6 BMP Costs

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6.0 INTRODUCTION

Cost is an integral part of BMP design. The purpose of this chapter is to provide information on how to estimate the cost of structural BMPs. Costs associated with nonstructural BMPs are not included here as they are generally not as easily quantified as structural BMPs due to their indirect and highly variable implementation levels. The cost for constructing a structural BMP depends on many factors. They include the time of year, site conditions and topography, accessibility of equipment, economics of scale, and government regulations. Out of these factors, site conditions and topography are usually the most influential. Site preparation costs may be greatly reduced if existing conditions and vegetation are carefully integrated into the design of any BMP; e.g., a natural depression could be developed into some type of detention pond (Ferguson *et al.*, 1997).

It is normally less expensive from a unit cost standpoint to construct a larger project than a smaller one. This is because large portions of the costs are involved in mobilizing and demobilizing a project. Both overestimating and underestimating can occur by not considering the magnitude of the project (Ferguson *et al.*, 1997). However, a larger project usually involves significantly more land costs than does distributing BMPs into already set aside landscaping areas.

The cost of constructing any BMP is variable and can be substantial. Several documents have been published that address cost estimating for BMPs, but most of these report only construction costs (Young *et al.*,1996; Sample *et al.*, 2003). In addition, costs are often documented as base costs and do not include land costs, which according to the U.S. EPA (1999) is the largest variable influencing overall BMP cost.

Design, operation, and maintenance (O&M) are other significant cost considerations discussed in only a few sources. Ferguson *et al.* (1997) published a fairly comprehensive BMP cost estimating guide as part of the Rouge River restoration project that includes construction and O&M costs for many BMPs. This guide could be used outside the Rouge River watershed provided adjustments are made for local labor rates and associated real estate costs. Young *et al.* (1996) compiled the results of past highway runoff research into a single volume users manual for highway practitioners which provide construction cost data for each BMP, but no cost data for design and maintenance. The Southeastern Wisconsin Regional Planning Commission (SWRPC) (1991) documents the most comprehensive analysis of construction and maintenance costs. The Water Environment Research Foundation (WERF) has summarized construction and maintenance costs for commonly used BMPs (WERF, 2003). The wide range of cost data reported in the literature indicates that much more information is needed in this area. Identifying the primary element that drives construction cost upward is a high priority and could help reduce the initial cost associated with BMPs.

In general, initial construction cost and maintenance cost were the factors considered in computing the cost effectiveness of BMPs. Recent studies have suggested that using construction and maintenance costs to compute cost effectiveness is insufficient. Landphair *et al.* of Texas Transportation Institute (2000) proposed that a real measure of cost effectiveness should include design, maintenance, and construction costs as well as pollutant removal performance of a selected BMP. Their research suggested that a cost index of this kind was only meaningful if special site considerations and land costs were ignored.

6.1 BMP Cost Estimating Methods

Four common methods of cost estimation are as follows (DOD, 1995):

- bottom-up method,
- analogy method,
- expert opinion method, and
- parametric method.

6.1.1 Bottom-Up Method

The bottom-up approach estimates costs on an item-by-item basis. Detailed methods typically rely on quantity take-offs and compiled sources of unit cost data for each item, taken from either a built-in database or other sources (e.g., cost-estimating references). This method is used when design information is available.

6.1.2 Analogy Method

This technique uses the cost of previously completed projects, as a comparison to the cost of the proposed project, to arrive at a final cost estimate. The actual costs from the completed project are extrapolated to estimate the cost of the proposed project (DOD, 1995). This method provides estimates by using the system or component level, which are obtained from using actual project costs from past experiences. The disadvantage of this method occurs when projects similar to the one in question do not exist, or the accuracy of the available data is questionable, or extrapolating the entire project cost does not accurately reflect evenly scaled costs.

6.1.3 Expert Opinion Method

Experts in this field can be consulted to provide a cost estimate for the project based upon their past experience and understanding of the proposed undertaking. The advantage of this is that the experts have the knowledge to account for the differences between past project experiences and the proposed project requirements, pointing out areas contributing to the cost estimate that may be overlooked. They can also factor in the impacts produced by new technologies or applications. The disadvantage of this technique is that the estimate is confined by the judgement and expertise of the consulted experts (DOD, 1995).

