INVER GROVE HEIGHTS
Northwest Area

Chapter 6

Additional Design Considerations

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Additional Design Considerations

Chapter 6

Key Topics: cold climate considerations, cold climate challenges for BMP engineering and design, potential stormwater hotspots (PSH), ground water, mosquitoes

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I. Introduction

The objective of this chapter is to raise the design engineer's awareness about certain factors that could affect the performance of best management practices (BMPs). These factors include:

- Cold Weather Design Considerations
- Potential Stormwater Hotspots (PSHs)
- Mosquito Control

How the design engineer decides to modify a BMP to address these factors depends on the site and the particular application of the BMP. Discussion of each of these factors will include an introduction to the issue, key points to consider in designing BMPs and suggestions for addressing these points. Ultimately, it will be up to the design engineer to determine the most suitable means for addressing these design considerations given the specifics of the site and their application.

II. Cold Climate

This section presents the latest national and international findings on stormwater management practices maintained in cold climate regions. It presents principles for adapting BMPs to provide effective pollutant removal and runoff control during cold weather months. Specific cold climate adaptations for specific BMPs are presented in callout boxes and are reiterated in Chapter 8 of the Manual.

The Designer must recognize that runoff from snowmelt has characteristics different from those of rainfall runoff, and that BMP design criteria addressing only rainfall runoff might not work well during cold periods. This can become a problem because a substantial percentage of annual runoff volume and loading can come from snowmelt in years when snowfall is high.

Nature of the Cold Climate Problem

Hydrology of Melt

The heart of the problem with snowmelt runoff is that water volume in the form of snow and ice builds for several months and suddenly releases with the advent of warm weather in the spring or during short interim periods all winter long. The interim melts generally do not contribute a significant volume of runoff when compared to the large spring melt. Snowmelt peaks are substantially less than those from rainfall, but the total event volume of a snowmelt, although it occurs over a much longer period, can be substantially more. Factors influencing the nature of this melt and the speed with which it occurs include solar radiation, the distribution of snow cover, the addition of de-icing chemicals to the pack, and the amount of freeze-thaw cycling. Ignoring the contribution of these large spring melts to the annual runoff and pollution loading analysis could be a major omission in a watershed analysis. This illustrates why facility design is critical to the proper quantity and quality management of this meltwater.

Three areas play roles in both the hydrologic and water quality character of snowmelt runoff.

1. Roadways and large paved surfaces like commercial parking lots are the direct recipients of fast and efficient snow removal. Because of the need for sanding and salting to promote safety, numerous loading events are generated every time it snows, and often in anticipation of a snowfall since pre-icing application of salt can be a common practice.
2. Areas immediately adjacent to the roadway or parking surface are often recipient of snow plowed and piled in these areas, resulting in both equivalent water volume and pollutant accumulation for an extended period of time over the winter. This material is then available for release and migration over a several week period in the spring. Since this critical area is usually contained within about 25 feet of the paved surface it easily flows to the storm drain system as it melts.
3. Snowmelt from less developed residential, open space, and low-density areas typical of suburban watersheds can be large contributors of meltwater volume, but the quality of the melt is better

than from roadways and parking areas. Typically a fair amount of the initial meltwater soaks into the ground and can continue to do so as long as the rate of melt does not exceed the infiltration capacity of the soil. However, depending on ground frost conditions and snowpack availability, saturation can occur, leading to this portion of the watershed acting as an impervious surface.

Snowpack builds throughout the winter and increases in moisture content as the winter season draws toward melt. When meltwater exits the snowpack, it moves into the ground or over the land surface. It is very common for the first part of the melt to soak into the ground. However, at some point in the melt sequence, particularly when there is a deep snowpack at the on-set, the ground can become saturated and turn a pervious, non-contributing part of the watershed into an essentially impervious surface from which all additional melt runs off. Hydrographs from melt events will typically show a period of little to no runoff, even though the melt rate might be high, followed by accelerating flow as the ground no longer soaks in the melting snowpack.

The source area for snowmelt plays a critical role in both the hydrologic and water quality character of snowmelt runoff, as shown in Figures 6.1a through 6.1c. Roadways and large paved surfaces (Figure 6.1a) like commercial parking lots are the direct recipients of fast and efficient snow removal. This can occur by plowing, which can include total site removal or relocation off of the surface, and/or chemical-induced (salt) melting. Because of the need to promote safety, obtaining an ice and snow-free surface is a focal point for winter management of these surfaces. As a result, these surfaces generate numerous loading events every time it snows or even in anticipation of a snowfall, since pre-icing application of salt can be a common practice. By the time the major spring melt occurs, many of these surfaces are free of snow and ice. However, in many instances the snow that has been removed is piled or plowed close to the surface and flows onto it. At this time it becomes part of the urban drainage system or is stored in a location where it immediately enters the drainage system upon melt. These road and parking surfaces can be a significant source of many of the most contaminating pollutants associated with urban runoff.

Figure 6.1b shows the second category of importance to snowmelt runoff and the area that is generally the most significant source of poor water quality during a melt. This is the area immediately adjacent to the roadway or parking surface. Because snow is plowed and piled in these areas, they accumulate both equivalent water volume and pollutants for an extended period of time over the winter. This material is then available for release and migration over a several week period in the spring. This critical area is usually contained within about 25 feet of the paved surface and easily flows to the storm drain system as it melts. Sometimes, as in commercial parking or roadside piles, the snow is actually sitting on an impervious surface.

The final contributing area to meltwater runoff is the less developed residential, open space, low density area typical of suburban watersheds (Figure 6.1c). Snowmelt from these areas can be large contributors of meltwater volume, but the quality of the melt is better than from roadways and parking areas. Typically a fair amount of the initial meltwater soaks into the ground and can continue to do so as long as the rate of melt does not exceed the infiltration capacity of the soil. If sufficient snowpack is available, saturation can occur, leading to this portion of the watershed acting as an impervious surface.

Quality of Melt

Figure 6.2 illustrates the accumulation of surface material on a snowpack compared to that occurring on the same urban surface during the rainfall season. The material builds for several months prior to wash -off. Since snow is a very effective scavenger of atmospheric pollutants, any airborne material present in snow catchment will show up in meltwater when it runs off.

Part of the severity of the water quality problem associated with melt is that it occurs when the hydrologic system is least able to deal with it. This melting sequence becomes a very important part of snowmelt quality management because the practices we use may or may not come close to treating a particular target pollutant depending upon where in the sequence it is captured. Routine assumptions on biological

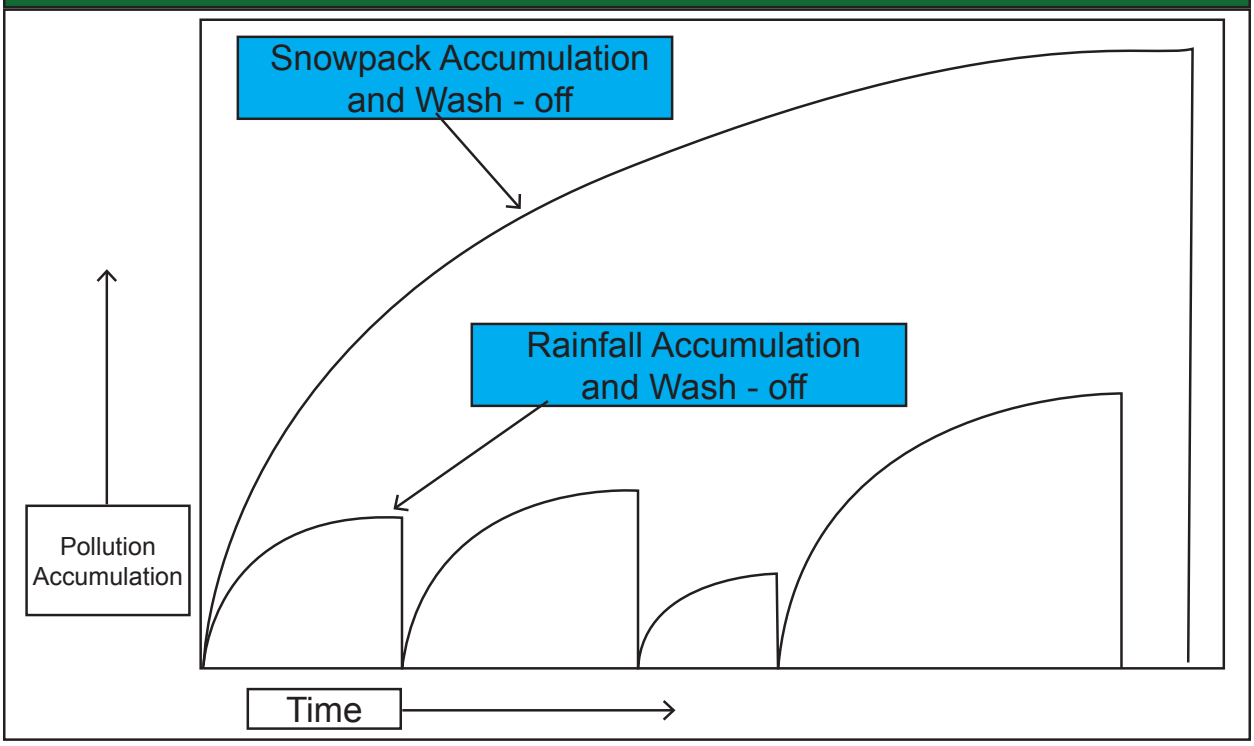
Figure 6.1a Direct Pave Surface with Heavy Traffic

