Alaska Department of Transportation & Public Facilities

Research & Technology Transfer

ALASKA DEPARTMENT OF TRANSPORTATION

Synthesis of Best Management Practices for Snow Storage Areas

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September, 2003

Prepared for:
Alaska Department of Transportation
Statewide Research Office
3132 Channel Drive
Juneau, AK 99801-7898

FHWA-AK-RD-03-04

REPORT DOCUMENTATION PAGE			Form approved OMB No.

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	9/30/03	Final July 2002 – September 2003

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Synthesis of Best Management Practices for Snow Storage Areas	DOT-01-33 DOT-01-11
6. AUTHOR(S) Robert F. Carlson, David L. Barnes, Nathanael Vaughan, Anna Forsstrom	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Alaska Fairbanks Department of Civil and Environmental Engineering Fairbanks, Alaska 99775	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) State of Alaska, Alaska Dept. of Transportation and Public Facilities Statewide Research Office 3132 Channel Drive Juneau, AK 99801-7898	10. SPONSORING/MONITORING AGENCY REPORT NUMBER FHWA-AK-RD-03-04

11. SUPPLENMENTARY NOTES

Performed in cooperation with the United States Department of Transportation, Federal Highway Administration

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
No restrictions	

13. ABSTRACT (Maximum 200 words)

The Alaska Department of Transportation and Public Facilities (AKDOT&PF) lacks guidance regarding Best Management Practices (BMPs) for centralized snow storage sites receiving snow from highway maintenance in Alaska. Interviews with AKDOT&PF characterized snow maintenance and operations practices across the climatological regions of Alaska. A literature search yielded many potential BMPs, which were evaluated for suitability based upon ability to treat deposits of variable size and frequency; deposits with high concentrations of solids, debris, and chemical contaminants; initial and maintenance costs; applicability to environmentally sensitive areas; and technology history. A review of potential regulations and interviews with representatives from regulatory agencies generated regulatory needs for each BMP type. Input from AKDOT&PF was used to create a final listing of potential BMPs. Additionally, the technical, economic, and regulatory feasibility of direct disposal to surface waters is reviewed.

14. KEYWORDS : Snow Removal, Snowmelt, Best Practices, Drainage, Runoff, Sediment discharge, Frigid regions, Contaminants	15. NUMBER OF PAGES 67 16. PRICE CODE N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	N/A

Synthesis of Best Management Practices for Snow Storage Areas

Final Report

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Alaska Department of Transportation & Public Facilities

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Acknowledgements

The research performed for this project was funded by the Alaska Department of Transportation and Public Facilities under Agreement No. RES-01-33.

The work was performed by the Department of Civil and Environmental Engineering, University of Alaska Fairbanks with Dr. Robert Carlson, Professor and Chair, and Dr. David Barnes, Assistant Professor, as co-principal investigators. The project staff included Research Assistants Nathanael Vaughan and Anna Forsstrom.

Scott Wheaton with the Watershed Management Group of the Municipality of Anchorage and Bill Rice with Montgomery Watson-Harza in Anchorage provided detailed project review as well as extensive background materials and studies. AKDOT&PF maintenance personnel, Greg Patz, Alan Gonsioroski, Jay Bottoms, Gerry Reed, Jim Adams, and Kerby Wright, contributed valuable background maintenance and operations information. Clint Adler and other AKDOT&PF research section staff provided much appreciated contract management and project review.

Abstract

The Alaska Department of Transportation and Public Facilities (AKDOT&PF) lacks guidance regarding Best Management Practices (BMPs) for centralized snow storage sites receiving snow from highway maintenance in Alaska. Interviews with AKDOT&PF characterized snow maintenance and operations practices across the climatological regions of Alaska. A literature search yielded many potential BMPs, which were evaluated for suitability based upon ability to treat deposits of variable size and frequency; deposits with high concentrations of solids, debris, and chemical contaminants; initial and maintenance costs; applicability to environmentally sensitive areas; and technology history. A review of potential regulations and interviews with representatives from regulatory agencies generated regulatory needs for each BMP type. Input from AKDOT&PF was used to create a final listing of potential BMPs. Additionally, the technical, economic, and regulatory feasibility of direct disposal to surface waters is reviewed.

Summary of Findings

BMPs for snow storage sites must address a variety of contaminant types and loadings. Contaminants prevalent in snow and snow meltwater in Alaska include sediment, metals, chlorides, litter, oil, and grease. Studies indicate water-soluble contaminants exit the snowpack early in the melt season creating time-varied concentrations with an early peak. Less soluble pollutants typically remain in the snowpack until the latter phases of melt. As melting progresses, sediment accumulates on the surface of the snowpack and may be rinsed by rain events; a significant portion of contaminants released during snowmelt adsorb to these sediments. Accordingly, sedimentation is the most widely recommended means of contaminant removal for storage sites. Dissolved solids such as chlorides generally cannot be treated by passive means and dilution represents the best management option.

