Appendix G
Treatment and Management Options Technical Memorandum

CH:CDM

Santa Monica Bay Beaches Wet Weather Bacteria TMDL Implementation Plan

Technical Memorandum Task 6: Treatment and Management Options

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Representing Jurisdiction 2 and 3 Agencies

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1.0 Introduction

1.1 Background

The CH:CDM team is assisting Jurisdiction groups 2 and 3, which consist of the Cities of Los Angeles, Santa Monica, and El Segundo, the County of Los Angeles, and Caltrans in developing an Implementation Plan to address the requirements of Santa Monica Bay (SMB) Beaches Wet Weather Bacteria Total Maximum Daily Load (TMDL). The Implementation Plan will incorporate input from multiple cities and agencies, as well as other affected stakeholders; and will consider and build on other planning efforts that are currently in progress with the City of Los Angeles' Integrated Resources Plan (IRP). The Implementation Plan will use an integrated water resources management approach that will address multiple pollutants, identify beneficial use opportunities, and integrate multiple agencies in its overall solution. There are seven jurisdictions, organized by watersheds, which are impacted by this TMDL. Of these seven jurisdictions, the City of Los Angeles is the lead agency for Jurisdiction 2 and is a participant in three other Jurisdictions (1, 3, and 7). The City of Santa Monica is the lead in Jurisdiction 3 and is a participant in Jurisdiction 2. This technical memorandum (TM) pertains to the joint implementation planning effort for Jurisdictions 2 and 3 (see Figure 1).

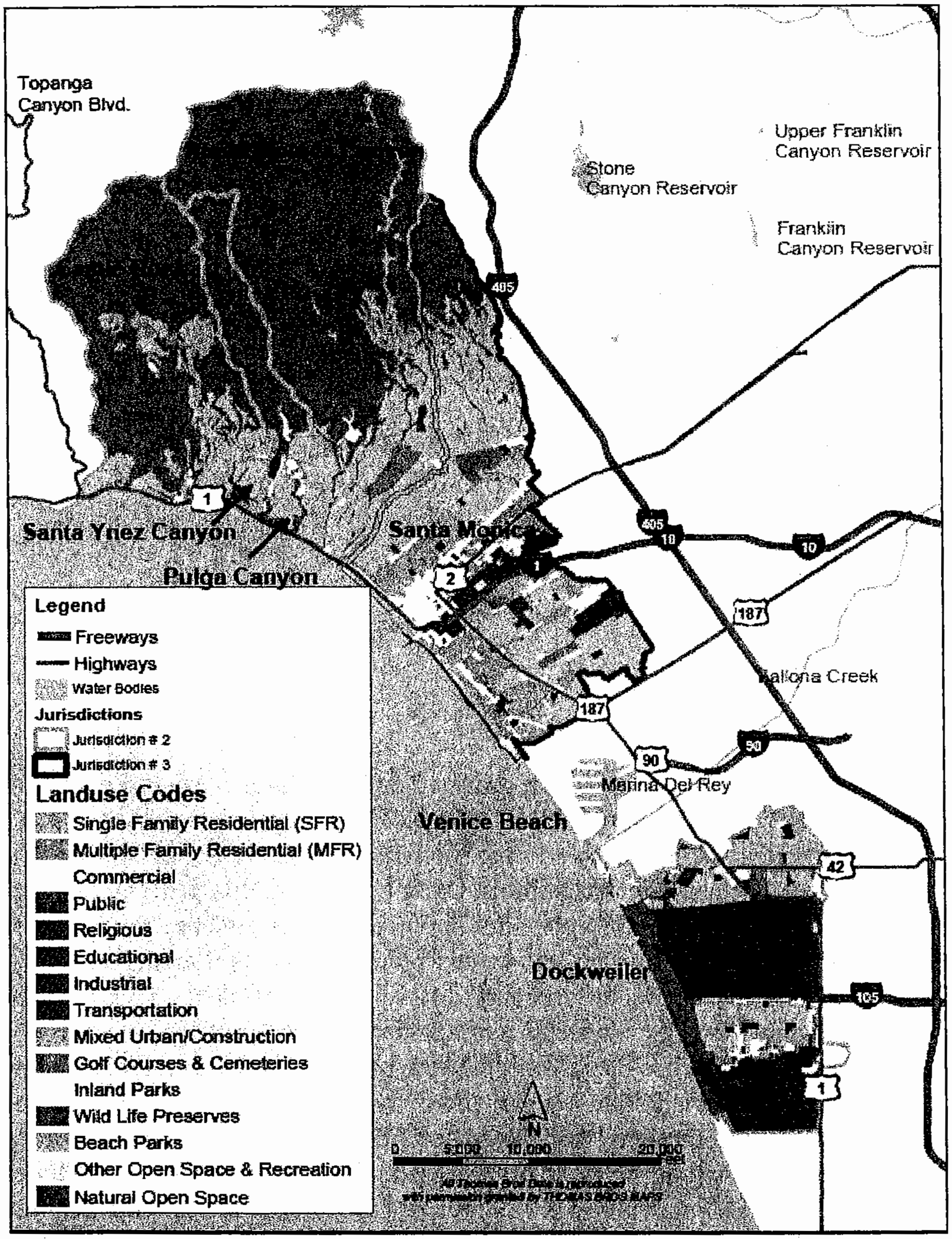


Figure 1. Jurisdictions 2 and 3 with Land Use

In support of the City of Los Angeles' efforts to prepare the Implementation Plan, the CH:CDM team is under contract with the City of Los Angeles to provide the following 11 tasks:

- Task 1: Assist with TMDL Development Planning
- Task 2: Provide Staff Support for the Development of an Integrated Implementation Plan
- Task 3: Regulatory Requirements
- Task 4: Detailed Hydrologic Study
- Task 5: Beneficial Use Evaluation
- Task 6: Treatment and Management Options Evaluation
- Task 7: Coastal Collection System Evaluation and Conceptual Alternatives
- Task 8: Research Potential Sites for Collection, Treatment and Diversion Facilities
- Task 9: Analysis of Implementation Alternatives
- Task 10: Prepare TMDL Implementation Plan
- Task 11: Task Management

Currently the CH:CDM team is also involved in the preparation of the City of Los Angeles' Integrated Resources Plan (IRP). As part of the IRP, the CH:CDM team and the City of Los Angeles developed a number of Interim Deliverable reports. This technical memorandum builds upon Volume 3, Runoff Management, which was prepared by the CH:CDM team and the City of Los Angeles and released in August 2003.

1.2 Purpose

The Implementation Plan will include specific recommended combinations of structural and non-structural measures (building blocks) to be implemented within each jurisdiction or combination of jurisdiction s that can quantitatively be predicted to have some success of achieving the reduction in exceedance days required by the TMDL. Some measures may be consistent across both Jurisdictional areas, whereas other combinations will be unique to each jurisdiction. The purpose of this analysis is to identify these structural measures, and in doing so, to satisfy the requirements of Task 6 of the Implementation Plan, the Treatment and Management Options Evaluation. This memorandum is intended to be utilized in the context of other task deliverables in support of the Implementation Plan.

1.3 Scope

The scope of Task 6 is to identify potential treatment requirements, technologies and management options for specific areas of wet weather runoff within the Santa Monica Bay coastal watershed that are to be treated for either discharge or reuse/recharge. The analysis will include planning level cost estimates consistent with the specificity of the treatment alternatives.

This effort has leveraged work conducted under the IRP runoff management task to evaluate candidate on-site and regional best management practices (BMPs) for treatment of bacteria. Because the implementation approach is an integrated watershed resources approach, other pollutants of concern that would be treated or managed by the candidate BMPs where applicable are also included in the analysis. On-site BMPs (source control) are discussed qualitatively, while quantitative evaluation of regional (structural, or treatment) BMPs is limited to documented performance and observance by others. Order of magnitude costs were developed based primarily on information developed as part of the IRP and supplemented with outside information as available.

2.0 Identification of Options

Based on work conducted under Tasks 4 and 5 and work in-progress for Task 7, three categories have emerged for potential runoff management options for Jurisdictions 2 and 3. The options were chosen because they not only manage runoff volume, but they also specifically help to reduce bacteria concentrations in the runoff. Many of these options help to reduce concentrations of other pollutants as well.

The intended purpose and types of options for each of these three categories in the overall implementation plan are generally:

<u>Institutional (non-structural source control) Options</u>

These options are intended to prevent/reduce levels of bacteria, or bacteria sources (e.g. garbage/trash) from initially being picked up by runoff whether on-site, in the curb/street, or in the storm drain system. They generally do not reduce the amount of flow or volume to be managed, but may reduce bacteria levels. Institutional options probably would help the most with dry weather runoff and would be only minimally effective in actually reducing any bacteria exceedances at the beach by themselves, but they should be part of an integrated solution, and could be some "quick hits" for early implementation steps. Examples of these options are pet waste programs and restaurant education/inspection programs (especially near the beach).

The City of Los Angeles recently revised its BMP program as presented in their Development Best Management Practices Handbook (DPW BOS, 2002). The BMP Handbook identifies 14 BMPs that provide source control. They generally consist of efforts such as education and implementation of "good housekeeping" practices for individuals, businesses, and industry. They also include industrial process changes to minimize waste production. Enforcement activities to prevent illegal discharges and connections and ensure industrial discharge permit compliance would also be considered non-structural BMPs.

<u>On-site (structural source control) Options</u>

These options include cisterns, on-site storage/reuse, onsite capture and infiltration, and they are intended to reduce the total volume and flow rate of runoff leaving properties and entering the storm drain system, including any bacteria that might be picked up in the runoff on-site. They directly reduce the amount of runoff that enters the downstream storm drain system, thereby reducing the amount that needs to be managed downstream. The Task 5 Technical Memorandum has demonstrated that only a relatively small fraction of the amount of runoff that needs to be managed to meet the TMDL targets could be addressed through these options in these jurisdictions, so these options will not represent a total solution for any of the major coastal jurisdictions. The presumption is that no treatment would be required for any bacteria/pathogens since water would either be infiltrated or applied with subsurface irrigation or otherwise locally managed techniques with minimal unrestricted public contact. Some limited pre-treatment might be required for a larger system to minimize operational problems.

