CARSON CITY

DRAINAGE MANUAL

Public Works Department

Storm Water Management Program

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I. Introduction

Stormwater runoff and the drainage systems that convey the runoff through the community, both naturally occurring and manmade, are integral elements of the watershed and the developed environment. While stormwater runoff is part of a natural hydrologic process, development and other human activities can change natural drainage patterns and add pollutants to streams, rivers, and lakes. Carson City's efforts to control stormwater discharge focus on both the quantity and quality of the stormwater. This Manual is an effort to improve stormwater management by improving stormwater quality and reducing the quantity of stormwater conveyed through the City's stormwater drainage system.

This Carson City Drainage Manual (Manual) includes and promotes the use of Low Impact Development (LID) practices. LID is a stormwater management approach to land development and redevelopment that works to manage stormwater close to its source. Design principles are used that minimize disturbance, maintain or create perviousness, and use on-site stormwater treatment techniques. LID practices can be effective in reducing runoff quantity, enhancing groundwater recharge, preserving flood plain storage, and removing pollutants by filtration and biological processes before entering the City's storm drainage system.

The Manual supersedes and has been created from the former Stormwater Division 14 of the City's Development Standards. The Manual is an update of the previous stormwater criteria for Carson City and incorporates LID practices and requirements for new and redeveloped properties in the City. The new Manual's formatting has been adjusted to include LID Best Management Practices (BMPs) that are most likely to be used in Carson City.

I.1 Purpose

The Manual's purpose is to reduce pollutants and control drainage by providing guidance on the selection, design, implementation, and management of stormwater source control and structural treatment control BMPs and LID measures for Carson City. The Manual provides information and potential references to aid in making informed selections of BMPs and LID practices.

I.2 NPDES Stormwater Permit and Legal Authority

Carson City is required to implement and enforce a Stormwater Management Program (SWMP) to reduce the pollutants in its stormwater and discharge through its Municipal Separate Storm Sewer System (MS4). Also required is the development of policies and procedures to implement and enforce the operation and maintenance of source controls and structural treatment controls for new development and redevelopment within the City. The requirements for the SWMP and a permit to discharge pollutants into waters of the United States from a MS4 are contained in Section 402 of the Federal Clean Water Act (CWA).

In 2021, Carson City amended and updated the provisions pertaining to drainage, stormwater, LID, and related topics in Titles 12 and 18 of its Municipal Code. As part of this update, Division 14, Storm Drainage, of the Title18 Appendix was removed from the Code and replaced by this Manual.

I.3 Relationship to Other Standards and References

Users of this Manual should be aware of other City standards that may be applicable to the development or redevelopment of property within Carson City. Users may also consult references cited in this Manual for more information and alternative practices. Pertinent Carson City and regional standards include, but are not limited to, those listed below.

- Carson City Municipal Code, Title 18 Appendix, Development Standards.
- Standard Specifications for Public Works Construction (SSPWC) (The "Orange Book") (2012 or the most current edition) provides general provisions, material specifications, and construction

methods for typical public works installations, including storm drainage infrastructure and landscaping.

- Truckee Meadows Structural Controls Design and Low Impact Development Manual.
- Truckee Meadows Structural Controls Design Manual, together with all addenda.
- Truckee Meadows Construction Site Best Management Practices Handbook, together with all addenda.
- Truckee Meadows Industrial Commercial Best Management Practices Handbook, together with all addenda.
- Chapter 4 of the Tahoe Regional Planning Agency Best Management Practices Handbook, together with all referenced addenda.

The standards, criteria, and requirements in this Manual are minimum standards that may not necessarily be adequate to address the highly variable conditions that must be covered by effective low impact development measures.

I.4 Updates and Revisions

Innovation and improvement continue to advance BMPs, LID practices, and the science and technology related to stormwater management and stormwater quality. The City Engineer may make technical engineering and clerical revisions to this manual at any time. For revisions that may have minor cost implications to the development community to comply with the specifications in this manual, the City Engineer must provide an opportunity for public input and update the Board of Supervisors prior to making the revisions. For major revisions that may have significant cost implications to the development community, the City Engineer must provide an opportunity for public input and obtain Board of Supervisor approval prior to making the major revision. Any revisions must be posted to the Carson City website where this manual is available for a period of 30 days before the revisions become effective.

1. Drainage Policy Introduction and Basic Principles

Adequate drainage systems shall be provided in order to preserve and promote the general health, welfare, and economic well-being of the region. Drainage is a regional feature that affects all of Carson City. Drainage plans shall be consistent with and integrated with BMPs, LID measures, and the Carson City Drainage Master Plan upon adoption. This characteristic of drainage requires coordination and cooperation from both the public and private sectors.

Stormwater drainage systems are an integral part of the development process. The planning of drainage facilities, BMPs, and LID measures shall be integrated into the development process and in preparation of improvement plans. Onsite stormwater drainage systems shall include BMPs and LID measures to reduce runoff and improve stormwater quality unless it is demonstrated to the satisfaction of the City Engineer that the site is not suitable.

Drainage systems require space to accommodate conveyance, storage, and treatment functions. When the space requirements are considered, the provision for adequate drainage becomes a competing use for space along with other land uses.

Storm drainage planning for all development and redevelopment shall include the allocation of space for drainage facility construction and maintenance, which may entail the dedication of right-of-way and/or easements. The provision of multi-use facilities such as combining with parks, open space, and recreation needs is strongly encouraged.

New development. New development is the conversion of previously undeveloped or pervious surfaces to impervious surfaces and managed landscape areas.

Redevelopment. Redevelopment is the replacement of impervious surfaces on a developed site. All new impervious surfaces added during redevelopment are considered new development.

The long-term goal of the redevelopment standard is to reduce stormwater pollution from existing developed sites, especially when the site is being upgraded to a use with a greater potential to contribute pollution to the receiving waters.

1.1 Water Rights

All drainage systems shall be planned and constructed with consideration given to the existing water rights and applicable water laws.

1.2 Reasonable Use of Drainage

Downstream properties shall not be unreasonably burdened with increased flow rates, negative impacts, or unreasonable changes in the manner of flow from upstream properties. Drainage problems shall not be transferred from one location to another. However, downstream properties cannot block natural or existing runoff through their site and shall accept runoff from upstream properties.

"Reasonable Use of Drainage" is defined for planning purposes, as providing an economic and hydraulically efficient drainage system which is demonstrated not to adversely and unreasonably impact downstream properties within reason. This "Reasonable Use of Drainage" therefore allows development to occur while preserving the rights of adjacent property owners.

1.3 Change in Manner of Flow

Development shall tend to concentrate existing natural sheet flow into point flows at property lines. These point flows are generally associated with outlets from gutter flow, storm drains, and detention facilities. Downstream properties may experience a longer duration of storm flows, and greater flows in general due to a shortened time of concentration. Discharge of point flows on downstream property can cause increased erosion at the discharge point and further downstream. The manner by which runoff is discharged from the project site must not cause a significant adverse impact to downstream receiving waters and down-gradient properties. Therefore, downstream facilities shall be evaluated for runoff capacity during the design and review process. Mitigation of these point flows can be accomplished through energy dissipaters or flow spreaders. Point flows shall be discharged to downstream properties at non-erosive velocities and depths of flow.

All outfalls must address energy dissipation as necessary. A project proponent who believes that energy dissipation should not be required for a new outfall must provide justification in the project's conceptual or technical drainage study.

Where no conveyance system exists at the adjacent down-gradient property line, and the discharge was previously unconcentrated flow or significantly lower concentrated flow, then measure must be taken to prevent down-gradient impacts. Drainage easements or right-of-way from downstream property owners may be needed and should be obtained prior to approval of engineering plans.

1.4 Diversion of Drainage

Development can alter the historic or natural drainage paths. When these alterations result in a local on-site drainage system that discharges back into the natural drainage-way or wash at or near the historic location, then the alterations (inter-basin transfer) are generally acceptable. However, when flows from the local on-site drainage system do not return to the historic drainage-way or wash, then inter-basin transfer may result. These inter-basin transfers are generally not acceptable. Planning and design of drainage systems shall not be based on the premise that stormwater can be transferred from one basin to another unless part of an adopted City Regional Drainage System Plan.

The flow of storm runoff shall be maintained within its natural drainage course unless reasonable use is demonstrated otherwise. When stormwater is discharged into an existing drainage course, the peak discharge into the water course shall not adversely affect or cause damage to property along the drainage course now or in the future based on existing zoning and the Carson City Master Plan build-out conditions. Erosion impacts due to concentration of flows and increased flow durations shall be evaluated and mitigated.

1.5 Water Quality

Storm drainage improvements shall incorporate water quality, erosion control, BMPs, and LID measures in accordance with the Nevada "Handbook of Best Management Practices," Title 18 Appendix, Division 13, this Manual, and accepted engineering practice. Storm drainage leaving a development during the construction phase or post-construction may not be of a quality that shall adversely affect downstream uses. Flow based post-construction water quality controls shall be designed to capture and treat the flow rate for the 2-year runoff event from the drainage area connected to the BMP. Volume based post-construction water quality controls shall be designed to provide adequate storage to capture and treat 90 percent of the average annual stormwater runoff events.

Water quality controls to minimize stormwater pollution shall be provided for all development where the total of new and/or replaced impervious surface coverage equals or exceeds 10,000 square feet or causes disturbance equal to or greater than one (1) acre, except for the development of one (1) single-family residence that causes less than one (1) acre of land disturbance. Also, standard maintenance practices are exempt if the site remains similar to the existing flow patterns as determined by the City Engineer. In addition, commercial and industrial projects must include source control BMPs to the maximum extent practicable.

Direct discharge of untreated stormwater from pollution generating impervious surfaces is prohibited. The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms so that beneficial uses of receiving waters are maintained, and where possible, restored. The water quality parameters of concern in the Carson River basin include, but are not limited to, total suspended solids, total phosphorus, and turbidity. Water quality treatment facilities should be chosen, designed, and maintained to minimize total phosphorus, turbidity and total suspended solids discharged into receiving waters.

Non-pollution generating impervious surfaces (NPGIS) are considered to be insignificant or low sources of pollutants in stormwater runoff. If the runoff from NPGIS is separated from the runoff from pollution generating impervious surfaces (PGIS), the NPGIS runoff does not need to be treated. However, if NPGIS and PGIS are combined, the entire amount of runoff must be treated.

NPGIS include the following:

1. Roofs that are subject only to atmospheric deposition or normal heating, ventilation and air conditions vents;
2. Paved bicycle pathways and pedestrian sidewalks that are separated from and not subject to drainage from roads for motor vehicles;
3. Fenced fire lanes; and
4. Infrequently used maintenance access roads.

Sidewalks that are regularly treated with salt or other de-icing chemicals are not considered NPGIS.

PGIS are considered to be significant sources of pollutants in stormwater runoff. Such surfaces include:

1. Surfaces subject to vehicular use;
2. Surfaces subject to industrial activities or subject to storage of erodible or leachable materials that receive direct rainfall or run-on or blow-in of rainfall;
3. Metal roofs unless coated with an inert, non-leachable material;
4. Roofs subject to the venting of manufacturing, commercial or other indoor pollutants;
5. Any surface, whether paved or not, that is regularly used by motor vehicles, including roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways.

High-use sites generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil and/or other petroleum products. High-use sites are land uses where sufficient quantities of free oil are likely to be present such that they can be effectively removed with special treatment. A high-use site is any one of the following:

1. A road intersection with expected average daily trips (ADT) of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements;
2. A commercial or industrial site with an expected trip end count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;
3. A customer or visitor parking lot with an expected trip end count equal to or greater than 300 vehicles;
4. Commercial on-street parking areas on streets with an expected total ADT count equal to or greater than 7,500;
5. Fueling stations and facilities;
6. A commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including locations where heating fuel is routinely delivered to end-users (heating fuel handling and storage facilities are subject to this definition);
7. A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight;
8. Maintenance and repair facilities for vehicles, aircraft, construction equipment, railroad equipment or industrial machinery and equipment; or
9. Outdoor areas where hydraulic equipment is stored.

Exemptions

NPGIS areas are exempt from basic treatment requirements *unless* the runoff from these areas is not separated from the runoff generated from PGIS areas. All runoff treatment facilities must be sized for the entire flow that is directed to them.

1.6 Treatment Requirements

Runoff treatment is required for all projects unless it can be demonstrated to the satisfaction of the City Engineer that runoff treatment is not feasible due to specific site limitations (e.g., wellhead protection areas, high groundwater conditions that preclude LID practices, and areas of vector control concern). The basic treatment requirements include removal of 80 percent of total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations less than 100 mg/l, the facilities should achieve an effluent goal of 20 mg/l total suspended solids. Additionally, the basic treatment requirements are intended to achieve a goal of 50 percent total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. The performance goals apply to either the water quality design storm volume or flow rate as appropriate.

High-use sites must provide facilities adequate to meet the basic treatment goals as well as oil control goals. The oil control facilities must achieve the goal of no ongoing or recurring visible sheen and to have a 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/l, and a maximum of 15 mg/l for a discrete sample (grab sample).

1.7 Drainage Improvements

Drainage improvements consist of curb and gutter, inlets and storm drains, culverts, bridges, swales, ditches, channels, detention areas, water quality facilities, and other drainage facilities required to convey and treat design storm runoff to the point of discharge. Drainage improvements are further defined as on-site (private) facilities that serve a specific development and are privately owned and maintained or off-site (public) facilities. Public and private drainage facilities shall be constructed in accordance with the requirements of this Manual, Title 18 Appendix, Division 13, and accepted engineering practice.

1.8 Floodplain Management

Floodplain management shall provide the guidance, condition, and restriction for development in floodplain areas while protecting the public's health, safety, welfare, and property from danger and damage. Development within the Federal Emergency Management Agency (FEMA) designated Special Flood Hazard Areas shall comply with CCMC and requirements of the National Flood Insurance Program (NFIP).

1.9 Storm Runoff Detention

Detention is considered a viable method to reduce storm runoff from developed properties. Temporarily detaining storm runoff can significantly reduce downstream flood hazards, pipe and channel requirements, and downstream erosion and sedimentation. Storage also provides for sediment and debris collection, which reduces maintenance requirements for downstream channels and streams.

Detention used in conjunction with other BMPs and LID measures can be particularly effective. The City requires the use of BMPs and LID measures unless it can be demonstrated that they are not suitable for the site.

Local detention storage for land development, which includes subdividing land, shall be required when the development increases flow and downstream conveyance capacities of the drainage system are not capable of handling non-detained flows, and the developer elects not to upgrade the existing storm drainage system. Onsite detention storage shall be sized to detain sufficient runoff to limit post-development flows from a 10-year storm (Q10) to the flows under the predevelopment condition. Volume credit will be granted for water quality features on a one-for-one basis.

The capacity of downstream conveyance systems shall be analyzed in accordance with this Manual and shall be based on runoff from the development as fully improved. Local detention can also be required when designated in flood or drainage master plans to reduce the peak rate in regional facilities.

The City may grant exemptions to the detention policy for the following:

1. Developments which discharge directly to a regional flood control facility, provided the facility is completed per the adopted plan and designed for the contributing flows.

2. Locations where a local detention facility is designed and constructed to serve several developments and the contributing flows.

3. Downstream facilities are upgraded to accommodate the increased flow.

4. Where the downstream facilities are adequate to carry up to 100-year flows.

All exemptions are subject to approval by the City.

1.10 Lower Watershed Design

In certain circumstances, i.e., close to the drainage system's point of discharge, it may be desirable not to detain stormwater runoff. The option to directly discharge shall be at the sole option of the City and after review of a flood route analysis. Water quality treatment will be required even if the stormwater runoff is directly discharged.

1.11 Storm Runoff Retention and Infiltration

Storm runoff retention and infiltration have been used to eliminate the need for constructing outlet structures and for ease of construction. However, problems with retention basins and infiltration facilities receiving runoff from pollution generating surfaces include perpetual maintenance requirements, soil expansion, siltation, decreasing infiltration capacity, and insect abatement. Retention basins and infiltration facilities receiving runoff from pollution generating surfaces also pose a hazard to City groundwater resources through possible contamination. The use of infiltration facilities is encouraged for runoff from non-pollution generating surfaces such as roofs. Percolation tests shall be conducted to verify that on-site soils are adequate for infiltration. Retention basins used to mitigate the increase of runoff from development must meet the requirements of detention basins and are only allowed on a case by case basis.

1.12 Drainage Facilities Maintenance

An important part of all storm drainage facilities is the continued maintenance of the facilities to ensure they function as designed. Maintenance of detention facilities involves the removal of debris and sediment. Such tasks are necessary to preclude the facility from becoming unhealthy and to retain the effectiveness of the detention basin. Sediment and debris must also be periodically removed from channels and storm drains. Trash racks and street inlets must be regularly cleared of debris to maintain system capacity. Channel bank erosion, damage to drop structures, crushing of pipe inlets and outlets, and deterioration to the facilities must be repaired to avoid reduced conveyance capability, unsightliness, and ultimate failure.

All drainage facilities shall be designed to minimize facility maintenance as well as to provide ease of maintenance and include maintenance access to the drainage facility. The owner of the drainage facilities shall be responsible for mosquito control, and the method of control shall comply with the Carson City Environmental Health Department.

The property owner or developer shall be responsible for the maintenance of all privately owned on-site drainage facilities, including but not limited to, inlets, pipes, channels, and detention basins unless otherwise required or modified by a separate agreement. An operation and maintenance schedule shall be provided for all proposed stormwater facilities and BMPs, and the party (or parties) responsible for maintenance and operations shall be identified. Prior to issuance of any permit for any regulated activity covered under this section, the City shall require the applicant and owner to execute an inspection and maintenance agreement binding on all subsequent owners of land served by the private storm drainage system. If the property owner or developer fails to maintain said facilities adequately, Carson City shall have the right to enter the said property, upon proper notice, for the purposes of maintenance. All such maintenance costs shall be assessed against the owner(s).

An operation and maintenance schedule shall be developed for any storm drainage system. The schedule shall state the required maintenance to be performed, the equipment and skill level necessary to perform the maintenance, and the required frequency of maintenance. The operation and maintenance schedule shall either be printed on the stormwater management agreement or submitted under a separate cover.

1.13 Drainage Easements and Right-of-Way

Easements or Rights-of-Way shall be provided where necessary for access and maintenance of storm drain systems. Simple Fee Title of land is preferred.

1.14 Storm Runoff Water Quality Treatment

All development and redevelopment projects, except for the development of one (1) single-family residence that causes less than one-quarter (1/4) acre of land disturbance, must control the quality of stormwater leaving the site to the maximum extent practicable. Title 18 Appendix, Division 13, contains the Best Management Practices (BMPs) that must be included in an Erosion and Sediment Control Plan to control the water quality of stormwater runoff generated on construction sites. This Manual contains BMPs that must be included in site drainage plans to permanently control the quality of runoff from a developed or redeveloped site.

2. Technical Criteria

2.1 Design Storm Events

Drainage facilities shall be designed to convey the runoff from the 24-hour duration storm with a recurrence interval for a minor storm event (10-year) and a major storm event (100-year).

Water quality facilities will be designed to treat either the peak flow rate produced by the 2-year storm event if the treatment facility is flow-based or the volume of runoff produced by the 2-year, 24-hour storm event if the treatment facility is volume-based.

2.1.1 Storm Runoff Determination

Storm runoff (rates and volumes) shall be determined in accordance with the following methods (other methods may be used if approved by Development Engineering):

2.1.1.1 Conveyance Design

Contributing Basin Area (A)	Computation Procedure
A ≤ 100 Acres	Rational formula, SCS TR-55, or HEC-1, (SCS Unit Hydrograph or Kinematic Wave)
10 S.M > A ≥ 100 Acres	SCS TR-55 or HEC-1 (SCS Unit Hydrograph or Kinematic Wave)
A > 10 S.M.	HEC-1 (SCS Unit Hydrograph or Kinematic Wave)

2.1.1.2 Flow-Based Water Quality Control Design

Flow-based design standards apply to those structural treatment controls whose primary method of pollutant removal is based on the flow and filtration of runoff through the BMP. The water quality flow rate (WQF) for flow-based stormwater treatment controls should be determined by using the following methods to estimate the peak discharge produced by the 2-year storm event in the drainage area of the BMP.

Contributing Basin Area (A)	Computation Procedure
A ≤ 100 Acres	Rational formula, SCS TR-55, or HEC-1, (SCS Unit Hydrograph or Kinematic Wave)
A ≥ 100 Acres	SCS TR-55 or HEC-1 (SCS Unit Hydrograph or Kinematic Wave)

2.1.1.3 Volume-Based Water Quality Control Design

Volume-based BMP design standards apply to those stormwater treatment controls whose primary method of pollutant removal is based on the facilities' ability to capture and detain, retain and/or infiltrate a specific water quality volume. Volume-based stormwater treatment controls should be designed to capture and treat the volume of stormwater runoff determined based on the following formulas:

$$WQ_V = [(P)(R_V)(A)]/12$$
$$R_V = 0.05 + 0.009I$$

Where: WQ_V = water quality volume (ft3)
P = the 90th percentile precipitation depth
I = percent of basin impervious area
A = drainage area (ft2)

(For P, use 1.5 inches for areas west of Carson Street and 0.5 inches for areas east of Carson Street unless otherwise directed by the City.)

2.1.2 Rainfall

Rainfall data tables and storm design information shall be derived from the NOAA Atlas, latest edition, or other City approval.

2.1.3 Streets

The use of streets to convey runoff, although naturally occurring, interferes with the primary function of the street for transportation purposes. Streets are, however, an important component in the storm drainage system due to their large storm carrying capacity obtained for little or no drainage costs. In order to balance these two (2) competing street uses, limits on the street carrying capacity are required based on the street classification related to emergency usage during storm and flood events. All development shall provide clear emergency flow paths for the onsite/offsite 100-year peak storm.

The allowable street capacity for different roadway functional classification shall be determined in accordance with Table 1 and Table 2. To ensure cleaning velocities at low flows, gutters shall have a minimum slope of 0.40 percent.

2.1.4 Culverts, Bridges, Valley Gutter, and Dip Sections

Culverts and bridges shall be installed where natural or manmade drainage channels are crossed by streets. Valley gutters, or "dip" sections, shall be permitted on local streets. The amount of channel flow that crosses over the street shall be minimized (not more than 0.5 feet) to protect the street embankment and pavement from erosion damage as well as to protect vehicles and pedestrians from dangerous flow depths and velocities. Bridges and culvert crossings under streets shall be sized for the required design storm capacity in accordance with Table 1.

Table 1 – Design Storm Events for Crossings

Design Storm Criteria	Design Storm Event (see Notes)
1. Local Streets	25-year return period, 24-hour duration
2. Arterial and Collector Streets	100-year return period, 24-hour duration
3. Developments (commercial, industrial, residential)	10-year return period, 24-hour duration
Notes: 1. All development shall provide emergency flow paths for a 100-year peak storm in accordance with Table 2. 2. Refer to Section 8.1 for additional situations where the drainage system shall be designed for not less than a 100-year return period, 24-hour duration. 3. Refer to Section 1.8 for additional requirements for projects located within a floodplain.	

3. Submittal and Review Process

The purpose of the submittal and review process is to determine whether or not the drainage plan and improvements for a given project meet Carson City drainage requirements. These requirements include overall facility planning to assure an integrated and coordinated design as well as design standards to ensure consistent design and analysis. Drainage study submittal requirements for all land development in Carson City are presented in the following section and summarized in Table 2. The submittal requirements are intended to provide the necessary information for each development and minimize review time. The submittal and review process does not relieve the design engineer of the responsibility to provide a correct and safe drainage design or the developer to construct the designed drainage facilities properly.

By reviewing and approving drainage designs for given developments, Carson City shall not assume liability for improper drainage design, nor guarantee that the final drainage design review shall absolve the developer or designer of future liability for improper design or construction.

Table 2 – Drainage Study Submittal Requirements

Land Development and/or Land Action Process	Required Drainage Submittals (5)
Parcel Map:	Conceptual Study
Improvement Plans	Technical Study
Subdivision (including planned unit developments):	
Conceptual Plan	Conceptual Study
Tentative map	Conceptual Study
Improvements Plans	Technical Study
Building Permit	Technical Study
Clearing, Grading, Filling and/or Excavation	Conceptual Study
Other:	
MPR/CLU	Conceptual Study
Special Use Permit	Conceptual Study
Development Master Drainage Plans	Technical Study
Transportation Studies	Technical Study
Floodplain Modification Study	
Conditional Letter of Map Revision, Letter of Map Amendment, Letter of Map Revision, etc.	Technical Study

Notes:

1. Development Engineering may require a Technical Drainage Study in lieu of or in addition to a Conceptual Drainage Study.
2. If the City does not perceive a flooding hazard with the proposed development, the City may approve the development subject to review and approval of the Drainage Study and acceptance of conditions of approval by the owner.
3. All Floodplain Modification Studies shall be prepared in accordance with FEMA requirements and the CCMC.
4. Development Engineering may waive this requirement.
5. Carson City reserves the right to request additional information of the developer/design engineer after a drainage study has been submitted.

Drainage studies shall be submitted for all development and redevelopment, except for the development of one (1) single-family residence that causes less than one-quarter (1/4) acre of land disturbance. Additionally, Development Engineering may require drainage studies where a proposal may endanger the life, safety, and welfare of the public. Two (2) copies of the required drainage studies and attachments shall be submitted to Development Engineering for review with the required applications or improvement plans. Additional copies, as necessary, shall be submitted as requested by Development Engineering. All submitted reports shall be clearly and cleanly reproduced. Copies of charts, tables, nomographs, calculations, or other referenced material shall be legible. In addition, final approved reports and attachments shall be submitted in Adobe pdf format.

4. Drainage Study Information Page

A Drainage Study Information Form Page shall be included with all drainage study submittals. The Drainage Study Information Page shall provide basic information regarding the proposed development. A form will be provided at the request of the Project Engineer.

The Drainage Study shall contain the seal and signature of the professional engineer licensed in Nevada who is responsible for the drainage study.

5. Conceptual Drainage Study

A Conceptual Drainage Study is a descriptive report that addresses existing and proposed drainage conditions. The Conceptual Drainage Study documents the existing drainage conditions of the project site and presents the details of the proposed drainage system. Additionally, it includes sufficient data to evaluate storm flows and proposed mitigation.

The conceptual drainage study shall contain sufficient information in order for Development Engineering to make a recommendation to the appropriate Carson City hearing body.

5.1 Conceptual Drainage Study Outline

The Conceptual Drainage Study shall contain a brief narrative letter, a calculation appendix (if required), and a drainage plan in accordance with the following outline:

I. Introduction
   - A. Drainage Study, Information page
   - B. Project Name, Type of Study, Study Date
   - C. Preparer's Name, Seal and Signature
   - D. Description of Project, including land use, site development plan, lot coverage, and amount of new and replaced impervious surface
   - E. Existing Site Conditions, including topography, existing ground cover, wetlands, sensitive areas, and stormwater and irrigation systems
   - F. General Location May (8 ½ x 11 is suggested)

II. Existing and Proposed Hydrology
   - A. Discuss existing and proposed drainage basin boundaries
   - B. Provide design storm and 100-year return period, 24-hour duration storm flow calculations for both on- and off-site flows
   - C. Discuss existing drainage problems (if applicable)
   - D. Discuss on-site and downstream drainage, identify downstream conveyance deficiencies, and identify areas with high potential for erosion and sediment deposition
   - E. Discuss Floodplain (if applicable)
   - F. Existing Irrigation
   - G. Discuss locations of sensitive and critical areas (e.g., vegetative buffers, wetlands, steep slopes, streams, etc.)
   - H. Tributary Exhibit

III. Erosion and Sediment Control Measures
   - A. Discuss how the requirements of Section 13 will be met.
   - B. Discuss erosion and sediment control measures implementation and maintenance.

IV. Proposed Drainage Facilities (on-site and off-site)
   - A. Discuss routing of flow in and/or around the site, downstream, and location of drainage facilities. Downstream analysis should extend downstream for the entire flow path from the project site to the receiving water or up to one (1) mile or to a point where the impact to receiving waters is minimal or nonexistent as determined by the City Engineer. The downstream analysis should assess the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project
   - B. Discuss stormwater quantity and water quality mitigation measures, including operation and maintenance procedures and responsibility
   - C. Discuss floodplain modifications (if applicable)
   - D. Provide Exhibit.

V. Conclusions
   - A. Compliance with the CCMC and the Carson City Development Standards
   - B. Compliance with FEMA (if applicable)
   - C. Discuss the effect of development on off-site flow rates and properties
   - D. Implementation measures necessary for project completion

VI. Exhibits
   A. Drainage Plan
   B. FEMA Floodplain Map (show on drainage plan also)

VII. Calculation Appendix (if required)
   A. Runoff calculations including hydrology computations
   B. Street and drainage facility capacity calculations, including inlet capacities, culvert and pipe system capacities, and outlet velocities, ditch capacities and velocities (if applicable)
   C. Stormwater quantity and water quality control facility calculations (if applicable)

5.2 Conceptual Drainage Plan

An 8 ½ " x 11" or larger legible drainage plan which covers the development area shall be submitted and bound with the Conceptual Drainage Study. The plan shall contain as a minimum the following:

1. Locate and label the development boundary
2. Locate and label adjacent streets
3. Locate and label known 100-year floodplains
4. Locate and label existing and/or planned local flood control facilities
5. Show flow paths
6. Identify design inflow points and design outflow points and corresponding design storm and 100-year return period, 24-hour duration storm flow rates
7. Show existing and proposed topography
8. Show the time of concentration path for developed and existing conditions

6. Technical Drainage Study

The Technical Drainage Study shall discuss, at a detailed level, the existing site hydrologic conditions, erosion and sediment control during construction, and the proposed drainage plan to accommodate or modify site drainage conditions in the final development plan for the site. The Technical Drainage Study shall address both on-site and off-site drainage analysis and improvements necessary to mitigate the impact of the proposed development on downstream properties.

6.1 Technical Drainage Study Contents

The Technical Drainage Study shall be in accordance with the following outline and contain as a minimum the information listed:

I. Title Page
   A. Project Name, Type of Study, Date of Preparation, and Revisions
   B. Preparer's Name, Seal and Signature
   C. Drainage Study Information Page

II. General Location and Development Description
   A. Location of Property
      1. Street Location and Assessor's Parcel Number(s) adjacent to the development
      2. Township, range, section, ¼ section
      3. Drainage basin(s) encompassing the development, watershed name
      4. Location of the development in relation to existing drainage facilities
      5. Names of surrounding developments
      6. General location map (8 ½ x 11 is suggested)

   B. Description of Property
      1. Area in acres
      2. Existing site conditions (land use, buildings, drainage structures, floodplains, and other site conditions that may impact the project)
      3. General site topography, ground cover, and soil maps

4. Existing irrigation facilities such as ditches and canals
5. Adjacent and downstream developments, drainages and infrastructure

C. Project Description
1. Purpose and nature of land-disturbing activity; include the estimated amount of grading
2. Type and size of proposed new or replaced impervious surfaces
3. Critical areas on the site which have the potential for serious erosion and/or sedimentation, or other drainage problems

III. Drainage Basin Description

A. Off-Site drainage description
1. Discuss historical drainage patterns (overland flow, channelized flow, points of discharge) for off-site flows that enter the project site.
2. Discuss off-site flows that enter the project site.
3. Provide a map of drainage basins.
4. Discuss drainage basin characteristics (topography, area, land use, coverage, soil types, locations of critical areas, areas with high potential for erosion and sediment deposition, etc.).
5. Identify the design storm and 100-year return period, 24-hour duration storm flows for each drainage basin and sub-basin impacting or impacted by the project site.
6. Discuss downstream flow paths, rates, and conveyance capacity. Downstream analysis should extend downstream for the entire flow path from the project site to the receiving water or up to one (1) mile or to a point where the impacts to receiving waters are minimal or nonexistent as determined by the City Engineer. The downstream analysis should assess the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project.

B. On-site drainage description
1. Discuss historical on-site drainage patterns and capacity of the property (flow directions through the site and at property lines).
2. Discuss historical drainage patterns of upstream runoff through the property.
3. Provide a map of drainage basins.
4. Discuss historical drainage basin characteristics (topography, area, land use, coverage, soil types, locations of critical areas, areas with high potential for erosion and sedimentation, etc.).

C. Floodplain Information
1. Identify all FEMA regulated floodplains which impact the subject site. Locate the same on the drainage plan.
2. Note the lowest floor and other pertinent elevations(s).
3. Floodplain/Floodway calculations where pertinent.

D. Previous Drainage Studies
1. Identify previous drainage studies for the site and provide a copy if required by Carson City.
2. Identify previous drainage studies or previously approved projects which affect the site and provide copies of the studies if required by Carson City.

IV. Proposed Drainage Facilities

A. General Description
1. Discuss criteria and methodology.
2. Discuss the proposed construction erosion and sediment control and stormwater pollution prevention methodology. A Stormwater Pollution Prevention Plan prepared per the requirements of Title 18 Appendix, Division 13, may be submitted in compliance with this requirement.

3. Discuss the proposed permanent on-site water quantity control, water quality control, and drainage system plan and layout.
4. Discuss the proposed off-site drainage system plan and mitigation measures.

B. Compliance with Regulations and Adopted Plans
1. Discuss compliance with FEMA floodplain regulations and CCMC, and all proposed modifications to or verifications of the FEMA regulated floodplain through the subject site.
2. Discuss compliance with previously approved drainage studies for the subject site.
3. Identify all requests for variances from the requirements of the drainage criteria individually.

C. Hydrologic Criteria
1. Discuss design rainfall computations.
2. Discuss design runoff computations, including peak flow rate for stormwater quantity control facilities and either peak flow rate or volume for water quality treatment facilities as appropriate.
3. Discuss peak flow rates from off-site areas and facilities.
4. Discuss off-site limiting conditions and constraints (see Section 14.1.3 Increase in Rate of Flow).
5. Provide schematic of pre- and post-development time of concentration paths and calculations.

D. Facility Design Calculations
1. Discuss design calculations for the on-site drainage system (design storm and 100-year storm flow).
   a. Street and ditch flow calculations
   b. Storm drains, inlets, and ditch flow calculations
   c. Channel and culvert flow calculations
   d. Other hydraulic structure flow calculations (trash rack, grates, etc.)
   e. Detention storage and outlet design calculations and flows
   f. Provide detail of control structure device
   g. Erosion and sediment deposition and mitigation measures during construction
   h. Permanent stabilization description of how the site shall be stabilized after construction is complete
   i. Water quality design calculations
2. Discuss design calculations for the off-site drainage system that is accepting post-development runoff and impacts from the same.
   a. Street flow calculations
   b. Storm drain, inlets, and ditch flow calculations, including velocities
   c. Channel and culvert flow calculations
   d. Other hydraulic structure flow calculations
   e. Alluvial fan analysis and calculations (when required)
3. Discuss Floodplain/Floodway calculations as related to FEMA requirements and compliance with CCMC.
4. Discuss maintenance access, potential maintenance requirements, and maintenance responsibilities.
5. Discuss easement requirements for the proposed drainage facilities.
6. Discuss phasing of all drainage facilities.
7. Energy and hydraulic grade lines.

V. Conclusions
A. Compliance with Drainage Laws
B. Compliance with the CCMC
C. Compliance with FEMA requirements

D. Compliance with Development Standards
E. Effectiveness of proposed drainage facilities to control storm runoff
F. Impact of the proposed development on off-site property and facilities
G. Mitigation of impacts and implementation schedule

VI. Appendices as required by the report.

6.2 Technical Drainage Study Plan

A detailed drainage plan(s) for the subject site shall be submitted with the Technical Drainage Study. The plan(s) shall be on a 24” x 36” drawing at an appropriate scale (a scale of 1” = 20’ to 1” = 200’ is recommended). The following information shall be shown on this drawing, except that the off-site drainage basin boundaries may be shown at an appropriate legible scale on an exhibit:

1. Property lines and streets (roads) including right-of-way widths within 100 feet of the development.

2. Street names, grades, and widths.

3. Existing contours and proposed elevations sufficient to analyze drainage patterns extending a minimum of 100 feet past property lines of the project limits. If required by Development Engineering, more extensive off-site topography shall be required.

4. Existing drainage facilities and structures, including ditches, storm drains, channels, street flow direction, and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included.

5. Limits of existing floodplains based on flood insurance rate maps (FIRM) and best available information. Provide tie to FEMA datum if all or a portion of the site is within a FEMA regulated floodplain and base flood elevation information when available. Establish base flood elevations if not determined on FIRMs.

6. Proposed on-site drainage basin boundaries. Include off-site drainage basins if the same runoff enters the project.

7. Proposed future on-site and off-site flow directions and paths for design storm and 100-year storm flows at pertinent locations.

8. Proposed street and ditch flow paths and slopes. Trace peak flows leaving the project site to the nearest drainage facility; identify capacity and improvements, if needed.

9. Proposed storm drain locations, type, size, capacities, depth of flow, and slope. Include inlet types, sizes and locations, and manhole locations. Correlate to drainage calculations.

10. Proposed channel alignment with a typical cross-section. Provide street cross-sections showing design storm and 100-year return period, 24-hour duration storm depth of flow.

11. Proposed culvert locations, type, size, and slope.

12. Proposed construction erosion and sediment control measures and BMPs.

13. Proposed detention facilities, type, size, and outlet characteristics.

14. Proposed water quality treatment facilities, type, and size.

15. Miscellaneous proposed drainage facilities (i.e., hydraulic structures, etc.)

16. Easements/right-of-way widths and boundaries (existing and proposed).

17. Ditch and channel sections with lining, if required.

18. Construction details, including control structures and identify construction materials.

19. Legend for all symbols used on drawing.

20. Scale, Bar Scale, North Arrow, Date, Bench Mark based on Carson City's Control Network, Title Block, Professional Engineers Signature, Seal.

21. Energy grade lines (EGL's) and hydraulic grade lines (HGL's) for storm drain and channel storm runoff.

22. Show clear emergency flow paths for 100-year peak storm.

7. Improvement Plans

Where drainage improvements are to be constructed, the improvement plans (on 24" x 36" sheets) and specifications shall be submitted to Development Engineering. Approval of the final improvement plans by Development Engineering shall be obtained prior to issuing construction permits, building permits, or grading permits. Plans for the drainage improvements shall include the following as a minimum:

1. Storm drains, inlets, outlets, and manholes with stationing, elevations, dimensions, type, and horizontal control indicated.

2. Culverts, end sections, and inlet/outlet protection with dimensions, type, elevations, and horizontal control indicated.

3. Channels, ditches, and swales (including side/rear yard swales) with lengths, widths, cross-sections, grades, and erosion control (i.e., rip-rap, concrete, grout) indicated.

4. Checks, channel drops, erosion, and sediment control facilities and measures.

5. Detention facility size, type, grading, low flow channels, outlets, landscaping, fencing, and maintenance access.

6. Water quality facility size, type, landscaping, and maintenance access.

7. Other drainage related structures and facilities (including underdrains and sump pump lines).

8. Maintenance access considerations.

9. Drainage easements and right-of-way with horizontal distance to improvements.

10. Plan and profile sheets showing all improvements.

11. Details for drainage structures, facilities, and improvements, including detention basin outlet control structures.

12. Erosion and sediment control plan. See Division 13, Carson City Development Standards for erosion and sediment control plan requirements.

The information required for the plans shall be in accordance with sound engineering principles, Division 13 of the Title 18 Appendix, this Manual, the Standard Details, and the "Standards Specifications for Public Works Construction." Construction documents shall include geometric, dimensional, structural, foundation, bedding, hydraulic, landscaping, specifications, and other details as needed to construct the drainage improvements. Improvement plans shall be signed and sealed by a professional engineer licensed in Nevada and be in accordance with the approved drainage report/drawings.

8. Storm Drain System

8.1 Introduction

The design storm peak flows generally govern the size of the storm drain system flows, as shown in Table 2. There are conditions, however, when the storm drain system design shall be governed by the 100-year return period, 24-hour duration storm flows. Storm drain systems shall be designed for not less than a 100-year peak storm for the following situations:

Locations where the street flow is collected in a sump with no allowable overflow capacity.

Locations where the desired 100-year return period, 24-hour duration storm flow direction is not reflected by the street flow direction during a 100-year return period, 24-hour duration storm (i.e., flow splits at intersections).

If a storm drain is to be designed to convey 100-year return period, 24-hour duration storm flows, then the inlets to the storm drain shall be designed accordingly.

Table 3 – Design Storm Street Capacity Limitations

Roadway Functional Classification	Maximum Limits of Street Inundation (See Notes)
1) Arterial	**Q10 Storm:** Flow contained in R/W. No curb overtopping. A minimum 48-foot wide dry lane centered shall be maintained and in each direction 24 feet. Runoff in excess of street capacity shall be piped. **Q100 Storm:** Flow contained to not inundate structures. Maximum depth at gutter flow line shall be 1 foot. A minimum 12-foot wide dry lane shall be maintained in each direction or 24 feet centered.
2) Collector	**Q10 Storm:** Flow contained in R/W. No curb overtopping. A minimum 18-foot wipe dry lane centered shall be maintained. Runoff in excess of street capacity shall be piped. **Q100 Storm:** Flow contained to not inundate structures. Maximum depth at gutter flow line shall be 1 foot. A minimum 12-foot wide dry lane shall be maintained centered.
3) Local or Industrial Street	**Q10 Storm:** Flow contained in R/W. No curb overtopping. A minimum 12-foot wide dry lane centered shall be maintained. Runoff in excess of street capacity shall be piped. **Q100 Storm**: Flow contained to not inundate structures. Maximum depth at gutter flow line shall be 1 foot. Street flooded.
Notes: 1. Where no curb exists, encroachment onto adjacent property shall be allowed but must be contained to not inundate structures. 2. Other criteria, such as the Federal Housing Administration regulations, may impose standards more restrictive than cited.	

