ISSUE PAPER "H"

Potential Stormwater Hotspots, Pollution Prevention, Groundwater Concerns and Related Issues
V.3 (final)

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To: Minnesota Stormwater Manual Sub-Committee

From: CWP and EOR

I. INTRODUCTION AND RECOMMENDATIONS

This Issue Paper addresses a series of "grab bag" issues that are important to cover in the Manual, but that are difficult, due to their unique subject matter, to incorporate into future Issue Paper format. The Issue Paper is organized into six sections as follows:

I. Introduction
II. BMP Constraints and Design Criteria for Special Soil Conditions
III. Potential Stormwater Hotspots
IV. Industrial NPDES Stormwater Requirements
V. Guidance on Infiltration of Runoff From Potential Stormwater Hotspots
VI. BMP Sediment Quality, Testing and Disposal Guidelines

To a large extent each topic area stands on its own. However, if there is a common thread across the areas it relates to protecting groundwater and designing sites and stormwater practices as a function of groundwater-related constraints. Rather than having an executive summary with key recommendations as past Issue Papers have, this paper provides such recommendations within the individual topic section.

It is important to note that these topics involve several challenging stormwater management issues that do not always have clear or universal answers and which do not always lend themselves to a strict regulatory approach. Rather, many of these topics require thoughtful consideration by designers and plan reviewers to ensure that the most appropriate structural and nonstructural measures are implemented at a site. Finding the best solutions for these unique site constraints often requires a collaborative approach between designer and regulator. With that in mind, the project team envisions much of the content presented in this Issue Paper will appear in various locations of the Manual as "technical assistance" material.

This Issue Paper is not intended to prompt any direct regulatory reform, but it will hopefully be a useful document to reference in the future when permits are being renewed and regulations are being revisited. Under each of the major topics, the project team poses a handful of "issue questions" that are intended to promote discussion and exchange on some of the challenging aspects of the subject matter covered in this Issue Paper. It is probably unrealistic to fully resolve all of the issues in the current Manual effort, but we can at least be aware of them and think about how best to address them at the appropriate time.

II. BMP CONSTRAINTS AND DESIGN CRITERIA FOR SPECIAL SOIL CONDITIONS

Background

Certain regions of Minnesota contain challenging physiographic features that require thoughtful stormwater design. Specifically, the following three conditions merit special attention:

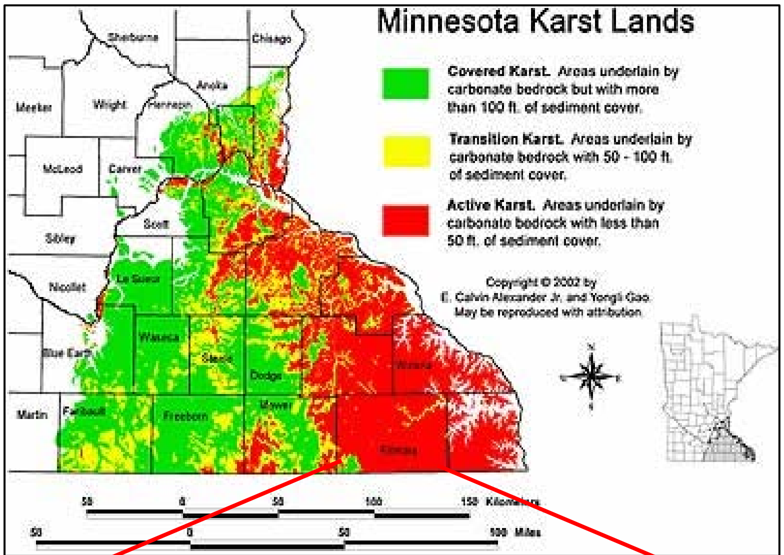
- Karst
- Bedrock and shallow soils
- Soil with low infiltration capacity

Karst regions are predominantly found in the southeastern portion of the state (Figure 1a) and have important implications with respect to geotechnical testing, infiltration, pretreatment and ponding of runoff. Figure 1b shows that caution must be used in interpreting the geographic depiction of "Karst lands". The figure shows the difference in a generalized map (1a) of "active" karst versus a county-scale map (1b) of actual karstic features.

Bedrock and shallow soils are found in many portions of the state, but are a particular problem in the northeastern region of the state (Figure 2). The stormwater management implications of shallow bedrock affect infiltration, ponding depths, and the use of underground practices.

Soils with low infiltration capacity are found throughout the state. Details of where to find soils that can and cannot be used for infiltration systems should begin with available county soil surveys, most of which are available digitally (Figure 3). However, these surveys are not accurate enough to determine site specific characteristics suitable for infiltration systems, so a detailed site analysis is recommended. Stormwater management limitations in areas with "tight" soils generally preclude large-scale infiltration and groundwater recharge (infiltration that passes into the groundwater system). These soils will typically be categorized under Hydrologic Soil Group (HSG) D and have other characteristics as shown in Table 1. The infiltration rates noted in Table 1 are conservative estimates of long-term, sustainable infiltration rates that have been documented in Minnesota. They are based on in-situ measurement within existing infiltration practices in Minnesota, rather than national numbers or rates based on laboratory columns.

Figure 1a. Minnesota Karst Lands (Alexander and Gao, 2002)



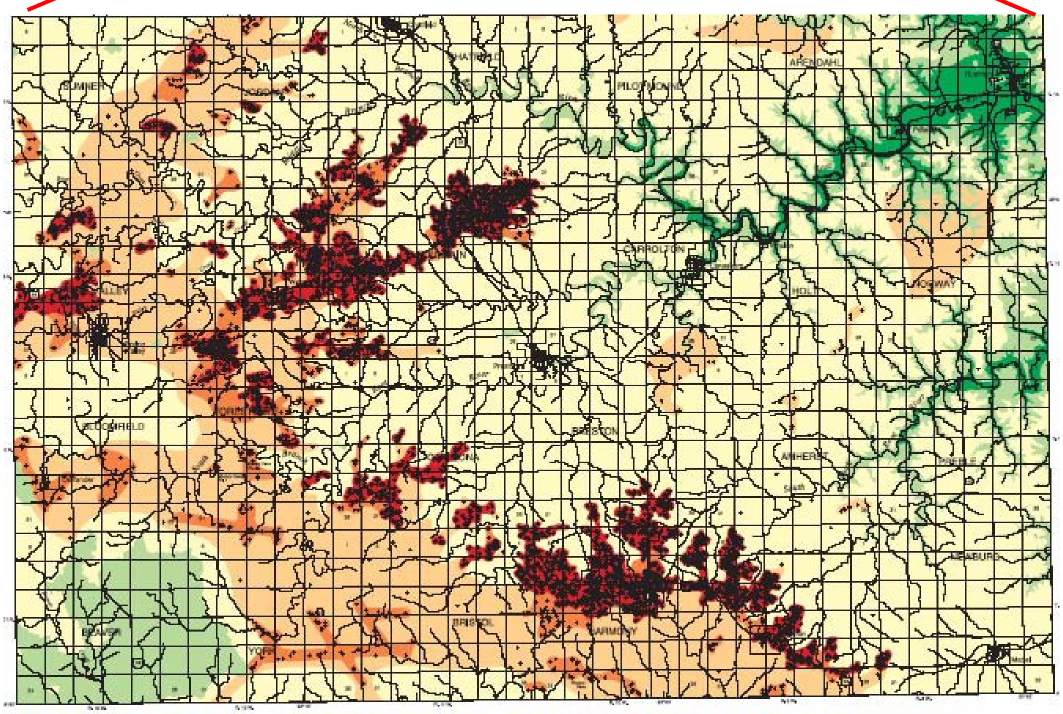


Figure 1b. Fillmore County Geologic Atlas (red and orange shades indicate varying likelihood of underlying karst geology) (Minnesota Geological Survey).

Figure 2. Bedrock Outcroppings Areas in Northern Minnesota

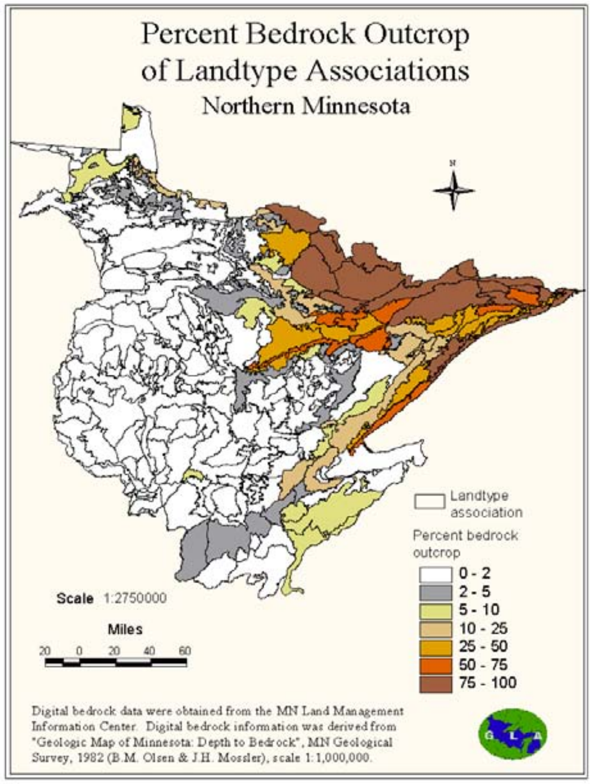


Figure 3. Availability of Digital Soil Surveys in Minnesota

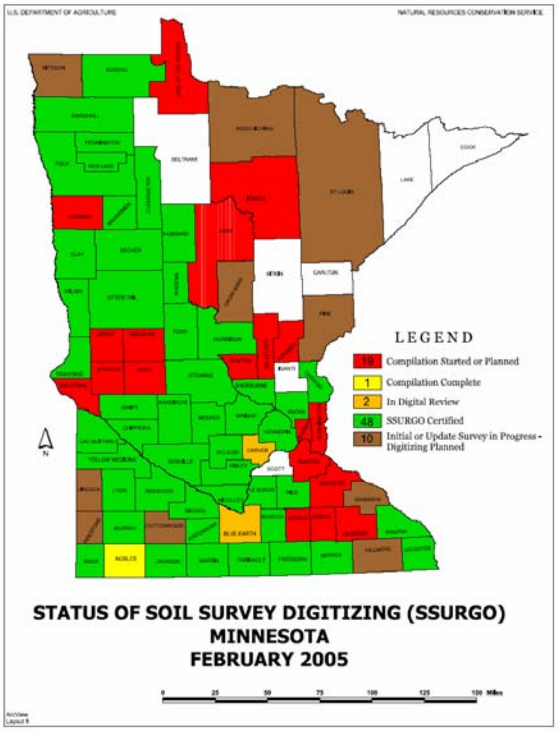


Table 1. Infiltration Rates of Hydrologic Soil Group Classifications (Browns Creek Watershed District).

Hydrologic Soil Group	**Infiltration Rate** [inches/hour]	**Soil Textures**	**Corresponding Unified Soil Classification**
A	1.0 – 0.6	Sand, loamy sand or sandy loam	**GW -** Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW -** Well-graded, gravelly sands **SP -** Gap-graded or uniform sands, gravelly sands
B	0.6 – 0.3	Silt loam or loam	**SM -** Silty sands, silty gravelly sands **MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.3 – 0.1	Sandy clay loam	**ML -** Silts, very fine sands, silty or clayey fine sands
D	< 0.1	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

Karst

In karst settings where karstic conditions are known to exist (see Figures 1a and 1b), additional constraints and considerations need to be evaluated prior to implementing most structural BMPs. Of particular concern in karst settings is the formation of sinkholes as a result of hydraulic head build up and/or dissolution of carbonate rock (i.e., limestone) present underneath or adjacent to BMPs. Where karst conditions exist, there are no prescriptive rules of thumb or universally accepted management approaches because of the variability intrinsic to karst terrain. An adaptation of a familiar old saying is very appropriate: the only thing predictable about the behavior of water in a karst system is its unpredictability.

In general when underlying karst is known or even suspected to be present at the site, stormwater runoff should not be concentrated and discharged into known sinkholes, but should rather be dispersed, or soaked into the ground after adequate pre-cleaning, or conveyed to a collection and transmission system away from the area via vegetated areas. In other cases, it may be impossible to remove water from an area with sinkholes or away from karst geology, so common sense clean-up of the water and discharge into the karstic area is a reasonable management approach, especially if some filtering soil is available between the land surface and the karst formation.

Some communities around the country have developed karst area design specifications and soil investigation procedures for siting and designing stormwater BMPs. The following sections represent adaptations from a handful of these communities (e.g., Carroll County, MD [1996a and b]; St. Johns River Water Management District, FL [2001]; and Jefferson County, WV [Laughland 2003]) and should be viewed as a potential starting point for the Manual Sub-Committee and MPCA staff to consider. That is, the complete Minnesota experience is not represented by these resources, but they do represent products that have been put together to assist local stormwater managers deal with karst problems. Additional input was obtained from Professor Calvin Alexander (University of Minnesota) and Jeff Green (Minnesota DNR).

Note that Figure 1a displays three depictions of karst terrain from Professor Alexander. The category under "Covered" karst will likely not need any special stormwater management provisions because of the +100-foot sediment cover. The middle category of "Transition" karst is when caution should begin (but not necessarily always lead to action) to shift to stormwater management provisions intended to protect groundwater. The final category of "Active" karst (less than 50-feet of cover) is when special attention should be paid. Figures 1a and 1b show why generalized maps of differing categories cannot be used with exact geographic accuracy. For this reason, state, county and local information sources (such as Figure 1b) and regulations should be checked before assuming which of the three categories exist in the location of interest. Factors such as location within a drinking water source protection area, the nature of soil cover between the surface and the karst zone, and the karstic nature (or lack of karst) of the carbonate bedrock should be considered when determining the level of geotechnical study needed prior to construction or stormwater management.

General Stormwater Management Guidelines for Karst Areas

The following general guidelines are based on advice offered by many different sources. Again, the uncertainty characteristic of karst terrain and water movement should be the primary dictate when considering how much additional information to collect in these areas before proceeding with BMP installation. The following guidelines do not contain substantial prescriptive information because of the variability inherent to karst geology in Minnesota.

1. Developers, communities, public works agents and others managing stormwater should conduct thorough geotechnical investigations prior to proceeding with projects or building in active karst areas. The level of geotechnical investigation will depend on the likelihood of active karst being present and the regulatory requirements within the area. They should identify the karst features encountered and report to the appropriate state (such as DNR and MGS) and local agencies (such as the city, township or county) any existing sinkholes on a piece of land intended for development. These known occurrences should be surveyed for specific location and permanently recorded on the property deed. For transition karst areas, local discretion and the likelihood of karstic features should be used to determine the amount of geotechnical investigation.
2. Knowledge of the presence of sinkholes is an absolute indication of active karst. In these cases, an easement or reserve area should be identified on the development plats for the project so that all future landowners know of the presence of active karst on their property.
3. In many cases, identified sinkholes can and should be remediated and stormwater directed away. In other cases, remediation is not possible and the normal regional hydrologic patterns must be maintained. In this case, however, precautions should be taken to pre-treat any water that drains into a known sinkhole area. If at all possible, runoff should be routed away from active karst features because of the possibility of subsurface flow into the karst formation.
4. BMPs should be designed off-line to better manage volumes and flow rates from individual facilities.
5. Discharges from stormwater management facilities or directly from impervious surfaces should not be routed directly to the nearest sinkhole. Because active karst areas can be quite large in Minnesota, discharges may be routed to a baseflow stream via a pipe or lined ditch or channel to remove flow from the area, provided the stream does not disappear into an active karst feature.
6. Sinkholes developing within stormwater management facilities should be reported as soon as possible after the first observation of occurrence. They should then be repaired, abandoned, adapted, managed and/or observed for future changes, whichever of these are appropriate for "proper management".
7. Sinkhole formation is less likely when water is allowed to soak diffusely into the soil and when stormwater is managed for smaller, more diffuse quantities that limit the volume and rates of flow handled by each BMP. Practices such as swales, bioretention, and vegetated filters should be considered first at a site. However, not all sites lend themselves to this type of management approach and could require use of the active karst region for proper management. Under these conditions, adequate precautions should be taken to assure that all potential contaminants are removed from the infiltrating stormwater.
8. Where ponds and wetlands are deemed necessary, they should be designed and constructed with a properly engineered synthetic liner. A minimum of three feet (ten feet is preferred) of unconsolidated soil material should exist between the bottom of the pond

or wetland and the surface of the carbonate rock layer. Pond and wetland depths should be fairly uniform and limited to no more than ten feet in depth.

Table 2 provides an overview of karst related design considerations for the five practice groups identified in Issue Paper A.

Table 2. Structural BMP Use in Karst Settings

BMP		Karst Considerations*
Bioretention		• If contaminant levels remain high after treatment or if water inflow presents a threat, an underdrain and/or use of a synthetic or other impermeable membrane liner should be considered to seal the bottom of the system
Filtration	**Media**	• See the note above
	Vegetative	• Avoid water ponding • Should be engineered to avoid channel erosion and optimize pollutant removal
Infiltration	**Infiltration Trench**	• Not typically recommended in active karst areas due to sinkhole formation and inadequate treatment by a scarcity of underlying soils • If used, should have supporting geotechnical investigations and calculations • Pretreatment should be extensive to limit risk of groundwater contamination • Local review authority should be consulted for approval
	Infiltration Basin	
Ponds		• Should be constructed with a synthetic or clay liner in active karst areas • Should have supporting geotechnical investigations and calculations • Should be limited to a maximum ponding depth (e.g., < 10 feet)
Stormwater Wetlands		• Should be constructed with a synthetic or clay liner in active karst areas • Should have supporting geotechnical investigations and calculations • Should be limited to a maximum ponding depth (e.g., < 10 feet)

* Many of these recommendations will be dictated by the findings of the geotechnical study done at the site by qualified and experienced personnel, and will be a reflection of the type of karst exposure likely.

Investigation for Karst Areas

Karst investigations are recommended for all stormwater facilities that are located in an active karst area with known karstic features (sinkholes, solution cavities, direct hydraulic connection between surface water and groundwater). The purpose of a karst investigation is to identify subsurface voids, cavities, fractures, or other discontinuities which could pose an environmental concern or a construction hazard to an existing or proposed stormwater management facility. Of special concern is preventing the possibility that an unimpeded route will be provided to move polluted runoff into the regional groundwater system. The guidelines outlined below should not be interpreted as all-inclusive. The design of any geotechnical investigation should reflect the size and complexity of the proposed project, as well as local knowledge of the threat posed by the karstic geology.