<u>Regional Options</u>
The following are potential regional options:

- Divert to wastewater treatment – This option is intended to divert dry and wet weather runoff to the Hyperion wastewater collection system where it receives equivalent to secondary treatment (no disinfection required) and it is discharged through the five mile outfall. Diverting runoff eliminates discharge of that quantity of water downstream to the beach, thereby potentially reducing the number of exceedance days, especially at lower flows. This option can only be done when capacity exists in collection system and at Hyperion, and therefore short-term operational storage would likely be required to balance the rainfall hydrograph with available capacity.

- Capture, store, treat and discharge – This "end of pipe" solution treats runoff either in-line or off-line to reduce bacteria to levels that presumably would not cause an exceedance of water quality objectives at the beach. This option assumes the treatment objective would meet the AB411 beach standards. To minimize peak capacity of treatment, short-term operational storage will be required to balance the rainfall hydrograph with capacity. It is likely that some level of treatment and discharge will have to be considered in most jurisdictions, as most of the other options may not be able to achieve full compliance with TMDL quantitative targets by themselves.

- Capture, store and beneficially reuse for irrigation or similar non-potable uses – This option is intended to divert wet-weather runoff to beneficial use with appropriate treatment for the intended use. The capture and reuse of runoff eliminates discharge of that quantity of water downstream to the beach, thereby potentially reducing the number of exceedance days, especially at lower flows. To minimize capacity of treatment and/or off-stream diversion pumping to storage, short-term operational storage will likely be required to balance the hydrograph, and longer-term storage may be required to balance water availability with seasonal demand. It is assumed that treatment objective would be equivalent to Title 22 standards for unrestricted irrigation with recycled water (filtration, disinfection, 2.2 MPN coliform).

- Capture, store, treat and inject – This option is intended to divert runoff to be a source of regional groundwater injection with appropriate treatment for the intended use. The capture and injection of runoff eliminates discharge of that quantity of surface water downstream to the beach, thereby potentially reducing the number of exceedance days. To minimize capacity of treatment and/or off-stream diversion pumping to storage, short-term operational storage will likely be required to balance runoff hydrographs, and longer-term storage may be required to balance water availability with seasonal demand. However, the Task 5 TM does not consider this option to be feasible for these Jurisdictions 2 and 3, unless the water could be considered as a supplemental source of supply to the existing West Basin MWD system.

- Extended outfall and discharge to the ocean – This option is intended to extend the discharge point of runoff without treatment for bacteria/pathogens sufficiently beyond the water contact area (in terms of distance and depth) such that urban runoff-caused exceedances at beaches would not occur. At this point, no readily available criteria exist to establish what the sufficient depth/distance would be as this would require significant analysis of shoreline wave and current patterns.

2.1 On-Site Options

On-site options provide an important step in managing wet weather runoff. This Technical Memorandum focuses on several treatment control BMPs identified by the City of Los Angeles in the Development BMP Handbook that will reduce runoff volumes and improve runoff quality prior to entering the storm water collection system. Of these, three options have been identified as providing source control at the individual lot level for Jurisdictions 2 and 3: 1) residential cisterns, 2) on-site storage and reuse, and 3) capture and infiltration. Since runoff would be retained and not discharged, bacteria and other pollutants would not be discharged and would therefore be effectively removed.

It should be recognized that on-site options, like institutional options, may not fully mitigate the impacts of pollutant loading, but their implementation could contribute to integrated water quality solutions, and could contribute to the reduction of the magnitude and extent of downstream (regional) options.

2.1.1 Residential Cisterns

Cisterns are low-cost water conservation devices that could be used to reduce runoff volume and, for smaller storm events, delay and reduce the peak runoff flow rates. They store and divert runoff from impervious roof areas on residential properties. This stored runoff could provide a source of chemically untreated 'soft water' for gardens and compost, free of most sediment and dissolved salts. Because residential irrigation could account for up to 40 percent of domestic water consumption, water conservation measures such as cisterns could be used to reduce the demand on the municipal water system, especially during the hot summer months. Photos of cisterns (one attached to a roof drain system) are presented in Figure 2.

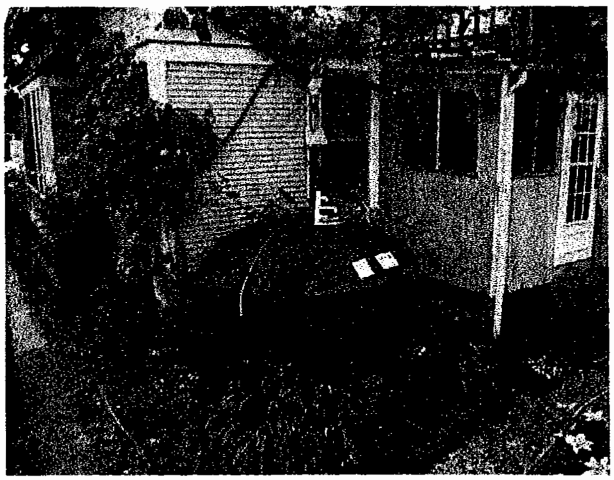


Figure 2. Cisterns (Source: www.lid-stormwater.net and www.watertanks.com)

Individual cisterns could be located above ground and beneath each downspout, or the desired storage volume could be provided in one large, common cistern that collects rainwater from several sources. Pre-manufactured residential-use cisterns are available in sizes ranging from 100 to 10,000 gallons. A thorough description of this option is presented in the Task 5 Technical Memorandum (TM).

As presented in the Task 5 TM, if cisterns were to be installed at five to ten percent of available sites, approximately 96 to 191 acre-feet (AF) of wet weather runoff per year could be beneficially used for irrigation. Since the total wet weather runoff generated within Jurisdictions 2 and 3 from a long-term average annual rainfall is approximately 15,440 AF per year, these estimates represent 0.6 to 1.2 percent of the total annual wet weather runoff. Although the cistern option would not manage sufficient quantities of runoff to eliminate the need for other runoff management options, it should be encouraged due to its positive effect from a water conservation standpoint, and its ability to eliminate low flow runoff from very small storm events. Table 1 provides a summary of selected information.

Table 1
Cistern Data

Control Measure	Cisterns
TMDL compliance method and performance	Reduces volumes of runoff potentially contributing to increased discharge/exceedance days. Not feasible for implementation as the primary BMP for TMDL compliance.
Cost-related data	Product cost: $1 to $2/gallon for cistern sizes ranging from 50 to 10,000 gallons
Site-related data	BMP is contained on site and does not require additional right-of-way
References	www.watertanks.com www.cleanairgardening.com www.lid-stormwater.net

2.1.2 On-site Storage and Reuse Projects

This option involves capturing runoff from areas other than, or in addition to, rooftops and storing it for subsequent reuse on-site. These other areas include driveways, parking lots, and paved sports areas. This option could also include some treatment (such as chlorination) and would require careful management, and consideration of water distribution systems.

The potential sites for this type of system would be public parks, government facilities, or schools at which the runoff could be reused for irrigation without meeting full Title 22 treatment Standards (requiring filtration and disinfection). They would be installed underground since they would need to be big enough to storage large volumes of runoff. The landscape maintenance could involve a controlled subsurface distribution system (i.e., no sprinkler system) so that direct public contact is essentially eliminated. The opportunities for these types of projects would have to be identified and developed on a case-by-case basis.

In addition to chlorination, treatment options could include trash/gross solids removal and removal of oil and grease where needed to minimize operational problems. Wet weather runoff would be directed to the underground system by either conveyance piping or through infiltration of the surface soil, or a combination of both. The runoff would be stored in the underground system and could be pumped and used for on-site irrigation. Each system would be designed and sized to collect and treat runoff (from either on-site or additional street areas) and stored underground in a system sized to appropriately supply a percentage of the irrigation demand.

The Open Charter School Demonstration Project in the Ballona Creek Watershed is an example of this option. It is being built in cooperation between government and non-profit agencies in the creation of an environmentally sustainable school. Funded by County Proposition A (Safe Neighborhood Parks Act), and financed by the City Bureau of Sanitation, the project is designed to reduce the amount of polluted runoff to Ballona Creek and Santa Monica Bay.

Working in conjunction with the Los Angeles Department of Water and Power's (DWP's) Cool Schools Program and the Los Angeles Unified School District, TreePeople supervised the installation of an integrated set of BMPs at the site. The system consists of a runoff collection system, pipes to route the runoff to a small-footprint treatment unit, a cistern, an automatic chlorinator, and a pump. The treatment unit is a proprietary system designed to remove trash, grit, and oil from the collected runoff. It consists of an inlet, a grit chamber, an oil-water separator, and flow control. The cistern stores 110,000 gallons of captured storm water for reuse as irrigation supply. It consists of an excavated area, an impermeable liner, and subsurface storm water storage "blocks" to store the runoff. A photo of this installation during construction is presented in Figure 3. An agreement on monitoring the performance of the site's BMPs is currently being negotiated. Table 2 summarizes the on-site storage and reuse option.

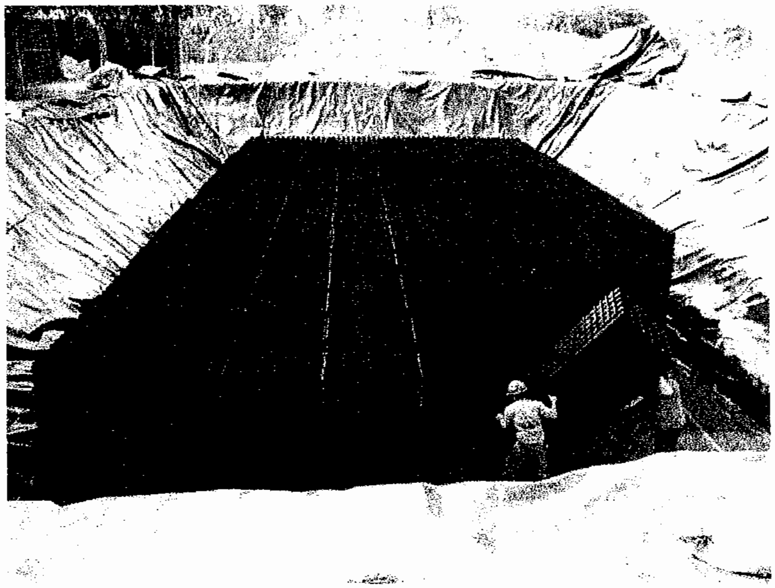


Figure 3. Subsurface Storage Blocks for On-site Storage and Reuse

Table 2 On-Site Storage and Reuse Summary	
Control Measure	**On-site Storage and Reuse**
TMDL compliance method and performance	Reduction of runoff contributing to potential TMDL discharge exceedances and treatment of captured volumes. Multiple pollutants addressed.
Cost-related data	Approximately $4/gallon Based on Open Charter School • Construction Costs $435,000 • Treated volume = 110,000 gal
Site-related data	Underground site
References	TreePeople (O'Donnell, 2004)

2.1.3 Small Scale Infiltration Projects

Many on-site options have been identified that capture storm water and allow it to infiltrate into the ground at rates that would provide water quality treatment and reduce the downstream flow. The options porous pavement, retention grading, infiltration basins and trenches, bioretention, and infiltration culverts are discussed. As with any infiltration option, the pre-design considerations include the following:

- Soil types and groundwater depths
- Presence of contaminated groundwater/subsurface soils, and the potential impacts of introducing pollutants into the subsurface system.
- Proximity to potentially impacted structures
- Maintenance to prevent long-term clogging

2.1.3.1 Porous Pavement

Areas such as roadways, driveways and parking areas covered with impermeable (non-porous) pavement are one of the largest contributors to wet weather urban runoff. Porous pavement is a special type of material that allows water to pass through yet is strong enough to structurally support vehicular traffic.

