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Maintenance for Stormwater Treatment Practices

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Abstract: Maintenance is imperative to preserve performance and extend useable life of stormwater treatment practices. Increased attention to mass balance, numerical goals, total maximum daily loads (TMDLs), and antidegradation requirements has created the need for more emphasis on stormwater treatment practice maintenance in order to meet permitting and reporting requirements. The purpose of this paper is to advance short and long-term maintenance considerations so as to develop more realistic maintenance plans. To do so, a municipal public works survey was developed, distributed, and the results were analyzed. The results of the survey revealed that most (61 percent) cities and counties perform routine maintenance once or more per year. Complexity of maintenance is most often minimal or simple, but is more complicated for constructed wetlands, soil/sand filters, and permeable pavement. The most common causes of required maintenance are sediment buildup and litter/debris. Survey results for maintenance cost compare well with data gathered from a national literature review.
Keywords: *Stormwater, maintenance, BMPs*

Maintenance for stormwater treatment practices is the purposeful management of a practice so as to preserve a desired level of performance and efficiency and extend useable life. It's practices consists of short-term (routine and more frequent), long-term (non-routine and often less frequent), and major (rare) actions (Figure 1).

Performance longevity of stormwater treatment practices from their creation (design and construction) through operation is dependent on maintenance actions. Because maintenance involves a significant amount of resources (personnel, equipment, materials, sediment disposal expense, etc.), it is important to understand maintenance effort, frequency, and cost to efficiently allocate those resources. The purpose of this paper is to advance short and long-term maintenance considerations so as to develop more realistic maintenance plans. A municipal public works survey was developed, distributed, and the results were analyzed to achieve this purpose.

The specific goals of the survey were to identify and inventory stormwater treatment practice maintenance efforts and costs. Survey responses were received from 28 Minnesota cities, 8 Wisconsin cities, and 2 Wisconsin counties. The survey included questions on the following topics:

- Types of stormwater treatment practices in watersheds.
- Frequency of stormwater treatment practices inspected or maintained.
- Average staff-hours spent per regular inspection/ maintenance.
- Complexity of stormwater treatment practice maintenance.
- Factors that most frequently cause reduced performance in stormwater treatment practices.
- Costs for non-routine maintenance activities.

The questions for the survey were chosen to reflect key parameters necessary to reasonably budget and schedule inspection and maintenance. These factors will vary based upon stormwater treatment practice design, climate conditions, stormwater treatment practice accessibility, desired level of stormwater treatment practice performance, personnel and budgetary constraints, and maintenance strategies (e.g., proactive or reactive).

This survey to define maintenance needs and guidelines was conducted by the University of

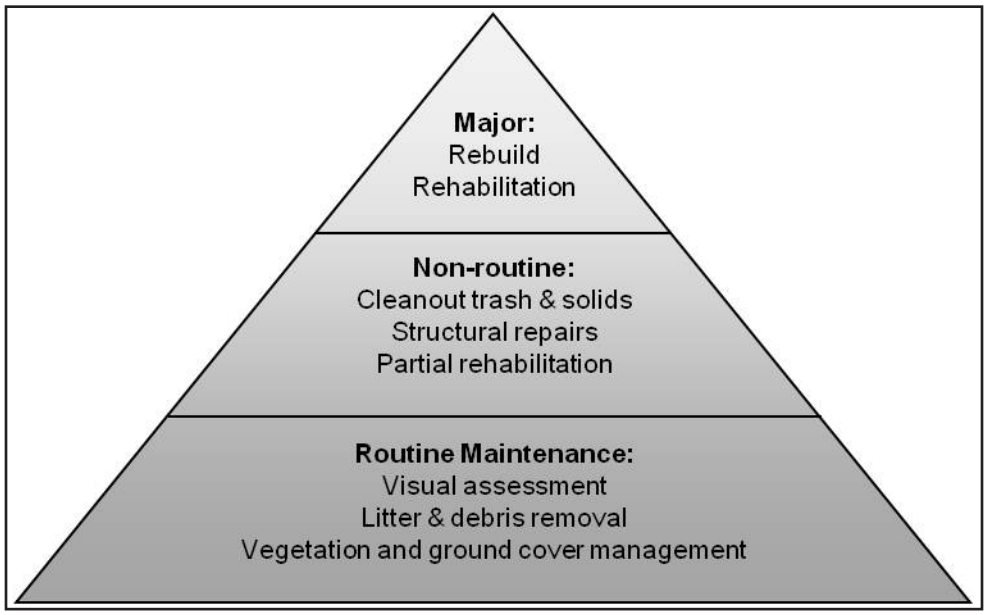

Figure 1. Stormwater treatment practice maintenance pyramid.

