A. Narayanan and R. Pitt
August 31, 2005

Costs of Urban Stormwater Control Practices

Introduction

This report is a consolidated and summary of information obtained from the following major reports on costs of stormwater controls, plus additional specialized references:

- *Costs of Urban Nonpoint Source Water Pollution Control Measures* prepared by Southeastern Wisconsin Regional Planning Commission, 1991.
- *Costs of Urban Stormwater Control* by Heaney, Sample, and Wright for the US EPA, 2002.
- *BMP Retrofit Pilot Program* prepared by CALTRANS, 2001.

This report presents information on the costs of stormwater quantity and quality control devices and methods in urban areas, including collection, control and treatment systems.

This report presents available data from several major reports that have extensively reviewed costs of stormwater controls and programs, plus selected data from other sources. This information is presented in the form given in the reports (tables, equations, and figures), and describes the sources (locations and dates) of the information (if available), for each reference. The last section also has a comparison of the different costs for a typical application. The report also contains a review of Engineering News Record (ENR) cost indices that can be used to adjust the costs for different years and locations to current conditions for many US locations.

Control Practices Cost Analysis Elements

Total Costs

The total costs include capital (construction and land) and annual operations and maintenance costs. Capital costs occur in the first year when the stormwater control is installed unless retrofits or up-sizing occurs. However, capital costs are also subject to financing costs and are amortized over the life of the project. The operations and maintenance costs occur periodically throughout the life of the stormwater control device or practice.

Capital costs

Capital costs consist primarily of land cost, construction cost and related site work. Capital costs include all land, labor, equipment and materials costs, excavation and grading, control structure, erosion control, landscaping and appurtenances. It also oncludes expenditures for professional/technical services that are necessary to support the construction of the stormwater control device. Capital costs depend on site conditions, size of drainage area and land costs that greatly vary from site to site.

Land costs are site specific and also depend on the surrounding land use. The land requirements vary depending on type of stormwater control, as shown in the table below:

Relative Land Consumption of Stormwater Controls

Stormwater Control Type	Land Consumption (% of Impervious Area of the Watershed)
Retention Basin	2 to 3%
Constructed Wetland	3 to 5%
Infiltration Trench	2 to 3%
Infiltration Basin	2 to 3%
Porous Pavement	0%
Sand Filters	0 to 3%
Bioretention	5%
Swales	10 to 20%
Filter Strips	100%

(Source: *The use of BMPs in watersheds and NPDES Stormwater Cost Survey,* U.S.EPA, 1999)

Design, Permitting and Contingency Costs
Design and permitting costs include costs for site investigations, surveys, design and planning of stormwater controls. Contingency costs are the unexpected costs incurred during the development and construction of a stormwater control practice. They are expressed as a fraction of the base capital cost and have been considered uniform for all stormwater controls. During the calculation of capital costs, 25% of the calculated base capital cost should be added that includes design, permitting and contingency fees (Wiegand, *et al.* 1986; CWP 1998; and U.S.EPA 1999.) and 5% to 7% of the calculated base capital cost includes cost of erosion and sediment control (Brown and Schueler 1997; U.S.EPA 1999; and CWP 1998.).

Operation and Maintenance (O&M) Costs
Operation and maintenance are post construction activities and ensure the effectiveness of an installed stormwater control practice. They include labor; materials; labor, energy and equipment for landscape maintenance; structural maintenance; sediment removal from sediment control devices and associated disposal; and litter removal. Similar to the design, permitting and contingency costs, the operations and maintenance costs are usually expressed as an annual percentage of capital costs, or the actual costs can be determined.

Life Cycle Costs
Life cycle costs are all the costs that occur during the life time of the stormwater control device. It includes design, construction, O&M, and closeout activities. Life cycle costs can be used to help select the most cost-effective stormwater control option. Life cycle costs include the initial capital cost and the present worth of annual O&M costs that are incurred over time, less the present worth of the salvage value at the end of the service life (Sample, *et al.*, 2003).

Cost Estimates for Traditional Stormwater Collection Systems

Stormwater Pipelines

Wastewater collection network costs developed by Dajani, *et al*. (1972) by fitting regression models to data from actual construction bids by the following multiple regression equation:

$$C = a + bD^2 + cX^2$$

Where

C = construction cost,
D = pipe diameter,
X = average depth of excavation.

(Source: *Costs of Urban Stormwater Control*, USEPA)

Pipe construction costs as a function of diameter and invert depth was developed by Merritt and Bogan (1973) using graphical relationships. No database accompanied this graph.

Tyteca (1976) presented cost of wastewater conveyance systems as a function of diameter and length of pipe in the following form

$$\frac{C}{L} = K + aD^b$$

Where

C = total capital cost, $
L = length of pipe, m
K = fixed cost, $
D = diameter, m
a,b = parameters
Values of b range from 1.2 to 1.5.

(Source: *Costs of Urban Stormwater Control*, USEPA)

Storm sewer pipe cost was estimated by Han, *et al.* (1980) as a part of an optimization model. They used the following equations:

For $H \le 20$, $D \le 36$ $C = 1.93D + 1.688H - 12.6$
For $H > 20$, $D \le 36$ $C = 0.692D + 2.14H + 0.559DH - 13.56$
For $D > 36$ $C = 3.638D + 5.17H - 111.72$

Where

C = installation cost of the pipe, 1980 $/ft
D = diameter, in.
H = invert depth, ft

(Source: *Costs of Urban Stormwater Control*, USEPA)

To estimate the costs of water resources infrastructure, the U.S. Army Corps of Engineers (1979) developed MAPS software. The software used a process engineering oriented approach for estimating costs. For estimation of costs for gravity pipes, the following data were required:

- Flow (maximum and minimum), MGD
- Length, ft
- Initial elevation, ft
- Final elevation, ft
- Terrain multipliers
- Design life (default = 50 years)
- Manning's *n* (default = 0.015)
- Number and depth of drop manholes
- Rock excavation, % of total excavation
- Depth of cover, ft (default = 5 ft)
- Dry or wet soil conditions
- Cost overrides

The average annual cost is calculated as:

AAC = AMR + TOTOM

Where
AAC = average annual cost, $/yr
AMR = amortized capital cost, $/yr
TOTOM = annual O&M cost, $/yr

The amortized capital cost is:

AMR = CRF * PW

Where
CRF = capital recovery cost
PW = capital cost, $

The capital costs are estimated as

PW = CC + OVH + PLAND

Where
CC = construction cost, $
OVH = overhead costs, $
PLAND = land costs, $

Overhead costs are estimated as:

OVH = 025 * CC

$$CC = AVC * WETFAC * DEPFAC * XLEN * SECI * CITY * CULT * \frac{(1 + Rock * 2)}{255.6}$$

Where
AVC = unit cost of pipe for average conditions, $/ft
WETFAC = wetness factor
= 1.2 for wet soil
= 1.0 for average soil
= 0.8 for dry soil

DEPFAC = depth of cover factor
= 0.725 + 0.048 * DEPTH

DEPTH = depth of cover, ft
XLEN = length of pipe, ft
SECI = ENR Construction Cost Index
CITY = city multiplier
CULT = terrain multiplier
Rock = rock excavation percent of total excavation, in decimal form

$$CULT = \frac{(C1 * 0.8131 + C2 * 0.6033 + C3 * 0.6985 + C4 * 0.7169 + C5 * 0.7911 + C6 * 1.3127)}{100}$$

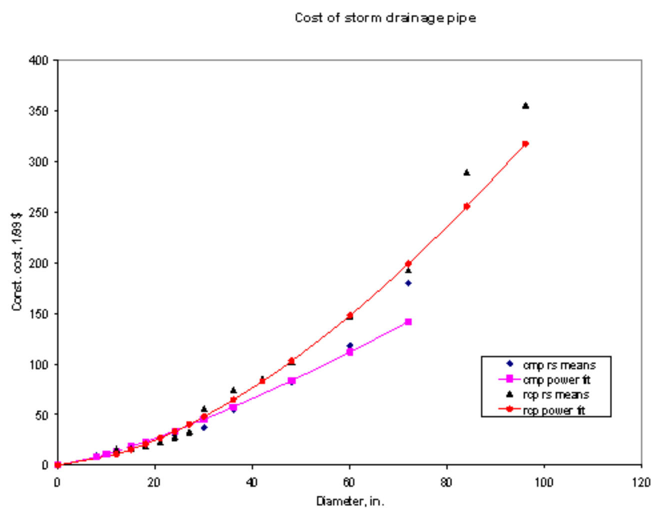
Where
C1 = % open country
C2 = % new residehtial
C3 = % sparse residential
C4 = % dense residential
C5 = % commercial
C6 = % central city

The MAPS formulation is a blend of regression equations and other cost factors. However, the database does not consider all possible costs. For example, the effects of different terrains on costs is not included..

(Source: *Costs of Urban Stormwater Control*, USEPA)

Moss and Jankiewicz (1982) presented the use of life cycle costing for different pipe materials. They considered three types of sewer materials in their case study in Winchester, Virginia: reinforced concrete (service life = 75 years), aluminum coated steel (service life = 25 years), and asphalt-coated galvanized steel (service life = 20 years). The service life depends on various factors such as material durability, in-place structural durability, abrasive characteristics of the drainage, and corrosive characteristics of both ground water and drainage. The least common multiple of service life, 300 years in this case, is used for comparison. The present worth is calculated by comparing the cost of the original installation and three replacement cycles for reinforced concrete, eleven replacement cycles for aluminum coated steel, and fourteen replacement cycles for asphalt-coated galvanized steel. The salvage cost for each replacement was also included.

The following plots only consider pipe diameter and type (not depth). The magnitudes of the possible errors are shown on the following figure when these equations are fitted to published R.S. Means cost estimating values. Cost information provided by R.S.Means includes materials costs, labor costs, and equipment costs. R.S.Means also states that the labor costs it provides includes time spent during the normal work day for tasks other than actual installation, such as material receiving and handling, mobilization at site, site movement, breaks and cleanup. For materials costs, R.S.Means provides the national average materials costs across U.S. The labor costs are the average rates for 30 major U.S.cities. Excavation and bedding costs are discussed in the next subsections and are in addition to these costs.



A nonlinear function was readily apparent and a power function was fitted to the data. The equation below is for corrugated metal pipe (CMP) pipe, using updated RS Means data:

$$C_p = 0.54\ D^{1.3204}$$

Where

Cp = construction cost, January 1999, \$/ft
D = pipe diameter, in.

(Source: *Costs of Urban Stormwater Control*, USEPA)

The following tables show the January 1999 unit length cost data for corrugated metal pipe (CMP) and reinforced concrete pipe (RCP).

Lookup table for corrugated metal pipe (CMP) (updated from RS Means, 1996a)

Diameter (in.)	Cost (January 1999, $/ft.)
8	9.4
10	11.8
12	14.4
15	18.4
18	20.9
24	30.1
30	37.2
36	54.8
48	81.6
60	118.2
72	179.5

(Source: *Costs of Urban Stormwater Control*, USEPA)

Look up table for reinforced concrete pipe (RCP) (updated from RS Means, 1996a)

Diameter (in.)	Cost (January 1999, $/ft)
12	15.7
15	16.6
18	19
21	23
24	27.6
27	32.9
30	55.8
36	74.4
42	85.4
48	102.3
60	146.7

72	192.6
84	288.9
96	355.6

(Source: *Costs of Urban Stormwater Control*, USEPA)

In case of multipurpose facilities, the cost is affected by the other objectives that the stormwater system serves. For example, a combined sewer system transports both wastewater and stormwater. Stormwater detention systems can serve as both quantity and quality controls. Streets serve as traffic conduits and transport stormwater along their edges. One method used to divide the costs of multipurpose facilities for individual purposes is to design systems for each purpose independently, and then design the multipurpose system. The individual costs and the costs for the combined multipurpose facility are prorated to determine the costs for each purpose.

The average non-pipe cost associated with sanitary sewer as a percent of total in-place pipe costs is shown below. These estimated added costs of sanitary sewer pipes were developed by Dames and Moore, 1978.

Category	Pipe Cost (%)
Sanitary sewer miscellaneous appurtenances	7
Manholes	32
Drop manholes	2
Throughfare crossings	13
Stream crossings	1
Rock excavation	2
Pavement removal and replacement	13
Special bedding	1
Miscellaneous costs not categorized	28
Utility reconnection and removal	1
Total	100

(Source: *Costs of Urban Stormwater Control*, USEPA)

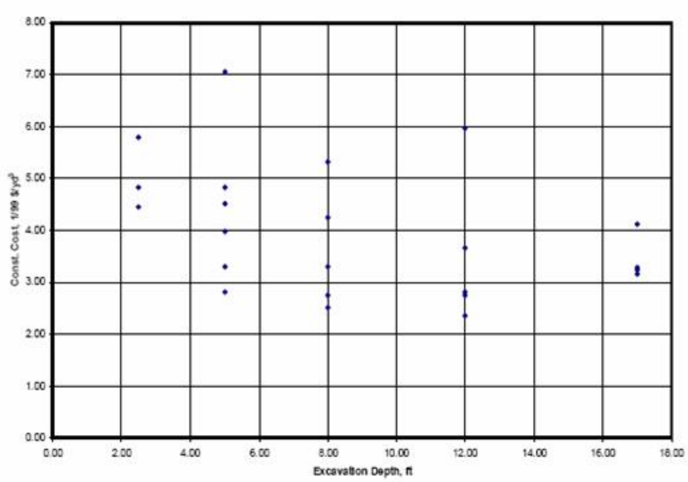
Trench Excavation Costs
Trench excavation costs data depends on fixed costs like labor, equipment and materials costs, but vary with depth and backhoe bucket size (not shown here). The excavation costs for various soils, including blasting and backfilling, are shown below. They include the fixed operations costs such as labor, equipment, and materials costs.

Trench excavation costs, includes backfill and blasting (updated from RS Means, 1996a)

Soil Type	horizontal	vertical	excavation cost (1/99, $/yd^3)
Clay	1	1	7.09
Moist loam	2	1	5.87
Rock	0	1	86.29
Sand	2	1	6.12
Salt	1.5	1	6.72

(Source: *Costs of Urban Stormwater Control*, USEPA)

An example for a moist loam soil is shown below for different excavation depths, indicating the range of values for each depth:



Trench excavation costs (Updated from RS Means, 1996a).

(Source: *Costs of Urban Stormwater Control*, USEPA)

Bedding Costs
Bedding provides sufficient compacted material necessary to protect the pipe from external loading forces. Pipe bedding costs vary with diameter and side slope of trench, and the type of bedding used. In the following example, compacted sand is used as the bedding material and is filled to 12 in. above the pipe. These costs are for January 1999.

