Article 68

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The Economics of Stormwater Treatment: An Update

Stormwater management can be the single greatest "out-of-pocket" cost that developers have to pay to meet local watershed protection requirements. Yet, surprisingly, very little is known about the actual cost of constructing stormwater practices. The last major study on the cost of urban stormwater management occurred over a decade ago when Wiegand and his colleagues (1986) investigated the construction cost of 65 stormwater management ponds in the Washington metropolitan area.

Since then, developers and watershed managers alike continue to be keenly interested in questions about the economics of stormwater practices. For example, has the cost of constructing stormwater management facilities increased over the last decade? If so, by how much? To what extent have new design and permitting requirements pushed up these costs? How much does it cost to build sand filters, bioretention areas or stormwater wetlands and other practices that were unheard of a dozen years ago? Are they cheaper to construct than ponds? What share of total stormwater management costs are due to water quality requirements as opposed to stormwater detention for peak discharge control? Do stormwater practices still exhibit economies of scale, i.e., is it still cheaper to construct a single large stormwater practice than a series of smaller ones to serve the same drainage area?

To address these questions, the Center undertook a second study in 1996 to update design and construction cost data for urban stormwater practices. The cost survey included 73 stormwater practices in the Mid-Atlantic area for which bond estimates, engineering estimates and actual construction contracts were available. The major stormwater practices that were analyzed included 41 pond systems (18 dry extended detention ponds and 20 wet extended detention and wet ponds and three wetlands); 11 bioretention areas, 11 sand filters and five infiltration trenches. Cost estimates for the practices were obtained from 14 private engineering firms and public agencies operating in Maryland and Virginia. Consequently, the population of stormwater practices that were sampled spanned a wide range of local design criteria and stormwater permitting requirements. In addition, the Center reviewed each stormwater practice design to determine watershed area, impervious cover, water quality storage volume and stormwater detention storage. Not all cost estimates were complete. In particular, specific cost information for control structures, landscaping, and erosion and sediment control (ESC) were frequently missing. These gaps were filled by using "unit rates" for each construction component developed from a survey of typical design and construction costs in the region. Unit rates for the basic component costs involved in stormwater practice construction are compared in Table 1.

The adjusted stormwater practice cost database was then statistically analyzed to examine the relationship between storage volumes (stormwater quality and quantity) and base construction cost (i.e., excavation and grading, ESC, and control structure costs) first established in the earlier Wiegand study. In general, the new study confirmed that stormwater storage volume was a reasonably strong indicator of construction cost for urban stormwater practices.

The new cost study found a strong relationship between pond storage volume and total construction cost of 41 stormwater ponds (see Figure 1). The equation describing the relationship had about the same slope and correlation coefficient as the 1986 pond cost equation (Table 2). The two cost equations are graphically compared in Figure 2. From this analysis, it is evident that the cost of providing a cubic foot of pond storage has climbed by 75% over the last decade. When inflation is factored out, the real cost increase is much smaller—about 30%. The higher cost is attributed to the adoption of enhanced pond design criteria, particularly those that have specified longer-lived but more costly construction materials (e.g., concrete vs. corrugated metal pipes).

In general, about a third of every dollar spent on stormwater pond construction was devoted to water quality control, with the remainder spent on flood control

Table 1: Comparison of Basic Component Cost of Stormwater Practice Construction

Basic Components of Construction Costs	Ponds	Sand Filters	Bioretention
Excavation/Grading	48 %	21 %	25 %
Control Structure	36	68	50
Appurtenances	16	11	25[a]