Minnesota through work funded by the Minnesota Pollution Control Agency. Through this effort the University of Minnesota published the manual, "Stormwater Treatment: Assessment and Maintenance" (Gulliver et al. 2010) that includes assessment techniques for source reduction and stormwater treatment practices using four levels of assessment from visual inspection to state-of-the-art monitoring and maintenance recommendations. The manual is available online at http://stormwater.safl.umn.edu.

Survey Results and Discussion

Number and Type of Stormwater Treatment Practices

As listed in Table 1, most cities in Minnesota and Wisconsin have at least one wet pond, and most of the cities with wet ponds have more than 20 wet ponds in their jurisdiction and one third have filter strips or swales. Most cities also have less than five of most other stormwater treatment practices although nearly half of the respondents have more than five underground sedimentation practices.

Inspection Frequency

The frequency and associated staff-hours of stormwater treatment practice maintenance are two key parameters necessary to reasonably budget and schedule inspection and maintenance. As listed in Table 2, the majority (61 percent) of cities conduct routine maintenance actions once or more per year. Surface filters, wet and dry ponds, and filter strips or swales have required less frequent maintenance. Inspection frequency varies significantly due to stormwater treatment practice accessibility and management strategy (proactive vs. reactive).

Staff Hours

For most stormwater treatment practices, staff-hours per activity range from 1 to 4 hours as listed in Table 3. Constructed wetlands and rain gardens may require more staff-hours (typically between 1 and 16 hours) for inspection and maintenance because vegetation management can be significant in these practices.

Maintenance Complexity

For most stormwater treatment practice types, respondents indicated that maintenance was minimal or simple (i.e., stormwater professional is occasionally needed), as listed in Table 4. Maintenance was viewed as moderate to complex most often for constructed wetlands (47 percent), sand or soil filters (38 percent), and permeable pavements (37 percent). Permeable pavements are fairly new in Minnesota and Wisconsin, which

Table 1. Number and type stormwater treatment practices in select Minnesota and Wisconsin municipalities.

	Number of Responses					
Stormwater Treatment Practice (STP) Type	**Total**	**None**	**1-5 STPs**	**6-10 STPs**	**11-20 STPs**	**20 STPs**
Surface Sand or Soil Filter	29	22	3	2	1	1
Underground Filtration Devices	30	19	4	5	1	1
Infiltration Basins or Trenches	31	10	11	3	2	5
Permeable Pavements	32	15	16	1	0	0
Wet Ponds	35	1	6	4	4	20
Dry Ponds	32	5	14	5	2	6
Underground Sedimentation Devices	31	10	6	6	2	7
Rain Gardens	34	7	16	4	4	3
Constructed Wetlands	31	12	6	5	2	6
Filter Strips or Swales	30	8	8	1	3	10

Table 2. Frequency of routine inspection and maintenance activities.

Stormwater Treatment Practice Type	**Number of Responses (n)**	**Less than once (percent)**	**Once per year (percent)**	**More than once (percent)**
Surface Sand or Soil Filter	9	67	33	0
Underground Filtration Devices	9	44	56	0
Infiltration Basins or Trenches	19	21	68	11
Permeable Pavement	14	29	43	29
Wet Ponds	32	53	44	3
Dry Ponds	27	52	48	0
Underground Sedimentation Devices	17	12	59	29
Rain Gardens	22	23	41	36
Constructed Wetlands	16	38	56	6
Filter Stripes or Swales	13	54	31	15
Average		**39**	**48**	**13**

Table 3. Staff-hours spent on rountine maintenance actions.