Bedding costs (updated from RS Means, 1996a)

Horizontal	Vertical	H/V	Diameter (in.)	Trench width (ft)	Cost (1/99 $/ft)
0	1	0	6	1	0.92
0	1	0	8	2	2
0	1	0	10	2	2.07
0	1	0	12	3	2.12
0	1	0	14	3	3.47
0	1	0	15	3	3.51
0	1	0	16	3	3.57
0	1	0	18	4	3.62
0	1	0	20	4	5.25
0	1	0	21	4	5.29
0	1	0	24	4	5.44
0	1	0	30	6	5.55
0	1	0	32	6	9.72
0	1	0	36	7	9.98
0	1	0	48	8	13.01
0	1	0	60	10	16.23
0	1	0	72	12	23.39
0	1	0	84	1	31.8
0.5	1	0.5	6	2	1.9
0.5	1	0.5	8	2	3.16
0.5	1	0.5	10	3	3.43
0.5	1	0.5	12	3	3.67
0.5	1	0.5	14	3	5.55
0.5	1	0.5	15	3	5.88
0.5	1	0.5	16	4	7.77
0.5	1	0.5	18	4	7.95
0.5	1	0.5	20	4	8.52
0.5	1	0.5	21	4	9.56
0.5	1	0.5	24	6	14.06
0.5	1	0.5	30	6	15.08
0.5	1	0.5	32	7	20.58
0.5	1	0.5	36	8	26.81
0.5	1	0.5	48	10	37.47
0.5	1	0.5	60	12	49.71

Bedding costs (updated from RS Means, 1996a) (continued)

Horizontal	Vertical	H/V	Diameter (in.)	Trench width (ft)	Cost (1/99 $/ft)
1	1	1	72	1	2.9
1	1	1	84	2	4.36
1	1	1	6	2	4.77
1	1	1	8	2	5.25
1	1	1	10	3	7.06
1	1	1	12	3	7.3
1	1	1	14	3	7.56
1	1	1	18	3	8.14
1	1	1	20	4	10.28
1	1	1	21	4	10.59
1	1	1	24	4	11.61
1	1	1	30	4	13.5
1	1	1	32	6	18.46
1	1	1	36	6	20.17
1	1	1	48	7	28.17
1	1	1	60	8	37.4

1	1	1	72	10	51.76
1	1	1	84	12	67.7
1.5	1	1.5	6	1	3.91
1.5	1	1.5	8	2	5.69
1.5	1	1.5	10	2	6.15
1.5	1	1.5	12	2	6.81
1.5	1	1.5	14	3	8.83

(Source: *Costs of Urban Stormwater Control*, USEPA)

The above table is a two-way lookup table relating the horizontal-vertical ratio and the pipe diameter to the projected cost. It relates the horizontal and vertical side slope, diameter, width to bedding cost, which include fixed operation cost and profit. Such a two-way lookup table is considered more accurate than using regression relationships.

Manhole Costs

For individual manhole costs, the following single variable equation developed by Han, *et al*. (1980) can be used:

$$C_m = 259.4 + 56.4h$$

Where

C_m = manhole cost,
h = depth of manhole.

(Source: *Costs of Urban Stormwater Control*, USEPA)

Manhole costs are related to the diameter of the manhole and its depth (i.e. the maximum difference between the ground elevation and the invert elevations of the storm sewers entering the manhole, plus the extra depth for a sump). The January 1999 costs of precast concrete manholes (including excavation, installation, and covers) are shown in the table below. The costs include fixed operations cost and profit, labor, equipment and materials cost for installation of precast concrete manholes.

Precast Concrete Manhole Costs (updated from RS Means, 1996a)

Riser Internal Diameter (ft)	Depth (ft)	Cost (January, 1999, $/unit)
4	4	1860
4	6	2460
4	8	3250
4	10	3970
4	12	4830
4	14	6060
5	4	2310
5	6	3120
5	8	3970
5	10	5070
5	12	6260
5	14	7600
6	4	3150
6	6	4070
6	8	5340
6	10	6710
6	12	8350
6	14	9930

(Source: *Costs of Urban Stormwater Control*, USEPA)

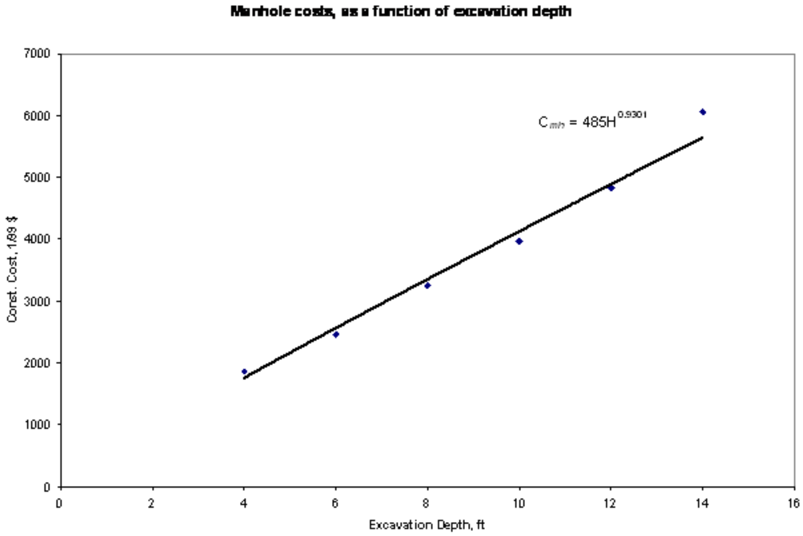
A power relation plotted for this data for 4 ft diameter manholes (the most common size) gives the equation

$$C_{mh} = 485\ H^{0.9301}$$

Where

C_{mh} = cost of manhole, 1/99 $
H = height of manhole, ft

The fit of the power equation is good at most depths.



Similar data on pump costs and pavement costs (along with subbase costs) were obtained by the EPA from R.S.Means and are shown below. The costs include fixed operations cost and profit, and labor, equipment and materials costs.

Capital Costs of Sewage Pump Stations (updated from RS Means 1996a)

Description	flow rate (gpm)	cost (January 1999 $)
sewage pump station	200	59,000.00
sewage pump station	1000	112,000.00

(Source: *Costs of Urban Stormwater Control*, USEPA)

Paving costs (updated from RS Means, 1996a)

Activity	Material	Diameter (in.)	Unit	Depth (in.)	Cost (January 1999 $)
Prepare and roll subbase > 2500 yd^3	Crushed Stone		yd^3		0.88
Base Course	Crushed Stone	0.75	yd^3	3	3.39
Base Course	Crushed Stone		yd^3	6	6.07
Base Course	Crushed Stone		yd^3	9	8.92
Base Course	Crushed Stone		yd^3	12	11.49
Base Course	Crushed Stone	1.5	yd^3	4	3.52
Base Course	Crushed Stone		yd^3	6	5.85
Base Course	Crushed Stone		yd^3	8	7.82
Base Course	Crushed Stone		yd^3	12	12.36
Base Course	Bank run gravel		yd^3	6	2.63
Base Course	Bank run gravel		yd^3	9	3.22
Base Course	Bank run gravel		yd^3	12	5.1
Base Course	Bituminous Concrete		yd^3	4	8.37
Base Course	Bituminous Concrete		yd^3	6	12.04
Base Course	Bituminous Concrete		yd^3	8	15.86
Base Course	Bituminous Concrete		yd^3	10	19.58
Prime and seal	-		yd^3		1.82
Asphaltic Concrete Pavement	Binder Course		yd^3	1.5	3.14
Asphaltic Concrete Pavement	Binder Course		yd^3	2	4.09
Asphaltic Concrete Pavement	Binder Course		yd^3	3	5.91
Asphaltic Concrete Pavement	Binder Course		yd^3	4	7.77
Asphaltic Concrete Pavement	Wearing Course		yd^3	1	2.31
Asphaltic Concrete Pavement	Wearing Course		yd^3	1.5	3.44
Asphaltic Concrete Pavement	Wearing Course		yd^3	2	4.52
Asphaltic Concrete Pavement	Wearing Course		yd^3	2.5	5.47

Asphaltic Concrete Pavement	Wearing Course		LF	3	6.51
Curb and Gutter, machine formed	Concrete	24			6.95

(Source: *Costs of Urban Stormwater Control*, USEPA)

An example use of this data to calculate paving costs of a 30 ft wide subdivision street, with 12 in. bank run gravel base material, a primer, a wearing course of 2 in. of asphaltic concrete pavement, and curb and gutter (both sides):

Base course: 5.1 $\$/yd^3 * 30\ ft * yd^2/9\ ft^2 = 17\ \$/ft$

Primer: 1.82 $\$/yd^2 * 30\ ft * yd^2/9\ ft^2 = 6.07\ \$/\ ft$

Pavement: 4.52 $\$/\ yd^2 * 30\ ft * yd^2/9\ ft^2 = 15.07\ \$/ft$

Curb and gutter: 6.95 $/ft * 2 = 13.90 $/ft

Total cost per linear ft: $17 + $6.07 + $15.07 + $13.09 = $52.04

The cost per linear foot would increase with an increase in projected traffic that requires an increase in pavement thickness.

Costs of Stormwater Quality Control Practices

Combined Sewage Overflow Controls that can be Applied to Stormwater

There is substantial information concerning the costs of large-scale applications of combined sewer controls due to massive installations over the past few decades. Some of these controls are very suitable for the control of separate stormwater. A selection of these is discussed in the following subsections.

Surface Storage

Surface storage units are offline storage units at or near the surface and are generally made of concrete. The cost of construction of a surface storage, such as a large culvert, is given by the following equation:

$$C = 4.546V^{0.826}$$

Where

C = construction cost in millions, January 1999 costs

V = volume of storage system, Mgal

(Source: *Costs of Urban Stormwater Control*, USEPA)

Storage costs depend heavily on land costs. Land costs range from zero if the land is assumed part of an easement or donated by the developer, to full costs, based on highly alternative use of land. Storage is used to detain or retain stormwater flows for later release at a slower rate. Storage can improve or degrade downstream water quality depending on how it is operated. Empirical cost on surface storage relating cost as a function of area or volume of the facility can be found in US EPA.

Estimated Capital Cost of Storage as a Function of Volume

Type	Equation	Cost, C ($ Units)	Volume, V (range)	V (units)	Year	Reference
Reservoir	$C = 160\ V^{0.4}$	1,000	10^4-10^6	Acre-ft	1980	U.S.Army Corps of Engineers (1981
Covered concrete tank	$C = 614\ V^{0.81}$	1,000	1 - 10	Mgal	1976	Gummerman, *et al.* (1979)
Concrete tank	$C = 5320\ V^{0.61}$	1,000	1 - 10	Mgal	1976	Gummerman, *et al.* (1979)
Earthern basin	$C = 42\ V^{0.61}$	1,000	1 - 10	Mgal	1976	Gummerman, *et al.* (1979)
Clear well, below ground	$C = 495\ V^{0.61}$	1,000	1 - 10	Mgal	1980	Gummerman, *et al.* (1979)
Clear well, ground level	$C = 275\ V^{0.61}$	1,000	0.01 - 10	Mgal	1980	Gummerman, *et al.* (1979)
CSO storage basin	$C = 3637\ V^{0.83}$	1,000	0.15 - 30	Mgal	1993	Gummerman, *et al.* (1979)
CSO deep tunnel	$C = 4982\ V^{0.80}$	1,000	1.8 - 2,000	Mgal	1993	U.S.EPA (1993b)

Source: *Costs of Urban Stormwater Control*, USEPA)

Deep Tunnels

Because of space limitations for near-surface storage in urban areas, deep tunnels are bored into bedrock to store receiving waters. Although they function similarly to surface storage units, little additional treatment is suitable in these devices, beyond a component of a storage-treatment system in conjunction with a conventional wastewater treatment system, or for hydrograph modification. Sedimentation is not desirable due to the difficulty and high cost of cleaning these units. They are therefore usually constructed with self-cleaning flushing devices, or other methods to remove any settled debris. Since these are associated with combined systems, the flushed material is usually treated at the wastewater treatment plant after the runoff event has ended, and not discharged untreated. If used in a separate stormwater system, the flushed material would also have to be flushed to a treatment facility, and not discharged to the receiving water.

US EPA relates the construction cost to volume of storage as:

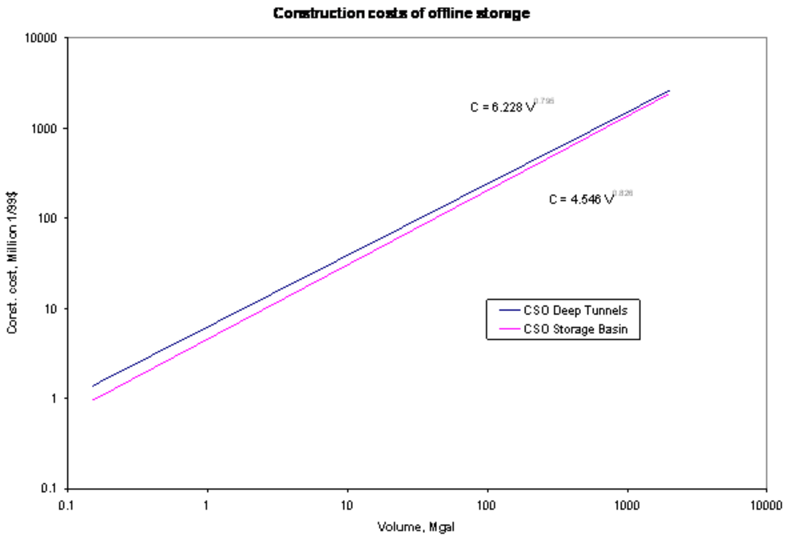
$$C = 6.22V^{0.795}$$

Where, C = construction cost, millions, January 1999 costs

V = volume of storage system, Mgal

(Source: *Costs of Urban Stormwater Control*, USEPA)

The graph below shows plots of these two equations (January 1999 costs):



Swirl Concentrators, Screens, Sedimentation Basins and Disinfection
Swirl concentrators use centrifugal force and gravitational settling to remove heavier sediments and floatable material from combined sewer overflows. Similar devices have been used for the treatment of separate stormwater, although the settling characteristics of the pollutants of these two wastewaters can be vastly different. They are usually used in conjunction with storage facilities to treat relatively uniform flows. The best source of cost data for swirl concentrator, screens, sedimentation basins, and disinfection is the US EPA which relates cost as a function of size or design flow:

$$C = 0.22Q^{0.611} \text{ (where, } 3 \leq Q \leq 300 \text{ MGD)}$$

Coarse screens can also be used to remove large solids and floatables from wastewater discharges:

$$C = 0.09Q^{0.843} \text{ (where, } 0.8 \leq Q \leq 200 \text{ MGD)}$$

Sedimentation basins allow physical settling prior to discharge. They have baffles to eliminate short circuiting of flow:

$$C = 0.281Q^{0.668} \text{ (where, } 1 \leq Q \leq 500 \text{ MGD)}$$

Disinfection is used to kill pathogenic bacteria prior to CSO discharges:

$$C = 0.161Q^{0.464} \text{ (where, } 1 \leq Q \leq 200 \text{ MGD)}$$

Where
C = construction cost, millions, January 1999 cost
Q = design flow rate, MGD
(Source: *Costs of Urban Stormwater Control*, USEPA)

These equations are plotted on the following graph:

Gross Solids Controls
The term "gross solids" include litter, vegetation, and other particles of relatively large size such as, manufactured items made from paper, plastic, cardboard, metal, glass, etc., that can be retained by a 5 mm mesh screen (Caltrans 2003). The following costs are for initial purchase and installation only (operation and maintenance costs not included) of three types of gross solids removal devices (GSRD) designed for a pilot study done by CALTRANS (Phase I and Phase II), to evaluate their performance and implement them on highway drainage systems. Phase III – V consists of several variants in the existing GSRD designs, in their monitoring stages and the associated costs were unavailable.

