3. Ponds

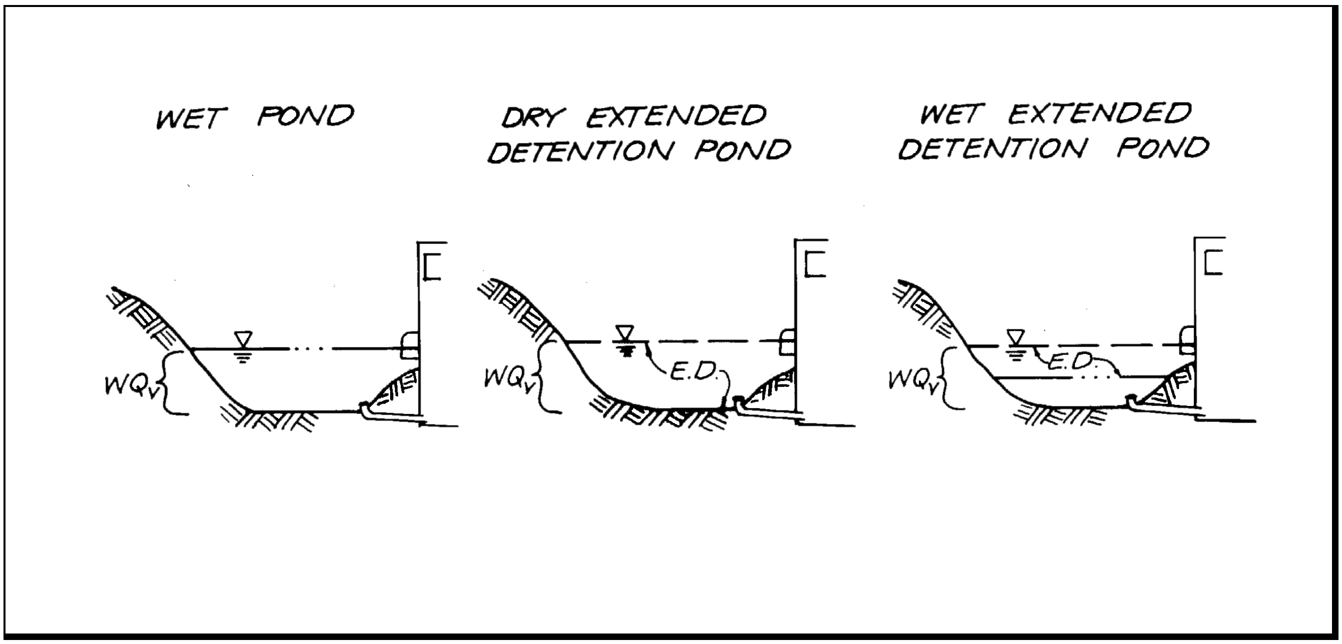
Although ponds have reduced effectiveness in cold conditions, they are the most highly recommended BMPs in cold regions (CWP, 1997). The following section discusses methods to improve the performance of pond systems in cold climates.

3.1 Types of Ponds

Three types of stormwater ponds are wet ponds, dry extended detention ponds, and wet extended detention ponds. These ponds differ in the volume of permanent pool versus extended detention used to treat stormwater runoff (Figure 3.1). Wet ponds rely entirely on the permanent pool to treat stormwater runoff. This treatment is accomplished through biological activity and settling while runoff resides in the system. The concept in this design is that incoming runoff displaces the permanent pool, and the treated water flows out of the system.

Dry extended detention ponds treat runoff by detaining it for a given period of time (usually 24-hours). In these ponds, pollutant removal is accomplished through settling when runoff is detained. Wet extended detention ponds combine the concepts in wet ponds and dry extended detention ponds by dividing treatment between a permanent pool and extended detention. Part of the runoff is detained, and a remainder is treated in the permanent pool.

FIGURE 3.1 TYPES OF STORMWATER PONDS



3.2 Base Criteria

The standard features of stormwater pond designs (CWP et al., 1997) are presented in Table 3.1. These standard features represent the base stormwater pond design criteria. The base criteria ensure that stormwater ponds effectively treat stormwater runoff and efficiently remove pollutants. In cold climates, the effectiveness of pond systems may be compromised by climatic conditions. This chapter discusses design modifications to compensate for cold climate impacts.

TABLE 3.1 FEATURES OF A STANDARD STORMWATER POND SYSTEM

Criteria	Description
Adequate Water Quality Treatment Volume	(See Section 2).
Multiple Treatment Pathways	Provide longer flowpaths, high surface to volume ratio or different treatment methods (e.g., pool and marsh).
Pond Geometry	Ponds should be wedge-shaped, narrowest at the inlet and widest at the outlet. Maximum depth should be 8', with an average depth of 4'-6'.
Pretreatment	Each pond should have a sediment forebay, with maintenance access for cleaning.
Non-Clogging Low-Flow Orifice	Accomplish this with a trash rack or other protection mechanism.
Riser in the Embankment	For convenience, safety, maintenance access and aesthetics.
Pond Drain	Used to drain the pond for maintenance or emergencies.
Adjustable Gate Valve	The pond drain and the extended detention pipe (if a pipe is used) should be equipped with an adjustable gate valve.
Principal Spillway	Designed to safely pass the 5- to 10-year storm.
Emergency Spillway	Designed to safely pass the 50- to 100- year storm.
Embankment Specifications	Designed to prevent dam breach or seepage (NRCS dam safety criteria).
Inlet Protection	Protect against erosion or scour at the inlet.
Outfall Protection	Use flared end pipe sections, and stabilize the downstream channel. Prevent stream warming with an underdrain channel or by limiting tree-clearing.
Pond Benches	Provide flat-sloped safety and aquatic benches at the pond edge for safety purposes and to promote wetland vegetation.
Pondscaping Plan	The plan describes how the pond areas will be vegetated.
Wetland Elements	Use of wetlands plants in pond systems is encouraged in shallow pond areas.
Buffers	A vegetated buffer should be provided at least 25' outward from the edge of the pond.
Maintenance Measures	Maintenance will include some mowing, annual inspection, periodic removal of sediment from the forebay, spillway structural measures as necessary and correction of erosion problems.
Maintenance Access	A right-of-way should be provided for maintenance vehicles, and riser structures should be easily accessible through lockable manhole covers.

3.3 Cold Climate Modifications

Many of the cold climate factors outlined in Chapter 1 can significantly impair the effectiveness of pond systems. Despite these challenges, ponds are considered the most functional and reliable of BMPs used in cold regions (with the exception of completely dry extended detention ponds). Pond systems can perform well in cold climates because many modification options are available to increase their effectiveness in frigid and snowy conditions.

3.3.1 Conveyance

Inlets, outlet structures and outfall protection for pond systems require modifications to function well in cold climates. Most of these modifications address the problems associated with pipe freezing.

<u>Inlets</u>

Guidelines for protecting inlets under various scenarios are presented in Table 3.2. Two slightly different criteria are used for cold and extremely cold (based on January temperature) climates. In very cold climates, criteria are slightly stricter (e.g., larger diameter pipes) and there are fewer exceptions.

