APPENDIX F – STORMWATER QUALITY

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F.1 GENERALLY

F.1.1 Scope

This appendix provides guidance for the continuing maintenance of stormwater runoff quality in the implementation of the requirements of Article 17 of this Chapter and in the utilization of low impact development techniques for stormwater management as required by various provisions of this Chapter and in conjunction with the design and development of conservation subdivisions provided for in Article 2 of this Chapter.

F.1.2 Modifications

The City Engineer may add to or modify the contents of this appendix when appropriate and for valid reasons to clarify or update best management practices associated with stormwater quality management. Such modifications shall be documented and forwarded to the Planning Commission as information. In specific cases and for documented reasons, the City Engineer may waive the submission of documents or specific activities required herein. The reasons for any such waiver shall be recorded in the project application file.

F.2 STORMWATER QUALITY

F.2.1 Introduction

Designing stormwater management practices (STPs) with water quality considerations is not a new practice, but over time the science of water quality treatment has advanced and local regulations have tightened. Water quality has typically been addressed through extended detention using a dry detention pond. Research has demonstrated that this method is not effective nor is it comparable to other types of treatments.

The North Augusta Stormwater Management Department (SMD) requires treatment of the runoff from the first one-inch of rainfall from a project site. The following equation may be used to determine the Water Quality Volume (WQv):

WQv = (1in)(Rv)(A)/12

Where A = Site Area (acres)

Where Rv = 0.05 + 0.009I

Where I = Site Impervious Cover (%)

This equation uses the runoff coefficient (RV), described in the *Simple Method*. Other simple regressions or methods could be used as a substitute to calculate the runoff volume. Regressions based on local data are preferred.

F.2.1.1 Tools of Analysis – For quantity-based water quality sizing criteria, several simple regressions can be used to calculate the runoff volume. A few methodologies for methods that calculate on-site loads include:

a. The Simple Method is a way of calculating runoff and pollutant loads based on impervious cover, rainfall and event mean concentration (EMC) data for different water quality parameters. This model has been expanded to incorporate subsurface flows as well in the Simplified Urban Nutrient Output Model (SUNOM).
b. SWIMM is a model developed by the EPA for analyzing stormwater quantity and quality associated with runoff from urban areas. Both single-event and continuous simulation can be performed on catchments having storm sewers, or combined sewers and natural drainage, for prediction of flows, stages and pollutant concentrations.
c. SLAMM This model is based on small storm hydrology and pollutant runoff from urban land uses. Pollutant sources are identified and both structural and nonstructural stormwater practices can be accounted for in the model.

Pollutant removal effectiveness of the practices found in this manual will obviously vary widely based on site conditions and practice design. There are many programs available to determine pollutant removal rates for all practices covered here. In addition, vendors of proprietary treatment practices size their product based on specific site conditions. A general overview of pollutant removal rates for some of the more common STPs is presented in Table F-1.

TABLE F-1 STP SELECTION MATRIX PERCENT POLLUTANT REMOVAL

A		B	C	D	E	F
STP Group		**TSS**	**TP**	**TN**	**Metals[1]**	**Bacteria**
1.	**Ponds**	80	51	33	62	70
2	**Wetlands**	76	49	30	42	78[2]
3.	**Filters[3]**	86	59	38	69	37[2]
4.	**Infiltration**	95[2]	70	51	99[2]	N/A
5.	**Open Channels [4]**	81	34[2]	84[2,5]	61	-25[2]

Notes to Table F-1

a. [1]: Average of zinc and copper. Zinc only for infiltration practices.
b. [2]: Based on fewer than five data points.
c. [3]: Excludes vertical sand filters and filter strips.
d. [4]: Highest removal rates for dry swales.
e. [5]: No data available for grass channels.
f. N/A: Data not available.

F.2.2 Stormwater Ponds

Stormwater ponds are practices that have a combination of a permanent pool, extended detention or shallow marsh equivalent to the entire WQv. Design variants include:

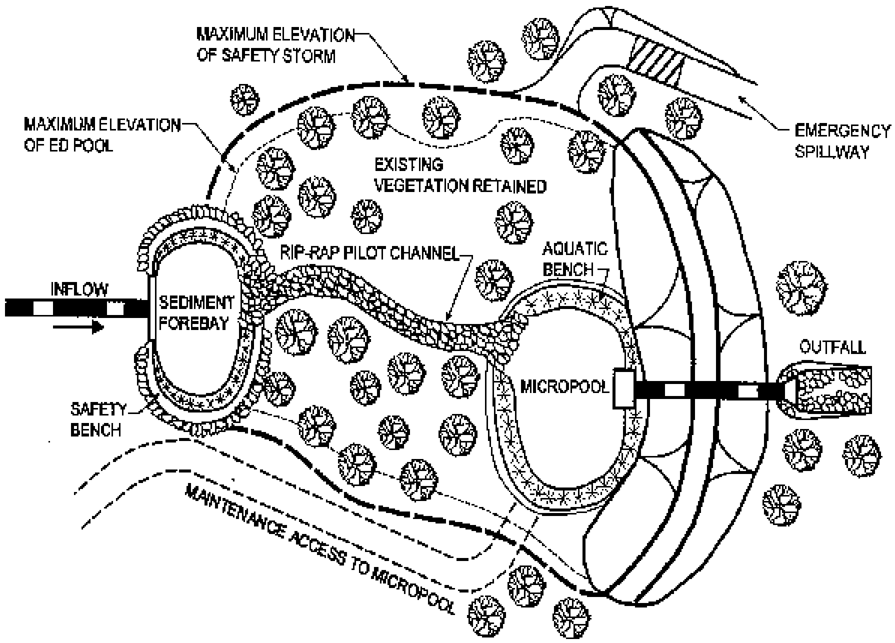
a. Micropool Extended Detention Pond (Figure F-1)
b. Wet Pond (Figure F-2)
c. Wet Extended Detention Pond (Figure F-3)
d. Multiple Pond System (Figure F-4)
e. Pocket" Pond (Figure F-5)

Dry extended detention ponds that have no permanent pool are not considered an acceptable option for meeting WQv due to poor pollutant removal and chronic maintenance problems.

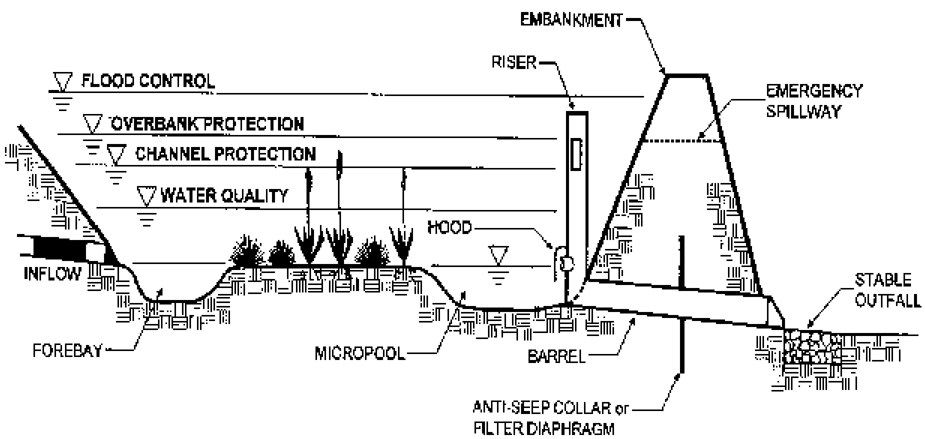
The term "pocket" refers to a pond or wetland that has such a small contributing drainage area that little or no baseflow is available to sustain water elevations during dry weather. Instead, water elevations are heavily influenced and, in some cases, maintained by a locally high water table.

Stormwater ponds can also be used to provide Channel Protection volume as well as overbank and extreme flood attenuation.