The three design concepts developed in the Phase I pilot scale study were: Linear Radial, Inclined Screen and Baffle Box. There were two variants in Linear Radial designs and three variants in Inclined Screen. The Linear Radial - Configuration #1 uses a modular well casing with louvers to serve as a screen. The Linear Radial – Configuration #2 utilizes rigid mesh screen housing with nylon mesh bags that capture gross solids. The inclined screen – configuration #1 utilizes parabolic wedge-wire screen to screen out gross solids. The Inclined Screen – Configuration #2 utilizes parabolic bars to screen out gross solids. The Baffle Box applies a two-chamber concept: the first chamber utilizes an underflow weir to trap floatable gross solids, and the second chamber uses a bar rack to capture solids that get past the underflow weir. The Phase II pilot project developed a modification of the Linear Radial – Configuration #1 by using a parabolic wedge wire screen to screen out gross solids. The device was designed so that it could be cleaned using front-end loader equipment.

Installation costs for these GSRDs are shown in the table below. They vary from site to site and also between GSRD types.

GSRD Installation Costs

Design	Drainage Area (ac)	Total Cost (including cost of monitoring equipment)	Cost (without monitoring equipment)
Linear Radial #1	3.7	$66,200	$48,300
Linear Radial #2 (Site 1)	6.2	$172,009	$155,935
Linear Radial #2 (Site 2)	0.9	$110,462	$94,388
Inclined Screen #1	2.5	$100,800	$82,800
Inclined Screen #2 (Site 1)	3.4	$150,425	$134,351
Inclined Screen #2 (Site 2)	2.1	$151,337	$135,263
Baffle Box (Site 1)	3.0	$129,422	$113,348
Baffle Box (Site 2)	2.3	$135,629	$119,555
Inclined Screen #3	3.3	$370,059	$345,000

(Source: *Phase I and II Gross Solids Removal Devices Pilot Study*, CALTRANS 2003)

Outfall Stormwater Controls
Outfall stormwater controls are located at outfalls from developed areas and treat all flows coming from the area before discharge to the receiving water. They may have bypasses or overflows so excessive flows can be routed around the devices without damage, but with resulting reduced removal rates.

Wet Detention Ponds and Wetlands
Wet detention ponds are one of the most effective methods of removing pollutant loadings from stormwater. If designed properly and in conjunction with a hydrologic basin analysis, they are also very suitable for attenuating peak runoff flows. When properly sized and maintained, they can achieve high rates of removal of sediment and particulate-bound pollutants.

Cost information on wet detention ponds are available from Young, *et al*. presents cost as a function of storage volume:

$$C = 55{,}000V^{0.69}$$

and the cost of dry detention ponds is also a function of volume from Young, *et al* and .is represented as:

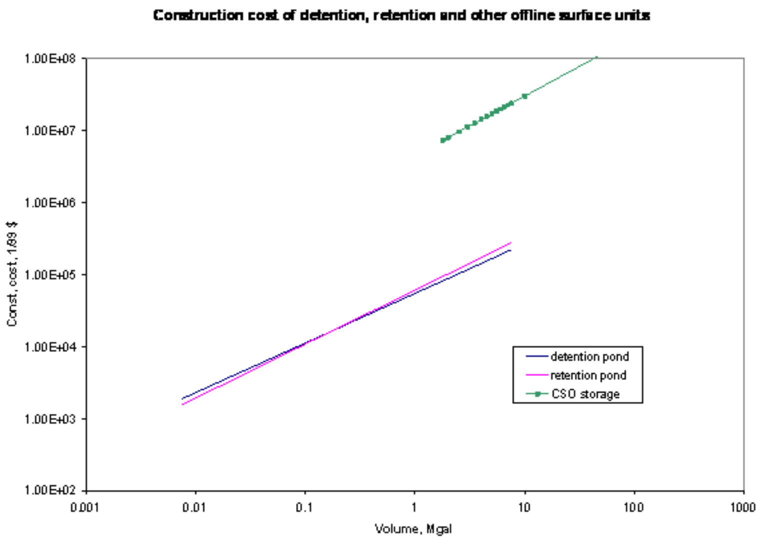
$$C = 55{,}000V^{0.69}$$

Where

C = January 1999 construction cost,
V = volume of pond, Mgal
The land cost is not included in this equation.

(Source: *Costs of Urban Stormwater Control*, USEPA)

Wet detention ponds also provide waterfowl and wildlife habitat, provisions for non-contact recreational opportunities, landscape and aesthetic amenities. They also provide streambank erosion control benefits, if properly designed. In the following figure "retention" ponds are wet-detention ponds, while "detention" ponds are dry-detention ponds. Dry ponds, which empty between most rains, are not as effective in removing pollutants as wet ponds due to lack of scour protection. Basic wetland costs would be similar to wet-detention pond costs, but with substantial additional costs associated with acquiring and planting the wetland plants.



Routine and periodic maintenance of wet detention ponds include lawn and other landscape care, pond inspection, debris and litter removal, erosion control and nuisance control, inlet and outlet repairs and sediment removal. The following table presents a summary of the reported costs of wet detention ponds.

The estimated capital cost of a 0.25 acre wet detention pond is shown in table below, excluding land costs. This includes mobilization and demobilization costs of heavy equipment, site preparation, site development and contingencies.

Summary of reported costs of wet detention basins (All costs updated to January 1989)

Description	capital cost	annual operation and maintenance cost	Comments	Location	Reference
ı with a 20-Acre age area	construction cost = 85 $V^{0.483}$ V = basin volume(cubic feet)	$1870/basin	Excludes planning, design, administration and contingencies	Montgomery County, Maryland	Metropolitan Washington Council of Governments, March 1983
ı Capacities to 1.0 Million cubic feet	capital cost = 107.4$V^{0.51}$ V=basin volume (cubic feet)	--	Capital cost includes planning, design, administration and contingencies	Washington, D.C., area	Metropolitan Washington Council of Governments, March 1983
ı size: 00 gallons/acre served 600 galons/acre served 200 gallons/acre served 700 gallons/acre served 6000 gallons/acre served	a) $311/acre served b) $1038/acre served c)$1470/acre served d) 2076/acre served e) $6228/acre served	a) $61/acre served b) $52/acre served c) $52/acre served d) $52/acre served e) $43/acre served	Valid for basins serving ≤ 50 acres	General	SEWRPC Technical Report No. 18, July 1977
size ıcres 5 acres acres .5 acres	a) $1,231,163/basin b) $1281757-251978/basin c)$7207230/basin d) $1204538/basin	a) $5521/basin b) $2096-3064/basin c) $2290/basin d) $10288/basin	All drainage area ≤50 percent impervious. Basins a), b), c) include discharge pump and canal. Design d) percolates discharge.	Fresno, California	Midwest Research Institute, March 1982
capacity of 6.5 acre-feet	$81243/basin	$2020/basin	--	Tri-County Michigan	Midwest Research Institute, March 1982
cre basin serving a ıcre drainage area	$53068/basin	$722/basin	Capital cost includes construction, materials, land, soil testing, and other indirect costs. Operation and maintenance cost includes labor, equipment and dispossal costs.	Salt Lake County, Utah	Midwest Research Institute, March 1982

Summary of reported costs of wet detention basins (All costs updated to January 1989) (continued)

Description	capital cost	annual operation and maintenance cost	Comments	Location	Reference
to 1 million cubic feet serving a drainage area to 1000 acres	capital cost = $108.36V^{0.51}$ V=basin volume (cubic feet)	operation and maintenance cost is 5 percent of capital cost	--	Washington, D.C., area	USEPA, Dec 1983
volumes 00000 cubic feet	capital cost = $6.1V^{0.75}$ V=basin volume (cubic feet)	--	Capital cost excludes engineering, administration and contingencies.	Washington, D.C., area	T.R.Schueler July 1987
volumes 100000 cubic feet	capital cost = $34V^{0.64}$ V=basin volume (cubic feet)	--	Capital cost excludes engineering, administration, land acquisition and contingencies.	Washington, D.C., area	T.R.Schueler July 1987
s of nine connected basins	$51900/basin	--	25 percent of capital cost includes grading, drainage and paving	Southern California	Robert Pitt, April 1987
volume: acre foot acre-foot acre-foot acre foor acre foot	a) $19504-45580/basin b) $62540-60377/basin c) $94022/basin d) $146492/basin e) $227900/basin	--	Capital cost excludes land acquisition, engineering, administration and contingencies.	Southeastern Wisconsin	SEWRPC Community Assistance Planning Report No.173 March 1989

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1989, WI)

Estimated capital cost of a 0.25 acre wet detention pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610
site preparation								
clearing………………	acre	0.50	$2200	$3800	$5400	$1100	$1900	$2700
grubbing……………..	acre	0.13	3800	5200	6600	494	676	858
general excavation….	cubic yard	908	2.1	3.7	5.3	1907	3360	4812
place and compact fill	cubic yard	608	0.6	1.1	1.6	365	669	973
site development								
salvaged topsoil, seed and mulch……..	sq yard	1089	$0.4	$1	$1.6	$436	$1089	$1742
sod……………………	sq yard	121	1.2	2.4	3.6	145	290	436
riprap…………………	cubic yard	16	16.4	29.6	42.8	262	474	685
pond inlet……………	pond	1	2620	5740	8860	2620	5740	8860
pond outlet…………	pond	1	2640	6760	10880	2640	6760	10880
landscape, fence, etc	acre	0.25	1000	2000	3000	250	500	750
Subtotal	--	--	--	--	--	$10,609	$22,459	$34,306
contingencies, engineering, legal fees, and administration………..	pond	1	25 percent	25 percent	25 percent	$2,652	$5,610	$8,577

Total	--	--	--	--	--	$13,261	$28,069	$42,883

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1989, WI)

The next 3 tables show the calculated component costs and total capital costs for wet-detention ponds of 1, 3 and 5 acres in size, again excluding land costs:

estimated capital cost of a 1 acre wet detention pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610
site preparation								
clearing…………………	acre	2	$2200	$3800	$5400	$4400	$7600	$10800
grubbing……………….	acre	0.5	3726	5175	8901	1863	2588	3300
general excavation……	cubic yard	5771	2.1	3.7	5.3	11699	20613	29526
place and compact fill	cubic yard	3867	0.6	1.1	1.6	2320	4254	6187
site development								
salvaged topsoil, seed and mulch……….	sq yard	4356	$0.4	$1	$1.6	$1742	$4356	$6970
sod……………………..	sq yard	424	1.2	2.4	3.6	581	1162	1742
riprap…………………..	cubic yard	48	16.4	29.6	42.8	787	1421	2054
pond inlet……………..	pond	1	2620	5740	8860	2620	5740	8860
pond outlet……………	pond	1	2640	6760	10880	2640	6760	10880
landscape, fence,etc	acre	1	1000	2000	3000	250	2000	3000
Subtotal	--	--	--	--	--	$30,079	$57,506	$84,929
contingencies, engineering, legal fees, and administration	pond	1	25 percent	25 percent	25 percent	$7,520	$14,377	$21,232
Total	--	--	--	--	--	$37,599	$71,883	$106,161

(Source: *Costs of Urban Nonpoint Source Control Measures*, SWRPC, 1989, WI)

estimated capital cost of a 3 acre wet detention pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610

site preparation clearing…………….. grubbing……………. general excavation… place and compact fill	 acre acre cubic yard cubic yard	 6 1.5 21260 14244	 $2200 3800 2.1 0.6	 $3800 5200 3.7 1.1	 $5400 8901 5.3 1.6	 $13200 5700 44646 8546	 $22800 7800 78662 15668	 $32400 9900 112678 22790
site development salvaged topsoil, seed and mulch……. sod…………………… riprap………………… pond inlet…………… pond outlet………… landscape, fence,etc	 sq yard sq yard cubic yard pond pond acre	 13068 1452 145 1 1 3	 $0.4 1.2 16.4 2620 2640 1000	 $1 2.4 29.6 5740 6760 2000	 $1.6 3.6 42.8 8860 10880 3000	 $5227 1742 2378 2620 2640 3000	 $13068 3485 4292 5740 6760 6000	 $20909 5227 6206 8860 10880 9000
Subtotal	--	--	--	--	--	$90,089	$165,275	$240,460
contingencies, engineering, legal fees, and administration……….	pond	1	25 percent	25 percent	25 percent	$22,522	$41,319	$60,115
Total	--	--	--	--	--	$112,611	$206,594	$300,575

(Source: *Costs of Urban Nonpoint Source Control Measures*, SWRPC, 1989, WI)

estimated capital cost of a 5 acre wet detention pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization- demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610
site preparation clearing………………. grubbing…………….. general excavation….. place and compact fill	 acre acre cubic yard cubic yard	 10 2.5 37013 24799	 $2200 3800 2.1 0.6	 $3800 5200 3.7 1.1	 $5400 6600 5.3 1.6	 $22000 9500 77727 14879	 $38000 13000 136948 27279	 $54000 16500 196196 39678
site development salvaged topsoil, seed and mulch…….. sod……………………. riprap…………………. pond inlet……………. pond outlet………….. landscape, fence,etc	 square yard sq yard cubic yard pond pond acre	 21780 2420 242 1 1 5	 $0.4 1.2 16.48 2620 2640 1000	 $1 2.4 29.6 5740 6760 2000	 $1.6 3.6 42.8 8860 10880 3000	 $8712 2904 3969 2620 2640 5000	 $21780 5808 7163 5740 6760 10000	 $34848 8712 10358 8860 10880 15000
Subtotal	--	--	--	--	--	$150,341	$273,478	$396,642
contingencies, engineering, legal fees, and administration………..	pond	1	25 percent	25 percent	25 percent	$22,522	$41,319	$60,115
Total	--	--	--	--	--	$187,926	$341,848	$495,803

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1989, WI)

The distribution of the component capital costs is largely a function of the pond area. The operation and maintenance costs of wet detention ponds range from $1300 for a 0.25 acre pond to nearly $8700 for a 5 acre pond.

