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CONSTRUCTION SITE STORMWATER DISCHARGE CONTROL

AN INVENTORY OF CURRENT PRACTICES

Prepared for

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Construction Site Stormwater Discharge Control
An Inventory of Current Practices

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1.0 Introduction

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The information presented in this report has been prepared to assist municipalities in preparing the Stormwater Management and Sediment and Erosion Control program portions of their system-wide National Pollutant Discharge Elimination Service (NPDES) Stormwater permit applications. This report discusses the stormwater discharges of construction sites and provides an inventory of stormwater management technologies currently implemented to control both the quantity and quality of post-construction storm water discharges. The inventory is intended to be comprehensive; providing general information including technology description, application, advantages, and disadvantages for structural and non structural methods of storm water management. The inventory also addresses methods considered "Best Management Practices", i.e., storm water management practices which provide pollutant removal benefits, and methods considered primarily quantity control measures. In addition to the inventory, this report discusses a variety of planning considerations which influence the selection and design of storm water management facilities on an individual site or within a particular drainage area or watershed.

2.0 Construction Site Stormwater Discharges

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The quantity and quality of storm water discharged from a construction site varies according to the stage of construction and the effectiveness of measures implemented on-site to control the quality of storm water discharges. These controls include structural measures such as erosion and sediment control practices which control the discharge of sediment related pollutants, and non-structural measures such as site management or housekeeping plans which control non-sediment related pollutants on the construction site.

2.1 Construction Stages

Typical construction stages and the changes in site erosion potential and storm water runoff that accompany each stage are described below:

Stage 1 Pre-Construction

Storm water runoff from the site is at predeveloped levels, erosion is minimal. Site perimeter erosion controls should be installed for initial disturbed areas.

Stage 2 Clearing and Grading for Access

Clearing and grading is accomplished for access only. Measures are implemented to protect off-site properties, including installation of inlet protection measures in the downstream storm drain system, and the installation of construction entrances (large aggregate aprons which transition from the construction site to paved off-site roadways). Erosion from the site increases to moderate levels, and storm water runoff volume begins to increase as vegetation is removed and site areas become compacted by heavy equipment. At this stage, the installation of sediment controls and storm water management facilities should occur.

Stage 3 Full Clearing and Grading

Full clearing and grading results in moderate to high levels of erosion. Major storms can wash away sediment control structures, and can deposit substantial sediment in control structures, significantly reducing capacity. Runoff volume is increasing as disturbed area increases. Regular inspection and maintenance of sediment control practices is essential to maintain effectiveness of the devices.

Stage 4 Installation of Storm Drainage System

Storm water management facility construction is complete and storm drains are installed and gradually connected to concentrate and divert runoff to the structure or structures. Erosion continues to be moderate to high, and storm water runoff volume continues to increase as disturbed areas become more compacted.

Stage 5 Active Construction of Structures

Construction is at its peak. Moderate to high erosion rates continue, and storm water runoff volumes approach maximum. The impact of high erosion rates can be significant if sediment control practices have not been maintained during previous stages of construction and are clogged or have inadequate capacity to control site storm water discharges.

Stage 6 Site Stabilization

Disturbed areas are stabilized with vegetation or other suitable, non-erosive cover, and erosion rates decline. Once all areas of the site are stabilized, temporary sediment control measures are removed from the site, and sediment collected during the construction phase is removed (dredged) from permanent storm water control structures to restore design capacity, if necessary. Storm water runoff volume reaches post-development rates and may be less than the volume that occurred in stage 5, due to areas of the site that are stabilized with vegetation.

2.2 Erosion and Sediment Control

The overall plan of erosion and sediment control for a construction site includes implementation and regular maintenance of sediment control practices. These practices include various erosion and sediment control measures that can be categorized as follows;

1. Perimeter controls
2. Slope protection
3. Sediment traps and basins
4. Drainageway and stream protection
5. Temporary stabilization
6. Permanent stabilization.

These measures are described in an inventory prepared under Task 2 of this work assignment entitled "Sediment and Erosion Control Measures, An Inventory of Current Practice". Perimeter controls, slope protection, and sediment traps are temporary forms of stabilization that are generally removed from the construction site at the end of the construction period. These facilities are usually replaced with permanent stabilization measures such as vegetation or other permanent (non eroding) surfaces. The sediment and erosion control measure most often converted to a permanent structure for storm water management is the sediment basin. The sediment basin can often be dredged to remove sediment accumulated during the project construction phase, and with minor improvements including the installation of an appropriate outlet structure, can be converted to provide long-term storm water management for the site.

2.3 Construction Site Housekeeping

Non-structural storm water controls on construction sites focus on methods of preventing non-sediment related pollutants from entering storm water runoff, sediment control structures, the down stream storm drain system, and receiving streams. Pollutants that may be generated on a construction site, and could potentially enter storm water runoff from the site if not controlled, include gasoline, oils, grease, paints, raw materials used in the manufacture of concrete including sand, aggregate, cement, water and admixtures, solvents, paper, plastic, styrofoam, aluminum cans, glass bottles, and other forms of liquid and solid wastes. Construction site management plans should include the following elements to prevent these pollutants from entering site storm water discharges:

- Designated areas for equipment maintenance and repair which include appropriate waste recepticals for spent oils, gasoline, grease and solvents, and regular collection and disposal schedules.

- A site solid waste plan which provides waste receptacles of adequate capacity at convenient locations to site workers and provides regular collection of accumulated wastes.

- Equipment washdown areas located on-site only in areas which drain to regularly maintained sediment control devices designed to accommodate such discharges.

- Storage areas protected from storm water in accordance with the manufacturers guidelines for storage of chemicals, paints, solvents acids, pesticides, fertilizers or other potentially toxic water pollutants.

- Storage areas for raw materials used in construction which can be carried by storm water runoff located only in drainage areas controlled by retention-type sediment control devices.

- Water used during dust control activities discharged only to on-site retention-type sediment control devices.

- Adequately maintained sanitary facilities.

Routine site housekeeping in accordance with a construction site management plan can minimize non sediment related pollutants from entering storm water runoff. Sediment which enters storm water during rainfall events, washdown of construction equipment, or from dust control activities can be controlled by properly maintained sediment control devices. The remaining sections of this report focus on the purpose and general design basis of storm water management facilities which control storm water discharges after construction is completed and includes the technology inventory of current storm water management practice.

3.0 Stormwater Management Theory And General Design Basis

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Water flowing over the land during and immediately following a rainstorm is called stormwater runoff. The characteristics of stormwater runoff in an urbanizing watershed change substantially in terms of quantity, quality, and timing of the discharge to the natural hydrologic system, during and after construction activities. Prior to construction, stormwater runoff is managed by a natural hydrologic system created by the vegetation, soils, geology and topography of the watershed. Rainfall enters the hydrogic system via a number of routes:

- a portion falls on leaf or plant where it eventually evaporates;
- a portion is absorbed into the ground near the surface, to ultimately be absorbed through the root systems of vegetation and returned to the atmosphere through transpiration;
- a portion percolates through surface soils to replenish groundwater;
- a portion collects into rivulets which flow down gradient to natural depressions and ultimately to receiving waters; i.e., tributaries, streams, rivers, lakes, and the sea. This portion is termed storm water runoff.

The quantity of storm water that will be converted to runoff on a given site is a function of the storm event (the quantity of rainfall delivered to the system), vegetative cover, soil type, and topography. Construction activities remove vegetation and create impervious surfaces such as streets, parking areas, sidewalks and roofs, and the change in land use created by the construction results in changes in the natural hydrologic system. These changes reduce the amount of rainfall that evaporates from plant surfaces, is absorbed and transpired by vegetation, or infiltrates through the soil column to replenish groundwater supplies, and increase the amount of rainfall converted to direct surface runoff. Post-construction runoff is often concentrated in peaks that are sharper, faster and higher than those produced by the undeveloped site. The concentrated, faster moving runoff dislodges and dissolves pollutants which build up on the impervious land surfaces between storm events and thus create changes the quality of storm water runoff discharged to surface waters.

The cumulative effects of these changes can be observed in receiving streams where the increased peak discharges create unstable and unvegetated stream banks, scoured or heavily deposited stream channels, accumulations of in-stream trash and debris, reduced base-flow (non-storm flow), and the regular disruption or absence of aquatic communities. Storm water management facilities are intended to reduce the impact of the long term changes in the site storm water runoff characteristics by controlling the quantity, and in some facilities, the quality of post-construction storm water discharges.

In order to address the impacts of the increased peak storm water discharges in receiving streams, storm water management facilities are designed to retain the peak storm water runoff from the developed site within the structure and control the release rate to a level equal to or less than the peak runoff rate that would have been generated by the site under the predevelopment conditions. The volume of storage provided within the facility is controlled by the design storm (the amount of rainfall) assumed for calculation of the pre-development and post-development site runoff, and the criteria which specify the allowable release rate. Many localities specify the 10-year design storm as the design basis for storm water management structures to protect downstream drainage structures such as road crossing culverts originally designed to pass a 10-year pre-development storm. In the metropolitan Washington area, most jurisdictions require control of the 2 and 10 year return interval storms to predevelopment release rates. In areas where downstream flooding is an existing problem, control may be required for the 25, 50 and 100 year storms to reduce downstream effects of these major storms. In general, the larger the storm event controlled within the structure and the slower the allowable release rate, the greater the storage volume and cost of the facility.

Water quality controls address the impacts of increasing the amount and type of pollutants discharged to receiving streams via storm water. The National Urban Runoff Project (NURP) studies found that the majority of pollutants discharged to receiving streams via storm water are washed from impervious land surfaces during the early stages of a storm, and are contained within the first 1/2 to 1 inch of runoff from the contributing drainage area. To reduce the impact of these "first flush" discharges on receiving streams, storm water management facility designs can be modified to improve discharge quality by providing treatment within the structure. Additionally, a number of structural and nonstructural facilities and management practices have been developed to remove or reduce pollutants in storm water runoff and in discharges from storm water management facilities. These methods are termed "Best Management Practices", or BMPs. The facilities and methods referred to as BMPs may provide only water quality control, or both quantity and quality control within the same facility.

4.0 Stormwater Management Planning Considerations

4.0 Stormwater Management Planning Considerations

Stormwater management facilities control the volume, quality and release rate of storm water runoff from the developed site once construction is complete and the site is stabilized. The development of a storm water management plan for a site includes the selection of the most appropriate type of facility, method or combination of methods to provide quantity and water quality control and is influenced by the physical site conditions, the size of the contributing drainage area, and the water quality and classification of the receiving stream.

Site conditions include topography, soils, slopes, geology, and the location of on-site surface waters including intermittent and flowing streams and drainageways, ponds, lakes and wetlands. In addition to the natural features, the site conditions includes the existing zoning designation and the land use proposed by the owner/developer.

The size of the site and the contributing drainage area influence the selection of control structures. In general, the use of infiltration-type storm water management structures is limited to smaller drainage areas (generally less than ten acres), while the use of pond type facilities, particularly wetponds, is limited to larger drainage areas (generally greater than 10 acres) where sufficient base flow to support the permanent pool is available. In addition to size of the site and contributing drainage area, soils and topography influence selection of control methods. For example, infiltration-type structures are limited to sites with sandy, or sandy loam soils which are capable of infiltrating the required volumes, and grassed swale type conveyance systems are only appropriate on sites with gentle slopes so that erosive velocities do not scour the bottom of the swale. These types of constraints are addressed in the inventory provided in the appendix.

Site planning techniques are used to develop a concept plan for a proposed construction activity which accomplishes the long-term land-use change objectives of the development within the framework of existing site conditions. Site planning which minimizes disturbed area, reduces the need for mass grading of the site, and preserves, to the maximum extent practicable, the natural site topography and drainage features, can reduce the number of sediment control structures and practices necessary to protect receiving waters during construction, and can reduce the volume of storage necessary in storm water management structures. Site planning which clusters development in areas most suited to construction allows preservation of more sensitive areas such as on-site streams and wetlands, and areas of unstable soils and steep slopes. Cluster development techniques also increase the opportunity to provide undisturbed buffer areas adjacent to on-site streams which can provide water quality benefits.

The concept site plan indicates the proposed location of structures including buildings, roadways and parking facilities. Using this information, and a rough grading plan of the site, storm water management options can be developed.

The plan for managing site storm water will include methods of storm water collection, conveyance and management in control structures, and may include additional control measures which provide water quality improvement as well as quantity control. The selection of the appropriate facility for a given site is influenced by size of the receiving drainage area and other site specific considerations. For example, a proposed large-lot single-family residential development storm water management concept plan may include storm water collection and conveyance by a combination of grassed swales and enclosed pipes which discharge to a central storm water management wet pond. Quantity control would be provided by the storm water management wetpond, which controls the discharge of the two and ten year return interval storms from the developed site to predevelopment levels. Quality control would be provided by the grassed swales (with check dams) which provide some physical filtering of storm water runoff and encourage infiltration, and by the design of the pond which provides at least 24 hours of detention for the mean storm event. A commercial site in the same watershed might implement a completely different set of management practices.