Stormwater Treatment Practice Type	**Number of Responses**	**Max. Hours**	**75th %tile**	**Median**	**25th %tile**	**Minimum Hours**
Surface Sand or Soil Filter	7	3	2	1	0.5	0.5
Underground Filtration Devices	7	5	3.5	1	0.75	0.5
Infiltration Basins or Trenches	17	60	2	1	0.5	0.5
Permeable Pavements	9	6	4	2	1	0.5
Wet Ponds	24	120	3.5	2	1	0.5
Dry Ponds	19	5	2	1	0.5	0.5
Underground Sedimentation Devices	14	360	3	1.25	1	0.5
Rain Gardens	13	80	16	1	1	0.5
Constructed Wetlands	14	60	9.5	1.5	1	0
Filter Strips or Swales	11	30	1.75	1	0.5	0.5

Table 4. *Complexity of maintenance activites.

Stormwater Treatment Practice Type	Number of Responses (n)	Maintenance Complexity* (percent of responses)			
		Minimal	Simple	Moderate	Complex
Surface Sand or Soil Filter	8	63	0	25	13
Underground Filtration Devices	10	50	20	10	20
Infiltration Basins or Trenches	18	33	44	11	11
Permeable Pavements	16	44	19	31	6
Wet Ponds	27	63	26	4	7
Dry Ponds	25	72	24	0	4
Underground Sedimentation Devices	16	44	31	6	19
Rain Gardens	22	41	32	9	18
Constructed Wetlands	15	40	13	40	7
Filter Strips or Swales	14	64	29	0	7
Average		51	24	14	11

*Maintenance Complexity is defined as:
Minimal-stormwater professional or consultant is seldom needed.
Simple- stormwater professional or consultant is need about half of the time.
Moderate- stormwater professional or consultant is needed about half of hte time.
Complicated-stormwater professional or consultant is always needed.

may explain the more frequent requirement for evaluation by stormwater professionals.

Factors Reducing Stormwater Treatment Practice Performance

One of the key purposes of maintenance for stormwater treatment practices is to preserve performance for capturing pollutants or reducing runoff volume or rates. Stormwater treatment practice performance can be reduced by many factors including sediment buildup, litter and debris, or pipe clogging, thus requiring the need for maintenance. The factors listed most frequently for reducing performance in stormwater treatment practices are listed in Table 5. Sediment buildup and litter & debris accumulation were reported as the most frequent factors reducing performance for most stormwater treatment practices. Pipe clogging was reported frequently for wet ponds and dry ponds while invasive vegetation was reported frequently for dry ponds, constructed wetlands, rain gardens, filter strips, and swales.

Maintenance Costs

Maintenance for sediment removal, converted to an annual cost, was the most reported and costly maintenance activity. There was also considerable variation in the maintenance costs, as illustrated in Figure 2 for sediment removal. The highest median sediment removal costs were for permeable pavement ($1,700/yr) and underground sedimentation devices ($1,000/yr).

Literature values of annual maintenance expenses as a function of construction costs are available for dry ponds, wet ponds, constructed wetlands, rain gardens, sand filters, and grassed/vegetative swales (Weiss et al. 2005; USEPA 1999), as listed in Table 6. Other analyses (Landphair et al. 2000; Wossink and Hunt 2003) have shown that the range for annual maintenance costs can be larger than those recommended by the U.S. EPA (1999). Maintenance cost data from respondents in Wisconsin correlate well with maintenance data reported by Weiss et al. (2005, 2007), as shown in Figure 3.

Maintenance costs are a substantial portion of life-cycle stormwater treatment practice costs Weiss et al. 2005, 2007). For all practices with the exception of rain gardens, maintenance costs exhibited an economy of scale in that maintenance for more expensive practices cost less as a fraction of construction cost than less expensive (i.e., smaller)

Table 5. Percentage of respondents who indicated the listed factors for most frequently reducing performance in stormwater treatment practices.