Concrete block pavement is one type of porous pavement that has been available for many years and has been used primarily as aesthetic treatments to parking areas and low volume roadways. In the last 20 years, high-density plastic grids have also entered the market place. There are many configurations and applications that have been developed for both of these materials. Most of the systems are supported by a stone base that has large pore spaces. This base acts both as pavement support and as a reservoir to store water so that it can be infiltrated, if the soil conditions allow, or detained and slowly released to the storm drain system. Supplemental storage facilities, such as underground vaults or drainage blankets, can be used in conjunction with these systems. Each pavement type is generally described below.

- **Porous Concrete**: This pavement has stable air pockets encased within it that allow water to drain uniformly through into the ground below, where it can be naturally filtered (See Figure 4). The material becomes stronger and more stable when it gets wet, so it does not deteriorate as fast as other paving materials. Its use should be restricted to parking lots and local roads since it supports lighter loads than standard concrete. Since it is cement based, it will not release harmful chemicals into the environment such as with oil-based asphalt. It has been in use throughout Europe for about fifty years, and a domestic formula known as the Portland Cement Pervious Pavement has been used successfully since the 1970s in the U.S., particularly in Florida. The pavement is a special blend of Portland cement, sand-free coarse aggregate rock, and water.

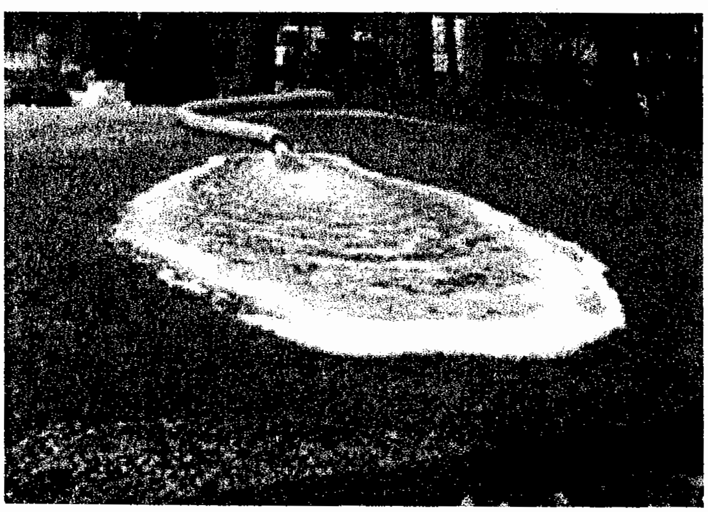


Figure 4. Porous Pavement Section (http://www.gcpa.org/pervious_concrete_pavement.htm)

- **Grass Pavers**: Plastic rings in a flexible grid system or concrete pavers are placed on a base of blended sand, gravel and topsoil, then filled with topsoil such as sandy loam and planted with vegetation (see Figure 5) . This pavement provides an alternative to asphalt or concrete for low-traffic areas such as firelanes, overflow and event parking, golf cart paths, residential driveways, and maintenance and utility access lanes. The support base and the rings' walls prevent soil compaction and reduce rutting and erosion by supporting the weight of traffic and concentrated loads, while the large void spaces in the rings allow a strong root network to develop. The end result is a load-bearing surface covered with natural grass and which is typically around 90 percent pervious, allowing for storm water pollution filtration and treatment. Ancillary benefits include airborne dust capture and reductions in the urban heat island effect. Most manufacturers also produce the paver rings from post-consumer recycled plastic materials. It should be noted, however, that this approach involves installing grass that will require irrigation and could increase the potable water demand.

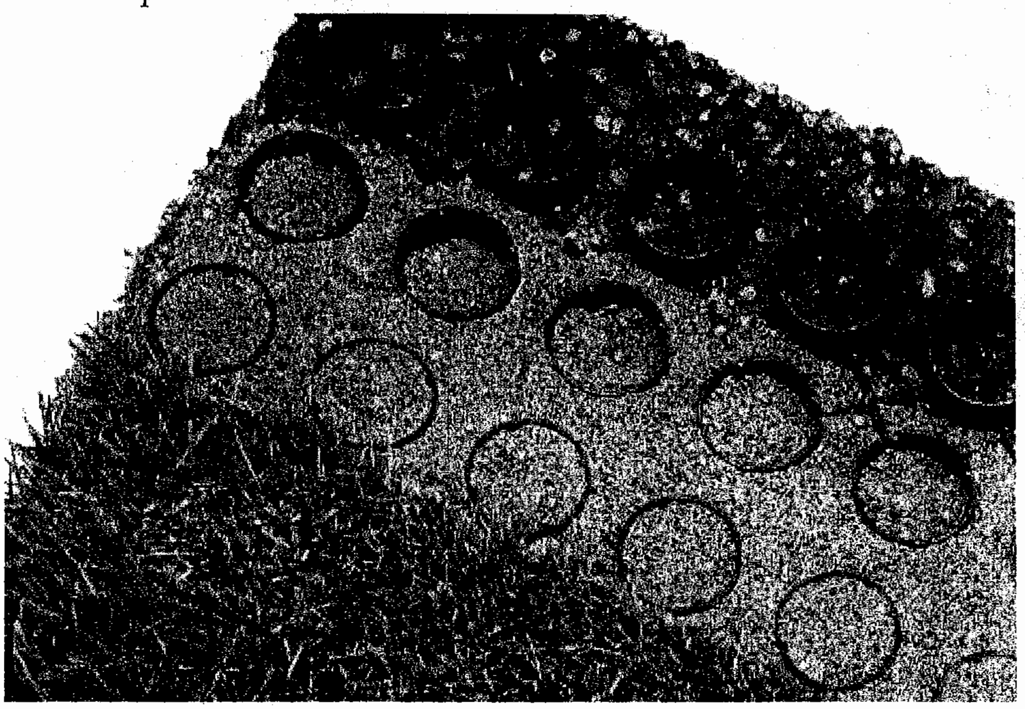


Figure 5. Grass Paver Example

- **Gravel Pavers**: This pavement option is intended for high frequency, low-speed traffic areas (see Figure 6). The same ring structure as with the grass paver is used, but the voids are filled with gravel to provide greater load bearing. Manufacturers provide specifications on the sieve analysis that should be used to generate the clean gravel fill for the rings, and a geotextile fabric is used to prevent the gravel infill from migrating to the soil subbase. Gravel pavers can be used for automobile and truck storage yards, high-throughput parking lots, service and access areas, loading docks, boat ramps, and outdoor bulk storage areas. It should be noted, however, that this approach does not require irrigation and therefore does not increase the potable water demand.

