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Technical Memorandum

To: Minnesota Pollution Control Agency (MPCA)
From: Greg Wilson and Michael McKinney, Barr Engineering Co. (Barr)
Subject: Guidance for Determining the TSS/TP Treatment Effectiveness of Stormwater Ponds
Date: December 20, 2019
Project: TMDL Toolkit (Objective 2, MS4 Pond Assessment)

1.0 Background

Per Objective 2 of the TMDL Toolkit, MS4 Pond Assessment and Accelerated Implementation project (TMDL Toolkit), Barr Engineering Co. (Barr) has developed guidance related to assessing the total suspended sediment (TSS) and total phosphorus (TP) removal efficiency of permittee owned/operated ponds constructed and used for the collection and treatment of stormwater. Specifically, this technical memorandum outlines guidance and recommendations related to four (4) evaluation strategies:

- Evaluation of MPCA stormwater pond design criteria (Section 2.0);
- Stormwater pond inspection/assessment (Section 3.0);
- Stormwater pond pollutant removal modeling (Section 4.0); and
- Stormwater pond water quality monitoring (Section 5.0).

The TSS and TP removal efficiency of constructed stormwater ponds degrades over time due to the loss of storage volume to sedimentation and/or sediment phosphorus release. For this reason, it is critical that stormwater ponds be sized correctly for their contributing drainage area (Section 2.0) and that pond inspection and assessments be performed routinely to monitor sedimentation and identify potential maintenance needs (Section 3.0). In addition to evaluating pollutant removal efficiency through comparison to design standards and evaluation of sedimentation, the water quality performance of stormwater ponds can be evaluated using various water quality modeling programs (Section 4.0) or measured directly through water quality monitoring (Section 5.0).

Guidance presented in this technical memorandum has been developed to assist MS4s evaluate the TSS and TP treatment effectiveness of ponds post-construction and over their design life. The four (4) strategies listed above were selected based on input from and coordination with the MPCA. Throughout this document, “MS4s” refers specifically to National Pollutant Discharge Elimination System (NPDES) regulated MS4s (i.e., Phase I and Phase II MS4s required to obtain NPDES permit coverage for their stormwater discharges). Table 1 provides a summary of the four (4) TSS and TP removal efficiency evaluation strategies discussed within this memorandum.

Table 1 TSS and TP Removal Efficiency Evaluation Strategies

Pollutant Removal Assessment Strategy	Description	Relative Effort	Relative Accuracy
Evaluation of MPCA stormwater pond design criteria (Section 2.0)	Evaluation of pond sizing criteria against MPCA stormwater pond design standards to produce a relative evaluation of pond performance.	Low	Low
Stormwater pond inspection/assessment (Section 3.0)	Guidance related to scheduling and performing routing visual inspections and less-frequent assessments of pond sedimentation depth.	Medium / High	NA[1]
Stormwater pond pollutant removal modeling (Section 4.0)	Evaluation of the pollutant reduction achieved by stormwater ponds through the use of empirically-based or physically-based water quality models.	Low / Medium	Medium
Stormwater pond water quality monitoring (Section 5.0)	Evaluation of the pollutant reduction achieved by stormwater ponds through direct monitoring of pollutant concentrations into and leaving the pond.	High	High

[1] Stormwater pond inspection/assessment does not inherently provide an estimate of TSS/TP removal. However, inspection/assessment efforts are critical to ensuring a stormwater pond is performing as originally designed.

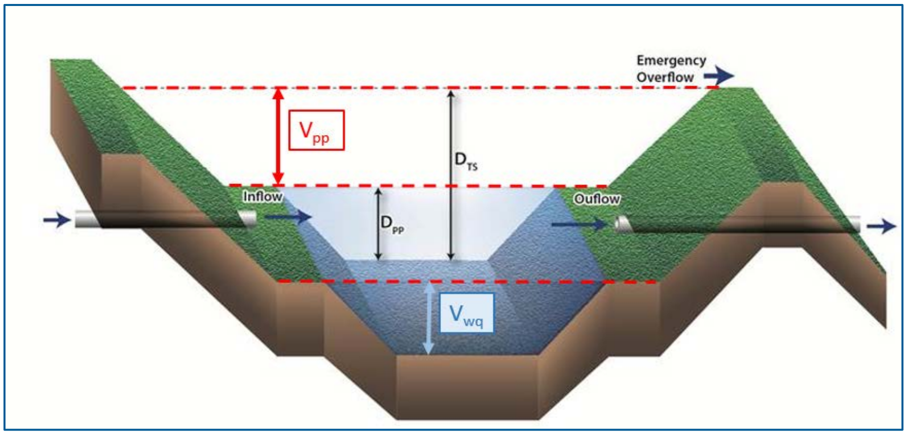
2.0 Evaluation of MPCA Stormwater Pond Design Criteria

The MPCA Minnesota Stormwater Manual contains detailed design criteria for many water quality best management practices (BMPs), including constructed stormwater ponds. In addition to outlining construction stormwater pond requirements stipulated by the MPCA Construction General Permit (CGP), the Minnesota Stormwater Manual's Design Criteria for Stormwater Ponds contains guidance and recommendations related to many aspects of stormwater pond design and construction, from grading and site layout, to overflow spillway design and development of a landscaping plan.

Although guidance within the Design Criteria for Stormwater Ponds is primarily focused on requirements related to construction of design of stormwater ponds for new development, elements within the guidance related to sizing of the pond permanent pool volume and live storage water quality volume can be used to evaluate (a) the impact of sedimentation over time and (b) the impact of development and changing land use over time on the water quality performance of existing stormwater ponds. The following subsections outline how design criteria can be used to evaluate the water quality treatment efficiency of existing stormwater ponds and how design criteria can be used to estimate pollutant load reduction.

2.1 Estimating Water Quality Performance of Existing Stormwater Ponds

As discussed in Section 2.0, the Minnesota Stormwater Manual's Design Criteria for Stormwater Ponds contains guidance and requirements related to the sizing of pond permanent pool volume (V_{pp}) and live storage water quality volume (V_{wq}). As defined by the Minnesota Stormwater Manual, the permanent pool (aka, "dead storage") is the volume of water below the pond outlet, and the water quality volume (aka, "live storage") is the storage volume between the pond outlet and the pond overflow elevation as shown in Figure 1.



Source (modified): https://stormwater.pca.state.mn.us/index.php?title=File:Constructed_pond_1_for_credit_page.jpg

Figure 1 Stormwater pond schematic: permanent pool volume and water quality volume.

The Minnesota Stormwater Manual's Design Criteria for Stormwater Ponds outlines minimum requirements for permanent pool volume (V_{pp}) and water quality volume (V_{wq}) as outlined by the CGP. Narrative descriptions and resulting equations used to evaluate minimum volume required are outlined below:

The Required minimum permanent pool volume, or dead storage (V_{pp}), below the outlet elevation), is 1800 cubic feet of storage below the outlet pipe for each acre that drains to the pond:

$$\boldsymbol{V_{pp} = 1800 \times A} \quad \textbf{[1]}$$

Where,

V_{pp} = the permanent pool volume in cubic feet (ft^3); and

A = the drainage area to the stormwater pond in acres (ac).

The Required minimum water quality volume, or live storage (V_{wq}), is 1.0 inch of runoff from the net increase in impervious surfaces created by the project:

$$\boldsymbol{V_{wq} = 1inch \times A_{imp} \times \frac{43{,}560\ ft^2}{12\ inches}} \quad \textbf{[2]}$$

Where,

V_{wq} = the water quality volume in cubic feet (ft^3); and

A_{imp} = tributary impervious area (acres).

The equations and definitions, above, were created for designing and constructing a stormwater pond to treat runoff from new development. Existing stormwater ponds may have larger V_{pp} than the minimum required by the CGP, or may have larger or smaller V_{wq} than required. To estimate the water quality performance of existing stormwater ponds, methodology outlined in the Minnesota Stormwater Manual's MIDS Calculator documentation for stormwater ponds requires the user to evaluate the tributary area to the pond and volume dimension of the pond to determine the "design level" (e.g., Design Level 2) of the pond, and recommends assumed pollutant removal efficiency values based on the design level (e.g., 84% TSS removal for Design Level 2). Criteria for each MIDS stormwater pond design level are summarized in Table 2.

Table 2 MIDS Calculator stormwater pond design level criteria related to pond volume.

MIDS Stormwater Pond Design Level[1]	Perm. Pool Volume (V_{pp}), ft^3	Water Quality Volume (V_{wq}), ft^3	Pollutant Reduction (%)[2]			
			TSS	TP	PP	DP
Design Level 1	≥ 1,800 ft^3 per acre of tributary area	≤ 1 inch from impervious area	60%	34%	62%	0%
Design Level 2		≥ 1 inch from impervious area	84%	50%	84%	8%
Design Level 3		≥ 1.5 inch from impervious area	90%	60%	90%	23%

1 From MIDS Calculator documentation for stormwater ponds. Note: the table summarizes design-level criteria related to permanent pool volume and water quality volume. The complete list of criteria for each design level is summarized on the MIDS calculator website linked above.

2 TSS = total suspended solids; TP = total phosphorus; PP = particulate phosphorus; and DP = dissolved phosphorus. Pollutant reduction values cited assume no upstream treatment within tributary area to pond (i.e., untreated urban runoff).

Steps for summarizing the estimating water quality performance of existing stormwater ponds using methodology outlined in the Minnesota Stormwater Manual's Design Criteria for Stormwater Ponds and MIDS Calculator documentation for stormwater ponds are outlined, below.

1) **Determine the permanent pool volume (V_{pp}) of the pond** – the V_{PP} can be determined through a number of sources, including record drawings, as-builts, and bathymetric survey. Note: before using record drawing or as-built data, a pond assessment (Section 3.0) should be conducted to determine the extent to which sedimentation has reduced the V_{pp}. If estimating volume from bathymetric contour data, the following equation can be used to calculate volume between any two bathymetric contours. The total bathymetric volume can then be calculated by summing the volume between all available bathymetric contours:

$$\boldsymbol{V_{1-2}} = \left(\frac{\boldsymbol{A_1+A_2}}{\boldsymbol{2}}\right) \times (\boldsymbol{E_2} - \boldsymbol{E_1}) \qquad \textbf{[3]}$$

Where,

V_{1-2} = the volume between contours 1 and 2;

A_1 and A_2 = the area of contours 1 and 2, respectively; and

E_1 and E_2 = the elevation of contours 1 and 2, respectively.

After calculating the volume between each bathymetric contour, the total bathymetric volume can be calculated by summing the volume calculated between each set of contours:

$$\sum_{i=1}^{n} \boldsymbol{V_i} = \left(\frac{\boldsymbol{A_{n+1}+A_n}}{\boldsymbol{2}}\right) \times (\boldsymbol{E_{n+1}} - \boldsymbol{E_n}) \quad \textbf{[4]}$$

If only the area at the bottom of the pond (A_{pp}) and the area at the permanent pool of the pond (A_{bot}) is known, the bathymetric volume can be calculated using the simplified equation, below:

$$\boldsymbol{V_{bathymetric}} = \left(\frac{\boldsymbol{A_{pp}+A_{bot}}}{\boldsymbol{2}}\right) \times (\boldsymbol{E_{pp}} - \boldsymbol{E_{bot}}) \quad \textbf{[5]}$$

Where,

$V_{bathymetric}$ = bathymetric volume;

A_{pp} = area at the permanent pool of the pond;

A_{bot} = area at the bottom of the pond;

E_{pp} = elevation at the bottom of the pond; and

E_{bot} = elevation of the bottom of the pond.

2) **Determine the water quality volume (V_{wq}) of the pond** – as shown in Figure 1, the V_{wq} is the volume between the ponds permanent pool and the natural or designed overflow elevation. The V_{wq} can be determined through a number of sources, including record drawings, as-builts, survey data, and surface LiDAR data. A rough estimate of V_{wq} can be calculated by determining the permanent pool area and the area at the natural or designed overflow elevations. Equation 3, above, can then be used using these two elevations and areas.

3) **Evaluate the V_{pp} of the pond** – determine the CGP required V_{pp} based on the total drainage area to the stormwater pond using Equation 1, above (i.e., 1,800 ft^3 per acre of drainage area). If the V_{pp} is greater than 1,800 ft^3, proceed to step 4. If the V_{pp} of the pond is less than 1,800 ft^3 per acre of drainage area, guidance within the Minnesota Stormwater Manual suggests that the pond should not be included in site pollutant removal calculations, as the pond is unlikely to provide adequate treatment. To estimate the water quality performance of a stormwater pond not meeting minimum V_{pp} requirements, calculations in the following steps can proceed by using only the area for which the V_{pp} is sized to adequately treat (i.e., V_{pp} ÷ 1,800 ft^3/acre = treated area (acres)). The remaining portion of the total drainage area to the pond would then be assumed to bypass (i.e., 0% treatment). Alternatively, water quality performance of undersized stormwater ponds can be evaluated through modeling (Section 4.0) or monitoring (Section 5.0).

4) **Evaluate the tributary impervious area to the pond** – for small sites (e.g., developments less than two acres, etc.), impervious area can be determined through manual evaluation of site impervious cover from record drawings or site plans. For larger drainage stormwater ponds with larger drainage areas (e.g. regional stormwater ponds with drainage areas greater than five acres), land use datasets

can be used to estimate total impervious area within the ponds drainage area. The Minnesota Geospatial Information Office (MnGeo) maintains a database of current and historic land use which can be used to evaluate land use and estimate impervious area. Additionally, the University of Minnesota (UMN) provides land cover and impervious data at varying resolution statewide and for specific regions throughout Minnesota (e.g. Twin Cities Metro, Duluth, Rochester, etc.).

5) **Determine the impervious area treatment depth in the pond V_{wq}** – using the pond V_{wq} (Step 2) tributary impervious area (step 4), calculate the impervious area treatment depth using Equation 4, below. Note: Equation 4 is the same as Equation 2 but rearranged to calculate the impervious area treatment depth provided by the pond V_{wq}.

$$\boldsymbol{D_{imp} = \frac{V_{wq}}{A_{imp}} \times 12 \frac{in}{ft}} \qquad \textbf{[6]}$$

Where,
D_{imp} = impervious area treatment depth (inch);
V_{wq} = water quality volume in cubic feet (ft^3); and
A_{imp} = tributary impervious area (ft^2).

6) **Determine the MIDS pond design level and corresponding pollutant reduction (%)** – after confirming the V_{pp} is greater than 1,800 ft^3 per tributary acre (Step 3) and determining the impervious area treatment depth in the V_{wq} (Step 5), reference Table 2 to determine the MIDS pond design level (e.g., Design Level 2) and corresponding pollutant reduction (e.g. 84% TSS reduction). Note: pollutant reduction values (%) included in Table 2 assume no upstream water quality BMPs in the tributary area to the stormwater pond (i.e., untreated stormwater runoff). If BMPs within the watershed to the stormwater pond provide significant treatment (e.g., 50% of the tributary area passes through a large infiltration basin before discharging to the stormwater pond), water quality performance should instead be evaluated through modeling (Section 4.0) or monitoring (Section 5.0).

7) **Determine influent pollutant loading and pollutant load reduction (lbs)** – after determining the pond level design pollutant removal efficiency (%) from Table 2, annual pollutant mass removal (e.g., pounds to TSS removal per year) can be determined by applying the pollutant removal efficiency (%) to the annual influent pollutant mass load. Methodology for determining the annual influent pollutant mass load to the stormwater pond and calculating the pollutant mass removal within the stormwater pond is discussed in Section 2.2.

2.2 Estimating Annual Pollutant Load Reduction Existing Stormwater Ponds

To estimate the pollutant mass reduction (e.g., pounds of TSS removal per year) in an existing stormwater pond, it is first critical to determine the annual pollutant mass load from the tributary watershed to the stormwater pond. One method of estimating annual pollutant export associated with runoff from a watershed is the Simple Method (Schueler, 1987; CWP & CSN, 2008). The Simple Method is utilized by many annualized water quality models (e.g., the MPCA Simple Estimator spreadsheet model, see Section 4.0) and is a recommended method for calculating credits for stormwater ponds in the Minnesota Stormwater Manual. The Simple Method equation is shown below (Equation 5), followed by steps for determining Simple Method parameter inputs, calculating annual pollutant loading, and calculating annual pollutant reduction:

$$\boldsymbol{L_{annual} = 0.227 \times A \times P \times P_j \times R_v \times EMC_{pollutant}} \quad \textbf{[7]}$$

Where,

L_{annual} = annual pollutant load to the stormwater pond (e.g., pounds of TSS per year, lbs TSS/yr);

A = drainage area to stormwater pond (acres);

P = annual precipitation depth (in);

P_j = fraction of rainfall events that produce runoff (default value of 0.9);

R_v = runoff coefficient (see discussion in Step 1, below);

$EMC_{pollutant}$ = the flow-weighted event mean concentration (EMC) of pollutant in runoff (mg/L, see discussion in Step 1, below); and

0.227 = unit conversion factor.

