ISSUE PAPER "E"
Receiving Water Based Stormwater Criteria **Final (V.3)**
Date: March 17, 2005
To: Minnesota Stormwater Manual Sub-Committee
From: CWP and EOR

EXECUTIVE SUMMARY

This Issue Paper reviews the diversity of special watershed and water resources designations in the State of Minnesota, and proposes a unified approach for presenting watershed-based stormwater criteria for them in the forthcoming Manual. The proposed approach condenses the more than 30 existing special watershed stormwater criteria into 11 general watershed management categories, as shown in Table ES-1. The memo further reviews the technical basis for establishing additional or expanded stormwater criteria for each watershed management category, beyond the basic criteria adopted for regular waters in Issue Paper D. A brief summary of recommended stormwater sizing criteria for each watershed management category is profiled in Table ES-2. Special BMP design criteria for each watershed management category are described in Table ES-3.

The Committee is asked to review both the proposed watershed management categories and the recommended stormwater sizing/design criteria, and provide guidance on how each should be handled in the context of the Manual.

Table ES-1: Unified Approach to MN Watershed Stormwater Criteria				
Group	**Resource**	**MN Designation (see Notes below)**	**Watershed Mgmt. Categories**	**Recommended Stormwater Criteria [a]**
A	Lakes	**1,4,5,6,7**	Most-Sensitive	TP Load Reduction
		12,13	Sensitive	Increased WQ Sizing
B	Trout	**3,5,8**	Naturally Reproducing	2 Year Storm Infiltration, Temperature Controls
C	Drinking Water	**14, 15**	Groundwater	Infiltration Requirements
		2, 4, 10, 15, 18	Surface Water	Same as Sensitive Lakes
D	Wetlands	**9, 11**	Susceptible [b]	Maintain Hydroperiod
		11	Non-Susceptible	Discharge Restrictions
E	Impaired Waters	**16**	Computable Pollutants [c]	Load Reduction
			Non-Computable	MPCA Enhanced
F	ORVW[d]	**1 to 9**	Fall into Groups 1 to 4	Stormwater Category
G	Regular	**12, 13, 17, 18**	MPCA CGP [e]	MPCA Regular

[a]. See Table ES-2 for expanded definitions [b]. As defined by MNSWAG (1997)
[c].Listed pollutants for which stormwater loads can currently be computed
[d] Outstanding Resource Value Waters [e] Construction General Permit Sizing Criteria

Notes: **1-**Wilderness area, **2-**Upper Mississippi River **3-**Wild, Scenic and Rec Rivers, **4-**Lake Superior, **5-** Scientific and Natural Areas, **6-**Lake Trout Lakes, **7-**Trout Lakes, **8-** Trout Streams, **9-**Calcareous Fens, **10-**Public waters, **11**-Wetlands, **12-**Surface Waters, **13**-Shoreland and Floodplain, **14-**Karst, **15-** Aquifer/Wellhead/Water Supply, **16**-Impaired waters (14 listed pollutants), **17-**Drainage System, **18**-Mississippi River Critical Area

Table ES-2 Summary of Suggested Sizing Criteria for MN Watershed Management Categories	
Management Category	*Suggested Stormwater Criteria*
Most-Sensitive Lakes	• *Required* Site-Based Phosphorus Load Reduction*: Must compute pre- and post-development phosphorus load at the development site using Simple Method, P8 or equivalent**. The post-development phosphorus load from a development site should not increase from pre-development conditions. Additional restrictions as high as a 25% reduction from pre-development conditions have been used in Minnesota, depending on the sensitivity of the receiving lake. Designers document load reduction achieved using a list of BMP removal efficiencies (to be developed for the Manual). If on-site compliance is not possible, an offset fee can be charged which is equivalent to cost of removing similar mass of phosphorus elsewhere in the watershed. This technique can be applied at the time of permit application, for example, through a bond held by the issuing agency. • *Recharge* (Rev) required if lake is fully or partially groundwater dependent, recommended otherwise • *Channel Protection* (CPv) required if site drains to tributary stream to a lake.
Sensitive Lakes	• *Increased Water Quality (WQv) Sizing*: For sites less than 30% impervious cover (IC), MPCA pond rule 2 for "special waters" applies (see Issue Paper D). Walker Rule applies to sites with greater than 30% Site IC. • *Shorter BMP List:* Only BMP design variants in Table 6 with a high TP removal capability ($\geq$ 50%) can be used. • *Recharge* (Rev) required if lake is fully or partially groundwater dependent, recommended otherwise • *Channel Protection* (CPv) recommended if site drains to tributary stream to a lake.
Naturally Reproducing Trout Streams	• *Additional Infiltration and Channel Protection*: Infiltrate additional runoff that occurs over pre-development conditions from 2 year-24 hour storm event, where soils allow. • *WQv:* Infiltrate and/or filter the entire WQv (rule 4) (if not fully covered above) at the site regardless of soils (infiltration details will be developed in the Manual) • *Channel Protection (Cpv).* If soils do not permit full infiltration then provide 12 hour extended detention of 1 year 24 hour

Table ES-2 **Summary of <u>Suggested</u> Sizing Criteria for MN Watershed Management Categories**	
	runoff volume in an acceptable pond option. • *Temperature Restrictions*: Ponds and wetlands used for channel protection must be designed (ex. with a small dead pool volume) so as not to induce stream warming; shading of BMPs and surface conveyance channels is required to extent practical.

Groundwater Drinking Water Source Areas	• *WQv:* MPCA Rules 2 and 4 applied • *Pretreatment*: No infiltration of stormwater without pretreatment • *Recharge:* Encouraged at residential development and some commercial and institutional rooftops • *Stormwater Pollution Sources*: No infiltration of runoff from potential pollution generating land uses (PPGLU) that can contaminate groundwater with toxic material (Issue Paper H)
Surface Water Drinking Supplies	• Same Sizing Criteria as Sensitive Lakes for pollutants of concern related to sediment and particulate phosphorus; additional pollutants of concern will need to be addressed with programs specifically designed to reduce them
Susceptible Wetlands	• *Maintain Wetland Hydroperiods*: For wetlands identified as highly or moderately susceptible in Table 17 (section VIII of Issue Paper E), meet the storm bounce and inundation duration requirements as set forth in Table 18 (section VIII of Issue Paper E). This may be done through infiltration, extended detention, or diversion • *WQv*: Require site-based phosphorus load reduction as described for Most Sensitive Lakes to control nutrients. • *Recharge* (Rev): Required • *Channel Protection*: only required if channel is direct tributary to the wetland • *No use for stormwater treatment* • *No constrictions at wetland outlets*
Non-Susceptible Wetlands	• (For wetlands identified as slightly or least susceptible in Table 17), *no untreated stormwater discharges to wetlands,* which is operationally defined as providing WQv via appropriate MPCA Rules. • *Channel Protection (Cpv)* recommended only if channel is direct tributary to the wetland

	• *Recharge* (Rev) recommended but not required • *No use for stormwater treatment*
Impaired Waters for Computable Pollutants	Designers should determine whether their project is located in a watershed for which a TMDL is in place, and then determine if the listed pollutant is computable or non-computable, and if a new source cap is in place that requires no increase pollutant load after development. Designers should also identify if the receiving water is listed by the MPCA as "impaired" for any pollutant and examine the timeframe under which the water will fall under the TMDL program. • *WQv*: If new development site is located in a watershed subject to a TMDL that has no remaining stormwater allocation, designer may need to document no net increase in pollutant load, using the general method proposed for the most sensitive lakes management category (but using the appropriate pollutant). Currently, sufficient data is only available to perform this calculation for four of the 14 TMDL pollutants in MN (sediment, phosphorus, nitrogen and ammonia). • *Channel Protection (CPv*): recommended when water body impaired for sediment or sediment related pollutant

Impaired Waters for Non-Computable Pollutants	• *WQv*: For the remaining pollutants which may be subject to a TMDL but have no remaining stormwater allocation, designers must satisfy MPCA sizing rules 2 or 4. The Manual will not make specific recommendations about how to design BMPs for impaired waters, but will include typical runoff EMCs and BMP removal rates for computable pollutants
Outstanding Resource Value Waters	• All ORVW designations are subsumed into the most sensitive lakes, naturally reproducing trout streams, groundwater source protection areas, surface water drinking supplies, and susceptible wetlands, as shown in Table ES-1.
Regular Waters of the State	• *Sizing per Issue Paper D agreed upon by MSC* • *WQv:* Basic MPCA water quality sizing applies (Rule 1 and 3) • *Rev*: recommended but not required, particularly to offer stormwater credits • *Channel Protection (CPv*): recommended but not required

*Note that terms such as “required” are used as guidance for a community or entity that wants to adopt this approach

**Note that the local or state regulatory agency will need to determine a minimum project size for which this analysis would be required. The regulatory review requirements and the staff resources needed to assess the criteria application will need to be considered.

Table ES-3 BMP Design Restrictions for Special Watersheds					
BMP Group	**Watershed Management Category[b]**				
	A Sensitive Lakes	**B Trout Streams**	**C Ground Water [a]**	**D Wetlands**	**E Impaired Waters**
General	Outside of Shoreline Buffer	Outside of Stream Buffer	Setbacks from wells, septic systems	Outside of Wetland Buffer	Selection based on Pollutant Removal for Target Pollutants
Bioretention	PREFERRED	PREFERRED	OK with cautions for PPGLUs	PREFERRED	PREFERRED
Filtration	Some variations RESTRICTED due to poor P removal, combined with other treatments	PREFERRED	PREFERRED	OK	PREFERRED
Infiltration	PREFERRED	PREFERRED	RESTRICTED if potential stormwater pollution sources evident (PPGLU)	PREFERRED	RESTRICTED for some target TMDL pollutants
Ponds	PREFERRED	Some variations RESTRICTED due to pool and stream warming concerns	PREFERRED	PREFERRED but no use of natural wetlands	PREFERRED
Wetlands	Some variations RESTRICTED due to poor P removal, combined with other treatments.	RESTRICTED except for wooded wetlands	PREFERRED	PREFERRED but no use of natural wetlands	PREFERRED
Supplemental Treatment Practices[c]	RESTRICTED due to poor P removal, must combine with other treatments	RESTRICTED must combine with other treatments	RESTRICTED must combine with other treatments	RESTRICTED must combine with other treatments	RESTRICTED must combine with other treatments
[a] applies to groundwater drinking water source areas only; use the sensitive lakes category to define BMP Design restrictions for surface water drinking supplies [b] Category F (ORVW) is not included since it falls within Categories A-D and Category G is not included since it was discussed in Issue Paper D in detail [c] See Issue Paper "A" for listing					

The remainder of this issue paper is organized into ten sections, as follows:

I. INTRODUCTION

This paper expands on the basic unified stormwater sizing criteria adopted in Issue Paper D in February (2005) for special watersheds. The State of Minnesota has many different kinds of special watershed and water resource designations, and this paper outlines how to interpret stormwater management requirements for each one. In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health within a designated watershed. The basic unified sizing criteria that apply to all waters of the State provide a high level of protection, so new watershed stormwater criteria were only developed when all of the following conditions apply:

- *Specific Impact*: The criteria must be associated with a specific stormwater pollutant or hydrologic stressor known to be a primary factor in degrading the important aquatic resource in the watershed.
- *Existing State or District Designation*: The watershed or water resource must be specifically designated as warranting additional stormwater protection under current state or watershed statutes, rules, permits or programs.
- *BMP Capability*: Enough comparative data must be available to characterize the capability of different stormwater BMPs to influence the pollutant or stressor.
- *Location*: An inappropriate location of a BMP or stormwater discharge point may cause direct harm to the aquatic resource in question.

Assuming these four conditions are met, it is then possible to devise or adjust special watershed-based stormwater criteria. The expanded criteria can involve the sizing, selection, design or location of BMPS, as indicated by the six major adjustments shown below.

1. Increase water quality sizing requirements above current MPCA rules
2. Require specific pollutant load reduction requirements
3. Add or expand other sizing criteria (e.g., require recharge or channel protection)
4. Restrict or promote specific BMPs in the watershed
5. Add special design criteria for individual BMPs to increase performance
6. Specify where in the watershed individual BMPs may be located or stormwater discharges may occur (or not occur)

The remainder of this paper provides the technical justification for expanded stormwater criteria based on these six adjustments. In many cases, additional watershed protection tools such as buffers, land conservation, erosion and sediment controls may be needed to fully protect the watershed or water resource in question. While a full discussion of these additional tools is outside the scope of this paper, they should be fully integrated into the proposed stormwater management plan for the site.