6.1.4 Parametric Method

The parametric approach relies on relationships between cost and design parameters. These relationships are usually statistically-based or model-based. Statistically-based approaches rely on “scaled-up” or “scaled-down” versions of projects where historical cost data is available. Model-based approaches utilize a generic design that is linked to a cost database and adjusted by the user for site-specific information. This method, also known as top-down estimating, is used when design information is not available (U.S. EPA, 2000).

6.2 BMP COST ANALYSES ELEMENTS

6.2.1 Total Costs

The total costs of BMPs include both capital (construction and land) and annual O&M costs. The first category of costs only occur in the year when the BMP is installed unless retrofits or up-sizing occur. The other costs may occur either yearly (e.g., operation cost) or some other frequency throughout the life of the BMP to maintain it.

6.2.1.1 Capital Costs

Capital costs are those expenditures that are required to construct a BMP. They are exclusive of costs required to operate or maintain the BMP throughout its lifetime. Capital costs consist primarily of expenditures initially incurred to build or install the BMP (e.g., land cost, construction of a wetland, and related site work).

Capital costs include all land, labor, equipment and material costs, excavation and grading, control structure, sediment control, landscaping, and appurtenances. Capital costs also include expenditures for professional/technical services that are necessary to support the construction of a BMP. The cost of constructing any BMP is variable and depends largely on site conditions and drainage area. For example, if a BMP is constructed in very rocky soils, the increased excavation costs may substantially increase the cost of construction. Land costs, which can be the largest variable influencing overall BMP cost, vary greatly from site to site.

Capital costs typically can be estimated using equations based on the size or volume of water to be treated (U.S. EPA, 1999). Stormwater practices have certain spatial requirements for surface area or volume necessary to treat a quantity of stormwater from a watershed and this variation is incorporated into the equations (U.S. EPA, 1999). These equations typically follow the single determinant equation as shown below. This equation is linear in the log transform.

$$C = aP^{b}$$

Where C is the estimated cost ($); P is the determinant variable (area or volume); and a and b are statistical coefficients determined from regression analysis. The exponent b represents the economics of scale factor. If $b < 1$, the unit cost decreases as size increases. When $b = 1$, the equation simplifies to a linear relationship and no economics-of-scale are present. If $b < 1$, then diseconomics of scale exist. Table 6-1 shows the unit costs of commonly used BMPs as reported in the literature. Unless indicated otherwise, all costs are expressed in terms of 2002 dollars based on the Engineering News Record (ENR) average annual cost index of 6538 (ENR, 2002). The cost equations show that the capital costs of most BMPs correlate well with basin volume. The same was noted by Koustas and Selvakumar (2003).

Traditionally, capital costs were calculated using the standard estimation guides such as the R.S. Means Building Construction Cost Data Handbook used by many engineers. The Means book provides unit cost data for materials of construction, labor, equipment, installation, and excavation for cities across the U. S. However, linear equations are gaining popularity as they offer a way to replace a cost database with a single equation. These equations are based on data gathered from existing projects and assumptions that similar installations should cost about the same.