The inventory of storm water management practice provided in the Appendix addresses site conditions most appropriate for each of the practices, and other application considerations.

In addition to selection of storm water management practices appropriate to site conditions, the overall plan for storm water management must consider the water quality and existing storm water management practices of the entire watershed. Watershed conditions can affect the selection of the method of storm water management quantity control and the level and type of water quality protection provided by the facility. The storm water management plan for the residential subdivision described above would be designed as a dry pond, not a wetpond, if it were discharging to a watershed protected for trout propagation to minimize the potential for thermal impacts. Development within the protected watershed would likely have to conform to standards which limit impervious area and establish stream setbacks for water quality and aquatic habitat protection. Similarly, if the storm water management facility discharged to receiving waters protected for water supply, the facility might include extended detention features and a planted wetlands permanent pool to provide maximum removal of pollutants in storm water discharges. If the proposed development were located in the lower reaches of a drainage basin where quantity controls are least effective, the proposed storm water management plan might focus on quality controls, and provide minimal quantity control within the structures. Similarly, if the site is located immediately upstream of a proposed major regional storm water management facility, a waiver of on-site storm water management quantity and quality control might be appropriate in the event that acceptable conveyance of site storm water runoff can be provided to the regional facility.

5.0 Stormwater Management Practice Inventory

5.0 Stormwater Management Practice Inventory

As noted in previous sections of this report, storm water management facilities are installed during the construction phase to control the quantity and/or quality of storm water discharged from the site once construction is completed. The storm water management inventory provided in the appendix is addresses structural and non structural methods of storm water management, and identifies which methods are considered "Best Management Practices", or storm water management methods which provide water quality control.

5.1 Non-structural Storm Water Management

Non-structural storm water management methods include vegetation practices designed to limit site impervious area and reduce the need for volume control storm water management facilities, and pollution prevention techniques designed to control pollutants prior to contact with storm water and discharge in storm water runoff.

Vegetation practices include grassed swales and grassed and wooded filter strips, and various landscaping techniques which encourage the preservation of existing woodlands, and the replanting of woodlands where preservation is not possible. These practices are often used in combination with other quantity control based storm water management practices to improve the quality of storm water discharged from the site. In addition to swales, filter strips, and landscaping techniques used individually as water quality control methods, vegetation plantings are often proposed within the basins of volume control storm water management facilities such as dry ponds and wetponds to improve the pollutant removal capabilities of these facilities.

Non-structural storm water management practices include housekeeping practices such as street sweeping, urban litter control programs, and fertilizer and pesticide control programs. These storm water management methods focus on controlling the build-up of pollutants on the land surface in between storm events to prevent pollutants from entering storm water runoff.

5.2 Structural Storm Water Management Facilities

Structural storm water management facilities described in the inventory provided in the appendix are grouped in three categories: pond systems, infiltration-based systems, and underground and other storage systems.

Pond systems designed primarily as volume control structures provide minimal pollutant removal capabilities and cannot be considered water quality controls, or BMP facilities. However, pond systems can be designed with extended detention, sediment forebays, planted wetlands basins and permanent pools, which improve water quality performance significantly by creating conditions within the basin for physical and biological treatment of pollutants in storm water runoff.

Infiltration -based storm water management facilities include infiltration basins and trenches, pavement alternatives including porous asphalt and grid pavers, and rooftop storage-disposal alternatives which direct rooftop runoff to underground facilities which discharge to the surrounding soils. Infiltration devices are all considered BMPs because they treat storm water by filtration through gravel and the soil column, and discharge treated storm water to ground water. In addition to the treatment provided by percolation through the soil column, infiltration devices are particularly favored because storm water replenishes groundwater and thus replicates as much as possible the predevelopment hydrology of the site. Pavement alternatives reduce site impervious area, and thus reduce the need for volume control storm water management facilities. Rooftop storage-disposal facilities are similar to infiltration trenches and basins in that ultimate disposal of storm water is to on-site soils and ultimately to local groundwater.

Underground storage facilities include vaults and pipe storage systems that are typically installed on urban and suburban commercial/industrial sites where site area is limited. These systems are typically designed as volume control facilities only, and provide only temporary detention for time periods insufficient to provide for significant sedimentation or removal of other storm water pollutants. For this reason, underground vaults and pipe storage facilities are not considered BMP facilities. Similarly, parking lot storage, and rooftop storage facilities provide temporary storage of storm water and a controlled release rate to receiving streams, but provide only minimal pollutant removal benefits. These facilities are also not considered BMP facilities.

APPENDIX

NON STRUCTURAL STORMWATER MANAGEMENT PRACTICES

Street Sweeping

Definition:

Regular sweeping of urban areas to remove accumulated debris including sediment, trash, materials from atmospheric deposition and motor vehicle sources.

Purpose:

To remove accumulated materials between storms to prevent the dislodge and transport of these pollutants to surface waters during storm events.

Conditions Where Practice Applies:

Urban areas and particular industrial sites where accumulation of materials on paved surfaces is significant.

Effectiveness:

The practice has received limited application in urban areas that has been monitored to provide data sufficient to estimate effectiveness.

Advantages:

Can be implemented in urban areas to improve storm water runoff quality without committing costly land area necessary for volume controls. Can be implemented as a retrofit storm water management BMP.

Disadvantages:

Method is labor and equipment intensive. In addition to purchase/rental of the street sweeping equipment, operators are necessary, and schedules must be developed which do not conflict with periods of high use/ activity by pedestrian and motor vehicle traffic. Equipment is noisy, and may generate complaints from residential portions of the urban area.

Fertilizer and Pesticide Application Controls

Definition

Managing the application of fertilizers and pesticides to encourage proper application.

Purpose

To reduce pesticides and fertilizers in storm water runoff from residential, commercial and industrial land uses.

Condition Where Practice Applies

Suburban and urban areas including residential lots, common areas, recreation areas, parks, roadway right of ways, commercial sites, industrial sites, cemeteries, and other institutions and public facilities.

Effectiveness

Unknown

Advantages

A storm water management BMP that can be applied on a system-wide or jurisdiction basis to reduce nutrient loadings and pesticides in receiving waters from the entire system.

Disadvantages

Implementation of a public information program to encourage proper application of pesticides and fertilizers would be costly, and estimates of effectiveness would be conjecture at best.

Vegetative Practices

Description

Grass filter strips, wooded filter strips, preservation of wooded areas, reforestation areas and tree-shrub landscaping instead of "turfscaping".

Purpose

To provide vegetated areas between structural development and receiving streams to provide a filtering area for storm water and to promote infiltration into the soil.

Conditions Where Practice Applies

Mostly applies to developing areas, but in some instances can also be used as a water quality BMP in retrofit situations.

Effectiveness

Treatment of storm water in filter strip applications is accomplished physically by a combination of filtration through the standing vegetation and infiltration into the underlying soils. In order to treat storm water effectively, filter strips must be designed to function as overland flow systems where storm water is evenly distributed. There is a high potential for short circuiting and reduced pollutant removal from these systems.

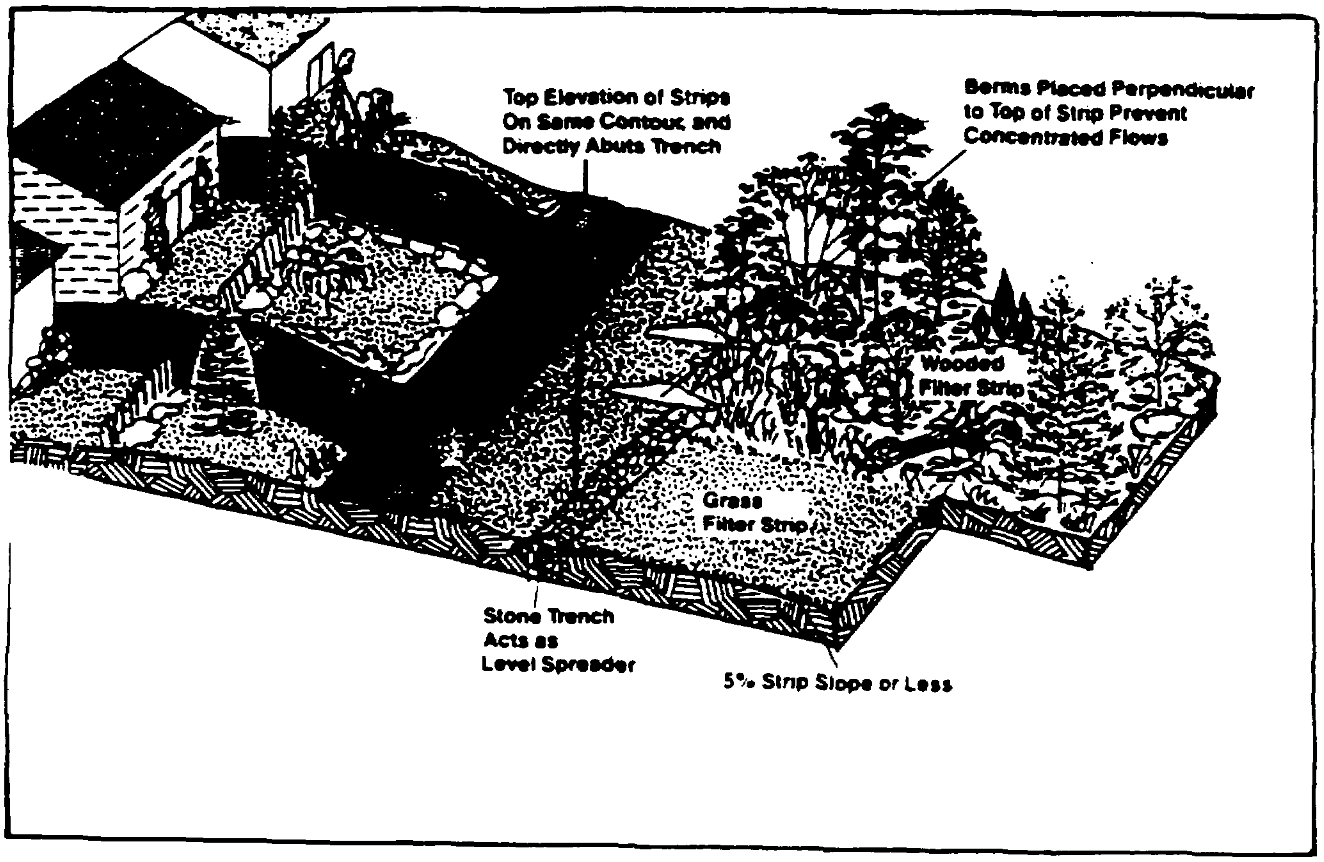
Advantages

In addition to water quality benefits provided by vegetative filter and infiltration, vegetative practices, particularly those involving preservation of woodlands, reforestation, or tree-shrub landscaping provide aethetic features for the community, and provide wildlife habitat in urban and suburban areas.

Disadvantages

Filter strips are considered BMPs, but provide limited storm water volume control and are usually implemented in combination with other volume control storm water management facilities. Sufficient land area must be available for grassed and woodland filter strips and woodland preservation areas and reforestation areas. Land availability constrains application of this BMP in retrofit situations.

Schematic of a Filter Strip



Reference:
Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's, Thomas R. Schueler, July, 1987.

Grassed Swales

Description

Grassed lined channels used to collect and convey storm water runoff.

Purpose

An alternative to closed pipe systems which provides opportunities to reduce storm water velocity and promote infiltration.

Conditions Where Practice Applies

Low density development and in medians and adjoining roadways. Soil and slope conditions dictate application.

Effectiveness

Treatment of pollutants is primarily physical filtration through standing vegetation, with some infiltration into underlying soils. By slowing velocity of runoff and providing some infiltration, grassed swales reduce the time of concentration (the time it takes runoff to reach the receiving stream).

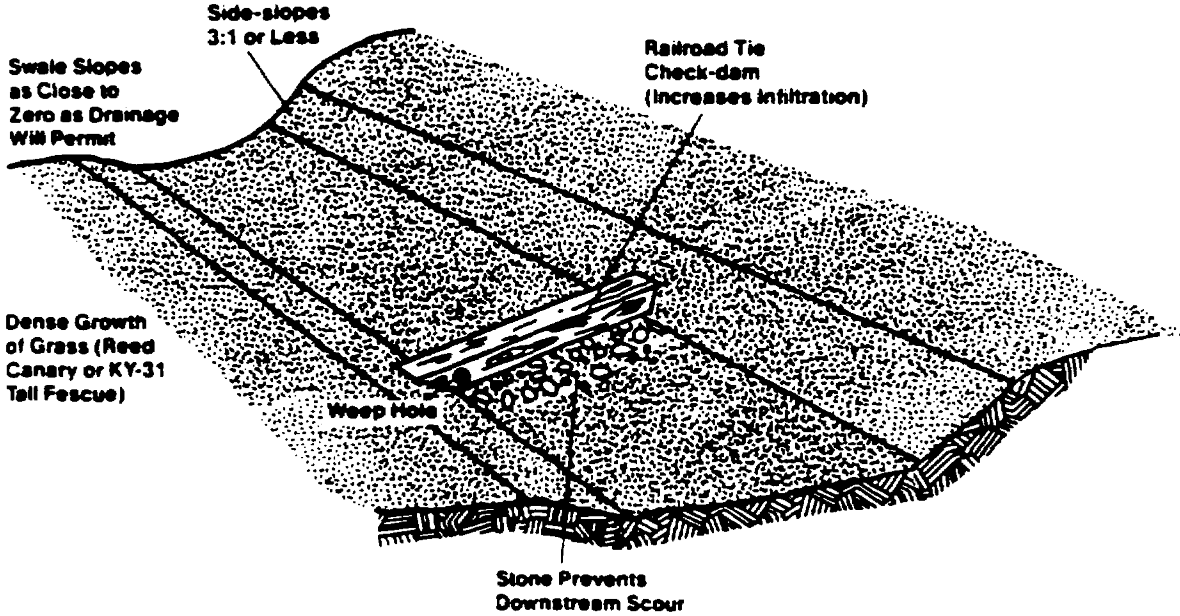
Advantages

Provides a low cost alternative to enclosed pipe systems which offers some water quality benefits if properly designed.

