City of Houston

Design Manual

Chapter 13

STORMWATER QUALITY DESIGN REQUIREMENTS

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13.01 CHAPTER INCLUDES

A. Criteria for the design of Stormwater pollution prevention procedures and controls for construction activities.

B. Criteria for the design of permanent Stormwater pollution prevention facilities and controls to minimize impacts for new development and decrease impacts for redevelopment on tracts of land of *5* acres or more.

13.02 REFERENCES

A. Stormwater Management Handbook for Construction Activities, City of Houston, Harris County, Harris County Flood Control District, 2006 or Current Edition.

B. Stormwater Quality Management Guidance Manual, City of Houston, Harris County, Harris County Flood Control District, 2001 or current edition.

C. Minimum Design Criteria (MDC) for Implementation of Certain Best Management Practices for Stormwater Runoff Treatment Options, 2001 edition, City of Houston.

D. Article XII of Chapter 47 of the City of Houston Code of Ordinances.

E. National Pollutant Discharge Elimination System Permit Number TXS001201.

F. Texas Pollutant Discharge Elimination System (TPDES) Permit No. WQ0004685000 (known as the Municipal Separate Storm Sewer System - MS4 permit)

G. Texas Pollutant Discharge Elimination System (TPDES) General Permit No. TXR150000 (known as the Construction Stormwater General Permit)

H. Texas Pollutant Discharge Elimination System (TPDES) General Permit No. TXR050000 (known as the Industrial Stormwater Multi-Sector General Permit)

I. Texas Pollutant Discharge Elimination System Permit Number WQ000468500

J International Stormwater Best Management Practices (BMP) Database, www.bmpdatabase.org

13.03 DEFINITIONS

A. Dwelling Unit - A structure, or a portion of a structure, that has independent living including provisions for non-transient sleeping, cooking and sanitation.

B. Best Management Practice (BMP) - Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. Stormwater management BMP to control or abate the discharge of pollutants when authorized under section 402(p) of the Clear Water Act (CWA) for the control of Stormwater discharges.

C. Impervious Surface - Any area that does not readily absorb water, including, but not limited to, building roofs, parking and driveway areas, sidewalks, compacted or rolled areas, and paved recreation areas.

D. Low Impact Development (LID) **–** is a term used to describe a land planning and engineering design approach to managing Stormwater runoff. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source. LID based practices are used to reduce Stormwater runoff volume and pollutant loading from developed sites.

E. Notice of Intent (NOI). A written submission to the executive director from an applicant requesting coverage under general permit, reference G.

F. Significant New Development - Development on a currently undeveloped parcel of land five acres or larger without regard to the amount of land that will actually be disturbed, except for development on an existing undeveloped and undivided parcel of five acres or more of one single-family dwelling unit and/or the types of non-commercial building(s) typically associated with a single-family dwelling unit, including, but not limited to, a garage, carport or barn. If the occupancy for any structure excluded under the foregoing exception at any time changes to a commercial use, the owner of the property will at that time have to comply with all requirements of this program. The term also does not include a Stormwater detention basin that includes a water quality feature.

G. Development shall mean (i) any activity that requires a subdivision plat or development plat pursuant to Chapter 42 of this Code; (ii) the further subdivision of any reserve tract that is part of a subdivision plat approved by the city planning commission or pursuant to article II of Chapter 42 of this Code; or (iii) any activity that requires a construction permit.

H. Significant Redevelopment shall mean changes of one acre or more to the impervious surface on a five acre or larger developed parcel, but does not include a Stormwater detention basin that includes a water quality feature.

I. Undeveloped parcel shall mean a parcel on which there are no structures at the time that a construction permit, subdivision plat or other city approval is applied for or required.

J. Applicant - The owner of the land on which the new development or significant redevelopment will occur, or authorized agent.

K. NPDES - National Pollutant Discharge Elimination System.

L. SWQMP - Stormwater Quality Management Plan.

M. Regulated Construction Activity - Construction activities, including clearing, grading, and excavation that disturb either five acres or more, or less than five acres if the activities are part of a larger plan of development or sale.

N. SWPPP – Stormwater Pollution Prevention Plan - A SWPPP is a site-specific, written document that: • Identifies potential sources of Stormwater pollution at the construction site • Describes practices to reduce pollutants in Stormwater discharges from the construction site. Reduction of pollutants is often achieved by controlling the volume of Stormwater runoff (e.g., taking steps to allow Stormwater to infiltrate into the soil). • Identifies procedures the operator will implement to comply with the terms and conditions of a construction general permit.

O. TPDES – Texas Pollutant Discharge Elimination System

P. BMP - A number of Stormwater structural and non-structural control strategies, commonly known as best management practices (BMPs), have become the national focus for the mitigation of Stormwater pollution. BMP types include ponds, bio retention facilities, infiltration trenches, grass swales, and filter strips (Ref EPA.gov- TMDL 2007).

