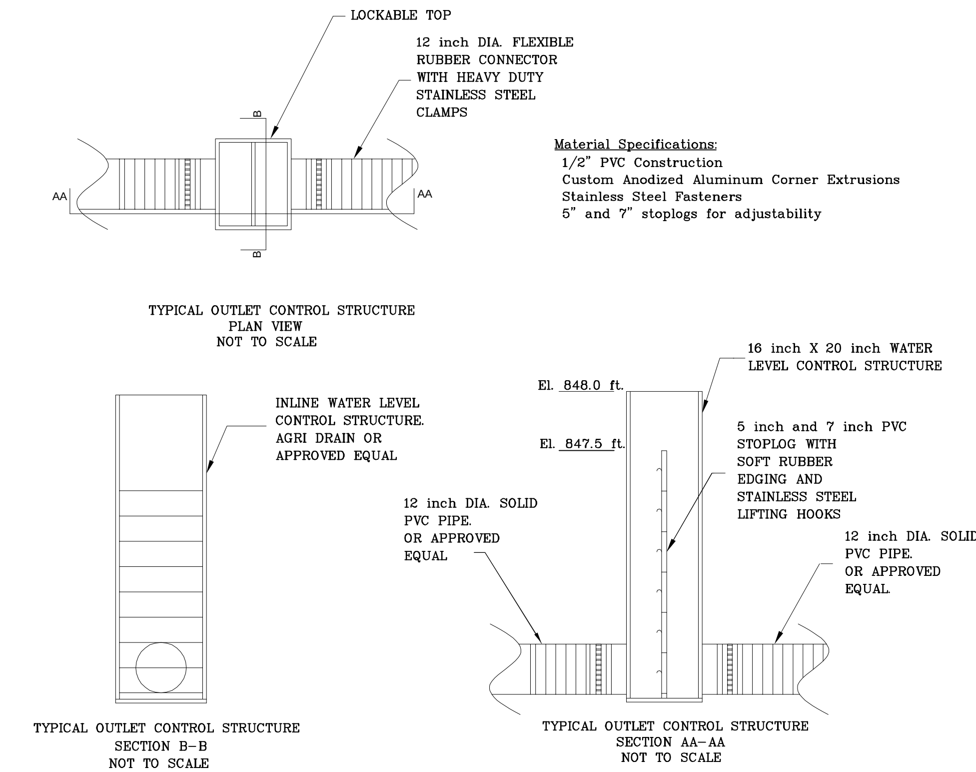
Area of Excavation

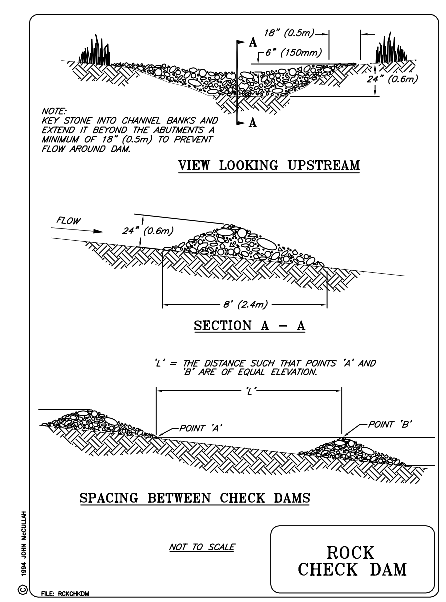
S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HoskelDesign2.dwg

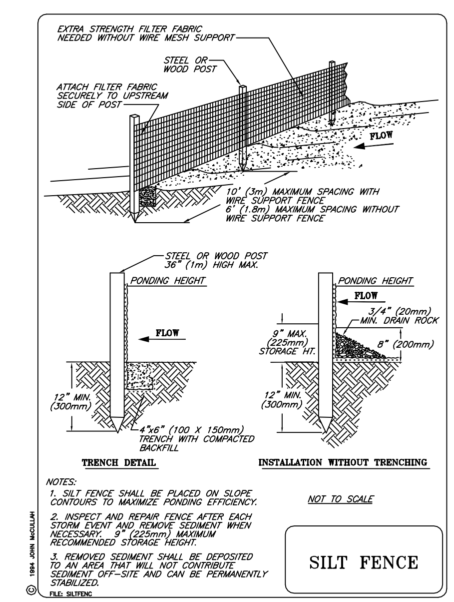
AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-3 ADOPTED:



Details







SOURCE: CITY OF LAWRENCE, KANSAS 2003

Note: Existing well to be plugged according to Article 30, "Water Well Construction Abandonment", Kansas Department of Health and Environment. A record of well plugging must be filed with KDHE.

Contractor is responsible for complying with all Building and Environmental permits, including Section 401 and 404.

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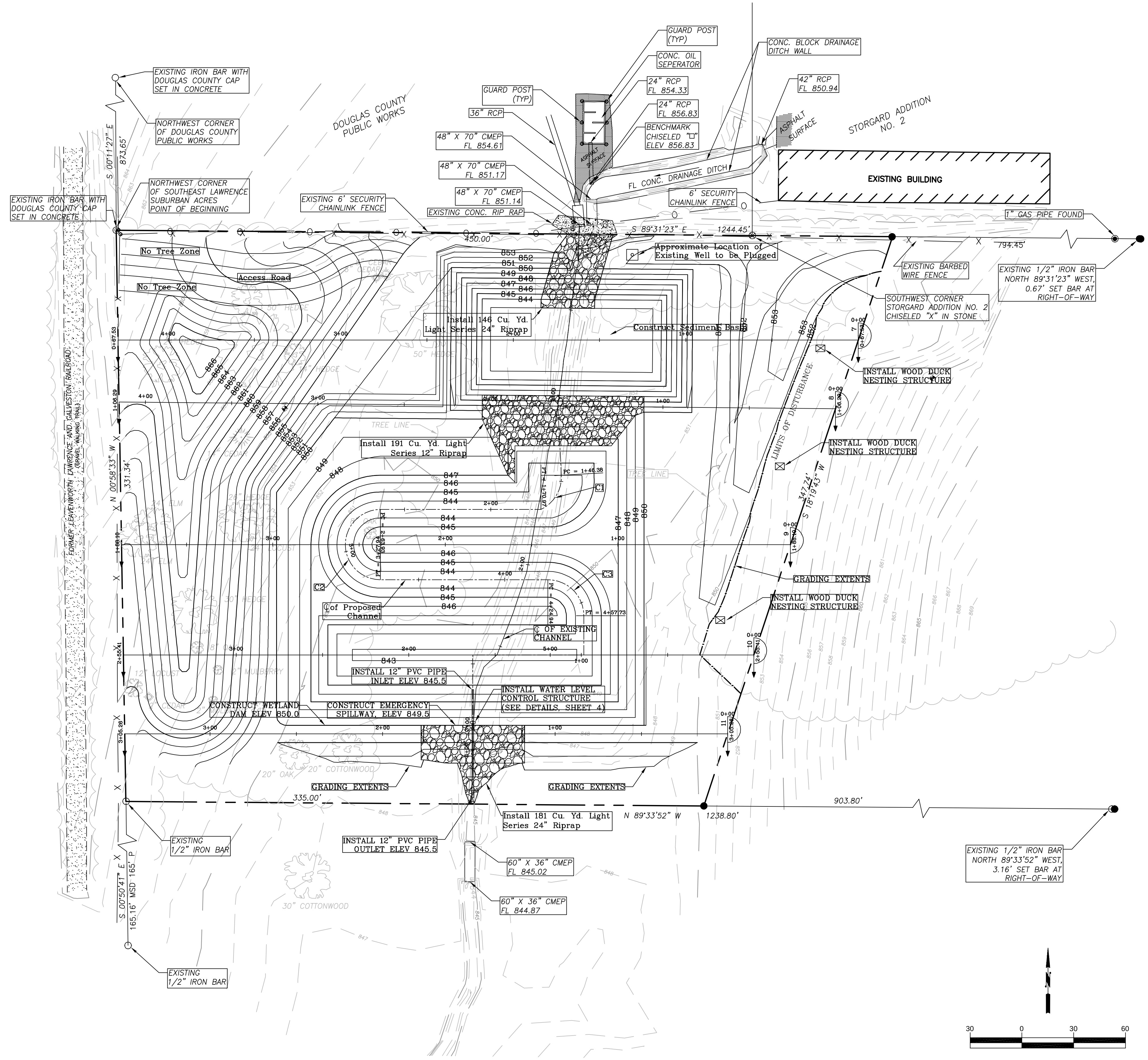
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-2 ADOPTED:

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg



CURVE TABLE

	RADIUS	LENGTH
C1	20.68	24.58
C2	20.37	64.01
C3	20.87	32.79

LEGEND

- ○ EXISTING IRON PIN ORIGIN UNKNOWN
- ◉ EXISTING GAS PIPE ORIGIN UNKNOWN
- ⊗ EXISTING CHISELED "X" ORIGIN UNKNOWN
- ● 5/8" x 24" IRON BAR SET THIS SURVEY W/CAP MARKED "BARTLETT&WEST CLS 14"
- PROPERTY LINE
- EXISTING MAJOR CONTOUR LINE
- EXISTING MINOR CONTOUR LINE
- 6' SECURITY CHAIN LINK FENCE
- BARBED WIRE FENCE
- PROPOSED MAJOR CONTOUR LINE
- PROPOSED MINOR CONTOUR LINE
- PROPOSED GRADING EXTENTS
- ☒ WOOD DUCK NESTING STRUCTURE

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
RIPRAP–12" dia., Light Series	Sq. Yd.	290
RIPRAP–24" dia., Light Series	Sq. Yd.	330
EXCAVATION	Cu. Yd.	7870
EMBANKMENT	Cu. Yd.	5280
PIPE, 12" dia. PVC, SDR 21	Lin. Ft.	65
COMPACTED BACKFILL	Lin. Ft.	50
WATER LEVEL CONTROL STRUCTURE	Ea.	1
FILTER FABRIC	Sq. Yd.	350
RODENT GUARD	Ea.	2
DECOMMISSION WATER WELL	Ea.	1
WOOD DUCK NESTING STRUCTURE	Ea.	3
WETLAND PLANTINGS – TYPE 1	Ac.	0.76
WETLAND PLANTINGS – TYPE 2	Ac.	0.10
WETLAND PLANTINGS – TYPE 3	Ac.	1.22
WETLAND PLANTINGS – TYPE 4	Ac.	0.63
SILT FENCE	Lin. Ft.	340

30 0 30 60

SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION

DRAFT

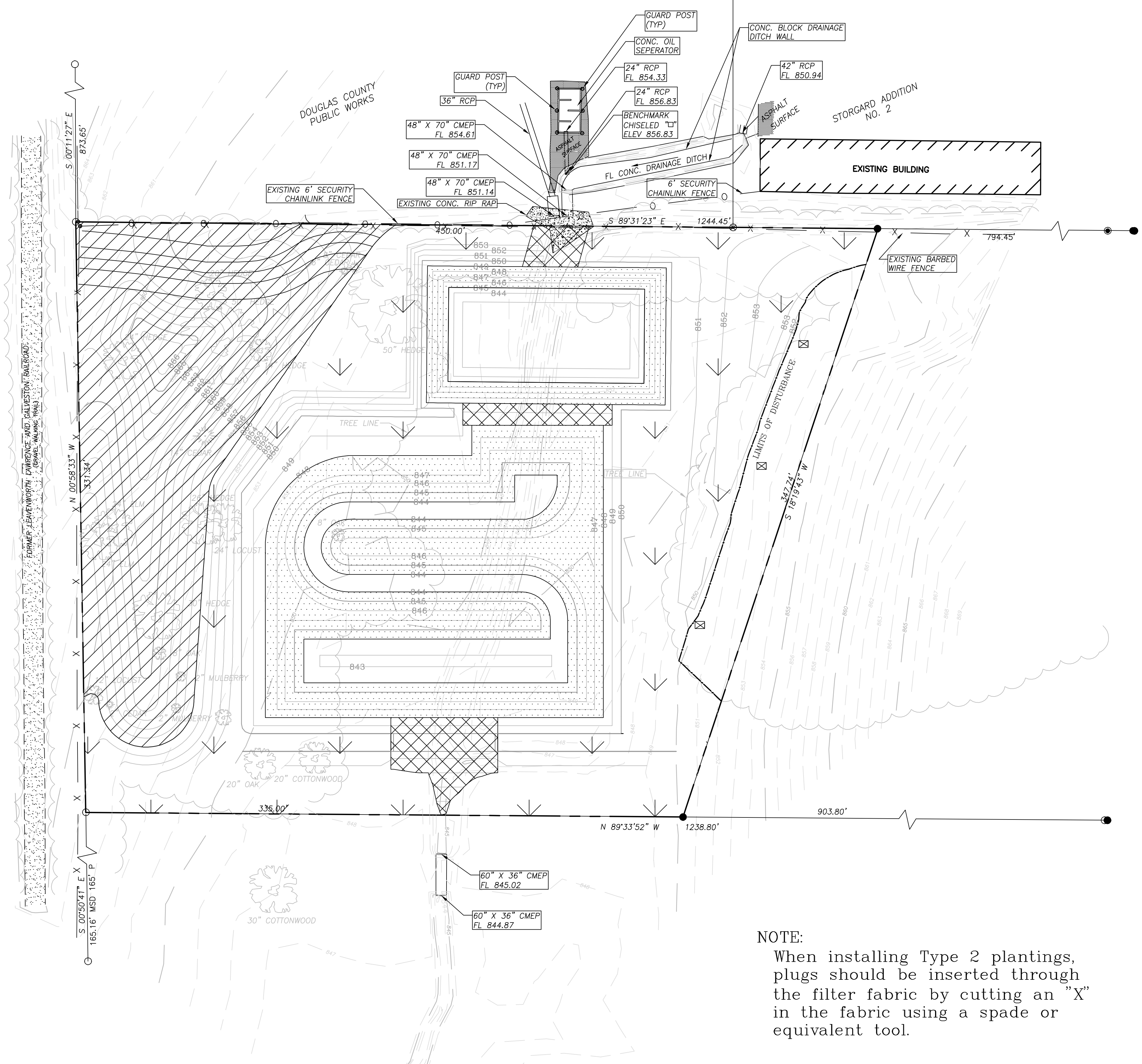
KANSAS CITY METROPOLITAN CHAPTER

EXTENDED DETENTION EXAMPLE

STANDARD DRAWING NUMBER ED-1

ADOPTED:

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg



LEGEND

- Type 1
- Type 2
- Type 3
- Type 4
- Wood Duck Nesting Structures

30 0 30 60

NOTE:

When installing Type 2 plantings, plugs should be inserted through the filter fabric by cutting an "X" in the fabric using a spade or equivalent tool.

SOURCE: CITY OF LAWRENCE, KANSAS 2003

AMERICAN PUBLIC WORKS ASSOCIATION	
DRAFT	KANSAS CITY METROPOLITAN CHAPTER
EXTENDED DETENTION EXAMPLE	STANDARD DRAWING NUMBER ED-10 ADOPTED:

S:\Projects\Black & Veatch 3(P1996)\Specifications\DWG\HaskellDesign2.dwg

APPENDIX B

WATER QUALITY WORKSHEETS

MITIGATING WATER QUALITY IMPACTS

STEP 1 - Determine the required Level of Service (LS) using Table 1.

STEP 2 - Calculate the composite LS rating of the proposed development -- including vegetative cover and preserved vegetation or landscaping, and stormwater management practices:

A. Select any applicable cover types and BMPs from Table 2 (BMP Applicability Matrix) and determine the Value Rating (VR) of the cover type or practice. See Notes 1 and 2 about applicability.
- If the governing municipality or special watershed study requires treatment for a specific pollutant, use Treatment Ratings (TR) from Table 3. TR is a ranking of the treatment efficiency of various BMPs derived from runoff and water quality data.
- If a "treatment train" of two or more vegetative or structural BMPs are proposed to treat the same area, see Note 4 below.

To determine a site-specific VR (such as a filter strip), use the values in Table 2 and the procedure provided in Note 3 below.