II. REVIEW OF CURRENT WATERSHED DESIGNATIONS IN MINNESOTA

The State of Minnesota currently has designated at least 18 different categories of watersheds or water resources that merit special protection, including specific development restrictions relating to stormwater criteria. For the sake of convenience, they are listed below, and described in greater detail in Tables 1 and 2. In general, the restrictions may involve increased water quality volume, temperature controls, peak discharge and volume controls, or submittal of special management plans.

1. Wilderness Areas
2. Portions of Mississippi River
3. Wild, Scenic or Recreational River Segments
4. Lake Superior
5. Scientific and Natural Areas
6. Lake Trout Lakes
7. Trout Lakes
8. Trout Streams
9. Calcareous Fens
10. Public Waters
11. Wetlands
12. Surface Waters
13. Shoreland and Floodplain
14. Karst Areas
15. Aquifer/Wellhead Protection / Drinking Water Supply
16. Impaired Waters
17. Drainage System
18. Mississippi River Critical Area (Federal MNRRA)

Table 1: Special Provisions for Stormwater Discharges to Outstanding Resource Value Waters									
Special Water	**Regulating Agency**	**Additional BMPs**[1]	**During Construction**[2]	**Post Construction**[3]	**Buffer Zone**[4]	**Enhanced Runoff Controls**[5]	**Temperature Controls**[6]	**Sequencing Requirements**[7]	**Special Mgmt. Plan / Individual Permit**[8]
1. Wilderness Areas	MDNR / NPS / USDA/MPCA	X	X	X	X	X			
2. Portions of Mississippi River	MPCA	X	X	X	X				
3. Wild, Scenic or Recreational River Segments	MDNR / MPCA	X	X	X	X				
4. Lake Superior	MPCA	X	X	X	X				
5. Scientific and Natural Areas	MDNR/MPCA	X	X	X	X	X			
6. Lake Trout Lakes	MPCA / MDNR	X	X	X	X	X			
7. Trout Lakes	MPCA / MDNR	X	X	X	X	X			
8. Trout Streams	MPCA / MDNR	X	X	X	X		X		
9. Calcareous Fens	MDNR / MPCA	X	X	X	X	X		X	X
10. Public Waters	MDNR / BWSR							X	

- **Shaded cells indicate stormwater related criteria.**
- **Explanatory notes for this table provided in Appendix A.**

It should be also noted that the impaired waters category pertains to 14 different pollutants in various waters of the state that are not currently meeting standards. When the state designations are combined with the even more numerous local and watershed organization special criteria used to protect certain kinds of lakes, trout streams and wetlands (see for example, WCWC, 2003 and BCWD, 2000), there is a great deal of potential for overlap and confusion. Indeed, it seems likely that there may be more land area in the state designated as special waters than regular ones.

Table 2: Special Provisions for Stormwater Discharges to Other Waters									
Other Circumstances	**Regulating Agency**	**Additional BMPs[1]**	**During Construction[2]**	**Post Construction[3]**	**Buffer Zone / Setback[4]**	**Runoff Controls[5]**	**Temperature Controls[6]**	**Sequencing Requirements[7]**	**Special Mgmt. Plan / Individual Permit[8]**
11. Wetlands (not calcareous fens or public waters)	BWSR (oversight)/ LGU / ACOE / MPCA	X	X	X		X		X	X
12. Surface Waters	MPCA	X	X	X		X			
13. Shoreland and Floodplain	MDNR / City / County	X	X		X	X			X
14. Karst Areas	MPCA, DNR, MDH	X	X	X	X				X
15. Aquifer/Wellhead Protection / Drinking Water Supply	MDH				X				X
16. Impaired Waters	MPCA	X	X	X		X			X
17. Drainage System	County / Watershed					X			
18. Mississippi River Critical Area (MNRRA)	DNR and Communities	X	X		X	X			X
• **Shaded cells indicate stormwater related criteria.** • **Explanatory notes for this table provided in Appendix B.**									

Table 3 presents a directory of on-line maps and lists to help designers and reviewers determine if their development project is located in special waters in the state. *Note: The Manual Sub-Committee is asked to review Table 3 and let us know if there are additional mapping resources to link to in the final Manual*. Although detailed state-wide maps of special watersheds and water resources are not included in this paper, they will be supplied in the Final Manual.

Table 3: Directory of On-Line Minnesota Maps and Resources on Special Waters	
Resource	**Website Address**
Special Waters	
Map of Special Waters and Impaired Waters in Minnesota, including: • Wilderness Areas • Mississippi River • Scenic and Recreational River Segments • Trout Streams • Trout Lakes • Lake Trout Lakes • Trout Lake and Lake Trout Lake • Calcareous Fens (MPCA Listed Fens and DNR Listed Fens) • Scientific and Natural Area • Impaired Streams • Impaired Lakes	http://www.pca.state.mn.us/water/stormwater/stormwater-c.html (scroll down, select "Special Waters Search)

Trout Streams	
• Interactive Trout Stream Maps	http://www.dnr.state.mn.us/fishing/trout_streams/interactive.html
• List of Minnesota Trout Lakes	http://www.dnr.state.mn.us/fishing/trout_lakes/list.html
Karst Areas	
• Information on Karst in Minnesota	http://www.pca.state.mn.us/water/groundwater/karst.html
• Map – Minnesota Karst Lands	http://www.geo.umn.edu/images/MNKarst.gif
Wetlands	
• U.S. Fish & Wildlife Service National Wetlands Inventory Wetlands Mapper	http://www.nwi.fws.gov/mapper_tool.htm
Impaired Waters	
• Information on Minnesota's Impaired Waters and TMDLs	http://www.pca.state.mn.us/water/tmdl/index.html
• Map of Major Drainage Basins of Minnesota with Impaired Streams	http://www.mda.state.mn.us/agdev/impairedwater/default.htm
• Map of Northern Minnesota Lakes with DNR Mercury Advisories	http://www.ncrs.fs.fed.us/gla/pollute/mn_merc.htm
Land Use / Land Cover	
• Map of Minnesota Land Use and Cover	http://mapserver.lmic.state.mn.us/landuse/

Ecoregions	
• Statewide Map of Minnesota Ecoregions	http://waterontheweb.org/under/lakeecology/18_ecoregions.html
Watershed Boundaries	
• Map of Minnesota River Basins	http://www.mnplan.state.mn.us/maps/RiverBasins.gif
• Map of Sub-regions of Minnesota (4-digit Hydrologic Unit Code (HUC))	http://www.dnr.state.mn.us/watersheds/subregions.html
• Map of Basins of Minnesota (6-digit HUC)	http://www.dnr.state.mn.us/watersheds/basins.html#Regions
• Map of Sub-basins of Minnesota (8-digit HUC)	http://www.dnr.state.mn.us/watersheds/subbasins.html
Shoreland	
• Web-site for determining shoreland regulatory requirements; comprehensive map of shoreland areas not available at this time	http://www.dnr.state.mn.us/waters/watermgmt_section/shoreland/shoreland_rules_update.html
Drinking Water Source Protection Areas	
• Web-site for MDH can be used to determine source water protection areas, nitrate probability mapping and sensitive waters for Class V wells	http://www.health.state.mn.us/divs/eh/water/index.html

III. PROPOSED CONDENSED APPROACH TO MINNESOTA WATERSHEDS CRITERIA

This paper recommends collapsing the many different local and state watershed designations into seven basic watershed groups:

A. Lakes
B. Trout Streams
C Drinking Water Sources
D. Wetlands
E. Impaired Waters
F. Outstanding Resource Value Waters (ORVW)
G. Regular Waters

Within each of the seven watershed groups, there may be up to two specific watershed management categories. Each of the 18 state designated waters has been slotted into these management categories. Please note that the ORVW group is a simple placeholder: the nine state waters designated as ORVW are actually slotted in Groups A, B, C, or D, depending on their dominant aquatic characteristic. The recommended watershed-based sizing criteria for the prescribed watershed management group is applied to the appropriate ORVW.

Impaired waters require a slightly different approach – as stormwater pollution prevention plans must be consistent with the assumptions, allocations and requirements for the listed pollutant in an approved TMDL. In this regard, the stormwater pollutant of interest can either be computable or non-computable. Computable is defined as a pollutant for which enough runoff concentration and BMP performance data are available to perform a site-based stormwater pollutant load calculation documenting no increase in loading. Non-computable, similarly, is the absence of this information.

Table 4: Seven Proposed Groups of Watersheds			
Group	**Resource**	**State Designation**	**Watershed Management Category**
A	Lakes	**1,4,5,6,7**	Most-Sensitive
		12,13	Sensitive
B	Trout	**3,5,8**	Naturally Reproducing
C	Drinking Water	**14, 15**	Groundwater
		2, 4, 10, 15, 18	Surface Water
D	Wetlands	**9, 11**	Susceptible [b]
		11	Non-Susceptible
E	Impaired Waters	**16**	Computable Pollutants [c]
			Non-Computable
F	ORVW[d]	**1 to 9**	Fall into Groups A to D
G	Regular	**12, 13, 17, 18**	MPCA CGP [e]

[a]. See Table E-2 for expanded definitions [b]. As defined by MNSWAG (1997)
[c]. Listed pollutants for which stormwater loads can currently be computed
[d] Outstanding Resource Value Waters [e] Construction General Permit Sizing Criteria

Notes: **1-**Wilderness area, **2-**Upper Mississippi River **3-**Wild, Scenic and Rec Rivers, **4-**Lake Superior, **5-** Scientific and Natural Areas, **6-**Lake Trout Lakes, **7-**Trout Lakes, **8-** Trout Streams, **9-**Calcareous Fens, **10-**Public waters, **11-**Wetlands, **12-**Surface Waters, **13**-Shoreland and Floodplain, **14-**Karst, **15-** Aquifer/Wellhead/Water Supply, **16**-Impaired waters (14 listed pollutants), **17-**Drainage System, **18**-Mississippi River Critical Area

IV. GROUP A RESOURCES: LAKES

Research has shown that urban development increases eutrophication in lakes. For purposes of this paper, lakes are divided into two broad management categories based on their current trophic status and sensitivity to additional phosphorus.

- Most-Sensitive Lakes are classified as being oligotrophic
- Sensitive Lakes are defined as mesotrophic or slightly eutrophic

In many cases, these designations have already been made by the state, watershed, regional or local authorities, or perhaps by a university or local educational institution. If they do not already exist, data on clarity, phosphorus content and algal abundance using Chlorophyll-*a* as a surrogate measure can be used. If none of these data exist, a program that simply collects clarity would be a good place for a local interest to start.

Nature of Pollutant or Stressor

Major impacts to lakes resulting from stormwater runoff include:

- Eutrophication caused by high phosphorus loads
- Degraded drinking water source and impaired recreation due to high bacteria loads and turbidity
- Impairment of shoreline habitat

According to the U.S. EPA (1986), half of all U.S. lakes are classified as either eutrophic or hyper-eutrophic. However, of the 3,700 urban lakes evaluated by the U.S. EPA (1980), the percentage that are eutrophic or hyper-eutrophic exceeds 80%. Urban lakes tend to receive higher phosphorus loads, and therefore, become more eutrophic than non-urban lakes, unless fertilizer input from rural lawns or agricultural activity is high. This is due to the fact that urban watersheds produce higher unit area phosphorus loads from stormwater runoff, compared to other watersheds (Caraco and Brown, 2001). A summary of the impacts of eutrophication on lakes is provided in Table 5 (Brown and Simpson, 2001).

Table 5: Impacts of Eutrophication on Lake and Reservoir Quality (Brown and Simpson, 2001)	
• Nuisance algal blooms in the summer • Reduced dissolved oxygen in the bottom of the lake • Fish kills due to low dissolved oxygen • Taste and odor problems with drinking water • Formation of THMs (trihalomethanes) and other disinfection byproducts in water supplies • Increased cost to treat drinking water • Reduced water clarity	• Decline in fish community (more rough fish, fewer game fish) • Blockage of intake screens by algal mats • Reduced quality of boating, fishing and swimming experience • Decline in lakefront property values • Floating algal mats and/or decaying algal clumps • Increased density of aquatic weeds in shallow areas

Although the recommended controls for lakes always focus on phosphorus reductions, the BMPs that yield these reductions also reduce other pollutants. Any BMP that is effective for total phosphorus will usually settle or filter particulate material and the pollutants associated with the particulate phase, such as many metals, oxygen-demanding substances, hydrocarbons and organic chemicals. If a BMP is effective also at soluble phosphorus removal, it too will likely remove other soluble contaminants, such as nitrogen species and dissolved metals and pesticides. Unfortunately, very conservative pollutants like chloride will not be easily removed by any commonly used BMP. This association becomes very important when applying the BMP suite for lakes to other target receiving waters, such as drinking water source areas.

