SECTION 9

STORM WATER BEST MANAGEMENT PRACTICES

Page

LIST OF TABLES

LIST OF FIGURES

9.1 STORM WATER MANAGEMENT PLANS

9.1.1 Purpose. In accordance with Chapter 27, Article II of the City of Temple's Code of Ordinances (Post Construction Storm Water Runoff Control Ordinance), proposed new development and significant redevelopment of one (1) or more acres or any land situated along a creek will be required to submit Storm Water Management Plans (SWMP) that propose structural, non-structural or vegetative controls to reduce pollutants in storm water runoff. Approval requirements for SWMPs are outlined in Sec. 27-5 of City Code.

9.1.2 Plan Requirements. The SWMP should contain a site description, planned controls, and procedures for maintenance and inspection. The contents of a SWMP are described below and in Sec. 27-6 of City Code.

9.1.2.1 Site Description.

a. Site location.
b. Names, addresses, and phone numbers of owner and contact person.
c. Type of development or redevelopment.
d. Nature of activities.
e. Any existing NPDES storm water permit numbers or provide a copy of the General Permit Notice of Intent (NOI) or NPDES permit application.
f. Estimates of the total site area and the total area affected by the development.
g. Site map(s).
    1. Vicinity map.
    2. Areas of development.
    3. Areas not to be developed.
    4. Drainage areas and their acreage, patterns and proposed grading plan.
    5. Wetlands and surface waters.
    6. Locations and listing of activities which may generate pollutants and potential discharge, including hazardous materials treatment, storage or disposal facilities, parking areas, loading areas, etc.
    7. Location and listing of structural controls, and non-structural controls as applicable, that are identified in the plan.
    8. Locations where storm water is discharged to the MS4 and the name of the MS4 operator.
h. Natural Resource Inventory.
    1. Soil conditions.
    2. Forest cover.
    3. Topography.
    4. Wetlands.
    5. Other native vegetative areas on the site.

9.1.2.2 Controls.

a. Non-Structural Controls – Describe non-structural best management practices (BMPs) and how they will be used at the site.
b. Structural Controls – Structural BMPs should be shown on construction drawings. Supporting data (specifications, calculations, etc.) should be provided upon request.

9.1.2.3 Maintenance.

A maintenance plan meeting the requirements of Sec. 27-6 of City Code developed by the design engineer and acceptable to the City of Temple will be required prior to approval of the SWMP. The following information should be included in the proposed maintenance plan.

a. Specification of routine and non-routine maintenance activities to be performed.
b. A schedule for maintenance activities.
c. Provision for access to the tract by the City of Temple or other designated inspectors.
d. Name, qualifications and contact information for the party(ies) responsible for maintaining the BMP(s).
e. The plan should be signed and dated by the party responsible for maintenance.

General maintenance items and frequencies are listed below. Some items will not be applicable to all BMPs.

a. Sediment removal – at least twice per year or when the depth reaches 3-inches.
b. Erosion Control – side slopes and embankment may periodically suffer from slumping and erosion and should be repaired as soon as problems are identified.
c. Irrigation areas – maintain in natural state to greatest extent possible such that spray from sprinkler heads is not impeded; tree and shrub trimmings and larger debris should be removed immediately.
d. Mowing – grass areas should be mowed at least twice per year to limit vegetation height to 18-inches; more frequent mowing is required for aesthetic appeal in landscaped areas; mowing should be done either with a mulching mower or by capturing and removing grass clippings with a bagger or by raking.
e. Debris and litter removal – perform at least twice per year, usually in conjunction with mowing, or more frequently as needed.
f. Structural repairs – damage to structural elements (pipes, concrete drainage structures, retaining walls, etc.) should be identified and repaired immediately. These repairs should include patching of cracked concrete, sealing of voids, and removal of vegetation from cracks and joints.
g. Pest management – an Integrated Pest Management (IPM) Plan should be developed for vegetated areas. This plan should specify how problem insects and weeds will be controlled with minimal or no use of insecticides or herbicides.

Maintenance of BMPs frequently requires disposal of accumulated sediment and other material. These materials are normally classified as special wastes when disposed of in municipal landfills. Special waste is a waste that requires special handling at a Type I Municipal Solid Waste (MSW) landfill. The process to obtain authorization to dispose of a special waste begins with a request for approval called the "Request for Authorization for Disposal of Special Waste TCEQ Form 0152." The request is completed by the generator and submitted to the MSW permits section of the TCEQ for Executive Director review/approval. The MSW permits section performs the review described in 30 TAC 330.136 or most current applicable subsection of 30 TAC. A maintenance plan developed by the design engineer and acceptable to the City of Temple will be required prior to approval of the SWMP. The following information should be included in the proposed maintenance plan.

9.1.2.4 Inspections.

BMP facilities must be inspected at regular intervals, preferably during or immediately after a period of wet weather, to evaluate facility operation. Below is a list of frequencies for inspections for various BMP facilities.

a. Grassy Swales – At least 2 times per year.
b. Vegetated Filter Strips – At least 2 times per year.
c. Permeable and Semi-Pervious Pavement – At least 2 times per year.
d. Extended Detention Basins, Retention Ponds, Detention Ponds – At least 2 times per year.
e. Irrigation Systems, Pumps – Every 2 months.
f. Subsurface Treatment Devices – After rain events.
g. Preserved Tree Canopies – At least 2 times per year.

During each inspection, erosion areas inside and downstream of the BMP must be identified and repaired or revegetated immediately. With each inspection, any damage to the structural elements of the system (pipes, concrete drainage structures, retaining walls, etc.) must be identified and repaired immediately. Cracks, voids and undermining should be patched/filled to prevent additional structural damage. Trees and root systems should be removed to prevent growth in cracks and joints that can cause structural damage.

Irrigation systems and pumps should be inspected for functionality. Broken or 'frozen' sprinkler heads should be replaced immediately. Pumps shall be inspected and maintenance performed to the manufacturer's specifications.

Subsurface treatment devices should be inspected for larger debris captured during rain events which could plug openings in the device as well as sediment accumulation.

Inspections of tree canopies should include identification of sick/dying/dead trees to be removed from the canopy area.

9.1.3 Bibliography.

1. Barrett, M., Texas Commission on Environmental Quality, *Edwards Aquifer Technical Guidance Manual*. June 2005.

2. Houston, City of, Harris County, Harris County Flood Control District, *Stormwater Quality Management Guidance Manual*. 2001 Edition.

9.2 CONSTRUCTION (TEMPORARY) BEST MANAGEMENT PRACTICES

9.2.1 Introduction. Sedimentation involves three basic processes: erosion, transportation, and deposition. These are natural geologic phenomena which have been in continuous operation since the beginning of time. Man's land development activities, however, have initiated severe, highly undesirable, and damaging alterations in the natural sedimentation cycle by drastically accelerating the erosion-sedimentation process.

9.2.1.1 Erosion.

This term includes all of the processes by which soil or rock material is loosened and removed, that is, weathering, solution, downcutting, and transportation. Soil erosion is usually caused by the force of water falling as raindrops and by the force of water flowing in rills and streams. The raindrops falling on bare or sparsely vegetated soil particles but have little capacity for transporting them. Water running in a sheet on the surface of the ground picks up these particles and carries them along as it flows downhill towards a stream system. As the runoff gains in velocity and concentration, it detaches more soil particles, cuts rills and gullies into the surface of the soil, and adds to its sediment load. Coalescing rivulets produce streams which have a larger volume and usually increased velocity; hence, a greater capacity to remove sediment and transport it downstream. The greater the distance the water runs uncontrolled, the greater its erosive force and the greater the resultant damage. Moreover, control becomes increasingly more difficult as the distance and volume increase.

9.2.1.2 Factors Influencing Erosion.

The erosion potential of a site is principally determined by the erodibility of the soil, vegetative cover, topography, climate and season. Although the factors are interrelated as determinants of erosion potential, they are discussed separately for ease of understanding.

The vulnerability of a soil to erosion is known as erodibility. The soil structure, texture, and percentage of organic matter influence it erodibility. The most erodible soils generally contain high proportions of silt and very fine sand. The presence of clay or organic matter tends to decrease soil erodibility. Clays are sticky and tend to bind soil particles together. Organic matter helps maintain stable soil structure.

There are several ways in which vegetation protects soil from the erosive forces of raindrop impact and runoff scour. The top growth shields the soil surface from raindrop impact while the root mass holds soil particles in place. Grass buffer strips can be used to filter sediemtn from the surface runoff. Grasses slow the velocity of runoff which results in sedimentation, and also helps maintain the infiltration capacity of the soil. The establishment and maintenance of vegetation can be most effective in minimizing erosion during development.

Slope length and steepness are key influences on both the volume and velocity of surface runoff. Long slopes deliver more runoff to the base of slopes and steep slopes increase runoff velocity; both conditions enhance the potential for erosion to occur.

Erosion potential is also affected by the climate of the area. Rainfall characteristics, such as frequency, intensity, and duration directly influence the amount of runoff that is generated. As the frequency of rainfall increases, water has less chance to drain through the soil between storms. The soil will remain saturated for longer periods of time and storm water runoff volume may be potentially greater. Therefore, when rainfall events are frequent, intense, or lengthy, erosion risks are high.

Seasonal variation in wind, humidity, temperature and rainfall defines periods of high erosion potential during the year. A high erosion potential may exist in the spring when the surface soil first thaws and the ground underneath remains frozen. A low intensity rainfall may cause substantial erosion as infiltration is impossible because of the frozen subsoil. The erosion potential is also high during the summer months because of more frequent, intensity rainfall.

9.2.2 Standards for Erosion and Sediment Control.

The principles of reducing erosion and sedimentation from developing areas are:

A. Plan the development to fit the particular topography, soils, waterways, and natural vegetation at the site.

   Initially, this is best achieved through adoption of a general land-use plan based upon a comprehensive inventory of soil, water, and related resources.

   Slope length and gradient are key elements in determining the volume and velocity of the runoff and its associated erosion. As both slope length and steepness increase, the rate of runoff increases and the potential for erosion is magnified. Where possible, steep slopes should be left undisturbed. By limiting the length and steepness of the designed slopes, runoff volumes and velocities can be reduced and erosion hazards minimized.

   Soils which contain a high proportion of silt and very fine sand are generally the most erodible. The erodibility of these soils is decreased as the percentage of clay organic matter content increases. Well-drained and well-graded gravel-sand mixtures with little silt are the least erodible soils. By reducing the length and steepness of a given slope, even a highly erodible soil may show little evidence of erosion. Long steep slopes should be broken by benching, or constructing diversion structures.

