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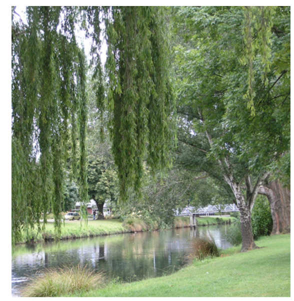
THE GREEN VISIONS PLAN

for 21st century southern california



10. Stormwater Quality Control through Retrofit of Industrial Surfaces

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Cover Photos: Industrial surfaces - parking lots and commercial buildings, Signal Hill, California; Streamside park, Christchurch, New Zealand (top right); Retention basin also serving as wildlife habitat, Christchurch, New Zealand – Joseph S. Devinny.

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THE GREEN VISIONS PLAN

for 21st century southern california

The mission of the Green Visions Plan for 21st Century Southern California is to offer a guide to habitat conservation, watershed health and recreational open space for the Los Angeles metropolitan region. The Plan will also provide decision support tools to nurture a living green matrix for southern California. Our goals are to protect and restore natural areas, restore natural hydrological function, promote equitable access to open space, and maximize support via multiple-use facilities. The Plan is a joint venture between the University of Southern California and the San Gabriel and lower Los Angeles Rivers and Mountains Conservancy, Santa Monica Mountains Conservancy, Coastal Conservancy, and Baldwin Hills Conservancy.

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EXECUTIVE SUMMARY

1. This study examined opportunities for municipalities or other agencies to rehabilitate industrial surfaces for the purpose of stormwater quality control in the Los Angeles region. Two approaches were considered. Partnerships with industry could produce facilities that infiltrate the stormwater that falls on the site, or that also infiltrate stormwater from the surrounding area. Purchases of sites could produce facilities that remediate stormwater from a much larger watershed in a manner compatible with public use such as wildlife habitat or recreational park.
2. Surfaces that are amenable for stormwater quality control are mostly industrial, but include others such as schools. Together these constitute about 25% of developed land in the Los Angeles region. Utilized in partnership facilities that would remediate stormwater falling on the facilities, these could be used to remediate as much as 20% of the polluted stormwater in the region. Utilized as purchased and fully dedicated sites, the area in total is sufficient to remediate all of the polluted stormwater generated in the region. It is not certain, however, that available sites are distributed appropriately to match the need.
3. Older industrial sites (those occupied by industrial uses for a longer period of time) may be more difficult to use because of possible contamination and the presence underground appurtenances such a pipes, wires, and foundations. However, this varies from site to site, and a well-characterized site may be usable even if it has been occupied for many years.
4. Partnerships with industry will be possible where there are benefits for both the industry and the municipalities or agencies. Industry may improve its public relations, become better ready for future legislation, obtain better and more modern facilities, develop environmental mitigation credits, and improve the esthetic value of their sites. The Municipalities will be able to develop a stormwater quality control facility without paying for land or maintenance. The most important opportunity is parking lot rehabilitation.
5. Purchase of sites will allow development of facilities optimized for stormwater quality control and compatible uses. While the costs of purchase are high, such a site could handle water from a substantial surrounding watershed and provide valuable multiple-use benefits.
6. The predicted costs per acre of watershed run from $31,000 to $62,000 for partnerships that modify parking lots to handle on-site water. Creation of an infiltration gallery beneath a parking lot may be much cheaper--$18,000 per acre of watershed—if the site owners are willing to accept responsibility for maintenance. Purchases, because of the expense for land, may cost from $36,000 to $94,000 per acre of watershed. However, the multiple-use benefits will be far greater. Costs will vary substantially with specific site characteristics, so it is likely that carefully chosen sites will be significantly cheaper that “average” sites. In particular, municipalities may already own land that could be used at no cost as an optimized stormwater quality control site. This would be exceptionally economical.
7. A general strategy for rehabilitation is suggested. For a given watershed, efforts should first be made to locate low-cost land for purchase. At the lower end of the predicted range, costs are competitive, and the multiple-use benefits will make the acquisitions particularly attractive to municipalities. Where there are portions of the watershed that cannot be served in this way, efforts should be made to form partnerships that can build infiltration galleries. Finally, in areas where soil quality will not support infiltration galleries, partnerships for infiltration of on-site water should be pursued.

INTRODUCTION

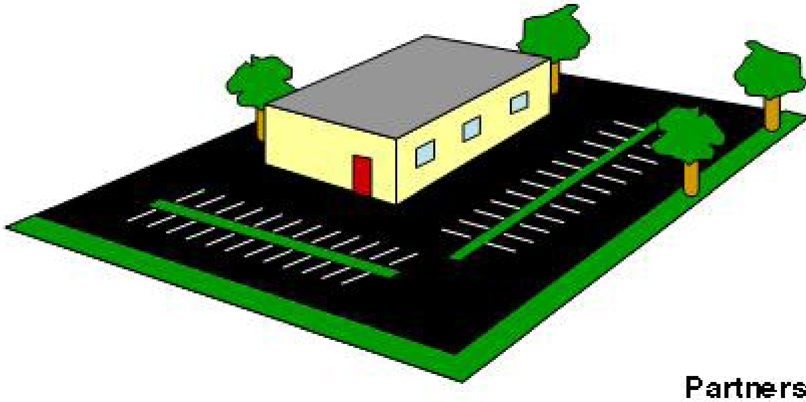
Restoration of more a more natural environment in the greater Los Angeles area—establishment of recreational green space, wildlife habitat, and more naturalized rivers—is inevitably closely tied to the area's systems for stormwater quality management. Green space and habitat will be economically more attractive if they are created as multi-use facilities that also serve runoff infiltration. Rivers can be naturalized only if the water quality is sufficient to support wildlife and allow human contact. Any regional hydrologic system that does not provide safety from floods will not be politically and economically sustainable.

Industrial surfaces—buildings, parking lots, and plant facilities—occupy a substantial portion of the land in the Los Angeles region. Almost all of these are currently designed simply to avoid ponding and to transfer water rapidly to the storm drain system. They prevent infiltration of rainfall into the soil, increasing the fraction of rainfall that enters the storm drains after a storm—the "runoff coefficient". The runoff coefficient for the Los Angeles area is now about 55%, in comparison to the 5% that is thought to have been the case before widespread modification of the landscape. The loss of infiltration capacity reduces replenishment of the local groundwater supply and increases flooding. Industrial surfaces contribute to the increased runoff coefficient and frequently include pollutant sources such as manufacturing processes, cars and people.

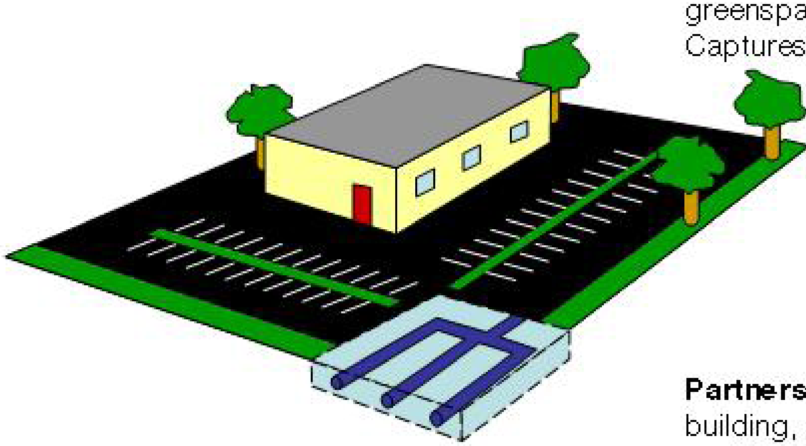
Rehabilitation of industrial surfaces thus represents a substantial opportunity for improvement of the hydrologic system in the Los Angeles area. Two administrative approaches are considered in this study. The first would involve the formation of partnerships between the municipalities or public agencies and industry. In these partnerships, industries would continue to operate on their sites while rehabilitating their stormwater systems to promote detention, infiltration, and treatment. The agencies and the industrial partner would share the cost. This would produce a multiple-use facility, but the primary use would be the original industrial function of the site, most likely parking. It would be necessary to maintain the function of the site even during rainstorms. Working facilities generally find parking space in short supply, and indeed, are often required by municipal ordinance to maintain the current space. For this reason, it is presumed that large surface detention facilities would not be possible. Similarly, while greenspace and habitat would be included where possible, as gardens and green strips, it is not anticipated that more than 10% of the land would be converted to this purpose. Converted facilities would either consist of porous pavement and infiltration trenches to handle the water falling on the site, or subsurface infiltration galleries to handle that water plus additional water from off site (Figure 1).

In the second approach, industrial facilities would be purchased outright and converted to multiple-use facilities that include runoff quality control. A stormwater park, for example, could be created that would combine substantial runoff detention and infiltration capacity with other uses. Because rainfall occurs in Los Angeles only about 22 days per year, it would be possible to combine runoff detention, infiltration, and treatment within recreational facilities such as baseball or soccer parks or with wildlife habitat. Because these facilities could be optimized for stormwater control functions, and could be flooded, they would be constructed to collect not only the water that falls directly on them but also runoff from a watershed up to 120 times their size. In this approach the municipality or agency would buy the land and take responsibility for its maintenance, but a much larger watershed would be served.