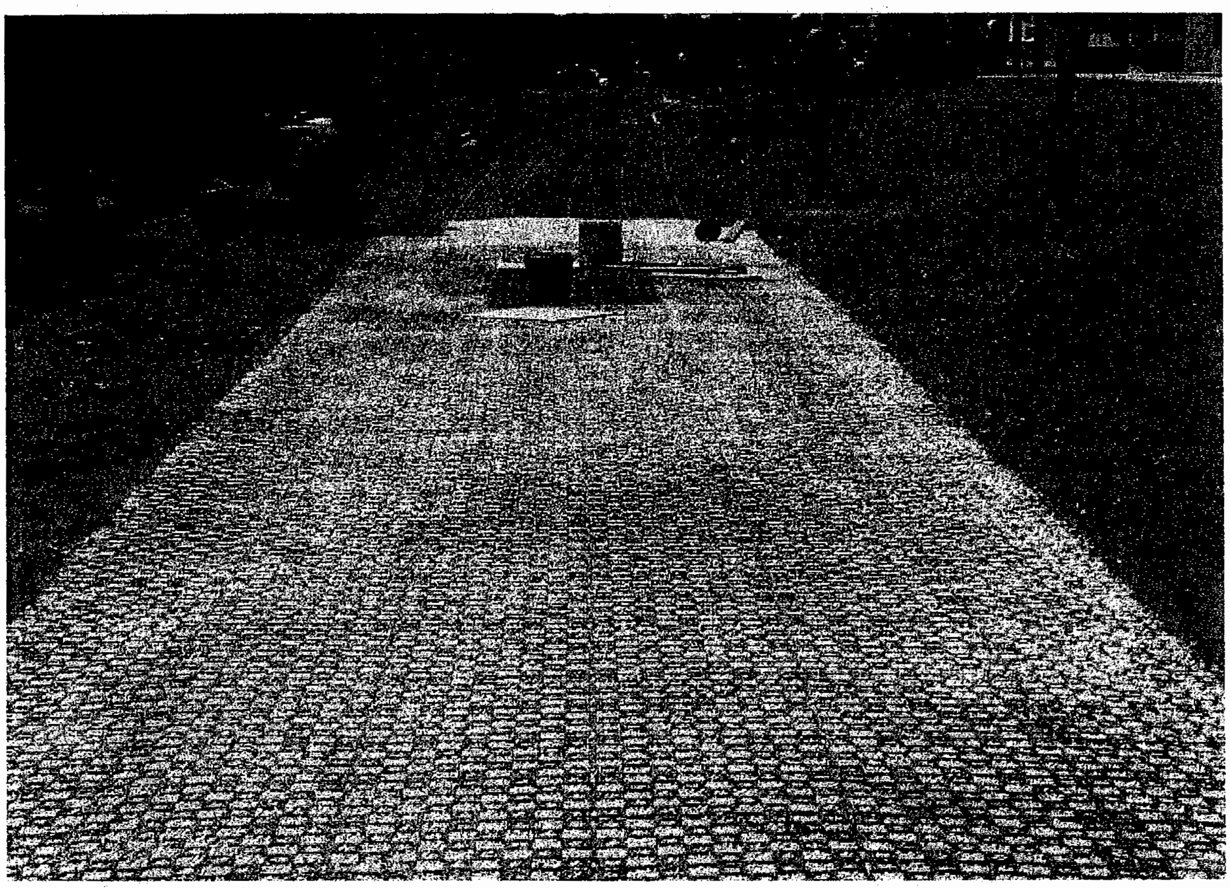


Figure 6. Gravel Paver Example

- **Interlocking Paving Blocks**: The shape of these interlocking pre-cast units leaves drainage openings that typically comprise approximately 10 percent of the paver surface area (See Figure 7). They are made of concrete or plastic. When properly filled with permeable material, the voids allow for movement of storm water through the pavement surface into the layers below. The system is a highly durable, yet permeable pavement capable of supporting heavier vehicular loads than grass or gravel pavers and it offers the most flexibility in widespread application. Interlocking concrete paving blocks are resistant to heavy loads and both concrete and plastic ones are easy to repair, require little maintenance, and are of high quality. These systems, however, have the highest materials and construction costs.

- **Pervious Crushed Stone:** Parking stalls could be covered with a pervious crushed stone. The pervious stone surface would allow storm water and auto-related contaminants to be absorbed and trapped in the soils.

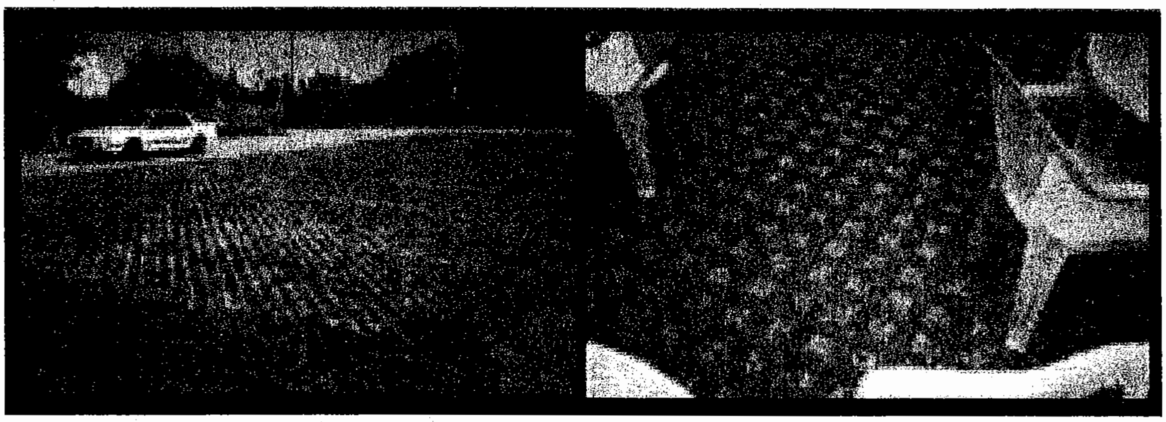


Figure 7. Permeable Paving Blocks

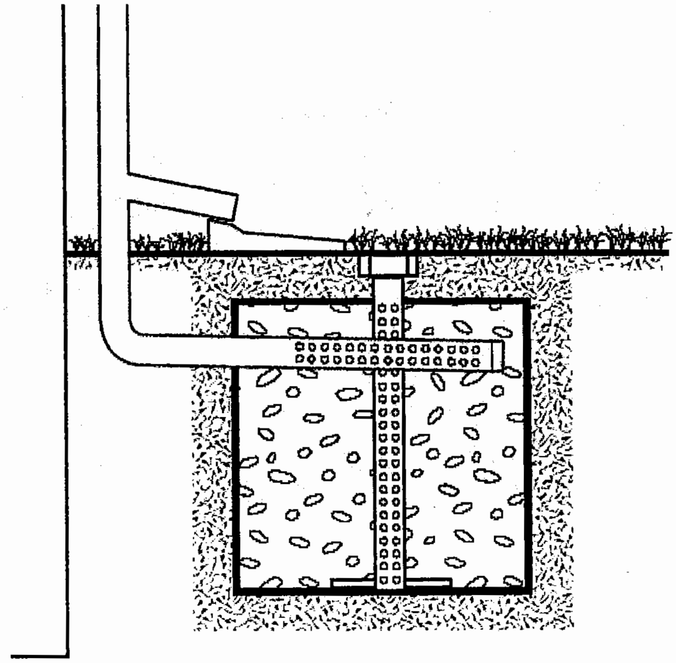
2.1.3.2 Retention Grading

Residential front and backyard retention grading is a concept whereby a site is graded to create a "sunken garden" that holds runoff and rainwater until it can be absorbed into the ground. This type of grading works best in highly permeable soils. While in some locations, mini retention structures are capable of handling a flash flood that could occur during a 100-year storm event, this is not expected to be the case in Jurisdictions 2 and 3. The depressed area, however, could retain small storms and could also be placed over coarse aggregate rock to achieve a higher infiltration rate to prevent nuisance and vector-breeding conditions. In all cases precautions must be taken during design to ensure that standing water could either be infiltrated or evapotranspirated within three days and that County requirements for sump conditions are met.

2.1.3.3 Infiltration Basins and Trenches

Infiltration basins and trenches are a common means of storm water management in many areas of the United States. They have sometimes also been called "French Drains". An infiltration basin involves installing a rock basin can be constructed at a roof downspout (see Figure 8). An infiltration trench involves adding a grate with a rock pit below at the lowest end of paved areas such as driveways and parking lots. They are designed to capture and store storm water until the water percolates into the subsurface soils. They serve the dual purpose of retaining and cleansing runoff and rainwater, giving the water within it time to percolate into the ground rather than carrying pollutants into the City storm drain system.

Figure 8 - Infiltration Basin



2.1.3.4 Bioretention Areas

With bioretention, runoff is directed into shallow landscaped depressions (see Figure 9). It is applicable to large areas. These depressions and the surrounding areas are designed to provide onsite treatment, incorporating many of the pollutant removal mechanisms that operate in forested ecosystems. They are commonly located in parking lot islands, median strips, swales or within small pockets of residential land uses.

The bioretention area is commonly graded so that excess flow is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. Runoff first passes over or through a sand bed, which slows the runoff's velocity and distributes it evenly along the length of the ponding area; this area consists of a surface organic layer and/or ground cover and the underlying planting soil. The ponding area is graded and its center area is depressed. Water is impounded to a depth of about six inches and gradually infiltrates the bioretention area or is evapotranspired. The design can be modified to include an underdrain within the sand bed to collect the infiltrated water and discharge it to a downstream storm drain system. This modification is needed in areas where impervious subsoil could prevent complete infiltration in the soil system. In the case of this modification, the bioretention area would act more as a filter that discharges treated water than as an infiltration device.

These installations could provide as high as 90 percent removal of suspended solids and bacteria. (www.lid-stormwater.net). Innovations in the designs of bioretention areas could include both aerobic and anaerobic treatment zones in the treatment bioretention area to promote nitrogen removal if a nitrogen removal requirement was added within Jurisdiction 2 or 3. The anaerobic zone will promote denitrification. Testing of installations has shown removal of between 93 and 98 percent of metals, between 68 and 80 percent of total Kjeldahl nitrogen, and between 70 and 83 percent of total phosphorus

Figure 9. Bioretention

2.1.3.5 Infiltration Culverts

The runoff from a small area could be routed to a treatment system to remove grit and oil and then be routed to an infiltration system located in an area with well draining soils. A typical treatment system would consist of an inlet, a grit chamber, an oil wall separator, and flow control. The infiltration system would consist of a perforated culvert under the boardwalk that could store the runoff until it is infiltrated.

While pilot testing would be required to determine the actual infiltration rate, an estimate of the rate can be developed based on data provided by the Los Angeles County DWP (LADWP, 2004) The soils in the Venice Beach area are of a type designate Number 3 by the County. This soil type has a runoff rate (Cu) of 0.32 at a rainfall intensity of 2-inches per hour. Thus, 68 percent of the rainfall will infiltrate at this rainfall intensity. For the purposes of this study, it was assumed that a perforated culvert will have a zone of influence that extends 5 feet in both directions from the culvert centerline (a total area of 10 square feet per foot of culvert). At a rainfall intensity of 2-inches per hour, about 12.5 gallons of water would accumulate on this area and about 8.5 gallons would infiltrate. Over a day, about 200 gallons would infiltrate. To be conservative, it was assumed that the actual infiltration rate would be about 100 gallons per day/foot of culvert.

A 48" perforated culvert, located parallel to the coast, under the boardwalk, would have a storage capacity of 94 gallons per foot of culvert. Based on an estimated infiltration rate of 100 gallons per day, the stored runoff in the culvert should empty in one day. Based on data presented in the Memorandum for Task 4, the 100 gallon runoff would correspond to a developed surface area of about 1,300 square feet for the target storm of 0.45 inches per day.

Thus, for each foot of culvert, the runoff from a surface area of 1,300 square feet could be accommodated.

2.1.3.6 Analysis of Capture and Infiltration

Regional environmental factors, such as the amount, intensity, and frequency of rainfall, local soil permeability, groundwater levels, and subsurface soil quality (i.e., absence of contaminants) will determine the ability of the these systems to pass storm water through the top soil layers and then store and release the water in a timely manner into the underlying soil.

As described in the Task 5 TM, infiltrating runoff requires that the soils be permeable enough to allow percolation into the groundwater basin. Since a significant portion of the groundwater aquifer in Jurisdictions 2 and 3 is confined, it is unlikely that there is opportunity for groundwater recharge through on-site infiltration projects on a large scale. There is the potential, however, for some runoff to infiltrate into the top layers of soil, where it will reduce the overall runoff volume leaving the site. Sandy or sandy loam soils have the highest percolation rates (infiltration capacity), while clay soils tend to have the lowest infiltration capacity. The clay in poorly draining soils quickly expands when wet and holds water almost immediately when exposed to moisture.