8.2 Design Criteria

8.2.1 Allowable Storm Drain Capacity

The storm drain capacity calculations shall begin at the storm drain outlet and proceed upstream, accounting for all energy losses. The Energy Grade Line (EGL) and Hydraulic Grade Line (HGL) shall be calculated to include all hydraulic losses, including friction, expansion, constriction, bend, and junction losses. The available energy at all junctions and transitions shall be checked to determine whether or not the flow in the storm drain shall be pressurized due to backwater effects even if the design flow is less than the full flow capacity of the storm drain.

If any section of the storm drain is pressurized due to backwater effects, then the storm drain system shall be designed to convey the design storm under surcharged or pressure flow conditions. The storm drain shall be considered surcharged when the depth of flow (HGL) in the storm drain is greater than 80 percent of full flow depth. The maximum level of surcharging for the capacity analysis shall be limited to maintaining the HGL to one foot (1') below the final grade above the storm drain at all locations. Special site conditions that warrant additional surcharging shall require locking type manhole covers or grated covers and shall be reviewed on a case-by-case basis by the City.

8.2.2 Allowable Storm Drain Velocity

The maximum allowable storm drain velocity is dependent on many factors, including the type of pipe, the acceptable wear level during the pipe design life, proposed flow conditions (open channel versus pressure flows), and the type and quality of construction of joints, manholes, and junctions. In consideration of the above factors, the maximum velocity in all storm drains and culverts shall not exceed the erosion resisting capabilities of the conduit and storm drain system. However, in no case shall the maximum velocity exceed 15 feet per second (fps).

All storm drains, culverts, and low flow outlets shall be designed to maintain a minimum velocity of three (3) fps at half or full conduit conditions, but in no case shall the storm drain slope be less than 0.25 percent.

8.2.3 Manning's Roughness Coefficient

All storm drain system hydraulic calculations shall be performed using Manning's Formula. A Manning's roughness factor, or "n," shall be as defined by the specific pipe manufacturer provided that the coefficient is within the range of accepted engineering standards.

8.2.4 Pipe Size

The minimum pipe size of storm inlet laterals and storm drain mains shall be 15 inches in diameter for round pipe or an equivalent flow area for other pipe shapes. Systems in all parking lots shall conform to the minimum standards.

8.2.5 Minimum and Maximum Cover

The required cover over a storm drainpipe is dependent on many factors, including the design pipe strength, pipe size, and cover material. For practical purposes, the storm drain shall be protected from potential surface disturbances and displacements. The minimum and maximum cover are dependent upon the design pipe strength.

8.2.6 Manhole and Junction Spacing

A manhole, catch basin, or junction box shall be located at all changes in pipe size, direction, elevation, and grade for all pipes with a diameter (or rise dimension) of less than 36 inches, and at the end of all public storm drain lines (unless the storm drain daylights at the end of the line). Maximum spacing between manholes or junction boxes shall be 350 feet. For pipes with a diameter (or rise dimension) of 36 inches and greater, the designer shall consult with Development Engineering for the location of manholes and junctions based on hydraulic and maintenance considerations.

8.2.7 Horizontal Alignment

The horizontal alignment of storm drains shall generally be straight between manholes and/or junctions. All storm drains shall be placed within the right-of-way dedicated for public streets unless Development Engineering approves the use of easements.

When storm drains are to be installed in existing streets, factors such as curbs, gutters, drainage ditches, sidewalks, traffic conditions, pavement conditions, future street improvement plans, and existing utilities shall be considered by the design engineer when selecting the storm drain location and alignment.

8.2.8 Utility Clearances

Storm drains and culverts shall be located to minimize potential contamination and disturbance of water supply and sanitary sewer mains. The local utility companies, or the Nevada Division of Health, may impose additional requirements. Where requirements differ, the more stringent shall apply.

8.2.9 Storm Inlet and Catch Basin Types, Locations, and Capacity Factors

Standard storm inlet and catch basin details are included in the Standard Details. The allowable use of these storm inlet and catch basin types is presented in Table 4. Allowable inlet capacity factors for each of the standard inlets and catch basins are also presented in Table 4. These capacity factors shall be applied to the theoretical capacity of the inlets and catch basins to account for conditions that decrease the capacity of the standard inlets. These conditions include plugging from debris and sediment, pavement overlaying, variations in design assumptions, and the general deterioration of the inlet and catch basin conditions over time. All catch basins may have sumps (12 inches minimum, 24 inches maximum) as determined by Development Engineering.

Catch basins or inlets shall be installed at low points of vertical curves, at all street intersections, and at sufficient intervals to intake the design storm peak flow such that flows shall not interfere with traffic or flood adjoining property in accordance with the requirements of Table 3. Catch basins and inlets at street intersections shall be located on the upstream side of the intersection and upstream of crosswalk locations.

When storm drainpipes are connected to a catch basin, inlet, or manhole with concrete/grout, both the inside and outside of the catch basin, manhole, or inlet shall be grouted at the pipe connection.

8.3 Materials

8.3.1 Pipe Material and Shape

The material and shape of the storm drain shall be in accordance with the “Standard Specifications for Public Works Construction”. Round, square, or rectangular reinforced concrete pipe (RCP) in accordance with ASTM C-789 or C-850 is preferred for use under roadways, driveways, and other traffic areas. Reinforced concrete pipe shall be at a minimum Class III, or the appropriate class when the design requires a greater pipe support strength. Other pipe materials, as approved by the City for storm drain use, except for corrugated metal (permitted for residential driveway culverts), are permitted.

8.3.2 Manholes

Precast manhole tees are not allowed where there is a change in storm drain slope or alignment or where there are intersecting storm drain mains or laterals. Pipes may be directly cast into the manhole base. Gasketed joints, locking type manhole covers, and/or grated manhole covers for pressure flow conditions may be required.

8.3.3 Storm Drain Outlet Protection

Storm drain outlets shall be designed to prevent the receiving channel from scour erosion or sediment deposition and shall be constructed with outlet protection for discharges to channels with unlined bottoms in accordance with the following:

Outlet Velocity (fps)	Minimum Outlet Protection
Less than 5	Rip-rap Protection
Between 5 and 15	Rip-rap Protection or Energy Dissipater
Greater than 15	Energy Dissipater

For channels with unlined bottoms, the outlet discharge velocity shall not exceed the maximum allowable channel velocity without an energy dissipation structure. Specifications for the outlet protection shall be submitted with the improvement plans.

8.4 Storm Drain Hydraulic Analysis

A hydraulic analysis of all storm drains shall be performed and submitted to Development Engineering as part of the Technical Drainage Report. Storm drain hydraulic and capacity analysis shall account for changes in flow conditions (open channel versus pressure flow) in the HGL and EGL calculations. Both the HGL and EGL for the design flow shall be included on storm drain improvement plans as part of the drainage report.

Table 4 – Allowable Storm Inlet Types and Capacity Factors

Inlet or Catch Basin Type	Permitted Use	Permitted Location Condition	Capacity Factor
Catch Basin Type - 1	Private Use Only	Sump	0.65
Catch Basin Type 1A	Street with Curb and Gutter	Continuous Grade **or** Sump	0.70 (Grate), 0.80 (Curb Opening) 0.65
Catch Basin Type 3	Landscaped or Unimproved Areas	Sump	0.50
Catch Basin Type 4	Street with Curb and Gutter	Continuous Grade **or** Sump	0.70 (Grate), 0.80 (Curb Opening) 0.65
Notes: 1. Capacity factor is applied to the theoretical inlet capacity to obtain the allowable inlet capacity to account for factors that reduce actual inlet capacity.			

8.5 Design Standards for Culverts

Culverts shall be designed and constructed using the following standards. The analysis and design shall consider design flow, culvert size and material, entrance structure layout, outlet structure layout, and erosion protection.

8.5.1 Culvert Sizing Criteria

8.5.1.1 Design Frequency

As indicated in Section 2.1.4 (Culverts), all culverts shall be designed to pass the flow from the design storm, including an overflow section where permitted.

8.5.1.2 Minimum Size

The minimum culvert size shall be 18 inches diameter for round pipe or an equivalent flow area for other pipe shapes.

8.5.2 Culvert Materials

Culverts shall be RCP in accordance with the Standard Details under roadways and other traffic areas. For rural residential driveways, CMP is allowed. The use of dip sections rather than culverts is encouraged for rural residential driveway crossings.

8.5.3 Outlet Protection

Outlet Velocity (fps)	Minimum Outlet Protection
Less than 5	Rip-rap Protection
Between 5 and 15	Rip-rap Protection or Energy Dissipater
Greater than 15	Energy Dissipater

Specifications for the outlet protection shall be submitted with the improvement plans.

8.5.4 Headwater Criteria

The maximum headwater for the design storm for culverts greater than 36 inches diameter or a culvert rise of 36 inches shall be 1.5 times the culvert height. The maximum headwater for culverts with a height of 36 inches or less shall be five feet (5') if adjacent properties are not adversely affected.

8.5.5 Alignment

Whenever possible, culverts shall be aligned with the natural channel to reduce inlet and outlet transition problems.

8.5.6 Temporary Crossing

Temporary crossings are defined as dip road sections with a culvert sized to pass nuisance flows or a culvert system that does not meet the criteria presented in this manual. Temporary crossings shall be reviewed on a case-by-case basis. Consideration shall be given to the following items:

1. Drainage area contributing to the crossing.
2. Level of roadway traffic.
3. Vertical and horizontal roadway alignment (sight distance).
4. Alternate access routes.
5. Time frame for temporary crossing (time to construction of permanent crossing).
6. Current and projected development density.
7. 25-year and 100-year storm flows.

8.5.7 Multiple Barrel Culverts

Multiple culverts may be used if available fill height limits the size of the culvert needed to convey the flood flow and the amount of debris is limited.

8.5.8 Inlet and Outlet Configurations

Culverts shall be designed with protection at the inlet and outlet areas. The culvert inlet shall include a headwall with wingwalls or a flared end-section.

The outlet area shall also include a headwall with wingwalls or a flared end-section. Where outlet velocities exceed the limitation set forth in Section 3.5.3 (Outlet Protection), an energy dissipater shall be required.

8.5.9 Structural Design

All culverts shall be designed to withstand, as a minimum, an H-20 loading in accordance with the design procedures of AASHTO "Standard Specifications for Highway Bridges" and with the pipe manufacturer's recommendations.

8.6 Drainage Channels

When open drainage channels are permitted, the potential for erosion and scour shall be determined and submitted as part of the drainage report. Recommended mitigation measures to prevent erosion and sediment deposition shall be identified and incorporated into the design of the drainage channels. Flow velocities in drainage shall not exceed the maximum permissible flow velocities for the design storm as recommended in the American Society of Civil Engineers (ASCE) Manuals and Reports of Engineering Practice No. 77, "Design and Construction of Urban Stormwater Management Systems."

Side slopes of unlined channels shall be 3:1 (horizontal to vertical) or flatter. Side slopes for lined channels shall be 2:1 (horizontal to vertical) or flatter. The use of rip rap as a channel lining is discouraged due to maintenance requirements.

All drainage channels that are not located within public rights-of-way shall be located in easements or lands dedicated to the City or the appropriate entity, and shall be provided with a permanent maintenance access road in accordance with Development Standard Division 12.11.14 (Improved Maintenance Access) to provide access for maintenance.

9. Stormwater Runoff Reduction BMPs

9.1 Introduction

The principal of runoff reduction starts by recognizing that developing or redeveloping land within a watershed inherently increases the imperviousness of the areas and, therefore, the volume and rate of runoff and the associated pollutant load.

Best management practices (BMPs) for reducing runoff include passive systems such as minimization of directly connected impervious areas and low impact development techniques and structural controls such as detention or infiltration facilities.

The main purpose of detention BMPs is to temporarily store runoff and reduce peak discharge by allowing flow to be discharged at a controlled rate. This controlled discharge rate shall be determined so that post-development runoff shall not exceed pre-development runoff leaving the site and that the appropriate LID feature is being used. The controlled release of storm drainage minimizes impact on downstream properties and also minimizes the potential for downstream erosion that may occur as a result of increased flow velocity. There are three (3) primary types of detention facilities: detention ponds, tanks, and vaults.

9.2 Minimize Directly Connected Impervious Areas (DCIA)

Impervious areas directly connected to the storm drain system are the greatest contributor to non-point source pollution. The first effort in site planning and design for stormwater quality protection is to minimize the directly connected impervious area (DCIA) as shown in Table 5.

Any impervious surface that drains into a catch basin, area drain, or other conveyance structure is a DCIA. As stormwater runoff flows across parking lots, roadways, and paved areas, the oils, sediments, metals, and other pollutants are collected and concentrated. If this runoff is collected by a drainage system and carried directly along impervious gutters or in closed underground pipes, it has no opportunity for filtering by plant material or infiltration into the soil. It also increases in speed and volume, which may cause higher peak flows downstream and may require a larger capacity storm drain system, increasing flood and erosion potential.

Minimizing directly connected impervious areas can be achieved in two (2) ways:

1. Limiting overall impervious land coverage.
2. Directing runoff from impervious areas to pervious areas for infiltration, retention/detention, or filtration.

9.3 Low-Impact Development Techniques

The low-impact development (LID) approach combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. The primary goal of LID methods is to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff. The use of these techniques helps to reduce off-site runoff and ensure adequate groundwater recharge. Since every aspect of site development affects the hydrologic response of the site, LID control techniques focus mainly on-site hydrology. Specific LID controls can reduce runoff by integrating stormwater control throughout the site in many small, discrete units. LID controls are distributed in a small portion of each lot, near the source of impact, and may eliminate the need for a centralized BMP facility such as a stormwater management pond.

The Regional Water Planning Commission for the Truckee Meadows has developed the Truckee Meadows Structural Controls Design and Low Impact Development Manual, which may be used as a reference. Information on LID control techniques can also be found in the publication “Low-Impact Development Design Strategies, An Integrated Design Approach, 2,000”, Prince George’s County, Maryland, Department of Environmental Resources, Programs and Planning Division and at the Low Impact Development Center website http://www.lowimpactdevelopment.org.

LID control techniques include the following broad categories of stormwater control:

1. Zero Discharge Areas
2. Self-Treatment Areas
3. Runoff Reduction Areas

Site planning strategies and techniques provide the means to achieve stormwater management goals and objectives; facilitate the development of site plans that are adapted to natural topographic constraints; maintain lot yield; maintain site hydrologic functions; and provide for aesthetically pleasing, and perhaps, less expensive stormwater management controls.

Table 5 presents a list of site design and landscaping techniques and indicates whether they are applicable for use in Zero Discharge Areas, Self-Treating Areas, and Runoff Reduction Areas. Several techniques may be implemented within the same design philosophy. Some techniques may be used to implement more than one design philosophy. Where feasible, combinations of multiple techniques may be incorporated into new development and redevelopment projects to minimize the amount of treatment required.

Table 5 – Site Design and Landscaping Techniques

(From: California Stormwater BMP Handbook, New Development and Redevelopment)

Site Design and Landscape Techniques	Design Criteria		Design Philosophy		
	Volume-Based Design	Flow-Based Design	Zero Discharge	Self-Treating	Runoff Reduction
Permeable Pavements					
Pervious concrete	X				X
Pervious asphalt	X				X
Turf block	X			X	X
Un-grouted natural stone	X				X
Un-grouted concrete unit pavers	X				X
Unit pavers on sand	X				X
Crushed aggregate	X				X
Cobbles	X				X
Wood mulch	X				X
Streets					
Urban curb/swale system	X	X			X
Rural swale system	X	X			X
Dual drainage systems	X	X			X
Concave median	X	X	X		X
Pervious island	X	X			X
Parking Lots					
Hybrid surface parking lot	X				X
Pervious parking grove	X				X
Pervious overflow parking	X			X	X
Driveways					
Not directly connected impervious driveway		X			X
Paving only under wheels	X			X	X
Flared driveways	X				X
Buildings					
Dry-well	X		X		X
Cistern	X	X	X		X
Foundation planting	X	X			X
Pop-up drainage emitters		X			
Landscape					
Grass/vegetated swales	X	X		X	X
Extended detention (dry) ponds	X		X	X	X
Wet ponds	X		X	X	X
Bio-retention areas	X		X	X	X

9.3.1 Zero Discharge Areas

A zero discharge area is an area within a development project that is designed to infiltrate, retain, or detain the volume of runoff requiring treatment from that area. Site design techniques available for designing areas that produce no treatment-required runoff include:

1. Retention/Detention Ponds
2. Wet Ponds
3. Infiltration Areas
4. Large Fountains
5. Retention Rooftops

6. Green Roofs (roofs that incorporate vegetation) and blue roofs (roofs that incorporate detention or retention of rain).

Infiltration areas, ponds, fountains, and green/blue roofs can provide “dual-use” functionality as stormwater retention measures and development amenities. Detention ponds and infiltration areas can double as playing fields or parks. Wet ponds and infiltration areas can serve dual roles when meeting landscaping requirements.

9.3.2 Self-Treatment Areas

Self-treatment areas are developed areas that provide “self-treatment” of runoff if properly designed and drained. Self-treating site design techniques include:

1. Conserved Natural Spaces
2. Large Landscaped Areas (including parks and lawns)
3. Grass/Vegetated Swales
4. Turf Block Paving Areas

The infiltration and bio-treatment inherent to such areas provide the treatment control necessary. These areas act as their own BMP and no additional BMPs to treat runoff should be required.

9.3.3 Runoff Reduction Areas

Using alternative surfaces with a lower coefficient of runoff or C-factor may reduce runoff from developed areas. The C-factor is a representation of the surface’s ability to produce runoff. Surfaces that produce higher volumes of runoff are represented by higher C-factors, such as impervious surfaces. Surfaces that produce smaller volumes of runoff are represented by lower C-factors, such as more pervious surfaces.

Site design techniques that incorporate pervious materials may be used to reduce the C-factor of a developed area, reducing the amount of runoff requiring treatment. These materials include:

1. Pervious Concrete
2. Pervious Asphalt
3. Turf Block
4. Brick (un-grouted)
5. Natural Stone
6. Concrete Unit Pavers
7. Crushed Aggregate
8. Cobbles
9. Wood Mulch

Other site design techniques such as disconnecting impervious areas, preservation of natural areas and designing concave medians may be used to reduce the overall C-factor of development areas.

The following site design BMPs are included in this Manual.

Table 6 – Site Design BMPs

Design	
SD-1	Low Impact Development Site Planning
SD-2	Landscape Planning
SD-3	Downspout Dispersion
SD-4	Concentrated Flow Dispersion
SD-5	Sheet Flow Dispersion
Materials	
SM-1	Pervious Pavements
SM-2	Alternative Building Materials

10. Detention

10.1 Introduction

The main purpose of a detention basin is to temporarily store runoff and reduce peak discharge by allowing flow to be discharged at a controlled rate. This controlled discharge rate shall be determined so that post-development runoff shall not exceed pre-development runoff leaving the site.

Detention facilities shall be designed by and financed by developers or local property owners. The facilities are intended to allow development by protecting a site from existing flooding conditions or protecting downstream properties from increased runoff caused by development.

10.2 Detention Facilities – Ponds or Basins

Detention facilities shall comply with the following:

1. Impounding of water for stormwater control purposes shall comply with regulations of the Nevada State Engineer for the construction of dams where pertinent.

2. The potential for the use of detention basins for multiple uses must be reviewed with the Parks Department, and if acceptable to the City, must be designed to accommodate these additional uses.

3. Basins shall be sited within drainage easements.

4. Detention basin outlet capacity shall be based on the downstream channel capacities (existing or build-out conditions) with consideration given to inflows occurring downstream of the detention basin and changes in flow conditions and hydraulics due to the use of the upstream detention basin, and shall not exceed the pre-developed flow rate (up to the design storm) for the affected property (see Section 1.9 Storm Runoff Detention).

5. In-channel detention basins shall, at a minimum, be required to pass the 100-year event discharge safely.

6. Detention ponds shall be designed to include provisions for security, public safety, landscaping, and erosion control.

7. Ponds may be designed as flow-through systems. Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.

8. Pond bottoms should be level and be placed a minimum of 0.5 foot (preferably one (1) foot) below the inlet and outlet to provide sediment storage.

9. Basins shall be drained in not more than 48 hours. (Drain time is defined as the time from the end of precipitation until the basin is drained of 90 percent of design capacity.)

10. The design of all detention basins shall include emergency spillways for 100-year storms protected against erosive forces.

11. A minimum of one foot (1') of freeboard is required above the emergency spillway design water surface elevation.

12. Basin discharge shall be self-regulating (passive).

13. Generally, detention basins having side slopes no steeper than 5:1 horizontal to vertical is preferred but steeper side slopes are allowed if soil conditions allow and if proper armoring is provided. Access to larger basins (greater than 0.5 acres bottom area) shall be provided by a paved ramp with a slope no steeper than 6:1 horizontal to vertical with a minimum width of 12 feet.

14. Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the pond, such as the inlet or bypass structures. If possible, the manhole and catch basin lids should be in or at the edge of the access road and at least three feet (3') from a property line. The maximum grade of the road should be 20 percent, and the outside turning radius should be a minimum of 40 feet. Access roads should be 15 feet wide on curves and 12 feet wide on straight sections. A paved apron must be provided where access roads connect to pave public roadways.

15. An access ramp for the removal of sediment with a track hoe and a truck should be provided. The ramp should extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp) and it may end at an elevation four feet (4') above the pond bottom if the pond bottom is less than 1,500 square feet (measured without the ramp). Access ramps must meet the requirements for the design and construction of access specified in item 13.

16. Exposed earth on the pond bottom and interior side slopes may be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract may be planted with grass or landscaped.

10.3 Detention Facilities – Pipes or Tanks

Detention tanks or pipes are underground storage facilities typically constructed with large diameter corrugated metal pipe.

1. Tanks may be designed as flow-through systems with manholes in line to promote sediment removal and facilitate maintenance.

2. The detention tank bottom should be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.

3. The minimum pipe diameter for a detention tank is 36 inches. The minimum pipe diameter for a detention pipe is 18 inches.

4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (two-foot (2') maximum length) of a 36-inch minimum diameter pipe.

5. Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads, or other loading criteria applicable to the site, must be accommodated for tanks lying under parking areas and access roads. Metal tank endplates must be designed for structural stability at maximum hydrostatic loading conditions. Flat endplates generally require thicker gauge material than the pipe and/or require reinforcing ribs. Tanks must be placed on stable, well consolidated native material with suitable bedding. Tanks must not be placed in fill slopes unless analyzed in a geotechnical report for stability and constructability.

a. Tank access.
b. The maximum depth from the finished grade to tank invert should be 20 feet.
c. Access openings should be positioned a maximum of 50 feet from any location with the tank.
d. All tank access openings should have round, solid locking lids.
e. 36-inch minimum diameter CMP riser-type manholes of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system.
f. All tank access openings must be readily accessible by maintenance vehicles.
g. Tanks must comply with the OSHA confined space requirement, which includes clearly marking entrances to confined space areas.

6. Access roads are needed for all detention tank control structures and risers. The access roads must be designed and constructed as specified for detention ponds in Section 10.2.

10.4 Detention Facilities - Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete.

1. Detention vaults may be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized.

2. The invert elevation of the outlet should be elevated above the bottom of the vault to provide an average of six inches (6”) of sediment storage over the entire bottom. The outlet should also be elevated a minimum of two feet (2’) above the orifice to retain oil within the vault.

3. Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops.

4. All vaults must meet structural requirements for overburden support and H-20 traffic loading (see Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet any live load requirements of Carson City. Cast-in-place wall sections must be designed as retaining walls. A licensed civil engineer with structural expertise must stamp structural designs for cast in-place vaults. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes unless analyzed in a geotechnical report for stability and constructability.

5. Access must be provided over the inlet pipe and outlet structure. The following guidelines for access should be followed.
   a. Access openings should be positioned a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults.
   b. For vaults with greater than 1,250 square feet of floor area, a 5-foot by 10-foot removable panel should be provided over the inlet pipe (instead of a standard frame, grate, and solid cover). Alternatively, a separate access vault may be provided.
   c. For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided. Ladders and handholds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified below.
   d. All access openings, except those covered by removable panels, may have round, solid locking lids, or three-foot (3’) square, locking diamond plate covers.
   e. Vaults with widths 10 feet or less must have removable lids.
   f. The maximum depth from finished grade to the vault invert should be 20 feet.

g. Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells.
h. The minimum internal height should be seven feet (7') from the highest point of the vault floor and the minimum width should be four feet (4'). However, concrete vaults may be a minimum three feet (3') in height and width if used as tanks with access manholes at each end and if the width is not larger than the height. Also, the minimum internal height requirement may not be needed for any areas covered by removable panels.
i. Vaults must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas.
j. Ventilation pipes (minimum 12-inch diameter or equivalent) should be provided in all four (4) corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively, removable panels over the entire vault may be provided.

6. Access roads are needed to the access panel, the control structure, and at least one access point per cell. Access roads should be designed and constructed as specified for detention ponds.

10.5 Flow Restrictor Outlets

The flow restrictor outlet shall be sized to control discharge from a detention facility. The outfall from a flow restrictor shall be provided by a culvert or pipe conduit. The types of flow restrictors for parking lot detention may be under-sidewalk weirs or pipes.

In all ponds, tanks, and vaults, a primary overflow must be provided to bypass the 25-year developed peak flow over or around the restrictor system. The bypass should be designed to prevent breaching of the pond embankments or overflows upstream of the detention facility during periods of high flow or in the event that the primary outlet is plugged by debris.

The restrictor device usually consists of two (2) or more orifices and/or a weir section sized to meet performance requirements. In most cases, control structures need only two (2) orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary, to meet performance requirements. A one-inch (1") diameter minimum orifice is recommended.

An access road to the control structure is needed for inspection and maintenance and must be designed and constructed as specified for detention ponds in Section 10.2.

Manhole and catch basin lids for control structures must be locking and rim elevations must match the proposed finish grade.

Manholes and catch-basins must meet the OSHA confined space requirements, which include clearly marking entrances to confined space areas.

10.6 Spillways

All detention facilities shall have the ability to pass flows in excess of the design storm without endangering the structural integrity of the facility or diverting flows from their historical drainage pattern. Impacts to downstream properties shall be considered when siting and designing the spillway(s). Emergency overflow spillways are intended to control the location of pond overtopping in the event of total control structure failure or extreme inflows, and to direct overflows back into the downstream conveyance system or other acceptable discharge points.

The emergency overflow spillway must be armored with rip-rap. The spillway must be armored within its full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system. Guidance for the design of the rip-rap can be found in HEC-11, "Design of Rip-rap Revetment," and GEC-14, "Hydraulic Design of Energy Dissipaters for Culverts and Channels."

10.7 Sizing Requirements

All detention basins shall have emergency spillways that safely pass, as a minimum, a hydrograph developed by using the 100-year return period, 24-hour duration storm.

10.8 Embankment Protection

Embankments shall be protected from structural failure from overtopping. Overtopping can be caused by a larger than design inflow, or from obstruction of the low flow outlet. Embankment protection shall be provided by embankment armoring (i.e., rip-rap), use of slopes of 5:1 (horizontal to vertical) or flatter, or by a design overflow section (i.e., emergency spillway). The invert of the emergency spillway shall be set equal to or above the design stormwater surface elevation.

10.9 Planting Requirements

Exposed earth on the pond bottom and interior side slopes may be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract may be planted with grass or should be landscaped.

10.10 Landscaping

If provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide recreational space. In other instances, “naturalistic” stormwater facilities may be placed in open space tracts.

The following guidelines should be followed if landscaping is proposed for facilities.

1. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, should be avoided within 50 feet of pipes or manmade structures.

2. Planting should be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.

    a. Trees or shrubs may not be planted on portions of water impounding berms taller than four feet (4’) high. Only grasses may be planted on berms taller than four feet (4’).

    b. Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.

    c. Trees planted on portions of water-impounding berms less than four feet (4’) high must be small, not higher than 20 feet mature height, and have a fibrous root system.

    d. These trees reduce the likelihood of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

10.11 Maintenance Requirements

All detention facilities shall be designed to minimize maintenance and to allow access by equipment and workers to perform maintenance. Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance of on-site facilities is the responsibility of the owner and shall be transferred with the property to the new owner. The Owner may be a private party, corporation, partnership, or homeowner’s association.

Maintenance of sediment forebays and attention to sediment accumulation with the pond is extremely important. Sediment deposition should be periodically monitored in the basin. Owners, operators, and maintenance personnel should be aware that significant concentrations of metals, as well as some organics such as pesticides, might be expected to accumulate at the bottom of these facilities. Testing of sediment, especially near points of inflow, should be conducted periodically to determine the level of accumulation of materials that may require special handling prior to disposal.

Additional maintenance information is contained in Appendix A.

11. Trash Racks, Headwalls, and Access Control

All outlet works, the upper end of all closed conduits, and low flow conduits shall be provided with a trash rack for debris control. The trash rack shall provide a maximum bar spacing not to exceed two-thirds (2/3) of the outlet opening or diameter. The total area of the trash rack shall allow for the passage of the design outlet flow with 50 percent of the trash rack blocked. Concrete headwalls may be required on any inlet or outlet pipe. Outlet pipes may be required to provide access control.

12. Water Quality Treatment Facilities and BMPs

Stormwater runoff can alter natural drainage patterns and add pollutants such as sediment, oil and grease, chemicals, organics, pesticides, nutrients, bacteria and viruses and trash to the Carson River, Clear Creek, and the numerous small waterways and wetlands in the Carson City area. Numerous studies have shown urban runoff to be a significant source of water pollution, causing declines in fisheries, restrictions on swimming, and limiting the ability of the public to enjoy the benefits of these water resources. The emphasis of the Carson City Stormwater Pollution Prevention Program is to promote the concept and practice of preventing pollution at the source before it can cause environmental problems.

Stormwater pollutants are described in Table 7.

Table 7 – Pollutant Impacts on Water Quality

(From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003)

Sediment	Sediment is a common component of stormwater and can be a pollutant. Sediment can be detrimental to aquatic life (primary producers, benthic invertebrates, and fish) by interfering with photosynthesis respiration, growth, reproduction, and oxygen exchange in water bodies. Sediment can transport other pollutants that are attached to it, including nutrients, trace metals, and hydrocarbons. Sediment is the primary component of total suspended solids (TSS), a common water quality analytical parameter.
Nutrients	Nutrients, including nitrogen and phosphorous, are the major plant nutrients used for fertilizing landscapes and are often found in stormwater. These nutrients can result in the excessive or accelerated growth of vegetation, such as algae, resulting in impaired use of water in lakes and other sources of water supply. For example, nutrients have led to a loss of water clarity in Lake Tahoe. In addition, un-ionized ammonia (one of the nitrogen forms) can be toxic to fish.
Bacteria and viruses	Bacteria and viruses are common contaminants of stormwater. For separate storm drain systems, sources of these contaminants include animal excrement and sanitary sewer overflow. High levels of indicator bacteria in stormwater have led to the closure of beaches, lakes, and rivers to contact recreation such as swimming.
Oil and Grease	Oil and grease include a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations. Sources of oil and grease include leakage, spills, cleaning, and sloughing associated with vehicle and equipment engines and suspensions, leaking and breaks in hydraulic systems, restaurants, and waste oil disposal.
Metals	Metals, including lead, zinc, cadmium, copper, chromium, and nickel, are commonly found in stormwater. Many of the artificial surfaces of the urban environment (e.g., galvanized metal, paint, automobiles, or preserved wood) contain metals, which enter stormwater as the surfaces corrode, flake, dissolve, decay, or leach. Over half the trace metal load carried in stormwater is associated with sediments. Metals are of concern because they are toxic to aquatic organisms, can bioaccumulate (accumulate to toxic levels in aquatic animals such as fish), and have the potential to contaminate drinking water supplies.

Organics	Organics may be found in stormwater in low concentrations. Often synthetic organic compounds (adhesives, cleaners, sealants, solvents, etc.) are widely applied and may be improperly stored and disposed of. In addition, deliberate dumping of these chemicals into storm drains and inlets causes environmental harm to waterways.
Pesticides	Pesticides (including herbicides, fungicides, rodenticides, and insecticides) have been repeatedly detected in stormwater at toxic levels, even when pesticides have been applied in accordance with label instruction. As pesticide use has increased, so have concerns about the adverse effects of pesticides on the environment and human health. Accumulation of these compounds in simple aquatic organisms, such as plankton, provides an avenue for biomagnification through the food web, potentially resulting in elevated levels of toxins in organisms that feed on them, such as fish and birds.
Gross Pollutants	Gross Pollutants (trash, debris, and floatables) may include heavy metals, pesticides, and bacteria in stormwater. Typically resulting from an urban environment, industrial sites and construction sites, trash and floatables may create an aesthetic “eyesore” in waterways. Gross pollutants also include plant debris (such as leaves and lawn-clippings from landscape maintenance), animal excrement, street litter, and other organic matter. Such substances may harbor bacteria, viruses, vectors, and depress the dissolved oxygen levels in streams, lakes, and estuaries, sometimes causing fish kills.
Vector Production	Vector production (e.g., mosquitoes, flies, and rodents) is frequently associated with sheltered habitats and standing water. Unless designed and maintained properly, standing water may occur in treatment control BMPs for 72 hours or more, thus providing a source for vector habitat and reproduction.

Stormwater quality protection may involve such strategies as reducing or eliminating post-project runoff, control of sources of pollutants, and, if necessary, treating contaminated stormwater runoff before discharge to the storm drain system or receiving water.

Stormwater quality control in arid regions such as Carson City cannot rely on many of the water quality treatment techniques developed in humid regions due to the lack of rainfall, high evaporation rates, and highly erosive soils. The emphasis of the Carson City water quality program is aggressive source control, better site design practices, and application of stormwater treatment practices adapted for arid regions.

12.1 Stormwater Pollutants and Impacts on Water Quality

Stormwater runoff naturally contains numerous constituents. Urbanization and urban activities, including development and redevelopment, typically increase constituent concentration to levels that impact water quality.

Stormwater pollution control must be practiced during construction to eliminate impacts to water quality due to erosion and sedimentation and discharge of pollutants associated with construction. Equally important is the control of stormwater pollution from the completed development and associated land uses. Stormwater pollution from completed developments may occur as a result of the following:

1. New sources of dry-weather runoff that may contain pollutants;
2. Increased amounts of impervious surface that increase the rate and volume of runoff that may increase downstream erosion potential and associated potential water quality impairment;
3. Urban activities and increased impervious surfaces which can increase the concentration and/or the total load of many of the pollutants mentioned above in wet weather stormwater runoff.

12.2 Stormwater Pollution Source Controls

Source control BMPs prevent pollution or other adverse effects of stormwater from occurring in the first place. Most of these BMPs are common-sense “good housekeeping” measures targeted for various pollutant generating activities and sources. Source control BMPs may be either operational or structural; examples include methods as varied as pollution prevention for residential and commercial areas, street sweeping, and more frequent storm drain clean-outs. Each source control BMP acts to reduce the accumulation of pollutants on impervious surfaces or within the storm drain system during dry weather, which reduces the supply of pollutants that can wash off when it rains.

It is generally more cost-effective to use source controls to prevent pollutants from entering runoff than to treat runoff to remove pollutants. However, source controls cannot prevent all impacts from stormwater; a combination of measures is usually needed.

Stormwater pollution source control BMPs that should be considered for incorporation into new development or redevelopment projects are described in the following sections. The source control fact sheets that are included are listed in Table 9. The fact sheets detail planning methods and concepts that should be taken into consideration by developers during project design.

Table 8 – Source Control BMPs

Source Controls	
SC-1	Roof Runoff Controls
SC-2	Efficient Irrigation
SC-3	Storm Drain System Signs
SC-4	Fueling Areas
SC-5	Maintenance Bays
SC-6	Trash Enclosures
SC-7	Vehicle Washing Areas
SC-8	Outdoor Material Storage Areas
SC-9	Outdoor Work Areas
SC-10	Outdoor Processing Areas

12.3 Water Quality Treatment BMPs

Water quality treatment BMPs include facilities that remove pollutants from stormwater by filtration, biological uptake, adsorption, and/or gravity settling of particulate pollutants. The need for a project to provide runoff treatment facilities depends on (1) the type and amount of pollutants expected to be generated by the completed project and (2) the vulnerability of the receiving waters to the pollutants of concern. A combination of BMPs may be required to protect the receiving waters.

Water quality treatment BMPs are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorus); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides.

The major pollutants of concern for the Carson River and its tributaries are total suspended solids (TSS), phosphorus, turbidity, temperature, total iron, and mercury. Iron and mercury are not typically found in high quantities in municipal stormwater runoff but are more typically from naturally occurring mineral deposits or from uncontrolled runoff from industrial or mining activities. The focus for water quality treatment facilities will be the removal of TSS, phosphorus, and turbidity.

Several treatment options that are used across the country are not recommended for arid regions, including wet ponds, stormwater wetlands, and biofiltration swales unless there is a source of water that is available to sustain the plant growth. Because of the difficulty of designing and maintaining viable water quality treatment facilities in arid climates, implementation of the source control methods discussed in Section 12.2 and the site design methods discussed in BMP SD-1 are very important. General design modifications for stormwater treatment options for arid and semi-arid regions are shown in Table 9. Best management practice information and design criteria for many water quality treatment options will be provided to allow the designer to employ the option that best fits the project site.

Table 9 – Suggested Stormwater Treatment Options for Arid Regions

Stormwater Practice	Arid Watersheds <15 inches/year	Semi-Arid Watersheds 15 to 35 inches/year
Sand filters	PREFERRED • requires greater pretreatment • sensitive to sediment loadings • exclude pervious areas	PREFERRED
Bioretention/Bio-infiltration Swales	MAJOR MODIFICATION • no irrigation • better pretreatment • treat no pervious area • xeriscape plants or no plants • replace mulch with gravel	MAJOR MODIFICATION • use runoff to supplement irrigation • use xeriscaping plants • avoid trees • replace mulch with gravel
Extended detention dry ponds	PREFERRED • multiple storm extended detention • stable pilot channels • "dry" forebay	ACCEPTABLE • dry or wet forebay needed
Infiltration	MAJOR MODIFICATION • no recharge for hotspot land uses • treat no pervious area • multiple pretreatment • soil limitations	MAJOR MODIFICATION • no recharge for hotspot land uses • treat no pervious area • multiple pretreatment
Wet ponds	NOT RECOMMENDED • evaporation rates are too high to maintain a normal pond without extensive use of scarce water	LIMITED USE • liners to prevent water loss • require water balance analysis design for a variable rather than permanent normal pool • use water sources such as AC condensate for pool aeration unit to prevent stagnation
Rooftop Infiltration	PREFERRED • dry well design for recharge of residential rooftops	PREFERRED • recharge rooftop runoff on-site unless the land use is a hotspot
Infiltration	MAJOR MODIFICATION • no recharge for hotspot land uses • treat no pervious area • multiple pretreatment • soil limitation	MAJOR MODIFICATION • no recharge for hotspot land uses • treat no pervious area • multiple pretreatment
Swales	NOT RECOMMENDED • not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	LIMITED USE • limited use unless irrigated • rock berms and grade control essential to prevent erosion in open channels.
From: Stormwater Strategies for Arid and Semi-Arid Watersheds, Watershed Protection Techniques. 3(3): 695-706		

12.3.1 Performance Goals

The water quality design storm volume and flow rates are intended to capture and effectively treat at least 90 percent of the annual runoff volume.

Pollutant removal performance goals for basic treatment facilities is to remove 80 percent of the total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the facilities are intended to achieve an effluent goal of 20 mg/l total suspended solids. Facilities designed to remove phosphorus are intended to achieve a 50 percent reduction of total influent phosphorus for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorous. Water quality monitoring will not be required. The above criteria are meant for sizing structural BMPs

Water quality treatment BMPs fall into two (2) categories - public domain BMPs and manufactured (proprietary) BMPs. The public domain and manufactured treatment BMPs that are included in this manual are shown in Table 10.

Table 10 – Treatment Control BMPs

Public Domain	Manufactured (Proprietary)
Infiltration	Infiltration
TC - 1 Infiltration Trench TC - 2 Infiltration Basin	
Detention and Settling	Detention and Settling
TC - 3 Wet Pond TC - 4 Extended Detention Basin TC - 5 Constructed Wetland	MC-4 Wet Vaults
Biofiltration	Biofiltration
TC - 6 Vegetated Swale TC - 7 Vegetated Buffer Strip	
Filtration	Filtration
TC - 8 Sand Filter TC - 9 Sand Filter Vault TC - 10 Linear Sand Filter TC - 11 Water Quality Inlet	MC – 1 Media Filter
Flow-Through Separation	Flow-Through Separation
TC - 11 Water Quality Inlet TC - 12 Oil Water Separators	MC – 2 Catch Basin Inserts MC – 3 Manufactured Storm Drain Structures MC – 4 Wet Vaults

All of the BMPs in Table 9 can result in the removal of TSS. Generally wet vaults, compost filters, and infiltration in highly infiltrative soils provide lesser degrees of phosphorus treatment. BMPs can be combined to achieve TSS and phosphorus treatment. Table 11 indicates the ability of various treatment facilities to remove key pollutants such as TSS, dissolved metals, total phosphorus, pesticides and fungicides, and hydrocarbons, including oil and grease (O&G) and polyaromatic hydrocarbons (PAH).

Table 11 – Ability of Treatment Facilities to Remove Key Pollutants[2]
(Stormwater Management Manual for Eastern Washington, Final Draft, Washington Department of Ecology, 2003)

Treatment Facility	TSS	Dissolved Metals incl. Cu and Zn	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons Incl. O&G, PAH
Wet Pond	■	+	+		+
Wet Vault	■				
Biofiltration	■	+	+	+	+
Sand Filter	■	+	+		+
Constructed Wetland	■	■	+	■	■
Leaf Compost Filters	■	+		■	■
Infiltration [1]	■	+		+	+
Oil/Water Separator					■
Bio-infiltration	■	■	+		■

■ – Significant Process
+ - Lesser Process
(1) Assumes Loamy sand, Sandy loam or Loam soils
(2) If a cell is blank, then the treatment facility is not particularly effective at treating the identified pollutant.

