BMP COST ANALYSIS FOR SOURCE WATER PROTECTION

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ABSTRACT: Cost equations are developed to estimate capital, and operations and maintenance (O&M) costs for commonly used best management practices (BMPs). Total BMP volume and/or surface area is used to predict these costs. ENR construction cost index was used to adjust cost data to December 2000 value. Construction costs equations were adjusted for regional differences using ENR 20 city cost index. O&M costs were further adjusted for rainfall bias based on regional rainfall zones. Cost functions for the determination of BMP costs follow the single determinant equation: $C = aP^b$, where a and b are a constant coefficient and exponent, respectively, and P is the determinant variable. The regression results showed that the capital costs of all BMPs correlate well with basin volume ($R^2 > 0.70$) and reasonably well with basin area (R^2 range from 0.43 to 0.95) except for wet detention ponds and grass swales. The O&M costs correlate well with basin area for grassed swales and constructed wetlands ($R^2 > 0.86$) and not so well for wet detention ponds ($R^2 = 0.49$). These cost equations, in conjunction with BMP performance models, will become a useful decision-making tool for evaluation of BMPs cost-effectiveness and placement for protection of drinking water sources.
KEY TERMS: best management practices; capital cost; O&M cost; detention ponds.

INTRODUCTION

Stormwater pollution is an extensive problem throughout the United States. Constituents frequently found as pollutants in stormwater include visible matter, infectious (pathogenic) microorganisms, oxygen demanding materials, suspended solids, nutrients, and toxicant (e.g., heavy metals, pesticides, and petroleum hydrocarbons). The 1987 amendment to the Clean Water Act mandated U.S. Environmental Protection Agency (USEPA) to develop a strategy for the National Pollution Discharge Elimination System (NPDES) for stormwater discharges. Soon after, USEPA promulgated regulations governing permits for stormwater discharges. The Stormwater Phase II Final Rule (USEPA, 1999a) covers stormwater discharges associated with industrial activity and discharge from storm sewer system. Operators of the regulated activities are required to apply for NPDES permit coverage and implement stormwater discharge management controls (e.g., BMPs) that effectively reduce or prevent discharge of pollutants into receiving waters. No single BMP will satisfy all the stormwater control objectives. Therefore, consideration should be given to cost-effective combinations of measures that will achieve the overall objectives of a particular site. In order to implement effective BMPs, the operators of regulated activities need proper design guidance and tools to estimate capital, and operating and maintenance (O&M) costs.

This paper presents the cost data and methods for calculating capital, operation and maintenance cost and cost adjustments for commonly used urban storm runoff BMPs. The costs for retention/detention ponds, swales, and constructed wetlands are presented in this paper.

Base Capital Costs (Construction Costs)

Base capital costs primarily refer to BMP construction costs that include expenditures for labor, materials, and equipment. Capital cost includes costs for engineering, excavation and grading, control structure, sediment control, landscaping, and appurtenances. Base capital costs of BMPs can vary significantly depending on site drainage characteristics and site conditions (USEPA, 1999b). Capital costs also vary based on regional cost of living (Ruggles, 1997). These regional differences can be found in the section on inflation and regional costs.

Cost per total BMP volume can be used to predict the overall construction costs and may be reported as cost per total basin volume (USEPA, 1999b). Costs are calculated based on formulas that vary based on the total

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volume of the storage facility. These models are typically based on cost functions. Cost functions typically follow the single determinant formula (Novotny and Chesters, 1981):

$$C = aP^b$$

where: C is the cost unit ($); P is total pond storage volume (the magnitude of the primary determinant); and a, b are statistical coefficients determined from regression analysis.

Design, Permitting, and Contingency Costs

Other costs to consider during the construction phase include: design (engineering and administrative), permitting, and contingency costs. Design and permitting costs include costs for site investigations, surveys, designing, and planning of a BMP (Novotny and Chesters, 1981). Contingency costs are simply any unexpected costs incurred during the development 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 (USEPA, 1999b).

Operation and Maintenance (O&M) Costs

O&M costs incorporate the value of materials and labor needed to ensure proper operation and functionality of a BMP facility. O&M activities are typically divided into two categories: aesthetic and functional (USEPA, 1999b). Functional maintenance includes activities needed for performance and safety; aesthetic maintenance is primarily for public acceptance. O&M costs may include costs for site maintenance, chemicals, insurance, real estate taxes, and plant supplies (Novotny and Chesters, 1982). O&M costs are calculated on an annual basis throughout the life of a BMP facility. O&M costs have been expressed as a fraction of the base capital costs.

Inflation and Regional Cost Adjustments

All dollar figures expressed in various studies are presented in different year dollars. For example, the Sears *et al.* (199) study dollar value is in 1995 dollars, where as those of Brown and Schueler (1997) are in 1997 dollars. In order to accurately assess the costs data used for developing the cost equation, all cost data are adjusted for inflation and reported in December 2000 dollars. To adjust for inflation, the Engineering News Record (ENR) construction cost index history data is used to adjust BMP cost data to December 2000 dollars.