Because of the complexity inherent to active karst areas, there is no single set of investigatory guidelines that works for every location. Typically, however, the sequence involves some visual observation for the presence of sinkhole features (the single easiest evidence that active karst is present), followed by an assessment of the subsurface heterogeneity (variability) of the site through geophysical investigation and/or excavation. With this information in-hand, borings or observation wells can then be accurately installed to obtain vertical data surrounding or within a karst feature. The following sections describe general guidance that may or may not be used depending upon the local situation and information deemed as needed.

<u>Subsurface Material</u>
The investigation should determine the nature and thickness of subsurface materials, including depth to bedrock and the water table. Subsurface data may be acquired by backhoe excavation and/or soil boring. These field data should be supplemented by geophysical investigation techniques deemed appropriate by a qualified professional, which will show the location of karst formations under the surface. This is an iterative process that might need to be repeated until the desired detailed knowledge of the site is obtained and fully understood. The data listed below should be acquired under the direct supervision of a qualified and experienced karst scientist. Pertinent site information to collect includes the following:

1. Bedrock characteristics (ex. type, geologic contacts, faults, geologic structure, rock surface configuration).
2. Soil characteristics (ex. type, thickness, mapped unit, geologic source/history).
3. Photo-geologic fracture trace map.
4. Bedrock outcrop areas.
5. Sinkholes and/or other closed depressions.
6. Perennial and/or intermittent streams, and their flow behavior (ex. a stream in a karst area that loses volume could be a good indication of sinkhole infiltration).

<u>Geophysical and Dye Techniques</u>
There are many different techniques available to “view” the nature of the subsurface in karst areas. These techniques can be used to detect the presence of karst features or to collect additional data on the character of a known feature. Stormwater managers in need of subsurface geophysical surveys are encouraged to obtain the services of a qualified geophysicist experienced in karst geology. Some of the geophysical techniques available for use in karst terrain include: seismic refraction, ground-penetrating radar, electric resistivity.

The surest way to determine the flow path of water in karst geology is to inject dye into the karst feature (sinkhole or fracture) and watch to see where it emerges, usually from a spring. The emergence of a known dye from a spring grants certainty to a suspicion that groundwater moves in a particular pattern. Dye tracing can vary substantially in cost depending upon the local karst complexity, but it can be a reasonably priced alternative, especially when the certainty is needed.

<u>Location of Borings</u>
Once the character of the cover material is know and understood, borings can be used to obtain the details of the subsurface karst features at specific locations. It must be noted, however, that

the local variability typical of karst areas could mean that a very different subsurface could exist a very small distance away, perhaps as little as six-inches. To accommodate this variability, the number and type of borings must be carefully assessed. If the goal is to locate a boring down the center of a sinkhole, the previous geophysical tests or excavation results can show the likely single location to achieve that goal. If the goal is to "characterize" the entire site, then an evaluation needs to occur to determine the number and depth needed to adequately represent the site. Again, the analyst must acknowledge the extreme variability and recognize that details can easily be missed. Some general guidance for locating borings include:

1. Getting at least one boring in each geologic unit present, as mapped by the Minnesota (MGS) and U.S. Geological Surveys (USGS) and local county records;
2. Placing an adequate number as determined by a site investigation near on-site geologic or geomorphic indications of the presence of sinkholes or related karst features;
3. Locating along photo-geologic fracture traces;
4. Locating adjacent to bedrock outcrop areas;
5. Locating a sufficient number to adequately represent the area under any proposed stormwater facility; and
6. Documenting any areas identified as anomalies from any existing geophysical or other subsurface studies.

Number and Depth of Borings

The number and depth of borings will depend entirely upon the results of the subsurface evaluation obtained from the observational, geophysical, and excavation studies, and other borings. There are no prescriptive guidelines to determine the number and depth of borings. These will have to be determined by the qualified staff conducting the BMP management evaluation based upon the data needs of the installation. The borings must extend well below the bottom elevation of the designed BMP, however, to make sure that there are no karst features that will be encountered or impacted as a result of the installation.

Identification of Material

All material identified by the excavation and geophysical studies and penetrated by the boring should be identified, as follows:

1. Description, logging, and sampling for the entire depth of the boring.
2. Any stains, odors, or other indications of environmental degradation.
3. A minimum laboratory analysis of two soil samples, representative of the material penetrated including potential limiting horizons, with the results compared to the field descriptions.
4. Identified characteristics should include, as a minimum: color; mineral composition; grain size, shape, sorting and degree of saturation.
5. Any indications of water saturation should be carefully logged, to include both perched and groundwater table levels, and descriptions of soils that are mottled or gleyed* should be provided. Be aware that groundwater levels in karst can change dramatically in short periods of time and will not necessarily leave mottled or gleyed evidence.
6. Water levels in all borings should be recorded over a time-period reflective of anticipated water level fluctuation. That is, water levels in karst geology can vary dramatically and

rapidly. The boring should remain fully open to a total depth reflective of these variations and over a time that will accurately show the variation. Be advised that to get a complete picture, this could be a long-term period. Measurements could of course be collected during a period of operation of a BMP, which could be adjusted based on the findings of the data collection.

7. When conducting a standard penetration test (SPT), estimation of soil engineering characteristics, including "N" or estimated unconfined compressive strength, should be reported.

* Mottled – Soil marked with irregular brown and gray/black colors indicative of poor drainage and routine saturation cycles
Gleyed - A blue-gray, sticky, compacted soil, usually indicative of saturated conditions

Evaluation

At least one subsurface cross section should be provided for the BMP installation, showing confining layers, depth to bedrock, and water table (if encountered). It should extend through a central portion of the proposed installation, using the actual geophysical and boring data. A sketch map or formal construction plan indicating the location and dimension of the proposed practice and line of cross section should be included for reference, or as a base map for presentation of subsurface data.

Sinkhole Remediation

There are several approaches to sinkhole remediation if it is found that such an approach is desirable. Sinkhole sealing involves investigation, stabilization, filling and final grading. In the investigation phase, the areal extent and depth of the sinkhole(s) should be determined. The investigation may consist of excavation to bedrock, soil borings, and/or geophysical studies. Sealing small-sized sinkholes is normally achieved by digging out the sinkhole to bedrock, plugging the hole with concrete, installing several impermeable soil layers interspersed with plastic or geotextile, and crowning with an impermeable layer and topsoil. For moderate sinkholes, an engineered subsurface structure is usually required.

It is often not feasible to seal large sinkholes so other remediation options must be pursued. These could include construction of a low-head berm around the sinkhole, clean-out of the sinkhole to make sure all potentially contaminating materials are removed, landscaping and conversion of land use in the sinkhole to open space or recreation, provided it can be done in a manner that provides adequate safety. In any of these cases, pre-treatment of any stormwater entering the sinkhole is imperative. Final grading of sinkholes in open space settings should include the placement of low permeability topsoil or clay and a vegetative cover, with a positive grade maintained away from the sinkhole location to avoid ponding or infiltration, if feasible.

Monitoring of BMPs in Karst Regions

A water quality monitoring system installed, operated and maintained by the owner/operator may be desirable or even required under some circumstances, particularly where drinking water supplies are derived from groundwater or in association with known sources of contamination. The location of monitoring wells or BMP performance monitoring will again depend upon the nature of the BMP and surrounding karst characteristics. As with all nonpoint source related monitoring, the capture of runoff events is the key goal. In karst areas, this could mean the installation of a monitoring system designed to reflect variable water behavior typical of karst water flow. Attempting to monitor this behavior without a thorough understanding of the local geology will be difficult and could lead to a wasted effort.

Shallow Bedrock and Groundwater

Sites with shallow bedrock or groundwater (defined for the purpose of this paper as bedrock within six feet or less of ground surface and groundwater less than three feet below the ground surface) present a host of challenges to the design engineer. However, these challenges can be managed and designed to. Similar to karst, there are general guidelines to consider when designing stormwater management practices in these areas, as presented below. Special caution for steep slopes and hidden bedrock fractures is urged.

General Stormwater Management Guidelines for Areas with Shallow Bedrock and Soils

1. Developers should conduct thorough geotechnical investigations in areas with defined shallow bedrock and soils when contact with the bedrock or lack of adequate soil depth could cause a stormwater-related problem.
2. A site geotechnical analysis similar to karst is recommended.
3. Where infiltration is used, practice depths will be limited. In fact, infiltration may be altogether infeasible at the site if a minimum three foot separation between the bottom of the practice and bedrock cannot be achieved.
4. Design specifications for allowable ponding depths (i.e., live storage) in filters, swales, and bioretention should be considered to up to 12 inches (typical allowable depths range from six to nine inches). This will help reduce the required surface area of these facilities.
5. Underground practices such as filters will be possible but very expensive if blasting required.
6. Potential Stormwater Hotspot (PSH) infiltration may not be desirable due to potential for connections with bedrock fracture zones (see Section III for a detailed discussion of PSHs).
7. Stormwater wetlands will have greater potential than ponds for larger storage facilities due to limitation on ponding depths. However, this means larger surface area to drainage area ratios will be required.
8. Engineered soil compost amendments may be required where soils are less than three feet deep to be eligible for certain stormwater credits (see Paper F for credits discussion, specifically Credits D and E, Surface Impervious Cover Disconnection and Rooftop Disconnection, respectively).

Table 3 provides an overview of shallow bedrock and soil related design considerations for the five practice groups identified in Issue Paper A.

Table 3. Structural BMP Use in Shallow Bedrock and Soil Settings

BMP		Shallow Bedrock and Soil Considerations
Bioretention		• Should be constructed with an underdrain if minimum separation distance of three feet is not present between practice bottom and bedrock
Filtration	**Media**	• Recommended practice in areas of shallow bedrock and soil • Can be located in bedrock, but will be expensive due to blasting
	Vegetative	• Recommended practice in areas of shallow bedrock and soil • Dry swales with engineered soil media will need an underdrain if minimum separation distance of three feet is not present between practice bottom and bedrock
Infiltration	**Infiltration Trench** **Infiltration Basin**	• Will be limited due to minimum separation requirement. Surface area to depth ratios of practices may need to be larger. Arch pipe and other perforated storage "vault" practices can help increase treatment volumes within limited spaces. • If used, should have supporting geotechnical investigations and calculations • Use with PSHs should be carefully considered. Pretreatment should be extensive to limit risk of groundwater contamination • Local review authority should be consulted for approval
Ponds		• Will have depth limitation to consider, making surface areas larger for a given storage volume • Shallower depths may be undesirable from an aesthetic standpoint, particularly if wide fluctuations in water level are expected • Bedrock should act like a liner and help to maintain a permanent pool, unless fracture zone is present
Stormwater Wetlands		• Applied more easily than ponds, but will also require larger surface area to drainage area ratios. • Bedrock should act like a liner and help to maintain a permanent pool, unless fracture zone is present

Investigation for Shallow Bedrock Areas

Geotechnical investigations are recommended for all proposed stormwater facilities located in regions with shallow bedrock and soils. The recommended approach is similar to those for karst areas. The purpose of the investigation is to identify subsurface conditions which could pose an environmental concern or a construction hazard to a proposed stormwater management practice. The guidelines outlined below should not be interpreted as all-inclusive. The design of any subsurface investigation should reflect the size and complexity of the proposed project.

<u>Subsurface Material</u>

The investigation should determine the nature and thickness of subsurface materials, including depth to bedrock and to the water table. Subsurface data may be acquired by backhoe excavation and/or soil boring. These field data should be supplemented by geophysical investigation techniques deemed appropriate by a qualified professional, which will show the location of bedrock formations under the surface. The data listed below should be acquired under the direct supervision of a qualified geologist, geotechnical engineer, or soil scientist who is experienced in conducting such studies. Pertinent site information shall be collected which should include the following:

1. Bedrock characteristics (type, geologic contacts, faults, geologic structure, rock surface configuration).
2. Soil characteristics (type, thickness, mapped unit).
3. Bedrock outcrop areas.

Location of Borings

Borings should be located in order to provide representative area coverage of the of the proposed BMP facilities. The location of borings should be:

1. In each geologic unit present, as mapped by the Minnesota (MGS) and U.S. Geological Surveys (USGS) and local county records;
2. Next to bedrock outcrop areas (e.g., within ten feet);
3. Near the edges and center of the proposed practice and spaced at equal distances from one another; and
4. Near any areas identified as anomalies from any existing geophysical studies.

Number of Borings

The number of recommended borings are:

1. Infiltration trenches, bioretention, and filters - a minimum of 2 per practice.
2. Ponds/wetlands - a minimum of three per practice, or three per acre, whichever is greater.
3. Additional borings - to define lateral extent of limiting horizons, or site specific conditions, where applicable.

Depth of Borings

Borings should be extended to depths as follows:

- A minimum depth of 5 feet below the lowest proposed grade within the practice unless auger/backhoe refusal is encountered.

Identification of Material

All material penetrated by the boring should be identified, as follows:

1. Description, logging, and sampling for the entire depth of the boring.
2. Any stains, odors, or other indications of environmental degradation.
3. A minimum laboratory analysis of two soil samples, representative of the material penetrated including potential limiting horizons, with the results compared to the field descriptions.
4. Identified characteristics should include, as a minimum: color; mineral composition; grain size, shape, and sorting; and saturation.
5. Any indications of water saturation should be carefully logged, to include both perched and groundwater table levels, and descriptions of soils that are mottled or gleyed should be provided.

6. Water levels in all borings should be taken at the time of completion and again 24 hours after completion. The boring should remain fully open to total depth of these measurements.
7. When conducting a standard penetration test (SPT), estimation of soil engineering characteristics, including "N" or estimated unconfined compressive strength.

Evaluation

At least one subsurface cross section through the proposed practice should be provided, showing confining layers, depth to bedrock, and water table (if encountered). It should extend through a central portion of the proposed practice, using the actual or projected boring data. A sketch map or formal construction plan indicating the location and dimension of the proposed practice and line of cross section should be included for reference, or as a base map for presentation of subsurface data.

Shallow Depth to Groundwater (provided by MPCA staff)

There is a large portion of the state (more than 50%) where the groundwater is located less than three feet from the surface. In these areas it may be impossible to get the three feet of separation from the bottom of an infiltration practice and the seasonally saturated groundwater table required under the NPDES Construction General Permit. Other treatment methods need to be considered in these areas.

When constructing a pond that will likely intercept the groundwater table, a close examination of the land uses that will contribute runoff to the pond should be the first step in the design process. If a potential stormwater hotspot (see Section III) is identified as a contributor then it is the recommendation of the MPCA that the pond include a liner to protect against groundwater contamination.

MPCA is often asked why it would allow a sedimentation pond (no liner) to be constructed that may intercept the water table, but require a minimum of three feet of separation from the bottom of any constructed infiltration practice and the water table. The treatment processes for these two practices are very different and may help to explain the requirements. A sedimentation pond achieves treatment of stormwater runoff through the act of settling out suspended solids before the discharge point. If the basin is large enough and has a long detention time, additional treatment through biological uptake and microbial action can also occur. An infiltration practice removes pollutants through filtering that occurs in the three foot soil layer beneath the practice along with the biologic and microbial activity that takes place in the layer under aerobic conditions. The soils under the practice need time between events to aerate so they function hydraulically as well as provide aerobic treatment.

Soil with Low Infiltration Capacity

Sites with poorly infiltrating soils (defined in this paper as soils with infiltration rates less than 0.2 inches per hour) limit the number of practices that can used for stormwater management on a site or specific area of a site. Certain watershed organizations in Minnesota do not allow the use (or strongly discourage the use) of infiltration practices where soil infiltration capacity is low. This does not mean, however, that these “tight” soils don’t have any infiltration and recharge capabilities. So it may be possible for sites to meet recharge objectives so long as appropriate design modifications have been incorporated.

General guidelines to consider when designing stormwater management practices in areas with poor infiltration capacity are presented below.

General Stormwater Management Guidelines for Sites with Low Infiltration Capacity Soils

1. Local soil surveys should be used for preliminary determination of infiltration capacity of site soils; however, on-site soils testing is recommended to accurately characterize on site soils if local soils surveys characterize site soils as either HSG C or D.
2. Recharge criteria, if applicable, can still be met using infiltration practices or modified filter designs (Figures 4 and 5), so long as they are appropriately designed.
3. Soil compost amendments may be required to increase pervious area storage and filtration rates for sites with HSG C and D soils that are expected to receive either rooftop or surface IC disconnection in accordance with certain stormwater credits (see Paper F for credits discussion, specifically Credits D and E, Surface Impervious Cover Disconnection and Rooftop Disconnection, respectively).
4. Where volume reduction is a primary objective for a site (e.g., potentially a watershed-based goal due to channel erosion, nuisance flooding, or inadequate infrastructure capacity), emphasis should be placed on practices that promote runoff reuse and evapotranspiration such as cisterns, rain barrels, greenroofs, rain gardens, and bioretention.

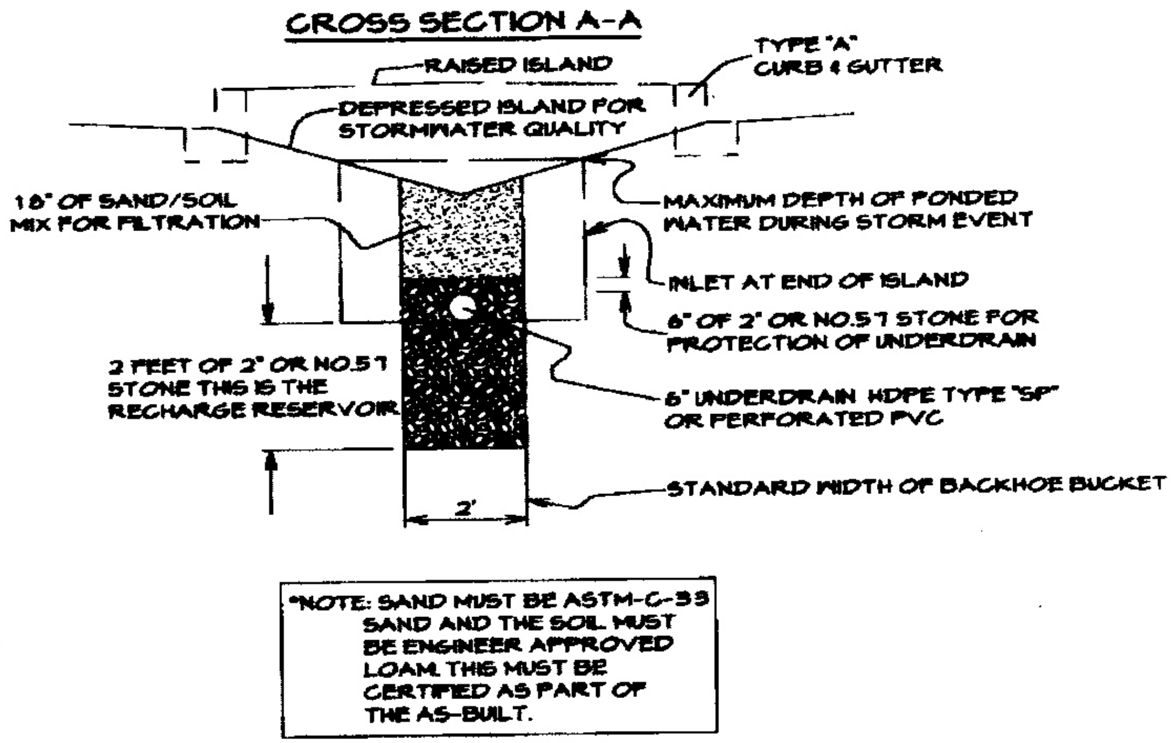


Figure 4. Modified Sand Filter Design (Covington, 2002). Note that this graphic will be revised in the Manual to reflect applicable Minnesota standards.