Brief Review of Comparative Performance

Table 6 summarizes the general removal capabilities of several common BMPs to remove phosphorus from urban runoff. While most lake eutrophication models utilize total phosphorus, soluble phosphorus is of particular interest since it is most readily available for algal uptake (see Table 6). BMPs employed for lake protection should have a moderate to high capability to remove total and soluble phosphorus .

Extensive data have been collected on the phosphorus removal capability of a wide range of BMPs (Winer, 2000), and the removal data can be used to differentiate the removal performance for as many as twenty BMP design variants (Table 6). As a general rule, the median total phosphorus removal achieved by the typical BMP is about 50%. However, this removal represents an ideal efficiency, and should probably be discounted to account for practice age, imperfect application, and partial runoff capture. Specific BMP mperformance data will be presented with the BMP design sheets in Issue Paper I.

Table 6: General Summary of Comparative BMP Phosphorus Removal Performance [a]

BMP Group[e]	BMP Design Variation	Average TP Removal Rate [b]	Maximum TP Removal Rate [c]	Average Soluble P Removal Rate [d]
Bioretention	Underdrain	50%	65%	60%
	Exfiltration	60	75	70
Filtration	Sand Filters	50	60	0
	Organic Filter	50	70	30
	Dry Swale	65	75	70
	Wet Swale	30	40	0
Infiltration	Infiltration Trench	65	90	80
	Infiltration Basin	65	90	80
Ponds	Micropool ED	25	45	10
	Wet Pond	50	65	70
	Wet ED Pond	55	70	70
	Multiple Pond	60	75	75
Wetlands	Shallow Wetland	45	65	50
	ED Wetland	40	55	50
	Pond/Wetland	55	75	65

[a] Removal Rates Shown in this Table are a composite of four sources: Caraco (2001), MDE (2000), Winer (2001) and Issue Paper D P8 modeling
[b] Average removal efficiency expected under MPCA WQv sizing Rules 1 and 3
[c] Upper limit on phosphorus removal with increased sizing and design features, based on national review
[d] Average rate of soluble phosphorus removal in literature
[e] See Issue Paper "A"

IMPORTANT NOTE: Removal rates shown here are composite averages intended solely for use in comparing performance between BMP designs and for use in calculating load reduction in site-based TP models. They have been adapted, rounded and slightly discounted from statistical values published in BMP performance databases.

Infiltration practices tend to have the highest phosphorus removal, but may not always be feasible due to soil constraints or poor longevity. Pond systems are generally a reliable removal option for both soluble and total phosphorus. Filters are fairly effective at removing total phosphorus, but exhibit little or no capability to remove soluble phosphorus. This can be explained by the fact that most sand filters have no biological or chemical processes to bind soluble phosphorus. The addition of organic matter or binding agents to sand filters may show promise in boosting removal, but early monitoring of experimental filters have yet to demonstrate this result conclusively (Schueler, 2000a).

Wetlands have a highly variable capability to remove both soluble and particulate forms of phosphorus. The variability can be explained in part by internal phosphorus cycling within the wetland, sediment release, and vegetative dieback during the non-growing season (Schueler, 1992). Factors such as soil pH, oxygen conditions, nutrient saturation and presence of Ca, Mg or Fe in the soil can also make a big difference in P removal or release. The best design variation for phosphorus removal in the stormwater wetland group is the pond-wetland system (i.e., wetland with a relatively large portion of its storage devoted to a deep pool).

Given the range of phosphorus removal that can be achieved by BMPs, detailed guidance on the design of BMPs to enhance phosphorus removal will be provided in Issue Paper I and the Manual. A summary of recommendations is provided in Table 7.

Table 7: Design Tips for Stormwater Treatment Practices to Remove Phosphorus (Caraco, 2001)
• Infiltration practices are preferable in watersheds where soils and other site conditions permit.
• Wet ponds are also recommended, particularly if they have a large permanent pool
• Design wet ponds with a depth no greater than ten feet to prevent stratification, and potential release of phosphorus from bottom sediments. Also consider a surface or mid-depth release from the pond. Landscape ponds to discourage geese.
• Avoid the use of dry or dry extended detention ponds, which have very limited phosphorus removal capabilities.
• Use stormwater wetlands sparingly, given their variable phosphorus removal and potential loss of removal capacity over time (Oberts, 1999). Promote the pond/wetland system where possible.
• Designers should explicitly consider the snowmelt runoff volume and phosphorus concentrations in Northern areas, which Oberts (1994) has shown can deliver a large fraction of the annual P load. Designers may wish to consider seasonal operation for ponds, and provide pervious areas on-site for meltwater treatment.
• Bioretention areas show greater promise than sand filters to remove phosphorus, and are a preferred option for small sites.
• Any practice can release phosphorus over time if improperly maintained. A stormwater management program should include specific maintenance requirements, as well as a mechanism to ensure that these actions are completed.
• Although open channels are a preferred method of stormwater conveyance, they cannot be relied on as the only practice to remove phosphorus at a development site, with the exception of an engineered dry swale.
• Most practices require a vigorous vegetative cover to function properly (e.g., grass swales, filter strips). Landscaping plans for these practices should specify minimal use of phosphorus fertilizer.

Recommended Criteria

Recommended sizing criteria to protect sensitive lakes are presented in Table 8.

Table 8: Recommended Sizing Criteria for Lake Protection*
Two sets of stormwater sizing criteria are recommended for the "most-sensitive lakes" and "sensitive" lakes". Local, regional, watershed and state goal setting will set the target level for lake load reduction. Physical characteristics of a lake can be the controlling factor for defining whether a lake is "sensitive", but the role of phosphorus loading will still need to be evaluated. **MOST-SENSITIVE LAKES** *Required Site-Based Phosphorus Load Reduction*: Must compute pre- and post-development phosphorus load at the development site using Simple Method, P8 or equivalent. The Simple Method to compute annual pre- and post- development pollutant loads utilizes a simple six step process described in Appendix C. 1. Calculate site imperviousness 2. Calculate the pre-development phosphorus load 3. Calculate post-development pollutant load 4. Calculate the pollutant removal requirement 5. Identify feasible BMPs and calculate load removed (using standard BMP removal efficiencies, see Table 6) 6. Select off-site mitigation option The post-development phosphorus load from a development site should not increase from pre-development conditions. Additional restrictions as high as a 25% reduction from pre-development conditions have been used in Minnesota, depending on the sensitivity of the receiving lake. A TP load reduction requirement is then calculated for the difference between the post-development load and the target pre-development load. Designers then document load reduction achieved using a list of BMP removal efficiencies. If on-site compliance is not possible, an offset fee can be charged which is equivalent to cost of removing similar mass of phosphorus elsewhere in the watershed (see Appendix C). This technique can be applied at the time of permit application, for example, through a bond held by the issuing agency. *Recharge* (Rev) recommended but not required *Channel Protection* (CPv) required if the site drains to a tributary stream to a lake. **SENSITIVE LAKES** *Increased Water Quality (WQv) Sizing*: For ponds, use an approach that combines the Walker

Rule and the MPCA water quality sizing rule for ponds located within special waters (Rule 2). For development sites with less than 30% impervious cover, the MPCA rule should apply. For development site with equal to or greater than 30% impervious cover, the Walker Rule should apply (see Issue Paper D for an explanation of this difference).

For non-ponds, use the MPCA water quality sizing rule for non-ponds BMPs located in special waters. However, set a minimum water quality storage volume of 0.2 watershed inches, regardless of site impervious cover.

Shorter BMP List: Only BMP design variants in Table 6 with a high TP removal capability (over 50%) can be used in sensitive lakes.

Recharge (Rev) recommended but not required as set forth in Issue Paper D.

Channel Protection (CPv) recommended if a site drains to tributary stream to a lake and exceeds the minimum IC area thresholds. CPv not required if the development site drains directly to the lake.

*Note that the local or state regulatory agency will need to determine a minimum project size for which this analysis would be required. The regulatory review requirements and the staff resources needed to assess the criteria application will need to be considered.

Special BMP Design Criteria for Lakes

Guidance on the selection, design and location of BMPs for protection of sensitive lakes is provided in this section and will be directly incorporated into the appropriate sections of the Manual. Issue Paper I will also address BMP design specifics.

Several BMP design variations do not reliably remove enough phosphorus to be used as the sole form of stormwater treatment to protect lakes. The BMPs highlighted in Table 9 are on the "short list" and are preferred for use in lake watersheds. BMPs that are not on the short list can still be used, but must be combined with a more effective BMP. More guidance on BMP selection and design for maximum phosphorus removal is provided below and in Table 10.

- BMPs with high phosphorus removal rates should be promoted, such as infiltration, wet ponds, and bioretention.
- BMPs with low phosphorous removal rates, such as dry ponds or dry extended detention ponds should be discouraged.
- BMPs with variable phosphorus removal capabilities, including some wetlands and sand filters, should be used in conjunction with more effective BMPs or in a "treatment train" approach.
- The use of multiple treatment pathways should be encouraged. For instance, stormwater runoff might be directed to filtering or infiltration BMPs, and then routed to ponds.

- BMPs should not be permitted within the shoreline buffer, as defined locally.
- There should be no direct discharge of untreated stormwater runoff to a lake

Table 9: BMP Removal Rates for Total Phosphorus (see also Table 6)			
BMP Group	**BMP Design Variation**	**Total Phosphorus Removal Efficiency (%)***	**Recommended for Lake Watersheds**
Bioretention	Bioretention	50	Yes
Filtration	Sand Filters	50	No
	Organic Filter	50	Yes
	Dry Swale	65	Yes
	Wet Swale	30	No
Infiltration	Infiltration Trench	65	Yes
	Infiltration Basin	65	Yes
Ponds	Micropool ED	25	No
	Wet Pond	50	Yes
	Wet ED Pond	55	Yes
	Multiple Pond	60	Yes
Wetlands	Shallow Wetland	45	Yes
	ED Wetland	40	No
	Pond/Wetland	55	Yes
* Source: 2000 Maryland Stormwater Design Manual, Appendix D.4			

Table 10: Stormwater Practice Design Recommendations to Enhance Phosphorus Removal	
BMP Design	**Design Criteria**
Bioretention	• Bioretention are preferred practices.
Filtration	• Organic filters are the preferred filtering practice, although caution should be used since they could be a source of soluble phosphorus. • Employ finer-grained media in the filter bed with a small diameter (15 microns), or provide a finer-grained layer at mid-depth in the filter profile. • The process for pretreatment and/or filtration should be 40 hours or more. • Filters should be oriented to provide maximum solar exposure. • Wet swales are not recommended. • Open channels should be designed to be either self-cleansing or promote maximum sediment retention. • Open channels should not be relied on as the only BMP to remove phosphorus at a site, with the exception of an engineered dry swale.
Ponds	• Design wet ponds with a depth no greater than 10 feet to prevent stratification and potential release of phosphorus from bottom sediments. • Use a surface or mid-depth release from the pond. • Landscape pond to discourage geese. • Add shallow benches and wetland areas to enhance the plankton community.
Wetlands	• Pond/ wetland system is the preferred wetland design. • Use a surface or mid-depth release from the wetland. • Maximize surface micro-topography. • Landscape wetland to discourage geese.
Infiltration	• Infiltration BMPs are preferred practices. • Provide a minimum 3-foot separation from the seasonally-high water table, bedrock or impervious soil layer.

V. GROUP B WATERSHEDS: TROUT STREAMS

Nature of Pollutant or Stressor

Trout populations are threatened from the degradation of stream habitat, stream warming, possible chloride toxicity, and other impacts associated with increased development.