Q. Residence Time: Removal efficiency is primarily dependent on the length of time that runoff remains in the pond, which is known as the pond's Hydraulic Residence Time (HRT).

R. Engineered Soil - Cement-Based Engineered Soil technology is used to stabilize the soil on a work site where it is not solid enough to safely support a building or roadway. Portland cement is blended with soil (sometimes including aggregate) and water and then compacted. The resulting mix, known as soil cement provides a secure and stable base for construction. It is also used for flood control structures.

13.04 DESIGN REQUIREMENTS

A. Obtain approval from the Office of the City Engineer (OCE) for exceptions or deviations from these requirements. Exceptions or deviations may be granted on a project-by-project basis.

B. Construction Activity:

1. Stormwater Pollution Prevention Plans (SWPPPs) and Best Management Practices (BMPs) will be developed in accordance with the Stormwater Management Handbook for Construction Activities. (Reference A)

2. Construction plans will include a note requiring contractor to comply with the Construction Stormwater General Permit including preparation of a SWPPP and to provide a copy of the Site Notice, Notice of Intent (NOI), and maintenance checklist to the City *5* work days prior to commencement of any construction activity to City Engineer or Building Official.

C. New Development and Significant Redevelopment:

1. All design must be consistent with the Stormwater Quality Guidance Manual (SWQGM) and the Minimum Design Criteria for Certain Stormwater Runoff Treatment Options (MDC), 2001 edition.

2. A letter of availability must be included with the Stormwater Quality Management Plan

3. Pollutants expected from the site must be identified in the SWQMP. BMPs must be designed and selected to remove the pollutants identified.

4. At a minimum, the system must be designed to treat the first 1/2 inch of runoff, except as noted in the SWQGM or the MDC.

5. BMPs listed in the SWQGM but not in the MDC may be acceptable for implementation pending review of design calculations and site applicability. BMPs not listed in the SWQGM may be considered on a case by case basis. Acceptance of these BMPs will require not only review of design calculations and site applicability, but also review of case studies or other data provided by an uninterested third party indicating the effectiveness of the BMP. All calculations and literature must be provided as part of the plan submittal.

6. In addition to meeting the Stormwater quality requirements of this Chapter the Stormwater system must also meet the requirements of Chapter 9 of this Manual.

13.05 DESIGN STANDARDS

A. When design approaches/Features of this section are incorporated in designs requiring City Engineer approval, the standards of this section will apply.

B. Low Impact Development (LID):

1. Bioretention

a. Overview

Bioretention is a terrestrial-based (up-land as opposed to wetland), water quality and water quantity control practice using the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from Stormwater runoff. Some of the processes that may take place in a bioretention facility include: sedimentation, adsorption, filtration, volatilization, ion exchange, decomposition, phytoremediation, bioremediation, and storage capacity. Bioretention may also be designed to mimic predevelopment hydrology.

b. Design Criteria

(1) Determine volume of bioretention area below maximum design water surface. Depth of ponding limited to a maximum of 6 inches.
(2) Demonstrate that sufficient area contributes stormwater runoff to the bioretention area to fill the area to its maximum design water surface for the design storm under consideration.
(3) Using in-situ or new soils, design the bioretention area to empty within 48 hours. This may be accomplished through infiltration, evapotranspiration, and/or the design of a subsurface drainage system.
(4) Mitigating detention volume requirements can be reduced by the volume in the bioretention area below its maximum design water surface.
(5) Runoff from commercial areas and parking lots require pretreatment; grass buffer strip or vegetated swales, prior to draining into bioretention area.
(6) Infiltration rates less than 0.5 inches per hour will require a subsurface drainage system.
(7) Geotechnical testing is required to confirm infiltration rates.
(8) The cross section for typical Porous Bioretention Basin is shown on Figure 1.

c. Inspection and Maintenance Requirements

(1) Verify presence of vegetation considered in design computations (if any) quarterly.
(2) Verify the bioretention area has adequate volume quarterly by checking whether sedimentation has encroached on design volume. This can be done by comparing actual maximum depth against design maximum depth.

(3) Verify ability of bioretention area to drain within 48 hours twice yearly after rainfall event.
(4) Correct deficiencies related to items 1-3 above as needed.

2. Infiltration Trenches

a. Overview

Trenches or basins that temporarily detain a design water quality volume while allowing infiltration to occur over a prescribed period of time. Trenches are applicable for both water quality and water quantity control practices.

b. Design Criteria

(1) In-situ subsoil shall have a minimum infiltration rate of 0.5 inches per hour. Geotechnical testing including one boring per 5000 square feet or two per project is required to confirm infiltration rate.
(2) Subsurface drainage systems are required where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.
(3) Avoid placement on slopes greater than 15% in fill areas.
(4) Design of the trench area to empty with 48 hours.
(5) Backfill using clean aggregate larger than 1.5” and smaller than 3” surrounded by engineered filter fabric.
(6) Provide overflow structure or channel to accommodate larger runoff events.
(7) Provide 4” PVC observation well into subgrade.
(8) Runoff from commercial areas and parking lots require pretreatment; grass buffer strip or vegetated swales, prior to draining into infiltration trench.
(9) Locate bottom of facility at least 4 ft. above seasonal high water table elevation.
(10) Locate at least 100 ft. from any water supply well.
(11) Maximum contributing drainage area is 5 acres.
(12) Mitigating detention volume can be reduced by the amount of infiltration into the subsoil and the volume of voids within the trench area.

c. Inspection and Maintenance Requirements

(1) Inspect observation well for water level and drainage times.
(2) Conduct landscaping, mowing, and desilting of facility.

