Article 71

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Performance of Stormwater Ponds and Wetlands in Winter

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Stormwater ponds and wetlands are common practices for treating stormwater runoff in northern regions. Until recently, however, very little winter monitoring data was available. Oberts and his colleagues sampled four stormwater ponds in Minnesota during both rainfall and snowmelt conditions. They found that ponds were generally effective in removing pollutants during non-winter conditions. However, there was a marked reduction in the performance of stormwater ponds in treating snowmelt runoff. Most ponds did a fair job of removing sediment and organic matter in the winter, but were mediocre at removing nutrients and lead (Figure 1).

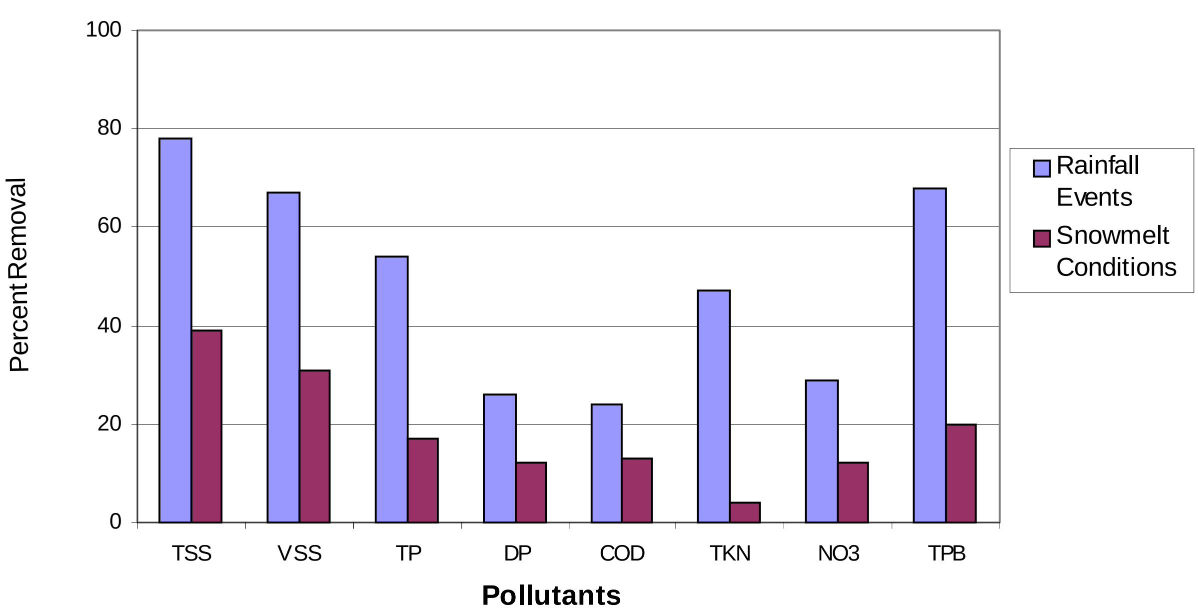
There are several reasons for the poor performance of stormwater ponds in winter. One primary reason is the thick ice layer that can form, sometimes reaching three feet in depth. This ice layer can effectively eliminate as much as half of the permanent storage volume needed for effective treatment of incoming runoff. In this case, the first increment of meltwater runoff entering the pond dove beneath the ice layer and created a turbulent, pressurized condition that scoured and resuspended bottom sediments in the pond.

Once the available pool volume under the ice was filled, meltwater runoff was forced to flow over the top of the ice. This further reduced performance, since the settling depth above the effectively impermeable ice layer was minimal. Pollutants that settled on the ice were easily resuspended during the next melt or runoff event. In addition to the physical limitations of settling, biological activity in the pond was also greatly reduced during the winter.

The same forces working against wet ponds in winter also work against wetland systems. In fact, wetland efficiency may drop even further because wetlands are shallower, have larger amounts of detritus available for re-suspension, and are biologically dormant during winter.