Disadvantages

Although grassed swales provide some flow attenuation, they are not considered volume control storm water management facilities. Pollutant removal effectiveness is a function of proper design and application, and can be variable.

Schematic of a Grassed Swale



Reference:
Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's, Thomas R. Schueler, July, 1987.

Structural Stormwater Management Practices

Stormwater Detention Wetpond

Description

Wetponds are natural or man made depressions which provide storage of the permanent pool and storm water runoff from a site or drainage area, and allows gradual release of the post-development peak runoff from the site to down stream areas.

Purpose

Wetponds regulate the discharge of post-development site runoff, and provide water quality control by providing physical settling of storm water pollutants and by providing an aquatic system for biological treatment.

Conditions Where Practice Applies

Wetponds are appropriate where the contributing drainage area provides sufficient base flow to support the permanent pool area of the wetpond. Generally, the minimum contributing drainage area for wetponds is about 10 acres unless a known water source such as a spring is present. Larger ponds are preferred.

Advantages

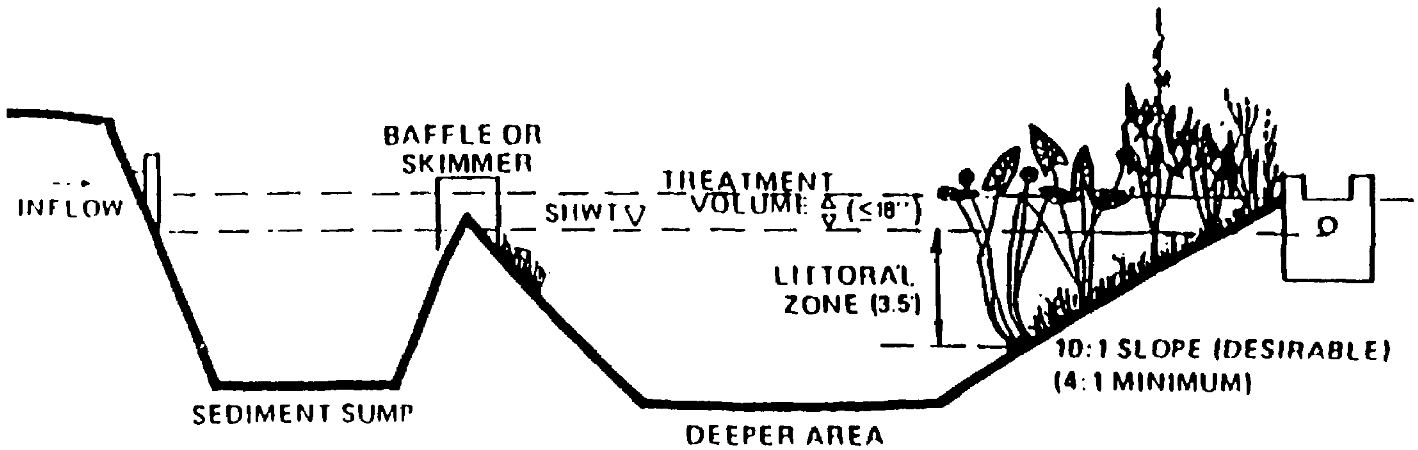
Wetponds provide both volume and water quality control, and provide additional advantages by offering opportunities for recreation and wildlife habitat in the community. Water quality performance of wetponds is variable, but generally high. Extended detention and other design features such as sediment forebays and permanent pool areas managed as shallow wetland marshes improve water quality performance.

Disadvantages

Permanent pool areas can dry up during periods of drought in marginal watersheds, creating odors and nuisance. Wetponds are typically placed in stream valleys which meet the regulatory definition of wetlands and require U.S. Corps of Engineers and State water quality certification approvals for construction. Pond construction in the stream valley alters riparian wetland habitat and precludes the migration of aquatic species through the pond. Wetponds can present safety hazards in residential communities. Fencing can control access but affects aesthetics of the pond.

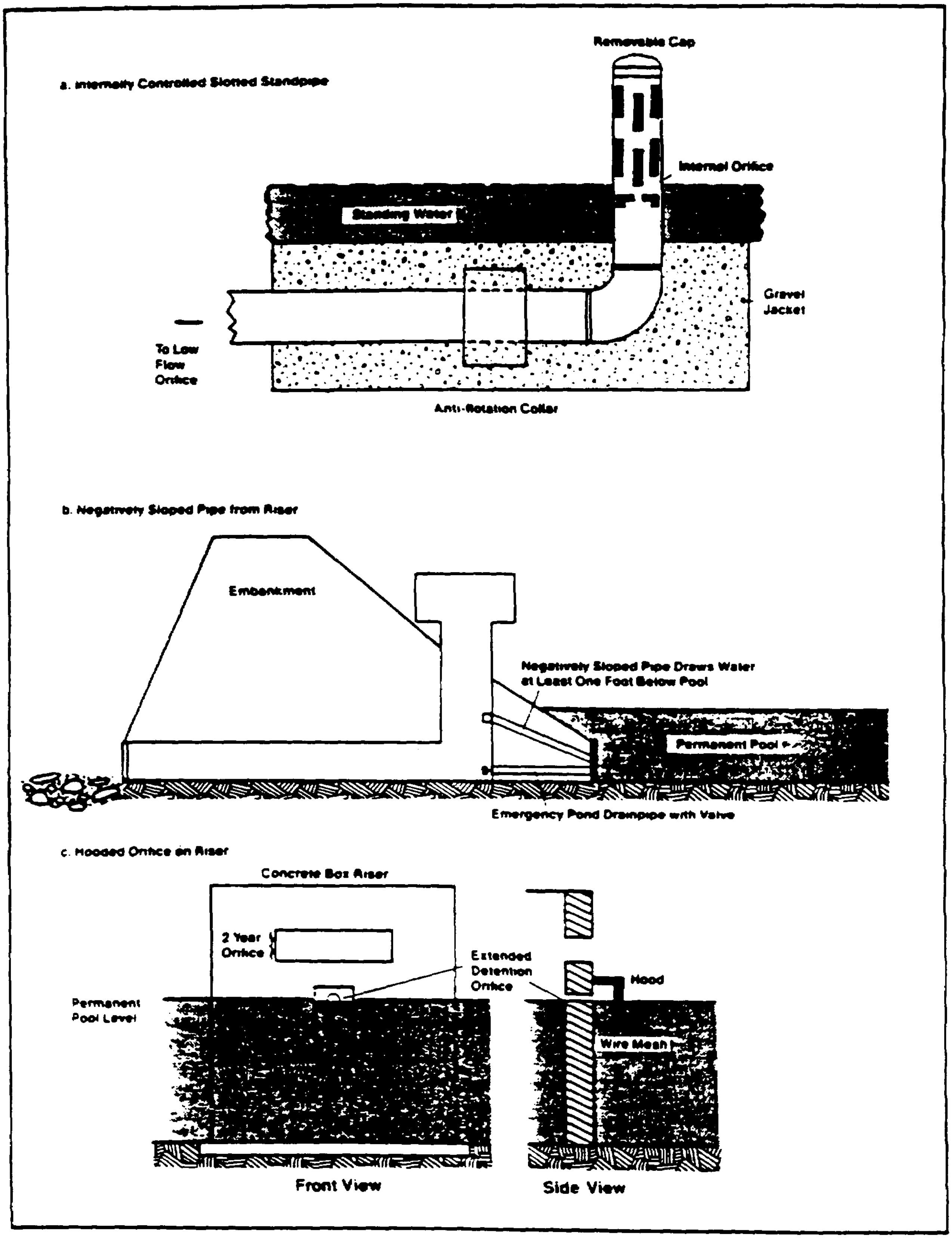
WET DETENTION SYSTEM

POND CONFIGURATION - A



Source: Southwest Florida Water Management District
Management and Storage of Surface Waters, Permit Information
Manual, Vol.I, March 1988.

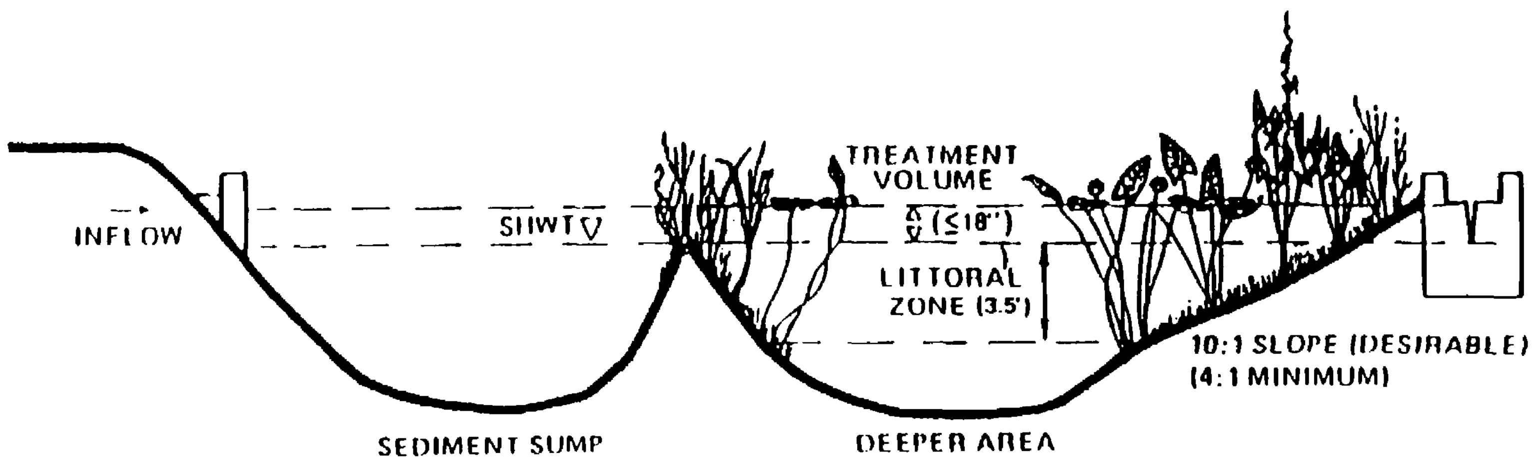
Methods For Extending Detention Times In Wet Ponds



Reference:
Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's, Thomas R. Schueler, July, 1987.

WET DETENTION SYSTEM

POND CONFIGURATION - B



Source: Southwest Florida Water Management District
Management and Storage of Surface Waters, Permit Information
Manual, Vol.I, March 1988.

Stormwater Detention Dry Pond

Definition

Dry ponds are man made storage facilities which remain dry between storm events, and provide temporary storage and gradual release of the post development runoff during and after storm events.

Purpose

Dry ponds contain post-development storm water runoff and control the release to predevelopment peak levels. Unless modified to provide extended detention, dry ponds provide only minimal water quality improvement, and are considered primarily a volume control facility.

Advantages

Dry ponds can be implemented in watersheds and drainage areas where thermal impacts are a concern. Dry ponds are generally the least costly storm water management volume control alternative. Additionally, recreation areas such as playing fields can be used as dry detention areas.

Disadvantages

Dry ponds provide little water quality control unless designed for extended detention.

Porous Asphalt Pavement

Definition

Pavement alternative which allows infiltration of storm water to gravel and soil layers underlying the pavement surface.

Purpose

To reduce the quantity of storm water runoff from paved areas and infiltrate storm water to underlying soils. Practice is applicable only in areas with suitable subsurface soil conditions.