3. Porous Pavement

a. Overview

Porous Pavement consists of a permeable surface course (typically, but not limited to, asphalt or concrete) that allows infiltration of stormwater runoff into a permeable layer of uniformly graded stone bed. The underlying permeable layer serves as a storage reservoir for runoff and/or infiltration. Porous Pavement is applicable for both water quality and water quantity control practices.

b. Design Criteria

(1) Porous Pavement should be limited to lightly traveled surfaces such as parking pads in parking lots, residential driveways, trails and sidewalks.
   a. Porous Pavement for residential driveways may be determined as pervious for up to 10% of the 35% pervious area of a Single Family Residential (SFR) lot: (1) qualifying for exemption from detention under 9.05.H.3 and (2) for basis of City Drainage Utility charges.
   b. Porous Pavement will not be determined as pervious for commercial areas designed for heavy traffic volume and/or vehicles, and areas of pavement likely to be coated or paved over because of lack of awareness.

(2) In-situ subsoil shall have a minimum infiltration rate of 0.5 inches per hour. Geotechnical testing including one boring per 5000 square feet or two per project is required to confirm infiltration rate.

(3) Subsurface drainage systems are required for stormwater detention where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.

(4) Typical section of porous pavement and underlying permeable stone bed is shown on Figure 2 with a description of each layer of material.

(5) Subsurface drainage systems are required to be drained in 48 hours.

(6) If the volume of storage within the voids of the subsurface drainage system's stone bed meets the detention volume rate of 0.5 acre-feet per acre of development or 0.2 acre-feet per acre for tracts less than one acre, the area of the porous pavement is considered undeveloped. Otherwise, the total voids storage volume will be credited toward the required detention volume.

(7) If the time of concentration (Tc) from a project site that includes porous pavement and subsurface drainage system, is equal to the undeveloped time of concentration, the development of the project site is considered undeveloped.

(8) Soft porous pavement area shall be considered undeveloped.

(9) The cross-section typically consists of four layers, as shown in Figure 2.

The aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Descriptions of each of the layers are presented below:
Porous Concrete Layer – The porous concrete layer consists of an open-graded concrete mixture usually ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous concrete can be assumed to contain 18 percent voids (porosity = 0.18) for design purposes. Thus, for example, a 4 inch thick porous concrete layer would hold 0.72 inches of rainfall. The omission of the fine aggregate provides the porosity of the porous pavement. To provide a smooth riding surface and to enhance handling and placement a coarse aggregate of 3/8 inch maximum size is normally used.

Top Filter Layer – Consists of a 0.5 inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous concrete layer. Can be combined with reservoir layer using suitable stone.

Reservoir Layer – The reservoir gravel base course consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40 %. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer should be designed to drain completely in 48 hours. The layer should be designed to store at a minimum the water quality volume (WQv). Aggregate contaminated with soil should not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist.

Bottom Filter Layer – The surface of the subgrade should be a 6 inch layer of sand (ASTM C-33 concrete sand) or a 2 inch thick layer of 0.5 inch crushed stone, and be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

Filter Fabric – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity. Fabric should be MIRFI # 14 N or equivalent.

Underlying Soil – The underlying soil should have an infiltration capacity of at least 0.5 in/hr, but preferably greater than 0.50 in/hr. as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full infiltration system. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at subgrade elevation to determine the impermeable layer, and for safety, one-half the measured value is allowed for infiltration calculations.

c. Inspection and Maintenance Requirements

(1) Initial inspection of porous pavement shall be monthly for the first three months post construction.
(2) Semi-annual inspection to ensure pavement surface is free of sediment.
(3) Vacuum sweep hard porous pavement followed by high pressure hosing to keep voids free of sediment quarterly.
(4) Annually inspect pavement surface and subsurface drainage system (if any) for deterioration, spalling or malfunctioning.

d. Additional provisions regarding use as a pervious cover. Approval of plans considering the SFR exemption in cases including porous pavement will include the following condition:

Approval of the proposed development is based in-part on capacity for proposed porous pavement to mitigate increased stormwater runoff. As condition of approval, applicant is required to provide notice to the owner/buyer of the property that maintenance of porous pavement is necessary for continued functionality, that requirements for routine maintenance have been published by the Department of Public Works & Engineering and may be revised in the future, and that failure to fulfill maintenance actions and reporting may result in an increase of drainage utility charges for the property pursuant to City of Houston Ordinance 11-0254 and cited implementing guidelines , available on the **ReBuild Houston** webpage.