Research on a wetland in Minnesota shows how pollutants can pass through a stormwater wetland system, even when it appears as though the system might be working. The pollutant removal performance during snowmelt and for the first two rainfall events after snowmelt in a six-acre, six-chambered, lowhead wetland treatment system is presented in Figure 2. The wetland outlet was frozen for the entire winter and was thus effectively closed. This resulted in the formation of a thick ice layer and subsequent deposition and accumulation of all small midwinter events and baseflow in the final wetland chamber (approximately 2.5

Figure 1: Average Effectiveness of Four Stormwater Ponds (Oberts *et al.*, 1989)



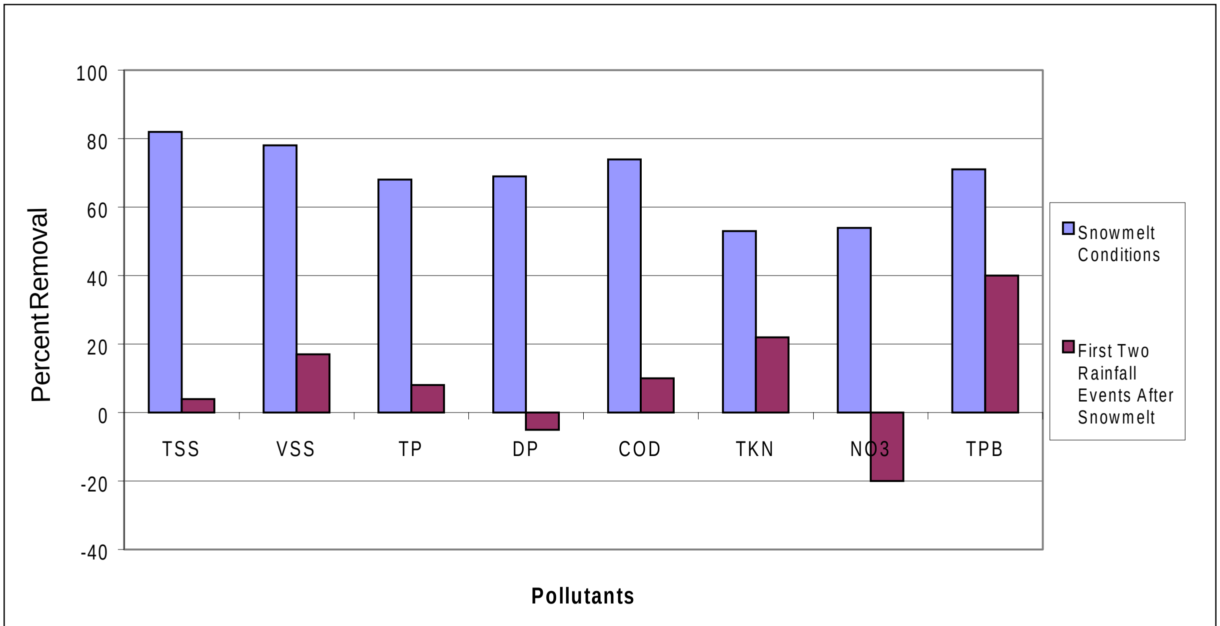


Figure 2: Effectiveness of a MN Wetland Treatment System (Oberts and Osgood, 1988)

acres). When the end-of-season melt began, runoff entering the final wetland cell ponded and dropped a portion of its load on top of the ice layer. Water began to move downgrade only when an opening in the outlet culvert formed. The material that settled was subsequently washed away by the next rain occurring after the snowpack had entirely melted from the catchment.

Are there design methods that can improve the performance of stormwater ponds during snowmelt conditions?

Meltwater Treatment

The first meltwater from a snowpack will likely be acidic and highly concentrated with soluble pollutants, particularly ions (Na^+, Ca^{2+}, SO_4^{2-}, Mg^{2+}, H^+, NO_3^-). Adverse impacts of meltwater on aquatic life are typically related to elevated levels of metals, organic toxicants, and salt. Thus, meltwater treatment should occur before it reaches a receiving waterbody. One option is to detain it so that it can infiltrate into the soil where soil adsorption and macrobiotic activity can occur (Zapf-Gilje *et al.*, 1986).

Hartsoe (1993) found that PAHs were essentially non-detectable in groundwater infiltrating through sand and gravel at a highway drainage infiltration pond in Minnesota. However, the most soluble meltwater pollutants, such as chloride, will likely pass through the soil relatively intact. This phenomenon should be taken into account when designing such a facility.

Two alternatives for meltwater treatment are shown in Figures 3 and 4. The first option is a nonstructural approach wherein meltwater is routed through an infiltration swale (e.g., grass, sand/gravel) to a flow diffuser that spreads the meltwater over a naturally vegetated or wetland surface (Figure 3). Even though the vegetation is dormant, some benefit will occur because the area will likely be able to infiltrate some water. Caution must be exercised, however, since chlorides and other ions can adversely impact the grass or wetland areas and induce a shift to less desirable plant species.