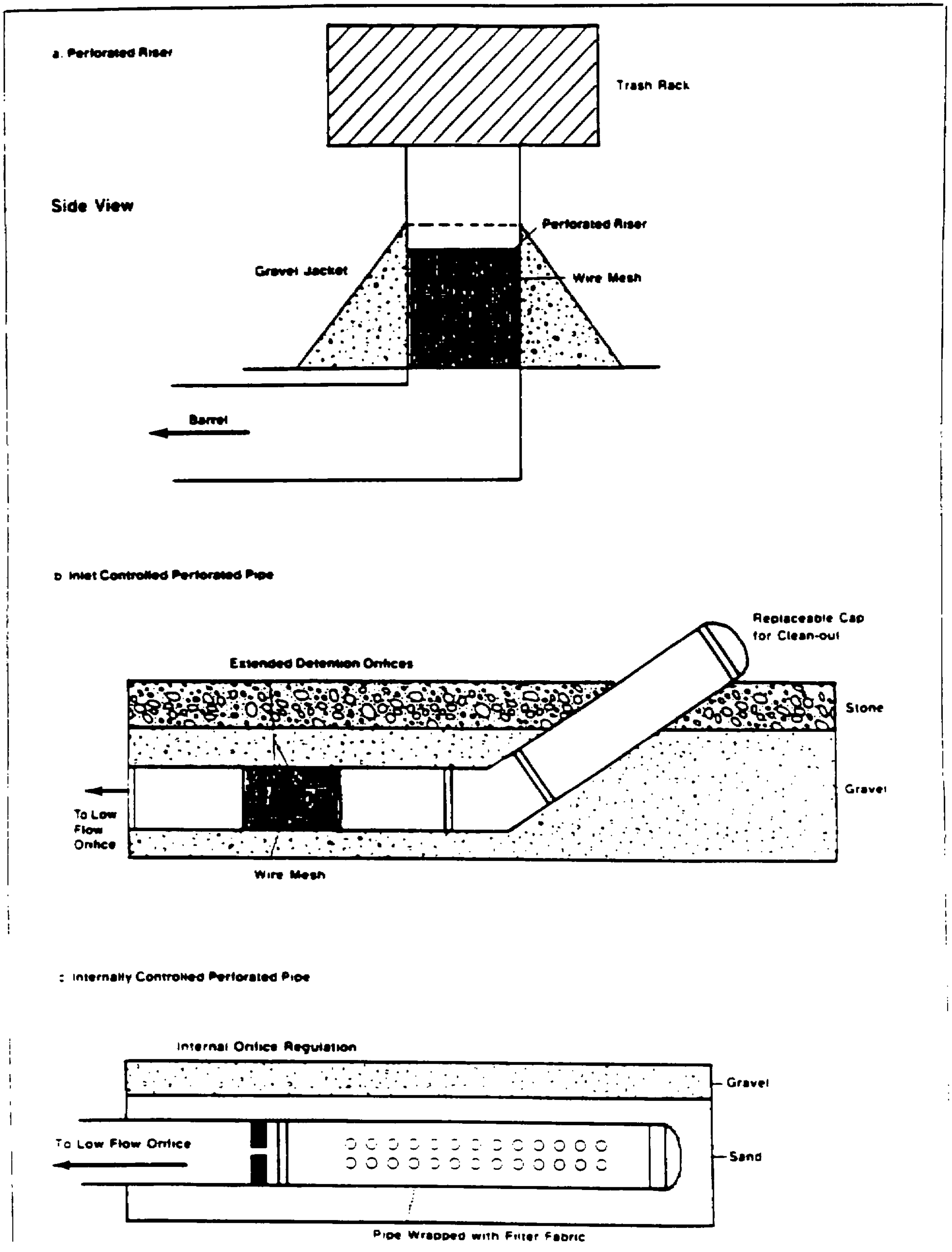
Advantages

Reduces the need for volume control storm water management facilities, and provides water quality control for storm water which infiltrates through the pavement to underlying soils.

Disadvantages

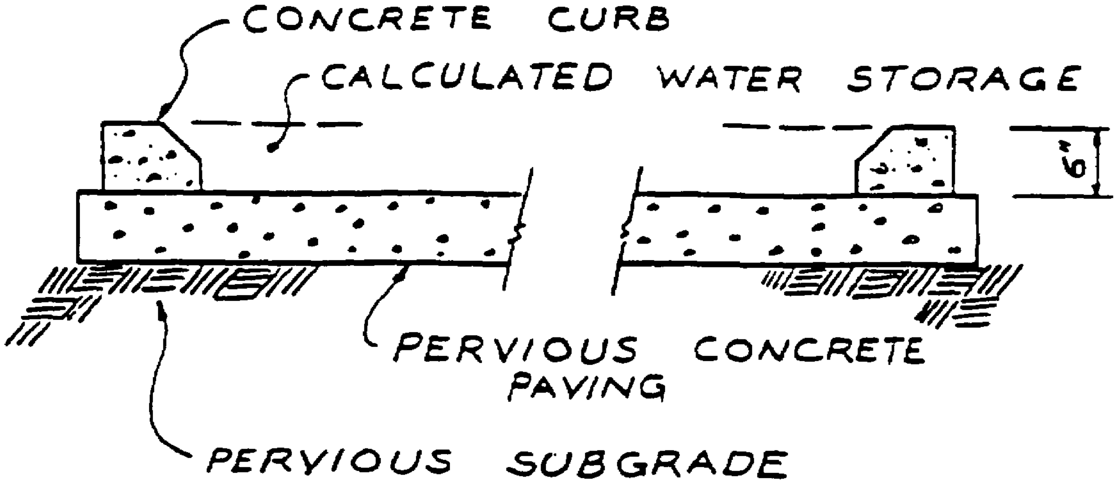
Voids in asphalt fill with sediment over time and surface eventually clogs. Must be combined with other volume control storm water management facilities. Water remaining in void areas is subject to freeze-thaw cycle which stresses and weakens pavement.

Methods For Extending Detention Times in Dry Ponds



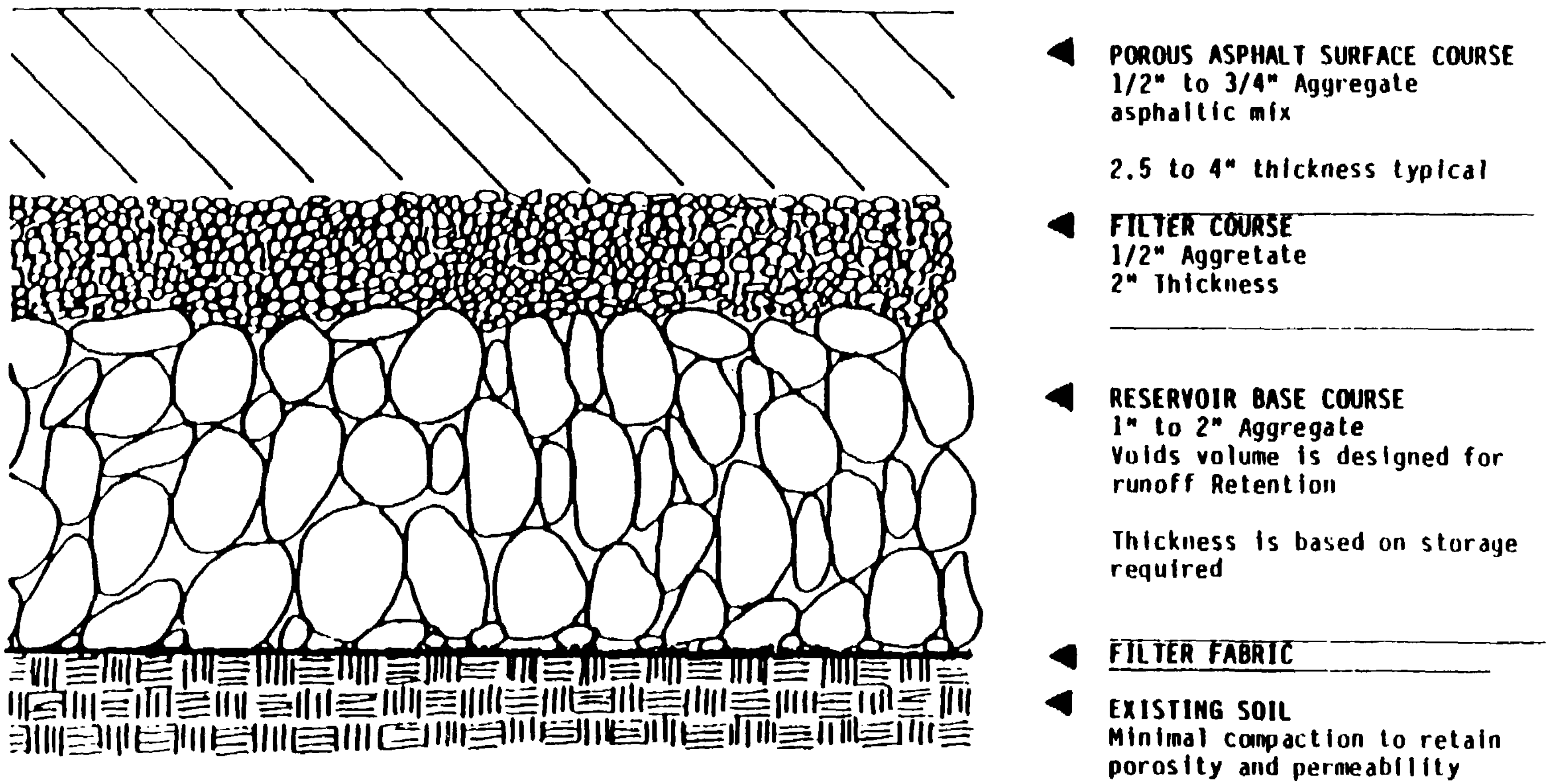
Reference:
Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's, Thomas R. Schueler, July, 1987.

PERVIOUS CONCRETE PAVEMENT
TYPICAL SECTION



A close-up view of no-fines concrete

Reference:
Florida Department of Environmental Regulation. The Florida Development Manual: A Guide To Sound Land And Water Management, June, 1988.



POROUS ASPHALT PAVING TYPICAL SECTION

Modified after Diniz, 1980 and City of Rockville, Maryland, 1982

Infiltration Trenches and Basins

Description

Infiltration facilities collect, store and infiltrate runoff through gravel areas and underlying soils.

Purpose

To provide both volume control and water quality control, and replicate as much as possible, predevelopment hydrologic conditions.

Conditions Where Practice Applies

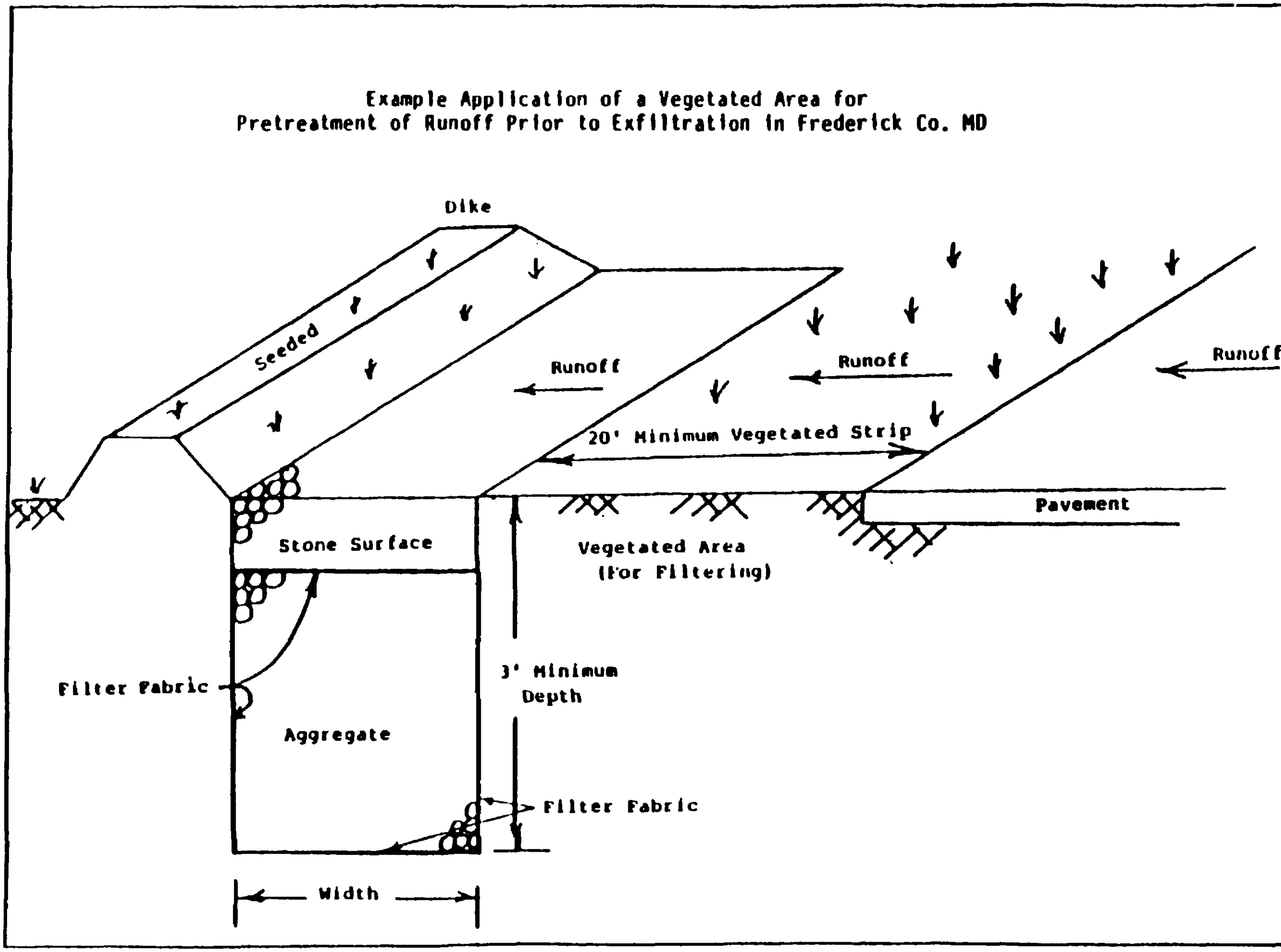
Infiltration devices are most applicable on smaller development sites, and installation requires careful management during the construction period to avoid clogging the structure with sediment.