Land cover at industrial sites can be divided into three categories: rooftops, working yards, and parking lots. Rooftops collect rainfall and direct it to drains, and provide no opportunity for infiltration short of removing the building. Water from buildings is typically lightly polluted with dust, settled air pollutants, bird droppings, and roofing compounds. While it cannot be managed within the outline of the building, it is easily collected in cisterns for subsequent treatment or infiltration in the surrounding area.
Working yards, dedicated to machinery, dismantled cars, materials storage, and other uses, are highly various. Dismantled cars release trace metals and hydrocarbons, and industrial equipment can release



Partnership first alternative: 30% building, 70% parking area, greenspace in medians, borders. Infiltration trench for roof runoff. Porous pavement and greenspace intercepts remaining water. Captures only water falling on the site.



Partnership second alternative: 30% building, 60% parking area, greenspace in medians, borders. Subsurface infiltration gallery occupies 10% of site, collects water from watershed 12 time site area.

Purchase: Site excavated to 24", converted to greenspace for wildlife habitat or recreational use. Site can intercept water from watershed 64 times its own area.

Figure 1. Schematic representation of analyzed alternatives.

toxic substances. Control of runoff from these yards falls under the jurisdiction of the Toxic Substances Control Board or the Los Angeles Regional Water Quality Control Board. Many of these facilities require constant access for vehicles, and so would not be amenable to multiple-use management including runoff control. Others might represent significant opportunities for rehabilitation, but they would have to be considered individually, and controls would likely be more expensive.

A substantial portion of the industrial space in the Los Angeles area is in the form of parking lots. Huge lots surround industrial facilities, plants, and shopping centers. A significant amount of work has been done on stormwater control methods for use in parking lots, showing that it is possible to maintain the original use (providing parking for customers and employees) while gaining substantial runoff control. Land that is currently used for medians and decorative landscaping can be converted to stormwater detention and infiltration. Areas "beyond the bumpers"—between the parking spaces—can be used for detention and infiltration, and various forms of porous pavement have been developed that will allow water to penetrate the surfaces being used as parking spaces and driveways. Some pollutants are released by cars, including dripping hydrocarbons and copper particles from brake linings, but it is likely that these can be handled safely by simple soil-barrier infiltration systems.

In contrast to working yards, parking lots are quite similar, whether they provide space for employees at a refinery or customers at a shopping mall. Methods for parking lot rehabilitation are relatively well established, and there is a very large area in the Los Angeles region over which they could be applied, so they have been chosen as the focus for investigation of partnerships with industry.

Definitions

This report describes possible efforts to control runoff quantities and quality. "Runoff" can include both stormwater, from rainfall, and dry weather runoff, which comes from car washing, lawn watering, and other activities that allow water to escape to the stormwater system. Dry weather flows are typically steadier and much smaller than those for stormwater, but may be even more polluted. In this report, the term "stormwater" is used generally, although facilities receiving water from surrounding watersheds will receive some dry weather flow as well.

Efforts to control stormwater pollution may include both "source control" and "structural best management practices" (structural BMPs). In general "source control" refers to efforts to prevent the release of pollutants into stormwater, while "structural BMPs" are simple treatment systems that remove pollutants from collected streams of the water after the contamination has occurred. Where it is possible, source control is generally cheaper—it is easier to avoid pollution than to clean it up afterwards. However, the highly dispersed nature of stormwater pollutant sources often makes source control impossible. Further, structural BMPs including infiltration have the advantage of reducing water discharge volumes and recharging groundwater.

Rehabilitation of parking lots for the purpose of stormwater control lies at a conceptual boundary. While it is commonly referred to as source control, it is actually managing water that has already been modestly polluted by cars, nearby rooftops or discarded trash. It relies heavily on infiltration, which is typical of structural BMPs. However, it does prevent the parking lot pollutants from entering the general stormwater stream, and it prevents further contamination of the runoff downstream. A subsurface infiltration gallery, built beneath a parking lot and collecting water from the surrounding area, is clearly a structural BMP. The list of structural BMPs that have been developed and employed is long. They have been described in considerable detail in the companion paper (Sayre et al., 2006), and these descriptions will not be repeated here. It is valuable, however, to review their general mechanisms and how they bear on this study.

Infiltration is an important part of the operation for porous parking lot pavements, infiltration trenches, subsurface infiltration galleries, greenspace, and other BMPs. Water is taken up by plants and transpired or passes downward through the soil and eventually enters subsurface aquifers. Pollutants are removed by filtration, adsorption, and biological activity in the soil. However, high concentrations of pollutants can overwhelm these processes, so source control must be used to keep concentrations moderate. Infiltration removes the water from the stormwater collections system, so the pollution is totally eliminated, flood flows are reduced, and valuable groundwater aquifers are replenished. For these reasons, it is considered the most desirable alternative.

Sedimentation refers to the settling of particulate matter to the bottom of a retention pond or wetland. Because most of stormwater pollutants are particles, or are adsorbed on particles, sedimentation can significantly reduce pollutant load. It is relatively slow, however, and requires that the water be detained for hours or days. Polluted material will collect at the bottom of the pond and may require removal. This approach is less desirable because the water must be returned to the stormwater flow and is lost as a resource. Treatment is only partial because the smallest particles will not settle out.

Biological treatment occurs when microorganisms in wetlands, bioswales, and soils come in contact with the water. Hydrocarbons can be converted to carbon dioxide and water, disease organisms may be killed, other contaminants may be absorbed, and dissolved pollutants may be converted to particles that are removed by sedimentation. Biological treatment requires time and space, and its best utilization is in treatment wetlands, which provide an ideal environment for microbiological activity as they provide habitat for larger organisms. Plants also take up some pollutants, especially fertilizers, and the roots of plants are important agents in cleaning water during infiltration processes.

Detention or retention refer to holding the stormwater for a period of time. Infiltration systems often detain the water which is collected during a short period of time and allow its infiltration over a period of hours or days. Detention is necessary for effective sedimentation or biological treatment. However, even simple detention and later release will have the benefit of holding the water until after the period of peak flow, reducing downstream flood risk. The detention capacity is an important characteristic for many systems. It determines how much water can be captured during a storm, and therefore how much can be eventually infiltrated or otherwise treated.

Because of the benefits for flood control and aquifer replenishment, and the complete removal of pollutants from the stormwater flow, the alternatives for stormwater quality control considered here rely heavily on infiltration. It is presumed that there will be sufficient source control implemented in the watershed so that this can be done without endangering groundwater quality. In the case of purchased properties, it is presumed that infiltration is done in a “stormwater park” that also supports wildlife and recreational uses. Wetlands could also be included, although their use is somewhat limited by the need for a year-round source of water to maintain plant life (Sayer et al., 2006).

INDUSTRIAL AND OTHER AVAILABLE SURFACES AND THE SCOPE OF POTENTIAL BENEFITS

The possible benefits to the Los Angeles area from rehabilitation of industrial surfaces can be estimated by considering the benefits per acre of rehabilitated land and the acres of land available for rehabilitation. Data from Southern California Association of Governments (SCAG) were used to calculate the percentage of industrial surfaces in Los Angeles County. Schools and some other sites, such as churches, were included. They are not specifically "industrial", but their large parking lots and open areas constitute equal opportunities for construction of stormwater facilities.

In their study, a geographical information system was used to define regions of land use in the county, and then to sum the areas devoted to each use (Southern California Association of Governments, 2000; Table 1). The land uses specified were classified for this study as non-urban (needing no stormwater quality control) and as possible rehabilitation sites on the basis of their SCAG descriptions. "Urban land" was presumed equal to the total minus the non-urban land, and the percentage of urban land where rehabilitation is presumed possible was calculated. Land use categorized as potentially useful for stormwater control amounted to 25% of total urban land area. Of this total, an unknown but likely substantial fraction is roads or sites that support incompatible uses. If the reasonably conservative assumption is made that only 40% of the area defined as potentially usable is actually available, this still constitutes 10% of urban land.

For the purposes of this study, it was assumed that a partnership facility being rehabilitated consists of buildings and a parking lot, and that the facilities are in daily use. Two stormwater control alternatives were evaluated. In the first, retention capacity, in the form of a cistern, bioretention facility, or basins on the lot will be sufficient to retain rooftop flow from a ¾" storm. The parking lot will include retention and infiltration capacity also sufficient to control the ¾" storm. Thus the benefits include complete pollution control and stormwater volume elimination corresponding to a ¾" storm over the area of the site. The ¾" depth was chosen to correspond to the value in the SUSMP rules promulgated by the Los Angeles Regional Water Quality Control Board for new development, and as representing a reasonable goal for rehabilitation efforts. 85% of storms in the Los Angeles area are less than ¾". Further, the "first flush effect" means the first ¾" of runoff from a larger storm will carry a disproportionate portion of the pollutants.