4. Vegetated Swales

a. Overview

Vegetated Swales (dry or wet) are earthen, planted stormwater conveyances designed to filter a shallow depth of runoff (<4”) for water quality improvement and to infiltrate stormwater. There are two types, dry or wet. Dry swales include an underdrain system. Wet swales do not. Swales are typically designed to convey runoff from larger storm events, however, treatment and infiltration is reduced during high flows. Infiltrative soils or an engineered porous subgrade is required for infiltration use. Vegetated Swales are applicable for both water quality and water quantity control practices.

b. Design Criteria for Dry Swale

(1) Soil infiltration rate of 0.27 to 0.50 inches/hour.
(2) Trapezoidal or parabolic cross section.
(3) Bottom width should be 2 ft. wide minimum or 6 ft. wide max.
(4) Longitudinal slope should range from 1% to 6%.
(5) Flow depth should be less than 4 inches for water quality treatment.
(6) Flow velocity should be less than 1 fps for water quality, less than 5 fps for 2-yr storm (non-erosive velocities for grass and soils).
(7) Length should yield a 10 minute residence time.
(8) Side slopes should be flatter than 3:1.
(9) Maximum ponding time should be 48 hours.
(10) Use proper vegetation (grass or wetland plants) consistent with climate, ecoregion, soils, and hydric conditions.
(11) Provide at least 3” of free-board during design storm.
(12) Provide pretreatment of runoff into the swale.
(13) Design details are shown in Figure 3.

c. Design Criteria for Wet Swale

(1) Soil infiltration rate of 0.27 to 0.50 inches/hour.
(2) Trapezoidal or parabolic cross section.
(3) Bottom width should be 2 ft. wide minimum or 8 ft. wide max. to avoid gullying or channel braiding.
(4) Longitudinal slope should range from 1% to 6%.
(5) Flow depth should be less than 4 inches for water quality treatment.
(6) Flow velocity should be less than 1 fps for water quality, less than 5 fps for 2-yr storm (non-erosive velocities for grass and soils).
(7) Length should yield a 10 minute residence time.
(8) Slide slopes should be flatter than 3:1.
(9) Maximum ponding time should be < 48 hours.
(10) Use proper vegetation (grass or wetland plants) consistent with climate, ecoregion, soils, and hydric conditions.
(11) Provide at least 3” of free-board during design storm.
(12) Provide pretreatment of runoff into the swale.
(13) Design details are shown in Figure 4.

d. Inspection and Maintenance Requirements

(1) Mow dry swales as required during growing season to maintain grass heights in the 4 to 6 inch range. Wet swales, employing wetland vegetation or other low maintenance ground cover do not require frequent mowing. Remove sediment when 25% of the original water quality volume has been exceeded.

5. Green Roof

a. Overview

A green roof, in simplest terms, is a vegetated roof. The vegetation varies, but must be suitable to the local climate and be drought tolerant, unless a method of irrigation is also installed. Installation generally consists of a waterproof membrane installed over a suitably constructed roof deck. For in-situ installations, an under-drain drainage system is installed over the membrane. A lightweight engineered soil is installed on top of the under-drain, as fill dirt or topsoil is typically too heavy to use in rooftop applications. The engineered soil is then planted with select vegetation. If a modular system is selected, the drainage system may already be incorporated into the design, along with the soil and vegetation, depending on the manufacturer. The substrate material and depth are also factors that influence the efficiency of the green roof to store and/ or treat stormwater. Roofs consisting of relatively thin soil layers, called extensive roofs, are not as heavy as the intensive roofs, which are covered with thicker soil layers.

b. Design Criteria

(1) Vegetation suitable to the climate and preferably a species that is drought tolerant, unless a method of irrigation is provided, should be installed. The effect of wind on the vegetation should also be considered when selecting the roof foliage, as wind velocities are typically higher at rooftop elevations.

(2) The amount of credit given for the rainfall amount stored shall be as prescribed by the manufacturer for a modular system.

(3) The amount of credit given for the rainfall amount stored for non-modular systems shall be calculated for the engineered soil. The rate shall be derived by in-situ porosity testing. The porosity test shall be performed four times with the first time results being discarded and the three remaining results averaged. The test shall require the first sample remain wet a minimum of 1 hour. The subsequent porosity tests shall be performed the same day. In no case should the storage volume be credited more than 33% of total volume, as that is the assumed volume

of clean graded washed gravel.

(4) The roof membrane must be sufficiently designed and installed to pond a minimum of 1-inch of water at the most shallow point on the roof for 24 hours without leaks. This should be tested in the same manner as shower pans are tested under the building code. Additionally, special consideration should be given for the plant root structure and prevention of soil migration during membrane selection. A root barrier may also be required to protect the waterproof membrane integrity.