- Bury Below the Frost Line

  Burying pipes below the frost line can prevent frost heave and pipe freezing. Many communities require burial of storm sewer pipes, so at least a portion of the inlet pipe may be below the frost line due to existing rules. "Daylighting" the inlet pipe at the point where it enters the pond will require some of the pipe to be above the frost line (Figure 3.2). Burying the point furthest from the pond deeper than the frost line minimizes the length of pipe exposed to frost.

  It may not be possible to bury pipes below the frost line in areas of low relief because of the difficulty in achieving positive drainage. In addition, it may not be feasible to bury pipes below the frost line when the frost line is very deep (greater than 5') because of high excavation costs.

- Pipe Slope>1%

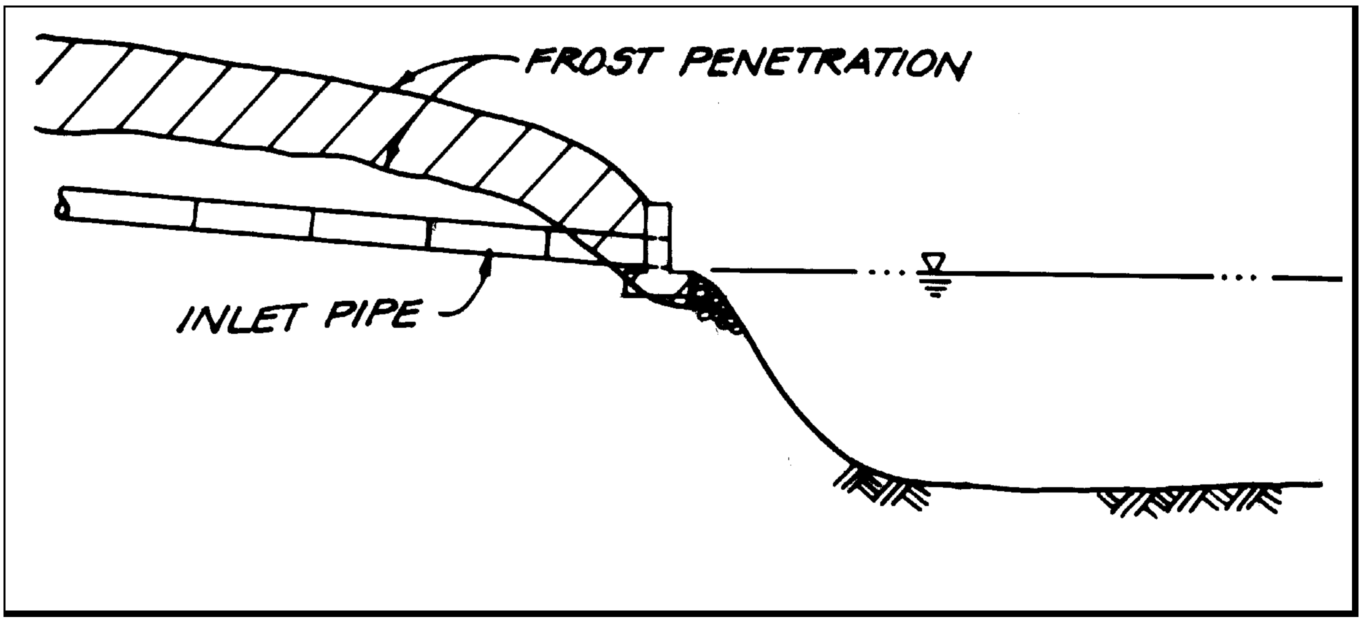
  Increasing the slope of the inlet pipe prevents standing water in the pipe, reducing the potential for ice formation. It may be difficult to achieve this goal in low relief. When the slope of the pipe is nearly equal to the slope of the ground, it will be difficult to daylight the pipe.

TABLE 3.2 DESIGN GUIDELINES FOR POND INLETS

Criteria	January Temperature 25 - 35	January Temperature <25
Bury below frost line	Use except in areas of low relief	Use except in areas of low relief *or* when the frost line >5'
Slope >1%	Use except in areas of low relief	Use except in areas of low relief
Minimum diameter	15" minimum diameter; 18" for low relief areas	18" minimum diameter; 21" for low relief
Overexcavate and backfill with gravel or sand	Surround pipe with >6" of gravel or sand	Surround pipe with >9" of gravel or sand
Avoid submerged inlet pipes[1]	Avoid in most cases	Always Avoid
Insulation	Not necessary	Not required when the growing season > 120 days
Use on-line treatment	Encouraged where possible	Encouraged where possible

[1] applies only to wet and wet extended detention ponds

FIGURE 3.2 DAYLIGHTING INLET PIPES



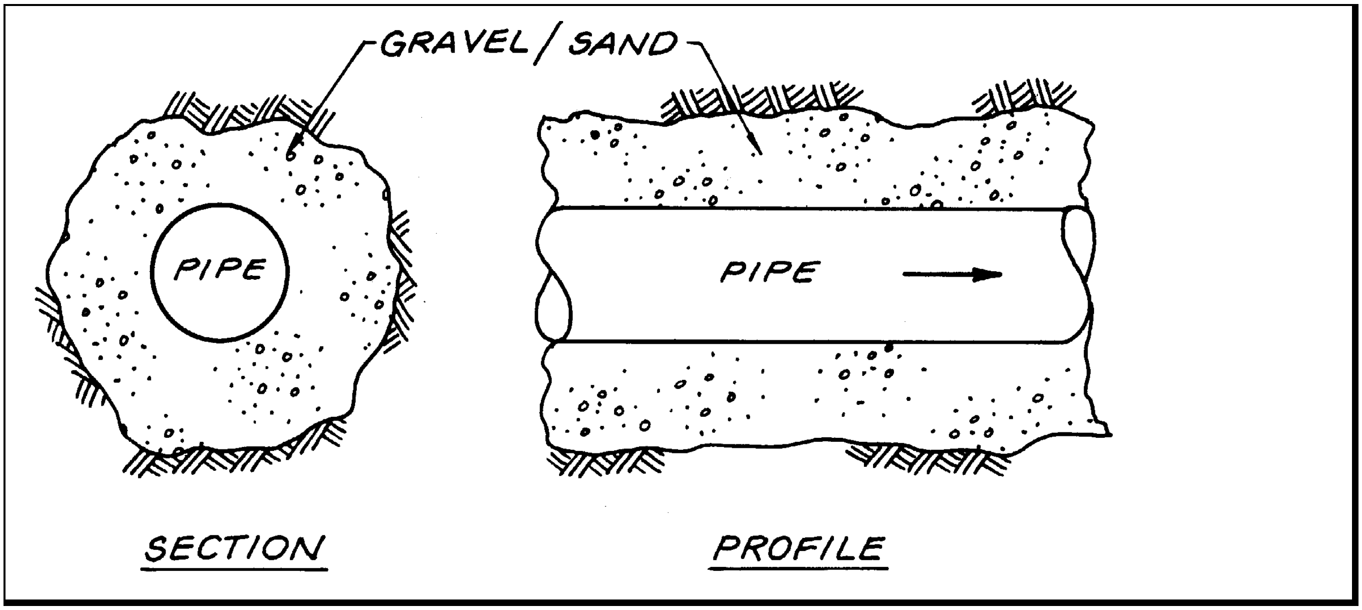
- Minimum Pipe Diameter

  By increasing the pipe diameter, ice is less likely to block the pipe. Larger diameter pipes have a larger area for flow to pass if some ice formation has occurred, and a lower exposed pipe to volume ratio, limiting freezing potential. In areas of low relief, the pipe diameter should be increased more to compensate for inability to bury pipes or achieve steep slopes.