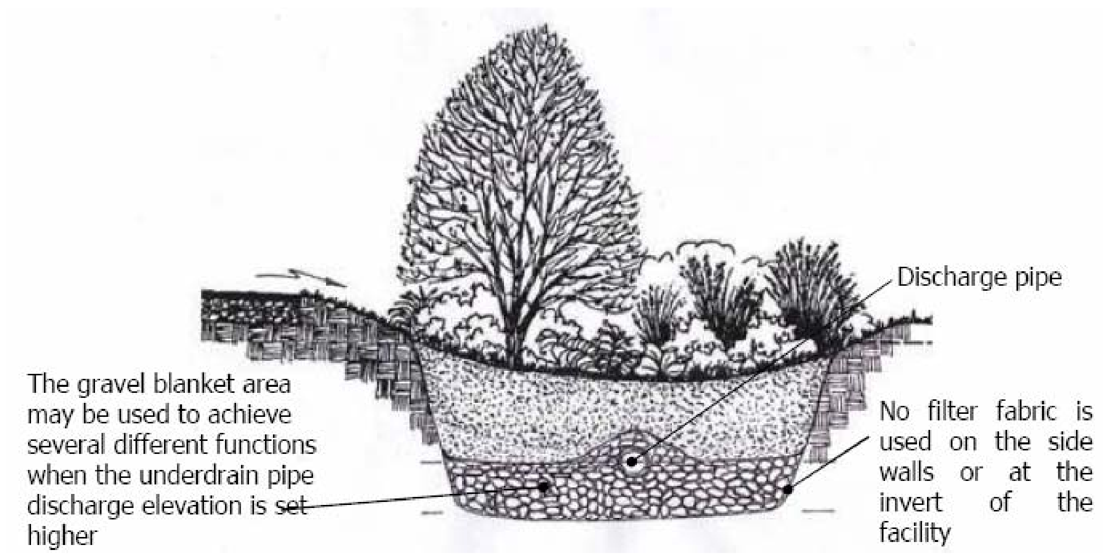


Figure 5. Bioretention with Infiltration Gallery (Prince George's County, 2002).

Table 4 provides an overview of low infiltration capacity soil related design considerations for the six practice groups identified in Issue Paper A.

Table 4. Structural BMP Use in Soils with Low Infiltration Capacity

BMP		Low Infiltration Capacity Soil Considerations
Bioretention		• Should be constructed with an underdrain. Recharge criteria, if applicable, can be met by modifying the design to include an infiltration gallery below the underdrain, so long as it is appropriately sized (Figure 5).
Filters	**Media**	• Recommended practice in "tight" soils. Some design variants can be modified to incorporate an infiltration gallery that can help meet recharge criteria, if properly sized (Figure 4).
	Vegetative	• Recommended practice in areas of shallow bedrock and soil • Dry swales with engineered soil media will need an underdrain if minimum separation distance of three feet is not present between practice bottom and bedrock
Infiltration	**Infiltration Trench**	• Not recommended as a practice • Soils analysis should be conducted to confirm limiting aspects of soil profile.
	Infiltration Basin	
Ponds		• Acceptable practice with "tight"soils. Soils should help maintain permanent pool.
Stormwater Wetlands		• Acceptable practice with "tight" soils. Soils should help maintain permanent pool if practice is not tied into groundwater table. • Compost amendments may be necessary to establish suitable planting beds.

Investigation for Low Infiltration Capacity Soils

Soil testing is recommended for all proposed stormwater facilities that plan to have a recharge or infiltration component to their design. Testing can be less rigorous than that for karst areas or sites with shallow bedrock and soils. The purpose of the testing is to identify and confirm the soil characteristics and determine their suitability, if any, for infiltration practices. The guidelines outlined below should not be interpreted as all-inclusive. The design of any subsurface investigation should reflect the size and complexity of the proposed project.

<u>Location of Borings</u>

Borings should be located in order to provide representative area coverage of the of the proposed BMP facilities. The location of borings should be:

1. In each geologic unit present, as mapped by the Minnesota (MGS) and U.S. Geological Surveys (USGS) and local county records;
2. Near the edges and center of the proposed practice and spaced at equal distances from one another; and

3. Near any areas identified as anomalies from any existing geophysical studies.

Number of Borings

The number of recommended borings are:

1. Infiltration trenches, bioretention, and filters - a minimum of 2 per practice.
2. Ponds/wetlands - a minimum of three per practice, or three per acre, whichever is greater.
3. Additional borings - to define lateral extent of limiting horizons, or site specific conditions, where applicable.

Depth of Borings

Borings should be extended to depths as follows:

- A minimum depth of 5 feet below the lowest proposed grade within the practice unless auger/backhoe refusal is encountered.

Identification of Material

All material penetrated by the boring should be identified, as follows:

1. Description, logging, and sampling for the entire depth of the boring.
2. Any stains, odors, or other indications of environmental degradation.
3. A minimum laboratory analysis of two soil samples, representative of the material penetrated including potential limiting horizons, with the results compared to the field descriptions.
4. Identified characteristics should include, as a minimum: color; mineral composition; grain size, shape, and sorting; and saturation.
5. Any indications of water saturation should be carefully logged, to include both perched and groundwater table levels, and descriptions of soils that are mottled or gleyed should be provided.
6. Water levels in all borings should be taken at the time of completion and again 24 hours after completion. The boring should remain fully open to total depth of these measurements.

Infiltration Rate Testing

Soil permeabilities should be determined in the field using the following procedure (MDE, 2000), or an accepted alternative method.

a. Install casing (solid 6 inch diameter) to 36” below proposed practice bottom.

b. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester’s discretion, a two-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring. Fill casing with clean water to a depth of 36” and allow to pre-soak for up to twenty-four hours.

c. Refill casing with another 36” of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate should be reported in inches per hour.

d. May be done through a boring or open excavation.

e. The location of the test should correspond to the practice location.

f. Upon completion of the testing, the casings should be immediately pulled, and the test pit should be back-filled.

Issues

Issue II.1. How should the Manual address hydrologic modeling and large storm criteria compliance in karst regions, if at all? Hydrologic effects in karst areas have been studied in some detail nationwide. The disappearance of surface water flow into karst terrain means that less volume of water might need to be treated in a runoff management practice, depending upon whether the water resurfaces later down-gradient. Translated to storage requirements associated with the unified stormwater sizing criteria, this implies more storage may be asked for than actually needed to meet stormwater management requirements. During Manual Sub-committee discussion it was noted that this condition could also exist in many parts of Minnesota not impacted by karst, so full coverage will occur in the Manual's hydrologic modeling sections.

Issue II.2: Problems with stormwater containment and routing in portions of the state underlain by karstic geology could result in groundwater contamination of public and domestic drinking water supplies, especially if a PSH is the source of the water. What additional protections, if any, are needed for the state and local units to adequately assess the risk and protect against this type of contamination commensurate with that risk? MPCA noted that it coordinates reviews of Construction General Permit reviews with MDH for this occurrence, and adjusts the requirements accordingly.

III. POTENTIAL STORMWATER HOTSPOTS

Background

Issue Paper E previously introduced the term "potential pollutant generating land uses" (PPGLUs), particularly as they relate to groundwater protection. This issue paper expands on these land uses and associated pollutant generating activities by looking in more depth at the broader considerations of stormwater management and source control at these sites.

For the purpose of this issue paper and in response to some feedback on the poor aesthetics and awkwardness of the term PPGLU, the project team proposes the use of the term Potential Stormwater Hotspot or "PSH" as a reasonable compromise between "stormwater hotspot" and "potential pollutant generating land uses." Designation as a PSH does not imply that a site *is* a hotspot but rather that the land use and associated on-site activities have the potential to generate higher pollutant runoff loads compared to other land uses. Designation as a PSH serves as a useful reminder to designers and reviewers that more careful consideration of the site is warranted. Ultimately, a PSH site designation may dictate that certain practices and/or design criteria are promoted or discouraged.

<u>Designation of PSHs</u>

PSHs are defined as commercial, industrial, institutional, municipal, or transportation-related operations (Figure 6) that produce higher levels of stormwater pollutants, and/ or present a higher potential risk for spills, leaks or illicit discharges (Schueler et al., 2004). Issue Paper E identified representative PSHs. Table 5 provides a more complete listing of potential PSHs associated by major land use category. A description of the major land use category is provided below. Note that some of these land uses fall under the requirements for Phase II NPDES industrial stormwater permits to be discussed in Section IV.

Figure 6: Five Types of PSHs

Table 5: Examples of Potential Pollutant Generating Land Uses (not all-inclusive)		
Land Use Category	**Land Use**	
Commercial	• Animal care services • Building material • Commercial car washes • Convenience stores • Laundries and dry cleaners • Lawn care companies • Gas stations	• Nurseries and garden centers • Petroleum wholesalers • Fast food restaurants • Shopping centers • Vehicle maintenance and repair • Wholesale food and beverage
Industrial (also see Section IV of this paper)	• Auto recyclers • Boat building and repair facilities	• Recycling centers and scrap yards • Warehouses
Institutional	• Cemeteries • Churches • Colleges • Corporate office parks	• Hospitals • Private schools • Private golf courses
Municipal	• Composting facilities • Fleet storage and school bus depots • Landfills/solid waste facilities • Local streets and storm drains • Pesticide use in rights-of-way • Public golf courses	• Public schools • Public works yards • Maintenance depots • Solid waste facilities • Wastewater treatment plants
Transport Related	• Airports • Bus depots • Rental car lots • Railroad stations and associated maintenance facilities	• Ports • State and federal highways and associated maintenance facilities • Trucking companies and distribution centers

Commercial PSHs consist of a small group of businesses associated with a specific activity or operation that generates higher pollutant loads in a subwatershed. Each kind of commercial hotspot generates its own blend of storm water pollutants, which can include nutrients, hydrocarbons, metals, trash and pesticides. Commercial PSHs typically have a great deal of vehicle traffic, generate waste or wash water, handle fuel or repair vehicles, or store products outside. While commercial PSHs are quite diverse, they are often clustered together. Most commercial PSHs are unregulated, although a few are regulated under the NPDES industrial storm water permit program (see Section IV), by local ordinance or by federal/state law if they handle even small quantities of hazardous material.

Industrial PSHs are a major focus for pollution prevention if they use, generate, handle or store pollutants that can potentially be washed away in storm water runoff, spilled, or inadvertently discharged to the storm drain system. Each type of industrial PSH generates its own blend of storm water pollutants, but as a group, they generally produce higher levels of metals, hydrocarbons and sediment.

Many industrial operations are regulated under the NPDES industrial storm water permit program (see discussion below in Section IV), although individual owners or operators may be unaware of their permit status.

Institutional PSHs include larger, privately-owned facilities that have extensive parking, landscaping, or turf cover. In addition, institutions may contain fleet vehicles and large maintenance operations. By and large, institutional PSHs are not regulated. The most common pollutants generated by institutional PSHs are nutrients and pesticides applied to maintain grounds and landscaping. In addition, large parking lots can produce storm water runoff and associated pollutants, and are natural targets for storm water retrofitting. Institutional landowners can be important partners in subwatershed restoration, given the importance of their stewardship practices on the open lands they maintain.

Municipal PSHs include many local government operations that handle solid waste, wastewater, road and vehicle maintenance, bulk storage areas for road salt and sand, and yard waste. Many of these municipal operations are regulated PSHs in MS4 communities. Municipal PSHs must prepare the same pollution prevention plans and implement source control practices as any other regulated PSHs. Municipal PSHs can generate the full range of storm water pollutants, including nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash. It is common in Minnesota for each municipality and many commercial centers to store a stockpile of road salt. Although these piles are generally not subject to regulation unless they cause a documented water quality problem, MS4 municipal programs should take responsibility for managing these piles in a pollution free manner. Further discussion of salt pile management will occur in the snow management section of the Manual.

Transport-related uses are the last category of PSHs to consider. Many, but not all, transport-related uses are regulated PSHs. They tend to generate higher loads of hydrocarbons, metals, and sediment in storm water runoff, can be associated with large areas of impervious cover, and have extensive private storm drain systems. Fluid leakage from these sites can be a major source of contamination, as can the addition of sand and salt during the cold weather season.

Pollutant Generating Operations/Activities

Perhaps of more significant consideration, is an understanding of the types of pollutant generating activities that commonly occur in association with various PSH operations (Figure 7). Table 6 provides a summary of six common operations and a subset of related activities that can contribute to stormwater quality problems at a site. A more detailed description of each operation is provided below.

Figure 7: Six Common Operations to Assess at PSHs

Table 6: Polluting Activities Associated With Common PSH Operations	
PSH Operation	**Polluting Activity**
Vehicle Operations	• Improper disposal of fluids down shop and storm drains • Spilled fuel, leaks and drips from wrecked vehicles • Hosing of outdoor work areas • Wash water from cleaning • Uncovered outdoor storage of liquids/oils/batteries spills • Pollutant wash-off from parking lot
Outdoor Materials	• Spills at loading areas • Hosing/washing of loading areas into shop or storm drains • Wash-off of uncovered bulk materials and liquids stored outside, of particularl concern in MN are road salt storage areas • Leaks and spills
Waste Management	• Spills and leaks of liquids • Dumping into storm drains • Leaking dumpsters (Dumpster juice) • Wash-off of dumpster spillage • Accumulation of particulate deposits
Physical Plant Maintenance	• Discharges from power washing and steam cleaning • Wash-off of fine particles from painting/ sandblasting operations • Rinse water and wash water discharges during cleanup • Temporary outdoor storage • Runoff from degreasing and re-surfacing
Turf and Landscaping	• Non-target irrigation • Runoff of nutrients and pesticides • Deposition and subsequent washoff of soil and organic matter on impervious surfaces • Improper rinsing of fertilizer/pesticide applicators
Unique PSH Operations (Pools, Golf Courses, Marinas, Construction, Restaurants, Hobby Farms)	Varies but includes • Discharge of chlorinated water from pools • Improper disposal of sewage and grease • Wash off of livestock manure • Soil erosion • Runoff of pesticides • Salt storage

Vehicle Operations - Nearly all PSHs devote some portion of the site to vehicle operations such as maintenance, repair, recycling, fueling, washing or long-term parking. Vehicle operations can be a significant source of trace metals, oil, grease, and hydrocarbons, and are the first operations inspected during a hotspot source investigation. Vehicle maintenance and repair operations often produce waste oil, fluids and other hazardous products, particularly if work areas are connected to the storm drain system. Routing protective rooftop runoff through a fueling area has become a common practice in Minnesota; simple re-routing of runoff away from a potential fuel wash-off location could eliminate this from the hotspot list.

Outdoor Materials - Most PSH sites handle some kind of material that can create storm water problems if not properly handled or stored. The first step is to inventory the type and hazard level of materials at the site. Next, it is important to examine loading and unloading areas to see if materials are exposed to rainfall and/or are connected to the storm drain system. Third, any materials stored outdoors that could potentially be exposed to rainfall or runoff should be investigated. Public and private road salt and sand storage areas are of particular concern for this category.

Waste Management - Every business generates waste as part of its daily operations, most of which is temporarily stored at the site pending disposal. The third common hotspot operation involves the way waste products are stored and disposed of at the site in relation to the storm drain system. In some sites, simple practices such as dumpster management (problem exemplified in Figure 8 – not in Minnesota) can reduce pollutants, whereas other sites may require more sophisticated spill prevention and response plans.

Figure 8. Leakage ("dumpster juice") from a Compacter/Dumpster Directly into a Storm Sewer.

Physical Plant Practices - The fourth hotspot operation relates to practices used to clean, maintain or repair the physical plant, which includes the building, outdoor work areas and parking lots. Routine cleaning and maintenance practices can cause runoff of sediment, nutrients, paints, and solvents from the site. Sanding, painting, power-washing, resealing or resurfacing roofs or parking lots always deserves particular scrutiny, especially when performed near storm drains.

Turf and Landscaping - The fifth common hotspot operation involves practices used to maintain turf or landscaping at the site. Many commercial, institutional and municipal sites hire contractors to maintain turf and landscaping, apply fertilizers or pesticides, and provide irrigation. Current landscaping practices should be thoroughly evaluated at each site to determine whether they are generating runoff of nutrients, pesticides, organic carbon, or are producing non-target irrigation flows.

Unique Hotspot Operations - Some operations simply resist neat classification, and this last category includes unique sites known to generate specific pollutants. Examples include swimming pools, construction operations, golf courses, fairgrounds/racetracks, marinas, hobby farms, and restaurants.

Issue Paper G discussed the common PSH of salt storage and the environmental threats that result from our need as a state for safe winter roads. Water quality problems from very soluble Na, Cl and cyanide have been documented as resulting from stored salt piles. MPCA does not regulate the storage of salt unless the storage becomes a documented contamination problem. Instead, the state encourages all public and private entities storing salt to follow the Salt Institute's recommended BMPs, which include such things as covering, impervious pads and drainage routing. MS4 communities are asked by MPCA to include a salt management component in their municipal pollution prevention programs. The Manual will devote a fair amount of attention to salt management and will also provide a link to the Salt Institute guidance.

The potential for each hotspot operation to generate nutrients, metals, hydrocarbons, toxins and other pollutants was previously presented in Issue Paper E and is represented here in Table 7.