FIGURE F-1 MICROPOOL EXTENDED DETENTION POND

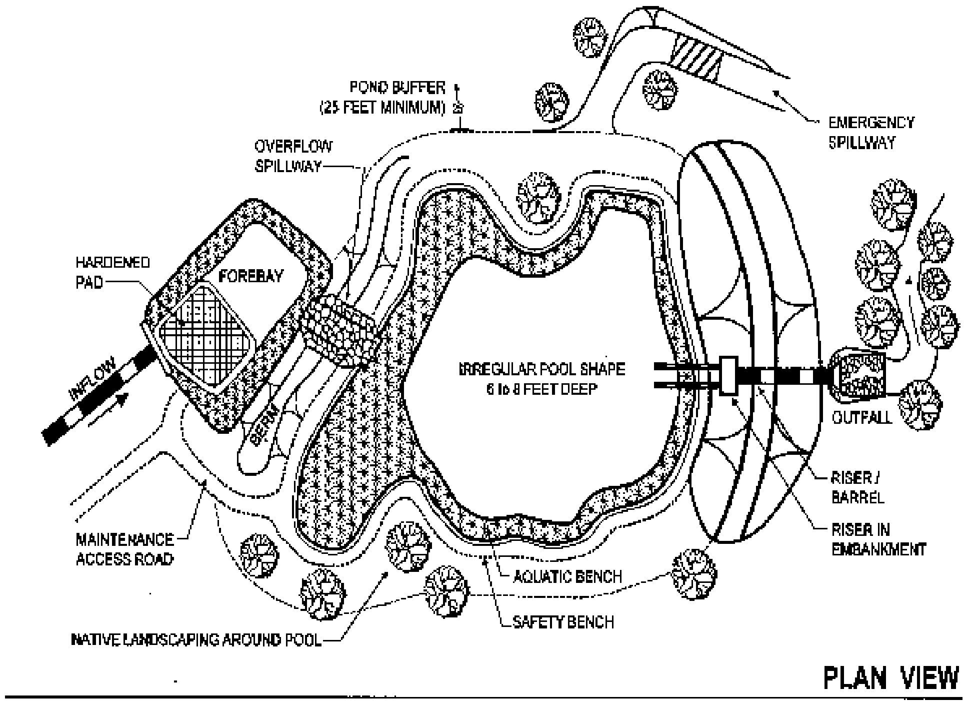


PLAN VIEW



PROFILE

FIGURE F-2 WET POND



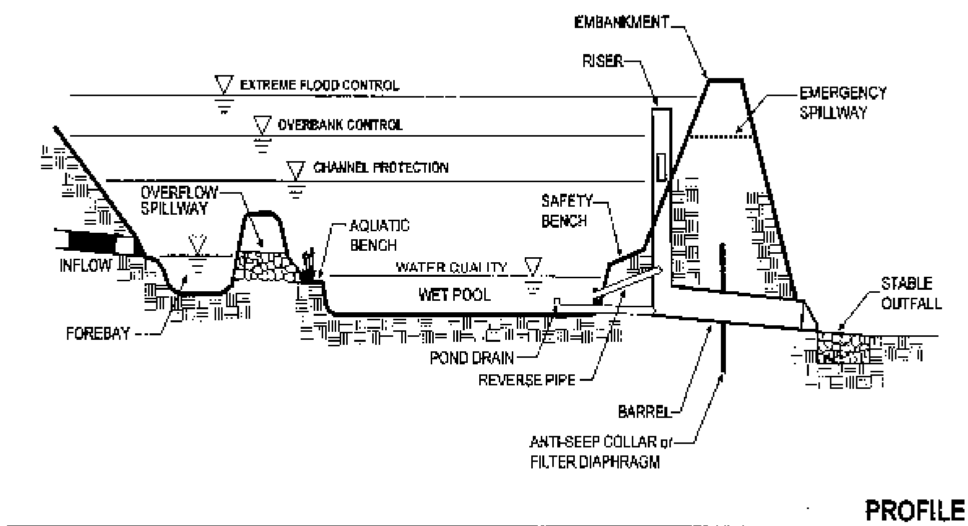


FIGURE F-3 WET EXTENDED DETENTION POND

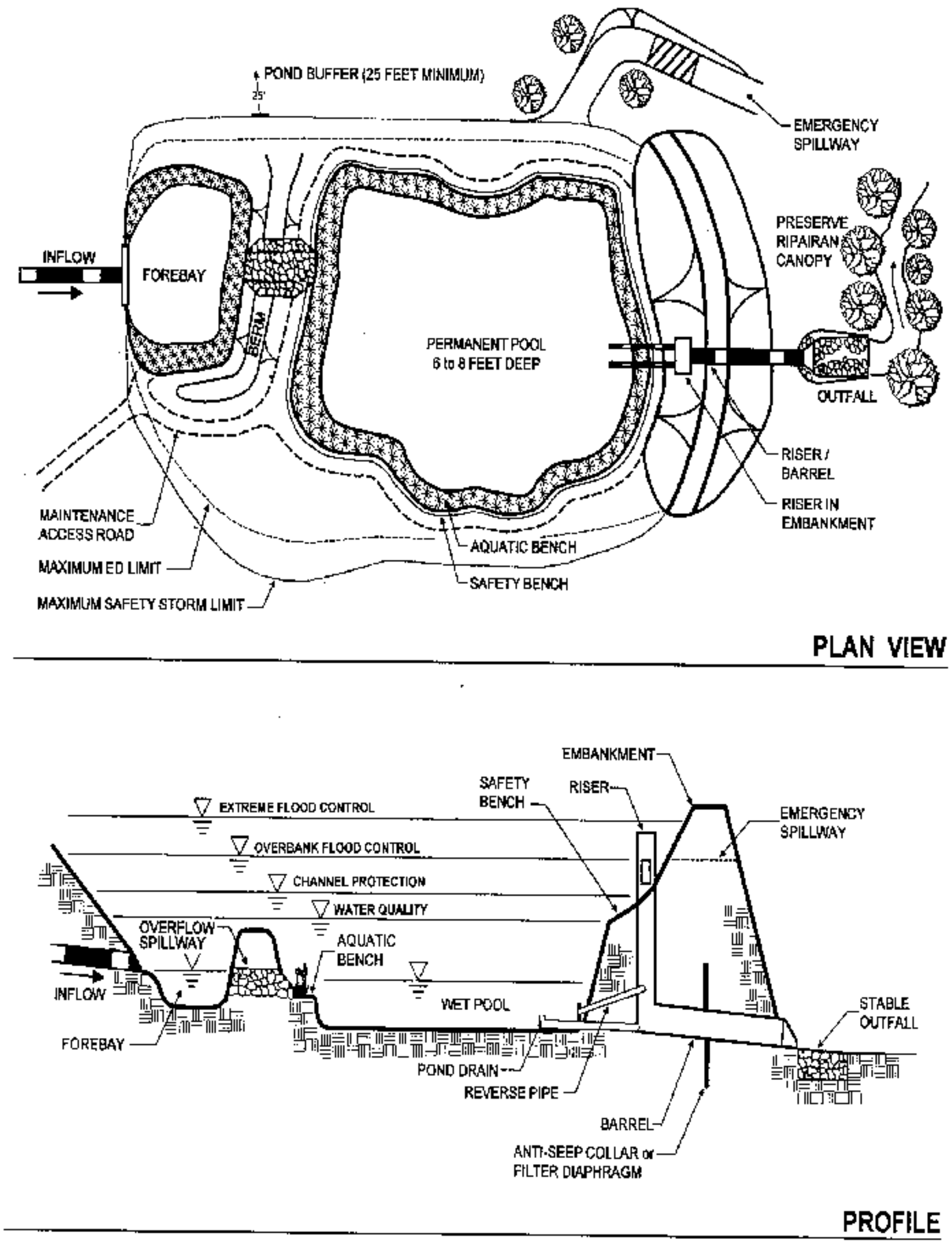
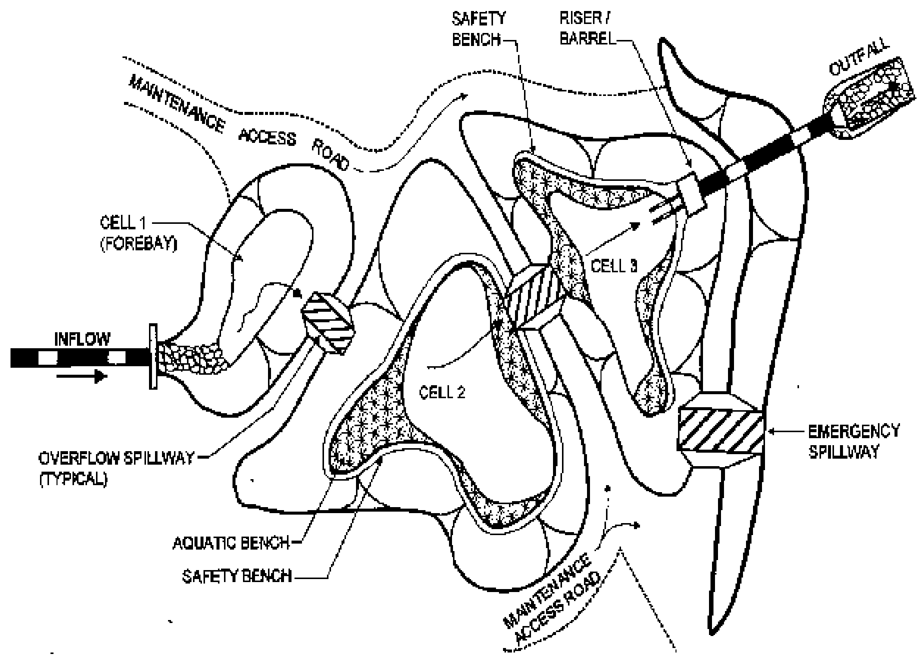
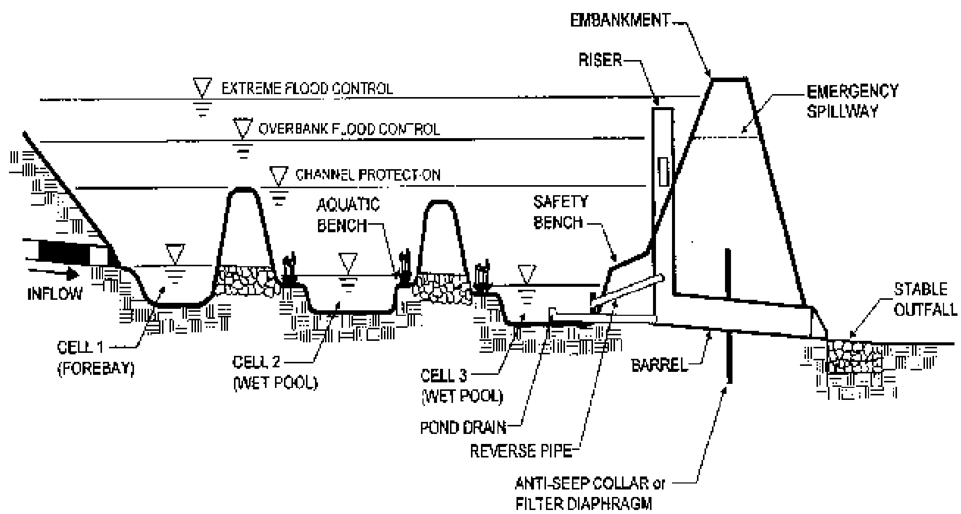


FIGURE F-4 MULTIPLE POND SYSTEM

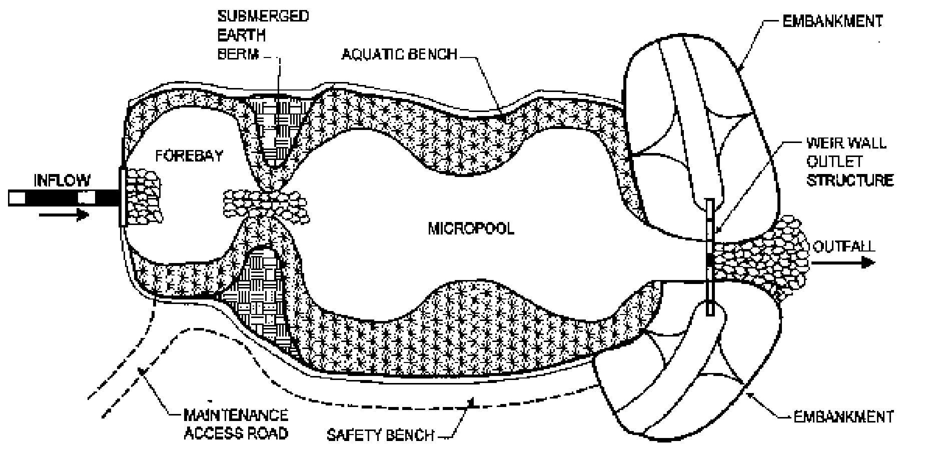


PLAN VIEW



PROFILE

FIGURE F-5 POCKET POND



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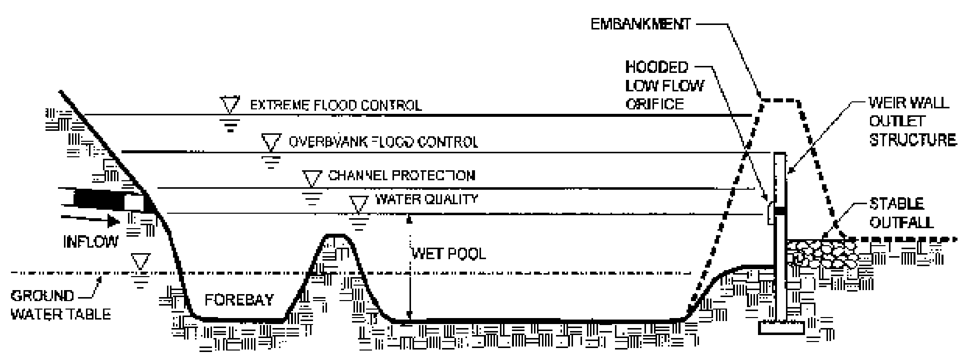


PROFILE

F.2.2.1 Pond Feasibility – Stormwater ponds should have a minimum contributing drainage area of ten acres or more unless groundwater is confirmed as the primary water source (i.e., pocket pond). This drainage area requirement ensures that the permanent pond can be maintained by the runoff from the contributing drainage. A water balance analysis may replace this requirement. In addition, the specific drainage area requirements will vary based on regional rainfall and temperature.

Stormwater ponds should not be located within jurisdictional waters, including wetlands.

F.2.2.2 Pond Conveyance – Conveyance should be provided which does not cause erosion. When reinforced concrete pipe is used for the principal spillway to increase its longevity, "O-ring" gaskets (ASTM C361) should be used to create watertight joints.

F.2.2.3 Inlet Protection – A forebay should be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. Inlet areas should be protected to reduce erosion. Inlet pipes to the pond can be partially submerged.

A sediment forebay is important for maintenance and longevity of a stormwater treatment pond. Each pond should have a sediment forebay or equivalent upstream pretreatment. The forebay should consist of a separate cell, formed by an acceptable barrier. The forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage, and should be 4 to 6 feet deep. The forebay storage volume can count toward the total WQv requirement. Exit velocities from the forebay should be non-erosive. Direct maintenance access for appropriate equipment should be provided to the forebay. A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened to make sediment removal easier.

F.2.2.4 Adequate Outfall Protection – Outfalls should be constructed such that they do not increase erosion or have undue influence on the downstream geomorphology of the stream. Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet. The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of large rip-rap placed over filter cloth. A stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities.

If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. Excessive use of rip-rap should be avoided to reduce stream warming.

F.2.2.5 Pond Treatment Criteria – Minimum Water Quality Volume (WQv)
Provide water quality treatment storage to capture the computed WQv from the contributing drainage area through any combination of permanent pool, extended detention (WQv-ED) or marsh. The following design considerations must be made:

a. If ED is provided in a pond, storage for Cp_v-ED and WQv-ED shall be computed and routed separately (i.e., the WQv cannot be met simply by providing Cpv storage for the one year storm). (need definition of Cp)
b. In the Wet Extended Detention Pond Design, at least 50% of the (WQv) should be stored in the permanent pool.
c. The minimum length to width ratio for the pond is 1.5:1 (i.e., length relative to width). Long flow paths and irregular shapes are recommended.
d. The perimeter of all deep pool areas (four feet or greater in depth) should be surrounded by two benches:
    1. A safety bench that extends 15 feet outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench shall be 6%.

2. An aquatic bench that extends up to 15 feet inward from the normal shoreline and has a maximum depth of eighteen inches below the normal pool water surface elevation.

F.2.2.6 Landscaping Plan – Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED wetlands) or within shallow areas of the pool itself. The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil. Existing trees should be preserved in the buffer area during construction. Planting guidance is provided in Appendix C, Approved Plants.

F.2.2.7 Maintenance Measures – Establishment of a maintenance plan is an important aspect of STP guidance. On going maintenance is essential to ensure that STPs operate properly and function as designed.

a. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.
b. The principal spillway should be equipped with a removable trash rack.
c. Sediment removal in the forebay should occur every 5 to 7 years or after 50% of total forebay capacity has been lost.
d. A maintenance right of way or easement should extend to a pond from a public or private road. Maintenance access shall be at least 12 feet wide; have a maximum slope of no more than 15%; and should be appropriately stabilized to withstand maintenance equipment and vehicles.
e. The maintenance access should extend to the forebay, safety bench, riser, and outlet.

F.2.2.8 Non-clogging Low Flow Orifice – A non-clogging low flow orifice must be provided. The low flow orifice shall have a minimum diameter of 6 inches, and shall be adequately protected from clogging by an acceptable external trash rack. The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation. An alternative method is to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round corrugated metal pipe (CMP) that extends at least 12 inches below the normal pool.

F.2.2.9 Riser in Embankment – The riser shall be located within the embankment for maintenance access, safety and aesthetics. Access to the riser is to be provided to the SMD.

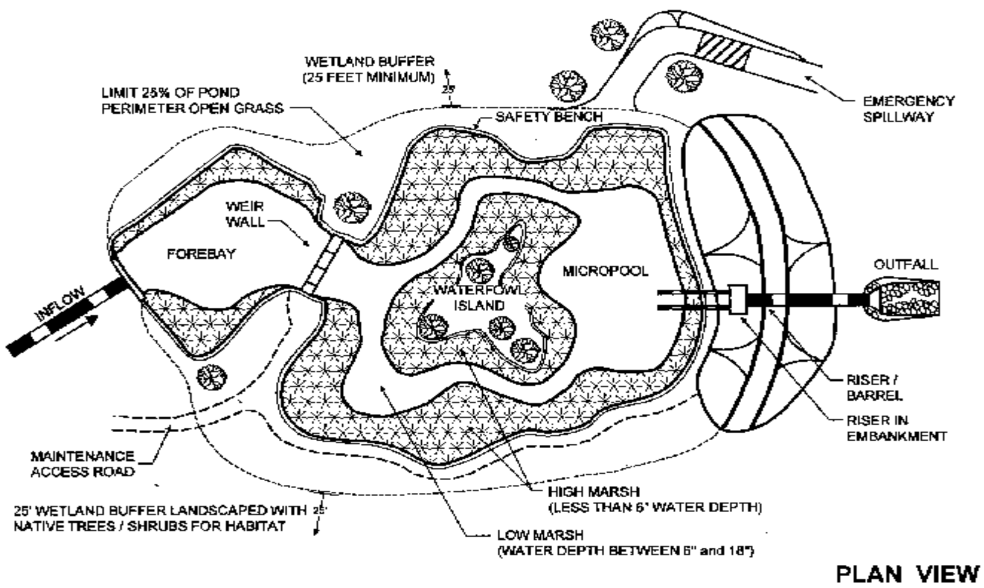
F.2.2.10 Pond Drain – Each pond shall have a drain pipe that can completely or partially drain the pond. The drain pipe shall have an elbow within the pond to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.