- Overexcavate and Backfill with Gravel or Sand (Figure 3.3)

  Overexcavating for pipes and backfilling with gravel or sand protects against frost heaving. This coarser-grained material is less susceptible to frost heave. This process increases construction costs because of the cost of hauling in sand or gravel, extra excavation and disposing of extra soil.

FIGURE 3.3 OVEREXCAVATION AND BACKFILL WITH GRAVEL/SAND



- Avoid Submerged Inlet Pipes (Figure 3.4)

  Submerged or partially submerged inlet pipes should be avoided in cold climates when possible. The permanent water storage in submerged pipes can freeze, creating upstream flooding. One disadvantage to unsubmerged pipes is that the runoff has more energy when it hits the pond surface. Riprap or other erosion control is needed to prevent erosion as a result of the increased runoff velocity.

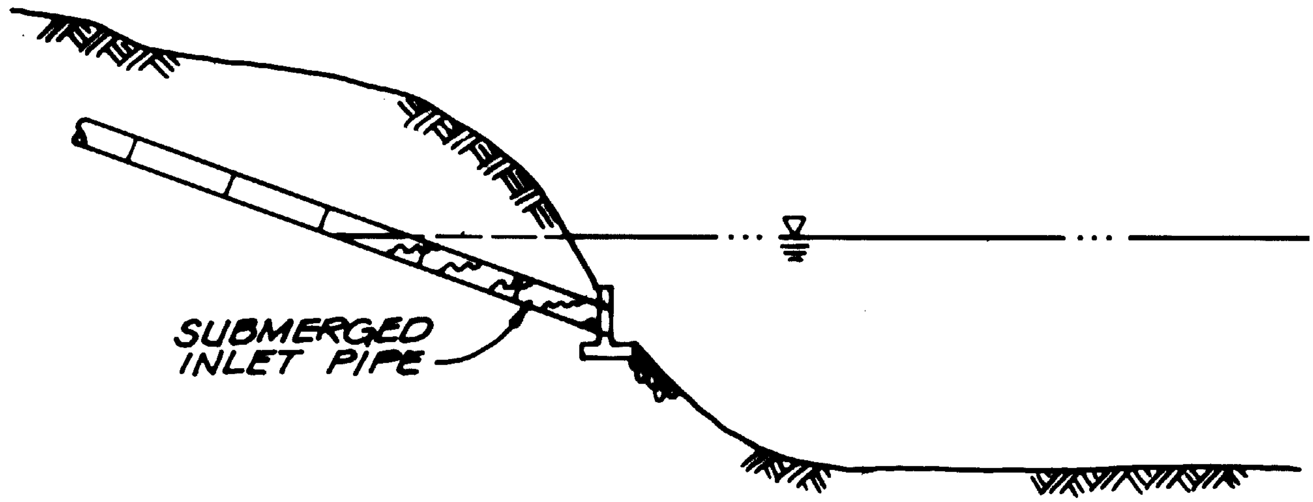
- Use Insulation

  Surrounding pipes with insulation is expensive, and is generally only needed in very cold climates (e.g., Anchorage DPW, 1988). Insulation protects pipes from freezing and frost heave by creating a temperature barrier between pipes and frozen ground.

- On-Line Treatment

  On-line ponds receive flows from all storms, as well as baseflow events. By continuously moving baseflow through a pond system, the constant baseflow will discourage ice build-up, especially at outlets. This method is particularly effective when combined with the outlet structure modifications described below, and in Appendix B. There are some caveats to the use of on-line designs, however. The use of on-line ponds is often not practical due to wetlands regulations. In addition, there is some concern that the use of on-line ponds can cause downstream degradation. These issues need to be addressed before an on-line system is used.

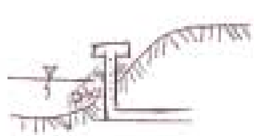
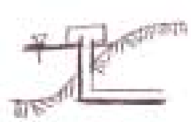
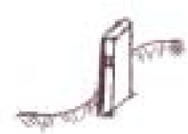
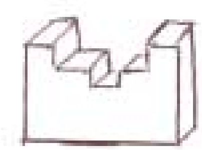
FIGURE 3.4 SUBMERGED INLET PIPES



<u>Outlet Structures</u>

Four basic outlet structures are discussed in this section: perforated riser pipes, riser pipes, concrete riser boxes and weirs (Table 3.3). Each outlet structure serves the same purpose: containing runoff in the pond for treatment or flood reduction.

TABLE 3.3 DESIGN GUIDELINES FOR POND OUTLET STRUCTURES

Outlet Type	Perforated Riser Pipe	Riser Pipe	Concrete Riser Box	Weir Structure
Schematic				
Application(s)	Wet ED Dry ED	Wet Ponds	Wet Pond Dry ED Wet ED	Wet Pond Dry ED Wet ED
Climates	Limited use in cold climates	January T_{max}>25 F	January Tmax>25 F *or* growing season>120 days	All cold climate
Modifications	Minimum 6" diameter Minimum ½" perforation diameter	Riser in the embankment Minimum 18" diameter.	Riser base below the frost line Low flow pipe diameter 6" Riser in the embankment	Weir base below the frost line Minimum weir slot width of 3” Alternate weir structures

- Perforated Riser Pipe

  These structures are used to control detention for water quality only. Flood storage is provided by a separate orifice. Holes, or perforations, in the pipe control the rate at which water leaves the pond above the permanent pool. They are often used in dry detention facilities as a low flow orifice. This low cost option is often attractive, especially for retrofits. It should be used with caution in cold climates, however, because ice cover can cause clogging of the orifices. If perforated riser pipes are used in cold climates, the minimum orifice diameter should be ½". In addition, the pipe should have a minimum 6" diameter.

- Riser Pipe

  Riser pipe structures consist of a pipe that is open on the top, and covered with some sort of hood or trash rack device. Riser pipe outlets do not provide any extended detention, but are used to maintain the permanent pool in wet pond designs. Some modifications are necessary to use these systems in cold climates, especially if a thick ice layer is present.

  A minimum 18" diameter is required. In addition, the riser pipe should be placed within the embankment. Both requirements prevent freezing in the riser pipe.