Table 7: Stormwater Pollutants Associated With Common PSH 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	●	⊙	⊙	●	Water volume
Vehicle Storage	X	⊙	●	○	Trash
Outdoor Loading	⊙	⊙	○	○	Organic Matter
Outdoor Storage	⊙	⊙	⊙	⊙	Chloride
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, sediment
Marinas	⊙	⊙	⊙	●	Bacteria
Restaurants	⊙	X	●	X	Grease
Key ● major contributor ⊙moderate ○ minor X not a pollutant source					

Stormwater Management Design at PSHs

Understanding the types of future operations expected to occur on a site helps designers develop a more thoughtful stormwater management and pollution prevention plan for a given site. This approach provides more flexibility in terms of what stormwater treatment approaches are appropriate for different portions of a site. Runoff management at PSHs should also be linked to the pollutant(s) of greatest concern in the subwatershed (see Issue Paper E for more detail). Similarly, understanding the pollutants potentially generated by a site operation provides designers with important information on proper selection, siting, design, and maintenance of the nonstructural (i.e., source control or pollution prevention) and structural practices that will be most effective at the PSH site.

The most cost effective approach to managing stormwater at potential hotspot sites is to employ a variety of non-structural pollution prevention, and source control measures. To do this effectively, it is necessary to have a thorough understanding of a site and the respective areas of the site where specific operations will occur. Hogland, et al. (2003) suggest most of the following principles for design:

- Develop detailed mapping of the different areas of the site along with associated planned activities and the preliminary drainage design.
- Separate hotspot activity areas from non-hotspot activity areas, if possible
- Prevent or confine drips and spills
- Enclose or cover pollutant generating activity areas and regularly provide cleanup of these areas
- Provide spill prevention and clean-up equipment at strategic locations on site
- Provide pretreatment and spill containment measures such as catch basins and inserts, oil-water separators, etc.
- Strategically locate slopes and separation berms to prevent co-mingling of dirty and clean runoff
- Retain and reuse stormwater for irrigation, wash down water, or other onsite uses
- Maintain equipment to minimize leaks
- Train and educate employees, management and customers

Meeting the design intent of the non-structural practices above typically involves simple and low-cost measures to address routine operations at a site. For example, the non-structural design components for a vehicle maintenance operation might involve the use of drip pans under vehicles, tarps covering disabled vehicles, dry cleanup methods for spills, proper disposal of used fluids, and covering and secondary containment for any outdoor storage areas. Each of these practices also requires employee training and strong management commitment. In most cases, these practices save time and money, reduce liability and do not greatly interfere with normal operations. Examples of common pollution prevention practices are illustrated in Figure 9.

Figure 9: Examples of Common Pollution Prevention Practices at PSHs

A more complete summary of 15 basic pollution prevention practices applied at PSH operations is provided in Table 8 (Schueler et al., 2004).

Table 8: Pollution Prevention Practices for PSH Operations (Schueler et al. (2004)

PSH Operation	Profile Sheet*	Pollution Prevention Practices
Vehicle Maintenance and Repair	H-1	Drip pans, tarps, dry clean-up methods for spills, cover outdoor storage areas, secondary containment, discharge washwater to sanitary system, proper disposal of used fluids, disconnect storm drains, automatic shutoff nozzles, signs, employee training, spill response plans
Vehicle Fueling	H-2	
Vehicle Washing	H-3	
Vehicle Storage	H-4	
Loading and Unloading	H-5	Cover loading areas, secondary containment, storm drain disconnection or treatment, inventory control, dry cleaning methods, employee training
Outdoor Storage	H-6	
Spill Prevention and Response	H-7	Inventory materials, employee training, spill planning, spill clean up materials, dumpster management, disconnect from storm drain or treat. Liquid separation/containment
Dumpster Management	H-8	
Building Repair and Remodeling	H-9	Temporary covers/tarps, contractor training, proper cleanup and disposal procedures, keep wash and rinse-water from storm drain, dry cleaning methods
Building Maintenance	H-10	
Parking Lot Maintenance	H-11	
Turf Management	H-12	Integrated pest management, reduce non-target irrigation, careful applications, proper disposal of landscaping waste, avoid leaf blowing and hosing to storm drain
Landscaping/Grounds Care	H-13	
Swimming Pool Discharges	H-14	Varies, depending on the unique hotspot operation
Other Unique Hotspots	H-15	

*Due to the volume of material, the reader is referred to Schueler et al. (2004) to see the profile sheets. Each profile sheet explains how the practice influences water quality, and lists the type of PSH operation where it is normally applied. The sheets also identify the primary people at the hotspot operation that need to be trained in pollution prevention. Next, each sheet reviews important feasibility and implementation considerations, and summarizes available cost data. Each profile sheet concludes with a directory of the best available internet resources and training materials for the pollution prevention practice.

It should also be noted that the profile sheets developed by Schueler et al. (2004) are written primarily from the perspective that the site(s) in question is an existing site and pollution prevention measures are recommended as a retrofit approach. Designers of new sites, however, can still use the guidance effectively.

Wright et al. (2004) provide a detailed description of a rapid field assessment protocol for identifying PSHs and the appropriate pollution prevention practices for the activities causing pollution. The protocol is known as the Unified Subwatershed and Site Reconnaissance (USSR) and the PSH assessment is called a Hotspot Site Investigation. These methods are not directly applicable to greenfield development or redevelopment situations; however, they have significant application for NPDES Phase II MS4 communities that are working towards compliance with minimum measure numbers 1, 2, 3, and 6 (public education and outreach, public participation/involvement, illicit discharge detection and elimination, and pollution prevention/good housekeeping, respectively).

After considering the non-structural elements to incorporate into a site based on its layout and proposed operations, designers need to assess what structural practices will be most appropriate given site constraints while providing the greatest pollutant loading reductions for targeted pollutants. Table 9 presents representative pollutant removal data for common PSH pollutants of concern as a function of practice group. Details on BMP design and performance will occur in design and fact sheets prepared for the Manual.

Table 9. Percent Removal of Key Pollutants by Practice Group

Practice	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydrocarbons [%]
Detention Ponds	25	26	78[2]	N/A
Wet Ponds	33	62	70	81[2]
Stormwater Wetlands	30	42	78[2]	85[2]
Filtering Practices and Bioretention	38	69	37[2]	84[2]
Infiltration Practices[3]	51	99[2]	N/A	N/A
Vegetated Swales and Grass Channels[4]	84[2]	61	N/A	62[2]

1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement as primarily a volume reduction BMP – MPCA does not consider porous pavement alone as a treatment practice.
4. Higher removal rates for dry swales.

N/A: Data not available

Removals represent median values from Winer (2000)

As indicated in Issue Paper E, it is often receiving water designation or watershed classification that will drive the criteria and associated practices that are acceptable for use. However, by virtue of being a PSH there are a set of general guidelines to always consider when designing structural stormwater management systems. The following should be carefully considered by designers when specifying and siting practices at PSHs.

- Convey and treat the mostly clean runoff separately from the dirty runoff.
- Infiltrate only the mostly clean water.
- Pretreatment, pretreatment, pretreatment. This includes oversizing sediment trapping features such as forebays and sedimentation chambers; incorporating appropriate proprietary and nonproprietary practices for spill control purposes and treatment redundancy; oversizing pretreatment features for infiltration facilities such as swales, filter strips, and level spreaders; and ensuring full site stabilization before bringing practices online.
- Consider “closed” systems with liners, under-drains, or comparable safeguards against infiltration for practices that manage dirty waters.
- Locate practices offline and minimize offsite run-on with appropriate diversions.

- Establish rigorous maintenance and inspection schedules for practices receiving the dirty waters.
- For ponds and wetlands, over-design by between 10-25% the allowable storage volume for sediment accumulation over time if sediment is a problem.

Infiltration practices are the practice group that requires the most scrutiny prior to implementation at a PSH. A conservative approach would avoid the use of infiltration practices at a PSH; however, with appropriate site and conveyance design it is possible for the designer to incorporate infiltration into many sites to treat areas sufficiently separated from pollutant generating activities. Most other practice groups should be acceptable for use in treating PSH runoff, so long as appropriate design modifications are incorporated. Most design modifications are simple and in the form of enhanced pretreatment, over-design, or design redundancies. Others are added features that limit the likelihood of groundwater recharge. For example, practice groups such as bioretention, ponds and wetlands that receive runoff from pollutant generating activities should be designed with the necessary features to minimize the chance of groundwater contamination. This includes using impermeable liners. The use of ponds and wetlands without liners should also be avoided where water tables are shallow and the practice would likely intercept the water table.

Importance of Plan Review at Proposed PSHs

Ultimately, the level of safeguards that are in place when providing stormwater management at PSHs should be related to the expected review process. Communities that can allocate adequate and qualified staff to effectively review all stormwater management plans for proposed PSHs can arguably provide designers with great flexibility as to how to meet the management criteria required at a site. In these cases, designers should have most of the accepted stormwater treatment practices at their disposal for implementation. However, for communities that don't have the resources to provide the necessary level of site and stormwater management plan review, a more conservative approach to allowable treatment practices should be taken.

In many cases, industrial PSHs will be covered by the NPDES industrial stormwater permit or by some other federal/state permitting program related to the materials they store or handle on site (see discussion in Section IV). Communities are encouraged to focus their attention on the unregulated PSH sites.

Issues

Much of the material presented in this section is provided as technical advice to communities and pollution control managers dealing with potential stormwater hotspots (PSHs). Few issues emerge from this discussion, but the following list is presented to again generate discussion among the Manual Sub-committee.

Issue III.1: Non-regulated PSHs are obviously a concern for the possible introduction of contaminating material to Minnesota's waters. Although not a problem that the Manual can solve, are there regulatory or non-regulatory vehicles that are available to communities to address a site they suspect as being a source of contamination?

Issue III.2: Is there a more effective way to consolidate programs on industrial PSHs other than further regulation under the NPDES/MS4 program?

IV. NPDES INDUSTRIAL STORM WATER REQUIREMENTS

Background

This section addresses a mix of programmatic issues, some of which border on state policy direction. For example, MPCA staffing shortages are recognized even though this is not a problem that can be solved by the Manual. The programmatic information is being presented, however, because of the issues that arise when the topic of NPDES industrial storm water permits is discussed. A proper discussion of this program cannot honestly occur unless these topics are touched upon.

Many industrial operations are regulated in Minnesota under the NPDES industrial storm water permit program. Although the MPCA attempted to notify all potential industrial permit holders of their need to obtain a permit twice during the 1990s, individual owners or operators may be unaware of their permit status. Industrial potential stormwater hotspots (PSHs) merit a major focus for pollution prevention if they use, generate, handle or store pollutants that can potentially be washed away in storm water runoff, spilled, or inadvertently discharged to the storm drain system. Each type of industrial PSH generates its own blend of potential storm water pollutants, but as a group, they generally produce higher levels of metals, hydrocarbons and sediment.

Minnesota currently has about 2000 industrial facilities under its permit program, which it suspects is far from the total number that should be permitted. Although many of the larger facilities are aware of the requirements related to proper use, transport and storage of potentially polluting material, some may not be. In addition, many medium and small operations might not have had the benefit of industrial trade advice and perhaps are unaware of the permit needs or were not included in the list of notified parties. These are the facilities where most of the focus locally should occur because of the potential for pollutant migration off-site and because they can fall outside of other federal and state regulations that often apply to larger facilities or facilities that handle certain types of regulated waste.

In addition, PSHs associated with commercial or institutional uses are generally not covered under the industrial permit. This means, for example, that the thousands of neighborhood gas stations, local auto repair, shopping center parking lots and small commercial chemical storage facilities will not be permitted under this program even though collectively they generate significant off-site runoff pollution potential (Schueler et al., 2004).

A good understanding of how the industrial permit program works and who exactly is covered is essential to develop an effective PSH source control program. This may not be easy, since the industrial permit program can be complex, confusing and at times ambiguous. Some key requirements for Minnesota are summarized in Table 10.

Table 10: Industrial NPDES Storm Water Permits: What They Really Mean	
What is an industrial storm water permit?	This NPDES permit regulates 11 categories (see Table 11 and Appendix A) of industrial activities that discharge storm water to surface waters or into a municipal separate storm sewer system (MS4).
Who is covered?	Most Minnesota permits have been issued as a single group, although a few instances of individual permitting have occurred. The multi-sector approach wherein separate categories of permittees are grouped and regulations separately applied will likely be used more in the future since EPA already has a multi-sector permit that it is revising for mid-2005 release. MPCA models its industrial permit program after EPA's. An industrial site can be excluded from the permit system if the operator can certify "No Exposure," which means that all industrial materials and activities are protected by a storm-resistant shelter that prevents exposure to precipitation and/or runoff. MPCA will begin to examine these requests once its 7090 rule is adopted and the EPA program guidance is ready.
What do they really have to do?	There are two basic requirements associated with an industrial storm water permit. First, the applicant must file an application to get a permit. Second, the applicant must develop a Storm Water Pollution Prevention Plan (SWPPP) that must be certified as complete and kept on-site. The SWPPP must include a site evaluation of how and where pollutants may be mobilized by storm water and discharged; a site plan for managing storm water runoff that includes appropriate structural and non-structural controls to reduce storm water-related pollution; a schedule for maintenance, inspection and visual monitoring; and a record-keeping process. An annual fee of $400 is charged by MPCA for industrial stormwater permits.
Who administers and enforces the permit?	State water quality agencies that have been given permitting authority by EPA to administer the permit system, and have inspection and enforcement authority. In Minnesota, this is the Pollution Control Agency. Local agencies have no direct role in enforcement, although they can refer a problem hotspot or non-filer to the MPCA for enforcement. Indeed, local governments have their own municipal industrial operations (ex. public works garages) that are regulated by the state. Municipalities with several facilities can get a single permit from MPCA covering all facilities, but each separate facility must have its own SWPPP.
Current Compliance	The staff resources at the MPCA to manage the NPDES Industrial Stormwater Permit Program (i.e., processing and issuing permits) have been minimal for several years. On-site inspections are fairly rare, and high rates of non-filers have been observed, particularly among small businesses. Progress in the permitting program may require greater coordination between local and state agencies to fill in major inspection, training and education gaps. The MS4 program provides communities with an opportunity to address industrial operations that they view as potential hotspots.
Want more information? Many guidance manuals, policy documents and fact sheets can be found on EPA's website at www.epa.gov/npdes/stormwater and at MPCA's website at http://www.pca.state.mn.us/water/stormwater/stormwater-i.html.	

Program Status in Minnesota

The NPDES Industrial Stormwater Permit Program in Minnesota has been relatively inactive, pending the outcome of the EPA industrial regulation revision. However, this does not relieve potentially permitted industrial dischargers from the responsibility of applying for a permit and reporting annually.

Industrial operations subject to coverage under the NPDES permit program are defined in law as having primary activities that fall into one of the 11 categories of industrial activity (see Table 11 in the next section). Other PSHs might not fall under any kind of pollution control program. For example, a neighborhood gas station or a shopping center salt storage pile are commercial activities that do not generally fall under the 11 industrial categories. There are some exceptions when a facility is covered under some other NPDES permitting provision, for example an individual stormwater discharge permit or part of an industrial wastewater discharge permit. MPCA does not prioritize industrial sites for purposes of stormwater permitting, although it has begun to collect some limited data to explore the severity of the problem.

Although it does not at this time appear as though any additional resources will pour into the program, agency staff believe some additional activity will be needed in the near future once the EPA adopts its nationwide program, from which MPCA will model the revised state permit program. The current program has been operating with an expired permit since 2002, leading to much frustration from permittees wanting for various reasons (see Issue Paper C) to operate under an active permit. Once the EPA regulations are finalized, MPCA will revise its expired permits for public input. During this process, all potentially regulated industries will again be notified of the need to obtain facility permits.

Until the industrial stormwater permit program at the MPCA is revitalized, some industrial wastewater program coordination will occur. This coordination involves the evaluation of stormwater pollution potential while inspecting permitted industrial wastewater facilities. Although not the primary focus of these site visits, information obtained during any inspection can help the industrial stormwater program remain viable.

MPCA can also use its general water pollution authorities (see Issue Paper C) if it appears as though any industrial facility is causing a water quality impact on the waters of Minnesota. Similarly, a community can report such apparent violations.

Although nothing in the Phase II industrial permit gives explicit authority to MS4 communities, they can use their NPDES program authorities to address suspected industrial pollution sources through selective application of the six MS4 elements. For example, the education component could focus on working with industry on runoff BMPs, or the illicit connection program could be used to pursue a suspected discharge.

Permit Coverage

The specific list of 11 major industries subject to NPDES industrial storm water permits is based on Standard Industrial Classification (SIC) codes[1] to determine permit status, and is provided in Table 11 and expanded upon in Appendix A. Appendix A also rates each industrial category based on its potential to produce illicit discharges, based on analysis by Pitt (2001). An industrial operation can be exempted from the permit program if "no exposure" is demonstrated (i.e., all of its operations are covered by a rooftop) for contact of exposed product with precipitation or runoff. MPCA will act on a backlog of no exposure requests once it has adopted rules under Chapter 7090.

Table 11. List of 11 Major Industries Subject to NPDES Storm Water Permits

Category One (i):	Facilities with effluent limitations
Category Two (ii):	Manufacturing
Category Three (iii):	Mineral, Metal, Oil and Gas
Category Four (iv):	Hazardous Waste, Treatment, or Disposal Facilities
Category Five (v):	Landfills
Category Six (vi):	Recycling Facilities
Category Seven (vii):	Steam Electric Plants
Category Eight (viii):	Transportation Facilities
Category Nine (ix):	Treatment Works
Category Ten (x):	Construction Activity *
Category Eleven (xi):	Light Industrial Activity
* Category Ten (x): Construction Activity that disturbs five or more acres of land is included in the definition of "storm water discharges associated with industrial activity." However, EPA opts to permit these types of activities separately from other industrial activities because of the significant difference in the nature of these activities. In addition, EPA also requires permit coverage for small construction that disturbs from 1 to 5 acres of land.	

Permit Requirements

Industrial PSHs that are regulated under NPDES storm water permits must prepare "storm water pollution prevention plans" or SWPPPs, and implement source control practices at the facility. These plans must include spill response and prevention, employee training, and implementation of pollution prevention practices to reduce exposure of products to rainfall or runoff. In some cases, storm water treatment practices may need to be installed at the site to remove pollutants from runoff. Permitted industrial PSHs should be regularly inspected to determine if they are complying with the SWPPP, or even possess a permit. However, as previously mentioned, the MPCA does not inspect any facilities because of the staffing cut-backs it has experienced. In

[1] More recently, federal agencies including EPA, have adopted the North American Industry Classification System (NAICS, pronounced "Nakes") as the industry classification system. For more information on the NAICS and how it correlates with SIC, visit http://www.census.gov/epcd/www/naics.html.

lieu of this, communities could conduct their own site visits as part of its local stormwater program. The storm drain system should also be investigated to determine if an industrial PSH is generating illicit discharges of sewage or other pollutants. Methods to detect and correct illicit discharges are described in Brown et al. (2004).

