Chapter 3

Cost Estimates for Stormwater Systems

The goal of this section is to provide the tools and data necessary to accurately estimate the costs of conventional stormwater systems; pipeline installation; excavation; bedding, and manhole installation. Section on open channels, storage, pumps, and paving costs are included as well for future reference

3.1 Stormwater Pipelines

This section describes the cost components of pipeline installation, i.e.:

1. Pipeline Installation: The pipelines themselves, and the material, labor, and equipment necessary for installation.
2. Trench Excavation Costs: The cost of excavating and constructing the trench into which the pipeline is installed. Backfill and rock blasting are included within this category.
3. Bedding Costs: These include the material, labor, and equipment necessary to install a simple compacted bedding system prior to backfilling the trench.

3.1.1 Pipeline installation

The costs of two different types of pipe were tabulated based on the data from RS Means (1996a). All values are updated to 1/99 $ using the ENR index of 6000 for January 1999, and 5584 for July 1995. The costs include fixed operations cost and profit, and the pipe materials, labor, and equipment. Because of the relative cost of the materials, pipes typically chosen for stormwater systems are corrugated metal (CMP), and reinforced concrete (RCP). The RS Means data was chosen for this analysis because of the longevity of this source of data (the user of this spreadsheet can easily swap databases, however).

A plot of the total installed costs (excluding excavation and backfill) vs pipe diameter for the CMP and RCP pipes is shown in Figure 3-1. A nonlinear relationship is readily apparent, and a power function was fit to the data. The resulting equation below is for CMP pipe, using the updated RS Means data:

$$C_p = 0.54D^{1.3024} \tag{3-1}$$

Where

C_p = construction cost, 1/99 $/ft

D = pipe diameter, in.

Although Equation 3.1 has a relatively high correlation coefficient (R^2) of .98, it is not a close fit for larger pipe diameters. A better way to estimate pipe costs is to use a lookup table, which is a standard feature in spreadsheets. Lookup tables are particularly useful for discrete data such as pipe diameters, and avoid the problem of trying to find a single equation that fits well over a wide range of pipe sizes.

The lookup tables for the design model is shown as Tables 3-1 and 3-2 for CMP and RCP pipe, respectively. A major disadvantage of using equations instead of direct cost data can be seen in Figure 3-1. The power function, although providing a good overall fit, can deviate from the actual cost/ft data point significantly, leading to an underestimation of project costs. However, an important advantage is that the equations provide a shorthand method of storing the relationship between costs and capacity. Equations facilitate the economic analytical evaluation of the component under consideration. With the use of a spreadsheet model, however, it becomes less necessary to make simplifying assumptions necessary to make regression fits possible, because simple lookup functions can replace these approximating equations.

Table 3-1. Lookup Table for Corrugated Metal Pipe (updated from RS Means, 1996a)

Diameter (in.)	Cost (1/99 $/ft)
8	9.40
10	11.80
12	14.40
15	18.40
18	20.90
24	30.10
30	37.20
36	54.80
48	81.60
60	118.20
72	179.50

Table 3-2. Lookup Table for Reinforced Concrete Pipe (updated from RS Means, 1996a)

Diameter (in.)	Cost (1/99 $/ft)
12	15.70
15	16.60
18	19.00
21	23.00
24	27.60
27	32.90
30	55.80
36	74.40
42	85.40
48	102.30
60	146.70
72	192.60
84	288.90
96	355.60

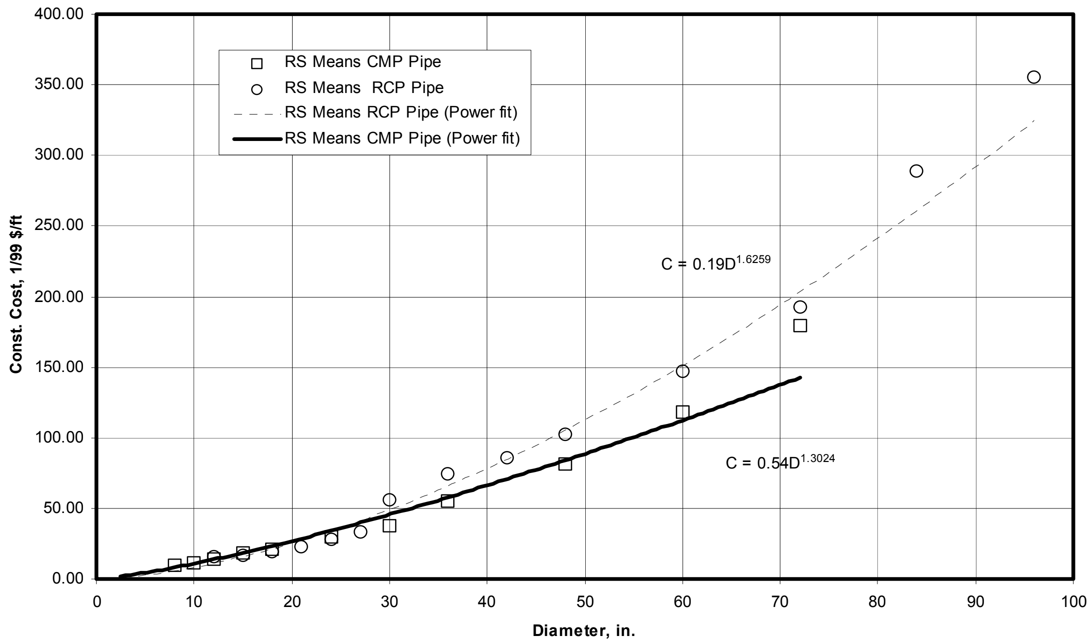

Figure 3-1. Cost of storm drainage pipe.

3.1.2 Trench excavation costs

Various trench excavation cost data were updated from RS Means (1996a) and plotted in Figure 3-2. Included are such fixed operations costs as labor, equipment, and materials costs. Although the excavation costs generally vary with depth and backhoe bucket size (not shown here), there was no statistical relationship that could explain this variation easily. For the purposes of the model, an average of this data was taken, which results an average excavation cost in $/yd^3 for a "moist loam" type of soil. Then, using productivity estimates from RS Means (1996a) for various soils, the excavation costs in Table 3-3 were obtained.

Table 3-3. 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
Silt	1.5	1	6.72

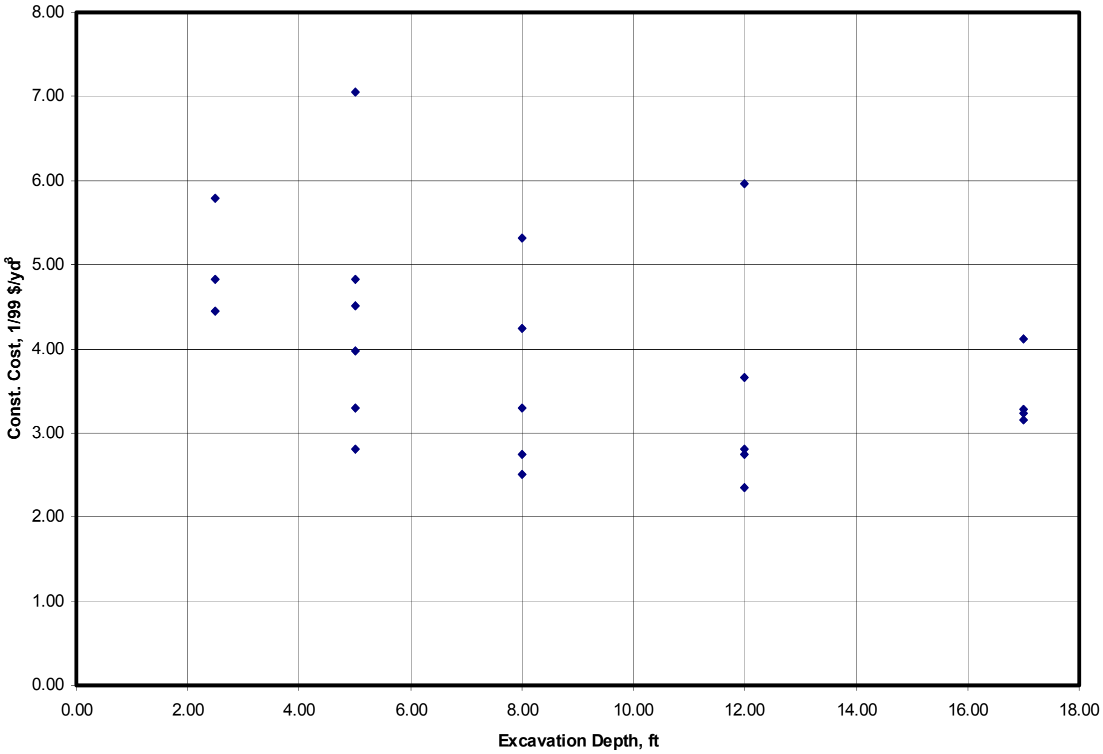

Figure 3-2. Trench excavation costs (Updated from RS Means, 1996a).

3.1.3 Bedding costs

Bedding provides sufficient compacted material necessary to protect the pipe from external loading forces. Bedding costs in the RS Means (1996a) system vary with diameter and side slope of the trench. The bedding material is compacted bank sand filled to 12 in. above the pipe. These costs were updated to 1/99 $ and can be found in Table 3-4. This table relates the horizontal and vertical side slope, the diameter, and the width to bedding costs, which include fixed operations cost and profit. Although several regression relationships were evaluated, it was decided that the most accurate model of these costs would be a two-way lookup table, relating the horizontal:vertical ratio and the pipe diameter to the projected cost.

Table 3-4. 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	2.00
0	1	0	10	2	2.07
0	1	0	12	2	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	3	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	4	5.55
0	1	0	32	6	9.72
0	1	0	36	6	9.98
0	1	0	48	7	13.01
0	1	0	60	8	16.23
0	1	0	72	10	23.39
0	1	0	84	12	31.80
0.5	1	0.5	6	1	1.90
0.5	1	0.5	8	2	3.16
0.5	1	0.5	10	2	3.43
0.5	1	0.5	12	2	3.67
0.5	1	0.5	14	3	5.25
0.5	1	0.5	15	3	5.39
0.5	1	0.5	16	3	5.55
0.5	1	0.5	18	3	5.88
0.5	1	0.5	20	4	7.77
0.5	1	0.5	21	4	7.95
0.5	1	0.5	24	4	8.52
0.5	1	0.5	30	4	9.56
0.5	1	0.5	32	6	14.06
0.5	1	0.5	36	6	15.08
0.5	1	0.5	48	7	20.58
0.5	1	0.5	60	8	26.81
0.5	1	0.5	72	10	37.47
0.5	1	0.5	84	12	49.71
1	1	1	6	1	2.90
1	1	1	8	2	4.36
1	1	1	10	2	4.77
1	1	1	12	2	5.25
1	1	1	14	3	7.06
1	1	1	15	3	7.30
1	1	1	16	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	13.50
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	37.40
1	1	1	72	10	51.76
1	1	1	84	12	67.70
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

Horizontal	Vertical	H/V	Diameter (in.)	Trench Width (ft)	Cost (1/99 $/ft)
1.5	1	1.5	15	3	9.18
1.5	1	1.5	16	3	9.56
1.5	1	1.5	18	3	10.38
1.5	1	1.5	20	4	12.80
1.5	1	1.5	21	4	13.24
1.5	1	1.5	24	4	14.63
1.5	1	1.5	30	4	17.64
1.5	1	1.5	32	6	22.77
1.5	1	1.5	36	6	25.23
1.5	1	1.5	48	7	35.76
1.5	1	1.5	60	8	48.21
1.5	1	1.5	72	10	65.65
1.5	1	1.5	60	8	48.21
1.5	1	1.5	72	10	65.65
1.5	1	1.5	84	12	86.16
2	1	2	6	1	5.01
2	1	2	8	2	6.73
2	1	2	10	2	7.49
2	1	2	12	2	8.37
2	1	2	14	3	10.59
2	1	2	15	3	11.04
2	1	2	16	3	11.54
2	1	2	18	3	12.66
2	1	2	20	4	15.32
2	1	2	21	4	15.89
2	1	2	24	4	17.71
2	1	2	31	4	21.61
2	1	2	32	6	27.15
2	1	2	36	6	30.22
2	1	2	48	7	43.22
2	1	2	60	8	58.67
2	1	2	72	10	79.32
2	1	2	84	12	103.94

3.2 Manholes

Manhole cost data, updated from RS Means (1996a), are tabulated in Table 3-5. The costs include fixed operations cost and profit, and labor, equipment, and materials costs for installation of precast concrete manholes. A plot of this data can be found in Figure 3-3. A power relationship was plotted and the following equation obtained:

$$C_{mh} = 482H^{0.9317} \quad \textbf{(3-2)}$$

Where

C_{mh} = cost of manhole, 1/99 \$

H = height of manhole, ft (maximum difference between the ground elevation and the invert elevations of sewers entering the manhole)

In general, the fit of the power equation was good, particularly at the lower heights. Some inaccuracies are introduced due to the regression relationship, however this is mitigated by the desire within the system model for a continuous function providing cost as a function of *H*. An alternative method is to use a lookup table and interpolate between the values of Table 3-5.

Table 3-5. Precast Concrete Manholes Costs (updated from RS Means, 1996a)

Riser Internal Diameter (ft)	Depth (ft)	Cost (1/99 $/ft)
4	4	1,860
4	6	2,460
4	8	3,250
4	10	3,970
4	12	4,830
4	14	6,060
5	4	2,310
5	6	3,120
5	8	3,970
5	10	5,070
5	12	6,260
5	14	7,600
6	4	3,150
6	6	4,070
6	8	5,340
6	10	6,710
6	12	8,350
6	14	9,990

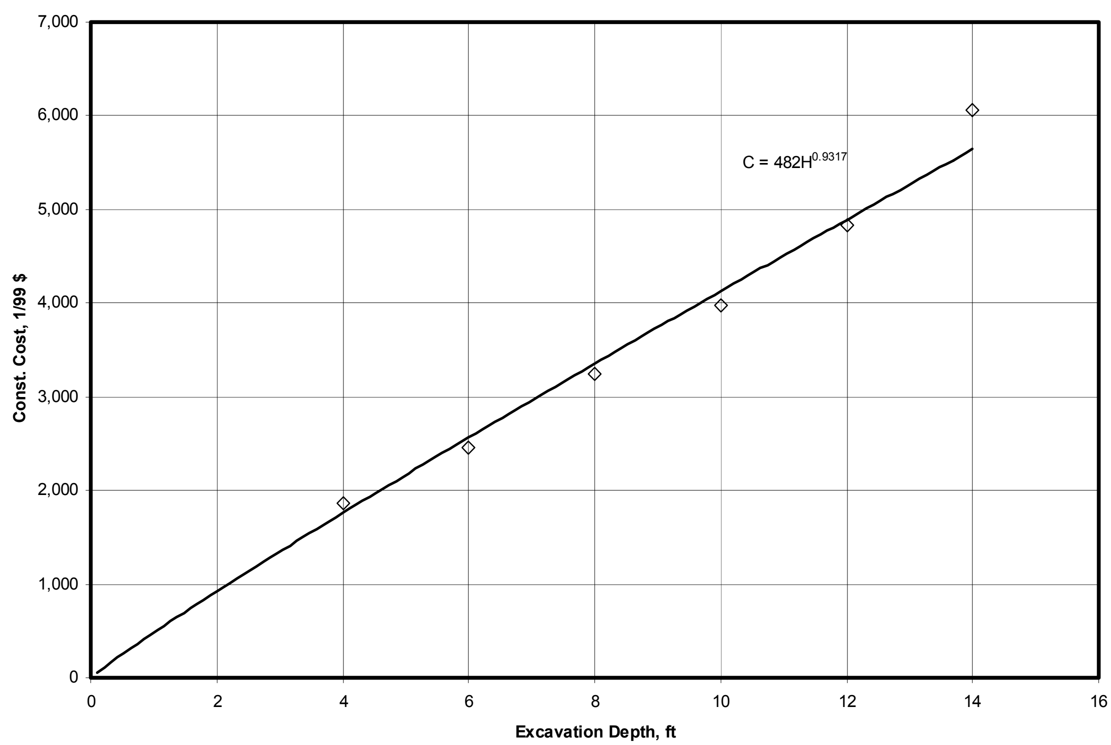

Figure 3-3. Manhole costs, as a function of excavation depth.

3.3 Open Channels

The cost of open channels needs to be estimated on a case by case basis since cut and fill calculations are required. Excavation costs are an important component of the construction of an open channel. MAPS (US Army Corps of Engineers, 1979) provides a general template for doing these calculations. The data presented in Table 3-3 on excavation costs may assist in this effort.

3.4 Pump Stations

Two different sized sewage pump stations are available in the RS Means database, as shown in Table 3-6. The costs include fixed operations cost and profit, and labor, equipment, and materials costs. An alternative method for calculating a pump station cost would be to develop a generic design of the structure that would be scaled based upon capacity and head, and include the appropriate pump costs. This work is beyond the scope of this effort.

Table 3-6. Capital Costs of Sewage Pump Stations (updated from RS Means, 1996a)

Description	Flow Rate (gpm)	Cost (1/99 $)
Sewage Pump Station	200	59,000.00
Sewage Pump Station	1000	112,000.00

3.5 Pavement and Creation of Impervious Surfaces

Fairly good data are available on the cost of various types of pavement, including porous pavement. Table 3-7 lists the main activities associated with paving and creation of impervious areas within developments. The costs include fixed operations cost and profit, and labor, equipment, and materials costs. An example of the use of this data is the following: Using a 32 ft wide subdivision street, with 6 in. crushed stone base material of 1½ in. in diameter, a primer, and a wearing course of 1½ in. of asphaltic concrete pavement, and curb and gutter (both sides) sums to a total of $58.80 per linear foot of pavement. This is shown below:

Base course:
$$5.85\ \frac{\$}{yd^2} * \frac{yd^2}{9\,ft^2} * 32\,ft = 20.80\ \$/ft \qquad \textbf{(3-3)}$$

Prime:
$$2\frac{gal}{yd^2} * 1.82\frac{\$}{gal} * \frac{yd^2}{9\,ft^2} * 32\,ft = 12.94\ \$/ft \qquad \textbf{(3-4)}$$

Paving:
$$3.14\frac{\$}{yd^2} * \frac{yd^2}{9\,ft^2} * 32\,ft = 11.16\ \$/ft \qquad \textbf{(3-5)}$$

Curb:
$$6.95\ \$/ft * 2 = 13.90\ \$/ft \qquad \textbf{(3-6)}$$

Total per linear ft:
$$\$20.80 + \$12.94 + \$11.16 + \$13.90 = \$58.80 \qquad \textbf{(3-7)}$$

Table 3-7. Paving Costs (updated from RS Means, 1996a)

Activity	Material	Diameter (in.)	Unit	Depth (in.)	Cost (1/99 $)
Prepare and Roll Subbase >2500 yd^2			yd^2		0.88
Base Course	Crushed Stone	0.75	yd^2	3	3.39
Base Course	Crushed Stone		yd^2	6	6.07
Base Course	Crushed Stone		yd^2	9	8.92
Base Course	Crushed Stone		yd^2	12	11.49
Base Course	Crushed Stone	1.5	yd^2	4	3.52
Base Course	Crushed Stone		yd^2	6	5.85
Base Course	Crushed Stone		yd^2	8	7.82
Base Course	Crushed Stone		yd^2	12	12.36
Base Course	Bank run gravel		yd^2	6	2.63
Base Course	Bank run gravel		yd^2	9	3.22
Base Course	Bank run gravel		yd^2	12	5.10
Base Course	Bituminous concrete		yd^2	4	8.37
Base Course	Bituminous concrete		yd^2	6	12.04
Base Course	Bituminous concrete		yd^2	8	15.86
Base Course	Bituminous concrete		yd^2	10	19.58
Prime and seal			gal		1.82
Asphaltic Concrete Pavement	Binder Course		yd^2	1.5	3.14
Asphaltic Concrete Pavement	Binder Course		yd^2	2	4.09
Asphaltic Concrete Pavement	Binder Course		yd^2	3	5.91
Asphaltic Concrete Pavement	Binder Course		yd^2	4	7.77
Asphaltic Concrete Pavement	Wearing Course		yd^2	1	2.31
Asphaltic Concrete Pavement	Wearing Course		yd^2	1.5	3.44
Asphaltic Concrete Pavement	Wearing Course		yd^2	2	4.52
Asphaltic Concrete Pavement	Wearing Course		yd^2	2 .5	5.47
Asphaltic Concrete Pavement	Wearing Course		yd^2	3	6.51
Curb and Gutter, machine formed	Concrete	24	LF		6.95

Note: gal = gallon; yd^2 = square yards; LF = linear foot.

This unit cost ($/ft) is for a lightly traveled subdivision street. As the projected traffic increases, the thickness used increases, thereby increasing the cost per linear foot.

This data is presented so that the cost of transportation related impervious surfaces is included in the system model.

3.6 Conclusions

In summary, detailed databases exist that can provide accurate cost information. The use of lookup tables, database functions, and regression (limited use where appropriate), a system model providing generic costing relationships can be built. Systematic evaluation of different designs through simulation enables repeated testing of various designs, leading to a method for optimization.