In the second partnership alternative, it is presumed that a subsurface retention and infiltration gallery will be built beneath the parking area. This will allow infiltration of larger amounts of water, so that the facility can manage water collected from beyond the boundaries of the facility. Such a system would be more expensive, but would have greater utility.

Other alternatives for control are possible, including almost all of those described in the companion paper, "Best Management Practices (BMP) for the Treatment of Stormwater Runoff" (Sayre et al., 2006). We have not tried to reevaluate all of these here. It is believed that the alternatives considered demonstrate the range of costs likely to be incurred.

Partnerships in the first alternative (porous pavement) will remediate just the water that falls on them, or 10% of total stormwater. About 50% of stormwater falls on residential areas and may require no remediation. If we assume that the partnership sites are likely to be in those areas where contamination occurs, they could remediate about 20% of the stormwater that requires quality control.

Utilization of all the available sites for the second alternative configuration (subsurface infiltration galleries) will substantially increase their capacity. A gallery might be assumed to have a detention volume equivalent to a depth of 4 feet (The detention volumes is 8 feet of gravel with a porosity of 50%). Assuming a runoff coefficient of 0.55 and a design event of ¾", the gallery could serve a watershed with

Table 1. Land Use and Areas of Potential Rehabilitation

Description of Land Use	Total Area of Land Use, square meters	Non-urban Land Use	Area of possible rehabilitation
High-Density Single Family Residential	1,344,835,826	0	0
Low-Density Single Family Residential	146,715,797	0	0
Mixed Multi-Family Residential	11,441,246	0	0
Duplexes, Triplexes and 2-or 3-Unit Condominiums and Townhouses	9,691,119	0	0
Low-Rise Apartments, Condominiums, and Townhouses	175,218,245	0	0
Medium-Rise Apartments and Condominiums	12,882,083	0	0
High-Rise Apartments and Condominiums	1,722,934	0	0
Trailer Parks and Mobile Home Courts, High-Density	19,830,237	0	0
Mobile Home Courts and Subdivisions, Low-Density	552,762	0	0
Mixed Residential	112,011,430	0	0
Rural Residential, High-Density	7,258,459	0	0
Rural Residential, Low-Density	114,730,369	114,730,369	0
Low- and Medium-Rise Major Office Use	31,753,741	0	0
High-Rise Major Office Use	4,089,790	0	0
Skyscrapers	317,225	0	0
Regional Shopping Center	8,364,314	0	8,364,314
Retail Centers (Non-Strip With Contiguous Interconnected Off-Stree	38,984,503	0	0
Modern Strip Development	90,915,561	0	90,915,561
Older Strip Development	56,345,629	0	56,345,629
Commercial Storage	5,307,898	0	5,307,898
Commercial Recreation	12,441,886	0	12,441,886
Hotels and Motels	6,138,949	0	6,138,949
Attended Pay Public Parking Facilities	1,948,139	0	1,948,139
Government Offices	9,827,091	0	9,827,091
Police and Sheriff Stations	1,449,973	0	0

Fire Stations	2,635,503	0	0
Major Medical Health Care Facilities	9,307,436	0	9,307,436
Religious Facilities	15,974,447	0	15,974,447
Other Public Facilities	5,011,151	0	5,011,151
Non-Attended Public Parking Facilities	1,250,276	0	1,250,276
Correctional Facilities	5,119,107	0	0
Special Care Facilities	5,832,499	0	0
Other Special Use Facilities	2,377,859	0	0
Pre-Schools/Day Care Centers	639,293	0	639,293
Elementary Schools	46,554,025	0	46,554,025
Junior or Intermediate High Schools	17,429,322	0	17,429,322
Senior High Schools	30,887,611	0	30,887,611
Colleges and Universities	22,534,514	0	22,534,514
Trade Schools and Professional Training Facilities	1,458,155	0	1,458,155
Base (Built-up Area)	4,391,204	0	0
Vacant Area	203,249,147	203,249,147	0
Air Field	11,235,620	11,235,620	0
Former Base (Built-up Area)	0	0	0
Former Base Vacant Area	0	0	0
Former Base Air Field	0	0	0
Manufacturing, Assembly, and Industrial Services	176,179,689	0	176,179,689
Motion Picture and Television Studio Lots	4,114,705	0	4,114,705
Packing Houses and Grain Elevators	263,322	0	263,322
Research and Development	6,325,994	0	6,325,994
Manufacturing	418,537	0	418,537
Petroleum Refining and Processing	16,935,984	0	16,935,984
Open Storage	18,301,713	0	0
Major Metal Processing	99,295	0	99,295
Chemical Processing	1,479,912	0	1,479,912
Mineral Extraction - Other Than Oil and Gas	19,583,976	19,583,976	0

Mineral Extraction - Oil and Gas	28,208,533	28,208,533	0
Wholesaling and Warehousing	37,113,717	0	37,113,717
Airports	28,078,296	0	0
Railroads	11,808,835	0	0
Freeways and Major Roads	82,135,514	0	0
Park-and-Ride Lots	1,435,429	0	1,435,429
Bus Terminals and Yards	2,353,666	0	2,353,666
Truck Terminals	5,242,239	0	5,242,239
Harbor Facilities	21,888,527	0	21,888,527
Navigation Aids	11,006	0	0
Communication Facilities	1,902,059	0	1,902,059
Electrical Power Facilities	77,373,211	0	77,373,211
Solid Waste Disposal Facilities	15,256,874	0	0
Liquid Waste Disposal Facilities	4,538,739	0	0
Water Storage Facilities	7,790,873	7,790,873	0
Natural Gas and Petroleum Facilities	3,874,933	0	0
Water Transfer Facilities	12,243,383	0	0
Improved Flood Waterways and Structures	39,855,068	0	0
Maintenance Yards	6,523,974	0	0
Mixed Transportation	11,919,510	0	0
Mixed Transportation and Utility	1,206,356	0	0
Mixed Commercial and Industrial	4,190,450	0	4,190,450
Mixed Urban	2,934,521	0	0
Under Construction	39,342,754	0	0
Golf Courses	47,892,971	47,892,971	0
Developed Local Parks and Recreation	44,153,571	44,153,571	0
Undeveloped Local Parks and Recreation	815,116	815,116	0
Developed Regional Parks and Recreation	13,701,028	13,701,028	0
Undeveloped Regional Parks and Recreation	40,779,225	40,779,225	0
Cemeteries	15,937,491	15,937,491	0

Wildlife Preserves and Sanctuaries	4,213,442	4,213,442	0
Specimen Gardens and Arboreta	2,030,630	2,030,630	0
Beach Parks	7,132,504	7,132,504	0
Other Open Space and Recreation	14,305,846	14,305,846	0
Irrigated Cropland and Improved Pasture Land	237,341,371	237,341,371	0
Non-Irrigated Cropland and Improved Pasture Land	46,404,395	46,404,395	0
Orchards and Vineyards	13,683,832	13,683,832	0
Nurseries	15,809,356	0	0
Dairy, Intensive Livestock, and Associated Facilities	597,774	0	0
Poultry Operations	559,614	0	0
Other Agriculture	4,497,557	4,497,557	0
Horse Ranches	17,322,931	17,322,931	0
Vacant Undifferentiated	6,359,149,686	6,359,149,686	0
Abandoned Orchards and Vineyards	2,167,942	2,167,942	0
Vacant With Limited Improvements	5,895,187	5,895,187	
Beaches (Vacant)	709,942	709,942	0
Water, Undifferentiated	44,758,318	44,758,318	0
Harbor Water Facilities	50,325,420	0	50,325,420
Marina Water Facilities	2,381,669	0	2,381,669
Water Within a Military Installation	1,894,923	1,894,923	0
Totals	**10,296,055,710**	**7,309,586,425**	**752,359,522**
	Total Urban Land =	**2,986,469,285**	
		Percent urban land for rehabilitation =	**25%**

an area 120 times the area of the gallery. However, it is likely that infiltration galleries could occupy only a small portion of the site. Their construction would interfere with any underground equipment, and EPA guidance suggests they should be built only for watersheds up to 15 acres. Thus, it is presumed that the galleries will cover no more that 10% of the site surface, and serve a watershed with an area 12 times the area of the site itself. If all of the available sites were used, this would constitute120% of the total regional watershed. However, it is also likely that infiltration characteristics of much of the land in the area are poor—clay soils are common in this region. Thus a more likely estimate is that widespread installation of galleries could infiltrate about half the region's stormwater. But if it is again assumed that only half of the region's water requires treatment, partnership sites developed with infiltration galleries could handle all of the problem runoff.

Site purchases were assumed to create high-intensity systems capable of remediating water from a surrounding watershed. Again the system is assumed to collect water from a ¾" storm with a runoff coefficient in the surrounding watershed is 0.55, equivalent to a depth of 0.41". If the site is allowed to flood to a depth of 24", it can therefore collect the runoff from a watershed 58 times larger than its own area. Thus control of all stormwater in the region could be accomplished using just 1.7% of the land, a small portion of what is available. If we again assume that only half of the stormwater requires remediation, the needed area is only 0.85%.