The natural vegetative cover is extremely important in controlling erosion since it: 1) shields the soil surface from the impact of falling rain; 2) increases infiltration of water into the soil; 3) reduces the velocity of the runoff water; and 4) holds soil particles in place while filtering surface runoff.

B. Keep disturbed areas small.

When earthwork is required and the natural vegetation is removed, keep the area and the duration of exposure to a minimum. Plan the phases or stages of development so that only the areas which are actively being developed are exposed. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after it is begun. Minimizing grading of large or critical areas during the season of maximum erosion potential (May or October) reduces the risk of erosion.

C. Protect disturbed areas from storm water runoff.

This principle requires practices that control erosion on a site to prevent excessive sediment from being produced. Practices which keep soil covered as much as possible with temporary or permanent vegetation or with various mulch materials are best. Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer may be used. Immediately after grading is complete, permanent vegetative cover should be established in the area. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated as the work progresses. Other practices include diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water.

Gross erosion in the form of gullies must be prevented by these control devices. Lesser types of erosion such as sheet and rill erosion should be prevented. When erosion is not adequately controlled, sediment control is more difficult and expensive.

D. Retain sediment within the site boundaries.

This principle relates to using practices that control sediment once it is produced and prevents it from leaving the site. Diversion ditches, sediment traps, vegetative filters, and sediment basins are examples of practices to control sediment. Vegetative and structural sediment control measures can be classified as either temporary or permanent depending on whether or not they will remain in use after development is complete. Generally, sediment can be retained by two methods: 1) filtering runoff as it flows through an area and 2) impounding the sediment-laden runoff for a period of time so that the soil particles are deposited. The best way to control sediment, however, is to prevent erosion.

E. Implement a thorough maintenance and follow-up program.

This principle is vital to success. A site cannot be effectively controlled without thorough, periodic checks of the control practices. An example of applying this principal would be to start a routine "end-of-day check" to ensure all control practices are working properly.

These five principles are integrated into a system of vegetative and structural measures, along with management techniques, to develop a plan to prevent erosion and provide sediment control. In most cases, a combination of limited grading, limited time of exposure, and a judicious selection of erosion control practices and sediment-trapping facilities will prove to be the most practical method of controlling erosion and the associated production and transport of sediment.

After the development process begins, effective erosion and sedimentation control depends upon careful, accurate installation in a timely fashion, and sufficient maintenance to ensure the intended results.

9.2.3 The Sediment Control Plan.

The required Sediment Control Plan is a plan for controlling erosion and sediment during construction in compliance with the laws, ordinances, and these Standards. This plan shall be a part of the total site development plan and prescribes all the steps necessary, including scheduling, to assure erosion and sediment control during all phases of construction including final stabilization.

Planning for sediment control should begin with the conceptual plan and its preparation. Such features as soils and topography should be considered for the conceptual plan as well as any requirements for sediment control or storm water management.

Planning for sediment control should also begin with first-hand knowledge of the site by the designer. The plan shall be based on a sufficiently accurate topographic map that reflects the existing topography and site conditions. Adjacent areas affecting the site or affected by the site and its development shall be shown on the plans in sufficient detail to accomplish the need. Examples of this would be areas draining onto the site or areas where storm runoff leaves the site and travels to a stream or drainage system.

The Sediment Control Plan will consist of the best selection of erosion control practices and sediment-trapping facilities, in conjunction with an appropriate schedule, to accomplish an adequate level of control. Particular attention must be given to concentrated flows of water, either to prevent its occurrence or to provide conveyance devices according to the Standards to prevent “major” or “gross” erosion. Sediment-trapping devices will usually be required at all pointes of egress of sediment-laden water. The plan must include permanent structures for conveying storm runoff, final site stabilization, removal of temporary sediment control features such as sediment basins, and finally, stabilization of the sites where temporary features were removed. Plans showing improvements or construction to be done outside the property line for the site will generally not be approved unless a plan is accompanied by an appropriate legal easement for the area in which the work is to be done.

The standardization of sediment control plans makes them easier to study and review. The List of Standard Symbols (Figure 2-1) was developed to facilitate plan review. The symbols should be bold and easily identifiable on the plans. Unless otherwise approved, one of the following scales shall be used for the detailed sediment control plans for urban development sites: 1″=20′, 1″=30′, 1″=40′, or 1″=50′. The contour interval for these plans shall be 2 feet or smaller.

The Sediment Control Plan shall include the existing and proposed topography. Existing topography can be either from actual field survey obtained from approved photogrammetric methods or from information obtained from responsible agencies. No proposed slopes will exceed 2H:1V. All slopes steeper than 3H:1V will require low-maintenance stabilization.

The existing and proposed improvements shall be shown on the sediment control plan and will include all buildings, roads, storm drains, etc. Proposed removal or alterations of existing facilities shall be indicated on the plan.

9.2.3.1 Sediment Control Practices.

All sediment control practices must be identified on the Sediment Control Plan. These practices will be shown in sufficient detail to facilitate implementation. All permanent sediment control structures will be labeled on the plan as PERMANENT. All temporary stabilization practices will be labeled on the plan as TEMPORARY. The location and methods of stabilization will be indicated on the Plan.

A schedule, or sequence, of operations will be included on the Sediment Control Plan. Special emphasis will be placed on the scheduled start of clearing and/or grading, sequence or installation of sediment control and storm water management facilities, duration or exposure, and the scheduled start and completion dates of stabilization measures (both temporary and permanent).

9.2.3.2 Drainage Plan.

A Drainage Plan shall be provided as per Section 1. Based on this Plan, indicate the velocity for: 1) pipe outfall, 2) outfall structure, and 3) natural or designed channel below outfall structures to point to entry into existing system or natural stream. On the Sediment Control Plan show the proposed method of stabilizing the outfall, consistent with computed velocities.

9.2.4 Standards For Structural Practices.

This section describes several control measures which are available for use in controlling erosion and sedimentation. The designer is encouraged to review the Soil Conservation Service publications, Erosion and Sediment Control Guidelines in Developing Areas in Texas[4] and Texas Engineering Handbook Section 17, Erosion Control Practices[5] for additional control measures.

9.2.4.1 Straw Bale Barrier

Definition
A temporary barrier of straw or similar material may be used to intercept sediment laden runoff from small drainage areas of disturbed soil. Figure 9-2 is a typical straw bale barrier.

Purpose
The purpose of a straw bale barrier is to reduce velocity and effect deposition of the transported sediment load. Straw bale barriers are to be used to intercept and detain small amounts of sediment from unprotected areas of less than 1/2 acre.

Application
The straw bale barrier is used where:

A. Contributing area is approximately 1/2 acre, or less.

B. There is no concentration of water in a channel or other drainage way above the barrier.

C. Erosion would occur in the form of sheet or rill erosion.

D. Length of slope above the straw bale dike shall not exceed 100 feet.

Straw bales must not be used on high sediment producing areas above "high risk" areas, where water concentrates, or where there would be a possibility of a washout.

Design Criteria
A design is not required. All bales shall be placed on the contour and shall be either wire bound or nylon-string tied. Bales shall be laid with the cut edge adhering to the ground and staked in place. At least two wooden or metal stakes shall be driven through each bale and

into the ground at least one foot. The first stake shall be angled toward the previously placed bale and driven through both the first and second bale. Stakes shall be driven flush with the bale.

The possibility of piping failure shall be reduced by setting the straw bales in a trench excavated to a depth of at least four (4) inches and by firmly tamping the soil along the upstream face of the barrier.

9. 2.4.2 Silt Fence

Definition

A silt fence is a temporary barrier made of geotextile fabric which is water-permeable but will trap water-borne sediment from small drainage areas of disturbed soil, as shown in Figure 2-3.

Purpose

The purpose of a silt fence is to reduce runoff velocity and effect deposition of transported sediment load. Limits imposed by ultraviolet stability of the fabric will dictate the maximum period the silt fence may be used.

Application

A silt fence may be used subject to the following conditions:

A. Maximum allowable slope lengths contributing runoff to a silt fence are listed in the Table 9-1.

TABLE 9-1 Silt Fence Slope Criteria

Constructed Slope	Maximum Slope Length (feet)
2H:1V	25
2.5H:1V	50
3H:1V	75
3.5H:1V	100
4H:1V	125
Flatter than 5H:1V	200

B. Maximum drainage area for overland flow to a silt fence shall not exceed 0.5 acre per 100 feet of fence.

C. Erosion would occur in the form of sheet erosion.

D. There is no concentration of water flowing to the barrier.

Design Criteria

Design computations are not required for a silt fence design. All silt fences shall be placed as close to the contour as possible. The filter fence shall be placed and constructed in such a manner that runoff from a disturbed upland area shall be intercepted, the sediment trapped, and the surface runoff allowed to percolate through the structure. The bottom of the fabric should be buried in a 6 inch by 6 inch trench. When a trench cannot be constructed, rock and soil shall be placed over the bottom of the fabric in such a manner as to prevent underflow.

A detail of the silt fence shall be shown on the plan, and contain the following minimum requirements:

A. The type, size, and spacing of fence posts;

B. the size of woven wire support fence;

C. the type of filter cloth used;

D. the method of anchoring the filter cloth; and

E. the method of fastening the filter cloth to the fencing support.

Where ends of filter cloth join they shall be overlapped, folded and stapled to prevent sediment bypass.

A. Silt Fence Fabric

The fabric shall meet the specifications in Table 9-2. Type W fabric is a Type 1 self-supported fence. Type NW is a nonwoven fabric which is used in a Type 2 net-reinforced fence or Type 3 triangular filter dike. Either fabric may be manufactured from polyester, polypropylene or polyamide and shall be resistant to ultraviolet degradation, mildew or rot. The edges of woven fabric shall be sealed or salvaged to prevent raveling.

TABLE 9-2 Silt Fence Fabric Criteria

Fabric Properties	**Minimum Acceptable Value**		**Test Method**
	Type W	**Type NW**	
Tensile Strength, lb	100	90	ASTM D4632
Elongation at Yield, %	10-40	100 Max	ASTM D4632
Trapezoidal Tear, lb	50	35	ASTM D4533
Permittivity, 1/sec	0.1	1.0	ASTM D4491
Apparent Opening Size	20-50	50-80	ASTM D4751
Ultraviolet Stability, %	80	80	ASTM D4355

B. Fence Reinforcement Materials

Silt fence reinforcement shall be one of the following systems.