Table 6-1. Base Capital Costs (Without Land Costs) for Commonly Used BMPs

BMP Type	Base Capital Costs ($)	Reference
Detention Ponds/Dry Extended Detention Ponds	$C = 60{,}742V^{0.69}$; V in Mgal	Young *et al.*, 1996
	$C = 12.4V^{0.76}$; V in ft^3	Brown and Schueler, 1997
Wet Ponds/Retention Basins	$C = 67{,}368V^{0.75}$; V in Mgal	Young *et al.*, 1996
	$C = 24.5V^{0.71}$; V in ft^3	Brown and Schueler, 1997
Constructed Wetlands	$C = 30.6V^{0.71}$; V in ft^3	U.S. EPA, 2003
Infiltration Trenches/Filter Drains/Soakaways	$C = 173V^{0.63}$; V in ft^3	Young *et al.*, 1996
	$C = 5V$; V in ft^3	Brown and Schueler, 1997
Infiltration Basins	$C = 16.9V^{0.69}$; V in ft^3	Young *et al.*, 1996
Sand and Organic Filters	C = KA; A in acres; K ranges from 12,369 to 24,738	Young *et al.*, 1996
Vegetated Swales	$0.25 to $0.50/$ft^2$	WERF, 2003
Vegetated Buffer Strips	$0.30 to $0.70/$ft^2$	WERF, 2003
Porous Pavement	$2 to $3/$ft^2$	U.S. EPA, 2003
Bioretention	$3 to $4/$ft^2$	Coffman, 1999
	$C = 7.3V^{0.99}$; V in ft^3	U.S. EPA, 2003; Brown and Schueler, 1997
Water Quality Inlets (enhanced catch basins)	$8,000 to $24,000	Young *et al.*, 1996
	$2,000 to $3,000/basin for precast basins	U.S. EPA, 2003
	$400 to $10,000/basin for drop-in retrofits	U.S. EPA, 2003

Note: Costs in December 2002 dollars. Cost of land acquisition not included.
V = BMP Volume and A = BMP Area.

6.2.1.2 Design, Permitting, and Contingency Costs

Design and permitting costs include costs for site investigations, surveys, design and planning of a BMP (Novotny and Chesters, 1981). Contingency costs are simply any unexpected costs incurred during the development and construction of a BMP. These costs are usually expressed as a fraction of the base capital costs and have been considered as a uniform percentage for BMPs (U.S. EPA, 1999). Design, permitting, and contingency costs are reported in Table 6-2. These costs are generally only estimates, based on the experience of designers. Design, permitting and contingency costs can be a significant portion of the total capital cost of a BMP construction project particularly in areas where endangered species occur in contentious projects. In addition, cost of erosion and sediment control represents about 5 to 7% of the base capital costs (Brown and Schueler, 1997; U.S. EPA, 1999).

Table 6-2. Design, Permitting, and Contingency Costs

Additional Percentage (fraction of base capital costs)	Notes	Source
25 %	Includes design, permitting and contingency fees	Wiegand, *et al*. 1986; CWP, 1998; and U.S. EPA, 1999.
32 %	Includes design, permitting, contingency fees and erosion and sediment control costs	Brown and Schueler, 1997; U.S. EPA, 1999; and CWP, 1998.

6.2.1.3 Operation and Maintenance (O&M) Costs

O&M costs are those post-construction costs necessary to ensure or verify the continued effectiveness of a BMP. Like engineering design and construction, proper O&M is important in order to ensure that BMPs will function properly. These costs are estimated mostly on an annual basis.

Annual O&M costs include labor, materials, energy, and equipment required for proper operation and functionality of a BMP facility. These include costs for landscape maintenance, structural maintenance, infiltration maintenance, sediment removal, and basin debris and litter removal.

O&M costs are divided into two main categories: aesthetic and functional (U.S. EPA, 1999). Functional maintenance is important for performance and safety reasons, while aesthetic maintenance is important primarily for public acceptance of BMPs. Aesthetic appearance is more important for BMPs that are visible.

O&M costs are calculated on an annual basis throughout the life of a BMP facility. These costs are seldom available on a comprehensive basis and have been expressed as a fraction of the base capital costs. O&M costs, expressed as annual percentages of capital costs, as reported in literature, are presented in Table 6-3. O&M costs to maintain a stormwater BMP over a 20 to 25-year period are roughly equal to its initial construction cost (Weigand *et al.*, 1986). Few property owners and homeowner associations are fully aware of the need for and magnitude of stormwater maintenance costs, and most fail to regularly perform routine and non-routine maintenance tasks. It is likely that performance and longevity of many BMPs will decline without adequate maintenance. The information on the maintenance of BMPs is limited, even though the long term maintenance costs can be an important component of the life cycle cost of the facility.