Average annual operation and maintenance costs of wet detention ponds

component	unit cost	pond surface (acres)				comment
		0.25	1	3	5	
lawn mowing	0.85/1000 sq feet	$74	$296	$889	$1,481	Maintenance area equals area cleared minus pond area. Mow 8 times per year
general lawn care	$9/1000 sq feet/year	$98	$392	$1,176	$1,960	maintenance area equals area cleared minus pond area
pond inlet maintenance	3 percent of capital cost in inlet	$172	$172	$172	$172	--
pond outlet maintenance	5 percent of capital cost in outlet	$338	$338	$338	$338	--
pond sediment removal	1 percent of capital cost	$281	$719	$2,067	$3,421	--
debris and litter removal	$100/yr	$100	$100	$100	$100	--
pond nuisance control		$50	$200	$600	$1,000	--
program administration and inspection	$50/pond/yr, plus $25/inspection	$200	$200	$200	$200	ponds inspected six times per year
total annual operation and maintenance	--	$1,313	$2,417	$5,542	$8,671	--

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1989, WI)

Chemical Treatment (Alum or Ferric Chloride Injection)

pe	Installation or Construction Cost	Operation, Inspection and Maintenance Costs	Maintenance Issues and Concerns
l Treatment	For an alum treatment facility, with an average cost of $245,000 per system serving a drainage area of less than 310 acres, the average initial cost is $790 per acre treated	Annual operation and maintenance cost is $100 per acre of drainage area served.	• Maintenance is high as chemicals are continuously added and the waste precipitate is removed for disposal. • Accumulated floc must be pumped out of sump area on a periodic basis.

(Source: *Best Management Practices for South Florida Urban Stormwater Management Systems, Appendix A*)

Infiltration Ponds

Infiltration ponds are similar to wet detention ponds. They perform similar to infiltration trenches in removing waterborne pollutants by capturing surface runoff and filtering it through the soil. An infiltration pond does not have an outlet other than an emergency spillway to pass excess runoff.

Periodic maintenance includes annual inspections and inspections after large storms, mowing side slopes and basin floor, debris and liter removal, erosion control, odor control, and management of mosquitoes. Deep tilling may be needed every 5 years to break up clogged layers. Tilling is then followed by grading, leveling and revegetating the surface.

Equations for estimating costs of infiltration ponds

Capital cost	annual operation and maintenance cost	location	reference
construction cost = 4.16 $V^{0.75}$ V = pond volume (cubic feet)	5 to 20 percent of basin cost construction: 4-9 percent of pond capital cost	Washington D.C Metropolitan area	Wiegend, *et al.* June 1986
construction cost = 73.52 $V^{0.51}$ V = pond volume (cubic feet)	3 to 5 percent of basin construction cost 2-4 percent of pond capital cost	Washington D.C Metropolitan area	T.R.Schueler, *et al.* April 1985
construction cost = 14.63 $V^{0.69}$ V = pond volume (cubic feet)	3-5 percent of basin construction cost; 2-4 percent of pond capital cost	Washington D.C Metropolitan area	T.R.Schueler, *et al.* April 1987
construction cost = 1.18 V V = pond volume (cubic feet)	$0.15/cubic foot, or 13 percent of capital cost	City of Oconomowoc Wisconsin	Donohue & Assocites, Inc, April 1989

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1987, WI)

The table below presents selected unit costs, the calculated component costs, and total capital costs for a 0.25 and 1.0 acre infiltration pond, both 3 feet deep. The cost of underground drainage systems is not included because such systems are required only when the soil has marginal permeability. In such cases, it is preferable to use a wet pond anyways.

Estimated capital cost of a 0.25 acre infiltration pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610
site preparation								
clearing………………..	acre	0.5	$2200	$3800	$5400	$1100	$1900	$2700
grubbing……………….	acre	0.13	3800	5200	6600	494	676	878
general excavation…...	cubic yard	834	2.1	3.7	5.3	1751	3086	4420
place and compact fill..	cubic yard	559	0.6	1.1	1.6	335	615	894
level and till……………	square yard	1076	0.2	0.35	0.5	215	377	538
site development								
salvaged topsoil, seed and mulch……….	sq yard	1210	$0.4	$1	$1.6	$484	$1210	$1936
sod……………………..	sq yard	1210	1.2	2.4	3.6	1452	2904	4356
riprap…………………..	cubic yard	10	16.4	29.6	42.8	164	296	428
pond inlet……………..	each	1	2620	5740	8860	2620	5740	8860
landscape, fence,etc….	acre	0.5	1000	2000	3000	500	1000	1500
subtotal	--	--	--	--	--	$9,505	$18,804	$28,100
contingencies	pond	1	25 percent	25 percent	25 percent	$2,376	$4,701	$7,025
total	--	--	--	--	--	$11,881	$23,505	$35,125

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1987, WI)

estimated capital cost of a 1 acre infiltration pond

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-heavy	pond	1	$390	$1,000	$1,610	$390	$1,000	$1,610

site preparation clearing………………. grubbing………………. general excavation….. place and compact fill.. level and till……………	 acre acre cubic yard cubic yard square yard	 2.0 0.5 4240 2841 4570	 $2200 3800 2.1 0.6 0.2	 $3800 5200 3.7 1.1 0.35	 $5400 6600 5.3 1.6 0.5	 $4400 1900 8904 1705 917	 $7600 2600 15688 3125 1600	 $10800 3300 22472 4546 2285
site development salvaged topsoil, seed and mulch………. sod…………………….. riprap…………………... pond inlet……………… landscape, fence,etc….	 sq yard sq yard cubic yard each acre	 4840 4840 10 1 2.0	 $0.4 1.2 16.4 2620 1000	 $1 2.4 29.6 5740 2000	 $1.6 3.6 42.8 8860 3000	 $1936 5808 164 2620 2000	 $4840 11616 296 5740 4000	 $7744 17424 428 8860 6000
subtotal	--	--	--	--	--	$30,741	$58,105	$85,469
contingencies	pond	1	25 percent	25 percent	25 percent	$7,685	$14,526	$21,367
total	--	--	--	--	--	$38,426	$71,631	$106,836

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1987, WI)

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1987, WI)

Average annual operation and maintenance costs of infiltration ponds

component	unit cost	pond top surface area(acres) 0.25	1	comment
lawn mowing	0.85/1000 sq feet	$148	$592	maintenance area equals two times pond area. Mow 8 times per year
general lawn care	$9/1000 sq feet/year	$196	$784	maintenance area equals two times pond area
pond inlet maintenance	3 percent of capital cost in inlet	$172	$172	--
soil leveling and tilling	$0.35/sq yard	$38	$160	pond bottom area leveled and tilled at 10-yr intervals following sediment removal
pond sediment removal	$421.1/pond bottom acre/year	$84	$379	--
debris and litter removal	$100/yr	$100	$100	area revegetated equals pond bottom area at 10-yr intervals
grass reseeding with mulch and fertilizer	$0.3/sq yard	$29	$131	--
program administration and inspection	$50/pond/yr, plus $25/inspection	$150	$150	ponds inspected four times per year
total annual operation and maintenance	--	$917	$2,468	--

Public Works Practices

Street Cleaning

Most street cleaning programs are intended to improve aesthetics and prevent clogging of inlets and storm drainage systems. Street cleaning is a relatively labor-intensive operation and also requires a large investment for street cleaner trucks, disposal facilities, and maintenance facilities.

reported costs of street cleaners

sweeper type	manufacturer and model	capital cost	reference
mechanical	Elgin Pelican EMC Vangaurd 4000 single broom double broom	$65,000-75,000 $89,225 93,550	Bruce Municipal Equipment, Inc Menomonee Falls, Wisconsin Bark River Culvert & Equipment Company, Milwaukee, Wisconsin

vacuum	Elgin Whirlwind	$120,000	Bruce Municipal Equipment, Inc Menomonee Falls, Wisconsin
	VAC/ALL Model E-10 single broom double broom	 $61,467 73,467	Bark River Culvert & Equipment Company, Milwaukee, Wisconsin
regenerative air	Elgin Crosswind	$110,000	Bruce Municipal Equipment, Inc Menomonee Falls, Wisconsin
	FMC Vangaurd 3000SP single broom double broom	 $73,165 77,700	Bark River Culvert & Equipment Company, Milwaukee, Wisconsin
	TYMCO Model 600	$87,000	Illinois Truck Equipment Appleton, Wisconsin

Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, 1989 cost data)

The unit costs for street cleaning programs (including capital, operation, and maintenance costs) are summarized in the following table:

Reported unit costs for street cleaning programs

Cost Factor	Nationwide Urban Runoff Program Studies						
	Milwaukee, Wisconsin	Winston-Salem, Forsyth County, North Carolina	San Francisco Bay area, California	Champaign, Illinois	San Jose, California (Pitt, 1979)	City of Milwaukee (1988)	Mean of all studies
$/ pound of solids collected	NA	0.17-0.93	0.12-0.34	NA	0.05-0.32	NA	0.32
$/cubic yard of solids collected	NA	NA	NA	NA	40	13.4	26.7
$/curb-mile swept	25	17.9	12.9-19.4	14.3-18	27.2	25	21.2
$/hour of sweeping operation	36	21.8-46.6	NA	NA	29.7	NA	33.3

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC 1991)

Catchbasin Cleaning

A catchbasin is a stormwater runoff inlet equipped with a small sedimentation basin or grit chamber with a capacity ranging from 0.5 to 1.5 yards. Stormwater runoff enters the catchbasin through the surface inlet and drops to the bottom where some of the sediment and other pollutants carried by runoff are deposited and accumulated. The water then enters the subsurface conveyance system.

Catchbasins must be periodically cleaned to remove sediment and debris accumulated in the grit chamber. The catchbasins are cleaned manually using shovels, a clamshell bucket, vacuum educators, or vacuum attachments to street cleaners. Cleaning frequency is decided based on available manpower and equipment, and by the level needed to prevent clogging of stormwater sewers. Cleaning frequencies typically range from twice a year to every several years. Materials removed from catchbasins are normally deposited in landfills. Catchbasins can be difficult to clean in areas with traffic and parking congestion and cleaning is difficult during winter when it snow or ice is present.

Capital costs for material and labor to install catchbasins generally range from $200 to $4000 per catchbasin. In Castro Valley Creek, California, catchbasins were cleaned once a year and approximately 60 pounds were removed each time. The cost of cleaning catchbasins at three different locations is shown below.

Location	cost of cleaning in $ per catchbasin, 1977 costs
Castro Valley, California	7.7
Salt Lake County, Utah	10.3
Weston-Salem, North Carolina	6.3

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC)

About $0.13 per pound of solids removed was the resulting cleaning cost at Castro Valley, California. In the city of Wisconsin, Milwaukee indicates catchment cleaning costs of $0.09 per pound of solids removed where the catchbasins were cleaned using attachments to a vacuum street sweeper. About $8 was estimated for each catchbasin cleaning in communities that use a vacuum attachment to a street sweeper, and $15 for manual cleaning operations.

Critical Source Area Controls

Critical source area controls are used at locations where unusually high concentrations of stormwater pollutants originate. It is usually more effective to reduce the concentrations at these locations than to allow the water to mix with other stormwaters, possibly requiring the treatment of much larger flows. These areas are usually located in commercial and industrial areas and include loading docks, storage areas, vehicle maintenance areas, public works yards, scrap yards, etc.

Hydrodynamic Separators

Hydrodynamic separators are flow-through structures with a settling or separation unit to remove gross pollutants, grit, and bed load sediments, and possibly other pollutants. No additional outside energy is required for operation. Separation usually depends on gravitational settling, possibly assisted by lamella plates or swirl action, and may also include coarse screens. These devices are available in a wide range of sizes and can be used in conjunction with other controls in the watershed to produce treatment trains. Four commonly used commercial hydrodynamic separators are:

Continuous Deflective Separator (CDS):

The CDS hydrodynamic separator is suitable for gross pollutant removal. The system utilizes a rotational action of the water to enhance gravitational separation of solids, plus a screen. Separated debris are captured by a litter sump located in the center of the unit. Flow rate capacities of CDS units vary from 3 to 300 cfs depending on the application and size of the unit. Precast modules are available for flows up to 62 cfs, while higher flows require cast-in-place construction. Polypropylene or copolymer sorbents can be added to the CDS unit separation chamber to assist in the capture of free floating oils.

Downstream Defender:
The downstream defender is also used to capture floatables and settleable solids. The hydrodynamic force of the swirl action increases the gravitational settling of gross pollutants and grit. It uses a sloping base, a dip plate and internal components to assist in pollutant removal. The Downstream Defender comes in standard manhole sizes ranging from 4 to 10 feet in diameter for flows from 0.75 to 13 cfs. For larger flows, units can be custom designed up to 40 feet in diameter.

Stormceptor:
The Stormceptor uses a deep settling chamber with a high flow by-pass to capture floatable materials, gross pollutants and settleable solids. They are available in prefabricated sizes up to 12 feet in diameter by 6 to 8 feet deep. The cost of the Stormceptor is based on costs of the two system elements, the treatment chamber and by-pass insert, and the access way and fittings.

Vortechs:
Vortechs removes floatable materials and settleable solids with a swirl-concentrator and flow-control system. It is constructed in precast concrete and consists of the following main components: baffle wall and oil chamber, circular grid chamber, and flow control chamber. Vortechnics manufactures nine standard-sized units that range from 9 feet by 3 feet to 18 feet by 12 feet.