BMP SD-1 Low-Impact Development Site Planning

Design Objectives

- ✓ Maximize Infiltration
- ✓ Minimize Runoff
- ✓ Minimize Impervious Land Coverage
- ✓ Water Quality Treatment
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Site planning strategies and techniques provide the means to achieve stormwater management goals and objectives, facilitate the development of site plans that are adapted to natural topographic constraints, maintain lot yield, maintain site hydrologic functions, and provide for aesthetically pleasing stormwater management controls.

The goal of low-impact development (LID) site planning is to allow for the full development of the property while maintaining the essential site hydrologic functions. This goal is accomplished in a series of incremental steps, including the following:

- Using hydrology as the integrating framework
- Thinking micromanagement
- Controlling stormwater at the source
- Using simplistic, nonstructural methods
- Creating a multifunctional landscape

LID techniques are being used on a limited basis in arid regions. Some of the techniques rely on vegetated bioretention facilities, green roofs, or other techniques that are more appropriate for areas with more rainfall. However, many of the LID techniques, such as minimization of impervious surfaces, minimization of ground disturbance during construction, and minimization of directly connected impervious areas can be of benefit in arid regions.

Approach

In LID technology, the traditional approach to site drainage is reversed to mimic the natural drainage functions. Instead of rapidly and efficiently draining the site, low-impact development relies on various planning tools and control practices to preserve the natural hydrologic functions of the site.

Potential site development and layout schemes are evaluated to reduce, minimize, and disconnect the total impervious area at the site. An analysis is conducted on the unavoidable impervious areas to minimize directly connected impervious surfaces. Bioretention areas, increased flow paths, infiltration devices, drainage swales, retention areas, and other practices can be used to control and break up these impervious areas. The end result is an integrated hydrologically functional site plan that maintains the predevelopment hydrology in addition to improving aesthetic values and providing recreational resources by adding additional landscape features.

The primary LID principle is to think small. This requires a change in perspective or approach with respect to the size of the area being controlled (i.e., microsubsheds), the size of the control practice (microtechniques), siting locations of controls, and the size and frequency of storms that are controlled. Micromanagement techniques implemented on small sub-catchments, or on residential lots, as well as common areas, allow for a distributed control of stormwater throughout the entire site. This offers significant opportunities for maintaining the site's key hydrologic functions, including infiltration, depression storage, and interception, as well as a reduction in the time of concentration.

The key to restoring the predevelopment hydrologic functions is first to minimize and then mitigate the hydrologic impacts of land use activities closer to the source of generation. Natural hydrologic functions such as interception, depression storage, and infiltration are evenly distributed throughout an undeveloped site. Trying to control or restore these functions using an end-of-pipe stormwater management approach is difficult. Therefore, compensation or restoration of these hydrologic functions should be implemented as close as possible to the point or source, where the impact or disturbance is generated. This distributed control strategy is one of the building blocks of low-impact development.

Traditionally, most stormwater management has focused on large end-of-pipe systems; and there has been a tendency to overlook the consideration of small, simple solutions. These simple solutions or systems have the potential to be more effective in preserving the hydrologic functions of the landscape, and they can offer significant advantages over conventional engineered facilities such as ponds or concrete conveyances.

Small, distributed, microcontrol systems also offer a major technical advantage: one or more of the systems can fail without undermining the overall integrity of the site control strategy.

The smaller facilities tend to feature shallow basin depths and gentle side slopes, which also reduce safety concerns. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions and add aesthetic value.

Design Considerations

The incorporation of LID concepts into the site planning process requires a number of steps. The steps of the LID site planning process may include the following:

Step 1: Define the development envelope.
Step 2: Reduce/minimize total site impervious area.
Step 3: Integrate the preliminary site layout plan.
Step 4: Minimize directly connected impervious area.
Step 5: Modify/Increase drainage flow paths.

Step 1: Define the development envelope.

The development envelope for the proposed site is done by identifying protected areas, setbacks, easement, topographic features, and existing subdrainage divides, and other site features. The site features that will be protected should be identified on the site map.

Identify the limits of clearing and grading, which should only be large enough to accommodate the developed areas, including roads, sidewalks, rooftops, and pervious areas such as graded lawn areas and open drainage systems. Development should be located in areas that are less sensitive to disturbance or have lower value in terms of hydrologic function to minimize hydrologic impacts on existing site land cover.

Clearing and grading and land-cover impacts can be reduced through minimal disturbance techniques that include the following:

- Reducing paving and compaction of highly permeable soils.
- Minimizing the size of construction easements and material storage areas, and siting stockpiles within the development envelope during the construction phase of a project.
- Siting building layout and clearing and grading to avoid removal of existing trees where possible.
- Minimizing imperviousness by reducing the total area of paved surfaces.
- Delineating and flagging the smallest site disturbance area possible to minimize soil compaction on the site and restricting temporary storage of construction equipment in these areas.
- Disconnecting as much impervious area as possible to increase opportunities for infiltration and reduce water runoff flow.
- Maintaining existing topography and associated drainage divides to encourage dispersed flow paths.

Step 2: Reduce/Minimize Total Impervious Area

After or concurrent with the mapping of the development envelope, the traffic pattern and road layout and preliminary lot layout are developed. The traffic distribution network, including roadways, sidewalks, driveways, and parking areas, is the greatest source of site imperviousness in most developments. For LID sites, managing the imperviousness contributed by road and parking area pavement is an important component of the site planning and design process. If allowed by development codes, the methods that can be used to achieve a reduction in the total runoff volume from impervious surfaces include the following.

Alternative Roadway Layout. Traffic or road layout can have a very significant influence on the total imperviousness and hydrology of the site plan. The total length of pavement for different road layouts can vary greatly. The typical gridiron pattern for streets with streets running north-south and east-west creates the greatest amount of impervious surface. Alternative layouts such as parallel streets, or loops and cul-de-sacs, can reduce impervious surfaces up to 26 percent.

Narrow Road Sections. Reduced width road sections are an alternative that can be used to reduce total site imperviousness as well as clearing and grading impacts. For example, reducing the width of paving from 36 feet to 24 feet represents a 33 percent reduction in paved width. Limiting sidewalks to one (1) side of the road can also reduce impervious surfaces.

Reduced On-Street Parking. Reducing on-street parking requirements to one (1) side, or even elimination of on-street parking altogether, has the potential to reduce road surfaces; and, therefore, overall site imperviousness by 25 to 30 percent. Two-sided parking requirements are often unnecessary to provide adequate parking facilities for each lot.

Rooftops. Rooftops contribute to site imperviousness, and the number of lots per acre (or lot coverage) generally determines the site's rooftop impervious area. House type, shape, and size can affect rooftop imperviousness. For example, more rooftop coverage is generally required for ranch-type homes that spread out square footage over one (1) level. With this in mind, vertical construction is favored over horizontal layouts to reduce the square footage of rooftops.

Driveways. Driveways are another element of the site plan that can be planned to reduce the total site imperviousness. Some techniques that can be used include:

- Limiting driveway width to nine feet (9').
- Minimizing building setbacks to reduce driveway length.
- Using driveway and parking area materials such as pervious pavers or gravel, which reduce runoff and increase travel times.

Step 3: Develop an Integrated Preliminary Site Plan

An integrated preliminary site plan can be developed after the development envelope has been developed and the total site imperviousness has been minimized. The preliminary site plan will provide a base for conducting the hydrologic analysis to compare the pre- and post-development site hydrology and to confirm that the overall objective of creating a hydrologically functional site is being met.

Step 4: Minimize Directly Connected Impervious Areas

After the total site imperviousness has been minimized and a preliminary site plan has been developed, achieve additional environmental benefits and reduce hydrologic impacts by disconnecting the unavoidable impervious areas as much as possible. Strategies for accomplishing this include:

- Disconnecting roof drains and directing flows to vegetated areas or dry wells.
- Directing flows from paved areas such as driveways to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Carefully locating impervious areas so that they drain to natural systems, vegetated buffers, natural resource areas, or zones/soils that can be used for infiltration.

Step 5: Modify/Increase Drainage Flow Paths

The time of concentration (Tc), in conjunction with the hydrologic site conditions, determines the peak discharge rate for a storm event. Site and infrastructure components that affect the time of concentration include:

- Travel distance (flow path)
- Slope of the ground surface and/or water surface
- Surface roughness
- Channel shape, pattern, and material components

Techniques that can affect and control the Tc can be incorporated into the LID concept by managing flow and conveyance systems within the development site:

- Maximize overland sheet flow.
- Increase and length flow paths.
- Lengthen and flatten site and lot slopes.
- Maximize use of open swale systems.

Overland Sheet Flow. The site should be graded to maximize the overland sheet flow distance and to minimize disturbance of woodland along the post-development TC flow path. This practice will increase travel times of the runoff and thus the time of concentration. Consequently, the peak discharge rate will be decreased. Flow velocity in areas that are graded to natural drainage patterns should be kept as low as possible to avoid soil erosion. Velocities in the range of two to five feet (2-5') per second are generally recommended. Flows can be slowed by installing a level spreader along the upland ledge of the natural drainage way buffer or creating a flat area about 30 feet wide on the upland side of the buffer where runoff can spread out.

Flow Path. Increasing the flow path of surface runoff increases infiltration and travel time. One of the goals of a LID site is to provide as much overland or sheet flow as allowed by local jurisdictional codes to increase the time it takes for rooftop and driveway runoff to reach an open swale drainage system. Rooftop and driveway runoff can be directed into bioretention facilities, infiltration trenches, dry wells, or cisterns that are strategically located to capture the runoff prior to its reaching the lawn. In addition, strategic lot grading can be designed to increase both the surface roughness and the travel length of the surface runoff.

Site and Lot Slopes. Constructing roads across steep-sloped areas unnecessarily increase soil disturbance to a site. Good road layouts avoid placing roads on steep slopes, by designing roads to follow grades and run along ridgelines. Steep site slopes often require increased cut and fill if roads are sited using conventional local road layout regulations. If incorporated into the initial subdivision layout process, slope can be an asset to the development. Alternative road layout options use road plans that designate the length of cul-de-sacs and the number of branches of side streets off collector streets based on the existing ridgelines and drainage patterns of a site.

For areas with rolling terrain with dissected ridges, use multiple short branch cul-de-sacs off collector streets. For flat terrain use fluid grid patterns. Interrupt grid to avoid natural drainage ways and other natural resources protection areas.

Open swales. Whenever possible, LID designs should use multi-functional open drainage systems in lieu of more conventional storm drain systems. To alleviate flooding problems and reduce the need for conventional storm drain systems, vegetated or grass open drainage systems should be provided as the primary means of conveying surface runoff between lots and along roadways. Lots should be graded to minimize the quantity and velocity of surface runoff within the open drainage systems.

From: Low-Impact Development Design Strategies, An Integrated Design Approach. Prince George's County, Maryland, Department of Environmental Resources, January 2000.

BMP SD-2 Landscape Planning

Design Objectives

- ✓ Maximize Infiltration
- ✓ Minimize Runoff
- ✓ Minimize Impervious Land Coverage
- ✓ Water Quality Treatment
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Each project site possesses unique topographic, hydrologic, and vegetative features, some of which are more suitable for development than others. Integrating and incorporating appropriate landscape planning methodologies into the project design is the most effective action that can be done to minimize surface and groundwater contamination from stormwater.

Approach

Landscape planning should couple the consideration of land suitability for urban uses with the consideration of community goals and projected growth. Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

Design requirements for site design and landscape planning should conform to applicable Carson City standards and specifications and policies.

Designing New Installations

Begin the development of a plan for the landscape unit with attention to the following general principles:

- Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
- Map and assess land suitability for urban uses. Include the following landscape features in the assessment: wooded land, open unwooded land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. Mapping and assessment should recognize not only these resources, but also additional areas needed for their sustenance.
- Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

Conserve Natural Areas during Landscape Planning

If applicable, the following items could be included in the site layout during the subdivision design process:

- Cluster development on least-sensitive portions of a site while leaving the remaining land in a natural undisturbed condition.
- Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
- Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.
- Promote natural vegetation by using parking lot islands and other landscaped areas.
- Preserve riparian areas and wetlands.

Maximize Natural Water Storage and Infiltration Opportunities Within the Landscape Unit

- Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases and either their negative effects or the expense of countering them with structural solutions.
- Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.

Protection of Slopes and Channels during Landscape Design

- Convey runoff safely from the tops of slopes.
- Avoid disturbing steep or unstable slopes.
- Avoid disturbing natural channels.
- Stabilize disturbed slopes as quickly as possible.
- Vegetate slopes with native or drought-tolerant vegetation.
- Control and treat the flow in landscaping and/or other controls prior to reaching existing natural drainage systems.
- Stabilize temporary and permanent channel crossings as quickly as possible and ensure that increases in runoff velocity and frequency caused by the project do not erode the channel.
- Install energy dissipaters, such as rip-rap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specifications to minimize erosion. Energy dissipaters shall be installed in such a way as to minimize impacts to receiving waters.
- Line on-site conveyance channels where appropriate, to reduce erosion caused by increased flow velocity due to increases in tributary impervious area. The first choice for linings should be grass or some other vegetative surface since these materials not only reduce runoff velocities but also provide water quality benefits from filtration and infiltration. If velocities in the channel are high enough to erode grass or other vegetative linings, rip-rap, concrete, soil cement, or geo-grid stabilization are other alternatives.
- Consider other design principles that are comparable and equally effective.

Redeveloping Existing Installations

If a redevelopment project meets the thresholds for water quality controls, the steps outlined under “designing new installations” above should be followed.

Redevelopment may present significant opportunity to add features which had not previously been implemented. Examples include the incorporation of depressions, areas of permeable soils, and swales in newly redeveloped areas. While some site constraints may exist due to the status of already existing infrastructure, opportunities should not be missed to maximize infiltration, slow runoff, reduce impervious areas, disconnect directly connected impervious areas.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Stormwater Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2010.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
- Stormwater Management Manual for Western Washington, Washington State Department of Ecology, July 2019.
- Truckee Meadows Structural Controls Design and Low Impact Development Manual, April 2015 Update.
- Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-1 Roof Runoff Controls

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Slow Runoff
- ✓ Contain Pollutants

Description

Various roof runoff controls are available to address stormwater that drains off rooftops. The objective is to reduce the total volume and rate of runoff from individual lots and retain the pollutants on-site that may be picked up from roofing materials and atmospheric deposition. Roof runoff controls consist of directing the roof runoff away from paved areas and mitigating flow to the storm drain system through one of several general approaches: cisterns or rain barrels; dry wells or infiltration trenches; pop-up emitters; and foundation planting. The first three (3) approaches require the roof runoff to be contained in a gutter and downspout system. Foundation planting provides a vegetated strip under the drip line of the roof.

Approach

Design of individual lots for single-family homes as well as lots for higher density residential and commercial structures should consider site design provisions for containing and infiltrating roof runoff or directing roof runoff to vegetative swales or buffer areas. Retained water can be reused for watering gardens, lawns, and trees. Benefits to the environment include reduced demand for potable water used for irrigation, improved stormwater quality, increased groundwater recharge, decreased runoff volume and peak flows, and decreased flooding potential.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

Designing New Installations

Cisterns or Rain Barrels
One method of addressing roof runoff is to direct roof downspouts to cisterns or rain barrels. A cistern is an above-ground storage vessel with either a manually operated valve or a permanently open outlet. Roof runoff is temporarily stored and then released for irrigation or infiltration between storms. The number of rain barrels needed is a function of the rooftop area. Some low impact developers recommend that every house has at least two (2) rain barrels, with a minimum storage capacity of 1,000 liters. Roof barrels serve several purposes, including mitigating the first flush from the roof, which has a high volume, number of contaminants, and thermal load. Several types of rain barrels are commercially available. Consideration must be given to selecting rain barrels that are vector proof and childproof. In addition, some barrels are designed with a bypass valve that filters out grit and other contaminants and routes overflow to a soak-away pit or rain garden.

If the cistern has an operable valve, the valve can be closed to store stormwater for irrigation or infiltration between storms. This system requires continual monitoring by the resident or grounds crews but provides greater flexibility in water storage and metering. If a cistern is provided with an operable valve and water is stored inside for long periods, the cistern must be covered to prevent mosquitoes from breeding.

A cistern system with a permanently open outlet can also provide for metering stormwater runoff. If the cistern outlet is significantly smaller than the size of the downspout inlet (say ¼ to ½ inch diameter), runoff will build up inside the cistern during storms and will empty out slowly after peak intensities subside. This is a feasible way to mitigate the peak flow increases caused by rooftop impervious land coverage, especially for the frequent, small storms.

Dry wells and Infiltration Trenches
Roof downspouts can be directed to dry wells or infiltration trenches. A dry well is constructed by excavating a hole in the ground and filling it with an open-graded aggregate and allowing the water to fill the dry well and infiltrate after the storm event. An underground connection from the downspout conveys water into the dry well, allowing it to be stored in the voids. To minimize sedimentation from lateral soil movement, the sides and top of the stone storage matrix can be wrapped in permeable filter fabric, though the bottom may remain open. A perforated observation pipe can be inserted vertically into the dry well to allow for inspection and maintenance. Figure SC-1-1 illustrates a typical downspout infiltration trench.

In practice, dry wells receiving runoff from single-roof downspouts have been successful over long periods because they contain very little sediment. They must be sized according to the amount of rooftop runoff received, but are typically four- to five-feet (4-5') square and two- to three-feet (2-3') deep, with a minimum of one-foot (1') soil cover over the top (maximum depth of 10 feet).

Dry wells must be set away from the building at least 10 feet to protect the foundation. They must be installed in solids that accommodate infiltration. In poorly drained soils, dry wells have very limited feasibility.

Infiltration trenches function in a similar manner and would be particularly effective for larger roof areas. An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. These are described under Treatment Controls.

Pop-up Drainage Emitter
Roof downspouts can be directed to an underground pipe that daylights some distance from the building foundation, releasing the roof runoff through a pop-up emitter. Similar to a pop-up irrigation head, the emitter only opens when there is flow from the roof. The emitter remains flush to the ground during dry periods for ease of lawn or landscape maintenance.

Foundation Planting
Landscape planting can be provided around the base to allow increased opportunities for stormwater infiltration and protect the soil from erosion caused by concentrated sheet flow coming off the roof. Foundation plantings can reduce the physical impact of water on the soil and provide a subsurface matrix of roots that encourage infiltration. These plantings must be sturdy enough to tolerate the heavy runoff sheet flows and periodic soil saturation.

Redeveloping Existing Installations

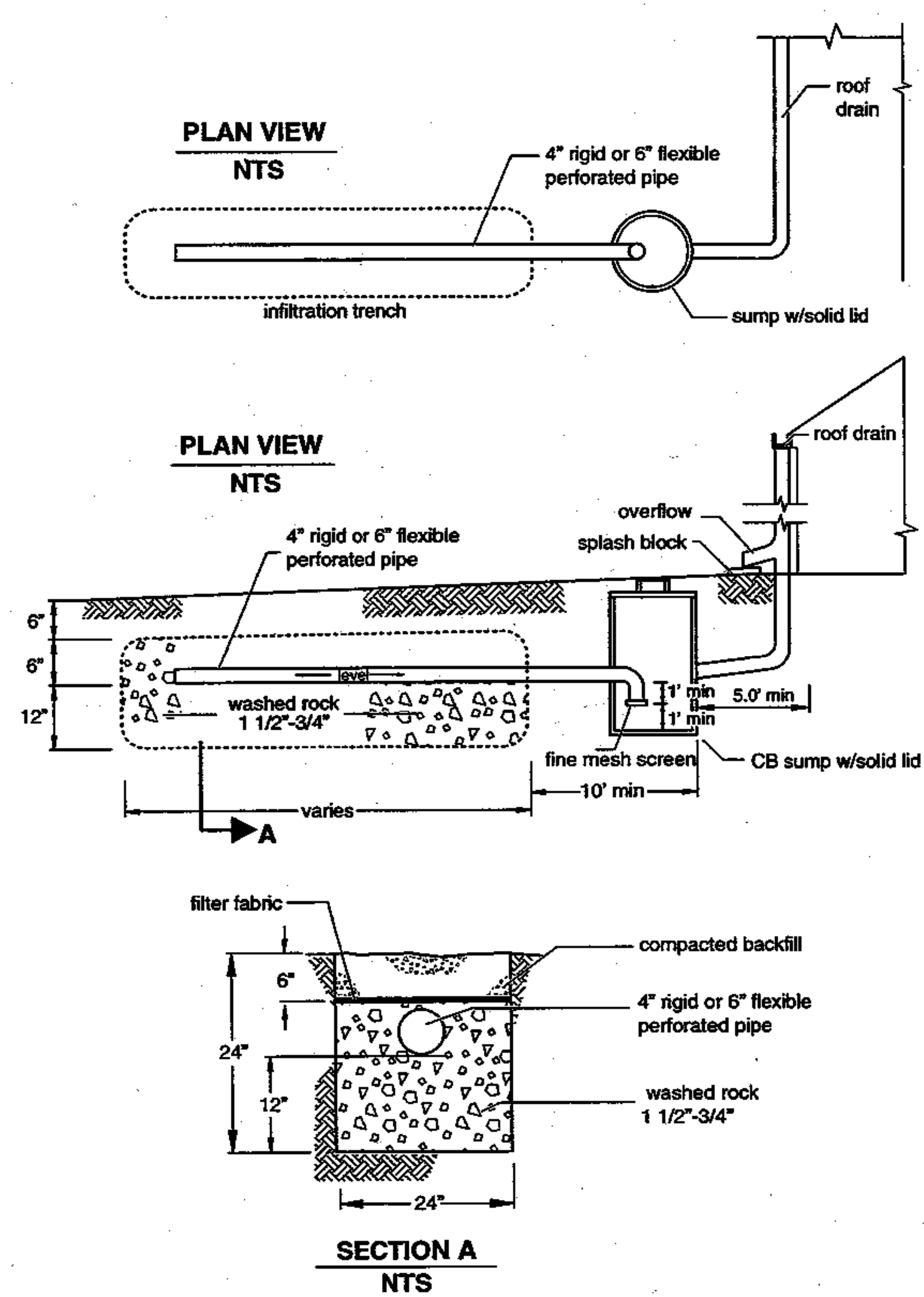
If a redevelopment project meets the thresholds for water quality controls, the steps outlined under "designing new installations" above should be followed.

Supplemental Information
Examples
- City of Ottawa's Water Links Surface –Water Quality Protection Program
- City of Toronto Downspout Disconnection Program
- City of Boston, MA, Rain Barrel Demonstration Program

Other Resources

- Hager, Marty Catherine, Stormwater, "Low-Impact Development", January/February 2003. www.stormh2o.com
- Low Impact Urban Design Tools, Low Impact Development Design Center, Beltsville, MD. www.lid-stormwater.net
- Start at the Source, Bay Area Stormwater Management Agencies Association, 1999 Edition
  From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association
- Truckee Meadows Structural Controls Design and Low Impact Development Manual, April 2015 Update.

Figure SC-1-1 Typical Downspout Infiltration Trench



Source: King County, 1998, Surface Water Design Manual

SC-2 Efficient Irrigation

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Slow Runoff

Description

Irrigation water provided to landscaped areas may result in excess irrigation water being conveyed into stormwater drainage systems.

Approach

Project plan designs for development and redevelopment should include application methods of irrigation water that minimizes runoff of excess irrigation water into the stormwater conveyance system.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

New Installations

The following methods to reduce excessive irrigation runoff should be considered, incorporated, and implemented where determined applicable and feasible by the applicant.

- Employ rain-triggered shutoff devices to prevent irrigation after precipitation.
- Design irrigation systems to each landscape area's specific water requirements.
- Include designs featuring flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken sprinkler heads or lines.
- Implement landscape plans that may include water sensors, programmable irrigation times, or other water conservation measures.
- Design timing and application methods of irrigation water to minimize the runoff of excess irrigation water into the stormwater drainage system.
- Group plants with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration. Choose plants with low irrigation requirements (for example, native or drought-tolerant species). Consider design features such as:
    - Using mulches (such as wood chips or bar) in planter areas without ground cover to minimize sediment in runoff
    - Installing appropriate plant materials for the location, in accordance with the amount of sunlight and climate, and use native plant materials where possible and/or as recommended by the landscape architect
    - Leaving a vegetative barrier along the property boundary and interior watercourses, to act as a pollutant filter, where appropriate and feasible
    - Choosing plants that minimize or eliminate the use of fertilizer or pesticides to sustain growth
- Employ other comparable, equally effective methods to reduce irrigation water runoff.

Redeveloping Existing Installations

When feasible, redevelopment projects should incorporate plans for efficient irrigation.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
- Truckee Meadows Structural Controls Design and Low Impact Development Manual, April 2015 Update.
- Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-3 Storm Drain Signage

Design Objectives

✓ Prohibit Dumping of Improper Materials

Description

Waste materials dumped into storm drain inlets can have severe impacts on receiving and groundwaters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. Storm drain signs and stencils are highly visible source controls that are typically placed directly adjacent to storm drain inlets.

Approach

The stencil or affixed sign contains a brief statement that prohibits the dumping of improper materials into the urban runoff conveyance system. Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal.

Suitable Applications

Stencils and signs alert the public to the destination of pollutants discharged to the storm drain. Signs are appropriate in residential, commercial, and industrial areas, as well as any other area where contributions or dumping to storm drains is likely.

Design Considerations

Storm drain message markers are required at all storm drain inlets within the boundary of a development project. The marker should be placed in clear sight facing anyone approaching the inlet from either side. All storm drain inlet locations shall be identified on the development site map.

The following methods shall be included in the project design and show on project plans:

- Provide markers at all storm drain inlets and catch basins, constructed, or modified, within the project area with Carson City standard markers saying “NO DUMPING – DRAINS TO RIVER” and includes a graphical icon to discourage illegal dumping.
- Post signs with prohibitive language and/or graphical icons, which prohibit illegal dumping at public access points along channels and creeks within the project area.

Additional Information

Maintenance Considerations

Legibility of markers and signs should be maintained. If required by the agency with jurisdiction over the project, the owner/operator or homeowner’s association should enter into a maintenance agreement with the agency or record a deed restriction upon the property title to maintain the legibility of placards or signs.

Placement

- Signage on top of curbs tends to weather and fade.
- Signage on the face of curbs tends to be worn by contact with vehicle tires and sweeper brooms.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
- Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-4 Fueling Areas

Design Objectives

- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Fueling areas have the potential to contribute oil and grease, solvents, car battery acid, coolant, and gasoline to the stormwater conveyance system. Spills at vehicle and equipment fueling areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices.

Approach

Project plans must be developed for cleaning near fuel dispensers, emergency spill cleanup, containment, and leak prevention.

Suitable Applications

Appropriate applications include commercial, industrial, and any other areas planned to have fuel dispensing equipment, including retail gasoline outlets, automotive repair shops, and major non-retail dispensing areas.

Design Considerations

Design requirements for fueling areas are governed by Building and Fire Codes and by current Carson City ordinances and zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements.

Designing New Installations

Covering

Fuel dispensing areas should provide an overhanging roof structure or canopy. The cover's minimum dimensions must be equal to or greater than the area within the grade break. The cover must not drain onto the fuel dispensing area, and the downspouts must be routed to prevent drainage across the fueling area. The fueling area should drain to the project's treatment control BMP(s) prior to discharging to the stormwater conveyance system. Note - If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent stormwater run-on and runoff. Grade to direct stormwater to a dead-end sump.

Surfacing

Fuel dispensing areas should be paved with Portland cement concrete (or equivalent smooth impervious surface). The use of asphalt concrete should be prohibited. Use asphalt sealant to protect asphalt paved areas surrounding the fueling area. This provision may be made to sites that have pre-existing asphalt surfaces. The concrete fuel dispensing area should be extended a minimum of 6.5 ft from the corner of each fuel dispenser or the length at which the hose and nozzle assembly may be operated plus one foot (1'), whichever is less.

Grading/Contouring

Dispensing areas should have an appropriate slope to prevent ponding and be separated from the rest of the site by a grade break that prevents run-on of urban runoff. (Slope is required to be two to four percent (2-4%) in some jurisdictions' stormwater management and mitigation plans.) Fueling areas should be graded to drain toward a dead-end sump. Runoff from downspouts/roofs should be directed away from fueling areas. Do not locate storm drains in the immediate vicinity of the fueling area.

Additional Information

In the case of an emergency, provide storm drain seals, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the stormwater conveyance system.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
- Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-5 Maintenance Bays & Docks

Design Objectives

- ✓ Prohibit Dumping of Improper Materials
- ✓ Contain Pollutants
- ✓ Source Control
- ✓ Collect and Convey

Description

Several measures can be taken to prevent operations at maintenance bays and loading docks from contributing a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the stormwater conveyance system.

Approach

In designs for maintenance bays and loading docks, containment is encouraged. Preventative measures include overflow containment structures and dead-end sumps. However, in the case of loading docks from grocery stores and warehouse/distribution centers, engineered infiltration systems may be considered.

Suitable Applications

Appropriate applications include commercial and industrial areas planned for development or redevelopment.

Design Considerations

Design requirements for vehicle maintenance and repair are governed by Building and Fire Codes, and by Carson City ordinances and zoning requirements. The design criteria described in this fact sheet are meant to enhance and be consistent with these code requirements.

Designing New Installations

Designs of maintenance bays should consider the following:

- Repair/maintenance bays and storage of vehicle parts with fluids should be provided indoors or designed to preclude urban run-on and runoff.
- Repair/maintenance floor areas should be paved with Portland cement concrete (or equivalent smooth impervious surface).
- Repair/maintenance bays should be designed to capture all wash water leaks and spills. Provide impermeable berms, drop inlets, trench catch basins, or overflow containment structures around repair bays to prevent spilled materials and wash-down waters from entering the storm drain system. Connect drains to a sump for collection and disposal. Direct connection of the repair/maintenance bays to the storm drain system is prohibited. If required by NDEP, obtain an Industrial Waste Discharge Permit.
- Other features may be comparable and equally effective.

The following designs of loading/unloading dock areas should be considered:

- Loading dock areas should be covered, or drainage should be designed to preclude urban run-on and runoff.

- Direct connections into storm drains from depressed loading docks (truck wells) are prohibited.
- Below-grade loading docks from grocery stores and warehouse/distribution centers of fresh food items should drain through water quality inlets, or to an engineered infiltration system, or an equally effective alternative. Pre-treatment may also be required.
- Other features may be comparable and equally effective.

Additional Information

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
- Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-6 Trash Storage Areas

Design Objectives

- ✓ Prohibit Dumping of Improper Material
- ✓ Source Control
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Trash storage areas are areas where a trash receptacle(s) is located for use as a repository for solid wastes. Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of stormwater pollution include dumpsters, litter control, and waste piles.

Approach

This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling. Preventative measures, including enclosures, containment structures, and impervious pavements to mitigate spills, should be used to reduce the likelihood of contamination.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment. (Detached residential single-family homes are typically excluded from this requirement.)

Design Considerations

Design requirements for waste handling areas are governed by Building and Fire Codes, and by Carson City ordinances and zoning requirements. The design criteria described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in federal, state, and Carson City codes.

Wastes from commercial and industrial sites are typically hauled by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria in this fact sheet are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection areas. Conflicts or issues should be discussed with the Development Services.

Designing New Installations

Trash storage areas should be designed to consider the following structural or treatment control BMPs:

- Design trash container areas so that drainage from adjoining roofs and pavement is diverted around the area(s) to avoid run-on. This might include berming or grading the waste handling area to prevent the run-on of stormwater.

- Make sure trash container areas are screened or walled to prevent off-site transport of trash. Use lined bins or dumpsters to reduce liquid waste leakage.
- Provide roofs, awnings, or attached lids on all trash containers to minimize direct precipitation and prevent rainfall from entering containers.
- Pave trash storage areas with an impervious surface to mitigate spills.
- Do not locate storm drains in the immediate vicinity of the trash storage area.
- Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

Additional Information

Maintenance Considerations

The integrity of structural elements that are subject to damage (i.e., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the local agency and the owner/operator may be required. Some agencies will require maintenance deed restrictions to be recorded on the property title. If required by the local agency, maintenance agreements, or deed restrictions must be executed by the owner/operator before improvement plans are approved.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
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SC-7 Vehicle Washing Areas

Design Objectives

- ✓ Maximize Infiltration
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Vehicle washing, equipment washing, and steam cleaning may contribute high concentrations of metals, oil and grease, solvents, phosphates, and suspended solids to wash waters that drain to stormwater conveyance systems.

Approach

Project plans should include appropriately designed area(s) for washing/steam cleaning of vehicles and equipment. Depending on the size and other parameters of the wastewater facility, wash water may be conveyed to a sewer, an infiltration system, a recycling system, or other alternatives. Pretreatment may be required for conveyance to a sanitary sewer.

Suitable Applications

Appropriate applications include commercial developments, restaurants, retail gasoline outlets, automotive repair shops, and others.

Design Considerations

Design requirements for vehicle maintenance are governed by Building and Fire Codes, and by current Carson City ordinances and zoning requirements. Design criteria described in this fact sheet are meant to enhance and be consistent with these code requirements.

Designing New Installations

Areas for washing/steam cleaning should incorporate one of the following features:

- Be self-contained and/or covered with a roof or overhang
- Be equipped with a clarifier or other pretreatment facility
- Have a proper connection to a sanitary sewer
- Include other features which are comparable and equally effective

It is generally advisable to cover areas used for regular washing of vehicles, trucks, or equipment; surround them with a perimeter berm; and clearly mark them as a designated washing area. Sumps or drain lines can be installed to collect wash water, which may be treated for reuse or recycling, or for discharge to the sanitary sewer.

Additional Information

Maintenance Considerations

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
  Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

SC-8 Outdoor Material Storage Areas

Design Objectives
✓ Contain Pollutants

Description

Proper design of outdoor storage areas for materials reduces the opportunity for toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to enter the stormwater conveyance system. Materials may be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Approach

Outdoor storage areas require a drainage approach different from the typical infiltration/detention strategy. In outdoor storage areas, infiltration is discouraged. Containment is encouraged. Preventative measures include enclosures, secondary containment structures, and impervious surfaces.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact. However, these materials may have toxic effects on receiving waters if allowed to be discharged with stormwater in significant quantities. Accumulated material on an impervious surface could result in a significant impact on the rivers or streams that receive the runoff.

Material may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Design requirements for material storage areas are governed by Building and Fire Codes, and by current City ordinances and zoning requirements. Control measures are site-specific and must meet local requirements.

Designing New Installations

Where proposed project plans include outdoor areas for storage of materials that may contribute pollutants to the stormwater conveyance system, the following structural or treatment BMPS should be considered:

- Materials with the potential to contaminate stormwater should be: (1) placed in an enclosure such as, but not limited to, a cabinet, shed, or similar structure that prevents contact with runoff or spillage to the stormwater conveyance system, or (2) protected by secondary containment structures such as berms, dikes, or curbs.
- The storage area should be paved and sufficiently impervious to contain leaks and spills.

- The storage area should slope towards a dead-end sump to contain spills, and direct runoff from downspouts/roofs should be directed away from storage areas.
- The storage area should have a roof or awning that extends beyond the storage area to minimize the collection of stormwater within the secondary containment area. A manufactured storage shed may be used for small containers.

Note that the location(s) of installations of where these preventative measures will be employed must be included on the map or plans identifying BMPs.

Additional Information

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permits.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
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SC-9 Outdoor Work Areas

Design Objectives
✓ Contain Pollutants
✓ Collect and Convey

Description

Proper design of outdoor work areas for materials reduces the opportunity for toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to enter the stormwater conveyance system.

Approach

Outdoor work areas require a drainage approach different from the typical infiltration/detention strategy. In outdoor work areas, infiltration is discouraged; collection and conveyance are encouraged. In outdoor work areas, infiltration is discouraged, and runoff is often routed directly to the sanitary sewer, not the storm drain. Because this runoff is being added to the loads normally received by the wastewater treatment plants, municipal stormwater programs and/or private developers must work with the local plant to develop solutions that minimize effects on the treatment facility. These concerns are best addressed in the planning and design stage of the outdoor work area.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

Design requirements for outdoor work areas are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements.

Designing New Installations

Outdoor work areas can be designed in particular ways to reduce impacts on both stormwater quality and sewage treatment plants.

- Create an impermeable surface such as concrete or asphalt, or a prefabricated metal drip pan, depending on the use.
- Cover the area with a roof. This prevents rain from falling on the work area and becoming polluted runoff.
- Berm or perform mounding around the perimeter of the area to prevent water from adjacent areas from flowing on to the surface of the work area.
- Directly connect runoff. Unlike other areas, runoff from work areas is directly connected to the sanitary sewer or other specialized containment system(s). This allows the more highly concentrated pollutants from these areas to receive special treatment that removes particular constituents. Approval for this connection must be obtained from the appropriate sanitary sewer agency.
- Locate the work area away from storm drains or catch basins.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
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SC-10 Outdoor Processing Areas

Design Objectives

- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

Outdoor process equipment operations such as rock grinding or crushing, painting or coating, grinding or sanding, degreasing or parts cleaning, landfills, waste piles, wastewater and solid waste treatment and disposal, and others operations may contribute a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the storm conveyance system.

Approach

Outdoor processing areas require a drainage approach different from the typical infiltration/detention strategy. In outdoor process equipment areas, infiltration is discouraged. Containment is encouraged, accompanied by collection and conveyance. Preventative measures include enclosures, secondary containment structures, dead-end sumps, and conveyance to treatment facilities in accordance with conditions established by the applicable sewer agency.

Suitable Applications

Appropriate applications include commercial and industrial areas planned for development or redevelopment.

Design Considerations

Design requirements for outdoor processing areas are governed by adopted building and fire codes, and by Carson City ordinances and zoning requirements.

Designing New Installations

Operations determined to be a potential threat to water quality should consider the following recommendations:

- Cover or enclose areas that would be the most significant source of pollutants or slope the area toward a dead-end sump; or, discharge to the sanitary sewer system following appropriate treatment in accordance with conditions established by the applicable sewer agency.
- Grade or berm area to prevent run-on from surrounding areas.
- Do not install storm drains in areas of equipment repair.
- Consider other features that are comparable or equally effective.
- Provide secondary containment structures (not double-wall containers) where wet material processing occurs (e.g., electroplating), to hold spills resulting from accidents, leaking tanks, or equipment, or any other unplanned releases (note: if these are plumbed to the sanitary sewer, they must be with the prior approval of Development Services).

Additional Information

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Other Resources

- A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.
- California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
- Low Impact Development Standards Manual, County of Los Angeles Department of Public Works, February 2014.
- Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, August 1, 2012.
- Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, May 19, 2011.
- Model Water Quality Management Plan (WQMP) for South Orange County, County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, September 28, 2017.
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SM-1 Pervious Pavements

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Slow Runoff
- ✓ Minimize Impervious Land Coverage

Description

Pervious paving is used for light vehicle loading in parking areas. The term describes a system comprising a load bearing, durable surface together with an underlying layered structure that temporarily stores water prior to infiltration or drainage to a controlled outlet. The surface can itself be porous such that water infiltrates across the entire surface of the material (e.g., grass and gravel surfaces, porous concrete, and porous asphalt), or can be built up of impermeable blocks separated by spaces and joints, through which the water can drain. This latter system is termed 'permeable' paving. An advantage of pervious pavements is that they reduce runoff volume while providing treatment. Another advantage is that they are unobtrusive, resulting in a high level of acceptability.

Approach

Attenuation of flow is provided by the storage within the underlying structure or subbase, together with appropriate flow controls. An underlying geotextile may permit groundwater recharge, thus contributing to the restoration of the natural water cycle. Alternatively, where infiltration is inappropriate (e.g., if the groundwater vulnerability is high or the soil type is unsuitable), the surface can be constructed above an impermeable membrane. The system offers a valuable solution for drainage of spatially constrained urban areas.

Significant attenuation and improvement in water quality can be achieved by permeable pavements; whichever method is used. The surface and subsurface infrastructure can remove both the soluble and fine particulate pollutants that occur within urban runoff. Roof water can be piped into the storage area directly, adding areas from which the flow can be attenuated. Also, within lined systems, there is the opportunity for stored runoff to be piped out for reuse.

Suitable Applications

Residential, commercial, and industrial applications are possible. The use of permeable pavement may be restricted in cold regions, arid regions, or regions with high wind erosion. There are some specific disadvantages associated with permeable pavement, which are as follows:

- Permeable pavement can become clogged if improperly installed or maintained. However, this is countered by the ease with which small areas of paving can be cleaned or replaced when blocked or damaged.
- Their application should be limited to highways with low traffic volumes, axle loads and speeds (less than 30 mph limit), car parking areas, and other lightly trafficked or non-trafficked areas. Permeable surfaces are currently not considered suitable for adoptable roads due to the risks associated with failure on high-speed roads, the safety implications of ponding, and disruption arising from their reconstruction.
- When using unlined, infiltration systems, there is some risk of contaminating groundwater, depending on soil conditions and aquifer susceptibility. However, this risk is likely to be small because the areas drained tend to have inherently low pollutant loadings.
- The use of permeable pavement is restricted to gentle slopes.
- Porous block paving has a higher risk of abrasion and damage than solid blocks.

Design Considerations

Designing New Installations

If the grades, subsoils, drainage characteristics, and groundwater conditions are suitable, permeable paving may be substituted for conventional pavement on parking areas, cul-de-sacs, and other areas with light traffic. Slopes should be flat or very gentle. Scottish experience has shown that permeable paving systems can be installed in a wide range of ground conditions, and the flow attenuation performance is excellent even when the systems are lined.

The suitability of a pervious system at a particular pavement site will, however, depend on the loading criteria required of the pavement.

Where the system is to be used for infiltrating drainage waters into the ground, the vulnerability of local groundwater sources to pollution from the site should be low, and the seasonal high-water table should be at least four feet (4') below the surface.

Ideally, the pervious surface should be horizontal in order to intercept local rainfall at the source. On sloping sites, pervious surfaces may be terraced to accommodate differences in levels.