Figure 6.1b Nearby Areas of Snow Accumulation from Distribution/Plowing

Figure 6.1c Aeas Well Removed from Roadways and High Traffic

Source: Minnesota Stormwater Manual 2005

Figure 6.1 Snowpack Accumulation and Wash-off as Compared to Rainfall



Source: Minnesota Stormwater Manual 2005

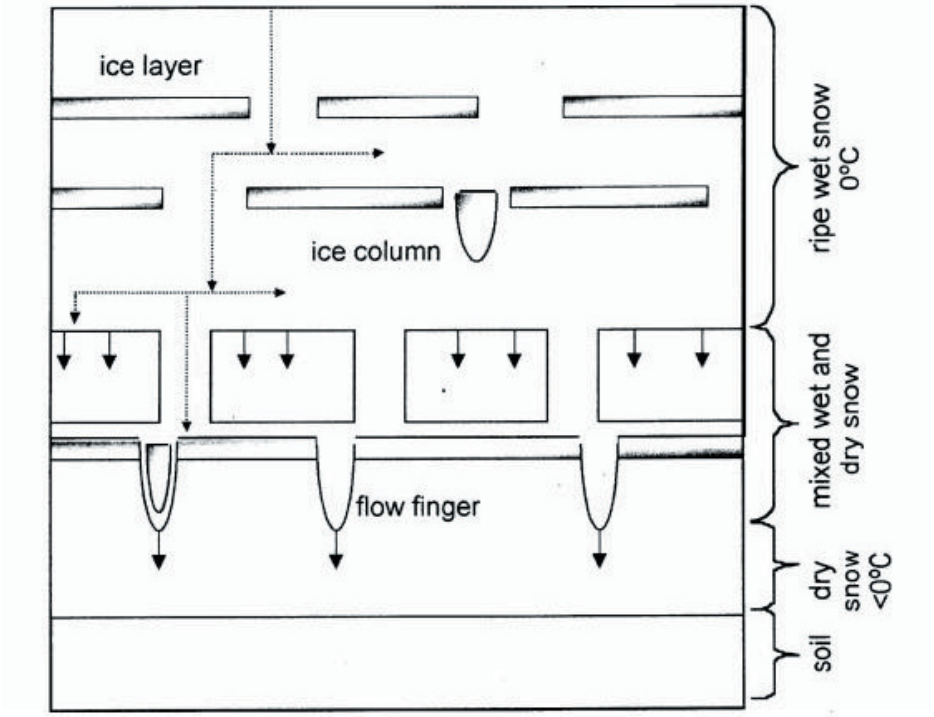
activity, aeration, settling, and pollutant degradation are altered by the cold temperatures, cold water and ice covered conditions that prevail for many months.

The variability of snow character and the repeated freeze-thaw cycles that occur throughout a long winter create a very heterogeneous snowpack. The complex melting pattern that occurs within a snowpack results in the release of pollutants at different times during the melt. The early part of the melt involves the very efficient elution of soluble constituents (ex. Cl, dissolved metals and nutrients, dissolved organics) at the crystal edges, yielding a highly soluble, acidic, and potentially toxic runoff volume. This process known as the first flush, results in a substantial release of the soluble component of a snowpack, often resulting in a “shock” effect as these pollutants reach a receiving water body. Later in the event, melt water from the snowpack is depleted in these soluble contaminants, but water flow can be at its highest providing enough energy to carry with it the finer-grained solids and associated contaminants (ex. hydrophobic PAHs) and leaving behind the larger particles. Alert sweeping can pick coarse material up from paved surfaces if there is an opportunity between the departure of snow and the first rains.

An end of the season rain-on-snow event often presents the worst-case scenario when rain falls onto a deep, possibly saturated snowpack. When this occurs, the movement of a well defined, rapidly moving wetted front through the snowpack results in the mobilization of soluble constituents and the energy associated with the rainfall is sufficient to mobilize the fine-grained or possibly larger solids and associated contaminants. This wave of melt also washes over urban surfaces and picks up material that has been deposited on these surfaces all winter. Meltwater can be extremely concentrated in many different toxic substances (metals, PAHs, organics, free cyanide, chloride). A major portion of annual pollutant loading can be associated with spring melt events.

Figure 6.3 shows how melt water can move downward in a snowpack through different flow-paths around “dry” snow and ice layers caused by repeated freeze-thaw cycles. As this water moves through, it picks up

Figure 6.3 Percolation of Water Through a Snowpack



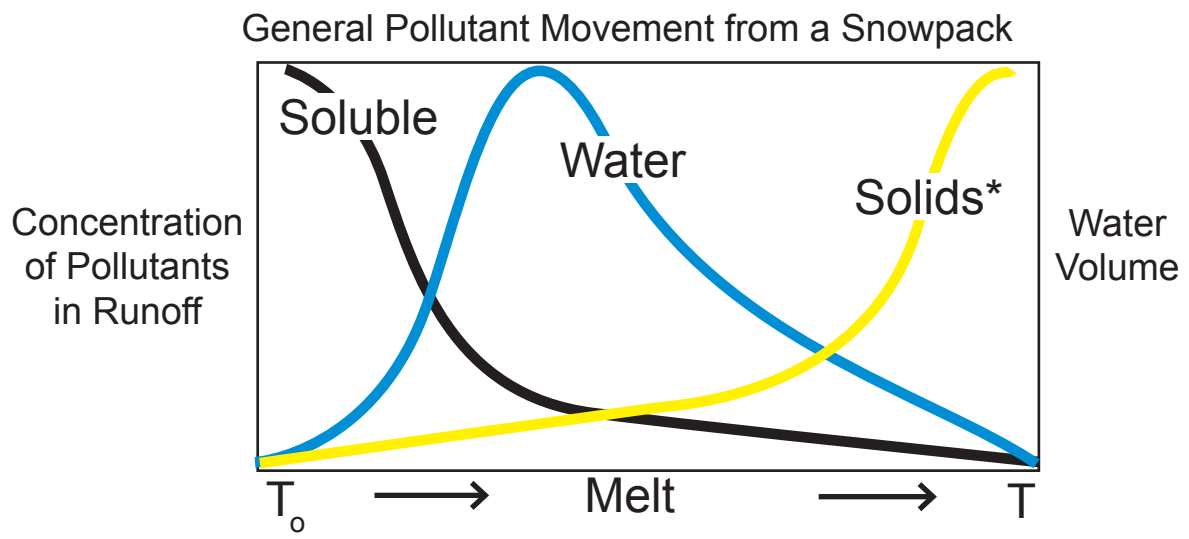
Source: UNESCO 2000, Chapter 2 of Semadeni-Davies and Bengtsson, as Adapted from Marsh and Woo, 1984

or mobilizes soluble ions that have pushed to the edge of ice crystals. Through this process, the snowpack cleanses itself of soluble contaminants that become available in the first phases of the melt, yielding a highly soluble, acidic and perhaps toxic (to animal and plant-life) runoff volume. Later in the event, melt water from the snowpack is depleted in these soluble contaminants, but water flow can be at its highest. Energy levels are only high enough to move fine- to medium-grained particulates when the snowpack allows their passage, leaving behind the coarser-grained material. The coarser material is available for wash-off during the higher energy spring rainfall events, and becomes a major source of contamination at that time. Alert sweeping can pick this coarse material up from paved surfaces if there is an opportunity between the departure of snow and the first rains.

The management implication of the preferential elution (or chemical dissolution) process is illustrated in Figure 6.4. The graphic shows that the early part of the melt involves the very efficient elution of soluble constituents (ex., Cl, dissolved metals and nutrients, dissolved organics) at the crystal edges, resulting in a substantial release of the soluble component of a snowpack, often resulting in a “shock” effect as these pollutants reach a receiving water body. Following the release of soluble is a period when much of the liquid volume of the snowpack releases (skewed toward the earlier part of the mid-melt event) and carries with it the remaining solubles along with the beginning portion of finer-grained solids and associated contaminants (ex. hydrophobic PAHs).

This mid-melt period generally has the largest portion of water runoff associated with the melt, and the mobilization of solids begins and continues as long as sufficient energy is available to move the finer particles, leaving behind the larger particles.