In summary, the first partnership alternative could make a substantial contribution to stormwater quality control in the region, while the second partnership alternative or the purchases could theoretically treat all of the contaminated water. Certain caveats are necessary, however. The effectiveness of the sites will vary widely because of topography and soil conditions. Both sites and contaminated stormwater are distributed unevenly, and it may be difficult to match the two throughout the region.

THE INFLUENCE OF SITE AGE

Industrial sites in Los Angeles vary widely in their characteristics and history. Some of the factors that influence their suitability as stormwater rehabilitation sites are likely to be a function of the site age (the period over which it has been utilized as industrial space). Age alone is not a determining factor. A site that has been used as an office building for a hundred years may be more acceptable than a site that has been polluted by ten years of use for auto dismantling. However, long periods of utilization may be associated with some of the factors that require consideration.

Site Contamination

Infiltration devices will be a significant component of most rehabilitated facilities. It will be necessary to ensure that the downward movement of water does not pollute the aquifers below. Soil has a considerable capacity for biodegrading some contaminants and for adsorbing others, and this allows infiltration of lightly contaminated water such as that from rooftops or parking spaces. However, either the biodegradation or adsorption capacities of soils can be overwhelmed by high concentrations of contaminants. Further, if a site has been contaminated more deeply, even modest amounts of infiltration may be sufficient to carry pollutants to the groundwater. Thus infiltration systems should only be built where there is confidence that the soils below are not contaminated.

The possibility of groundwater contamination is frequently raised in discussions of stormwater infiltration. It is important for the political acceptability of infiltration systems that no contamination incidents occur.

Types of contaminants

The soil in urban areas is polluted by a wide variety of contaminants—a condition more pronounced in industrial and commercial areas. The toxicity and mobility of the contaminants vary greatly. The following list categorizes some of the industries and pollutants that are likely to be produced:

- Automotive: metals, organic compounds, solvents, waste oils
- Cosmetics manufacturing: metals, solvents, acids
- Dry cleaning: volatile organic compounds (VOCs), solvents, fluorocarbon
- Glass manufacturing: arsenic, lead
- Hospitals: formaldehyde, photographic chemicals, solvents, mercury
- Landfills: metals, VOCs, polychlorinated biphenyl (PCB), ammonia, methane
- Leather manufacturing: toluene, benzene
- Machine shops: metals, VOCs, dioxin, beryllium, solvents, waste oils
- Munitions manufacturing: lead, copper, antimony
- Petroleum refining: petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylene (BTEX), fuels, oil and grease
- Plastics manufacturing: polymers, phthalates, cadmium, solvents, resins, chemical additives, VOCs
- Semiconductor manufacturing: metals, VOCs, carbon tetrachloride, solvents
- Pulp and paper manufacturing: chlorinated organic compounds, dioxin, furans, chloroform

Pollutants can also be considered according to their chemical properties. This helps to identify the categories of contaminants that are likely to be most troublesome for facility rehabilitation:

- Heavy metals: toxic to humans. Common sources are parking lots, streets, gas stations and rooftops.
- Organic compounds: gasoline, industrial solvents, paint, etc. Can cause major health problems.
- Nitrate-nitrogen: highly soluble and can easily reach the groundwater. Infants and pregnant women

are susceptible to health risks.
- Pesticides: may reach groundwater, but can often be broken down by the bacteria in the soil.

Some of the chemicals, especially hydrophobic organic compounds such as polychlorinated biphenyls and PAHs, might not migrate to significant depths because of their tendency to be adsorbed by soils, but highly soluble substances such as chlorides and nitrates will not be adsorbed. Remediation of contaminated groundwater is often expensive and time consuming and in many cases complete removal cannot be achieved. If a stormwater control system is installed above the area and subsequently the site must undergo cleanup procedures, the only option would be to remove and rebuild the stormwater system. It is necessary to pursue conservative policies to ensure that stormwater control systems do not exacerbate groundwater contamination.

Site age and contamination

The environmental risks of leakage from underground storage tanks increase with time. Corrosion develops as the tank ages. The leaking fuel migrates so that the contamination zone expands and approaches the groundwater table. Additional water infiltration during this period will promote contaminant spread and contamination generally worsens as the site ages.

At older sites, there is a higher probability of undiscovered and unsuspected contamination. Regulations requiring careful management of hazardous materials were generally instituted in the seventies and eighties. Since then, releases have become much less common and records are more complete. However, sites that are quite old may include contaminated soils that have not yet been discovered.

An important measure in this respect is the period since the last time the property was sold. Since the eighties, purchasers have generally been cautious about purchases, requiring investigation of the site history and soil sampling to ensure the absence of contamination before they buy. Thus, a recently transferred property is likely to have been investigated, while land that has been under the same owner for more than twenty years may not.

Among the general categories of the contaminants, some chemicals are used by many industries and some of them are specific to a few. It is useful to know the history of the site, types of industries that have been in place, the period of their operation, the activities, the list of significant spills and leaks, the volume and characteristics of the spilled materials and the remedial actions taken to clean up the area.

Possible Underground Appurtenances

Developed urban land includes underground appurtenances such as pipelines, drainage systems, electrical lines and foundations. Frequently these are left in place once they are no longer in use. To efficiently plan a site for a stormwater control system it is important to have information about these underground structures. The age of the site can be an important factor in this investigation. An older site may have several underground appurtenances with a range of ages, which presents difficulties for BMP installation. Removal of these appurtenances may be expensive. Newer sites usually have the drawings that describe the appurtenances while older sites may lack this information, or the indicated locations may be incorrect. Therefore the decisions about the choice of the site and the control system should include a subsurface assessment. Gathering such information will be more difficult for older sites.

Overall, older sites must be viewed with some caution. A greater investigative effort would be required be before such sites are rehabilitated and particularly before they are purchased. However, such investigations are now routinely done in industrial real estate transactions. If a site is otherwise attractive, the cost of such an investigation may be justified.

PARTNERSHIPS WITH INDUSTRY

It is assumed that a partnership between industry and municipalities or agencies will consist of a legal arrangement in which the two partners agree to share the cost of a stormwater rehabilitation. This would likely specify a period during which the industry agrees to maintain the stormwater control functions of the site. In the event that the site were sold or rebuilt such that the stormwater benefits were lost, the industry would return some portion of the municipality's investment, pro-rated for the amount of time that the site was maintained. For any such agreement to be made, there must be identifiable benefits for both participants. The advantages of the partnership approach are briefly described below.

Benefits to the Industrial Partner

Public relations

As the public becomes more aware of the environmental issues, people are becoming more interested in products and industries that are viewed as environmentally friendly. Partnership in the effort to control stormwater quality, which is an important issue, would be an advantage for industry image-making. A favorable corporate image can also make it easier to sell products and to hire top employees. If the residents in the neighborhood view the company favorably, this may smooth efforts to obtain permits from city agencies.

Future legislation

Early efforts to control stormwater problems may make it easier to comply with possible future legislation. The current law only requires certain industries to produce a Stormwater Pollution Prevention Plan (SWPPP) and obtain a National Pollution Discharge Elimination System (NPDES) permit. However, future regulations may require a broader range of industries to obtain NPDES permits and the process of acquiring a permit might be more extensive.

Better wet weather access

Many existing facilities do not work well during storms. Parking spaces may be flooded, access may be blocked, and facilities may experience water damage. Rehabilitation would alleviate these problems in the facility.

Mitigation credits

Industrial developments are sometimes legally required to mitigate environmental damage by performing some environmental restoration. Stormwater control systems can serve this purpose.

Aesthetic benefits

Parking lots are notoriously unappealing for customers and employees. The rehabilitation approaches envisioned here are heavily dependent on "greening". Much of the area will be converted to plantings, often including trees. Green foliage and shade will appear where only baking pavement was previously present. Infiltration basins will be dry most of the year and can serve as spots for a picnic lunch for employees. Native plants will be used. The overall effect is likely to be a substantially improved appearance for the site. Where trees provide shade for buildings, there will be savings in air conditioning costs.

Benefits to the Municipality or Agency

Reduced costs

Partnership arrangements will not require that the municipality purchase land. This substantially reduces the cost of site rehabilitation. While the cooperative agreements between the municipality and industry cannot be anticipated in detail, it seems likely that maintenance will become the responsibility of the site owners. This would also reduce the costs and administrative burden falling on the municipality.

Public Awareness

Public awareness and participation are key factors for the overall success of urban stormwater management. The public and industry may actively participate in the process without necessarily leading it. The partnerships will help industry to become more aware of the problem and get a chance to be a part of the solution.