Total capital costs for the construction of a BMP facility vary upon the region of the county or state in which facility is located. In this study cost data is adjusted for regional cost variation by using the ENR 20 city construction cost indexes for December 2000 (ENR, 2000). The cost data adjusted for inflation is multiplied by the 20 city index factor (city index/national index for December 2000) of the city closest to the region of study to adjust for the regional variation.

O&M costs are also adjusted for inflation and regional variation using the ENR indexes. Since the amount of regional rainfall may impact O&M costs, further adjustment to O&M cost is made based on a methodology presented by the American Public Works Association (APWA, 1992).

RESULTS

All of the capital and O&M cost data used in this study came from five main sources - BMP Cost Effectiveness Database by Tom Schueler and Whitney Brown (Brown and Schueler, 1997); Southeastern Wisconsin Regional Planning Commission Database (SWRPC, 1991); North American Wetland Database (NAWD) (USEPA, 1993); the EPA Design Manual for Wetlands (USEPA, 1998); and Cost data Format for the Nationwide Urban Runoff Program (NURP) Projects (MRI, 1980). These cost data are first adjusted for inflation and reported in December 2000 dollars. They are then adjusted for regional cost variation using the methodology described above using the nearest city index (from the 20 city ENR December 2000 index) closest to the region of study. The O&M cost data is further adjusted for the rainfall bias using the rainfall regions described in the previous section. The cost data from these databases adjusted for inflation and regional variation is the basis of regression analysis to develop the coefficients for the capital and O&M cost equations. The cost functions for the determination of BMP costs typically follow the single determinant equation: $C = aP^b$, where a and b are a constant coefficient and exponent, respectively, and P is the determinant variable. Linear regression for area, volume, and total cost was performed on a log-log scale to obtain the R^2 value and the relevant cost equation. A summary of results is provided in Table 1.

Table 1. Regression Results and Data Points

BMP	Description	Equation	R^2 Value	N
Dry Detention Ponds	Capital cost vs. area	$Y = 1.50A^{0.80}$	0.86	16
	Capital cost vs. volume	$Y = 20.4V^{0.757}$	0.94	13
Wet Detention Ponds	Capital cost vs. area	$Y = 3821A^{0.28}$	0.22	24
	Capital cost vs. volume	$Y = 385.8V^{0.515}$	0.56	17
	O&M cost vs. area	$Y = 46.40A^{0.40}$	0.49	8
Grassed Swales	Capital cost vs. area	$Y = 16.64A^{0.69}$	0.23	4
	O&M cost vs. area	$Y = 38.9A^{32}$	0.99	4
Wetland Data FWS Wetlands	Capital cost vs. area	$Y = 121.5A^{0.57}$	0.48	12
	Capital cost vs. volume	$Y = 53.1V^{0.67}$	0.70	5
	O&M cost vs. area	$Y = 2.2A^{0.65}$	0.86	6
SF Wetlands	Capital cost vs. area	$Y = 1016.9A^{0.49}$	0.43	20
	Capital cost vs. volume	$Y = 55.7V^{0.68}$	0.70	12

Where: A = Area in ft^2, V = Volume in ft^3, and N = number of data points.

The cost equation developed shows that the capital costs of all BMPs correlate well ($R^2 > 0.70$) with basin volume and reasonably well (R^2 range from 0.43 to 0.95) with basin area, except for wet detention ponds ($R^2 = 0.56$ and 0.22) and grassed swales ($R^2 = 0.23$). The O&M costs of wet detention ponds correlate well with basin area ($R^2 = 0.61$) but not so well for wetlands ($R^2 = 0.22$). The O&M costs show good correlation with grass swale area ($R^2 = 0.99$).

CONCLUSIONS

The equations predict significant construction cost decreases per unit volume or area with increasing basin or facility size for detention/retention basins and constructed wetlands. The base capital costs of grassed swales tend to be lower that the costs for the three other detention practices. This reduced cost can be attributed to the less invasive nature of grassed swale construction and cheaper material costs (grass seed). The cost equation developed on actual cost data is a rough estimate of the actual cost of the BMP=s capital and O&M costs. O&M costs are annual costs. All O&M costs for the life of the BMPs must be reduced to present value and added to the capital cost to obtain the total cost of the BMP over its life. This method can be used in screening process for selecting the appropriate BMP. The actual cost of constructing any BMP is variable and depends largely on the site conditions and drainage areas. For example, BMP constructed in a very rocky soil, the excavation cost may increase the construction cost substantially beyond those predicted by the equation. Actual capital cost may include cost of land acquisition which is not included here. Adjustment for inflation using the ENR cost index is a good methodology. Regional variations in cost can be estimated using the techniques presented here. However, further studies are needed to predict cost variation accurately within regions. Effort should be made to collect capital and O&M cost data along with performance. A larger cost database will help to develop a more accurate cost equation.

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