Figure 6.4 Residential Subdivision Illustrating Preservation of Natural Areas



Early	Middle	Late
Character		
High soluble content	Remaining solubles, beginning of fine- to medium-solids	High solids content
Low runoff volume, early infiltration	Large runoff volume	Large runoff volume (especially if rain-on-snow occurs), saturated soils
Initiated by chemical addition and/or solar radiation	Largely driven by solar radiation, aided by salt	Solar driven
Land Use Where Important		
Low density	High density	High density
Residential/neighborhood	Roads, parking lots	Roads, highways
Open space	Snow storage sites	Commercial
BMP Focus		
Infiltration	Pretreatment (settling)	Pretreatment (settling)
Dilution	Volume control	Filtration
Pollution prevention (salt, chemical application)	Detention/settling	Volume control
Retention		Pollution prevention (surface sweeping)
Wetlands/vegetation (infiltration, biological and soil uptake)		Detention/settling
Diffuse runoff paths		Wetlands/vegetation (filtration, settling)

Source: Minnesota Stormwater Manual 2005

Frozen Soils

Several studies have shown that frozen ground interferes with infiltration and reduces infiltration rates. These reduced rates are the result of a combination of things including frozen ground, formation of ice lenses, ice within soil pore spaces, snow cover, and depth of frost penetration. This interference however, only completely eliminates infiltration in the case of soils that are saturated upon freezing. Under most circumstances, infiltration through the soil profile still occurs. Temperature then becomes the primary factor in determining a soil's permeability under frozen conditions. In certain cases the freezing and thawing processes can actually increase the hydraulic conductivity of a soil through cracking (Benson et. al., 1995).

Spring melt is a complex process and occurs unevenly even at a site scale. Melt water tends to accumulate in depressions where it may be unable to drain for several days due to the underlying frozen soils. Thaw of the soils is patchy, usually occurring after the ground surface is exposed by melting snow, but it may occur more rapidly under ponds of melt water, allowing them to drain quickly through the thawed soils opening.

Wetland, Open Space and Biological Impacts

There are scant data available on the impact of meltwater on wetland systems and associated open space areas. This information is critical when the use of "natural systems" for runoff management is increasingly promoted. Among the impacts are species shifts to less desirable species, increased toxicity to various biota, and decreased diversity. Appendix E contains a list of recommended vegetative species for use in various surface water management approaches in Minnesota. A very good resource on the topic has been produced through MPCA, entitled *Plants for Stormwater Design - Species Selection for the Upper Midwest* (Shaw and Schmidt, 2003).

Groundwater Impact

The most damaging meltwater component affecting groundwater appears to be the two elements associated with the most commonly used road salt - Na and Cl. The damage begins at the soil interface where Na can displace Ca and Mg and disrupt the physical structure of the soil column. Chloride can lower pH and dissociate heavy metals into more soluble and mobile forms. Although both of these chemicals can continue to migrate downward, it is mostly the Cl that presents a major threat.

Key Challenges in Engineering and Design

List of Complicating Factors for Cold Climate Design

The physical and chemical processes under way in a snowpack present an extremely complicated and variable set of phenomena. The freeze-thaw cycle and the elution of chemicals that it drives have been understood for many years, but details on the migration and management of the many chemicals of concern from the snowpack are seldom pursued by runoff managers. In 1997, the Center for Watershed Protection produced a design manual intended to address many of these problems. One of the items reported in that manual was a survey of cold climate stormwater managers asking what the challenges were that they faced. Table 6.1 below is a reproduction of a table from the CWP report.

A special session was held at the 2003 Maine Cold Climate Conference during which practitioners were asked the same question. Also, a public input meeting during the development of this manual noted the basic problems in Table 6.1 were still of concern to managers. Frozen conditions complicate the movement and treatment of meltwater or rain-on-snow runoff. While no new practices exist to treat this runoff, some adaptation of our existing approach to design and snow management could be the key to addressing this situation in cold climates

Table 6.1 BMP Design Challenges in Cold Climates	
Climatic Condition	**BMP Design Challenge**
Cold Temperatures	▶ Pipe freezing ▶ Permanent pool ice covered ▶ Reduced biological activity ▶ Reduced oxygen levels during ice cover ▶ Reduced settling velocities
Deep Frost Line	▶ Frost heaving ▶ Reduced soil infiltration
Short Growing Season	▶ Short time period to establish vegetation ▶ Different plant species appropriate to cold climates than moderate climates
Significant Snowfall	▶ High runoff volumes during snowmelt and rain-on-snow ▶ High pollutant loads during spring melt ▶ Other impacts of road salt/deicers ▶ Snow management may affect BMP storage

Management Approaches

Meltwater Management

Special management of cold weather runoff is usually required because of the extended storage of precipitation and pollutants in catchment snowpack, the processes occurring in snowpack, and the changes in the catchment surface and transport network by snow and ice. The discharges that come from urban meltwater may cause physical, chemical, biological and combined effects in receiving waters and thereby limit their quality, ecosystems and beneficial uses.

For many years the old adage “one size fits all” was tried for the management of all runoff management. Once the effects of this approach were scrutinized, however, it became apparent that applying traditional rainfall runoff BMPs was not working for meltwater in spite of their success with rainfall. The problem is usually not the large volume resulting from a significant event, although serious flooding certainly can occur. Rather, it is that the BMPs can be prevented from working as intended because of ice, cold water, highly concentrated pollution and lack of biological activity. Complications encountered in cold climates can work against many of the commonly used warm weather BMPs, reinforcing the need for the development or adaptation (e.g. revised criteria and specifications) of existing treatment practices to better address melt runoff. Additionally, the reduced performance exhibited during cold weather is generally not considered when management approaches are designed because of the perceived uselessness in trying to overcome the items presented in Table 6.1. The problems cannot be entirely negated, but any improvement in the quantity and quality of runoff will be a step forward.

Typical results of the conditions listed above include flow by-passing and flooding, lack of reaeration in the water column, pond stratification, decreased settling and biological uptake, flushing of previously settled material, and reduced infiltration capacity.

Management Sequence

The manner in which meltwater runs off of different contributing surfaces was previously addressed. This behavior suggests that a sequence be followed to intercept and treat variable quantities and qualities of runoff as they emerge. It is required that the following approach be used in planning a strategy for optimizing treatment effectiveness (see sidebar). Specific BMP adaptations to account for these strategies will be discussed later in this section.

Pollution Prevention

Keeping contaminating materials away from paved surface and out of accumulated or dumped snow is the key to minimizing the pollution associated with meltwater runoff. The management approaches that should be developed to accomplish this include:

- Judicious use of de-icing and anti-skid chemicals, which then indirectly control secondary effects like heavy metal speciation and soil character changes from Cl
- Less additives like cyanide (CN) to salt
- Better chemical storage and mixing (covered storage and mix areas, mix only needed amount)
- Improved application technology with trucks, such as weather monitoring, direct application to roadway, and brine wetting
- Design of Cl dilution system to lower its direct impact

Snow Removal/Storage

The common Minnesota practice of pushing piles back from the paved surface as far as possible is encouraged. Research has shown that up to 90% of the pollution accumulated next to roadsides over the winter is deposited within about 25 feet of the road surface. Keeping the melt from this area off of the paved surface to the maximum extent possible is a positive water quality management strategy as it reduces exposure of the

The 5 Steps for Management

Step 1 - Pollution Prevention

Pollution Prevention is always the best way to manage the quality of runoff from urban and rural surfaces (see next section).

Step 2 – Snow Removal/Storage

The plowing, relocation and collection of snow presents some very real management issues. Recommended locations for snow storage are contributing areas to pretreatment BMPs (see next section).

Step 3 – Meltwater Storage and Pretreatment

The highly soluble and perhaps toxic "first flush" should be pretreated to the extent possible. This pretreatment will prevent the downstream infiltration practice from clogging with fine- and medium-grained solids being transported in meltwater as well as protect the groundwater resources from the potential impacts of pollutants typically associated with meltwater. Given the pretreatment requirements for infiltration practices in the NWA, there will be ample opportunity to treat meltwater although some cold climate adaptations may be necessary (see next section).

Step 4 – Infiltration

After the meltwater has been routed through a pretreatment practice, it should be suitable for infiltration. While the pretreatment practice may not remove all of the fines and pollutants typically associated with meltwater, the treatment available from infiltrating meltwater through soil (filtration, ion exchange, adsorption, and biological decomposition/transformation) will remove many of the most polluting contaminants typical of low-density urban areas (see next section).

Step 5* - Housekeeping

Much of the remaining solids are too heavy to be moved by melt so they remain near the roadside, in gutters, or in the location they were dumped as part of a snow pile, available for wash-off when spring rains come. After the snowpack has totally melted and before the first rainfall (if possible) preventive measures such as street and parking lot sweeping should be pursued. Note that Step 5 could occur after Step 1 for those facilities that practice cleaning activities during the winter.

Typical Snow Management Techniques

Figure 6.5a Snow Plowed Off the Road and Laft Piled on the Roadside

Figure 6.5b Snow Plowed Off Commecial Parking Lot and Piled in Corner

melt to particulates in the roadside area so adsorption can occur.

In most urban areas, a number of approaches are followed depending upon the level of urban density. In residential areas, snow is generally plowed to the side of the road and allowed to accumulate there all winter long. However, in commercial/ industrial zones, snow is often plowed to a corner of a parking lot, and in densely developed urban centers, snow is often removed to a totally different, often remote area, where it is dumped for an entire winter season (Figures 6.5 a and b in sidebar – see sidebar figure on page 16 Chapter 9 Volume 2 of Minn. Manual)

Local practices seem to vary considerably based on tradition, expectations and the cost of removal operations. Assuming snow is collected, the design of "snow dumps" must take into account the fact that snow eventually melts and needs somewhere to flow, either off of the land surface or into the ground.