Description of Possible Facilities

Rehabilitation of parking areas will primarily be aimed at promoting infiltration. Two alternatives are analyzed in detail here. In the first, it is presumed that the facility will manage only the water that falls on it, so that the capacity required for the ¾" storm is just ¾" multiplied by the area of the facility. It is assumed that this will be accomplished by providing porous pavements in the lot and an infiltration trench to handle rooftop runoff. The second alternative is more ambitious, presuming that a subsurface infiltration gallery will be constructed beneath a portion of the parking lot, greatly increasing its capacity and allowing it to treat water from the watershed upstream from the site.

While there are many other alternatives, such as swales, detention ponds, and others, it is beyond the scope of this paper to analyze them all, and site specific considerations might make such analysis difficult in any case. It is believed that the two cases chosen represent the economic range of possibilities, from an effort to control on-site water to a system for managing significant amounts of runoff from the surrounding watershed.

There are some pollutants in parking lot runoff, including hydrocarbons (oil and grease dripping from cars), trace metals (primarily copper from brakes), and air pollution particulates, but all of these are readily remediated by passing the water through a barrier of ordinary soil. Thus there is little threat to groundwater quality.

The first step in rehabilitating parking areas is regrading. Instead of draining to the street, lots should detain a portion of the water. Vegetated areas should be below the level of parking, and curbs should include cuts, so that water drains into these areas for infiltration (Figure 2).

Secondly, the surface of the lot should be made porous, so that infiltration can occur throughout. Many kinds of porous pavement are available, including porous asphalt and porous concrete. Open concrete pavers can produce even higher rates of infiltration (Figure 3). Durability is a major concern—pavements must be able to support cars and trucks. Typically open concrete pavers can be specified for parking spaces, while the asphalt or concrete are specified for the access lanes, which endure a greater volume and speed of traffic. A combined system of this type should be easily capable of infiltrating a ¾" storm without significant runoff.

Commercial and industrial sites also include buildings that shed all of the water that falls on them and represent no potential for infiltration. The water must be collected and managed in the land surrounding

Figure 2. Greenspace area within a parking lot used for stormwater detention and infiltration.

Figure 3. Perforated pavers used for parking spaces and stormwater infiltration.

the building. For the purposes of this analysis, it was assumed that this will be done with an infiltration trench—an excavation filled with gravel. During a storm, water from the rooftop is conducted to the trench, where it fills the spaces between the gravel and begins to infiltrate into the soil beneath. An infiltration trench can be designed with a detention capacity equal to the volume of water that will drain from the roof during the ¾" storm. Because the porosity of the gravel is about 50%, the trench must have an excavated volume twice that of the anticipated runoff.

Description of a typical infiltration gallery has been provided by EPA (1999). An excavation about ten feet deep is lined with geotextile, and a 6" to 12" layer of sand is placed at the bottom. A perforated pipe manifold, which delivers the stormwater, is placed on the sand. Eight feet of gravel are placed over the pipes, and finally, cover soil is placed at the top. During a storm, water flows through the pipes into the porous spaces in the gravel. Infiltration through the sand and geotextile and into the underlying soils occurs over some period of time after the storm. A pretreatment unit for removal of trash, oil and grease, and large-particle sediment precedes the inlet, and must be cleaned periodically.

Example Designs: Partnership Agreements for a Parking Lot

Analysis for First Alternative

The cost estimate for rehabilitation of a parking lot began with the assumption that the site has an area of one acre, with 30% of the area (13,068 square feet) occupied by a building. The remaining land is devoted to three covers: grass or other plantings are used for aesthetic purposes and for stormwater infiltration, porous asphalt is used for driveways and driving lanes between parking places, and the parking places are paved with open concrete pavers (Table 2).

This analysis indicated rehabilitation partnerships in the first alternative would cost from $62,000 to $124,000 per acre of watershed (= acres of site), with half of this cost being borne by the agency or municipality.

Table 2. Costs for First Alternative Parking Lot Rehabilitation

	% area	size	Cost (low)	Cost (high)	Total Cost (low)	Total Cost (high)
Greenspace	10	3049 sq. ft.	$1.50 /sq.ft.	$5.57 /sq.ft.	$4,574	$17,533
Porous Pavement	30	9147 sq. ft.	$0.50 /sq.ft.	$1.0 /sq.ft.	$4,574	$9,148
Open Concrete Pavers	30	9147 sq. ft.	$5.00 /sq.ft.	$10.00 /sq.ft.	$45,738	$91,476
Infiltration Trench	30 (building)	1620 cu. ft.	$4 /cu.ft.		$6,840	$6,840
Totals	100				$61,366	$124,637
Agency Portion (50%, rounded)					$31,000	$62,000

Analysis for Second Alternative

EPA guidance for construction of infiltration galleries (EPA, 1999) indicates that a gallery with a detention volume of 6000 cubic feet can be constructed for $72,090. Presuming a design storm depth of ¾" and a runoff coefficient of 0.55, such a gallery could serve a watershed of 4 acres. The cost is thus $18,022 per acre of watershed. The system requires a pretreatment basin that must be cleaned periodically, so it is assumed that maintenance costs will be about 10% of construction costs per year, or $1800. Assuming a discount rate of 4%, this has a present worth of $45,000.

Because this option has such a high ratio of maintenance to capital cost, it is assumed that the municipality will build the system and the industrial partner will assume the cost of maintenance.

Benefits to the Municipality or Agency

Multiple Use

Sites purchased by a municipality or agency will be under complete control, and will be rehabilitated as multiple use facilities for the indefinite future. A cooperative agreement will likely have a limited lifetime—industries will not commit the use of their site indefinitely—while a purchased site will be used as long as needed.

A purchased site will be used for the optimal stormwater control option. For example, the retention basin may occupy essentially the entire site, with the bottom of the basin being used as a park. A partnership parking lot rehabilitation will still include substantial areas of pavement, and must be available for parking even during rainstorms.

Flexibility

A purchased site provides more flexibility for future changes. Should the runoff change in quality or quantity because of further urban development, it would be easier to modify the site appropriately. At a site owned by industry the options are limited.

Description of Possible Facilities

A purchased facility will be completely renovated by the municipality and will therefore be used in a wide variety of ways. It could be converted to a wetland, and used for recreation and wildlife habitat as well as stormwater control. It could also be used as an infiltration basin, left dry during most of the season and allowed to flood during storms. This second alternative may be most appropriate in the semi-arid watersheds of the Los Angeles region, where the rainy season is short and the dry season is long. Keeping the wetlands wet during the dry season may involve significant additional cost, while the dry basin can support valuable uses such as athletics, greenspace recreation, or support of wildlife.
For the purpose of this analysis, we assume that a purchased facility will be capable of holding 24" of water during a rainstorm, and will be used for alternate purposes when it is dry. While many other plans are possible, it is believed that this is a typical approach that will provide a typical cost estimate.

Example Designs

These facilities will be essentially like those being built by municipalities to comply with stormwater regulations. The facilities to conduct water from the surrounding watershed to the facility will be expensive, and their planning and construction will require municipal cooperation. However, municipalities are now highly motivated in their efforts to achieve compliance, and it is presumed that they will provide these facilities.

General Examples

Some descriptions of dedicated facilities, with their costs (not including land costs), have been compiled by Devinny et al. (2004) and are excerpted in Table 3.

These results were plotted to determine the relationship between facility capacity and the cost per square mile of watershed served (Figure 4). Only facilities that cost less that $10 million per square mile of watershed were included (Several estimates were much higher. However, it is presumed that these outlier estimates are erroneous, or that if they are accurate, facilities of that kind will not be built.) The figure indicates a considerable economy of scale, as is common in water management projects. In particular,

Table 3. Summary of Case Study Project Costs From Devinny et al. 2004
"I" or "D" refer to Implemented or Designed

Project	I or D	Description	Unit Size, square miles of watershed	Cost, $M	Cost, $M per square mile
		Infiltration Systems			
Fresno Metropolitan Flood Control District Regional Infiltration Basins (NRDC, 1999; Dave Pomaville, 2003)	I	130 turfed or unturfed infiltration basins serving residential areas. Treats or infiltrates 98% of runoff over area of 120 square miles	1		2.5 to 3.7
Study of Stormwater Regulations Cost (Herrerra Environmental Consultants, 2001)	D	Hypothetical calculation of costs for new residential development	0.016	.24	15
Study of Stormwater Regulations Cost (Herrerra Environmental Consultants, 2001)	D	Hypothetical calculation of costs for new commercial development	0.0016	0.28 to 0.57	175 to 356
Wetlands					
Tule Pond, Alameda (Wetzig, 1999)	I	Stormwater treatment pond for urban runoff	0.8	0.36	0.45
Treasure Island, San Francisco Bay (NRDC, 1999: Galvanis, 2003)	D	Wetland treatment system for local runoff	0.65	0.8 to 1.1	1.2 to 1.7
Long Lake Retrofit, Littleton, Mass. (Roy et al., 2003)	I	Swales, constructed wetlands, bioretention cells, outreach	1.5	0.63	0.42
San Diego Creek Natural Treatment System Master Plan (Strecker et al., 2003)	D	Network of open-water ponds and wetlands in Newport Bay drainage, 120 square mile area	2.7	<60	<0.5
Murray City, Utah (NRDC 1999: Hill, 2003)	I	Golf course and wetlands treat runoff from 4.5 miles of I-215 and the city	9.5	1.0	0.11