(5) The under-drain drainage system should be designed for the selected plant's tolerance for drought and varying soil moisture contents by maintaining the proper balance of moisture and aerobic conditions within the soil media for optimum vegetation sustainability. Design provisions should address higher volume rainfall events to keep excessive amounts of water from ponding on top of the soil, to prevent erosion, and to prevent soil media saturation for extended periods. Structural calculations shall be submitted that demonstrate the structure's ability to sustain the additional loading of the green roof appurtenances plus the maximum water weight that could be stored.

c. Inspection and Maintenance Requirements

(1) A maintenance plan for the green roof system should be developed in accordance with the membrane manufacturer's instructions and plant species selected. At a minimum, maintenance inspections should be performed at least four times per year. The maintenance plan should include provisions for vegetation maintenance and replacement as needed to maintain a minimum 80% coverage/survival rate in order to sustain Stormwater quality and/or detention credits. Irrigation may be required initially in order to establish the roof vegetation and to supply water under severe drought conditions. Any requirements for initial or intermittent use of fertilizer and pesticides for disease or insect control should be identified in the plan. Plant species should be carefully selected to minimize intermittent fertilizer and pesticide applications.

(2) Each green roof installation shall be inspected by the agency responsible for issuing the Stormwater quality or detention credits to check compliance with the approved drawings before final acceptance is issued and the proper credits are approved. At a minimum, the following items should be checked during the inspection:

(a) Results from porosity testing (for non-modular installations).

(b) Certification from a registered Professional Engineer or registered Architect that the green roof, including membrane, drain system and engineered soil system, was installed per the approved (permitted) drawings and operates as designed.

(c) Drawings of the green roof installation.

(3) Once the green roof is installed and established, additional inspections will be required in order to properly maintain the vegetation, drainage system and roof membrane. Routine inspections should be conducted and associated maintenance activities performed on the following:

(a) Joints at adjoining walls, roof penetrations for vents, electrical and air conditioning conduits should be inspected regularly for leaks. The ceilings located directly below the green roof installation should also be visually inspected for signs of water staining or leaking.

(b) Designated drainage paths and drainage system components should be inspected to ensure proper surface drainage is maintained and that the soil layer is drained to prevent excessively saturated soils. Vegetation selected to tolerate drought conditions may rot or die if the soil is allowed to become saturated for extended periods.

(c) Vegetation should be visually inspected to identify weeds, accumulated trash or debris, dead or dying vegetation, disease or other infestation problems requiring maintenance attention. Weeds and dead vegetation should be removed on a regular basis, especially right after the roof is planted. If a certain plant or grass species continues to die, that plant or grass should be removed and replaced with a more tolerant species. Certified professionals should only be used to apply chemical applications for the control of disease or insects at trouble spot locations.

(d) Trimming and pruning should be done in accordance with horticulture practices to keep vegetation aesthetically groomed.

6. Hard Roof

a. Overview

Horizontal roof surfaces can be used to attenuate peak runoff associated with rainfall and effectively detain flow resulting from smaller rain events. The detention volume can be controlled in several ways, but typically a simple drain ring is placed around the roof drains. As stormwater begins to pond on the roof, flow into the roof drains is controlled by orifices or slits in the drain ring. Extreme flows can be designed to overflow the ring and drain directly to the roof drains or be directed to openings in the parapet walls to prevent structural and flood damage to the roof. The roof deck must be designed to withstand the live load and be properly waterproofed.

b. Design Criteria

(1) The structural capability of the roof system must be considered when designing a temporary rooftop storage system. For example, a three-

inch water depth is equivalent to a load of 15.6 lbs/sq.ft., which is less than most current building code requirements for live loads.

(2) Consideration must be given to the placement of electrical devices on the roof, such as air conditioning or ventilation systems and lights, and proper measures should be taken to protect the electrical devices from the collected water.

(3) Overflow mechanisms shall be provided so that there is no danger of overloading the roof storage system during major storms. Additionally, roof slopes should be designed to drain positively toward the roof drains to help minimize localized roof ponding or ‘bird bath’ formation after the detained water volume is released.

(4) It is recommended that Chapter 16 of the International Building Code, Current Edition be used for additional structural criteria along with ASCE Standard Reference Number 7, Minimum Design Loads for Buildings and Other Structures.

(5) The amount of credit given for detention volume for rooftop storage should take into account that many flat roofs already pond significant amounts of water; although not by design. Therefore, when measuring credit given for hard roof detention volume, it is recommended that only credit be given for the total rooftop storage volume less the rooftop storage volume associated with the first inch of rain. Typically, rooftop storage volumes are only effective during the smaller, more frequent rainfall events as the larger, less frequent storms typically exceed the rooftop storage capacity.

c. Inspection and Maintenance Requirements

(1) Each hard roof installation shall be inspected by the agency responsible for issuing the detention credits to check compliance with the approved drawings before final acceptance is issued and the proper credits are approved. At a minimum, the following items should be checked during the inspection:

(a) Roof penetrations for ventilation, electrical or plumbing connections to verify proper sealing against leaks.