F.2.3 Constructed Wetlands

Stormwater wetlands are practices that create shallow marsh areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQv. Design variants include:

a. Shallow Wetland (Figure F-6)
b. ED Shallow Wetland (Figure F-7)
c. Pond/Wetland System (Figure F-8)
d. "Pocket" Wetland (Figure F-9)

FIGURE F-6 SHALLOW WETLAND



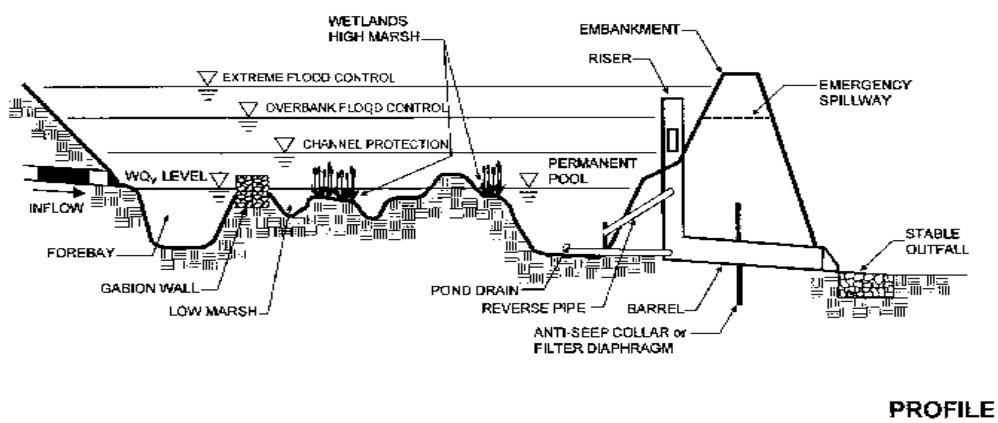
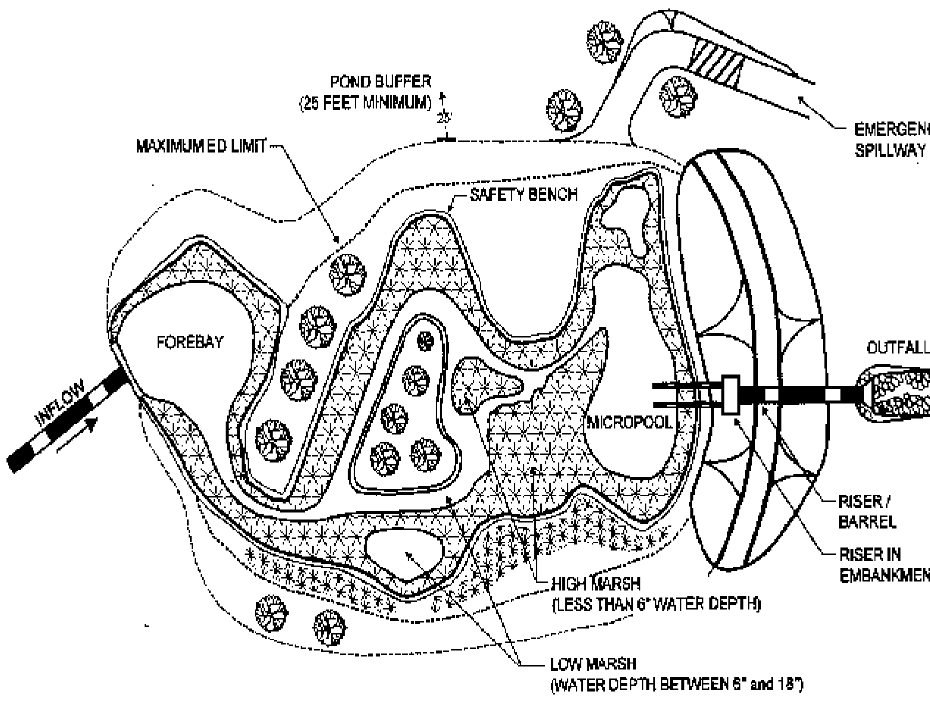
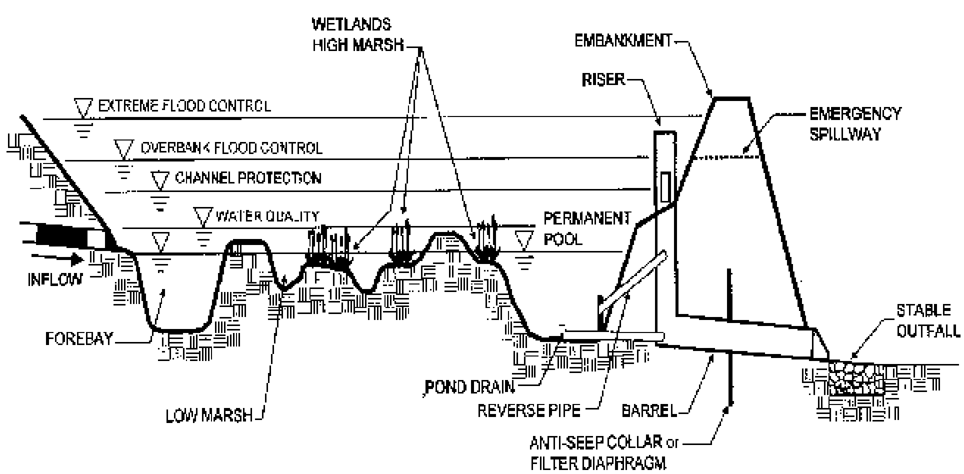


FIGURE F-7 EXTENDED DETENTION (ED) SHALLOW WETLAND

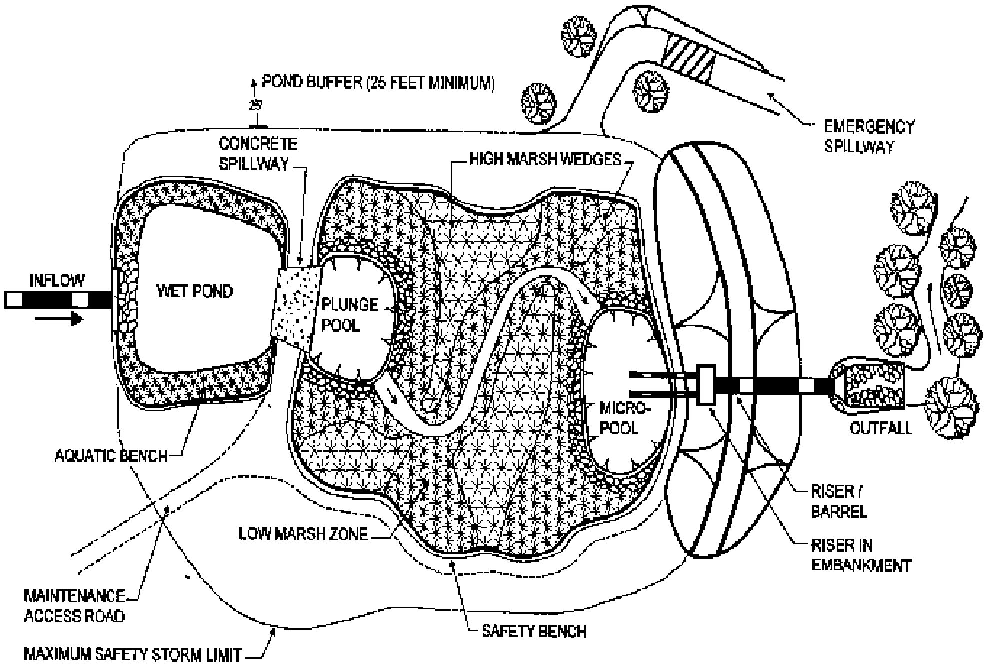


PLAN VIEW

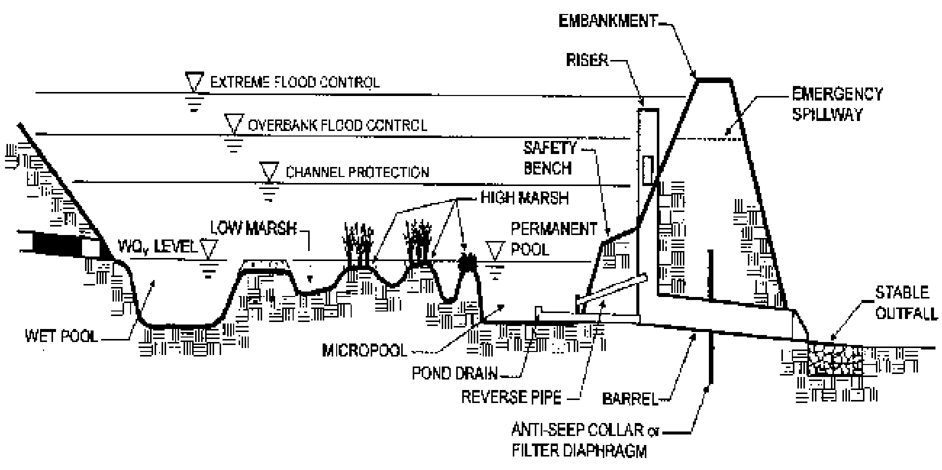


PROFILE

FIGURE F-8 POND / WETLAND SYSTEM

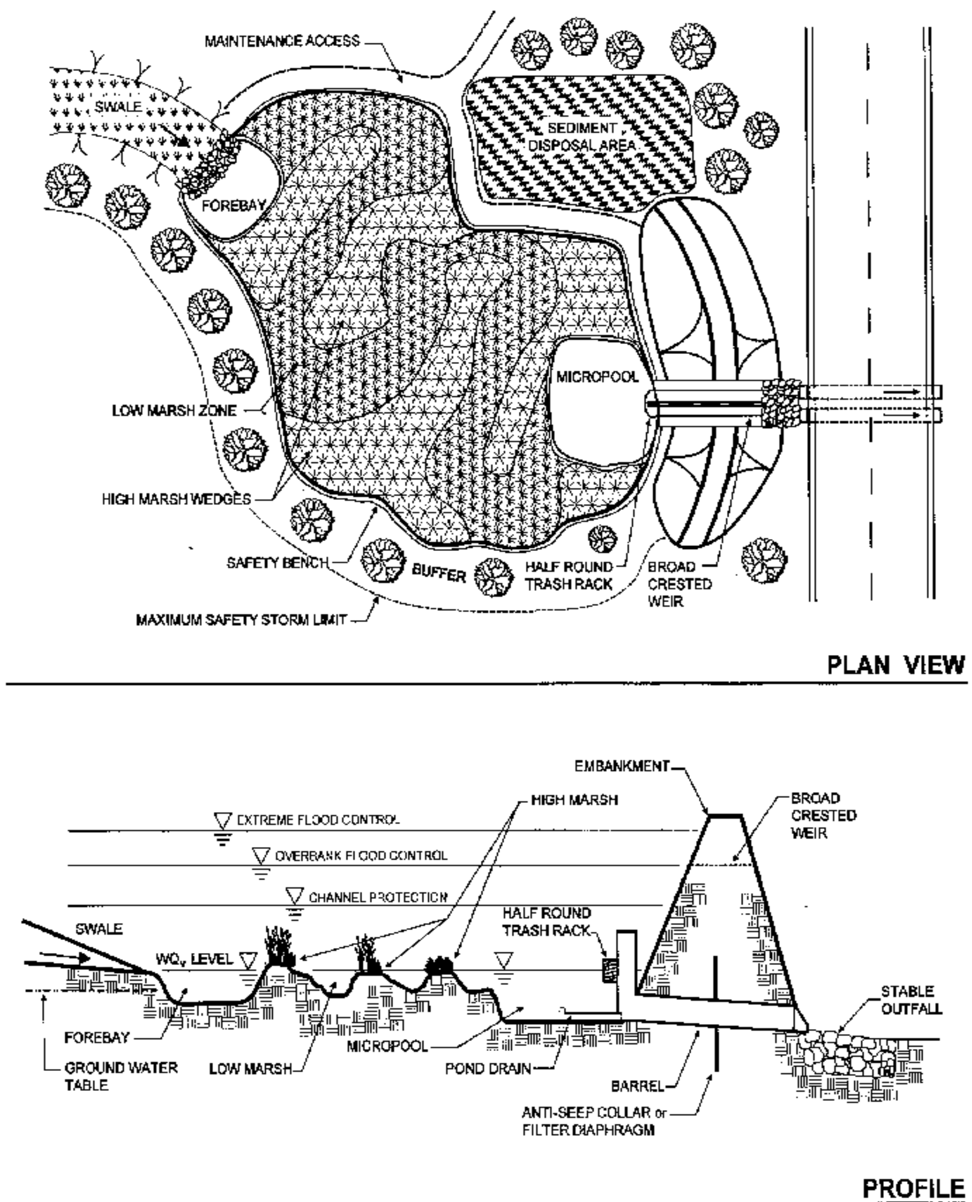


PLAN VIEW



PROFILE

FIGURE F-9 POCKET WETLAND



F.2.3.1 Wetland Feasibility – A water balance should be performed to demonstrate that a stormwater wetland can withstand a significant drought at summer evaporation rates without completely drawing down.

Stormwater wetlands should not be located within existing jurisdictional wetlands. In some isolated cases, a permit may be granted to convert an existing degraded wetland in the context of local watershed restoration efforts.

F.2.3.2 Wetland Conveyance – Flowpaths from the inflow points to the outflow points of stormwater wetlands shall be maximized. A minimum flowpath of 2:1 (length to relative width) should be provided across the stormwater wetland. This path may be achieved by constructing internal berms (e.g., high marsh wedges or rock filter cells).

F.2.3.3 Wetland Pretreatment Criteria – Sediment regulation is critical to sustain stormwater wetlands. Consequently, a forebay should be located at the inlet, and a micropool should be located at the outlet*.* For forebay design criteria, consult the previous section on ponds. A micropool three to six feet deep should be used to protect the low flow pipe from clogging and prevent sediment re-suspension.

F.2.3.4 Wetland Treatment –

a. At least 25% of the WQv should be in deepwater zones with a depth greater than four feet*.* The forebay and micropool may meet this criteria. In addition, the deepwater zones serve to keep mosquito populations in check by providing habitat for fish and other pond life that prey on mosquito larvae.
b. A minimum of 35% of the total surface area can have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches*.*
c. If extended detention is utilized in a stormwater wetland, the WQv ED volume should not comprise more than 50% of the total WQV, and its maximum water surface elevation should not extend more than three feet above the permanent pool. Available data suggest that pond designs that rely entirely or primarily on detention have significantly compromised pollutant removal.

F.2.3.5 Wetland Landscaping – A landscaping plan should be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, a selection of corresponding plant species, a planting plan, a sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material*.* A plant list is provided in Appendix C, Approved Plants.