Dover Mall, Delaware, (NRDC 1999)	I	Wetland installed on mall grounds drains 30 acres of 100% impervious cover	0.048	0.17	3.5
Sun Valley Project, Los Angeles County	D	Combination of various measures for flood and quality control in L.A. Basin	4.4	172 to 297	39 to 68
BMP Treatment Processes					
Oakland Park, Fla, industrial area (NRDC 1999)	I	Oil, grease, sediment, and trash removal by sedimentation and absorbance	0.008	0.261	33
Clear Lake Packed Bed Wetland Filter System (NRDC 1999: FHWA, 2003)	I	Oil, grease, nutrients, trace metal removal for water entering Clear lake	0.2	0.92	4.6
Compost Filter Facility, Hillsboro, Or. (FHWA, 2003)	I	Oil, grease, removal and filtration for highway runoff	0.12	0.12	0.11
Alexandria, Va, airport parking lot	I	Sand filters installed along the borders of a 1.95-acre parking lot	0.003	0.04	12.9
Bioretention Areas, FHWA cost estimate	D	Areas of highly permeable soil planted with trees and other vegetation	6.2		
Underground Sand Filters	D	Porous medium filters placed in underground vaults, appropriate for highly urban areas	8.7		
Dry Swales	D	Broad, shallow vegetated drainways covered with vegetation, usually grass	0.93		
Surface Sand Filters	D	Porous medium filters installed at the surface	2.1		
Filter Strips	D	Flat vegetated drainways covered with vegetation, usually grass	1.2		
Port of Seattle container area cleanup	I	High quality street sweeping with sediment trap catch basins	3.1		
Cost:Area Formulas from FHWA					
Infiltration trenches, FHWA cost estimate	D	Gravel-filled trenches. Infiltration eliminates runoff discharge.	$C_{mi2} = C_A/A$ $= (1/A)*1317*V^{(0.63)}$ $= 1.2*10^6*A^{(-0.37)}$		

Infiltration basins, FHWA cost estimate	D	Open basins, dry at most times, store and infiltrate runoff. Infiltration eliminates runoff discharge.	$C_{mi2} = C_A/A$ $= (1/A) * (V/0.02832)^{(0.69)}$ $= 204{,}000*A^{(-0.31)}$		
Detention and retention wetlands, FHWA cost estimate	D	Wetlands used for treating stormwater, with storage capacity available	$C_{mi2} = C_A/A$ $= (1/A)*168*V^{(0.699)}$ $= 324{,}000*A^{(-0.301)}$		
Detention vaults, FHWA cost estimate	D	Underground reservoirs for storage of runoff to reduce peak flows	$C_{mi2} =$ $(1/A) *38.1* (V/0.02832)^{(0.6816)}$ $= 690{,}000*A^{(-0.3184)}$		
Results from ASCE-EPA BMP Database					
Dry Detention Basins					
I-605/SR-91 EDB	I		0.0013	0.077	60
I-5/Manchester (East)	I		0.0077	0.33	43
I-5 SR 6	I		0.0085	0.14	17
I-75/SR-78 EDB	I		0.022	0.82	38
Wetlands					
Swift Run Wetland	I		1.95	0.049	0.025
Sand Filters					
I-5/SR-78 P&R	I		0.0013	0.22	170
Escondido MS	I		0.0013	0.45	348
Eastern Eastern Regional MS	I		0.0024	0.34	141
Foothill MS (Sand Filter)	I		0.0029	0.48	164
Termination P&R	I		0.0045	0.46	102
LaCosta P&R	I		0.0045	0.23	49
Hydrodynamic Devices					
Jensen Precast (UVA)-Phase II	I		0.00045	0.039	86
I-210/Orcas Avenue	I		0.0018	0.04	22
Jensen Precast, (Sacramento)	I		0.0032	0.062	19
I-210/Filmore Street	I		0.0040	0.05	12
Charlottesville Stormceptor	I		0.0040	0.017	4.2

Sunset Park Baffle Box	I		0.040	0.023	0.57	
Indian River Lagoon CDS Unit	I		0.098	0.055	0.56	
Austin Rec Center OSTC	I		0.15	0.05	0.34	
Grassy Swales						
I-650/SR-91 Swale	I		0.00032	0.11	341	
Cerrito MS	I		0.00065	0.06	93	
1-605/DelAmo	I		0.0011	0.13	115	
I5/I-605 Swale	I		0.0011	0.073	64	
Monticello High School	I		0.0013	0.015	11	
SR-78 Melrose Dr	I		0.0039	0.13	34	
I-5 North of Palomar Airport Road	I		0.0074	0.14	18	
I-650/SR-91 Swale	I		0.00032	0.11	341	

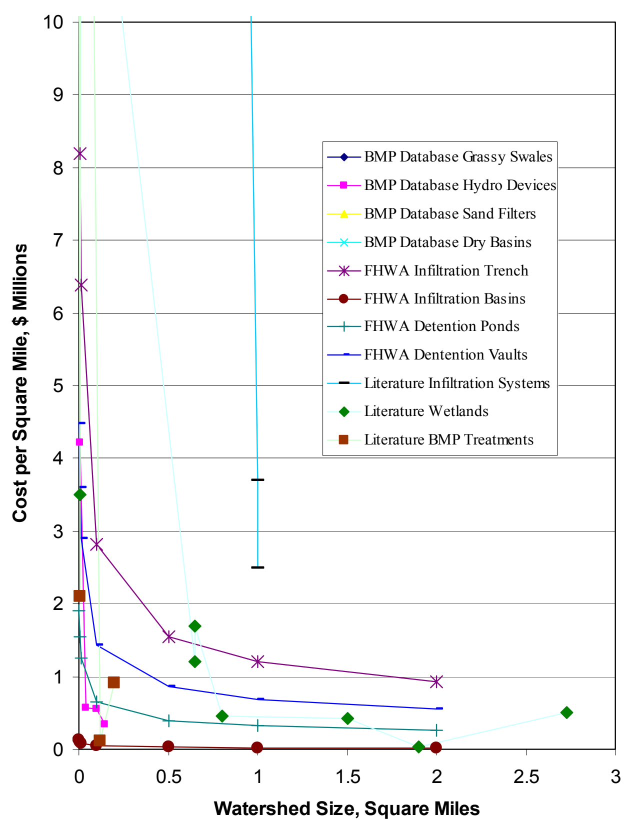


Figure 4. Economies of Scale in Structural BMPs.

costs decrease rapidly as the watershed area rises to one square mile. This corresponds to a facility area of one fifty-eighth square mile, or about 11 acres. While this is not an absolute minimum, it does suggest that purchases will be most economical if the sites chosen for this purpose are large.

Examples from the Sun Valley Watershed Management Plan

The Los Angeles County of Department of Public Works recently prepared a plan for stormwater quality control for Sun Valley, in Los Angeles. This area has no storm drains and is subject to frequent flooding. Because retrofitting with storm drains would be expensive, the plan included several alternatives for flow control, particularly infiltration systems. Some of these will not be built, but they were designed using cost factors that are current for the Los Angeles area, and can be considered realistic proposals. Four of these designs were used as examples of what could be achieved with sites purchased by municipalities. The analysis is taken largely from the Final Sun Valley Watershed Management Plan (County of Los Angeles Department of Public Works, 2004)

The Sun Valley project included several components (Figure 5). Four of those components, Sun Valley Park, Wentworth Park, Stonehurst Park and Strathern Pit are analyzed as examples of what could be done with purchased sites. The Sun Valley project has been briefly described in a companion paper (Sayre et

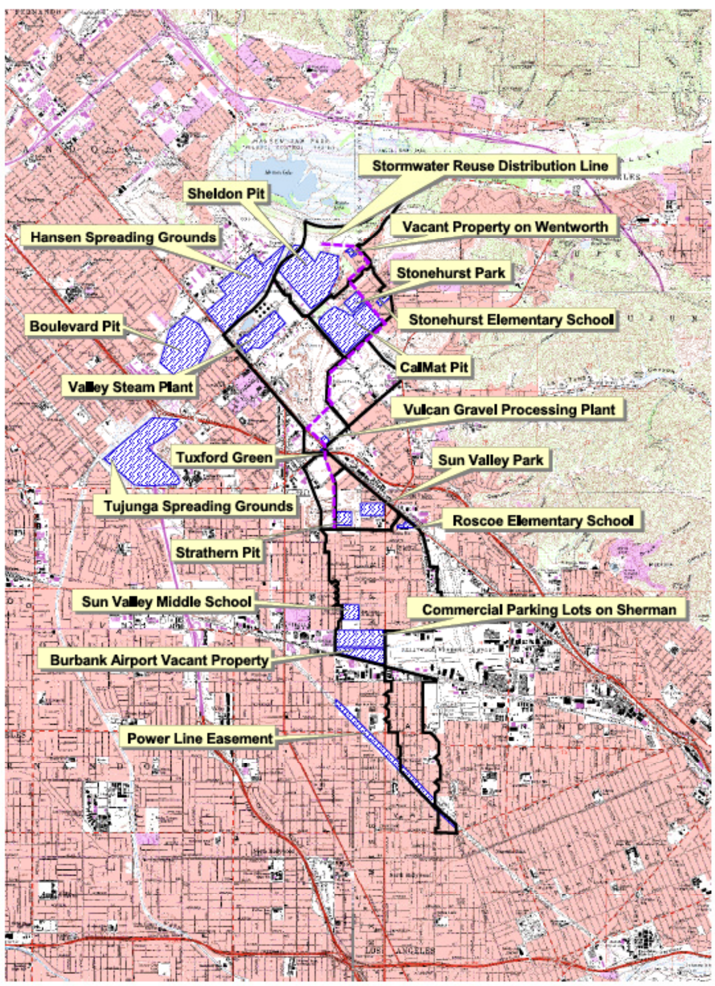


Figure 5. Overview of Sun Valley Watershed Project. The figure is taken from the Final Sun Valley Management Plan (2004).