		Percentages								
Stormwater Treatment Practice Type	**Number of Responses**	**Sediment Buildup**	**Litter & Debris**	**Pipe Clogging**	**Invasive Vegetation**	**Groundwater Level**	**Bank Erosion**	**Oil Spill**	**Structural Problems**	**Mechanical Problems**
Surface Sand or Soil Filter	10	50	30	10	0	0	0	10	0	0
Undeground Filtration Devices	8	50	25	13	0	13	0	0	0	0
Infiltration Basins or Trenches	39	36	21	10	5	13	5	3	5	3
Permeable Pavements	9	67	11	11	0	0	0	11	0	0
Wet Ponds	90	26	19	21	10	7	11	0	7	0
Dry Ponds	49	24	31	18	16	2	8	0	0	0
Underground Sedimentation Devices	19	58	21	11	0	5	0	0	5	0
Rain Gardens	27	33	22	7	26	7	0	4	0	0
Constructed Wetlands	37	24	19	14	22	8	11	0	3	0
Filter Strips or Swales	19	21	26	5	26	5	11	0	5	0

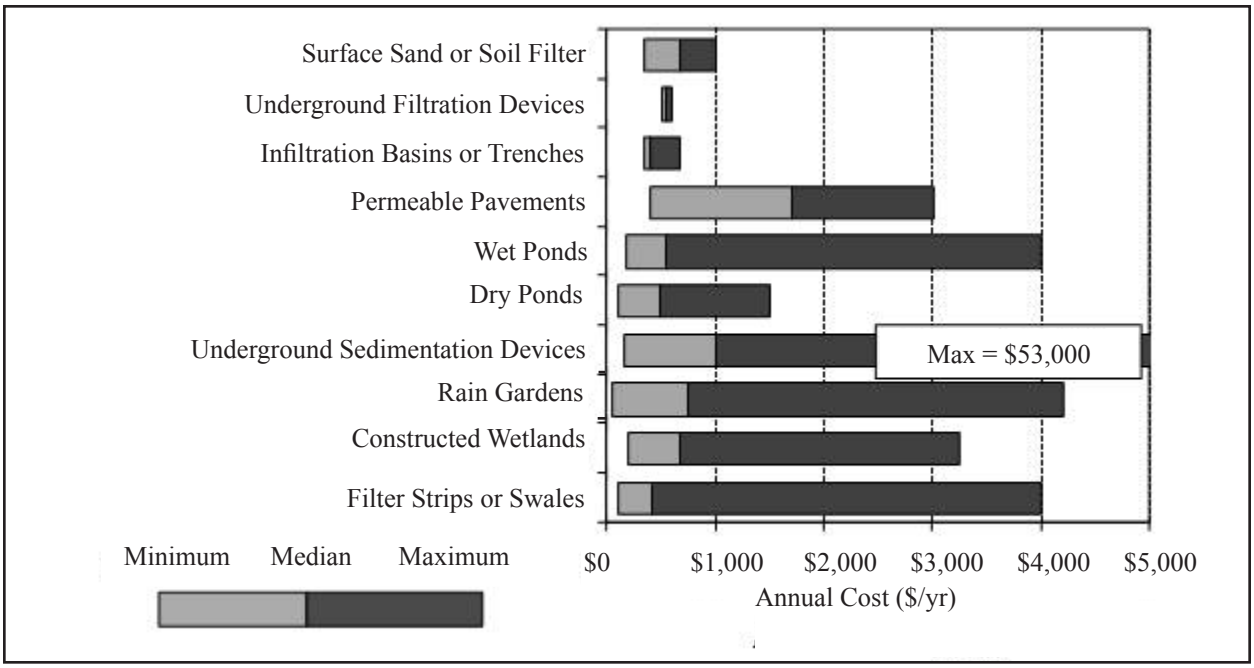

Figure 2. Annual cost of sediment removal for stormwater treatment practices.

practices. As shown in Figure 3, the annual predicted maintenance cost is roughly eight percent of total construction costs for wet ponds that cost $10,000 (2005 dollars) to construct. Therefore, maintenance cost for these stormwater treatment practices will roughly equal total construction cost after 12 years (in constant dollars). Similarly, for wet ponds that cost $100,000 (2005 dollars) to construct, annual maintenance cost is roughly four percent and will roughly equal total construction cost for these

Table 6. Expected (U.S. EPA 1999) and reported (Weiss et al. 2005) annual maintenance cost as a percent of total construction cost for several stormwater treatment practices.