- Concrete Riser

  Concrete risers are box-like structures at the outlet of pond systems. In these structures, pipes extending from the riser or slots in the concrete itself control flow. These structures can control both low-flow and high-flow events. They are generally effective in cold climates, although there may be problems with freezing if pipes are used to control flow.

  Low flow outlet pipes from concrete risers need to have a six inch minimum diameter to prevent freezing. In addition, concrete risers should be placed in the embankment to prevent frost heave and to protect pipes within the riser from freezing.

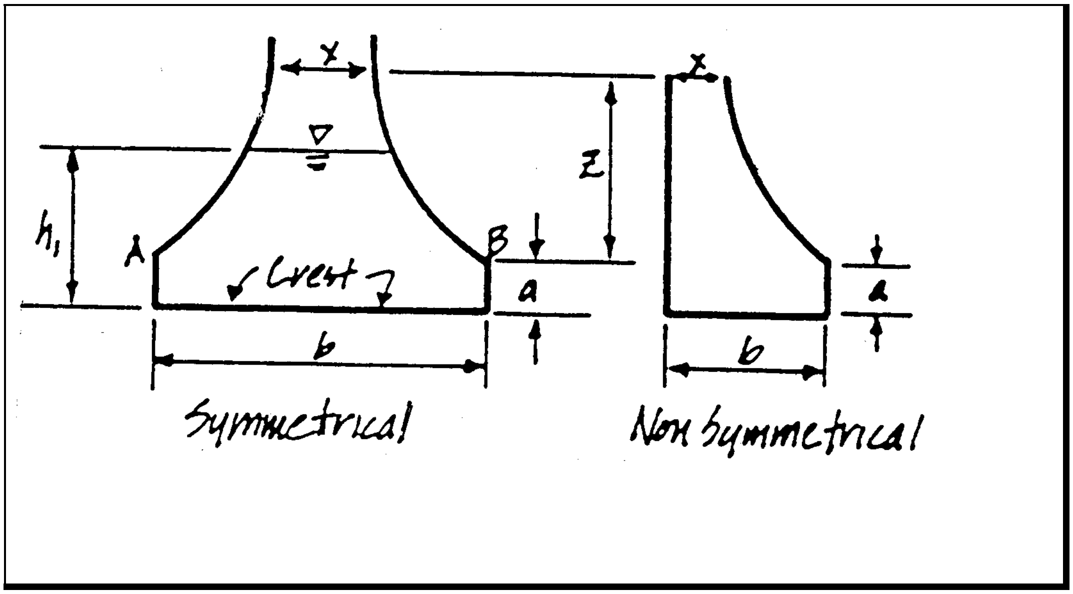
- Weir Structure

  Weir structures can control all flow events, by using various weir widths. These structures are attractive in cold climates because of their “non-icing” nature.

  When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall. The disadvantage to this approach is that the desired retention time may be difficult to achieve. Other weir design alternatives are available, such as the proportional weir (Figure 3.5). In this design, the weir is wider at the bottom and decreases in width near the top. It is easier to achieve slower release rates with this design.

- Alternative outfall designs are described in Appendix B. The designs focused on in that section are resistant to icing and clogging in cold conditions.

FIGURE 3.5 PROPORTIONAL WEIR
(SOURCE: MWCOG, 1996)



<u>Outlet Pipes</u>

The outlet pipe, the pipe that conveys runoff from the outlet structure to the outfall, needs modifications to be effective in cold climates. Four modifications: adjusting minimum piping diameter, adjusting minimum pipe slope, burying pipes below the frost line and splash prevention are recommended for cold climates. The objective of these modifications is to prevent ice build-up within the outlet and avert potential flooding conditions.

- Minimum Diameter

  Outlet pipes should have at least an 18" diameter in all cold climates. Larger diameter pipes are less prone to freezing and ice build-up.

- Minimum Slope

  The minimum slope recommended for outfall pipes is 1%. This slope maintains flow velocities to prevent standing water that can freeze and block the outlet pipe.

- Bury Below the Frost Line

  To the extent practical, the outlet pipe should be buried below the frost line. Of course, some of the pipe will be exposed at the outfall, but this distance should be minimized.

- Splash Protection

  One mechanism that causes ice build-up in outlets is splashing that occurs within the outlet pipe. Over a cold season, ice builds up as a result of this splashing. Simple precautions can reduce this risk somewhat. First, drop-offs at the beginning and end of the outlet pipe should be avoided, because these areas can cause splashing. Second, designs should not include constrictions immediately downstream. This conditions can cause turbulence in the pipe, which results in splashing. Finally, pipes should not be designed with sharp slope changes, as these changes in slope can result in splashing or turbulence.

Outfall Protection

In cold climates, two modifications are needed to ensure adequate outfall protection. First, the outfall channel should be stabilized as soon as possible following construction of the pond. Second, if an underdrain is used to prevent downstream warming, it should be encased in gravel and have at least an 8" diameter.

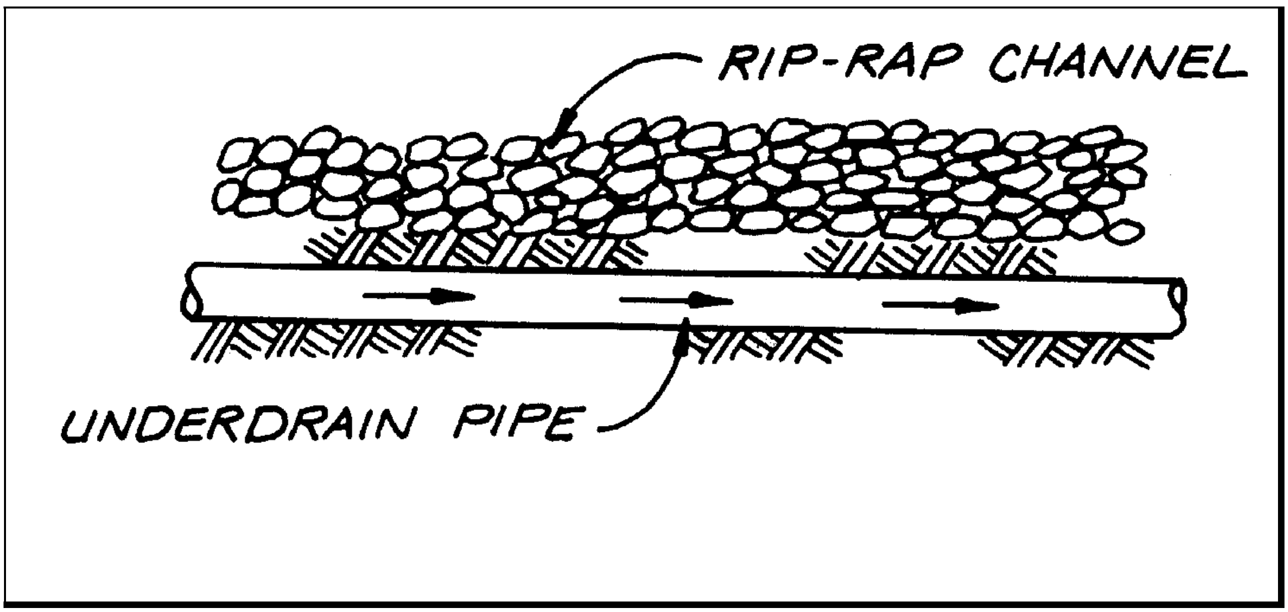
- Rapid Channel Stabilization

  In areas with a short growing season (<120 days), stabilizing the channel of the pond outfall is a challenge. Two options can prevent this problem. Fast-growing plant species can be used, but only if planted at the beginning of the growing season. Alternatively, structural measures such as rip rap or geotextile materials can be used to stabilize the channel.