Temperature

Trout are sensitive to increases in water temperature. The optimal temperature range for adult trout is from about 57°F to 65°F. Generally, adult trout can survive warmer temperatures if cool water refuge is present in the form of groundwater upwelling or springs. Juvenile trout, fry and eggs are much more susceptible to warm water temperatures and are not able to tolerate temperatures much above 68°F (Emmons & Olivier Resources, 2000).

Trout are affected by temperature in several ways. Increased temperature decreases the oxygen solubility of the water, thus decreasing the amount of oxygen available for the fish and other organisms for respiration. Increased temperatures can also increase the metabolic rates of aquatic organisms and increase the sensitivity of these organisms to other pollutants, parasites, and diseases (SSL SWCD, 2001).

The reduction in streamside vegetation, also known as riparian cover, removes much of the mechanisms that keep a stream cool. More solar radiation reaches the stream, raising the in-stream temperatures. In addition, an increase in urbanization brings along changes to the natural drainage patterns. Increased impervious area results in a larger volume and velocity of runoff from the watershed. The increased impervious area also decreases the amount of rainfall that infiltrates into the groundwater thus limiting recharge to the stream. Groundwater sources contribute cold water needed for trout fishery.

The heating of impervious surfaces by solar radiation also causes increased temperature. The heat from these surfaces is transferred to stormwater runoff ultimately increasing the temperature of the receiving waters (SSL SWCD, 2001). Runoff from an asphalt road or parking lot may have a temperature of 90°F or more in the summer. Johnson (1995) studied how stormwater influenced an urban trout stream in Minnesota and reported up to a 10°F increase in stream water temperatures after summer storm events.

A study by Galli (1990) indicates a change in coldwater aquatic insects due to thermal increases to a stream. Sensitive groups, such as stoneflies, are either eliminated or severely restricted, while more temperature tolerant species, such as mayflies and caddisflies are eliminated, severely restricted, and/or stressed at high temperature levels. Restructuring of the aquatic insect community also occurs, with intolerant species and/or groups of insects being replaced by thermally-tolerant ones. The preceding changes could, if particularly extensive, have a negative impact on the resident fish community.

Sediment
Sedimentation is also a major concern for trout. Construction runoff and channel erosion increase sediment loading, and sand applied to local roads may be washed into trout streams. This excess sediment can affect the productivity of a trout stream in several ways. Sediment can impede trout respiration by clogging gill plates. In addition, as sediment deposits in a stream, it can destroy spawning habitat and harm the benthic organisms upon which the trout feed. The sediment covers the gravel runs and riffles that trout need to spawn and aquatic insects need to survive. In a healthy stream, young trout hide in the interstitial spaces between cobbles and boulders to avoid predation. If fine sediment is clogging interstitial spaces between streambed gravel, juvenile trout lose their source of cover and food (http://www.krisweb.com). Sediment can also decrease light levels reaching lower levels in the water column. (SSL SWCD, 2001).

Chloride
Road salt may also significantly impact trout habitat. In addition to sand, tons of salt are used each year for deicing during the winter. Chloride is one of the main components of road salt, and is extremely soluble in water. As a result, there is virtually no way to remove chloride once it gets into either surface or groundwater. Chloride levels are the highest in late winter as initial melting occurs from snow containing significant amounts of road salt and stream flows are lowest. The chloride from the salt can become toxic in a freshwater system if the concentrations become too high (SSL SWCD, 2001).

Brief Review of Comparative BMP Performance

Trout are most sensitive to stream warming. A inflow/outflow study by Galli (1990) evaluated potential thermal impacts associated with four stormwater BMPs -- an infiltration/dry pond, an extended detention artificial wetland, an extended detention dry pond, and a wet pond. All four types of BMPs monitored in the study imparted additional heat to their receiving streams. Of the four practices, the infiltration/dry pond produced the smallest temperature increase. The average and maximum temperature increases are 2.5°F and 7.6°F respectively (Table 11). The next highest temperature increases were seen in the artificial wetland followed by the extended detention dry pond. The largest temperature increase occurred at the wet pond with average and maximum increases in temperature of 9.7°F and 15.1°F, respectively.

Table 11: BMP Temperature Performance

Parameter	Infiltration-Dry Pond	Extended Detention Artificial Wetland	Extended Detention Dry Pond	Wet Pond
Average increase in temperature (°F)	2.5	3.2	5.3	9.7
Maximum increase in temperature (°F)	7.6	8.7	11.2	15.1

The results show that infiltration BMPs provide the greatest level of water temperature protection and are the most appropriate practice for use in thermally sensitive watersheds. Several BMP design elements were shown to increase water temperature. These practices should be avoided in thermally sensitive waters. These include:

- Undersized infiltration treatment systems
- The presence of a large wet pool
- Poorly shaded pilot and outflow channels
- Poorly shaded storage pool areas
- Excessively long periods of extended detention control

Galli (1990) proposed several BMP design features that could help reduce stream warming, including:

- Increasing infiltration treatment to the maximum extent practical
- Constructing BMPs as “off-line” rather than “on-line” facilities
- Heavily shading pilot and outflow channels and storage pool areas with trees and shrubs
- Limiting the maximum period of extended detention control to 6 to12 hours
- Avoiding the use of permanent pools in thermally sensitive watersheds

The results of the Galli (1990) study show that stream temperature regime changes occur at relatively low levels of watershed imperviousness (i.e., $\leq$ 12%). They also strongly suggest that trout will most likely be lost when watershed imperviousness exceeds 12% to 15% imperviousness. Results from the study indicate that the average water temperature of urban streams increases on the order of 0.14°F per one percent increase in watershed imperviousness**.**

Miller Creek is an urban trout stream located in St. Louis County, Minnesota (South St. Louis Soil and Water Conservation District, 2001). The Miller Creek Clean Water Partnership Project was developed to provide for a viable, self-sustaining urban trout fishery, as well as to educate the public regarding watershed health and urban impacts to area trout streams. Water quality monitoring conducted on the stream includes flow, temperature, conductivity, chloride, TSS, and a macroinvertebrate study. Miller Creek has a significant subsurface flow pathway that plays an important role in the temperature dynamics of the creek. As the watershed is developed, less interflow enters the creek. Less interflow would then mean less cold water in the creek to help mitigate the heating influences along the creek. Protection of ‘significant’ cold-water source areas is important. Incorporation of BMPs that will enhance infiltration and, therefore, interflow in the watershed should be pursued. These BMPs include buffer areas, stormwater infiltration practices, creek channel and riparian area restoration.

A study in Dane County, Wisconsin (Roa-Espinosa, *et al*. 2003), used a Thermal Urban Runoff Model (TURM) to predict the effect of urban development on runoff thermal regime. Stream discharge data, temperature data and rainfall data were collected during the summer of 2000. The temperatures at St. Albert Pond, which collects drainage from an urbanized area, ranged from 72.7°F to 80.9°F, with an average temperature of 76.0°C. These temperatures were the highest that were recorded at any location during the course of this study and represent near lethal temperatures for many cold-water species; including fish such as Brown trout and Brook trout.

Riparian vegetation plays a key role in insulating small streams from the warming effect of solar radiation. Results show that stream temperatures can increase 1°F to 3°F per 100 feet of flow through either open or poorly shaded stream reaches. Creating a buffer zone improves the habitat for trout. A buffer zone creates cover from overhanging vegetation, and also increases the feeding value of the trout from wind blowing invertebrates onto the water from vegetation. A model stormwater ordinance developed for the Minnesota Pollution Control Agency (MPCA), recommends a minimum of a 100-foot wide protective buffer strip along each bank, providing a tree canopy in the buffer zone (MCPA, no date).

Another example of current trout protection practices is in the Kinnickinnic River in west-central Wisconsin. The Kinnickinnic River is a Wisconsin state "outstanding resource water" and a premiere trout stream. The City of River Falls is located in the heart of the Kinnickinnic River watershed. The rapid development of River Falls created a growing concern about the stormwater impacts of current and future development to the stream. In 1994, a water management plan to protect the Kinnickinnic River and its tributaries was developed. Key recommendations of the Kinnickinnic River Water Management Plan include; a limitation of 10% to 12% effective impervious area within the City; proper detention pond design to maximize thermal mitigation and achieve a minimum sediment removal efficiency of 85%; stringent erosion control ordinances; additional stormwater BMPs; and increased public awareness and involvement.

Recommended Stormwater Sizing Criteria for Trout Streams

The recommended stormwater sizing criteria for trout streams is presented in Table 12.

Table 12: Recommended Sizing Criteria for Trout Stream Protection
• *Additional Infiltration and Channel Protection*: Infiltrate excess runoff from 2 year-24 hour storm event, where soils allow (infiltration rates will be addressed in Manual). • *WQv:* Infiltrate and/or filter the entire WQv (if not fully covered above) at the site regardless of soils. BMPs that may be used include bioretention, dry swales, infiltration, and site design practices. Pre-treatment is usually necessary to remove particulate material. • *Channel Protection (CPv).* If soils do not permit full infiltration, then provide 12 hour extended detention of 1 year-24 hour runoff volume in an acceptable pond option. • *Temperature Restrictions*: Ponds and wetlands used for channel protection must have an

acceptable design with a small dead pool volume that will not induce stream warming; shading of BMPs and surface conveyance channels is required to extent practical.

Special BMP Design Criteria for Trout Stream Protection

General guidance on the selection, design and location of BMPs for protection of trout streams is provided in this section and will be directly incorporated into the appropriate sections of the Manual. Issue Paper I will also address the specific of BMP design.

In terms of BMP selection, wet ponds and un-shaded wetlands should be restricted in trout watersheds. In addition, any filtering practice that has a surface pool, exposed riprap or un-shaded channel should be avoided. Conversely, infiltration, bioretention, and wooded wetland practices are strongly preferred in trout watersheds

Specific design criteria can eliminate BMP features that induce stream warming, including:

- Ponds should not be placed on-line (e.g., in-stream).
- BMPs should not be placed in the forested buffer zone of a trout stream (except bioretention in the outer zone)
- No more than 12 hours of extended detention should be provided in any pond or wetland
- Trees should be planted in stormwater practices, where feasible.

Additional stormwater guidance is needed to prevent impacts from road or highway runoff, including:

- Enhanced pretreatment of roadway runoff to reduce chloride and sediment discharged to trout streams
- Roadway spill management plans should be developed and tested in all trout stream watersheds.

VI. GROUP C WATERSHEDS: DRINKING WATER SOURCES

This watershed group applies to the protection of both groundwater and surface waters used as a drinking water supply, although the stormwater criteria employed for each are quite different. All surface water drinking supplies should be managed using the same criteria as Sensitive Lakes, and are not discussed further in this section. The discussion is confined here to the management of groundwater drinking water source areas to maintain groundwater recharge while preventing the possibility of groundwater contamination. Each of these topics will be more thoroughly explored in the forthcoming Issue Paper H, but some initial thoughts on groundwater are presented here.

Nature of Pollutant or Stressor

Groundwater Sources

Groundwater is a critical water resource, as many residents depend on groundwater for their drinking water, and the health of many aquatic systems depends on steady recharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of wetlands. Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds. Thus, during prolonged periods of dry weather, streamflow sharply diminishes. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry.

Urban land uses and activities can also degrade groundwater quality, if stormwater runoff is directed into the soil without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals and are designated as stormwater "potential pollutant generating land uses" or the rather ugly acronym of PPGLUs. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids and some polycyclic aromatic hydrocarbons (PAHs) can migrate into groundwater and potentially contaminate wells. Stormwater runoff should never be infiltrated into the soil from sites designated as PPGLUs.

Surface Water

A large portion of the Minnesota population is served by drinking water obtained from surface water sources. The Mississippi River, Lake Superior, the Red River and Iron Range quarries are the source for most of this water. Protection of these sources can be even more difficult than protecting groundwater sources because of the lack of treatment between a potential contamination source and the drinking water intake. That is, a well pulls groundwater that has been filtered to some degree by flowing through soil and rock. A chemical spill into a surface water source might be reduced by processes such as dilution and diffusion, but proximity of an intake to a spill greatly increases the odds for a catastrophic event.

The list of "contaminants of concern" for surface water suppliers is significantly larger than groundwater suppliers because of the myriad number of activities that can result in spillage into a source water. Since some of this activity is directly related to surface water runoff and watershed management, source water protection efforts need to look to a wide area for management program application. Current controls outside of the community within which the water is supplied are limited (see Table 3 MDH reference and future Issue Paper "C"). The proposed MS4 permit amendment will require the mapping of source water protection areas by MS4 communities, as well as the development of a management program element to protect the source area.