B. Determine the percent acreage (of the total site) comprised of each cover type or treated by an existing or proposed BMP.
C. Calculate the LS for the development by:
   1. Multiplying each percent acreage determined in Step 2B by the appropriate VR (from Table 2 or 3).
   2. Sum the values obtained from Step 1 (See Worksheet 1 for examples).
D. If the proposed development meets the required LS, proceed to design criteria for each proposed BMP. It not, move to Step 3.

STEP 3 - Select Mitigation Package (any combination of preservation, cover type, and BMP(s) applied to all or part of the site) that provides a sufficient LS rating:

A. Select potential cover types and BMPs from Table 2, and apply them to all or part of the proposed development.
B. Recalculate postdevelopment CN if selected cover types and/or BMPs reduce the percentage of impervious surface below those assumed in TR-55 for the cover type (that is, recalculate CN for Commercial if total impervious area drops below 85 percent of the site -- consult TR-55, Pages 2-9 and 2-10 and Figures 2-3 and 2-4.
C. Recalculate the required LS (the difference between the predevelopment and postdevelopment CN) using Table1.
D. Determine the Value Rating (VR) of the cover type or practice using Table 2 and using the method described in Note 3 below, if applicable. Use TRs from Table 3 for specific pollutants, if required as described in Step 2 A.
E. Determine the area of the site comprised of each cover type and treated by each BMP; calculate the weighted LS for the proposed mitigation package.
F. Repeat as necessary, changing coverage areas and substituting BMPs, until the required LS is met with a mitigation package suitable for the proposed site and development.

Notes:
1. Preliminary applicability criteria for each BMP are provided in Table 2; consult the design criteria for each BMP before making a final determination of a BMP's applicability for a given site or proposed use.
2. BMPs need not be applied to the entire site if the required LS can be met by treating part of the site -- unless otherwise required by the governing jurisdiction.
3. Value Rating is a combination of (1) physical runoff retention and (2) mechanical and biological water quality treatment.
   VR = S + TR
   Where
   S (Potential Retention) of vegetative cover is a function of soil and cover condition, and is related to CN.
   The formula for calculating S is:
   S = (1000/CN) - 10
   Note: CN's are provided in Table 1.
   TR is provided in Col. 4 of Table 2; pollutant-specific TRs are provided in Table 3.
   The table below provides common S values.

<u>Table of S values</u>

Cover Type and Condition	HSGB		HSG C		HSG D	
	CN	S	CN	S	CN	S
Native grass, moderate maintenance	69	4.49	79	2.66	84	1.90
Native grass, low maintenance	61	6.39	74	3.51	80	2.50
Woods and native grass, poor	67	4.93	77	2.99	83	2.05
Woods and native grass, fair	65	5.38	76	3.16	82	2.20
Woods and native grass, good	55	8.18	70	4.29	77	2.99
Woods, poor	66	5.15	77	2.99	83	2.05
Woods, fair	60	6.67	73	3.70	79	2.66
Woods, good	55	8.18	70	4.29	77	2.99
Meadow	58	7.24	71	4.08	78	2.82
Native grass, shrubs and forbs, good	56	7.86	70	4.29	77	2.99
Native grass, shrubs and forbs, fair	48	10.83	65	5.38	73	3.70

Note: All S values are based on equivalent cover types in TR-55, and assume preserved or restored soils.
Distinctions between good, fair, and poor are based on percentage of viable cover from TR-55.

4. Two or more BMPs connected in series and applied to the same portion of the site constitute a "treatment train." A "treatment train" may help remove additional pollutants or maximize available space on the site. The effective value of the secondary practice is a function of the effectiveness of the primary practice as follows:

   <u>Example A:</u>
   Contributing area -- parking lot = 5 acres.
   BMP 1 -- Engineered swale, VR 8.08
   8.08 x 5 acres = weighted value of 40.4.
   BMP 2 -- Bioretention cell fed by the engineered swale, VR = 8.38;
   Effective VR = [(8.38+8.08)/8.08] = 2.04
   2.04 x 5 acres = weighted value of 10.2; 10.2 + 40.4 (BMP 1) = cumulative VR of 50.6 for the parking lot.

   <u>Example B</u>:
   Contributing area -- 20 acres of 1/4-acre residential housing.
   BMP 1 -- Turf grass, VR of 3.00 x 20 acres = weighted value of 60.
   BMP 2 -- Engineered swale, VR of 8.08; effective VR = [(3.00+8.08)/3.00] =
   3.69 x 20 acres = weighted value of 73.8 + 60 (BMP 1) = cumulative VR of 133.8 for the residential housing.

5. The total area treated by BMPs may exceed the total acreage of the site if treatment trains are applied; however, the weighted value is determined by dividing by the total acreage of the site <u>only (that is,</u> the total cannot exceed 100% of the actual area).
6. The BMP only counts in the CN calculation if it has a CN (a pervious or impervious cover). If the BMP is a water body (pond or wetland), its surface area is subtracted from the CN calculation. The surface area of the BMP is included in the LS calculations by applying the appropriate VR to the surface area of the BMP itself.

WORKSHEET 1: REQUIRED LEVEL OF SERVICE

Project: By: Date:
Location: Checked: Date:
Check one: _X__**Undeveloped** ___Developed

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

Area-Weighted CN = total product/total area = [ ] (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = [ ] (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN: [ ]

Postdevelopment CN: [ ]

Difference: [ ]

LS Required (see scale at right): [ ]

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

Source: U.S. Department of Agriculture, Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds, Technical Release 55* (TR-55). 1986.

WORKSHEET 1A: REQUIRED LEVEL OF SERVICE

Project: By: Date:
Location: Checked: Date:
Check one: ___Undeveloped **_X__Developed**

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

Area-Weighted CN = total product/total area = ______ (Round to integer)
Percent Impervious = total impervious area/total area = ______ (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = ______ (Round to integer)
Percent Impervious = total impervious area/total area = ______ (Round to integer)

C. Change in Percentage of Impervious Surface (%IMP) from Table 1A

Predevelopment %IMP ______

Postdevelopment %IMP ______

Change in %IMP ______

Change in Range of Imperviousness ______

Increase in Range of % IMP	LS
None	4
1	5
2	6
3	7

Required LS = ______

Source: U.S. Department of Agriculture, Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds, Technical Release 55* (TR-55). 1986.

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: By: Date:
Location: Checked: Date:
Sheet ___ of ___

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): [ ]

Note: Various BMPs may alter CN of proposed development and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Total[2]:		**LS:**	

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? [ ] (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Total[2]:		**LS:**	

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? [ ] (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 1: REQUIRED LEVEL OF SERVICE

Project: ***Example 1*** By: SAS Date: 4/14/03
Location: Smallville, Kansas Checked: Date:
Check one: _**X**_ **Undeveloped** ___Developed

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Pasture, good	B	69	54.00	3726
		Totals:	54	3726

Area-Weighted CN = total product/total area = 69 (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Buildings	NA	98	8.00	784
Parking	NA	98	37.00	3626
Turf grass lawn	C	74	6.50	481
Wet ponds	NA	NA	NA	NA
		Totals:	51.50	4891

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = 95 (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN: 69

Postdevelopment CN: 95

Difference: 26

LS Required (see scale at right): 8

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***Example 1*** By: SAS Date: 4/15/03
Location: Smallville, Kansas Checked: Date:
Sheet _1_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 8

Note: Various BMPs may alter CN of proposed development and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _1_

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building with wet pond	8	7.00	1.04
Parking with wet pond	37	7.00	4.80
Lawn with wet pond	6.5	5.17	0.62
wet pond	2.5	7.00	0.32
			0.00
Total[2]:	54.00	**LS:**	6.78

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _2_

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building	8.0	0.00	0.00
Parking with swale	37.8	8.08	5.65
Lawn	5.8	6.69	0.71
Wet pond	2.5	7.00	0.32
Wet pond (treatment train)	43.5	1.87	1.50
			0.00
Total[2]:	54.00	**LS:**	8.19

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***Example 1*** By: Date:
Location: Smallville, Kansas Checked: Date:
Sheet _2_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 8