Industrial NPDES storm water permits are an important regulatory tool at many PSH operations. NPDES permits require operators to prepare a pollution prevention plan (SWPPP) for the site and implement the practices specified in the plan. Significant penalties can be imposed for non-compliance. State and federal regulators are still grappling with the administration of industrial storm water permits, and they remain an imperfect tool for several reasons. First, the permit system allows potential hotspot operators to prepare and implement their own pollution prevention plans and to keep them on site rather than sending them to MPCA. If a particular plan is weak or is only a paper exercise, the Agency might never know until it is too late. Second, very few trained state or federal-level inspectors are available to inspect and enforce the thousands of industrial sites covered by the permit program. Third, although communities usually have the best understanding of how the local storm water network works, they lack direct authority to inspect or enforce regulated PSHs, although they can refer them to state agencies for enforcement. Communities can also address these sites through other programs, such as zoning, storm water utility or conditional use permits, and can address potential problems whenever new construction at the facility occurs. All three problems can be overcome if the locality works with industry and state regulatory agencies to share hotspot inspection and enforcement responsibilities as part of industrial permitting or MS4 programs. Portland (OR) recently negotiated such an agreement to expand the reach of its hotspot inspection program (Pronold, 2000).

From the regulated community standpoint, the lack of a viable, well funded state industrial stormwater permit program has resulted in uncertainty over regulatory status and frustration over paying an annual fee with no return. For example, many industrial facilities could be exempt from the industrial stormwater permit because they have “no exposure” of contaminating material to precipitation or runoff on their site. Currently, MPCA does not have the state authority or program resources it believes it needs to issue these exemptions. Until Chapter 7090 rules are adopted (expected in May 2005), MPCA will not open the permit process for no exposure exemptions. Facility owners who know that their facility has no exposure want the exemption granted so they can leave the program, but cannot get any action by the agency.

From an industry perspective, many industries are over-regulated under several different pollution control programs. For example, an industry that stores certain volumes of a chemical or oil will likely be regulated by the EPA and/or MPCA for its storage tank(s), for spill prevention planning, for any handling of hazardous materials and possibly other elements. Appendix C contains a list submitted by the Minnesota Chamber of Commerce of many other regulatory programs that contain stormwater management components covering individual facilities. This list was requested by EOR to make sure that affected industry input was received on programs within the list. An industrial stormwater permit holder could conceivably have several different programs that address stormwater management. It has been stated by industry representatives (see Issue Paper C) that a single facility could also fall under local MS4 authority and be subject to yet another, and possibly differing, set of stormwater controls. Some industry regulated under all of these programs has stated anecdotally, that is with no data substantiation, that the true pollution threat comes from smaller or unregulated facilities, not from a carefully regulated operation from which stormwater pollution is unlikely to flow.

To date, national compliance with the industrial storm water permit program has been spotty, and a significant fraction of regulated industries have failed to file their required permits. Although Minnesota data are not available from MPCA, Duke and Shaver (1999) and Pronold (2000) state that only 50% of industrial sites that are required to have a permit actually have one. The remaining sites are termed “non-filers,” and are often small businesses or operations that are unaware or ignore the regulations. It is therefore quite likely that many industrial PSHs in a community may not have a valid NPDES permit. These operations will again be notified by MPCA of the need to obtain a permit and will be educated about the industrial permit program, and encouraged to apply for a permit. Persistent non-filers could be referred for state enforcement, and may face stiff fines.

As noted earlier, state agencies are normally delegated authority to inspect industrial NPDES storm water hotspot sites and enforce requirements. A formal compliance investigation begins by checking whether the operation maintains a current SWPPP at the site. The SWPPP must include a site plan that shows how storm water runoff is managed using appropriate pollution prevention and documents storm water treatment practices, a schedule for maintenance, inspection and visual monitoring, and a record-keeping process. In most cases, education on the program or the mere threat of enforcement are sufficient to prompt compliance with pollution prevention practices, and enforcement actions are used as a last resort. However, if corrective actions are not taken in a timely manner, fines become a reasonable course of action.

Issues

Several issues related to industrial stormwater permitting emerge from the previous discussion. The following list of issues is presented to generate discussion among the Manual Sub-committee. It is not expected that these issues can be solved in the Manual.

Issue IV.1: Does the lack of an active state program for industrial stormwater permitting leave a major gap in the state’s ability to protect the waters of Minnesota? If so, is there anything that could be done in the near future to invigorate the program? Have other states used their Manuals to address industrial permit needs or stayed away from something that could be considered a policy question?

Discussion at the MSC meeting (5/12/05) resulted in a request by the committee for the consultant to prepare for the Manual guidance for the questions below for MS4s concerned that they might have industrial PSHs:

1. How does a community research what industrial permits have been issued for its community and which industries could be non-filers? That is, which industries are eligible for regulation?
2. How does a community know if a particular industry is causing a problem?
3. What resources are available for communities trying to get answers to potential industrial pollution problems?

Issue IV.2: Should the industries regulated under other pollution control permits somehow receive credit for those efforts and reduce the amount of regulation associated with the Phase II stormwater program? Is a pilot program with EPA oversight needed to see how this would actually work?

V. GUIDANCE ON INFILTRATION OF RUNOFF FROM PSHs

Background

Sections III and IV provide significant discussion on PSHs and associated regulatory, design, and maintenance considerations for the treatment of stormwater runoff. Preventing or minimizing the likelihood of contaminated runoff from leaving the site is the core objective of stormwater management at these sites. Introduction of contaminated runoff to the groundwater is probably the greatest concern in developing effective stormwater management plans at PSHs. This is for three primary reasons: 1) groundwater contamination is hard to detect immediately and therefore can persist over long periods of time prior to any mitigation; 2) there is an immediate public health threat associated with groundwater contamination in areas where groundwater is the primary drinking water source, which is most of Minnesota; and 3) mitigation, when needed, is often difficult and is usually very expensive. This Section focuses on these issues and presents a potential approach for establishing design guidelines for infiltration based on the six common operational areas presented in Section III plus a seventh area that addresses major transportation routes (i.e., highways). Figure 10 serves as a frame of reference for revisiting these areas.

Figure 10: Operational Areas Subject to Infiltration

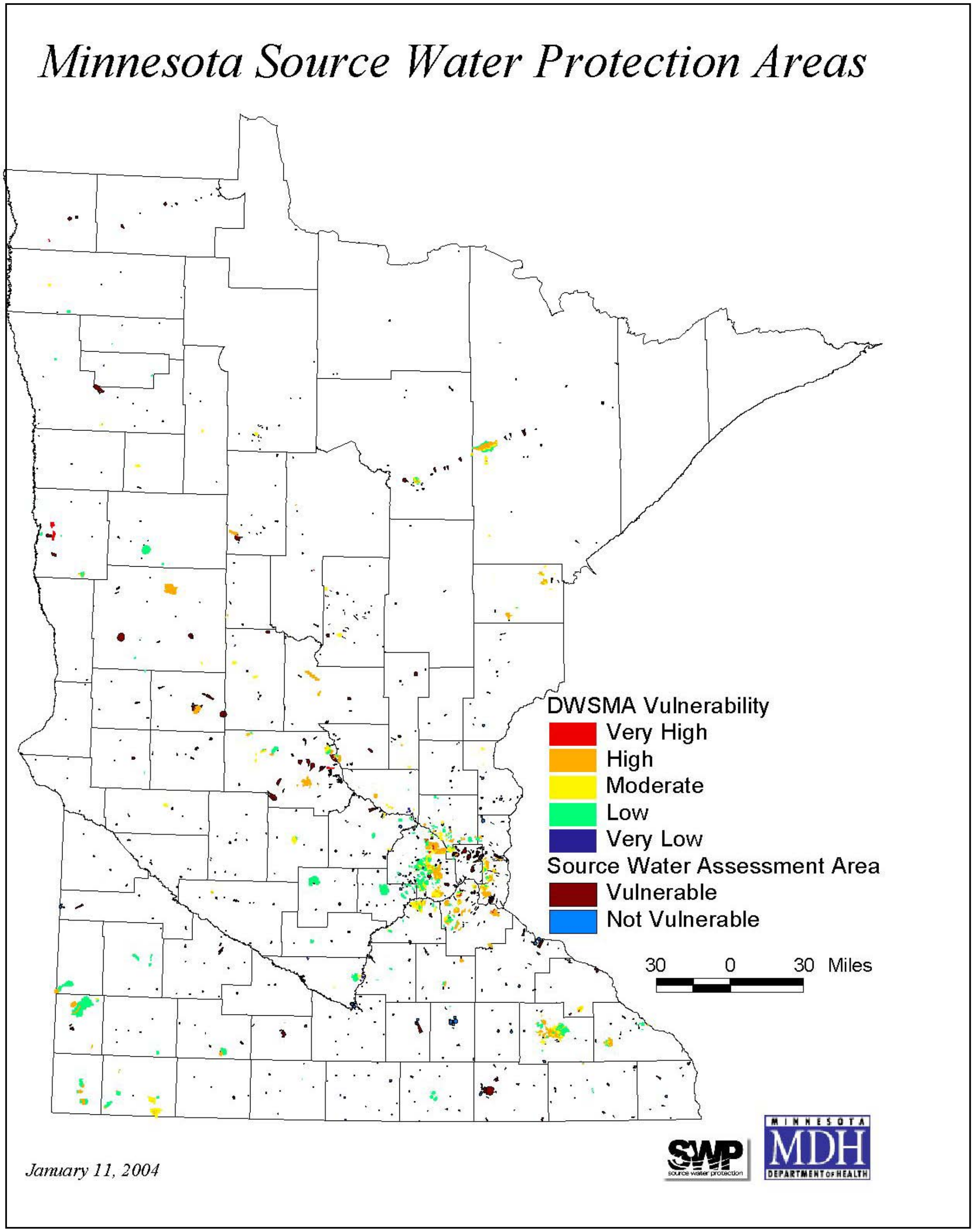
Potential for PSH Impact on Groundwater

Several of the previous Issue Papers have addressed the need for extreme caution when dealing with the introduction of stormwater runoff into the ground via infiltration systems or even low impact development-type techniques that encourage infiltration naturally. The information presented thus far in this Issue Paper again illustrates the potential for groundwater contamination from water emanating from sites with high levels of contaminating material wash-off.

This issue gets particularly important when the infiltration occurs within a defined drinking water source area. Issue Paper E discussed the need for increased runoff protection and provided a suggested link to the Minnesota Department of Health via [http://www.health.state.mn.us/divs/eh/water/swp/index.htm] to obtain site specific information on source water protection (including wellhead protection) areas. Figure 11 shows the locations of MDH source water protection areas in a graphic from January 2004. Please be aware that these coverages are subject to change and that new coverages are being added to these. For details on exact locations, please contact MDH through the web address above.

It is also important to note that Figure 11 shows only the public systems covered under the MDH program. There are thousands of additional private and domestic wells that could be impacted by PSHs and not subject to any special protections against stormwater runoff.

Figure 11. January 2004 location of Source Water Protection Areas.



Infiltration Guidance at PSHs

Table 12 provides potential infiltration guidelines associated with each of the seven operational areas.

Issues

As has been presented in Section III and IV, infiltration at PSHs relies on overall site design and facility operations management. Good design and committed, well-trained facility staff should make infiltration possible for certain areas of the site. Where uncertainty is present, designers should avoid infiltration practices. Some issues for the Manual Sub-committee to consider include:

Issue V.1: What documentation should be provided as part of the site design approval process for communities to ensure sites are maintained and managed as designed over time?

Issue V.2: What types of products (any criteria??) does the State want to see used as acceptable spill containment practices? MPCA should be aware that several proprietary products are available on the market to provide spill containment and pollution prevention benefits. Some of these products will undoubtedly perform better than others. Therefore, MPCA or local authorities may want to establish a list of acceptable products that are appropriate for spill containment and pollution prevention purposes. MPCA referenced its very active and effective spills program and asked that it be linked as the primary up-to-date reference for this type of information.

Issue V.3: Are drinking water source protection areas of such importance and high profile that there needs to be site wide prohibitions on infiltration (PSH or all??) or should infiltration in each be discouraged unless there is a way to allow infiltration if the inflow water is adequately pre-treated or if safety can be assured?

Table 12. Infiltration Guidelines for PSHs.

Operational Area	Potential Infiltration Guidelines
Turf Practices	Infiltration okay so long as no run-on or co-mingling from higher pollutant loading areas and appropriate pretreatment provided for specified practice. Chemical management needed to limit the amount of fertilizer and pesticides added to the turf.
Downspouts	Infiltration okay so long as no run-on or co-mingling from higher pollutant loading areas, no polluting exhaust from a vent or stack deposits on the rooftop, and appropriate pretreatment provided for specified practice
Parking Lots	Infiltration okay with following provisions: • No run-on from higher pollutant loading areas. • Limited salt application or use of alternative deicers • Enhanced pretreatment requirements such as (suggested unless better local information available) minimum vegetative filter length of 20 feet, maximum velocity in conveyance channels to infiltration practice of one foot per second, plunge pools and sediment basins/chambers with volumes of at least 25% of the water quality volume. • Only daily "commuter" parking areas and no long-term car/truck storage sites
Waste and Material Storage*	Infiltration not typically recommended but possible where spill prevention and containment measures are in place such as catch basin inserts and oil and grit separators. Also possible if redundant treatment is provided such as filtering prior to infiltration. Infiltration should be prohibited in areas of exposed salt and mixed sand/salt storage and processing.
Loading Docks*	Infiltration not typically recommended but possible where spill prevention and containment measures are in place such as catch basin inserts and oil and grit separators. Also possible if redundant treatment is provided such as filtering prior to infiltration.
Vehicle Fueling*	Infiltration not allowed by MPCA for new construction under the CGP.
Highways*	Infiltration possible where enhanced pretreatment is provided as described under parking lots. Where highways are within source water protection areas and other sensitive watersheds additional measures should be in place such as spill prevention and containment measures (e.g., non-clogging catch basin inserts and oil and grit separators).
* indicates operational area with likelihood of having higher pollutant loadings	

VI. BMP SEDIMENT QUALITY, TESTING AND DISPOSAL GUIDELINES

Background

Sedimentation is a primary removal process of most stormwater treatment practices. When practices are performing as intended, sediment is trapped and accumulates over time. Routine maintenance procedures are necessary and should be planned to evacuate and dispose of the accumulated sediment. The frequency of this action will be a function of the practice type, the land use draining to the practice, and design features that account for sediment accumulation over time.

There are several BMPs besides ponds that are intended to capture sediment or particulate material. For example, pre-treatment supplements such as forebays and proprietary chambers, non-clogging catch-basin inserts, filters, and bioretention all function well to remove particulate material from runoff. Each of these systems will need to have a maintenance program that removes and disposes of material.

Existing research on stormwater treatment practices has primarily focused on the movement of pollutants into and out of the practice as a measure of pollutant removal performance. Most of the monitoring studies have shown that the practice groups identified in Issue Paper A are quite effective in trapping sediment and associated pollutants carried in urban stormwater. Much less is known, however, about the fate and makeup of stormwater sediment and associated pollutants once they are trapped in a practice.

Of all the practice groups, we probably know the most about ponds and wetlands with respect to the nature and characterization of trapped sediment and its buildup. Due to the lack of data for other practice groups, it is necessary to extrapolate findings and knowledge from ponds and wetlands in combination with best professional judgment when considering design and maintenance implications for sediment removal.

The sediment layer in stormwater treatment practices builds up over time and pollutants can remain trapped within this layer until it is excavated during a maintenance clean-out. In most cases the sediment is eventually excavated, dewatered, and applied back to a land surface or disposed of in a conventional landfill. In very limited situations, depending upon the source of the contamination, sediment that builds up in stormwater quality treatment practices may be classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA) of 1976 (Jones et al., 1996). Understanding the potential for hazardous sediment and implementing appropriate controls and practices to minimize the risk of this characterization are important considerations for design engineers and property owners to be aware of. This section of Issue Paper H identifies these key considerations and associated design features to be applied with respect to managing accumulated sediment in stormwater treatment practices.

Schueler (2000) provides a good summary on the pollutant dynamics of pond muck, and is provided as Appendix B of this Issue Paper. The paper reviews research conducted on bottom sediment chemistry for 50 stormwater ponds and wetlands. Some key findings presented by Schueler are:

- Annual deposition rates of sediment range from 0.1 to 1.0 inches per year. The greatest rates tend to be observed near the inlets. Deposition rates are greater for ponds that are small in relation to the contributing drainage area and for facilities that are on-line (i.e., located directly on streams). A similar study in Minnesota (Polta, 2004), although with a mass rather than depth focus, found that an 80% effective stormwater pond in an urban area can retain from 350 - 2500 pounds of solids per acre of drainage area every year.
- Phosphorus levels in pond sediment are 2.5 to 10 times higher than parent soils. Trace metals concentrations are 5 to 30 times higher in the sediment compared to the parent soils and are directly related to the land use of the drainage area (enrichment increases from residential to commercial to highways).
- None of over 400 sediment samples from the 50 pond sites exceeded EPA's land application criteria for metals and usually less than 5% of the bulk metal concentration was susceptible to leaching.
- Macroinvertebrate communities found in pond sediment had poor diversity and characteristics of high pollution stress.
- Metal concentrations in pond sediment were similar to those found in dry pond soils, grassed swale soils, and sand filter sedimentation chambers and filter beds, although based on limited data.

When is Sediment Considered to be Hazardous?

MPCA does not have sediment quality standards with which to define levels of contamination. There are, however, two other ways in which MPCA defines "contamination". First, MPCA defines sediment quality targets (SQTs) that were adopted for use in the St. Louis River Area of Concern as the state benchmark values for making comparisons to surficial sediment chemistry measurements (see MPCA webpage at [http://www.pca.state.mn.us/water/sediments/index.html]). Secondly, several RCRA (federal Resource Conservation and Recovery Act) designated hazardous waste compounds have been detected in urban stormwater runoff. Examples include: solvents, degreasers, pesticides, herbicides, fungicides, and hydraulic fluids. Sampling of sediment and analysis for groups of potentially toxic chemicals (ex., metals, solvent, oil/hydrocarbons) will indicate the level of contamination in the material. The presence of a RCRA designated compound in sediment trapped by a stormwater treatment practice does not necessarily mean the sediment is considered hazardous, unless a defined level of the contaminant is exceeded through a sediment chemical extraction test called the TCLP (Toxicity Characteristic Leaching Procedure). If "hazardous" levels are exceeded (unlikely for urban BMPs), the waste must be disposed of in an authorized hazardous waste facility out of state because Minnesota does not have its own. If the waste is less than hazardous, but still showing signs of contamination, it can be disposed of in an industrial landfill, a municipal landfill or land applied (requiring an MPCA permit) depending upon the level and nature of the contaminant(s). If there are low levels of contamination or none is detected, BMP solids can be used (with caution!) as local fill. MPCA urges anyone interested in removing material from a BMP and not knowledgeable about the character of the material being removed to contact MPCA via its sediment web page located above. The BMP manager is ultimately responsible for any pollution caused by the improper disposal of these wastes.