Much of the area within Jurisdictions 2 and 3 has predominantly clay soils that do not permit extensive infiltration. The types of soil within the Santa Monica Bay area were identified based on data provided by the Los Angeles County Department of Public Works hydrology GIS database. As described in the Task 5 Memorandum, very limited opportunities exist for on-site infiltration projects to lead to quantifiable reductions in runoff volumes. They are located in the upper portions of the Santa Monica Canyon Sub-watershed and the beach areas of the Venice Beach and Dockweiler Sub-watershed.

In addition to the need for permeable soils, an infiltration system requires that the soil be uncontaminated to avoid degradation of the underlying aquifer. One major concern about the use of infiltration pits is that unmaintained or unmonitored installations could be a risk to groundwater quality (e.g. from illegal dumping). Specific installation requirements and monitoring could be developed to mitigate this risk. As with all the options maintenance of these installations is important to provide consistent treatment. For porous pavement, limits must be placed on the weight of the vehicles that can be used. A summary of On-Site Capture and Infiltration options is presented in Table 3.

Table 3 On-Site Capture and Infiltration	
Control Measure	**On-Site Capture and Infiltration**
TMDL compliance method and performance	Reduction of runoff volumes and full treatment when fully functional. Performance: Irregular (EPA estimates 75% failure for pavement)
Cost-related data	Porous Pavement ($6-8/sf) Permeable (grass and gravel) Pavers ($1.50-$3/sf + surface treatment ~ $10/sf)[1] Bioretention estimate: $2.50/sf Infiltration Culvert: ($42/ft materials , estimate $100-200/ft)
Site-related data	Varies; if properly designed, could have no impact on usable areas
References	USEPA, 1999

2.2 Regional Options

Regional options are treatment control practices that capture, store and treat runoff before releasing it back into the environment. This section discusses the different treatment requirements and technologies available for the potential options that have been identified for Jurisdictions 2 and 3: diversion to wastewater treatment facilities; capture, storage, treatment and then either discharging, beneficially reusing (i.e., for irrigation), or injecting runoff; and direct discharge of the runoff using an extended outfall.

Wet weather events result in high flows over a relatively short duration. Designing a system to accommodate all of the flows as they are generated would be prohibitively expensive. Therefore, all options for storm water treatment or direct discharge would involve the capture and storage of storm water runoff. Storage costs for all options are on the order of $1 - $1.5 M/mgd, and these costs are in addition to the treatment options discussed below. It should be noted that costs associated with any significant conveyance facilities, and land acquisition are not included in the cost discussion below.

The collected runoff would then be pumped from the storage facilities at a lower rate over a period of hours or days. Technical Memorandum 4 (Hydrology) describes target runoff volumes and storage requirements anticipated for treatment.

2.2.1 Divert to Wastewater Treatment

This option involves storing wet weather runoff and then routing it to the Hyperion Treatment Plant (HTP) for treatment. The HTP unit processes include grit removal, primary sedimentation, secondary treatment using high purity oxygen and secondary sedimentation, disinfection using chlorine, and ocean discharge. Portions of the treated effluent are routed to other agencies that provide further treatment to supply recycled water in the area. These

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1 Referenced Presto and Invisible Structures products

treatment facilities were designed to meet ocean discharge requirements for collected wastewater and are assumed to meet these standards for discharging treated wet weather runoff. The plant capacity available to treat runoff, however, may be limited. The potential for diversion of wet weather runoff generated in Jurisdictions 2 and 3 to the Hyperion Wastewater Treatment Plant will be discussed in detail in the Task 7 Technical Memorandum.

2.2.2 Capture, Store, Treat and Discharge

Capture, store, treat and discharge, or treatment and discharge, refers to diverting runoff from the storm drain system to a dedicated runoff treatment facility. The runoff would be captured and diverted, held in temporary storage for a maximum of 24 hours, pumped to new facilities for treatment, and discharged.

As discussed in the Task 4 Technical Memorandum, the target runoff management volume from Jurisdictions 2 and 3 is on the order of 174 million gallons per storm event. The proposed number and capacity of each treatment facilities will depend upon the siting analysis and development of alternatives.

Treatment would depend on target constituents (in this case, primarily bacteria). Trash and suspended solids would also be present in wet weather flow, and pretreatment of flows would therefore be required to remove these constituents before treatment to remove bacteria is implemented. This level of treatment, however, would be substantially below the level of treatment required to beneficially reuse the runoff as discussed in Subsection 2.2.3.

This section discusses traditional as well as candidate treatment technologies that could potentially be utilized for treatment of bacteria, where discharges are released. Traditional treatment methods would probably be most applicable with high wet weather runoff flowrates. The candidate treatments technologies have not been proved for this application but could possibly provide treatment on small-scale in localized drainage areas. The treatment technologies examined consist of the following:

- Traditional treatment
- Storm water Filtration Units
- Advanced Oxidation
- Peracetic Acid (PAA) and Other Bactericides
- Subsurface Constructed Wetlands

It should be noted that many of the information related to new and proprietary technologies were provided by vendors and manufacturers, and implementation should be carefully monitored and considered in the context of adaptive management practices.

2.2.2.1 Traditional Treatment

Constructing wet weather runoff treatment facilities is a relatively new concept. For this study, wastewater treatment facilities designed to treat dilute wastewater at high rates on an intermittent and as-needed basis will be used as the treatment model. Plants designed for the

East Bay Municipal Utility District in Oakland, California are described below. The results of research by the National Science Federation are also presented below. These data will be used to develop an assumed treatment scheme and plant area per mgd of design capacity.

The primary purpose of the East Bay Municipal Utility District Wet Weather Facilities Program is to reduce the frequency and volume of overflows during wet weather events when the wastewater flows are very high (EBMUD, 2004). They operate three wet weather treat plants to maximize the volume of wastewater delivered to their main wastewater treatment plant and to assure that all wastewater entering the interceptor receives some treatment prior to discharge (floatable removal, disinfection and dechlorination). These three plants are the Oakport Wet Weather Treatment Plant, the San Antonio Creek Wet Weather Treatment Plant, and the Point Isabel Wet Weather Treatment Facility. The San Antonio Creek Plant, however, will not be presented as a model facility. It includes only grit removal and chlorination/ dechlorination facilities because it is at a site that is too small to accommodate sedimentation basins.

The overall design criteria for the Wet Weather Facilities Program is handling the wastewater flows during a 5-year rainfall event when the soil is saturated and the wastewater interceptors are at capacity. It is estimated that all of these conditions occurring simultaneously has a 13 year return period. The current permit allows a discharge limit of 100 MG per year.

The treatment goal is to reduce the solids and pathogen load in the discharged effluent. The discharge permits for the wet weather facilities could be modified in the future. It may be that metals removal and other criteria will be added to the permit.

The Oakport plant is rated for 158 mgd and has a storage capacity of 2.85 million gallons. The plant consists of a diversion structure, influent pump station, ten sedimentation basins, a chlorination/dechlorination system, standby diesel engine generator, control building and associated inlet, outlet and effluent channels and outfall. If the volume of wet weather flow at Oakport exceeds 2.85 million gallons (the storage capacity of sedimentation basins) prior to the restoration of local interceptor capacity, the flow is treated and disposed via outfall.

This plant does not have solids handling facilities. Accumulated solids within the sedimentation basins are washed into the local wastewater interceptor when capacity is available.

The ten Oakport sedimentation basins are 20 feet wide by 200 feet long for a total area of 40,000 square feet and a surface loading rate of about 4,000 gallons per day per square foot. This is a very high surface loading rate when compared to plants treating a more typical wastewater. The recommended primary sedimentation tank surface loading rate for untreated wastewater is 600 to 1,200 gallons per day per square foot (Metcalf and Eddy, 1972). For the purposes of this study, it was assumed that these basins comprised half of the total land area for the plant. Thus, an 80,000 square foot plant was assumed for the entire plant (about 500 square feet per mgd).

The total construction cost for this plant in 1990 was about $25 M. This cost does not include land acquisition. At an assumed escalation rate of 5 percent per year, this corresponds to a current cost of $50M. At a design flowrate of 158 mgd, the unit capital cost for this plant is $0.3 M/mgd.

The operations and maintenance cost for this plant is about $200,000. This is for materials only and does not include labor costs. No personnel are assigned solely to the facility. District staff members operate the site only during and after a wet weather event. In addition, maintenance crews visit all of the wet weather facilities on a regular basis but are also assigned to the District's main wastewater treatment plant.

Because of the proposed operating scenario (passive diversion) and the variability of storm events and soil moisture, the actual pattern and magnitude of flows is difficult to predict. On the average, the plant is expected to be operated approximately 10 times per year and discharge an average of 2.5 times per year. Correspondingly, the average yearly discharge volume is approximately 38 million gallons (MG) while the maximum is estimated to be 272 MG. The plant discharges for relatively short periods. The average discharge is 8 hours/event and 21 hours per year and the maximum expected discharge is expected to be 38 hours per event and 102 hours per year. Based on these data, it is estimated that the unit O&M cost for this facility is about $5,300/MG for materials only.

The Point Isabel Wet Weather Treatment Facility provides dry weather pumping of wastewater, up to 14 million gallons per day (mgd), to the main treatment and also provides treatment of wet weather flows up to 100 mgd with a storage capacity of 3.0 million gallons. The facility is equipped with a dry weather wet well that normally collects and pumps wastewater to the treatment plant, but will overflow passive weirs into the wet weather wet well and begin activation of the wet weather treatment facility for storm operation when flows in the local interceptor reach capacity.

When the wet weather influent pump station is activated, pumps lift the diluted wastewater through bar screens and then grit removal chambers. Flows then enter into eight sedimentation basins from near the bottom of the influent channel so that scum and floatables are removed. The sedimentation/storage basins provide primary sedimentation, chlorine contact time and storage. Sodium hypochlorite for disinfection is injected into the wastewater at the suction of each operating pump. Wet weather flows that exceed the capacity of the sedimentation/storage basins flow into the effluent channel and are dechlorinated with sodium bisulfite before discharging into San Francisco Bay through a 72-inch outfall. Solids and stored wastewater are returned to the dry weather wet well and then pumped to the District's main wastewater treatment plant.