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _3_ ***[Exceeds Base LS by 1+ Per Local Requirements]***

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building	8.25	8.08	1.23
Parking with swale	37.75	8.08	5.65
Lawn with swale (treatment train)	5.5	6.69	0.68
Wet pond	2.5	7.00	0.32
Wet pond (treatment train)	51.5	1.87	1.78
Total[2]:	54.00	**LS:**	9.67

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Total[2]:		**LS:**	

[1] Refer to Mitigation instructions, and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 1A: REQUIRED LEVEL OF SERVICE

Project: ***Example 2*** By: SAS Date: 12/05/02
Location: Townsville, Missouri Checked: Date:
Check one: ___Undeveloped **_X__Developed**

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Building	NA	98	0.17	16.87
Parking	NA	98	1.23	120.93
Lawn	C	80	0.23	18.37
Residential 2-acre	C	77	2.00	154.00
Pond	NA	NA	NA	NA
Woods-grass, fair	C	76	5.66	430.49
		Totals:	9.30	740.65

Area-Weighted CN = total product/total area = 80 (Round to integer)
Percent Impervious = total impervious area/total area = 15% (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Building	NA	98	0.40	39.20
Parking	NA	98	2.75	269.50
Lawn	C	80	0.49	39.20
Pond	NA	NA	NA	NA
Woods-grass, fair	C	76	5.66	430.16
		Totals:	9.30	778.06

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = 84 (Round to integer)
Percent Impervious = total impervious area/total area = 34% (Round to integer)

C. Change in Percentage of Impervious Surface (%IMP) from Table 1A

Predevelopment %I: 15%

Postdevelopment %I: 34%

Change in %I: 19%

Change in Range of Imperviousness: 1

Increase in range of % IMP	LS
None	4
1	5
2	6
3	7

Required LS = 5

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***Example 2*** By: SAS Date: 12/05/02
Location: Townsville, Missouri Checked: Date:
Sheet _1_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 5

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _1__

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building	0.40	0.00	0.00
Parking	2.75	0.00	0.00
Lawn	0.49	3.00	0.15
Pond	1.60	7.00	1.13
Woods-grass, fair	4.66	7.40	3.48
Total[2]:	9.90	**LS:**	4.76

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _2_

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building	0.40	0.00	0.00
Parking with detention (new)	1.50	1.20	0.18
Parking w/o detention (existing)	1.25	0.00	0.00
Lawn	0.49	3.00	0.15
Existing Pond	1.60	7.00	1.13
Woods-grass, fair	4.66	7.40	3.48
Total[2]:	9.90	**LS:**	4.94

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***Example 2*** By: SAS Date: 12/05/02
Location: Townsville, Missouri Checked: Date:
Sheet _2_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 5

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _3__

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Building	0.40	0.00	0.00
Parking with filter strip (new)**	2.50	5.15	1.30
Parking w/o detention (existing)	1.25	0.00	0.00
Lawn	0.49	3.00	0.15
Existing Pond	1.60	7.00	1.13
Woods-grass, fair	3.66	7.40	2.74
Total[2]:	9.90	**LS:**	5.32

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? **YES** (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Total[2]:		**LS:**	

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***Example 3*** By: SAS Date: 9/10/03
Location: Bur Oak, Missouri Checked: Date:
Sheet _1_ of _1_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 6

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _1__

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Residential with turf grass	80.00	3.00	2.40
Streets	20.00	0.00	0.00
Total[2]:	100.00	**LS:**	2.40

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _2_ ***[Lowers weighted CN to 86, and LS to 5]***

Cover/BMP Description	Treatment Area	VR from Table 2 or Table 3[1]	Area x VR Total Treatment Area[2]
Residential w/native vegetation[a]	80.00	7.76	6.21
Streets	20.00	0.00	0.00
Total[2]:	100.00	**LS:**	6.21

[1] Refer to Mitigation instructions and Tables 2 and 3 as appropriate when determining VR.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, move to next sheet.)

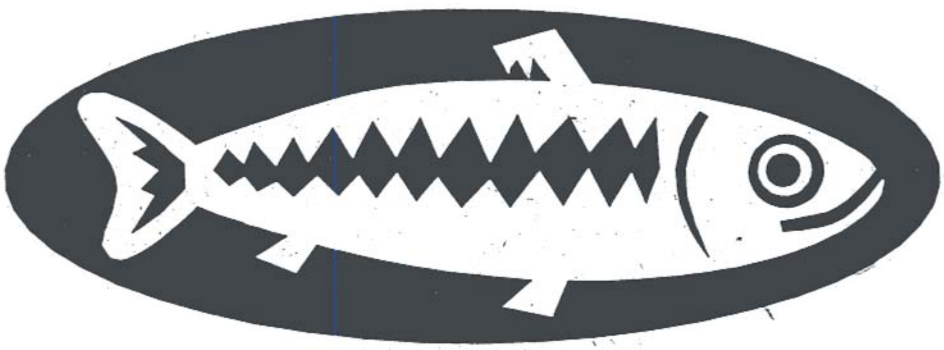
a Native vegetation and preserved soils maintain HSG C and lower the postdevelopment CN to 83
Residential w/native vegetation = Native grass, low maintenance, HSG C;
VR = TR + S = 4.25 + 3.51 = 7.76

APPENDIX C

WATER QUALITY PERFORMANCE DATA

National Pollutant Removal Performance Database

for Stormwater Treatment Practices
2nd Edition



June, 2000

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Table 3.1 Median Pollutant Removal (%) of Stormwater Ponds and Wetlands							
	TSS	TP	Sol P	TN	NO_x	Cu	Zn
Stormwater Dry Ponds							
Quantity Control Pond*	3	19	0	5	9	10	5
Dry Extended Detention Pond	61	20	-11	31*	-2*	29*	29*
Group Median ± 1 St. Dev	**47 ±32**	**19 ±13**	**-6 ±8.7**	**25 ±16**	**3.5 ±23**	**26***	**26 ±37**
Stormwater Wet Ponds							
Wet Extended Detention Pond	80	55	67	35	63	44	69
Multiple Pond System*	91	76	69	N/A	87	N/A	N/A
Wet Pond	79	49	62	32	36	58	65
Group Median ± 1 St. Dev	**80 ±27**	**51 ±21**	**66 ±27**	**33 ±20**	**43 ±39**	**57 ±22**	**66 ±22**
Stormwater Wetlands							
Shallow Marsh	83	43	29	26	73	33	42
Extended Detention Wetland*	69	39	32	56	35	N/A	-74
Pond/Wetland System	71	56	43	19	40	58*	56
Submerged Gravel Wetland*	83	64	-10	19	81	21	55
Group Median ± 1 St. Dev	**76 ±43**	**49 ±36**	**36 ±45**	**30 ±34**	**67 ±54**	**40 ±45**	**44 ±40**

* Data based on fewer than five data points
NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P = Soluble Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Table 3.2 Median Pollutant Removal (%) of Stormwater Filtering, Infiltration, Open Channel, and Other Practices

	TSS	TP	Sol P	TN	NO_x	Cu	Zn
Filtering Practices[1]							
Organic Filter	88	61	30[2]	41[2]	-15	66[2]	89
Perimeter Sand Filter[2]	79	41	68	47	-53	25	69
Surface Sand Filter	87	59	-17[2]	32	-13	49	80
Vertical Sand Filter[2]	58	45	21	5	-87	32	56
Bioretention[2]	N/A	65	N/A	49	16	97	95
Group Median ± 1 St. Dev	**86 ±23**	**59 ±38**	**3 ±46**	**38 ± 16**	**-14 ±47**	**49 ±26**	**88 ±17**
Infiltration Practices							
Infiltration Trench[2]	N/A	100	100	42	82	N/A	N/A
Porous Pavement[2]	95	65	10	83	N/A	N/A	99
Group Median ± 1 St. Dev	**95[2]**	**80 ±24**	**85[2]**	**51 ±24**	**82[2]**	N/A	**99[2]**
Open Channels							
Ditches[3]	31	-16	-25[2]	-9	24[2]	14[2]	0[2]
Grass Channel[2]	68	29	40	N/A	-25	42	45
Dry Swale[2]	93	83	70	92	90	70	86
Wet Swale[2]	74	28	-31	40	31	11	33
Group Median[4] ± 1 St. Dev	**81 ±14**	**34 ±33**	**38 ±46**	**84[2]**	**31 ±49**	**51 ±40**	**71 ±36**
Other							
Oil-Grit Separator[2]	-8	-41	40	N/A	47	-11	17
Stormceptor®[2]	25	19	21	N/A	6	30	21