(b) The overflow system that drains excessive rainfall off of the hard roof once the maximum storage volume is captured.

(c) Certification from a registered Professional Engineer or registered Architect that the hard roof, drain system and appurtenances have been installed and operate as designed.

(d) Drawings of the hard roof installation.

2. Once the hard roof is installed, additional inspections will be required in order to properly maintain the drainage system and roof membrane. Routine inspections should be conducted and associated maintenance activities performed on the following:

(a) Designated drainage paths and drainage system components should be inspected to ensure proper surface drainage is maintained and that the roof is draining properly after the collected stormwater volume is released from a rainfall event.

(b) Routine inspections to collect and remove any trash or debris from the roof should be conducted to prevent clogging of the roof drains and overflow drainage system.

(c) Visible cracks in the roof surface should be identified and repaired in accordance with the roof manufacturer's recommendations in order to maintain roof integrity.

7. Rain Barrels

a. Overview

A cistern ("rain barrel"), ranging from 55 gallons to several hundred gallons in capacity, is placed near the down spout of a house and is used to collect rain water runoff from the roof of the house. The captured water is then typically used as a pure water source for plants and lawns.

b. Design Criteria

(1) Gutters and downspouts carry water from the rooftops to rain barrels as shown on Figure 5.
(2) Screens are required on gutters to prevent clogging.
(3) Rain barrels should be equipped with a drain spigot.
(4) Overflow outlet must be provided to bypass rain barrel from large rainfall events.
(5) Rain barrel must be designed with removable, child resistant covers and mosquito screening.
(6) Minimum rain barrel capacity equal to 1" of runoff from roof top surface area.

c. Maintenance and Inspection

(1) Empty rain barrel after each rainfall event.
(2) Rain barrel should be inspected annually.

13.05 QUALITY ASSURANCE

A. Final design drawings, BMPs, SWPPPs, and SWQMPs will be sealed, signed, and dated by the Professional Engineer registered in the State of Texas responsible for their development.