1) **Determine Simple Method input parameters** – the following defines each Simple Method input parameter and provides a summary of how to determine or estimate each parameter:

- Drainage Area (**A**) – the total drainage area to the pond (acres).
- Annual Precipitation (**P**) – annual average precipitation depth (inches). Can be determined from local long-term rainfall records (e.g., 10-year average precipitation from local airport). Note: average annual precipitation depth within the state of Minnesota by zip code can be determined using the MIDS Calculator.
- Rainfall Fraction (**P_j**) – fraction of rainfall events which produce runoff (unitless). This Simple Method assumes some fraction of annual rainfall is delivered in small, low-intensity rainfall events that do not produce runoff. Typically, a P_J value of 0.9 is assumed.
- Runoff Coefficient (**R_v**) – the runoff coefficient is the fraction of annual rainfall that is converted into runoff. Runoff coefficient can be calculated as a function of site impervious area using the equation, below. Note: a description of how to determine site impervious area and impervious fraction is provided in Section 2.1, Step 4. Alternatively, the area-weighted watershed R_v value can be calculated using the land use-based R_v values from the MPCA

Simple Estimator shown in Table 3.

$$R_v = 0.05 + 0.009 \times I \quad [8]$$

Where,

I = impervious area percentage (i.e., if 75% impervious, I = 75).

- Pollutant Concentration (**$EMC_{pollutant}$**) – the flow-weighted average pollutant EMC (mg/L). Because localized monitoring of runoff pollutant EMCs is typically not available, standard literature values for pollutant EMC can be used to estimate pollutant loading. The MIDS Calculator suggests typical urban runoff EMC values of 54.5 mg/L and 0.3 mg /L for TSS and TP, respectively. Land used based EMC values from the MPCA Simple Estimator (Table 3) can be used to calculate a land use-based area weighted TSS and TP EMC based on land use within the drainage area to the stormwater pond. Additional literature values for typical TSS and TP EMC values are provided in Table 4.

Table 3 MPCA Simple Estimator: R_v, TSS EMC, and TP EMC Values for Land Use Types.

Land Use	Runoff Coef. (R_v)	EMC (mg/L)	
		TP	TSS
Commercial	0.8	0.25	201
Industrial	0.8	0.33	177
Institutional	0.75	0.21	91
Multi-use	0.5	0.29	189
Municipal	0.5	0.29	189
Open space	0.2	0.125	176
Residential - high density	0.44	0.4	132
Residential - low density	0.34	0.4	132
Residential - medium density	0.4	0.4	132
Transportation	0.8	0.43	114

Table 4 TSS and TP EMC Literature Values.

Reference	Average Annual EMC (mg/L)	
	TSS	TP
Residential (Pitt, 2011; NSQD, 2011/ Region 1)	135	0.4
Minnesota Stormwater Manual – Commercial	120 – 160	0.15 – 0.35
Minnesota Stormwater Manual – Industrial	130 – 170	0.15 – 0.35
Minnesota Stormwater Manual – Residential	100 – 170	0.2 – 0.6
Minnesota Stormwater Manual – Freeway/ Transportation	115 – 155	0.3 – 0.5
Nationally Pooled Urban EMCs (Lin, 2003)	54.5 – 78.4	0.266 – 0.315

2) **Calculate annual pollutant load reduction** – after calculating the annual pollutant loading to the stormwater pond (Step 1), the stormwater pond annual pollutant mass load reduction (e.g., pounds of TSS removed per year) can be calculated using the equation, below:

$$\boldsymbol{R_{annual}} = \boldsymbol{L_{annual}} \times \boldsymbol{PR_{pollutant}} \quad \textbf{[9]}$$

Where,

R_{annual} = annual pollutant load reduction (e.g. pounds of TSS removed per year, lbs TSS/yr);
L_{annual} = annual pollutant load to the stormwater pond (e.g., pounds of TSS per year, lbs TSS/yr); and
$PR_{pollutant}$ = pollutant reduction efficiency of the stormwater pond (%). Note: determination of pollutant reduction efficiency is discussed in Section 2.1 (see Table 2).

2.3 Limitation of MPCA Stormwater Pond Design Criteria Methodology

The MPCA stormwater pond design criteria described in Section 2.0 is a simplified methodology used to provide an estimate of stormwater pond water quality performance when other, more accurate methods (see methods listed in Table 1) are not feasible. The following list summarizes limitations of the MPCA stormwater pond design criteria methodology:

- **Input sensitivity**: because the methodology produces an annualized estimate of pollutant reduction, input assumptions can have a significant impact on pollutant reduction calculations. For example, assumed TSS pollutant event mean concentrations from Table 3 could impact TSS influent loading by ± 100%. For this reason, input parameters should be carefully evaluated based on site-specific and best-available information. The methodology is especially sensitive to the following parameters:
    - Directly connected imperious fraction (Section 2.1);
    - Pollutant event mean concentration (Section 2.2); and
    - Water quality and permanent pool volume of the pond (Section 2.1).
- **Upstream treatment**: this methodology assumes no water quality treatment in the tributary area to the stormwater pond. Because upstream, tributary BMPs have the potential to impact the pollutant loading and pollutant particle scale distribution, this methodology should not be used for stormwater ponds with significant upstream water quality treatment.
- **In-pond dynamics**: this methodology does not account for in-pond dynamics such as:
    - Internal phosphorus loading (i.e., the release of bound phosphorus from pond sediment);
    - Sediment resuspension (i.e., scour of previously-settled sediment during large inflow events);
    - Inlet/outlet short-circuiting (i.e., inlet flow moving directly to outlet, limiting the flow detention time);
    - Macrophyte growth (i.e., the growth and life cycle of aquatic plants and algae).

3.0 Stormwater Pond Inspection and Assessment

As discussed in Section 1.0, the pollutant removal efficiency of constructed stormwater ponds degrades over time due to the loss of storage volume to sedimentation. Additionally, routine maintenance issues (e.g., pond outlet trash rack clogged with debris after storm; sand bar formation at inlet(s); etc.) can significantly reduce the hydraulic and water quality performance of stormwater ponds. For this reason, the municipal separate storm sewer system (MS4) General Permit requires permittees to:

a) Perform routine visual inspection of structural BMPs (i.e., **inspection**), and
b) Develop procedures and a schedule to determining the total suspended solids (TSS) and total phosphorus (TP) treatment effectiveness of all municipally owned/operated stormwater ponds (i.e., **assessment**) (MS4 General Permit Part III.D.6.), including evaluation of sedimentation.

For the purposes of evaluating the pollutant removal efficiency of stormwater ponds, "**inspection**" is defined as all components of routine visual inspection (Section 3.1). This typically involves walking the pond perimeter, inspecting outlets, and looking for signs of sedimentation and potential maintenance needs (e.g., clogged outlet).

A stormwater pond "**assessment**" encompasses all activities related to determining the total suspended solids (TSS) and total phosphorus (TP) treatment effectiveness of permittee owned and operated stormwater ponds (Section 3.2). As outlined by the MS4 General Permit, this involves developing procedures to evaluate TSS and TP treatment effectiveness, including development of a schedule for completing assessments of all municipal owned and operated stormwater ponds. Because the pollutant removal efficiency of a stormwater pond can be reduced as permanent pool volume is lost to sedimentation, a pond assessment should include an evaluation of sediment accumulation within the pond. Guidance in Sections 2.0, 4.0, and 5.0 provides methods for estimating, modeling, and directly monitoring the TSS and TP removal efficiency of ponds, respectively, but do not provide guidance on evaluating the permanent pool volume lost to sedimentation. For this reason, the assessment subsection (Section 3.2) provides guidance on how to estimate and directly measure sedimentation volume.

The following subsections provide guidance and recommendations related to the development of inspection and assessment procedures for stormwater ponds.

3.1 Inspection

Although the MS4 General Permit requires annual inspection of structural BMPs (Part III.D.E), the permit makes special exception for stormwater ponds, requiring only one (1) inspection of all ponds and outfalls prior to the expiration date of the permit. Due to critical hydraulic, water quality, and flood protection functions of stormwater ponds, it is recommended that inspection plans be developed to ensure that that:

1) Visual inspection of all municipal stormwater ponds and associated inlets and outlets occurs at

least once per year; and that

2) Additional visual inspections are performed as needed in response to large storms (e.g., a rainfall event greater than 2 inches).

3.1.1 Visual Inspection SOP and Checklist

Developing a visual inspection standard operating procedure (SOP) for stormwater ponds is critical for ensuring that visual inspections are carried out in a **standardized** and **repeatable** fashion. **Standardization** allows results of inspections from different ponds to be compared to assess relative priority of inspection and maintenance needs, and **repeatability** allows results of inspections of the same pond to be tracked year to year to evaluate how condition of the stormwater pond has changed. In addition to allowing for evaluation of inspection prioritization (discussed further in Section 3.1.2), an inspection SOP checklist also increases the efficiency and effectiveness of inspectors / municipal operators while performing routing visual inspections.

Although there are many examples for visual inspection SOP checklists which can be used as templates for designing a stormwater pond inspection SOP (see example in Appendix A), it is recommended that an individual use these documents as templates and revise as needed based on conditions within the MS4 (e.g., number of stormwater ponds managed, staff availability and skills, etc.). The following list outlines specific recommendations that should be included or considered in the development of a visual inspection SOP for stormwater ponds:

- **Electronic documentation**: tracking inspection electronically, rather than relying on paper files, allows for more efficient analysis / tracking of pond inspections. If tracked with paper files in field, include instructions to scan and enter notes electronically within one (1) day of completing inspection. If possible, consider tracking inspection notes electronically in field using a laptop or tablet.
- **Quantitative metrics**: whenever possible, include quantitative (i.e., numerical) metrics, as being quantitative allows for tracking of maintenance needs over time and relative comparison of maintenance needs between ponds. For example, if including a checklist item for outlet clogging consider using a numerical scale (e.g., “Is the outlet clogged? Rate 1-5, where 1 indicates 0% clogged, and 5 indicates ≥ 90% clogged).
- **Photo documentation**: include photos of site in visual inspection protocol. As needed, be instructive regarding photos (e.g., “include photograph of inlet #1, inlet #2, pond outlet structure, and emergency overflow berm”). Photos can be useful in tracking evolving conditions over time (e.g. formation of sand bar near pond inlet).
- **Immediate action protocols**: include protocols / instructions for addressing maintenance needs requiring immediate action (e.g., blocked/obstructed inlet, pipe failure, etc.).
- **Infrastructure inventory**: include record drawing (e.g., as-built, aerial imagery with locations circled, sketch, etc.) for each pond indicating where critical infrastructure is located (e.g.,

inlets, outlets).

- **Field staking / marking / GPS coordinates**: include instructions related to field marking (e.g., place stake with orange ribbon to indicate inlet, orange spray paint to indicate structure damage such as joint operation, etc.) and/or recording the GPS coordinates of critical structures. This can greatly increase efficiency of maintenance and future site inspections.
- **Visual inspection of sedimentation**: include instructions to evaluate visual signs of sedimentation (e.g., formation of sand bars in pond, bank and channel erosion, bank failure, outlet silted in / buried, etc.). Direct assessment / measurement of pond sedimentation is typically not conducted during routine visual assessment, but signs of sedimentation/ changes in sedimentation observed during visual inspection can indicate need to perform an assessment of pond sedimentation (Section 3.2).
- **Visual inspection for short-circuiting**: include instructions to evaluate proximity of inlets to outlets. If inlets are located near to outlets, flow into the pond can "short-circuit" directly to the outlet, allowing for little residence time and sedimentation of influent particles, greatly reducing pollutant removal efficiency from the affected inlet(s). If short-circuiting is occurring, inlets may be realigned or baffles may be installed to prevent bypass of pollutants.

An example of a stormwater pond visual inspection SOP checklist from the EPA's Stormwater Wet Pond and Wetland Management Guidebook (USEPA, 2019) is included in Appendix A. In addition to providing a detailed inspection checklist, the guidebook outlines detailed recommendations related to recommended frequency of pond inspection and maintenance. Adapted from the guidebook (USEPA, 2019), Table 5 and Table 6 outline the inspection operator skill level required and recommended frequency for various inspection tasks. Note: some inspection tasks outlined in Table 6 are in excess of the once annual visual inspection recommendation outlined in this memorandum, and are included to provide context and frequency recommendations for a wide range of inspection actions which should be considered based on factors unique to the MS4 (e.g., number of ponds managed, staff availability and qualifications, etc.) when developing a stormwater pond inspection SOP.

Table 5 Inspection skill level descriptions (adapted from USEPA, 2009).

Inspection skill level	Definition
0 (low)	No special skills or prior experience required, but some basic training via manual, video, or other materials is necessary.
1	Inspector, maintenance crew member or citizen with prior experience with ponds and wetlands
2	Inspector or contractor with extensive experience with pond and wetland maintenance issues
3 (high)	Professional engineering consultant required.

Source (adapted): USEPA Stormwater Wet Pond and Wetland Management Guidebook (USEPA, 2019).

Table 6 Inspection action recommendations (adapted from USEPA, 2009).

Frequency Recommendation	Inspection Items (Skill Level from Table 5)
Monthly to Quarterly or After Major Storms (>1")	• Inspect low flow orifices and other pipes for clogging (0) • Check the permanent pool or dry pond area for floating debris, undesirable vegetation (0) • Investigate the shoreline for erosion (0) • Look for broken signs, locks, and other dangerous items (0)
Several Times per Hot/Warm Season	• Inspect stormwater ponds for possible mosquito production (0-1)
Semi-annual to annual	• Identify invasive plants (0-1) • Ensure mechanical components are functional (0-1)
Every 1 to 3 years	• Complete all routine inspection items above (0) • Inspect riser, barrel, and embankment for damage (1-2) • Inspect all pipes (2) • Monitor sediment deposition in facility and forebay (2)
2-7 years	• Monitor sediment deposition in facility and forebay (2)
5-25 years	• Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping (2-3)

Source (adapted): USEPA Stormwater Wet Pond and Wetland Management Guidebook (USEPA, 2019).

In addition to establishing a standardized, repeatable methodology for performing routing visual inspections, it is critical to inventory and rank the relative inspection priority of stormwater ponds to ensure ponds with higher likelihood of requiring maintenance are inspected with higher frequency. Development of an inspection prioritization system is discussed further in Section 3.1.2.

3.1.2 Inspection Prioritization

Due to the need for routine inspection, if an inventory of all stormwater ponds is available (as required by MS4 General Permit Part III.C.2), it is recommended that MS4s develop an inspection prioritization list for all municipal stormwater ponds. The purpose of an inspection prioritization list is to help ensure that ponds likely to have maintenance needs are inspected annually, and to help identify ponds with lower maintenance needs which may be inspected less frequently (e.g., once every two years). Note: this recommendation is targeted at MS4s responsible for inspection of many stormwater ponds and wetlands, where annual inspection may not be feasible for all ponds. For MS4s with a small number of stormwater ponds or staff availability and resources to perform annual inspection on all stormwater ponds, annual inspection is recommended and inspection prioritization may not be necessary.

After establishment of an, inspection program using a standardized stormwater pond inspection SOP checklist (see Section 3.1.1), inspection prioritization can be ranked using results of inspection SOP worksheets, including quantitative metrics used to rank maintenance needs. An example of ranking categories and associated inspection frequency is shown in Table 7. Note: ranking categories and the inspection frequency assigned to each can be highly dependent on conditions unique to the MS4 (e.g., number of stormwater ponds managed, staff availability, etc.). For this reason, the categories and recommendations provided in Table 7 are meant to serve only as an example of one method of inspection prioritization.

Table 7 Example of inspection prioritization categories.