Advantages

Changes in down stream peak flows are minimal because storm water is infiltrated to resupply local groundwater. Water quality control is provided by infiltration through the soil column and is considered high performance.

Disadvantages

Infiltration structures are costly to construct and require maintenance that eventually will involve reconstruction of the basin to restore infiltration capacity as systems become clogged over time. Infiltration systems can only be implemented on sites with suitable soil and ground water conditions.



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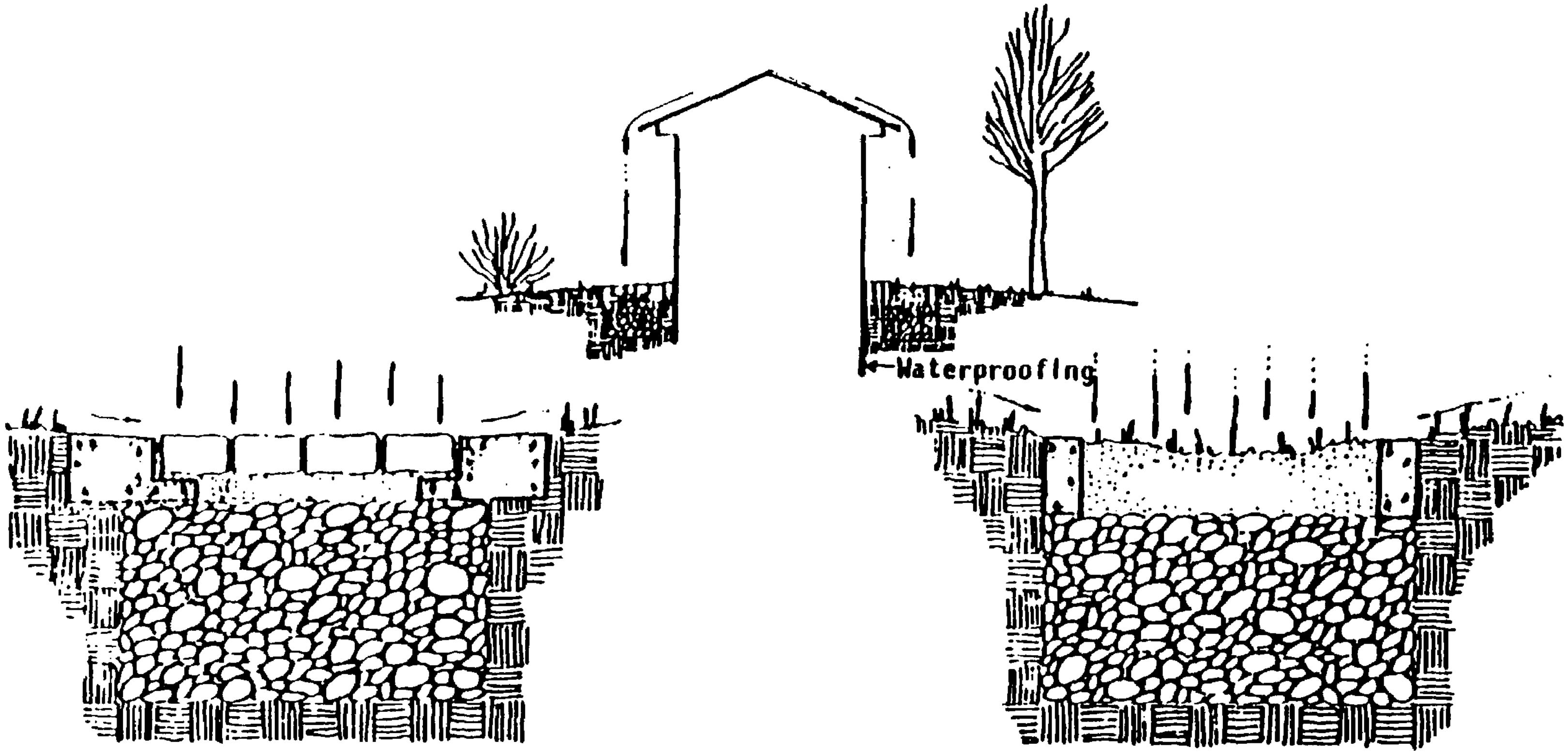
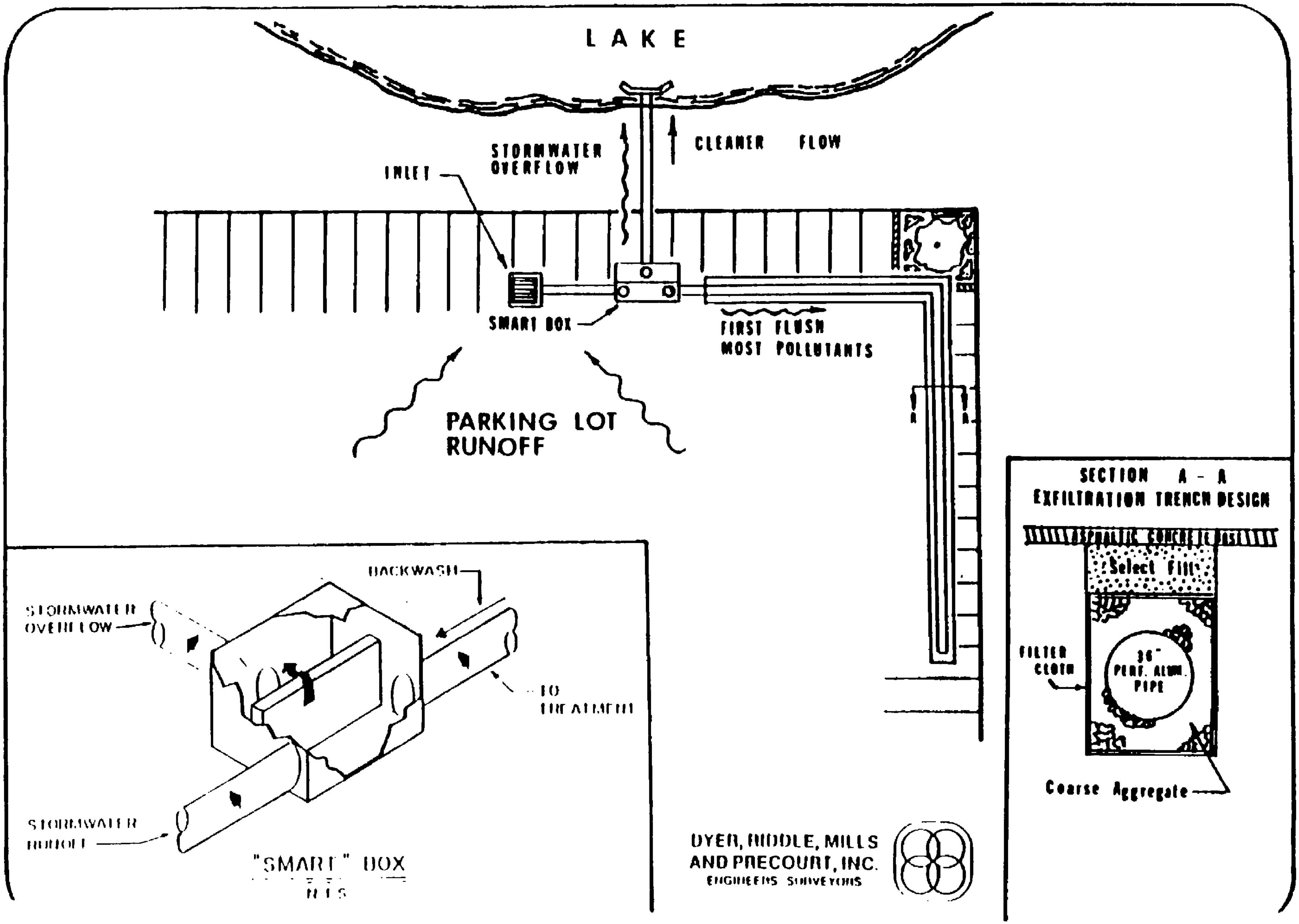


TYPICAL INFILTRATION TRENCH UNDER GUTTERLESS ROOF

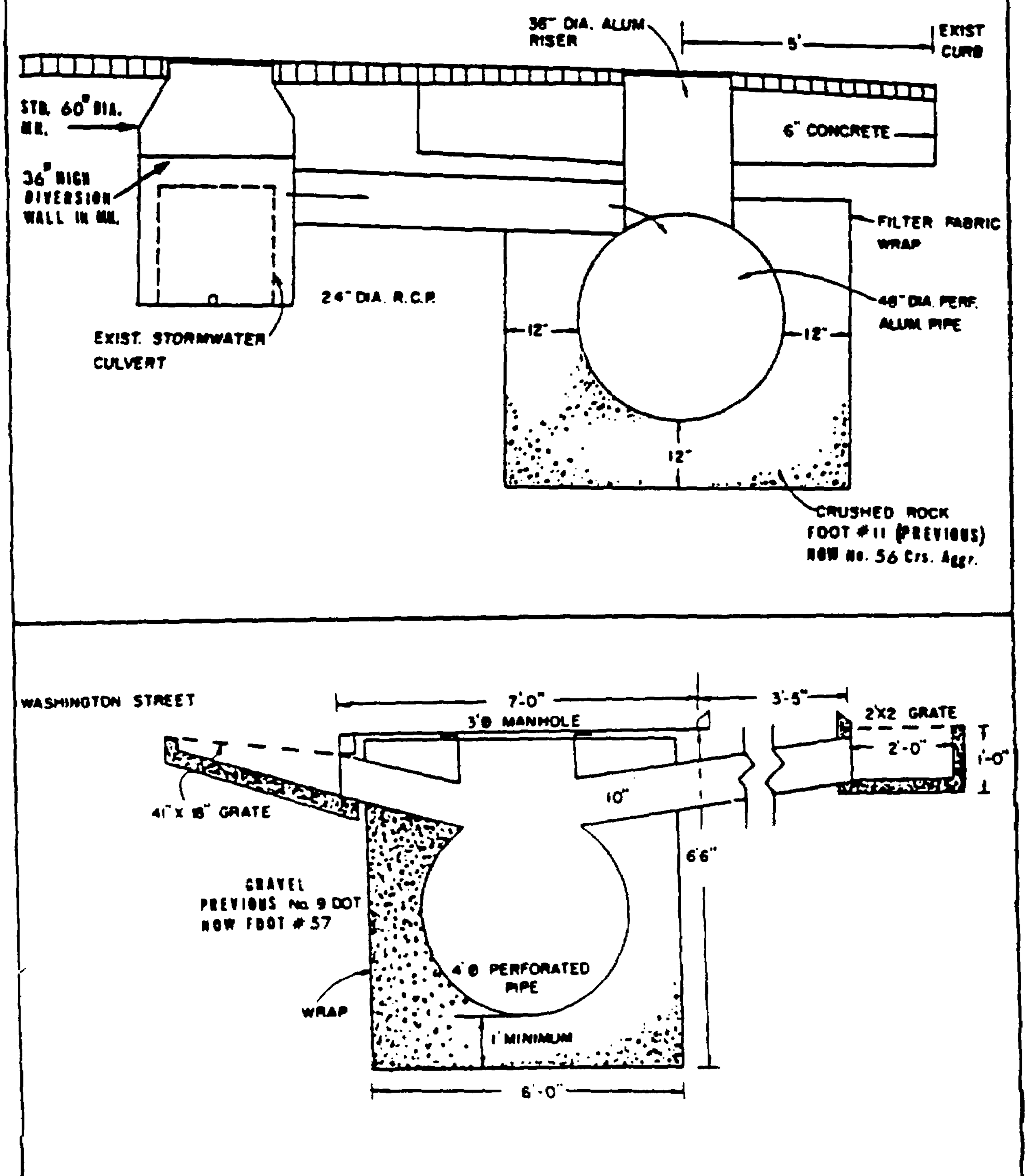
Source: Virginia Soil and Water Conservation Commission

Cross-Section of Typical Infiltration/Exfiltration Trench System for Parking Areas or Roadways