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from local aquatic plant nurseries. The following guidance is suggested when transplants are used to establish a wetland:

a. To add diversity to the wetland, five to seven species of emergent wetland plants should be planted.
b. No more than half the wetland surface area needs to be planted. If the appropriate planting depths are achieved, the entire wetland should be colonized within three years.
c. Individual plants should be planted 18 inches on center in clumps.
d. Because most stormwater wetlands are excavated to deep subsoils, they often lack the nutrients and organic matter needed to support vigorous growth of wetland plants. At these sites, three to six inches of topsoil or wetland mulch should be added to all depth zones in the wetland from one foot below the normal pool to six inches above.
e. In some cases, the use of "volunteer wetlands," allowing cattails and phragmites to colonize may be appropriate. Typically it will be difficult to maintain diversity in this case, and volunteer wetlands may be a low cost alternative.

F.2.3.6 Wetland Maintenance Criteria – If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required***.*** Stormwater wetlands that are separated from jurisdictional wetlands and regularly maintained are typically not regulated under State and Federal laws. Occasional removal of invasive species may be necessary.

F.2.4 Infiltration Practices

Stormwater infiltration practices capture and temporarily store the WQv before allowing it to infiltrate into the soil over a two day period. Design variants include:

a. Infiltration-Trench (Figure F-10)
b. Infiltration-Basin (Figure F-11)
c. Infiltration Planter Box (Figure F-12)

FIGURE F-10 INFILTRATION TRENCH

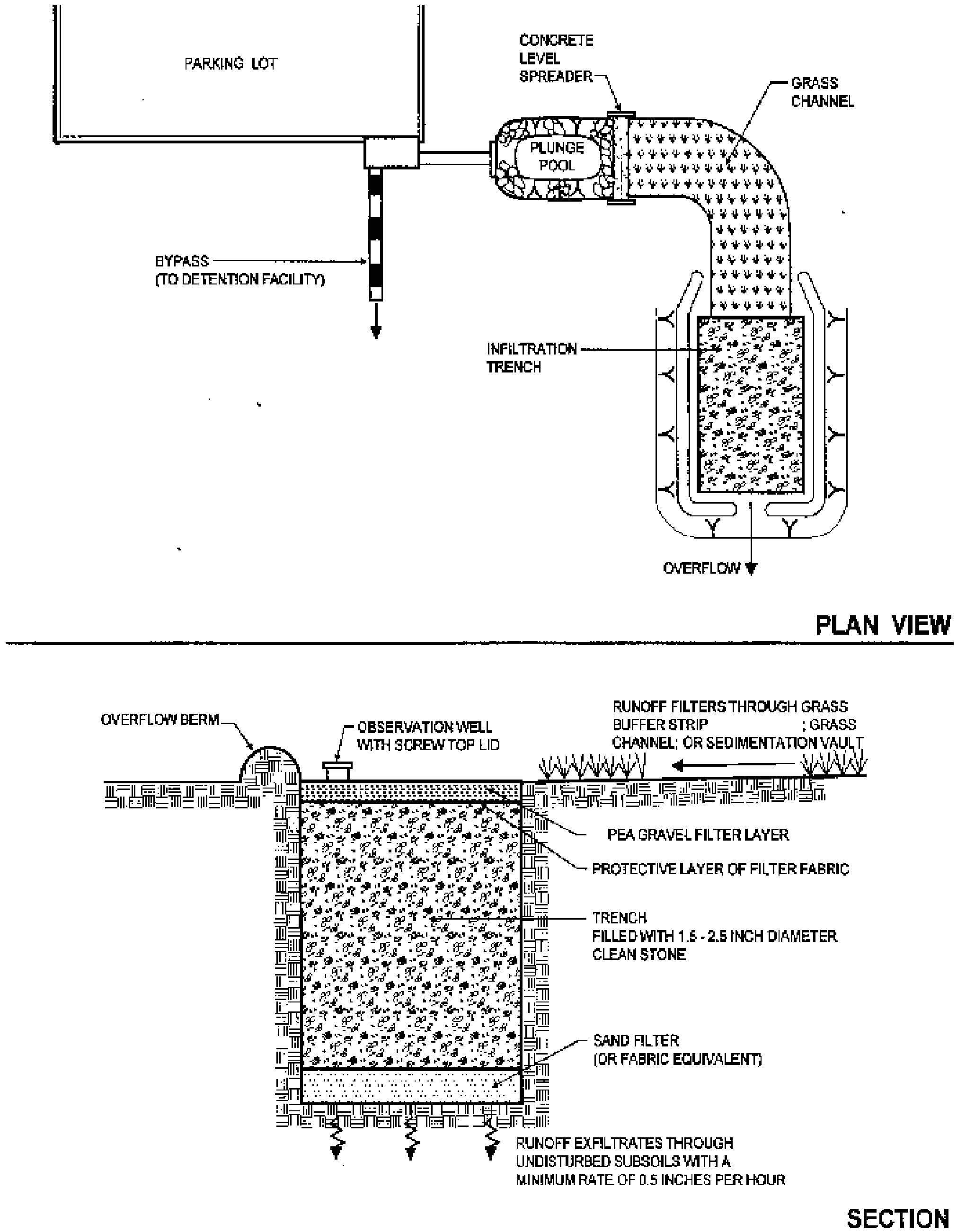
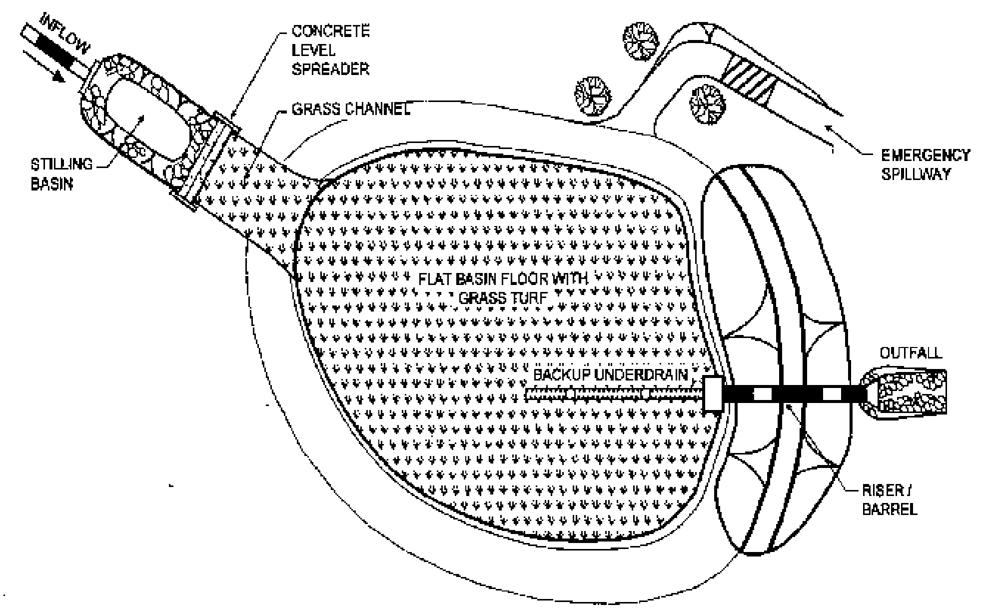


FIGURE F-11 INFILTRATION BASIN



PLAN VIEW

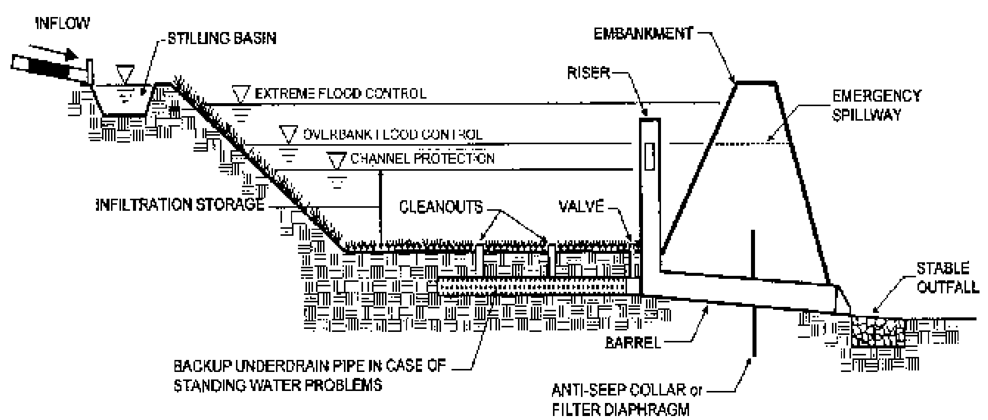


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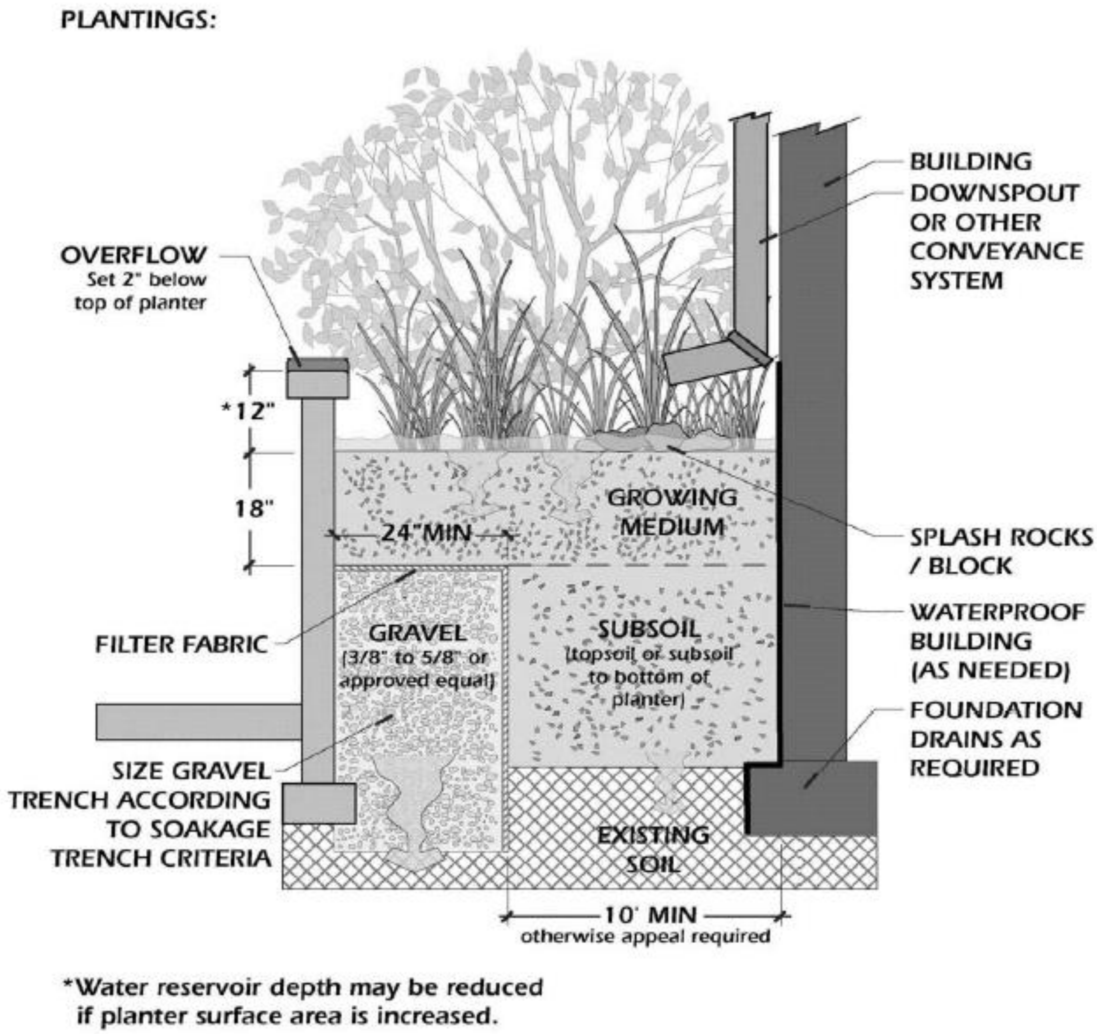
FIGURE F-12 INFILTRATION PLANTER BOX



Flow-Through Treatment Facilities

F.2.4.1 Guidance for Infiltration Planter Boxes

a. Infiltration Planter Boxes are ideal for very small sites and redevelopment projects.
b. The planters shall be designed to allow captured runoff to drain out in 3 to 4 hours after a storm event.
c. The sand/gravel area width, depth and length are to be determined by a qualified professional, or a drywell may be required for complete on-site infiltration.
d. Minimum planter width is 30 inches; there is no minimum length or required shape. The structural elements of the planters shall be stone, concrete, brick, or pressure-treated wood. Treated wood shall not leach out toxic chemicals that can contaminate stormwater.
e. Ideally, planters should be located at least 10ft. from the building.

F.2.4.2 Guidance for Infiltration Trenches and Basins Infiltration Feasibility – To be suitable for an infiltration facility, underlying soils can have an infiltration rate (fc) of 0.52 inches per hour or greater, as initially determined from Natural Resource Conservation Service (NRCS) soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square foot (sf), with a minimum of two borings per facility (taken within the proposed limits of the facility). The following conditions should also be placed on the use of infiltration:

a. Soils shall also have a clay content of less than 20% and a silt/clay content of less than 40%.
b. Infiltration cannot be located on slopes greater than 6% or within fill soils.
c. The bottom of the infiltration facility shall be separated by at least four feet vertically from the seasonally high water table or bedrock layer, as documented by on-site soil testing.
d. Infiltration facilities should be setback 25 feet down-gradient from structures.
e. The maximum contributing area to an individual infiltration practice should generally be less than 2 acres.
f. All infiltration practices must be equipped with and overflow as well as cleanouts.

F.2.4.3 Infiltration Conveyance Criteria –

a. All infiltration systems should be designed to fully de-water the entire WQv within 24 hours after the storm event.
b. If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice must be designed as an off-line practice.
c. Pretreatment shall be provided for storm drain pipes systems discharging directly to infiltration systems. Adequate stormwater outfalls shall be provided for the overflow associated with the ten-year design storm event (non-erosive velocities on the down-slope).