Prioritization Category	Inspection Frequency Goal
1 (high priority)	Perform visual inspection of 100% of rank 1 ponds annually.
2	Perform visual inspection of 50% of rank 2 ponds annually.
3 (low priority)	Perform visual inspection of 25% of rank 3 ponds annually.

Prior to the establishment of a routine visual inspection program (Section 3.1.1), other metrics related to the potential pollutant loading and hydraulic function of MS4 stormwater ponds can be used to create an inspection prioritization list. Prior to establishing a database of visual inspection metrics, it is recommended that any or all of the following metrics be used to create a ranked prioritization list, as available:

- **Institutional knowledge** (e.g. municipal operator experience, resident complaints, etc.): it is recommended that ponds with known maintenance issues (e.g., high water levels, sedimentation issues, etc.) be assign high inspection priority.
- **Drainage area**: it is recommended that ponds with larger drainage areas be assigned higher priority than those with smaller drainage areas. Note: drainage areas for small ponds may be determined from development plans, while determining drainage areas for larger, regional ponds may require delineation using available stormsewer infrastructure data and topography.
- **Pond surface area**: if pond drainage areas are not known, it is recommended that ponds with larger surface area be assigned high priority than those with smaller surface area.

Prioritization strategies and ranking methodology will be highly dependent on (a) what data is available, and (b) conditions unique to the MS4 (e.g., number of ponds managed, institutional knowledge of municipal operators, etc.). An example of an inspection prioritization methodology developed by the City of Oakdale is available on the Minnesota Stormwater Manual's stormwater pond assessment page.

3.2 Assessment

As outlined in Section 3.0, stormwater pond "assessment" encompasses all activities related to determining the total suspended solids (TSS) and total phosphorus (TP) treatment effectiveness of permittee owned and operated stormwater ponds. Additionally, the MS4 General Permit, Part III.D.6. Requires MS4s to develop a schedule based on measurable goals and priorities established by the permittee for completing assessments of all MS4 stormwater ponds. Because the pollutant removal performance of a stormwater pond can be greatly reduced as permanent pool volume is lost to sedimentation, an assessment plan must include an evaluation of the sedimentation volume within the stormwater pond.

Because methods of estimating, modeling, and directly monitoring the TSS and TP removal efficiency of ponds are outlined in Sections 2.0, 4.0, and 5.0, respectively, this subsection focuses on guidance related to evaluating pond sedimentation volume (Section 3.2.1) and developing a pond assessment plan and schedule (Section 3.2.2).

3.2.1 Evaluating Pond Sedimentation Volume

Determining the sedimentation volume within a stormwater pond requires the following:

a) Determining the original bathymetric volume (design volume, if constructed) of the stormwater pond; and
b) Determining the existing bathymetric volume of the stormwater pond. The difference between (a) and (b) is the permanent pool volume lost to sedimentation (i.e., sedimentation volume).

Determining the original bathymetric volume (e.g., constructed bathymetric volume, design bathymetric volume) typically requires gathering available background information. If the pond is a constructed feature, bathymetric volume should be determined from best-available record drawings or best available information (e.g., as-built drawings, design drawings, design calculations, etc.). If the pond is not a constructed feature or if design records are not available or were not maintained, original bathymetric volume may be estimated by determining the sedimentation depth using the survey rod transition or sediment core methods, described below.

Determining the existing bathymetric volume and sedimentation volume can be determined through the methods described below. Methodology is organized from most accurate and most labor intensive to lease accurate and least labor intensive:

- **Bathymetric volume**: a bathymetric survey can be used to obtain a direct measurement of the existing bathymetric volume. Several methods of surveying bathymetric volume are described and compared, below. Additionally, Table 8 provides a summary of the relative accuracy and relative cost of each method:
    - **Grid Survey – Relative Depth**: If water level is at a known elevation or there is a relative survey benchmark in the area, bathymetric survey can be performed by determining depth to pond bottom at points throughout the pond (relative depth, i.e., 2.3 feet deep). It is recommended that X,Y grid spacing be established to create a representative depth surface. Once digitized, the existing bathymetric surface can be compared to the design or original bathymetric volume to determine the sedimentation volume. Note: if comparing a bathymetric survey to design or record drawings, make sure the same benchmark reference is being used in both dataset (e.g., the outlet elevation, benchmark in area, etc.) or adjust the volume calculations accordingly to obtain an accurate

calculation of sedimentation volume.

- **Grid Survey – Total Station (TS), Real Time Kinematic (RTK) survey:** similar to the "relative depth" method described above, but rather than using relative depth measurements to water surface or a known benchmark, uses a TS or RTK station to measure bathymetric elevations. By establishing an X,Y grid or shooting many elevations at representative points within the pond, a bathymetric elevation model can be created and used to calculate an accurate estimate of bathymetric volume.
- **Continuous Survey: Sonar**: there are many "fish finder" sonar depth measurement devices available on the market today capable of recording continues depth measurements from a fixed position (e.g., a boat, kayak, etc.). Collected sonar data can be sent directly to cloud-based data processing services (e.g., C-MAP) which generate digital bathymetric elevation models form the collected data. Processing services have various pricing models, with some charging a fixed price per data set (i.e., a fixed price per pound). Although this method has the advantage of producing a continuous record of bathymetric depth and elevation, disadvantages include:
  - Horizontal GPS accuracy: the horizontal accuracy of various "fish finder" devices may not be sufficient for every application and may need to be supplemented with a more accurate GPS device.
  - Depths less than 2-feet & excessive vegetation: many sonar technologies are incapable of accurately measuring depths less than two feet (based on limitations related to the speed of sound through water). Additionally, many sonar technologies will not produce accurate depth measurements through dense vegetation.

Table 8 Comparison of Bathymetric Survey Methods

Pollutant Removal Assessment Strategy	Description	Relative Accuracy	Relative Cost
Grid Survey - Relative Depth	Measuring relative depths along an X,Y grid of points or at monitored GPS locations. This method relies on determining the water surface elevation on the day of survey, either through a known benchmark or known pond outlet elevation.	Low	Low
Grid Survey - Total Station (TS), Real Time Kinematic (RTK) Survey	Similar to "relative depth" method, but utilizes TS or RTK survey to measure pond depths directly.	Medium / High[1]	Low / High[1]
Continuous Survey – Sonar	Continuous monitoring of pond depth using sonar. Many "fish finder" style sonar devices can be used for this application. Collected data can be sent to cloud processing companies to develop bathymetric volumes directly form collected data.	Medium / High[2]	High

[1] Accuracy dependent on number of points collected, and cost dependent on if MS4 owns and has trained staff to operate TS/RTK survey equipment.

[2] Accuracy dependent on pond depth and vegetation (lower accuracy if less than 2 feet deep and/or highly vegetated.

- **Sedimentation volume: sediment core**: collection of sediment core(s) at several locations can be used to determine depth of accumulated sediment. Review of soil composition throughout the profile of the sediment core can help determine the transition from accumulated material (e.g., plant biomass, coarse sediment and sand, etc.) to native soil texture (e.g. fine grain soil texture such as silt and clay). If multiple cores are collected, a sediment depth surface can be created to calculate sedimentation volume. Alternatively, the average sediment depth can be assumed across the entire pond bathymetric surface, although this method will produce less-accurate results as sediment accumulation is typically concentrated at pond inlet locations.
- **Sedimentation volume: survey rod transition**: the simplest method of estimating depth of accumulated sediment is to manually push the survey rod point into pond sediment and to feel for a transition from soft, accumulated sediment to harder native material (i.e., the design pond bottom). Because this method is reliant on the accuracy of the surveyor to record the transition point and is inherently subjective, it is the least accurate method of estimating sedimentation volume. However, recording the depth at the top of accumulated sediment to the top of native material (the transition point) can provide an estimate of accumulated sediment depth which may be sufficient for determining when pond sediment management is required. If depth is estimated at many points throughout the pond, a sediment depth surface can be created to calculate sedimentation volume. Alternatively, the average sediment depth can be assumed across the entire pond bathymetric surface.

Note: the existing bathymetric volume, not the design volume, should be used as bathymetric volume referenced in Sections 2.0 and 4.0 for estimating the current, existing conditions pollutant removal efficiency of stormwater ponds. Although recommendations related to sediment management (i.e., dredging) are not included in this memorandum, the MCPA Stormwater Manual suggests that sediment management should occur every 25 years or once fifty percent (50%) of the design permanent pool volume has been lost to sedimentation.

3.2.2 Developing a Pond Assessment Plan and Schedule

The MS4 general permit (Part III.D.6.d) requires permittees to (a) assess the TSS and TP treatment effectiveness of all permittee owned/operated stormwater ponds and (b) develop a schedule (which may exceed the permit limit) based on measurable goals and priorities established by the permittee for completing assessments of all MS4 stormwater ponds. As discussed in Section 3.2.1, the TP and TSS removal effectiveness of stormwater ponds can be estimated or evaluated, or directly measured using methodology outlined in Sections 2.0, 4.0, and 5.0, respectively. A stormwater pond assessment plan and schedule can take many forms, as the schedule is not specified in the general permit and the measureable goals and priorities are established by the permittee.

The Minnesota Stormwater Manual Stormwater Pond Assessment page contains examples of assessment plans and schedules developed by MS4s and approved by the MPCA. The City of West St. Paul's Assessment Plan (City of West St. Paul, 2016) is included in Appendix B to provide an example of how an assessment plan and schedule can be structured.

3.3 Case Study: RWMWD inspection and assessment SOP

The Ramsey-Washington Metro Watershed District (RWMWD) has developed a stormwater pond inspection and assessment SOP document for its member municipalities and MS4s to insure stormwater pond inspection, assessment, and maintenance procedures are conducted using a standardized methodology, and to insure that ponds are inspected frequently and maintained as needed. The RWMWD SOP provides examples of inspection and assessment procedures, as well as guidance related to:

- Schedule (i.e., recommended schedule and frequency of inspection and assessment efforts);
- Visual inspection procedures;
- Pond assessment procedures;
- Bathymetric survey procedures;
- Information collection and recording procedures;
- Sediment characterization procedures;
- Pond sediment management procedures;
- Contracting and construction oversight; and
- Staff training and documentation.

The RWMWD inspection and assessment SOP document is included in Appendix C of this document.

4.0 Stormwater Pond Pollutant Removal Modeling

A common method of estimating the TSS and TP removal efficiency of stormwater ponds as well as other water quality best management practices (BMPs) is water quality modeling. There are a large number of water quality models that can be used to assess pollutant removal efficiency of BMPs, ranging from complex, physically-based models which simulate the transport of sediment particles and the transport, decay, and ultimate fate of associated pollutants, to simplified spreadsheet-based models which use empirical relationships to estimate the pollutant loading and removal. The following subsections provide a summary of available and recommended water quality models, as well as a case study which highlights how water quality modeling can be used to evaluate the pollutant removal efficiency of managed stormwater ponds, and how modeling results can be used to help inform and prioritize pond inspection and assessment efforts.

4.1 Available Water Quality Models

The Minnesota Stormwater Manual maintains a comprehensive list of available water quality models and provides guidance related to selecting a model based on a variety of criteria (see Available stormwater model and selecting a model). The online database contains a narrative summary of many commonly used water quality models as well as a tabular database summarizing general information for sixty (60) models. Using the tabular data regarding model capabilities, a user can select and filter the list of models to those that meet specific criteria (e.g., is the model public access? Does the model include build-in BMPs? Does the modeling include TSS and TP pollutant modeling? Runoff reduction and infiltration modeling? Etc.).

Due to the large, comprehensive nature of this database, even when filtering based on several criteria, there will typically be many models (e.g., greater than ten models) that meet a specified set of criteria. To help inform the selection of a water quality model, the MPCA has developed a TMDL Modeling Package (Objective 1, Task A of the TMDL Toolkit) which provides background information and modeling guidance for four (4) water quality models commonly used in Minnesota (Section 4.2).

4.2 Commonly Used and Recommended Water Quality Models in Minnesota

As discussed in Section 4.1, to help inform the selection of a water quality model for the purposes of evaluating TMDL compliance, the MPCA has developed a TMDL Modeling Package (Objective 1, Task A of the TMDL Toolkit) which provides detailed information and modeling guidance related to four (4) water quality models commonly used in Minnesota:

- Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds (**P8**; Walker, 1990);
- Minimal Impact Design Standards Calculator (**MIDS Calculator**; MPCA, 2017);
- Minnesota Pollution Control Agency Simple Estimator (**MPCA Simple Estimator**; MPCA, 2015); and
- Source Loading and Management Model for Windows (**WinSLAMM**; Pitt and Voorhees, 2002).

These models were selected based on survey of over eighty MS4s, watershed districts, watershed management organizations, and other regulatory entities (Table 9), as well as a comprehensive review of capabilities of each model referenced in the initial survey. To help inform model selection, it is recommended that and MS4 review the Water Quality Model Guidance for MS4s guidance (Barr, 2019a) and select the most-appropriate model based on conditions and water quality considerations unique to the MS4. Select tables from the Water Quality Model Guidance for MS4s guidance (Barr, 2019a) has been included in this memorandum to provide an overview of the four water quality model recommended within the memorandum:

- Table 9 – summarizes the results of MPCA-conducted survey regarding use of water quality models.
- Table 10 – provides a narrative description of each model. This table has been modified for this memorandum to summarize applicability for evaluation of pollutant removal efficiency of stormwater ponds.
- Table 11 – provides a summary matrix of model capabilities which can be used to compare each model based on water quality modeling requirements unique to the MS4.

Table 9 MPCA Water Quality Modeling Survey Results (2018)

Water Quality Model[1]	Percentage of Responds Referencing Use of model (n = 86) (%)
P8	**37%**
MIDS Calculator	**33%**
MPCA Simple Estimator	**24%**
WinSLAMM	**8%**
PondNet	5%
Bathtub	3%
BWSR Pollutant Estimator Spreadsheet	2%
HydroCAD	2%
Revised Universal Soil Loss Equation II	2%
SWAMP	2%

1 Only models referenced more than once (1) in the MPCA survey (2018) are included in this summary table.

Table 10 Water Quality Model Description and Overview

Water Quality Model	Model Description	Applicability for Evaluating Pond Pollutant Removal Efficiency[1]
P8	P8 is a physically-based water quality model which simulates the generation and transport of sediment and associated pollutants from urban watersheds. The model is capable of predicting sediment particulate removal of five (5) particle sizes (including one soluble fraction) and associated pollutants at a variety of BMP types.	P8 is an acceptable model for evaluating the TSS and TP removal efficiency of stormwater ponds.
MIDS Calculator	The MIDS Calculator is an Excel-based stormwater quality tool used to estimate runoff and pollutant removal at a variety of stormwater BMPs. The model was originally developed by the MPCA to assist designers and regulators evaluate conformance to MIDS performance goals for development-scale models. The MIDS Calculator is an empirical model which predicts pollutant removal based on correlation to P8 results and design-standard BMP removal rates from literature.	MIDS calculator is an acceptable model for modeling stormwater ponds for simplified study areas. Specifically, the tool is limited in its ability to evaluate bypass from undersized ponds and predict pollutant removal through non-volume reduction BMPs in series. Note: because this tool does not directly evaluate pond dimensions, this tool is not capable of modeling pollutant removal from ponds not meeting the MIDS Design Level 1 criteria (see Table 2).
MPCA Simple Estimator	The MPCA Simple Estimator is a spreadsheet-based tool that utilizes the Simple Method to estimate land use based pollutant loading from urban watersheds. The empirically-based model estimates pollutant removal from nine (9) BMP types based on design-standard BMP removal rates from literature.	The MPCA Simple Estimator is an acceptable model for evaluating the TSS and TP removal efficiency of stormwater ponds for simplified study areas. The tool is not capable of evaluating bypass from undersized ponds or pollutant removal through ponds in series. Note: because this tool does not directly evaluate pond dimensions, this tool is not

Water Quality Model	Model Description	Applicability for Evaluating Pond Pollutant Removal Efficiency[1]
		capable of modeling pollutant removal from ponds not meeting the MIDS Design Level 1 criteria (see Table 2).
WinSLAMM	WinSLAMM is a water quality model originally developed for the USGS to evaluate nonpoint pollution in urban areas. The model predicts pollutant loading from a variety of land use and impervious area types and calculates pollutant reduction at a variety of control devices (BMPs). Pollutant reduction at control devices is based both on experimental field results (empirical) and tracking of particulate settling and filtration (physically-based).	WinSLAMM is an acceptable model for evaluating the TSS and TP removal efficiency of stormwater ponds.