	Cost per unit	O & M Cost	Comments
Continuous Deflective Separators	$2300 to $7200 per cfs capacity (including installation)	NA	• Maintenance of CDS is site-specific and requires that the unit be checked after every runoff for first 30 days after installation. • The system is inspected for the amount of sediment deposition using a "dip stick". • Monthly inspections are also recommended during the wet season. • Yearly inspection to examine for damage of the screen and to determine if the unit needs to be cleaned out.
Downstream Defender	$10,000 to $35,000 per pre-cast unit (including installation)	NA	• Inspection every month for a period of one year of operation to determine rate of sediment and floatables accumulation. • Use of sump vac to remove captured floatables and solids.
Stormceptor	$7600 to $33,560 for units that range from 900 to 7200 gallons + cost of installation	Cleaning is required once a year and typical cleaning cost (equipment and personnel) is estimated to be $250 and disposal costs is estimated to be in the order of $300 to $500.	• Maintenance depends on site conditions and is indicated by sediment depth and needs a vacuum truck. • Cleaning is required when the sediment reaches 1 foot of its capacity limit. • Visual inspection is performed through the manhole by dipping a dip stick and is especially recommended for units that may capture petroleum based pollutants.
Vortechs	$10,000 to $40,000 per unit that can treat runoff flows from 1.6 cfs to 25 cfs. (not including shipping and installation)	NA	• Inspections once a month is required during the first year of installation and after heavy contaminant loadings like winter sandings, fuel spills etc. • The unit requires cleaning when sediment reaches one foot of inlet pipe. • Cleaning involves removal of sediments and is generally done using a vacuum truck.

(Source: *Storm water technology fact sheet – Hydrodynamic Separators*, *Stormceptor user manual*)

Oil-Water Separator (OWS)
One example oil-water separator for stormwater is the Aero-Power® 500 gallonSTI-P3 unit which separates oil and water by allowing the oil droplets to collide and coalesce to become large globules that are then captured in the unit. The OWS consists of three compartments: forebay, oil separator, and afterbay. The forebay captures gross sediments, the oil separator contains a parallel corrugated coalescer and a removable oleophallic fiber coalescer to promote separation of oil, and the afterbay discharges treated stormwater with less than 10 mg/L of grease and oil concentration.

Oil-Water Separator	Construction Cost (1999 dollars)	Cost $\$/m^3$ of water volume	Annual O&M Cost (1999 dollars)
One Location	128,305	1,970	790

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

The OWS needs to be inspected for accumulated sediments in the forebay and oil in the oil separator. Operation and maintenance efforts are based on: administration, inspection, maintenance, vector control, equipment use, and direct costs.

Expected Annual Maintenance Costs (1999) for Final Version of OWS

Activity	Labor Hours	Equipment and Matrials, $	Cost, $
Inspections	1	0	44
Maintenance	10	0	440
Vector Control	12	0	744
Administration	3	0	132
Direct Costs	-	180	180
Total	26	**$180**	**$1,540**

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

Storm Drain Inlet Inserts
Storm drain inlet inserts are typically bags or trays of filter media, filter fabrics, or screens, designed to trap contaminants and debris prior to discharge into storm drain systems. They are manufactured stormwater treatment controls and have low capital cost compared to other controls. They can also be placed into traditional storm inlets without alteration of the inlets. However, they may have very high maintenance costs if in areas of large debris loads to prevent clogging.

FossilFilter™ drain inlet inserts have a trough structure that is installed under the inlet of a storm drain inlet. The trough is made of fiberglass and consists of a large center opening for bypass of water when flow through capacity of the filter is exceeded. The trough contains stainless steel filter cartridges filled with amorphous alumina silicate for removal of petroleum hydrocarbons and other contaminants.

StreamGaurd™ drain inlet inserts are a conical shaped porous bag made of polypropylene fabric and contains an oil absorbent polymer. As stormwater flows through the insert, the fabric absorbs oil and retains sediment. The overflow cutouts near the top of the cone allow bypass when the fabric's flow through capacity is exceeded.

Although the size of the inlets vary, the variation is not enough to significantly affect the cost of an inlet insert. In most cases, they are installed on a unit (per drain inlet) basis and not according to runoff volume or flow basis.

	Construction Cost, 1999 costs	Cost/WQV $/m^3	Annual O&M Cost (1999 costs)
One Location	370	10	$ 1,100

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Maintenance involves frequent inspections for debris and trash during rainy seasons and monthly inspections during the dry season. Also, the inlets need to be inspected for oil and grease at the end of each target storm. The operation and maintenance efforts are based on: administration, inspection, maintenance, vector control, equipment use, and direct costs.

Average Annual Maintenance Effort – Storm Drain Inlet Inserts, (1999 costs)

Activity	Labor Hours	Equipment and Materials, $
Inspections	11	-
Maintenance	9	0
Vector Control	17	-
Administration	84	-
Direct Costs	-	563
Total	121	**$563**

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Stormwater Filters
A typical sand filter consists of two to three chambers or basins. The first chamber acts as a sedimentation chamber, where floatable and heavy sediments are removed. The second chamber has the sand bed which removes additional pollutants by filtration. The third is the discharge chamber, where treated filtrate is discharged through an underdrain system either into the storm drainage system or directly into surface waters. This section gives the costs associated with the Austin sand filter, the Delaware sand filter, the Washington, D.C., sand filter and the Storm-Filter™.

Austin and Delaware Sand-Filters
The Austin sand filter has a sedimentation basin and an open air filter separated by a concrete wall. Runoff from the sedimentation chamber flows into the filter chamber through a perforated riser. The orifice riser is placed in such a position such that the sedimentation basin under basin-full condition would drain in 24 hours. The filter basin has a level spreader to distribute runoff evenly over the 450mm deep bed. Construction cost estimates by the U.S.EPA (1997 dollars) is $18,500 for a 1 acre paved drainage area. The cost per acre decreases with larger drainage areas.

Construction Cost for Austin Sand Filter 1999 dollars

	Construction Cost, $	Cost $/m^3	Annual O&M Cost
One Location	242,799	1,447	2,910

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

The Delaware Sand-Filter consists of a separate sedimentation chamber and filter chamber, but a permanent pool of runoff is maintained in the sedimentation chamber. As runoff enters the sedimentation chamber, standing water is forced into the filter chamber through a weir. The sand filter is 300 mm deep and therefore storage in the unit for only 5mm runoff. The construction costs estimated by the U.S.EPA for a Delaware sand filter is similar to a precast Washington, D.C. sand filter system, with the exception of lower excavation costs because of the Delaware filters' shallower depth.

Construction Costs for Delaware Sand Filter, 1999 dollars

	Construction Cost, $	Cost $/m^3	Annual O&M Cost
One Location	230,145	1,912	2,910

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Maintenance involves removal of sediments from sedimentation basin when accumulation exceeds 300mm, removal of uppermost layer (50mm) of sand bed when drain time exceeds 48 hours. Also, the removed sand must be immediately replaced by new sand to restore the original depth. The filters need to be inspected weekly for trash accumulation and monthly for damage inside or outside structure, emergence of woody vegetation and evidence of graffiti or vandalism.

Expected Annual Maintenance Costs for Final Version of Sand Filter

Activity	Labor Hours	Equipment and Materials, $	Cost, $ (1999)
Inspections	4	0	176

Maintenance	36	125	1,709
Vector Control	0	0	0
Administration	3	0	132
Direct Costs	-	888	888
Total	43	**$1,013**	**2,905**

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Washington, D.C. sand filter
The Washington, D.C sand filter consists of three underground chambers. The sand filter is designed to accept the first 0.5 inches of runoff. The sedimentation chamber removes floatables and coarse sediments from runoff. Runoff is discharged from the sedimentation chamber through a submerged weir into a filtration chamber that consists of sand and gravel layers totaling 1 meter in depth with underdrain piping wrapped in filter fabric. The underdrain system collects the filtered water and drains them into a third chamber where the water is collected and discharged.

The sand filters should be inspected after every storm event. Sand filters experience clogging every 3 to 5 years. Accumulated trash, debris and paper should be removed from sand filters every 6 months. Corrective maintenance of the filtration system involves removal and replacement of the top layers of the sand and gravel or filter fabric that has become clogged. Sand filter systems require periodic removal of vegetative growth. The cost for precast Washington, D.C. sand filters, with drainage areas less than 0.4 hectares (1 acre), ranges between $6,600 and $11,000 (U.S.EPA, 1997 dollars). This is considerably less than the cost for the same size cast-in-place system. Also, the cost to replace the gravel layer, filter fabric and top portion of the sand for Washington, D.C. sand filter is approximately $1,700 (U.S.EPA, 1997 dollars).

Storm-Filter™
The Stormwater Management, Inc. Storm-Filter™ is a water quality treatment device that uses cartridges filled with different filter media. In this cost analysis provided, the filter media was perlite/zeolite and the following siting conditions were used:

- No construction activity up-gradient or no bare soil
- Tributary area of less than 8 ha
- Hydraulic head of 1 m to operate by gravity flow

The Storm-Filter™ is designed based on the runoff it is required to handle. The maintenance site chosen for the cost analysis used in *BMP Retrofit Pilot Program* prepared by CALTRANS was Kearny Mesa, San Diego (0.6 ha) for a design storm of 36mm, design storm discharge of 76 L/s, water quality volume (WQV) of 194 m^3 containing 86 canisters and 3 chambers. Perlite/zeolite combination was chosen for this site. Perlite is recommended for the removal of TSS, oil and grease and zeolite for the removal of soluble metals, ammonium and some organics.

Actual Construction Cost for Storm-Filter, 1999 dollars

Site	Actual Cost, $	Actual Cost w/o monitoring, $	Cost/WQV $/m^3
Kearny Mesa	325,517	305,355	1,575

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Adjusted Construction Costs for Storm-Filter

Storm-Filter	Adjusted Construction Cost, $	Cost/WQV $/m^3	Annual O&M Cost
One Location	305,356	1,572	7,620

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Maintenance of the Storm-Filter™ includes inspection of sediment accumulation, and removal from pretreatment chamber when accumulation exceeds 300m, weekly inspection during wet weather season, monthly inspection according to manufacturer's guidelines, including flushing of underdrains.

The following table presents the expected maintenance costs that would be incurred for a Storm-Filter™ serving about 2 ha, and following these maintenance activities (Caltrans 2003):

· Perform inspections and maintenance as recommended, which includes checking for media clogging, replacement of filter media, and inspection for standing water.
· Schedule semiannual inspection for beginning and end of the wet season to identify potential problems.
· Remove accumulated trash and debris in the pretreatment chamber, stilling basin, and the filter chamber during routine inspections.
· Remove accumulated sediment in the pretreatment chamber every 5 years or when the sediment occupies 10 percent of the volume of the filter chamber, whichever occurs first.

Expected Annual Maintenance Costs for Final Version of Storm-Filter

Activity	Labor Hours	Equipment and Materials, $	Cost, $
Inspections	1	0	44
Maintenance	39	131	1847
Vector Control	12	0	744
Administration	3	0	132
Direct Costs	-	2800	2800
Total	**55**	**2931**	**5,567**

(Source:*BMP Retrofit Pilot Program,* CALTRANS)

Multi-Chambered Treatment Train
The multi-chambered treatment train (MCTT) is a device that can be installed underground in areas having little space for more conventional surface treatment. It was developed by Pitt, *et al.* (1997) to provide high levels of treatment of a variety of metallic and organic pollutants, along with conventional pollutants. It includes a combination of unit processes, including a grit chamber to capture large particulates, a main settling tank to capture particulates down to very small sizes, and a final sorption/ion-exchange chamber to capture filterable forms of pollutants. Several MCTTs have been constructed as part of demonstration projects, and some cost information was developed as part of these projects.

A Milwaukee MCTT installation is at a public works garage and serves about 0.1 ha (0.25 acre) of pavement. This MCTT was designed to withstand very heavy vehicles driving over the unit. The estimated cost was $54,000 (including a $16,000 engineering cost), but the actual total capital cost was $72,000. The high cost was likely due to uncertainties associated with construction of an unknown device by the contractors and because it was a retro-fit installation. It therefore had to fit within very tight site layout constraints. As an example, installation problems occurred due to sanitary sewerage not being accurately located as mapped.

The Minocqua MCTT is located at a 1 ha (2.5 acre) newly paved parking area serving a state park and commercial area. It is located in a grassed area and is also a retro-fit installation, designed to fit within an existing storm drainage system. The installed capital cost of this MCTT was about $95,000. Box culverts 3.0 X 4.6 m (10ft X 15ft) were used for the main settling chamber (13 m, or 42 ft long) and the filtering chamber (7.3 m, or 24 ft long). The grit chamber (a 7.6 m^3, 2,000 gal. baffled septic tank) was also used to pre-treat water entering the MCTT.

It is anticipated that MCTT costs could be substantially reduced if designed to better integrate with a new drainage system and not installed as a retro-fitted stormwater control practice. Plastic tank manufactures have also expressed an interest in preparing pre-fabricated MCTT units that could be sized in a few standard sizes for small critical source areas. It is expected that these pre-fabricated units would be much less expensive and easier to install than the above custom built units.

Caltrans during its BMP retrofit pilot program installed MCTTs in two locations: Via Verde Park and Rides and Lakewood Park and Rides.

Site	Land Use	Watershed area (hectares)	Impervious Cover, %	Design storm, mm
Via Verde P&R	Park & Ride lot	0.44	100	25
Lakewood P&R	Park & Ride lot	0.76	100	25

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

MCTTs need a vertical clearance of at least 1.5 m for gravity flow. In most cases, this is provided by having the inlet at the surface of the paved area, dropping directly into the initial catchbasin/grit chamber. These two test sites lacked sufficient head and two pumps were therefore installed at each site, one to transfer runoff from the sedimentation chamber to the filter chamber and one to return treated discharge water tothe pre-existing drainage system. These pumps were triggered manually on the day following a storm event to ensure runoff remained in the sedimentation chamber for 24 hours.
Standard three-staged MCTTs were used at these sites. The first stage consisted of a catchbasin with a sump and packed column aerators. This is followed by a main settling chamber with tube settlers to improve particulate removal and sorbent pillows to capture floating hydrocarbons. The sedimentation basin was designed so that the water quality volume was held above the tube settlers, which are 0.6m deep with 0.3m of plenum space underneath. The dimension of the MCTT used in these sites is shown below. The final chamber consisted of 600mm thick filter media of 50/50 mixture of sand and peat moss.

Site	WQV (cu.m)	Sedimentation basin area, sq.m	Filter basin area, sq.m
Via Verde P&R	123	35.5	17.4
Lakewood P&R	173	61.2	32.9

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

The following construction costs of the Caltrans MCTTs included engineering design for the retrofit sites, excavation costs, grading, material, filter media, unknown field conditions (such as encountering boulders and unmapped utility lines), and labor.