- Stream-Warming Protection

  During the summer, pond discharge may significantly increase in temperature as it flows through heated riprap channels at pond outlets (Galli, 1990). One solution to this problem is to route base flows through an underdrain pipe below the riprap outlet (Figure 3.6). In cold climates, protections should be made against frost heaving, such as encasing the underdrain pipe in gravel.

FIGURE 3.6 UNDERDRAIN SYSTEM

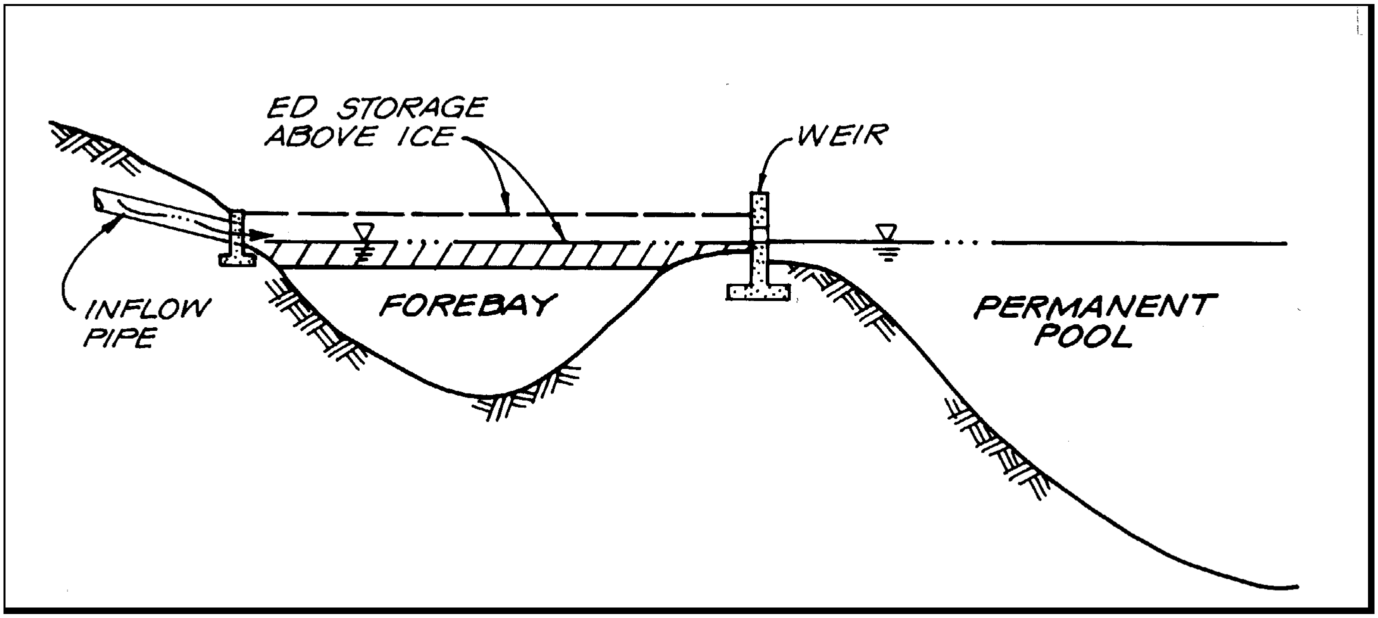


3.3.2 Pretreatment

All pond systems should be equipped with a forebay system. Two modifications can make the forebay more effective in cold regions. One modification is to increase the minimum size of the forebay from 0.1" to 0.25" per impervious acre. In cold climates, the capacity of the forebay system is reduced, due to icing, and this additional storage is necessary to provide pretreatment during the cold season.

The use of a weir system can provide some settling above a frozen forebay (Figure 3.7). This option slows incoming runoff, providing some settling in the forebay. When the pond is iced over, runoff can "skate" over the pond system, bypassing treatment. By slowing the runoff, this problem is mitigated somewhat.

FIGURE 3.7 FOREBAY WITH A WEIR SYSTEM



3.3.3 Treatment

Cold climate treatment modifications focus on three aspects of pond design: treatment volume, chloride treatment and geometry (Table 3.4).

TABLE 3.4 TREATMENT MODIFICATIONS FOR PONDS IN COLD CLIMATES

	Modification	Application	Restrictions/ Drawbacks
Treatment Volume	25% Minimum ED Storage	Needed for January Tmax <=25 F Applicable in all cold climates	• Wet ponds preferred in residential settings if the depth of detention is greater than 2'.
	Seasonal Operation	Applicable in all Cold Climates Substitute for 25% ED storage	• Sometimes conflicts with wetlands preservation • Requires physical manipulation of pond levels
	Add storage to compensate for ice build-up	Needed where ice depth exceeds 6"	• Adds to the cost of pond construction
	Use Circulation or Aeration to Prevent Ice Build-up	Applicable when Tmax <=25 F	• Expensive • Safety Hazard
Geometry	Ponds deepest at outlet	Needed in all cold climates	• Some safety concerns
	Use Multiple Ponds	Encouraged in all cold climates	• Adds to the cost of pond construction • Not always feasible • Inlets between ponds may freeze.

<u>Treatment Volume</u>

In cold climates, the treatment volume of a pond system should be adjusted to account for ice build-up on the permanent pool. Three adjustment options are presented below. These adjustments should be made after determining the water quality treatment volume (Section 2, Sizing Criteria).

- Use a Minimum of 25% Extended Detention Storage (Figure 3.8)

This recommendation is made for very cold climates to provide detention while the permanent pond is iced over. In effect, it discourages the use of wet ponds, replacing them with wet extended detention ponds.

- Seasonal Operation (Figure 3.9)

In this option, proposed by Oberts (1994), the pond has two water quality outlets, both equipped with gate valves. In the summer, the lower outlet is closed. During the fall and throughout the winter, the lower outlet is opened to draw down the permanent pool. As the spring melt begins, the lower outlet is closed to provide detention for the melt event. This method can act as a substitute to using a minimum extended detention storage volume.

When wetlands preservation is a downstream objective, seasonal manipulation of pond levels may not be desired. An analysis of the effects on downstream hydrology should be conducted before considering this option. In addition, the manipulation of this system requires some labor and vigilance; a careful maintenance agreement should be confirmed. Finally, gate valves can be substituted with simpler mechanisms, such as weir plates (Figure 3.10), if freezing is anticipated.