Design Guidelines

The design of each layer of the pavement must be determined by the likely traffic loadings and their required operational life. The following criteria should be considered to provide satisfactory performance:

- The subgrade should be able to sustain traffic loading without excessive deformation.
- The granular capping and sub-base layers should give sufficient load bearing to provide an adequate construction platform and base for the overlying pavement layers.
- The pavement materials should not crack or suffer excessive rutting under the influence of traffic. This is controlled by the horizontal tensile stress at the base of these layers.

There is no current structural design method specifically for pervious pavements. The following factors in the design and specification of materials:

- Pervious pavements use materials with high permeability and void space. All the current pavement design methods are based on the use of conventional materials that are dense and relatively impermeable. The stiffness of the materials must, therefore, be assessed.
- Water is present within the construction and can soften and weaken materials, and this must be allowed for.
- Existing design methods assume full friction between layers. Any geotextiles or geomembranes must be carefully specified to minimize the loss of friction between layers.
- Porous asphalt loses adhesion and becomes brittle as air passes through the voids. Its durability is, therefore, lower than conventional materials.

The single sized grading of materials used means that care should be taken to ensure that loss of finer particles between unbound layers does not occur.

Positioning a geotextile near the surface of the pervious construction should enable pollutants to be trapped and retained close to the surface of the construction. This has both advantages and disadvantages. The main disadvantage is that the filtering of sediments and their associated pollutants at this level may hamper the percolation of waters and can eventually lead to surface ponding. One advantage is that even if eventual maintenance is required to reinstate infiltration, only a limited amount of the construction needs to be disturbed since the sub-base below the geotextile is protected. In addition, the pollutant concentration at a high level in the structure allows for its release over time. It is slowly transported in the stormwater to lower levels where chemical and biological processes may be operating to retain or degrade pollutants.

The design should ensure that sufficient void space exists for the storage of sediments to limit the period between remedial works.

- Pervious pavements require a single size grading to give open voids. The choice of materials is, therefore, a compromise between stiffness, permeability, and storage capacity.
- Because the sub-base and capping will be in contact with water for a large part of the time, the strength and durability of the aggregate particles when saturated and subjected to wetting and drying should be assessed.
- A uniformly graded single size material cannot be compacted and is liable to move when construction traffic passes over it. This effect can be reduced by the use of angular crushed rock material with high surface friction.

In pollution control terms, these layers represent the site of long-term chemical and biological pollutant retention and degradation processes. The construction materials should be selected, in addition to their structural strength properties, for their ability to sustain such processes. In general, this means that materials should create neutral or slightly alkaline conditions, and they should provide favorable sites for colonization by microbial populations.

Construction/Inspection Considerations

- Permeable surfaces can be laid without cross-falls or longitudinal gradients.
- The blocks should be laid level.
- They should not be used for the storage of site materials unless the surface is well protected from the deposition of silt and other spillages.
- The pavement should be constructed in a single operation, as one of the last items to be built, on a development site. Landscape development should be completed before pavement construction to avoid contamination by silt or soil from this source.
- Surfaces draining to the pavement should be stabilized before construction of the pavement.
- Inappropriate construction equipment should be kept away from the pavement to prevent damage to the surface, sub-base, or sub-grade.

Maintenance Requirements

The maintenance requirements of a pervious surface should be reviewed at the time of design and should be clearly specified. Maintenance is required to prevent clogging of the pervious surface. The factors to be considered when defining maintenance requirements must include:

- Type of use
- Ownership
- Level of trafficking
- The local environment and any contributing catchments

Studies in the UK have shown the satisfactory operation of porous pavement systems without maintenance for over 10 years, and recent work by Imbe et al. at 9th ICUD, Portland, 2002 describes systems operating for over 20 years without maintenance. However, performance under such regimes could not be guaranteed. Table SM-1 shows typically recommended maintenance regimes:

Table SM-1 Typical Recommended Maintenance Regimes
Activity Schedule

Activity	Schedule
• Minimize use of salt or grit for deicing • Keep landscaped areas well maintained • Prevent soil being washed onto pavement	Ongoing
• Vacuum clean surface using commercially available sweeping machines at the following times: o End of winter (April) o Mid-summer (July/August) o After Autumn leaf-fall (November)	3 x per year
• Inspect outlets	Annual
• If routine cleaning does not restore infiltration rates, then reconstruction of part of the whole of a pervious surface may be required. • The surface area affected by hydraulic failure should be lifted for inspection of the internal materials to identify the location and extent of the blockage. • Surface materials should be lifted and replaced after brush cleaning. Geotextiles may need complete replacement. • Sub-surface layers may need cleaning and replacing. • Removed silts may need to be disposed of as controlled waste.	As needed (infrequent) Maximum 15-20 years

Additional Information

Cost Considerations

Permeable pavements are up to 25 percent cheaper (or at least no more expensive than the traditional forms of pavement construction) when all construction and drainage costs are taken into account. (Accepting that the porous asphalt itself is a more expensive surfacing, the extra cost of which is offset by the savings in underground pipework, etc.) (Niemczynowicz, et al., 1987)

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From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

SM-2 Alternative Building Materials

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Source Control

Description

Alternative building materials are selected instead of conventional materials for new construction and renovation. These materials reduce potential sources of pollutants in stormwater runoff by eliminating compounds that can leach into the runoff, reducing the need for pesticide application, reducing the need for painting and other maintenance, or by reducing the volume of runoff.

Approach

Alternative building materials are available for use as lumber for decking, roofing materials, home siding, and paving for driveways, decks, and sidewalks.

Suitable Applications

Appropriate applications include residential, commercial, and industrial areas planned for development or redevelopment.

Design Considerations

Designing New Installations
Decking

One of the most common materials for construction of decks and other outdoor construction has traditionally been pressure-treated wood, which is now being phased out. The standard treatment is called CCA, for chromated copper arsenate. The key ingredients are arsenic (which kills termites, carpenter ants, and other insects), copper (which kills the fungi that cause wood to rot), and chromium (which reacts with the other ingredients to bind them to the wood). The amount of arsenic is far from trivial. A deck just eight feet x ten feet (8'x10') contains more than 1 1/3 pounds of this highly potent poison. Replacement materials include a new type of pressure-treated wood, plastic, and composite lumber.

There are currently over 20 products in the market consisting of plastic or plastic-wood composites. Plastic lumber is made from 100 percent recycled plastic, # 2 HDPE and polyethylene plastic milk jugs, and soap bottles. Plastic-wood composites are a combination of plastic and wood fibers or sawdust. These materials are long-lasting exterior weather, insect, and chemical resistant wood lumber replacements for nonstructural applications. Use it for decks, docks, raised garden beds and planter boxes, pallets, hand railings, outdoor furniture, animal pens, boat decks, etc.

New pressure treated wood uses a much safer recipe, ACQ, which stands for ammoniacal copper quaternary. It contains no arsenic and no chromium. Yet the American Wood Preservers Association has found it to be just as effective as the standard formula. ACQ is common in Japan and Europe.

Roofing

Several studies have indicated that metal used as a roofing material, flashing, or gutters can leach metals into the environment. The leaching occurs because rainfall is slightly acidic and slowly dissolves the exposed metals. Common traditional applications include copper sheathing and galvanized (zinc) gutters.

Coated metal products are available for both roofing and gutter applications. These products eliminate contact of bare metal with rainfall, eliminating one source of metals in the runoff. There are also roofing materials made of recycled rubber and plastic that resemble traditional materials.

A less traditional approach is the use of green roofs. These roofs are not just green; they're alive. Planted with grasses and succulents, low-profile green roofs reduce the urban heat island effect, stormwater runoff, and cooling costs while providing wildlife habitat and a connection to nature for building occupants. These roofs are widely used on industrial facilities in Europe and have been established as experimental installations in several locations in the US, including Portland, Oregon. Their feasibility is questionable in areas with prolonged, dry, hot weather.

Paved Areas

Traditionally, concrete is used for the construction of patios, sidewalks, and driveways. Although it is non-toxic, these paved areas reduce stormwater infiltration and increase the volume and rate of runoff. This increase in the amount of runoff is the leading cause of stream channel degradation in urban areas.

There are a number of alternative materials that can be used in these applications, including porous concrete and asphalt, modular blocks, and crushed granite. These materials, especially modular paving blocks, are widely available and a well-established method to reduce stormwater runoff.

Building Siding

Wood siding is commonly used on the exterior of residential construction. This material weathers fairly rapidly and requires repeated painting to prevent rotting. Alternative “new” products for this application include cement-fiber and vinyl. Cement-fiber siding is a masonry product made from Portland cement, sand, and cellulose and will not burn, cup, swell, or shrink.

Pesticide Reduction

A common use of powerful pesticides is for the control of termites. Chlordane was used for many years for this purpose and is now found in urban streams and lakes nationwide. There are a number of physical barriers that can be installed during construction to help reduce the use of pesticides.

Sand barriers for subterranean termites are a physical deterrent because the termites cannot tunnel through it. Sand barriers can be applied in crawl spaces under pier and beam foundations, under slab foundations, and between the foundation and concrete porches, terraces, patios, and steps. Other possible locations include under fence posts, underground electrical cables, water and gas lines, telephone and electrical poles, inside hollow tile cells, and against retaining walls.

Metal termite shields are physical barriers to termites that prevent them from building invisible tunnels. In reality, metal shields function as a helpful termite detection device, forcing them to build tunnels on the outside of the shields, which are easily seen. Metal termite shields also help prevent dampness from wicking to adjoining wood members, which can result in rot, thus making the material more attractive to termites and other pests. Metal flashing and metal plates can also be used as a barrier between piers and beams of structures such as decks, which are particularly vulnerable to termite attack.

Other Resources

There are no good, independent, comprehensive sources of information on alternative building materials for use in minimizing the impacts of stormwater runoff. Most websites or other references to “green” or “alternative” building materials focus on indoor applications, such as formaldehyde-free plywood and low VOC paints, carpets, and pads. Some supplemental information on alternative materials is available from the manufacturers. Fires are a source of concern in many areas of the arid West. Information on the flammability of alternative decking materials is available from the University of California Forest Product Laboratory (UCFPL) website at http://www.ucfpl.ucop.edu/WDDeckIntro.htm.

From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

SD-3 Downspout Dispersion

Design Objectives

- ✓ Maximize Infiltration
- ✓ Source Control

Description

Downspout dispersion BMPs are splashblocks or gravel-filled trenches that serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, minimizes directly connected impervious area, and allows for some infiltration, and provides some water quality benefits.

Approach

Downspout dispersion is applicable for all subdivision single-family lots on which downspout infiltration is not provided.

Suitable Applications

Downspout dispersion is appropriate for most residential single-family lots.

Design Considerations

Dispersion trenches designed as shown in Figures SD-3-1 and SD-3-2 can be used for downspout dispersion applications except where splashblocks are allowed. Figure SD-3-3 shows a typical splashblock design.

Splashblocks may be used for downspouts discharged to a vegetated flow path at least 50 feet in length as measured from the downspout to the downstream property line, structure, sensitive steep slope, stream, wetland, or other impervious surfaces. Sensitive area buffers may count toward flowpath lengths. The vegetated flowpath must be covered with a well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

If the vegetated flowpath is less than 25 feet on a subdivision single-family lot, a perforated stub-out connection may be used in lieu of downspout dispersion. A perforated stub-out may also be used where the implementation of downspout dispersion might cause erosion or flooding problems, either on-site or on adjacent lots.

Trenches serving up to 700 square feet of roof area may be simple 10-foot long by 2-foot wide gravel-filled trenches. For roof areas larger than 700 square feet, a dispersion trench with notched grade board, as shown in Fig. SD-3-2 may be used as approved by Carson City Development Services. The total length of this design must provide at least 10 feet of trench per 700 square feet of roof area and not exceed 50 feet.

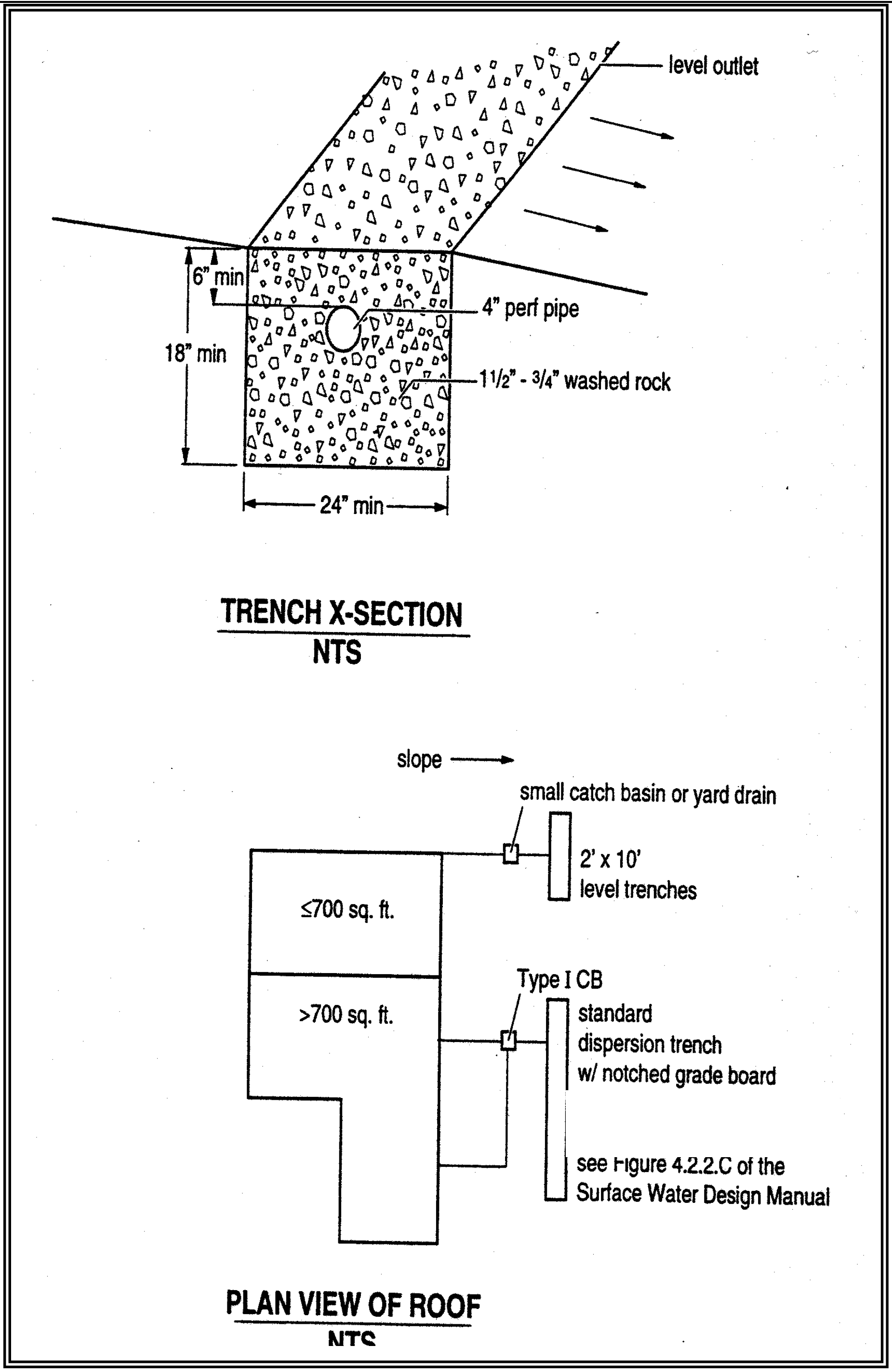
A setback of at least five feet (5’) must be maintained between any edge of the trench and any structure or property line.

No erosion or flooding of downstream properties may result.

Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. Several downspouts could discharge at the same location. This configuration might pose a potential hazard for lower-lying lots or locations where dispersed flows could create problems for adjacent offsite lots. This provision does not apply to situations where lots are flat and onsite downspout dispersal would result in saturated yards.

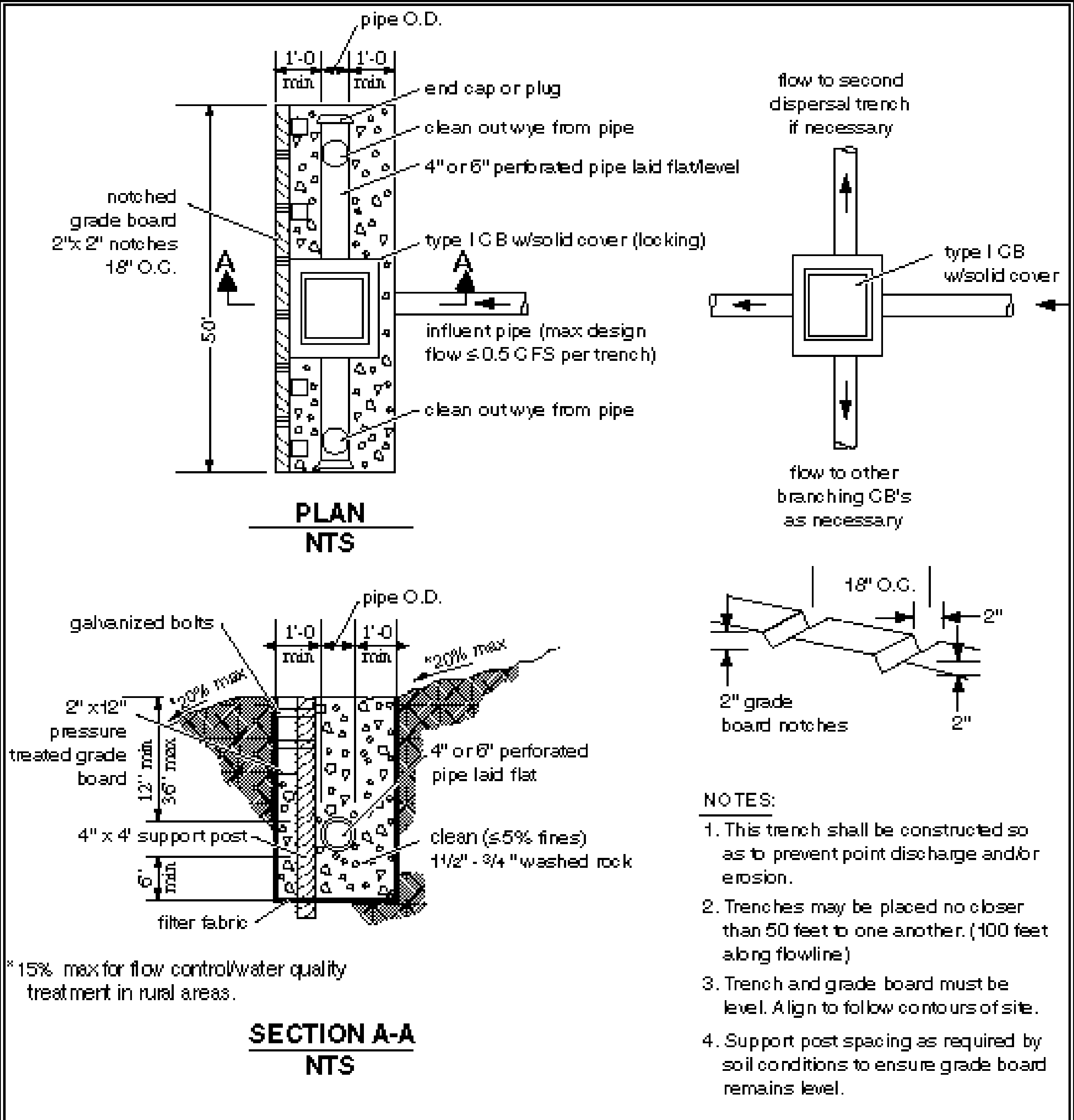
From: Stormwater Management Manual for Western Washington, 2001, Washington Department of Ecology

Figure SD-3-1 Typical Downspout Dispersion Trench



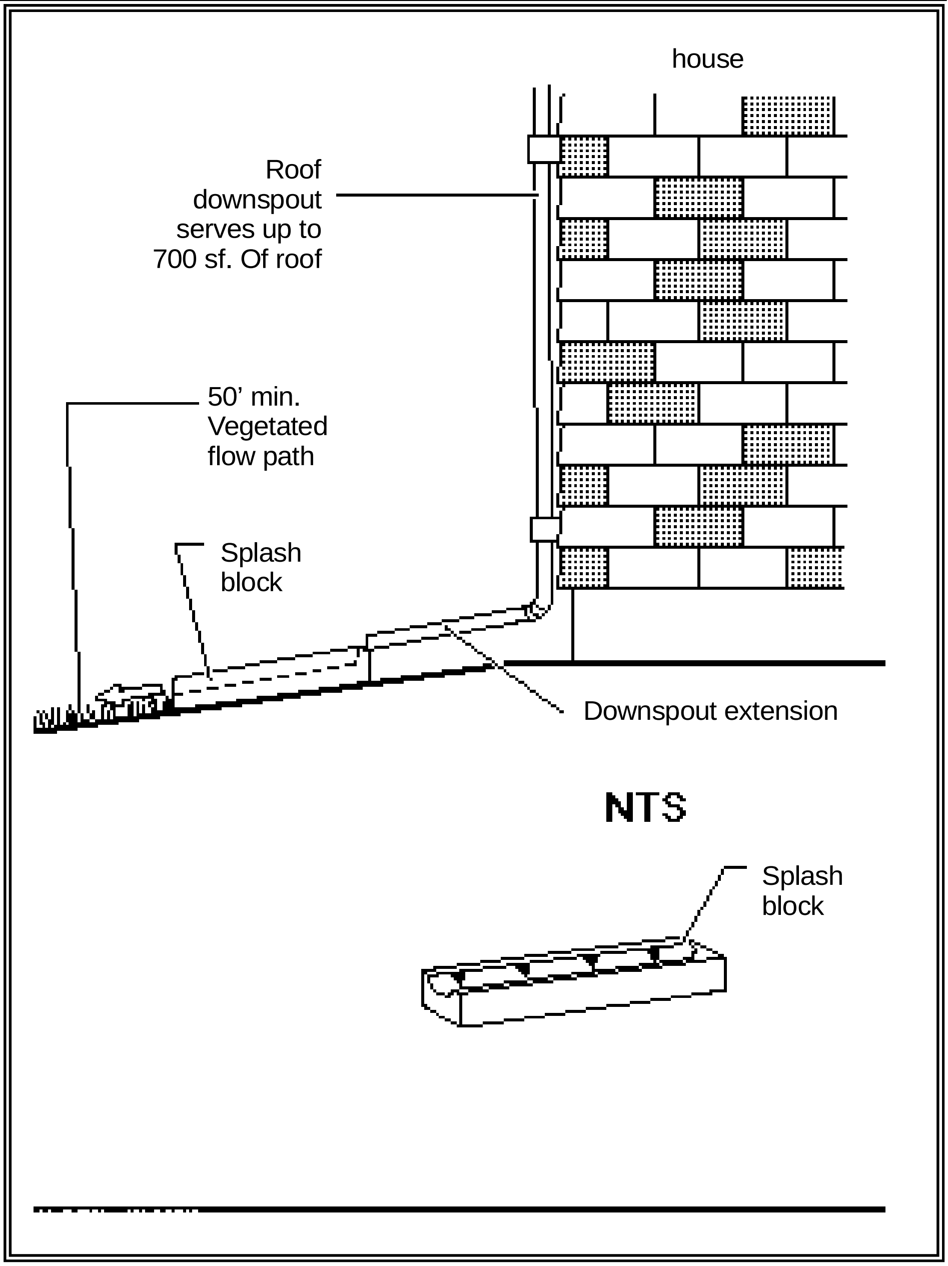
Source: King County, 1998, Surface Water Design Manual

Figure SD-3-2 Standard Dispersion Trench with Notched Grade Board



Source: Washington Department of Ecology, 2005, Stormwater Management Manual for Western Washington

Figure SD-3-3 Typical Downspout Splashblock Dispersion



Source: Washington Department of Ecology, 2005, Stormwater Management Manual for Western Washington

SD-4 Concentrated Flow Dispersion

Design Objectives

- ✓ Maximize Infiltration
- ✓ Source Control

Description

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits.

Approach

Concentrated flow dispersion is appropriate for use on all larger single-family subdivision lots on which infiltration is not provided.

Suitable Applications

Concentrated flow dispersion may be used in any situation where the concentrated flow can be dispersed through vegetation.

Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.

Figure SD-4-1 shows two (2) possible ways of spreading flows from steep driveways.

Design Considerations

A vegetated flowpath of at least 50 feet should be maintained between the discharge point and any property line, structure, steep slope, stream, wetland, or other impervious surfaces.

A maximum of 700 square feet of an impervious area may drain to each dispersion BMP.

A pad of crushed rock (two feet (2') wide by three feet (3') long by six inches (6") deep) shall be placed at each discharge point.

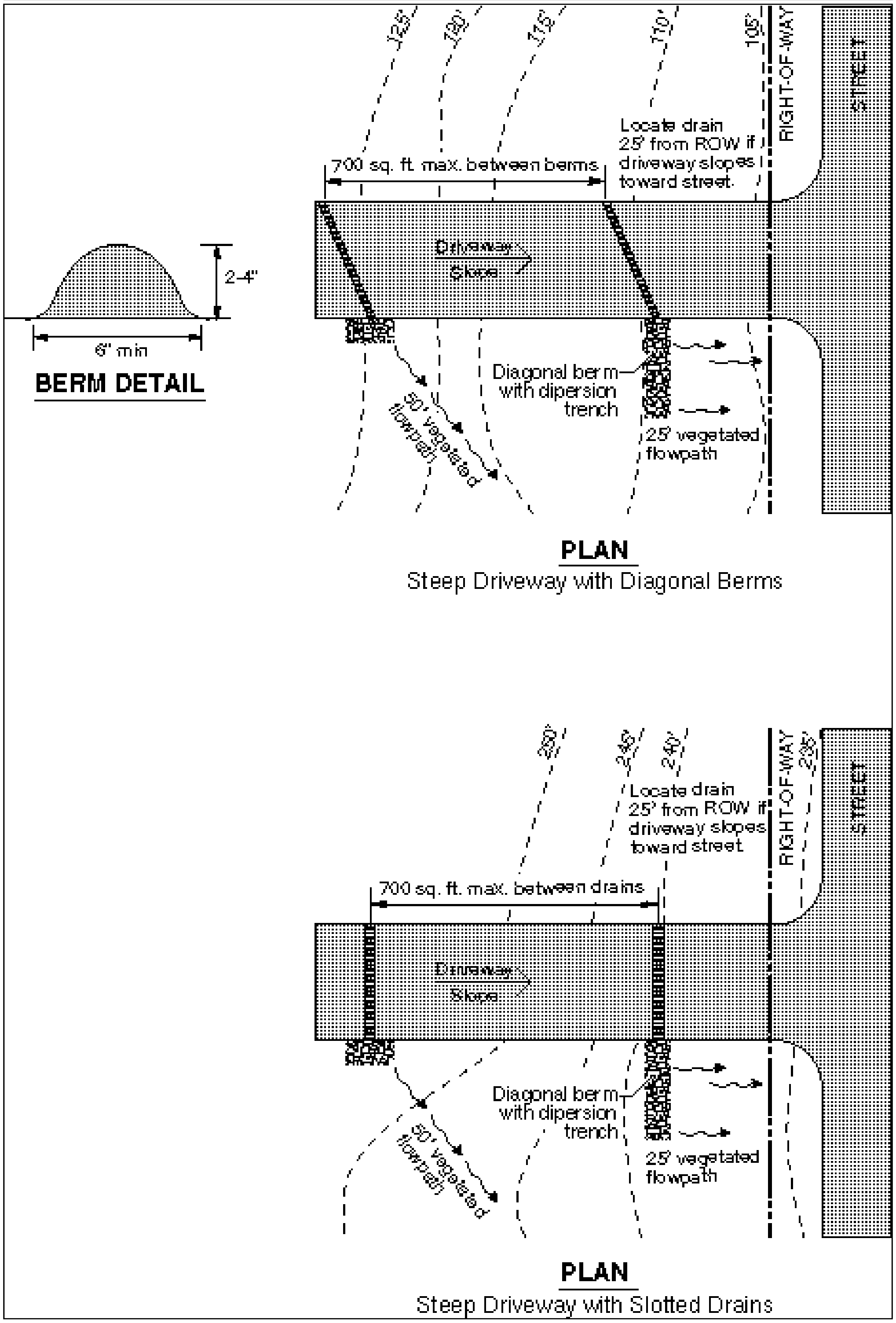
No erosion or flooding of downstream properties may result.

Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes greater than 20 percent or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by Carson City Development Services.

For sites with septic systems, the discharge point should be downgradient of the drainfield primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drainfield.

From: Stormwater Management Manual for Eastern Washington, 2003, Washington Department of Ecology

Figure SD-4 Typical Concentrated Flow Dispersion for Steep Driveways



Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

SD-5 Sheet Flow Dispersion

Design Objectives
✓ Maximize Infiltration
✓ Source Control

Description

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded so as to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.

Approach

Sheet flow dispersion is appropriate for use on flat or moderately sloping areas to minimize directly connected impervious areas and concentrated flow.

Suitable Applications

Flat or moderately sloping (<15% slope) impervious surfaces such as driveways, sports courts, patios, and roofs without gutters; slowing cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture; or any situation where the concentration of flows can be avoided.

Design Considerations

A two-foot (2') wide transition zone to discourage channeling should be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material acceptable to Carson City Development Services.

A vegetated buffer width of 10 feet of vegetation must be provided for up to 20 feet of the width of paved or impervious surface. An additional five feet (5') of width must be added for each additional 20 feet of width or fraction thereof.

A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, and/or pasture). Slopes within the 25-foot minimum flowpath through vegetation should be no steeper than eight percent (8%). If this criterion cannot be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in the slope above eight percent (8%).

No erosion or flooding of downstream properties may result.

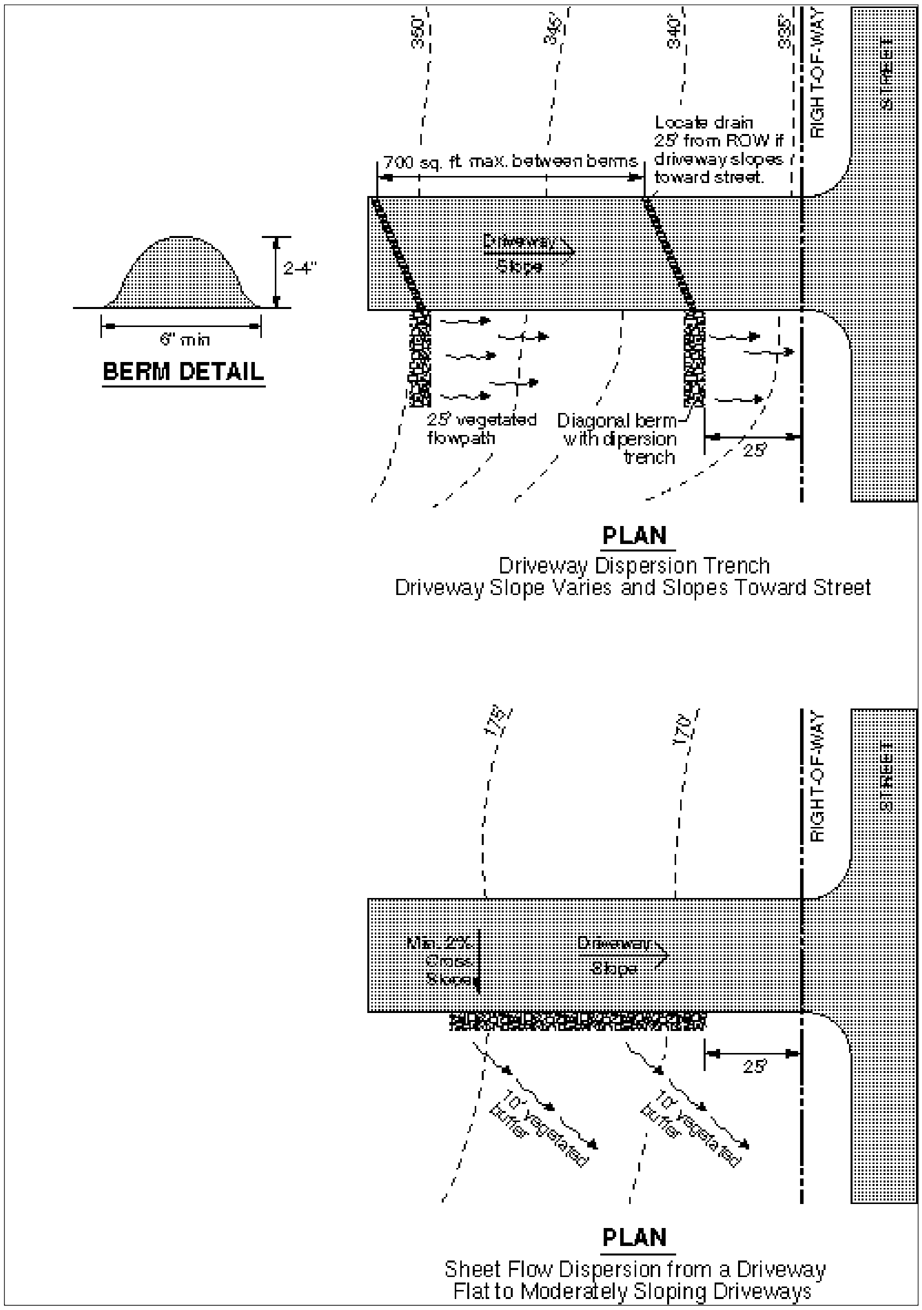
Runoff discharge toward landslide hazard areas must be evaluated by a geotechnical engineer or a qualified geologist. The discharge point may not be placed on or above slopes greater than 20 percent or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval of Carson City Development Services.

For sites with septic systems, the discharge point must be down gradient of the drainfield primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drainfield.

Figure SD-5-1 shows a typical method for sheet flow dispersion for relatively level driveways.

From: Stormwater Management Manual for Eastern Washington, 2003, Washington Department of Ecology

Figure SD-5-1 Sheet Flow Dispersion for Driveways



Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

TC-1 Infiltration Trench

Design Objectives
✓ Maximize Infiltration
✓ Provide Retention
✓ Collect and Convey

Description

An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. Infiltration trenches are generally at least 24 inches wide and are backfilled with coarse stone aggregate. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or grass-covered areas with a surface inlet. Infiltration trenches perform well for the removal of fine sediment and associated pollutants. Pretreatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench, which can clog and render the trench ineffective.

Figures TC-1-1 through TC-1-3 illustrate various methods of infiltration trench design.

Advantages

- It provides a 100 percent reduction in the load discharged to surface waters.
- An important benefit of infiltration trenches is the approximation of pre-development hydrology during which a significant portion of the average annual rainfall runoff is infiltrated rather than flushed directly to creeks.
- If the water quality volume is adequately sized, infiltration trenches can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.
- As an underground BMP, trenches are unobtrusive and have little impact on site aesthetics.
- Infiltration trenches typically consume about two to three percent (2-3%) of the site draining to them, which is relatively small. In addition, infiltration trenches can fit into thin, linear areas. Thus, they can generally fit into relatively unusable portions of a site.

Limitations

- Have a high failure rate if soil and subsurface conditions are not suitable.
- In addition to reduced water quality performance, clogged infiltration trenches with surface standing water can become a nuisance due to mosquito breeding. If the trench takes more than 72 hours to drain, then the rock fill should be removed, and all dimensions of the trench should be increased by two inches (2") to provide a fresh surface for infiltration.
- May not be appropriate for industrial sites or locations where spills may occur.
- The maximum contributing area to an individual infiltration practice should generally be less than five (5) acres.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- Upstream drainage areas must be completely stabilized before construction.
- Difficult to restore the functioning of infiltration trenches once clogged.
- One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly sited or maintained, infiltration trenches have a high failure rate. In general, maintenance costs for infiltration trenches are estimated at between five percent (5%) and 20 percent of the construction cost. More realistic values are probably closer to the 20 percent range, to ensure long-term functionality of the practice.

Siting Criteria

The use of infiltration trenches may be limited by a number of factors, including the type of native soils and the location of the groundwater table. Site characteristics, such as the excessive slope of the drainage area, fine-grained soil types, and proximate location of the water table and bedrock, may preclude the use of infiltration trenches. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils containing clay and silt or in areas with fill.

As with any infiltration BMP, the potential for groundwater contamination must be carefully considered, especially if the groundwater is used for human consumption or agricultural purposes. The infiltration trench is not suitable for sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from entering the trench. In these areas, other BMPs that do not allow interaction with the groundwater should be considered.

The potential for spills can be minimized by aggressive pollution prevention measures. For example, diversion structures can be used to prevent spills from entering the infiltration trench. Because of the potential to contaminate groundwater, extensive site investigation must be undertaken early in the site planning process to establish site suitability for the installation of an infiltration trench.

Longevity can be increased by careful geotechnical evaluation prior to construction and by designing and implementing an inspection and maintenance plan. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for the proper operation of an infiltration trench. Pretreatment structures, such as a vegetated buffer strip or water quality inlet, can increase longevity by removing sediments, hydrocarbons, and other materials that may clog the trench. Regular maintenance, including the replacement of clogged aggregate, will also increase the effectiveness and life of the trench.

Evaluation of the viability of a particular site is the same as for infiltration basins and includes:

- Determine soil type (consider RCS soil type 'A, B, or C' only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than

30 percent clay or more than 40 percent of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.

- The base of all infiltration trench systems should be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan), or other low permeability layers.
- Location away from buildings, slopes, and highway pavement (greater than 20 feet) and wells and bridge structures (greater than 100 feet). Sites constructed of fill, having a base flow or with a slope greater than 15 percent, should not be considered.
- Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.
- Base flow should not be present in the tributary watershed.

Secondary Screening Based on Site Geotechnical Investigation

- At least three (3) in-hole conductivity tests shall be performed using USBR 7300-89 or Bouwer-Rice procedures (the latter if groundwater is encountered within the boring), two (2) tests at different locations within the proposed basin and the third down gradient by no more than approximately 30 feet. The tests shall measure permeability in the side slopes and the bed within a depth of 10 feet of the invert.
- The minimum acceptable hydraulic conductivity as measured in any of the three (3) required test holes is 0.5 inches/hr. If any test hole shows less than the minimum value, the site should be disqualified from further consideration.
- Exclude from consideration sites constructed on fill or partially on fill unless no silts or clays are present in the soil boring. Fill tends to be compacted, with clays in a dispersed rather than flocculated state, greatly reducing permeability.
- The geotechnical investigation should be such that a good understanding is gained as to how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

Design and Sizing Guidelines

- Provide pretreatment for infiltration trenches in order to reduce the sediment load. Pretreatment refers to design features that provide for the settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural stormwater management practices, but it is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate practices such as grassed swales, vegetated filter strips, detention, or a plunge pool in series.
- Consider including an access port or open or grated top for accessibility to conduct inspections and maintenance.
- Backfill Material - The aggregate material for the infiltration trench should consist of a clean aggregate with a maximum diameter of three inches (3") and a minimum diameter of 1.5 inches. Void space for these aggregates should be in the range of 30 to 40 percent. For calculations, assume a void space of 30 percent maximum.
- Perforated Pipe – a minimum of eight-inch (8") perforated pipe should be provided to increase the storage capacity of the infiltration trench and to enhance conveyance of flows throughout the trench area.
- Determine the trench volume by assuming the WQV will fill the void space based on the computed porosity of the rock matrix (normally about 35 percent).
- Determine the bottom surface area needed to drain the trench within 72 hours by dividing the WQV by the infiltration rate.
- Calculate trench depth using the following equation:

$$d = \frac{WQV + RFV}{SA}$$

where:
D = Trench depth
WQV = Water quality volume
RFV = Rock fill volume
SA = Surface area of the trench bottom

- The use of vertical piping, either for distribution or infiltration enhancement, shall not be allowed to avoid device classification as a Class V injection well per 40 CFR146.5(e)(4).
- Observation Well - Provide observation well at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. The observation well should consist of a perforated PVC pipe, which is four to six inches (4-6") in diameter, and it should be constructed flush with the ground elevation. For larger trenches, a 12- to 36-inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well should be capped to discourage vandalism and tampering.
- Geotextile Fabric Liner – The aggregate fill material should be completely encased in an engineering geotextile material. In the case of an aggregate surface, geotextile should surround all of the aggregate fill material except for the top one foot (1'), which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging.

Construction/Inspection Considerations

- Stabilize the entire area draining to the facility before construction begins. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction. Stabilize the entire contributing drainage area before allowing any runoff to enter once construction is complete.
- Trench Preparation – Excavated material must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from the slopes, neighboring property, sidewalks, and streets. It is recommended that this material be covered with plastic.
- Stone Aggregate Placement and Compaction – The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.
- Potential Contamination – Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.
- Overlapping and Covering – Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12-inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of two feet (2') over the downstream roll in order to provide a shingled effect.
- Voids Behind Geotextile – Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence should be avoided by this remedial process.
- Unstable Excavation Sites – Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft of cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

Performance

Infiltration trenches eliminate the discharge of the water quality volume to surface receiving waters and consequently can be considered to have 100 percent removal of all pollutants within this volume. Transport of some of these constituents to groundwater is likely, although the attenuation in the soil and subsurface layers will be substantial for many constituents.

Infiltration trenches can be expected to remove up to 90 percent of sediments, metals, coliform bacteria, and organic matter, and up to 60 percent of phosphorus and nitrogen in the infiltrated runoff (Schueler, 1992). Biochemical oxygen demand (BOD) removal is estimated to be between 70 to 80 percent. Lower removal rates for nitrate, chlorides, and soluble metals should be expected, especially in sandy soils (Schueler, 1992). Pollutant removal efficiencies may be improved by using washed aggregate and adding organic matter and loam to the subsoil. The stone aggregate should be washed to remove dirt and fines before placement in the trench. The addition of organic material and loam to the trench subsoil may enhance metals removal through adsorption.

Maintenance Criteria

- Sediment buildup in the top foot of the stone aggregate or the surface inlet should be monitored on the same schedule as the observation well.