Designation of Stormwater PPGLUs

Stormwater PPGLUs are defined as commercial, industrial, institutional, municipal, or transportation-related operations that produce higher levels of stormwater pollutants, and/ or present a higher potential risk for spills, leaks or illicit discharges (Schueler et al., 2004). Table 13 designates common operations that may be PPGLUs and may require special stormwater management

Table 13: Potential PPGLU Operations (adapted from MDE, 2000)	
• Vehicle salvage yards and recycling facilities	• Outdoor liquid container storage
• Vehicle service and maintenance facilities	• Outdoor loading/unloading facilities
• Vehicle and equipment cleaning facilities	• Public works storage areas
• Fleet storage areas (bus, truck, etc.)	• Facilities that generate or store hazardous materials
• Industrial sites	• Commercial container nursery
• Marinas (service and maintenance)	• Large parking lots
• Transportation routes and fueling areas	• Large chemically managed turf areas

Runoff from these operations may contain soluble pollutants that can contaminate groundwater quality, and cannot be effectively removed by current BMP technology, including:

- Nitrates
- Chloride
- MTBE
- Diazinon
- Soluble metals

Sources of potentially polluting nutrients, metals, hydrocarbons, toxins and other pollutants are summarized in Table 14. It should be noted that not all facilities that fall under these or similar categories indeed do pollute. In fact substantial industrial operations are the most regulated facilities under state and federal programs. There are, however, many small or unregulated facilities (such as gas stations or auto salvage yards) that are of concern because of the potential for release of toxic material to stormwater.

Table 14: Stormwater Pollutants Associated With Common PPGLU Operations (Schueler et al., 2004)					
Operation or Activity	**Nutrients**	**Metals**	**Oil / Hydrocarbons**	**Toxics**	**Others**
Vehicle Repair	○	●	●	●	
Vehicle Fueling	○	●	●	●	(MTBE not used in MN)
Vehicle Washing	●	⊙	⊙	●	
Vehicle Storage	X	⊙	●	○	Trash
Outdoor Loading	⊙	⊙	○	○	Organic Matter
Outdoor Storage	⊙	⊙	⊙	⊙	
Liquid Spills	⊙	⊙	●	●	
Dumpsters	⊙	⊙	⊙	●	Trash
Building Repair	○	⊙	⊙	⊙	Trash
Building Maintenance	X	●	○	⊙	
Parking Lot Maintenance	○	⊙	●	⊙	Chloride
Turf Management	●	X	X	●	Pesticides
Landscaping	●	X	X	●	Pesticides
Pool Discharges	X	X	X	X	Chlorine
Golf Courses	●	○	X	●	Pesticides
Hobby Farms/Race Tracks	⊙	X	X	X	Bacteria
Construction	○	○	○	⊙	Trash, sanitary waste
Marinas	⊙	⊙	⊙	●	Bacteria
Restaurants	⊙	X	●	X	Grease
Key ● major contributor ⊙moderate ○ minor **X** not a pollutant source					

Brief Review of Comparative Performance

The key design issue is to prevent possible groundwater contamination by preventing infiltration of untreated PPGLU runoff. At the same time, recharge of unpolluted stormwater is needed to maintain flow in streams and wells during dry weather. Surface water protection relies upon good surface water management practices to keep the land surface free of contaminating material that can wash-oo into receiving waters that supply drinking water. In both cases, spill prevention and rapid clean-up if a spill occurs are essential.

As such, structural BMPs alone should not be relied upon as a sole stormwater management strategy at a PPGLU. A stormwater pollution prevention plan for a PPGLU should also incorporate a combination of:

- Good housekeeping
- Preventive maintenance
- Spill prevention and clean-up
- Employee training
- Inspections
- Recordkeeping
- Chemical use restrictions

Recommended Stormwater Sizing Criteria for Drinking Water Protection

While Issue Paper H will more thoroughly explore the protection of groundwater, Table 15 presents initial recommendations for stormwater sizing.

Table 15: Recommended Sizing Criteria for Groundwater and Surface Drinking Water
Groundwater Drinking Water Source Areas *WQv:* MPCA Rules 2 and 4 applied *Pretreatment*: No infiltration of stormwater without pretreatment *Recharge:* Encouraged at residential development and some commercial and institutional rooftops *Stormwater PPGLUs*: No infiltration or recharge of runoff from designated PPGLU operations that can contaminate groundwater (to be defined as Paper H) **Surface Water Drinking Supplies** Managed in the same manner as a Sensitive Lake with additional attention for bacteria, toxic substances and solids that could raise THM concerns.

Special BMP Design Criteria for Groundwater Protection

Guidance on the selection, design and location of BMPs to protect groundwater water supply is provided in this section and will be directly incorporated into the appropriate sections of the Manual.

Specific design criteria for groundwater are presented in Table 16. In general, infiltration of residential and most rooftop clean runoff should be promoted. Stormwater ponds, wetlands, bioretention, and organic filters also provide effective treatment if infiltration cannot be achieved. Other design restrictions to protect groundwater could include:

- Promote infiltration with pretreatment
- No infiltration from PPGLUs, especially those with potentially high chloride levels and/or vulnerable groundwater resources
- Minimum setbacks from wells, septic systems, sinkholes and wellhead protection zones in conformance with state and local regulations (contact Minnesota Department of Health) and plans
- Avoid pooling or infiltrating stormwater in karst areas

Table 16: BMP Design Considerations for Groundwater

BMP Group	Aquifer Protection
Bioretention	• OK with proper caution for PPGLUs
Filtration	• OK with proper caution for PPGLUs • Open channels are OK, but polluted runoff must be adequately pretreated
Infiltration	• Provide a 100-foot horizontal separation distance from wells and three-foot vertical distance from the water table. • No PPGLU runoff, unless treated by another practice, such as a filtering system. • Require pretreatment of all runoff except rooftop.
Ponds	• Require liner if A soils or karst are present • Pretreat PPGLU runoff • Provide a separation distance from well or water table to BMP
Wetlands	• May require liner if A soils or karst are present • Pretreat PPGLU runoff • Provide a separation distance from well or water table to BMP

VII. GROUP D RESOURCES: WETLANDS

Not all wetlands respond the same to stormwater runoff impacts. In the context of this paper, wetlands are defined as susceptible or non-susceptible, loosely based on the MN SWAG (1997) wetland classification scheme. Note that this discussion does not address the Minnesota State or Federal regulatory programs, but rather addresses the use of wetlands in an overall stormwater management framework. This is a common framework within which local or watershed "function and value" assessments are performed. The state, local and federal regulatory aspects of wetland use will be discussed in Issue Paper "C".

Nature of Pollutant or Stressor

Until recent years, wetlands were viewed as wastelands that were better drained or filled. It is estimated Minnesota has lost nearly 42 percent of its original wetland acreage (MN

SWAG, 1997). Wetlands are now recognized as contributing significant watershed functions and values, and greater protections are warranted.

Stormwater runoff has the potential to impact the soils, flora and fauna, and water quality of wetlands. Disturbance to wetland hydrology can cause changes in the character of the ecosystem including species composition and richness, primary productivity, organic deposition and flux, and nutrient cycling. Naturally occurring quantities of runoff with seasonal fluctuations are essential for the maintenance of a wetland, and moderate amounts of nutrients and sediment in the runoff can increase a wetland's productivity. However, excessive stormwater discharge on a continuous basis has the potential to alter wetland hydrology, topography, and the vegetative community (U.S. EPA, 1993).

Greater frequency and duration of inundation can degrade native wetland plant communities and deprive them of their water supply. Stormwater inputs can cause changes in water or soil chemistry that can degrade wetlands that have a specific pH range such as the acidic conditions of sphagnum bogs and alkaline conditions of calcareous fens (MN SWAG, 1997).

Calcareous fens are the rarest wetland plant community in Minnesota and probably one of the rarest in North America. A calcareous fen is a peat-accumulating wetland dominated by distinct ground-water inflows having specific chemical characteristics. The water is characterized as circum-neutral to alkaline, with high concentrations of calcium and low dissolved oxygen content. The chemistry provides an environment for specific and often rare hydrophytic plants. Calcareous fen communities in general have a disproportionate number of rare, threatened, and endangered plant species as compared to other plant communities in the Great Lakes region (MN SWAG, 1997). As urbanization increases, temperature, conductivity and suspended solids increase in stormwater runoff and likewise in wetlands. Chemically, water quality parameters of concern include nutrients, metals, and other toxics. Changes in water quality have the potential to affect the vegetative community structure and to reduce the availability of plant species preferred by fish, mammals, birds, and amphibians for food and shelter (U.S. EPA, 1993).

Highly susceptible wetland communities can be composed of dozens of species of vegetation, providing habitat for a variety of wildlife in addition to providing excellent water quality functions. Urban stormwater input can exceed the water depths and frequency/duration of inundation that occurred under natural conditions, leading to a die-out of vegetative species. Deposition of sediment carried by urban stormwater can have the same effect, causing replacement of diverse species with monotypes of reed canary grass or cattails, which are much more tolerant of sedimentation and fluctuating water levels. Schueler (2000b) reported that invasive or aggressive plant species are favored when water level fluctuation (WLF) is high (e.g., reed canary grass). The result is low vegetative diversity and lower quality wildlife habitat values (MN SWAG, 1997). A modest change in WLF sharply decreases plant species richness, and amphibian species richness a study in the Pacific Northwest (Horner, et al. 1996).

Table 17 presents the MN SWAG classification of wetland types according to their presumed susceptibility to degradation by stormwater. Given this diversity of wetland types, it's not surprising that wetlands have a broad range of tolerance to urban stormwater input. Some wetlands (i.e. calcareous fens) are sensitive to any disturbance and will show signs of degradation with even low-level inputs of urban stormwater. Note that "susceptible" wetlands are defined as highly and moderately susceptible in Table 17, and "non-susceptible" are defined as slightly and least in the table.

Table 17: Susceptibility of Wetland Types to Degradation by Stormwater Input
(Source: State of Minnesota Storm-Water Advisory Group, 1997)

Highly Susceptible Wetland Types[1]	Moderately Susceptible Wetland Types[2]	Slightly Susceptible Wetland Types[3]	Least Susceptible Wetland Types[4]
• Sedge Meadows • Open Bogs • Coniferous Bogs • Calcareous Fens • Low Prairies • Coniferous Swamps • Lowland Hardwood Swamps • Seasonally Flooded Basins	• Shrub-carrs[a] • Alder Thickets[b] • Fresh (Wet) Meadows[c,e] • Shallow Marshes[d,e] • Deep Marshes[d,e]	• Floodplain Forests[a] • Fresh (Wet) Meadows[b] • Shallow Marshes[c] • Deep Marshes[c]	• Gravel Pits • Cultivated Hydric Soils • Dredged Material / Fill Material Disposal Sites

1. Special consideration must be given to avoid altering these wetland types. Inundation must be avoided. Water chemistry changes due to alteration by stormwater impacts can also cause adverse impacts.
Note: All scientific and natural areas and pristine wetlands should be considered in this category regardless of wetland type.
2a., 2b., 2c. Can tolerate inundation from 6 inches to 12 inches for short periods of time. May be completely dry in drought or late summer conditions.
2d. Can tolerate +12" inundation, but adversely impacted by sediment and/or nutrient loading and pro- longed high water levels.
2e. Some exceptions.
3a. Can tolerate annual inundation of 1 to 6 feet or more, possibly more than once/year.
3b. Fresh meadows which are dominated by reed canary grass.
3c. Shallow marshes dominated by reed canary grass, cattail, giant reed or purple loosestrife.
4. These wetlands are usually so degraded that input of urban stormwater may not have adverse impacts.

Notes:
- There will always be exceptions to the general categories listed above. Use best professional judgment.
- Pristine wetlands are those that show little disturbance from human activity.

Table 18 presents hydroperiod standards for wetlands, as developed by MN SWAG (1997). This guidance recommends these standards unless better site-specific data is available. The term "existing" in this chart means the existing hydrologic conditions. If there have been recent significant changes in conditions, it means the conditions that established the current wetland. Wetland alteration for any reason should only be conducted after careful analysis to insure that the desired outcome will result.