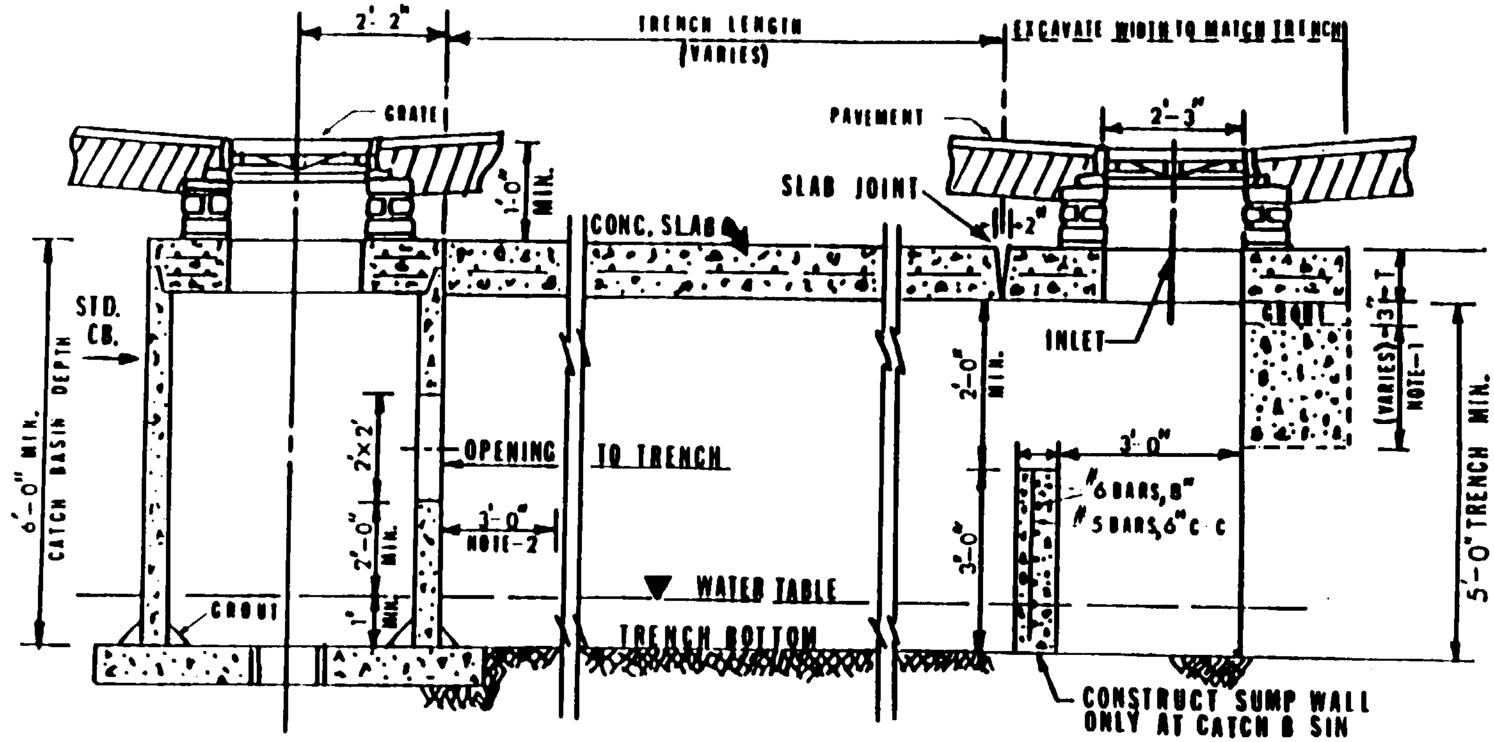
Reference:
Florida Department of Environmental Regulation. The Florida Development Manual: A Guide To Sound Land And Water Management, June, 1988.

Examples of Typical Underground Percolation Systems
for
Retrofitting Existing Stormsewer Systems in Orlando, Florida



Reference:
Florida Department of Environmental Regulation, The Florida Development Manual: A Guide To Sound Land And Water Management, June, 1988.

TYPICAL SECTION, SLAB COVERED TRENCH, DADE COUNTY, FLORIDA



LONGITUDINAL SECTION

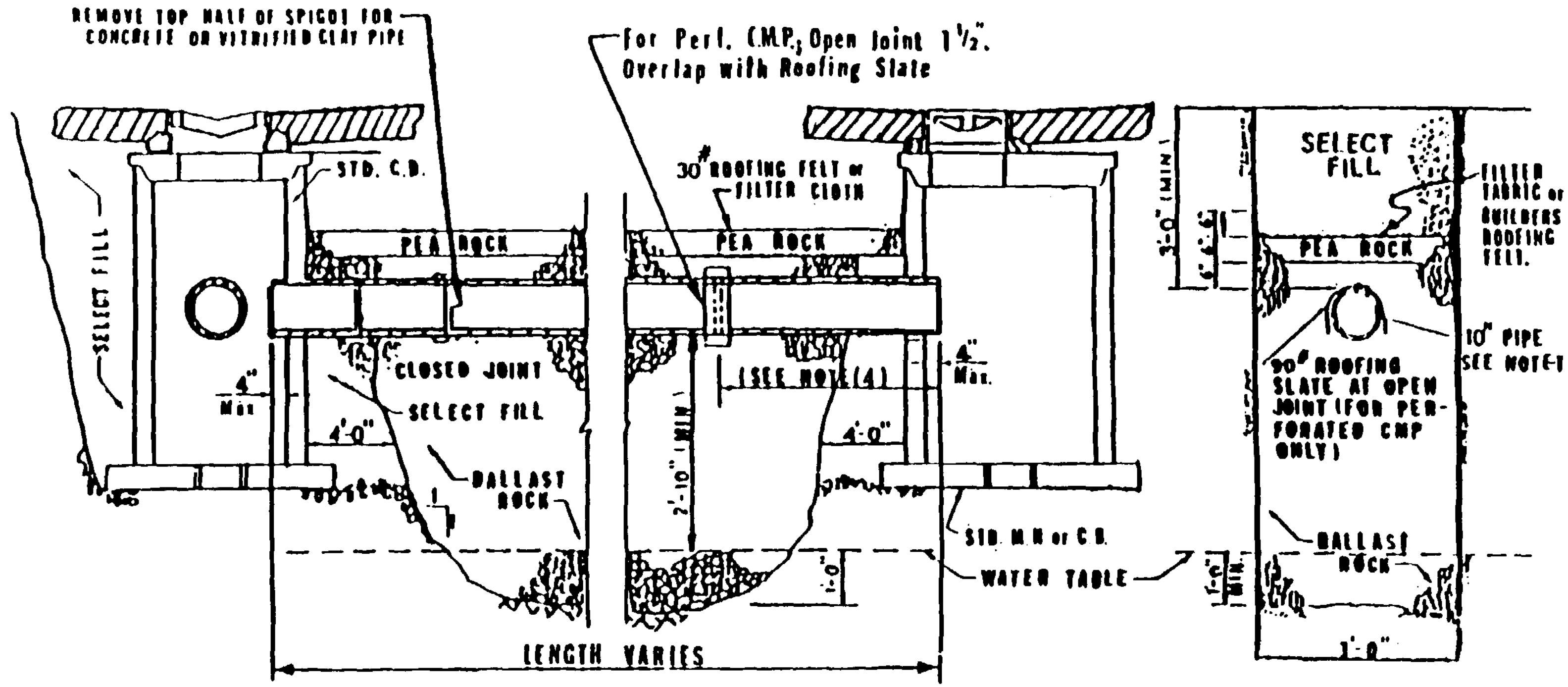
NOTES:

1) If material at edge of ditch is unsuitable for foundation underslab, clean out and backfill with concrete. Depth of backfill varies.

2) Transition to trench bottom when it is lower than catch basin bottom.

Reference:
Florida Department of Environmental Regulation. The Florida Development Manual: A Guide To Sound Land And Water Management, June. 1988.

FRENCH DRAIN (EXFILTRATION TRENCH), DADE COUNTY, FLORIDA



LONGITUDINAL SECTION

TRANSVERSE SECTION

NOTES:

1) If 10" conc bell & spigot pipe 5' long is not available, pipe, up to 24" in diameter may be substituted.

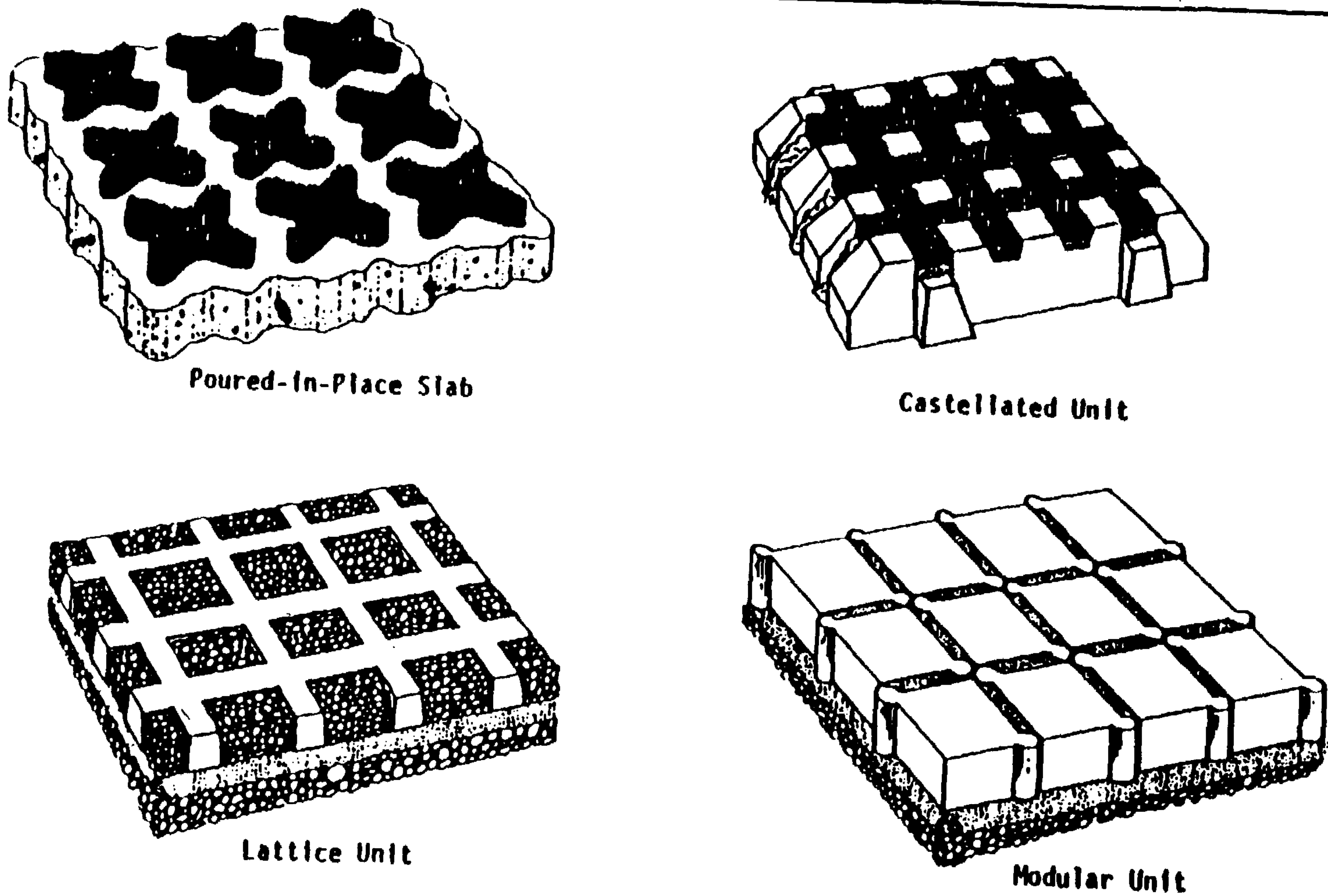
2) If conc bell & spigot pipe is not used or if the length of pipe used is greater than 5', 3/4" saw cuts shall be made at intervals of 2' thru the upper half of pipe, 5' lengths may be used for vitrified clay pipe.

3) The contractor has the option of installing the following pipe types:
   A. Concrete - perforated or non-perforated (bell spigot)
   B. Vitrified Clay - " " " " " "
   * C. Corrugated Metal - Bituminous coated (perforated)
   * D. Corrugated Aluminum (perforated)

4) No pipe perforations for 10' $\pm$.

* 1/4" to 3/8" dia. hole, spaced at 2-3/4" $\pm$ (minimum 162 holes per lin.ft.)

Reference:
Florida Department of Environmental Regulation. The Florida Development Manual: A Guide To Sound Land And Water Management, June, 1988.



TYPES OF GRID AND MODULAR PAVEMENTS

Source: Virginia Soil and Water Conservation Commission

Rooftop Runoff Disposal

Description

Disposal of rooftop runoff by systems and techniques which avoid or replace direct connections to storm or sanitary sewers. Disposal alternatives include underground vaults, cisterns, infiltration trenches and basins.

Purpose

To detain roof top runoff and provide opportunities for reuse and eventual infiltration to underlying soils.

Conditions Where Practice Applies

In urban and suburban areas where space constrains use of other volume control storm water management alternatives. Only applicable on sites where adequate storage can be provided, or soil and ground water conditions are suitable for the infiltration of runoff.