F.2.4.4 Infiltration Pretreatment –

a. A minimum pretreatment volume of at least 25% of the WQv must be provided prior to entry to an infiltration facility, and can be provided in the form of a sedimentation basin, sump pit, grass channel, plunge pool or other measure. Note that extensive pretreatment is required because infiltration systems tend to clog easily.
b. Exit velocities from pretreatment chambers shall be non-erosive during the two year storm.

F.2.4.5 Infiltration Treatment Criteria – Infiltration practices should be designed to exfiltrate the entire WQv through the floor of each practice. Infiltration practices are best used in conjunction with other practices. The longevity of infiltration practices is strongly influenced by the care taken during construction.

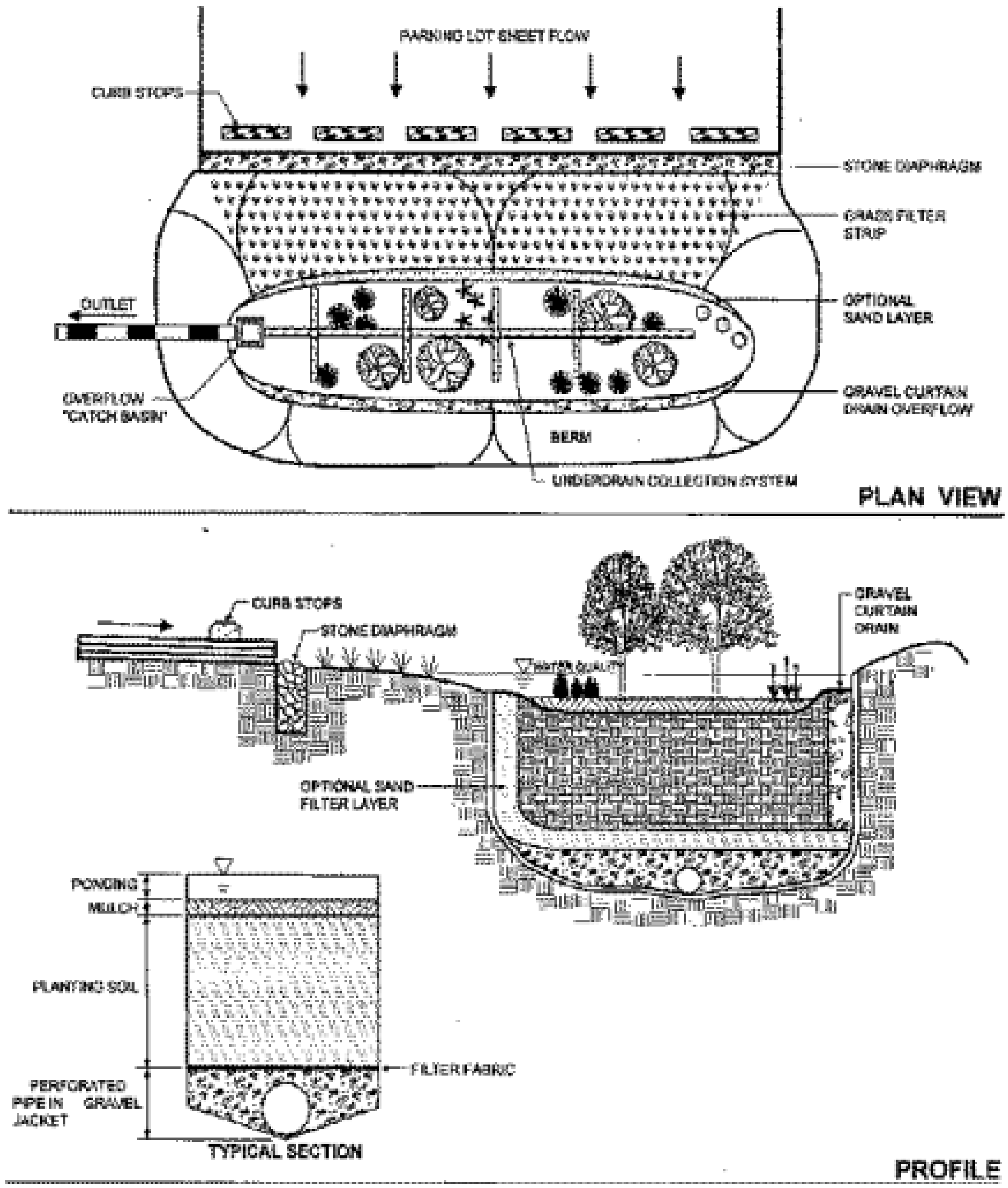
F.2.4.6 Infiltration Landscaping Criteria – A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas before runoff can be accepted into the facility.

F.2.4.7 Infiltration Maintenance Criteria – An observation well should be installed in every infiltration trench, consisting of an anchored six-inch diameter perforated PVC pipe with a lockable cap installed flush with the ground surface.

F.2.5 Bioretention

Stormwater filtering systems capture and temporarily store the WQv and pass it through a filter bed of sand, organic matter, soil or other media. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include: Various Sand Filters which are not encouraged in North Augusta due to high failure rates.

FIGURE F-13 BIORETENTION



F.2.5.1 Filtering Feasibility Criteria – Bioretention is best suited for small watershed areas, stormwater retrofits for redevelopment, and use in conjunction with other practices such as water quantity detention.

F.2.5.2 Filtering Conveyance Criteria –

a. If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice should be designed off-line.
b. An overflow should be provided within the practice to pass a percentage of the WQv to a stabilized water course. In addition, overflow for the ten year storm should be provided to a non-erosive outlet point (i.e., prevent downstream slope erosion).
c. A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the filtering practice.
d. Bioretention filters should be equipped with a minimum 4" perforated pipe underdrain (6" is preferred) in a gravel layer. A permeable filter fabric should be placed between the gravel layer and the filter media.
e. A sedimentation basin prior to the filter will improve performance.

F.2.5.3 Filtering Treatment Criteria –

a. The entire treatment system (including pretreatment) should temporarily hold at least 75% of the WQv prior to filtration.
b. Most filtering practices cannot provide stormwater detention or downstream channel protection (Q_p and Cp_v) under most site conditions.
c. The filter area for sand and organic filters should be sized based on the principles of Darcy's Law. A coefficient of permeability (k) should be used as follows:

    The required filter bed area is computed using the following equation:

    1. $A_f = (WQv)\ (d_f)\ /\ [\ (k)\ (h_f + d_f)\ (t_f)]$ where
    2. A_f = Surface area of filter bed (ft^2)
    3. d_f = filter bed depth (ft)
    4. k = coefficient of permeability of filter media (ft/day)
    5. (0.5 ft/day for bioretention planting soil)
    6. h_f = average height of water above filter bed (ft)
    7. t_f = design filter bed drain time (days)
    8. (1.67 days is the recommended maximum for sand filters; 2 days for bioretention)

F.2.5.4 Filtering Landscaping Criteria –

a. A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas before runoff can be accepted into the facility.
b. Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas. Planting recommendations for bioretention facilities are as follows:
    1. Native plant species should be specified over non-native species.
    2. Vegetation should be selected based on a specified zone of hydric tolerance.
    3. A selection of trees with an understory of shrubs and herbaceous materials should be provided.
    4. Woody vegetation should not be specified at inflow locations.
    5. Trees should be planted primarily along the perimeter of the facility.

A plant list is included in Appendix C, Approved Plants.

F.2.5.5 Bioretention Maintenance –

a. Silt/sediment shall be removed from the filter bed when the accumulation exceeds one inch.
b. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), the top few inches of

discolored material shall be removed and shall be replaced with fresh material. The removed sediments should be disposed in an acceptable manner (i.e., landfill).

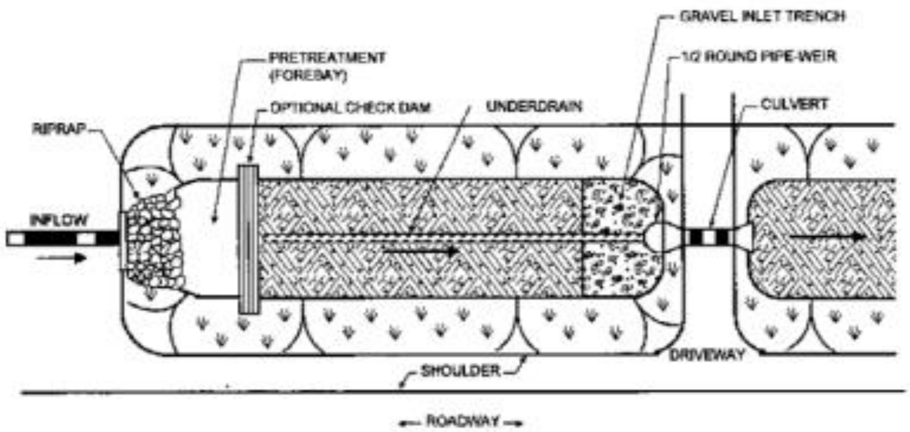
c. A stone drop of at least six inches shall be provided at the inlet of bioretention facilities (F-6) (pea gravel diaphragm).
d. Areas devoid of mulch should be re-mulched on an annual basis.
e. Dead or diseased plant material shall be replaced.
f. Direct maintenance access shall be provided to the pretreatment area and the filter bed.

F.2.6 Open Channel Systems

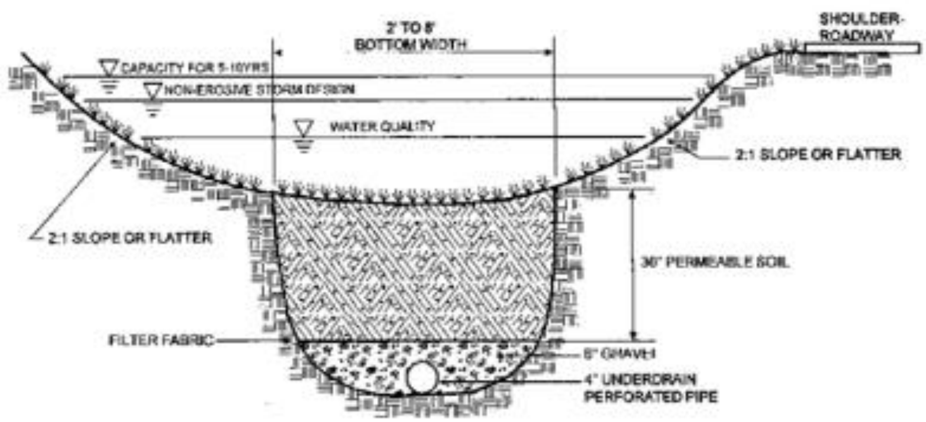
Open channel systems are vegetated open channels that are explicitly designed to capture and treat the full WQv within dry or wet cells formed by checkdams or other means. Design variants include:

a. Dry Swale (Figure F-14)
b. Wet Swale (Figure F-15)
c. Grass Channels (Figure F-16)