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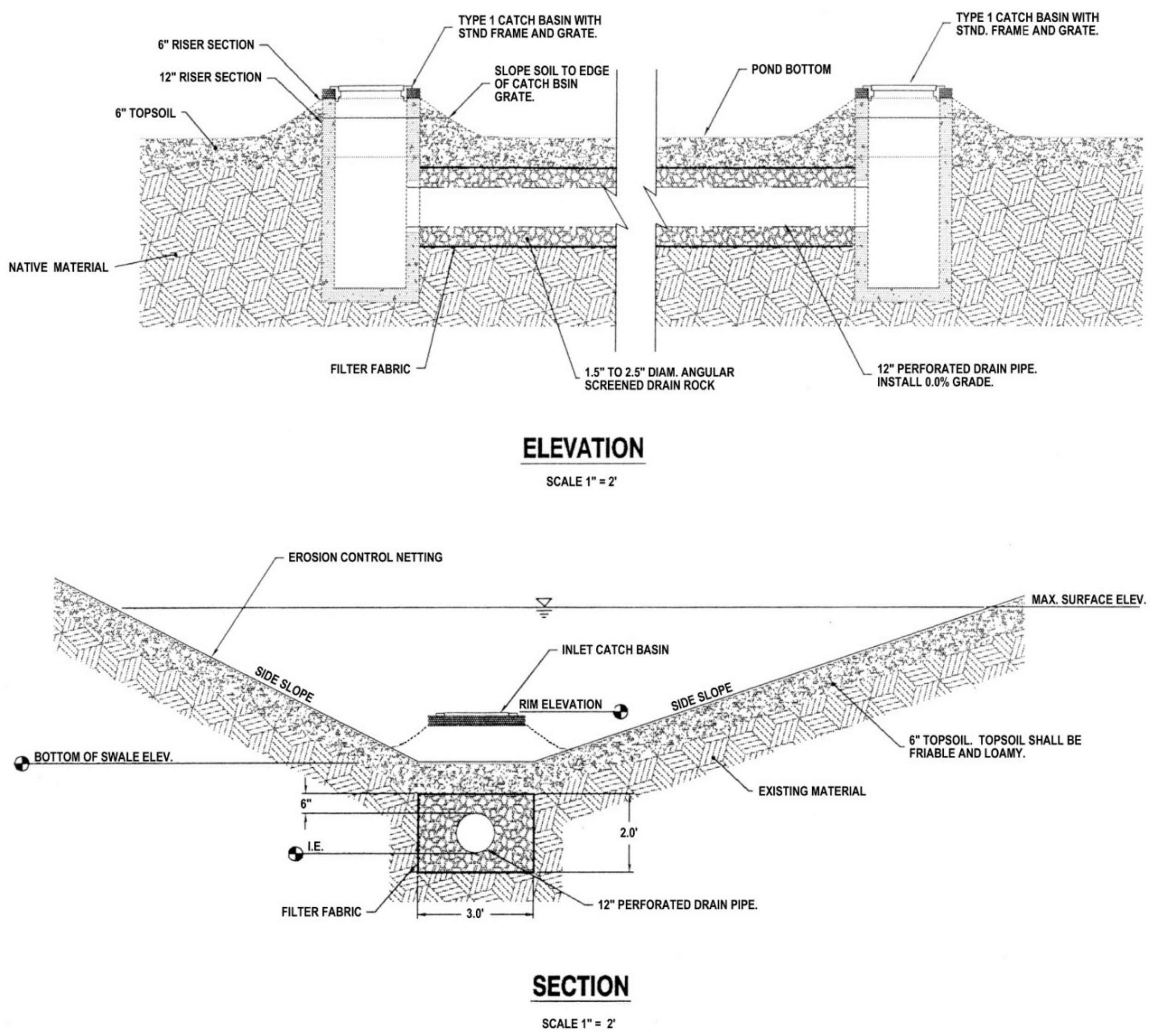
From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

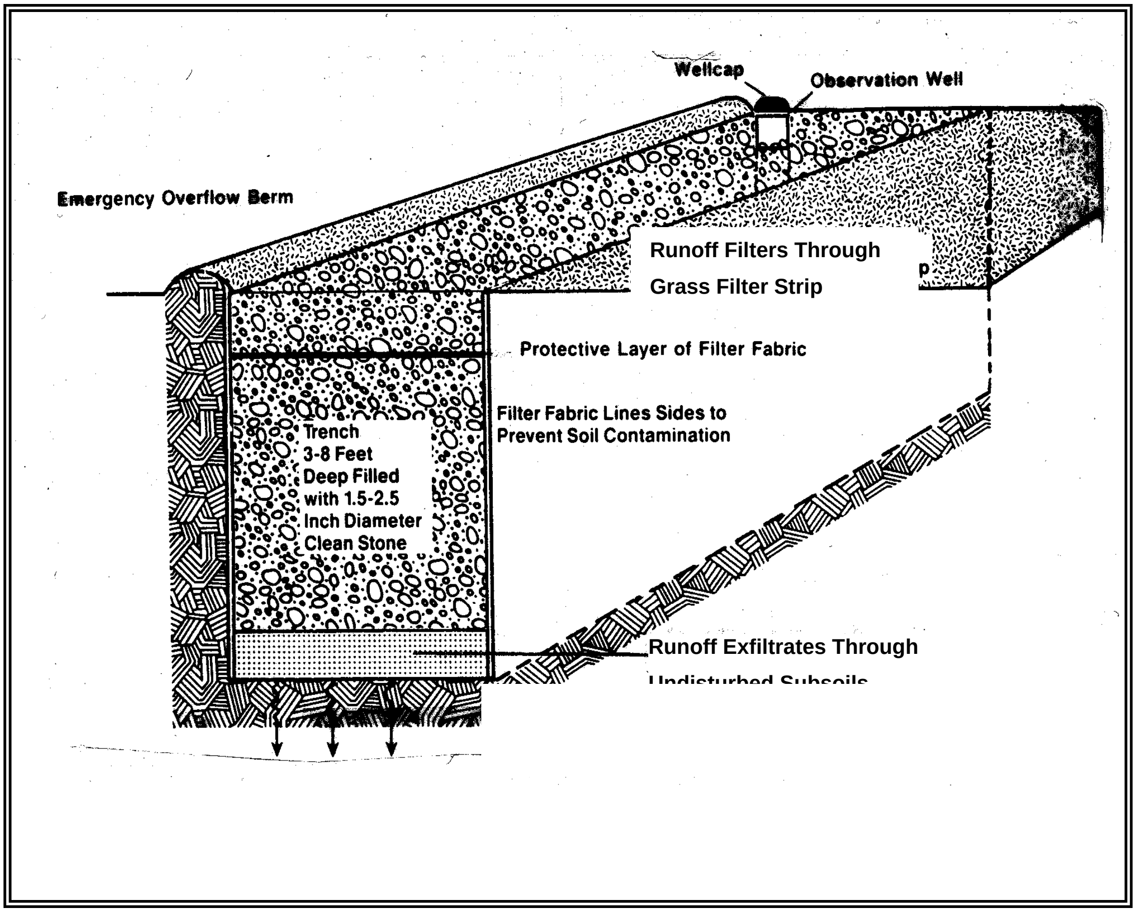
Stormwater Management Manual for Eastern Washington, 2003, Washington Department of Ecology

Figure TC-1-1 Sample Infiltration Trench/pond with Catch Basin Inlet



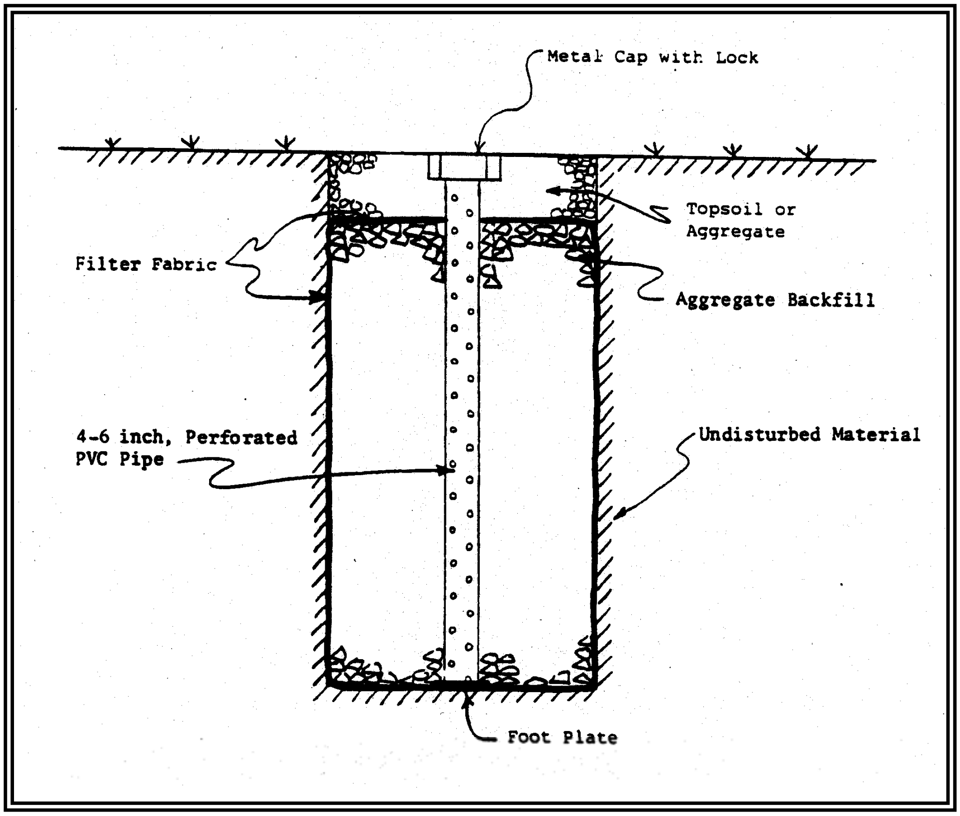
Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

Figure TC-1-2 Schematic of Infiltration Trench



Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

Figure TC-1-3 Observation Well Details



Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

TC-2 Infiltration Basin

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

An infiltration basin is a shallow earthen impoundment that is designed to collect, temporarily store and infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually exfiltrates through the soil and eventually into the water table. This practice has high pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems. However, infiltration basins can be challenging to apply on many sites because of soil requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

Figure TC-2-1 shows a typical infiltration pond configuration.

Advantages

- It provides a 100 percent reduction in the load discharged to surface waters.
- The principal benefit of infiltration basins is the approximation of pre-development hydrology during which a significant portion of the average annual rainfall runoff is infiltrated and evaporated rather than flushed directly to creeks.
- If the water quality volume is adequately sized, infiltration basins can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

Limitations

- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.

- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- The upstream drainage area must be completely stabilized before construction.
- Difficult to restore the functioning of infiltration basins once clogged.

Siting Criteria

The key element in siting infiltration basins is identifying sites with appropriate soil and hydrogeologic properties, which is critical for long-term performance. In one study conducted in Prince George's County, Maryland (Galli, 1992), all of the infiltration basins investigated clogged within two (2) years. It is believed that these failures were, for the most part, due to allowing infiltration at sites with rates of less than 0.5 in/hr, basing siting on soil type rather than field infiltration tests and poor construction practices that resulted in soil compaction of the basin invert.

A study of 23 infiltration basins in the Pacific Northwest showed better long-term performance in an area with highly permeable soils (Hilding, 1996). In this study, few of the infiltration basins had failed after 10 years. Consequently, the following guidelines for identifying appropriate soil and subsurface conditions should be rigorously adhered to.

- Determine soil type (consider RCS soil type ‘A, B, or C’ only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than 30 percent clay, or more than 40 percent of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.
- Groundwater separation should be at least 3 m from the basin invert to the measured groundwater elevation. There is a concern at the state and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.
- Location away from buildings, slopes, and highway pavement (greater than 6 m) and location away from wells and bridge structures (greater than 30 m). Sites constructed of fill, having a base flow or with a slope greater than 15 percent should not be considered.
- Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.
- Base flow should not be present in the tributary watershed.

Secondary Screening Based on Site Geotechnical Investigation

- At least three (3) in-hole conductivity tests shall be performed using USBR 7300-89 or Bouwer-Rice procedures (the latter if groundwater is encountered within the boring), two (2) tests at different locations within the proposed basin, and the third down gradient by no more than approximately 10 m. The tests shall measure permeability in the side slopes and the bed within a depth of 3 m of the invert.
- The minimum acceptable hydraulic conductivity, as measured in any of the three (3) required test holes, is 13 mm/hr. If any test hole shows less than the minimum value, the site should be disqualified from further consideration.
- Exclude from consideration sites constructed on fill or partially on fill unless no silts or clays are present in the soil boring. Fill tends to be compacted, with clays in a dispersed rather than flocculated state, greatly reducing permeability.
- The geotechnical investigation should be such that a good understanding is gained as to how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

Design and Sizing Guidelines

- Water quality volume determined so that 85 percent of the annual runoff volume is captured.
- Basin sized so that the entire water quality volume is infiltrated within 48 hours.
- Vegetation establishment on the basin floor may help reduce the clogging rate.

- Access should be provided for vehicles to easily maintain the forebay (presettling pond) area and not disturb vegetation or resuspend sediment any more than necessary.
- A minimum of one foot (1’) of freeboard is recommended when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.
- Lining Material – Ponds can be open or covered with a 6- to 12-inch layer of filter material such as coarse sand or suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. A nonwoven geotextile should be selected that will function sufficiently without plugging. The filter layer can be replaced or cleaned when/if it becomes clogged.
- Basin Sizing - The required water quality volume is determined by local regulations or sufficient to capture 85 percent of the annual runoff.
- Provide pretreatment if sediment loading is a maintenance concern for the basin.
- Include energy dissipation in the inlet design for the basins. Avoid designs that include a permanent pool to reduce the opportunity for standing water and associated vector problems.
- Basin invert area should be determined by the equation:

$$A = \frac{WQV}{kt}$$

where A = Basin invert area (m2)
WQV = water quality volume (m3)
k = 0.5 times the lowest field-measured hydraulic conductivity (m/hr)
t = drawdown time (48 hr)

- The use of vertical piping, either for distribution or infiltration enhancement, shall not be allowed to avoid device classification as a Class V injection well per 40 CFR146.5(e)(4).

Construction/Inspection Considerations

- Before construction begins, stabilize the entire area draining to the facility. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction or remove the top two inches (2”) of soil after the site is stabilized.
- Stabilize the entire contributing drainage area, including the side slopes, before allowing any runoff to enter once construction is complete.
- Place excavated material such that it cannot be washed back into the basin if a storm occurs during the construction of the facility.
- Build the basin without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide (“low pressure”) tires. Prior to any construction, rope off the infiltration area to stop entrance by unwanted equipment.
- After final grading, till the infiltration surface deeply.
- Use appropriate erosion control seed mix for the specific project and location.

Performance

As water migrates through porous soil and rock, pollutant attenuation mechanisms include precipitation, sorption, physical filtration, and bacterial degradation. If functioning properly, this approach is presumed to have high removal efficiencies for particulate pollutants and moderate removal of soluble pollutants. Actual pollutant removal in the subsurface would be expected to vary depending upon site-specific soil types. This technology eliminates discharge to surface waters except for the very largest storms; consequently, complete removal of all stormwater constituents can be assumed.

There remain some concerns about the potential for groundwater contamination despite the findings of the NURP and Nightingale (1975; 1987a,b,c; 1989). For instance, a report by Pitt et al. (1994) highlighted the potential for groundwater contamination from intentional and unintentional stormwater infiltration. That report recommends that infiltration facilities not be sited in areas where high concentrations are present or where there is a potential for spills of toxic material. Conversely, Schroeder (1995) reported that there was no evidence of groundwater impacts from an infiltration basin serving a large industrial catchment in Fresno, CA.

Maintenance

Regular maintenance is critical to the successful operation of infiltration basins. Recommended operation and maintenance guidelines include:

- Inspections and maintenance to ensure that water infiltrates into the subsurface completely (recommended infiltration rate of 72 hours or less) and that vegetation is carefully managed to prevent creating mosquito and other vector habitats.
- Observe drain time for the design storm after completion or modification of the facility to confirm that the desired drain time has been obtained.
- Schedule semiannual inspections for beginning and end of the wet season to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Remove accumulated trash and debris in the basin at the start and end of the wet season.
- Inspect for standing water at the end of the wet season.
- Trim vegetation at the beginning and end of the wet season to prevent the establishment of woody vegetation and for aesthetic and vector reasons.
- Remove accumulated sediment and regrade when the accumulated sediment volume exceeds 10 percent of the basin.
- If erosion is occurring within the basin, revegetate immediately and stabilize with an erosion control mulch or mat until vegetation cover is established.
- To avoid reversing soil development, scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Always remove deposited sediments before scarification, and use a hand-guided rotary tiller, if possible, or a disc harrow pulled by a very light tractor.

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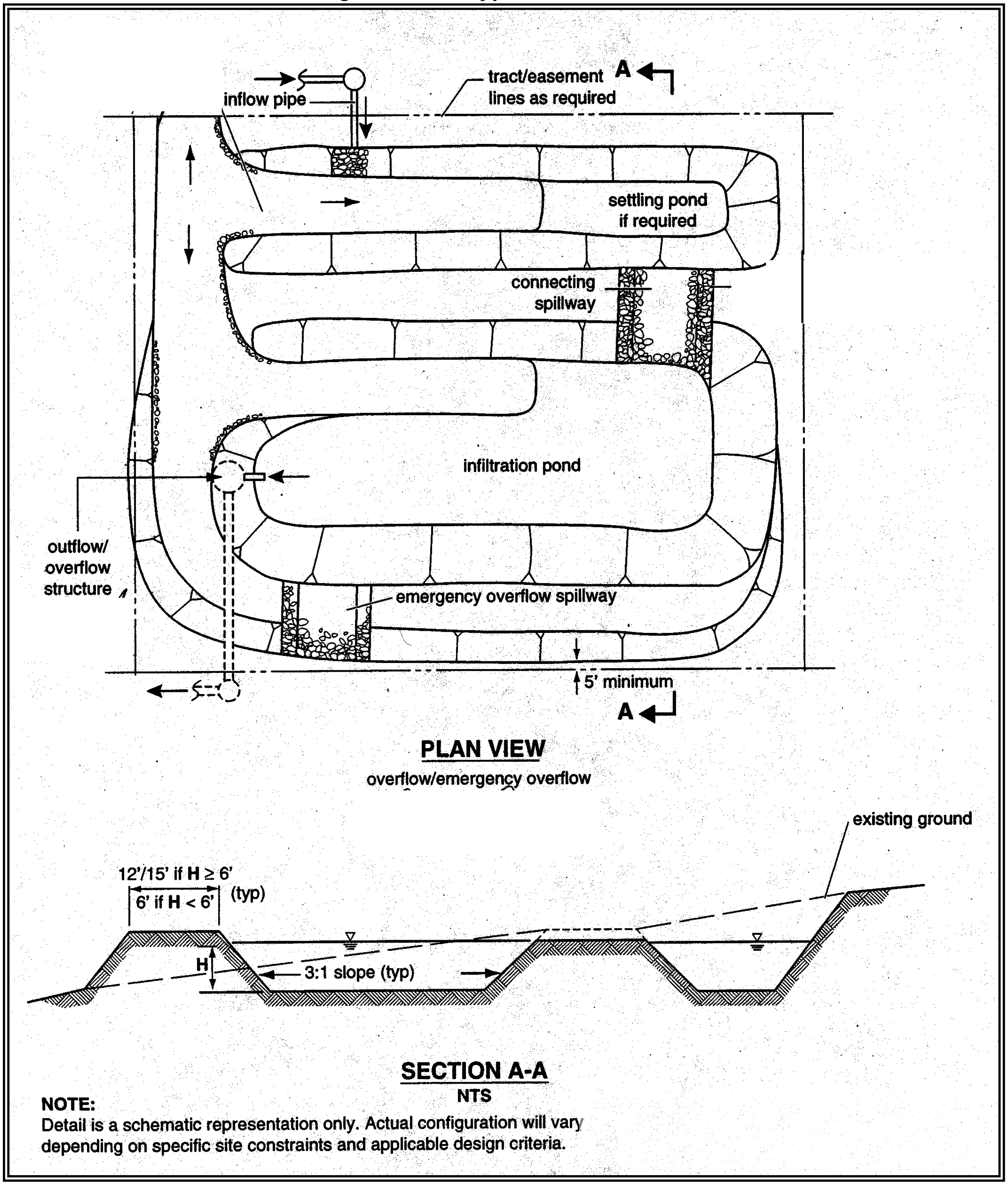
From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

Stormwater Management Manual for Eastern Washington, 2003, Washington Department of Ecology

Figure TC-2-1 Typical Infiltration Pond



Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

TC-3 Wet Ponds

Design Objectives

- ✓ Provide Retention
- ✓ Contain Pollutants
- ✓ Collect and Convey

Description

A wet pond is a constructed stormwater pond or portion of the facility that retains a pool of water (the "wet pool"). In some areas, the wet pool may be permanent, at least during the wet season. The volume of the wet pond is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Ponds treat incoming stormwater runoff by settling and biological uptake. The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological activity in the pond.

Although wet ponds are among the most widely used stormwater practices, they are often impractical in arid watersheds since it is not possible to maintain a permanent pool without supplemental water, and the ponds become stagnant between storms. Wet ponds may have limited applicability in Carson City due to on-site conditions and available supplemental water sources.

The following design, construction, and operation and maintenance criteria cover two (2) wet pond applications - the basic wet pond and the large wet pond. Large wet ponds are designed for higher levels of pollutant removal.

Advantages

- If properly designed, constructed, and maintained, wet basins can provide substantial aesthetic/recreational value and wildlife and wetlands habitat.
- Ponds are often viewed as a public amenity when integrated into a park setting.
- Due to the presence of the permanent wet pool, properly designed and maintained wet basins can provide significant water quality improvement across a relatively broad spectrum of constituents, including dissolved nutrients.

- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed.

Limitations

A wet pond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated into the contours of a site fairly easily. In clayey or silty soils, the wet pond may hold a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wet ponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner is one way to deal with this situation. As long as the first cell retains a permanent pool of water, this situation will not reduce the pond's effectiveness but may be an aesthetic drawback.

Wet ponds may be single-purpose facilities, providing only runoff treatment, or they may be combined with a detention pond to also provide flow control. If combined, the wet pool can often be stacked under the detention pond with little further loss of development area.

Additional limitations in the use of wet ponds may include the following items:

- Some safety concerns when constructed where there is public access.
- Mosquito and midge breeding are likely to occur in ponds.
- Cannot be placed on steep unstable slopes.
- Need for base flow or supplemental water if the water level is to be maintained.
- Require a relatively large footprint.
- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

Design Criteria

The primary design factor that determines a wet pond's treatment efficiency is the volume of the wet pool. The larger the wet pool volume, the greater the potential for pollutant removal. The wet pool volume provided shall be equal to or greater than the total volume of runoff from the water quality design storm.

Also important are the avoidance of short-circuiting and the promotion of plug flow. Plug flow describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- Dissipating energy at the inlet.
- Providing a large length-to-width ratio.
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the extended detention dry pond into two (2) cells rather than a constricted area such as a pipe.
- Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.

Sizing Procedure

Procedures for determining a wet pool's dimensions and volume are outlined below.

Step 1: Identify the required wet pool volume using the following table; for a Large Wet Pond increase the size of the basic pond by 50 percent:

Table TC-3-1. Wet pond sizing table for basic treatment design

2-YEAR 24-HOUR PRECIPITATION (in)		POND VOLUME PER 1,000 SQUARE-FEET OF IMPERVIOUS AREA
FROM	TO	
0.60	0.80	43.3 cubic feet
0.81	1.00	57.1 cubic feet
1.01	1.20	79.7 cubic feet
1.21	1.40	97.1 cubic feet
1.41	and greater	Hydrologic Method Required

Step 2: Determine wet pool dimensions. Determine the wet pool dimensions satisfying the design criteria outlined below and illustrated in Figures 5.7.1 and 5.7.2. A simple way to check the volume of each wet pool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

Where: V = wet pool volume (cu. ft.)
h = wet pool average depth (ft.)
A_1 = water quality design surface area of wet pool (sq. ft.)
A_2 = bottom area of wet pool (sq. ft.)

Step 3: Design primary overflow water surface. Overflow must be able to safely pass the flow from the 100-year design storm.

Step 4: Determine extended detention dry pond dimensions. General extended detention dry pond design criteria and concepts are shown in Figures TC-3-1 and TC-3-2.

Wet Pool Geometry

The wet pool should be divided into two (2) cells separated by a baffle or berm. The first cell should contain between 25 to 35 percent of the total wet pool volume. The baffle or berm volume shall not count as part of the total wet pool volume. The term baffle means a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

Intent: The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by the local jurisdiction.

Sediment storage should be provided in the first cell. The sediment storage should have a minimum depth of 1 foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.

The minimum depth of the first cell should be four feet (4'), exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.

The maximum depth of each cell should not exceed eight feet (8') (exclusive of sediment storage in the first cell). Pool depths of three feet (3') or shallower (second cell) should be planted with emergent wetland vegetation.

Inlets and outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1. The flowpath length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2.

Ponds with wet pool volumes less than or equal to 4,000 cubic feet may be single-celled (i.e., no baffle or berm is required). However, it is especially important in this case that the flow path length is maximized. The ratio of flow path length to width should be at least 4:1 in single-celled extended detention dry ponds, but should preferably be 5:1.

All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets. The first cell may be lined as needed.

Berms, Baffles, and Slopes

A berm or baffle should extend across the full width of the wet pool, and tie into the wet pool side slopes. If the berm embankments are greater than four feet (4') in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if authorized by a geotechnical engineer based on specific site conditions. The geotechnical analysis should address situations in which one (1) of the two (2) cells is empty while the other remains full of water.

The top of the berm may extend to the water quality design water surface or be one foot (1') below the water quality design water surface. If at the water quality design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged one foot (1').

Intent: Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V. An alternative to the submerged berm design is the use of barrier planting to prevent easy access to the divider berm in an unfenced extended detention dry pond.

If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the pond is initially filled.

The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged one foot (1') below the design water surface to discourage access by pedestrians.

Embankments

Embankments that impound water of more than 20 ac-ft or higher than 10 feet above existing ground must comply with Dam Safety Regulations.

Inlet and Outlet

See Figures TC-3-1 and TC-3-2 details on the following requirements:

The inlet to the wet pool should be submerged with the inlet pipe invert a minimum of two feet (2') from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least one foot (1'), if possible.

Intent: The inlet is submerged to dissipate the energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jailhouse window) or a manhole with a cone grate (birdcage) may be used. No sump is required in the outlet structure for extended detention dry ponds not providing detention storage. The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged. The overflow criteria provided below specify the sizing and position of the grate opening.

The pond outlet pipe (as opposed to the manhole or Type 2 catch basin outlet pipe) should be back-sloped or have a turn-down elbow and extend one foot (1') below the WQ design water surface. Note: A floating outlet, set to draw water from one foot (1') below the water surface, is also acceptable if vandalism concerns are adequately addressed.

Intent: The inverted outlet pipe provides for trapping of oils and floatables in the extended detention dry pond.

The pond outlet pipe shall be sized, at a minimum, to pass the WQ design flow. Note: The highest invert of the outlet pipe sets the WQ design water surface elevation.

The overflow criteria for single purpose (treatment only, not combined with flow control) wet pools are as follows:

- The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.
- The bottom of the grate opening in the outlet structure should be set at or above the height needed to pass the WQ design flow through the pond outlet pipe. Note: The grate invert elevation sets the overflow water surface elevation.
- In on-line ponds, the grated opening should be sized to pass the 100-year design flow. The capacity of the outlet system should be sized to pass the peak flow for the conveyance requirements.
- An emergency spillway shall be provided and designed according to the requirements for detention ponds (see Chapter 6 – Flow Control Facility Design).
- A gravity drain for maintenance is recommended if grade allows.

Intent: It is anticipated that sediment removal will be needed only for the first cell in the majority of cases. The gravity drain is intended to allow water from the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.

All metal parts should be corrosion resistant. Galvanized materials should not be used unless unavoidable.

Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.

Access and Setbacks

All facilities shall be a minimum of 20 feet from any structure, property line, and any vegetated buffer required by the local government, and 100 feet from any septic tank/drainfield.

All facilities shall be located away from any steep (greater than 15 percent) slope. The minimum setback from such a slope is greater than or equal to the height of the slope unless the design professional can justify a lesser setback based on a comprehensive site evaluation. A geotechnical report must address the potential impact of a wet pond on a steep slope.

Access and maintenance roads shall be provided and designed according to the requirements for detention ponds. Access and maintenance roads shall extend to both the extended detention dry pond inlet and outlet structures. An access ramp (5H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached, and sediment loaded from the top of the pond.

If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

If desired, the pond may be planted with dryland grasses. Sod or wetland plants should be avoided unless irrigation will be provided during the dry months.

Recommended Design Features

The following design features should be incorporated into the extended detention dry pond design where site conditions allow:

The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.

For permanent wet pool depths in excess of six feet (6'), it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.

A flow length-to-width ratio greater than the 3:1 minimum is desirable. If the ratio is 4:1 or greater, then the dividing berm is not required, and the pond may consist of one (1) cell rather than two (2).

A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond, is preferred since it minimizes dead zones caused by corners.

A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.

Columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

Intent: Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop, except on the south and west sides, which may inhibit the melting of ice during the winter. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar) typically have fewer leaves than other deciduous trees.

The number of inlets to the facility should be limited; ideally, there should be only one (1) inlet. The flowpath length should be maximized from inlet to outlet for all inlets to the facility.

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 rip-rap placed over filter cloth. Energy dissipation may be required to reduce flow velocities from the primary spillway to non-erosive velocities.

Safety is provided either by fencing the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter should be fenced.

The access and maintenance road could be extended along the full length of the extended detention dry pond and could double as play courts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian-friendly.

The following design features should be incorporated to enhance aesthetics where possible:

- Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
- Include fountains or integrated waterfall features for privately maintained facilities.
- Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.
- Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

Construction Criteria

Sediment that has accumulated in the pond must be removed after construction in the drainage area of the pond is complete (unless used for a liner - see below).

Sediment that has accumulated in the pond at the end of construction may be used as a liner in excessively drained soils if the sediment meets the criteria for a low permeability liner and is approved for use as such by a geotechnical engineer. Sediment used for a soil liner must be graded to provide uniform coverage and thickness.

Operation and Maintenance

Maintenance is of primary importance if wet pools are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or a property owner should accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations.

The pond should be inspected annually. The maintenance standards contained in Appendix A are measures for determining if maintenance actions are required, as identified through the annual inspection.

Site vegetation should be trimmed as necessary to keep the pond free of leaves and to maintain the aesthetic appearance of the site. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

Sediment should be removed when the one-foot (1') sediment zone is full plus six inches (6"). Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed of in accordance with current local health department requirements for handling solid waste.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is to discharge to a sanitary sewer at an approved location. Other disposal options include discharge back into the wet pool facility or the storm sewer system if approved by the operator of the storm sewer system.

Information Resources

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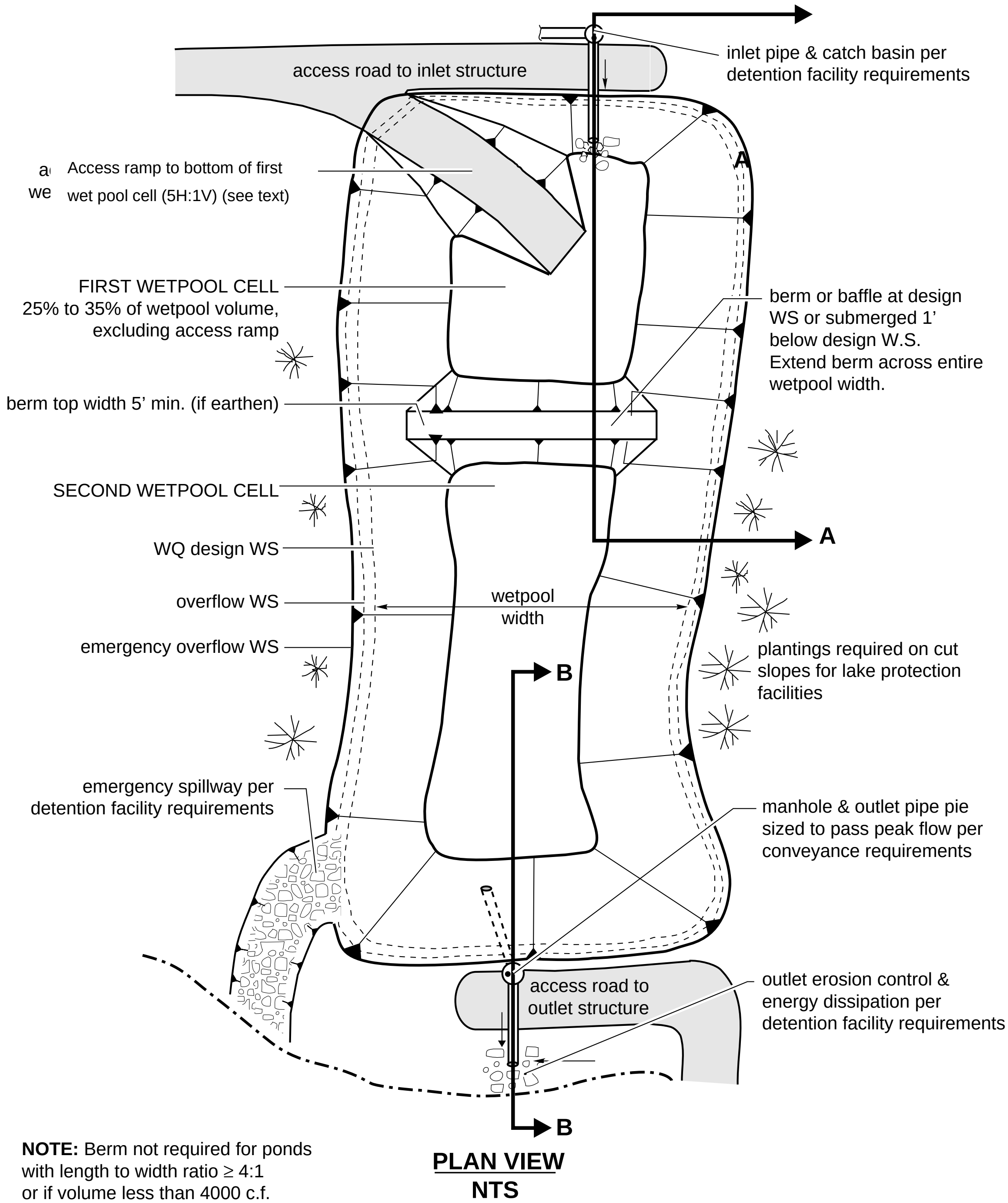
From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology

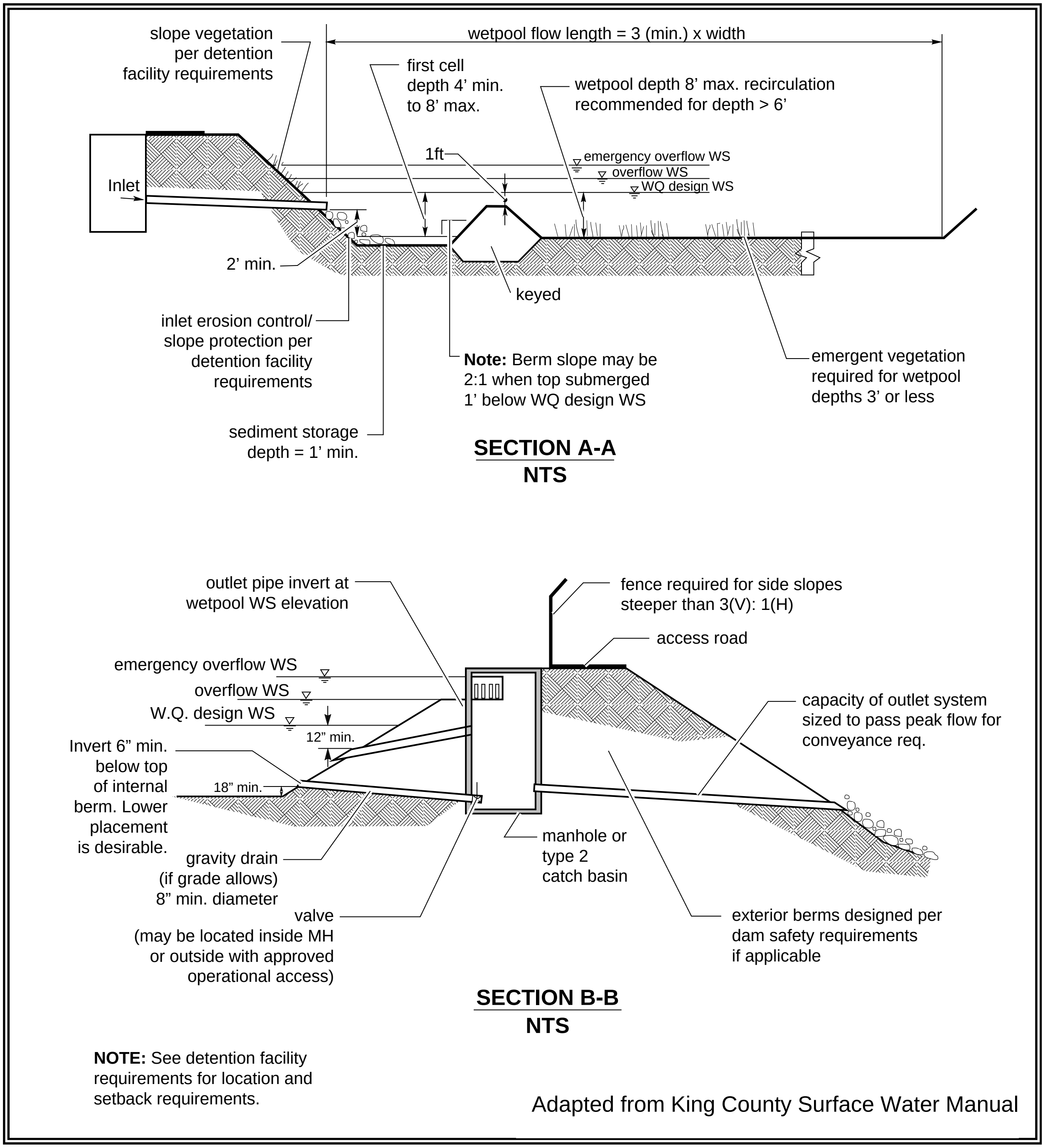
Figure TC-3-1 Wet Pond/Wet Pool (plan view)



Adapted from King County Surface Water

Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

Figure TC-3-2 Wet Pond (sections)



Source: Washington Department of Ecology, 2004, Stormwater Management Manual for Eastern Washington

TC-4 Extended Detention Basin

Design Objectives

- ✓ Provide Retention
- ✓ Collect and Convey

Description

Dry extended detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain the stormwater runoff from a water quality design storm for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. A perforated riser or outlet control device enables water to slowly drain from the pond. Unlike wet ponds, these facilities do not have a large permanent pool. They can also be used to provide flood control by including additional flood detention storage.

Dry ponds are some of the most widely used facilities in urban stormwater infrastructure. With the emergence of water quality issues, dry ponds have been attempted to be used as a dual-purpose detention/water quality facility. However, standard dry ponds are generally not very effective at treating water quality.

Advantages

- Due to the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate.
- Extended detention basins can provide substantial capture of sediment and the toxics fraction associated with particulates.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed.

Limitations

- Limitation of the diameter of the orifice may not allow the use of extended detention in watersheds of less than five (5) acres (would require an orifice with a diameter of less than 0.5 inches that would be prone to clogging).

- Dry extended detention ponds have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home due to the adverse aesthetics of dry, bare areas and inlet and outlet structures.

Design and Sizing Guidelines

- Capture volume sized to treat 85 percent of the annual runoff volume.
- Outlet designed to discharge the capture volume over a period of 48 hours. No more than 50 percent of the water quality volume should drain from the facility within the first 24 hours.
- The outflow structure can be fitted with a valve so that discharge from the basin can be halted in case of an accidental spill in the watershed.
- Length to width ratio of at least 1.5:1 where feasible.
- Basin depths optimally range from two to five (2-5') feet.
- For online facilities, the principal and emergency spillways must be sized to provide one foot (1') of freeboard during the 25-year event and to safely pass the flow from the 100-year storm.
- Side slopes of the pond should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice.
- Basins must be constructed to prevent possible contamination of groundwater below the facility.
- Include energy dissipation in the inlet design to reduce resuspension of accumulated sediment.
- 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 rip-rap placed over filter cloth. Energy dissipation may be required to reduce flow velocities from the primary spillway to non-erosive velocities.
- A maintenance ramp and perimeter access should be included in the design to facilitate access to the basin for maintenance activities and for vector surveillance and control.

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 one foot (1') of freeboard along pond side slopes.

- Refer to Figures TC-3-1 and TC-3-2 for pond details.

Extended detention basins can be used with almost all soils and geology, with minor design adjustments for regions of rapidly percolating soils such as sand. In these areas, extended detention ponds may need an impermeable liner to prevent groundwater contamination.

The base of the extended detention facility should not intersect the water table. A permanently wet bottom may become a mosquito breeding ground. Research in Southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produce more mosquitoes than other pond systems, particularly when the facilities remained wet for more than three (3) days following heavy rainfall.

In order to enhance the effectiveness of extended detention basins, the dimensions of the basin must be sized appropriately. By effectively configuring the basin, the designer will create a long flow path, promote the establishment of low velocities, and avoid having stagnant areas of the basin.

Energy dissipation structures should be included for the basin inlet to prevent resuspension of accumulated sediment. The use of stilling basins for this purpose should be avoided because the standing water provides a breeding area for mosquitoes.

A large aspect ratio may improve the performance of detention basins; consequently, the outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 1.5:1 (L:W) where feasible. 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 two to five (2-5') feet. Basin depths optimally range from two to five (2-5') feet.