Table 18: Recommended Hydroperiod Standards for Wetlands **(Source: State of Minnesota Storm-Water Advisory Group, 1997)**				
Hydroperiod Standard	**Highly Susceptible Wetlands**	**Moderately Susceptible Wetlands**	**Slightly Susceptible Wetland**	**Least Susceptible Wetlands**
Storm Bounce	Existing	Existing plus 0.5 ft	Existing plus 1.0 ft	No limit
Discharge Rate	Existing	Existing	Existing or less	Existing or less
Inundation period for 1 & 2 yr. precipitation event	Existing	Existing plus 1 day	Existing plus 2 days	Existing plus 7 days
Inundation period for 10 yr. precipitation event & greater	Existing	Existing plus 7 days	Existing plus 14 days	Existing plus 21 days
Run-out control elevation (free flowing)	No change	No change	0 to 1.0 feet above existing run out	0 to 4.0 feet above existing run out
Run-out control elevation (landlocked)	Above delineated wetland	Above delineated wetland	Above delineated wetland	Above delineated wetland

Brief Review of Comparative Performance

Some communities have utilized existing wetlands for stormwater treatment by increasing the depth of ponding on a permanent or temporary basis. The end result is the transformation of a natural wetland into a stormwater wetland, with the attendant loss of diversity and functional values. Schueler (1992) suggests several structural alternatives to fingerprint stormwater around wetlands and reproduce their natural hydrology. The preferred course of action is to locate the stormwater control in an upstream or off stream location. An alternative is to install a parallel pipe system that diverts storm flows around the existing wetland to a downstream stormwater control system (Figure 1). A flow splitter is installed above the sensitive wetland that diverts the storm flows from the development away from the wetland, and sends dry weather base flow to the wetland. The design should attempt to mimic the original water balance to the wetland. In some cases, it is possible to split the needed base flow away form the stream into an off-line or stormwater system, which empties downstream of the wetland to be protected. A second technique involves employing a series of smaller stormwater pools and wetland areas above and below the sensitive wetland. Runoff is pre-treated before it enters the sensitive wetland. This scenario will still result in significant stormwater influence to the existing wetland, but by lowering peak flows it can reduce the overall degradation that might occur.

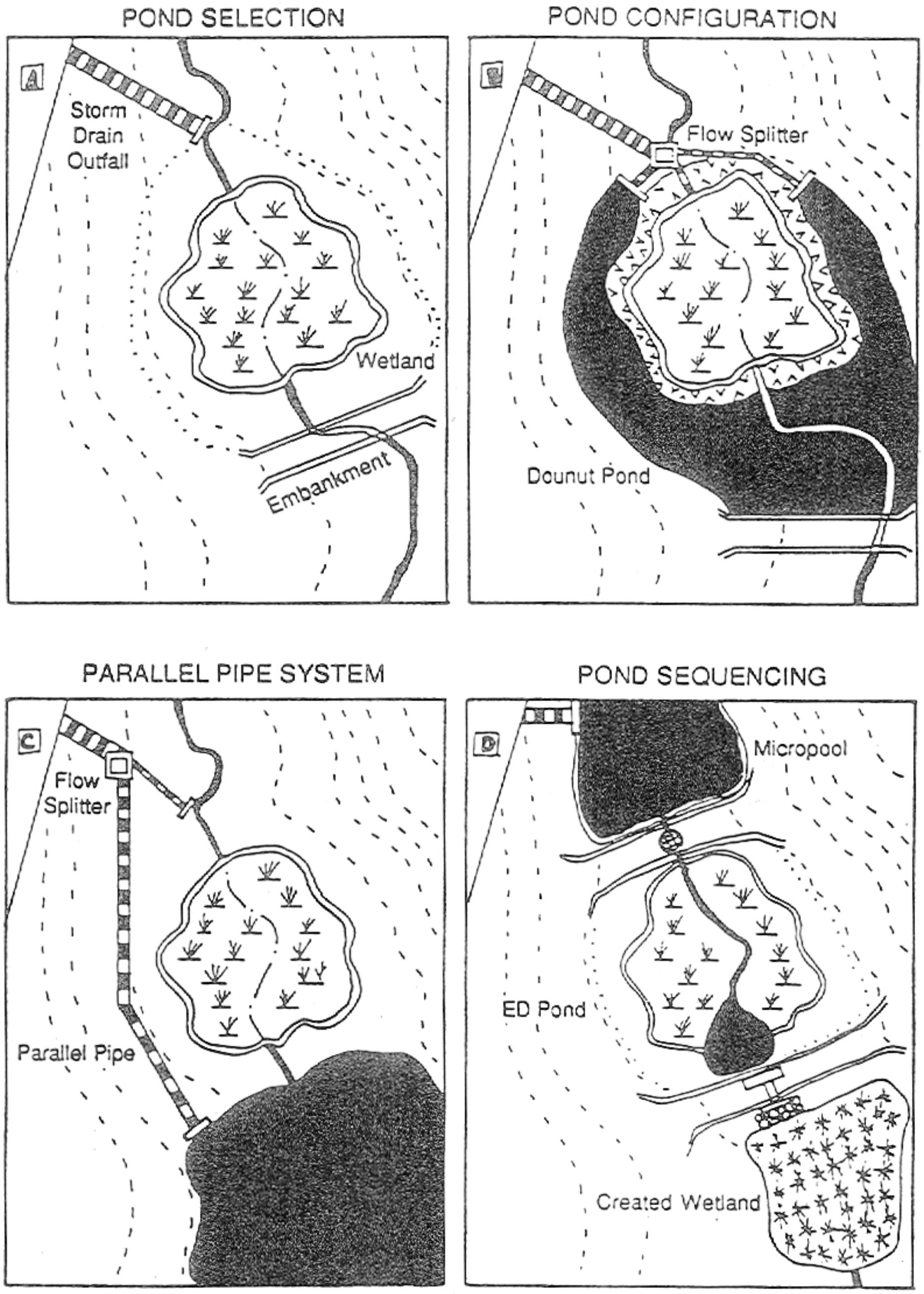

Figure 1: Techniques for Fingerprinting a Stormwater Wetland Around a Natural Wetland. Panel A: Existing natural wetland is severely impacted by upstream stormwater inputs and frequent inundation. Panel B: Existing wetland is protected by berm; stormwater bypassed to two arms of the wet pond. Panel C: Excess stormwater diverted around natural wetland to a more favorable location via a parallel pipe system. Panel D: Stormwater pretreated before it reaches wetland, where temporary extended detention is provided; a downstream wetland is created to compensate for impacts to the existing wetland.

Wetland alteration should only be conducted after careful analysis to insure that the desired outcome will result. For most wetlands, especially the sensitive and highly sensitive wetlands, changes in the hydroperiod may have detrimental impacts. Therefore, it is essential to avoid hydrologic changes to sensitive wetlands and to minimize the impacts where discharges of urban stormwater to wetlands are unavoidable (MN SWAG, 1997).

Recommended Stormwater Sizing Criteria for Wetland Protection

Recommended sizing criteria for wetland protection is presented in Table 19.

Table 19: Recommended Sizing Criteria for Wetland Protection
Any wetlands present at the site should be investigated in the field to determine their wetland type and contributing hydrologic source area, and then determine if any additional runoff will be delivered to the wetland as a result of the proposed project. Based on this determination, a wetland will be classified as either susceptible or non-susceptible, using the criteria outlined in Table 17. **SUSCEPTIBLE WETLANDS (**For wetlands identified as highly or moderately susceptible in Table 17): *Maintain Wetland Hydroperiods*:, Meet the storm bounce and inundation duration requirements as set forth in Table 18. This may be done through infiltration, extended detention, or diversion. *WQv*: Require site-based phosphorus load reduction to control nutrients, as described for Most-Sensitive Lakes. *Recharge* (Rev): Required *Channel Protection*: only required if the channel is a direct tributary to the wetland *No use of existing wetlands for stormwater treatment* *No constrictions at wetland outlets* **NON-SUSCEPTIBLE WETLANDS** (For wetlands identified as slightly or least susceptible in Table 17): *No untreated stormwater discharges to wetlands,* which is operationally defined as providing WQv via appropriate MPCA Rules. *Channel Protection (CPv)* recommended only if the channel is a direct tributary to the wetland

Recharge (Rev) recommended but not required *No use of existing wetlands for stormwater treatment*

BMP Design Criteria for Wetlands

A summary of basic criteria for the selection, design and location of BMPs to protect wetlands follows, and will be incorporated into the relevant section(s) of the Manual and Issue Paper I.

Specific guidance should be provided on selecting the appropriate BMP(s) for a wetland watershed:

- BMPs such as stormwater wetlands, infiltration systems, and bioretention should be promoted.
- Direct pipe outfalls to wetlands should be restricted (ex., not allowed, allowed if energy dissipated, or routed through pre-treatment system).
- For sensitive bogs and fens, BMPs should be designed for site-based nutrient load reduction (see Most-Sensitive Lakes).
- Stormwater should be routed around sensitive wetlands using a diversion or bypass system.
- Constrictions at wetland outlets should be avoided.
- Natural wetlands should not be used for stormwater treatment, unless they are severely impaired and construction would enhance or restore wetland functions; if natural wetlands are used in this manner, 7050 requires the sequence of avoid, minimize and compensatory replacement
- The discharge of untreated stormwater to a wetland is prohibited.

VIII. GROUP E. IMPAIRED WATERS

"Impaired Waters" include those streams and lakes that do not meet their designated uses because of excess pollutants or identified stressors. The 2004 final list of Impaired Waters for Minnesota (approved by the U.S. EPA on May 13, 2004) includes 916 lakes and 199 river and creek segments (Appendix E). A Total Maximum Daily Load (TMDL) study must be prepared for each pollutant that causes a water body to fail to meet state water quality standards or its designated uses. A TMDL is the amount of a pollutant, from both point and nonpoint sources, that a waterbody can receive and still meet water quality standards (i.e., no impairment). Water quality sampling and computer modeling determine how much each pollutant source must reduce its contribution to assure the water quality standard is met.

Rivers and streams may have several TMDLs, each one determining the limit for a different pollutant. Four final TMDLs and implementation plans have been completed to date in Minnesota. No TMDL Implementation Plans currently contain construction stormwater requirements. When development is taking place in a watershed that has a TMDL allocation for sediment and parameters associated with sediment transport, the stormwater pollution prevention plan (SWPPP) for the development site must be consistent with the assumptions, allocations and requirements in the approved TMDL.

Nature of Pollutants

Currently, there are 14 pollutants causing water quality standard violations in some part of the state (http://www.pca.state.mn.us/water/tmdl/index.html), including:

- Sediment
- Phosphorus
- Nitrogen
- Ammonia
- Fecal Coliform
- Oxygen Demand
- Turbidity
- Chloride
- DDT
- Dieldrin
- Mercury
- PCBs
- Toxaphene

Computable and Non-Computable Pollutants

Impaired waters require a slightly different approach, as SWPPPs must be consistent with the assumptions, allocations and requirements for the listed pollutant in an approved TMDL. In this regard, the pollutant can either be computable or non-computable. For stormwater, computable is defined as a pollutant for which enough runoff concentration and BMP performance data are available to perform a site-based pollutant load calculation documenting no increase in loading.

A “computable” pollutant is one that passes the following four part test:

1. Enough stormwater EMC data is available to characterize its average level in stormwater
2. Stormwater concentrations are high enough to constitute a major source in the stormwater Load allocation

3. Sufficient BMP performance data is available to estimate expected removal for a range of stormwater practices
4. Stormwater removal rates are high enough to warrant performing the calculation.

Table 20 presents a determination of the computability of the 14 different pollutants that are listed in MN waters.