FIGURE F-14 DRY SWALE

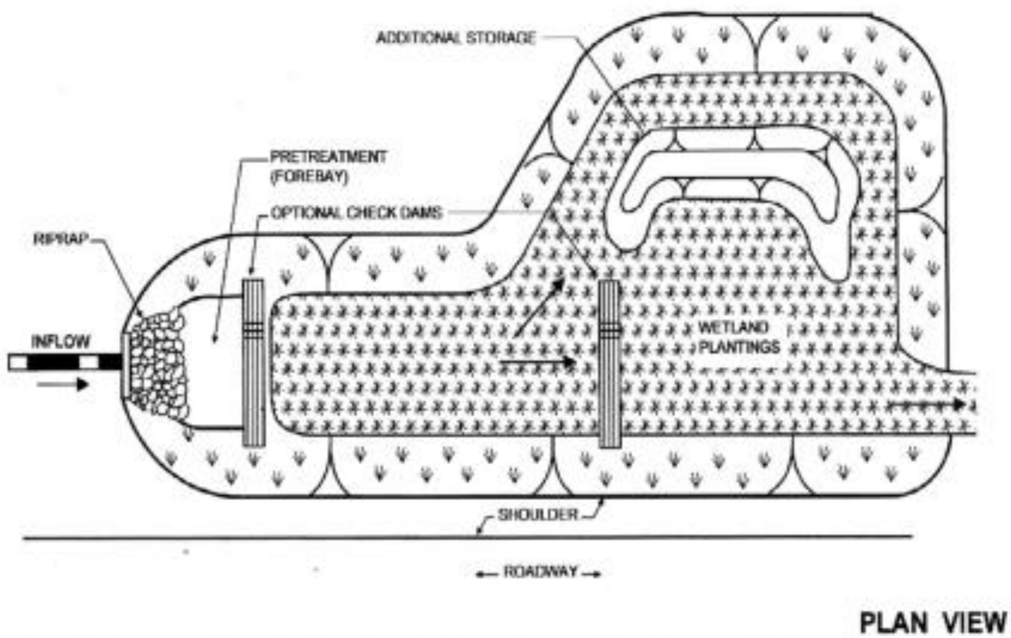


PLAN VIEW



SECTION

FIGURE F-15 WET SWALE



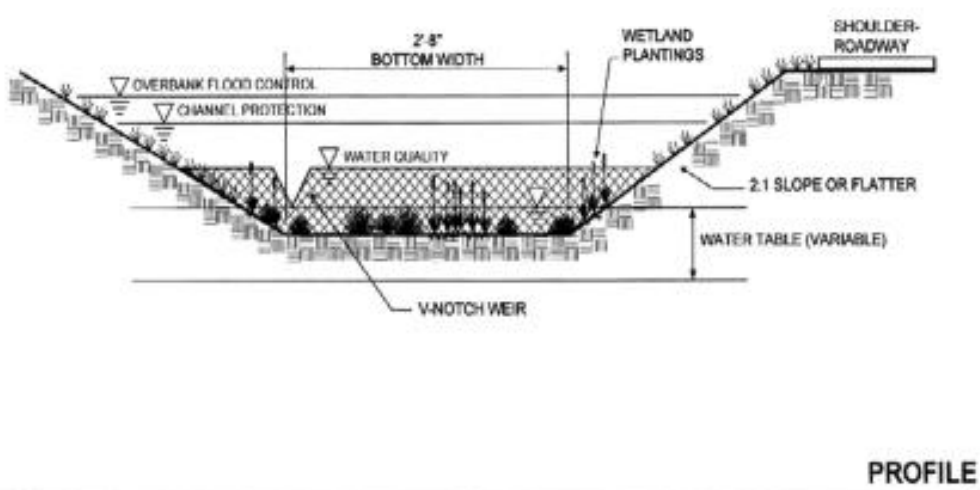
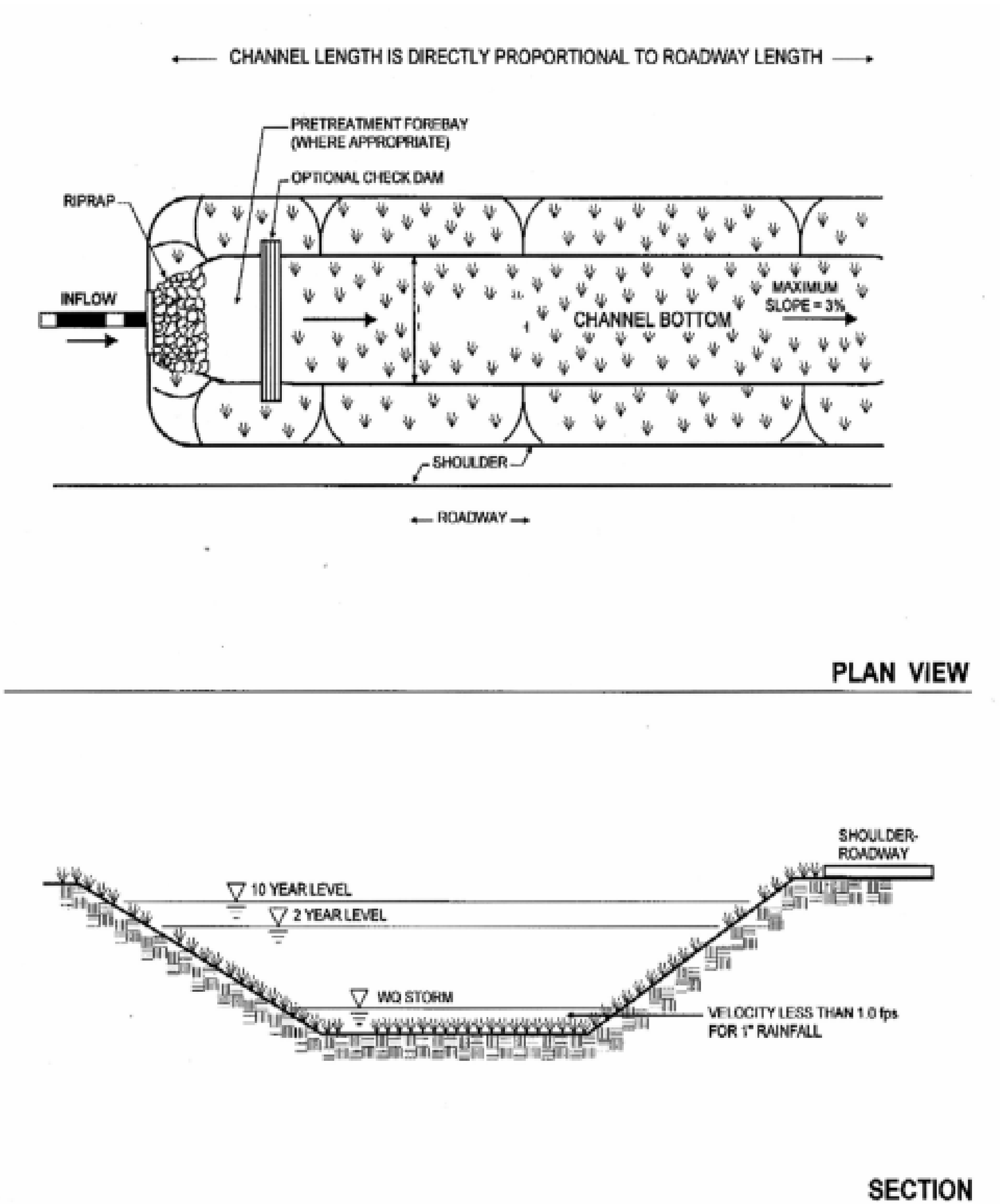


FIGURE F-16 GRASS CHANNEL



F.2.6.1 Open Channel Feasibility Criteria –

a. Open channel systems should have longitudinal slopes less than 4.0% to qualify for WQv treatment.
b. Open channel systems, designed for WQv treatment, are primarily applicable for land uses such as roads, highways, residential development, and pervious areas.
c. Often used in conjunction with "parking lot" or dry detention.

F.2.6.2 Open Channel Conveyance Criteria –

a. The peak velocity for the 2 year storm must be non-erosive.
b. Open channels should be designed to safely convey the ten year storm with a minimum of 6 inches of freeboard.
c. Channels should be designed with moderate side slopes (flatter than 3:1) for most conditions.
d. Side slopes should not be steeper than 2:1.
e. The maximum allowable temporary ponding time within a channel should be less than 48 hours.
f. Open channel systems which directly receive runoff from impervious surfaces may have a 6 inch drop onto a protected shelf (pea gravel diaphragm) to minimize the clogging potential of the inlet.
g. An underdrain system should be provided for the dry swale to ensure a maximum ponding time of 48 hours.

F.2.6.3 Open Channel Pretreatment Criteria –

a. Pretreatment of 0.1 inch of runoff per impervious acre storage should be provided. This storage is usually obtained by providing checkdams at pipe inlets and/or driveway crossings.
b. A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

F.2.6.4 Open Channel Treatment Criteria –

a. Dry and wet swales should be designed to temporarily store the WQv within the facility to be released over a maximum of 48 hour duration.
b. Open channels should have a bottom width no wider than 8 feet to avoid potential gullying and channel braiding.
c. Dry and wet swales should maintain a maximum ponding depth of one foot at the "mid-point" of the channel, and a maximum depth of 18" at the end point of the channel (for storage of the WQv).
d. Grass channels should be designed to retain the water quality volume in the practice for a minimum of 10 minutes, with no greater than a 1.0 fps velocity. Note that the grass channel design is the only practice with a "rate-based" design. The designer determines the peak flow rate from the water quality storm event, and then uses Manning's equation to ensure that the velocity required to retain flow can be achieved with the channel's cross section and slope.

F.2.6.5 Open Channel Landscaping Criteria –

a. Wet swales are not recommended for residential developments as they can create potential nuisance or mosquito breeding conditions.
b. Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel.

F.2.6.6 Open Channel Maintenance Criteria – Open channel systems and grass filter strips should be mowed as required during the growing season, to maintain grass heights in the 4 to 6 inches range. Wet swales, employing wetland vegetation, do not require frequent mowing of the channel. Sediment build-up within the bottom of the channel or filter strip should be removed when 25% of the original WQv volume has been exceeded.

F.2.7 Better Site Design

F.2.7.1 Traditional Cul-de-sac Alternatives –

a. **Description –** Cul-de-sac alternatives are designs for end-of-street vehicle turnaround that replace the traditional cul-de-sac and reduce the amount of impervious cover created in a residential neighborhood. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a stormwater perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of stormwater runoff. For this reason, reducing the impervious area of cul-de-sacs through the use of islands or eliminating them altogether can reduce the amount of impervious cover created at a site.
b. There are two alternatives to the traditional 40-foot cul-de-sac approved for use in North Augusta, which create less impervious cover. These include loop roads (including the option of narrower one-way loop roads serving four to five homes) or creating pervious islands in the middle of the traditional cul-de-sac.
c. **Applicability –** Cul-de-sac alternatives can be applied in the design of residential, commercial and mixed-use developments. A center island can also be used as an infiltration or bioretention water quality treatment practice.
d. **Maintenance Considerations –** If islands are constructed as part of a turnaround, these areas will need to be maintained. Kept as a natural area, the costs could be minimal. Bioretention areas will also require maintenance.

F.2.7.2 Open Space Design –

a. **Description –** Open space design, also known as conservation development or cluster development, is a better site design technique that concentrates dwelling units in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. The minimum lot sizes, setbacks and frontage distances for the residential zone are relaxed in order to create the open space at the site. Open space designs have many benefits in comparison to the conventional subdivisions that they replace: they can reduce impervious cover, stormwater pollutants, construction costs, grading, and the loss of natural areas. In North Augusta, the Planned Development process is used to pursue this type of development. It should also be noted that the benefits of open space design are amplified when combined with other better site design techniques such as cul-de-sac alternatives and open channels.
b. **Maintenance Considerations –** Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the open space is protected by legally enforceable deed restrictions, conservation easements and maintenance agreements. In most communities, the authority for managing open space falls to a homeowner or community association or a land trust.
c. Annual maintenance tasks for open space managed as natural areas are almost non-existent, and the annual maintenance cost for managing an acre of natural area is less than $75 (CWP, 1998). It may be useful to develop a habitat plan for natural areas that may require periodic management actions.
d. **Effectiveness –** Recent redesign research indicates that open space design can provide impressive pollutant reduction benefits compared to the conventional subdivisions they replace. For example, the Center for Watershed Protection (1998) reported that nutrient export declined by 45% to 60% when two conventional

subdivisions were redesigned as open space subdivisions. Other researchers have reported similar levels of pollutant reductions when conventional subdivisions were replaced by open space subdivisions (Maurer, 1996; DE DNREC, 1997; Dreher, 1994; and SCCCL, 1995). In all cases, the reduction in pollutants was due primarily to the sharp drop in runoff caused by the lower impervious cover associated with open space subdivisions. And indeed, in the redesign studies cited above, impervious cover declined by an average of 34% when open space designs were utilized.

1. Along with reduced imperviousness, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce potential pressure to encroach on resource and buffer areas, as enough open space is usually reserved to accommodate resource protection areas. As less land is cleared during the construction process, the potential for soil erosion is also greatly diminished. Perhaps most importantly, open space design reserves 25% - 50% of the development site in green space that would not otherwise be protected, preserving a greater range of landscapes and habitat "islands" that can support considerable diversity in mammals, songbirds and other wildlife.

e. **Cost Considerations –** Open space developments can be significantly less expensive to build than conventional subdivisions. Most of the cost savings are due to savings in road building and stormwater management conveyance costs. In fact, the use of open space design techniques at a residential development in Davis, California provided an estimated infrastructure construction costs savings of $800 per home (Liptan and Brown, 1996). Other examples demonstrate infrastructure costs savings ranging from 11 to 66%.

1. While open space developments are frequently less expensive to build, developers find that these properties often command higher prices than homes in more conventional developments. Several regional studies estimate that residential properties in open space developments garner premiums that are 5 to 32% higher than conventional subdivisions and moreover, sell or lease at an increased rate. In Massachusetts, cluster developments were found to appreciate 12% faster than conventional subdivisions over a twenty year period (Lacey and Arendt, 1990).
2. In addition to being aesthetically pleasing, the reduced impervious cover and increased tree canopy associated with open space development reduces the size and cost of downstream stormwater treatment facilities.

F.2.7.3 Alternative Pavers –

a. **Description –** Alternative pavers are permeable or semi-permeable surfaces that can replace asphalt and concrete and can be used for overflow parking lots and walkways. From a stormwater perspective, this is important because alternative pavers can replace impervious surfaces, creating less stormwater runoff. The two broad categories of alternative pavers are paving blocks and other surfaces including gravel, cobbles, wood, mulch, brick, and natural stone.

b. **Porous Pavement –** Porous pavement is a more expensive but effective surface used to reduce runoff. These products may be especially applicable to redevelopment areas. Porous pavement is targeted for driveways, walking trails, parking lots, playgrounds, open spaces, and golf cart paths. Porous pavement techniques only work if the design engineer takes into account the proper selection of technique for the location, the design is correct, and the structure is built properly. If any of these considerations are not done correctly, the structure may fail.

Researchers at the University of Georgia have identified nine categories of porous pavements. Below is a brief overview of each.

1. *Decks* are level or elevated wooden structures that can serve as porous pavements. They are beneficial in situations where they can be built around existing environments such as wetlands.
2. *Open celled paving grids* are open spaces with ribbing in between. They can be difficult to walk on and it takes time to grow turf over the grids. They work well in open spaces. They can be used in low-traffic areas such as loading areas and emergency access lanes.
3. *Open-graded aggregate* is the most permeable material and the lowest-cost that you can get. About 30 to 40 percent of the material is void space and its permeability is measured in thousands of inches per hour.
4. *Open-jointed paving blocks* are segmental pavers that can handle high weights and heavy traffic. Paving blocks are cement or plastic grids with gaps between them. Paving blocks make the surface more rigid and gravel or grass planted inside the holes allows for infiltration. Depending on the use and soil types, a gravel layer can be added underneath to prevent settling and allow further infiltration.
5. *Plastic geocells* are plastic cells held together with ribs and filled with aggregate or turf. They can be used for a variety of activities including emergency-access lanes, auxiliary parking areas, trails, pedestrian and wheelchair access ways, golf cart paths.
6. *Porous asphalt* can be used as an overlay on parking lots.
7. *Pervious concrete* is created by mixing water and cement-like materials into a paste that forms a thick coating around aggregate particles. It contains little or no sand and forms a highly permeable surface. It is advocated as a BMP by the EPA. It can be used in waste transfer stations and low traveled parking areas.
8. *Porous turf* is used by itself and with reinforcements. It is used for parking lots and open spaces.
9. *Soft paving materials* such as wood mulch, crushed shell, and other organic material can be used for areas of pedestrian traffic.

c. **Applicability –** Alternative pavers can replace conventional asphalt or concrete in parking lots, driveways, and walkways. At the same time, traffic volume and type can limit application. For this reason, alternative pavers for parking are recommended only for overflow areas. In residential areas, alternative surfaces can be used for walkways, but are not ideal for areas that require handicap accessibility.

d. **Siting and Design Criteria –** Accessibility, climate, soil type, traffic volume and long term performance should be considered along with costs and stormwater quality controls when choosing paving materials. Soil types will affect the infiltration rates and should also be considered when using alternative pavers. Clay soils (D soils) will limit the infiltration on a site. It is important to consider that failure of porous surfaces can occur. These failures can be a result of poor design, inadequate construction techniques, low soil permeability, heavier traffic use than designed for, or resurfacing with a non porous material. If you are considering these techniques for your projects, strict adherence to the design standards and construction methods must be used.

e. The durability and maintenance cost of alternative pavers also limits use to low traffic volume areas. At the same time, alternative pavers can abate stormwater management costs. Used in combination with other better site design techniques, the cumulative effect on stormwater can be dramatic.

f. **Benefits –** The most obvious benefit of utilizing alternative pavers includes reduction or elimination of other stormwater management techniques. Applied in combination with techniques like bioretention, pollutant removal and stormwater management can be further improved.

g. **Limitations –** Alternative pavers are not recommended for high traffic volumes for durability reasons. Access for wheelchairs is limited with alternative pavers. In addition, snow removal is also difficult since plows cannot be used, sand can cause the system to clog, and salt can be a potential pollutant.

h. **Effectiveness –** Alternative pavers provide better water quality effectiveness than conventional asphalt or concrete and the range of effectiveness depends on the type of paver. Table F-6 provides a list of pavers and the range of water quality effectiveness for different types of alternative pavers.