The facility's drawdown time should be regulated by an orifice or weir. The outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes.

Safety is provided either by fencing the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter should be fenced.

Maintenance

Routine maintenance activity includes sediment and trash and debris removal, vegetation management routine mowing and inspection, and maintenance of the outlet structure to ensure that the basin dewaters completely in 48-72 hours. Mowing should be done at least annually to avoid the establishment of woody vegetation but may need to be performed much more frequently if aesthetics are an important consideration.

Typical maintenance and inspection activities and frequencies include:

- Schedule semiannual inspection for the beginning and end of the wet season for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows.
- Remove accumulated trash and debris in the basin and around the riser pipe during the semiannual inspections. The frequency of this activity may be altered to meet specific site conditions.
- Trim vegetation at the beginning and end of the wet season and inspect monthly to prevent the establishment of woody vegetation and for aesthetic and vector reasons.
- Remove accumulated sediment and regrade about every 10 years or when the accumulated sediment volume exceeds 10 percent of the basin volume. Inspect the basin each year for accumulated sediment volume.

Construction/Inspection Considerations

- Inspect facility after first large to storm to determine whether the desired residence time has been achieved.
- When constructed with a small tributary area, orifice sizing is critical, and inspection should verify that flow through additional openings such as bolt holes does not occur.

Information Resources

- Center for Watershed Protection (CWP). 1995. *Stormwater Management Pond Design Example for Extended Detention Wet Pond*. Center for Watershed Protection, Ellicott City, MD.
- Center for Watershed Protection (CWP). 1997. *Stormwater BMP Design Supplement for Cold Climates*. Prepared for U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Washington, DC, by the Center for Watershed Protection, Ellicott City, MD.
- Denver Urban Drainage and Flood Control District. 1992. *Urban Storm Drainage Criteria Manual—Volume 3: Best Management Practices*. Denver Urban Drainage and Flood Control District, Denver, CO.
- Galli, J. 1992. *Preliminary Analysis of the Performance and Longevity of Urban BMPs Installed in Prince George's County, Maryland*. Prince George's County, Maryland, Department of Natural Resources, Largo, MD.
- MacRae, C. 1996. Experience from Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Runoff Event the Best Basis for Stream Channel Protection? In *Effects of Watershed Development and Management on Aquatic Ecosystems*. American Society of Civil Engineers. Snowbird, UT. pp. 144–162.

- Minnesota Pollution Control Agency. 1989. *Protecting Water Quality in Urban Areas: Best Management Practices*. Minnesota Pollution Control Agency, Minneapolis, MN.
- U.S. Environmental Protection Agency (USEPA). 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA-840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology

TC-5 Stormwater Treatment Wetlands

Design Objectives

- ✓ Provide Retention
- ✓ Water Quality Treatment

Purpose and Definition

In land development situations, wetlands are usually constructed for two (2) main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands), and to treat stormwater runoff (stormwater treatment wetlands). Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants (see the stormwater wetland details in Figure TC-5-1 and Figure TC-5-2).

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment facilities. This is because of the different, incompatible functions of the two (2) kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wet ponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested, and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater wetlands is highly variable.

Stormwater wetlands will have limited applicability in Carson City since constructed wetlands require a dependable source of water to sustain the wetland vegetation.

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wet ponds but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. A source of irrigation water may be needed. Since water depths are shallower than in wet ponds, water loss by evaporation is an important concern. Stormwater wetlands are a good water quality facility choice in areas with high winter groundwater levels.

Design Criteria

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wet ponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus, when designing wetlands, water volume is not the dominant design criteria. Rather, factors which affect plant vigor and biomass are the primary concerns.

Wetland Geometry Criteria

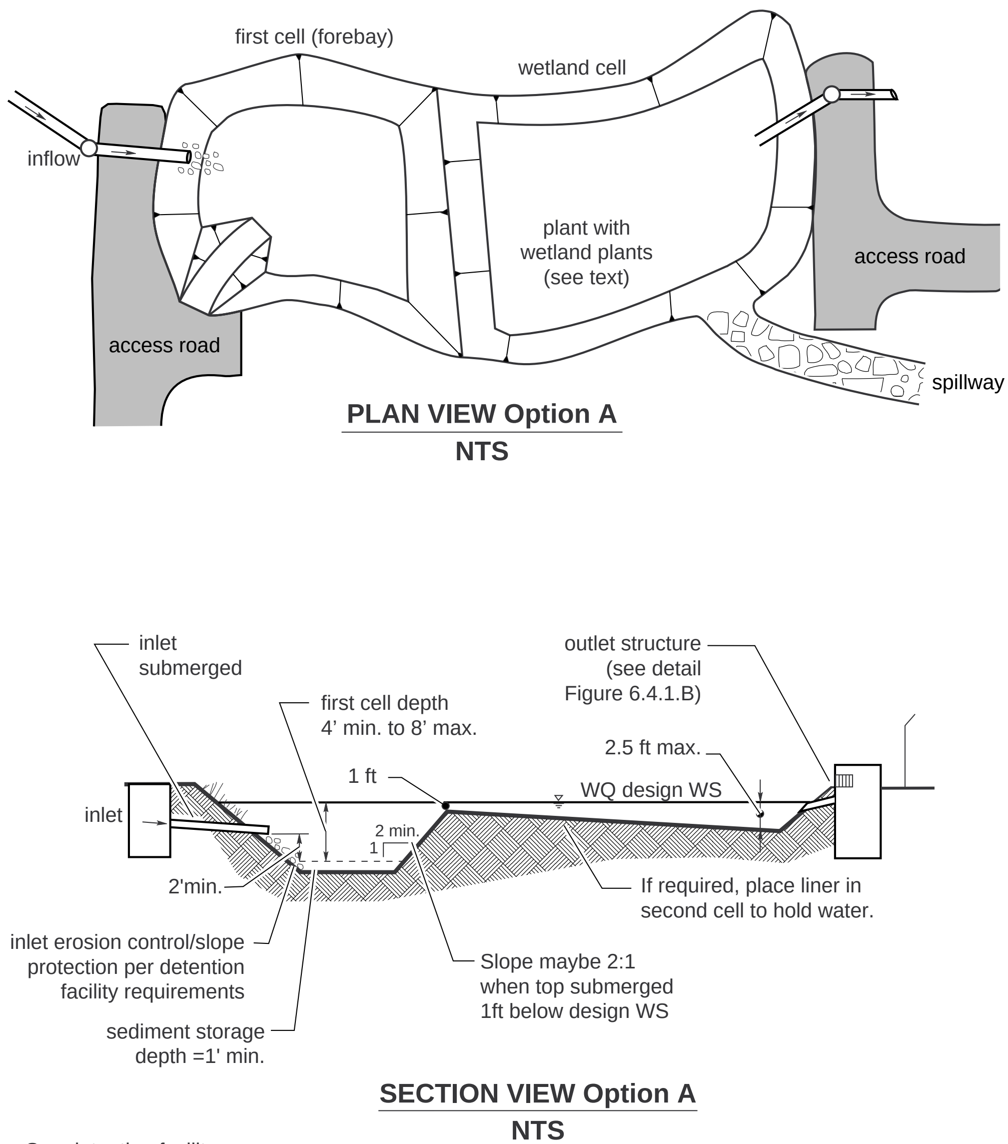
1. Stormwater wetlands shall consist of two (2) cells comprised of a pre-settling cell and a wetland cell.
2. The pre-settling cell shall contain approximately 33 percent of the wet pool volume.
   - There is currently no single accepted method for computing volume requirements for constructed wetlands. The procedure may be left to local practice. The volume needs to include a slowly draining portion as well as a permanent pool. The slowly draining pool should release the design runoff volume over a period of at least five (5) days. No more than half the volume should be released within about two and a half (2.5) days.
   - The general rule of thumb for the permanent pool is that it should provide a residence time of at least 14 days. It is not drained through an outlet but rather through evapotranspiration and infiltration. However, this is inadequate for Nevada due to the precipitation patterns during our hot summers and dry winters: a dry wetland with dead vegetation does not provide much protection during fall precipitation events, and a dry pond does not promote much biological uptake of nutrients during early spring events.
   - See Koob et al. (1999) for a statistical procedure for analyzing the time between precipitation events versus the risk of a dry pond. Local infiltration data and evapotranspiration data are essential to produce reliable estimates.
3. The depth of the pre-settling cell shall be between four feet (4') (minimum) and eight feet (8') (maximum), excluding sediment storage.
4. One foot (1') of sediment storage shall be provided in the pre-settling cell.
5. The permanent pool in the wetland cell shall have an average water depth of about 1.5 feet (plus or minus three inches (3")). The average water depth required for the total storage volume is typically three feet (3').
6. The "berm" separating the two (2) cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure TC 5-1). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).
7. The top of the berm shall be either at the water quality design water surface or submerged one foot (1') below the water quality design water surface, as with wet ponds. Correspondingly, the side slopes of the berm must meet the following criteria:
   a. If the top of the berm is at the water quality design water surface, the berm side slopes shall be no steeper than 3H:1V.
   b. If the top of the berm is submerged one foot (1'), the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope should not be greater than 3:1, just as the pond banks should not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in one foot (1') of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.
8. Two (2) examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 5.7.4). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure TC 5-2). A distribution of depths shall be provided in the wetland cell, depending on whether the dividing berm is at the water surface or submerged (see Table 5.7.2 below). The maximum depth is two and a half (2.5) feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by the local jurisdiction.
9. A minimum length-to-width ratio of 2:1 is recommended. The shape is generally dictated by the surrounding site geometry, but the purpose of this recommendation is to prevent short-circuiting of water across the pond. Baffles, islands, and creative inlet structures can be used to promote adequate mixing in challenging settings.

10. It is intended that the intent of the Wetland Geometry Criteria listed above generally be met. Appropriate deviations may be necessary based upon site-specific considerations.

Table TC-5-1 Distribution of Depths in Wetland Cell

Dividing Berm at WQ Design Water Surface		**Dividing Berm Submerged 1-Foot**	
Depth Range (feet)	Percent	Depth Range (feet)	Percent
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

Figure TC-5-1 Stormwater Treatment Wetland — Option A

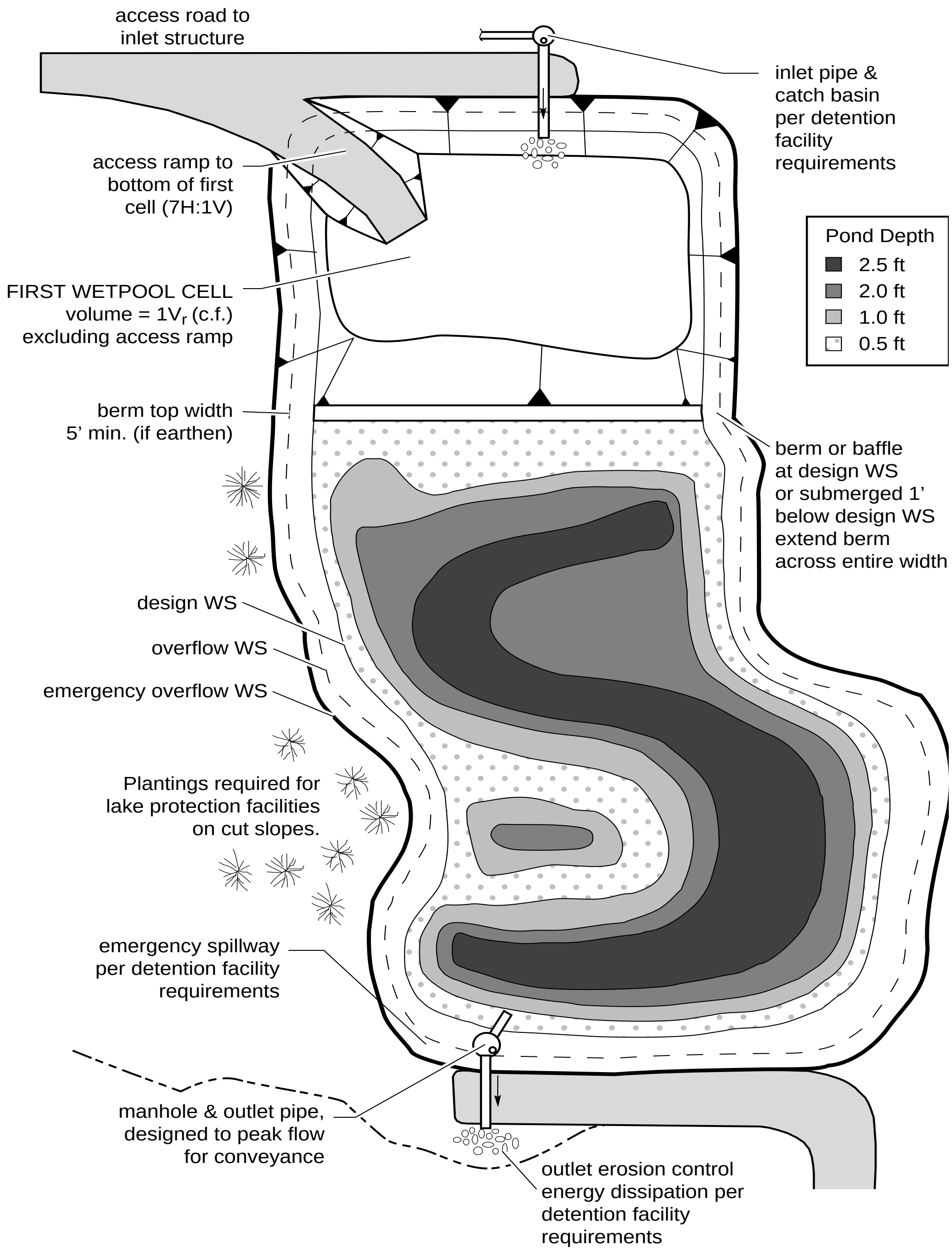


Note: See detention facility requirements for location and setback requirements.

Adapted from King County Surface Water Design Manual

From: Stormwater Management Manual for Eastern Washington, Washington Department of Ecology, 2004

Figure TC-5-2 Stormwater Treatment Wetland — Option B



PLAN VIEW Option B

NTS

Adapted from King County Surface Water Design Manual
From: Stormwater Management Manual for Eastern Washington, Washington Department of Ecology, 2004

Sizing Procedure

Step 1: The volume of a basic wet pond is used as a template for sizing the stormwater wetland. See BMP TC-3 for sizing procedure.

Step 2: Calculate the surface area of the stormwater wetland. The surface area of the wetland shall be the same as the top area of a wet pond sized for the same site conditions. Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (typically three feet (3')).

Step 3: Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under "Wetland Geometry," and the actual depth of the first cell.

Step 4: Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).

Step 5: Determine water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under "Wetland Geometry" (below). Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.

Intent: The surface area of the stormwater wetland is set to be roughly equivalent to that of a wet pond designed for the same site so as not to discourage the use of this option.

Step 6: Choose plants. A wetland scientist should be consulted regarding appropriate plant species and planting design. Table TC-5-2 is a list of plants that are being used in a demonstration wetland pond at the City of Henderson.

Table TC-5-2. Plant Species, Demonstration Wetlands Pond, Henderson, NV

Species	Common Name
Schoenoplectus acutus	Hard-stem bulrush
Schoenoplectus pungens	Common three-square bulrush
Schoenoplectus americanus	Olney's bulrush
Schoenoplectus californicus	California bulrush
Bolboschoenus maritimus	Saltmarsh bulrush
Distichlis spicata	Inland saltgrass
Sources: Las Vegas Wash Comprehensive Adaptive Management Plan, Chapter 5, 1999.	

Lining Requirements

In infiltrative soils, both cells of the stormwater wetland shall be lined. To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability allows sufficient water retention, the lining may be waived.

1 The second cell must retain water for at least 10 months of the year.
2. The first cell must retain at least three feet (3') of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

   Intent: Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. This may allow a treatment liner rather than a low permeability liner to be used for the second cell. The first cell must retain water year-round in order for the presettling function to be effective.

4. If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one (1) part compost mixed with three (3) parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of three feet (3') is recommended to prevent damage to the liner during planting. Hydric soils are not required.

Inlet and Outlet

Same as for wet ponds (see BMP TC-3).

Access and Setbacks
- Location of the stormwater wetland relative to site constraints (e.g., buildings, property lines) shall be the same as for detention ponds (see Chapter 6). See Section 5.3.3 for typical setback requirements for WQ facilities.
- Access and maintenance roads shall be provided and designed according to the requirements for detention ponds (see Chapter 6). Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp (7H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.
- If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations of a wetland specialist. Note: Cattails (Typha latifolia) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wet pool unless they are removed.

Construction Criteria

- Construction and maintenance considerations are the same as for wet ponds.
- Construction of the naturalistic alternative (Option B) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

Operation and Maintenance

- Wetlands should be inspected at least twice per year during the first three (3) years during both growing and non-growing seasons to observe plant species presence, abundance, and condition; bottom contours and water depths relative to plans; and sediment, outlet, and buffer conditions.

- Maintenance should be scheduled around sensitive wildlife and vegetation seasons.
- Plants may require watering, physical support, mulching, weed removal, or replanting during the first three (3) years.
- Nuisance plant species should be removed, and desirable species should be replanted.
- The effectiveness of harvesting for nutrient control is not well documented. There are many drawbacks to harvesting, including possible damage to the wetlands and the inability to remove nutrients in the below-ground biomass. If harvesting is practiced, it should be done in late summer.

From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.
Las Vegas Wash Comprehensive Adaptive Management Plan, Las Vegas Wash Coordination Committee, 1999.

TC-6 Vegetated Swales

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Water Quality Treatment
- ✓ Collect and Convey

Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. Vegetated treatment systems, also known as biofiltration systems, remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or filter strips. These facilities are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater. The vegetated swale biofiltration BMP is described in this section. The vegetated filter strip is described in BMP TC-7.

Application

Biofiltration treatment facilities can be used as a basic treatment BMP for contaminated runoff from roadways, driveway, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as high-use sites, a pretreatment system for those components would be necessary. Off-line location is preferred to avoid flattening vegetation and the erosive effects of high flows.

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration swale is a sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to BMPs designed for that purpose.

General Criteria

- Though the actual dimensions for a specific site may vary, the swale should generally have a length of 200 feet. The maximum bottom width is typically 10 feet. The depth of flow should not exceed four inches (4") during the design storm. The flow velocity should not exceed one (1) ft/sec.
- The channel slope should be at least one percent (1%) and no greater than five percent (5%).
- The swale can be sized as both a treatment facility for the 6-month storm and as a conveyance system to pass the peak hydraulic flows of the 25-year storm if it is located "on-line."

- The ideal cross-section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1.
- Roadside ditches should be regarded as significant potential biofiltration sites and should be utilized for this purpose whenever possible.
- If a flow is to be introduced through curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches wide to prevent clogging.
- Biofilters must be vegetated in order to provide adequate treatment of runoff.
- It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing grasses (or other vegetation) that can withstand prolonged periods of wetting, as well as prolonged dry periods (to minimize the need for irrigation). Consult the local NRCS office for specific vegetation selection recommendations.
- Biofilters should generally not receive construction-stage runoff. If they do, pre-settling of sediments should be provided. See BMPs (Sediment Trap) and (Temporary Sediment Pond) in Development Standard Division 13 – Erosion and Sediment Control Manual. Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction. The maintenance of pre-settling basins or sumps is critical to their effectiveness as pretreatment devices.
- If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, protect graded and seeded areas with suitable erosion control measures.

Design Procedure

- Step 1 - Determine the peak flow rate to the biofilter from the Water Quality Design Storm.

- Step 2 - Determine the slope of the biofilter. This will be somewhat dependent on where the biofilter is placed. The slope should be at least one percent (1%) and shall be no steeper than five percent (5%). When slopes less than two percent (2%) are used, the need for underdrainage must be evaluated.

- Step 3 - Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.

- Step 4 - Use Manning's Equation to estimate the bottom width of the biofilter. Manning's Equation for English units is as follows:

$$Q = (1.486\ A\ R^{0.667}\ S^{0.5})\ /\ n$$

Where: Q = flow (cfs)
A = cross sectional area of flow (ft^2)
R = hydraulic radius of flow cross section (ft)
S = longitudinal slope of biofilter (ft/ft)
n = Manning's roughness coefficient. Values for grasses range from 0.15 to 0.40. Use n = 0.30 for a typical biofilter with turf/lawn vegetation; n = 0.20 for a biofilter with less dense vegetation such as meadow or pasture; or other n values for specific site vegetation as determined by the site professional. These values may be subject to approval by the project review authority.

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow, the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$$B = ((0.135\ Q) / (y^{1.667}\ S^{0.5}))-zy$$

For n = 0.20 and where:

B = bottom width of the swale
y = depth of flow
Z = the side slope of the biofilter in the form of z:1

For other values of n, use the following equation:

$$B = (((n / 1.486)\ Q) / (y^{1.667}\ S^{0.5}))-zy$$

Typically, the depth of flow for turfgrass is selected to be four inches (4"). For dryland grasses, the depth of flow should be set to three inches (3"). It can be set lower, but doing so will increase the bottom width. Sometimes when the flow rate is very low, the equation listed above will generate a negative value for B. Since it is not possible to have a negative bottom width, the bottom width should be set to one foot (1') when this occurs.

Biofilters are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel biofilters should be used in conjunction with a device that splits the flow and directs the proper amount to each biofilter.

- Step 5 - Calculate the cross-sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.
- Step 6 - Calculate the velocity of flow in the channel using: V = Q / A
  If V is less than or equal to 1 ft/sec, the biofilter will function correctly with the selected bottom width. Proceed to design Step 7.

  If V is greater than 1 ft/sec, the biofilter will not function correctly. Increase the bottom width, recalculate the depth using Manning's Equation and return to Step 5.
- Step 7 - Select a location where a biofilter with the calculated width and a length of 200 feet will fit. If a length of 200 feet is not possible, the width of the biofilter must be increased so that the area of the biofilter is the same as if a 200-foot length had been used.
- Step 8 - Select a vegetation cover suitable for the site. Consult the local NRCS office for guidance.
- Step 9 - Determine the peak flow rate to the biofilter during the 25-year, 24-hour storm (a 10-year storm is acceptable, provided that reparative maintenance will be performed following every 10-year event). Using Manning's Equation, find the depth of flow (typically, n = 0.04 during the 25-year flow; n may need to be adjusted if a 10-year event is used). The depth of the channel shall be one foot (1') deeper than the depth of flow. Check to determine that shear stresses do not cause erosion; the velocity needs to stay below two (2) ft/sec. This step can be skipped if all storms larger than the short duration water quality storm bypass the biofiltration swale.

Construction and Maintenance Criteria

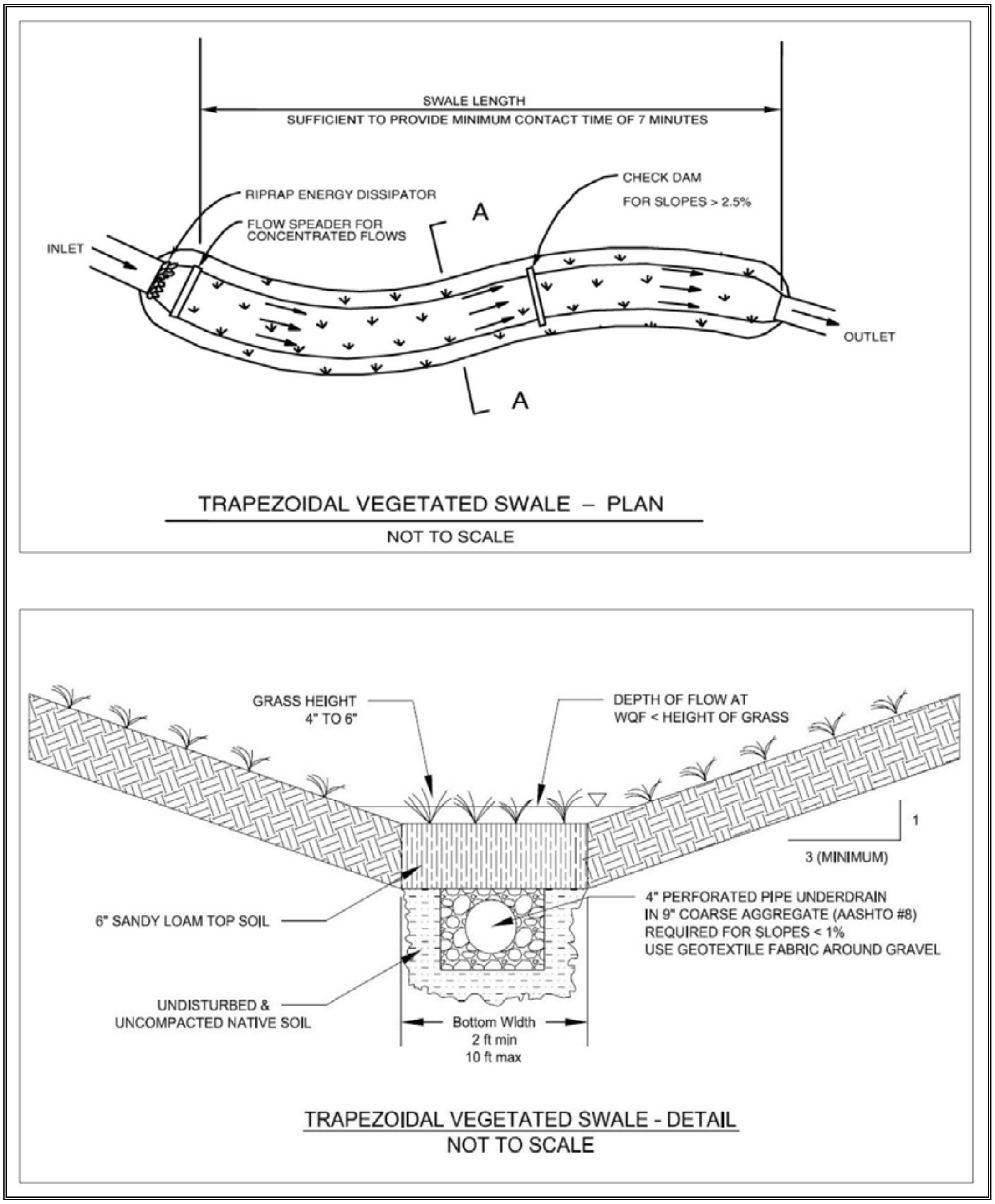
- Groomed biofilters planted in grasses shall be mowed during the summer to promote growth and pollutant uptake.
- Remove sediments during summer months when they build up to four inches (4") at any spot, cover biofilter vegetation, or otherwise interfere with biofilter operation. Reseed bare spots created by removal equipment.
- Inspect biofilters periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or groundwater.
- Clean curb cuts when soil and vegetation buildup interfere with flow introduction.

- Remove litter to keep biofilters free of external pollution.

From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.

Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

Figure TC 5-1 Vegetated Swale Plan View/Section



From: Stormwater Quality Design Manual for the Sacramento Region, July 2018

Figure TC 5-2 Vegetated Swale Section View

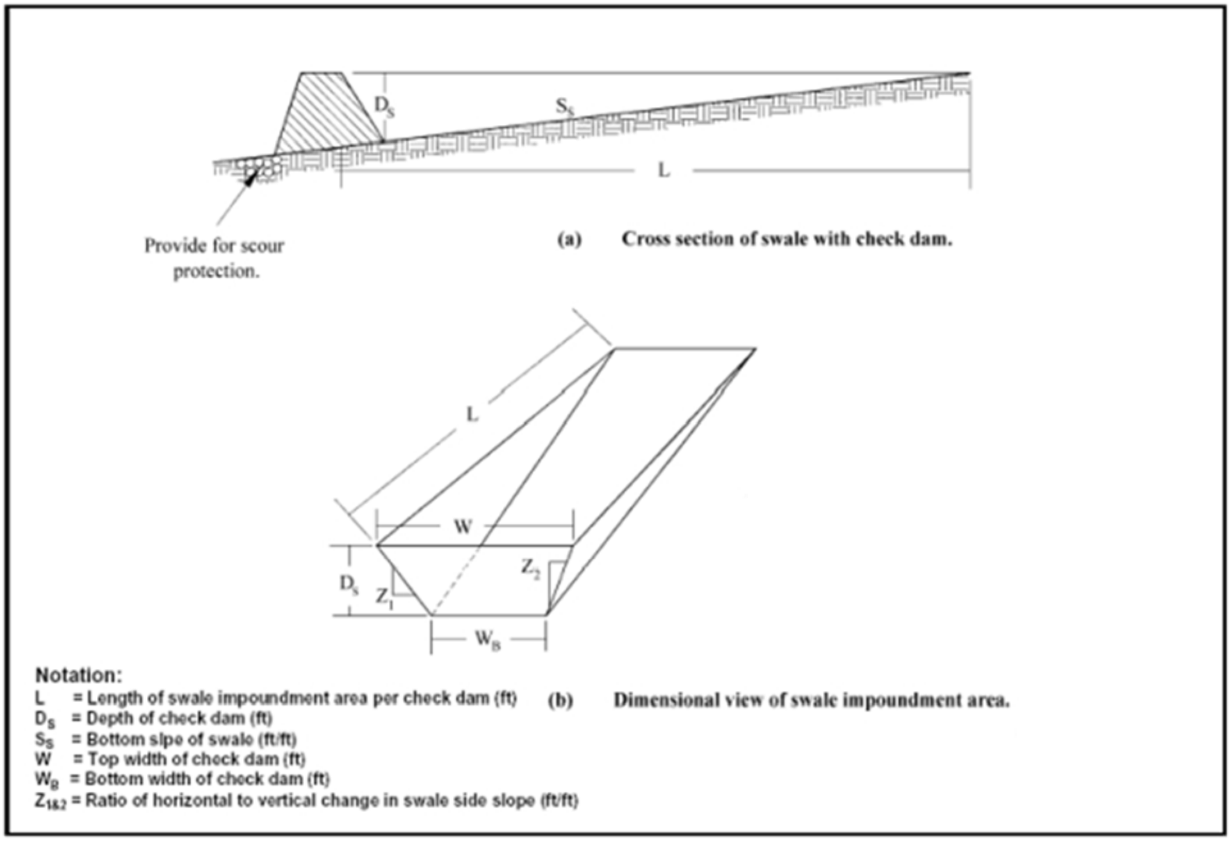


Figure adapted from California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association

TC-7 Vegetated Filter Strip

Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Water Quality Treatment
- ✓ Collect and Convey

Description

A vegetated filter strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants but not nutrients. See Figure TC-7-1. This BMP will not provide stormwater quantity control. Vegetated filter strips are primarily used adjacent and parallel to paved areas such as parking lots or driveways, and along rural roadways where sheet flow from the paved area will pass through the filter strip before entering a conveyance system or a quantity control facility, or is dispersed into areas where it can be infiltrated or evaporated. The vegetated filter strip is still in an interim phase of development. This BMP is acceptable for use on any project that meets the General Criteria listed below; however, the General Criteria may change in the future as research projects and field tests involving this BMP are completed.

General Criteria

- Along roadways, filter strips should be placed at least one foot (1'), and preferably three to four feet (3-4') from the edge of pavement, to accommodate a vegetation-free zone.
- Once stormwater has been treated by a filter strip, it may need to be collected and conveyed to a stormwater quantity BMP.
- The flow from the roadway must enter the filter strip as sheet flow.
- Vegetated filter strips must not receive concentrated flow discharges.
- A maximum flowpath of each 30 feet can contribute to a filter strip designed via this method.
- Filter strips should be used where the roadway ADT is less than 30,000.
- Vegetated filter strips should not be used on roadways with longitudinal slopes greater than five percent (5%) because of the difficulty in maintaining the necessary sheet flow conditions.
- Vegetated filter strips should be constructed after other portions of the project are completed.
- The use of this BMP may be limited to crowned roads where filter strips can be added along both sides of the road. It should not be used for banked roads that drain solely to one side without additional analysis to account for the extended flowpath length.

Design Procedure

The sizing of the filter strip is based on the length of the flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flowpath).

Step 1: Determine the length of the flowpath draining to the filter strip. Determine the length of the flowpath from the upstream to the downstream edge of the impervious area draining to the filter strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer. In the case of crowned roadways, the flowpath may be half the width of the roadway.

Step 2: Determine the average longitudinal or cross slope of the filter strip: Calculate the longitudinal or cross slope of the filter strip (parallel to the flowpath), averaged over the total width of the filter strip. If the slope is less than two percent (2%), use two percent (2%) for sizing purposes. The maximum longitudinal or cross slope allowed is 6:1 or 17 percent.

Step 3: Determine the required length of the filter strip: Use Figure TC-7-2 or an approach based on determining the hydraulic residence time of runoff, to size the filter strip. To use the figure, find curve representing the appropriate length of the flowpath (interpolate between curves as necessary; identifying appropriate filter strip lengths for flowpaths longer than 30 feet may require additional analysis for practical application – see General Criteria above, last bullet). Find the point along the curve where the design longitudinal or cross slope of the filter strip is directly below and read the filter trip length to the left on the y axis. Note that the minimum required filter strip length is: 4’ for a 10’ flowpath; 4.5’ for a 25’ flowpath; and 5.5’ for a 30’ flowpath. The filter strip must be designed to provide this minimum length “L” along the entire stretch of pavement draining to it.

Construction and Maintenance Criteria

- Construct filter strips after completion of paving operations.
- Groomed filter strips planted in grasses should be mowed during the summer to promote growth.
- Inspect filter strips periodically, especially after periods of heavy runoff. Remove sediments and reseed as necessary. Catch basins or sediment sumps that precede filter strips should be cleaned to maintain proper function.

From: California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.
King County Surface Water Design Manual, 1998, King County, Washington.
Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

Figure TC-7-1 Typical Vegetated Filter Strip Details

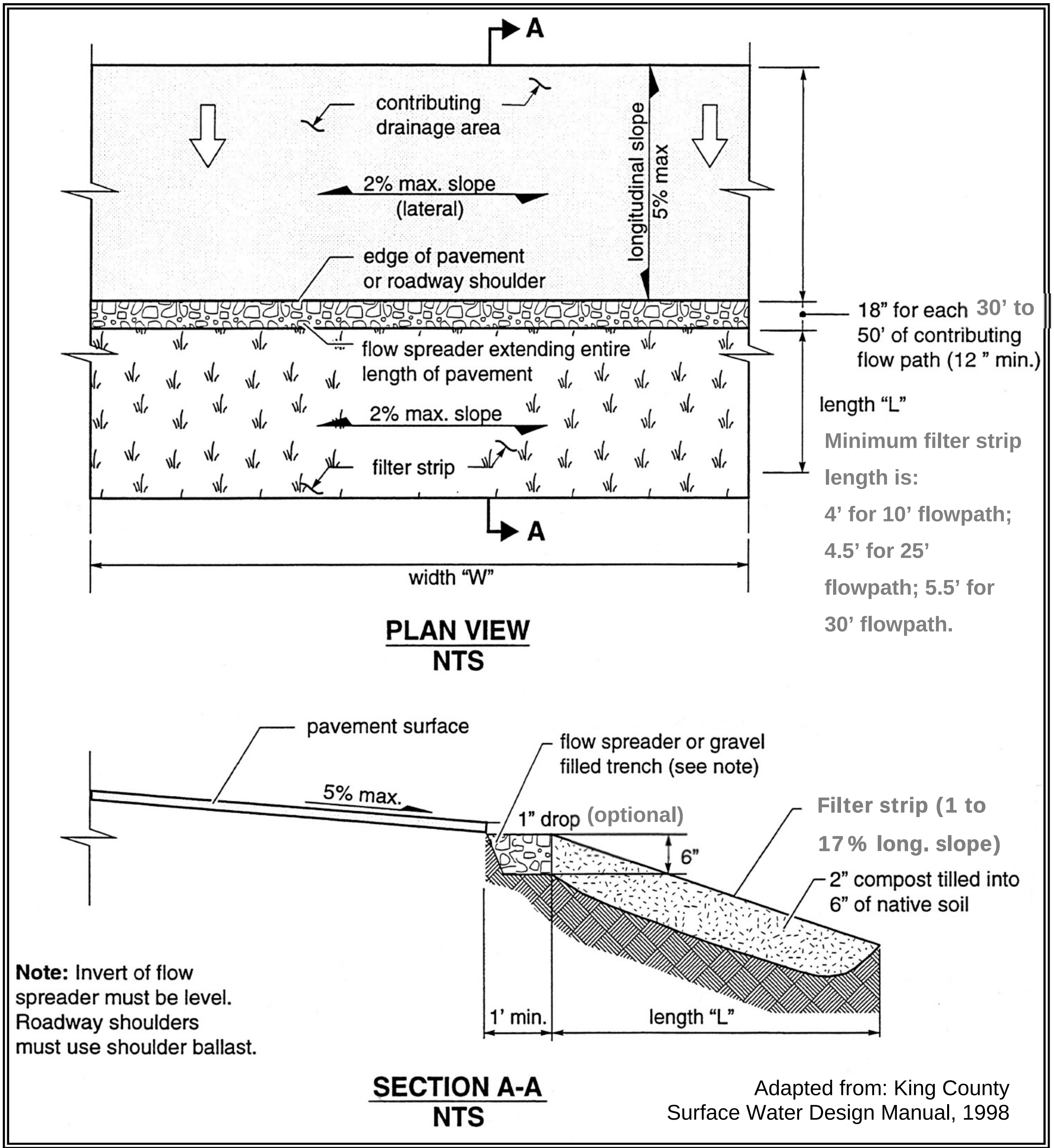
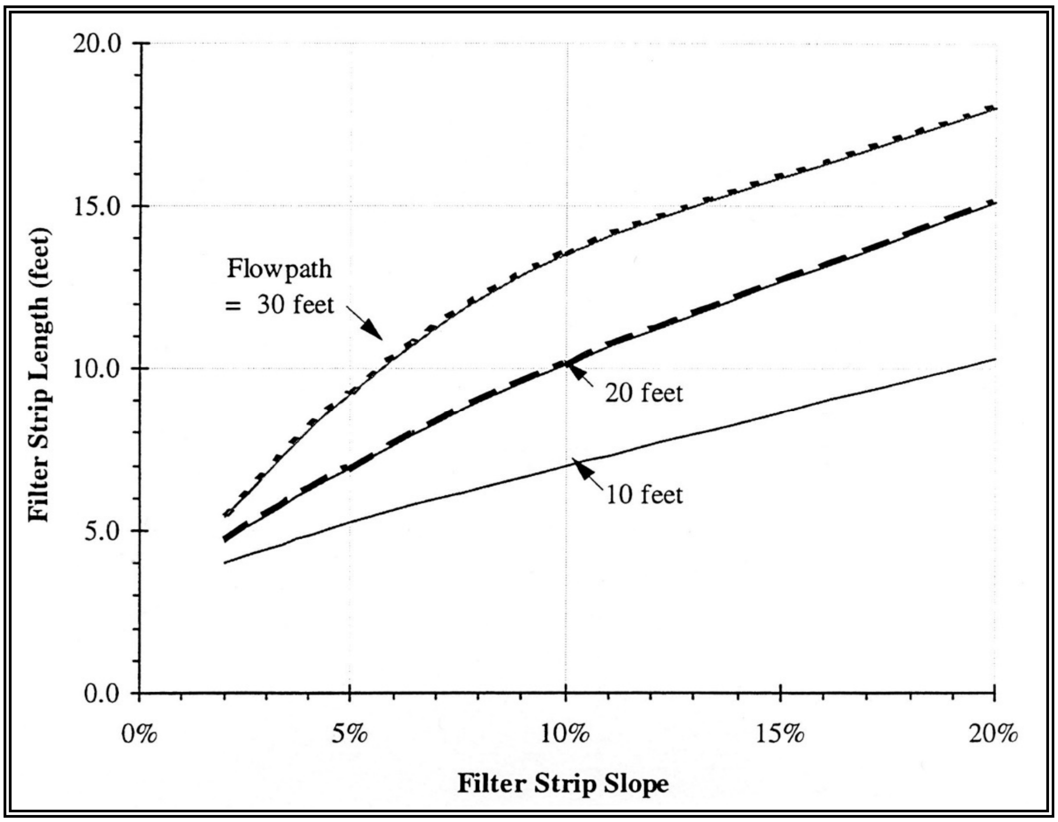


Figure TC-7-1 Vegetated Filter Strip (design graph)

Source: King County Surface Water Design Manual, King County, Washington 1998



TC-8 Sand Filtration Treatment Facilities

Design Objectives

- ✓ Water Quality Treatment
- ✓ Contain Pollutants

Description

A typical sand filtration system consists of a pretreatment system, flow spreader(s), a sand bed, and the underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system. An impermeable liner under the facility may also be needed if the filtered runoff requires additional treatment to remove soluble groundwater pollutants, or in cases where additional groundwater protection is mandated. The variations of a sand filter include a basic or large sand filter, sand filter with level spreader, sand filter vault, and linear sand filter. (See Figure TC-8-1 for a basic sand filter.)

This BMP fact sheet describes basic and large sand filters and sand filters with level spreaders. BMP TC-9 describes sand filter vaults and BMP TC-10 describes linear sand filters.

Performance Objectives

Basic Sand Filter

Basic sand filters are expected to achieve 80 percent TSS at influent Event Mean Concentrations (EMCs) of 30-300 mg/L (King County, 1998) (Chang, 2000) oil and grease to below 10 mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge.

Large Sand Filter

Large sand filters are expected to remove at least 50 percent of the total phosphorous compounds (as TP) by collecting and treating 95 percent of the runoff volume (ASCE and WEF, 1998).

Application and Limitations

Sand filtration can be used in most residential, commercial, and industrial developments where debris, heavy sediment loads, and oils and greases will not clog or prematurely overload the sand, or where adequate pretreatment is provided for these pollutants. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, high-density multi-family housing, roadways, and bridge decks.