BMPs for land-based storage sites address snow melt behavior and pollutant characteristics. Constructed sedimentation practices, such as ponds and wetlands, remove particulate and sorbed pollutants from meltwater, while snow placement and pad design can prevent snow-entrained sediment from contacting meltwater flows. Buffer areas, such as berms and filter strips, provide additional assurance of protection for surrounding areas and surface water. Snow melters and sewer inlets represent less traditional forms of treatment with limited practical service ranges for parts of Alaska.

Direct disposal into waterbodies represents a small footprint option for disposal, however a number of regulations address the solid debris accumulated in collected snow and limit the viability of large-scale disposal into surface waters. While operational costs for direct disposal may be lesser than for land-based options, permitting costs, if permits are approved, may be substantially greater. Applicable regulations vary depending upon the type of water body considered; marine areas can best assimilate chloride loading from snowmelt, but suffer from more regulatory oversight of snow-entrained solids. Due to their potential for groundwater contamination, areas with shallow potable aquifers may benefit from direct disposal options.

Chapter 1 – Introduction and Research Approach

Introduction

Snow removed from roads and highways contain contaminants such as suspended solids, organic chemicals, phosphates, dissolved salts, heavy metals, trash, and oil. During melting, pollutants may eventually reach groundwater. If improperly disposed, contaminants may pose a risk to the environment.

Due to their northern latitudes, Alaskan cities are subject to months-long snow deposition and accumulation. To facilitate safe travel, highway maintenance requires chemicals and materials be applied to the road surface in addition to the removal of accumulated snow. In urban areas without sufficient and immediate roadside storage, snow must be collected from roadways and transported off-site for disposal.

Off-site disposal entails storing snow for future melting or immediate disposal. Options for immediate disposal include constructed melting devices or placement in a waterbody. Accomplishing off-site removal minimally requires equipment to place the snow in transport vehicles, transport of the snow to a disposal area, and proper maintenance of the disposal site. Costs associated with disposal vary with transportation distance, removal frequency, snow volume, and site design/disposal type.

Promulgated under the Clean Water Act (CWA), the National Pollution Discharge Elimination System (NPDES) lists regulations which require Urban Areas (as classified by the most recent U.S. Census) to treat stormwater discharges using Best Management Practices (BMPs). For the purposes of this project, a BMP is any procedure or technology which

- Reduces use of pollutants that may cause an impact.
- Reduces exposure of a pollutant to precipitation.
- Removes a pollutant from a runoff stream by natural or man-made treatment.

The United States Environmental Protection Agency (USEPA) advocates the selection of BMPs from a "menu" of available practices; this report presents a "menu" for centralized snow storage areas in Alaska. Presently, a guidance document from the Alaska Department of Environmental Conservation (AKDEC), titled "Best Management Practices for Snow Storage Sites," is the only statewide, guidance document available for snow storage sites.

Direct Disposal to Surface Water

In some Alaskan communities, snow is disposed directly into surface waters. The feasibility and impacts of expanded direct disposal into Alaskan surface waters are not currently known. The technical, economic, and regulatory feasibility of direct snow disposal into surface waters is also reviewed.

Research Approach

Research was conducted in three basic phases:

- Agency Interviews
- Literature Search
- Analysis

Interviews conducted with agencies within Alaska provided information regarding current snow management practices and pollutants. Further, budgeting and service information collected from Alaska Department of Transportation and Public Facilities (AKDOT&PF) maintenance personnel allows for feasibility and contextual comparisons for procedures and technologies investigated. Interviews were conducted with AKDOT&PF personnel in Anchorage, Fairbanks, and Juneau as well as storage/disposal site visits. Municipality of Anchorage (MOA) personnel provided extensive documentation related to Anchorage's stormwater management program and narration for site visits.

A literature review yielded information on alternate technologies utilized in other regions as well as economical and environmental concerns associated with snow storage operations. On-line and periodical searches were used to find BMP information from other countries including Canada, Japan, and Sweden.

During analysis, potential BMP technologies were evaluated based upon applicability to varying snow capacity (volumetric rate), environmentally sensitive areas, snow entrained with solids, and chemically contaminated snow. Additional parameters such as technology history, limitations, annual costs, regulatory impacts, and potential for improvement through research were also considered.