FIGURE 3.8 MINIMUM 25% EXTENDED DETENTION

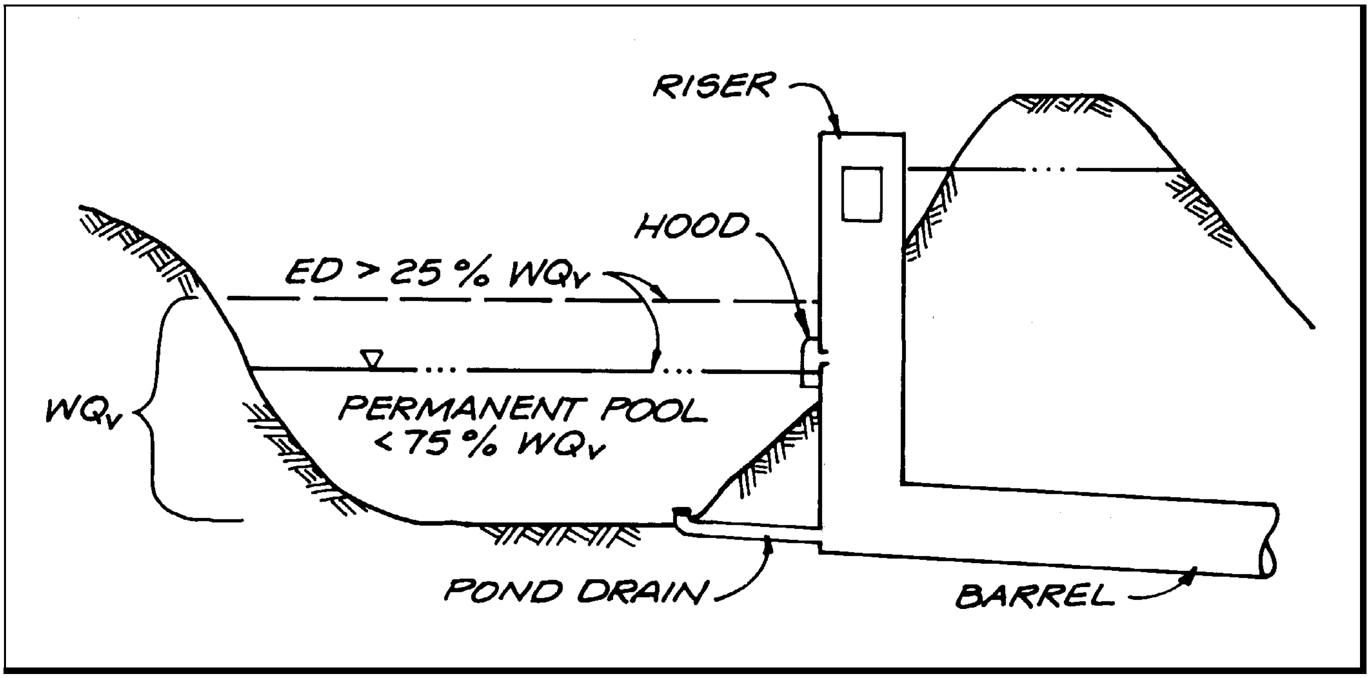


FIGURE 3.9 SEASONAL POND OPERATION
(SOURCE: OBERTS, 1994)

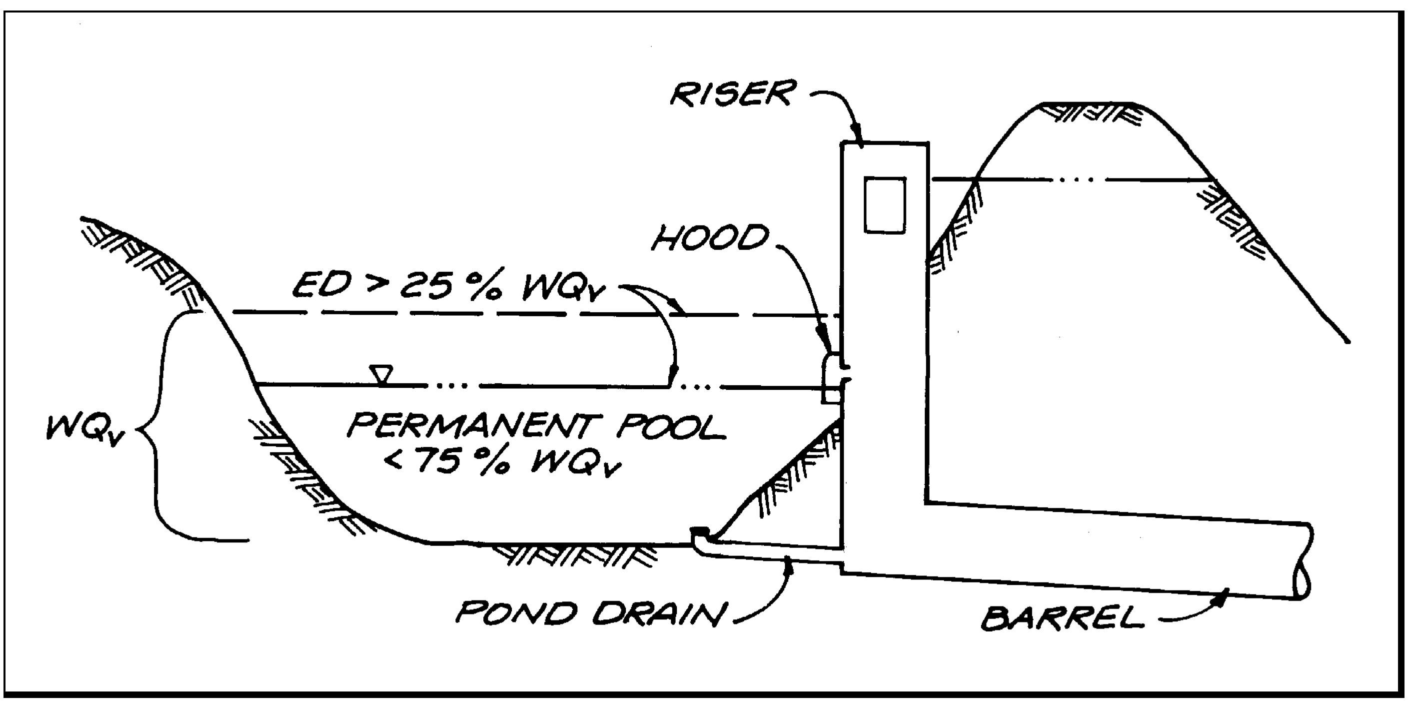
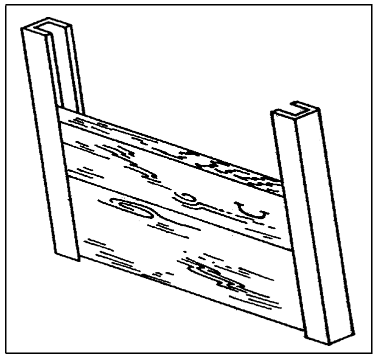


FIGURE 3.10 WEIR PLATE



- Additional Storage to Compensate for Ice Build-Up

  This recommendation is commonly made in cold climate areas. For example, Maine DEP (1995) suggests adding one foot of storage to compensate for the build-up of ice on the surface. This storage should not be added simply by digging the pond deeper, because factors other than the water quality volume influence the performance of stormwater BMPs (Schueler, 1993). The additional storage should be provided by increasing the surface area of the pond (Figure 3.11), maintaining a recommend maximum depth of eight feet (CWP et al., 1997).