Sand filters should be located off-line before or after detention. Sand filters are also suited for locations with space constraints in retrofit and new/re-development situations. Overflow or bypass structures must be carefully designed to handle the larger storms. An off-line system is sized to treat 90 percent of the annual runoff volume. If a project includes flow control requirements, the flows bypassing the filter and the filter discharge must be routed to a retention/detention facility or other appropriate flow control BMP (for example, infiltration BMPs such as infiltration trenches or dry wells).

Pretreatment is necessary to reduce velocities to the sand filter and remove debris, floatables, large particulate matter, and oils. In high water table areas, adequate drainage of the sand filter may require additional engineering analysis and design considerations. Surface filters will not provide treatment in the winter if the ground is frozen, but may still provide adequate treatment during warmer months. An underground filter should be considered in areas subject to freezing conditions (Urbonas, 1997).

Site Suitability

The following site characteristics should be considered in siting a sand filtration system:

- Space availability, including a presettling basin
- Sufficient hydraulic head, at least four feet (4') from inlet to outlet
- Average winter conditions at the project site do not create snow or ice conditions that prevent the filter from operating as designed
- Adequate Operation and Maintenance capability including accessibility for O & M
- Sufficient pretreatment of oil, debris, and solids in the tributary runoff

Design Criteria

Objective: To capture and treat the Water Quality Design Storm volume (when using the Simple Sizing Method described below). Off-line sand filters can be located either upstream or downstream of detention facilities. Online sand filters should only be located downstream of detention.

Simple Sizing Method: This method applies to the off-line placement of a sand filter upstream or downstream of detention facilities. A conservative design approach is provided below using a routing adjustment factor that does not require flow routing computations through the filter. A simple alternative approach for off-line placement downstream of detention facilities is to route the full two-year release rate from the detention facility (sized for duration control) to a sand filter with sufficient surface area to infiltrate at that flow rate.

Basic Sand Filter: For sizing a Basic Sand Filter, a 0.7 routing adjustment factor is applied to compensate for routing through the sand bed at the maximum pond depth. A flow splitter should be designed to route the water quality design flow rate to the sand filter.

Large Sand Filter: For sizing a Large Sand Filter, use the same procedure as outlined above for the Basic Sand Filter. Then apply a scale-up factor of 1.6 to the surface area. This is considered a reasonable average for various impervious tributary sources.

For a Large Sand Filter, the flow splitter upstream or downstream of the detention facility should be designed to route the flow rate associated with conveying 95 percent of the annual runoff volume to the sand filter. Use the standard water quality design flow rate multiplied by 1.2.

Note*: An overflow should be included in the design of the sand filter pond. The overflow height should be at the maximum hydraulic head of the pond above the sand bed.*

Design Specifications:

Background: The sizing of the sand filter is based on routing the design runoff volume through the sand filter and using Darcy's Law to account for the increased flow through the sand bed caused by the hydraulic head variations in the pond above the sand bed. Darcy's Law is represented by the following equation:

$$Q_{sf} = KiA_{sf} = FA_{sf} \quad \text{where: } i = (h+L)/L$$

Therefore, $A_{sf}=Q_{sf}/Ki$
Also, $Q_{sf}=A_tQ_dR/t$

Substituting for Q_{sf}, $A_{sf}=A_tQ_dR/Kit$
Or, $A_{sf}=A_tQ_dR/ \{K(h+L)/Lt\}$
Or, $A_{sf}=A_tQ_dR/Ft$

Where:

- Q_{sf} is the flow rate in cu. feet per day (or ft^3/sec.) at which runoff is filtered by the sand filter bed.
- A_{sf} is the sand filter surface area (sq. ft.).
- Q_d is the design storm runoff depth (ft.) for the water quality storm. It is estimated using the SCS Curve Number equations detailed in Chapter 4.
- R is a routing adjustment factor. Use R = 0.7.
- A_t is the tributary drainage area (sq. ft.).
- K is the hydraulic conductivity of the sand bed. Use 2 ft./day or 1.0 inch/hour at full pre-sedimentation.
- i is the hydraulic gradient of the pond above the filter; (h+L)/L, (ft/ft).
- F=Ki is the filtration rate, feet/day (or inches per hour).
- d is the maximum sand filter pond depth, and h = d/2 in ft.
- t is the recommended maximum drawdown time of 24 hours from the completion of inflow into the sand filter pond (assume ponded pre-settling basin) of a discrete storm event to the completion of outflow from the sand filter underdrain of that same storm event.
- L is the sand bed depth; typically, 1.5 ft.

Design Example: Example calculation using the simple sizing method and a routing adjustment factor.

Sedimentation basin fully ponded and no pond water above the sand filter
(Full sedimentation prior to sand filter-24 hours residence of WQ storm runoff)

> A_t = 10 acres is the tributary drainage area
> Q_d = 0.92 inches (0.0767 ft.), assumed
> CN = 96.2 for 85% impervious and 15% grass tributary surfaces
> R = 0.7, the routing adjustment factor
> Maximum drawdown time through the sand filter, 24 hours
> Maximum pond depth above sand filter, example at 3 and 6 feet,
> h = 1.5 and 3 feet
> Design Hydraulic Conductivity of basic sand filter, K, 2.0 feet/day
> (1 inch/hour)

Using Design Equation

> $A_{sf} = A_{sf} = A_t Q_d R / \{K(h+L)/Lt\}$
> At pond depth of 3 feet:
>
> A_{sf} = (10 acres)(43,560 ft^2/acre)(0.0767 ft)(0.7)/ {(2.0 ft/day)(1.5 ft + 1.5 ft)/(1.5 ft) (1 day)}=
> 5,846 square feet

Therefore A_{sf} for Basic Sand Filter becomes: 5,846 square feet at pond depth of 3 feet

Additional Design Information

1. Runoff to be treated by the sand filter must be pretreated (e.g., pre-settling basin, depending on pollutants) to remove debris and other solids, and oil from high use sites.

2. Inlet bypass and flow spreading structures (e.g., flow spreaders, weirs, or multiple orifice openings) should be designed to capture the applicable design flow rate, minimize turbulence, and spread the flow uniformly across the surface of the sand filter. Stone rip-rap or other energy dissipation devices should be installed to prevent gouging of the sand medium and to promote uniform flow. Include emergency spillway or overflow structures.

3. The following are design criteria for the underdrain piping: *(types of underdrains include: a central collector pipe with lateral feeder pipes, or, a geotextile drain strip in an eight-inch (8”) gravel backfill*

or drain rock bed, or, longitudinal pipes in an eight-inch (8") gravel backfill or drain rock with a collector pipe at the outlet end.)

- Upstream of detention underdrain piping should be sized to handle double the two-year design storm. Downstream of detention, the underdrain piping should be sized for the two-year design storm. In both instances, there should be at least one foot (1') of hydraulic head above the invert of the upstream end of the collector pipe.
- Internal diameters of underdrain pipes should be a minimum of six inches (6") and two (2) rows of ½-inch holes spaced six inches (6") apart longitudinally (maximum), with rows 120 degrees apart (laid with holes downward). The maximum perpendicular distance between two (2) feeder pipes must be 15 feet. All piping is to be schedule 40 PVC or greater wall thickness. Drain piping could be installed in basin and trench configurations. Minimum underdrain size should be eight inches (8") in diameter if the filter is subject to freezing for a month or more.
- Main collector underdrain pipe should be at a slope of 0.5 percent minimum (one percent (1%) if subject to freezing for a month or more.)
- A geotextile fabric must be used between the sand layer and drain rock or gravel and placed so that one inch (1") of drain rock/gravel is above the fabric. Drain rock should be 0.75-1.5 inch rock or gravel backfill, washed free of clay and organic material. Increase gravel depth at the base of filter to 18 inches if subject to freezing for a month or more.
- Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the surface of the filter. A valve box must be provided for access to the cleanouts. Access for cleaning all underdrain piping should be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand bed. An inlet shutoff/bypass valve is recommended to facilitate the maintenance of the sand filter.
  Note*: Other equivalent energy dissipaters can be used if needed.*

4. Sand Specification: The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table TC-8-2 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met.

Table TC-8-1 - Sand Medium Specification

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: King County Surface Water Design Manual, September 1998

5. Impermeable Liners for Sand Bed Bottom: Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. Impermeable liners may be clay, concrete, or geomembrane. Clay liners should have a minimum thickness of 12 inches and meet the specifications give in Table TC-8-2.

Table TC-8-2 - Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	$1 \times 10^{-6 \text{ max.}}$
Plasticity Index of Clay	ASTM D-423 & D-424	Percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	Percent	Not less than 30
Clay Particles Passing	ASTM D-422	Percent	Not less than 30
Clay Compaction	ASTM D-2216	Percent	95% of Standard Proctor Density

Source: City of Austin, 1988

If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.

Concrete liners may also be used for sedimentation chambers and for sedimentation and sand filtration facilities less than 1,000 square feet in area. Concrete should be five inches (5”) thick Class A or better and should be reinforced by steel wire mesh. The steel wire mesh should be 6-gauge wire or larger and six-inch by six-inch (6” x 6”) mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 tons per square foot or less, the concrete should have a minimum six-inch (6”) compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone, or equivalent with a diameter of 0.75 to one inch (1”).

If an impermeable liner is not required, then a geotextile fabric liner should be installed that retains the sand unless the sand filter has been excavated to bedrock.

If an impermeable liner is not provided, then an analysis should be made of possible adverse effects of seepage zones on groundwater, and near building foundations, basements, roads, parking lots, and sloping sites. Sand filters without impermeable liners should not be built on fill sites and should be located at least 20 feet downslope and 100 feet upslope from building foundations.

6. Include an access ramp with a slope not to exceed 7:1, or equivalent, for maintenance purposes at the inlet and the outlet of a surface filter. Consider an access port for inspection and maintenance.

7. Side slopes for earthen/grass embankments should not exceed 3:1 to facilitate mowing.

8. High groundwater may damage underground structures or affect the performance of filter underdrain systems. There should be sufficient clearance (at least two feet (2’) is recommended) between the seasonal high groundwater level (highest level of groundwater observed) and the bottom of the sand filter to obtain adequate drainage.

9. A sport-field sod, grown in sand, may be used on the sand surface. No other soil may be used due to the high clay content in most sod soils. No topsoil may be added to sand filter beds because fine-grained materials (e.g., silt and clay) reduce the hydraulic capacity of the filter.

Construction Criteria

No runoff should enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to a pretreatment sedimentation facility, but discharge from sedimentation facilities should bypass downstream sand filters. Careful level placement of the sand is necessary to avoid the formation of voids within the sand that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system. Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 PSIG or less). After the sand layer is placed, water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

Maintenance Criteria

Inspections of sand filters and pretreatment systems should be conducted every six (6) months and after storm events, as needed during the first year of operation and annually thereafter if filter performs as designed. Repairs should be performed as necessary. Suggestions for maintenance include:
Accumulated silt and debris on top of the sand filter should be removed when their depth exceeds one-half (½) inch. The silt should be scraped off during dry periods with steel rakes or other devices. Once sediment is removed, the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Finer sediments that have penetrated deeper into the filtration media can reduce the permeability to unacceptable levels, necessitating replacement of some or all of the sand.

Sand replacement frequency is not well established and will depend on suspended solids levels entering the filter (the effectiveness of the pretreatment BMP can be a significant factor).

Frequent overflow into the spillway or overflow structure or slow drawdown are indicators of plugging problems. A sand filter should empty in 24 hours following a storm event (24 hours for the pre-settling chamber), depending on pond depth. If the hydraulic conductivity drops to one inch (1”) per hour corrective action is needed, e.g.:

- Scraping the top layer of fine-grain sediment accumulation (mid-winter scraping is suggested)
- Removing of vegetation
- Aerating the filter surface
- Tilling the filter surface (late-summer rototilling is suggested)
- Replacing the top four inches (4”) of sand
- Inspecting geotextiles for clogging
- For sand filters with sport sod/grass cover, removing and replacing sod, as appropriate. Sod removal may not be necessary for aeration of top of filter sand.

Rapid drawdown in the sand bed (greater than 12 inches per hour) indicates short-circuiting of the filter. Inspect the cleanouts on the underdrain pipes and along the base of the embankment for leakage. Drawdown tests for the sand bed could be conducted, as needed, during the wet season. These tests can be conducted by allowing the filter to fill (or partially fill) during a storm event, then measuring the decline in water level over a four- to eight-hour (4-8) period. An inlet and an underdrain outlet valve would be necessary to conduct such a test.

The formation of rills and gullies on the surface of the filter indicates the improper function of the inlet flow spreader or poor sand compaction. Check for accumulation of debris on or in the flow spreader and refill rills and gullies with sand.

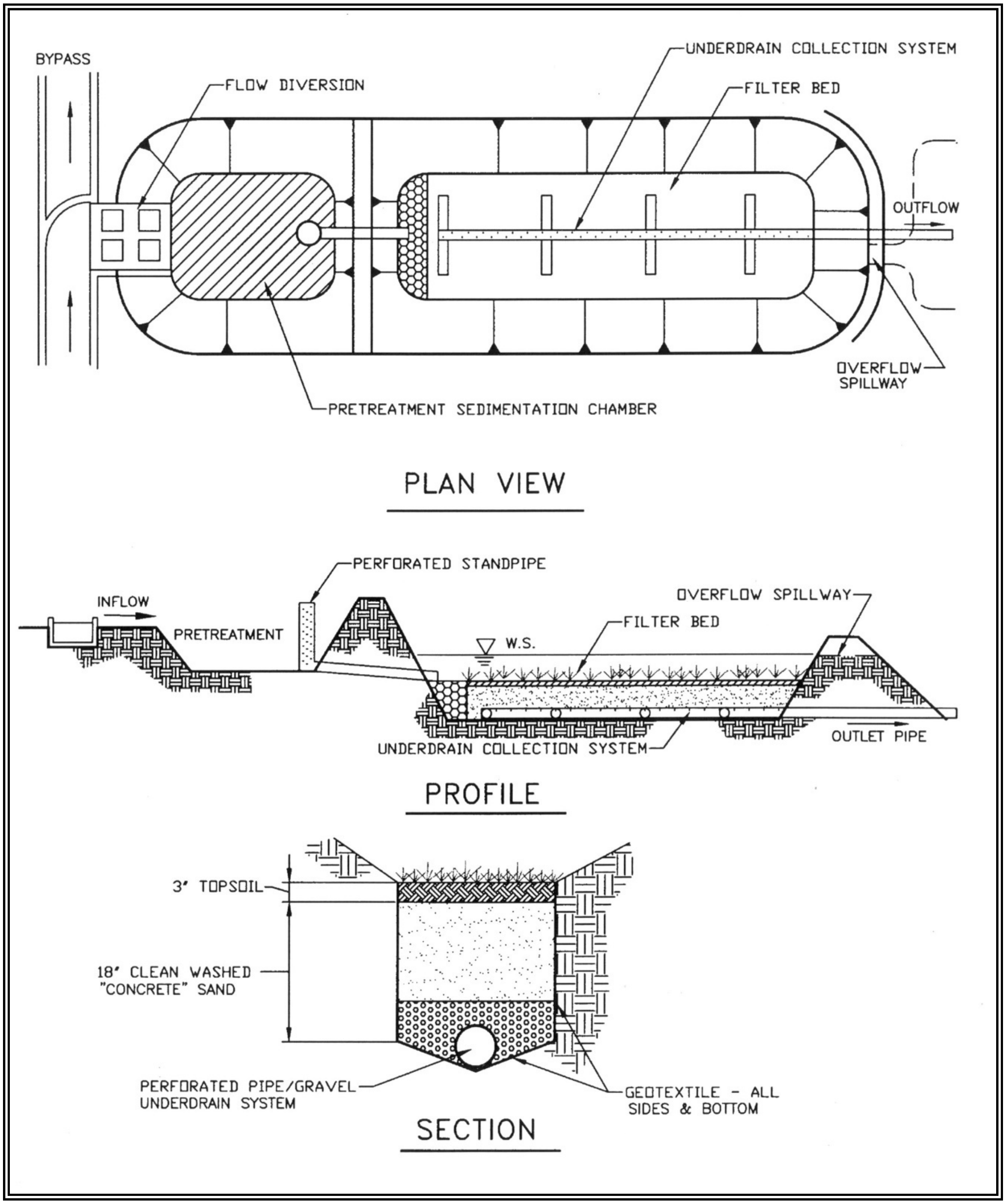
Avoid driving heavy equipment on the filter to prevent compaction and rut formation.

References:

- ASCE and WEF, Urban Runoff Quality Management, WEF Manual of Practice No. 23, 1998.
- Chang, George, C., “Review of Stormwater Manual-Sand Filtration Basins for Department of Ecology, State of Washington,” November 5, 2000.
- King County (1998), *King County Surface Water Design Manual,* September 1998.
- Urbonas, Ben, Hydraulic Design of Sand Filters for Stormwater Quality, 1997.

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.
Stormwater Management Manual for Western Washington, 2005, Washington Department of Ecology.

Figure TC-8-1 Sand Filter



TC-9 Sand Filter Vault

Design Objectives
✓ Water Quality Treatment
✓ Contain Pollutants

Description

See Figures TC-9-1 and TC-9-2. A sand filter vault is similar to an open sand filter except that the sand layer and under-drains are installed below grade in a vault. It consists of pre-settling and sand filtration cells.

Applications and Limitations

- Use where space limitations preclude above-ground facilities
- Not suitable where high water table and heavy sediment loads are expected
- An elevation difference of four feet (4') between inlet and outlet is needed

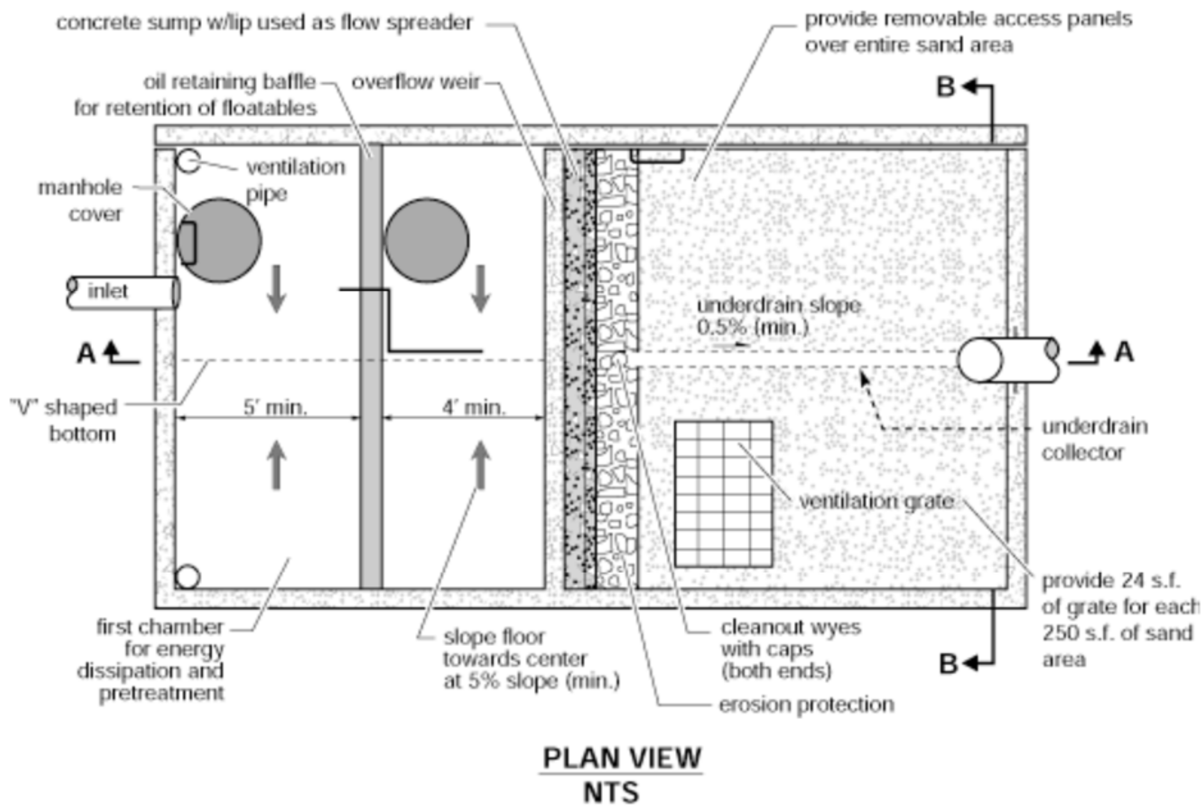
Additional Design Criteria for Vaults

- Vaults may be designed as off-line systems or on-line for small drainages.
- In an off-line system, a diversion structure should be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet downstream capacity requirements), or to surface water.
- Optimize sand inlet flow distribution with minimal sand bed disturbance. A maximum of eight-inch (8") distance between the top of the spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad, or alternatively, a pipe and manifold system may be used. Any pipe and manifold system must retain the required permanent pool volume in the first cell, minimize turbulence, and be readily maintainable.
- If an inlet pipe and manifold system is used, the minimum pipe size should be eight inches (8"). Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
- Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.
- The filter bed should consist of a sand top layer and a geotextile fabric second layer with an underdrain system.
- Design the pre-settling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system should be used. One foot (1') of sediment storage in the pre-settling cell must be provided.
- The pre-settling chamber should be constructed to trap oil and trash. This chamber is usually connected to the sand filtration chamber with an invert elbow or underflow baffle to protect the filter surface from oil and trash.
- If a retaining baffle is necessary for oil/floatables in the pre-settling cell, it must extend at least one foot (1') above to one foot (1') below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. Access opening and ladder must be provided on both sides of the baffle.
- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate should be provided for every 250 square feet of sand bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.

- Provision for access is the same as for wet vaults. Removable panels must be provided over the sand bed.
- Sand filter vaults must conform to the materials and structural suitability criteria specified for wet vaults.
- Provide a sand filter inlet shutoff/bypass valve for maintenance.
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

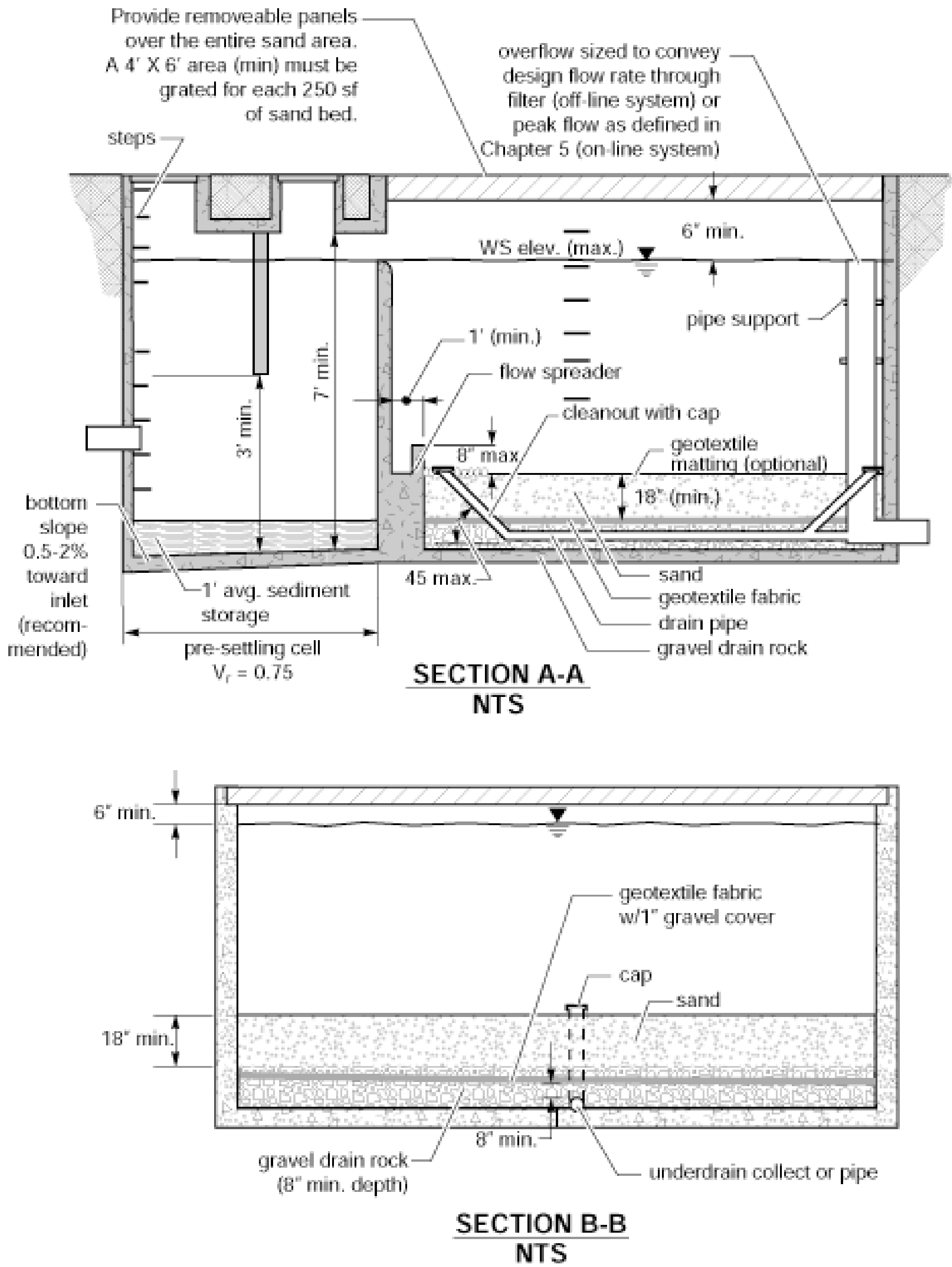
From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.
Stormwater Management Manual for Western Washington, 2005, Washington Department of Ecology.
Surface Water Design Manual, 1998, King County, Washington.

Figure TC-9-1a Sand Filter Vault



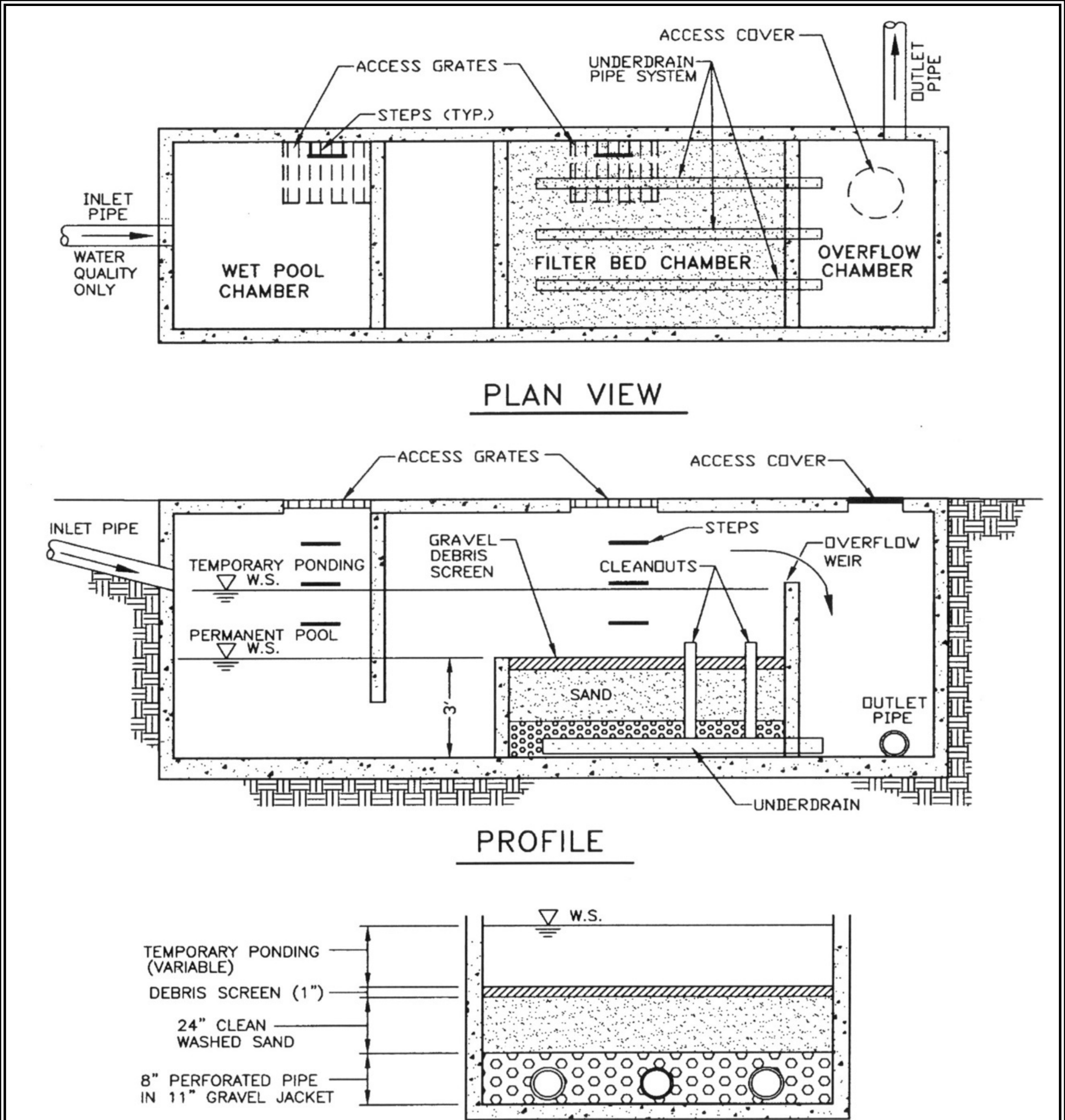
Source: King County Surface Water Manual

Figure TC-9-1b Sand Filter Vault (continued)



Source: King County Surface Water Manual

Figure TC-9-2 Sand Filter Vault (also called underground sand filter)



Source:
Boise Stormwater Manual

TC-10 Linear Sand Filter

Design Objectives
✓ Water Quality
✓ Contain Pollutants

Description

Linear sand filters (Figure TC-10-1) are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader.

Application and Limitations

- Applicable in long narrow spaces such as the perimeter of a paved surface.
- As a part of a treatment train downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control.
- To treat small drainages (less than two (2) acres of impervious area).
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable.

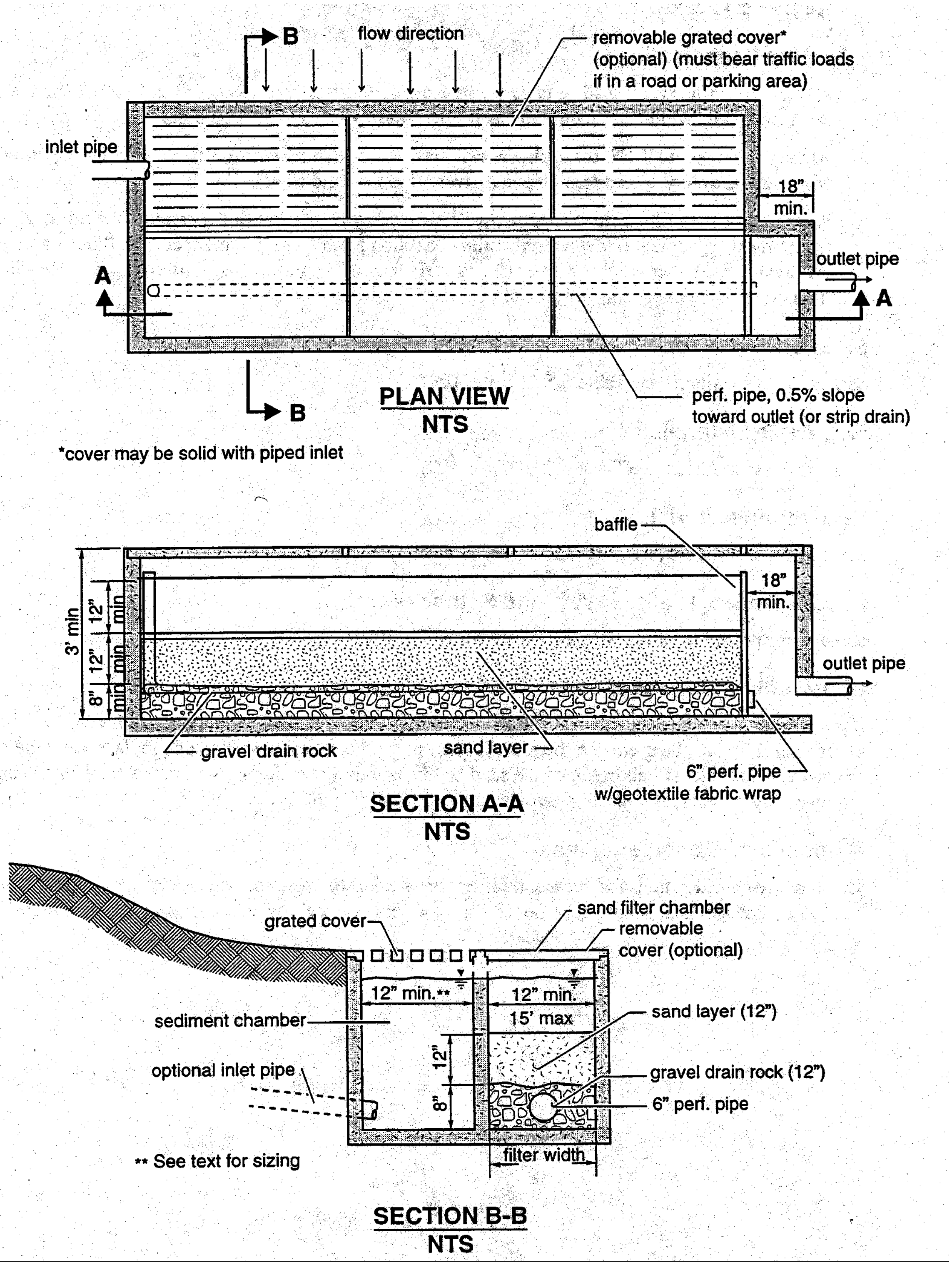
Additional Design Criteria for Linear Sand Filters

- The two (2) cells should be divided by a divider wall that is level and extends a minimum of 12 inches above the sand bed.
- Stormwater may enter the sediment cell by sheet flow or a piped inlet.
- The width of the sand cell must be one-foot (1') minimum to 15 feet maximum.
- The sand filter bed must be a minimum of 12 inches deep and have an eight-inch (8") layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be a six-inch (6") diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
- Maximum sand bed ponding depth: one foot (1').
- Must be vented as for sand filter vaults.
- Linear sand filters must conform to the materials and structural suitability criteria specified for wet vaults.
- Set sediment cell width as follows:

Sand filter width (w), in inches	12-24	24-48	48-72	72+
Sediment cell width, in inches	12	18	24	w/3

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.
Stormwater Management Manual for Western Washington, 2005, Washington Department of Ecology.
Surface Water Design Manual, 1998, King County, Washington.

Figure TC-10-1 Linear Sand Filter



Source: King County Surface Water Manual

TC-11 Oil and Water Separators

TC-11a API (Baffle type) Separator Bay

TC-11b Coalescing Plate (CP) Separator Bay

Design Objectives
✓ Source Control
✓ Water Quality Treatment
✓ Contain Pollutants

Description

This section provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators. Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Figures TC-11-1 and TC-11-2. Oil removal separators typically consist of three (3) bays: forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. A spill control (SC) separator (Figure TC-11-3) is a simple catch basin with a T-inlet for temporarily trapping small volumes of oil. The spill control separator is included here for comparison only and is not designed for, or to be used for, treatment purposes.

Purpose of Oil and Water Separators

To remove oil and other water-insoluble hydrocarbons and settleable solids from stormwater runoff.

Performance Objectives

Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hour average and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge or in the receiving water.

Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. (Seattle METRO, 1990; Watershed Protection Techniques, 1994; King County Surface Water Management, 1998). For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

Facilities that would require oil control BMPs include parking lots at convenience stores, fast-food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery and commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.

Without intense maintenance, oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels.

Pretreatment should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small drainage areas (fueling stations, maintenance shops, etc.), a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis.

Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)

Design Criteria-General Considerations

There is concern that oil/water separators used for stormwater treatment have not performed to expectations (Watershed Protection Techniques, 1994; Schueler, Thomas R., 1990). Therefore, emphasis should be given to proper application, design, O & M (particularly sludge and oil removal), and prevention of CP fouling and plugging (US Army of Engineers, 1994). Other treatment systems, such as sand filters and emerging technologies, should be considered for the removal of insoluble oil and TPH.

The following are design criteria applicable to API and CP oil/water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH, and empirical oil rise rates in the runoff and the viscosity and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved (Washington State Department of Ecology, 1995). Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.
- Locate the separator off-line and bypass flows in excess of 2.15 times the Water Quality design flow rate.
- Use only impervious conveyances for oil-contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.
- Add pretreatment for TSS that could cause clogging of the CP separator or otherwise impair the long-term effectiveness of the separator.

Criteria for Separator Bays

- Size the separator bay for the Water Quality design flow rate x a correction factor of 2.15.
- To collect floatables and settleable solids, design the surface area of the forebay at 20 ft^2 per 10,000 ft^2 of area draining to the separator. The length of the forebay should be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings should be about 3/4 inch.
- Include a submerged inlet pipe with a turn-down elbow in the first bay at least two feet (2') from the bottom. The outlet pipe should be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.
- Include a shutoff mechanism at the separator outlet pipe (King County Surface Water Management, 1998).
- Use absorbents and/or skimmers in the afterbay as needed.

Criteria for Baffles

- Oil retaining baffles (top baffles) should be located at least at ¼ of the total separator length from the outlet and should extend down at least 50 percent of the water depth and at least one foot (1') from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

Oil and Water Separator BMPs

Two (2) BMPs are described in this section. BMP TC-11a for baffle type separators and BMP TC-11b for coalescing plate separators.

BMP TC-11a API (Baffle type) Separator Bay

Design Criteria

The design criteria for small drainages are based on the design velocity, oil rise rate, residence time, width, depth, and length considerations. As a correction factor, the American Petroleum Institute (API) turbulence criterion is applied to increase the length.

The API criterion for treating stormwater runoff from small drainage areas (fueling stations, commercial parking lots, etc.) is modified by using the design hydraulic horizontal velocity, V_h, for the design V_h/V_t ratio rather than the API minimum of $V_h/V_t = 15$. The API criterion appears applicable for greater than two (2) acres of impervious drainage area.

The following is the sizing procedure using the modified API criterion:

- Determine the oil rise rate, V_t, in cm/sec, using Stoke's Law (Water Pollution Control Federation, 1985), or empirical determination, or 0.033 ft./min for 60°F oil. The application of Stoke's Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases, the design basis would not be the 60 micron droplet size and the 0.033 ft/min rise rate.

- Stoke's Law equation for rise rate, V_t (cm/sec):

$$V_t = g(\sigma_w - \sigma_o)D^2 / 18\eta_w)$$

  Where: g = gravitational constant (981 cm/sec^2)
  D = diameter of the oil particle in cm
  Use oil particle size diameter D=60 microns (0.006 cm)
  σ_w =0.999 gm/cc. at 32°F
  σ_o: Select conservatively high oil density, for example:
  if diesel oil @ $\sigma_o = 0.85$ gm/cc and motor oil @ $\sigma_o = 0.90$ can be present, then use $\sigma_o = 0.90$ gm/cc
  $\eta_w = 0.017921$ poise, gm/cm-sec at $T_w = 32$°F
  (See API Publication 421, February 1990)

- Use the following separator dimension criteria:

  Separator water depth d = between 3 and 8 feet to minimize turbulence (API, 1990; US Army Corps of Engineers, 1994)
  Separator width w = between 6 and 20 feet (WEF & ASCE, 1998; King County Surface Water Management, 1998)
  Depth to width ratio d/w = between 0.3 and 0.5 (API, 1990)

For stormwater inflow from drainages less than two (2) acres:

- Determine V_t and select the depth and width of the separator section based on the above criteria.

- Calculate the minimum residence time (t_m) of the separator at depth (d):

$$t_m = d/V_t$$

- Calculate the horizontal velocity of the bulk fluid, V_h, vertical cross-sectional area, A_v, and actual design V_h/V_t (API, 1990; US Army Corps of Engineers, 1994).

$V_h = Q/dw = Q/A_v$
(V_h maximum at < 2.0 ft/min; American Petroleum Institute, 1990)
Q = 2.15 times the water quality design flow rate in ft³/min, at minimum residence time, t_m

At V_h/V_t determine F, turbulence and short-circuiting factor from the following table. API F factors range from 1.28-1.74. (API, 1990)

Table TC-11-1: Turbulence and Short-Circuiting Factor
(Stormwater Management Manual for Western Washington,2005, Washington Department of Ecology)

v_H/Vt	Turbulence Factor (F_t)	F = 1.2(F_t)
20	1.45	1.74
15	1.37	1.64
10	1.27	1.52
6	1.14	1.37
3	1.07	1.28

- Calculate the minimum length of the separator section, l(s), using:

  $l(s) = FQt_m/wd = F(V_h/V_t)d$
  l(t) = l(f) + l(s) +l(a)
  l(t) = l(t)/3 + l(s) + l(t)/4

  Where:
  l(t) = total length of 3 bays
  l(f) = length of forebay
  l(a) = length of afterbay

- Calculate V = l(s)wd = FQtm, and Ah = wl(s)
  V = minimum hydraulic design volume
  A_h = minimum horizontal area of the separator

BMP TC-11b API (Baffle type) Separator Bay

Design Criteria

- Calculate the projected (horizontal) surface area of plates needed using the following equation:

  $A_p = Q/V_t = Q/0.00386(\sigma_w - \sigma_o/\eta_w)$
  $A_p = A_a(\text{cosine } b)$

  Where:
  Q = the water quality design flow rate, ft^3/min
  V_t = Rise rate of 0.033 ft/min, or empirical determination, or based on Stoke's Law
  A_p = projected surface area of the plate in ft^2; .00386 is unit conversion constant
  σ_w = density of water at 32º F
  σ_o = density of oil at 32º F
  A_a = actual plate area in ft^2 (one side only)
  b = angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).
  η_w = viscosity of water at 32º F

- Plate spacing should be a minimum of 3/4 inches (perpendicular distance between plates). (WEF & ASCE, 1998; US Army Corps of Engineers, 1994; US Air Force, 1991; Jaisinghani, R., 1979)
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least six inches (6") from the bottom of the separator for sediment storage.
- Add 12 inches minimum headspace from the top of the plate pack and the bottom of the vault cover.
- Design the inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow, especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent. (WEF & ASCE, 1998)
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 inches. (King County Surface Water Management, 1998).
- Design plates for ease of removal and cleaning with high-pressure rinse or equivalent.