1. Excludes vertical sand filters and filter strips
2. Data based on fewer than five data points
3. Refers to open channel practices not designed for water quality
4. Median value excludes ditches

NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P = Soluble Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Figure 3.1 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen

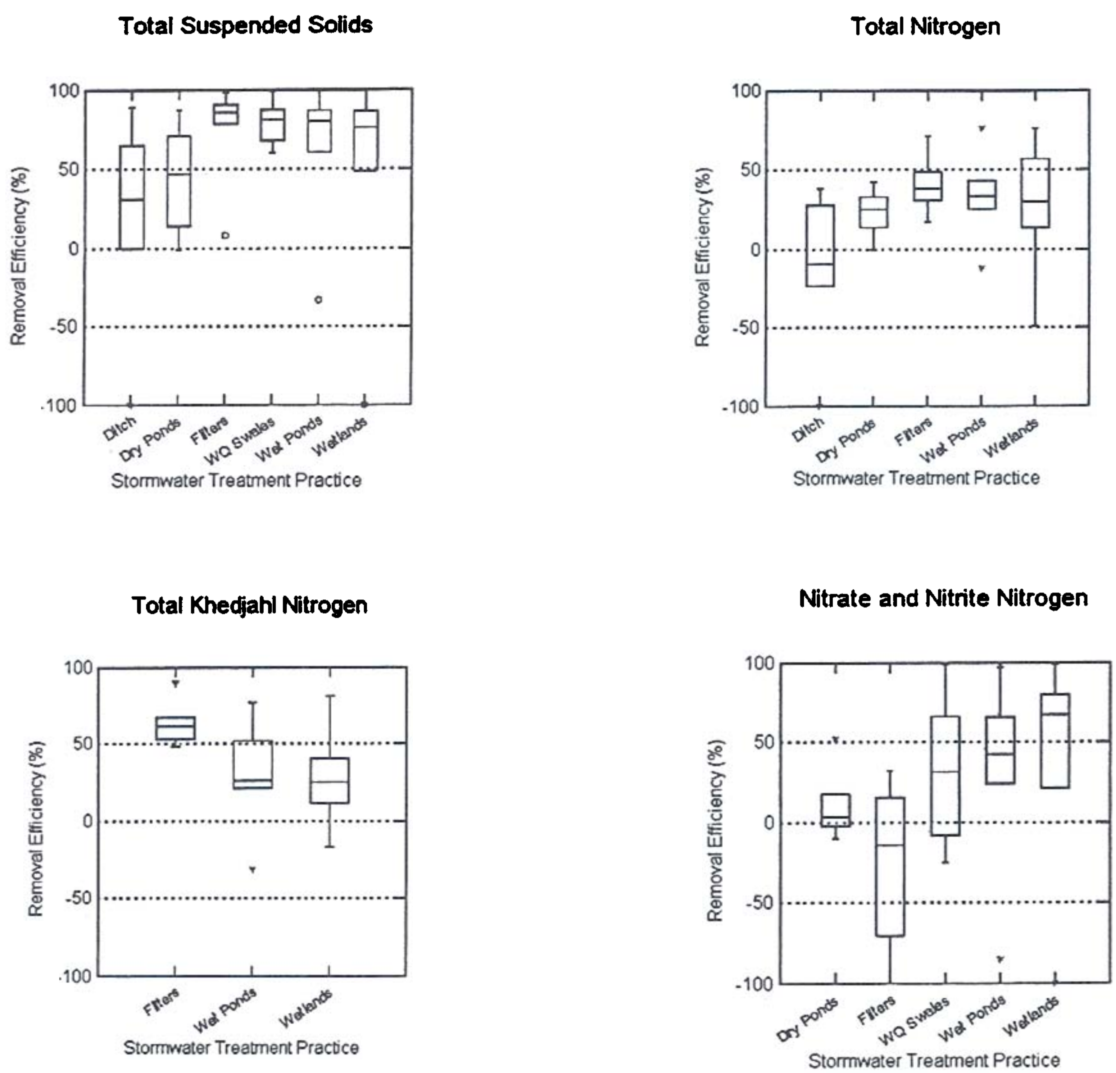
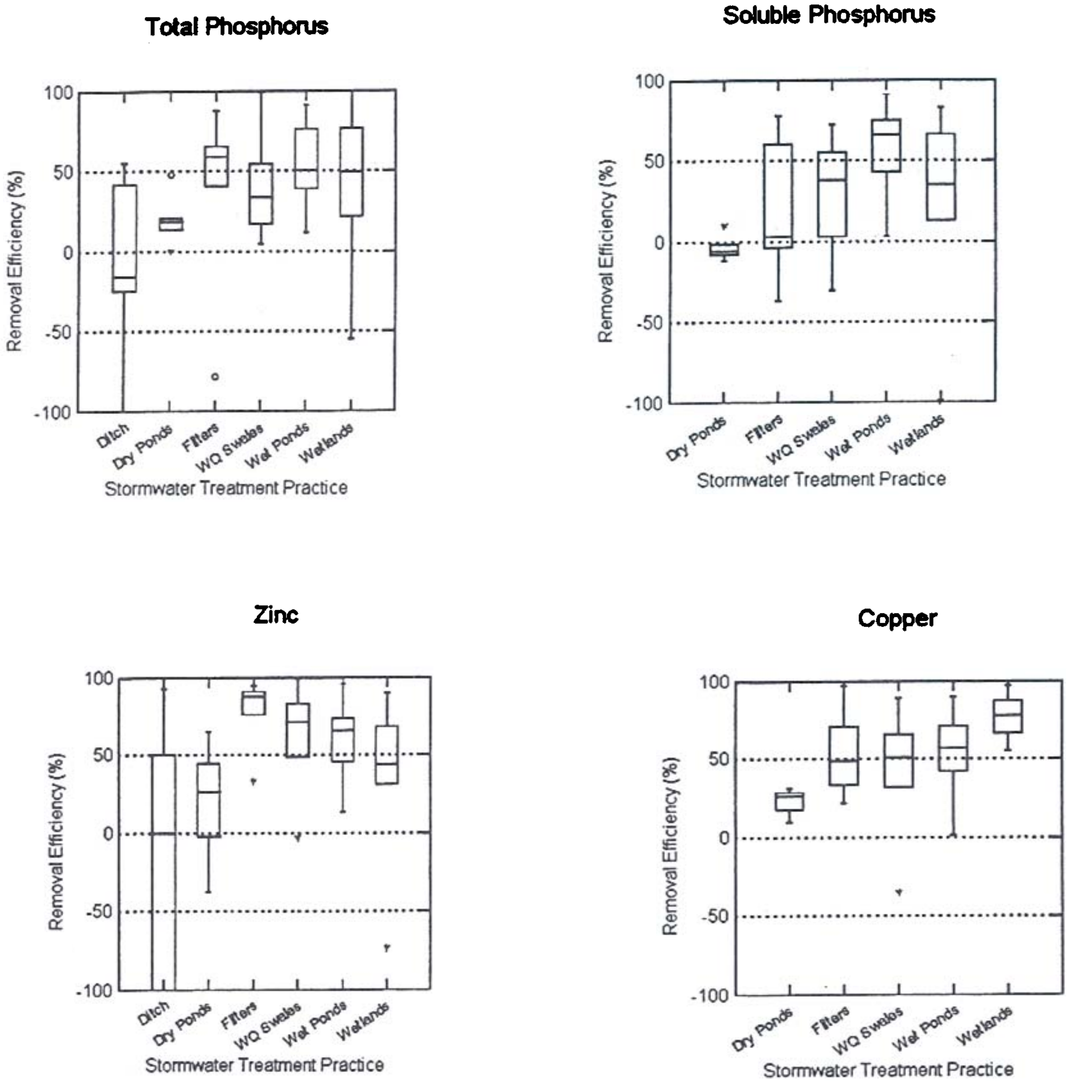


Figure 3.2 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Phosphorus, Soluble Phosphorus, Zinc, and Copper



APPENDIX D

POLLUTION CONTROLS FOR HOT SPOTS

APPENDIX D

POLLUTION CONTROLS FOR HOT SPOTS

D.1 SUMMARY

This appendix describes stormwater pollution controls for sites that generate or may generate pollutants.