Meltwater infiltration can also be accomplished using a gravel level spreader that acts as a diversion channel. This simple feature can be incorporated into many different kinds of meltwater handling systems. The diversion channel can be used to route highly concentrated water around a particularly sensitive receiving water or into a best management practice.

The second option for meltwater treatment is an infiltration-detention basin that incorporates two design features to enhance meltwater treatment (Figure 4). The first feature is a variable outflow control structure that allows for drawdown of the water level to increase runoff storage. The second feature is an underdrain with a control valve to drain the porous bottom substrate in the fall. The goal is to decrease the moisture levels that lead to an impermeable layer of frozen soil.

Both the underdrain and outflow controls should be closed prior to the spring melt in preparation for runoff treatment. Once the melt begins, the initial function of the basin is to promote the infiltration of the "first flush" of meltwater. As the melt event proceeds and reaches its peak end-of-season flow, the basin acts as a detention facility, since inflow to the pond will exceed the infiltration capacity of the soil. Critical design features include the underdrain, the relatively flat slopes, soil type, and the predicted end-of-season snowmelt volumes that will discharge into the basin.

Local groundwater quality must be considered since the first meltwater entering the basin may contain soluble pollutants that could migrate through the substrate. Even though a very large volume of meltwater enters the basin, the combination of added detention with enhanced infiltration may dampen the “shock” effect of the highly concentrated first melt.

Additionally, the available storage helps to settle some of the particulate pollutants that leave the snowpack last. A basin of this type requires active management to assure desired infiltration capabilities are maintained and to regulate storage and substrate conditions.

Seasonal Stormwater Ponds

A conceptual design for a “seasonal” pond that might overcome ice layer problems is shown in Figure 5. Water is drawn down in the fall from the pond to prevent the formation of a layer of ice at the normal summer elevation.

A low-flow channel discourages the formation of channel ice. The channel, which must have a high velocity, helps move baseflow and small melt through the pond during the winter and prevent ice buildup. As the melt progresses and meltwater flows increase, the lower outlets are closed, allowing the pond to again act as a normal detention pond, capable of impounding water to summer design levels.

Other Pond Design Considerations

When drawdown is not possible or desirable, there are still some design options to improve the winter performance of stormwater ponds. First, the pond bottom should be sloped so that the deepest part is near the outlet. This configuration minimizes scouring of bottom material as water emerges from under the ice on its way out of the pond. Installation of a baffle weir, floatable skimmer, or a riser hood around the outlet can also help keep a constant movement of water below the ice, thus preventing the buildup of ice at the outlet. These measures assure that the outlet remains clear in the winter and can partially reduce the upwelling pressure of runoff from below the ice layer.

If an ice layer is unavoidable, the outflow device can be totally closed to allow for some detention capacity between the ice layer and the spillway elevation. Overflow can occur via an emergency spillway, provided adequate safety and erosion control measures are taken. Another approach to dealing with ice cover is to prevent its formation through aeration or circulation. This practice can be a safety problem, however, if the public has access to the facility. Thus, aeration or circulation should only be used if safety can be assured.