Advantages

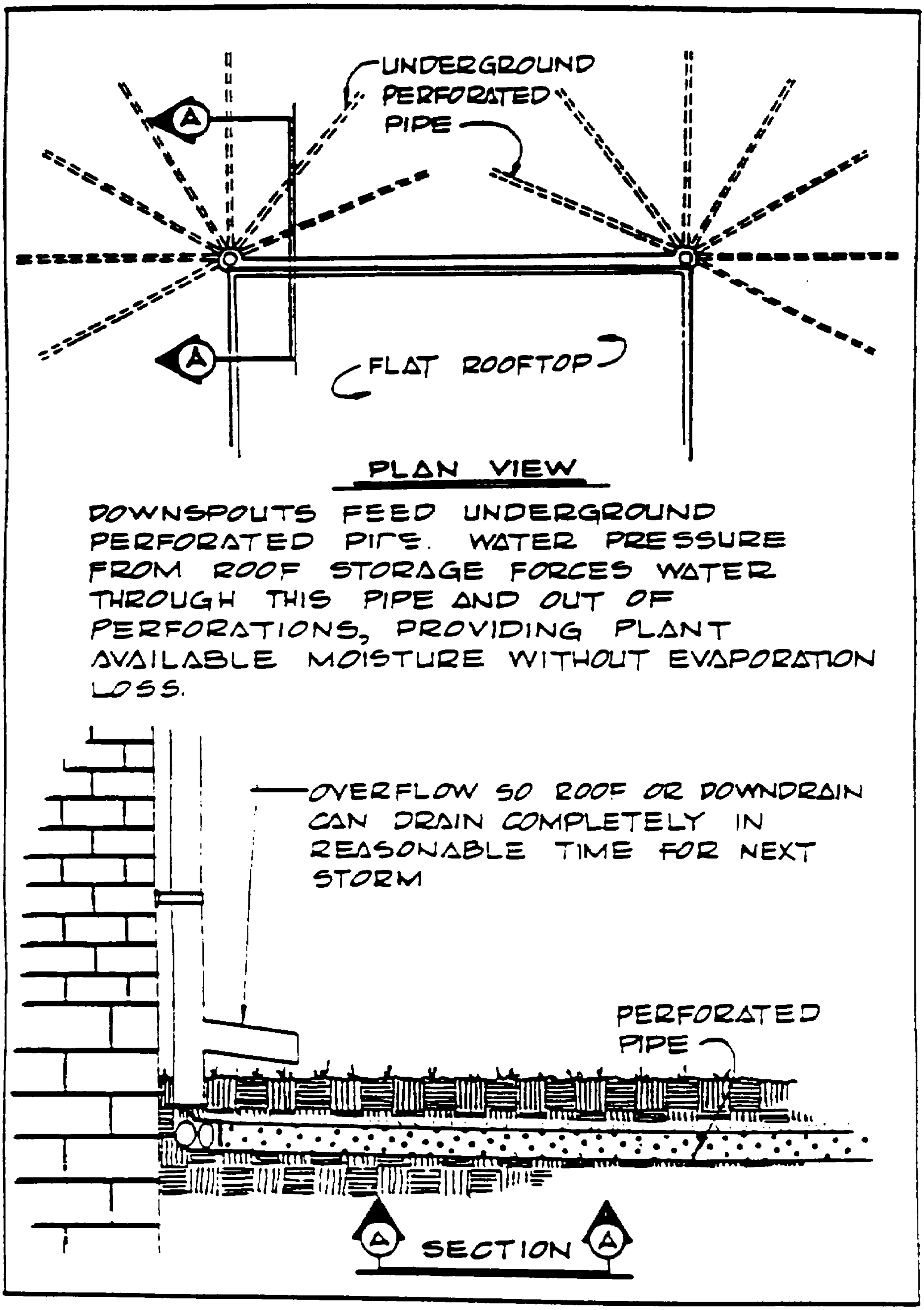
When used on an area wide basis, can provide effective volume and quality control for rooftop runoff. Particularly applicable in areas where thermal impacts are a concern.

Disadvantages

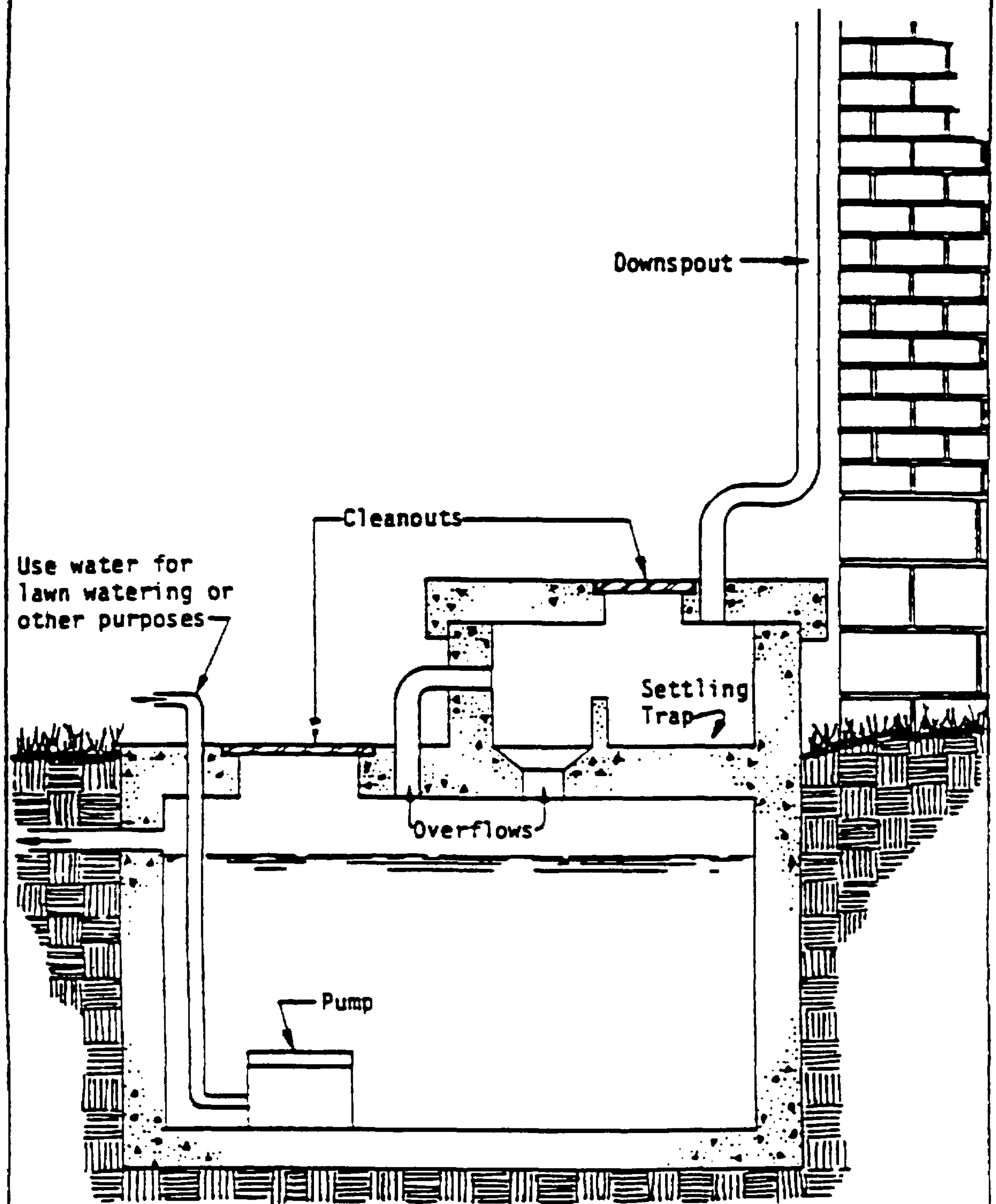
Similar to other infiltration-type devices in terms of maintenance/ reconstruction requirements for infiltration portion of the system. Roof top detention may require building structural improvement to accommodate weight of storm water detained temporarily on roof.

URE 6-35

INFILTRATION DRAINAGE OF ROOFTOP



Source: Virginia Soil and Water Conservation Commission



TYPICAL RETENTION CISTERN

Source: Virginia Soil and Water Conservation Commission

Underground and Other Storage Systems

Water Quality Inlet

Description

A water quality inlet is basically a three chambered oil/grit separator provided at curb inlets in the storm drain system which receives runoff from parking areas and access drives.

Purpose

Water quality inlets are intended to provide removal of oil and grease and gross solids from storm water runoff entering the storm drain system. Water quality inlets provide minimal storage and are not considered volume control facilities.

Conditions Where Practice Applies

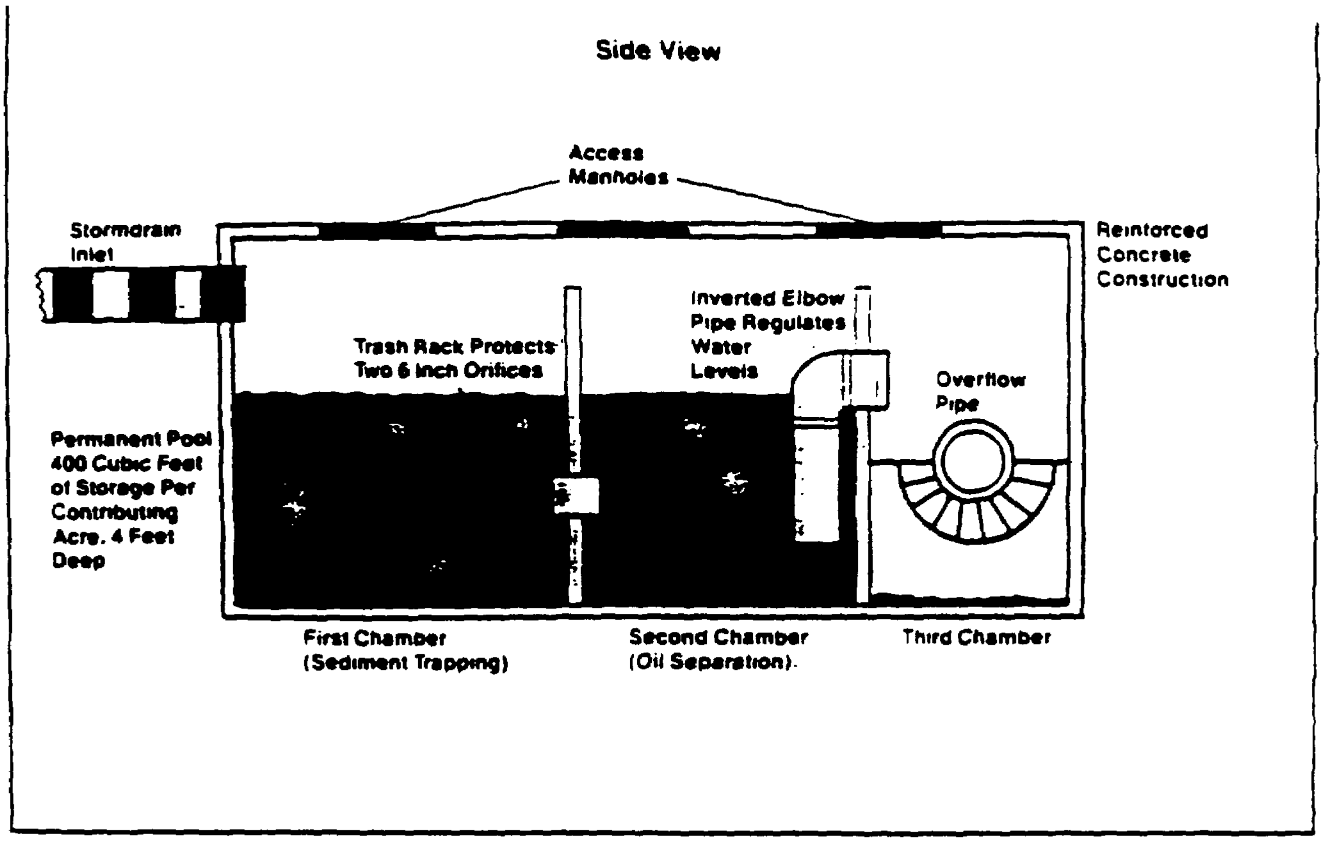
In urban and suburban area parking lots and streets in commercial and industrial land use areas.