END OF CHAPTER

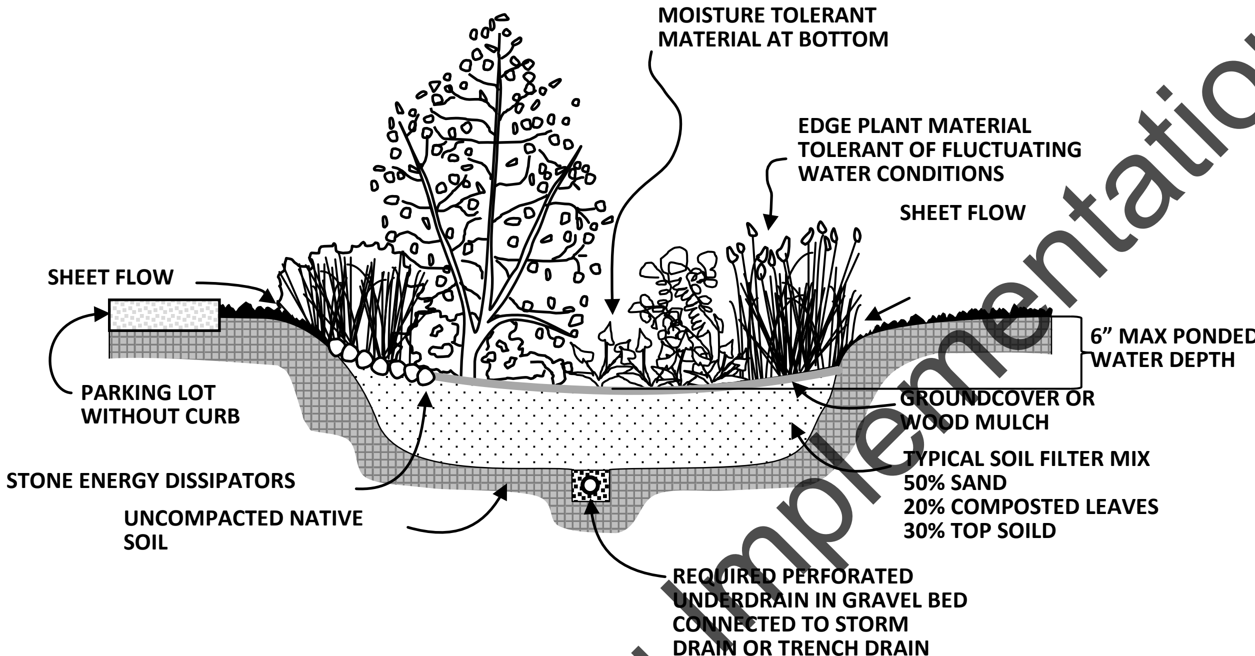

FIGURE 1
POROUS BIORETENTION BASIN

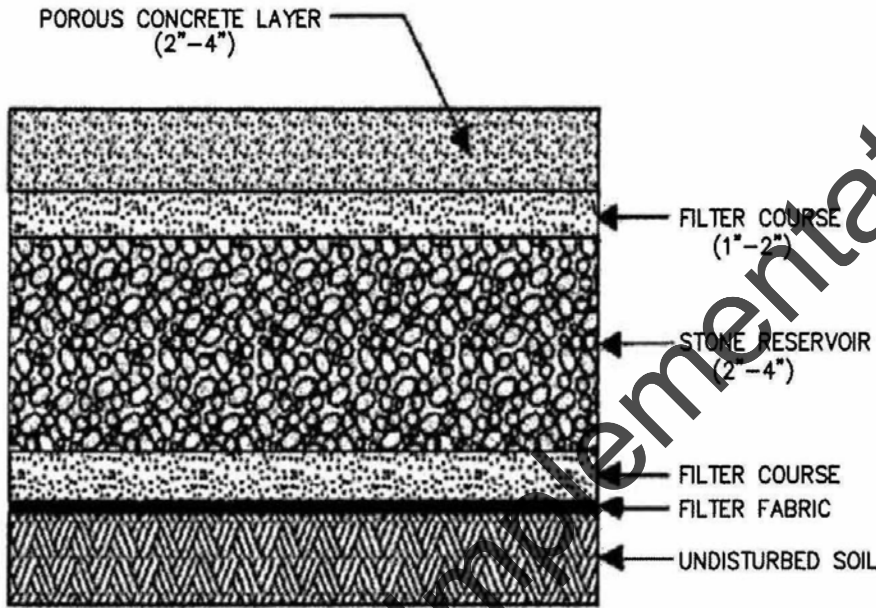

FIGURE 2
POROUS CONCRETE TYPICAL SECTION