Design engineers and facility managers at PSHs should be familiar with RCRA-listed pollutants and the likelihood of these compounds being present on site. Similarly, these individuals and runoff control managers (ex. MS4 communities, watershed organizations, Mn/DOT) should be aware of the fact that many pollutants regulated by RCRA adsorb onto sediments and that most stormwater facilities require sediment removal as a component of their long-term maintenance regimen (Jones et al., 1996).

Reducing the Risk

Several prudent measures should be taken to reduce the risk that sediments in stormwater treatment practices will be classified as hazardous. The following guidelines (adapted from Schueler, 2000 and Jones et al., 1996) should be assessed as stormwater management plans are developed for individual sites.

1. Prevent or reduce to the maximum extent practicable contact between RCRA-listed pollutants and precipitation or stormwater runoff. This can be accomplished by educating facility staff; maintaining detailed and accurate

inventory of materials; providing covered and contained storage areas; using acceptable sanitary sewer connections with appropriate pretreatment procedures[2] for proper disposal of certain non-stormwater waste streams, and developing effective pollution prevention and spill containment practices and procedures.

2. Consider site drainage carefully with an eye towards separating cleaner runoff from dirty runoff. Treat areas such as rooftops (not near hazardous material releases), walkways, and some parking areas with separate water quality practices where there is a low risk of hazardous pollutant loads. Practices such as bioretention, infiltration trenches, and swales can be effectively used to treat these areas. Isolate and minimize potential problem areas, and provide enhanced pretreatment for these locations using sedimentation basins or traps and appropriate proprietary practices.
3. Minimize the quantity of sediment that enters facilities over time by ensuring good erosion and sediment control practices are in place during and after construction. Post-construction considerations include maintaining complete vegetative cover in pervious areas and limiting use of sand during winter periods. Much of the post-construction sediment is knocked off of vehicular carriers (tires, mud-flaps and under-carriage) during loading and unloading at a facility.
4. Employ techniques such as aerators or fountains in ponds to promote pollutant removal of certain organic compounds through volatilization. If there are hazardous levels of any of these chemicals, MPCA needs to be contacted to develop a mitigation program that might not allow the volatilization system.
5. Oversize sediment storage volumes in stormwater treatment practices to reduce the frequency of needed sediment removal.
6. Where ponds are used, design forebays to provide optimized pretreatment by sizing for at least 10% of the water quality volume, providing adequate depth, and designing for exit velocities no greater than one foot per second at the maximum design inflow to reduce likelihood of scouring and resuspension.
7. PSHs should design practices and adjacent areas with sufficient space to accommodate dewatering of sediments once evacuated from a practice. Even when sediment is not considered to be hazardous, they will not typically be accepted at conventional solid waste landfills unless sufficiently dewatered.
8. Construct facilities off-line to avoid consequences associated with impacting “waters of the state.”
9. Institute strict and regular housekeeping and source control measures.

Sampling and Disposal of Sediment

Operators and owners of PSH sites with a high likelihood of having trapped stormwater sediments being classified as hazardous should be aware of the requirements associated with sampling and characterizing the sediments. Operators and owners should communicate with regulators in advance of plans to evacuate and dispose of sediment

[2] see EPA’s pretreatment program guidelines (for more information) at http://cfpub.epa.gov/npdes/home.cfm?program_id=3

from stormwater treatment practices in these situations. EPA sampling guidelines exist to aid in the determination of the appropriate number of samples to collect, selecting the appropriate analytical techniques, ensuring proper QA/QC, and identifying qualified labs to conduct the analyses. Potential hazardous pollutants should be identified in advance to streamline this process. The MPCA web-site for guidance on sampling of suspected contaminated sediment is [http://www.pca.state.mn.us/water/sediments/]. EPA guidance on sediment sampling is tied to specific programs available through [http://www.epa.gov/waterscience/cs/].

As previously stated, available data indicates that most accumulated sediment in stormwater treatment practices does not constitute a hazardous or toxic waste. Therefore, it can be safely disposed of using conventional techniques such as for fill, land application, or landfill material, according to MPCA rules and guidance. Sites and associated stormwater facilities where the risk of hazardous waste characterization is deemed to be high should sample sediment prior to evacuation to determine whether it is hazardous or not. If the sediment is not hazardous, then disposal as described above is acceptable. If a hazardous characterization is made, then sediment must be disposed of at facilities authorized and certified to receive the waste so that it can be properly handled and disposed of. Because there are no hazardous waste landfills in Minnesota, this necessitates exporting it out of state.

Issues

Issue VI.1: Does Minnesota need to improve its program for removal and testing of sediment accumulated in various runoff management BMPs?

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APPENDIX A - STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODE DISCUSSION

The information presented in this Appendix refers to the Standard Industrial Classification (SIC) system. This system has historically been used to classify industries and other businesses for census, tax, permit and other purposes. It should be noted that, more recently, federal agencies, including EPA, have adopted the North American Industry Classification System (NAICS, pronounced "Nakes") as the industry classification system. For more information on the NAICS and how it correlates with SIC, visit **http://www.census.gov/epcd/www/naics.html**.

Overview

Identification of land uses that may impact water quality in local streams can be a difficult and time-consuming task. Research suggests that program managers might wish to preferentially investigate certain land uses when looking for the sources of possible pollutant loads. These land uses are all considered to be sites where routine operations can generate higher levels of storm water pollutants, and/or present a higher potential risk for highly polluted runoff, spills, leaks or illicit discharges. There are two basic types of generating sites: *regulated PSHs* that are known sources of pollution and are subject to federal or state regulations, and *unregulated PSHs* which are operations suspected to be potential pollution sources, but which are not currently regulated.

Identifying PSHs

The number and type of PSHs present in a subwatershed may vary greatly, and currently there is no public database available to identify all the regulated sites on a subwatershed basis. Instead, multiple databases need to be queried to identify generating sites that may be targets for source control or illicit discharge investigations. A three-phase approach is useful for gathering as much information as possible on generating sites within a subwatershed that may qualify for more intensive scrutiny.

Phase 1. Consult Publicly Available Databases

The federal government has a number of databases that may help identify locations for investigation. The Environmental Protection Agency (EPA) operates two such databases. The first is the Enforcement and Compliance History Online (ECHO) database. With this system, facility compliance history can be queried and facilities can be found based on geographic location (county level), or zip code (http://www.epa.gov/echo/index.html). The other database is Envirofacts (http://www.epa.gov/enviro/). This website provides access to multiple EPA databases to provide information about environmental activities (including Resource Conservation and Recovery Act [RCRA] and Toxic Release Inventory [TRI] facilities) that may affect air, water, and land anywhere in the United States. The website also provides access to Enviromapper, which will display the location of regulated facilities. There are also commercial databases that can provide information on regulated industries based on manufacturing or industrial SIC codes. These databases are not free, and have limitations since they are designed primarily for marketing.

Phase 2. Consult State and Local Agencies

Most states have NPDES permit programs, and track permit application to some extent. In Minnesota, the Pollution Control Agency is the designated regulator. State or local regulatory agencies can be contacted to obtain lists of industries that have filed NOIs (Notices of Intent) to obtain storm water permits, as well as those that have filed under TRI requirements. Other agencies that may have information on local generating sites include fire departments (for hazardous waste), and sanitation or wastewater treatment agencies.

Phase 3. Permit Review

The final source for information is through a review of local permits. Most permit databases have SIC codes as one of the fields. These codes can be matched against the SIC codes in Table A.1 that list common generating sites under major land use headings. If a local permit database does not exist, it may be worthwhile to simply get the local phone book and do a quick look for businesses that are similar to those listed in Table A.1.

Compiling the findings from the various databases will provide an initial list of potential generating sites for future investigation. However, research has found that most of these databases can miss many of the industries that are subject to regulation (Duke *et al.*, 1999; Duke and Shaver, 1999), and further identification may be necessary. Field investigations using techniques such as the Unified Subwatershed and Site Reconnaissance (Wright *et al.*, 2004) can assist in identifying many of these generating sites that should likely be regulated by communities.

Appendix A Tables

This appendix is designed to assist in identifying the land uses and associated generating sites in a subwatershed where routine activities may result in pollution being discharged to the storm drain system.

Table A.1 presents a listing of PSHs under common land uses where polluted discharges can occur based on regular activities or practices. Column one describes the general industry type. Column two lists their associated SIC codes, if known. Column three identifies whether an industry type is subject to NPDES industrial storm water permit requirements (designated by “X”). Facilities where only certain activities or facilities at the site are subject to regulation are noted (this pertains mostly to the transport-related industries). In addition, for many “light” industrial facilities, storm water permits are required only if material handling equipment or activities, raw materials, immediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water. Industries where this applies are noted with an “**”. If only specific SIC codes within a major group qualify for this exception they are noted in parentheses. Municipal facilities that are subject to NPDES MS4 permit requirements are designated by “MS4.” Column four identifies those businesses that can be considered an unregulated storm water hotspot (also designated by “X”). Column five looks at the illicit discharge potential of each of the businesses listed. The potential for a business to produce an illicit discharge is rated as either high (H) medium (M) or low (L) based on the likelihood that it has a direct connection to the storm drain system (direct) or that it can produce a transitory discharge (indirect).

Table A.2 is a list of the SIC Codes that are regulated by the Industrial Multi-Sector General Permit (MGSP). The list includes the four-digit SIC code level along with the official description. This table is provided for those who wish to know the full description of each SIC code that is regulated by NPDES industrial storm water permits.

Table A.1: Common Generating Sites and their Pollution Potential (from Schueler *et al.*, 2004)					
Land Use Generating Site Description	Associated SIC Code(s)	Regulated PSH	Unregulated PSH	Illicit Discharge Potential*	
				Direct	Indirect
Commercial					
Animal Care Services	0742, 0752		X	L	L
Auto Repair	7532-7539, 7549		X	M	M
Automobile Parking	7521		X	L	M
Building Materials	5211-5251		X	L	L
Campgrounds/RV parks	7033		X	L	M
Car Dealers	5511-5599,		X	M	M
Car Washes	7542		X	L	L
Commercial Laundry/Dry Cleaning	7211-7219		X	L	L
Convenience Stores	5399		X	L	L
Food Stores and Wholesale Food and Beverage	5141-5149 5411-5499		X	L	M
Equipment Repair	7622-7699		X	L	L
Gasoline Stations	5541		X	M	M
Heavy Construction Equipment Rental and Leasing	7353		X	L	H
Building and Heavy Construction **(For land disturbing activities)**	1521-1542 1611-1629	X		L	H
Marinas	4493	X		L	M
Nurseries and garden centers	5261		X	L	M
Oil Change Shops	7549		X		M
Restaurants	5812,5813,7011		X	M	L
Swimming Pools	7997, 7999		X	L	L
Warehouses	4221-4226	X** (4221-4225)		L	L
Wholesalers of Chemical and Petroleum	5162-5169,5172		X	L	L
Industrial					
Apparel and Other Fabrics	2311–2399 3131–3199	X**		2300 **L** 3100 **H**	L M
Auto Recyclers and Scrap Yards	5015, 5093	X		L	H
Beverages and Brewing	2082-2087	X**		L	L
Boat Building and Repair	3731,3732	X		L	H
Chemical Products	2812-2899	X** (2830, 2850)		2810 H 2820 H 2840 H **2860**	2810 L 2820 L 2840 L **2860** L

Table A.1: Common Generating Sites and their Pollution Potential (from Schueler *et al.*, 2004)					
Land Use Generating Site Description	Associated SIC Code(s)	Regulated PSH	Unregulated PSH	Illicit Discharge Potential*	
				Direct	Indirect
				M **2830** L **2850** L **2870** L 2890 L	**2830** L **2850** L **2870** L 2890 L
Industrial (continued)					
Food Processing	**2011–2141**	**X****		2010 H 2020 H **2030** H 2040 H 2050 L. 2060 L 2070 M 2090 L 2110 M	2010 L 2020 L **2030** L 2040 L 2050 L. 2060 L 2070 L 2090 L 2110 L
Garbage Truck Washout Activities	**4212**		**X**	L	**H**
Industrial or Commercial Machinery, Electronic Equipment	**3511–3599** **3612–3699**	**X****		**L**	**L**
Instruments; Photographic and Optical Goods, Watches and Clocks and other Miscellaneous Manufacturing	**3812–3873** **3933-3999**	**X****		L	**L**
Leather Tanners	**3411**	**X**		H	**M**
Metal Production, Plating and Engraving Operations	**2514, 2522, 2542, 3312-3399, 3411-3499, 3590**	**X**** **(2514,2522, 2542, 3411-3433, 3442-3499, 3590)**		**H**	L
Paper and Wood Products	**2411-2499, 2511, 2512, 2517, 2519, 2521, 2541, 2611–2679**	**X**** **(2434, 2652–2657, 2671–2679)**		2400 L 2500 L 2600 H	2400 H 2500 L 2600 H
Petroleum Storage and Refining	**2911**	**X**		2911 H	**H**
Printing	**2711–2796**	**X****		L	**L**
Rubber and Plastics	**3011-3089**	**X****		**M**	**L**
Stone, Glass, Clay, Cement, Concrete, and Gypsum Product	**3211-3299**	**X**** **(3233)**		L	**L**
Textile Mills	**2211–2299**	**X****		**H**	**L**

Table A.1: Common Generating Sites and their Pollution Potential (from Schueler *et al.*, 2004)					
Land Use Generating Site Description	Associated SIC Code(s)	Regulated PSH	Unregulated PSH	Illicit Discharge Potential*	
				Direct	Indirect
Transportation Equipment	**3711–3728, 3743-3799**	**X****		**H**	**M**
Institutional					
Cemeteries	**6553**		**X**	**L**	**L**
Churches	**8661**		**X**	**L**	**L**
Colleges and Universities	**8221-8222**		**X**	**L**	**M**
Corporate Office Parks			**X**	**L**	**L**
Hospitals	**8062-8069 8071-8072**		**X**	**L**	**L**
Private Golf Courses	**7997**		**X**	**L**	**L**
Private Schools	**8211**		**X**	**L**	**L**
Municipal					
Composting Facilities	**2875**	**X**		**L**	**L**
Public Golf Courses	**7992**		**X**	**L**	**L**
Landfills and Hazardous Waste Material Disposal	**4953, HZ, LF**	**X**		**L**	**H**
Local Streets		**MS4**	**X**	**L**	**H**
Maintenance Depots	**4173**	**MS4**		**M**	**H**
Municipal Fleet Washing	**4100**	**MS4**		**L**	**M**
Public Works Yards		**MS4**		**M**	**H**
Steam Electric Plants	**SE**	**X**		**L**	**L**
Treatment Works	**TW**	**X**		**L**	**L**
Transport Related (NPDES regulation is for the portion of the facility dedicated to **vehicle maintenance shops, equipment-cleaning operations, and airport deicing operations).**					
Airports	**4581**	**X**		**L**	**M**
Streets and Highways Construction	**1611, 1622**	**X**		**L**	**H**
Ports	**4449, 4499**	**X**		**L**	**H**
Railroads	**4011, 4013**	**X**		**L**	**H**
Rental Car Lots	**7513-7519**	**X**		**L**	**M**
US Postal Service	**4311**	**X**		**L**	**M**
Trucking Companies and Distribution Centers	**4212-4215, 4231**	**X**		**L**	**M**
Petroleum Bulk Stations or Terminals	**5171**	**X**		**L**	**H**
*Adapted from Pitt (2001) ** Generating sites where storm water permits are required only if material handling equipment or activities, raw materials, immediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water.					

Table A.2: SIC and Activity Codes for EPA's Multi-Sector General Permit for Industrial Activity	
Sector A. Timber Products	
2411	Log Storage and Handling
2421	General Sawmills and Planning Mills
2426	Hardwood Dimension and Flooring Mills
2429	Special Product Sawmills, Not Elsewhere Classified
2431–2439	Millwork, Veneer, Plywood, and Structural Wood (except 2434)
2448, 2449	Wood Containers
2451, 2452	Wood Buildings and Mobile Homes
2491	Wood Preserving
2493	Reconstituted Wood Products
2499	Wood Products, Not Elsewhere Classified
Sector B. Paper and Allied Products Manufacturing	
2611	Pulp Mills
2621	Paper Mills
2631	Paperboard Mills
2652–2657	Paperboard Containers and Boxes
2671–2679	Converted Paper and Paperboard Products, Except Containers and Boxes
Sector C. Chemical and Allied Products Manufacturing	
2812–2819	Industrial Inorganic Chemicals
2821–2824	Plastics Materials and Synthetic Resins, Synthetic Rubber, Cellulosic and Other Manmade Fibers Except Glass
2833–2836	Medicinal chemicals and botanical products; pharmaceutical preparations; invitro and invivo diagnostic substances; biological products, except diagnostic
2841–2844	substances
2851	Soaps, Detergents, Cleaning Preparations; Perfumes, Cosmetics, Other Toilet
2861–2869	Preparations
2873–2879	Paints, Varnishes, Lacquers, Enamels, and Allied Products
	Industrial Organic Chemicals
2891–2899	Agricultural Chemicals, Including Facilities that Make Fertilizer Solely from
3952 (limited	Leather Scraps and Leather Dust
to list)	Miscellaneous Chemical Products
	Inks and Paints, Including China Painting Enamels, India Ink, Drawing Ink, Platinum Paints for Burnt Wood or Leather Work, Paints for China Painting, Artist's Paints and Watercolors
Sector D. Asphalt Paving and Roofing Materials Manufacturers and Lubricant Manufacturers	
2951, 2952	Asphalt Paving and Roofing Materials
2992, 2999	Miscellaneous Products of Petroleum and Coal
Sector E. Glass, Clay, Cement, Concrete, and Gypsum Product Manufacturing	
3211	Flat Glass
3221, 3229	Glass and Glassware, Pressed or Blown
3231	Glass Products Made of Purchased Glass
3241	Hydraulic Cement
3251-3259	Structural Clay Products
3261-3269	Pottery and Related Products
3271-3275	Concrete, Gypsum and Plaster Products
3281	Cut Stone and Stone Products
3291–3292	Abrasive and Asbestos Products
3295	Minerals and Earth's, Ground, or Otherwise Treated
3296	Mineral Wool
3297	Non-Clay Refractories

Table A.2: SIC and Activity Codes for EPA's Multi-Sector General Permit for Industrial Activity	
3299	Nonmetallic Mineral Products, Not Elsewhere Classified