1. Type 1: Self-Supported Fence

This system consists of fence posts, spaced no more than 8 1/2 feet apart, and Type W fabric without net reinforcement. Fence posts shall be a minimum of 42 inches long, embedded at least 1 foot, and constructed of either wood or steel. Soft wood posts shall be at least 3 inches in diameter or nominal 2 x 4 inches and essentially straight. Hardwood posts shall have minimum dimensions of 1.5 x 1.5 inches. Fabric attachment may be by staples or locking plastic ties at least every 6 inches, or by sewn vertical pockets. Steel posts shall be T or L shaped with a minimum weight of 1.3 pounds per foot. Attachment shall be by pockets or by plastic ties if the posts have suitable projections.

2. Type 2: Net-Reinforced Fence

   This system consists of fence posts, spaced no more than 8-1/2 feet apart, and Type NW fabric with an attached reinforcing net. Net reinforcement shall be galvanized welded wire mesh of at least 12.5-gauge wire with maximum opening size of 4 inches square. The fabric shall be attached to the top of the net by crimping or cord at least every 2-feet, or as otherwise specified.

3. Type 3: Triangular Filter Dike

   This system consists of a rigid wire mesh, at least 6-gauge, formed into an equilateral triangle cross-sectional shape with sides measuring 18 inches, wrapped with Type NW silt fence fabric. The fabric shall be continuously wrapped around the dike, with a skirt extending at least 12 inches from its upslope corner.

C. Prefabricated Units

   Envirofence or approved equal may be used in lieu of the above method providing the unit is installed per manufacturer's instructions.

9. 2.4.3 Stabilized Construction Entrance

Definition
A stabilized pad of aggregate located at any point where traffic will be entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk, or parking area.

Purpose
The purpose of a stabilized construction entrance is to reduce or eliminate the tracking or flowing of sediment onto public rights-of-way or streets.

Application
A stabilized construction entrance applies to all points of construction ingress and egress.

Design Criteria
A design is not required for a stabilized construction entrance, however, the following criteria in Table 9-3 shall be used.

TABLE 9-3 Stabilized Construction Entrance Design Criteria

Aggregate:	Use 2 inch stone, or reclaimed or recycled concrete equivalent
Thickness:	Not less than six (6) inches
Width:	Not less than full width of all points of ingress and egress Twenty (20) foot minimum
Length:	As required, but not less than 50 feet

Maintenance

The entrance shall be maintained in a condition which will prevent tracking or flowing of sediment onto public rights-of-way or streets. This may require periodic top dressing with additional aggregate as conditions demand. All sediment spilled, dropped, washed, or tracked onto public rights-of-way must be removed immediately.

When necessary, wheels must be cleaned to remove sediment prior to entrance onto public right-of- way. When washing is required, it shall be done on an area stabilized with crushed stone which drains into an approved sediment trapping device. All sediment shall be prevented from entering any storm drain, ditch, or watercourse.

9.2.4.4 Sediment Basin

Definition

A sediment basin is constructed across a waterway or at other suitable locations to collect and store debris or sediment.

Purpose

The purpose of a sediment basin is to preserve the capacity of reservoirs, ditches, canals, diversions, waterways, and streams; to prevent undesirable deposition on bottom lands and developed areas; to trap sediment originating from construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural wastes, and other detritus.

Application

This practice applies where physical conditions, land ownership or other restrictions preclude the treatment of a sediment source by the installation of erosion-control measures to keep soil and other material in place, or where a sediment basin offers the most practical solution to the problem.

Design Criteria

A. Compliance with Laws and Regulations

Design and construction shall comply with state and local laws, ordinances, rules, and regulations. The designer is cautioned that water impounding structures higher than six (6) feet may be considered dams and is encouraged to contact the Texas Natural Resource Conservation Commission regarding applicable rules.

B. Location

The sediment basin should be located to obtain the maximum storage benefit from the terrain and for ease of cleanout of the trapped sediment. It should be located to minimize interference with construction activities and construction of utilities.

C. Size of the Basin

The capacity of the sediment basin, as measured from the bottom of the basin to the elevation of the crest of the principal spillway, shall equal or exceed the trapped volumes of debris or sediment expected to be trapped at the site during the planned useful life of the structures or improvements it is designed to protect. The minimum capacity provided shall be in accordance with criteria in Texas Engineering Handbook, Erosion Control Practices, Section 17[5]

The Universal Soil Loss Equation (USLE) can be used to determine the size of the sediment basin. The USLE determines the gross sheet and rill erosion (tons/ac./yr). The actual sediment yield at the point of concern (sediment basin) is the gross erosion minus the sediment deposited enroute. The ratio of sediment yield to gross erosion can be estimated from relationships discussed in the SCS publication NEH-Chapter 3, Sedimentation.

The USLE equation is defined by six (6) factors. The designer should consult the Soil Conservation Service's Technical Release No. 51[1] and USDA Handbook No. 537, for the proper tables and figures. The Universal Soil Loss Equation is defined by Equation 2-1.

$$A = R\,K\,L\,S\,C\,P \qquad (2\text{-}1)$$

where:

A = sediment yield, in tons per acre per year

R = rainfall factor, R = 300 for Temple, Texas

K = soil erodibility factor, 0.05 = K = 0.41

L = slope length factor

S = slope gradient factor

C = cropping management factor, 0.001 = C = 0.99

P = erosion control practice factor, 0.10 = P = 1.0

Sediment basins shall be cleaned out when the capacity as described above is reduced by sedimentation to 60% full, except in no case shall the sediment level by permitted to build up higher than one (1) foot below the principal spillway crest. At this elevation, cleanout shall be performed to restore the original design volume to the sediment basin. The elevation corresponding to the maximum allowable level shall be determined and shall be stated in the design data as a distance below the top of the riser and shall be clearly marked on the riser.

The basin dimensions necessary to obtain the required basin volume as stated above shall be clearly shown on the plans to facilitate plan review, construction, and inspection.

The Sediment Basin Plan shall indicate the method(s) of disposing of the sediment removed from the basin. The sediment shall be placed in such a manner that it will not erode from the site. The sediment shall not be deposited downstream from the basin or adjacent to a stream or floodplain.

The sediment basin plans shall also show the method of disposing of the sediment basin after the drainage area is stabilized, and shall include the stabilizing of the sediment basin site. Water lying over the trapped sediment shall be removed from the basin by pumping, cutting the top of the riser, or other appropriate methods prior to removing or breaching the embankment. Sediment shall not be allowed to flush into the stream or drainageway.

D. Entrance of Runoff into Basin

Points of entrance of surface runoff into excavated sediment basins shall be protected to prevent erosion. Diversions, grade stabilization structures or other water control devices shall be installed as necessary to ensure direction of runoff and protect points of entry into the basin.

E. Principal Spillways

A pipe spillway is recommended on all basins. The pipe spillway shall consist of a vertical pipe riser or box riser joined to a conduit which will extend through the embankment and outlet below the downstream toe of the fill.

The pipe spillway shall be proportioned to convey not less than 0.2 cfs per acre of drainage area without causing flow through the emergency spillway. The minimum size pipe shall be 4 inches in diameter. The vertical pipe riser or box riser shall have a cross-sectional area at least 1.5 times that of the pipe.

One anti-seep collar shall be installed around the pipe when any of the following condition exist:

1. The settled height of the dam exceeds 15 feet;

2. the conduit is of smooth pipe larger than 8 inches in diameter; or,

3. the conduit is of corrugated metal pipe larger than 12 inches in diameter.

The anti-seep collars and their connection to the pipe shall be watertight. Protection against scour at the discharge end of the spillway shall be provided. Trash racks shall be installed where needed.

F. Earth Emergency Spillways

All debris basins shall have an earth emergency spillway unless the peak flow from the major storm is carried through a pipe spillway or other mechanical spillway. The earth spillway shall be excavated in undisturbed earth or compacted fill. The spillway shall be designed to be stable for the major storm flow.

Peak discharges for design of the emergency spillway shall be computed using an accepted method and shall be based on the soil and anticipated cover conditions in the drainage area during the expected life of the structure.

The crest of the emergency spillway shall be at least 0.5 feet above the crest of the principal spillway. For debris basins, the combined capacities of pipe and emergency spillways shall be sufficient to convey the peak discharge from the major storm. The top of a dam for all debris basins shall be at least 0.5 feet higher than the stage reached by the major storm.

The crest elevation of the emergency spillway will be determined by the head required on the principal spillway. The minimum top width shall be as per Table 9-4.

TABLE 9-4 Minimum Top Width Embankment (Earth Fill)

Height of Dam	Top Width
10 feet or less	6 feet
10-14	8 feet
14-20	9 feet

Source: Soil Conservation Services Erosion and Sediment Control Guidelines for Developing Areas in Texas.[4]

G. Safety

Sediment basins are attractive to children and can be very dangerous. Therefore they shall be fenced or otherwise secured unless this is deemed unnecessary due to the remoteness of the site or other circumstances. In any case, local ordinances and regulations regarding health and safety must be adhered to.

9. 2.4.5 Diversion

Definition

A drainageway of parabolic or trapezoidal cross section that is constructed across the slope, perpendicular to the direction of flow. The drainageway should be equipped with a supporting ridge on the lower side.

Purpose

The purpose of a diversion is to intercept and convey runoff to stable outlets at non-erosive velocities. Temporary diversions are installed as an interior measure to facilitate some phase of construction and usually have a life expectancy of 1 year or less. A permanent diversion is an integral part of an overall water disposal system and remains for protection of property.

Application

Diversions are used where:

A. Runoff from higher areas is or has potential for damaging properties causing erosion or interfering or preventing the establishment of vegetation on lower areas.

B. Surface and shallow subsurface flow caused by seepage is damaging sloping upland.

C. The length of slopes need to be reduced so that soil loss will be kept to a minimum.

D. Required as a part of a pollution abatement system.

E. To control erosion and runoff on urban or developing areas and construction sites.

Design Criteria

The design procedures for trapezoidal channels are provided in Section 6 of the City of Temple Drainage Criteria and Design Manual.

A. Location
Diversion location shall be determined by considering outlet conditions, topography, land use, soil type, length of slope, and the layout of the proposed development. Avoid locations in or immediately below unstable or highly erosive soils, unless special treatment or stabilization measures are previously applied.

B. Capacity

Peak runoff values used in determining the capacity requirements shall be determined as outlined in Section 2 of the City of Temple Drainage Criteria and Design Manual. The minimum design 24-hour storm frequencies and freeboard shall comply with criteria in Table 9-5.

Diversions designed to protect urban area, buildings and roads, and those designed to function in connection with other structures, shall have enough capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved.