Advantages

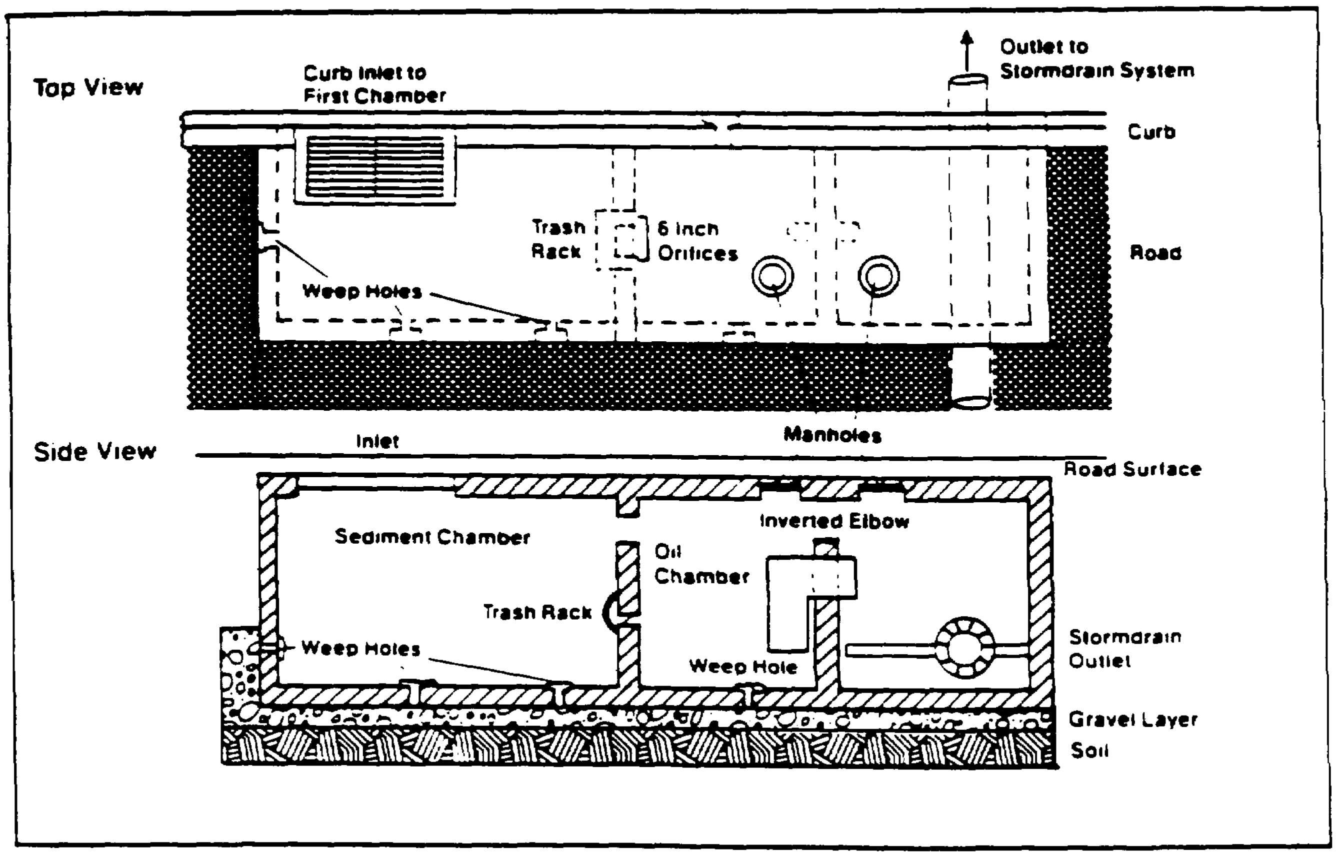
If properly maintained, water quality inlets can provide removal of solids including grit (heavy portion of sediment load which readily settles out of the water column), and floatable trash, debris, oil and grease. Chambers of the oil grit separator must be regularly cleaned to remove accumulated sediment and debris to avoid wash through of these materials or clogging of the facility during subsequent storm events.

Disadvantages

Water quality inlet provides removal of gross solids in storm water runoff only. These facilities do not provide adequate storage to allow significant settling of solids or removal of other pollutants. Adequate maintenance is necessary to maintain effectiveness of gross solids removal process. Water quality inlets are an improvement over traditional storm drain inlets because they provide for screening of gross debris and prevent debris from entering the downstream storm drain system and receiving waters. However, water quality inlets are more costly to install and maintain and do not provide significant pollutant removal or volume control benefits.



Schematic of a Water Quality Inlet, Rockville Percolating Inlet Design



Source: City of Rockville (1984b)

Underground Storage

Definition:

Underground storage is the practice of storing storm water runoff in underground vaults, oversized pipes, and other structures beneath site structures such as parking lots.

Purpose:

The purpose of underground storage is to provide volume control on space limited sites.

Conditions Where Practice Applies:

Underground storage is applicable where there is a lack of surface storage area or the land cost is greater than that of underground storage construction.

Effectiveness:

Underground storage is effective for volume control only. Water quality control is not provided by these facilities.

Advantages:

The advantage of underground storage is that it can be used on space limited sites and facility location is not greatly influenced by site topography.

Disadvantages:

Cost is the major disadvantage. Underground facilities are expensive to construct and are not easily maintained. Accordingly, underground structures are applicable only in areas where land costs are high and space is limited.

Rooftop Detention

Definition:

Rooftop detention facilities provide temporary stormwater storage on flat roof surfaces allowing gradual release of runoff to ground-level storm drain systems.

Purpose:

The purpose of rooftop detention is to provide quantity or volume control of storm water collected on the roof of the structure.

Conditions Where Practice Applies:

Rooftop detention can be incorporated into design of most new buildings. In addition, many existing flattop structures can be modified. Rooftop storage can be used as a quantity control retrofit technology in urban areas.

Effectiveness:

Rooftop detention is effective for quantity control but does not provide quality control.

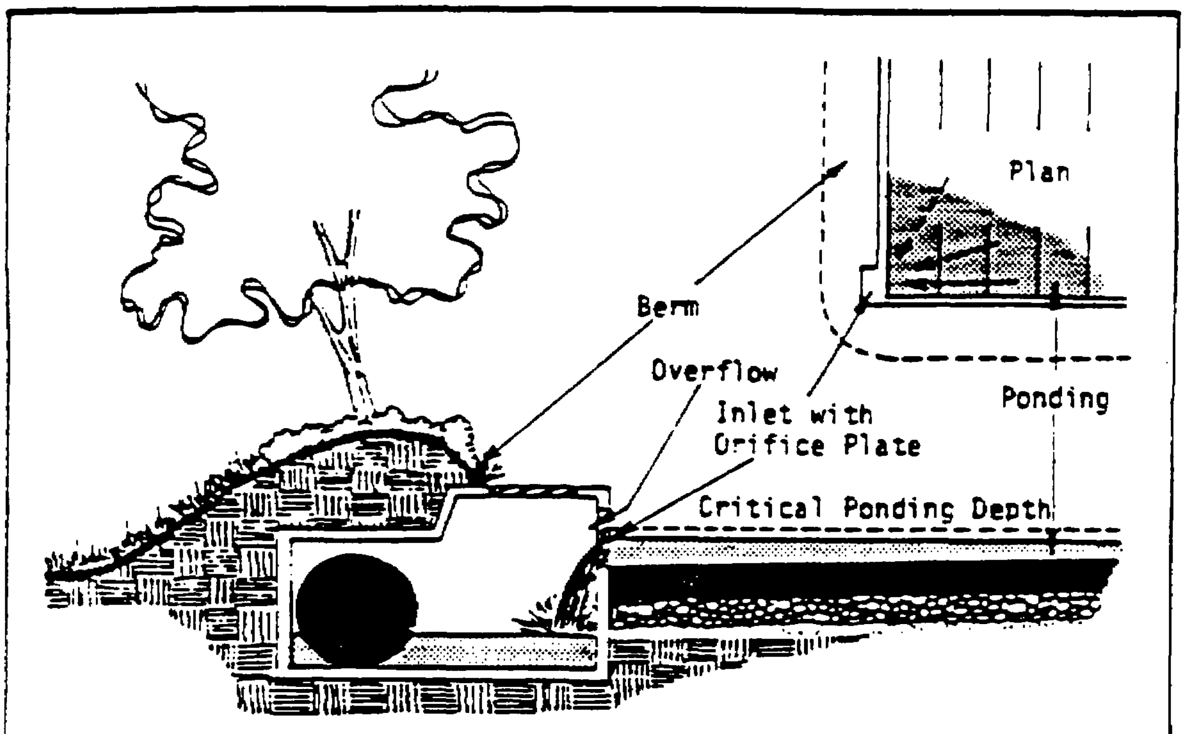
Advantages:

Rooftop detention can be implemented in urban areas as a retrofit technology for quantity control, and to correct existing uncontrolled connections to the storm drain system.

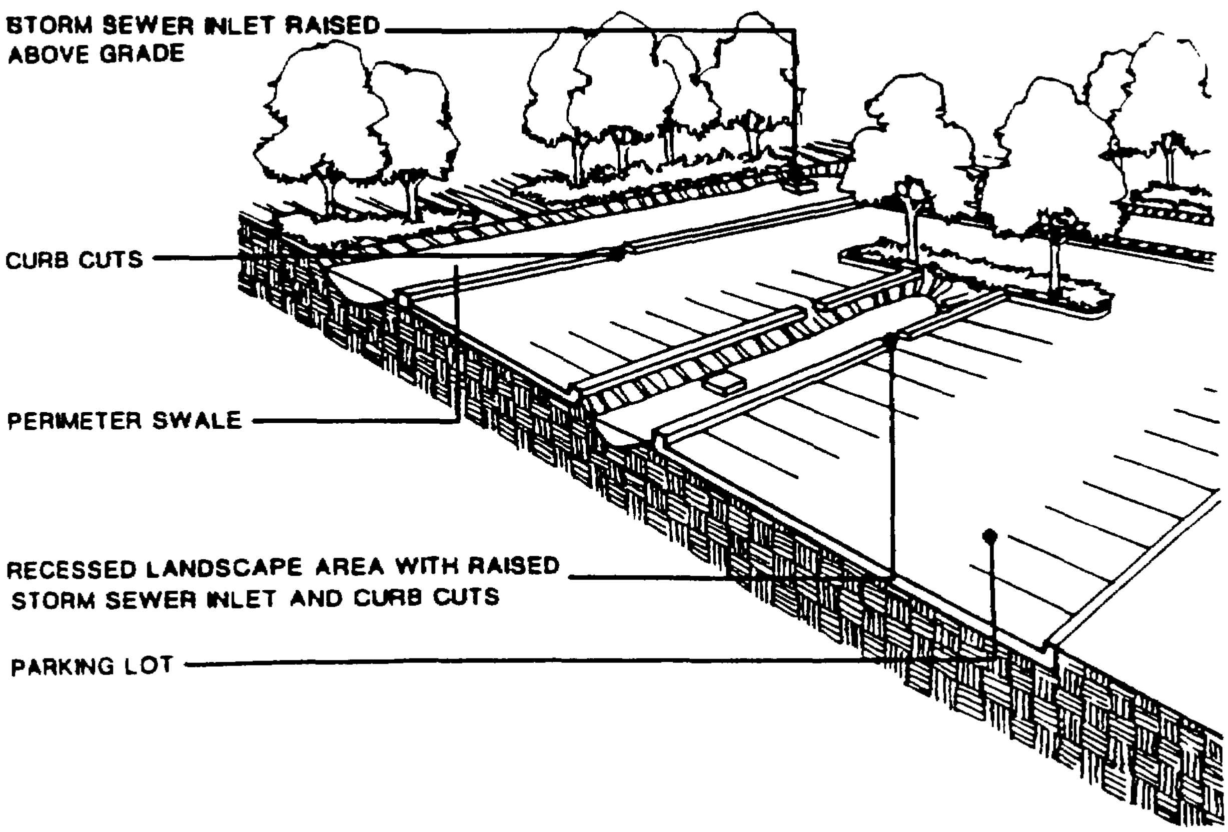
Disadvantages:

The building must be structurally designed to accommodate the additional weight of water storage at the roof level. Water quality control cannot be provided unless connected to a ground level infiltration facility. Effective volume control can only be realized when applied on an area-wide basis.

Parking Lot Detention Configurations



SECTION THROUGH A TYPICAL PARKING LOT STORAGE AREA



Reference:
Florida Department of Environmental Regulation, The Florida Development Manual: A Guide To Sound Land And Water Management, June, 1988.

Parking Lot Storage

Description

Method of storm water management volume control which provides temporary storage (ponding) of storm water runoff in paved parking areas an/or within landscaped islands of parking lots, and allows a controlled rate of release to receiving streams.

Purpose

Parking lot stage is an alternative to dry pond systems.and basically provides volume control for the post development peak storm water runoff from the contributing drainage area.

Conditions Where Practice Applies

Parking lot storage is applicable where portions of large, paved surface parking can be used for temporary storm water storage without interfering with normal pedestrian or vehicular traffic. Large commercial parking areas and employee parking areas have been used for this purpose.

Advantages

Parking lot storage allows the use of existing or planned parking facilities for temporary volume control storage, and is a low cost method of providing volume controls. Parking lot storage can be used in combination with infiltration practices to provide volume control and water quality control for a site. Additionally, use of parking areas for temporary storage allows site open space to be used for other purposes.

Disadvantages

Large surface areas are required to provide adequate storage volume without creating unacceptable water depth in parking areas. Parking lot surfaces are normally subject to heating due to sun exposure and will transfer heat to stored runoff. Practice is not appropriate where thermal impacts are a concern.