1 This table adapted from the Water Quality Model Guidance for MS4s memorandum to reference stormwater pond modeling.

Table 11 Water Quality Model Comparison Matrix

Comparison Categories		Water Quality Model			
		P8	MIDS Calculator	MPCA Simple Estimator	WinSLAMM
Relative Input Complexity		High	Medium	Low	High
Public Domain		Yes	Yes	Yes	No
TSS Modeled?		Yes	Yes	Yes	Yes
TP Modeled?		Yes	Yes	Yes	Yes
Volume Reduction Modeled?		Yes	Yes	Yes	Yes
Model time step		Event / Continuous	Annual	Annual	Event
Pollutant Loading Methodology		EMC & Buildup/ Wash-off	Simple Method	Simple Method	EMC & Buildup/ Wash-off
Pollutant Removal Methodology		Physically Based	Empirical	Empirical	Physically-based / Empirical
Pollutant Removal Mechanisms		Filtration, Sedimentation, Infiltration	Empirically based	Empirically based	Filtration, Sedimentation, Infiltration, Empirically based
Capable of evaluating bypass from undersized BMPs?		Yes	Only for volume-reduction BMPs	No	Yes
Capable of modeling removal from BMPs in series?		Yes	Only for volume-reduction BMPs	No	Yes
GIS Compatibility		Low	Low	Low	Medium
Model used for TMDL Development and Modeling		Yes	No	No	Yes
Costs	Software	None	None	None	Medium
	Model Development	Medium	Low	Low	High

Although each of the four (4) water quality models summarized have a unique set of inputs required to the generate model results, there are many inputs (e.g., watershed hydrologic inputs, BMP inputs, etc.) that are required by a majority of water quality models. To provide an overview of the typical inputs required by water quality model and the level of effort required to generate required inputs, Section 4.3 provides a summary of typical water quality model inputs and summarizes publically available data sources and methods by which inputs may be estimated.

4.3 Common Inputs Required for Water Quality Modeling

The Water Quality Model Guidance for MS4s guidance (Barr, 2019a) provides a detailed summary of required inputs, and guidance related to generating required inputs. Although each water quality model requires a unique set of inputs, there are many inputs that are common to the majority of available water quality model (Section 4.1). The following subsections provide a summary of inputs commonly required for water quality modeling. Note: more detailed documentation related to generation of model inputs can be found within the Water Quality Model Guidance for MS4s (Barr, 2019a) as well as within the model documentation for each model. Guidance within this section is meant to provide general guidance and summarize the level of effort required to generate common water quality modeling inputs (i.e., this section does not include summary of all parameters required for each of the four model highlighted in Section 4.2).

4.3.1 Hydrologic and Pollutant Inputs

The following is a list of hydrologic inputs (i.e., inputs required for modeling rainfall, runoff, and associated pollutant loading) typically required for water quality modeling:

- **Rainfall**: water quality models typically require rainfall inputs at the same temporal resolution of the model. For example, and annualized model (e.g., MIDS Calculator) requires annual rainfall depth, while continuous models (e.g., P8) require daily, event-based, or hourly rainfall. Local rain gauges (e.g., airport rain gauges) can be used to develop annualized and/or continuous rainfall inputs. As noted in Section 2.0, the MIDS Calculator contains a database of annual rainfall depth by Minnesota zip code.
- **Watershed area**: water quality models require the use to specify the tributary area (i.e. watershed area) tributary to individual BMPs or groups of BMPs. For small, development scale stormwater plans, tributary area may be determine from site plans and record drawings. For larger, regional stormwater ponds, watershed area is determined by evaluating topography and stormsewer infrastructure tributary to the pond.
- **Watershed hydrologic parameters**: water quality models use a variety of methods for estimating the amount of rainfall which is infiltrated, abstracted, or leaves the watershed as stormwater runoff (e.g., SCS Curve Number Method, Simple Method, etc.). Although many methodologies are used, typically models will require input directly or indirectly related to impervious area, soil type / infiltration rate, and/or land use:

- **Land Use / Impervious data**: determining the tributary impervious area to a BMP is required by a majority of water quality models, as pollutant loading and runoff loading are often highly correlated to the amount of tributary impervious area. Rather than define impervious area directly (i.e., percent directly connected impervious area (%)), some models instead require the user to define tributary area into categories of land use which are correlated to impervious area within the model (e.g., the MPCA Simple Estimator). As outlined in Section 2.1, impervious area can be determined through manual evaluation of site impervious cover from record drawings or site plans. For larger drainage stormwater ponds with larger drainage areas (e.g. regional stormwater ponds with drainage areas greater than five acres), land use datasets can be used to estimate total impervious area within the ponds drainage area. The Minnesota Geospatial Information Office (MnGeo) maintains a database of current and historic land use which can be used to evaluate land use and estimate impervious area. Additionally, the University of Minnesota (UMN) provides land cover and impervious data at varying resolution statewide and for specific regions throughout Minnesota (e.g. Twin Cities Metro).
- **Soil type / infiltration**: to determine the amount of rainfall which is infiltrates and is therefore not routed to downstream BMPs, many models require inputs related to soil type (e.g., infiltration rate). For small developments, site-specific soil boring data may be available. If site specific information soils information is unavailable, it is recommended that the spatial NRCS Soil Survey Geographic Database (SSURGO) be used. SSURGO soils data is available for download online through the Web Soil Survey: https://websoilsurvey.nrcs.usda.gov/. Table 12, adapted from the Minnesota Stormwater Manual, correlates soil texture and hydrologic soil groups (HSGs) to infiltration rates.

- **Pollutant parameters**: water quality models typically require user input to determine the amount of pollutant associated with stormwater runoff and routed to BMPs. Some models require the user to specify an event mean concentration (EMC) of specific pollutants (e.g., mg or TSS per liter of runoff, see typical values in Table 4), while others require inputs related to the sediment particle scale distribution (PSD) associated with runoff, pollutant concentrations associated various particle sizes, etc. Guidance related to generation of pollutant input parameters is typically highly specific to the model and, for this reason, individual model documentation should be reviewed.

Table 12 Hydrologic soil group summary from Minnesota Stormwater Manual.

Hydrologic soil group	Inf. Rate (in/hr)	Soil textures	Corresponding Unified Soil Classification
A	>1.63	gravel	GW - well-graded gravels, sandy gravels
		sandy gravel	GP - gap-graded or uniform gravels, sandy gravels
	1.63	silty gravels	GM - silty gravels, silty sandy gravels
		gravelly sands	SW - well-graded gravelly sands
		sand	SW - uniformly graded sands
	0.8	sand	SP - gap-graded or poorly graded sands
		loamy sand	
		sandy loam	
B	0.45		SM - silty sands, silty gravelly sands
	0.3	loam, silt loam	MH - micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	ML - silts, very fine sands, silty or clayey fine sands
D	0.06	clay loam	GC - clayey gravels, clayey sandy gravels
		silty clay loam	SC - clayey sands, clayey gravelly sands
		sandy clay	CL - low plasticity clays, sandy or silty clays
		silty clay	OL - organic silts and clays of low plasticity
		clay	CH - highly plastic clays and sandy clays
			OH - organic silts and clays of high plasticity

4.3.2 Water quality BMP inputs

The following is a list of water quality BMP input parameters (i.e., inputs related to defining BMP dimensions and outlet hydraulics) typically required for modeling stormwater ponds:

- **Bathymetric volume / water quality volume**: water quality modeling typically require the user to enter the permanent pool volume (V_{pp}) and water quality volume (V_{wp}) of each stormwater pond (see Figure 1). A detailed description of how the calculate / evaluate V_{pp} and V_{wq} is provided in Section 2.1. If available, bathymetric volume and water quality volume should be determined from an updated bathymetric survey (see discussion in Section 3.2.1) of each pond to ensure that modeled bathymetric volume is reflective of existing conditions. In not available, water quality and bathymetric volume should be determined from best-available record drawing data.
- **Outlet parameters**: many water quality model, particular those that model on a continuous, rather than annualized basis (see Table 11), require inputs related to the outlet of the pond (e.g., outlet pipe dimeter, outlet rating curve, etc.). Annualized models typically do not require pond outlet parameters.

The following section provides a case study of how water quality modeling can be used to evaluate the TSS and TP treatment effectiveness of stormwater ponds and utilize results to help inform prioritization of pond inspection efforts.

4.4 Water Quality Modeling Limitations

Limitations of water quality models to evaluate BMP performance in series and bypass from undersized BMPs are highlighted in Table 10 and Table 11. In addition to these limitations, a majority of one-dimensional water quality models (including all models evaluated within Section 4.0) are not capable of modeling complex in-pond processes, such as:

- Internal phosphorus loading (i.e., the release of bound phosphorus from pond sediment);
- Sediment resuspension (i.e., scour of previously-settled sediment during large inflow events);
- Inlet/outlet short-circuiting (i.e., inlet flow moving directly to outlet, limiting the flow detention time);
- Macrophyte growth (i.e., the growth and life cycle of aquatic plants and algae).

If it is suspected that in-pond processes, such as those listed above, may impact stormwater pond performance, it is recommended that pond water quality performance be evaluated through water quality monitoring (Section 5.0).

4.4.1 Sedimentation Modeling

Although all water quality models evaluated in Section 4.0 produce estimates of TSS removal, none are capable of evaluating bathymetric volume loss to sedimentation in real-time. In all of these models, bathymetric volume remains a static value throughout the duration of the model run. For a majority of pond systems, this modeling limitation does not have a significant impact on model results. Figure 2, adapted from *Phosphorus Removal by Urban Runoff Detention Basins* (Walker, 1987) shows stormwater pond total phosphorus reduction as a function of "relative volume" (i.e., pond volume / (watershed area) x (runoff coefficient)) and mean pond depth. Figure 2 shows that beyond typical design standards (i.e., National Urban Runoff Program (NURP) standards), the mean depth has relatively minor impact on percent reduction over a wide range of mean pond depth values (i.e., 0.5 – 8.0 meters). For example, for a NURP design pond, a decrease in mean depth from 2.0 meters to 1.0 meters results in a reduction in TP removal efficiency from 60% to 55% (see Figure 2).

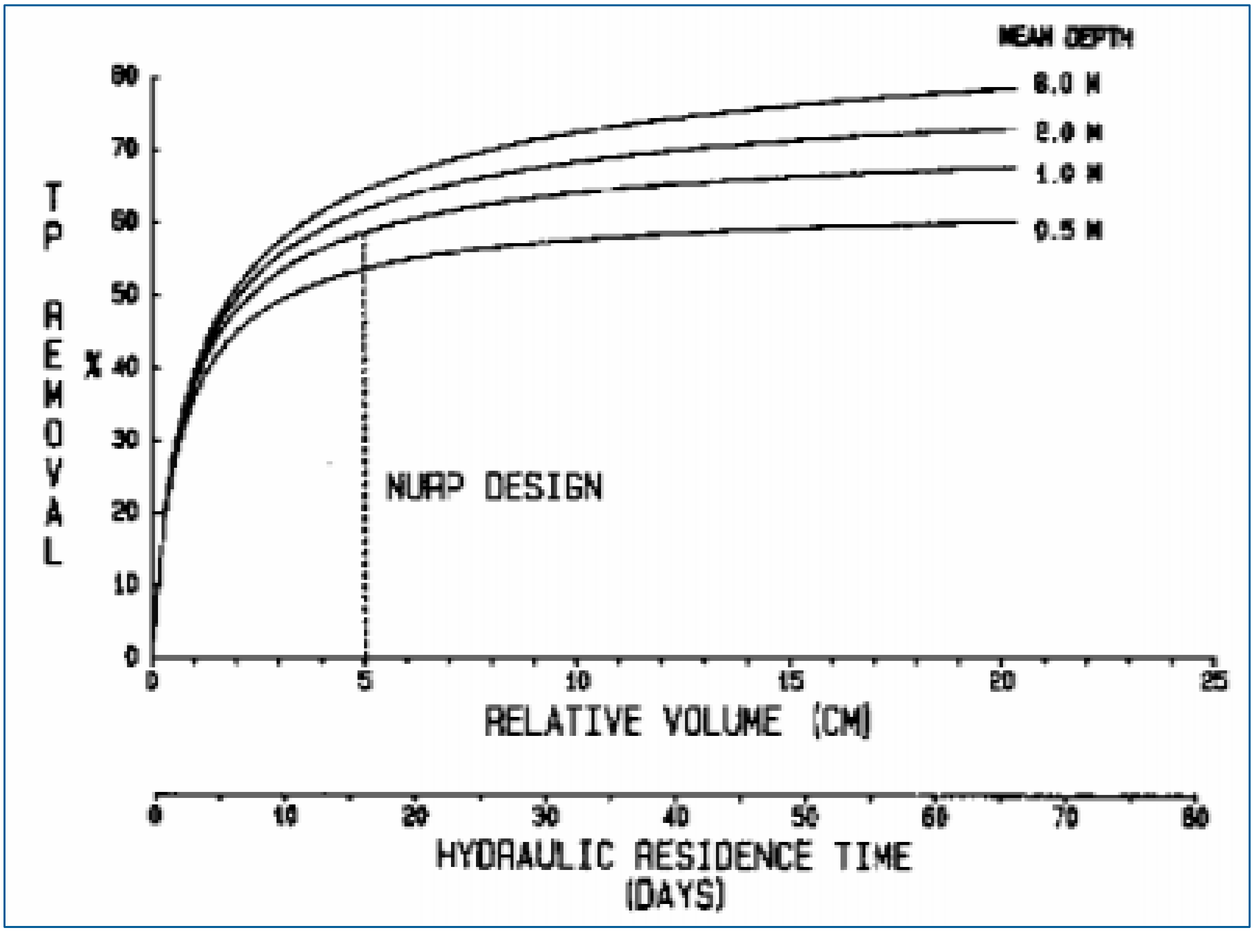
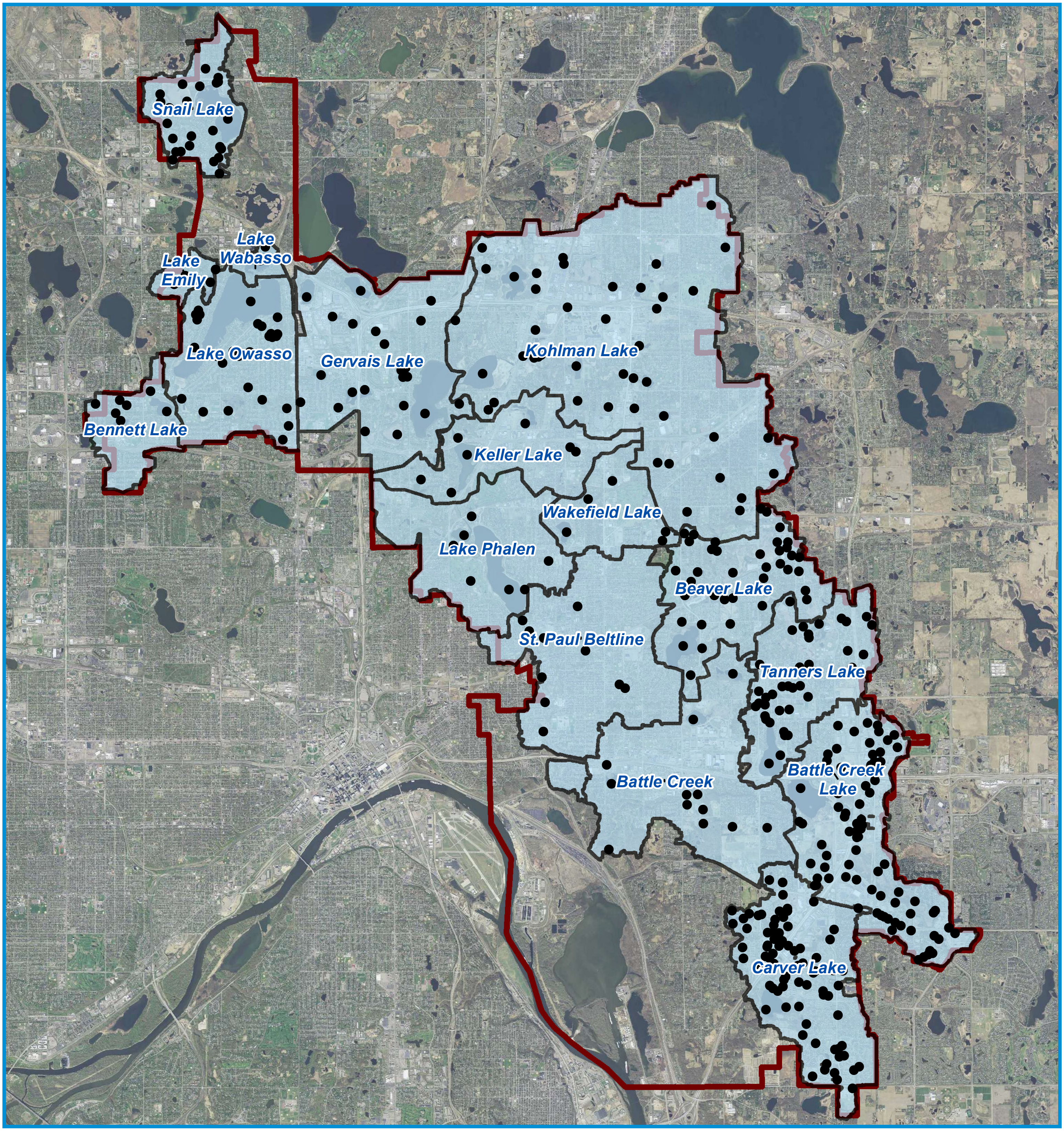


Figure 2 **Total phosphorus removal as a function of relative volume and mean depth (adapted from Walker, 1987).**

4.5 Case Study: RWMWD Pond Performance Study

The Ramsey Washington Metro Watershed District (RWMWD) has developed water quality models spanning over 75 percent of the entire watershed district jurisdictional boundary (Figure 3). Modeling was performed using the P8 water quality model (P8; Walker, 1990), and include all significant BMPs including over 350 stormwater ponds. The models were originally created to evaluate pollutant loading to District managed lakes and waterbodies, but have been utilized for a wide variety of applications (e.g., used for development of area TMDLs, used to identify and prioritize areas for water quality BMP implementation, etc.).