[a] includes landscaping costs

Table 2: Comparison of Cost Prediction Equations in 1986 and 1996 Studies

Practice Category	1986 Equation	(r^2)	1996 Equation	(r^2)
All Ponds	$CC = 6.11\ V_s^{0.75}$	(0.80)	$CC = 20.80\ V_s^{0.70}$	(0.77)
Dry ED Ponds	$CC = 10.71\ V_s^{0.69}$	(0.73)	$CC = 8.16\ V_s^{0.78}$	(0.93)
Bioretention	N/A	—	$CC = 5.67\ V_s^{0.99}$	(0.92)
Sand Filters	N/A	—	No acceptable equation	—
Infiltration Trenches	$CC = 26.55\ V_s^{0.63}$	(0.93)	Testing indicates 1986 equation is no longer valid	—

CC = Base construction cost, does not include costs for design, engineering and contingencies. To compute total cost, multiply base construction cost by 1.25 (1986 equations) and 1.32 (1996 equation) respectively.

V_s = Storage volume up to the crest of emergency spillway in cubic feet.

N/A = Not analyzed as part of study.

storage (detention of the two- and 10-year design storms). The cost study confirmed that significant economies of scale exist in pond construction, i.e., it is much cheaper to build a cubic foot of storage in a large pond than a small one. Lastly, the study indicated that dry extended detention ponds were only marginally less expensive than other pond options (wet ponds, wetlands, and wet extended detention ponds).

An example of how the pond cost equations can be used is provided in Table 3, which describes two typical development scenarios. To get a planning level estimate of stormwater cost, a designer needs to compute the combined storage volume needed for water quality and detention requirements. Once the cubic feet of pond storage is known, it is a simple matter to plug it into the 1996 pond equation to obtain a preliminary cost estimate. For the 50-acre residential development scenario shown in Table 3, the estimated total cost to design and construct a stormwater pond is computed to be over $98,000, of which $36,500 is specifically for water quality treatment. For the sake of comparison, the predicted pond cost for the same development scenario 10 years ago was computed using the 1986 cost equation and adjusting for inflation. An estimate of the lifetime nutrient reduction cost of the stormwater pond is also easily calculated, in this case about $84 and $20 per pound of phosphorus and nitrogen removed, respectively.

A very strong relationship was developed to predict the cost of bioretention areas on the basis of the water quality volume they provide (see Figure 3). Bioretention areas are becoming a very popular water quality practice in the mid-Atlantic region (they are designed for pollutant removal but not flood control).

The study found no economies of scale for bioretention, which is consistent with the fact that these

Table 3: Costs of Stormwater Management for Two Development Scenarios

	Scenario 1 5-acre commercial	Scenario 2 50-acre residential subdivision
Required WQ Storage	0.264 acre-feet	1.41 acre-feet
Required Detention Storage	0.740 acre-feet	3.25 acre-feet
Pond Construction Cost, 1986 [a]	$25,210 ($9,328)	$76,709 ($28,382)
Pond Construction Cost, 1996	$34,787 ($12,871)	$98,738 ($36,533)
Annual P and N Loads [b]	9.8 lbs P / 65 lbs N	36.7 lbs P/ 242 lbs N
P and N Removal [c]	115 lbs P / 487 lbs N	431 lbs P / 1815 lbs N
Cost per Pound Removed [d]	$ 112 per lb P / $26 per lb N	$ 84 per lb P / $20 per lb N

[a] Adjusted to 1996 dollars using an inflation factor of 1.32. Parentheses indicate water quality treatment costs.
[b] As computed by the Simple Method.
[c] Assuming national TP and TN removal of 47% and 30% respectively, over a 2- year period.
[d] Total cost divided by 25-year design life.