TABLE F-2 WATER QUALITY EFFECTIVENESS OF VARIOUS PAVERS (BASMAA, 1998)

A		B
Material		**Water Quality Effectiveness**
1.	**Conventional Asphalt/ Concrete**	Low
2.	**Brick (in a loose configuration)**	Medium
3.	**Natural Stone**	Medium
4.	**Gravel**	High
5.	**Wood Mulch**	High
6.	**Cobbles**	Medium

i. **Costs**

The range of installation and maintenance costs of various pavers is provided in Table F-7. Depending on the material used, installation costs can be higher or lower for alternative pavers than conventional asphalt or concrete, but maintenance costs are almost always higher.

TABLE F-3 INSTALLATION AND MAINTENANCE COSTS (BASMAA, 1997)

A		B	C
Material		**Installation Cost**	**Maintenance Cost**
1.	**Conventional Asphalt/ Concrete**	Medium	Low
2.	**Brick (in a loose configuration)**	High	Medium
3.	**Natural Stone**	High	Medium
4.	**Gravel**	Low	Medium
5.	**Wood Mulch**	Low	Medium

F.2.8 Proprietary Treatment Practices

Water quality regulatory requirements affecting communities has created a need for new technologies that not only improve water quality from storm sewers and other devices but also remain cost effective. This chapter will give a brief overview of the types of technologies that are available for use in storm treatment processes. There are many other available techniques and technologies available.

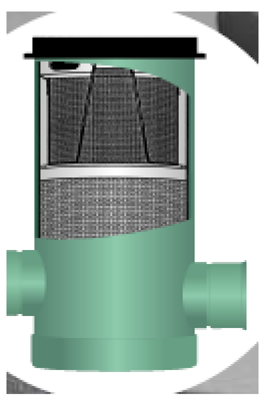
Pollutant removal effectiveness of the practices found in this manual will obviously vary widely based on site conditions and practice design. There are many programs available to determine pollutant removal rates for all practices covered here. In addition, vendors of proprietary treatment practices size their product based on specific site conditions.

A general overview of pollutant removal rates for some of the more common STPs is presented in the following narrative. Most of the information presented regarding pollutant removal rates is represented by the company that promotes the specific product. The City of North Augusta has not verified that the removal rates are accurate and will expect that design engineers that intend to use these products verify the accuracy of the statements to the best of their ability.

F.2.8.1 In-ground Technologies – The following technologies are used within the storm water sewer system to separate and remove pollutants

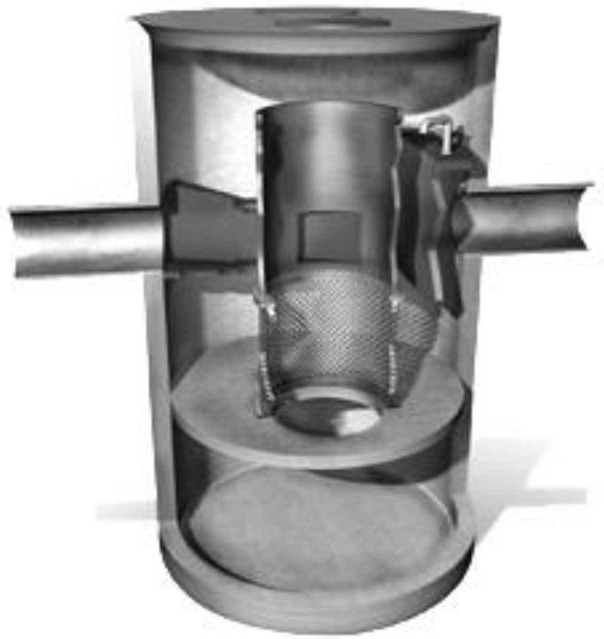
F.2.8.2 Storm Pure™ Catch Basin Inserts – For areas where potential pollutant loads are higher (roadways, parking lots, loading areas), a catch basin insert will provide greater protection to by filtering stormwater. ADS's Nyoplast Division offers Storm-Pure inserts. The Storm-PURE catch basin insert (Figure F-17), a two-stage unit that will fit into new or existing catch basins will remove suspended solids, hydrocarbons and other pollutants. Rates of removal are available from the company.

FIGURE F-17 STORMPURE™ CATCH BASIN INSERT



F.2.8.3 CDS Unit (Continuous deflective separation) **–** This technology that uses a non-blocking, non-mechanical screening process to remove pollutants from storm water flow and combined sewer overflows (Figure F-18). The unit captures fine sands and solids and are capable of removing more than 80% of annual TSS from stormwater. It is said to move 100% of floatables and 100% of particles that are equal to or greater than one-half the size of the screen opening. The system comes in an off-line unit also. The units come with a conventional oil baffle to control oil and grease. They can be fitted with the CDS Media Filtration System cartridges that can target project specific pollutants as well.

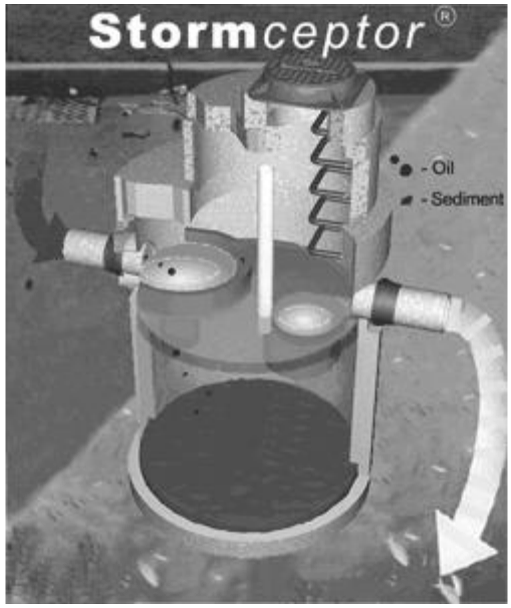
FIGURE F-18 INLINE CDS UNIT



F.2.8.4 Stormceptor® – The stormceptor captures pollutants from stormwater as it passes through the system. The system is based on an “internal” bypass system that eliminates up to 80% of TSS and 98% of free oils and hydrocarbons (Figure F-19). Under normal operating conditions (more than 90% of all storm events), storm water flows into the upper chamber and is diverted by a sloped weir into the lower chamber. Flow is diverted by horizontal outlets around the walls of the lower chamber, settling out coarse and fine sediments to the floor of the chamber. Petroleum products rise and become trapped beneath the fiberglass insert. During infrequent, high flow events (less than 10% of all storm events), storm water flows pass over the diverting weir into the downstream sewer system, preventing scouring of previously trapped pollutants. The high flow by-pass prevents previously collected pollutants from scour and re-suspension.

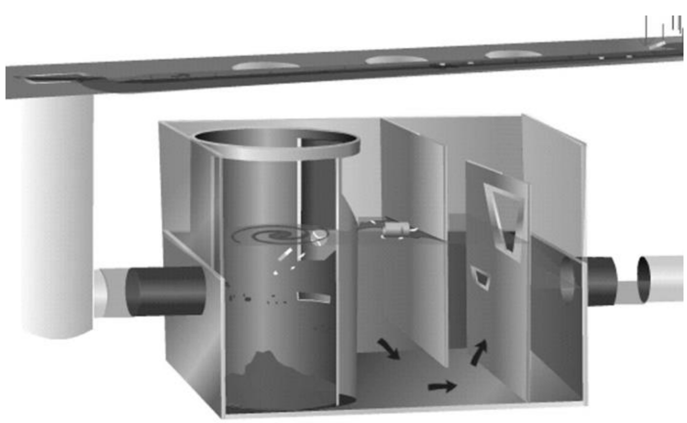
The Inlet Stormceptor® takes the place of a traditional inlet structure in a storm sewer system. The Inlet Stormceptor® is ideal for small drainage areas, such as truck loading bays, electrical transformer stations, and vehicle refueling stations.

FIGURE F-19 STORMCEPTOR® DEVICE



F.2.8.5 Vortechnics™ – The Vortecnics™ system is available for manhole and vault configurations. It is a filter technology system that removes very fine particulates. It uses sedimentation, floatation, and filtration methods (Figure F-20). Vortechnics™ System is a concrete, underground structure comprised of three chambers – an initial grit chamber that concentrates and deposits sediments, an oil chamber and baffle wall that traps floatables, and a flow control chamber. The system removes 80% of total suspended solids.

FIGURE F-20 VORTECHNICS SYSTEM



F.2.8.6 Ecostorm™ – The Ecostorm consists of 2 circular concentric precast structures. An outer structure forms the swirl-chamber/vortex separator, the inner cylinder serves as a floatables collection chamber and outlet chamber (Figure F-21).

Swirl-chamber technology combined with vortex design principles, effectively treat the stormwater by removing and retaining sediments and floatables from site runoff.

FIGURE F-21 ECOSTORM™

F.2.8.7 StormTech™ – StormTech develops control systems for stormwater runoff that maintain the balance between land development and the protection of natural resources. StormTech chambers have been subjected to advanced in-ground testing protocols and high-level industry expert review. They have been evaluated to support HS-20 live loads following current AASHTO procedures for loads, structural capacity and factor of safety when installed per StormTech's Chamber Installation Instructions. StormTech chambers are molded from Polypropylene resin and chemicals typically found in stormwater runoff. StormTech recommends using the Isolator Row Inlet Control System or a treatment train approach. The Isolator Row has been tested for sediment removal efficiency and can be a stand-alone sediment control system. The treatment train approach incorporates a pretreatment device prior to the Isolator Row and an eccentric header for coarse or heavy materials removal.

The Isolator Row is a row of chambers wrapped in filter fabric. Runoff is directed into the Isolator Row via a manhole or basin with a diversion weir. When the Isolator Row reaches capacity, storm water overtops the weir and flows to the other chambers through a header system.

FIGURE F-22 STORMTECH™ SYSTEM

F.2.8.8 Conspan Stormvault™ – The Stormvault™ Mitigation System by CON/SPAN® is a below grade detention and sedimentation vault. Stormwater is discharged with TSS concentration of less than 20 mg/L with a 95% level of confidence, independent of influent concentrations or inflow volume. Detention time promotes sedimentation of particles less than 70 microns.

F.2.8.9 Filterra® – Filterra® relies on a specially engineered high flow rate treatment system to provide exceptional pollutant removal. Monitoring data shows Filterra® can treat over 90% of the total annual volume of rainfall with maximum pollutant removal rates reaching 95% for total suspended solids, 82% total phosphorus, 76% total nitrogen and 91% heavy metals (measured as Cu).

The high pollutant removal efficiency is primarily due the multiple treatment systems inherent in its unique plant / soil / microbe treatment media. Its unique design and use of typical landscape plants also provides many added values such as low maintenance costs, enhanced aesthetics, improved habitat value, and easy / safe inspection.

The system consists of a concrete container, a 3-inch mulch layer, 1.5 to 3.5 feet of a unique soil filter media, an observation / cleanout pipe, an under-drain system and an appropriate type of plant i.e., flowers, grasses, shrub, or tree (see photo in Figure F-23). Stormwater runoff drains directly from impervious surfaces through an inlet structure in the concrete box and flows through the mulch, plant, and soil filter media. Treated water flows out of the system via an under-drain connected to a storm drain pipe or other appropriate outfall. The "at-the-source" treatment strategy is highly adaptable for any urban setting to achieve multiple stormwater management water quality and quantity goals including combined sewer overflow control.

FIGURE F-23 FILTERA SYSTEM

F.2.8.10 Alternative Paver Systems – *Grass Pave/Gravel Pave*

a. Grasspave[2] is a structure which provides incredible load bearing strength while protecting vegetation root systems from deadly compaction. High void spaces within the entire cross-section enable excellent root development, and storage capacity for rainfall from storm events. It is a turf based system that consists of a sandy gravel base course, a *Hydrogro*w polymer fertilizer mixture, the Grasspave ring and grid structure, sharp concrete sand, and grass seed or sod (Figure F-24). Runoff moves through the surfaces allowing suspended sediments to drop out. Table F-8 shows expected storage volumes.