Sector F. Primary Metals	
3312–3317	Steel Works, Blast Furnaces, and Rolling and Finishing Mills
3321–3325	Iron and Steel Foundries
3331–3339	Primary Smelting and Refining of Nonferrous Metals
3341	Secondary Smelting and Refining of Nonferrous Metals
3351–3357	Rolling, Drawing, and Extruding of Nonferrous Metals
3363–3369	Nonferrous Foundries (Castings)
3398, 3399	Miscellaneous Primary Metal Products
Sector G. Metal Mining (Ore Mining and Dressing)	
1011	Iron Ores
1021	Copper Ores
1031	Lead and Zinc Ores
1041, 1044	Gold and Silver Ores
1061	Ferroalloy Ores, Except Vanadium
1081	Metal Mining Services
1094, 1099	Miscellaneous Metal Ores
Sector H. Coal Mines and Coal Mining-Related Facilities	
1221–1241	Coal Mines and Coal Mining-Related Facilities Sector
Sector I. Oil and Gas Extraction and Refining	
1311	Crude Petroleum and Natural Gas
1321	Natural Gas Liquids
1381–1389	Oil and Gas Field Services
2911	Petroleum refining
Sector J. Mineral Mining and Dressing	
1411	Dimension Stone
1422–1429	Crushed and Broken Stone, Including Rip Rap
1481	Nonmetallic Minerals, Except Fuels
1442, 1446	Sand and Gravel
1455, 1459	Clay, Ceramic, and Refractory Materials
1474–1479	Chemical and Fertilizer Mineral Mining
1499	Miscellaneous Nonmetallic Minerals, Except Fuels
Sector K. Hazardous Waste Treatment Storage or Disposal Facilities	
HZ	Hazardous Waste Treatment, Storage or Disposal
Sector L. Landfills and Land Application Sites	
LF	Landfills, Land Application Sites and Open Dumps
Sector M. Automobile Salvage Yards	
5015	Automobile Salvage Yards
Sector N. Scrap Recycling Facilities	
5093	Scrap Recycling Facilities

Table A.2: SIC and Activity Codes for EPA's Multi-Sector General Permit for Industrial Activity	
Sector O. Steam Electric Generating Facilities	
SE	Steam Electric Generating Facilities
Sector P. Land Transportation	
4011, 4013 4111–4173 4212–4231 4311 5171	Railroad Transportation Local and Highway Passenger Transportation Motor Freight Transportation and Warehousing United States Postal Service Petroleum Bulk Stations and Terminals
Sector Q. Water Transportation	
4412–4499	Water Transportation
Sector R. Ship and Boat Building or Repairing Yards	
3731, 3732	Ship and Boat Building or Repairing Yards
Sector S. Air Transportation Facilities	
4512–4581	Air Transportation Facilities
Sector T. Treatment Works	
TW	Treatment Works
Sector U. Food and Kindred Products	
2011–2015 2021–2026 2032 2041–2048 2051–2053 2061–2068 2074–2079 2082–2087 2091–2099 2111–2141	Meat Products Dairy Products Canned, Frozen and Preserved Fruits, Vegetables and Food Specialties Grain Mill Products Bakery Products Sugar and Confectionery Products Fats and Oils Beverages Miscellaneous Food Preparations and Kindred Products Tobacco Products
Sector V. Textile Mills, Apparel, and Other Fabric Product Manufacturing	
2211–2299 2311–2399 3131–3199	Textile Mill Products Apparel and Other Finished Products Made From Fabrics and Similar Materials Leather Products (except 3111)
Sector W. Furniture and Fixtures	
2511–2599 2434	Furniture and Fixtures Wood Kitchen Cabinets
Sector X. Printing and Publishing	
2711–2796	Printing, Publishing and Allied Industries
Sector Y. Rubber, Miscellaneous Plastic Products, and Miscellaneous Manufacturing Industries	
3011 3021 3052, 3053 3061, 3069 3081–3089 3931 3942–3949 3951–3955 3961, 3965 3991–3999	Tires and Inner Tubes Rubber and Plastics Footwear Gaskets, Packing, and Sealing Devices and Rubber and Plastics Hose and Belting Fabricated Rubber Products, Not Elsewhere Classified Miscellaneous Plastics Products Musical Instruments Dolls, Toys, Games and Sporting and Athletic Goods Pens, Pencils, and Other Artists' Materials (except 3952) Costume Jewelry and Novelties, Buttons, and Miscellaneous Notions, Except Precious Metal Miscellaneous Manufacturing Industries
Sector Z. Leather Tanning and Finishing	

Table A.2: SIC and Activity Codes for EPA's Multi-Sector General Permit for Industrial Activity	
3111	Leather Tanning and Finishing
Sector AA. Fabricated Metal Products	
3411–3499 3911–3915 3479	Fabricated Metal Products, Except Machinery and Transportation Equipment and Cutting, Engraving and Allied Services Jewelry, Silverware, and Plated Ware Coating, Engraving, and Allied Services
Sector AB. Transportation Equipment, Industrial or Commercial Machinery	
3511–3599 3711–3799	Industrial and Commercial Machinery (except 3571–3579) Transportation Equipment (except 3731, 3732)
Sector AC. Electronic, Electrical, Photographic and Optical Goods	
3612–3699 3812–3873 3571–3579	Electronic, Electrical Equipment and Components, Except Computer Equipment Measuring, Analyzing and Controlling Instrument, Photographic/Optical Goods, Watches/Clocks Computer and Office Equipment
Miscellaneous	
1521-1542 **1611-1629**	Building Construction General Contractors And Operative Builders Heavy Construction Other Than Building Construction Contractors

Article 80

Feature article from Watershed Protection Techniques. 1(2): 39-46

Pollutant Dynamics of Pond Muck

Historically, most research on stormwater ponds has focused on the movement of pollutants into and out of the pond. This is quite understandable, as knowledge about inputs and outputs of pollutants helps to estimate pollutant removal performance. An impressive amount of input/output monitoring data has been collected: nearly 65 pond monitoring studies have been conducted in the U.S. and Canada.

Most of the monitoring studies have shown that stormwater ponds and wetlands are quite effective in trapping pollutants carried in urban stormwater. Much less is known, however, about the fate of stormwater pollutants once they are trapped in a pond. It is generally assumed that most of the pollutants eventually settle out to the pond bottom and form a muck layer. (The term **muck layer** is used here to distinguish newly-deposited bottom sediments from the older parent soils that formed the original pond bottom.)

The muck layer deepens as the pond ages. Pollutants may remain trapped within the muck layer until the entire layer is excavated during a pond clean-out. In most cases the muck is eventually dewatered, excavated, and applied back to the land surface. Research on bottom sediments in other shallow water systems, however, suggests that the muck layer may not be so inert. Figure 1 illustrates how a given pollutant can follow a number of diverse and complex pathways into and out of the muck layer.

Some runoff pollutants are transformed within the muck layer, while others are decomposed through chemical and microbial processes involved in sediment diagenesis. Indeed, diagenesis is often a key pathway for decomposition of organic matter and some nutrients. Alternatively, pollutants can migrate further below the muck layer and into the original soil profile. In some extreme cases, pollutants can travel into groundwater.

Alternatively, pollutants might enter the food chain while in the muck layer, either through uptake by wetland plants or by bottom feeding fish. Under the right conditions, some pollutants could also be released from the muck into the water column (where they could exit the pond during the next storm).

In this article, we examine the internal dynamics within the muck layer of stormwater ponds, based on an extensive review of research studies on the physical, chemical, and biological nature of the muck layer of over 50 stormwater ponds and wetlands. While it must be admitted that the study of muck is somewhat lacking in glamour, it can have many important implications for the design and operation of stormwater ponds and wetlands. Typical questions include:

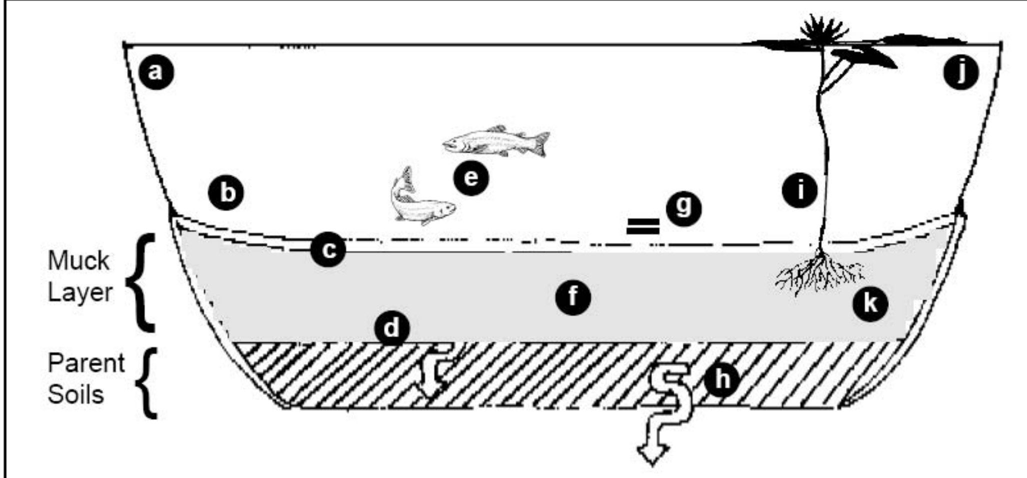
- What is the average deposition rate of muck in ponds?
- After how many years of deposition will muck need to be removed?
- Can the deposition rate be used to calculate the size of the sediment forebay for a pond?
- How tightly are pollutants held in the muck layer?
- Is there any risk that pollutants could be released back into the water column? Or migrate into groundwater supplies? Or enter the aquatic food chain where toxicity might be magnified?
- If pollutants do remain in the muck layer, should muck be considered hazardous or toxic?
- Can muck be safely applied back on the land surface after it is cleaned out from the pond? Or are more exotic and expensive methods needed to safely dispose of muck?
- Finally, the depth of accumulated muck generally represents the long term work of a pond in trapping pollutants. Can the characteristics of pond muck allow us to infer anything about the pollutant removal processes operating in ponds or the land uses that drain to it? Can muck pollutant concentrations “fingerprint” upstream land uses?

To answer these questions, we reviewed bottom sediment chemistry data from 37 wet ponds, 11 detention basins, and two wetland systems, as reported by 14 different researchers. Although the studies covered a broad geographic range, almost 50% of the sites were located in Florida or the Mid-Atlantic states. Analysis was restricted to mean dry weight concentrations of the surface sediments that comprise the muck layer (usually the top five centimeters). The stormwater ponds ranged in age from three to 25 years.

The Nature of Pond Muck

The muck layer can be easily distinguished from the parent soils that comprise the pond’s original bottom.

Figure 1: A Field Guide to the Muck Layer



Pond muck represents a long term repository for the pollutants trapped within a stormwater pond. A pollutant, however, can take many different pathways through the mucklayer, as shown in the diagram above.

(a) Pollutant inflow. Sediment, nutrients, trace metals, and hydrocarbons enter the pond during each storm. The total pollutant load delivered to the pond depends to some degree on land use. Some evidence exists that metal and hydrocarbon loads are significantly greater from watersheds draining roads or industrial areas.

(b) Sediment Deposition. A steady rain of sediment particles, attached pollutants, and algal detritus forms the muck layer over time. Field measurements indicate that the muck layer grows from 0.1 to 1 inch per year, with greater deposition noted near the inlet.

(c) Muck Microlayer. The uppermost layer of muck represents the recently deposited sediments and pollutants. Consequently, it is very high in organic matter and constantly worked over by microbes, worms and other organisms.

(d) Downward Migration. Most pollutants are tightly bound to sediment particles and remain fixed within the muck layer. Other pollutants can migrate downward into the subsoil via pore spaces between sediment particles.

(e) Fish Bio-magnification. Bottom feeding fish that dwell in larger ponds, such as carp and catfish, ingest detritus from the muck layer. Not much is known about pollutants accumulating in their tissues over time.

(f) Sediment Diagenesis. Organic matter and nutrients are gradually reduced and decomposed over time in the muck layer through a process known as sediment diagenesis. Diagenesis is a key pollutant removal pathway that combines physical, chemical, and biological processes within the sediment to slowly break down organic matter, in the presence or absence of oxygen.

(g) Phosphorus Release. In the summer, low oxygen levels near the bottom of pond can induce a "burp" of soluble phosphorus, ammonia, or methane back into the water column. The potential for this phenomena is greatest in deeper ponds in warmer latitudes.

(h) Groundwater Migration. Pollutants not tightly bound to the pond muck can migrate downward through sediment pore spaces and ultimately reach the water table. Soluble pollutants, such as chloride and nitrate, are the most mobile and have been reported to migrate outward from ponds into groundwater at modest levels. Most monitoring studies, however, reveal little if any risk of groundwater contamination from stormwater pond muck.

(i) Wetland Plant Uptake. The roots of wetland plants take up both nutrients and metals from the muck layer and transport them upward to tubers, stems, and leaves. At the end of the growing season, this above-ground plant matter often dies off. Some of the nutrients are released back into the pond, while others settle back to the muck layer as detritus.

(j) Pollutant Export from the Pond. Pollutants remaining in the pond's water column will often flush out during the next storm event. Consequently, any pollutants that were released from the muck layer back into the water column may exit as well, thereby reducing the long term pollutant removal performance of the pond.

(k) Sediment Clean-outs. The ultimate removal of stormwater pollutants is accomplished when the muck layer is excavated from the pond and applied back on the land. This operation may need to be conducted every 25 to 50 years, depending on whether the pond has a forebay. Based on existing data and sediment quality criteria, pond muck does not usually constitute a toxicity hazard.

Distinguishing features include the following:

- **Very "soupy" texture** — 57% moisture; number of studies reporting (N) = 15
- **Distinctive grey to black color**
- **High organic matter content** — nearly 6% volatile suspended solids on average (N=16)
- **Low density** (about 1.3 gms/cm) (Dorman *et al*., 1989)
- **Poorly-sorted sands and silts dominating the muck layer**

Deposition of Muck

Muck essentially represents the bulk of all sediments and pollutants that have been historically trapped within a pond (excepting those that are microbially broken down into gaseous forms or those pollutants that migrate below the pond). Therefore, the long term deposition rate of the muck layer is of great interest.

The annual deposition rate can be easily calculated if the age of the pond and the depth of the muck layer are known. The depth of the muck layer is relatively easy to estimate in the field, due to its unique physical characteristics. Annual muck deposition rates on the order of 0.1 to 1.0 inch per year have been reported for a series of ponds in Florida (Yousef *et al*., 1991). These rates compare favorably with other pond sedimentation rates calculated at 0.5 inches/yr (Galli, 1993) and 0.8 inches/yr (Schueler, 1994) utilizing different techniques.

The deposition rate of muck is not always the same throughout a pond, however. The greatest rates tend to be observed near the inlets of wet ponds, and to some extent, the outlets of detention basins (Grizzard *et al*., 1983). In addition, muck deposition rates increase sharply for ponds that are small in relation to the contributing watershed areas and for ponds that located directly in streams (Galli, 1993).

Nutrient Content of Pond Muck

As might be expected, the muck layer is highly enriched with nutrients (Table 1). Phosphorus concentration for the 23 studies reviewed averaged 583 mg/kg (range 110 to 1,936 mg/kg, N=23). Nearly all the nitrogen found in pond muck is organic in nature, with a mean concentration of 2,931 mg/kg (range 219 to 11,200, N=20). Nitrate is present in extremely small quantities, which may indicate that some denitrification is occurring in the sediments, or perhaps merely that less nitrate is initially trapped in muck.

In the entire pond data set, the nitrogen to phosphorus (N:P) ratio of the muck layer averages about five to one, whereas the average N:P ratio for incoming stormwater runoff is typically around seven to one. This lower N:P ratio is not unexpected. Ponds are generally more effective in trapping phosphorus than nitrogen and the decay rate for nitrogen in the muck layer is generally thought to be more rapid than for phosphorus (Avinmelich *et al*., 1984).

Researchers have expressed concern that phosphorus trapped in the muck layer might be released back into the water column, particularly when oxygen levels are low in the summer. A number of investigators have observed hypoxic and even anoxic conditions near the muck layer in ponds as shallow as five feet deep (Galli, 1993; Yousef *et al*., 1990).

An intriguing suggestion for possible sediment phosphorus release is evident in a handful of Florida ponds (Table 1). These ponds had unusually high N:P ratios of the muck layer, often in excess of 10 to one. One explanation for the apparent depletion of phosphorus in the muck layer would be the mobilization and release of phosphorus from recurring anoxia over many years.

Still, most of the more Northern ponds, as well as many Southern ones, appear to retain most of the phosphorus deposited in the muck layer. For example, phosphorus levels in the muck layer are 2.5 to 10 times higher than the soils underlying the pond bottom. Also, muck layer phosphorus levels do not normally show a decrease as ponds grow older.

Trace Metal Content of the Muck Layer

The muck layer of stormwater ponds is heavily enriched with trace metals. This phenomenon is consistent with reported performance data (Table 2). Trace metal levels are typically five to 30 times higher in the muck layer, compared to parent soils. Trace metal levels in the muck layer also follow a consistent pattern and distribution, (zinc > lead >> chromium = nickel = copper > cadmium).

This pattern is nearly identical to their reported concentrations monitored in urban stormwater runoff. It also suggests that rarely monitored (or detected) trace metals, such as chromium, copper, nickel, and possibly cadmium, are actually trapped by stormwater ponds. The muck layers of older ponds often contain more lead than zinc, whereas in younger ponds the converse is true. This may reflect the gradual introduction of lead-free fuels over the last decade, with the consequent reduction in lead loadings delivered to the younger ponds.

The trace metal content of the muck layer happens to be directly influenced by the type of land use that drains to it (Table 3). Muck layers in stormwater ponds that drain residential areas had the lightest metal enrichment. Commercial sites were subject to slightly greater enrichment, particularly for copper, lead, and zinc. Ponds that primarily served roads and highways were highly enriched with metals, presumably due to the influence of automotive loading sources (e.g., cadmium, copper, lead, nickel, and chromium).