TABLE 9-5 Diversion Frequency and Freeboard

Diversion Type	Typical Areas of Protection	Design Frequency (Years)	Freeboard Required (Feet)
Temporary	Construction roads; land areas, etc.	2	0.0
	Building Sites	5	0.0
Permanent	Land areas; playfields, recreation areas, etc.	25	0.3
	Homes, schools, industrial bldg., etc.	50	0.5

Source: Soil Conservation Service, Erosion and Sediment Control Guidelines for Developing Areas in Texas.[4]

C. Velocity and Grade

Channel grades may be uniform or variable. Maximum permissible velocities of flow for the stated conditions of stabilization are shown in Tables 9-6 and 9-7.

TABLE 9-6 Selection of Vegetal Retardance

Average Length of Vegetation (inches)	Retardance	
	Good Stand	Fair Stand
11-24	B	C
6-10	C	D
2-6	D	D

Source: Soil Conservation Service, Erosion and Sediment Control Guidelines for Developing Areas in Texas.[4]

TABLE 9-7 Permissible Velocities

		Permissible Velocity (fps)			
Soil Texture	Bare Channel	Channel Vegetation			
		Retardance	Poor	Fair	Good
Sand, silt		B		3.0	4.0
Sandy loam	1.5	C	1.5	2.5	3.5
Silty loam		D		2.0	3.0
Silty clay loam		B		4.0	5.0
Sandy clay loam	2.0	C	2.5	3.5	4.5
		D		3.0	4.0
Clay		B		5.0	6.0
	2.5	C	3.0	4.5	5.5
		D		4.0	5.0

Source: Soil Conservation Service, Erosion and Sediment Control Guidelines for Developing Areas in Texas.[4]

D. Cross Section

The channel may be parabolic, V-shaped or trapezoidal in shape. The diversion is to be designed to have stable side slopes. The side slopes for permanent diversions should not be steeper than 3H:1V for maintenance purposes and preferably 4H:1V. The back slope of the ridge is not to be steeper than 3H:1V and preferably 4H:1V. In determining the cross section on temporary diversions, consideration should be given to soil type, frequency and type of equipment that is anticipated to be crossing the diversion. In no case should side slopes be steeper than 1H:1V.

E. Outlets

Each diversion must have an adequate outlet. The outlet may be a grassed waterway, vegetated or paved area, grade stabilization structure, stable watercourse, or tile outlet. In all cases the outlet must convey runoff to a point where outflow will not cause damage. Vegetative outlets shall be installed prior to, and have vegetation established before diversion construction.

Underground outlets consist of an inlet and underground conduit, and the release rate when combined with storage is to be such that the design storms will not encroach on the design freeboard of the diversion ridge.

All areas where vegetation has been disturbed during construction and all other earth construction where vegetation is included in design, shall be seeded following completion of construction.

9. 2.4.6 Grassed Waterway or Outlet

Definition

A natural or man-made drainageway or parabolic or trapezoidal cross section that is below adjacent ground level and is stabilized by suitable vegetation for the safe disposal of runoff or water.

Purpose

The purpose of a grassed waterway or outlet is to convey runoff from terraces, diversions, or from natural concentrations without causing damage from erosion or flooding.

Application

Grass waterways and outlets are used on sites where added capacity or vegetative protection, or both, are required to control erosion resulting from concentrated runoff. In short reaches of the grassed waterways or outlet where vegetation is not suitable for non-erosive disposal of runoff, other linings may be used to control erosion.

Grassed waterways are used where added channel capacity or stabilization is required to control erosion resulting from concentrated runoff and where such control can be achieved by this practice along or in combination with others.

Design Criteria

A. Compliance with Laws and Regulations

Planning and construction shall be in compliance with state and local laws and regulations. Such compliance is the responsibility of the landowner or developer.

B. Capacity

The minimum capacity is to be that required as stated in Section 6 of the City of Temple Drainage Criteria and Design Manual for open channels. Channel dimensions may be determined from Section 6.

C. Velocity

The design velocity is to be based upon soil, duration of flow, and type and quantity of vegetation. The maximum design velocity should be 4.0 feet per second for vegetation established by seeding and 6.0 feet per second for that established by sodding.

D. Cross Section

The cross section may be parabolic, trapezoidal, or triangular in shape. The bottom width of trapezoidal waterways or outlets shall not exceed 100 feet unless multiple or divided waterways are provided to control meandering of low flows.

The minimum depth of a waterway receiving water from diversions or tributary channels is to be that required to keep the design water surface in the waterway or outlet at or below the design water surface elevation in the diversion or other tributary channel at their junction. To provide for loss in channel capacity due to vegetal matter accumulation, sedimentation, and normal seedbed preparation, the channel depth and width should be increased proportionally to maintain the hydraulic properties of the waterway. In parabolic channels, this may be accomplished by adding 0.3 foot to the depth and 2 feet to the top width of the channel. This is not required on waterways located in natural watercourses.

Where a paved bottom is used in combination with vegetated side slopes, the paved section is to be designed to handle the base flow or runoff from a one-year frequency storm, whichever is greater. The flow depth of the paved section shall be a minimum of 0.5 foot.

E. Outlets

Each waterway shall have a stable outlet. The outlet may be another waterway, a stabilized open channel, or a grade stabilization structure.

In all cases, the outlet must discharge in such a manner as not to cause erosion. Outlets shall be constructed and stabilized prior to the operation of the waterway.

F. Drainage

In areas with high water table, seepage problems or prolonged low flows, the designer shall provide for a subsurface drain, lined pilot channel, or other subsurface drainage methods. An open joint storm drain or lined pilot channel may be used to serve the same purpose and also handle frequently occurring storm runoff, base flow, or prolonged flow. The storm drain should be designed to handle base flow or the runoff from a one-year frequency storm, whichever is greater.

9. 2.4.7 Lined Waterway or Outlet

Definition

A waterway or outlet with an erosion resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to designed depth. The earth above the permanent lining may be vegetated or otherwise protected.

Purpose

The purpose of a lined waterway or outlet is to provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, in situations where lined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.

Application

This practice applies where the following or similar conditions exist.

A. Concentrated runoff is such that lining is required to control erosion.

B. Steep grades, wetness due to prolonged base flow, seepage, or piping would cause erosion.

C. The location is such that damage from use by people or animals preclude use of vegetated waterways or outlets.

D. High value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.

E. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

Design Criteria

A. Capacity

The minimum capacity shall be adequate to carry the peak rate of runoff. Capacity shall be computed using Manning's formula.

B. Velocity

Maximum design velocity shall be as stated in Section 6.0 for the appropriate channel type. Velocities exceeding critical velocity will be restricted to straight reaches. Waterways or outlets with velocities exceeding critical velocity shall discharge into an energy dissipator to reduce velocity to less than critical.

C. Cross Section

The cross section shall be triangular, parabolic, or trapezoidal. Monolithic concrete may be rectangular.

D. Freeboard

The minimum freeboard for lined waterways shall be as stated in Section 6 for the appropriate channel type.

E. Side Slopes

Steepest permissible side slopes shall be according to Table 9-8.

TABLE 9-8 Permissible Side Slopes for Lined Waterway

Non-Reinforced Concrete	Permissible Side Slope
Hand-placed, formed concrete:	
Height of lining 1.5 feet or less	Vertical
Hand-placed, screened concrete or in-place mortared flagstone:	
Height of lining less than 2 feet	1H:1V
Height of lining more than 2 feet	2H:1V
Slip form concrete:	
Height of lining less than 3 feet	1H:1V
Rock Riprap	2H:1V

F. Lining Thickness

Minimum lining thickness shall be as follows:

Concrete - 4 inches

Rock riprap - maximum stone size plus thickness of filter or bedding

Flagstone - 4 inches including mortar bed

G. Filters or Bedding

Filters or bedding are utilized to prevent piping. Drains shall be used to reduce uplift pressure, and to collect water as required. Filters, bedding, and drains shall be designed in accordance with Soil Conservation Service Standards. Weep holes and drains will be provided as needed.

H. Concrete

Concrete used for lining shall be so proportioned that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product will be required.

9. 2.4.8 Riprap

Definition

A layer of loose rock or aggregate placed over an erodible soil surface.

Purpose

The purpose of riprap is to protect the soil surface from the erosive forces of water.

Application

This practice applies to soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover, and groundwater conditions are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at such places as storm drain outlets, channel banks and/or bottoms, roadside ditches, drop structures, and shorelines. Broken concrete is not suitable as riprap.

Design Criteria

The minimum design discharge for channels and ditches shall be the peak discharge. See Section 6 of the City of Temple Drainage Criteria and Design Manual for further design criteria.

9. 2.5 Standards For Vegetative Practices For Critical Area Stabilization

Definition
Critical area stabilization is planting short-term vegetation on critical areas.

Purpose
The purpose of critical area planting is to stabilize the soil, reduce damage from sediment and runoff to downstream areas, improve wildlife habitat, and enhance beauty of the area.

Application
Critical area stabilization is used on sediment-producing, highly erodible or severely eroded areas, such as dikes, levees, cuts, fills, and denuded or gullied areas where vegetation is difficult to establish with usual seeding or planting methods.

Design Criteria

A. Site Preparation

1. If necessary, divert outside water away from the critical area. This may require a permanent diversion, or in other instances, a temporary measure that will be effective during the period of establishment.

2. Where practical, grade to permit use of conventional equipment for seedbed preparation, seeding, mulch application and anchoring. (Cabling of equipment may be necessary on steep slopes.)

3. On construction sites where the exposed and underlying soil material will not maintain adequate vegetation, a topsoil dressing of six (6) inches will be applied as part of construction.

4. Where slopes must be steeper than 2H:1V use some means other than vegetation to stabilize the slope.

B. Seedbed Preparation

1. The seedbed, immediately before seeding, shall be firm but not so compact as to prohibit covering the seed. Tillage implements shall be used as necessary to provide approximately a three (3) inch depth of firm but friable soil that is free of large clods.

2. If fertilizer is to be applied, work this in during final seedbed preparation.

C. Fertilizing

1. Unless soil fertility is known to be adequate, refer to the City of Temple for appropriate fertilizer application rates.