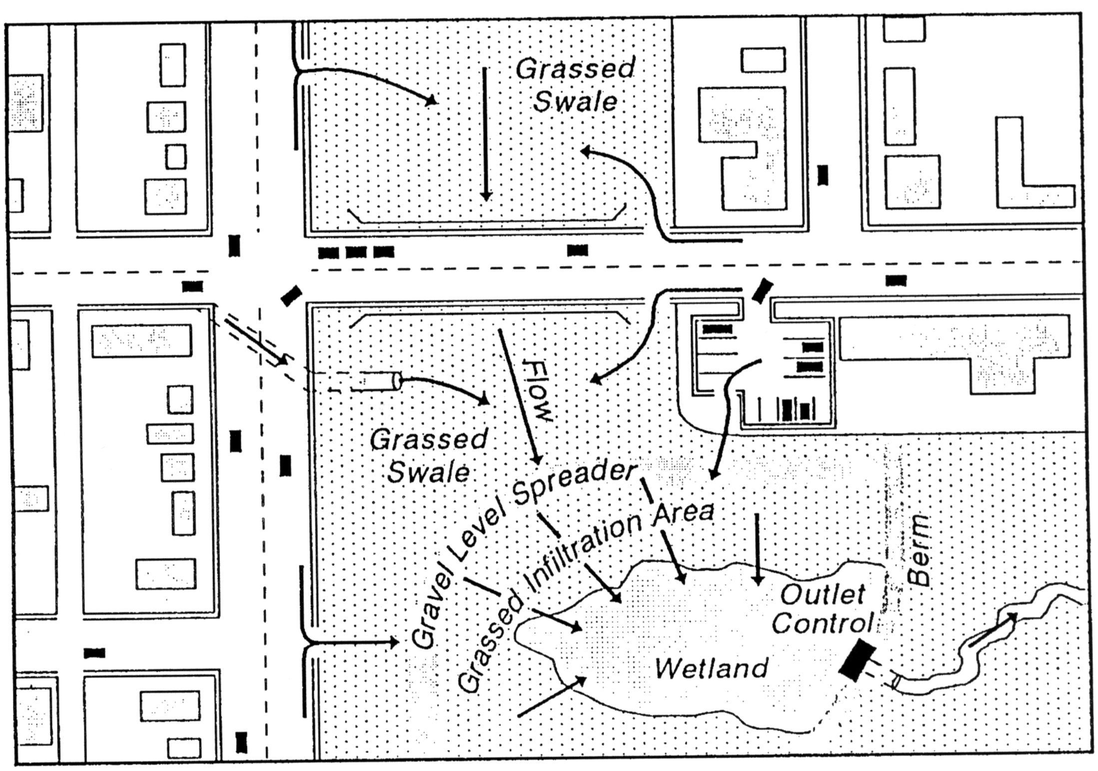


Figure 3: Minimum Structural Approach to Meltwater Treatment

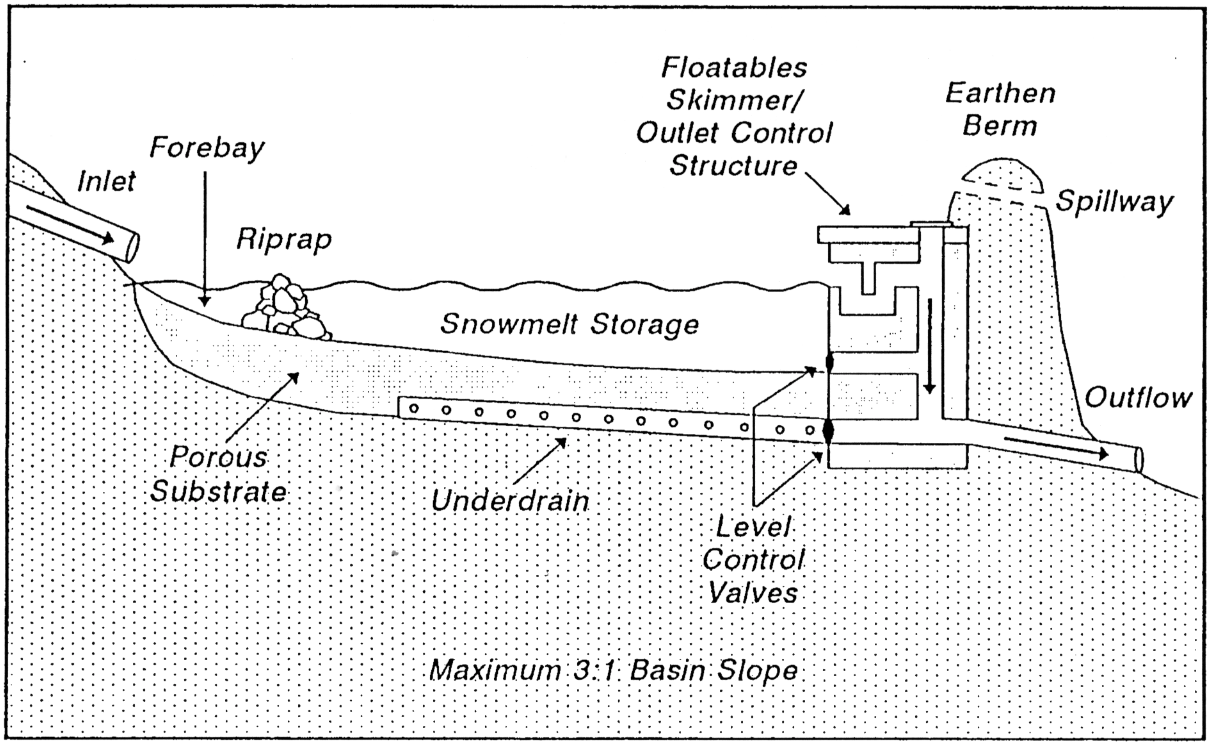


Figure 4: Seasonal Operation of a Stormwater Pond

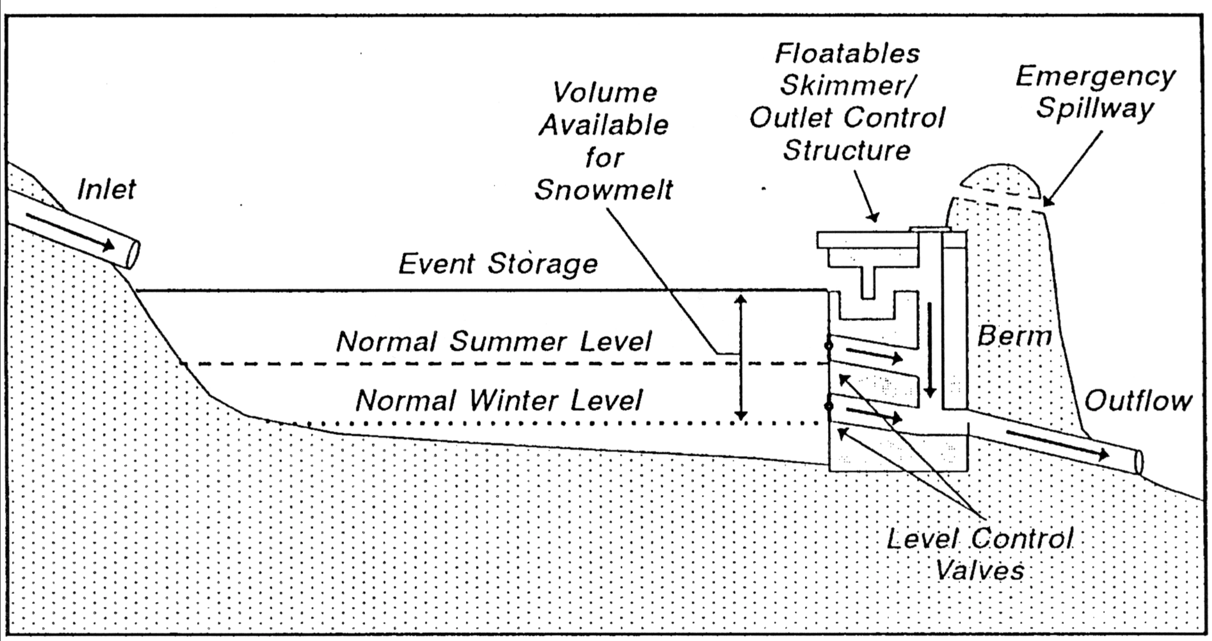


Figure 5: Combined Infiltration/Detention Basin

Other problems are often encountered in the winter months. Ice can form a barrier that interferes with proper flow through the conveyance system. Frozen culverts are a very common occurrence, especially when water velocity is not sufficient to keep water moving, or when splash occurs, which slowly builds a thick layer of ice.

The use of moving parts in stormwater ponds should be carefully scrutinized because of the potential for freeze-up at the time when they are most expected to function (plates/gates, flashboards, valves, or similar controls). Orifice or weir outlet control may be used as an alternative. For example, if a pond is scheduled to be drawn down in the fall, and there is concern that a movable control valve will freeze in winter, an inserted flashboard or a bolted metal plate over an orifice could be used.

Warm weather methods of treating stormwater need to be adapted to more effectively handle pollutants during snowmelt. Useful approaches include seasonal detention facilities, specially designed outlet structures, meltwater infiltration, off-channel diversion, and aeration/circulation. **See also article 3.**

References

Hartsoe, J.A. 1993. *The Groundwater Impact of Polycyclic Aromatic Hydrocarbons From Infiltrating Highway Runoff.* Met. Council, St. Paul, MN. Publ. No. 590-93-036. 88 pp.

Oberts, G.L. and R.A. Osgood. 1988. *Lake McCarrons Wetland Treatment System: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons.* Met. Council, St. Paul, MN. Publ. No. 590-88-095. 227 pp.

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. *The Water Quality Performance of Select Urban Runoff Treatment Systems.* Met. Council, St. Paul, MN. Publ. No. 590-89-062a. 170 pp.

Zapf-Gilje, R., S.O. Russell and D.S. Mavinic. 1986. "Concentration of Impurities During Melting Snow Made From Secondary Sewage Effluent." *Water Science and Technology*. 18:151-156.