Stormwater Treatment Practice Type	USEPA Percentages (1999)	Weiss et al. Percentages (2005)
Sand Filters	11-13	0.9 - 9.5
Infiltration Trenches	5 - 20	5.1 - 126.0
Infiltration Basins	1 - 10	2.8 - 4.9
Wet Ponds	Not reported	1.9 - 10.2
Dry Ponds	less than 1	1.8 - 2.7
Rain Gardens	5 - 7	0.7 - 10.9
Constructed Wetlands	2	4.0 - 14.2
Swales	5 - 7	4.0 - 178.0
Filter Strips	$320/Acre (maintained)	----

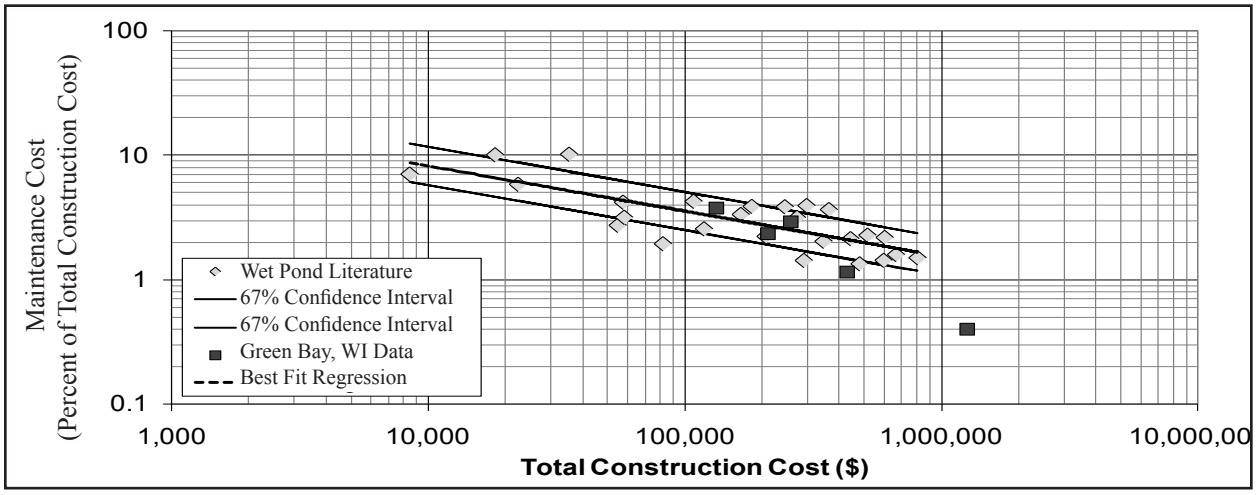

Figure 3. Predicted annual life-cycle maintenance costs as a function of total construction costs in 2005 U.S. dollars for wet ponds (Weiss et al. 2005, 2007).

practices after 25 years (in constant dollars). These values (8 percent annual maintenance for $10,000 construction cost in 2005 dollars and four percent annual maintenance for $100,000 construction cost in 2005 dollars) are similar for most stormwater treatment practices reported by Weiss et al. (2005, 2007). This estimation can be used as a general rule of thumb when planning, designing, and budgeting for installation and maintenance of stormwater treatment practices.

Conclusion

Many communities are struggling to define stormwater treatment practice maintenance needs without readily available guidelines. As a step towards providing this information, a survey of cities was conducted to quantify the typical frequency of inspection, level of effort, factors reducing performance, and maintenance complexity. In addition, survey results for maintenance cost for sediment removal from wet ponds was compared to maintenance cost previously reported in the literature.

The results of the survey revealed that most (61 percent) cities in Minnesota and Wisconsin perform routine maintenance once or more per year. Complexity of maintenance is most often minimal or simple, but is more complicated for constructed wetlands, soil/sand filters and permeable pavements. The most common causes of reduced performance are sediment buildup and litter/debris for stormwater treatment practices.

Maintenance cost is a substantial portion of life-cycle cost for all stormwater treatment practices and requires serious consideration. As a general rule-of-thumb, maintenance cost for stormwater treatment practices will roughly equal the construction cost (in constant dollars) after 12 years for a $10,000 installation and 25 years for a $100,000 installation (2005 dollars).

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