Operation and Maintenance

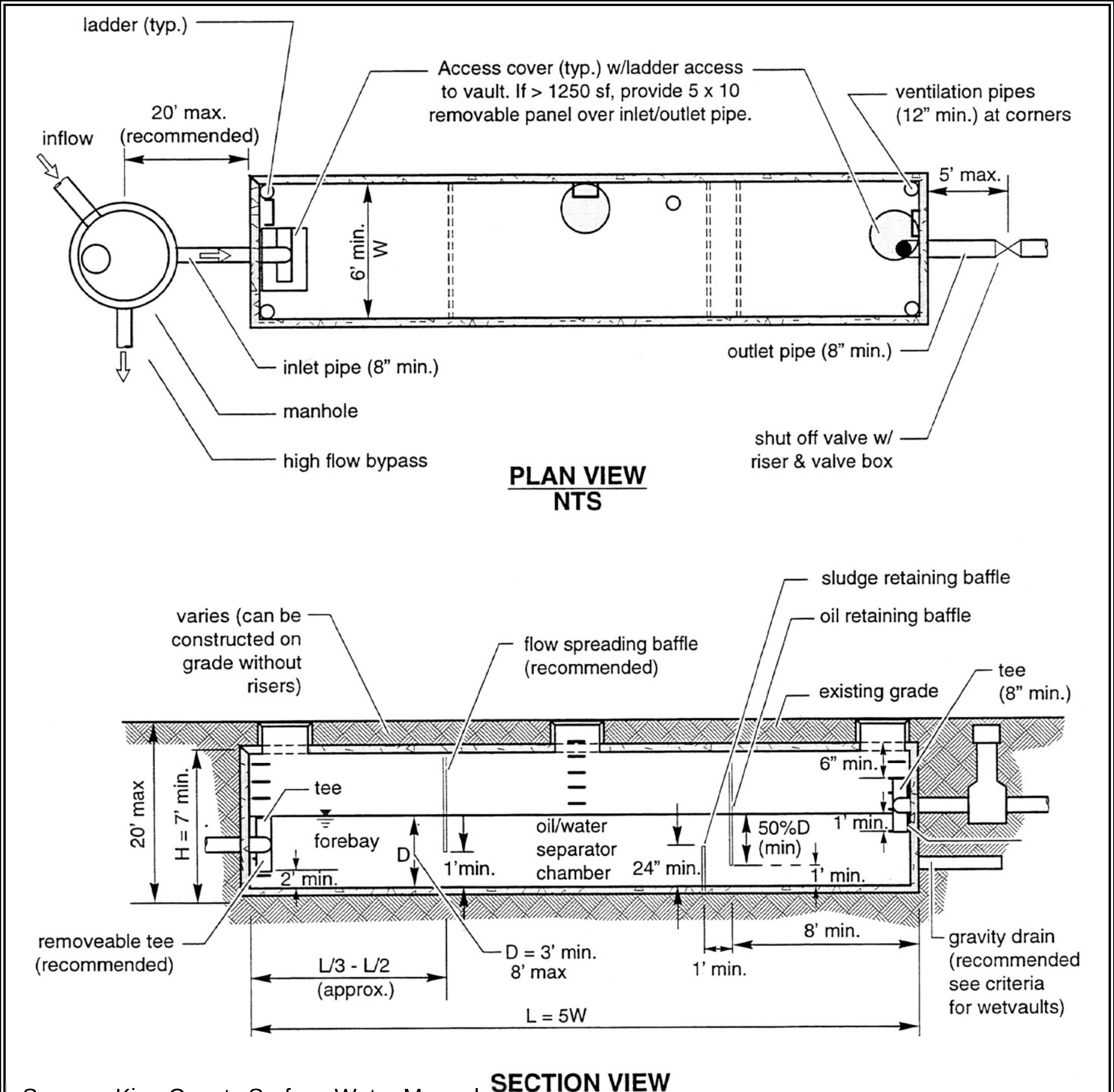
- Prepare, regularly update, and implement an O&M manual for the oil/water separators.
- Inspect oil/water separators monthly during the wet season of October 1-June 30 (WEF & ASCE, 1998; Woodward-Clyde Consultants) to ensure proper operation, and during and immediately after a large storm event of greater than or equal to one inch (1") per 24 hours. In Region 2, it is most important to check these facilities in the spring before the summer thunderstorm season begins; one (1) annual check done at this time of year should be sufficient for oil/water separators in Region 2.
- Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde Consultants), after all spills and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and wash water removal (King County Surface Water Management, 1998). Replace wash water in the separator with clean water before returning it to service.
- Remove the accumulated oil when the thickness reaches one inch (1"). Also, remove sludge deposits when the thickness reaches six inches (6") (King County Surface Water Management, 1998).
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.

Reference:

- American Petroleum Institute, “Design and Operation of Oil-Water Separators,” Publication 421, February 1990.
- Jaisinghani, R., A., et al., “A Study of Oil/Water Separation in Corrugated Plate Separators,” Journal of Engineering for Industry, 11/79.
- King County Surface Water Management, Design Manual, September 1998.
- Schueler, Thomas R., “Water Quality Inlets/Oil Grit Separators,” BMP Fact Sheet #11, Current Assessment of Urban Best Management Practices, March 1992.
- Seattle METRO, “Oil and Water Don’t Mix,” October 1990.
- U.S. Air Force, “Gravity Oil and Water Separator Design Criteria”, circa 1991.
- U.S. Army Corps. Of Engineers, “Selection and Design of Oil and Water Separators,” August 26, 1994.
- Washington Department of Ecology, “NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated with Industrial Activities, November 18, 1995.
- Washington Department of Ecology, Stormwater Management Manual for Western Washington, February 2005.
- Water Pollution Control Federation, “Clarifier Design,” Manual of Practice FD-8, 1985.
- Watershed Protection Techniques, “Hydrocarbon Hotspots in the Urban Landscape: Can They Be Controlled?”, February 1994.
- WEF & ASCE, “Urban Runoff Quality Management”, 1998.
- Woodward-Clyde Consultants “Oil/Water Separators”.

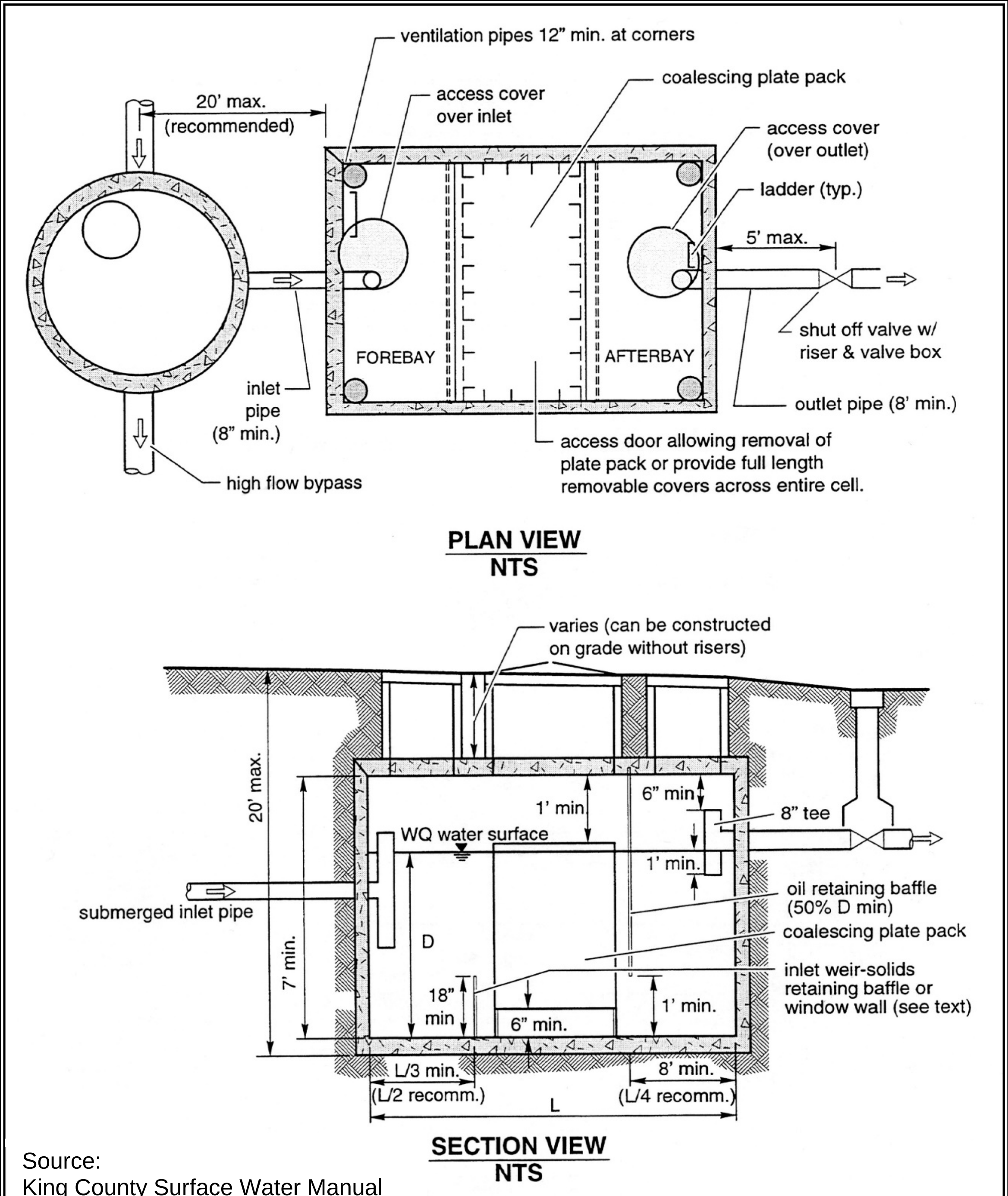
From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology

Figure TC-11-1 API (Baffle Type) Separator



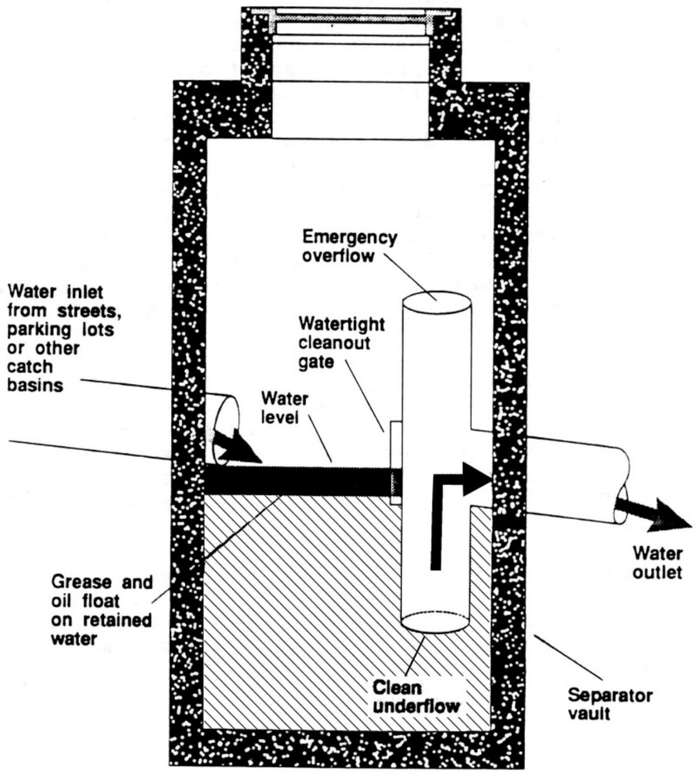
Source: King County Surface Water Manual

Figure TC-11-2 Coalescing Plate Separator



Source:
King County Surface Water Manual

Figure TC-11-3 Spill Control Separator (not for oil treatment)



Source: Ecology's Stormwater Management Manual, 1992

MC-1 Media Filters

Design Objectives

- ✓ Source Control
- ✓ Water Quality Treatment
- ✓ Contain Pollutants

Description

Stormwater media filters are usually two-chambered, including a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering media in the second chamber.

The media can be housed in cartridge filters enclosed in concrete vaults or in fixed beds such as the sand filters. There are currently three (3) manufacturers of stormwater filter systems. Two are similar in that they use cartridges of a standard size. The cartridges are placed in vaults, the number of cartridges a function of the design flow rate. The water flows laterally (horizontally) into the cartridge to a centerwell, then downward to an underdrain system. The third product is a flatbed filter, similar in appearance to sand filters. An assortment of filter media is available, including leaf compost, pleated fabric, activated charcoal, perlite, amended sand and perlite, and zeolite. The system functions by routing the stormwater through the filtering or absorbing medium, which traps particulates and/or soluble pollutants.

Performance Objectives

Media can be selected for removal of TSS, oil/grease or total petroleum hydrocarbons, soluble metals, nutrients, and organics.

Advantages

- Requires a smaller area than standard flatbed sand filters, wet ponds, and constructed wetlands.
- May be designed as on-line systems for small drainage areas, or as off-line systems.
- There is no standing water in the units between storms; minimizing, but not entirely eliminating the opportunity for mosquito breeding.
- Media capable of removing dissolved pollutants can be selected.
- The modular concept allows the design engineer to more closely match the size of the facility to the design storm.

Applications and Limitations

Typical applications and limitations include:

- Pretreatment is required for high TSS and/or hydrocarbon loadings and debris that could cause premature failures due to clogging.
- Since some of the manufactured filter systems function at higher flow rates and/or have larger media than found in flatbed filters, the form may not provide the same level of performance as standard sand filters.
- These systems may be designed as on-line systems for small drainage areas, or as off-line systems.
- For off-line applications, flows greater than the design flow must be bypassed.

Site Suitability

Consider:

- Space requirements
- Design flow characteristics
- Target pollutants
- O & M requirements
- Capital and annual costs

Design Criteria for TSS Removal

Determine TSS loading and peak design flow.

- Determine TSS loading capacity per cartridge based on the manufacturer's loading and flow design criteria to determine the number and size of cartridges.
- Evaluate for pre-treatment needs. Typically, roadways, single-family dwellings, and developments with steep slopes and erodible soils need pretreatment for TSS. Developments producing sustained oil and grease loads should be evaluated for oil and grease pretreatment needs.
- Select media based on pollutants of concern which are typically based on land use and local agency guidelines.

Pretreatment and Bypassing

- Use source control where feasible, including gross pollutant removal, sweeping, and spill containment. Maintain catch basins as needed to minimize inlet debris that could impair the operation of the filter media.
- Sedimentation vaults/ponds/ tanks, innovative more efficient catch basins, oil/water separators for oil > 25 ppm, or other appropriate pre-treatment systems to improve and maintain the operational efficiency of the filter media.
- Bypassing of flows above design flows should be included.

Construction

- A precast or cast-in-place vault is typically installed over an underdrain manifold pipe system. This is followed by the installation of the cartridges.
- Prior to cartridge installation, construction sites must be stabilized to prevent erosion and solids loading.

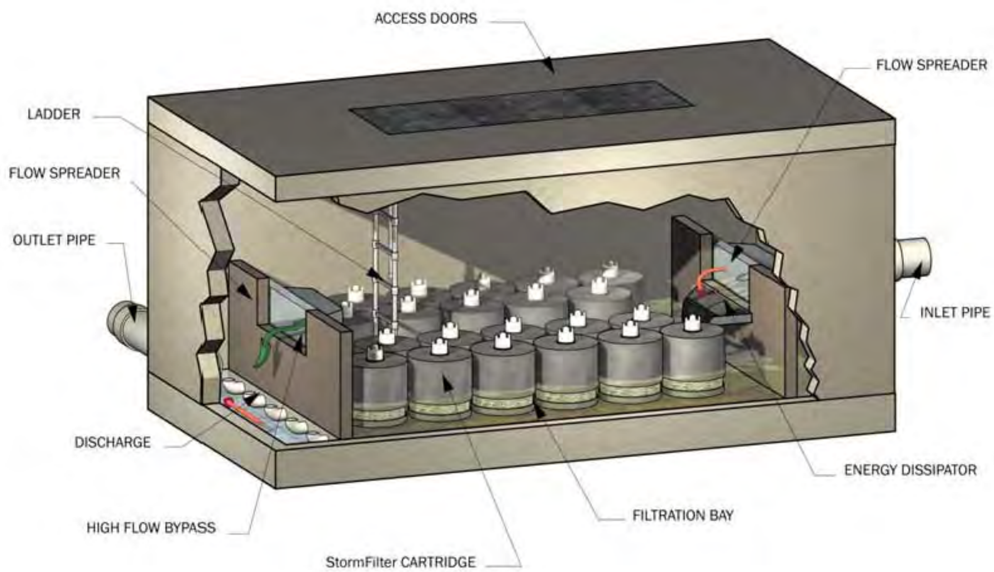
Maintenance

- Follow manufacturers O & M guidelines to maintain design flows and pollutant removals.

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.

Figure MC-1 Vertical Media Filter



Source: Courtesy of Stormwater Management, Inc.

MC-2 Catch Basin Inserts

Design Objectives
- ✓ Source Control
- ✓ Water Quality Treatment
- ✓ Contain Pollutants

Description

Catch basin or drain inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris. Inserts are typically one (1) of three (3) configurations: socks, boxes, and trays. The sock consists of a fabric, usually constructed of polypropylene. The fabric may be attached to a frame or the grate of the inlet holds the sock. Socks are meant for vertical drop inlets. Boxes are constructed of plastic or wire mesh. Typically, a polypropylene "bag" is placed in the wire mesh box. The bag takes the form of the box. Most box products are one (1) box; that is, the setting area and filtration through media occur in the same box. Some products consist of one (1) or more trays or mesh grates. The trays may hold different types of media. Filtration media vary by manufacturer. Types include polypropylene, porous polymer, treated cellulose, and activated carbon. The three (3) types of inserts function similarly to media filtration except that they are typically limited by the size of the catch basin. They also are likely to be maintenance intensive.

Catch basin inserts typically consist of the following components:
- A structure (screened box, brackets, etc.) which contains a pollutant removal medium
- A means of suspending the structure in a catch basin
- A filter medium such as sand, carbon, fabric, etc.
- A primary inlet and outlet for the stormwater
- A secondary outlet for bypassing flows that exceed design flow

Applications and Limitations

By treating runoff close to its source, the volume of flow is minimized, and more effective pollutant removal is therefore possible. Depending on the insert medium, removals of TSS, organics (including oils), and metals can be achieved. Performance is likely significantly less than treatment systems that are located at the end of the drainage system, such as ponds and vaults. The main drawbacks are the limited retention capacities and maintenance requirements on the order of once per month in the wet season to clean or replace the medium. These types of treatment systems are usually not suitable for large areas or areas with trash or leaves that can plug the insert.

The following are potential limitations and applications for catch basin inserts.
- Catch basin inserts are not recommended as a substitute for basic BMPs such as wet ponds, vaults, constructed wetlands, grass swales, sand filters, or related BMPs.
- Catch basin inserts can be used as temporary sediment control devices and pretreatment at construction sites.
- Catch basin inserts can be considered for oil control at small sites where the insert medium has sufficient hydrocarbon loading capacity and rate of removal, and the TSS and debris will not prematurely clog the insert.
- Catch basin inserts can be used in unpaved areas and should be considered equivalent to currently accepted inlet protection BMPs.
- Catch basin inserts can be used when an existing catch basin lacks a sump or has an undersized sump.
- Catch basin inserts can cause flooding when plugged.

- Catch basin inserts may be considered in specialized small drainage applications for specific target pollutants where clogging of the medium will not be a problem.

Design and Sizing

Refer to the manufacturer's guidelines.

Construction/Inspection Considerations

Be certain that installation is done in a manner that makes certain that the stormwater enters the unit and does not leak around the perimeter. Leakage between the frame of the insert and the frame of the drain inlet can easily occur with vertical drop inlets.

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.

MC-3 Manufactured Storm Drain Structures

Design Objectives

- ✓ Source Control
- ✓ Water Quality Treatment
- ✓ Contain Pollutants

Description

Manufactured storm drain structures are gravity separators and, in principle, are essentially wet vaults. Most of these types of systems marketed thus far are cylindrical in shape and are designed to fit into or adjacent to existing storm drainage systems or catch basins. The removal mechanisms include vortex-enhanced sedimentation, circular screening, and engineered designs of internal components, for large particle TSS and large oil droplets.

Vortex-enhanced Sedimentation

Vortex-enhanced sedimentation consists of a cylindrical vessel with tangential inlet flow, which spirals down the perimeter, thus causing the heavier particles to settle. It uses a vortex-enhanced settling mechanism (swirl-concentration) to capture settleable solids, floatables, and oil and grease. This system includes a wall to separate TSS from oil. See Figure MC-3-1.

Advantages

- May provide the desired performance in less space and, therefore, less cost.
- May be more cost-effective pre-treatment devices than traditional wet or dry basins.
- Mosquito control may be less of an issue than with traditional wet basins.

Limitations

- It is likely that vortex separators are not as effective as wet vaults at removing fine sediments, on the order of 50 to 100 microns in diameter and less.
- The area served is limited by the capacity of the largest models.
- The products come in standard sizes and may be oversized in many cases relative to the design treatment storm, increasing the cost.
- The non-steady flows of stormwater decrease the efficiency of vortex separators from what may be estimated or determined from testing under constant flow.
- Does not remove dissolved pollutants.
- A loss of dissolved pollutants may occur as accumulated organic matter (e.g., leaves) decompose in the units.

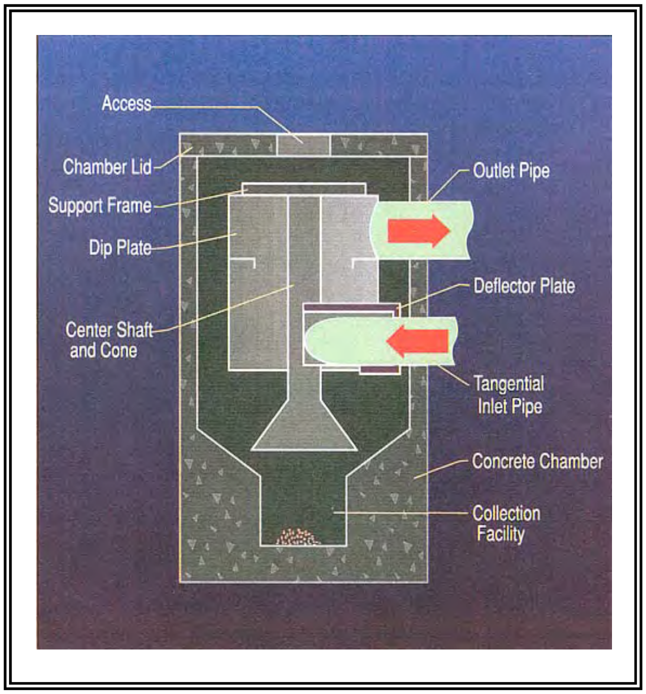
Design and Sizing Guidelines

- Size is based on the peak flow of the design treatment event.
- If an in-line facility, the design peak flow is four (4) times the peak of the design treatment event.
- If an off-line facility, the design peak flow is equal to the peak of the design treatment event.
- Head loss differs with the product and the model but is generally on the order of one foot (1') or less in most cases.

Maintenance

Maintenance consists of the removal of accumulated material with an eductor truck. This may be necessary to remove and dispose of the floatables separately due to the presence of petroleum product.

Figure MC-3-1 Vortex-enhanced settling mechanism

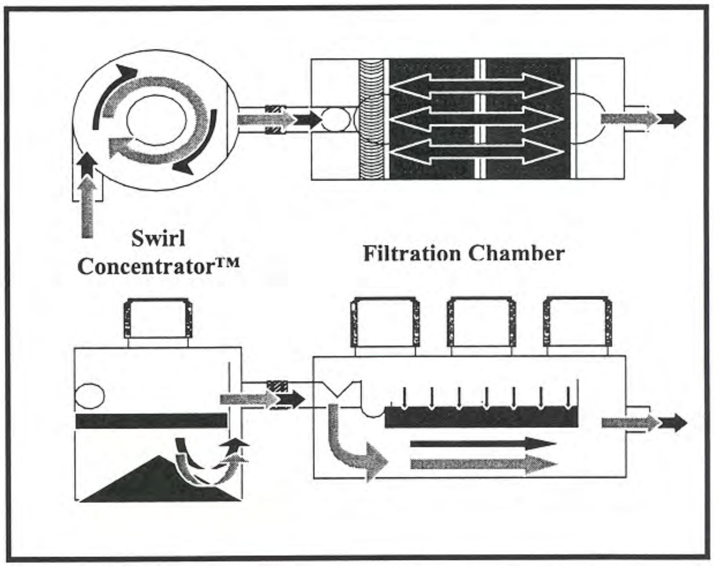


Source: courtesy of HIL, Inc.

Vortex-enhanced Sedimentation and Media Filtration

Description: This system uses a two-stage approach, which includes a swirl concentrator followed by a filtration chamber. See Figure MC-3-2.

Figure MC-3-2 Vortex-enhanced Sedimentation and Media Filtration

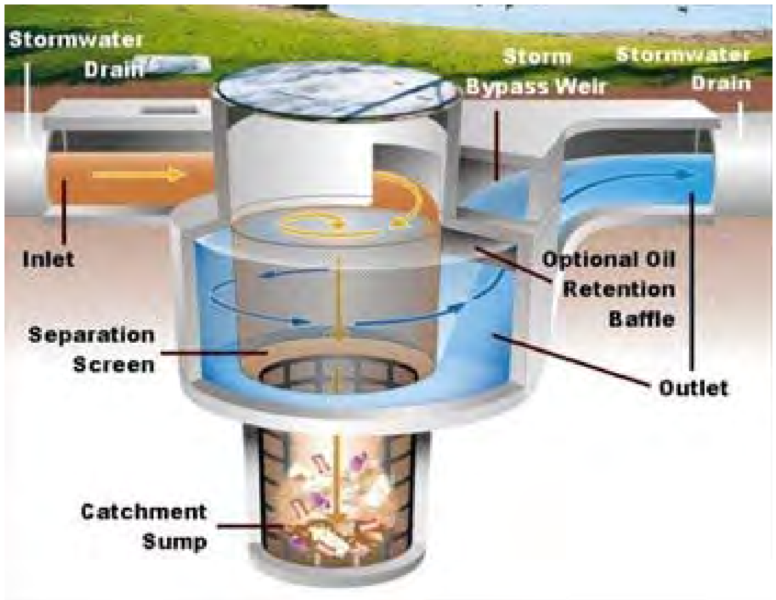


Source: courtesy of Aquafilter, Inc.

Cylindrical Screening System

This system is comprised of a cylindrical screen and appropriate baffles and inlet/outlet structures to remove debris, large particle TSS, and large oil droplets. It includes an overflow for flows exceeding the design flow. Sorbents can be added to the separation chamber to increase pollutant removal efficiency. See Figure MC-3-3.

Figure MC-3-3 Screen Separator



Source: courtesy of CDS Technologies, Inc.

Engineered Cylindrical Sedimentation

This system is comprised of an engineered internal baffle arrangement and oil/TSS storage compartment designed to provide considerably better removals of large particle TSS and oil droplets than the standard catch basins. It includes a bypass of flows higher than design flows, thus preventing scouring of collected solids and oils during the bigger storms.

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

California Stormwater BMP Handbook, New Development and Redevelopment, 2003, California Stormwater Quality Association.

MC-4 Wet Vaults

Design Objectives

- ✓ Provide Detention
- ✓ Source Control
- ✓ Water Quality Treatment
- ✓ Contain Pollutants

Purpose and Definition

A wet vault is an underground structure similar in appearance to a detention vault, except that a wet vault has a permanent pool of water (wet pool) which dissipates energy and improves the settling of particulate pollutants (see the wet vault details in Figure MC-4-1). The wet vault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface extended detention dry ponds due to the wet vault being underground.

UIC regulations do not apply to these facilities if the outlet structure discharges exclusively to a conveyance system and (or) to surface water. However, UIC regulations do apply to these facilities if the outlet structure discharges into the ground, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply.

Applications and Limitations

A wet vault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other treatment BMPs. The use of wet vaults for residential development is highly discouraged. Combined detention and wet vaults are allowed.

A wet vault is believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper. There is also concern that oxygen levels will decline, especially in warm summer months, because of limited contact with air and wind. However, the extent to which this potential problem occurs has not been documented.

Below-ground structures like wet vaults are relatively difficult and expensive to maintain. The need for maintenance is often not seen and as a result, routine maintenance does not occur.

If oil control is required for a project, a wet vault may be combined with an API oil/water separator.

Design Criteria

Sizing Procedure: As with wet ponds, the primary design factor that determines the removal efficiency of a wet vault is the volume of the wet pool. The larger the volume, the higher the potential for pollutant removal. Performance is also improved by avoiding dead zones (like corners) where little exchange occurs, using large length-to-width ratios, dissipating energy at the inlet, and ensuring that flow rates are uniform to the extent possible and not increased between cells.

The sizing procedure for a wet vault is identical to the sizing procedure for an extended detention dry pond. The wet pool volume for the wet vault shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event.

Typical design details and concepts for the wet vault are shown in Figure MC-4-1.

Wet Pool Geometry: Same as specified for wet ponds (see BMP TC-3) except for the following two (2) modifications:

The sediment storage in the first cell shall be an average of one foot (1'). Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the sidewall is roughly proportional to vault width according to the schedule below:

Vault Width	Sediment Depth (from bottom of sidewall)
15'	10"
20'	9"
40'	6"
60'	4"

The second cell shall be a minimum of three feet (3') deep since planting cannot be used to prevent re-suspension of sediment in shallow water as it can in open ponds.

Vault Structure: The vault shall be separated into two (2) cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:

> The baffle shall extend from a minimum of one foot (1') above the water quality design water surface to a minimum of one foot (1') below the invert elevation of the inlet pipe.
>
> The lowest point of the baffle shall be a minimum of two feet (2') from the bottom of the vault, and greater if feasible.
>
> If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted, and the vault may be one-celled.
>
> The two (2) cells of a wet vault should not be divided into additional sub-cells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.

Intent: Treatment effectiveness in wet pool facilities is related to the extent to which plug flow is achieved and short-circuiting and dead zones are avoided. Structural walls placed within the cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.

The bottom of the first cell shall be sloped toward the access opening. The slope should be between 0.5 percent (minimum) and two percent (2%) (maximum). The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is to direct the sediment accumulation to the closest access point for maintenance purposes. Sloping the second cell towards the access opening for the first cell is also acceptable.

The vault bottom shall slope a minimum of five percent (5%) laterally from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one (1) "v" may be used to minimize vault depth.

Exception: The local jurisdiction may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than five (5) tons per panel.

The highest point of a vault bottom must be at least six inches (6") below the outlet elevation to provide for sediment storage over the entire bottom.

Provision for passage of flows should the outlet plug shall be provided.

Wet vaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of six feet (6’).

Intent: To prevent decreasing the surface area available for oxygen exchange.

Where pipes enter and leave the vault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet: The inlet to the wet vault shall be submerged with the inlet pipe invert a minimum of three feet (3’) from the vault bottom. The top of the inlet pipe should be submerged at least one foot (1’), if possible.

Intent: The submerged inlet is to dissipate the energy of the incoming flow. The distance from the bottom is to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe should be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of six inches (6”).

The outlet pipe shall be back-sloped or have a tee section, the lower arm of which should extend one foot (1’) below the WQ design water surface to provide for trapping of oils and floatables in the vault.

The local jurisdiction may require a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements: Same as for detention vaults (see Section 14.10.4) except for the following additional requirement for wet vaults:

> A minimum of 50 square feet of grate should be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, four percent (4%) of the top should be grated. This requirement may be met by one (1) grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement.

Intent: The grate allows air contact with the wet pool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.

Access Roads, Right of Way, and Setbacks: Same as for detention vaults (Section 14.10.4).

Recommended Design Features

The following design features should be incorporated into wet vaults where feasible, but they are not specifically required:

- The floor of the second cell should slope toward the outlet for ease of cleaning.
- The inlet and outlet should be at opposing corners of the vault to increase the flowpath.
- A flow length-to-width ratio greater than 3:1 minimum is desirable.
- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wet pool.
- Galvanized materials shall not be used unless unavoidable.
- The number of inlets to the wet vault should be limited, and the flowpath length should be maximized from inlet to outlet for all inlets to the vault.

Construction Criteria

Sediment that has accumulated in the vault must be removed after construction in the drainage area is complete. If no more than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete. In general, sediment accumulation from stabilized drainage areas is not expected to exceed an average of four inches (4”) per year in the first cell. If sediment accumulation is greater than this amount, it will be assumed to be from construction unless it can be shown otherwise.

Operation and Maintenance

Accumulated sediment and stagnant conditions may cause noxious gases to form and accumulate in the vault. Vault maintenance procedures must meet OSHA confined space entry requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Facilities should be inspected annually. The maintenance standards contained in Appendix A are measures for determining if maintenance actions are required, as identified through the annual inspection.

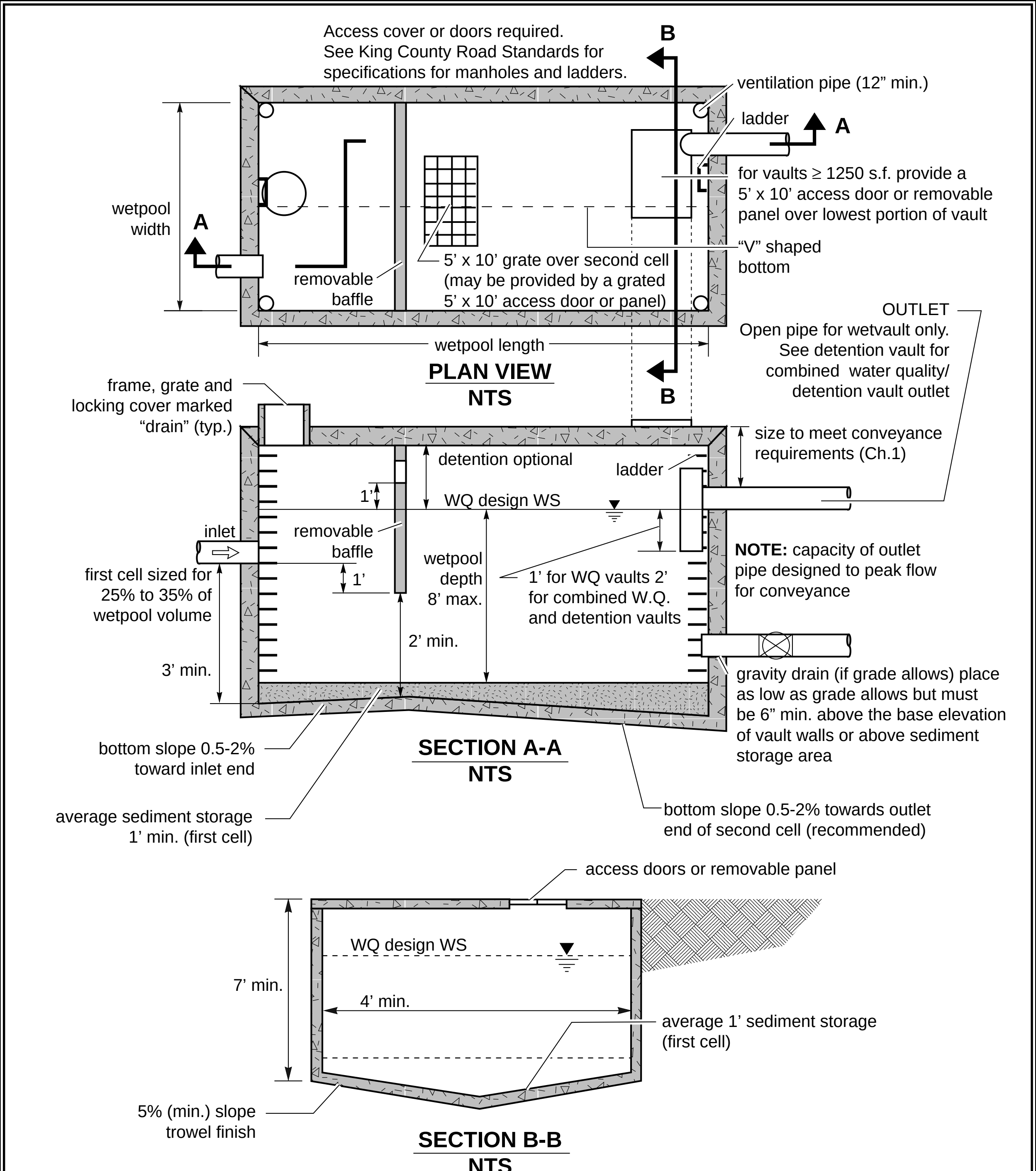
Sediment should be removed when the one-foot (1’) sediment zone is full plus six inches (6”). Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is to discharge to a sanitary sewer at an approved location.

See Appendix A for more detailed information.

From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology.

Figure MC-4-1 Wet Vault



Adapted from:
King County Surface Water Manual

Appendix A – Recommended Maintenance Criteria

(From: Stormwater Management Manual for Eastern Washington, 2004, Washington Department of Ecology)

The facility-specific maintenance standards contained in this section are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, the exceedance of these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

No. 1 – Wet Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by state or local regulations. (Apply requirements of adopted IPM policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.

No. 1 – Wet Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)
	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies.)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies.
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove. If dead, diseased, or dying trees are identified. (Use a certified Arborist to determine health of tree or removal requirements.)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees.
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s), e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms, a licensed civil engineer should be consulted to resolve source of erosion.

No. 1 – Wet Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary, to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway and Berms over 4 feet in height.	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches), the root system may be left in place. Otherwise, the roots should be removed, and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.

No. 1 – Wet Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/ Spillway	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of outflow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
General	Water level	First cell is empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Trash and Debris	Accumulation that exceeds 1 CF per 1000-SF of pond area.	Trash and debris removed from pond.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

No. 2 – Bio-infiltration/Infiltration Trenches/Basins

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Poisonous/Noxious Vegetation	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Contaminants and Pollution	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Rodent Holes	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases, and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates the facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that the infiltration system works according to design.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rainstorms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Piping	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Emergency Overflow Spillway	Rock Missing	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Erosion	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Pre-Settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

No. 3 – Closed Treatment Systems (Tanks/Vaults)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.

No. 3 – Closed Treatment Systems (Tanks/Vaults)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Catch Basins	See “Catch Basins” (No. 5)	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 4 – Control Structure/Flow Restrictor for Wet Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.

No. 4 – Control Structure/Flow Restrictor for Wet Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Manhole	See “Closed Treatment Systems” (No. 3)	See “Closed Treatment Systems” (No. 3).	See “Closed Treatment Systems” (No. 3).
Catch Basin	See “Catch Basins” (No. 5)	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60% of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin.
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch. (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached.	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
		Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.
	Contamination and Pollution	See "Wet Ponds" (No. 1).	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is to keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (If Applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

No. 6 – Debris Barriers (e.g., Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than 3/4 inch.
		Bars are missing or entire barrier missing.	Bars in place according to design.
		Bars are loose and rust is causing 50% deterioration to any part of barrier.	Barrier replaced or repaired to design standards.
	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe.	Barrier firmly attached to pipe.

No. 7 – Energy Dissipators

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
External:			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed so that it matches design.
	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench). Intent is to prevent erosion damage.	Trench redesigned or rebuilt to standards.
	Perforations Plugged	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Perforated pipe cleaned or replaced.
	Water Flows Out Top of “Distributor” Catch Basin	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or is causing or appears likely to cause damage.	Facility rebuilt or redesigned to standards.
	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal:			
Manhole/Chamber	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.	Structure replaced to design standards.
	Other Defects	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 8 – Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the bio-swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
	Flow spreader	Flow spreader uneven or clogged, so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation start to take over.	Mow vegetation or remove nuisance vegetation so that flow is not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back overhanging limbs and remove brushy vegetation on adjacent slopes.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.

No. 8 – Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from bioswale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

No. 9 – Vegetated Filter Strip

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and debris from filter.
	Erosion/ Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

No. 10 – Wet Vaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe, or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Pipe repaired or replaced to proper working specifications.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.

No. 10 – Wet Vaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

No. 11 – Sand Filters (above-ground/open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above-Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.
	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged, so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

No. 12 –Sand Filters (below-ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below-Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2-inch.	No sediment deposits on sand filter section that which would impede permeability of the filter section.
	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault or pipe inlet/outlet, floatables, and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment in Drainpipes/ Cleanouts	When drainpipes, cleanouts become full of sediment and/or debris.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.

No. 12 –Sand Filters (below-ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired to specifications and is safe to use as determined by inspection personnel.

No. 13 – Media Filter

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below-Ground Vault	Sediment Accumulation on Media	Sediment depth exceeds 0.25-inches.	No sediment deposits which would impede permeability of the media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6 inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on filter bed.	Trash and debris removed from the filter bed.
	Sediment in Drainpipes/ Clean-Outs	When drainpipes, clean-outs, become full with sediment and/or debris.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/ inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications and is safe to use as determined by inspection personnel.
Below-Ground Cartridge Type	Filter Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

No. 14 – Baffle Oil/Water Separators (API Type)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear without thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1 inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local rules and regulations.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	See “Catch Basins” (No. 5)	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications and is safe to use as determined by inspection personnel.

No. 15 – Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault or pipe inlet/outlet, floatables, and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage - Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/ inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.

No. 15 – Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications and is safe to use as determined by inspection personnel.

No. 16 – Catch Basin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulate on insert unit creating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert.
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.