D. Seeding

1. Method of Seeding

The proper amount of seed must be evenly distributed, placed at the proper depth (1" or less), and packed so that the seed is in contact with the soil. This may be done by one of the following methods.

a. Drilling

Drilling is the preferred method and should be used when possible. Drill must be equipped with seed hoppers that will properly meter out the kind of seed being planted. This may require a special drill for fluffy seeds. The drill should have double disk furrow openers with depth bands to obtain proper depth of placement. The drill should be equipped with packer wheels or the seeded area should be packed with a land roller immediately after drilling.

b. Broadcasting

This method is to be used only on areas that are inaccessible to a grass drill. The seeding rates shall be increased by one and one half (1-1/2) times when the seed is broadcasted. Seed must be evenly distributed. The seed must be covered and this can be done by light dicing, cultipacking, harrowing or raking by hand. If at all possible, the seeded area should then be packed.

c. Hydro-seeding

Where hydro-seeding equipment is used, seed, fertilizer, and wood-fiber mulch materials are mixed into a slurry with water. Care should be used to spread the mixture evenly and soon after the mixture is made. Keep the mixture well agitated when seeding.

E. Mulching

1. Where to Use

   Mulch is essential on critical areas and slopes greater than 3H:1V. Mulch should be used on all treated critical areas where the goal is to attain a grass stand as soon as possible and where there is danger of damaging erosion occurring during the period of establishment.

2. Material

   Mulch shall consist of clean cereal grain straw, grass hay, wood chips, long fibered wood cellulose or gravel.

3. Rate

   Mulch shall be applied uniformly at a rate of 3,000 pounds minimum to 4,000 pounds maximum per acre of hay or straw. For long fibered wood cellulose the rate will be 1,500 pounds minimum to 2,500 maximum per acre.

4. Anchoring

   a. Anchor mulch with a dull disk or other suitable machine. The operation should be across the slope. The mulch should be anchored a minimum of two inches in the soil and the disks spaced not more than 12 inches apart. Where it is impossible to use such a machine the mulch should be anchored by hand with a square point spade.

   b. In some cases, properly anchored mulch netting may be used to hold the mulch in place.

9. 2.6 Bibliography

1. Soil Conservation Service, US Department of Agriculture, Technical Release No. 51 Procedure for Computing Sheet and Rill Erosion on Project Areas, US Government Printing Office, Washington, D.C., September 1977.

2. Environmental Protection Agency, Storm Water Pollution Prevention for Construction Activities, April, 1992.

3. Pitt, Robert and Roger Bannermann, Management Alternatives for Urban Stormwater, EPA/et. al. Nonpoint Pollution Abatement Symposium, pp. TIIH 1 - TIIH 16, April 1985.

4. Soil Conservation Service, Erosion and Sediment Control Guidelines in Developing Areas in Texas, 1976.

5. Soil Conservation Service, Texas Engineering Handbook, Section 17, Erosion Control Practices.

9.3 POST CONSTRUCTION (PERMANENT) BEST MANAGEMENT PRACTICES

9. 3.1 Required Permanent BMPs. To preserve the existing natural resources in Temple and promote sustainable development, demonstration of compliance with the following permanent BMPs, where applicable, are required in the SWMP of all land disturbing activities.

9. 3.1.1 Site Layout.

Each SWMP is required to show the site layout as well as the placement of the selected BMPs.

9. 3.1.2 Creek Buffer Zone.

All property located on or adjacent to a natural, vegetated, earthen or grass lined creek, waterway, stream, or channel is hereby deemed to be within a creek buffer zone. When a property is located within a creek buffer zone, the developer, builder, or owner must comply with the techniques found within this manual.

9. 3.1.2a Establishment of Creek Buffer Zones

The city code establishes that all property located on or adjacent to a natural, vegetated, earthen or grass lined creek, waterway, stream, or channel is deemed to be within a creek buffer zone (CBZ); and shall comply with the DCDM and SWBMPM. For definitions of most terms used in this design criteria refer to the city code.

The following are four methods of establishing creek buffer zones (CBZ):

1. Method A - Property outside of FEMA Mapped Floodplain
2. Method B - Property located inside FEMA Zone AE
3. Method C - Property located inside FEMA Zone AE and Floodway
4. Method D - Property located inside FEMA Zone A

Method A – Property outside of FEMA Mapped Floodplain.

a. Includes all property located outside FEMA mapped flood plain.
b. Requirements:
   i. None,
   ii. Unless property is adjacent to or encompasses a crest of slope steeper than the ratio shown in Figure 1.

Method B – Property located inside FEMA Zone AE.

a. Includes all property located inside of FEMA Zone AE.

b. Requirements:
   i. Chapter 13 Flood Damage Prevention Ordinance applies,
   ii. Flood plain development permit required,
   iii. If encroachment into floodway is proposed see Zone C, and
   iv. If adjacent to or encompasses a crest of slope steeper than the ratio shown in Figure 1.

Method C – Property located inside FEMA Zone AE and Floodway.

a. Includes all property located inside of FEMA Zone AE and Floodway.
b. Requirements:
   i. Chapter 13 Flood Damage Prevention Ordinance applies,
   ii. Flood plain development permit required,
   iii. Engineering study required,
   iv. No rise certificate,
   v. Letter of map change required, and
   vi. If adjacent to or encompasses a crest of slope steeper than the ratio shown in Figure 1.

Method D – Property located inside FEMA Zone A.

a. Includes all property located inside of FEMA Zone A.
b. Requirements:
   i. Chapter 13 Flood Damage Prevention Ordinance applies,
   ii. Flood plain development permit required,
   iii. Engineering study required, and
   iv. If adjacent to or encompasses a crest of slope steeper than the ratio shown in Figure 1.

9. 3.1.2b Creek Buffer Zone Restrictions

a. <u>Occupied Structures</u>. No occupied structure shall be allowed in CBZ; unless engineered by a professional engineer and approved by the City, or existing at the time of passage of the ordinance.
b. <u>Private amenity structures or private amenities</u>. Property owners with private amenity structures or private amenities assume responsibility for all risks associated with erosion, including but not limited to full replacement cost if loss or damage occurs due to active erosion. City assumes no responsibility for loss or damage to private amenities or private amenity structures that may occur from creek erosion.

9. 3.1.2c Design Standards for Creek Buffer Zones

Creek Buffer Zones must be designed and designated by the requirements and standards found in the city code and this manual.

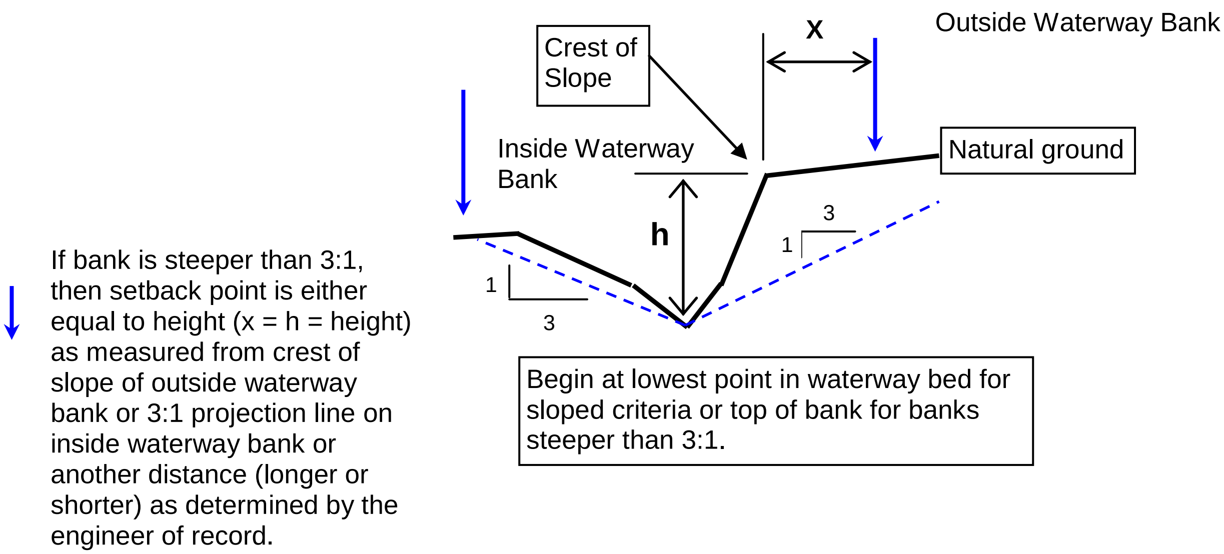
9. 3.1.2d Creek Buffer Zone Designation Requirements

a. Preliminary plats, final plats, plans, construction and building permit applications must clearly show the limits of creek buffer zones based on criteria in this chapter.
b. The limits must be indicated by dashed lines and labeled “Creek Buffer Zone.”
c. Creek Buffer Zone designation may be combined with other lines in cases where erosion hazard zone lines coincide with flood plain limits or other public utility easements, such as drainage easements.
d. Properties next to natural or constructed channels with a minimum of the ratio found in Figure1 or flatter side slopes are not required to comply with these erosion hazard zone criteria unless, in the opinion of a licensed professional engineer, erosion hazard zone delineation is warranted. Creek Buffer Zones may not apply to waterways that have been engineered to convey a 1% chance storm (100-year frequency storm) and to withstand erosive forces or that have been adequately stabilized by manmade construction materials such as concrete rip-rap and concrete retaining walls. Wood timbers ties shall not be considered to adequately stabilize waterways due to their relatively short life span of service.

9. 3.1.2e Licensed Professional Engineer’s Responsibilities

a. It is the licensed professional engineer’s responsibility to adhere to these criteria when preparing preliminary plats, plans or building permit applications.
b. The licensed professional engineer shall recognize these criteria as the minimum standards such that unique or site specific geological, topographical, or other factors may require detailed study during design. Adjustments from these minimum standards are allowed based on the findings from engineering analysis and engineering judgment.
c. It is the licensed professional engineer’s responsibility for determining and providing creek buffer zones delineation on preliminary plats, final plats, plans, construction and building permit applications based on engineering judgment and best practices.

Figure 1. Creek Buffer Zone Design Standard



9.3.2 Required Permanent BMP Credit Point Requirements. In addition to the required BMPs, the following number of BMPs shall be provided based on the size of the project:

Table 9-9: Additional BMP Requirements

Non-Residential	
	Number of additional BMP Credits required
1 acre ≤ Disturbed Area < 5 acres	1
5 acres ≤ Disturbed Area < 10 acres	2
10 acres ≤ Disturbed Area < 20 acres	3
≥ 20 acres	4

Residential	
	Number of additional BMP Credits required
1 acre ≤ Disturbed Area < 5 acres	1
5 acres ≤ Disturbed Area < 20 acres	2
≥ 20 acres	3

Table 9-10 lists additional BMPs, basic requirements and the associated credits received for application of each BMP.