Actual Construction Costs for MCTTs (1999 costs)

Site	Actual Construction Cost, $	Actual Cost (w/o monitoring), $	Cost (w/o monitoring)/WQV $/$m^3$
Via Verde P&R	383,793	375,617	3,054
Lakewood P&R	464,743	456,567	2,639

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

The following table shows the adjusted costs for the MCTTs excluding the cost of pumps (site did not allow gravity drainage) and extensive shoring (due to space constraints at the site). The costs were reduced by 41 percent and 52 percent for both locations. Also, miscellaneous site factors that adjusted the cost by 1 percent were also excluded. The Caltrans costs also reflect the mandated LA County design storm of 25 mm. The recommended design, based on continuous long-term simulations for the area, was much less than this volume (closer to 8 mm or runoff).

Adjusted Construction Costs for MCTTs (1999 costs)

MCTT	Adjusted Construction Cost, $	Cost/WQV, $/$m^3$
Mean	275,616	1,875
High	320,531	1,895
Low	230,701	1,856

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

Maintenance of the MCTTs included removal of sediments from the sedimentation basins when accumulation exceeds 150mm and removing and replacing the filter every 3 years, and replacement of sorbent pillows if darkened by oily stains. Neither of these maintenance activities were needed during the CALTRANS study, since even after two wet seasons, the total accumulated sediments was less than 25mm. Inspections for structural repairs and leaks, and repair or replacement of pumps, plus vector control are included in the following maintenance costs.

Actual Average Annual Maintenance Effort-MCTT, 1999 costs

Activity	Labor Hours	Equipment and Materials, $
Inspections	24	-
Maintenance	84	308
Vector Control	70	-
Administration	131	-
Direct Cost	-	2,504
Total	309	$2,812

(Source*: BMP Retrofit Pilot Program,* CALTRANS)

Conservation Design Controls

Conservation design stormwater controls include a wide range of practices, including better site layout and decreased use of directly connected paved and roof areas. These practices are almost exclusively part of initial developments, and are difficult to retrofit. The following discussions are for some of the more common conservation design elements.

Grass Filter Strips

Grass filter strips differ from grassed swales in that the strips are designed to accommodate overland sheet flow, rather than channelized flow. The advantages of grass filter strips are low cost and ease of maintenance. The disadvantages of the filter strip include the land requirements and the tendency for stormwater runoff to concentrate and form a channel, which essentially "short circuits" the filter strip causing erosion and reduced pollutant reductions.

The costs for vegetated filter strips can be divided into mobilization and demobilization of equipment, site preparation, site development, and contingencies. Site construction activities include the placement of salvaged top soil, seeding and mulching, or sodding. Contingencies include planning, engineering, administration, and legal fees.

Maintenance of a grassed filter strip includes management of a dense vegetative cover; prevention of channel or gully formation, frequent spot repairs, fertilization (very minimal), and watering. Also, exposed areas should be quickly reseeded, or sodded. The strips should be examined annually for damage by foot or vehicular traffic, gully erosion, damage to vegetation and evidence of concentrated flows.

Estimated capital cost of a 25 foot wide grassed filter strip, 1987 costs

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light	strip	1	$107	$274	$441	$107	$274	$441
site preparation								
clearing…………….	acre	0.7	$2200	$3800	$5400	$1540	$2600	$3780
grubbing……………	acre	0.7	3800	5200	6600	2660	3640	4620
grading……………..	square yard	3333	0.1	0.2	0.3	333	667	1000
site development salvaged topsoil,								
seed and mulch…...	sq yard	1667	$0.4	$1	$1.6	$667	$1667	$2667
sod………………….	sq yard	1667	1.2	2.4	3.6	2000	4001	6001
Subtotal	--	--	--	--	--	$7,307	$12,909	$18,509
Contingencies……..	strip	1	25 percent	25 percent	25 percent	$1,827	$3,227	$4,627
Total	--	--	--	--	--	$9,134	$16,136	$23,136

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Estimated capital cost of a 50 foot wide grassed filter strip, 1987 costs

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light	strip	1	$107	$274	$441	$107	$274	$441
site preparation								
clearing……………	acre	1.3	$2200	$3800	$5400	$2860	$4940	$7020
grubbing…………..	acre	1.3	3800	5200	6600	4940	6760	8580
grading…………….	square yard	6292	0.1	0.2	0.3	629	1258	1888
site development salvaged topsoil,								
seed and mulch…..	sq yard	3146	$0.4	$1	$1.6	$1258	$3146	$5034
sod…………………	sq yard	3146	1.2	2.4	3.6	3775	7550	11326
Subtotal	--	--	--	--	--	$13,569	$23,928	$34,289
Contingencies……..	strip	1	25 percent	25 percent	25 percent	$3,392	$5,982	$8,572
Total	--	--	--	--	--	$16,961	$29,910	$42,861

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Estimated capital cost of a 100 foot wide grassed filter strip, 1987 costs

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light…	strip	1	$107	$274	$441	$107	$274	$441
site preparation								
clearing………………	acre	2.5	$2200	$3800	$5400	$5500	$9500	$13500
grubbing……………..	acre	2.5	3800	5200	6600	9500	13000	16500
grading……………….	square yard	12100	0.1	0.2	0.3	1210	2420	3630
site development salvaged topsoil,								
seed and mulch……..	sq yard	6050	$0.4	$1	$1.6	$2420	$6050	$9680
sod……………………	sq yard	6050	1.2	2.4	3.6	7260	14520	21780
Subtotal	--	--	--	--	--	$25,997	$45,764	$65,531
Contingencies……….	strip	1	25 percent	25 percent	25 percent	$6,499	$11,441	$16,383
Total	--	--	--	--	--	$32,496	$57,205	$81,914

(Source: *Costs of Urban Nonpoint Source Control Measures*, SWRPC)

Average annual operation and maintenance costs for grassed filter strips, 1987 costs

component	unit cost	strip width			comment
		25 feet	50 feet	100 feet	
lawn mowing	0.85/1000 sq feet	$0.17/linear foot	$0.34/linear foot	$0.68/linear foot	maintenance area equals width times strip length. Mow 8 times per year
general lawn care	$9/1000 sq feet/year	$0.23/linear foot	$0.45/linear foot	$0.9/linear foot	law maintenance area equals width times strip length

grass reseeding with mulch and fertilizer	$0.3/sq yard	$0.01/linear foot	$0.02/linear foot	$0.03/linear foot	area revegetated equals 1 percent of lawn maintenance area per year
filter strip inspection	$25/inspection	$0.1/linear foot	$0.1/linear foot	$0.1/linear foot	inspect four times per year
total	--	$0.51/linear foot	$0.91/linear foot	$1.71/linear foot	--

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Grass Swales

Grass swales are natural or man-made grass-lined channels, normally of parabolic or trapezoidal cross sections, used to carry stormwater in place of curb and gutters and underground pipes. Pollutants are removed by settling and infiltration into soil and by biological uptake of nutrients. Swales may reduce runoff from roadway and adjacent tributary land areas by allowing water to infiltrate. They also increase the time of concentration within the watershed, further reducing the peak flows. Grassed swales have the advantage of reducing peak flows, increasing pollutant removal, and low capital cost. Swales are not practicable in areas with flat grades, steep grades, or in wet or poorly drained soils.

The cost data on grassed swales found in Young, *et al.* is as follows:

$$C = KL$$

Where, C = construction cost, January 1999 costs
L = length of swale, ft
K = constant, 5 to 14 ($/ft)

(Source: *Costs of Urban Stormwater Control*, USEPA)

The costs of grassed swales can be divided into number of components: mobilization and demobilization of equipment, site preparation, site development, and contingencies. The tables below present selected unit costs, calculated component costs, and total capital costs for a 1.5 foot deep swale with a bottom foot of 1 foot and top width of 10 feet; and for a 3 foot deep swale that is 3 feet deep having a top width of 21 feet. They have a length of 1000 feet, gradient of 2 percent, and side slopes of three horizontal to one vertical.

estimated capital cost of a 1.5 foot deep, 10 foot wide grass swale (1,000 ft length) 1987 costs

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light	swale	1	$107	$274	$441	$107	$274	$441
site preparation								
clearing………………	acre	0.5	$2200	$3800	$5400	$1100	$1900	$2700
grubbing……………..	acre	0.25	3800	5200	6600	950	1300	1650
general excavation…	cubic yard	372	2.1	3.7	5.3	781	1376	1972
level and till…………	square yard	1210	0.2	0.35	0.5	242	424	605
site development								
salvaged topsoil, seed and mulch…….	sq yard	1210	$0.4	$1	$1.6	$484	$1210	$1936
sod……………………	sq yard	1210	1.2	2.4	3.6	1452	2904	4356
Subtotal	--	--	--	--	--	$5,116	$9,388	$13,660
Contingencies	swale	1	25 percent	25 percent	25 percent	$1,279	$2,347	$3,415
Total	--	--	--	--	--	$6,395	$11,735	$17,075

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Estimated capital cost of a 3.0 foot deep, 21 foot wide grass swale (1,000 ft length) 1987 costs

Component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light	swale	1	$107	$274	$441	$107	$274	$441

site preparation								
clearing………………	acre	0.75	$2200	$3800	$5400	$1650	$2850	$2700
grubbing……………..	acre	0.5	3800	5200	6600	1900	2600	1650
general excavation….	cubic yard	1563	2.1	3.7	5.3	3283	5783	1972
level and till………….	square yard	2420	0.2	0.35	0.5	484	847	605
site development salvaged topsoil,								
seed and mulch……..	sq yard	1815	$0.4	$1	$1.6	$726	$1815	$1936
sod……………………	sq yard	1815	1.2	2.4	3.6	2178	4356	4356
Subtotal	--	--	--	--	--	$10,327	$18,525	$26,723
Contingencies	swale	1	25 percent	25 percent	25 percent	$2,582	$4,631	$6,681
Total	--	--	--	--	--	$12,909	$23,156	$33,404

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

The following swale maintenance costs include selected unit costs for debris removal, grass mowing, spot reseeding and sodding, weed control, swale inspection, and program administration.

Average annual operation and maintenance costs for grass swales, 1987 costs

component	unit cost	swale size (depth and top width)		comment
		1.5 feet deep, one foot bottom width, 10 foot top width	3 feet deep, three foot bottom width, 21 foot top width	
lawn mowing	0.85/1000 sq feet	$0.14/linear foot	$0.21/linear foot	maintenance area= (top width+10 feet) * length. Mow 8 times per year
general lawn care	$9/1000 sq feet/year	$0.18/linear foot	$0.28/linear foot	maintenance area = (top width+10 feet)* length
swale debris and litter removal	$0.10/sq yard	$0.10/linear foot	$0.10/linear foot	--
grass reseeding with mulch and fertilizer	$0.3/sq yard	$0.01/linear foot	$0.01/linear foot	area revegetated equals 1 percent of lawn main- tenance area per year
program administration and inspection	$0.15/linear foot/year, plus $25/inspection	$0.15/linear foot	$0.15/linear foot	ponds inspected four times per year
total	--	$0.58/linear foot	$0.75/linear foot	--

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Porous Pavement

Porous pavement removes waterborne pollutants from stormwater runoff and allows it to filter through the underlying soil. Porous pavements functions similar to other infiltration measures, with the pavement trapping some particulate bound pollutants.

A porous pavement is constructed of a porous asphalt or bituminous concrete surface with a 2.5 to 4 inch thickness that is placed over a highly permeable layer of crushed stone or gravel, 24 inches thick. A filter fabric is placed beneath the gravel or stone layer to prevent movement of fines into these layers. Runoff from the stone and gravel layer then infiltrates into the soil. If the infiltration rate is slow, perforated underdrain pipes can be placed in the stone layer to convey the water back to a surface waterway.

The primary advantage of porous pavement is that it can be put to dual usage reducing land use requirements. But, porous pavements are not as durable as conventional pavements because of the increased potential for drainage problems and freeze-thaw conditions during cold weather. Also, they are costlier than conventional pavements.

Construction costs involve site excavation, development and contingencies. Site development components include construction of porous layer, placement of stone fill, filter cloth and supplemental underdrain system. Contingencies include planning, engineering, administration and legal fees.

Estimated Incremental Costs (over conventional pavement) of a 1.0-Acre Porous Pavement Parking Lot (1989 costs)

component	unit	extent	unit cost			total cost		
			low	moderate	high	low	moderate	hig
site preparation								
general excavation….	cubic yard	1,452	$2.10	$3.70	$5.30	$3,049	$5,372	:
site development								
geotextile fabric……..	sq yard	5,082	$1.00	$2.00	$3.00	$5,082	$10,164	$
crushed stone fill……	cubic yard	1,452	14.80	19.40	24.00	21,490	28,169	:
porous pavement…...	sq yard	4,840	0.50	0.50	1.00	2,420	3,630	
Subtotal	--	--	--	--	--	$32,041	$47,335	$
Contingencies	site	1	25 percent	25 percent	25 percent	$8,010	$11,834	$
Total	--	--	--	--	--	$40,051	$59,169	**$**

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Maintenance involves the need for frequent cleaning as they are prone to easy clogging. Vacuum cleaning of the pavement is required at least four times a year, followed by jet hosing to open up asphalt pores. The pavement surface needs to be annually inspected, and after large storm events, for cracks and potholes. An observation well may be installed at the downslope end of the pavement to monitor water levels in the underdrain and to collect water samples. Incremental maintenance costs are estimated to be $200 per acre per year regardless of the depth of the stone reservoir.

Incremental Average Annual Maintenance Costs (over conventional pavement) of a Porous Pavement Parking Lot, (1989 dollars)

component	unit cost	porous pavement parking lot	comment
vacuum sweeping and high-pressure jet hosing	$17/acre vacuum sweeping, plus $8.00/acre jet hosing	$100/acre/year	vacuum and hose area four times per year
inspection	$25/inspection	$100/acre/year	inspect four times per year
total	--	$200/acre/year	--

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Infiltration Trenches, Rain Gardens, Biofilters, and Bioretention Devices

Infiltration trenches remove stormwater pollutants by filtering it through the soil. There are a number of different, but closely related devices that operate in a similar manner; rain gardens, biofilters, and bioretention devices. Infiltration trenches are used in places where space is a problem. They consist of excavating a void volume, lining it with a filter fabric, and then installing underdrains and back-fill material. The media can range from crushed stone (infiltration trenches providing more storage) to soils amended with compost (enhanced evapotranspiration and treatment of infiltrating water).

Infiltration trenches are used to serve areas less than 10 acres. The surface of the trench consists of vegetation and with special inlets to distribute the water evenly. Infiltration trenches help recharge groundwater, reduce runoff and augment low stream flows. Rain gardens generally serve a much smaller area, generally just a portion of runoff from an adjacent roof.