There has been a shift in recent years by many public works departments to reduction in anti-skid sand and greater use of salt. This shift has been propelled by the high cost of removing sand from street surfaces and stormwater conveyance and treatment systems. If this trend continues, the adverse impact of salt on Minnesota's receiving waters is likely to increase. As difficult as sand is to deal with, it is generally inert and can be easily removed. Salt is a conservative substance that readily migrates into soil, groundwater, lakes and streams, causing problems at each step along the way. Alternatives to NaCl for road salting are not currently feasible because of cost (high relative to NaCl) and secondary environmental effects (like high BOD). Until such alternatives become available, a wise-use ethic should be the goal of every salt user. Adaptations in equipment, adequate driver training on application methods, and monitoring of driver salt use are other approaches to wiser salt use.

The following snow removal/storage guidelines should be adhered to in the NWA:

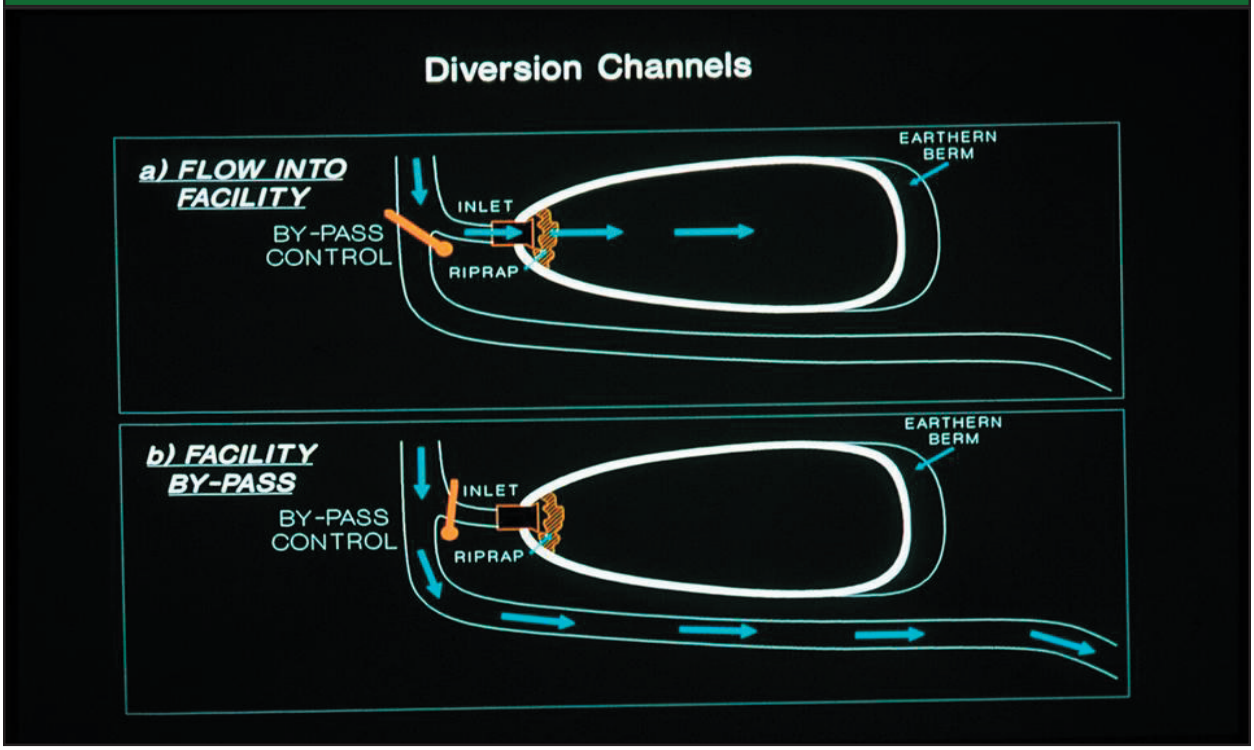
► Collect snow on a pervious pad and divert melt for treatment (e.g. pretreatment practice, detention, routing to a wastewater treatment facility).
► Develop a road de-icing plan that minimizes the use of road salt and identifies proper application techniques.

Meltwater Storage and Pretreatment

The highly soluble and perhaps toxic "first flush" should be pretreated to the extent possible provided the source area is not concentrated in Cl or other toxic pollutants. Given that the pretreatment requirement for the NWA is the removal of 85% TSS, it will be the Designers responsibility to evaluate whether or not additional treatment is necessary given the meltwater being routed to the facility during winter months. More information on the pretreatment requirements for the NWA can be found in Chapter 7.

If the Designer finds that it is infeasible to treat meltwater with high concentrations of Cl or other toxic pollutants, routing meltwater away from the pretreatment/infiltration system is an active meltwater management decision that can be made depending upon specific site conditions. For example, highly Cl-laden water can be routed away from an infiltration system that might operate during three seasons, but not the winter (see Figure 6.6).

Figure 6.6 Infiltration Design Adaptation Illustrating Re-Routing of Highly Cl-laden Meltwater



Source:

The following sections address some of the cold climate considerations associated with specific pretreatment practices.

Stormwater Ponds

Difficulties applying warm weather detention concepts to cold weather meltwater treatment occur because of the higher runoff volumes and increased pollutant loads, ice layers and frozen/sand-plugged conduits, anaerobic conditions, greatly enriched under-ice accumulation of pollutants, circulation problems and resuspension.

There are many processes that work to limit the effectiveness of ponding during meltwater events, including:

- Pond stratification;
- Anaerobic conditions;
- Release of pollutants from both bottom sediment and interstitial waters that were once thought to be permanently removed; and
- Displacement and flushing of highly polluted under-ice pond water with the first waves of meltwater that sink below the ice layer in ice-free areas near the inflow.

In spite of the fact that detention systems may not work well under typical designs in cold weather, they play a prominent role in the treatment of meltwater. Near paved areas, particulate content can become extremely high because of a winter's accumulation of anti-skid sand and urban debris. Routing this runoff to a detention facility prior to release to an infiltration practice or a receiving water is recommended. The large mass of particulates near these surfaces also plays an important role in adsorbing and settling soluble pollutants that otherwise might escape further treatment. For both of these reasons, an adapted ponding system is first among the list of recommended treatment methods for meltwater management. Specific adaptations are presented in the next section of this chapter.

It is important to recognize the potential pollution problems that Cl and toxic contaminant build-up in a pond can cause when released. A delicate balance needs to be pursued in deciding whether to adjust pond levels to pass Cl-laden water downstream or retain as much as possible for later release when flows are higher. Retaining polluted water all winter long only to discharge it all at once in the spring is not is the best interest of an infiltration facility, underlying groundwater resources or a downstream receiving water body, but this is what can happen in a pond not managed for seasonally changing conditions.

In no case should ponds be drained in the spring following a winter's long accumulation of under-ice contaminants. If lowering is done, it should be done in the late fall before freeze-up.

Wetland and Biological Based Systems

Wetlands and biological-based systems often act as modified detention facilities by virtue of their sheer numbers and the location they occupy in the drainage landscape. Most of the constraints listed above for ponds also apply to the proper operation of wetland treatment systems. In addition, however, is the sparse biological activity present during the cold weather season. Vegetative uptake, filtering and microbial activity are all effective mechanisms to reduce pollution related to biological activity during warm weather that are much reduced when the weather is cold. Although sedimentation might continue to play a role in meltwater treatment, provided an ice layer does not prevent it, decomposition, chemical adsorption and biological transformation will all likely be reduced.

Even though the pollutant removal effectiveness of biological systems is less during cold weather, these systems certainly have their place in an overall runoff management program. Low-lying wetlands and bioretention areas are the first place that soluble-laden first meltwater will migrate and soak into the ground. Standing vegetation, although not green and vibrant, still provides a measure of filtration as meltwater flows through. Soil microbes still live and consume nutrients even in the dead of winter. Accumulation of Cl is generally not a problem in shallow biological systems, as long as very highly concentrated levels are not routed directly to them, and even when this does occur, salt tolerant vegetation can survive. For more detailed information on salt tolerant vegetation see Appendix B of this Manual.

Filtration, Hydrodynamic Structures and Treatment Trains

Filtration through a granular inorganic (sand, perlite) or organic (compost, leaf pellet) medium can be a fairly effective way to treat many of the pollutants associated with meltwater. These systems can be particularly effective when placed as a sub-grade unit below the frost-line. Sub-grade construction also allows for surface land to be used for other things, such as parking or open space.

Many new proprietary management systems are on the market today with promises of year-round effectiveness. While many of these proprietary systems are promising, most are untested in cold climates. The most promising practices for meltwater are the treatment trains that incorporate settling, floatables skimming, and filtration through some kind of organic or synthetic media. Theoretically, these systems should be able to settle the solids associated with anti-skid grit added over the winter, then remove a fair portion of the soluble toxics also washing off in a melt. Unfortunately, conservative elements like Cl will move through most systems unchanged.