Table 9-10 - Best Management Practices Design Criteria

BMP	Requirements	BMP Credits	Relative Cost
Site Layout	**Required with each Storm Water Management Plan per ordinance.**	**Required**	
Creek Buffer Zone	**Required with each development adjacent to natural creek, waterway, channel per ordinance.**	**Required - where applicable**	
Additional BMPs	**Required to meet based on land disturbance area per ordiance.**		
1. Vegetated Swales	100' Min. Length; trapezoidal section 0.5% Min. Channel Slope, 2.5% Max. Channel Slope; maximum 2 fps for 2-yr storm Max. 3:1 Side Slopes 80% Min. Vegetative Cover	1	$
2. Vegetated Filter Strips	20' Min. Width, 72' Roadway Max. Width 20% Max. Slopes 1 ft/sec max. flow velocity for 1-year storm 80% Min. Vegetative Cover Min. 6" grass height	1	$
3. Permeable & Semi-Pervious Pavement	Max. drainage area 50 acres Vegetative buffers or sediment traps around edges to prevent clogging of pavement pores Locate away from heavy traffic areas	1	$$$
4. Roof Drain Discharge to Pervious Surface	Discharge to Vegetated Swale, Vegetated Filter Strip or retention facility	1	$$
5. Extended Detention Basins	Oversize volume by 20% to account for sed. or first 1/2" of runoff, whichever less Ratio of flowpath length to width min. 2:1 (L:W) Optimal depth 2 to 5 feet No more than 50% drawdown within first 24 hours Complete drawdown within 48 hours Treats up to 25-year storm event with ability to pass 100-year storm event	3	$$$$
6. Retention Ponds	Pond volume sufficient to capture & hold the design runoff Max. 3:1 Side Slopes Bypass structure capable of passing 100-year storm Empty Pond within 72 hours (infiltration, irrigation, or evapo-transpiration Rock riprap at inlet to pond 15' public access easement around pond Min. 1 access point into pond with max. 5:1 slope Remove sediment from pond once accumulation reaches 6-inches	3	$$$$
7. Detention Pond Outlet for Erosion Protection and Storm Water Quality Benefits	post-dev flows < pre-dev flows for the 1, 2, 5, 10 & 100 Yr Storm Events Complete drawdown within 72 hours	1	$$

Table 9-10 - Best Management Practices Design Criteria

BMP	Requirements	BMP Credits	Relative Cost
Site Layout	**Required with each Storm Water Management Plan per ordinance.**	**Required**	
Creek Buffer Zone	**Required with each development adjacent to natural creek, waterway, channel per ordinance.**	**Required - where applicable**	
8. Subsurface Treatment Devices	HS-20 Structural Design Treat 75-90% Annual rainfall runoff Remove 50-80% TSS Remove 90% floatable free oil Perform maintenance when stored volume reaches 15% of total capacity	2	$$
9. Landscaping	Document plant species to be used and maintenance schedule Details of maintenance schedule including amount, types and frequency of chemical use Must demonstrate impervious cover runoff interception and water quality treatment benefit	1	$$
10. Cluster Design	Reserve 12.5%-25.49% of available land on parcel as conservation area Reserve 25.5%-32.49% of available land on parcel as conservation area Reserve >32.5% of available land on parcel as conservation area	1 2 3	$$$
11. Preservation of Existing Tree Canopy	Min. Tree Height 6', Min. Caliper 2" (new trees), 4" (existing trees) Existing or new tree canopy shall be no greater than 25' from impervious ground surfaces to receive credit 25%-49.9% of existing canopy covering 50% or more of site 50%-65% of existing canopy covering 50% or more of site >66% of existing canopy covering 50% or more of site	1 1 2 3	$$
12. Other BMPs	Consider: bioretention, low impact development techniques, floatable exclusion systems, etc	TBD	Varies

9.3.3 Additional BMPs. The following items are acceptable permanent BMPs to be utilized when meeting the requirements of Table 1 and Table 2 based on the size of the land disturbing activity and complying with DCDM and this manual.

1. Vegetated swales.
2. Vegetated filter strips.
3. Permeable and semi-pervious pavement.
4. Discharge of roof drains to pervious surface.
5. Extended detention basins for storm water quality benefits.
6. Retention ponds.
7. Detention pond outlet for erosion protection and storm water quality benefits.
8. Subsurface treatment devices.
9. Landscaping.
10. Cluster design.
11. Preservation of existing tree canopy.
12. Other BMPs. Other BMPs and innovative designs will be considered when submitted to the City Engineer with supporting calculations and references.

9.3.3.1 Vegetated Swales.

Definition

Vegetated swales are sloped, vegetated channels or ditches that provide both conveyance and water quality treatment of storm water runoff.

Design Criteria

Vegetated swales shall be designed to have a hydraulic residence time of at least five (5) minutes for the storm flow to be treated. Below are additional design parameters which must be followed for the development of vegetated swales.

1. Minimum bottom width = 6-feet
2. Maximum bottom width = 10-feet
3. Minimum channel slope = 0.5%
4. Maximum channel slope = 2.5%
5. Maximum side slope = 3H:1V
6. Minimum vegetative cover = 80%
7. Minimum swale length = Channel velocity (ft/s) x 300 (s)

The channel velocity is calculated by dividing the peak flow rate from a storm producing a constant rainfall rate of 1.1-inch/hour by the cross-sectional area of the swale. The depth of flow in the swale shall not exceed 4-inches in a 1.1-inch/hour storm. Trapezoidal shapes are generally used for channel cross-sections, although the geometry of the channel is not critical as long as a broad, relatively flat bottom is provided. Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, pavement should be placed slightly above the elevation of the vegetated areas and curb cuts should be at least 12-inches wide to prevent clogging.

Maintenance

Maintenance requirements typically include activities such as irrigation, mowing, trimming, removal of invasive species, and replanting when necessary.

9.3.3.2 Vegetated Filter Strips.

Definition

Filter strips may be natural or engineered. The use of natural filter strips is limited to perimeter lots and other areas that will not drain by gravity to other BMPs on the site.

Design Criteria

Natural filter strips should extend along the entire length of the contributing area. The slope should not exceed 10%. The minimum dimension in the direction of flow for natural filter strips should be 50-feet. All of the filter strip should lie above the elevation of the 2-year, 3-hour storm of any adjacent drainage. There is no requirement for vegetation density or type.

Engineered filter strips incorporate many of the general criteria of swale design. Vegetated roadside shoulders provide one of the best opportunities for incorporating filter strips into roadway and highway design. The design goal is to produce uniform, shallow overland flow across the entire filter strip. Landscaping on residential lots is not considered to function as a vegetated filter strip because fertilizers and pesticides are commonly applied in these areas. Below is additional design criteria for engineered filter strips.

1. Maximum width in the direction of flow of the contributing impervious area = 72-feet
2. Minimum length of the filter strip in the direction of flow = 15-feet
3. Maximum slope = 20%
4. Minimum vegetative cover = 80%

The area contributing runoff to a filter strip should be relatively flat so that the runoff is distributed evenly to the vegetated area without the use of a level spreader. The area to be used for the strip should be free of gullies or rills that can concentrate overland flow. The top edge of the filter strip should be slightly lower than the pavement surface to ensure drainage off the pavement to the filter strip. Filter strips should be established after other portions of the project are completed.

Maintenance

Maintenance requirements typically include activities such as irrigation, mowing, trimming, removal of invasive species, and replanting when necessary. The use of fertilizers and pesticides should be minimized.

9.3.3.3 Permeable and Semi-Pervious Pavement.

Definition

Permeable and Semi-Pervious Pavement can be either permeable concrete or porous asphalt. Permeable concrete consists of concrete that is made without the fine (sand) fraction. Porous asphalt, also known as pervious, permeable, "popcorn", or open graded asphalt, is standard hot-mix asphalt with reduced sand or fines and allows water to drain through it. Modular pavement blocks are an alternative to permeable concrete and porous asphalt.

Design Criteria

In permeable concrete, eliminating the sand portion of the mix design increases the permeability, but greatly reduces the strength. Additives may be applied to the mix design to increase strength to a level that is comparable to a standard concrete mix. The lack of sand also shortens the setup time for concrete which makes it difficult to get a consistent texture. Use of permeable concrete should be done only with highly detailed specifications and an experienced contractor to minimize potential problems.

Permeable pavement is not meant to treat runoff from other areas, so the placement of permeable pavement should be such that it does not receive any runoff other than what falls directly on the surface of the paved areas. Parking lots constructed with permeable pavement should utilize curbs which are configured in such a way as to store the required rainfall treatment depth (1.64-inches for a 1.1 inch/hour storm) on the surface of the parking lot in case the pavement becomes plugged. When permeable concrete is used for sidewalks or residential driveways, no edging is required. In no case should runoff from other portions of the tract, including roofs and landscaped areas, be allowed to run onto the permeable surface.

There are two possible configurations of permeable pavement: with and without an underdrain. Systems constructed with an underdrain should include a layer of sand to filter the stormwater prior to surface discharge. This type of system does not require an impermeable liner. Permeable pavement systems without an underdrain treat stormwater runoff via filtration with an appropriate soil layer located beneath the pavement.

Porous asphalt over an aggregate storage bed will reduce storm water runoff volume, rate and pollutants. When properly constructed, porous asphalt is a durable and cost competitive alternative to conventional asphalt.

Porous asphalt comprises the surface layer of the permeable pavement structure and consists of open-graded coarse aggregate, bonded together by bituminous asphalt. A typical reduced fines mix is shown in Table 9-11.

Table 9-11: Asphalt Mix (Adams, 2003)	
Sieve Size	% Passing
½ in.	100
$^3/_8$ in.	95
#4	35
#8	15
#16	10
#30	2
Percent bituminous asphalt 5.75-6.0% by weight	

Polymers can also be added to the mix to increase strength for heavy load applications. The thickness of porous asphalt ranges from 2 to 4 inches depending on the expected traffic loads. The porous asphalt should have a minimum of 16% air voids.

Modular pavement comes in pre-formed modular pavers of brick and concrete. When the brick or concrete is laid on a permeable base, water will be allowed to infiltrate. Typically, the permeable base consists of 4”-6” of crushed stone beneath 2” of sand. Grass can be planted between the pavers, allowing structural support in infrequently used parking areas. Apply in low-volume parking lots and roads, and in high activity recreational areas like basketball and tennis courts or playground lots.

The area that can be served by permeable or semi-pervious pavement is generally limited to 0.25 to 10.0 acres and generally serves only a small section of the watershed. This BMP can also accept rooftop and adjacent parking lot runoff.