Table 6-3. Annual Operation & Maintenance Costs

BMP Type	Annual Maintenance Costs (% of Construction Cost without Land Cost)	Source
Detention Ponds/Dry Extended Detention Ponds	<1%	Wiegand *et al*., 1986; Schueler, 1987; SWRPC, 1991
Wet Ponds/Retention Basins	3 to 6%	Brown and Schueler, 1997; SWRPC, 1991
Constructed Wetlands	3 to 6%	Wiegand *et al*. 1986; Schueler, 1987; SWRPC, 1991
	2%	Livingston *et al*. 1997; Brown and Schueler, 1997
Infiltration Trench	5 to 20%	Schueler, 1987; SWRPC, 1991
Infiltration Basin	1 to 3%	Livingston *et al*. 1997; SWRPC, 1991
	5 to 10%	Wiegand *et al*. 1986; Schueler, 1987; SWRPC, 1991
Sand Filters	11 to 13%	Livingston *et al*. 1997; Brown and Schueler, 1997
Grassed Swales	5 to 7%	SWRPC, 1991
Vegetated Buffer Strips	$350/acre/year	SWRPC, 1991

6.2.1.4 Land Costs

Land cost is of critical importance because it constitutes a significant, if not major, component of total costs. The cost of land is site specific and extremely variable both regionally and by surrounding land use. For example, many suburban jurisdictions require open space allocations within the developed site, reducing the effective cost of land for BMPs to zero (Schueler, 1987). On the other hand, the cost of land may far outweigh construction and design costs in ultra urban settings. It should be noted that in some cases where a BMP can be incorporated into a planned or required landscaped area, there is no additional cost. For example, Portland, Oregon has a 15% landscaping requirement for multi-family, commercial, and light-industrial developments. Automatically, there is enough land for stormwater BMPs. The land requirement varies considerably depending on the type of BMP as shown in the Table 6-4 below.

Table 6-4. Relative Land Consumption of Stormwater BMPs

BMP 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: U.S. EPA, 1999

6.2.1.5 Inflation and Regional Cost Adjustments

Any costs reported in the literature need to be adjusted for inflation and regional differences. To adjust for inflation, the ENR construction cost index history data can be used to adjust BMP cost data to current year dollars. The ENR index is published every month. The ENR index for the years 1990 to 2003 is shown in Table 6-5. To obtain current cost, the total capital BMP cost data is multiplied by current year index and divided by base year indexes. The total cost increase resulting from inflation can be calculated using the following equation:

$$\text{Capital Cost (adjusted)} = \frac{\text{Capital cost (base year) x ENR cost index for the current year}}{\text{ENR cost index for the base year}}$$

Table 6-5. ENR Annual Average Construction Cost Index History

Year	Construction Cost Index
1990	4732
1991	4835
1992	4985
1993	5210
1994	5408
1995	5471
1996	5620
1997	5826
1998	5920
1999	6059
2000	6221
2001	6343
2002	6538
2003	6695

Source: Engineering News Record (ENR, 2003)

Total capital costs for the construction of a BMP facility vary based on the region of the county or state in which the facility is located. Regional cost differences reflect differences in the cost of living, labor, and material costs for a particular location (U.S. EPA, 1999). Regional cost variations are perhaps the most difficult costs to estimate. Cost data can be adjusted for regional cost variation by using the ENR twenty city construction cost indexes for December 2002 (ENR, 2002). The twenty city construction cost index for December 2002 is shown in Table 6-6. The cost data adjusted for inflation is multiplied by the twenty city index factor (city index/national index for December 2002) of the city closest to the region of study to adjust for the regional variation.

Since the amount of regional rainfall may impact costs, further adjustment to cost is necessary. Based on a methodology presented by the American Public Works Association (APWA, 1992), a cost adjustment factor is assigned to each EPA rainfall region (shown in Figure 6-1). A regional cost adjustment factor based on regional rainfall zones is shown in Table 6-7. The cost adjusted for inflation and regional variation is reconciled for the rainfall bias by dividing the cost by the rainfall factor. For example, data for Florida (Region 3) is divided by 0.67 to adjust for the rainfall bias.