Many new proprietary management systems are on the market today with promises of year-round effectiveness. Many of these systems are promising, yet most are untested in cold climates.

Infiltration

Although infiltration has not been a commonly used meltwater BMP in Minnesota, studies from many similar climates show that it is a feasible practice when used with precautions. As Chapter 5 indicated, specific BMPs that involve infiltration include practices such as trenches and basins, pervious surfaces, vegetated swales and bioretention. Additional criteria for the design of infiltration practices is provided in Chapter 8 of this Manual.

Snow deposits should not be located directly over an infiltration facility because of the possibility of clogging from debris in the snow.

Housekeeping

Much of the remaining solids are too heavy to be moved by melt so they remain near the roadside, in gutters, or in the location they were dumped as part of a snow pile, available for wash-off when spring rains come. After the snowpack has totally melted and before the first rainfall (if possible) preventive measures such as street and parking lot sweeping should be pursued. The following housekeeping guidelines should be adhered to in the NWA:

- Rapid sweeping as soon as snow is gone from paved surfaces
- Litter control
- Erosion control

Design Adaptations for Cold Climates

BMP Sizing for Snowmelt

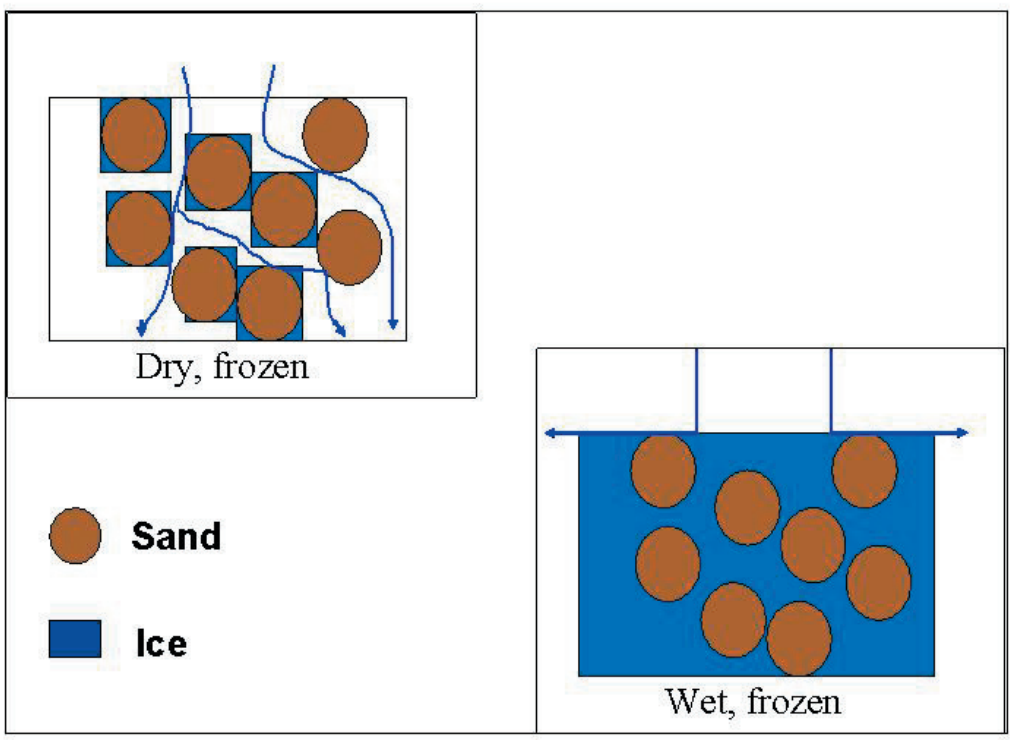
Climatology data supports a common rule of thumb that most of the snowpack disappears in the spring over a period of about ten days. The question can be raised as to why this volume should be important if BMP facilities are generally designed for treating a runoff event lasting only 24-hours. That is, aren't we merely dealing with on average 1/10th of a snowmelt runoff volume going into a facility designed to treat a much larger volume? Clearly, if the systems are built to store a large volume of rainfall runoff, there will be no problem. The difficulty arises when complicating factors in cold weather prevent the full storage volume for a pond, or infiltration capacity of an infiltration device, or conveyance for a diversion to be available during the period of time when they are designed to operate. Suddenly snowmelt could receive less than adequate treatment or by-pass any treatment whatsoever. The following cold climate adaptations need to be addressed in designing stormwater BMPs in the NWA.

Infiltration Practices

Depending upon the need, various options for the use of infiltration in cold climates are available. Some of the installations are built below the frost-line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. Surface systems, however, may need some special consideration.

The problem with infiltration in cold weather is the ice that forms both over the top of the facility and within the soil interstices (Figure 6.7).

Figure 6.7 Applicability of BMPs for Cold Climate Use



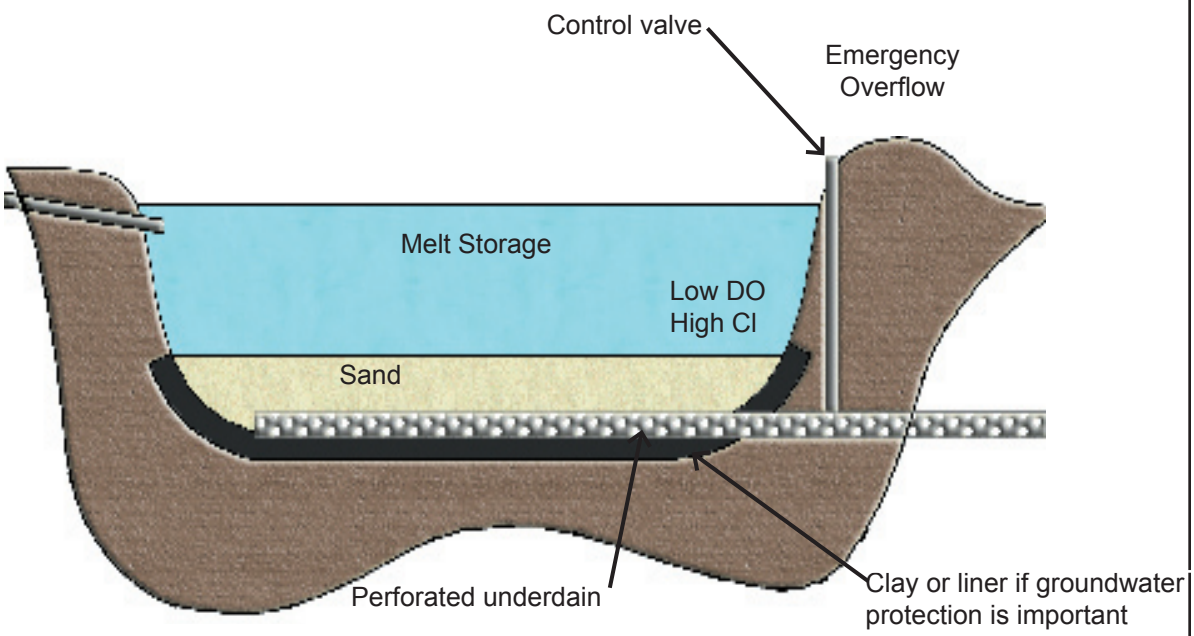
Source: Minnesota Stormwater Manual, 2005

To avoid these problems to the extent possible, the facility must be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods including limiting inflow, under-drainage and surface disking. Even if the infiltration properties of an infiltration basin are marginal for melt, the storage available in the facility will provide some storage if it is dry entering the melt season. Again, the designer is required to evaluate the need for additional pretreatment given the source and quality of meltwater being routed to the infiltration practice during winter months and in the spring.

Infiltration practices must be actively managed to keep it dry before it freezes in the late fall. Given the source and quality of meltwater, additional pretreatment may be necessary.

Figure 6.8 is a general graphic portrayal of an infiltration basin adapted for handling spring meltwater runoff. The adaptation in this graphic is a sub-drain installed to dewater the basin of any water heading into the freeze-up. This drain can be closed just prior to meltwater inflow and during the non-winter seasons to allow infiltration to continue downward. Also note that a clay liner can be added if the need to protect local groundwater from infiltrating meltwater is important. If this adaptation is made, the basin is no longer an infiltration system, but instead becomes a filtration system or dry pond.

Figure 6.8 Seasonal Infiltration Basin (or Filtration Basin if Liner Installed)



Source: Minnesota Stormwater Manual, 2005

Proprietary, sub-grade infiltration systems provide an alternative to standard surface based systems. These systems, in essence, provide an insulated location for pre-treated meltwater to be stored and slowly infiltrated, or simply filtered and drained away if groundwater sensitivity is an issue. The insulating value of

these systems adds to their appeal as low land consumption alternatives to ponds and surface infiltration basins.

Filtration Practices

In cold climates, stormwater filtering systems need to be modified to protect the systems from freezing and frost heaving. Physical design and operational considerations to keep in mind for filtration systems are included in Chapter 8.