al., 2006) and is presented in detail in the *Sun Valley Watershed Management Plan* (LADWP, 2003). Four of the sites within the project are described here, primarily in terms of their management capacities and costs.

Project 1: Sun Valley Park

Infiltration of runoff is the primary objective of the Sun Valley Park design (Sun Valley Park is a park within the overall Sun Valley watershed). The flow will be collected and conveyed to the infiltration basins in the park from 45 acres of land surrounding the park. The basins will capture about 48 acre-ft of water. Initial treatment units are planned for the removal of suspended solids, debris, and oil and grease prior to the infiltration. The first flush flow will also be treated for heavy metals (Figure 6).

If this system were used to collect water from the upstream watershed during a ¾" storm (assuming a runoff coefficient of 0.55), it could collect all of the water from 1395 acres. (This calculation uses the assumptions of this report rather than those used for the design in the Sun Valley plan). The capital cost was estimated at $2,800,000. The operations and maintenance costs were estimated at $16,000 per year, with a present worth of $400,000 (assuming an interest rate of 4%).

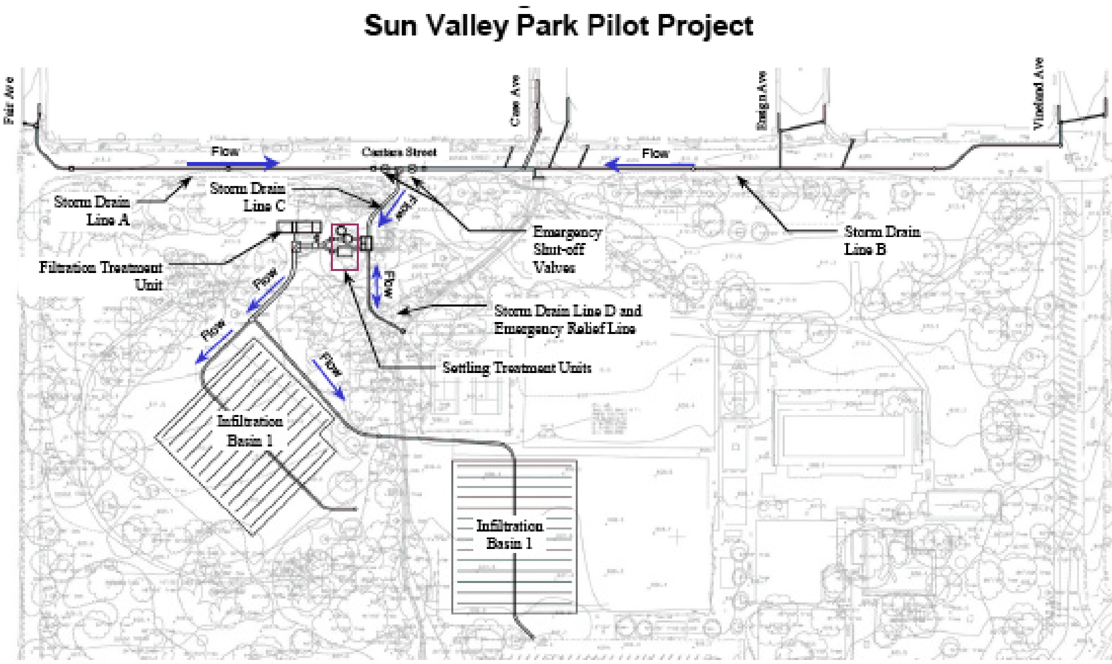


Figure 6. Schematic of facilities designed for Sun Valley Park. The figure was taken from the Final Sun Valley Watershed Management Plan (2004).

Project 2: Strathern Pit

Strathern Pit is an excavation currently used by LA Byproducts as a landfill. The site is situated on the northeast corner of Strathern Street and Tujunga Avenue and has an area of 30 acres. The landfill will be converted to a park with a retention basin and a wetland to be used for stormwater retention, treatment and reuse.

Under average annual conditions, there will be a permanent pool of water in a deep section of the project area. Four terraces are planned at different locations to have dry areas for various uses. The terraces will be planted with vegetation based on their their need for water (Figure 7). In storm events with intensities greater than those of 10-year frequency storms, the site will be temporarily under water.

Concept Design of Strathern Multi-use Park

Figure 7. Diagram of the proposed Strathern Park. The figure was taken from the Final Sun Valley Watershed Management Plan (2004).

The storage volume planned for the site (infiltration alternative) is 736 acre-feet. If this system were used to collect water from the surrounding area during a ¾" storm, it could collect all the water from 21, 395 acres of watershed. The capital cost was estimated at $17,450,000. The operations and maintenance costs were estimated at $239,000 per year, with a present worth of $5,975,000 (assuming an interest rate of 4%).

Project 3: Park on Wentworth

The proposed Wentworth project site is currently a vacant lot (Figure 8). The site occupies approximately three acres. Most of the project area will be excavated to a depth of about two feet.

The park will have a storage capacity of eight acre-feet and peak flow acceptance of two cubic feet per second. The capital cost of the project will be about $816,000. Maintenance costs were not provided in the Sun Valley Watershed Management Plan, but are estimated here as being like those for Stonehurst Park, reduced proportionately according to the areas of the parks. This produces an estimate of $18,000, with a present worth of $450,000 The park could infiltrate the runoff from an area of 233 acres during a ¾" storm.

Project 4: Stonehurst Park

Stonehurst Park is approximately 13 acres (Figure 9). About 20 percent of the site will be excavated to two feet to create a storage capacity of 4.3 acre-ft. The park will receive runoff from an area of approximately 49 acres.

The park will have a storage capacity of 16 acre-ft and peak flow acceptance of 34 cfs. The capital cost of the project will be about $833,000 and operation and maintenance will cost approximately $78,000

Proposed Park on Wentworth

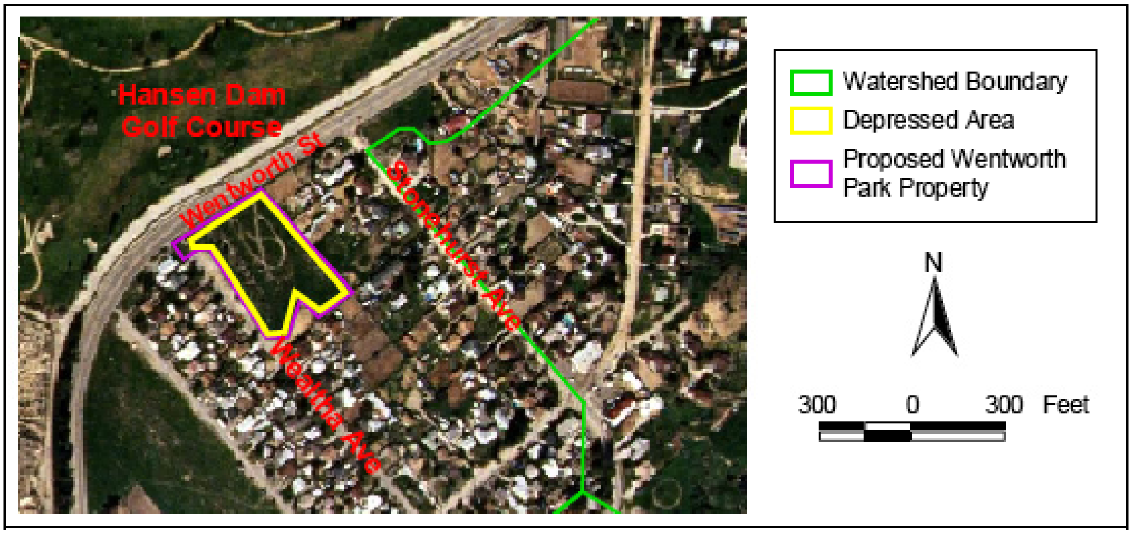


Figure 8. Aerial Photo of Wentworth Park. The figure was taken from the Final Sun Valley Watershed Management Plan (2004).