To Use This Appendix:

1) Determine if the project has any characteristics or site uses listed in Section D.2.0

2) If so, go to the applicable section for that characteristic or site use, and follow the instructions to design pollution controls for the project.

D.1.1 INTRODUCTION AND APPLICABILITY

Some site characteristics and uses may generate pollutants or levels of pollution not addressed solely by implementing pollution reduction measures described in Sections 7, 8, and 9. Site characteristics and uses in this appendix are potential sources of chronic loadings or acute releases of pollutants: oil and grease, hydrocarbons, heavy metals, toxic compounds, solvents, abnormal pH levels, nutrients, organics, bacteria, and suspended solids. This appendix offers pollution controls to manage these pollutants at their sources.

Section D.2.0 lists the site uses and characteristics subject to the requirements of this appendix. Sections D.2.4 through D.2.11 provide detailed information about the recommended pollution controls.

These pollution controls apply to all new development and redevelopment projects with the defined uses or characteristics listed in Section D.2.0. With cumulative improvements, only those areas of a structure being disturbed under the permit should undergo the structural changes identified in the pollution controls.

The pollution controls are *in addition to* the selected BMP package determined in accord with Section 4.

D.2 SITE USES AND CHARACTERISTICS THAT TRIGGER POLLUTION CONTROLS

Projects with the following site uses and characteristics are subject to the requirements of this appendix:

- Fuel Dispensing Facilities (Section D.2.4)
- Aboveground Storage of Liquid Materials (Section D.2.5)
- Solid Waste Storage Areas, Containers, and Trash Compactors (Section D.2.6)
- Exterior Storage of Bulk Materials (Section D.2.7)
- Material Transfer Areas and Loading Docks (Section D.2.8)
- Equipment and Vehicle Washing Facilities (Section D.2.9)
- Covered Vehicle Parking Areas (Section D.2.10)
- High-Use Vehicle and Equipment Traffic Areas, Parking, and Vehicle Storage (Section D.2.11)

D.2.1 GOALS FOR POLLUTION CONTROLS

The pollution control requirements seek the following goals:

1) Prevent stormwater pollution by eliminating pathways that may introduce pollutants into stormwater.

2) Protect soil, groundwater, and surface water by capturing acute releases and reducing chronic contamination of the environment.

3) Segregate stormwater and wastewater flows to minimize additions to the sanitary and combined sewer systems.

4) Direct wastewater discharges and areas with potential for consistent wastewater discharges (such as vehicle washing facilities) to the sanitary or combined sewer system.

5) Provide an approved method of containment or disposal to areas that do not receive flow regularly or require water use and have the potential for acute releases or accidental spills.

6) Contain spills onsite.

7) Emphasize structural controls over operational procedures, because structural controls are not operator dependent and are considered to provide more permanent and reliable pollution control. Proposals for operation-based pollution controls must speak to the long-term viability of the maintenance program.

8) Furnish permanent structural solutions for the range of impacts that could result from multiple-site uses and tenant turnover.

D.2.2 MULTIPLE POLLUTION CONTROL REQUIREMENTS

Applicants should address all site characteristics and uses listed in Sections D.2.4 through D.2.11. For example, if a development includes both a fuel dispensing area and a vehicle washing facility, the pollution controls in both Sections D.2.4 and D.2.9 apply.

D.2.3 ADDITIONAL REQUIREMENTS

Compliance with this appendix does not relieve the applicant of other applicable local, state, or federal regulatory or permit requirements. This appendix complements any additional requirements—its recommendations do not oppose, exclude, or replace those requirements. In case of a conflict, apply the more stringent local, state, or federal regulation(s).

Some common requirements are as follows:

D.2.3.1 Spill Response Supplies

Spill response supplies such as absorbent material and protective clothing should be available at all potential spill areas. Employees should be familiar with the site's operations and maintenance plan that should include proper spill cleanup procedures.

D.2.3.2 Stormwater and Wastewater Discharge Permits

Some facilities should obtain a NPDES stormwater permit before discharging to the storm sewer system or to waters of the state. Applicants also should acquire an industrial wastewater permit for discharges to the sanitary sewer system. Facilities subject to these requirements are generally commercial or industrial. Typical discharges include process wastewater, cooling water, or other discharges generated by some pollution controls described in this appendix that drain to a public sewer system (storm, sanitary, or combined). Contact the governing jurisdiction for a list of current discharge requirements.

D.2.3.3 Other Local, State, and Federal Regulations

The recommendations in this appendix do not exclude or replace requirements of other applicable codes or regulations, such as: hazardous substance storage requirements; the spill prevention control and containment (SPCC) regulations of 40 Code of Federal Regulations (CFR) 112 (U.S. Environmental

Protection Agency [EPA]); the Resource Conservation and Recovery Act (RCRA); or any other applicable local, state, or federal regulations or permit requirements.

D.2.4 FUEL DISPENSING FACILITIES

The following sections provide information about facilities that dispense fuels.

D.2.4.1 Applicability

This section applies to all development where vehicles, equipment, or tanks are refueled on the premises—whether a large-sized gas station, a single-pump maintenance yard, or a small-sized fueled tank.

A fuel dispensing facility is defined as the area where fuel is transferred from bulk storage tanks to vehicles, equipment, and mobile containers (including fuel islands, aboveground or belowground fuel tanks, fuel pumps, and the surrounding pad). Propane tanks are exempt from these recommendations.

D.2.4.2 Management Practices

The following sections describe management practices for various circumstances.

D.2.4.2.1 Cover

Cover the fuel dispensing area with a permanent canopy, roof, or awning to prevent contact between precipitation and the fueling activity area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

D.2.4.2.2 Pavement

Place a paved fueling pad under and around the fueling activity area. Size the pad to cover the activity area—including area for fueling vehicles or equipment.

Gasoline and other materials can react with asphalt pavement to release oils from the pavement; therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks.

D.2.4.2.3 Drainage

Hydraulically isolate the paved area beneath the cover using grading, berms, or drains. This prevents uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated fueling pad to a stormwater disposal system that meets all stormwater management recommendations of this appendix.

D.2.4.2.4 Sedimentation Manhole With Tee Outlet

Install a sedimentation manhole with tee outlet on the discharge line of the fueling pad before tying in the domestic waste line. The tee section should extend 18 inches below the outlet elevation, and include an additional 4 feet of dead volume below the tee to store oil and grease. Locate the manhole on private property.

D.2.4.2.5 Shut-Off Valves

Before tying in the domestic waste line, install shut-off valves downstream of all applicable stormwater-quality facilities that serve the surrounding fueling activity areas, and downstream of the sedimentation manhole recommended for the fueling pad. Locate shut-off valves on private property.

D.2.5 ABOVEGROUND STORAGE OF LIQUID MATERIALS

The following sections describe conditions required to store aboveground liquid materials.

D.2.5.1 Applicability

This section applies to all developments with exterior storage of liquid chemicals, food products, waste oils, solvents, or petroleum products in aboveground containers equaling or exceeding 50 gallons. This includes permanent storage and temporary storage areas.

The recommendations do not apply to underground storage tanks or to businesses permitted by the state to treat, store, or dispose of regulated substances or wastes.

Note: Storage of reactive, ignitable, or flammable liquids should comply with the Uniform Fire Code.

D.2.5.2 Management Practices

The following sections describe management practices for various circumstances.

D.2.5.2.1 Containment

Store and contain liquid materials so that if the container ruptures, the contents cannot move into a receiving system.