  Providing additional storage to compensate for storage loss due to ice build-up is important, but it is not the only option to improve pond performance. Modifications such as non-icing outlets and pond geometry designed for cold climates also need to be taken into consideration.

- Circulation/Aeration

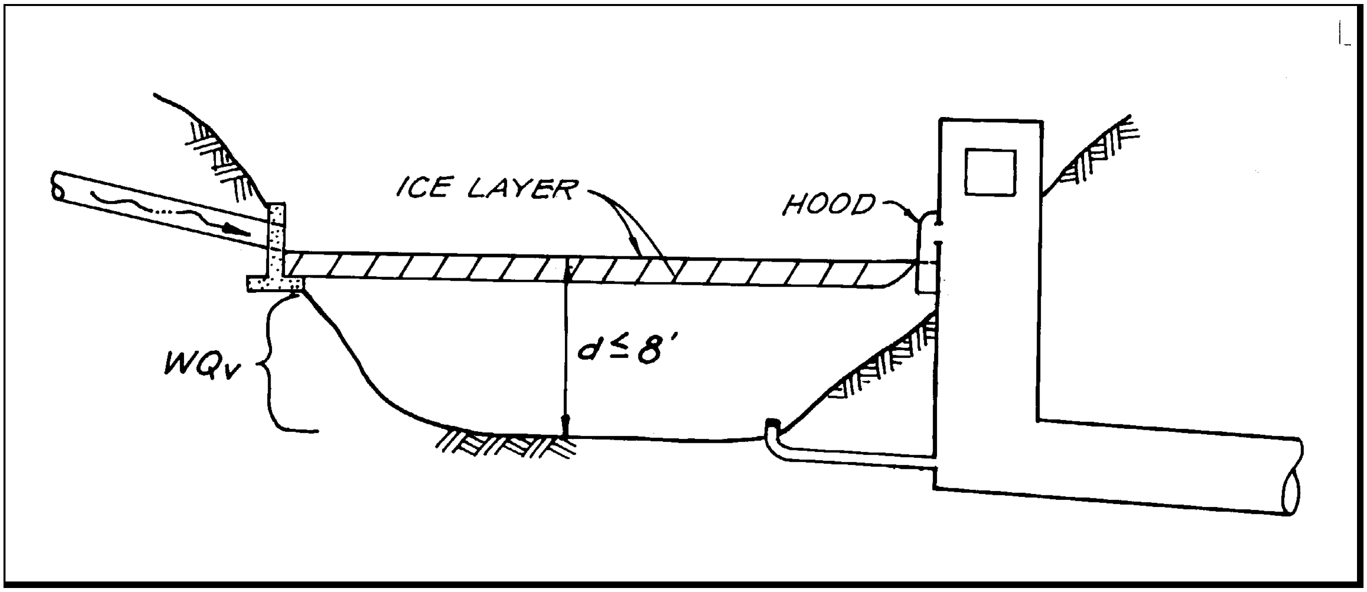
  Using pumps or bubbling systems can reduce ice build-up and prevent the formation of an anaerobic zone in pond bottoms. These systems are rarely used, however (CWP, 1997) because they can create a safety hazard due to thin ice and are an expensive option.

<u>Geometry</u>

Ponds should be deepest at the outlet to prevent scouring as water flows out from under the ice at the exit of the pond (Oberts, 1994). One concern associated with this design is that having a deep zone near the edge of the pond may be a safety hazard. This concern can be alleviated by taking other precautions such as planting thick shrubs, including signs and using flat slope, or "benches" near the outlet.

Multiple pond systems are recommended regardless of climate because they provide redundant treatment options. In cold climates they prevent flows from bypassing the pond system by “skating” over the ice. The barrier between multiple ponds increases the internal flowpath. In cold climates, a berm or simple weir should be used instead of pipes to separate multiple ponds. These pipes have a high potential to freeze.

FIGURE 3.11 STORAGE TO COMPENSATE FOR ICE BUILD-UP



3.3.4 Maintenance

The maintenance of a pond system includes both design elements such as non-clogging outlets and routine maintenance procedures to keep the pond functional. These elements need to be modified slightly to adjust to cold climate conditions.

Non-Clogging Outlets (Skimmers and Trash Racks)

Non-clogging outlets are essential in a pond system. In cold climates, clogging can occur due to ice formation as well as trash build-up. Four non-clogging outlet design options are baffle weirs, hoods, trash racks and reverse-slope pipes

Note: All of these mechanisms work best when used with an on-line pond (Section 3.3.1)

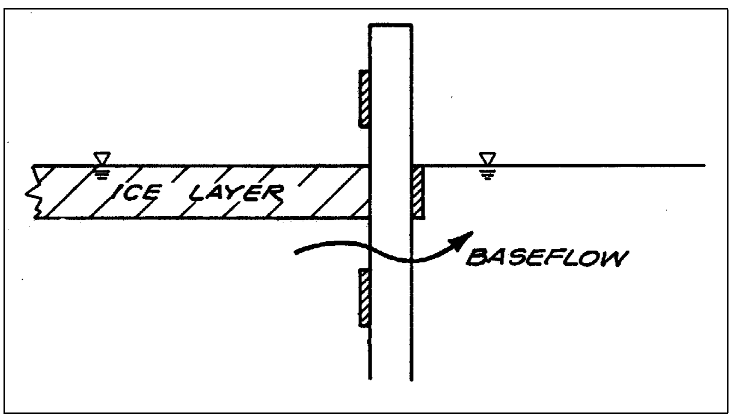
TABLE 3.5 MODIFICATIONS TO SKIMMERS AND TRASH RACKS

Practice	Climate	Outlet Type	Modifications
Baffle weirs	All Cold Climates	Concrete Riser Weir Outlet	None
Hood	All Cold Climates	Riser Pipe Concrete Riser Weir Outlet	Draw from 6" below normal ice layer
Trash Rack	All Cold Climates	Higher flow spillways (Not water quality)	Shallow Slope
Reverse-Slope Pipe	Only with an on-line pond	Concrete Riser	Minimum 6" diameter. Draw from 6" below normal ice layer

- Baffle Weirs

Baffle weirs are essentially fences in the pond that prevent trash from reaching the outlet structure. They are also recommended in cold climates because they prevent ice formation near the outlet by preventing surface ice from blocking the inlet (Figure 3.12), encouraging the movement of baseflow through the system.