Stormwater Ponds

The difficulties of operating an effective storage and treatment pond in a cold climate were discussed previously. Problems exist with the thick ice cover (lack of reaeration, “impervious” cover for settling purposes, reduced storage volume) and under the ice (anaerobic conditions, resuspension of settled material, concentration of Cl and toxic material, dissolution and density stratification).

To overcome these difficulties, some seasonal adjustments can be made to account for winter conditions. The obvious need in this situation is to eliminate the effect of the ice layer. This layer can be up to several feet thick during a hard winter and can greatly reduce the availability of the designed storage volume. The result is usually a small amount of the initial melt diving under the ice in a somewhat pressurized manner forcing out water that might have sat stagnant all winter long. When the available capacity provided by limited uplift of the ice cover is filled, meltwater begins to flow over the top of the ice, which usually means outflow at the other end after very limited exposure to settling due to the “impervious” ice cover.

Minimizing the effect of the ice cover can be done passively through the design of surplus storage or actively through the management of water levels before ice has a chance to form and after meltwater inflow begins. While the following adaptation requires more active management, it is required for the NWA as it will result in improved performance and fewer downstream water quality problems. The significant change made in this adaptation (Figure 6.9) is the addition of a controlled outlet mechanism for the permanent storage pool. Lowering this pool to a lower level will minimize the effect of an ice layer and maximize the storage available once the lower control is closed and the large spring melt occurs. The poor under-ice water quality concerns will be minimized. The “reclaimed” storage volume will equal most of the permanent pool and all of the water quality volume. The storage of all phases of the melt sequence means that solubles will be held, volume will be stored, and particulates will have a chance to both adsorb soluble pollutants and settle.

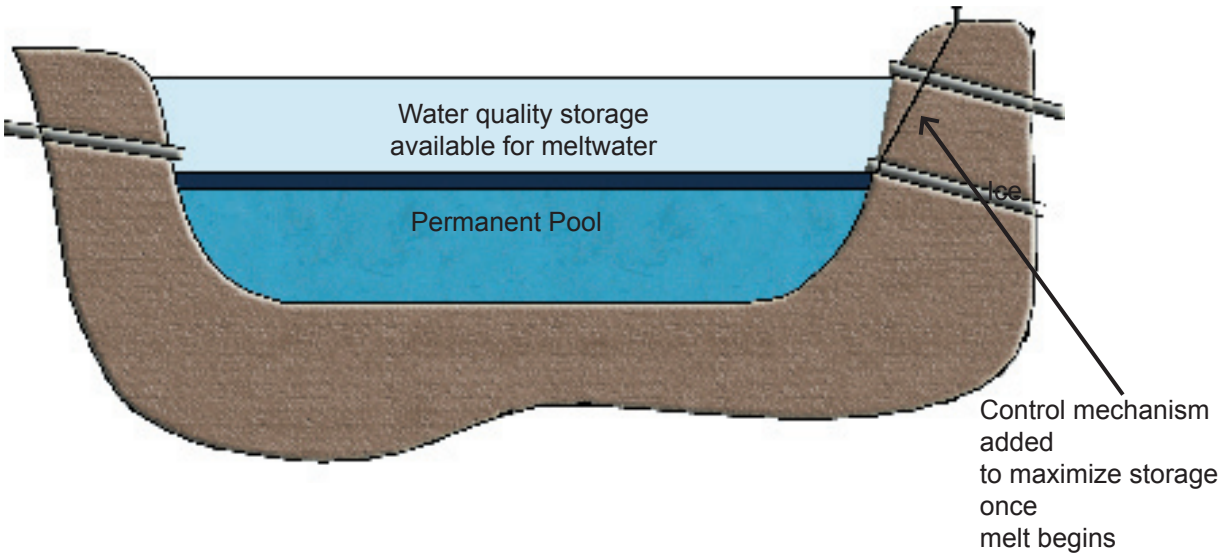
Manage water levels in stormwater ponds to minimize or eliminate the effect of ice cover during spring snowmelt event.

One caution for this system is that the permanent pool could completely freeze or possibly disappear entirely if the drawdown is complete. Since maintaining a healthy biological system is part of a successful detention system, it is recommended that the permanent pool not be drawn too far down such that total freeze-up or elimination occurs.

Details on various outlet configurations are also provided in Chapter 8. Some basic outlet concepts, however, should be mentioned. Perhaps as important as the layer of ice over the permanent pool is the blockage or hindrance of outflow from a pond because of a frozen outlet. There is a need to get water from under an ice layer to exit in a manner that does not cause splashing or gradual freezing of layer after layer

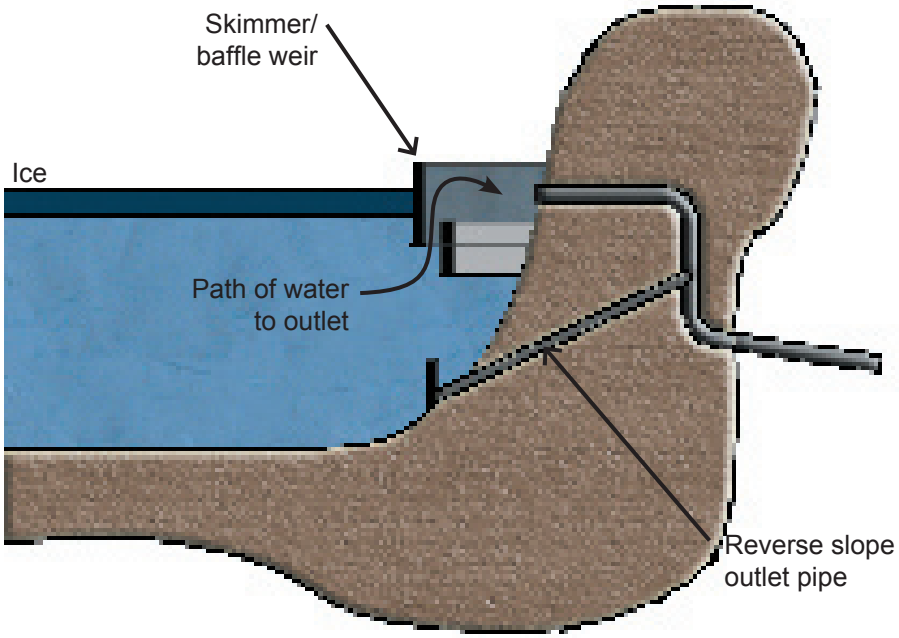
of outflow. Drawing water from below the ice via a reverse sloped outlet pipe and installation of a skimmer device (baffle weir) that draws water from below the ice are two options shown in Figure 6.10.

Figure 6.9 Simple Meltwater Storage



Source: Minnesota Stormwater Manual, 2005

Figure 6.10 Drawing Outflor Water from Below the Ice



Source: Minnesota Stormwater Manual, 2005

III. Potential Stormwater Hotspots (PSHs)

Background and Designation of PSHs

PSHs are defined as commercial, industrial, institutional, municipal, or transportation-related operations that produce higher levels of stormwater pollutants, and/or present a higher potential risk for spills, leaks or illicit discharges (Schueler *et al*., 2004). It is important to note that 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. One of the design considerations should be an evaluation of the need for additional pretreatment prior to discharge to an infiltration practice. Ultimately, a PSH site designation may dictate that certain practices and/ or design criteria are promoted or discouraged. Table 6.2 provides a listing of potential PSHs associated by major land use category. A description of the major land use category is provided below.

Table 6.2 Examples of Potential Stormwater Hotspots (PSHs)

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	▶ 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 ▶ Highway maintenance facilities ▶ Trucking companies and distribution centers

*Please note that this list is not all-inclusive, nor does mention here indicate that all such occurrences will be PSHs; rather, these are examples of typical land uses that could be PSHs.

Commercial PSHs

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 stormwater 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 stormwater permit program, by local ordinance or by federal/state law if they handle even small quantities of hazardous material.

Industrial PSHs

Industrial PSHs are a major focus for pollution prevention if they use, generate, handle or store pollutants that can potentially be washed away in stormwater runoff, spilled, or inadvertently discharged to the storm drain system. Each type of industrial PSH generates its own blend of stormwater pollutants, but as a group, they generally produce higher levels of metals, hydrocarbons and sediment. Many industrial operations are regulated under the NPDES industrial stormwater permit program, although individual owners or operators may be unaware of their permit status.

Institutional PSHs

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.

Municipal PSHs

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 stormwater pollutants, including nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash.

Transport-Related PSHs

Many, but not all, transportation related uses are regulated PSHs. They tend to generate higher loads of hydrocarbons, metals, and sediment in stormwater runoff, can be associated with large areas of impervious cover, and have extensive 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. Road surfaces are not automatically considered as PSHs unless they have been shown locally to be such sources.

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.

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. The 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 stormwater 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 can reduce pollutants, whereas other sites may require more sophisticated spill prevention and response plans.

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. Water quality problems from very soluble Na, Cl and cyanide have been documented as resulting from stored salt piles. It is recommended that all public and private entities storing salt to follow the Salt Institute's (http://www.saltinstitute.org/) recommended BMPs, which include such things as covering, impervious pads and drainage routing.

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. 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 (e.g., 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 pre-treatment 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.