Table 6-6. Twenty City Construction Cost Index Regional Factors for December 2002

City	Index December 2002	Regional Factor
Atlanta	4189	0.64
Baltimore	4580	0.70
Birmingham	4686	0.71
Boston	7546	1.15
Chicago	7965	1.21
Cincinnati	6156	0.94
Cleveland	7067	1.08
Dallas	3895	0.59
Denver	4744	0.72
Detroit	7654	1.17
Kansas City	6782	1.03
Los Angeles	7403	1.13
Minneapolis	7621	1.16
New Orleans	3906	0.60
New York	10009	1.52
Philadelphia	8226	1.25
Pittsburgh	6419	0.98
St. Louis	7197	1.10
San Francisco	7644	1.16
Seattle	7562	1.15

Cost regional and inflation adjusted (December 2002) = Cost inflation adjusted (December 2002) x Regional Factor
Source: Engineering News Record (ENR, 2003); National Index for December 2002 is 6563

Table 6-7. Precipitation Regional Cost Adjustment Factors

Rainfall Zone	1	2	3	4	5	6	7	8	9
Adjustment Factor	1.12	0.90	0.67	0.92	0.67	1.24	1.04	1.04	0.76

Source: U.S. EPA, 1999

Note: This is very approximate as there are large differences in precipitation patterns.

6.2.2 Life Cycle Costs

Life cycle costs are costs incurred from "cradle to grave". Life cycle cost refers to the total project cost across the life span of a BMP, including design, construction, O&M, and closeout activities. It includes the initial capital costs 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). Life cycle cost analysis can be used to choose the most cost effective BMP from a series of alternatives so that the least long term cost is achieved.

A present worth analysis of future payment involves four basic steps:

1. define the period of analysis,
2. calculate the annual expenditures or cash outflow for each year of the project,
3. select a discount rate to use in the present worth calculation, and
4. calculate the present worth.

The present worth of a future payment is calculated using the following equation:

$$PW = \frac{x_t}{(1+i)^t}$$

where x_t is the payment in year t and i is the discount rate. The denominator, $(1 + i)^t$, is referred as a "discount factor." For a series of future payments, the total present worth from 1 to n years would be calculated as:

$$PW_{total} = \sum_{t=1}^{t=n} \frac{x_t}{(1+i)^t}$$

where, $\sum_{t=1}^{t=n} \frac{1}{(1+i)^t}$ is referred as the multi-year discount factor. When the annual cost, x_t, is constant over a period of years, the calculation of present worth can be simplified by using a multi-year discount factor.

Calculation Example - Wet Pond

In order to present how to calculate the life cycle cost of a BMP, a wet pond with a 1 acre-foot facility is selected. From Table 6-1, the construction cost for a wet pond can be calculated using the equation:

$$C = 24.5V^{0.71}$$

For a 1 acre-foot facility, the construction cost is equal to $45,700. From Table 6-2, the cost for design, permitting, and contingency is 25% of the construction cost, which is equal to $11,425.

For wet ponds, the annual cost of routine maintenance is typically estimated at about 3 to 6% of the construction cost (Table 6-3). Assuming 5%, the annual cost of maintenance becomes $2,285. Ponds are long-lived facilities (typically longer than 20 years). Assuming a period of analysis of 20 years and a discount rate of 7%, the multi-year discount factor is equal to 10.594. The present worth of maintenance for 20 years is calculated as 10.594 x $2,285 or $24,207.

Thus, for this example the life cycle cost equals the construction cost ($45,700), plus the design, permitting, and contingency cost ($11,425) and the present worth maintenance cost ($24,207) totaling $81,332. Land cost, which is extremely variable is not included.

6.3 ECONOMIC BENEFITS OF BMPS

BMPs can present several tangible economic benefits in spite of their construction, O&M costs. BMPs have the ability to mitigate potential downstream flooding associated with medium to larger storms. BMPs reduce flooding downstream from developments by reducing the peak flows and stretching out the flow over a long time. Avoiding floods eliminate property damages. Benefits of avoiding flood damages are relatively easy to estimate. Reducing peak flows can also potentially reduce capital and maintenance costs of drainage infrastructure.