Maintenance of infiltration trenches involve annual inspections and inspections after every storm event, mowing, vegetative buffer strip maintenance, and rehabilitation of trench when clogging begins to occur. Infiltration trenches have a history of failure due to clogging, while the smaller rain gardens have a better operational history.

The available cost data for construction of infiltration trenches by Young, *et al*. gives total cost as a function of the total volume of the trench:

$$C = 157V^{0.63}$$

Where, C = construction cost, January 1999 costs

V = volume of trench, ft^3

(Source: *Costs of Urban Stormwater Control*, USEPA)

The SEWRPC (Southeastern Wisconsin Regional Planning Commission) data in the following tables gives the cost of mobilization and demobilization of equipment, site preparation, site development, and contingencies for infiltrations trenches of varying sizes.

Estimated capital cost of a three-foot-deep, four-foot-wide, 100 feet long infiltration trench (1989 costs)

component	unit	extent	unit costs			total costs		
			low	moderate	high	low	moderate	high
mobilization-demobilization-light……..	trench	1	$107	$274	$441	$107	$274	$441
site preparation								
clearing………………….	acre	0.12	$2200	$3800	$5400	$264	$456	$648
grubbing…………………	acre	0.01	3800	5200	6600	38	52	66
trench excavation………	cubic yard	43.3	2.1	5.6	9.1	91	242	394
site development								
salvaged topsoil,				$1				
seed and mulch…………	sq yard	111	$0.4	2.4	$1.6	$44	$111	$178
sod………………………..	sq yard	444	1.2	19.4	3.6	533	1066	1598
crushed stone fill…………	cubic yard	43.3	14.8	2	24	641	840	1039
				160				

geotextile fabric………… shallow observation well..	square yard vertical foot	171 4	1 66		3 254	171 264	342 640	513 1016
subtotal	--	--	--	--	--	$2,153	$4,023	$5,893
contingencies	trench	1	25 percent	25 percent	25 percent	$538	$1,006	$1,473
total	--	--	--	--	--	$2,691	$5,029	$7,367

(Source: *Costs of Urban Nonpoint Source Control Measures*, SWRPC, WI)

estimated capital cost of a six-foot-deep, ten-foot-wide, 100 feet long infiltration trench, (1989 costs)

			unit costs			total costs		
component	**unit**	**extent**	**low**	**moderate**	**high**	**low**	**moderate**	**high**
mobilization- demobilization-light	trench	1	$107	$274	$441	$107	$274	$441
site preparation clearing………………… grubbing………………… trench excavation………	 acre acre cubic yard	 0.14 0.02 222	 $2200 3800 2.1	 $3800 5200 5.6	 $5400 6600 9.1	 $308 76 466	 $532 102 1243	 $756 132 2020
site development salvaged topsoil, seed and mulch………… sod……………………… crushed stone fill………. geotextile fabric……….. shallow observation well..	 sq yard sq yard cubic yard square yard vertical foot	 111 444 222 388 4	 $0.4 1.2 14.8 1 66	 $1 2.4 19.4 2 160	 $1.6 3.6 24 3 254	 $44 533 3268 171 264	 $111 1066 4307 776 1120	 $178 1598 5328 1164 1778
subtotal	--	--	--	--	--	$2,153	$9,533	$13,395
contingencies	basin	1	25 percent	25 percent	25 percent	$1,418	$2,383	$3,349
total	--	--	--	--	--	$7,088	$11,916	$16,744

(Source: *Costs of Urban Nonpoint Source Control Measures*, SWRPC)

Maintenance costs include buffer strip maintenance and trench inspection and rehabilitation. Maintenance costs include buffer strip maintenance and trench inspection and rehabilitation. The average annual operation and maintenance costs for infiltration trenches of two different sizes are listed below.

Average annual operation and maintenance costs for infiltration trenches (1989 costs)

		trench size	
component	**unit cost**	**100 feet long by three feet deep by four feet wide**	**100 feet long by six feet deep by 10 feet wide**
buffer strip mowing	$0.85/1000 square feet/mowing	$10	$10

general buffer strip lawn care	$9/100 square feet/year	$45	$45
program administration and trench inspection	$25/inspection, plus $50/trench/year for administration	$100	$100
major trench rehabilitation	$0.4 to 19 per linear foot at 15 year intervals	$79	$334
minor trench rehabilitation	$0.25 to $3.7 per linear foot at 5-year intervals	$51	$126

(Source: *Costs of Urban Nonpoint Source Control Measures*, SEWRPC, WI)

Green Roofs
A green roof consists of a growing material placed over a waterproofing membrane on a relatively flat roof. A green roof not only provides an attractive roofing option but also uses evapotranspiration to reduce runoff volume, and provides some detention storage. Although green roofs may reduce some pollutants from the rainwater, they usually are significant sources of phosphorus due to leaching from the growing media.

Currently, the up-front cost of an extensive green roof in the U.S. starts at about $8 per square foot, which includes materials, preparation work, and installation. Maintenance involves watering, trimming, inspection for drainage and leaks and replacement of roof. An extensive green roof has low lying plants designed to provide maximum groundcover, water retention, erosion resistance, and transpiration of moisture. Extensive green roofs usually use plants with foliage from 2 to 6 inches in height and from 2 to 4 inches of soil. An intensive green roof is intended to be more of a natural landscape, installed on a rooftop. Intensive green roofs may use plants with foliage from 1 to 15 feet tall and may require several feet of soil depth and are therefore not common.

(Source: http://www.epa.gov/heatisland/strategies/greenroofs.html)

Comparing the costs among three types of roofs in 31 years of use:

Roof #1: A three-ply, asphalt built-up-roofing system with a price of $9.00 per sq. ft.
Average life expectancy is 10 years.
Roof #2: A modified hot applied roofing system with a price of $10.00 per sq. ft.
Average life expectancy is 20 years.
Roof #3: Two-ply modified bitumen, green roofing system with a price of $12.00 per sq. ft.
Average life expectancy is 40 years.

	Roof #1	**Roof #2**	**Roof#3**
Initial Capital Expense	$225,000	$250,000	$300,000
Capital Expense/Inflation In year 31	$1,154,595 (replaced 2x)	$591,764 (replaced 1x)	$300,00 (original roof)
Maintenance Costs/ Inflation In year 31	$26,607	$26,607	$26,607
Life Cycle Costs In year 31	$359,682	$283,939	$270,447

(Source: Eco-Roof Systems, W.P.Hickman systems Inc. http://www.ecoroofsystems.com/cost_files/c_cost.html)

Bioretention/Rain gardens
Bioretention/rain gardens are landscaped and vegetated filters for stormwater runoff. Stormwater is directed into a shallow, landscaped depression. The bedding material contains a high percentage of sand and smaller amounts of clay, silt and organic material. The recommended organic matter content of the amended soil should be about 5 to 10% to protect groundwater. Stormwater is allowed to pool over this soil and infiltrate through the mulch and prepared soil mix. Excess filtered runoff can be collected in an underdrain and returned to the storm drain system.

The cost of construction of rain gardens is represented as a function of area of watershed as shown below,

$$C = 10{,}162\ X^{1.088}, \text{ in clay soil}$$

$$C = 2{,}861\ X^{0.438}, \text{ in sandy soil}$$

Where,
C = cost, $
X = size of watershed, acres

(Source: *An Evaluation of Cost and Benefits of Structural Stormwater Best Management Practices in North Carolina*, 2003).

This cost estimate includes labor, installation cost and a 30% overhead rate. The construction cost does not include the cost of any piping or stormwater conveyance external to the device. Also, not included are land costs.

Maintenance and inspection of rain gardens involve pruning the shrubs and trees twice a year, mowing seasonally, weeding monthly, remulching 1-2 times over the life time of the device, removing accumulated sediment every 10 to 20 years, and underdrain inspection once a year. These factors were taken into account for estimating the total 20-year maintenance cost as shown below. This cost estimate is the same for clayey and sandy soils.

$$C = 3{,}437\ X^{0.152}$$

Where
C = cost, $
X = size of watershed, acres

(Source: *An Evaluation of Cost and Benefits of Structural Stormwater Best Management Practices in North Carolina*, 2003).

Cisterns and Water Storage for Reuse
Water conservation has many urban water benefits, including reducing wastewater flows and reduced delivery of highly treated and possibly scarce water. A sizeable fraction of the water needs in many areas can be satisfied by using water of lesser quality, such as stormwater. However, the stormwater must be stored for later use. Typical beneficial uses of stormwater include landscape irrigation and toilet flushing. The following is an excerpt of an urban water reuse analysis using WinSLAMM, with some basic cost information. The site being investigated was a new cluster of fraternity housing at Birmingham Southern University.

The runoff from the rooftops is estimated to contribute about 30% of the annual runoff volume for this drainage area. Each building has about 4,000 ft^2 of roof area. One approach was to capture as much of the rainwater as possible, using underground storage tanks. Any overflow from the storage tanks would then flow into rain gardens to encourage infiltration, with any excess entering the conventional stormwater drainage system. The storage tanks can be easily pumped into currently available irrigation tractors, which have 500 gal tanks. The total roof runoff from the six buildings is expected to be slightly more than 100,000 ft^3 (750,000 gal) of water per year. With a cost of about $1.50 per 100 ft^3, this would be valued at about $1,500 per year. It is expected that the storage tanks would have a useful life of at least 20 years, with a resultant savings of at least $30,000. One source for plastic underground water storage tanks (Chem-Tainer, New York) lists their cost at about $1,500 for 300 ft^3 units.

The efficiency of these storage units is based on their expected use. The following table lists the assumed average water use, in gal per day, for the roof runoff for each house. This was calculated assuming pumped irrigation near the buildings, with each house irrigating about ½ acre of turf. If the above mentioned tanker tractors were used so water could be delivered to other locations on campus, the water use would be greater, and the efficiency of the system would increase.

	Irrigation Needs (inches per month on turf)	**Average use for ½ acre (gal/day)**
January	1	230
February	1	230
March	1.5	340
April	2	460
May	3	680
June	4	910
July	4	910
August	4	910
September	3	680
October	2	460
November	1.5	340
December	1	230
Total	28	

The following table shows the estimated fraction of the annual roof runoff that would be used for this irrigation for different storage tank volumes per building (again assuming pumped irrigation to ½ acre per building):

Tankage Volume per Building (ft^3)	**Fraction of Annual Roof Runoff used for Irrigation**
1,000	56%
2,000	56
4,000	74
8,000	90
16,000	98

With this irrigation schedule, there is no significant difference between the utilization rates for 1,000 and 2,000 ft^3 of storage tankage per building. Again, with the tractor rigs, the utilization could be close to 100% for all tanks sizes, depending on the schedule for irrigation for other campus areas: larger tanks would only make the use of the water more convenient and would provide greater reserves during periods of dry weather. Also, small tanks would overflow more frequently during larger rains. For this reason, at least 1,000 ft^3 of tankage (3 or 4 of the 300 ft^3 tanks) per building is recommended for this installation.

Education Programs
Public education programs are intended for raising public awareness and therefore creating support of environmental programs. It is difficult to quantify actual pollutant reductions associated with educational efforts. However, public attitude can be gauged to predict how these programs perform. Public education program include programs like fertilizer and pesticide management, public involvement in stream restoration and monitoring projects, storm drain stenciling and overall awareness of aquatic resources. All education programs aim at reducing pollutant loadings by changing people's behavior and also to make people aware and gain support fir programs in place to protect water resources. Some unit costs for educational program components (based on two different programs) are included in the table below.

Unit Program Costs for Public Education Programs, 1999$

Item	Cost
Public Attitude Survey	$1,250-$1,750 per 1000 households
Flyers	10-25 ¢/flyer
Soil Test Kit*	$10
Paint	25-30 ¢/SD Stencil
Safety Vests for Volunteers	$2
*Includes cost of testing, but not sampling	

(Source: *Preliminary Data Summary of Urban Stormwater Best Management Practices* EPA-821-R-99-012, August 1999)

The following table provides information on some educational expenditure (a portion of the entire annual budget) in Seattle with a population of 535,000. The city of Seattle has a relatively aggressive public education program for wet weather flow issues, including classroom and field involvement programs.

1997 budget for some aspects of the public education costs in Seattle, Washington (1999 costs)

Item	Description	Budget
Supplies for Volunteers	Covers supplies for the Stewardship through environmental partnership program	$17,500
Communications	Communications strategy highlighting a newly formed program within the city	$18,000
Environmental Education	Transportation costs from schools to field visits (105 schools with four trips each)	$46,500
Education Services/ Field Trips	Fees for student visits to various sites	$55,000
Teacher Training	Covers the cost of training classroom teachers for the environmental education program	$3,400
Equipment	Equipment for classroom education, including displays, handouts, etc.	$38,800
Water Interpretive Specialist: Staff	Staff to provide public information at two creeks	$79,300
Water Interpretive Specialist: Equipment	Materials and equipment to support interpretive specialist program	$12,100
Youth Conservation Corps	Supports clean-up activities in creeks	$210,900

(Source: *Preliminary Data Summary of Urban Stormwater Best Management Practices*
EPA-821-R-99-012, August 1999)

Cost Adjustments for Different Locations and Dates

This report shows the costs involved in the construction, operation and maintenance of several stormwater controls. These costs are representative of costs incurred in a specific year or in a specific period of time, and location. To determine the cost of construction of these stormwater controls in 2005, or in any other particular year or location, the corresponding cost index values are used from the attached cost index chart.

These Cost Index values are prepared by McGraw Hill, the publisher of the *Engineering News Record* (ENR) and are available from www.ENR.com. ENR has price reporters covering 20 U.S. cities who check prices locally. The prices are quoted from the same suppliers each month. ENR computes its latest indexes from these figures and local union wage rates. The 20 cities are: Atlanta GA, Baltimore MD, Birmingham AL, Boston MA, Chicago IL, Cincinnati OH, Cleveland OH, Dallas TX , Denver CO, Detroit MI, Kansas City MO, Los Angeles CA, Minneapolis MN, New Orleans LA, New York NY, Philadelphia PA, Pittsburgh PA, San Francisco CA, Seattle WA, St. Louis MO. The Construction Cost Index values for these 20 cities in the US from 1978 to 2005 are shown in the attached table. Also, the 20-city averaged construction cost index, materials price index, common labor index and building cost indices for the 20 cities are also attached.

For determining the cost index for cities not listed in the chart, the index value can be obtained by averaging the cost of the nearest cities. The attached US map shows the 20 cities with Thiessen Polygons drawn around each city. These polygons define the closest areas of influence around each of the 20 cities. They were constructed by joining perpendicular bisectors between each pair of cities.