The eight Pt. Isabel sedimentation basins are 20 feet wide by 210 feet long and for a total area of 33,600 square feet and a loading rate of about 3,000 gallons per square foot. For the purposes of this study, it was assumed that these basins comprise half of the total land area for the plant. Thus, a 67,000 square foot plant was assumed for the entire plant (about 670 square feet per mgd).

The total construction cost for this plant in 1993 was about $25 M. This cost does not include land acquisition. At an assumed escalation rate of 5 percent per year, this corresponds to a current cost of $43M. At a design flowrate of 100 mgd, the unit capital cost for this plant is $0.4 M/mgd.

A high degree of variability is expected from storm to storm and within each storm event. The variability is also reflected in constituent characteristics of the wastewater. As a result, the facility design emphasis was based on flexibility and passive flow control. The actual pattern and magnitude of flows to the Point Isabel WWTF will be difficult to predict because of the proposed operating scenario and the high variability of storm events and soil moisture. The reported O&M cost for materials only for this plant is $32,200 per year. If the average O&M cost of $5,300/MG for the Oakport plant is similar for this plant, this would correspond to an average discharge of about 6 MG.

Small packaged systems using traditional treatment methods are also available to handle flows from small watershed areas. An example of these systems treats dry weather runoff in the creek upstream of the Paradise Cove area in Jurisdiction 1. This system operates at flows at flows ranging from 60 to about 160 gpm. It consists of an 8,000-gallon pond to equalize flow, a multimedia filter to remove solids; an organic clay filter to remove oil, grease, and pesticides; and an ultraviolet disinfection system. Similar systems are in operation in the City of Encinitas and on Aliso Creek in Orange County.

The capital cost of a system to treat about 150 gpm ranges from $150,000 to $250,000 depending on factors such as the level of automation. This corresponds to a unit cost of $700,000 to $1.2M/mgd. The labor for these systems involves visiting the site a few times a week to ensure that it is operating correctly and routine maintenance. Electricity is the only operating expense as no consumable chemicals are used.

The National Science Federation conducted the Environmental Technology Verification (ETV) testing program for Urban Wet Weather Technologies in 1999. The goal of this program was to verify the operational performance of technologies applicable to the treatment of effluents generated by wet weather conditions in urban areas - storm water discharges, combined sewer overflows, or sanitary sewer overflows resulting from infiltration into the separate sanitary sewer system. High rate sedimentation and ultraviolet disinfection were found to meet many design goals (NSF. 1999). Their conclusion that high rate sedimentation appears feasible is consistent with the high surface loading rates for the EBMUD plants. Using UV for disinfection would eliminate the need for dechlorination and the potential for chlorinated organics in the plant discharge.

Based on the design criteria presented above, it is assumed that traditional treatment would consist of storage, influent pumping, bar screens to remove trash, sedimentation basins to remove settleable solids such as grit and organic material, and disinfection. A sedimentation tank surface loading rate on the order of 3,000 to 4,000 gpd/SF will be assumed. The assumed footprint area for the treatment facilities would range up to about 700 square feet per mgd.

Grit removal and fine screening would be considered in lieu of sedimentation if a site is very constrained. UV disinfection should also be considered.

The option of treating wet weather runoff could be coupled with a reuse project either initially or in the future. All or a portion of the effluent could be routed to a plant that would provide filtration and disinfection to meet Title 22 requirements. Traditional treatments are summarized in Table 4.

Table 4
Traditional Treatment

Control Measure	Traditional Treatment
TMDL compliance method and performance	No reduction in storm water volumes. Performance may not be good enough for non-bacteria applications such as metals removal.
Cost-related data	$0.3 to 0.4M/mgd plus land acquisition cost $5,300 / MG for materials cost $1.2M/mgd for small systems
Site-related data	Requires a significant footprint on the order of 700 square feet per mgd
References	EBMUD (2004) Clear Creek (2004)

2.2.2.2 Storm Water Filtration Units

Storm water filtration units (see Figure 10) are available as proprietary filtration systems equipped with vertical filter media that utilize filtration media specifically chosen to treat a particular site's pollutants of concern. In this case, the main constituent of concern is bacteria.

The performance of storm water filtration units is highly dependent on filter media. The units alone have not been proven to reduce pollutant concentrations of flows with bacteria loads to TDML discharge standards (requiring some 99.9% removal). They can, however, be used in combination with other methods (such as biocides) to improve performance. Effectiveness for bacteria applications is still undergoing testing.

Manufacturers have indicated that two media technologies currently being researched may provide some level of bacteria control without creating residuals with toxicity characteristics that would prohibit their use for surface water applications. These media are not currently available for purchase, and estimated removal rates are not available. They have; however, been used as pretreatment for suspended solids TSS, removals on the order of 80% and higher are achievable, depending on the media used.

Typical placement of these devices includes catch basins, manholes, and pre-cast underground vaults that can be placed wherever space is available on-site and hydraulics allow. A typical pre-cast structure measures 8' x 16' in area. Filter cartridges have a treatment flow of 15 gpm, and a typical pre-cast structure can house approximately 35 cartridges, allowing for a flow of 525 gpm. This corresponds to a unit size of about 200 square feet/mgd.

A capital cost of $30,000 per mgd of flow to be treated is typical. Maintenance costs for cleaning and/or replacement of cartridges on an annual basis are on the order of $2,000 - $5,000 for a typical system depending on number of cartridges and frequency of maintenance and cell replacement (Harris, 2004). If the unit operated five times per year at a rate of 525 gpm for a duration of one day (3.8 MG/year), this O&M cost corresponds to a unit rate of $500 to $1,300/MG. A summary of storm water filtration is provided in Table 5.

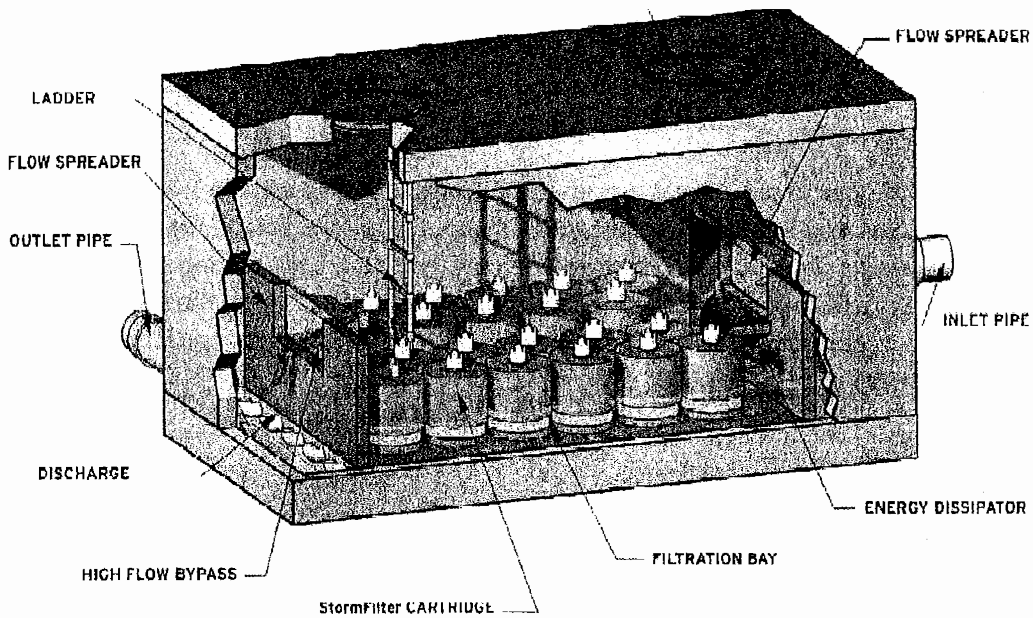

Figure 10. Storm Water Filter schematic (from Stormwater Management, Inc)

Table 5 Storm Water Filtration	
Control Measure	**Storm water filtration**
TMDL compliance method and performance	No reduction in storm water volumes. Performance: good for non-bacteria applications. Further testing needed; cannot meet bacteria standards without additional treatment.
Cost-related data	$30,000 per MGD $500 to $1,300/MG (O&M) Costs not fully developed for bacteria treatment. Only typical filter costs available.
Site-related data	Requires either detention or expanded vault. Requires an underground footprint on the order of 200 square feet/mgd.
References	Harris (2004)

2.2.2.3 Advanced Oxidation

This technology uses fully fluidized biofilm carrier elements to provide attached-growth aerobic treatment. It has typically been used to treat wastewater, but could be considered for storm water applications as it has been shown to control fecal coliform to levels that are safe for discharge. Removal efficiencies for fecal coliform are on the order of <2 MPN/100 ml.

Hydroxyl Systems™ is a proprietary system that provides this biological treatment technology (see Figure 11 and Table 6). The system could treat storm water flows prior to discharge to the receiving waters. The treatment system is modular and may be installed in new or existing systems.

Typical placement is in above or below-ground tanks wherever space is available on-site and hydraulics allow, as shown in Figure 11. While system footprint varies with flowrate and target contaminants, a housing size of 8′ x 40′ is typical.

The process includes the use of air, ozone or other oxidants as both positive flotation mechanism (PFM) and as an oxidant of pollutants. The pollutant oxidation takes place in a oxidation cell that contains the fluidized biofilm carrier elements. This technology is accepted by some permitting agencies for groundwater contamination applications; the fact that this technology is chlorine-free makes it more likely to be accepted by project regulatory agencies for storm water treatment applications.