Stonehurst Park Proposed Infiltration Area

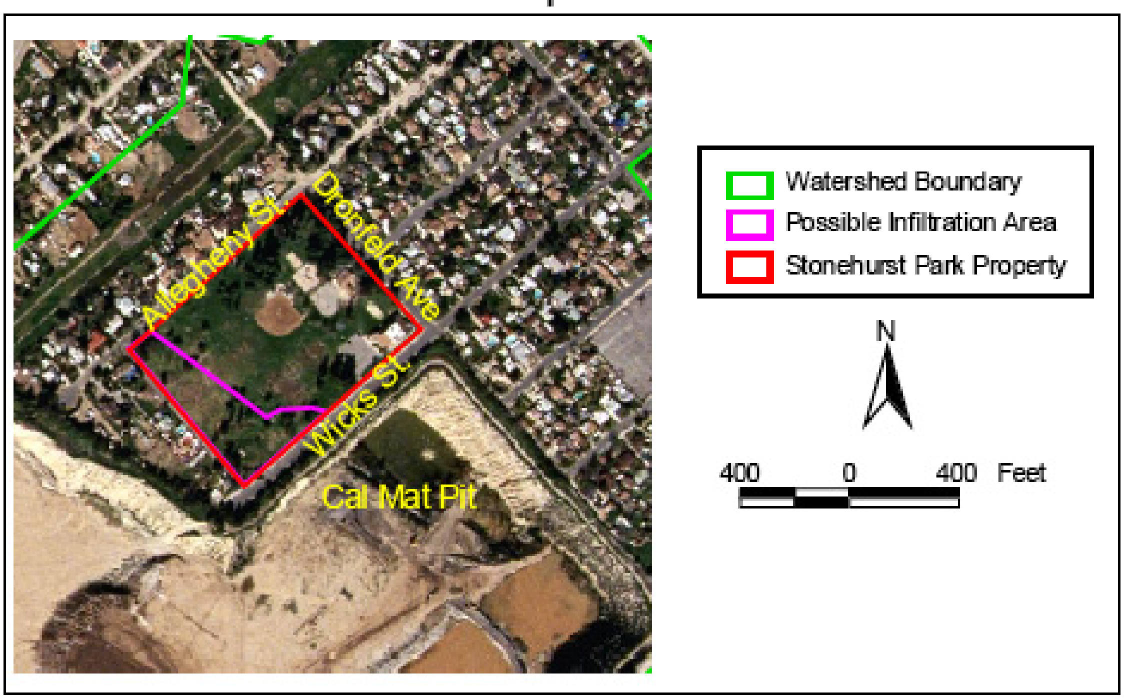


Figure 9. Aerial photograph of Stonehurst Park. The figure is taken from the Final Sun Valley Watershed Management Plan (2004).

(present worth at 4% is $1,950,000). The park could infiltrate the runoff from an area of 456 acres based on a ¾" storm event.

Analysis

Data have been compiled for the four sites and compared (Table 4). A fifth "general trend" example was taken from Figure 4 assuming a watershed area of one square mile. It is recognized that the size of watersheds may be limited by the opportunities for collecting the water and bringing it to the site. In the Strathern Pit example a watershed of 33 square miles is computed. An area this large could be served only by locating the site near a major channel and constructing substantial diversion structures. However, the literature (Table 3) indicates watersheds up to 2.5 square miles, so the presumption of one square mile seems reasonable. The larger examples below are included to provide data on cost per unit watershed area, not because it is expected that sites this large will actually be built.

The four sites may be compared in terms of their costs, the watershed area served, and the cost per unit area. Strathern Pit, which forms a deep reservoir of high capacity, is the most economical of the Sun Valley examples, costing about $1,000 per acre of watershed. The general trend prediction, derived from the larger data set, is $1212 per acre of watershed (Table 5).

Table 4. Cost Summary for Stormwater Infiltration Site Renovations

Site	Area, acres	Cost (purchase + present worth of O&M	Watershed area served, acres*	Cost, $ per acre of watershed
Sun Valley Park		2,800,000 + 400,000 = 3,200,000	1411	2,267
Strathern Pit	30	17,450,000 + 5,975,000 = 23,425,000	21,600	1,084
Wentworth	3	816,000 + 450,000 = 1,266,000	235	5,387
Stonehurst Park	13	833,000 +1,950,000 = 2,783,000	470	5,921
General Trend, 1 square mile	20	500,000 + 276,000 = 776,000	640	1212

*Watershed area is calculated from the detention capacity presuming a ¾" storm and a runoff coefficient of 0.55.

Table 5. Comparison of Approaches
Costs in Dollars per Acre of Watershed

	Land	BMP Construction	Maintenance, present worth	Total (rounded)
Partnerships first alternative				
High Estimate	0	62,000	0	62,000
Low Estimate	0	31,000	0	31,000
Partnerships second alternative				
Estimate	0	18,000	0	18,000
Purchases				
High Estimate [1]	86,200	1,772	5,921	94,000
Low Estimate [2]	34,482	808	1,084	36,000

For partnerships, construction costs are one-half of the total: it is presumed that the other half is borne by the industrial partner. Land and maintenance costs in partnerships are presumed to be fully borne by the partner.

[1] Data for Stonehurst Park
[2] Data for Strathern Pit
Assumes land cost $2,000,000 to $5,000,000 per acre, watershed to land ratio = 58.

COST COMPARISON OF PARTNERSHIPS AND PURCHASES

Partnerships and purchases are best compared on the basis of the cost per acre of watershed served. For the purposes of this analysis it is presumed that the first alternative partnership project is a parking lot rehabilitation that serves only the land being modified (including collection of runoff from buildings on site).

The second partnership alternative is a subsurface infiltration gallery that serves a larger watershed. It is presumed that the purchased site is fully dedicated to stormwater control facility and includes a detention volume 48” deep. For a ¾” storm and a runoff coefficient of 0.55, this means that the site can retain water from a surrounding impervious watershed 58 times its size, and the land cost per acre of watershed is 1.7% of the cost per acre of the facility. It is presumed that the industrial partner will be responsible for maintenance in both cases.

The results indicate a substantial cost advantage for the partnership second alternative, which is the subsurface gallery. It should be noted, however, that this model assumes the site owner will accept responsibility for maintenance. If this assumption is not made, and the present worth of maintenance ($45,000) is added to the estimate, the total cost is $63,000 per acre of watershed, quite similar to the others.

The partnership first alternative estimates range from $31,000 to $62,000, while the range for purchases is somewhat higher, at $36,000 to $94,000. However, given the many approximations in the calculations, the difference is not prohibitive. Purchases are more expensive, in particular because they involve large areas, but they serve much larger watersheds. It is likely that favorable sites will be found with economics competitive with those of partnerships.

These numbers should be viewed with some caution. The following factors may change the results:

- Individual sites vary greatly in their characteristics
- Partnerships were evaluated on the basis of a 50% sharing of construction costs—better deals may be possible.
- Purchased sites were assumed to be entirely devoted to stormwater detention capacity—but it may be necessary in some cases to preserve buildings or valuable ecosystems, preventing excavation of the entire site.
- The surrounding watershed was presumed to have a runoff coefficient of 0.55. For actual watersheds, this number might vary substantially.

The advantage of partnerships is that they do not require land purchases. It is also possible, however, that land already owned by municipalities could be rehabilitated. The interest municipalities have in meeting regulatory requirements makes this a good deal for them. This would provide the high effectiveness of fully dedicated facilities without incurring the expense for land, and would produce lower costs than either of the approaches described.

While costs per acre of watershed may be similar, it should also be noted that the secondary benefits of purchases, which include complete conversion of the site to wildlife habitat or recreational use, are far greater.

CONCLUSIONS

The results of this study support a strong conclusion that rehabilitation of industrial surfaces has the potential to make a significant contribution to stormwater quality control in the Los Angeles region.

Sites might be either rehabilitated for compatible uses in partnerships with industry, or purchased outright to maximize their capacity and their collateral benefits for recreation and wildlife habitat.

The predicted costs per acre of watershed run from $31,000 to $62,000 for partnerships that modify parking lots to handle on-site water. Creation of an infiltration gallery beneath a parking lot may be much cheaper—$18,000 per acre of watershed—if the site owners are willing to accept responsibility for maintenance. Purchases, because of the expense for land, may cost from $36,000 to $94,000 per acre of watershed. However, the multiple-use benefits will be far greater.

These results suggest a general strategy for rehabilitation. For a given watershed, efforts should first be made to locate low-cost land for purchase. At the lower end of the predicted range, costs are competitive, and the multiple-use benefits will make the acquisitions particularly attractive to municipalities. Where there are portions of the watershed that cannot be served in this way, efforts should be made to form partnerships that can build infiltration galleries. Finally, in areas where soil quality will not support infiltration galleries, partnerships for infiltration of on-site water should be pursued.

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