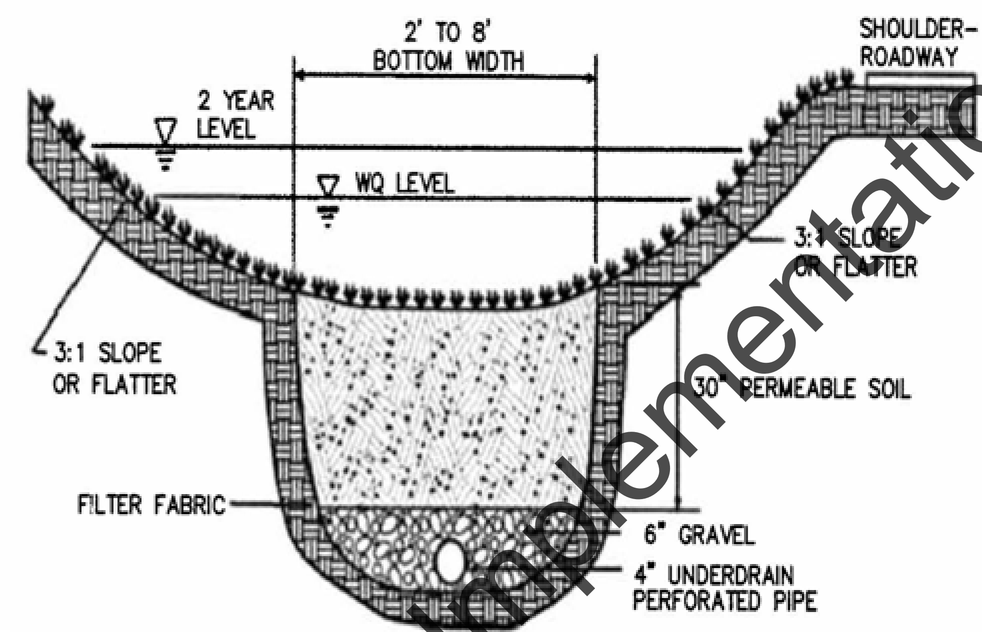

FIGURE 3
DRY SWALE CROSS SECTION

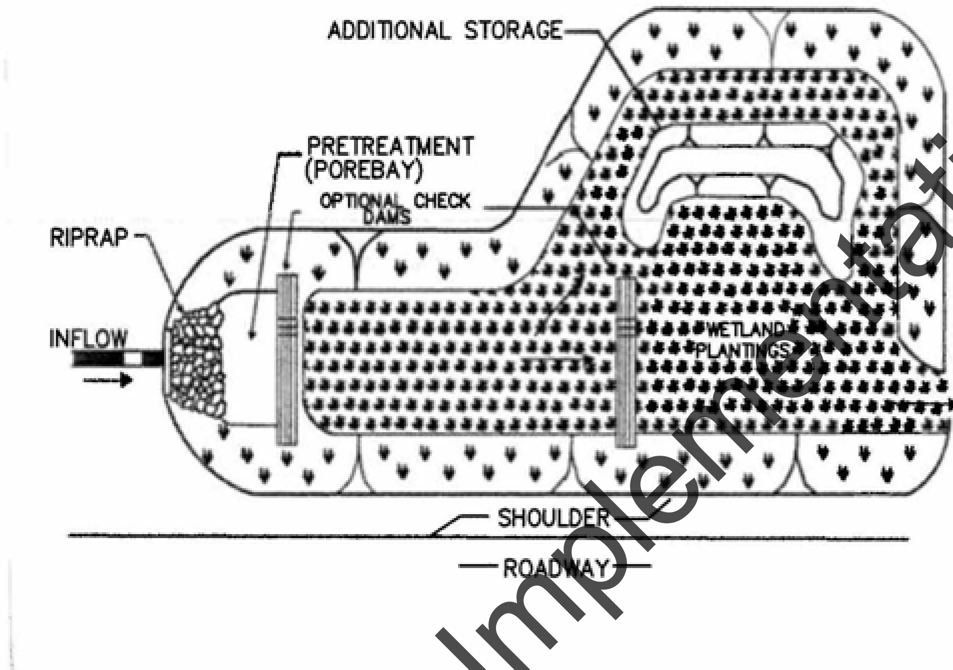

FIGURE 4
WET SWALE PLAN

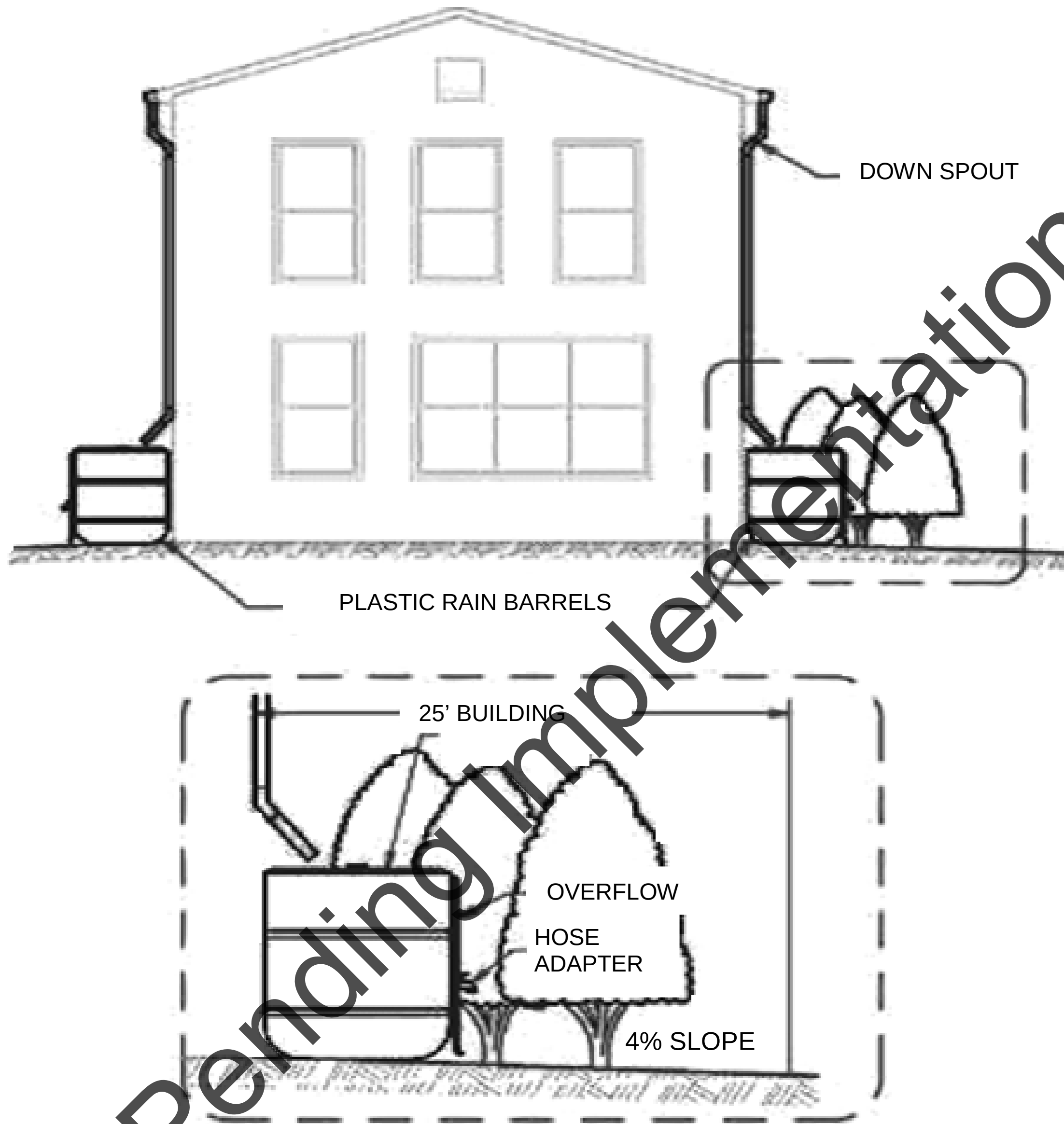

FIGURE 5
TYPICAL RAIN BARREL