Table 1: Characteristics of the Muck Layer in Wet Stormwater Ponds (mg/kg Dry Weight Unless Otherwise Noted)

Location	Land Use	% Moisture	% Volatile Suspended Solids	Total Kjeldahl Nitrogen	Total Phosphorus	Nitrogen to Phosphorus Ratio	Hydro-carbons
FL	Road	63	7.1	5180	510	10:1	
FL	Road	77	10.2	4140	301	14:1	
FL	Road	50	9.7	3110	1116	3:1	
FL	Road	60	6.8	1130	100	11:1	
FL	Road	52	6.5	2290	270	9:1	
FL	Road	62	4.5	1440	370	4:1	
FL	Road	65	4.8	2070	480	4:1	
FL	Road	60	4.3	2110	110	20:1	
FL	Road	76	10.4	11200	420	26:1	
FL	Residential	33	2.4	889	292 #	3:1	
FL	Road	64		2306 *	3863	0.6:1	
FL	Residential		6.4	624	619	1:1	
FL	Residential		1.1	256	389	0.7:1	
FL	Commercial		4.1	5026	1936	3:1	
FL	Road				1100		
VA	Residential		4.3	828	232	4:1	
NZ	Industrial			2471	995	3:1	12892
NZ	Residential			5681	1053	5:1	2087
MN	Residential	70	9.5		405		
MN	Residential	32	4.8		606		
MN	Road	51		3271	695	5:1	
CT	Road	32		219	499	0.4:1	
MD	Institutional			11000	917	12:1	474
	MEANS	**57**	**6.0**	**2931**	**583**	**5:1**	

* = Total Nitrogen
# = May have been influenced by fuel spill

Although the sample size was small (N=2), industrial catchments had, by far and away, the greatest level of trace metal enrichment in the muck layer of any land use. Clearly, further monitoring of heavily industrial catchments is warranted to confirm if muck enrichment represents a problem.

Most trace metals are very tightly fixed in the muck layer and do not migrate more than a few inches into the soil profile. Many researchers have examined soil cores to determine the distribution of trace metal concentration with depth. A consistent pattern is noted. Trace metal levels are at their maximum at the top of the surface layer, and then decline exponentially with depth. Eventually they reach normal background levels within 12 to 18 inches below the pond. Representative sediment metal profiles are shown in Figure 2.

Although the muck layer is highly enriched with metals, it should not be considered an especially toxic or hazardous material. For example, none of over 400 muck layer samples from any of the 50 ponds sites examined in this study exceeded current EPA's land application criteria for metals (Giesy and Hoke, 1991) (Table 2). In fact, metal levels in the muck layer are usually less than 10 times higher than the national mean for agricultural soils in the U.S. (Holmgren *et al.*, 1993) (Table 4).

Of perhaps greater interest is whether soluble metals can easily leach from the muck layer where they could exert a biological or groundwater impact. The capacity for metals to leach from sediments is measured by EPA's Toxicity Characteristics Leaching Procedure (TCLP). The TCLP test, or a slight variant, has been applied by four different investigators to pond muck (Dewberry and Davis, 1990; Harper, 1988; Yousef *et al.*, 1990, 1991) with much the same result—usually less than 5% of the bulk metal concentration is susceptible to leaching.

In general, cadmium and zinc exhibited the greatest potential for leaching (usually less than 10%) while copper and lead showed little or no leaching potential. Moreover, leachate concentrations seldom exceeded the mean metal concentrations reported for urban stormwater runoff.

Table 2: Trace Metal Content in the Muck Layer of 50 Stormwater Ponds and Wetlands (mg/kg dry weight)

Practice	Location	Land Use	Cadmium	Copper	Lead	Zinc	Nickel	Chromium
WP	FL	Residential	4.8	13	38.2	35.7	10.8	4.8
WP13	VA	Mix	3.2		45.3			25
WP	VA	Residential	0.8	17.2	48	78	12.2	
WP	NZ	Industrial		173	578	3171		
WP	NZ	Commercial		18.2	48.9	146		
WP9	FL	Road	15	28	374	161	52	61
WP	MD	Institutional	12	130	202	904		120
WP	MN	Residential			32.9			
WP	MN	Residential			17.0			
WP	OR	Institutional		60.2				
WP	CT	Road	0.4	19	39	53		13
WP	FL	Road	ND	13	125	105		31
WP	MN	Road	ND	57	139	261		51
WP	FL	Road	6	49	620	250		20
WP	FL	Residential	1.5	7	11	6	3	6
WP	FL	Residential	0.6	2	12	11	4	12
WP	FL	Commercial	2.7	6	42	103	6	11
SM	MN	Residential			82			
SM	MN	Residential			56			
DPSM	MD	Industrial	12	140	400	1098		
EDP	MD	Residential	0.4	8	223	45		
DP	VA	Commercial	1.7	30	748	202		
DP8	VA	Residential	3.0		50		30	
EPA land application criteria			380	3300	1600	8600	990	3100

KEY: WP = Wet pond; SM = Shallow marsh; DPSM = Detention basin with shallow marsh; DP = Detention basin; EPA = Maximum metal limits for land application

Hydrocarbon Content in Muck

One aspect of the muck layer that has yet to be well explored is the potential for hydrocarbons and PAH contamination. The limited data on hydrocarbon levels in the muck layer (Table 1) are a cause for some concern, particularly at an Auckland, New Zealand industrial site. Gavens *et al.* (1982) reported that the concentration of total PAH and aliphatic hydrocarbons in the muck layer of a 120 year old London basin were three and 10 times greater, respectively, than the basal sediments. Only limited biodegradation of the hydrocarbons trapped in the muck appeared to have occurred in the basin in recent years. Yousef (1994) on the other hand, reports that hydrocarbons were rarely detected in the muck of Florida ponds.

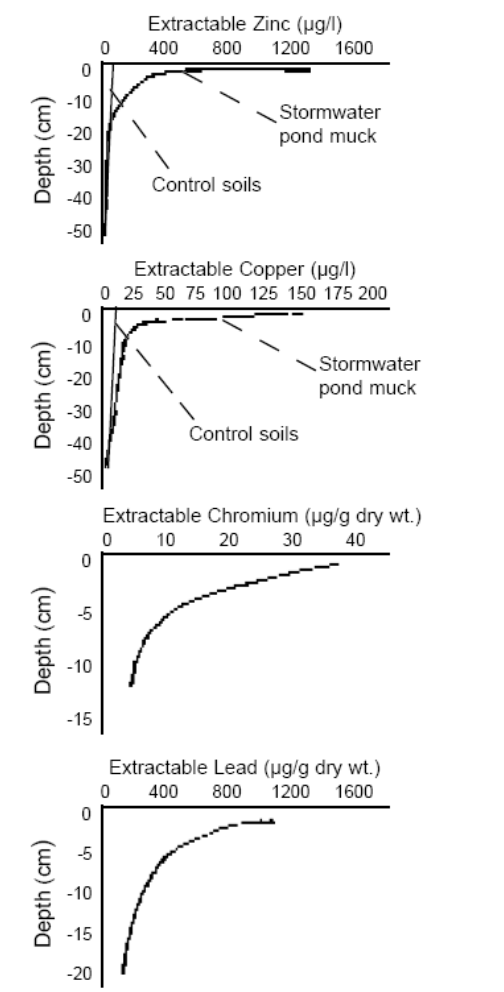
Aquatic Community

A soupy substrate, high pollutant load, and periodically low oxygen level render the muck layer a rather poor habitat for aquatic life. Macroinvertebrate sampling conducted by Yousef *et al.* (1990) and Galli (1988) indicate that the muck layer community has poor diversity and characteristics of high pollution stress. Chironomid and tubificid worms comprised over 90% of all organisms counted in a Florida pond muck layer, and dipteran midge larvae constituted 95% of all organisms collected in the muck layer of a Maryland pond. While the diversity of the community is extremely low, the benthic population can become very dense at certain times of the year. This is not surprising, given that extensive microbe population that uses the highly organic muck layer as an attractive food source.

Table 3: The Effect of Land Use on Trace Metal Concentrations in the Muck Layer (mg/kg)

Land Use	No. of Sites	Cadmium	Copper	Lead	Zinc	Nickel	Chromium
Residential	18	2	9.4	44	35	831	
Commercial	5	2	18	214	150	6	22
Road	13	11	30	330	163	52	51
Industrial	2	—	157	489	2135	—	—

Figure 2: Metal Profiles With Depth (Grizzard *et al.*, 1983; Yousef *et al.*, 1991)



Comparison of Pond Muck to Sediments Trapped in Other Stormwater Practices

How does pond muck compare to the sediments trapped in other stormwater practices? Table 4 shows that the metal content of the muck layer of wet ponds and stormwater wetlands is quite similar to concentrations seen in the soils of "dry" detention basins. The metal content of pond muck and grassed swale soils are also quite similar in most respects, although swale soils tend to have about twice as much phosphorus and lead as their pond counterparts. Sediments trapped within the filter bed and sedimentation chamber of sand filters also appear to be generally comparable to pond muck, although only one sand filter has been sampled to date (Shaver, 1991).

The one stormwater treatment practice that sharply departs from this pattern is the oil grit separator (OGS). The metal content of trapped sediment within OGSs is five to 20 times higher than other stormwater practices, particularly if the OGS drains a gas station (Schueler and Shepp, 1993). Hydrocarbon and priority pollutant levels in OGS sediments are also much higher.

This condition reflects the fact that OGSs often exclusively serve hydrocarbon hotspots and are designed to trap lighter fractions of oil (Schueler, 1994). It is doubtful that metal and hydrocarbon levels in pond muck could approach the level seen in OGSs, since they typically drain larger watersheds that dilute the influence of individual hydrocarbon hotspots.

Implications for Pond Design and Maintenance

An understanding of the dynamics of the pond muck layer has many implications for the design and maintenance of stormwater ponds.

Pond Clean-out Frequency

Based on observed muck deposition rates, stormwater ponds should require sediment clean-out on a 15 to 25 year cycle (Schueler, 1994; Yousef *et al.*, 1991). For

Table 4: Comparative Metals Concentration in Stormwater Practice Sediments (mg/kg) Dry Weight

Practice	No. of Observations	Cadmium	Copper	Lead	Zinc	Nickel	Chromium
Wet pond	38	6.4	24.5	160	299	38	36
Detention Basin	11	4	59	161	448		30
Grassed swale	8	1.9	27	420	202	13	30
Oil grit separator	13	14	210	320	504		284
Oil grit separator [A]	4	36	788	1198	6785		350
Sand filter	1	1.3	43	81	182	30	30
Sand filter [B]	1	4.6	71	171	418	49	52
Agricultural soils[C]	3000	0.28	30	12	56	24	
Resid. yards	9	0.1	5	13	9		

A = Oil Grit Separator, serving gas stations B = Sand filter with sedimentation chamber
C = Holmgren *et al.*, 1993

example, using a 0.5 inch/year muck deposition rate, and assuming that the muck consolidates over time as it deepens, up to 15 to 25% of pond depth can be lost over a 25 year period. The loss of capacity would be faster if construction occurs in the contributing watershed over this time period.

Most ponds are now designed with a forebay to capture sediments. A common forebay sizing criteria is that it constitutes at least 10% of the total pool volume. Based on a 0.5 inch/yr muck deposition rate, and the *untested* assumption that a forebay traps 50% of all muck deposited in the pond, the forebay could lose 25% of its capacity within five to seven years. At the same time, the sediment removal frequency for the main pool might be extended to about 50 years. These calculations assume that turbulence in the forebay does not cause muck to be resuspended and exported to the main pool. To meet this critical assumption, the forebay must be reasonably deep (four to six feet) and have exit velocities no greater than one foot/second at the maximum design inflow.

The Proper Disposal of Muck

All of the available evidence strongly argues that pond muck does not constitute a hazardous or toxic material. Thus it can be safely land-applied with appropriate techniques to contain any leachate as it dewaters. The high organic matter and nutrient content of pond muck might even make it useful as a soil amendment. Chemical testing of pond muck prior to land application is probably not needed for most residential and commercial sites, given the consistent pattern in the distribution of pond data reviewed in this paper.

Greater care should probably be exercised when disposing of pond muck from industrial sites and perhaps some heavily travelled highways. Although only a few industrial sites have been sampled to date, the data suggests these sites may pose a risk. In addition, there is a much greater chance of pollutant spills, leaks, or illegal discharges occurring in a pond over the 20 or 25 year time span in between clean-outs. It would seem prudent, therefore, to require prior testing at selected industrial and roadway ponds to reduce this risk.

Further Research Into the Muck Layer

While our emerging understanding about the muck layer is probably sufficient to make reasonably good management decisions regarding clean-outs and disposal, further research on muck layer dynamics is needed in several areas.

- Ponds need to be sampled to verify the deposition rate of muck over a broader range of geographic and regional conditions. Based on this data a predictive model of muck deposition rates could be developed to help practitioners who design and maintain ponds.
- Much more data needs to be collected concerning the accumulation of hydrocarbons and PAHs in the muck layer, particularly in ponds draining roads and industrial sites. Further testing of the muck layer for these compounds would give managers greater confidence about the proper method for muck disposal, as well as providing inferences about how well stormwater ponds can trap these key pollutants.
- The significance of muck layer phosphorus release as a factor in reducing the long term pollutant removal performance of a stormwater pond remain an open question. Perhaps direct, in-situ measurements of phosphorus flux in a stormwater pond, such as those used for many years in estuarine studies, could help resolve this issue.
- So far, few researches have explored the possible risk of pollutant bio-magnification in the muck layer, either by wetland plant uptake or by bottom feeding fish. A systematic sampling program to define pollutant levels in plant and animal tissue in a large population of stormwater ponds and wetlands would help assess the nature of this risk. Such a survey would also provide helpful guidance to designers on the issue of whether efforts should be made to attract wildlife to these systems.

—TRS

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Partial Summary of Industrial Regulatory Programs Affecting Stormwater

Information provided by the Minnesota Chamber of Commerce – May 2005
(*Keith Hanson, Steve Pedersen, Erik Silvola, Roger Clay, Paul Nelson)

The following is a list of other regulatory programs which business entities must comply with and have an overlap with or are protective of stormwater. In addition this list does not address stormwater requirements in individual permits issued by federal and state agencies, conditional use permits, or agreements with local governmental units permitting programs.

Under these programs many of the industrial sites have operational plans which either directly or indirectly address stormwater and other containment requirements. Examples of these plans include but are not limited to:

- Contingency Plan
- SPCC Plan (Spill Prevention, Control and Countermeasures)
- Emergency Response Plan
- Black Start Plan
- Security Plan
- Industrial Stormwater Pollution Prevention Plan (SWPPP)
- Construction Stormwater Pollution Prevention Plan (SWPPP)
- Waste Management Plan
- Fuel Management Plan
- Solid Waste Plans of Operation
- Water Monitoring Plan
- Risk Management Plan
- Documented Operating Procedures and Guidelines

Other programs outside of environmental requirements also come into play. For instance, regulatory requirements for reliability of power generation and transmission reliability necessitate regular maintenance and testing of equipment which has an indirect affect of protecting stormwater. Voluntary programs such as developing an EMS and stewardship projects also can provide additional protection.

Statement - Attached is a very rough draft…It is far from complete. What we are attempting to say is, when looking at stormwater requirements for industrial facilities, and to some extend municipal and construction activities these other regulatory programs have a significant influence on the reduction of impacts to stormwater. These additional regulatory requirements need to be recognized in the context of stormwater management. It is our belief that these other programs need to be considered when addressing industrial stormwater impacts. The guidance manual could mention these programs to ensure those making decisions on construction activities are aware that others programs are addressing activities which are aimed at reducing stormwater runoff and have a significant influence on reduction of stormwater impacts. Beyond that we are not clear how the guidance manual could address these concerns. We do believe these programs need full consideration when considering non-degradation, monitoring, MS4 and watershed permitting. We hope this is helpful.

Program	Items	Affect
Federal Oil Pollution Act of 1990 (**OPA**) and Spill Prevention, Control and Countermeasures (**SPCC**) regulations	• SPCC Plan Meeting Requirements • Secondary Containment/Diversion Structures • Conduct Multiple Inspections • Integrity Testing • Security- Fully fence and lock or guard facility • Lock valves pumps • Cap connections • Substance transfer • Facility drainage – Design and inspection requirements • Inspect piping and vehicles • Training • Discharge Response • Reporting • Waste handling • Contingency Plan/FRP (Facility Response Plan): Drills/Training/Response Equipment	Reduces exposure with equipment requirements and inspections. Limits exposure if a release of oil with reporting and response requirements. Requires inspection and certification prior to release of stormwater from containment
Federal Comprehensive Environmental Response, Compensation and Liability Act of 1980 (**CERCLA**) and Superfund Amendments Reauthorization Act of 1986 (**SARA**)	• Part 302: Listed Substances and Reportable Quantities • Part 355: Emergency Planning and Notification • Part 370: Community Right-to-Know, Tier 1 and Tier 2 Reporting	Reduces exposure by requiring inventory, planning and limits exposure due to release; refer also to Emergency Planning and Community Right to Know Act of 1986 (also know as Title III of SARA)

Program	Items	Affect
Federal Resource Conservation and Recovery Act of 1976 (**RCRA**)	• Requires inspections and inventory • Limits storage, • Dictates storage method (Secondary containment, covered storage, and compatible containers etc.) • Training • Emergency Planning • Shipping requirements • Reporting	Limits exposure from hazardous/universal wastes
Federal Toxic Substances Control Act of 1976 (**TSCA**)	• Requires inspections • Limits storage • Dictates storage method (Secondary containment, covered storage, and compatible containers etc.) • Training • Reporting	Limits exposure from TSCA substances
State and Federal Requirements – Federal Insecticide, Fungicide and Rodenticide Act of 1996 (**FIFRA**) and Herbicide Management	• Application requirements • Notice • Emergency procedures • Certification Standards	Limits exposure and sets procedures
MN7045 State Hazardous Waste	Storage time limits, storage requirements, inspections, storage area requirements similar to RCRA.	As RCRA but slightly different requirements
MN Rules Chs. 7035 and 7037 etc. Solid Waste, Petroleum Contaminated Soils, Operator requirements, etc.	• Monitoring Plans • Plan of Operation • Cover and drainage requirements • Waste handling requirements	Variety of rules that result in protection of stormwater

Program	Items	Affect
MN Rules Chs. 7150 & 7151 State Underground Storage Tanks (UST) and Aboveground Storage Tanks (AST)	Tanks and piping , secondary containment, overfill protection, corrosion protection, substance transfer , maintenance, inspections	Limits exposure from tanks and piping covered under rules.
U.S. Department of Agriculture (USDA)	Rural Utilities Service (RUS) regulation implementing National Environmental Policy Act of 1969 (NEPA) for siting	
Federal Energy Regulatory Commission (FERC)	Regulation implementing NEPA for siting	
MN Rules Chs. 4400, 4410, 7829, 7848, 7849	MN Environmental Quality Board (EQB) and Public Utilities Commission (PUC) – Siting and routing, environmental review, Certificate of Need	

This list is not meant to be all inclusive nor provide the detail of the regulatory issue paper since each program and its overlaps would be extensive (i.e., The SPCC program has potential overlap w/ CERCLA/SARA, RCRA and associated state programs). The regulatory issue paper went into detail on water programs so that analysis was not included in this listing.