Maintenance

Maintenance requirements for permeable concrete and porous asphalt include sweeping with a vacuum type street sweeper at least twice per year to remove surface accumulations of sediment and other material. Pressure washing may also prove to be effective if the resulting water is immediately vacuumed from the surface. For modular pavements, routine mowing and irrigation of the grass is required. Any accumulated silt/debris should be removed as necessary.

9.3.3.4 Discharge of Roof Drains to Pervious Surface.

Definition

Roof drains which are set up to discharge to a pervious surface can both reduce the overall amount of runoff as well as increase the time of concentration of runoff that does remain on the surface.

Design Criteria

Gravel, crushed stone, modular paving blocks or pervious paving blocks can be used in addition to vegetated or landscaped areas as surfaces in which to direct flow from roof drains. Gravel or crushed stone should be placed to a thickness of 4”-6”. The area of pervious surface should be at least equal to the drainage area of the roof drain (i.e. the area of the roof top which is served by the roof drain). The slope of the pervious surface shall not exceed 5% in any direction.

Maintenance

The pervious surface should be inspected regularly after rain events for accumulation of sediment/debris. Any accumulations should be promptly removed. If modular pavements are used for the pervious surface, maintenance of the grass shall include regular irrigation and mowing as needed.

9.3.3.5 Extended Detention Basins for Storm Water Quality Benefits.

Definition

Extended detention facilities are ponds that capture and temporarily detain the water quality volume as well as reduce maximum runoff rates. They are intended to serve primarily as settling basins for the solids fraction and as a means of limiting downstream erosion by controlling peak flow rates during erosive events.

Design Criteria

Extended detention facilities may be constructed either online or offline. They are generally best suited to drainage areas greater than 5 acres, since the outlet orifice becomes prone to clogging for small water quality volumes. In addition, extended detention basins tend to accumulate debris deposits rapidly, making regular maintenance necessary to minimize aesthetic and performance problems. They can be combined with flood and erosion control detention facilities by providing additional storage above the water quality volume.

The facility should be sized to remove 80% of the increase in total suspended solids loading resulting from development plus a 20% increase to accommodate reductions in the available storage volume due to deposition of solids in the time between full-scale maintenance activities. A fixed vertical sediment depth marker should be installed in the basin to indicate when sediment accumulation equals 20% of the water quality volume and sediment removal is required.

The basin should be configured such that the flowpath is maximized between the entrance points and the outlets. The ratio of flowpath length to width from the inlet to the outlet should be at least 2:1 (L:W). The flowpath length is defined as the distance from the inlet to the outlet as measured at the surface. The width is defined as the mean width of the basin. Basin depths optimally range from 2 to 5 feet. The basin should include a sediment forebay to provide the opportunity for larger particles to settle out. The forebay volume should be about 10% of the water quality volume and be provided with a fixed vertical sediment depth marker to measure sediment accumulation.

Both conventional and enhanced extended detention should be designed with a dual stage configuration. Stage 1 is intended to serve primarily as a sediment forebay for larger particulates. Stage 2 is generally planted with vegetation adaptable to periodic inundation and may contain a permanent micropool for enhanced extended detention. The design depth of Stage 1 should range from 2 to 5 feet. A stabilized low flow channel is required to convey low flows through Stage 1 to Stage 2. Rock riprap should be utilized to reduce velocities and spread the flow into the Stage 2 pond. The channel should maintain a longitudinal slope of 2-5%. The lateral slope across Stage 1 toward the low flow channel should be 1.0-1.5%. The bottom of Stage 2 should be 1.5 to 3.0-feet lower than the bottom of Stage 1. The extended detention basin is optimally designed to have a gradual expansion from the inlet toward the middle of the facility and a gradual contraction toward the basin outfall.

The side slopes of the pond should be 3:1 (H:V) or flatter for grass slopes. Energy dissipation is required at the basin inlet to reduce resuspension of accumulated sediment. For the outflow structure, a reverse slope outflow pipe design is preferred if a second stage micropool is provided in the facility. Otherwise, the facility’s drawdown time should be regulated by a gate valve or orifice plate located downstream of the primary outflow opening. The outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes.

The outflow structure should be sized to allow for complete drawdown of the water quality volume in 48 hours. No more than 50% of the water quality volume should drain from the facility within the first 24 hours. A valve or orifice can be used to regulate the rate of discharge from the basin.

The facility should have a separate drain pipe with a manual valve that can completely or partially drain the pond for maintenance purposes. To allow for possible sediment accumulation, the submerged end of the pipe should be protected, and the drain pipe should be sized one pipe schedule higher than the calculated diameter needed to drain the pond within 24 hours. The valves should be located at a point where they can be operated in a safe and convenient manner. For online facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard and pass the flow from the 100-year storm.

The facility should be planted and maintained to provide for a full and robust vegetative cover. The following wet tolerant species are recommended for planting within the bottom stage (LCRA, 1998):

- Bushy Bluestem
- Sedges
- Cyperus
- Switch Grass
- Spike Rush
- Green Sprangletop
- Indian Grass
- Bullrush
- Scouring Rush
- Eastern Gamma
- Dropseed Iris

A plan should be provided indicating how aquatic and terrestrial areas will be stabilized. A minimum 25-foot vegetative buffer area should extend away from the top slope of the pond in all directions. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.

When the pond is designed as an offline facility, a splitter structure is used to isolate the water quality volume. The splitter box, or other flow diverting approach, should be designed to convey the 25-year storm event while providing at least 1.0 foot of freeboard along pond side slopes.

For online facilities, special consideration should be given to the facility's outfall location. Flared pipe end sections that discharge at or near the stream invert are preferred. The channel immediately below the pond outfall should be modified to conform to natural dimensions, and lined with large stone riprap placed over filter cloth. A stilling basin may be required to reduce flow velocities from the primary spillway to non-erosive velocities.

Maintenance

Maintenance requirements for extended detention basins should include mowing at least twice annually. Vegetation should be mowed so as to limit maximum height to 18-inches. During mowing operations, debris and litter should be removed from the site. After significant rain events, the facility should be inspected and any areas of erosion should be repaired and revegetated. Similarly, any accumulations of sediment should be removed after significant rain events.

9.3.3.6 Retention Ponds.

Definition

Retention ponds are basins which capture and dispose of storm water runoff without directly releasing the captured flow into receiving streams.

Design Criteria

Capture of storm water in retention ponds can consist of virtually any kind of runoff facility ranging from a fully dry, concrete-lined to vegetated with a permanent pool. This flexibility allows for excellent aesthetic appeal. Retention ponds should have a pump and wet well system that is automated with a rainfall or soil moisture sensor to allow for irrigation only during periods when required infiltration rates can be realized.

Storage volume can be flexible as long as an appropriate pump and wet well system can be accommodated. The water quality volume should be increased by 20% to accommodate reductions in the available storage volume due to deposition of solids in the time between full-scale maintenance activities.

A reliable pump, wet well, and rainfall or soil moisture sensor system should be used to distribute the water quality volume. A pump capable of delivering 100% of the design capacity should be provided. Valves shall be located outside the wet well on the discharge side of each pump to isolate the pumps for maintenance and for throttling, if necessary. Pumps should be selected to operate within 20% of their best operating efficiency. A high/low-pressure pump shut off system should be installed in the pump discharge piping.

The pond should have an intake riser with a screen for stormwater to pass through prior to entering the wet well. This is to prevent clogging of distribution pipes and sprinklers by large debris.

The pond should be designed as an offline facility and a splitter box should also be included in the design of the pond to isolate the water quality volume. The splitter box should be designed to convey the 25-year storm event while providing at least 1.0 foot of freeboard along basin side slopes.

Detention time in the retention pond should allow for complete drawdown of the water quality volume within 72 hours. Irrigation should not begin within 12-hours of the end of rainfall so that direct storm runoff has ceased and soils are not saturated. Consequently, the length of the active irrigation period is 60 hours. The irrigation should include a cycling factor of ½, so that each portion of the area will be irrigated for only 30 hours during the total of 60 hours allowed for disposal of the water quality volume. Continuous application on any area should not exceed 2-hours. Division of the irrigation area into two or more sections such that irrigation occurs alternately in each section is an acceptable way to meet this requirement. Irrigation should not occur during subsequent rainfall events.

The irrigation site must be pervious and on slopes of less that 10%. A geological assessment is required for proposed irrigation areas to assure that there is a minimum of 12-inches of soil cover and no geologic/sensitive features that could allow the water to directly enter the aquifer. Rocky soils are acceptable for irrigation; however, the coarse material (diameter greater than 0.5-inches) should not account for more than 30% of the soil volume. Optimum sites for irrigation include recreational and greenbelt areas as well as landscaping in commercial developments. The irrigation area should also have at least a 100-foot buffer from wells, septic systems, natural wetlands, and streams.

The irrigation rate must be low enough so that the irrigation does not produce any surface runoff (i.e. the irrigation rate shall not exceed the permeability of the soil). The minimum required irrigation area should be calculated using the following formula:

$$A = (12xV) / (Txr)$$

Where:

A = area required for irrigation (ft^2)

V = water quality volume (ft^3)

T = period of active irrigation (30 hr)

r = permeability (in/hr)

The permeability of the soils in the area should be determined using a double ring infiltrometer (ASTM D 3385-94) or from county soil surveys prepared by the Natural Resource Conservation Commission (NRCS). If a range of permeabilities is reported, the average value should be used for the calculation. If no permeability data is available, a value of 0.1 in/hr shall be used.

Vegetation in irrigated areas should consist of native vegetation or re-established native vegetation species. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.

Maintenance

Maintenance requirements for retention ponds should include mowing at least twice annually. Vegetation should be mowed so as to limit maximum height to 18-inches. During mowing operations, debris and litter should be removed from the site. After significant rain events, the facility should be inspected and any areas of erosion should be repaired and revegetated. Similarly, any accumulations of sediment should be removed after significant rain events.

9.3.3.7 Detention Pond Outlet for Erosion Protection and Storm Water Quality Benefits.

Definition

Detention pond outlets for erosion protection and storm water quality benefits include features which aid in settling sediments and reducing the energy of storm water as it exits the detention pond.

Design Criteria

Riser pipe outlets, rock riprap and micropools are several examples of ways a detention pond can be improved to also provide storm water quality benefits.

Riser pipe outlets provide an opportunity for sediments to settle out prior to draining storm water out of the pond. Riser pipes can be sized to release pre-development flow for a given storm event or they can be sized to be used in conjunction with other elements for metering out flow such as culverts and weirs.

Rock riprap placed on the downstream side of the outlet structure has the dual effect of dissipating the energy of the storm water as it leaves the outlet structure and also providing a place for sediments to settle out. Rock riprap should be sized according to the flow and velocity out of the pond for the design storm.