The following subsections outline the general model development procedure, and summarize how District models were used to help MS4s within the District prioritize pond inspection efforts.



- P8 Modeled Ponds and Wetlands
- P8 Model Areas
- RWMWD Legal Boundary

0 4,500 9,000
Feet

BARR

EXISTING P8 MODEL COVERAGE
Pond and Wetland Performance Study
Ramsey-Washington Metro Watershed District (RWMWD)

Figure 03

4.5.1 General Overview of Model Development

The RWMWD P8 water quality models shown in Figure 3 were developed on as as-needed basis per major watershed area over a period of about 10-years. The general process used to develop major watershed area P8 models is outlined, below. Note: the steps provided below are highly generalized and included only to outline the general steps and level of effort required to create a P8 model. For more-detailed descriptions of P8 model development, refer to information compiled in the Water Quality Model Guidance for MS4s guidance (Barr, 2019a) and P8 model documentation:

1) Identify all significant water quality BMPs within the major watershed, including all stormwater ponds;
2) Identify and assign the routing of water quality BMPs and pipe devices and assign in model;
3) Develop input parameters for each BMP type (e.g., permanent pool volume, outlet rating curve, etc. See example in Figure 5);
4) Delineate subwatersheds to each BMP based on topography and stormsewer utility routing;
5) Generate hydrologic inputs for all subwatersheds using spatial land use, impervious area, and soil datasets;
6) Develop rainfall inputs for the modeled period (e.g., hourly rainfall precipitation depths for the 10-year modeling period);
7) Assign water quality and particle parameters (if divergent from standard assumptions in the nurp50.p8p file;
8) Assign general inputs related to model duration, time steps per hour, passes thru storm file, etc.; and
9) Run model and debug any modeling errors (e.g., runoff mass balance error greater than 2%, etc.).

Figure 4 through Figure 6 show the hydrologic and hydraulic BMP input parameters required for one stormwater pond within the Battle Creek Lake major watershed model, as well as model results for the pond. These figures are included to summarize the detail of input requirements required for P8 modeling. Note: more-simplified, annualized models (e.g., MIDS Calculator, MPCA Simple Estimator) typically do not require this level of detail of inputs, but may not be capable of accurately modeling water quality loading and pollutant removal in BMPs for complex areas (see model comparison matrix, Table 11).

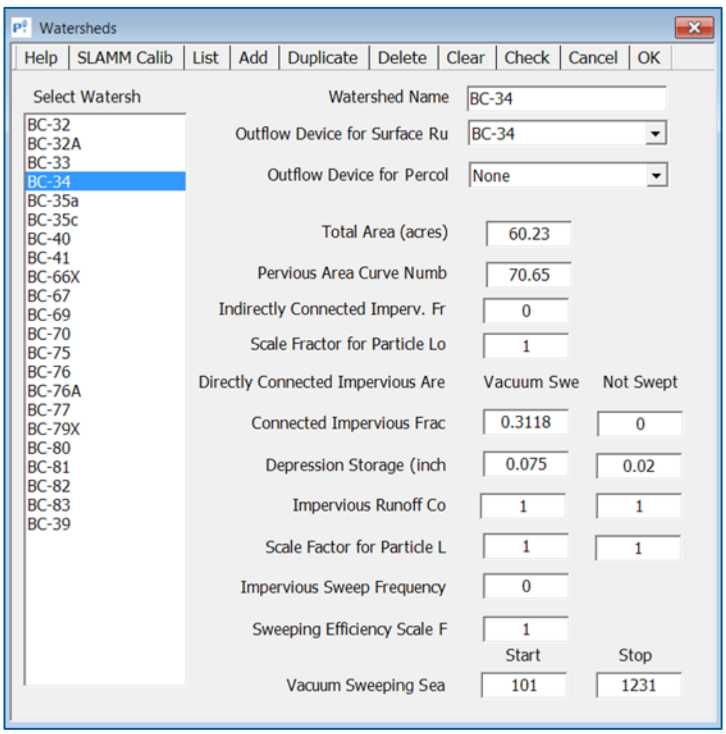


Figure 4 Direct watershed to Pond ID BC-34 (top) and P8 subwatershed inputs (bottom)

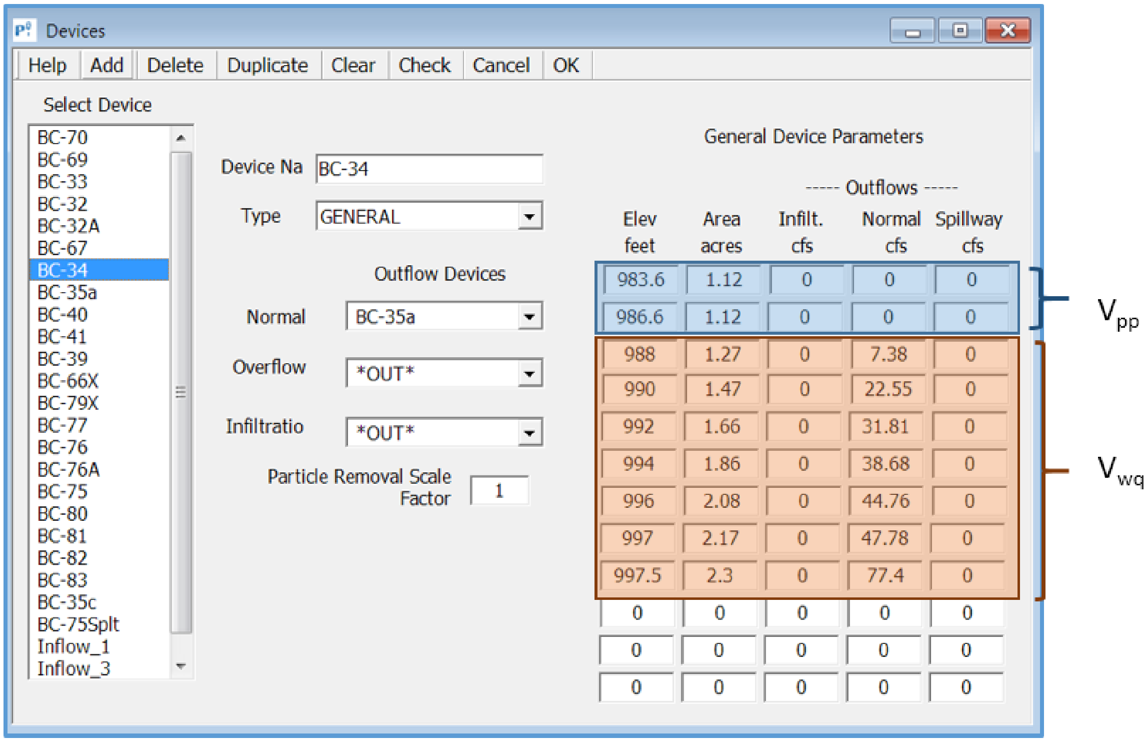
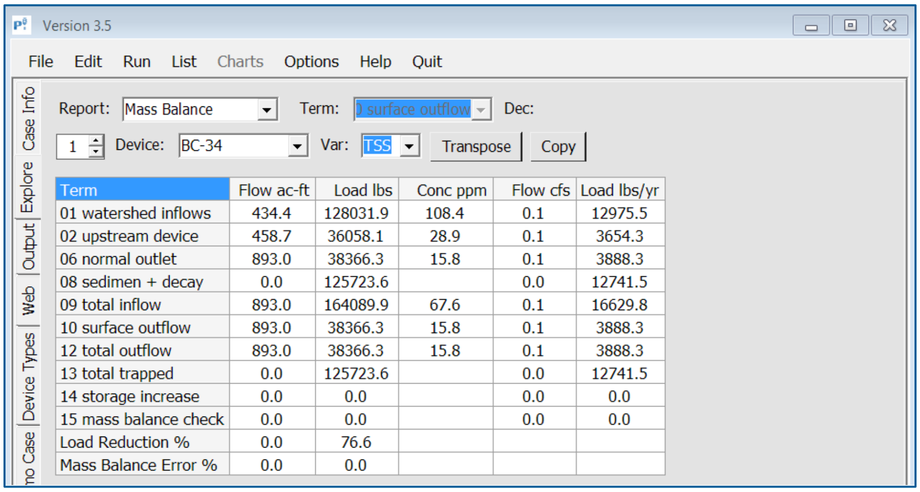
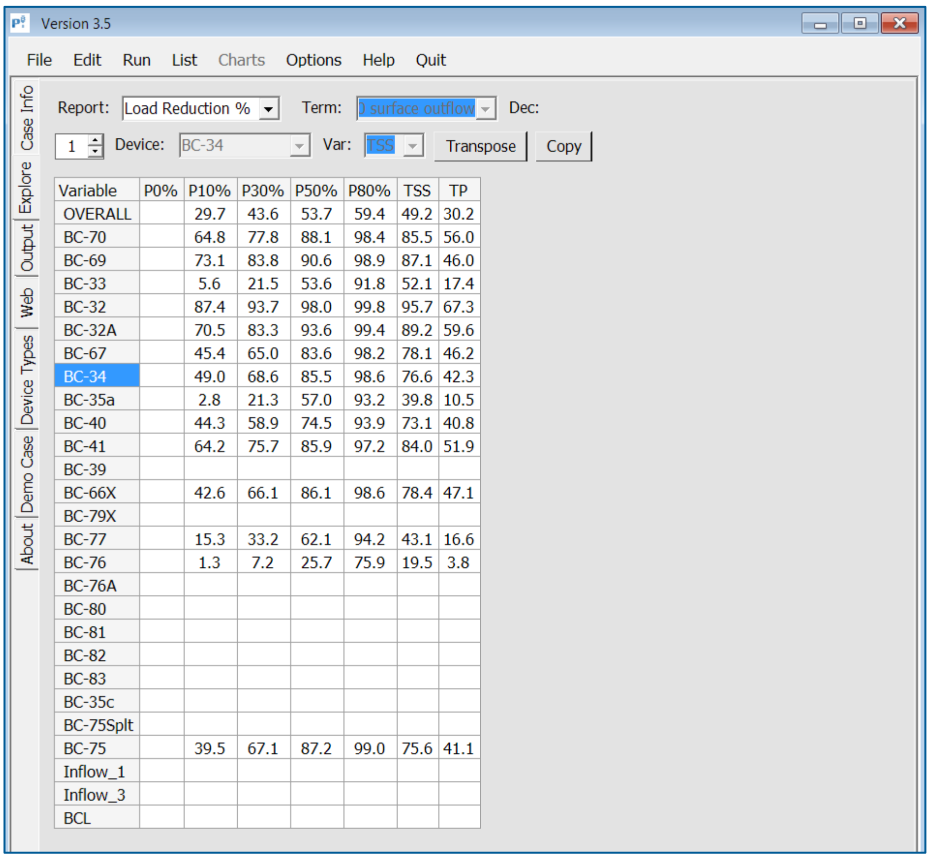


Figure 5 P8 device inputs for Pond ID BC-34



Term	Flow ac-ft	Load lbs	Conc ppm	Flow cfs	Load lbs/yr
01 watershed inflows	434.4	128031.9	108.4	0.1	12975.5
02 upstream device	458.7	36058.1	28.9	0.1	3654.3
06 normal outlet	893.0	38366.3	15.8	0.1	3888.3
08 sedimen + decay	0.0	125723.6		0.0	12741.5
09 total inflow	893.0	164089.9	67.6	0.1	16629.8
10 surface outflow	893.0	38366.3	15.8	0.1	3888.3
12 total outflow	893.0	38366.3	15.8	0.1	3888.3
13 total trapped	0.0	125723.6		0.0	12741.5
14 storage increase	0.0	0.0		0.0	0.0
15 mass balance check	0.0	0.0		0.0	0.0
Load Reduction %	0.0	76.6			
Mass Balance Error %	0.0	0.0			



Variable	P0%	P10%	P30%	P50%	P80%	TSS	TP
OVERALL		29.7	43.6	53.7	59.4	49.2	30.2
BC-70		64.8	77.8	88.1	98.4	85.5	56.0
BC-69		73.1	83.8	90.6	98.9	87.1	46.0
BC-33		5.6	21.5	53.6	91.8	52.1	17.4
BC-32		87.4	93.7	98.0	99.8	95.7	67.3
BC-32A		70.5	83.3	93.6	99.4	89.2	59.6
BC-67		45.4	65.0	83.6	98.2	78.1	46.2
BC-34		49.0	68.6	85.5	98.6	76.6	42.3
BC-35a		2.8	21.3	57.0	93.2	39.8	10.5
BC-40		44.3	58.9	74.5	93.9	73.1	40.8
BC-41		64.2	75.7	85.9	97.2	84.0	51.9
BC-39							
BC-66X		42.6	66.1	86.1	98.6	78.4	47.1
BC-79X							
BC-77		15.3	33.2	62.1	94.2	43.1	16.6
BC-76		1.3	7.2	25.7	75.9	19.5	3.8
BC-76A							
BC-80							
BC-81							
BC-82							
BC-83							
BC-35c							
BC-75Splt							
BC-75		39.5	67.1	87.2	99.0	75.6	41.1
Inflow_1							
Inflow_3							
BCL							

Figure 6 P8 results for Pond ID BC-34: mass balance (top) and load reduction (bottom)