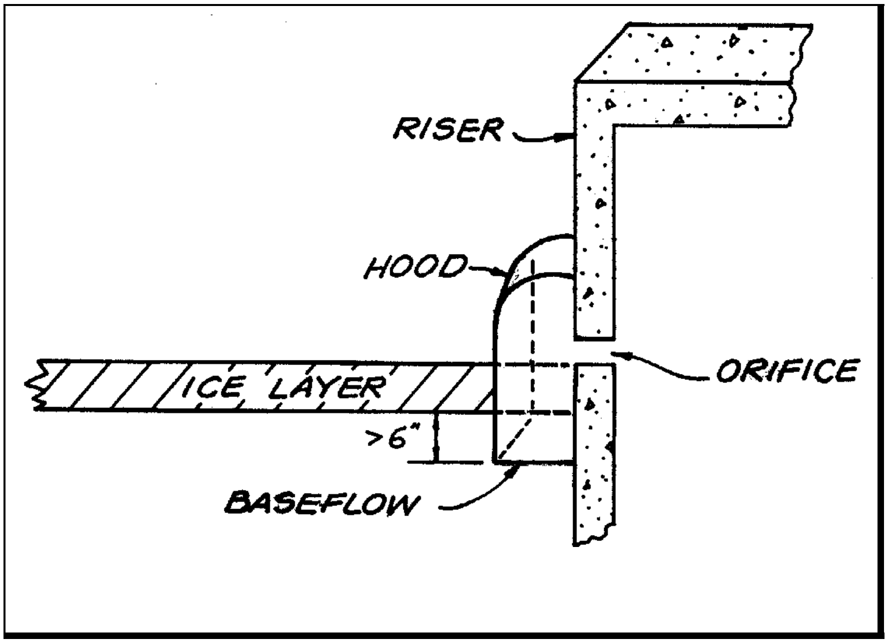
FIGURE 3.12 BAFFLE WEIR
(SOURCE: MODIFIED FROM MPCA, 1989)



- Hood

  In cold climates, riser hoods should draw from at least 6" below the typical ice layer. This design encourages circulation in the pond, preventing stratification and formation of ice at the outlet (Figure 3.13).

FIGURE 3.13 RISER HOOD



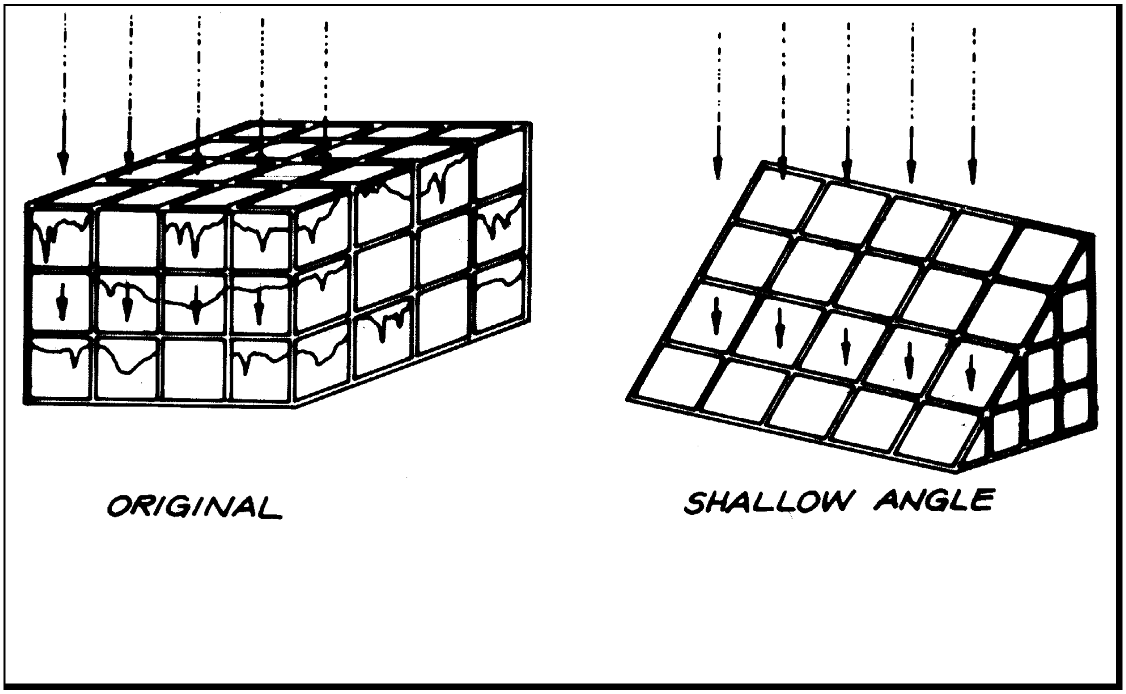
- Trash Rack

Trash racks prevent large debris from flowing out of the pond system or clogging outlets. In cold climates, trash racks can become ice-covered. One possible modification is to install the trash rack at a shallow angle. In this design, ice formation does not cover the grate of the inlet as quickly (Figure 3.14).

- Reverse-Slope Pipe

  In this outlet design, a low-flow pipe extends from the riser through the embankment, drawing from below the permanent pool. In on-line systems, the pipe is prevented from freezing by the constant flow of baseflow through the pipe. Reverse slope pipes should be used sparingly in cold climates, and only in combination with an on-line pond. When reverse slope pipes are used, they should have a minimum diameter of 6" and should draw from 6" below the normal ice layer.

FIGURE 3.14 ALTERNATE TRASH RACK DESIGN



<u>Routine Maintenance</u>

Routine maintenance is similar in cold and moderate climates. In cold climates, some additional maintenance may be needed for ice removal, ponds should not be drained during the spring season and extra sand removal may be required.

- Ice Removal

  In extremely cold climates (T_{max} for January <25 F and growing season<120 days) , a “heat tracing” (electric) or steam ice removal system may be used to prevent ice build-up. In other cold regions, these measures should not be necessary.

- Pond Draining

  Ponds should not be drained during the spring season. Due to temperature stratification and high chloride concentrations at the bottom, the water may become highly acidic and anoxic. Draining water from the pond bottom may cause negative downstream effects.

- Sand Removal

  Most of sand applied to streets in snowy regions washes off during the spring snowmelt and subsequent storm events unless street sweeping is used. This additional sand can become a maintenance problem to pond systems. In areas where road sand is used, the forebay should be inspected each spring to determine if dredging is necessary. In general, dredging is needed if one half of the capacity of the forebay is full.

3.3.5 Landscaping

In both cold and moderate climates, ponds should be landscaped with wetland materials in shallow areas where possible, and the area surrounding the pond should be vegetated. Guidelines on plant selection for and planting techniques for cold climates are included in Section 4.3.5, Table 4.5.

3.3.6 Snow Management

Dry extended detention ponds can be used to store plowed snow throughout the season. Other pond systems should not be used for this purpose, as the permanent pool makes this practice impractical. Also, the concentrated pollutants in the snowpack may damage vegetation in pond systems.