Table 20: Determination of Computable and Non-Computable Pollutants

Pollutant	Runoff Concentration Data? [a]	BMP Removal Performance Data? [b]	Demonstrated Removal Capability? [c]	Computable Load Reductions? [d]
Sediment	Yes	Yes	Yes	YES
Phosphorus	Yes	Yes	Yes	YES
Nitrogen	Yes	Yes	Yes	YES
Ammonia	Yes	Yes	Yes	YES
Fecal Coliform	Limited	Limited	Yes	NO
Oxygen Demand	Limited	Limited	Yes	NO
Turbidity	Limited	Limited	Modest	NO
Chlorides	Yes	Yes	Zero	NO
DDT	None	No	N/a	NO
Dieldrin	None	No	N/a	NO
Mercury	None	No	N/a	NO
PCBs	None	No	N/a	NO
Toxaphene	None	No	N/a	NO

[a] Sufficent event mean concentration data has been monitored to characterize the average pollutant concentration in urban stormwater runoff.
[b] Enough performance monitoring data has been collected over a range of urban stormwater BMPs to characterize expected removal rates
[c] Removal rates are significant enough to warrant a load reduction calculation
[d] Sufficient data exists to compute pre and post development pollutants and compute needed pollutant reduction to satisfy a TMDL requirement

Event Mean Concentrations of Pollutant from Various Land Uses

In an effort to characterize the quality of stormwater runoff, the National Stormwater Quality Database (Pitt et al., 2004) summarizes data from 3,770 separate events collected by 66 NPDES Phase I agencies and municipalities from 17 states. Event mean concentrations (EMCs) or median values are presented for 25 commonly analyzed pollutants. Data are separated into 11 land use categories: residential, commercial, industrial, institutional, freeways, and open space, plus mixtures of these land uses. Event mean concentrations for selected parameters are presented in Table 21. These values are consistent with values normally seen in Minnesota.

Table 21: Event Mean Concentrations for Selected Parameters (Source: Pitt et al., 2004)												
	Overall Summary	Residential	Mixed Residential	Commercial	Mixed Commercial	Industrial	Mixed Industrial	Institutional	Freeways	Mixed Freeways	Open Space	Mixed Open Space
TDS (mg/L)	80	72	86	74	70	92	80	52.5	77.5	174	125	109
TSS (mg/L)	58	49	68	42	54	78	82	17	99	81	48.5	83.5
BOD_5 (mg/L)	8.6	9	7.6	11	9.25	9	7.2	8.5	8	7.4	5.4	6
COD (mg/L)	53	55	42	60	60	60	40.4	50	100	48	42.1	34
Fecal Coliform (mpn/100 mL)	5,091	8,345	11,000	4,300	4,980	2,500	3,033		1,700	730	7,200	2,600
NH_3 (mg/L)	0.44	0.32	0.39	0.5	0.6	0.5	0.43	0.31	1.07		0.18	0.51
$N0_2$+NO_3 (mg/L)	0.6	0.6	0.6	0.6	0.58	0.73	0.57	0.6	0.28	0.6	0.59	0.7
Nitrogen, Total Kjeldahl (mg/L)	1.4	1.4	1.35	1.6	1.39	1.4	1	1.35	2	1.6	0.74	1.12
Phosphorus, filtered (mg/L)	0.13	0.17	0.12	0.11	0.12	0.11	0.08	0.13	0.2	0.04	0.13	0.09
Phosphorus, total (mg/L)	0.27	0.3	0.27	0.22	0.26	0.26	0.2	0.18	0.25	0.26	0.31	0.27
Mercury*, total (ug/L)	0.2	0.2	0.2	0.2		0.2	0.25					

*There is some lack of clarity over the method used to describe Hg in this reference; this will be examined prior to inclusion of any Hg EMC data in the Manual

Pollutant Removal Effectiveness of BMPs

Numerous studies have been undertaken to determine the pollutant removal effectiveness of a range of BMPs. Winer (2000) examined the results of 139 studies and summarized the general removal capability of various groups and design variations of BMPs (results summarized in Appendix D and will be part of Issue Paper I and Manual).

Recommended Stormwater Sizing Criteria for Impaired Waters

Recommended stormwater criteria for Impaired Waters presented in Table 24.

Table 24: Recommended Stormwater Criteria for Impaired Waters
Designers should determine whether their project is located in a watershed for which a TMDL is in place, and then determine if the listed pollutant is computable or non-computable, and if a new source cap is in place that requires no increase pollutant load after development. Designers should also identify if the receiving water is listed by the MPCA as “impaired” for any pollutant and examine the timeframe under which the water will fall under the TMDL program. COMPUTABLE POLLUTANT WQ_v: If new development site is located in a watershed subject to a TMDL that has no remaining stormwater allocation, designers may need to document “no net increase” in pollutant load, using the general method proposed for the most-sensitive lakes management category (but using the appropriate pollutant). Currently, sufficient data is only available to perform this calculation for four of the 14 TMDL pollutants in MN (sediment, phosphorus, nitrogen and ammonia). Cp_v: For TMDLs related to sediment, some control of channel erosion might be included. The specific control needs will be addressed as part of the implementation program. Pollutant removal calculations should be conducted on a site-by-site basis. An example of an approach for calculating phosphorus removal is provided in Appendix A. NON-COMPUTABLE POLLUTANTS *WQv*: For the remaining pollutants which may be subject to a TMDL but have no remaining stormwater allocation, designers must satisfy MPCA sizing rules 2 or 4. The Manual will not make specific recommendations about how to design BMPs for impaired waters, but will include typical runoff EMCs and BMP removal rates for computable pollutants

IX. GROUP F. OUTSTANDING RESOURCE VALUE WATERS (ORVW)

All Outstanding Resource Value Waters (ORVW) are assigned to one of the four watershed management groups (A, B, C, or D), depending on their dominant aquatic characteristic. The stormwater sizing criteria for the prescribed watershed management category is then applied to the appropriate ORVW water. In the event that a project is located in more than one ORVW category, the most restrictive one should apply

X. GROUP G. REGULAR WATERS OF THE STATE

The "regular waters of the state" include those waters that are regulated under statutes and rules adopted by the State of Minnesota. The standard unified sizing criteria contained in Issue Paper "D" are applied.

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Appendix A. Notes for Use in Table 1: Special Provisions for Stormwater Discharges to Outstanding Resource

1. Required for areas of project draining to discharge point on project within 2,000 feet of special water and flows to a special water.

2. Exposed soil areas with a slope of 3:1 or steeper that have continuous, positive slope must have temporary erosion protection or permanent cover within 3 days. All other continuous positive slopes to a special water must have temporary erosion protection or permanent cover within 7 days. Temporary sediment basins must be used for locations that serve an area with 5 or more acres disturbed at one time.

3. Treatment of 1" of runoff from the new impervious areas created by the project if more than 1 acre impervious is created.

4. Maintain an undisturbed buffer zone of not less than 100 linear feet from the special water (not including tributaries).

5. Pre- and post-project runoff rate and volume from the 1- and 2-year 24-hour precipitation events remains the same.

6. Minimize any increase in the temperature of receiving waters resulting from the 1, and 2-year 24-hour precipitation events, including all tributaries of designated trout streams. Minimize impact using (in descending order of preference): new impervious surface, discharge from connected impervious surface, infiltrate or evapotranspire runoff in excess of pre-project conditions (up to 2 year 24 hour precipitation event), for ponding use shading and other methods to limit temperature increases and design pond to drawdown in 24 hours or less, other methods to minimize temperature increase.

7. Demonstration that the activity impacting a wetland complies with all of the following principles in descending order of priority: avoids direct or indirect impacts, minimizes impact by limiting the degree or magnitude of activity, replace unavoidable impacts through restoration or creation.

8. Individual or other program permit may be required. SWPPP must provide additional measures as necessary to ensure protection and be in compliance with requirements of other programs

Appendix B. Notes for Use in Table 2: Special Provisions for Stormwater Discharges to Other Waters

1. Required for areas of project draining to discharge point on project within 2,000 feet of special water and flows to a special water.

2. Exposed soil areas with a slope of 3:1 or steeper that have continuous, positive slope must have temporary erosion protection or permanent cover within 7 days. Temporary sediment basins must be used for locations that serve an area with 10 or more acres disturbed at one time.

3. 1/2" of runoff from new impervious surface must be treated if more than 1 acre impervious created, Normal wetted perimeter must be stabilized within 200 lineal feet of property edge or point of discharge within 24 hours of connection to surface water.

4. Varies according to ordinances

5. 5.66 cfs per acre surface area outflow or infiltration within 48 hours

6. Minimize any increase in the temperature of receiving waters resulting from the 1, and 2-year 24-hour precipitation events, including all tributaries of designated trout streams. Must minimize impact using (in descending order of preference): new impervious surface, discharge from connected impervious surface, infiltrate or evapotranspire runoff in excess of pre-project conditions (up to 2 year 24 hour precipitation event), for ponding use shading and other methods to limit temperature increases and design pond to drawdown in 24 hours or less, other methods to minimize temperature increase.

7. Demonstration that the activity impacting a wetland complies with all of the following principles in descending order of priority: avoids direct or indirect impacts, minimizes impact by limiting the degree or magnitude of activity, replace unavoidable impacts through restoration or creation.

8. Individual or other program permit may be required. SWPPP must provide additional measures as necessary to ensure protection and be in compliance with requirements of other programs.

Appendix C: Simple Method For Calculating Phosphorus Export (revised)

This appendix provides a method for determining the pre- and post-development total phosphorus loads from a development site. The methodology is based on the Simple Method.

The Simple Method

> The Simple Method is a technique used for estimating storm pollutant export delivered from urban development sites. The method was developed to provide an easy yet reasonably accurate means of predicting the change in pollutant loadings in response to development. This information is needed by planners and engineers to make rational non-point source pollution decisions at the site level.

The Simple Method Calculation, Table C-1, is intended for use on development sites less than a square mile in area. As with any simple model, the method to some degree sacrifices precision for the sake of simplicity and generality. Even so, the Simple Method is still reliable enough to use as a basis for making non-point pollution management decisions at the site level.

Phosphorus pollutant loading (L, in pounds per year) from a development site can be determined by solving the equation displayed in Table C-1.

Table C-1: Phosphorus Pollutant Export Calculation

Pollutant Loading, $L = [(P)(P_j)(R_v)/12]\ (C)\ (A)\ (2.72)$

Where:

- P = Rainfall depth over the desired time interval (inches)
- P_j = Fraction of rainfall events that produce runoff
- R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff. $R_v = 0.05 + 0.009(I)$
- C = Flow-weighted mean concentration of the pollutant in urban runoff (mg/l)
- A = Area of the development site (acres)

12 and 2.72 are unit conversion factors

P, Depth of Rainfall

The value of P represents the number of inches of precipitation that falls during the course of a normal year of rainfall. Long-term weather records around the state of Minnesota suggest that the average annual rainfall depth ranges from 20-32 inches. This can be used to estimate P or a user can substitute the average annual rainfall depth from the closest National Weather Service long-term weather station or other suitable locations for which a reliable record can be demonstrated (> 10 years).

P_j, Correction Factor

The P_j factor is used to account for the fraction of the annual rainfall that does not produce any measurable runoff. Many of the storms that occur during the year are so minor that all of the rainfall is stored in surface depressions and eventually evaporates. As a consequence, no runoff is produced. An analysis of regional rainfall/runoff patterns indicates that only 90% of the annual rainfall volume produces any runoff at all. Therefore, P_j should be set at 0.9, unless better local data are available.

R_v, Runoff coefficient

The R_v is a measure of the site response to rainfall events, and in theory is calculated as:

> $R_v = r/p$, where r and p are the volume of storm runoff and storm rainfall, respectively, expressed as inches.

The R_v for the site depends on the nature of the soils, topography, and cover. However, the primary influence on the R_v in urban areas is the amount of imperviousness of the site. Impervious area is defined as those surfaces in the landscape that cannot infiltrate rainfall consisting of building rooftops, pavement, sidewalks, driveways, etc. In the equation:

$$R_v = 0.05 + 0.009(I)$$

"I" represents the percentage of impervious cover expressed as a whole number. A site that is 75% impervious would use I = 75 for the purposes of calculating R_v.

A, Site Area

The total area of the site (in acres) can be directly obtained from site plans. If the total area of the site is greater than one square mile (640 acres), the Simple Method may not be appropriate and applicants should consider utilizing other approaches, such as modeling or monitoring.

C, Pollutant Concentration

Statistical analysis of several urban runoff monitoring datasets has shown that the average storm concentrations for total phosphorus in developed urban areas do not significantly differ. Therefore, in this exercise a pollutant concentration, C, of 0.30 mg/l should be used in this equation. However, if local data shows a difference in pre- and post-project phosphorus concentration, the local data should be used. Note that the 0.30 mg/l figure only refers to areas already experiencing urban development. It does not hold true when comparing undeveloped land with urbanized land.

The Simple Method equation listed in Table C-1 can be simplified to the equation shown in Table C-2. Applicants with verified data indicating alternative values may choose to use the original Simple Method equation as represented in Table C-1; otherwise, Table C-2 represents the revised Simple Method equation and associated values.