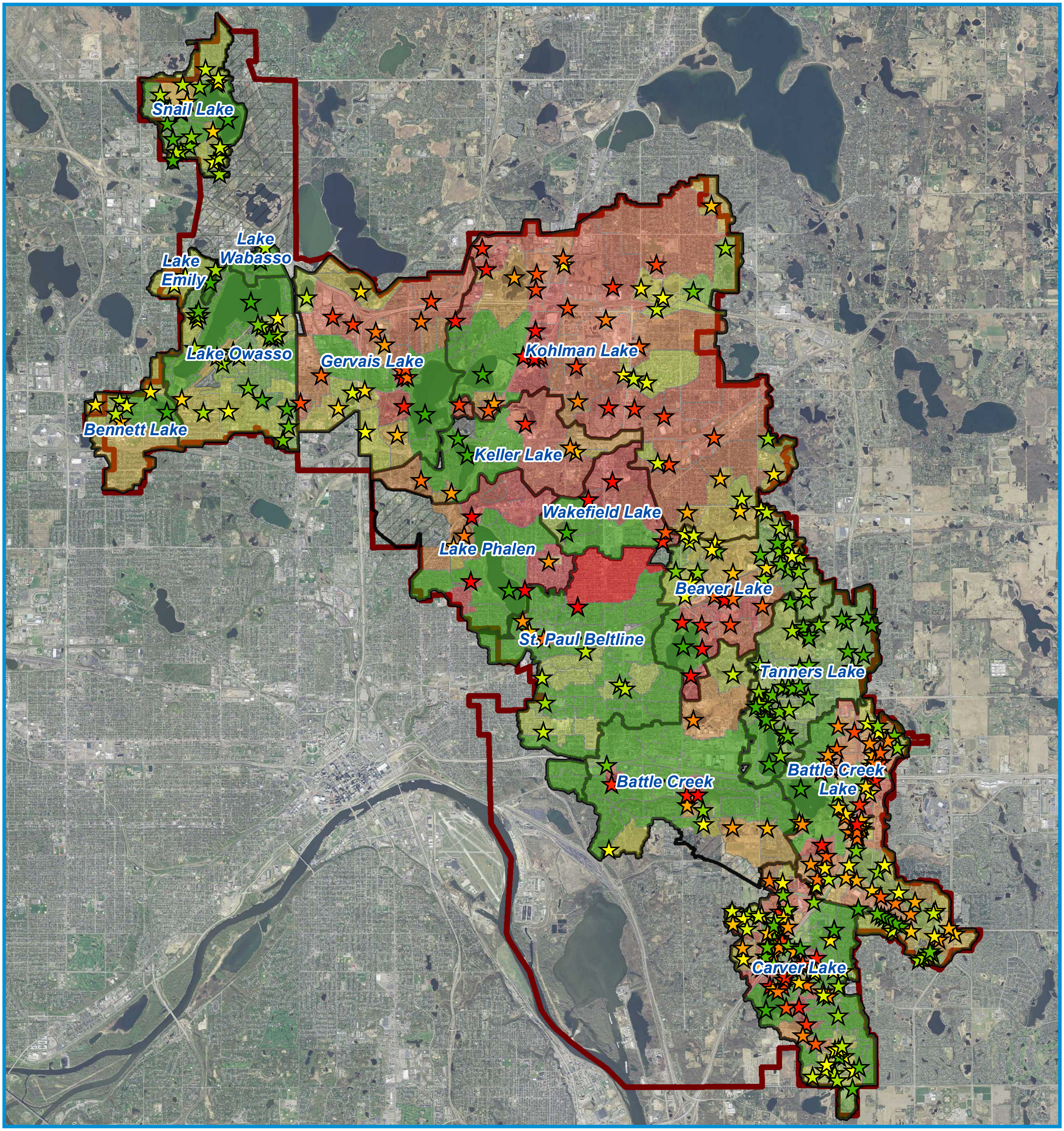
4.5.2 Overview of Model Application: Pond Inspection Prioritization

In 2016, RWMWD performed study to evaluate the performance of stormwater pond and wetlands in all modeled portions of the District. A major goal of the Stormwater Pond and Wetland Performance Study (Barr, 2016) was to utilize P8 model results to help MS4s within the RWMWD prioritize stormwater pond inspection and assessment efforts. It is District policy that MS4s perform routine visual inspection (see Section 3.1.1) of all municipal stormwater ponds at least once annually. Based on the large number of ponds within the District (see Figure 3), municipalities were struggling to meet this goal. For this reason, the RWMWD working in coordination with Barr Engineering Co. (Barr) developed a study to utilize District-wide P8 results to prioritize inspection efforts.

As discussed in Section 3.1.2, an inspections prioritization plan can take many forms based on available data, conditions within the MS4, available resources, and water quality management goals of the MS4. Based on the District goal of minimizing pollutant loading to district managed waterbodies (i.e., major lakes and streams) it was determined that stormwater inspection efforts within each municipality should be targeted at stormwater ponds that are (a) providing significant water quality benefit (i.e., removing significant mass of TSS and TP) and (b) are filling quickly due to sedimentation. Annual sedimentation volume was calculated based on the mass of five (5) particle classes removed annually and assumptions related to the wet bulk density of each particle class. The annual sedimentation volume was then compared to the modeled pond bathymetric volume to estimate the percentage of bathymetric volume lost to sedimentation per year (i.e., % per year). Based on this prioritization framework, Barr developed a methodology to rank the relative inspection priority of all ponds based on:

a) The percentage of permanent pool volume lost to sedimentation per year determined through modeling in P8 (% per year); and
b) The annual mass of pollutant prevented from reaching District managed water bodies (referred to as the “effective” reduction, e.g., lbs TSS / year).

Using this methodology, stormwater ponds which remove significant annual pollutant mass load from the watershed, and are filling quickly, are ranked with higher inspection priority (i.e., routine visual inspection) that ponds removing less pollutant and filling less quickly. All district ponds were assigned an inspection rank number (e.g., rank number 1 = the highest inspection priority stormwater pond in the District), and these ranking were then interested with MS4 areas to generate unique inspection prioritization rankings for each MS4. Relative stormwater pond inspection priority across all modeled areas in the District is shown in Figure 7, and an example prioritization table for an individual MS4 (i.e., Woodbury) is shown in Table 13.



P8 Modeled Waterbodies

Lower inspection priority

Higher inspection priority

P8 Model Areas

RWMWD Legal Boundary

P8 waterbody tributary subwatersheds*

Lower inspection priority

Higher inspection priority

* Subwatershed symbology is shown to help highlight where higher and lower inspection priority waterbodies are located throughout the District.

0 4,500 9,000
Feet

BARR

INSPECTION PRIORITY RANKING
Pond and Wetland Performance Study
Ramsey-Washington Metro Watershed District (RWMWD)

Figure 07

Results of the inspection prioritization were shared with municipal engineers and operators at a technical advisory committee (TAC) meeting. In many cases, ponds ranked within highest inspection priority within a given MS4 were identified as "problematic" ponds by municipal operators (i.e., ponds which require a higher degree of active management, such as inlet/outlet clearing, sediment management, etc.), anecdotally verifying the methodology used to identify the inspection priority of ponds. Moving forward, MS4s will reference the inspection prioritization lists when scheduling and allocating resources for annual pond inspections. As sediment management projects occur and in response to development changes within the MS4s, the modeling effort may need to be updated to re-prioritize ponds based on new and updated conditions within the ponds and within the watersheds.

Table 13 RWMWD pond inspection prioritization table for Woodbury.

Pond ID	Major Watershed	MNRAM Classification	Municipality	RWMWD Ranking	Municipal Ranking
BC-26X	Battle Creek Lake	MA	Woodbury	11	1
CARV-56	Carver Lake	S	Woodbury	17	2
CARV-66	Carver Lake	S	Woodbury	18	3
BC-35a	Battle Creek Lake	MC	Woodbury	19	4
BC-31	Battle Creek Lake	MC	Woodbury	24	5
CARV-49a	Carver Lake	MC	Woodbury	25	6
CARV-57	Carver Lake	MC	Woodbury	33	7
BC-28A	Battle Creek Lake	MC	Woodbury	37	8
CARV-7a	Carver Lake	MB	Woodbury	38	9
CARV-79	Carver Lake	MB	Woodbury	39	10
CARV-22	Carver Lake	MA	Woodbury	40	11
CARV-59	Carver Lake	MC	Woodbury	46	12
CARV-9	Carver Lake	NA	Woodbury	49	13
CARV-51a	Carver Lake	MC	Woodbury	55	14
CARV-58	Carver Lake	MC	Woodbury	59	15
BC-25Xa	Battle Creek Lake	S	Woodbury	64	16
CARV-78	Carver Lake	MB	Woodbury	68	17
CARV-92	Carver Lake	MB	Woodbury	69	18
BC-20	Battle Creek Lake	S	Woodbury	71	19
BC-34[1]	**Battle Creek Lake**	**MB**	**Woodbury**	**72**	**20**

1 BC-34 is the pond highlighted in Figure 4 through Figure 6. Table truncated to only show top 20 ponds.

5.0 Stormwater Pond Water Quality Monitoring

Water quality monitoring is the most comprehensive method of evaluating the TSS and TP removal efficiency of stormwater ponds, but poses many challenges related to implementation feasibility and cost. Although performance of individual stormwater ponds is typically estimated from design standard values (Section 2.0) or calculated through water quality modeling (Section 4.0), MS4s may choose to monitor individual stormwater ponds to (a) verify and calibrate modeling results and/or (b) evaluate performance of complex stormwater pond systems (e.g., network of ponds in series, large regional ponds, ponds potentially impacted by internal loading or other phenomena not captured through modeling, etc.).

MPCA has developed a TMDL Modeling Package which includes detailed recommendations and guidance related to establishing a BMP monitoring program and associated monitoring protocols (see Monitoring Guidance for MS4s (Barr, 2019b); Objective 1, Task B of the TMDL Toolkit). Monitoring program guidance and protocols outlined should be reviewed and incorporated into the development of a stormwater pond monitoring program. The following subsections highlight guidance specifically related to the monitoring of stormwater ponds, and highlights emerging research related to evaluating the potential for phosphorus release from stormwater pond sediment.

5.1 Stormwater Pond Monitoring Feasibility

Prior to establishing a stormwater pond monitoring program, the goals of the monitoring program should be clearly outlined, and the feasibility of monitoring should be evaluated. Optimizing Stormwater Practices: A Handbook of Assessment and Maintenance (Erickson et. al, 2013, available online), designed to supplement stormwater practice information in the Minnesota Stormwater Manual, provides detailed information related to establishing and implementing a monitoring program for many varieties of BMPs, including sedimentation BMPs (e.g., stormwater ponds). To provide context for the level or effort of various monitoring efforts, the handbook ranks the "relative effort" of several monitoring procedures (Table 14). In addition to the staff time and cost, the handbook estimates implementing of a monitoring program will take over a year (14 months).

Due to the cost and difficulty of implementing a monitoring program, it is recommended that monitoring only be considered for:

- Large, regional stormwater ponds where accurately estimating pollutant reduction performance is critical to evaluating regional pollutant loading and/or the pond treatment has a disproportionate impact on receiving water quality;
- Regional stormwater ponds with complex interactions with groundwater and/or other water quality BMPs and receiving water bodies; and
- Water quality model calibration efforts.

An MS4 considering developing a monitoring program should first develop a scope of work to ensure sufficient resources are available (staff time, cost considerations, etc.). A detailed outline of how to develop a scope of work for a BMP monitoring program is included in the USEPA's Urban Stormwater BMP Performance Monitoring (USEPA, 2002) guidance manual, and additional information related to monitoring program development is summarized in the Monitoring Guidance for MS4s (Barr, 2019b; Objective 1, Task B of the TMDL Toolkit).

If developing a monitoring program is not feasible, it is recommended that stormwater pond TSS and TP removal efficiency be determined from design standards (Section 2.0) or water quality modeling (Section 4.0). If developing a monitoring program is feasible and is critical to MS4 goals related to water quality (e.g., evaluating waste load allocation (WLA) reduction requirements stipulated by a TMDL), it is recommended that the program and protocol outlined in the Monitoring Guidance for MS4s (Barr, 2019b; Objective 1, Task B of the TMDL Toolkit) be reviewed and incorporated into program development. Section 5.2 provides a summary of the pollutant reduction effluent probability method (USEPA, 2002), which can be used to evaluate pollutant loading reduction based on monitoring of influent and effluent pollutant event mean concentrations (EMCs).

Table 14 Comparison of Four Levels of Assessment (adapted from Erickson et. al, 2013)

Title	Objectives	Relative Effort	Typical Elapsed Time
Visual Inspection	Determine if stormwater BMP is malfunctioning	1	1 day
Capacity Testing	Determine infiltration or sedimentation capacity and rates	10	1 week
Synthetic Runoff Testing	Determine infiltration rates, capacity, and pollutant removal performance	10–100	1 week–1 month
Monitoring	**Determine infiltration rates, capacity, and pollutant removal performance**	**400**	**14 months**

5.2 Pollutant Reduction Effluent Probability Method

The USEPA's Urban Stormwater BMP Performance Monitoring Manual (USEPA, 2002) summarizes many methods of water quality monitoring data collection and data analysis methods. Based on review of historic and current methods of data analysis, ease of implementation, and accuracy the "pollutant reduction effluent probability method" is the recommended method for analyzing BMP treatment efficiency within the manual.

The pollutant reduction effluent probability method relies on continuous or event based monitoring of all influent (e.g., all pond inlets) and effluent (e.g., all pond outlets) pollutant concentration. For simplified stormwater pond systems with one (1) inlet and one (1) outlet, the TSS and TP removal efficiency of stormwater ponds can be determined as followed:

1) Determine the influent and effluent event mean concentration (EMC) through monitoring either continuous or event based monitoring. Note: specific recommendations related to pollutant concentration monitoring methods are outlined in the Monitoring Guidance for MS4s (Barr, 2019b; Objective 1, Task B of the TMDL Toolkit);
2) Determine if the influent and effluent EMCs are statistically different (i.e., determine if reduction in pollutant EMC concentration is occurring from inflow to pond outflow) as outlined in the

manual (USEPA, 2002); and

3) Evaluate pollutant EMC reduction as a function of the observed pollutant concentration duration curve as outlined in the manual (USEPA, 2002). Figure 8 (USEPA, 2002) shows the resulting plot from monitoring of influent and effluent TSS (i.e., particulate residue) concentrations. As can be seen, percent reduction is not constant and varies based on influent event loading to the pond.

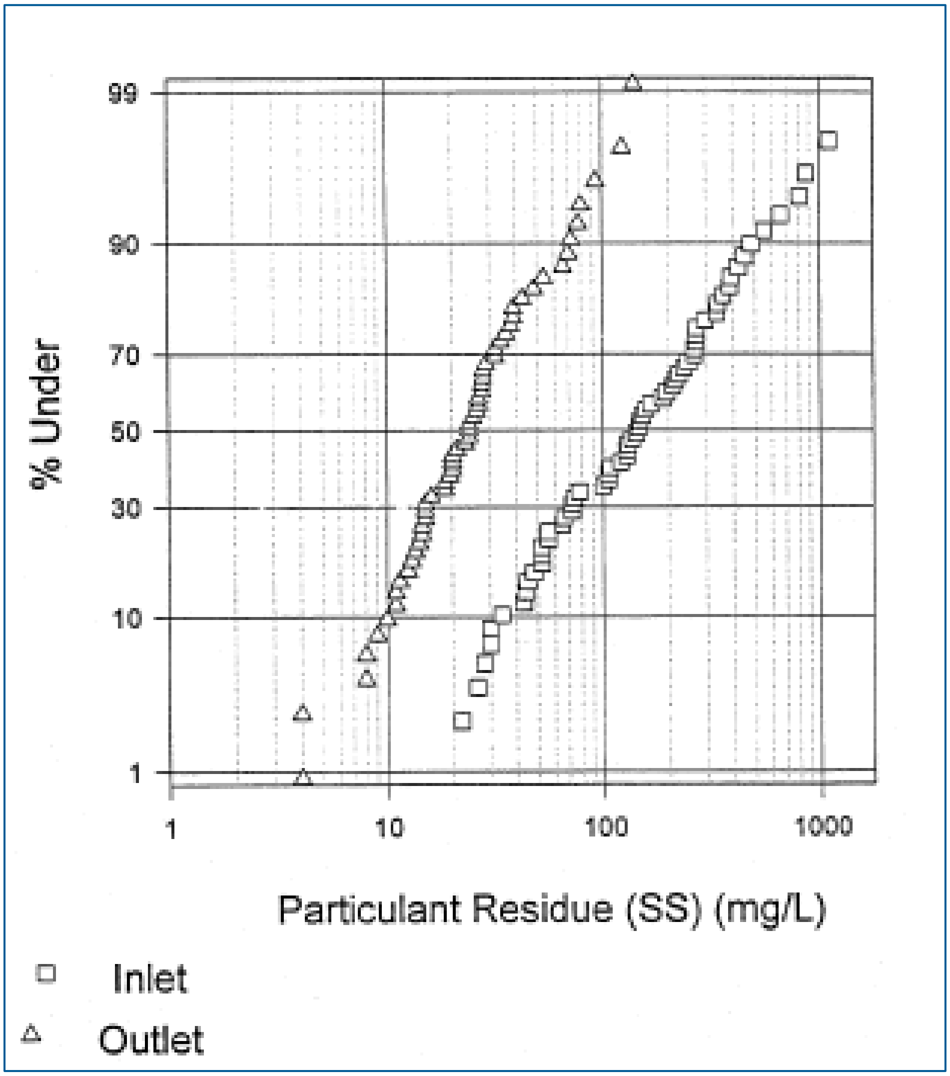


Figure 8 Effluent reduction probability plot (adapted from USEPA, 2002).