A device or structure to contain accidental spills should have enough capacity to capture a minimum of 110 percent of the product's largest container or 10 percent of the total volume of product stored—whichever is larger.

D.2.5.2.2 Cover

Completely cover storage containers (other than tanks) so precipitation cannot contact them. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

Do not cover liquid storage tanks with a canopy or roof. However, when transferring liquids or making and breaking connections, completely cover with rain shields all taps, couplings, pumps, and other potential drip, spill, and leak-prone spots. Place drip pans under the rain shields. Reuse, recycle, or appropriately dispose of any materials collected in the drip pans and any soiled absorbent materials. Record disposal locations and dates as part of the facility's operations and maintenance log.

D.2.5.2.3 Pavement

A paved storage area is recommended. Size the paved area to cover the area intended for storage.

Gasoline and other materials can react with the asphalt pavement to release toxic oils from the pavement. Therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks.

When an exception to the requirement is allowed, stored material must be raised from the ground by pallets or similar methods, and provisions for spill control must be established.

D.2.5.2.4 Drainage

Hydraulically isolate all paved storage areas using grading, berms, or drains to prevent uncontaminated stormwater from entering a storage area.

Covered Storage Areas:
Significant amounts of precipitation are not expected to accumulate in covered storage areas, and drainage facilities are not recommended for the contained area beneath the cover. The applicant electing to install drainage facilities should direct the drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility.

Uncovered Storage Areas With Containment:
Water accumulates in uncovered storage areas during and after rain. Do not drain any *contaminated* water from the area. Collect, inspect, and possibly test it before specifying proper disposal. Monitoring the stormwater characteristics and level of contamination may also be necessary.

Discharging to the sanitary sewer may require approval, and pretreatment may be necessary. Contact the governing jurisdiction for requirements.

D.2.5.2.5 Additional Recommendations

Additional recommendations are as follows:

- Covered storage areas: A shut-off valve may be recommended for the covered storage area, if the applicant elects to install drainage facilities to an approved sanitary sewer.
- Uncovered storage areas: Install a shut-off valve in the storage area to drain excess stormwater from the activity area. Direct it to the storm drainage facilities (*if clean*), or into the sanitary sewer, or to the authorized pretreatment facility (*if contaminated*). Keep the valve closed to contain any spills within the activity area, except when discharging excess stormwater.
- Storage of hazardous materials: Toxic, carcinogenic, or halogenated solvents stored in designated groundwater resource protection areas are subject to additional state and federal requirements.

- Storage of reactive, ignitable, or flammable liquids: When storing these materials, comply with the Uniform Fire Code. Pollution controls in this section are to complement, not oppose, current fire code requirements.

D.2.6 SOLID WASTE STORAGE AREAS, CONTAINERS, AND TRASH COMPACTORS

The following sections furnish information about storing solid waste.

D.2.6.1 Applicability

The recommendations in this section apply to all developments with facilities to store solid wastes (food and non-food) outdoors in one or more solid-waste storage areas. A solid-waste storage area is where solid waste containers are stored. Solid waste containers include compactors, dumpsters, and garbage cans (including those used to contain recyclable materials).

D.2.6.2 Management Practices

The following sections describe management practices for various circumstances..

D.2.6.2.1 Cover

Permanent canopies, roofs, or awnings are recommended for solid waste storage areas containers. Construct them to cover the activity area so precipitation cannot contact stored waste materials. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated solid waste storage area.

Dumpsters and garbage cans used to store non-food solid waste do not require a permanent canopy, roof, or awning. Non-food solid wastes include refuse typically generated by a household or non-food-related business. Do not necessarily cover these areas structurally, but do cover them with lids. Use only leak-proof containers.

Dumpsters and garbage cans used to store food wastes and materials other than solid waste require permanent canopies , roofs, or awnings. Here ”solid waste” refers to fertilizers, chemicals, and animal wastes. Food waste refuse is typically generated by restaurants, food handlers, and other food industry businesses. Food waste includes foods not consumed by customers and excess or spoiled food.

Dumpsters and garbage cans used to store food wastes and materials other than solid wastes should be covered with permanent cover to prevent stormwater contact and minimize the quantity of stormwater entering the waste storage area. Hydraulically isolate the area beneath the cover from other portions of the site using grading, berms, or drains.

Trash compactors need not have permanent cover. But they are assessed an impervious area charge at sanitary rates for stormwater discharging to the sanitary system. The amout depends on annual rainfall data. Hydraulically isolate the area beneath the compactor from other portions of the site using grading, berms, or drains.

D.2.6.2.2 Pavement

Pave the area beneath the cover with asphalt or concrete, and meet all applicable code requirements. A paved waste storage area is recommended for waste storage areas with structural cover or use of trash compactor. Size the paved area to cover the area intended to store refuse or trash compactor(s) and associated equipment. Hydraulically isolate the area beneath the cover using grading, berms, or drains.

D.2.6.2.3 Drainage

Hydraulically isolate drainage beneath any covered area using berming, grading, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated waste storage area to a stormwater disposal system that meets all applicable code requirements.

D.2.7 EXTERIOR STORAGE OF BULK MATERIALS

The following sections discuss how to store bulk materials in outside containers.

D.2.7.1 Applicability

The recommendations in this section apply to developments that stockpile or store erodible materials in outside containers. This includes, but is not limited to, the following general categories:

- Pesticides and fertilizers
- Food items and wastes

- Scrap and recycling materials and yards
- Soil, sand, and other materials that increase total suspended solids (TSS) in stormwater (including contaminated soil)
- Raw by-product materials, waste, or final product.

Materials with any of the following characteristics are exempt from the recommendations of this section:

- Have no measurable solubility or mobility in water and no hazardous, toxic, or flammable properties
- Exist in a gaseous form at ambient temperature
- Are contained in a manner that prevents contact with stormwater (excluding pesticides and fertilizers).

Exhibit D.2-1 (below) lists some common bulk materials. The list is separated into three categories based on risk assessments for each material stored: high-risk, low-risk, and exempt.

Exhibit D.2-1

BULK MATERIAL CATEGORIES

High-Risk Bulk Materials	**Low-Risk Bulk Materials**	**Exempt Bulk Materials**
• Recycled materials with potential effluent • Stored and processed food items • Chalk or gypsum products • Feedstock or grain • Material byproducts with potential effluent • Asphalt • Fertilizer • Pesticides • Lime or lye or soda ash • Animal or human wastes	• Recycled materials without potential effluent • Scrap or salvage goods • Metal • Sawdust or bark chips • Sand or dirt or soil (including contaminated soil piles) • Material byproducts without potential effluent • Unwashed gravel or rock • Compost	• Washed gravel or rock • Finished lumber • Rubber and plastic products (hoses, gaskets, pipe, and so on) • Clean concrete products (blocks, pipe, and so on) • Glass products (new, non-recycled) • Inert products

D.2.7.2 Management Practices

The following sections discuss how to manage bulk products in outside containers.

D.2.7.2.1 Cover

Cover low-risk bulk materials with a temporary plastic film or sheeting (at a minimum).

Permanently cover high-risk bulk materials with a canopy or roof to prevent stormwater contact and minimize the precipitation entering the storage area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

D.2.7.2.2 Pavement

Low-Risk bulk material storage areas may or may not be paved.

High-risk bulk material storage areas should be paved beneath the structural cover.

Gasoline and other materials can react with asphalt pavement to release toxic oils from the pavement. Therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks that could contribute to soil contamination.

D.2.7.2.3 Drainage

Protect low-risk bulk material storage areas from precipitation and erosion if materials are erodible. If materials are erodible, place a containment barrier on at lease three sides of every stockpile to act as a barrier or filter for runoff.

For high-risk bulk material storage areas, hydraulically isolate the paved area beneath the structural using grading, berms, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants. Since significant amounts of precipitation are not expected to accumulate in covered storage areas, drainage facilities are not recommended for the containment area beneath the cover.

D.2.7.2.4 Additional Recommendations

Storage of pesticides and fertilizers: This may need to comply with specific regulations issued by the state.

Sampling manhole: This or another suitable stormwater monitoring access point may be recommended to monitor stormwater runoff from the storage area. Certain types of storage activities and materials or proposed alternative pollution control may apply to this circumstance.