Table C-2: Simplified Pollutant Loading Calculation
Pollutant Loading, L = (P) (R_v) (C) (A) (0.20) Where: P = Rainfall depth over the desired time interval (inches) R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = 0.05 + 0.009(I) I = Site imperviousness (i.e., I = 75 if site is 75% impervious) C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l A = Area of the development site (acres) 0.20 is a regional constant and unit conversion factor

Calculating Pre-Development and Post-Development Phosphorus Load

The methodology for comparing annual pre-development pollutant loads to post-development pollutant loads is a six-step process (Table C-3).

Table C-3: Process For Calculating Pre- and Post-Development Pollutant Loads	
Step No.	**Task**
1.	Calculate Site Imperviousness
2.	Calculate the Pre-Development Phosphorus Load
3.	Calculate Post-Development Pollutant Load
4.	Calculate the Pollutant Removal Requirement
5.	Identify Feasible BMPs
6.	Select Off-Site Mitigation Option

Step 1: Calculate Existing and Proposed Site Imperviousness

In this step, the applicant calculates the impervious cover of the predevelopment (existing) and post-development (proposed) site conditions.

Impervious cover is defined as those surfaces in the landscape that impede the infiltration of rainfall and result in an increased volume of surface runoff. As a simple rule, human-made surfaces that are not vegetated will be considered impervious. Impervious surfaces include roofs, buildings, paved streets and parking areas and any concrete, asphalt, compacted dirt or compacted gravel surface.

Step 2: Calculate Predevelopment Phosphorus Load

In this step, the applicant calculates stormwater phosphorus loadings from the site prior to development. Depending on the development classification, the applicant will use one of two equations (Table C-4). The equation to determine phosphorus loading in a redevelopment situation is based on the Simple Method. The equation to determine phosphorus loading in a new development situation utilizes a benchmark load for undeveloped areas, which is based on average phosphorus loadings for a typical mix of undeveloped land uses.

Table C-4: Method For Calculating Predevelopment Phosphorus Loading
New Development Phosphorus Loading, L_{pre} = 0.5 (A)
Where:
L_{pre} = Average annual load of total phosphorus exported from the site prior to development (lbs/year)
0.5 = Annual total phosphorus load from undeveloped lands (lbs/acre/year)
A = Area of the site (acres)
Redevelopment Phosphorus Loading, L_{pre} = (P) (R_v) (C) (A) (0.20)
Where:
L_{pre} = Average annual load of total phosphorus exported from the site prior to development (lbs/year)
P = Rainfall depth over the desired time interval (inches)
R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = 0.05 + 0.009(I_{pre})
I_{pre} = Predevelopment (existing) site imperviousness (i.e., I = 75 if site is 75% impervious)
C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l
A = Area of the development site (acres)
0.20 is a regional constant and unit conversion factor

Step 3: Calculate Post-Development Pollutant Load

In this step, the applicant calculates stormwater phosphorus loadings from the post-development, or proposed, site. Again, an abbreviated version of the Simple Method is used for the calculations, and the equation is the same for both new development and redevelopment sites (Table C-5).

Table C-5: Method For Calculating Post-Development Phosphorus Loading
Post-Development Phosphorus Loading, L_{post} = (P) (R_v) (C) (A) (0.20)
Where:
L_{post} = Average annual load of total phosphorus exported from the post-development site (lbs/year)
P = Rainfall depth over the desired time interval (inches)
R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = 0.05 + 0.009(I_{post})
I_{post} = Post-development (proposed) site imperviousness (i.e., I = 75 if site is 75% impervious)
C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l
A = Area of the development site (acres)
0.20 is a regional constant and unit conversion factor

Step 4: Calculate the Pollutant Removal Requirement

The phosphorus load generated from the post-development site must be reduced so that it is 90% or less of the load generated prior to development[1]. The amount of phosphorus that must be removed through the use of stormwater BMPs is called the Pollutant Removal Requirement (RR). The equation in Table C-6 expresses this term numerically.

Table C-6: Computing Pollutant Removal Requirements		
Pollutant Removal Requirement, RR = L_{post} - 0.9(L_{pre})		
Where:		
RR	=	Pollutant removal requirement (lbs/year)
L_{post}	=	Average annual load of total phosphorus exported from the post-development site (lbs/year)
L_{pre}	=	Average annual load of total phosphorus exported from the site prior to development (lbs/year)

Step 5: Identify Feasible BMPs

Step 5 looks at the ability of the chosen BMP to meet the site's pollutant removal requirements. The pollutant load removed by each BMP (Table C-7) is calculated using the average BMP removal rate (Table C-8), the computed post-development load, and the drainage area served.

Table C-7: Estimate of Pollutant Load Removed by Each BMP		
Load Removed, LR = (L_{post}) (BMP_{RE}) (% DA Served)		
Where:		
LR	=	Annual total phosphorus load removed by the proposed BMP (lbs/year)
L_{post}	=	Average annual load of total phosphorus exported from the post-development site prior to development (lbs/year)
BMP_{RE}	=	BMP removal efficiency for total phosphorus, Table 8 (%)
% DA Served	=	Fraction of the drainage area served by the BMP (%)

[1] In this example, a 10% reduction in phosphorus loading from pre-development conditions is used. This should not be construed as a recommended reduction for the State of Minnesota.

Table C-8: General Summary of Comparative BMP Phosphorus Removal Performance [a]			
BMP Group	**BMP Design Variation**	**Average TP Removal Rate [b] (%)**	**Maximum TP Removal Rate [c] (%)**
Bioretention	Underdrain	50	65
	Exfiltration	60	75
Filtration	Sand Filters	50	60
	Organic Filter	50	70
	Dry Swale	65	75
	Wet Swale	30	40
Infiltration	Infiltration Trench	65	90
	Infiltration Basin	65	90
Ponds	Micropool ED	25	45
	Wet Pond	50	65
	Wet ED Pond	55	70
	Multiple Pond	60	75
Wetlands	Shallow Wetland	45	65
	ED Wetland	40	55
	Pond/Wetland	55	75

a. Removal Rates Shown in this Table are a composite of four sources: Caraco (2001), MDE (2000), Winer (2000) and Issue Paper D P8 modeling.
b. Average removal efficiency expected under MPCA WQv sizing Rules 1 and 3.
c. Upper limit on phosphorus removal with increased sizing and design features, based on national review.

IMPORTANT NOTE: Removal rates shown here are composite averages intended solely for use in comparing performance between BMP designs and for use in calculating load reduction in site-based TP models. They have been adapted, rounded and slightly discounted from statistical values published in BMP performance databases.

If the Load Removed is equal to or greater than the Pollutant Removal Requirement computed in Step 4, then the on-site BMP complies. If not, the designer must evaluate alternative BMP designs to achieve higher removal efficiencies, add additional BMPs, design the project so that more of the site is treated by the proposed BMPs, or design the BMP to treat runoff from an off-site area.

Step 6: Select Off-Site Mitigation Option

If the pollutant removal requirement has been met through the application of on-site stormwater BMPs, the process is complete.

In the event that on-site BMPs cannot fully meet the pollutant removal requirement and on-site design cannot be changed, an offset fee should be charge (e.g., $X per pound of phosphorus).

References

Caraco, D. 2001. "Managing Phosphorus Inputs Into Lakes III: Evaluating the Impact of Watershed Treatment." *Watershed Protection Techniques*. 3 (4): 791-796. Center for Watershed Protection. Ellicott City, MD.

Maryland Department of the Environment (MDE). 2000. 2000 Maryland Stormwater Design Manual. MDE. Baltimore, MD.

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Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

Appendix D: National Summary (Winer, 2000) of BMP Removal Rates for Possible Use in Impaired Waters

Table D-1: Median Bacteria and Organic Carbon Removal (%) by Stormwater Treatment Practice (Source: Winer, 2000)

BMP Group	Bacteria[1]	Organic Carbon[2]	Hydrocarbons
Filtration[3]	37	54	84[4]
Ponds	70	43	81[4]
Wetlands	78[4]	18	85[4]

1. Bacteria data include fecal streptococci, enterococci, fecal coliform, E. coli, and total coliform
2. Organic carbon data includes BOD, COD, and TOC removal data
3. Excludes vertical sand filters and filter strips
4. Data based on fewer than five data points

Table D-2: Median Pollutant Removal (%) of Stormwater Treatment Practices (Source: Winer, 2000)

BMP Group	TSS	TP	Sol P	TN	NO_x	Cu	Zn
Bioretention[1]	N/A	65	N/A	49	16	97	95
Filtration[2]	86	59	3	38	-14	49	88
Infiltration	95[1]	70	85[1]	51	82[1]	N/A	99[1]
Ponds	80	51	66	33	43	57	66
Wetlands	76	49	35	30	67	40	44

1. Data based on fewer than five data points
2. Excludes vertical sand filters and filter strips

NOTES:

- N/A indicates that the data are not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P= Soluble Phosphorus; TN = Total Nitrogen; NOx = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Appendix E: Summary of Impaired Waters in Minnesota

Summary of Impaired Waters in Minnesota **(Source: MPCA 2004 303(d) List, http://www.pca.state.mn.us/water/pubs/tmdl-coverletter-04.pdf)**
Lake Superior Basin (257 individual TMDL reports needed) • 14 rivers and creeks impaired for one or more of the following: mercury, pH, turbidity, high temperature, impaired biota (fish and/or invertebrates), DDT, dieldrin, dioxin, toxaphene, and low dissolved oxygen • 165 lakes having impairments with one or more of the following impairments: mercury or PCBs in the water column and/or fish tissue
Upper Mississippi River Basin (515 individual TMDL reports needed) • 43 rivers and creeks impaired for one or more of the following: low dissolved oxygen, impaired biota (fish and/or invertebrates), mercury, fecal coliform, turbidity, excess ammonia, chloride, PCBs, and eutrophication • 292 lakes impaired for one or more of the following: excess nutrients and mercury or PCBs in the water column and/or fish tissue
Minnesota River Basin (345 individual TMDL reports needed) • 48 rivers and creeks impaired for one or more of the following: low dissolved oxygen, impaired biota (fish and/or invertebrates), mercury, fecal coliform, turbidity, excess ammonia, chloride, PCBs, and eutrophication • 84 lakes impaired for one or more of the following: excess nutrients and mercury or PCBs in the water column and/or fish tissue
St. Croix River Basin (128 individual TMDL reports needed) • 22 rivers and creeks impaired for one or more of the following: impaired biota (fish and/or invertebrates), mercury, fecal coliform, and eutrophication • 49 lakes impaired for one or more of the following: excess nutrients and mercury or PCBs in the water column and/or fish tissue
Lower Mississippi River Basin (108 individual TMDL reports needed) • 25 rivers and creeks impaired for one or more of the following: impaired biota (fish and/or invertebrates), mercury, fecal coliform, turbidity, excess ammonia, PCBs, and eutrophication • 23 lakes impaired for one or more of the following: excess nutrients and mercury in the water column and/or fish tissue
Cedar River Basin (16 individual TMDL reports needed) • 2 rivers and creeks impaired for one or more of the following: fecal coliform, mercury, turbidity, PCBs, and excess ammonia • 1 lake impaired for excess mercury in fish tissue
Des Moines River Basin (23 individual TMDL reports needed) • 9 rivers and creeks impaired for one or more of the following: fecal coliform, excess ammonia, low dissolved oxygen, and turbidity • 1 lake impaired for excess nutrients

Red River of the North River Basin (175 individual TMDL reports needed) • 22 rivers and creeks impaired for one or more of the following: impaired biota (fish and/or invertebrates), low dissolved oxygen, fecal coliform, mercury, turbidity, excess ammonia, and PCBs • 45 lakes impaired for one or more of the following: excess nutrients and mercury in the water column and/or fish tissue
Rainy River Basin (300 individual TMDL reports needed) • 8 rivers and creeks impaired for one or more of the following: low dissolved oxygen and mercury • 254 lakes impaired for one or more of the following: mercury or PCBs in the water column and/or fish tissue or excess nutrients
Missouri River Basin (23 individual TMDL reports needed) • 6 rivers and creeks impaired for one or more of the following: turbidity, fecal coliform, mercury, excess ammonia, and low dissolved oxygen • 2 lakes impaired for one or more of the following: excess mercury in fish tissue and excess nutrients