As described above, the pollutant reduction effluent probability method is best suited for stormwater ponds with one (1) inlet and one (1) outlet. The method may also be utilized for ponds with multiple inlets and outlets but only if influent concentrations are statistically equal between the multiple inlets and effluent concentrations are statistically similar between the multiple outlets.

For the scenarios listed below, **continuous flow monitoring** (see Monitoring Guidance for MS4s; Barr, 2019) would be required in addition to pollutant EMC monitoring so that pollutant influent and effluent mass loading (e.g., pounds of TP in and out of the pond) can be calculated and compared to evaluate pollutant removal efficiency:

- If the pond is losing volume to or gaining more than twenty percent of flow-through volume from groundwater (e.g., ponds with significant infiltration or influent baseflow from groundwater); and/or
- If influent concentration from multiple inlets are not statistically similar (i.e., significant difference between influent concentrations at different inlets).

The following case study (Section 5.3) highlights how influent and effluent monitoring from a stormwater pond was used to evaluate pollutant removal efficiency and guide implementation activities to increase the pollutant removal efficiency of the pond.

5.3 Case Study: Stormwater Pond Monitoring

The Sweeney Lake Total Phosphorus TMDL (SEH and Barr Engineering Company, 2011) was approved in 2011 after the lake was originally listed for excess nutrient (phosphorus) impairment. The Sweeney Lake TMDL allocations called for a watershed phosphorus load reduction of 99 pounds from June 1 through September 31 each year. Since there is limited space available for additional stormwater treatment, TMDL implementation strategies were primarily targeted to improve the performance of existing BMPs to contribute to the watershed phosphorus reduction goal. One option in the report was modification of a pond to improve phosphorus removal performance because it is the last pond in the largest drainage area tributary to Sweeney Lake.

The Bassett Creek Watershed Management Organization initiated the development of a Feasibility Report (Barr Engineering Company, 2012) to determine if and what kind of pond modification could enhance phosphorus removal, the cost and permitting requirements of potential modifications, and identify the most cost-effective modification to the pond to partially or fully meet the applicable external phosphorus loading reduction requirements. Design alternatives provided in the feasibility report were based on the average flow conditions used for TMDL development, but it was suspected that high flows may affect performance through scouring or short-circuiting of flow through the pond.

Auto samplers, level sensors, and area velocity meters were installed at the pond outlet, southern inlet (called Highway 55 inlet in the feasibility report), and northern inlet (called Rail Road inlet in the report) to evaluate the pond's phosphorus removal performance and develop a model to evaluate how removal could be enhanced by pond modifications. Samples were collected simultaneously at both inlets and the outlet for several storm events. For all events, samples were analyzed for total phosphorus, total dissolved phosphorus, total suspended solids, and volatile suspended solids. Flow was measured continually during the summer. It cost approximately $40,000 to complete the monitoring (including field sampling and laboratory analytical work) for this study.

The monitoring determined that the Rail Road (north) inlet provided approximately 10 percent of the flow, while the Highway 55 (south) inlet contributed 90 percent of the storm event flow (and approximate TP load) to the pond. However, the pond is configured such that 65 percent of its total volume is located at the Rail Road (north) inlet (see Figure 9).

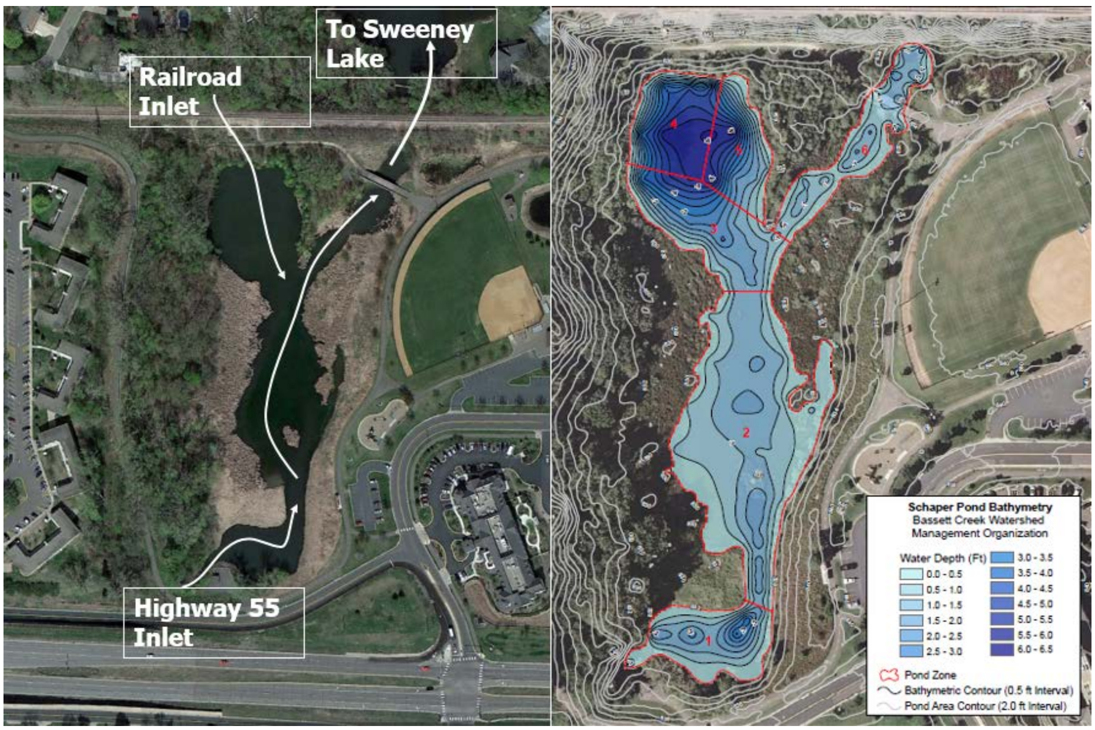


Figure 9 Pond configuration and bathymetry.

Another important monitoring finding was that particulate phosphorus (based on difference between total phosphorus and soluble phosphorus concentrations) accounts for the majority of total phosphorus loading to the pond. Collected particle settling data (Figure 10) shows that particles entering the pond are large and settleable. Particles currently being removed by the pond are greater than 150 µm in diameter, hence, any additional performance improvements will need to be achieved by removing smaller particles (i.e., particles less than 150 µm in diameter). Because most of the phosphorus is bound to particles (particulate phosphorus = total phosphorus – total dissolved phosphorus), improved phosphorus removal could result from improved particle settling conditions in the pond.

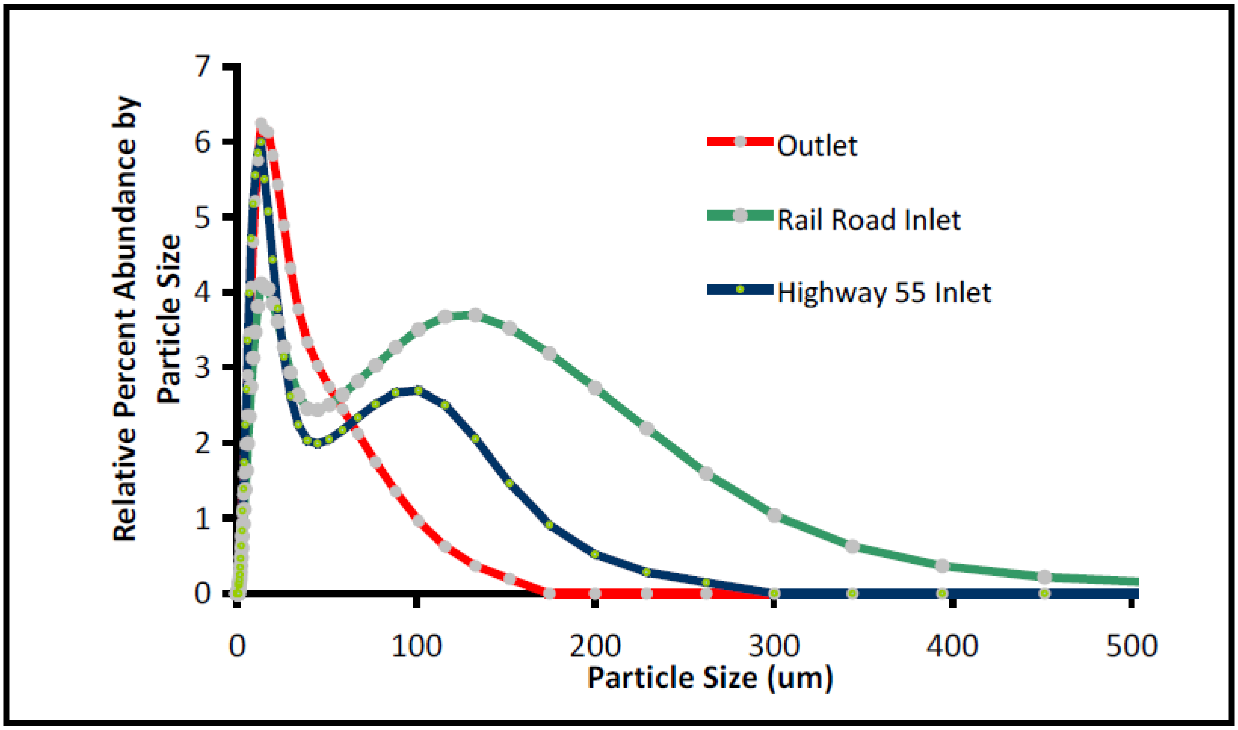


Figure 10 Suspended sediment particle sizes from both inlets and the pond outlet.

Since approximately 90 percent of the phosphorus load to the pond came from the Highway 55 inlet, but only 35 percent of the pond volume is provided to settle phosphorus from this source, diversion of influent water to the north west lobe of the pond was identified as a way to provide additional phosphorus settling time and improve overall phosphorus removal performance in the pond. This improvement option was implemented and is currently being monitored by the Bassett Creek Watershed Management Commission for treatment performance.

6.0 References

Barr Engineering Co. (Barr). 2012. Feasibility Report for the Schaper Pond Improvement Project. Prepared for the Bassett Creek Watershed Management Commission.

Barr Engineering Co. (Barr). 2016. Stormwater pond and wetland performance study. Prepared for the Ramsey-Washington Metro Watershed District.

Barr Engineering Co. (Barr). 2019a. Water Quality Model Guidance for MS4s guidance. Prepared for the Minnesota Pollution Control Agency.

Barr Engineering Co. (Barr). 2019b. Monitoring Guidance for MS4s. Prepared for the Minnesota Pollution Control Agency.

Center for Watershed Protection & Chesapeake Stormwater Network (CWP & CSN), 2008. Technical Memorandum: The Runoff Reduction Method. April

City of West St. Paul. 2016. Stormwater Pond Total Suspended Solids /Total Phosphorus Effectiveness Evaluation Procedures. November 9, 2016.

Erickson, Andrew J., Weiss, P., and Gulliver, J. 2013. Optimizing Stormwater Practices: A Handbook of Assessment and Maintenance.

Lin, J.P.: Review of Published Export Coefficient and Event Mean Concentration (EMC) Data. Wetlands Regulatory Assistance Program ERDC TN-WRAP-04-3 (September 2004).

Minnesota Pollution Control Agency (MCPA). 2015. Guidance and Examples for Using the MPCA Simple Estimator. Accessed from: https://stormwater.pca.state.mn.us/index.php?title=Guidance_and_examples_for_using_the_MPCA_Estimator

Minnesota Pollution Control Agency (MCPA). 2017. MIDS Calculator. Accessed from: https://stormwater.pca.state.mn.us/index.php/MIDS_calculator

Pitt, R. 2011. National Stormwater Quality Database (NSQD). Department of Civil and Environmental Engineering, v. 3.1 University of Alabama, Tuscaloosa.

Pitt, R. and J. Voorhees. 2002. SLAMM, the Source Loading and Management Model. Wet-Weather Flow in the Urban Watershed (Edited by Richard Field and Daniel Sullivan). CRC Press, Boca Raton. pp 103-139.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C

SEH Inc. 2011. Sweeney Lake Total Phosphorus TMDL. Prepared for the Bassett Creek Watershed Management Commission.

United States Department of Agriculture (USDA). Soil Survey Staff, Natural Resources Conservation Service (NRCS). Web Soil Survey. Available online at https://websoilsurvey.nrcs.usda.gov/.

United Stated Environmental Protection Agency (USEPA). 2002. Urban Stormwater BMP Performance Monitoring Manual.

United Stated Environmental Protection Agency (USEPA). 2009. Stormwater Wet Pond and Wetland Management Guidebook.

Walker, William W. 1987. Phosphorus removal by urban runoff detention basins. Lake Reservoir Management, 3:314-328.

Walker, William W. 1990. P8 Urban Catchment Model Program Documentation: Version 1.1. Prepared for IEP, Inc. and Narragansett Bay Project.

Appendix A

Example of stormwater pond inspection standard operating procedure (SOP) checklist: Field data sheet for Level 1 Assessment: Visual Inspection Wet Ponds (USEPA, 2009)

UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Wet Ponds

Inspector's Name(s):________________________________
Date of Inspection:________________________________
Location of the wet pond:________________________________
Address or Intersection:________________________________
Latititude, Longitude:________________________________
Date the wet pond began operation: ________________________
Wet pond dimensions. Depth (ft.): ________________________
Area (ft. x ft.) ________________________________
Time since last rainfall (hr): ________________________
Quantity of last rainfall (in): ________________________
Rainfall Measurement Location: ________________________

Site Sketch (include inlets, outlets, north arrow, etc.)

Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? □ Yes □ No □ I don't know
   1. a) If yes, enter date:________________________
   1. b) Based on previous visual inspections, have any corrective actions been taken?
      □ Yes □ No □ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? □ Yes □ No □ I don't know

3. Access
   3. a) Access to the wet pond is:
      □ Clear □ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
      □ temporary **and** □ no action needed **or** □ action needed
      □ permanent **and** □ before or during installation **or** □ new since installation
   3. c) Access to the upstream and downstream drainage is:
      □ Clear □ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
      □ temporary **and** □ no action needed **or** □ action needed
      □ permanent **and** □ before or during installation **or** □ new since installation

Comments

4. Inlet Structures

4. a) How many inlet structures are present? □ 0 □ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. How many cells are in the wet pond system? ______________________

5. a) Does the water in the pond have:

□ Surface sheen (from oils or gasoline)
□ Murky color (from suspended solids)
□ Green color (from algae or other biological activity)
□ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

□ Yes □ No □ I don't know (if yes, describe in comment box)

7. Does the wet pond smell like gasoline or oil? □ Yes □ No

8. Are there indications of any of the following in the wet pond? (If yes, mark on site sketch)

□ Sediment deposition in excess of 50% of the sediment storage capacity
□ Erosion or channelization
□ Excessive or undesirable vegetation (that needs mowing or removal)
□ Bare soil or lack of healthy vegetation significantly different from the original design
□ Litter or debris
□ Other
□ No

8. a) If sediment deposition is evident, what is the source?

□ Erosion or channelization inside the wet pond
□ Erosion or channelization outside the wet pond
□ Construction site erosion
□ Other
□ Unknown

Comments

9. Are there indications of any of the following on the banks of the wet pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - □ Trees on constructed slopes

10. Are any outlet or overflow structures clogged? □ No □ Partially □ Completely □ NA

10. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

10. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

11. Is there any evidence of any of the following downstream of the outlet structure?
□ Sediment deposition □ Erosion or channelization □ Other □ No

11. a) If sediment deposition is evident, what is the source?
   - □ Erosion or channelization inside the filtration practice
   - □ Erosion or channelization outside the filtration practice
   - □ Construction site erosion
   - □ Other, Specify____
   - □ Unknown

12. Inspector's Recommendations. When is maintenance needed?
   - □ Before the next rainfall
   - □ Before the next rainy season
   - □ Within a year or two
   - □ No sign that any is required

Comments

12. Summarize the results of this inspection and write any other observations in the box below.

Summary and other observations

Appendix B

Example of stormwater pond assessment plan and schedule:
Stormwater Pond Total Suspended Solids / Total Phosphorus Effectiveness Evaluation Procedure
(City of West St. Paul, 2016)

November 9, 2016

City of West St. Paul

Stormwater Pond Total Suspended Solids /Total Phosphorus

Effectiveness Evaluation Procedures

Purpose: These procedures outline the City's stormwater pond effectiveness evaluation and schedule in accordance with the requirements of the MS4 NPDES/SDS General Stormwater Permit, MNR040000, effective August 1, 2013.