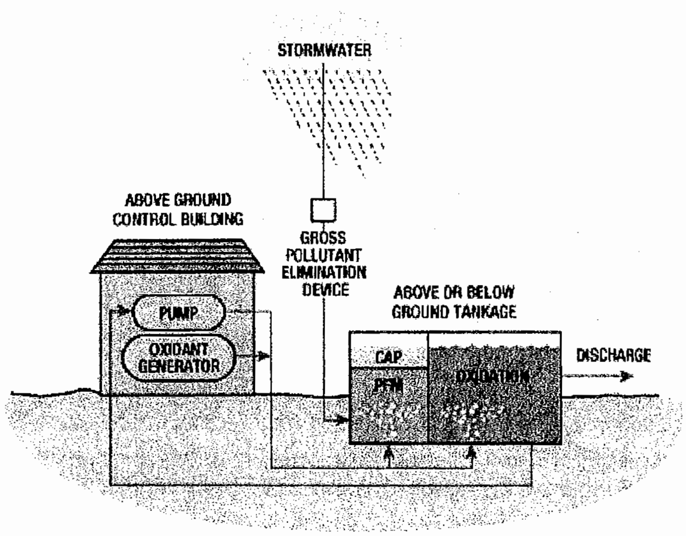

Figure 11. Hydroxyl Treatment System for Storm Water Applications

Table 6 Advanced Oxidation	
Control Measure	**Advanced Oxidation**
TMDL compliance method and performance	Should meet TMDL discharge requirements. No applications/data to confirm for storm water usage.
Cost-related data	Estimated capital cost for a 1,000 gpm (1.4 mgd) system was about $825,000 in 2002. Based on an assumed 10 percent escalation rate since that time and 25 percent for engineering, this would correspond to a current total cost of $1.1 M. ($780K/MGD) These costs include initial purchase and installation, as well as maintenance.
Site-related data	This system would include a 60,000 gallon tank and would require an area of 24 feet by 54 feet (1,300 square feet).
References	Featherstonhaugh (2002)

2.2.2.4 Peracetic Acid (PAA)

PAA is an emerging product that can be used in storm water treatment. PAA is a stabilized equilibrium solution concentrate that is a mixture of peracetic acid, acetic acid, and hydrogen peroxide. It is primarily used as a disinfectant that acts through oxidation. PAA is more effective than chlorine dioxide and has virtually no odor at end-use concentrations. It degrades to water, carbon and oxygen. It does not have disinfection byproducts like chlorine, but does have a residual concentration. These features make PAA a good alternative to common disinfectants such as chlorine, potassium permanganate, or hydrogen peroxide alone. PAA is primarily used in the food and beverage industry, but it also has potential wastewater and storm water treatment applications. Removal efficiencies for bacteria depend on % PAA, dosage, length of contact and bacteria type.

Placement of PAA treatment systems depends on application; such systems are most likely to be placed in underground treatment tanks wherever space is available on-site and hydraulics allow. Manufacturers indicate that application rates should run less than 20 mg/L and typically between 5 mg/L and 10 mg/L. PAA systems generally see removals on the order of 90% and higher for 1-3 hours of contact time.

Costs depend on concentration of PAA (either 6% or 15%), method of application, and include initial purchase and installation of treatment system, purchase of PAA, and maintenance requirements.

PAA has been approved for discharge to land; discharge to surface waters will require obtaining a permit from the applicable project regulatory agency. Residual PAA concentrations and additional permitting requirements remain a concern. See Table 7 for a summary of Peracetic Acid.

Table 7 Peracetic Acid (Biocide)	
Control Measure	**Biocide (PAA)**
TMDL compliance method and performance	Requires controlled storage and post-application facilities to remove residual.
Cost-related data	The cost of application is estimated to be between $150 and $300 per million gallons of storm water treated **(Chemical cost only)**
Site-related data	Footprint to depend on storage facility size.
References	Harvey (2004)

2.2.2.5 Subsurface Flow Constructed Wetlands

Constructed wetlands provide an effective means of treating surface water, urban runoff and wastewater. Free-water-surface constructed wetlands (FWSCWs) are characterized by open water, a variety of submerged and emergent aquatic plants and varying degrees of depth. In sub-surface flow constructed wetlands (SSFCWs), water flows beneath the surface through a gravel matrix out of which wetland plants grow. The gravel provides an approximate thousand-fold increase in surface area for the growth of bacterial biofilms that increase the rate of contaminant degradation. Within the gravel matrix there are distinct oxygen rich (aerobic) and oxygen free (anaerobic) zones where specific microbial processes take place. In both cases, the majority of water treatment is a function of microbial processes on the FWSCW bottom or the biofilm covering the gravel in the SSFCW. The SSFCWs have gained popularity, because the water level is maintained below the media surface thus controlling odor and there is less likelihood of avian nutrient loading (bird droppings). In addition, there are fewer vector (mosquito) issues associated with SSFCW.

Constituents Targeted

SSFCWs have been studied for over 25 years and showed that they are highly effective in the removal of nitrogen (ammonium, nitrate and nitrite), phosphorus (organically bound-P and orthophosphate), suspended solids, biochemical oxygen demand (BOD), heavy metals and pathogenic microorganisms including protozoans (e.g. Giardia), bacteria (coliforms, fecal coliforms and other pathogens) and viruses (bacterial and human). The degree of constituent removal is most often a function of the loading rate, residence time and available carbon (BOD) to drive the microbial processes. Nitrogen is removed via microbial denitrification where the nitrate is converted to nitrogen gas. Phosphorus is taken up by plants and bacteria for metabolic purposes and also precipitates as calcium phosphate on the gravel. Heavy metals either adsorb to the biofilm or form insoluble metal sulfides. The pathogenic organisms often adsorb to the biofilm and are inactivated by the bacterial enzymes, viruses, and plant secretions or eaten by grazing protozoans.

The general range of nitrogen removal is 85-99% for a 4-8 day residence time. Similar percent removals were found heavy metals such as copper, zinc and cadmium in SSF with a 5-day residence time. Indicator bacteria such as total coliform bacteria had a two-log or 99% reduction, fecal coliform bacteria had a three-log or 99.9% reduction and human/bacterial viruses had a 99% reduction with a 5-day retention time.

SSFCW Design

As currently tested by the Orange County Water District (personal communication with Stephen Lyon, OCWD,). The SSFCWs typically are three feet deep and rectangular with the influent applied across the shorter axis. The gravel matrix can use 3/8" or 3/4" pea gravel (see Figure 12). The smaller gravel provides more surface area, but if the application is for non-point source surface waters there can be substantial deposition of non-degradable suspended solids that could lead to clogging. The 3/4" gravel would allow greater porosity and less likelihood of clogging . Construction of a SSFCW begins with cutting into the ground and putting in either a base such as concrete or bentonite clay or some form of impermeable liner such as Hypolon or PVC sheeting. The base has a 1% slope to facilitate the flow and the plumbing is standard schedule 40 PVC tubing.

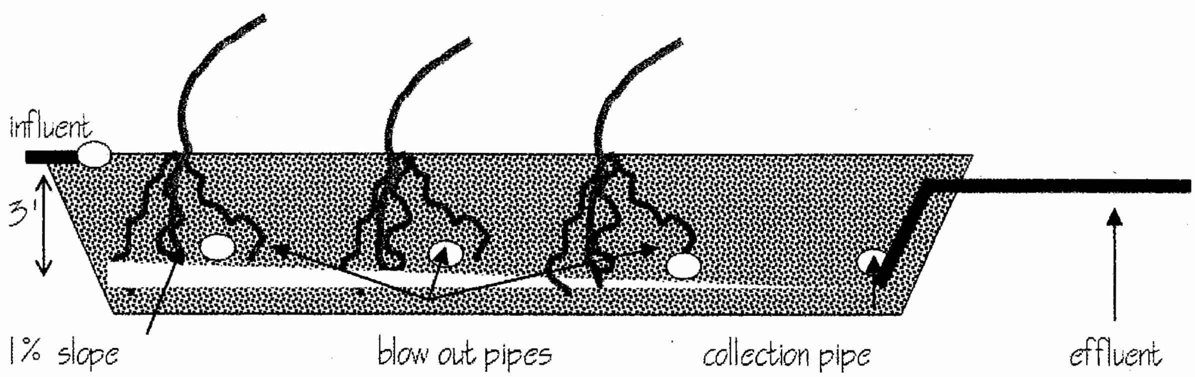

Figure 12. Typical SSF Constructed Wetland Configuration based on OCWD Research

One group of local plants that has been very successful is bulrushes (genus *Scirpus*). They have a deep root system that allows for the transport of oxygen to the anaerobic zone to allow for nitrification of the ammonium and subsequent denitrification of the nitrate. The sequential aerobic and anaerobic zones throughout the wetland improve the possibility of removing/oxidizing/reducing any contaminant in the influent.

A residence time of at least 48 hours would be necessary to impart a partial treatment of the influent. The values on constituent removal listed above were from studies using primary, secondary and dairy farm wastewater. Surface runoff should have far lower levels of contaminants as so should require shorter treatment times.

A typical system configuration would be a cell that is 3.5 feet deep by 100 feet wide by 162 feet long. With an estimated porosity of 0.45 this cell would accommodate a flow of up to

121,000 gallons per day. This corresponds to an area of 7.6 gpd/SF, 131,600 SF/mgd, 3 acres/mgd.

Initial costs for subsurface wetlands are estimated at $26,000 to $55,000 per acre of wetland constructed; excavation and plants make up the bulk of this cost. Maintenance costs are usually a percentage of the capital cost. Specific cost data was not available for this study.

Operation and Maintenance

Once constructed, the SSFCWs need relatively little maintenance. The flow rates should be checked on a weekly basis and the plants should be harvested each year prior to the spring growth cycle. The mulched plants could go into digester tanks to act as a carbon-rich feed source to drive denitrification and other microbial activities. The SSFCW is constructed such that if there is no inflow, the subsurface water level will be maintained save for losses due to evapotranspiration. If there is no inflow for more that two weeks, water should be added to keep the plants from drying out. Prior to the rainy season, the accumulated silt should be flushed out and removed.

Advantages

Since this is a built structure it is far easier to control the physical/chemical/biological processes that occur within the wetland without having to deal with issues such as endangered species habitat, vector control or other aspects of permitting. It also offers the possibility of controlling the residence time that has a direct impact on the quality of the effluent. This technology is accepted by all project permitting agencies.

See Table 8 for a summary of Subsurface Flow Constructed Wetlands.