Shut-off valve: This may be recommended for the structurally covered storage area if the applicant elects to install drainage facilities to an approved sanitary sewer.

Storage of hazardous materials: Storage of toxic, carcinogenic, or halogenated solvents (within designated groundwater protection areas) is subject to additional state and federal requirements.

D.2.8 MATERIAL TRANSFER AREAS AND LOADING DOCKS

D.2.8.1 Applicability

The following sections provide information about material transfer areas and loading docks.

The recommendations in this section apply to all developments proposing to install new material transfer areas or structural alternatives to existing material transfer areas (such as access ramp regrading or leveler installations).

Two standard types of material transfer areas associated with buildings are: 1) Loading or unloading facilities with docks, and 2) large bay doors without docks. The recommendations apply to these material transfer areas and any other building access point(s) with both of the following characteristics:

- The area is designed with the size and width to accommodate a truck or trailer backing up to or into it.

- The area will receive or distribute materials to and from trucks or trailers.

The recommendations may not apply to areas used only for mid-sized to small-sized passenger vehicles and restricted (by lease agreements or other regulatory requirements) to storing, transporting, or using materials classified as domestic use. Examples of domestic uses include primary educational facilities (elementary, middle, or high school), buildings used for temporary storage (a lease agreement must be provided), and churches.

D.2.8.2 Management Practices

The following sections discuss how to manage material transfer areas and loading docks.

D.2.8.2.1 Cover

Existing and New Buildings with Loading Docks:
Cover loading docks with a canopy, roof, or other permanent overhang that extends a minimum of 4 feet over the trailer or truck end. The cover should minimize the volume of precipitation discharged to the sanitary sewer or authorized pretreatment facility. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements.

Bay Doors and Other Interior Transfer Areas:
Conduct all transfer of materials with the truck or trailer end backed into the building a minimum of 5 feet (see additional recommendations below). An exterior cover is not necessary for these areas.

D.2.8.2.2 Pavement

Place a paved area underneath and around the loading and unloading activities. This reduces the potential for soil contamination that impacts groundwater and helps control any acute or chronic release of materials present in these areas.

Some materials can react with asphalt pavement to release oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

D.2.8.2.3 Drainage

Loading Docks:
Hydraulically isolate the first 3 feet of the paved area beneath the cover—measured from the building or dock face—using grading, berms, or drains to prevent uncontaminated stormwater from running into the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated loading dock area to a stormwater disposal system that meets all applicable recommendations of this appendix.

Bay Doors and Other Interior Transfer Areas:

Design bay doors and other interior transfer areas so stormwater does not enter the building. Grading or drains can accomplish this.

Because interior material transfer areas are not expected to accumulate precipitation, installation of floor drains is not necessary or recommended. Handle these areas with a dry mop or absorbent material. If interior floor drains are installed, they should be plumbed to an approved sanitary sewer or authorized pretreatment facility.

D.2.8.2.4 Additional Recommendations

Bay doors and other interior transfer areas: These require a 10-foot "no obstruction zone" beyond the entrance within the building. This allows transfer of materials to occur with the truck or trailer end placed at least 5 feet inside the building, with an additional staging area of 5 feet beyond that. Clearly identify the "no obstruction" zone on the building plan at the time of permit application.

Shut-off valve: This may be necessary for discharges to an approved sanitary sewer.

Transport and handling of hazardous materials: Transport and handling of toxic, carcinogenic, or halogenated solvents are subject to additional state and federal requirements.

D.2.9 EQUIPMENT AND VEHICLE WASHING FACILITIES

The following sections furnish information about equipment and vehicles washing facilities.

D.2.9.1 Applicability

The recommendations in this section apply to all development with a designated equipment and vehicle washing or steam cleaning area. This includes smaller activity areas such as wheel washing stations. Residential sites are not included.

Development intended to store 10 or more fleet vehicles should include a designated vehicle washing area—except if vehicles are routinely washed in an approved location.

D.2.9.2 Management Practices

The following sections discuss how to manage equipment and vehicle washing facilities.

D.2.9.2.1 Cover

Cover the washing area with a permanent canopy or roof so precipitation cannot come in contact with the washing activity area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

D.2.9.2.2 Pavement

Place a designated paved wash area underneath and around washing activity areas. Size the paved area to cover the activity area, including a place where the vehicle or piece of equipment is cleaned.

Some materials can react with asphalt pavement to release toxic oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

D.2.9.2.3 Drainage

Hydraulically isolate the paved area beneath the cover using grading, berms, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated washing pad to a stormwater disposal system that meets all applicable recommendations of this appendix.

D.2.9.2.4 Oil Controls

All vehicle and equipment washing activities should include oil controls. On-site wash recycling systems may be used for oil control, as long as they meet applicable effluent discharge limits for the sanitary sewer system.

D.2.9.2.5 Exceptions

Permanent Cover:
If a washing activity area is used generally to service oversized equipment that cannot maneuver under a roof or canopy (for instance, cranes, sail boats), a roof or canopy may not be necessary.

Surface Stormwater:
Because stockpile has the potential to erode, place a containment barrier on all four sides of every stockpile to prevent stormwater run-on and material runoff. Barriers can consist of concrete curbing, silt fencing, or other berming material—depending on the activity, size, and resources available.

D.2.10 COVERED VEHICLE PARKING AREAS

The following sections deal with covered vehicle parking areas.

D.2.10.1 Applicability

The recommendations in this section apply to all development with a covered vehicle parking area, except single-family and duplex residential sites. Existing parking structures do not need retrofitting. New parking structures should meet these specifications.

D.2.10.2 Drainage

Top Floor Drainage of a Multi-Level Parking Structure:
Direct stormwater runoff from the top floor to a stormwater disposal system that meets all water quality recommendations of this appendix and any other applicable code requirements.

Lower Floor Drainage of a Multi-Level Parking Structure:
Since significant amounts of precipitation are not expected to accumulate in covered vehicle parking areas, drainage facilities are not recommended for the lower floors. If the applicant elects to install drainage facilities, direct the drainage from the lower floors to an approved sanitary sewer.

Adjacent Uncovered Portions of the Site:
Design surrounding uncovered portions of the site so stormwater does not enter the covered parking areas. This can be accomplished through grading or drains.

D.2.10.3 Liquid Materials Stored In Aboveground Tanks

Stormwater runoff and spills from some materials storage, use, or transportation areas have the potential to contribute chemical, physical, and biological pollutants to receiving systems; these include toxic substances, organic compounds, oil and grease, heavy metals, bacteria, nutrients, and suspended solids. These substances can enter the groundwater or surface water through acute releases or chronic loading.

Potential pollutants can vary extensively in type and severity, depending on the characteristics of the stored material.

Hazardous materials are so defined if they or a constituent of them posses one of the following characteristics:

- Carcinogenity
- Toxicity
- Presence of halogenated solvent.

D.2.11 HIGH-USE VEHICLE AND EQUIPMENT TRAFFIC AREAS, PARKING, AND VEHICLE STORAGE

The following sections provide information about high-use vehicle or high-risk-vehicle areas.

D.2.11.1 Applicability

The recommendations of this section apply to all types of vehicle and equipment traffic areas, parking lots, and vehicle storage (commercial, public, and private) with any of the following high-use or high-risk conditions:

- A commercial or industrial site that stores wrecked or impounded vehicles
- Sites with high likelihood of oil and grease releases (such as fast-food restaurants, vehicle repair shops, vehicle sales establishments, and vehicle-fueling service areas).

D.2.11.2 Management Practices

The following sections discuss how to manage high-use-vehicle or high-risk-vehicle areas.

D.2.11.2.1 Pavement

Because of the potential for soil and groundwater contamination, all high-use or high-risk sites should be paved.

Gasoline and other materials can react with asphalt pavement to release toxic oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

D.2.11.2.2 Oil Water Separation

City will generally prohibit discharge of stormwater with a visible sheen to the storm sewer system. Together with pollution reduction facilities to meet the recommendations of this appendix, oil-water separators approved by the governing municipality may be recommended to provide oil control for these areas.