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 6.3 presents representative pollutant removal data for common PSH pollutants of concern as a function of practice group.

In the NWA it is often the protection of infiltration practices and ground water protection 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 guidelines should be carefully considered and incorporated as applicable by designers when specifying and siting BMPs at sites with PSHs.

- Convey and treat the non-hotspot runoff separately from the hotspot runoff. Pretreatment standards for hot-spot areas will be determined on a case-by-case basis based on contaminant(s) of concern. This evaluation will require up-front coordination with City staff.
- Infiltrate the non-hotspot runoff using the pretreatment standards identified in Chapter 7.
- The infiltration of runoff from PSHs may require oversizing sediment trapping features such as forebays and sedimentation chambers; incorporating appropriate proprietary and nonproprietary practices for spill control purposes and treatment redundancy; oversizing pre-treatment features for infiltration facilities such as swales, filter strips, and level spreaders.
- Consider closed systems with liners, under-drains, or comparable safeguards against infiltration for practices that manage hot-spot runoff.
- Establish rigorous maintenance and inspection schedules for practices receiving hot-spot runoff.

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 pre-treatment, over-design, or design redundancies. Others are added features that limit the likelihood of ground water 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 ground water 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.

Table 6.3 Percent Removal of Key Pollutants by Practice Group

Practice	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydrocarbons [%]
Detention Ponds	25	60	70[2]	80[2]
Wet Ponds	30	60	70	80[2]
Stormwater Wetlands	30	40	75[2]	85[2]
Filtering Practices and Bioretention	35	65	45[2]	80[2]
Infiltration Practices[3]	50	80[2]	N/A	N/A
Vegetated Swales and Grass Channels[4]	80[2]	60	N/A	60[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. In the NWA, infiltration practices are not used for the pretreatment of stormwater runoff. Rather, there is a pretreatment standard of 85% TSS removal prior to discharge to an infiltration practice.
4. Higher removal rates for dry swales.

N/A: Data not available

Removals represent median values from Winer (2000)

Guidance on Infiltration of Runoff from PSHs

Preventing or minimizing the likelihood of contaminated runoff from leaving a PSH site is the core objective of stormwater management at these sites. Introduction of contaminated runoff to the ground water is probably the greatest concern in developing effective stormwater management plans at PSHs. There is a 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. This is for three primary reasons: 1) ground water 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 ground water contamination in areas where ground water is the primary drinking water source as it is in the NWA; and 3) mitigation, when needed, is often difficult and is usually very expensive.

Infiltration at PSHs relies on overall site design and facility operations management. Table 6.4 provides potential infiltration guidelines associated with each of the seven operational areas.

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. The Minnesota Department of Health recommends that infiltration should not be used within the one-year wellhead protection area and limited in vulnerable wells for the 10-year wellhead protection area. Contact the MDH for specific information on exact locations.

Table 6.4 Infiltration Guidelines for Potential Stormwater Hotspots

Operational Area	Potential Infiltration Guidelines
Turf Practices	Infiltration okay so long as there is no co-mingling from higher pollutant loading areas and pretreatment standards are met. Hot-spot runoff may require additional treatment. Chemical management needed to limit the amount of fertilizer and pesticides added to the turf.
Downspouts	For commercial sites no polluting exhaust from a vent or stack deposits on the rooftop.
Parking Lots	Infiltration okay with following provisions: ► No direct discharge of hot-spot runoff from higher pollutant loading areas. ► Limited salt application or use of alternative deicers ► Pretreatment standards shall be met. ► Only daily "commuter" parking areas and no long-term car/truck storage sites
Waste and Material Storage*	Pretreatment measures must include spill prevention and containment measures such as catch basin inserts and oil and grit separators. Pretreatment may require redundancy such as filtering prior to infiltration. Infiltration should be prohibited in areas of exposed salt and mixed sand/salt storage and processing.
Loading Docks*	Pretreatment measures must include spill prevention and containment measures 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*	Pretreatment measures must include spill prevention and containment measures such as catch basin inserts and oil and grit separators. Pretreatment may require redundancy such as filtering prior to infiltration.
Highways*	Infiltration possible where enhanced pre-treatment 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

IV. Mosquito Control

Because stormwater management usually deals with the transmission, storage and treatment of water, there is much concern about the proliferation of mosquito breeding habitat associated with BMPs. This is a well-founded concern because mosquitoes will colonize any source of standing water provided there is a source of organic material to provide sustenance to larvae (Messer, 2003). Although this basic fact often means that BMPs will result in more mosquitoes, there are many design and management measures that can be followed to minimize this increase.

The primary threat to Minnesotans from mosquitoes, besides the nuisance, is the transmission of serious disease. West Nile Virus (WNV) and various forms of encephalitis are the major concerns. There are about 50 varieties of mosquito in the state, but only a few are efficient transmitters of WNV.

Minnesota is fortunate to have a major mosquito research and management agency in the Metropolitan Mosquito Control District (MMCD) which has been able to characterize the occurrence of mosquitoes and the problems they cause in the state. All mosquitoes need water for the larval and pupal stages of development. The larval stage lasts anywhere from 5-7 days, so holding water for less than five days will prohibit the progression of life past the larval stage. Standing water for over two weeks can easily breed mosquitoes if not treated.

The presence and behavior of water is the most important element to the continuing life cycle of the mosquito. Controlling standing and stagnant water, and adapting design and habitat conditions are the ways stormwater managers can avoid a proliferation of mosquito breeding in association with stormwater BMPs.

Stormwater Managers can take many actions to reduce the likelihood of problems with mosquitoes, including:

- Protect the water quality of all BMP facilities to avoid high levels of nutrient and algae (food for mosquitoes), low dissolved oxygen (inhibits development of predators like fish, frogs, dragonflies and damselflies), and stagnant water; be aware, however, that some mosquitoes thrive in clean water, where predation could be the most effective control
- Properly design and maintain all stormwater BMPs
- Work with vector control agencies on integrated pest management approach to larval control
- Maintain and clean-out sediment traps/basins and all drainage structures, inlets, outlets and orifices (use only openings >3” to prevent clogging) to keep positive water drainage
- Design facilities to minimize vegetation overgrowth, floating organic debris, algae, trash, sediment dead grass/clippings, and cattails
- Avoid the use of rip-rap that can catch and hold organic debris in a wet area
- Avoid the use of mulch that will wash into any BMP (use geotechnical material or secured mats instead)
- Keep dense emergent vegetation limited to narrow (<1m) bands around areas with standing water and prevent the development of cattail stands
- Avoid vegetation cutting operations that leave debris, blow into standing water, or leave ruts for water accumulation
- Do not allow water to collect in “temporary” facilities for longer than five days, preferably less than three
- Drain infiltration/filtration BMPs within 72 hours or 48 hours if it is being used to meet MPCA’s requirements
- Design healthy natural systems that encourage mosquito predators to thrive and have access to mosquito larvae; this includes open water (over four-feet deep) as part of wetland design (preferably oriented perpendicular to flow-through), minimization of stagnant, non-flowing water, creation of diverse vegetation only along periphery of ponds

- Eliminate standing stagnant water as part of any BMP appurtenance, including forebays, sediment traps, sump areas and pumps
- Use BSD/LID development techniques to reduce the amount of stormwater that needs to be conveyed and managed
- Minimize shallow depths (less than one-foot) as part of ponds and wetlands; if this cannot be done, make sure flow continually flows over the shallow area
- Keep permanent pool embankments steep to prevent emergent vegetation, especially cattails, from growing; carefully plan plant species for aquatic/safety benches to avoid cattail intrusion
- Minimize installation of BMPs that will collect stormwater for only brief periods then stagnate until the next event; this could include a water budget analysis to make sure some baseflow will occur through the BMP
- Avoid allowing standing water to collect in inlets and outlets and in conveyance pipes; avoid corrugated pipe without constant flow and sumps in catch basins
- Require written inspection and maintenance plan that addresses stagnant water, water quality, and vegetation and debris management
- Design de-watering capability into every BMP for routine dry-down and maintenance
- Place inlet and outlet pipes under water if no other control available (prevents fly-in)
- Always design access for vector control staff to reach entire BMP, not just the inlet or outlet

Compatibility with Common BMP Design

A cursory consideration of the list of commonly used Minnesota BMPs relative to the above list would seem to indicate that some BMPs might be more desirable than other when mosquitoes are concerned. Careful consideration of practices can avoid the mosquito impact, as follows:

- Avoiding excessive vegetative growth does not mean minimizing vegetation, rather it means keeping a healthy mix that thrives and does not overwhelm the BMP or an (upland) area adjacent to a BMP. The same applies for emergent vegetation that is planted as part of an overall planting scheme.
- Shallow vegetated benches are part of the recommended safety design for ponds. Although a recommendation above suggests that “shallow” water less than one-foot be avoided in standing water situations, it might be necessary, depending upon safety needs, to construct such a bench. In addition, a recommendation above suggests that dense periphery vegetation be limited to about 1m in width, whereas Chapter 8 recommends bench width at 10’. Designers are advised to use their judgment on the mix of recommendations for edge-of-pond depth, depending upon priorities for safety relative to mosquito control. Care should be taken in plant selection, particularly if bench depths less than one-foot are anticipated.
- Rip-rap or similar structural armor for bank stabilization are options that are sometimes needed in erosive situations. The tendency for these materials to capture vegetative debris and to create small pools of water make them ideal mosquito breeding sites. If mosquito breeding is a concern at these installations, smoothing with a grout material or size grading can be used to minimize edges and pools that promote mosquito habitat, or alternative materials can be used.
- Extended detention pools should recede within three days to minimize possible mosquito breeding. Floodwater mosquito egg-laying on the moist side slopes above the permanent pool is almost impossible to control in this situation because the eggs remain viable for up to five years and will wash into the pool whenever water levels rise. Standing water varieties can be minimized with a good vegetative management plan that allows these areas to fully dry out between events. If conditions cannot be improved to minimize breeding habitat, biologic larvicides should be used.
- Forebays, sediment traps and treatment sumps could all be part of a well designed treatment train. The recommendation above to keep these from becoming stagnant is consistent with good design principles and should not preclude their use. The essential elements in keeping them “fresh” are to either drain them fully after use or keep baseflow moving through them. MMCD began a monitoring program in underground structures in 2005 and has found evidence of mosquito breeding in half of the structures tested through mid-summer.