Table 8
Subsurface Flow Constructed Wetlands

Control Measure	Sub-surface flow constructed wetlands
TMDL compliance method and performance	Should meet TMDL discharge requirements. No applications/data to confirm for storm water usage.
Cost-related data	No specific data available, estimated $50-200K/MGD
Site-related data	Requires an area of about 3 acres/mgd
References	Lyon (2002) and Susilo (2003)

2.2.3 Capture, Store, Treat and Beneficially Reuse

This option involves diverting collected urban runoff, storing it as necessary, treating it, and beneficially reusing it as irrigation supply. Reuse options include landscape irrigation, industrial use, toilet flushing in buildings with dual piping systems, and other non-potable water uses. The Santa Monica Urban Runoff Recycling Facility (SMURRF), formerly the Santa Monica Dry-Weather Runoff Reclamation Facility (DWRRF), can be used as a model for the treatment plant that would be required to treat the runoff. It must be recognized that the SMURRF was designed to collect and treat dry weather runoff from two storm drains in the City of Santa Monica (the Pico-Kenter and Santa Monica Pier Storm Drains). Thus, it was designed to accommodate a relatively small and constant flow.

The SMURRF has an average capacity of 500,000 gallons per day (gpd) and a peak capacity 750,000 gpd (Antich, 2002). It employs a rotating drum screen and cyclone-type grit chamber to remove grit, small particles and debris, a dissolved air floatation (DAF) system to remove oil and grease, microfiltration and ultraviolet (UV) disinfection. A simplified schematic flow diagram of the SMURRF is presented in 13.

The finished water is used for landscape irrigation at various sites. Since there are no water reclamation regulations dealing with storm drain runoff, the SMURRF was designed to produce California Department of Health Services (DHS) Title 22 effluent for biological oxidation (CH2M HILL et al., 1997). This means that the effluent will meet the turbidity and disinfection criteria for irrigation in unrestricted access areas. The SMURRF does not include facilities to remove total dissolved solids (TDS). However, treatment processes that do not increase TDS were selected. For example, ultraviolet (UV) disinfection was selected instead of chlorine disinfection because the chlorination equipment requires the addition of chlorine and sulfur dioxide, which result in increased TDS levels. The SMURRF was designed to achieve a TDS limit of 1,000 mg/L. Space has been allocated for the future installation of reverse osmosis (RO) facilities should the need arise.

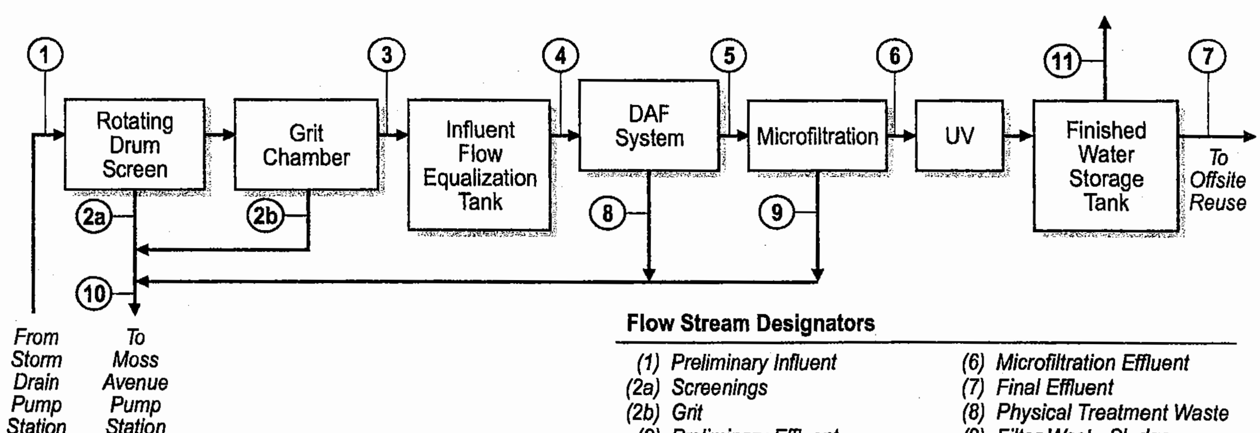

Figure 13. SMURFF Schematic Flow

Flow Stream Designators

(1) Preliminary Influent	*(6) Microfiltration Effluent*
(2a) Screenings	*(7) Final Effluent*
(2b) Grit	*(8) Physical Treatment Waste*
(3) Preliminary Effluent	*(9) Filter Waste Sludge*
(4) Physical Treatment Influent	*(10) Total Flow to Moss Av. PS*
(5) Physical Treatment Effluent	*(11) Plant Water, Total*

The total capital costs for the SMURRF were $9 million. Of this, about $6.3 million was for treatment, and $2.7 million was for the distribution system. Approximately 12% of the plant cost, or $750,000, was related to architectural components specifically designed to incorporate public art and education. A 500,000-gallon tank for the raw and treated water was designed to accommodate tight site conditions. One side of the tank is a retaining wall for a highway on/off ramp (Pacific Coast Highway) The estimated cost of storm water treatment is estimated at $2.9 million ($5.80/gal. or $5.8M/MGD).

A similar facility to treat wet weather runoff would be much larger and would require large storage volumes upstream and downstream of the plant. The treatment process, however, would probably be similar. See Table 8 for a summary of the Capture, Store, Treat and Beneficially Reuse option.

Table 9

Capture, Store, Treat, and Beneficially Reuse

Control Measure	Capture, Treat & Reuse (SMURFF)
TMDL compliance method and performance	Should meet TMDL discharge requirements. No applications/data to confirm for wet weather runoff usage.
Cost-related data	$5.8M/mgd
Site-related data	No data available
References	Antich (2002)

2.2.4 Capture, Store, Treat and Inject

This option deals with disposal by injection back into the groundwater table on a large scale. Subsections 2.1.3.5 and 6 address some of the physical limitations of infiltration on a small scale. Technical Memorandum 3 will address some of the regulatory requirements of injection.

As defined in the Task 5 Technical Memorandum, there appears to be no options for infiltrating runoff on a large scale within the Jurisdiction 2 and 3 areas. There may be options to transport runoff to the San Fernando Valley area where the soils types are more appropriate for infiltration. This, however, would appear to be an uneconomical option. For this purposes of this study, it is assumed that Title 22 treatment similar to that required for beneficial reuse would be required to accommodate this option.

2.2.5 Extend Outfall and Discharge to Ocean

This option involves disposing of runoff using ocean outfalls so that beach impacts are minimized. It should be noted that this option is not consistent with the integrated water resources management approach that is a goal of this study. The runoff would be treated solely as a waste without regard to potential beneficial use opportunities.

An outfall system generally consists of an inlet structure, pumps, an outfall pipe, and diffusers to distribute the flow over a wide area to promote dilution. Considerations in designing an outfall system include the outfall length and frequency of use.

The length of an outfall must be adequate to get beyond the wave wash and to attain proper dispersion to reduce the possibility of the discharge flowing back to the beach area. As an example, the required length for an outfall disposing of wastewater treated to a primary treatment level is 3,300 feet (Metcalf and Eddy, 1972).

With regard to frequency of use, an outfall can easily become plugged by settled solids or by bacterial growth if a minimum velocity, generally above 2 feet/sec, is not maintained (Metcalf and Eddy, 1972). Bacterial growth can plug outfall diffusers quickly if flow is not maintained. Thus, if flows are sporadic throughout the year, an alternate flow source would be required to maintain a minimum flow in the outfall.

The alternatives for a constructing an outfall system to dispose of wet weather runoff in the Jurisdiction 2/3 region include extending each existing outfall, building a new one, or using an existing outfall. For this study, it was assumed that extending the existing outfalls or constructing a new outfall would not be feasible due to the difficulty of gaining regulatory approval and the high cost of constructing long pipes in marine conditions. One option that could be considered is using the one-mile outfall at the Hyperion Treatment Plant.

The HTP has three ocean outfalls: one-mile, five-mile and seven-mile. The one-mile outfall was put in operation in 1951. By the mid-1950s, further clean up of the recreational waters in the Santa Monica Bay was required, making longer outfalls necessary. In response to this need, a five-mile outfall was constructed and put in operation in 1961, becoming the main effluent discharge outfall for HTP. While the one-mile outfall has not normally been in use since the five-mile outfall was placed in service, it is maintained in standby condition in case of an emergency to periodically discharge chlorinated secondary effluent during extremely high flows, power failures, storm water runoff, and to test the operability of the emergency bypass gates.

According to research by City personnel, the projected pumped capacity of the five-mile outfall is 765 mgd. Flows exceeding the pumping capacity would be discharged by gravity through the one-mile outfall. In case of a pump or power failure, all flows exceeding the gravity capacity of the five-mile outfall would have to be discharged through the one-mile outfall.

For the purposes of this study, it was assumed that runoff from the Dockweiller area only would be routed to the outfall. The estimated runoff from this area for the target storm is about 50 million gallons. Since the 1-mile outfall serves as the emergency backup for the HTP effluent disposal system, it is assumed that the runoff would be stored.

The distance for transporting the runoff was estimated to be 10,000 feet. It was assumed that all of the runoff would be transported in one day. At an average velocity of 5 feet per second, this corresponds to a pipe diameter of 18 inches. At an estimated unit cost of $11 per diameter-inch per foot of pipe, the estimated construction costs for the conveyance pipe is $200 per foot. A 10,000 foot pipe would cost an estimated $2 M.

Based on information prepared for the IRP, the estimated pumping operations and maintenance cost is $200 per million gallons for a total estimated O&M cost of $10,000 per rain event (City of Los Angeles, 2003). The capital cost is estimated at a rate of 15 percent of the estimated annual O&M cost if the pump station operated continuously. Thus, the estimated capital cost for the pump station is $0.5 M. The total estimated cost for this option is $2.5 M plus storage. At a flowrate of 50 mgd, this corresponds to a unit rate of $50,000/mgd (see Table 10).

Table 10

Outfall Disposal

Control Measure	Outfall disposal using the existing HTP 1-mile outfall
TMDL compliance method and performance	Should meet TMDL discharge requirements but does not meet project goal of providing opportunities for integrated resources approach
Cost-related data	About $2 M to construct a conveyance pipeline to accommodate a runoff flow of 50 mgd from the Dockweiller area and $0.5 M for a pump station. This corresponds to a unit cost of about $50,000/mgd. $200 /MG for operating the pump station
References	City of Los Angeles (2003)

3.0 Conclusions

A number of potential treatment options are presented here. Final recommendations will be based not only on technology, but on feasibility, costs, siting, permitting, reliability, and maintenance. However, modifications to the TMDL regulation may allow for adjustments to recommended treatment options, it is suggested here that should new technologies be proposed, they be proposed early in implementation to determine whether there is long term feasibility.

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