A micropool is a relatively shallow and undrained area at the outlet which has the purpose of concentrating finer sediment and reducing re-suspension. The micropool is normally planted with hardy wetland species such as cattails. It can be facilitated by the use of a reversed slope outlet pipe.

Maintenance

Outlet components should be inspected after significant storm events. Any accumulations of sediment or debris should be removed. Frequency of sediment and debris removal will depend on the amount of sediment accumulation that is incorporated into the pond's design as well as the nature of storm events experienced by the detention pond. Riser pipes should be checked after every significant storm to remove any debris which may cause clogging of the risers.

9.3.3.8 Subsurface Treatment Devices.

Definition

Subsurface treatment devices capture storm water and treat it in an underground facility before releasing it into a storm sewer, drainage channel or natural conveyance. Two types of subsurface treatment devices include catch basins and oil/grit separators. Typically these devices are designed as inlet devices for storm sewers. Catch basins primarily trap coarse sediments and large debris while oil and grit separators have several different designs and different removal capabilities.

Design Criteria

Catch basins are chambers or sumps installed in a storm sewer, usually at the curb, which allow surface runoff to enter the sewer. The catch basin typically has a low area below the flowline of the outlet pipe where sediment is retained. The volume of the catch basin typically ranges from 0.5 to 1.5 cubic yards. The rate at which catch basins fill, and thus require maintenance, varies depending on surrounding land uses. Cleaning should be done on at least a semi-annual basis and more frequently for areas which generate more sediment in runoff, such as areas under construction. Catch basins should not be used as stand-alone treatment devices, but instead should be incorporated into a system which includes additional forms of treatment, including non-structural controls.

Oil and grit separators are inlet devices which separate oil and sediments from storm water. These devices have chambers designed to remove sediment and hydrocarbons from urban runoff. They are normally used in areas with heavy traffic or high potential for petroleum spills such as parking lots, gas stations, roads, and loading areas. There are three general types of separators. The simple spill control (SC) separator typically used with storm water detention facilities, is effective at retaining only small spills. Diluted oil droplets are not captured in this system. More sophisticated designs for high load situations include the American Petroleum Institute (API) and Coalescing Plate Interceptor (CPI) designs. The API design uses a basin with baffles to improve hydraulic conditions for settling solids and floating oil. The CPI design improves coalescing and settling by directing the runoff through closely positioned parallel plates set at an angle. Removal efficiencies of each design are similar, but the CPI separator uses 50% to 80% less space.

Oil and grit separators are restricted to small, highly impervious drainage areas of two acres or less, and must connect to a storm sewer. They should be considered as a primary BMP only when properly sized and combined with a program of frequent inspection and maintenance.

In order to provide at least moderate sediment, oil and grease pollutant removal, oil and grit separators should be of the API-type or CPI-type sized to capture 90-micron particles, or an equivalent. The separator should be an off-line design, capturing only the first flush of runoff and should not interfere with normal storm sewer function.

Maintenance

Each structure should be checked weekly and maintenance should be performed as necessary. Each structure should be cleaned out at least twice per year to maintain pollutant removal capabilities. Sediment should be cleaned out with a vacuum truck. Waste oil and residuals should be disposed in a manner consistent with TCEQ requirements.

9.3.3.9 Landscaping.

Definition

Landscaping as a permanent best management practice keeps landscapes visually attractive while conserving water resources, reducing pollution and protecting the environment.

Design Criteria

On slopes of more than 10%, biodegradable erosion control blankets shall be used for temporary slope protection. The erosion control blankets shall be coarse in nature so as to allow varying leaf sizes to penetrate through the blankets.

By using the proper plant selection, irrigation, fertilization, and maintenance techniques, urban landscapes can better coexist with the natural environment. The following is a list of landscaping techniques that should be followed for utilization as a best management practice.

1. Select plants that match the existing light conditions; they will grow better and require less water.
2. Match surface and soil drainage conditions to plant moisture requirements.
3. Select plants that grow well in the temperature ranges of the area.
4. Select plants that are regionally adapted to the average rainfall of the area.
5. Preserve established vegetation growing on a site where possible; it has an extensive root system and requires less irrigation water than newly planted trees and shrubs.
6. Space plants according to their mature size to reduce competition for water.
7. Concentrate seasonal color in small, high impact areas to reduce overall water requirements.
8. Avoid constructing raised beds under trees due to root competition for available water.
9. Develop a landscape plan BEFORE designing an irrigation system.
10. Incorporate shade trees into the landscape to reduce evaporative water loss.
11. Select and group plants according to their water needs and drought tolerance.
12. Divide the landscape into water-use zones.

13. Avoid small, irregular-shaped island plantings in turf grass areas because they are difficult to irrigate.
14. Consider irrigation sprinklers when designing turf grass areas and planting beds.
15. Move or eliminate plants not suited to the existing site conditions and irrigation.

Plant selection should be based on adaptability to the local region's soil and climate. Most native plants have lower water demands, fewer pest problems and less fertilizer needs than many non-adapted, exotic plants brought into the local landscape.

The use of turf in a landscape should be minimized because most turf requires substantially more water than planted beds. Strips of grass, such as those commonly used in parking islands between sidewalks and the roadway, should be eliminated to the greatest extent possible. These strips are difficult to maintain and water efficiently. Bushes, mulch, or permeable hardscape are preferable alternatives to grass in these strips.

Maintenance

Maintenance can be significantly reduced in a properly planned landscape, however, some maintenance is required with all landscapes. Prune shrubs and trees during winter months to promote blossoms and to remove dead or damaged branches, which could promote disease. Remove dead flowers prior to seed pod development. This promotes more flowers and reduces the potential for self-sown seedlings to over-run the landscape. Aeration of mulched beds and turf areas should be performed semi-annually to ensure that roots are healthy and that anaerobic areas do not develop in mulched beds. Mow turf areas frequently enough such that less than 1/3 of the blade area is removed in a single mowing. Mowing should also be done at the recommended height for each species. Turf should not be mowed when wet. Pest management includes selecting pest-resistant plants and spraying insects with organic pesticides, such as orange oil or BT bacteria. Only as a last resort should chemical pesticides or herbicides be used.

The primary benefit of BMP landscaping is savings in water usage. In order to sustain water savings, regular maintenance and evaluation of irrigation systems is required. Maintenance programs must include pre-irrigation season checks for leaks and irrigation uniformity. Timers should be adjusted monthly or run manually.

9.3.3.10 Cluster Design.

Definition

Cluster design is a form of low impact development which sets aside key natural features and concentrates development in tighter patterns on the remaining land. The principal goal of cluster design is to ensure maximum protection of the ecological integrity of the receiving water by maintaining the existing hydrologic regime. Cluster design also provides consolidated spaces to support wetland plants and wildlife. As a result, it provides natural amenities in terms of plant and animal diversity in close proximity to human habitation.

Cluster design techniques alone do not offer flood protection. Additional flood design criteria should be reviewed to ensure flood protection is provided. Some specific planning considerations include:

1. Minimizing environmental impacts and hydrologic changes.
2. Preserve adequate open space within the development site for bio-retention, and treatment of runoff from rooftops and other impervious surfaces.

Design Criteria

To reduce development impacts and preserve the predevelopment hydrologic conditions, the following could be used as general design guidelines.

1. Minimize land clearing that requires removal of the native vegetation.
2. Minimize or avoid mass grading and utilize selective clearing.
3. Reduce impervious surface area and minimize connected impervious surfaces.
4. Increase opportunity for on-site retention, detention, and treatment.
5. Maintain predevelopment hydrologic pattern.
6. Utilize native vegetation.
7. Utilize undisturbed existing vegetation buffer strips and areas.
8. Whenever site condition permits, utilize extensive use of swales, grass filter strips, and randomly place biofilters. Direct roof and landscape open area runoff to vegetated biofilter strips and swales.
9. Preserve soils and areas with high infiltration rate.
10. Grade the site to maximize the overland sheet flow distance.
11. Grade the site to maximize the overland sheet flow distance.
12. Increase flow-paths or travel distances for surface runoff.
13. Maintain existing time of concentration and minimize impact of the runoff coefficient number.
14. Utilize cisterns, rain barrels, bioretention areas, and created seasonal or permanent wetlands.
15. Provide adequate buffers between development and natural resources, critical areas and drainage ways.
16. Handle road runoff separate from roof top and landscape area runoff.
17. Integrate low-rise and high-rise buildings, town houses, in single-family residential to reduce land consumption.
18. Utilize high points and natural topography to guide plan layout.
19. Preserve undisturbed vegetated buffer around perimeter of development.

Maintenance

Maintenance requirements associated with cluster design are generally limited to the preservation of existing natural areas since cluster design is focused around the layout of a development rather than a specific type of BMP facility. Any additional BMPs which are utilized within a cluster design shall be maintained as prescribed for that specific BMP.

9.3.3.11 Preservation of Existing Tree Canopy.

Definition

Preservation of the existing tree canopy consists of individual trees or groupings of trees which are to be permanently protected. These areas may be protected in either a natural state or by selective removal of underbrush and/or trees at the time of development plan approval.

Design Criteria

Tree Canopy Protection Areas (TCPAs) shall be clearly designated on approved development plans by location. The following are some basic requirements of a TCPA:

1. Minimum distance from edge of TCPA to nearest structure = 15-feet
2. Minimum distance from edge of TCPA to nearest street or parking lot = 10-feet
3. For selective tree removal, maximum tree caliper that may be removed = 2-inches

Maintenance

As trees are lost through natural causes, new trees shall be planted in order to maintain the minimum tree canopy as specified on the approved development plan. No clearing, grading or other land disturbing activity shall take place in a TCPA beyond pruning to improve the general health of a tree or to remove dead or declining trees may pose a public health or safety threat.

TCPAs shall be protected either by dedicated easement or other mechanism shown on the approved development plan. Subdivision deeds of restriction are used as one tool to inform future property owners of clearing restrictions.

One exception to the requirements listed above: Individual trees that are designated as TCPAs on individually owned lots within single-family residential subdivision developments may be removed as long as each removed tree is replaced with another tree of a similar type elsewhere on that lot.

9. 3.4 Bibliography

1. Adams, M., Porous Asphalt Pavement with Recharge Beds: 20 Years & Still Working. *Stormwater*. May/June 2003.

2. Houston, City of, Harris County, Harris County Flood Control District, *Stormwater Quality Management Guidance Manual*. 2001 Edition.

3. Barrett, M., Texas Commission on Environmental Quality, *Edwards Aquifer Technical Guidance Manual*. June 2005.