In summary, there are many ways in which stormwater BMPs can become mosquito breeding grounds if caution is not followed in their design, operation and maintenance. However, this section illustrates that the means exist to install BMPs that minimize the creation of mosquito habitat.

IV. References

Aichinger, C., 2004. Understanding the West Nile Virus. Woodbury Bulletin (newspaper opinion page), August 11, 2004. Contact Ramsey-Washington Metro Watershed District, North St. Paul, MN.

Andrews, W.J., J.R. Stark, A.L. Fong and P.E. Hanson, 1999. Ground-water quality along a flowpath in surficial outwash aquifer in the Upper Mississippi River Basin The influence of land use. Hydrological Science and Technology, 15(1-4):66-75. Special Issue: 4thUSA/CIS Joint Conference, November 7-10, 1999, San Francisco. American Institute of Hydrology.

Bäckström, M., 1999. Series of Papers in Licentiate Thesis, Luleå University of Technology.

Bäckström, M., 2002. Series of Papers in Doctorate Thesis, Luleå University of Technology.

Benson, C.H.; Abichou, M.A.; Bosscher, P.J. (1995) winter effects on hydraulic conductivity of compacted clay. Journal of geotechnical engineering. 121(1):69-79.

Buttle, J.M., 1990. Effect of suburbanization upon snowmelt runoff. Hydrol. Sci. Jour., 35(3):285-302.

Caraco, D. and R. Claytor, 1997. Stormwater BMP Design Supplement for Cold Climates. Center for Watershed Protection, Ellicott City, Maryland, USA.

Colbeck, S.C., 1978. Physical aspects of flow through snow. Advances in Hydroscience, 11: 165-206.

Colbeck, S.C., 1981. A simulation of the enrichment of atmospheric pollutants in snow cover runoff. Water Res. Research, 17(5): 1383-1388.

Colbeck, S.C., 1991. The layered character of snow covers. Rev. Geophys., 29(1):81-96.

Commonwealth of Virginia, 2003. Vector Control: Mosquitoes and Storm Water Management Stormwater Management Technical Bulletin No 8.

Duke, D., K. Patel, and B. Masek. 1999. “Widespread Failure to Comply with U.S. Storm Water Regulations for Industry-Part I: Publicly Available Data to Estimate Number of Potentially Regulated Facilities.” Environmental Engineering Science. Vol. 16(4).

Duke, D. and K. Shaver. 1999. “Widespread Failure to Comply with U.S. Storm Water Regulations for Industry-Part II: Facility-Level Evaluations to Estimate Number of Regulated Facilities.” Environmental Engineering Science. Vol. 16(4).

Granger, R.J., D.M. Gray and G.E. Dick, 1984. Snowmelt Infiltration to Frozen Soils. Canadian Journal of Earth Science, 21:669-677.

Hogland, W., M. Marques, and V. Karlaviciene. 2003. Stormwater Runoff From Industrial Areas and Pollution Transport. Proceedings from 1st International Conference on Urban Drainage and Highway Runoff in Cold Climate. Riksgränsen, Sweden.

Isabelle, P.S., L.J. Fooks, P.A. Kenny and S.D. Wilson, 1987. Effects of roadside snowmelt on wetland vegetation: An experimental study. Jour. of Envir. Management, 25:57-60.

Jeffries, D.S., 1988. Snowpack release of pollutants. National Water Research Institute (Burlington, Ontario, Canada), Report No. 88-06.

Marsalek, J., 2003. Road salts in urban stormwater: An emerging issue in stormwater management in cold climate. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.65-74.

Marsalek, J., G.L. Oberts, K. Exall and M. Viklander, 2003. Review of the operation of urban drainage systems in cold weather: Water quality considerations. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.1-11.

Marsalek, P.M., W.E. Watt, J. Marsalek, and B.C. Anderson, 2000. Winter flow dynamics on an on-stream stormwater management pond. Water Qual. Res. Jour. Canada,35(3): 505-523.

Marsh, P. and M-K. Woo, 1984. Wetting front advance and freezing of meltwater within a snow cover - 1. Observations in the Canadian Arctic. Water Res. Research,20(12): 1853-1864.

Maryland Department of the Environment (MDE), 2000. 2000 Maryland Stormwater Design Manual, Volumes I and II. Prepared by the Center for Watershed Protection and MDE.

Matheussen, B.V. and S.T. Thorolfsson, 2003. Estimation of snow-covered area for an urban catchment using image processing and neural networks. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.315-326.

Messer, D.F., 2003. Mosquitoes in Structural Stormwater BMPs: A Case Study. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Metzger, M.E., 2003. Mosquito Control Challenges Presented by Stormwater Treatment Devices in the United States. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Natural Resources Conservation Service (NRCS), 1984. Engineering Field Manual for Conservation Practices. U.S. Department of Agriculture, Washington, D.C.

Novotny, V., D.W. Smith, D.A. Kuemmel, J. Mastriano and A. Bartošová, 1999. Urban and Highway Snowmelt: Minimizing the Impact on Receiving Water. Wates Environment Research Foundation (WERF), Project 94-IRM-2.

Oberts, G.L., 2003. Cold climate BMPs: Solving the Management Puzzle. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.13-31.

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe, 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems, Metropolitan Council, Publication No.590-89-062a, 170 p.

Pitt, R. 2001. Methods for Detection of Inappropriate Discharges to Storm Drainage Systems: Background Literature and Summary of Findings. Tuscaloosa, AL Prince George's County Maryland. 2002. Prince George's County Bioretention Manual. Department of Environmental Resources.

Pronold, M., 2000. Administering the NPDES Industrial Storm Water Program in Proceedings: National Conference on Tools for Urban Water Resource Management and Protection. U.S. EPA, Office of Research and Development, EPA/625-R-00-001.

Sansalone, J.J. and S.G. Buchberger, 1996. Characterization of metals and solids in urban highway winter snow and spring rainfall-runoff. Trans. Res. Record, 1523:147-159.

Schueler, T., 2000. Pollutant Dynamics of Pond Muck. Watershed Protection Techniques, 1(2): 39-46. Center for Watershed Protection, Ellicott City, MD.

Schueler, T., C. Swann, T. Wright, and S. Sprinkle. 2004. Urban Subwatershed Restoration Manual No. 8: Pollution Source Control Practices, Version 1.0. Center for Watershed Protection. Ellicott City, MD.

Semadeni-Davies, A., 2003. Response surfaces for climate change impact assessments in urban areas. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.269-279.

Shaw, D. and R. Schmidt, 2003. Plants for Stormwater Design. Minnesota Polution Control Agency, 369 p.

St. Johns River Management District (SJRMD). 2001. Applicant's Handbook: Regulation of Stormwater Management Systems. Palatka, FL.

Stanek, S. (no date). West Nile Virus and Stormwater Management. Brochure prepared for the Minnehaha Creek Watershed District, Deephaven, MN.

UNESCO, 2000. Urban Drainage in Specific Climates: Vol.II. Urban Drainage in Cold Climates. ed. by S. Saegrov, J. Milina and S.T. Thorolfsson. IHP-V, Technical Documents in Hydrology, No. 40, Vol. II, Paris.

U.S. EPA Wetlands and West Nile Virus brochure

Wass, R.D., 2003. Mosquito Management Do's and Don'ts in an Engineered Arizona Treatment Wetland System. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Westerström, G., 1984. Snowmelt runoff from Porsön residential area, Luleå, Sweden. In Proceedings of the Third International Conference on Urban Storm Drainage, Gothenburg, Sweden, June 4-8, 1984, pp. 315-324.

Wheaton, S.R. and W.J. Rice, 2003. Siting, design and operational controls for snow disposal sites. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.85-95.

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

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2004. Urban Subwatershed Restoration Manual No. 11: Unified Subwatershed and Site Reconnaissance: A User's Manual, Version 1.0. Center for Watershed Protection. Ellicott City, MD.