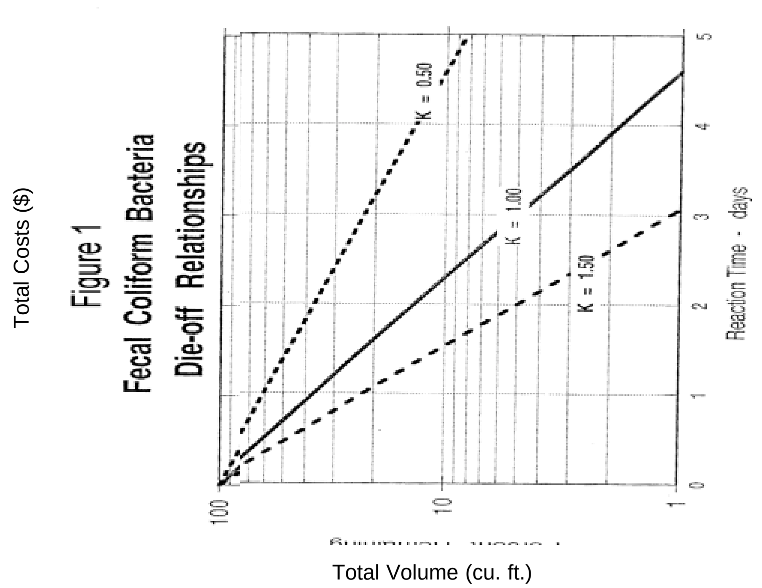


Figure 1: Relationship Between Total Construction Cost and Storage Volume for 40 Stormwater Ponds in the Mid-Atlantic Region

The cost of constructing a stormwater pond is directly related to the storage volume provided.

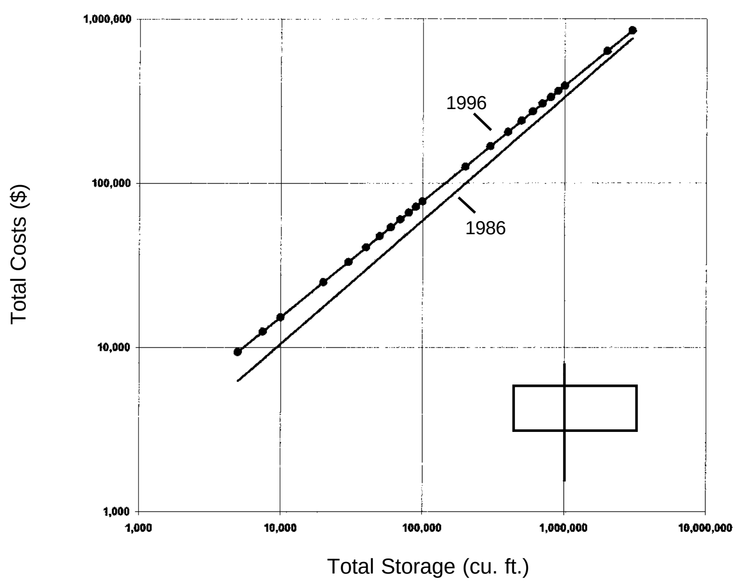


Figure 2: Comparison of 1986 and 1996 Pond Cost Prediction Equations

The two cost equations are both expressed in terms of 1996 dollars, and have the same basic slope and correlation coefficient. The top line represents the 1996 dataset,which is approximately 30% more expensive in real terms.

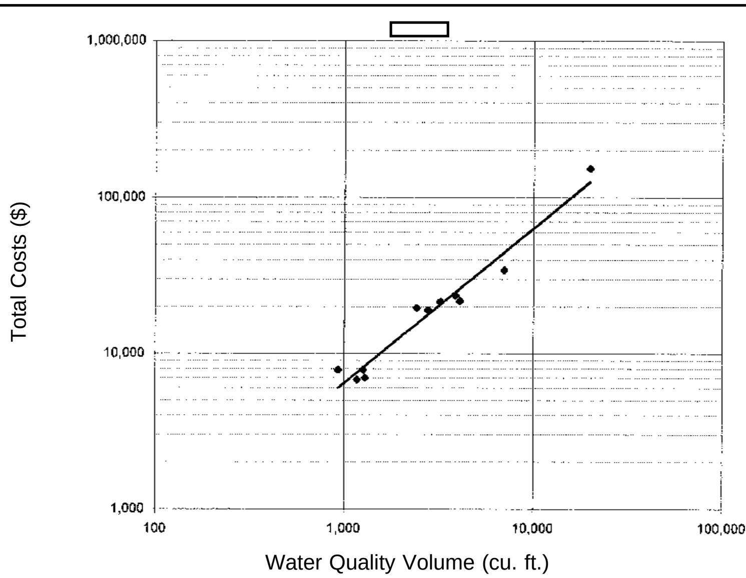


Figure 3: Relationship Between Total Construction Cost and Storage Volume for 12 Bioretention Areas

The cost of installing a bioretention area can be accurately predicted on the basis of the water quality volume it provides. Bioretention is seldom used to provide quantity control.

practices are sized as a flat percentage of site area. Another way of expressing the cost of bioretention is that they generally cost about $6.40 per cubic foot of quality treatment.

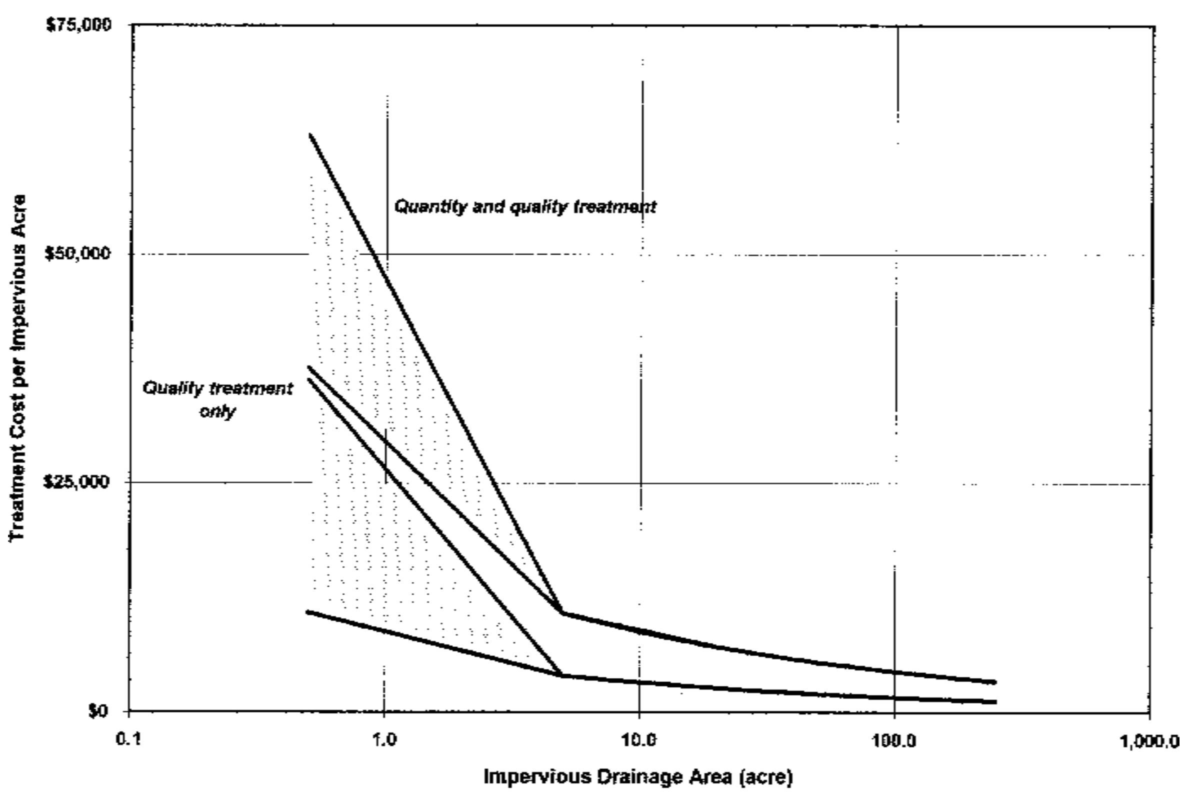
Cost data for sand filters was limited and extremely variable, and no predictive equations could be developed at this time. The variability was due to many diverse designs (surface and underground sand filters) and control structures. This data, however, were used to compute average costs. Filter costs ranged from $3 - $6 per cubic foot of quality storage, which is higher than an earlier surface sand filter cost study (Tull, 1990).

Since only five infiltration trenches were included in the Center study, no attempt was made to derive a cost equation. Instead, the data were used to determine whether the 1986 infiltration cost equation was still valid. This testing indicated that the older cost equation was no longer valid, as it consistently underestimated costs by a factor of two or more. Higher costs for infiltration trenches appeared to be a result of greater pretreatment measures and other enhanced design features that have come into more widespread use (observation wells, sand layers, etc.). Overall, the average construction cost for infiltration trenches ranged from $2 to $9 per cubic foot of water quality storage, with a mean of $3 per cubic foot, exclusive of design and geotechnical costs.

Summary

Our study suggests that the real costs of providing stormwater have increased over the past decade. Part of this increase is due to higher costs to design ponds and to secure permits. For a typical stormwater pond, the sum of all costs related to design, permitting, geotechnical testing, landscaping, contingencies, and ESC control now comprise 32% of the base construction cost (Table 4). If wetlands or streams are situated near a proposed pond site, these costs escalate to 37% of the base construction cost. These factors can be compared to the 25% of base construction cost rate that was an industry standard a decade ago. The Center survey indicates that these design cost increases can be attributed to longer plan review times: some seven months, on average, from plan submittal to final plan approval— even longer if wetlands permits are involved. Other reported factors that drive up costs are

Figure 4: Generalized Relationship Between Unit Stormwater Management Cost and Site Size



The cost of providing quantity and quality control climbs dramatically when development sites are small, due to the need for underground detention and separate quality practices. Considerable range in treatment costs is also common at small sites.

multiple and conflicting agency reviews and changes in local design criteria and submittal requirements.

The current cost study clearly supports the notion that ponds are the most cost-effective option to provide stormwater quantity and quality control. A generalized relationship illustrated typical unit costs to treat stormwater as a function of site size (Figure 4). The curves show a dramatic drop in the unit cost of providing both stormwater quantity and quality control once sites exceed five or more acres of contributing impervious drainage area. In this range, a single pond can provide both quantity and quality control in a cost-effective manner.

When sites become too small, however, surface ponds are no longer an effective option. Costs begin to skyrocket at small sites for two reasons. First, as available surface becomes scarce, engineers are increasingly driven "underground" to provide needed detention for quantity control. Second, quality control must be provided by an additional practice, such as sand filters, bioretention, or infiltration. In each case, the cost of each practice on a small sites is five to 10 times more expensive on a unit area basis than a comparable stormwater pond. The wide range in costs for small site stormwater practices shown in Figure 4 indicates that designers can expect to pay from $30,000 to $50,000 to treat the quality and quantity of runoff from a single impervious acre.

It is much more expensive to meet stormwater requirements on a small site than on a larger one. This clearly implies that larger "regional" or multi-site ponds are more cost-effective watershed strategy than on-site stormwater quality and quantity management, particularly at small sites.

Table 4: Typical Design and Engineering Costs for Stormwater Practices as a % of Basic Construction Cost

Rule-of-Thumb Estimates of Typical Practice Design and Engineering (D&E) Costs	Percent of Base Construction Cost
Engineering design	6
Engineering design, wetlands present	10
Standard permitting process	3
Permitting process, wetlands present	4
Geotechnical investigations	4
Structural design	3
Erosion and sediment control for practice	5
Landscaping	4
Contingency/unknown costs	7
Total additional D & E costs	32
Total additional D & E costs, wetlands present	37
Total additional D & E costs (1986)	25

References

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