FIGURE F-24 GRASSPAVE[2]

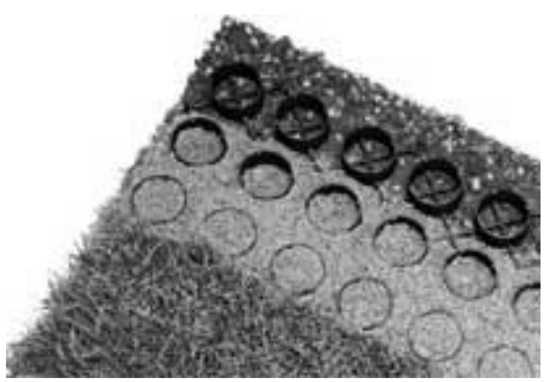


TABLE F-4 EXPECTED STORAGE VOLUMES OF THE GRASS PAVE SYSTEM (SOURCE: INVISIBLE STRUCTURES)

A		B	C	D	E
Base Depth (in)		Rainfall (in/ft²)	Volume (in³/ft²)	Volume (ft³/ft²)	Volume (gal/ft²)
1.	**4**	1.0	144	0.08	0.62
2.	**5**	1.3	180	0.10	0.78
3.	**6**	1.5	216	0.13	0.94
4.	**7**	1.8	252	0.15	1.09
5.	**8**	2.0	288	0.17	1.25
6.	**9**	2.3	324	0.19	1.40
7.	**10**	2.5	360	0.21	1.56
8.	**11**	1.8	396	0.23	1.71
9.	**12**	3.0	432	0.25	1.87
10.	**13**	3.3	468	0.27	2.03
11.	**14**	3.5	504	0.29	2.18
12.	**15**	3.8	540	0.31	2.34
13.	**16**	4.0	576	0.33	2.49

b. Gravelpave² is comprised of a porous geotextile fabric, molded directly to the one inch high integrated ring and grid system (Figure F-25). Gravelpave² sits atop an engineered porous base course, is anchored down with galvanized anchors, and is filled with decorative gravel. It is a structure to provide heavy load bearing support and true containment of gravel to create a porous pavement surface with unlimited traffic volume and/or duration time for parking. When used with a proper porous base course material, Gravelpave² can provide a void space of 35% for storage volume of rainfall during rain events. For example, an 8" deep cross-section would store 2.8" of rain.

FIGURE F-25 GRAVELPAVE² SYSTEM

F.2.9 Water Quality Credits

F.2.9.1 Stream Buffer or Filter Strip Credit – This credit encourages the use of stream buffers and filter strips to treat stormwater runoff at the site level. Specific criteria for the buffer itself will vary between communities.

TABLE F-5 STREAM BUFFER OR FILTER STRIP: SUMMARY

A		B	
1.	**Goals**	Preserve natural buffers. Use green space and buffers to treat stormwater runoff.	
2.	**Stormwater Management Objectives**	Recharge, water quality	Subtract area draining to the buffer from the water quality requirements.
3.		Channel Protection/Flood Control	Treat the area draining to the buffer as "woods in good condition."

F.2.9.1.1 Designers can receive credit for treating stormwater runoff areas adjacent to a filter strip or designated stream buffer using site grading. Credits include:

a. Area draining to the buffer is subtracted from the calculations for water quality and recharge volume.
b. The curve number of areas draining to the buffer preserved in natural vegetation shall receive a curve number adjustment to reflect woods in good condition.

F.2.9.1.2 To receive the credit, the buffer must meet the following criteria:

a. The minimum undisturbed buffer or filter strip width shall be 50 feet.
b. The maximum contributing length to the buffer or filter strip shall be 150 feet for residential developments, and 75 feet for commercial developments.
c. If the overland flow path is greater than 50 feet, a level spreader shall be used to establish sheet flow.
d. The average contributing overland slope shall be less than or equal to 3 percent.
e. The buffer shall be preserved in a conservation easement or similar protective mechanism.

F.2.9.1.3 The credit for water quality volume can be determined based on the required water quality volume, and the fraction of the site draining to buffers, such that $C = (A_B/A)WQv$

a. Where:
b. C = Buffer Credit (ac-ft)
c. A_b = Area Draining to the Buffer (Acres)
d. A = Total Site Area (Acres)
e. WQv = Original Water Quality Volume (ac-ft)

The water quality volumes can then be reduced by the volume of the credit (C). The example in Figure F-26 illustrates how this credit would be applied.

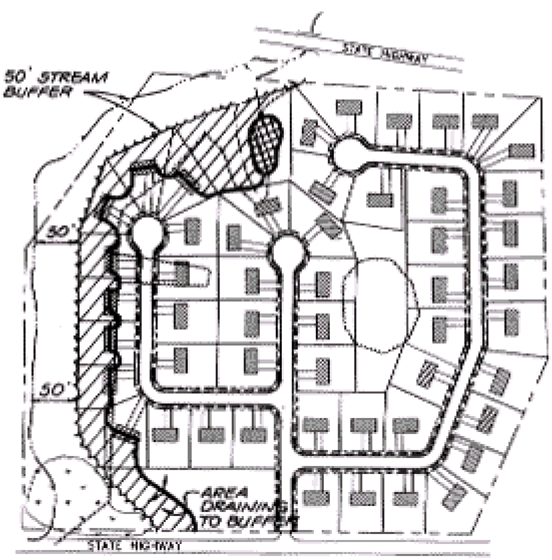
FIGURE F-26 STREAM BUFFER CREDIT EXAMPLE

Stream Buffer Credit Example

Site Data - 51 Single Family
Area = 38.0 ac
Original Impervious Area = 13.8 ac = 36.3%
Post-dev. CN = 78

Original WQ_v = 1.08 ac-ft
Rechage Fraction (S) = 0.22
Original Re_v = 0.24 ac-ft
Original Cp_v = 1.65 ac-ft
Original Qp_v = 2.83 ac-ft

Credit
5.0 ac draining to buffer/filter strip



Computation of Stormwater Credits

$C = (5/38) \bullet (1.08 \text{ ac-ft}) = 0.14 \text{ ac-ft}$

$WQ_v = (1.08 \text{ ac-ft}) - (0.14 \text{ ac-ft}) = 0.94 \text{ ac-ft}$

$Re_v = (0.24 \text{ ac-ft}) - (0.14 \text{ ac-ft}) = 0.10 \text{ ac-ft}$

Cp_v and Q_p : CN is slightly reduced.

F.2.9.2 Conservation of Natural Areas Credit – This credit rewards protection of natural vegetation or critical resource areas on site.

TABLE F-6 CONSERVATION OF NATURAL AREAS: SUMMARY

A		B	C
1.	**Goals**	Encourage the preservation of natural areas and critical resources on site.	
2.	**Stormwater Management Objectives**	Water Quality	Credit area in natural conservation areas toward water quality requirements.
3.		Recharge	Express as a fraction of the water quality credit.
4.		Channel Protection, Flood Control	Use "woods in good condition" to characterize conservation areas.

F.2.9.2.1 A stormwater credit is given when natural areas are conserved at development sites, thereby retaining their pre development hydrologic and water quality characteristics. Examples of natural area conservation areas include:

a. forest retention areas
b. wetlands and associated buffers
c. Areas known to contain threatened or endangered species
d. other lands in protective easement (floodplains, open space, steep slopes)

F.2.9.2.2 Under the credit, a designer can subtract conservation areas from total site area when computing the water quality volume. As an additional incentive, the post development curve number (CN) used to compute water quantity parameters shall be forest in good condition. The credit for the water quality volume can be based on the site area in natural conservation, such that $C_{WQ} = (A_{NA}/A)(WQv)$ Where:

a. C_{WQ} = Natural Area Credit for Water Quality (ac-ft)
b. A_{NA} = Natural Conservation Area (acres)
c. A = Total Site Area (acres)
d. WQv = Original Water Quality Volume (ac-ft)

F.2.9.2.3 **Impervious Area Disconnection –** This credit is applied to credit disconnection of impervious surfaces by encouraging drainage to overland treatment such as swales or filter strips.

TABLE F-7 IMPERVIOUS AREA DISCONNECTION: SUMMARY

	A	B	C
1.	**Goals**	Encourage the use of overland flow or infiltration areas to treat rooftop runoff.	
2.	**Stormwater Management Objectives**	Water Quality/ Recharge	Subtract the total disconnected area from the site's impervious cover.
3.		Channel Protection, Flood Control	Adjust disconnected impervious area to reflect woods in good condition.

In the impervious area disconnection credit, disconnected areas are subtracted from the total site impervious cover, and assigned a curve number for woods in good condition. In order to receive the credit, disconnections must meet the following criteria:

a. The credit is not applicable for residential construction.
b. The maximum contributing impervious flow path length shall be 75 feet.
c. The disconnection must drain continuously through a vegetated channel, swale, or filter strip to the property line or STP.
d. The length of the "disconnection" must be equal to or greater than the contributing length.
e. The entire vegetative "disconnection" shall be on a slope less than or equal to 3.0%.
f. The surface imperviousness area to any one discharge location cannot exceed 1,000 ft^2.
g. Disconnections discharging over relatively permeable soils (HSGs A and B) do not require geotechnical testing.

The water quality credit can be calculated with the following equation:

$C = (A_D/A_I)WQv$

Where:

a. C = Impervious area disconnection credit (ac-ft)
b. A_D = Disconnected Impervious Area (acres)
c. A = Total site area (acres)
d. A_I = Site Impervious Area (acres)
e. WQv = Original Water Quality Volume.

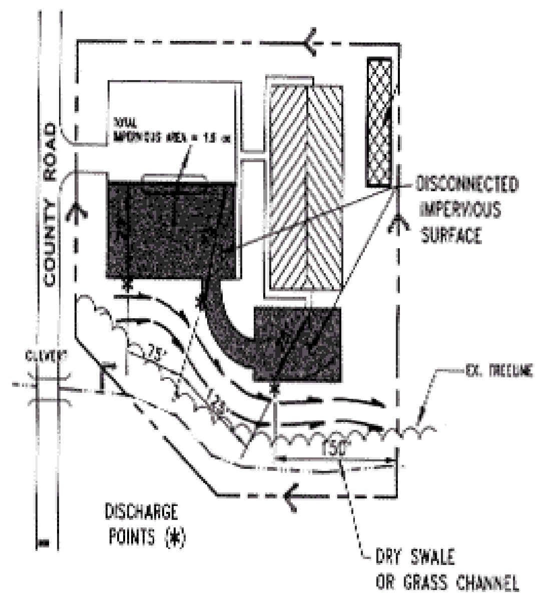
Water quality volumes are then reduced by the credit (C). Quantity credit is achieved by assigning disconnected rooftops a curve number equal to forest in good condition. The example in Figure F-27 illustrates how this credit would be applied.

FIGURE F-27 NON ROOFTOP DISCONNECTION CREDIT EXAMPLE

Non-Rooftop Disconnection Credit Example

Site Data - Community Center
Area = 3.0 ac
Original Impervious Area = 1.9 ac. = 63.3%
Post-dev. CN = 83
Original WQ_v = 6,752 ft^3
Recharge Fraction (S) = 0.25
Original Re_v = 1,688 ft^3
Original Cp_v = N/A
Original Qp_v = 10,630 ft^3

0.8 ac of surface imperviousness disconnected



Computation of Stormwater Credits

$C = (0.8/1.9) \bullet 6{,}752\ ft^3 = 2{,}843\ ft^3$

$WQ_v = 6{,}752\ ft^3 - 2{,}843\ ft^3 = 3{,}909\ ft^3$

Since the C value is greater than the original recharge volume, the recharge requirement is met by this credit.

Cp_v and Q_p: Post-dev CN reduced from 83 to 73

F.2.10 References

Anderson, L.M. and H.K. Cornell. "Residential Property Values Improved by Landscaping With Trees." *Southern Journal of Applied Forestry* pp 162-6.

Arendt, Randall. 1994. *Rural by Design*. American Planning Association. Planners Book Service. Chicago, IL.

Arendt, Randall. 1996. *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks.* American Planning Association Planners Book Service. Chicago, IL.

Center for Watershed Protection (CWP). 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community*. Ellicott City, MD.

Delaware Department of Natural Resources and Environmental Control (DE DNREC) and The Environmental Management Center of the Brandywine Conservancy. 1997. *Conservation Design for Stormwater Management.*

Dreher, D.W. and T.H. Price. 1994. *Reducing the Impacts of Urban Runoff: The Advantages of Alternative Site Design Approaches*. Northeastern Illinois Planning Commission. Chicago, Il.

Ferguson, Bruce K. 2005. *Porous Pavements*. Boca Raton, FL: CRC Press.

Hun-dorris, T. 2005. *Advances in Porous Pavement*. Stormwater, Vol. No. 2 March/April 2005 pp 82-88.

Lacey, J. and R. Arendt 1990. *An Examination of Market Appreciation for Clustered Housing with Permanently Protected Open Space*. Center for Rural Massachusetts, Amherst, MA. 14 pp.

Liptan, T. and C.K. Brown. 1996. *A Cost Comparison of Conventional and Water Quality-Based Stormwater Designs.* City of Portland. Bureau of Environmental Services. Portland, OR. 16 pp.

Maurer, George. 1996. *A Better Way to Grow: For More Livable Communities and a Healthier Cheasapeake Bay.* Chesapeake Bay Foundation, Annapolis, MD.

Montgomery County (Pennsylvania) Planning Commission. *Guidelines for Open Space Management in the Land Preservation District.* Norristown, PA.

National Association of Homebuilders (NAHB). 1986. *Cost Effective Site Planning*. Washington, D.C.

Schueler, Thomas R. 1995. *Site Planning for Urban Stream Protection.* Center for Watershed Protection. Ellicott City, MD.

South Carolina Coastal Conservation League (SCCCL). 1995. "Getting a Rein on Runoff: How Sprawl and Traditional Towns Compare." *SCCCL Land Development Bulletin* (Number 7). Charleston, SC.

APPENDIX F – STORMWATER QUALITY

Bay Area Stormwater Management Agencies Association (BASMAA). *Start at the Source: Residential Site Planning and Design Guidance Manual for Stormwater Quality Protection*. BASMAA, San Francisco, CA. January 1997.

Center for Watershed Protection. *Better Site Design: A Handbook for Changing Development Rules in Your Community.* Center for Watershed Protection, Inc., Ellicott City, MD. 1998.

Schueler, Thomas R. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. Metropolitan Washington Council of Governments, Washington, DC. 1987.

Schueler, Thomas R. *Urban Runoff in the Washington Metropolitan Area.* Metropolitan Washington Council of Governments, Washington, DC. 1983.

Smith, David R. *Life Cycle and Energy Comparison of Grass Pavement and Asphalt Based on Data and Experience from the Green Parking Lot*. The Heritage Conservation and Recreation Service, Order No. A-4331-4. 1981.

Smith, David R. and Sholtis, David A. *An Experimental Installation of Grass Pavement.* The Heritage Conservation and Recreation Service, Order No. A-4331-4. 1981.