BMPs can protect water resources downstream from urban development, which can prevent impact on human health through direct contact from swimming or through contamination of seafood. The economic benefits of avoiding human health problems include swimming and recreational benefits as well as saved medical costs. One study in Saginaw, Michigan estimated that the swimming and beach recreation benefits associated with a CSO retention project exceeded seven million dollars (U.S. EPA, 1998). BMPs also reduce the cost of water quality improvement.

BMPs are beneficial to developers as they create a "water" feature effect and people have a strong emotional attachment to water, arising from its aesthetic qualities– tranquility, coolness, and beauty. BMPs within developments can be used as marketing tools to set the tone for the entire project. BMPs that are visually aesthetic and safe for children can lead to increased property values. As such, beautification of land areas adjacent to BMPs should be considered an integral part of planning by developers. It was found that developers could charge per lot a premium of up to $10,000 for homes situated next to well-designed stormwater ponds and wetlands (U.S. EPA, 1995). A study conducted by the National Association of Home Builders indicates that the proximity to water raises the value of a home by up to 28% (U.S. EPA, 1995). If the BMPs are developed to allow passive recreation (e.g., a walking path around a lake or pond), the recreational area and the BMP can become the feature attraction when advertising the property. BMPs with standing water often appear to be natural systems. Many developers have capitalized on urban runoff regulations by designing aesthetic wet ponds and stormwater wetlands and marketing them as if they were natural lakes, ponds, or wetlands. In addition, U.S. EPA found that office parks and apartments next to a well-designed BMP could be leased or rented at a considerable premium and often at a much faster rate. BMPs may require more than periodic maintenance to preserve environmental and monetary benefits of "waterfront" lots. However, the benefits of higher resale value and quality of life typically outweigh the combined costs of the initial lot premium and annual maintenance fees charged by homeowners' associations (U.S. EPA, 1995).

Stormwater BMPs such as grassed swales and bioretention areas are actually less expensive to construct than enclosed storm drain systems and they also provide better environmental results (NJDEP, 2000). Also, the more natural drainage systems eliminate the need for costly manholes, pipes, trenches, and catch basins, while removing pollutants at the same time.

Stormwater BMPs must be maintained, and the cost burden falls on landowners or local government. Over a 20 to 25 year period, the full cost to maintain a stormwater BMP is roughly equal to its initial construction cost (Wiegand *et al.*, 1986). Poorly maintained BMPs may be unsightly due to excess algal growth or public littering. Few property owners and home owners' associations are fully aware of the magnitude of stormwater BMP maintenance costs, and fail to perform maintenance tasks.

Abatement or prevention of pollution from storm-generated flow is one of the most challenging areas in the environmental engineering field. The facts of life - from an engineering standpoint are difficult to face in terms of design and cost. Operational problems can be just as foreboding.

The full impacts of “marginal” pollution, particularly that caused by uncontrolled overflows, must be recognized now and planning initiated to improve drainage system efficiencies and bring all wastewater flows under control. Municipal programs with this objective cannot begin too soon because corrective action is time-consuming. Efforts devoted to improved sewerage and drainage systems will pay significant dividends in complete control of metropolitan wastewater problems and pollution abatement. Research and development are making available important answers on the most efficient and least costly methods needed to restore and maintain water resources for maximum usefulness to man.

It is clear that abatement requirements for storm-flow pollution are here. Already, federal and local governments have promulgated wet-weather flow treatment and control standards. Newly developed and developing watershed districts can take a crucial opportunity and assess what has transpired and determine their own best water management strategy.

To exemplify this, one can consider the water pollution control efforts in the U. S. Historically, this nation has always approached water pollution control in a series and segmented manner with respect to time and pollutant sources, respectively. The result is that the problem is still being fought after more than 60 years of effort and billions of dollars of expenditures. Initially, they abated sanitary sewage; first with primary treatment, and later only after a long time, with secondary treatment. Somewhere in between attempts to control sanitary sewage, industrial wastewater control became a requirement; however, pretreated industrial wastewaters are still released during an overflow event. Only recently were we forced to control combined sewer overflow, and now we are faced with requirements to abate separate-stormwater pollution. The aforementioned historical approach to water pollution control has taken a very long time, and only after trial and error of each individualized and fragmented approach was it learned that receiving water pollution problems remain. If instead, an entire watershed or multi-drainage area analysis was conducted earlier, a determination could have been made of the overall pollution problem in the receiving water bodies, the pollution sources (or culprits) contributing to the problem, and an optimized, integrated, area-wide program to correct the problem.