Construction Cost Index Values for Different Cities (ENR)

Year	Atlanta, GA	Baltimore, MD	Birmingham, AL	Boston, MA	Chicago, IL	Cincinnati, OH	Cleveland, OH
1978	2172.6	2396.39	2283.3	2772.83	2981.85	3088.21	3267.97
1979	2358.43	2719.34	2431.67	3096.16	3266.78	3349.05	3565.5
1980	2535.72	2904.39	2558.45	3173.98	3497.25	3609.93	3860.76
1981	2801.31	3060.78	2768.12	3659.88	3749.45	4045.44	4379.04
1982	3034.47	3097.4	2853.6	3993.72	4106.45	4234.64	4669.64
1983	2909	3107.35	2983.6	4204.75	4235.73	4398.6	4847.04
1984	2898.53	3158.77	3074.83	4497.4	4319.75	4437.58	5073.08
1985	2909.71	3236.9	3037.76	4685.85	4367.28	4548.2	4992.32
1986	3018.67	3372.26	3083.92	4722.66	4495.88	4567.24	5061.56
1987	3094.92	3560.91	3251.65	4941.39	4686.53	4647.13	5251.44
1988	3107.63	3576.83	3331.21	5137.58	4844.48	4700.51	5237.37
1989	3141.55	3707.18	3413.76	5373.14	4957.69	4877.51	5161.68
1990	3191.55	3884.43	3426.41	5614.79	4998.8	4933.91	5368.82
1991	3224.67	3858.19	3466.21	5722.5	5384.16	5011.1	5450.25
1992	3348.42	3997.47	3665.33	5973.33	5643.78	5209.18	5501.09
1993	3389.89	4171.75	3919.97	6380.25	5962.58	5344.53	5752.29
1994	3430.97	4198.95	3940.28	6404.34	6177.81	5504.43	5922.53
1995	3381.41	4324.86	4069.43	6407.28	6333.93	5450.56	6018.52
1996	3601.31	4544.51	4264.98	6772.2	6743.46	5488.81	6187.09
1997	3690.27	4502.11	4310.28	6747.28	6625.83	5585.21	6264.58
1998	3772.43	4534.38	4230.88	6921.04	7086.96	5641.21	6347.97
1999	3849.39	4564.19	4472.05	7103.92	7464.71	5888.56	6462.03
2000	4105.86	4532.08	4504.66	6986.61	7747.96	6044.89	6733.83
2001	4045.52	4542.29	4716.58	7042.39	7679.62	5858.12	6920.63
2002	4189.12	4580.15	4686.49	7546.61	7965.18	6155.81	7067.13
2003	4374.69	4818.78	4904.07	7976.09	8348.45	6286.9	7229.01
2004	4533.6	4978.88	5125.83	8216.29	8927.07	6587.24	7468.96
2005	4603.49	5186.73	5135.56	8310.54	9353.68	7003.8	7649.75

Construction Cost Index Values for Different Cities (ENR) continued

Year	Dallas, TX	Denver, CO	Detroit, MI	Kansas City, MO	Los Angeles, CA	Minneapolis, MN	New Orleans, LA
1978	2082.95	2564.77	3223.97	3039.64	3421.25	2902.6	2346.65
1979	2427.24	2739.14	3492.04	3256.47	3638.81	3154.37	2693.75
1980	2683.34	2947.14	3798.23	3551.83	4102.37	3238.86	2792.99

1981	2975.25	3200.57	4138.17	3838.22	4530.96	3612.6	3087.99
1982	3192.54	3445.7	4244.91	4069.74	4934.14	3924.98	3294.66
1983	3263.61	3690.22	4375.55	4199.38	5063.89	4322.45	3444.58
1984	2950.4	3106.45r	4331.1	4200.58	5259.93	4209.93	3427.64
1985	2997.36	3316.24	4468.09	4337.4	5446.69	4303.33	3411.86
1986	3152.84	3503.37	4674.95	4485.48	5452.2	4406.75	3513.96
1987	2985.85	3506.95	4859.89	4599.98	5474.14	4494.16	3572.49
1988	3184.72	3538.26	5092.67	4667.26	5770.84	4582.99	3571.19
1989	3208.39	3641.78	5171.88	4719.9	5789.77	4804.75	3590.13
1990	3195.21	3668.2	5153.9	4763.94	5994.55	4798.61	3602.41
1991	3336.53	3715.34	5244.65	4762.18	6090.12	4932.67	3638.65
1992	3476.69	3833.64	5395.34	4955.79	6348.55	5133.25	3730.37
1993	3570.97	4012.02	5917.92	5224.43	6477.84	5395.05	3764.21
1994	3640.03	4008.74	5979.62	5304.63	6532.95	5776.85	3831.08
1995	3641.12	4087.82	6135.27	5369.96	6526.22	5909.05	3833.36
1996	3870.81	4334.09	6428.7	5652.65	6558.44	6298.52	3973.26
1997	3935.95	4329.24	6619.64	5909.18	6663.55	6434.11	4013.79
1998	3960.19	4470.35	6817.65	5981.26	6851.95	6628.38	3994.93
1999	3968.5	4498.45	6943.56	5999.65	6825.97	6878.53	3945.01
2000	3985.86	4766.74	7100.4	6221.07	7068.04	6995.02	4016.26
2001	3854.32	4663.08	7378.92	6477.21	7226.92	7317.41	3984.38
2002	3895.46	4744.3	7654.06	6782.21	7402.75	7620.66	3906.42
2003	4044.04	5015.43	7860.94	6971.96	7531.77	7999.46	3899.73
2004	4207.65	5310.42	8191.41	7494.32	7899.48	8329.93	4257.45
2005	4345.89	5450.52	8444.8	7936.6	8232.32	8611.33	4360.01

Construction Cost Index Values for Different Cities (ENR) continued

Year	New York, NY	Philadelphia, PA	Pittsburgh, PA	San Francisco, CA	Seattle, WA	St.Louis, MO
1978	3325.43	2839.24	2945.44	3412.2	3197	3105.71
1979	3580.5	3183.93	3180.57	3806.14	3497.64	3344.2
1980	3774.64	3233.59	3383.37	4371.96	3909.16	3578.4
1981	4125.68	3603.48	3653.46	4592.45	4230.36	3834.64
1982	4553.93	3858.5	3894.97	4993.3	4490.38	4107.49
1983	4887.55	4175.74	4077.51	5122.74	4559.55	4325.69
1984	5160.95	4437.81	4234.49	5049.13	4546.01	4511.37
1985	5388.08	4549.62	4208.63	5055.04	4563.1	4733.37
1986	5621.15	4678.78	4280.39	5508.43	4585.4	4827.92
1987	5961.27	4883.56	4311.93	5732.37	4684.28	5056.78
1988	6231.12	5064.2	4331.7	5734.48	4738.35	5061.56
1989	6453.56	5299.78	4425.57	5932.57	4898.01	5132.97
1990	6846.49	5431.26	4580.56	6055.61	4933.39	5090.94
1991	7110.37	5616.96	4696.93	6222.06	5120.63	5172.41
1992	7367.49	5682.35	4988.38	6294.84	5320.37	5315.67
1993	7737.11	6022.23	5287.87	6477.95	5630.25	5765.31
1994	8117.64	6224.86	5485.79	6530.35	5818.49	5947.05
1995	8378.68	6431	5648.52	6558.16	5924.09	6053.67
1996	8554.47	6599.25	5984.29	6629.61	6086.77	6302.04
1997	8742.88	7057.36	5889.15	6731.08	6639.85	6474.56
1998	8899.59	7297.87	5976.05	6845.59	6957.81	6598.82
1999	9355.77	7487.01	6068.33	6816.7	7137.17	6806.23
2000	9379.14	7600.26	6198.9	7447.99	7368.25	6851.3
2001	10101.24	7960.76	6252.6	7399.07	7335.24	7047.92

2002	10009.06	8226.27	6419.37	7644.46	7561.98	7197.19
2003	10386.73	8403.02	6512.58	7788.8	7866.58	7414.09
2004	11279.53	8701.1	6884.92	8091.66	8014.67	7797.3
2005	11726.63	8631.64	6981.69	8236.56	8171.8	7921.41

Year	Construction Cost Index, 20 city average	Materials Cost Index, 20 city average	Common Labor Index, 20 city average	Building Cost Index, 20 city average
1978	2776	NA	NA	1654
1979	3003	NA	NA	1919
1980	3237	NA	NA	1941
1981	3535	NA	NA	2097
1982	3825	NA	NA	2234
1983	4066	1650.75	NA	2384
1984	4146	1620.83	NA	2417
1985	4195	1617.08	NA	2428
1986	4295	1634.17	NA	2483
1987	4406	1659.00	NA	2541
1988	4519	1694.00	NA	2598
1989	4615	1693.33	NA	2634
1990	4732	1720.17	9645.75	2702
1991	4835	1708.83	9935.17	2751
1992	4985	1760.92	10243.42	2834
1993	5210	1953.17	10524.75	2996
1994	5408	2068.17	10855.92	3111
1995	5471	1992.83	11146.25	3111
1996	5620	2045.83	11443.83	3203
1997	5826	2225.92	11697.33	3364
1998	5920	2179.25	12024.42	3391
1999	6059	2184.08	12382.58	3456
2000	6221	2195.08	12789.67	3539
2001	6343	2112.83	13242.25	3574
2002	6538	2043.67	13870.67	3623
2003	6694	1980.75	14385.67	3693
2004	7115	2295.83	14977.58	3984
2005				

Example Application of Cost Analyses

Example of the present value and annualized value cost calculations

Assume:
Interest rate = 4%
Project life = 20 years
Capital cost of project = $50,000
Land cost of project = $15,000
Annual maintenance cost = $6,000/year

Present value of all costs = Capital cost of project + land cost of project + present value of the annual maintenance and operation cost.
= $50,000 + $15,000 + 13.590 * $6,000 = $146,540

Annualized value of all costs = Annualized value of (capital cost of project + land cost of project) + annual maintenance and operation cost.
= 0.07358 * ($50,000 + $15,000) + $6,000 = $10,783 per year

References

American Public Works Association (APWA). 1992. *A Study of Nationwide Costs to Implement Municipal Storm Water Best Management Practices*. Southern California Chapter. Water Resource Committee.

Brown, W. and T. Schueler. 1997b. *The Economics of Storm Water BMPs in the Mid-Atlantic Region*. Center for Watershed Protection. Ellicott City, MD.

CALTRANS, Division of Environmental Analysis. 2001. *BMP Retrofit Pilot Program*. Report ID CTSW–RT–01–050.

CALTRANS, October 2003. *Phase I Gross Solids Removal Devices Pilot Study 2000-2002*. CTSW-RT-03-072.31.22

CALTRANS, November 2003. *Phase II Gross Solids Removal Device Pilot Study 2001-2003*. CTSW-RT-03-072.31.22

Dames and Moore. 1978. *Construction Costs for Municipal Waterwater Treatment Plants: 1973-1977.* 1978. Environmental Protection Agency, Office of Water Program Operations, Washington, D.C.

Eco-Roof Systems, W.P.Hickman systems Inc. http://www.ecoroofsystems.com/cost_files/c_cost.html

Ferguson, T., R. Gignac, M. Stoffan, A. Ibrahim and J. Aldrich. 1997. *Rouge River National Wet Weather Demonstration Project: Cost Estimating Guidelines, Best Management Practices and Engineered Controls*. Wayne County, MI.

Frank, J. 1989. *The Costs of Alternative Development Patterns: A Review of the Literature*. Urban Land Institute. Washington, DC.

Heaney, James P.; David Sample and Leonard Wright. 2002. *Costs of Urban Stormwater Control*. EPA Contract No. 68-C7-0011. National Risk Management Research Laboratory Office of Research and Development, U.S.Environmental Protection Agency, Cincinnati, OH.

McGraw Hill Construction. Engineering News Record. ENR.com.

Office of Water Programs and California State University, Sacramento. 2005. *NPDES Stormwater Cost Survey.* California State Water Resources Control Board.

Sample, D.J., J.P.Heaney, L.T.Wright, C.Y.Fan, F.H.Lai, and R.Field. 2003. *Cost of Best Management Practices and Associated Land for Urban Stormwater Control*. Journal of Water Resources Planning and Management, Vol. 129, No.1, pp. 59-68

Southeastern Wisconsin Regional Planning Commission. 1991. *Costs of Urban Nonpoint Source Water Pollution Control Measure.* Waukesha, WI.

Storm*ceptor*®. The Storm*ceptor*® System for Stormwater Quality Improvement.

Muthukrishnan, Swarna; Bethany Madge, Ari Selvakumar, Richard Field and Daniel Sullivan. *The Use of Best Management Practices (BMPs) in Urban Watersheds.* 2006. National Risk Management Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio. ISBN No. 1-932078-46-0.

USEPA. 1999*. Preliminary Data Summary of Urban Stormwater Best Management Practices*. EPA-821-R-99-012. Office of Water, United States Environmental Protection Agency, Washington, D.C.

USEPA. 1999. *Stormwater O&M Fact Sheet - Catch Basin Cleaning*. EPA 832-F-99-011, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Hydrodynamic Separators*. EPA 832-F-99-017, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Bioretention*. EPA 832- F-99-012, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Porous Pavement*. EPA 832-F-99-023, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet – Sand Filters*. EPA 832-F-99-007, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Stormwater Wetlands*. EPA 832-F-99-025, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Vegetated Swales*. EPA 832-F-99-006, Office of Water, United States Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Stormwater Technology Fact Sheet - Wet Detention Ponds*. EPA 832- F-99-048, Office of Water, United States Environmental Protection Agency, Washington, DC

Peluso, Vincent F.; Ana Marshall. 2002. *Best Management Practices for South Florida Urban Stormwater Management Systems*. Appendix A. Typical Costs Associated with Structural BMPs. Everglades Stormwater Program South Florida Water Management District, West palm, Florida.

Wiegend, C., T. Schueler, W.Chittenden and D.Jellick. 1986. *Cost of Urban Runoff Quality Controls*. pp 366-380. In: Urban Runoff Quality. Engineering Foundation Conference. ASCE, Henniker, NH. June 23-27.

Wossink, Ada, and Bill Hunt. 2003. *An Evaluation of Cost and Benefits of Structural Stormwater Best Management Practices in North Carolina*, North Carolina State University.

Young, G.K., S.Stein, P.Cole, T.Krammer, F.Graziano and F.Bank. 1996. *Evaluation and Management of Highway Runoff. Water Quality Technical Report*. Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC.