7.0 CAPITAL AND OPERATIONAL COSTS

7.1 Costing Information

This chapter provides information on capital as well as operation and maintenance costs for stormwater management practices (SWMPs). The cost of urban stormwater solutions is an important component to the overall economic viability of a development and needs to be considered when assessing alternative stormwater management measures. Maintenance and operation costs are critical considerations in the overall costs since these facilities will need to be maintained and operated in perpetuity.

Information outlined is based on 1997 to 1998 construction costs in the Greater Toronto Area and should only be used for planning purposes. Site-specific costs of SWMPs should be determined in all cases since there are many site-specific conditions that will affect capital, operation and maintenance costs.

SWP planning involves investigating SWMP alternatives at the site, subdivision, or subwatershed level. The information in this chapter can be used to estimate costs for various SWMP solutions (alone and in combination). This information will likely be most useful at a plan of subdivision level and subwatershed level since site-specific information will probably be available at the site plan level to provide more accurate costing estimates.

The total cost of a SWMP includes capital costs, the present value of operation and maintenance costs, engineering costs and contingency costs. Each of these costs is discussed in subsequent sections of this chapter.

7.2 SWMP Capital Costs

Stormwater facility capital costs are based on estimated construction costs including: excavation; cutting and filling; grading; structures; fittings; environmental site controls (sediment and erosion controls); and material costs. Engineering and design costs as well as land costs could also be included.

Table 7.1 outlines the type of construction and materials that may be required for various end-of-pipe stormwater management facilities. As noted in Table 7.1, several variations of items (e.g., reverse sloped outlet pipe, riser outlet pipe) have been included for different SWMP configurations. Therefore, when doing costs estimates, duplicate items in Table 7.1 should not be included twice (i.e., cost for a reverse sloped outlet pipe or a perforated riser outlet pipe, but not both).

Table 7.1: Capital Cost Items for End-of-Pipe Stormwater Management Facilities

Type of Construction or Material	wet pond	wetland	dry pond	infiltration basin	infiltration trench	soakaway pit	filter strip	sand filter	oil/grit* separator	grass swales	flow splitter
Excavation (off-site disposal)	×	×	×	×	×	×	×	×		×	×
Earthwork (cut and fill on site)	×	×	×	×	×	×	×	×		×	×
Erosion block/stone	×	×	×								
Concrete Outlet Structure	×	×	×								
Concrete Outlet Pipe	×	×	×								
Perforated Riser Outlet	×	×	×								
Perforated Riser Outlet Trash Rack	×	×	×								
Infiltration Observation Well					×						
Rip-rap	×	×	×							×	
Perforated Pipe				×	×	×	×	×			
Seed and Topsoil	×	×			×						
Clear Stone (gravel)					×	×		×			
Filter Cloth					×	×		×			
Filter Material (sand)					×			×			

Table 7.1: Capital Cost Items for End-of-Pipe Stormwater Management Facilities (cont'd)

Type of Construction or Material	wet pond	wetland	dry pond	infiltra-tion basin	infiltra-tion trench	soakaway pit	filter strip	sand filter	oil/grit* separator	grass swales	flow splitter
Submergent and Emergent Vegetation	✕	✕									
Shoreline Fringe and Flood Fringe Vegetation	✕	✕	✕								
Upland Vegetation	✕	✕	✕	✕			✕				
Temporary Fencing (post and wire)	✕	✕									
Grass Sod and Topsoil			✕	✕			✕	✕		✕	
Concrete (poured in place)									✕		✕
Trash Rack (metal)									✕		
Inverted Elbow Pipe									✕		
Outlet Valve/Gate Controls	✕	✕	✕								✕

✕ usually required

* *3 chamber oil/grit separator.*

Note: Several variations of items (e.g., reverse sloped outlet pipe, riser outlet pipe) have been included for different configurations. Therefore, when doing costs estimates, duplicate items should not be included twice (i.e., cost for a reverse sloped outlet pipe **or** a perforated riser outlet pipe, not both).

7.2.1 Pre-Treatment SWMPs

Some of the SWMPs listed in Table 7.1 require pre-treatment to ensure proper operation and longevity. Pre-treatment is required for infiltration SWMPs to reduce the potential for clogging and to avoid the deterioration of groundwater quality.

Storage (wet pond, wetland, dry pond) and/or vegetative SWM pre-treatment practices are generally used upstream of the SWMP requiring protection. To a certain extent the size of pre-treatment SWMP will depend on land availability. However, the size can be estimated using the sizing rules provided in Chapter 4. The size of the storage SWMPs should be based on the forebay sizing rules and not on providing full water quality treatment. Table 7.2 provides a list of SWMPs that require pre-treatment and possible pre-treatment SWMPs. In the case of surface end-of-pipe stormwater management facilities, forebays can be considered pre-treatment.

Table 7.2: Pre-Treatment SWMPs

		Pre-Treatment SWMPs				
SWMP	**Need for Pre-Treatment**	**Grassed Swales**	**Filter Screen**	**Filter Strip**	**Oil/Grit Separator**	**Wet Pond**
Wet Pond	⊠	×				×
Wetland	⊠	×				×
Dry Pond	⊠	×				×
Infiltration Basin	#	×		×	×	×
Infiltration Trench	#	×		×	×	×
Pervious Pipe	#	×			×	
Pervious Catchbasin	#	×				
Soakaway Pit	#		×			
Filter Strip	⊠	×				×
Sand Filter	⊠	×		×	×	×
Oil/Grit Separator	☐					
Grassed Swales	☐					

\# Pre-treatment required
⊠ Pre-treatment enhances performance
☐ Pre-treatment not required

Table 7.3 lists unit prices for different types of construction activities and material associated with the SWMP. These unit price estimates are for normal construction circumstances and include labour. Local or site and project-specific estimates should be made whenever possible.

Table 7.3: Unit Costs for Capital Construction

Type of Construction or Material	Unit	Price
Land Alterations		
Excavation (off-site disposal)	m^3	$ 5 - 10
Earthwork (cut and fill on site)	m^3	$ 3
Construction Materials		
Erosion block/stone	m^2	$ 50
Concrete Outlet Structure	each	$ 5,500
Concrete Outlet Pipe (300 mm / 600 mm / 900 mm)	m	$ 70 / $ 170 / $ 300
Observation Well (100 mm PVC)	each	$ 15
Rip-rap (450 mm)	m^2	$ 50
Perforated Pipe (100 mm, plastic)	m	$ 10
Perforated Riser Outlet Pipe (300 mm, plastic)	m	$ 90
Perforated Riser Outlet Trash Rack (400 mm CMP)	m	$ 100
Temporary Fencing (post and wire)	m	$ 15
Concrete (poured in place)	m^3	$ 400 - 500
Trash Rack (metal)	m^2	$ 100
Inverted Elbow Pipe	each	$ 300
Outlet Gate Valves (300 mm / 600 mm)	each	$ 1,200 / $ 4,800
Outlet Sluice Gates (300 mm / 600 mm / 900 mm)	each	$ 5,500 / $ 8,000 / $11,500
Clear Stone (gravel, 25 mm ~ 50 mm)	m^3	$ 45
Filter Cloth	m^2	$ 3
Filter Material (sand)	m^3	$ 30
Vegetative Plantings		
Seed and Topsoil	m^2	$ 2.5
Grass Sod and Topsoil	m^2	$ 4.5
Emergent and Submergent Vegetation	m^2	$ 12
Shoreline Fringe and Flood Fringe Vegetation	m^2	$ 12
Upland Vegetation	m^2	$ 5
Trees (wooded filter strips)	m^2	$ 25

Note: Cost estimates are based on construction costs in Greater Toronto Area (1997-1998).

7.3 SWMP Operation and Maintenance Costs

Operation and maintenance is required to ensure effective operation, longevity and aesthetic functioning of the SWMP and may include: sediment removal, trash removal, maintenance of vegetation and inspection of the inlet(s) and outlet(s).

Different types of SWMPs require different types of maintenance activities, and costs vary with type and size. Table 6.1 in Chapter 6 lists commonly required maintenance activities for various SWMPs.

Based on monitoring data to date, infiltration SWMPs have the shortest longevity of any practice (see Chapters 4 and 6). Pre-treatment practices cannot remove all suspended solids from the stormwater. Therefore, all infiltration SWMPs eventually become clogged. Once this occurs, the entire infiltration SWMP will need to be re-constructed. In comparing maintenance costs, the re-construction cost of the entire infiltration SWMP should be used based on estimated longevity.

Estimates of the longevity of infiltration SWMPs are based on professional opinion. Equation 7.1 and Table 7.4 may be used as guidance for estimating longevity (based on monitoring results in literature and the native soil permeability). Recognizing the subjectiveness of Equation 7.1, there needs to be flexibility in assessing the lifespan of infiltration SWMPs based on site-specific information.

$$L = (P \times T)^{0.4}$$ **Equation 7.1: Longevity of Infiltration SWMPs**

where L = longevity (years)
P = permeability (mm/h)
T = longevity factor from Table 7.4 (years)

Table 7.4: Estimated Infiltration SWMP Longevity*

Infiltration SWMP	Longevity Factor
Soakaway Pit	60
Infiltration Basin	15
Infiltration Trench	25

***** *The values in Table 7.4 assume that adequate pre-treatment is provided upstream of the infiltration SWMPs. Without adequate pre-treatment, the expected useful life of an infiltration SWMP is considerably shorter than that given in Table 7.4 (approximately 5 years).*

This method of estimating infiltration lifespan assumes that water table and bedrock site conditions are suitable for infiltration. These conditions must be confirmed since they will also have considerable impact on the lifespan/operation of infiltration SWMPs.

Table 7.5 provides a list of unit prices for the operation and maintenance activities listed in Table 6.1. Unit prices do not include transportation and equipment costs to perform the maintenance (e.g., backhoe). It was assumed that the owner of the stormwater management works would be the local municipality, and that it would have the required equipment as part of its works department. The unit prices in Table 7.5 include labour and represent typical maintenance conditions (e.g., dewatered forebay for sediment removal). Other maintenance activities such as dredging should be costed on a site-specific basis.

Table 7.5 provides planning estimates for long-term SWMP costs. Site-specific maintenance and operation costs should be calculated wherever possible. It also indicates that the frequency of sediment removal depends on the SWMP type and design storage volume. The required frequency of sediment removal can be estimated using information provided in Chapter 6.

Table 7.5: Unit Costs for Operations and Maintenance

Type of Maintenance	Maintenance Interval (yrs)	Unit	Price
Litter Removal	1	ha	$ 2,000
Grass Cutting	***	ha	$ 250
Weed Control	1	ha	$ 2,500
Vegetation Maintenance (Aquatic/Shoreline Fringe)	5	ha	$ 3,500
Vegetation Maintenance (Upland/Flood Fringe)	5	ha	$ 1,000
Sediment Removal (front end loader)	*	m^3	$ 15
Sediment Removal (vacuum truck or manual)	*	m^3	$ 120
Sediment Testing (lab tests on quality)	*	each	$ 365
Sediment Disposal (off-site landfill)	*	m^3	$ 300
Sediment Disposal and Landscaping (on-site)	*	m^3	$ 5
Inspection (Inlet/Outlet, etc.)	1		$ 100
Pervious Pipe cleanout (flushing)	5	m	$ 1
Pervious Pipe cleanout (Radial Washing)	5	m	$ 2
Seasonal Operation of Infiltration By-pass	0.5	**	$ 100
Infiltration Basin Floor Tilling and Re-vegetation	2	ha	$ 2,800

* *Frequency of sediment removal depends on SWMP type and volume.*

** *Dependent of infiltration facility (based on centralized facility). Seasonal operation of a system with many inlets (i.e., pervious pipe system) would be more expensive.*

*** *No grass cutting or minimal frequency of grass cutting (once or twice per year).*

7.4 Engineering and Contingency Costs

Engineering and contingency costs vary significantly from site to site and project to project. For planning purposes, costs can be estimated based on experience with other consulting projects.

7.4.1 Engineering Costs

Engineering costs include the planning, design and construction of all stormwater management works/measures. For planning purposes, engineering costs are based on the total capital cost of the stormwater works. As a general estimate, the engineering cost of a SWMP can be estimated as 10% of the total construction cost for that SWMP.

7.4.2 Contingency Costs

Contingency costs represent the unforeseen costs that may occur during the construction of a SWMP. These may include additional construction costs (i.e., bedrock excavation, dewatering, etc.), additional material costs and design alterations. Actual contingency costs will vary significantly from project to project, but is generally estimated to be about 15% of the total projected construction cost for a project.

The estimated contingency costs for stormwater management works that require maintenance (i.e., facilities that are designed for either water quality enhancement or erosion control using extended detention with a drawdown time ≥ 12 hours) should be estimated as 15% of the total of the construction cost and the present value of operations and maintenance costs.

7.5 SWMP Overall Cost Calculation

The total capital cost and maintenance cost of a SWMP can be estimated using Tables 7.1 through 7.5. The following steps can be used to calculate and compare present value capital and maintenance costs between various SWMP solutions.

Step 1: Review Table 7.1 to ensure that all capital cost items for a selected SWMP type have been identified.

Step 2: Review Table 7.2 to identify the need for pre-treatment SWMPs based on the selected SWMP. Review Table 7.1 to identify the capital cost items required for the pre-treatment SWMP.

Step 3: According to the preliminary design of the selected SWMP type, and pre-treatment SWMP requirements, estimate the required quantities of each of the capital cost items (including any site-specific requirements not identified in Table 7.1) identified in Steps 1 and 2.

Step 4: Use Table 7.3 (unit prices) to calculate the capital cost of each item identified in Steps 1 and 2 (capital cost is the product of the unit price and the required quantity), and then calculate the total capital cost as the sum of the costs of all the required capital cost items.

Step 5: Review Table 6.1 to identify the operations and maintenance activities that are required for the selected SWMP.

Step 6: Use Table 7.5 to identify the required maintenance interval and the unit price for each of the required operation/maintenance activities.

Step 7: Estimate quantities for the required operation/maintenance activities according to the preliminary design of the selected SWMP; and then calculate the maintenance cost for each activity. The quantity of accumulated sediments and sediment removal frequency can be estimated using figures and tables in Chapter 6.

Step 8: Group the operations and maintenance costs for activities that are performed numerous times per year into an annual maintenance cost. Sum up other operation/maintenance costs that have the same frequency of occurrence (i.e., 2 year, 5 year, 10 year, etc.). The summations should include re-construction of infiltration SWMPs when necessary based on Table 7.4 and Equation 7.1.

Step 9: Calculate the present value of operations/maintenance activities for similar frequency occurrences. Equation 7.2 can be used to calculate the present value of these activities based on an annual interest rate and service life of the SWMP.

$$PV = \sum_{t}^{T} \left[OM \times (1 + r)^{-t} \right]$$

Equation 7.2: Present Value

where PV = Present Value

OM = Sum of operations/maintenance costs that are required to be performed every t years

t = Interval between maintenance activities in years (i.e., if the interval is 3 years, the summation proceeds with t = 3, then t = 6, then t = 9, etc., until t = T)

r = annual interest rate

T = the service life of the selected SWMP

Equation 7.2 is best utilized in a simple spreadsheet format. The service life and interest rate are user defined. Typical values would be a 50 year service life and 3% interest rate (interest rate should be discounted to account for inflation, i.e., 8% interest rate – 5% inflation rate = 3% interest rate).

Step 10: Add the total capital cost (plus engineering cost) to the sum of all the present values for operation/maintenance activities. The contingency cost should then be added to the resultant number to obtain the total present value of the cost of implementing the SWMP.

Steps 1-10 can be used to estimate overall costs for each SWMP being considered and can facilitate cost comparisons between SWMPs.

7.6 Land Requirements for End-of-Pipe Stormwater Management Facilities

End-of-pipe stormwater management facilities (wet pond, dry pond, wetland and infiltration basins) require the use of land which might otherwise be available for development (since SWMPs should be located on the tableland and not in the floodplain). It is important to recognize this when estimating the area of developable land and the area required for these types of SWMPs. If land costs for different SWMP solutions are known, they can be added to the overall calculation of costs (Step 10 value – Section 7.5) and compared. Land costs are extremely variable, and therefore, land cost estimates can be contentious. In order for land cost estimates to be meaningful, site-specific data must be used in the analysis.

The cost of land depends on its location and size. The area of land required by an end-of-pipe stormwater management facility depends on the design storage volume, the side slopes, and its shape. The following sections provide methods to estimate the area of land required by a SWMP. It should be stressed that in order to simplify the analysis, the following equations were derived using specific assumptions concerning the side slopes and shape of the various SWMPs. Calculation results will only result in planning level information which can be used to compare SWMP concepts. The actual size of the SWMP will depend on the existing topography, servicing options and surrounding natural features.

7.6.1 Wet Ponds and Wetlands

The following configuration was assumed to be indicative of typical design parameters for wet ponds and wetlands:

- bottom of the wet pond/wetland was assumed to be rectangular in shape;
- length-to-width ratio of 3:1;
- side slopes of 4:1 within the permanent pool; and
- side slopes of 5:1 in the extended detention portion of the pond/wetland.

Based on these assumptions the area of land required by a wet pond or wetland can be estimated as follows:

Step 1: Determine the width of the bottom of the pond or wetland (X in metres).

$$X = \frac{\sqrt{256h_p^4 - 12h_p\left(\frac{64}{3}h_p^3 - PV\right)} - 16h_p^2}{6h_p}$$

Equation 7.3: Wet Facility Bottom Width

where h_p = the average depth of the permanent pool (m)
PV = the permanent pool volume (m^3)

Step 2: Determine the depth of the extended detention in the wet pond/wetland (h_e in metres).

$$h_e = \frac{\sqrt{(X + 8h_p)^2(3X + 8h_p)^2 + 20(3X + 8h_p)EV}}{10(3X + 8h_p)} - \frac{X + 8h_p}{10}$$

Equation 7.4: Active Storage Depth

where EV = extended detention volume (m^3)

Step 3: Determine the area of land required for the wet pond or wetland (LA in m^2).

$$LA = (X + 8h_p + 10h_e)(3X + 8h_p + 10h_e)$$

Equation 7.5: Wet Facility Area Requirement

7.6.2 Dry Ponds and Infiltration Basins

The same calculation method can be used to estimate the land area required by dry ponds and infiltration basins. The following configuration was assumed to be indicative of typical design parameters for dry ponds and infiltration basins:

- bottom of the pond/basin was assumed to be rectangular in shape;
- length-to-width ratio of 3:1; and
- side slopes of 5:1 in the pond/basin.

Step 1: Determine the width of the bottom of the pond/basin (X in metres).

$$X = \frac{\sqrt{400h^4 - 12h\left(\frac{100}{3}h^3 - EV\right)} - 20h^2}{6h}$$

Equation 7.6: Dry Facility Bottom Width

where EV = the design extended detention volume (m^3)
h = the average depth of the extended detention storage (m)

Step 2: Determine the area of land required for the infiltration basin or dry pond (LA in m^2).

$$LA = (X + 10h)(3X + 10h)$$

Equation 7.7: Dry Facility Land Requirements

It should be noted that the area of land required is not linearly related to the design storage volume of the SWMP. Accordingly, extrapolation should not be used to calculate the land area in cases where different design storages are considered.

7.6.3 Acceptable Ranges of Design Parameters

The calculation of land area in Sections 7.6.1 and 7.6.2 requires the average permanent pool depth (wet facilities) and active storage depth (dry facilities) as inputs. Acceptable ranges of these design parameters are summarized in Table 7.6. Detailed discussions on the requirements of the design parameters of various end-of-pipe stormwater management facilities are provided in Chapter 4.

Table 7.6: Acceptable Ranges of Design Parameters

Design Element	Wet Pond	Dry Pond	Wetland	Infiltration Basin
Permanent Pool Depth	1 to 3 m		0.15 to 0.30 m	
Extended Detention Storage Depth	1 to 1.5 m	1 to 3 m	≤ 1 m	≤ 0.6 m