After the macro- (or large-scale watershed) analysis is conducted, an optimized determination of what sources to be abated (or where to spend the monies) will be made. Then, with the resulting information, a micro- (or drainage area/pollutant source and control) analysis can be performed.

There is one other important consideration that must be made, i.e., the reuse and reclamation of stormwater for such beneficial purposes as aesthetic and recreational ponds, groundwater recharge, irrigation, fire protection, and industrial water supply.

An optimal approach to integrated stormwater management is a total watershed or basin-wide analyses including a macro- or large-basin-scale evaluation interfaced with a descretized micro- or small-catchment-scale evaluation involving the integration of: (1) all catchments or drainage areas, tributaries, surrounding water bodies, and groundwater; (2) all pollutant source areas, land uses, and flows; and (3) added storm-flow sludge and residual solids handling and disposal. Flood and erosion control along with reuse and reclamation technology must also be integrated with pollution control, so that the retention and drainage facilities required for flood and erosion control can be simultaneously designed or retrofitted for pollution control and stormwater reclamation.

In conclusion, knowledge of interconnecting basinwide waters and pollutant loads affecting the receiving water body and the subsurface and groundwater will result in knowing how to get the optimum water resource and pollution abatement and a much more expedient and cost-effective water management program.

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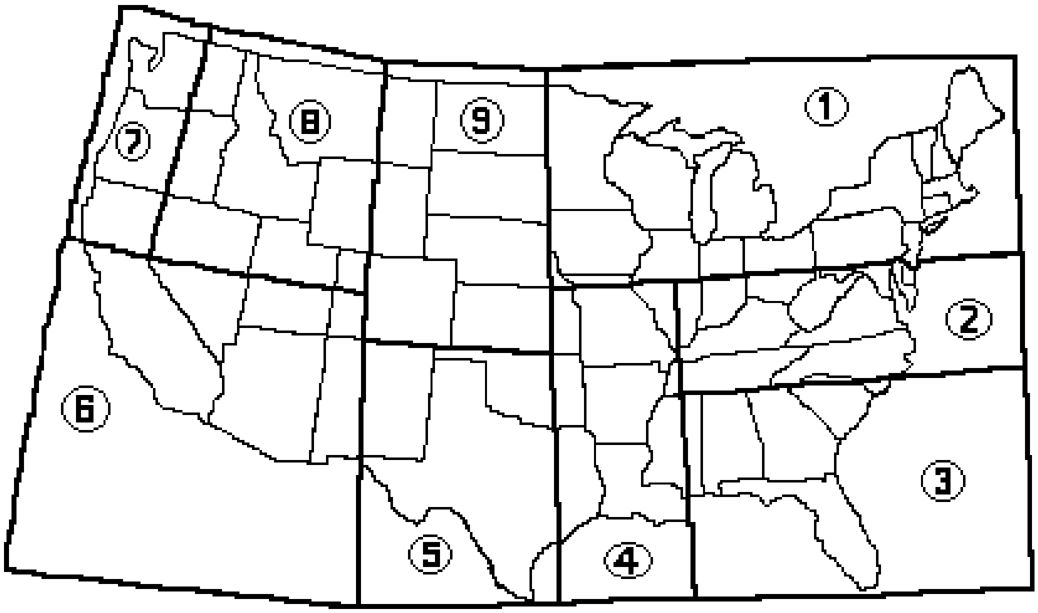

Figure 6-1. Regional Rainfall Zones for the United States

Rainfall Zones can be found in the NPDES Phase I regulations, 40 CFR Part 122, Appendix E (U.S. EPA, 1990)