The MS4 general permit (Part III.D.6.d) requires the permittees to develop procedures and a schedule for the purpose of determining the Total Suspended Solids (TSS) and Total Phosphorus (TP) treatment effectiveness of all permittee owned/operated ponds constructed and used for the collection and treatment of stormwater. These procedures are not used to determine stormwater credits.

I. PROCEDURES

a. Wet ponds are defined as constructed basins placed in the landscape to capture stormwater runoff. The pond is graded and outlet structures are designed in such a way that specified volumes of water are either held until displaced by future runoff or detained for a specified period of time. While the runoff is being held in the pond, sediment and associated pollutants settle to the bottom. Pollutants can also be removed from the stormwater through microbial, plant and algal biological uptake.[1]
b. Literature-based approach – The City will use a literature-based approach to assess stormwater pond effectiveness.
    i. Pollutant removal percentages for stormwater pond BMPs. Values for TP and TSS include a range of values, from lowest to highest percent removal, observed in the literature.[2]
        1. TSS (Low-median-high): 60-84-90
        2. TP (Low-median-high): 34-50-73
c. Evaluation- Staff will evaluate the pond's design, construction and maintenance before assigning TSS and TP effectiveness. Staff will evaluate three factors before assigning effectiveness: design, construction and maintenance. Staff will use their best judgement when records or data is not available.

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[1] Barr Engineering. *MIDS Subtask 2.2(1): Recommend Credits for MIDS Practices.* Memo to MIDS Workgroup. June 2011.

[2] *Pollutant Removal Percentages for Stormwater Pond BMPs*. Minnesota Pollution Control Agency, 15 July 2015. Web. 13 Sept. 2016.

i. New ponds will be assigned an estimated effectiveness based on the design and construction of the pond. Ponds will be reevaluated during subsequent inspection cycles for reduced effectiveness.

ii. Existing ponds that have reduced detention times due to sediment build up, but are receiving regular maintenance and still effectively functioning in removing sediment will be assigned median effectiveness.
   1. TSS – 84%
   2. TP – 50%

iii. Existing ponds that have substantial reduction in detention times due to sediment build up (50%) and are receiving regular maintenance, but sediment removal is significantly diminished by the buildup, will be assigned low effectiveness.
   1. TSS – 60%
   2. TP – 34%

iv. Existing ponds that have substantial reduction in detention times due to sediment build up such that there is no sediment removal after precipitation events will be assigned zero effectiveness.

v. Existing ponds that that have been dredged to remove sediment build up and restored to original design parameters will be assigned their original expected effectiveness.
   1. TSS – 90%
   2. TP – 73%

vi. In any situation above, staff may assign a lower pond effectiveness if they determine that the original design and/or construction and/or existing maintenance preclude the pond from effectively removing sediments. Assigned values can range anywhere from 0-90% for TSS and 0-73% for TP.

vii. The City will assume that a constructed basin is properly designed, constructed, and maintained in accordance with the Minnesota Stormwater Manual in the year it was constructed. If staff determines that any of these assumptions are not valid pond effectiveness may be adjusted downward as outlined in paragraph I.c.vi above.
   1. Staff will use the Minnesota Stormwater Manual wiki - *Design Criteria for Stormwater Ponds* http://stormwater.pca.state.mn.us/index.php/Design_criteria_for_stormwater_ponds) as a guide during pond evaluation. However, pond design has changed over the years and much of the sediment and nutrient removal effectiveness research was conducted on ponds that were built using different design criteria. The pond being evaluated by staff will compare the pond's design to the design parameters outlined in the literature. An example of such literature is William Walker's paper, "Phosphorus Removal by Urban Runoff Detention Basins."
   2. Staff will evaluate construction records to see if the actual pond construction deviated significantly from the engineer's design. This will

only be accomplished one time. As stated earlier, staff will use judgement when records do not exist or are inadequate.

3. Staff will complete a visual inspection to ensure that there is not significant sediment buildup, hydrologic short circuiting or repairs/maintenance needed that would affect sediment or nutrient removal effectiveness.

II. SCHEDULE - Pond effectiveness will be conducted in conjunction with the City's stormwater pond inspection cycle. The initial effectiveness evaluation will start with the 2017 inspection cycle and completed in 2021. Ponds will be re-evaluated beginning in 2022.

2016	2017	2018	2019	2020
Emerson North	**Christensen	Wentworth	**Mud Lake	Edgewood
*Lily Lake	Golf Course	**Humboldt	Southview	Emerson South
	Stryker	Marthaler	Duck	*Thompson Lake

NOTE: The inspection cycle and pond effectiveness will be repeated in 2021.

* Lily and Thompson Lakes are lakes as reported on the **MS4 Pond, Lake, and Wetland Inventory Form** submitted to the MPCA. As such, they will <u>not</u> be evaluated for TSS/TP effectiveness.

** Mud Lake, Christensen Pond and Humboldt Pond are wetlands as reported on the **MS4 Pond, Lake, and Wetland Inventory Form** submitted to the MPCA. As such, they will <u>not</u> be evaluated for TSS/TP effectiveness.

Appendix C

Ramsey-Washington Metro Watershed District (RWMWD):
MS4 SWPPP Standard Operating Procedures

Ramsey-Washington Metro Watershed District **MS4 SWPPP Standard Operating Procedures**	
SOP Title: Pollution Prevention/Good Housekeeping for Municipal Operations	MCM #: 6 - Pollution Prevention/Good Housekeeping for Municipal Operations
Pages:	Approved by:
Responsible District Staff:	Effective Date:
Revisions:	

PURPOSE:

To provide for implementation of proper systems maintenance activities and maintenance procedures to insure the ongoing operation of the MS4 to meet water quality reduction objectives.

RESPONSIBLE PARTIES:

District Administrator	**Water Quality Monitoring Coordinator**	**District Consulting Engineer**
	District Technician	Consulting Engineer Project Inspector

1. Stormwater pond performance for total suspended solids (TSS) and total phosphorous (TP) treatment effectiveness procedures and schedule
   A. Schedule.
      The following pond schedule and assessment procedures shall be followed to determine the TSS and TP treatment effectiveness of District maintained ponds constructed for collection and treatment of stormwater.
      a. The District goal is to complete "routine visual inspections" of all District ponds annually and at least one "pond assessment" every two (2) years.
         1) The District may adjust the frequency based on available budget, staff, and other factors that may affect the process.
         2) Inspection Priority: The District has not established priorities for stormwater treatment pond assessment and maintenance. All District ponds are created to address water quality improvement needs in downstream waters. Therefore, all ponds will receive equal attention for inspection. If multiple ponds require maintenance, the District may select pond maintenance projects based on the following factors:
            a) CIP project location.
            b) Watershed District and City Coordinated project opportunities.
            c) Age of pond.
            d) Contributing drainage area characteristics.
               i. Size
               ii. Land use
               iii. Upland treatment
               iv. Other applicable information

e) Known concerns based on inspections
f) Type and location of receiving water
g) Sensitivity of receiving water
h) Cost/benefit of the project

B. Inspection Procedures
   a. Routine Visual Inspection Procedures.
      1) Physically walk to the pond and review the status of the inlet and outlet of the pond to determine if the system is stable. Review the structures and look for erosion and the condition of the all riprap and pipe connections that may be failing due to flared end section undermining, piping or leakage.
      2) Walk around the pond perimeter to look for slope failure issues or other signs of erosion from seeps or contributing inflows from creeks or culverts.
      3) Look over the ponds water surface to see if there is any indication that sediment buildup, islands, debris piles, and deltas have formed in any fashion indicating that dead storage has been reduced.
      4) If there are physical signs of reduced storage, the pond is placed on the schedule for a pond assessment.
   b. Pond Assessment Procedures
      1) Gather background information. This may include the following:
         a) Original design information, if available, including:
            (1) Record drawings
            (2) Design calculations
            (3) Other applicable information
         b) As-built survey information, if completed and available.
         c) Other significant information available that pertains to the pond.
      2) Site investigation and/or survey of the existing pond condition. This may include the following:
         a) Determination of sediment levels in the pond. Allowable survey methods include:
            (1) Manual survey with survey station and survey rod using a standard grid approach. This method shall employ a plate on the survey rod to standardize a top of sediment reading.
               i. Set up survey level set or construction laser level set to determine the current water surface elevation, outlet elevation, and the differential changes in elevation across the bottom of the

pond. Establishment of the beginning benchmark is taken from the pond outlet to provide a reliable reference elevation.

ii. Establish a base line with a survey tape measure to provide stationing while taking bottom shots or cross sections in the pond and record the rod readings.

iii. Make additional field notes of other observations found during the survey in the water that may have been overlooked during visual inspections

iv. Reduce rod readings in the field book to establish elevation measurements taken from the pond bottom. This is generally done in the office.

v. If required, compare results to the design storage elevation originally established for the pond from plans or previous record surveys.

vi. If findings are such that the computed remaining storage volume is less than half of the pond's design volume, excavation of the sediment is recommended and the pond is placed on the list for pond dredging.

vii. If additional survey of the pond is necessary to confirm your findings, a request for bathymetric or total station equipment may be required.

(2) Total Station/GPS Topographic Pond Bottom Survey.

i. If simple field measurements are taken and need further supportive data collection, the total station or survey GPS equipment is used.

ii. Crew will work in and around the water and require a two-man crew to conform to safety protocols. The attendant is on site with the survey data collector person (surveyor) to assist with equipment set up and emergency response if necessary.

iii. Crew will generally survey the entire pond from the normal water line perimeter to the bottom of the deepest elevation to cover the entire area.

X, Y spacing on a grid is determined to establish good coverage of shots of the pond to develop a 3D bathymetric model of the existing bottom.

iv. Data collection is completed and the results are downloaded from the electronic survey collector in the office. The points and break lines are used to create the 3D drawing for pond storage volume analysis.

v. If your findings are such that the computed remaining storage volume is less than half of the pond's design volume, excavation of the sediment is recommended and the pond is placed on the list for pond excavation.

(3) A GPS and depth finder. This method shall use a standard survey method to verify depth readings, establish a base-line, and tie elevations into a known survey marker.

b) Comparison of surveys to original pond design.

Obtain a copy of the original pond grading plan to calculate the ponds original storage volume at the normal water level.

i. Transfer either the simple field measurements or the electronic topographic survey information to the original pond grading plan for appropriate comparison of volume reduction.

ii. Again, if the remaining storage volume is less than half of the pond's design volume ; it should be cleaned.

iii. The computed volume of excavation is generally done by computer comparison of surfaces or by average end cross section methods. Either way, to estimate the volume of excavation, good survey data is necessary to estimate the true value.

3) Information to be collected.

a) Identification of outlet details

(1) Elevations

(2) Type of outlet

(3) Condition of outlet

(4) Number of outlets

   (5) Other applicable information
b) Identification of inlet details
   (1) Elevations
   (2) Type of inlet
   (3) Condition of inlet
   (4) Number of inlets
   (5) Other applicable information
c) Evaluation of existing TSS and TP treatment effectiveness. The District will substitute a standard approach in lieu of a site-specific modeling procedure to identify the need for sediment removal. The standard methodology is evaluation of survey data to determine if sediment accumulation exceeds 50% of original dead storage volume.
d) Determination of the character of accumulated sediment for ponds scheduled for excavation.
   (1) Sample pond sediment for PAH and toxic medal concentrations.
   (2) Follow MPCA Dredged Materials Guidance for Stormwater Sediment Best Practices.
      i. Determine the minimum number of samples required based on the total area at the normal surface water elevation of the waterbody. .
      ii. Provide sampling crew with location of pond, schedule the work and determine if the sampling can be conducted on land or from inside a boat. All safety protocols will be implemented and enforced.
      iii. Crew will provide project manager the results of the sampling data taken and sent into the lab for testing. Site photos, a visual soil inspection log sheet, depth measurements of extracted material and all lab testing submittal records will be filed.
      iv. Generally, a sieve analysis is conducted for grain size, and toxicity chemical testing is conducted for copper, arsenic and Polycyclic Aromatic Hydrocarbons (PAH’s). Additionally, a toxicity characteristic

leaching procedure (TCLP) may be necessary for landfill disposal.

(3) Analyze pond sediment material for evaluation of the nature of the material and potential beneficial uses and disposal options. Laboratory results from the completed sediment characterization are used to determine the management level of the material.
   i. Level 1 dredged material is suitable for use or reuse on properties with a residential or recreation use category.
   ii. Level 2 materials are suitable for use or reuse on properties with a commercial or industrial use category.
   iii. Level 3 materials are characterized as having significant contamination and must be managed appropriately and disposed of at a permitted landfill with an approved industrial waste management plan.

C. Pond Maintenance Procedures
   a. Preparation of construction plan details including, pond cross section excavation requirements, total estimated cubic yards of excavation, unique construction procedures, access and egress details, temporary stockpile locations, sediment disposal specifications.
   b. Prepare bid documents. The District will strive to combine pond sediment removal projects with the District's annual CIP maintenance and repair project. The District will offer to complete pond assessments for its cities and include these sites in the District annual CIP project if assessments can be completed by October 1 of each year. Cities shall reimburse the District for the pond assessment, testing, and sediment removal project costs. Bid documents include the following.
      1) Pond excavation, pond muck cleanout, pond dredging are all bid items specific to the work involving sediment removal from storm water ponds.
      2) The bid quantity is estimated in cubic yards and listed by item number on the bid form for the specific pond.
      3) The bid item description includes the MPCA's management level for the material to be removed. This provides the bidder with the intended disposal requirements for sediment characterization from the testing results.

4) The lab reports are typically included in the contract documents as additional bidder information.

c. Advertise for bids.
d. Review bids and award contract.
e. Contracting and Construction Oversight. This work involves documentation of construction and measurement and payment in the field for work in progress and completed.
    1) Owner representative should record standard daily diary entries indicating the work being done that day, the weather, the crew size, equipment on the site and any other pertinent information useful in determining conditions for a safe and productive environment.
    2) Pond excavations require handling of wet and muddy material. Coordination with the contractor for proper pond dewatering, material excavation, loading, hauling and disposal is important.
    3) Load tickets can be used to determine the amount of volume removed during construction. Owner's representative is responsible to keep accurate removal quantity records.
    4) Dredged Material Tracking Report is used to "track" the transfer of ownership to the receiving facility owner. Owner's representative is asked to follow behind a loaded truck to the disposal location to document the company name, company owner, company address and take a photo for the record. Contractor is responsible to fill in the tracking report and provide a copy to the Owners representative.

2. Outfall and Pollution Control Device Inspections
    A. The District shall strive to perform annual inspections of all outfalls and pollution control devices:
        a. Structural stormwater BMP's (not including stormwater ponds) shall be inspected to:
            1) Determine structural integrity.
            2) Determine if the BMP is functioning properly.
            3) Determine any maintenance needs.
            4) Changes to the inspection frequency may be required if complaints received or pattern of maintenance indicate a greater frequency is necessary.
            5) Maintenance needs shall be incorporated into the District Annual CIP maintenance and repair project.
        b. Stockpiles, storage, and material handling areas

1) Not applicable – the District has none of these facilities.

3. Staff Training
   A. Ensure staff understands the importance of protecting water quality.
   B. Cover those requirements of the MS4 permit that are relevant to the job duties of the employees.
   C. Provide continuing education opportunities through seminars, MnDOT certification classes, educational material, and various other methods.

4. Documentation
   A. The following documentation shall be maintained for MS4 staff training.
      a. Date(s) of training.
      b. Name of course/seminar/trainer.
      c. List of topics covered and training materials used.
      d. Names of employees in attendance.
   B. Final training documentation. Annual training documentation shall be maintained in hardcopy or electronic MS4 files.