As BMPs are typically regulation-mandated, a regulatory study was also conducted. Interviews with Alaska Department of Environmental Conservation (AKDEC), USEPA Region 10, and the United States Army Corps of Engineers (USACE) were used to explore the regulatory background and significance of snow storage methods. An additional review of regulations and regulatory history specifically pertaining to direct disposal into waterbodies was also conducted.

Chapter 2 – Findings

BMP Matrix

The following matrix of applicable BMPs for centralized snow storage sites presents relative functional and cost information for various pollutant control measures. Additional suitability factors must be considered before implementing any BMP including site hydrology, geology, soil types, and pollutant loading. To facilitate matrix brevity, suitability and inhibiting factors with explication for each BMP are located in Chapter 3.

Table 1 - Snow Storage BMP Matrix

BMP Type	BMP Name	Pollutant Removal							Initial Cost	Maintenance and Operation Costs	Permitting Requirements
		Sediment	Metals	Phosphorus	TSS	TDS	Trash/Debris	Oil/Grease			
Structural	Infiltration Basin/Trench	High	Moderate	High	High	n/a	n/a	Moderate	Moderate	Moderate to High	Low/none
Structural	Constructed Filters	High	High	Moderate	High	n/a	High	Moderate	Low	Moderate	Low
Structural	Filter Strips	Moderate	Little/none	Little/none	Moderate	n/a	Moderate	Moderate	Low	Low	Low/none
Structural	Ponds	High	Moderate	Moderate	Moderate	n/a	High	Moderate	Moderate	Moderate	Low
Structural	Wetlands	High	Moderate	Moderate	Moderate	n/a	Moderate to High	Moderate	High	Moderate	High to Low
Structural	Pad Grading (initial)	High	Moderate	Moderate	Moderate	n/a	Moderate	Low/none	Moderate	Low/none	Low
Management	Agency Cooperation	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Low	Low to Moderate	None
Management	Snow Placement	High	n/a	n/a	n/a	n/a	High	n/a	None to Moderate	Low	None
Administrative	Fencing/Gate	n/a	n/a	n/a	n/a	n/a	High	n/a	Low to Moderate	Low to Moderate	None
Maintenance	Trash/Debris Removal	n/a	n/a	n/a	n/a	n/a	High	n/a	Low	Zero to Low	None
Proprietary/Other	Snow Melter	High	Moderate	n/a	n/a	n/a	High	High	High	High	Low
Proprietary/Other	Dogens	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Moderate	Low	Low

Direct Disposal to Surface Water

State and federal regulations prohibit the disposal of solid waste into waterbodies and AKDEC has classified snow-entrained debris as solid waste; without solids removal, direct disposal violates multiple laws.

Three types of receiving bodies were considered for direct disposal to surface water: marine, fluvial, and freshwater lakes/ponds. Ecological and habitat impacts to wetland ponds make them unsuitable as direct receptors for waste snow. The ubiquitous application of chlorides (in varying concentrations) in Alaska makes marine disposal preferable to freshwater alternatives due to low chloride tolerance in fresh water. Fluvial disposal, while less suitable than marine disposal, is preferable to lake disposal due to the presence of a discrete flow which potentially reduces local sedimentation at the disposal site while transporting and diluting contaminants. Disposal in higher flow rivers/streams is preferred and large-scale disposal in rivers may exceed the thermal capacity of the stream and create blockages or ice jams. Lakes and ponds are generally not recommended as disposal sites because of their low chloride tolerance, potential for sedimentation, and potential for stagnation or meromixis. Low volume lakes and ponds, as well as those with low flow, will be impacted at a greater rate than those of larger volume and/or flow.

Application of waste snow to frozen waterbodies is also not recommended. Application to a frozen surface stifles the benefits of direct disposal. Snow left to melt on a waterbody will favorably elute pollutants in the same manner as land disposal sites and closer proximity to a waterbody will limit any dilution or detention of pollutants, particularly for those released in the early phases of snowmelt. For rivers, upon dissolution of the ice cover, remaining snow on the ice surface may aggravate ice jam formation downstream. Impacts to aquatic life may also be increased for this type of application, as pollutants will be introduced at high concentrations while organisms and plants cease dormancy. In rivers, seasonally low flows may correspond with the "first flush" of pollutants from the stored snow pack and further limit dilution of pollutants.

Chapter 3 – Interpretation, Appraisal, and Applications

Roadway Maintenance Practices

Scale of operation and roadway maintenance activities vary significantly across Alaska. In Anchorage, AKDOT&PF maintains approximately 1100 lane miles of highway, while Juneau maintenance personnel service roughly 100 lane miles (Patz, 2003; Reed, 2003; Wright, 2003).

Types and quantities of traction-aid vary regionally and annually depending upon atmospheric conditions and risk perception. In northern parts of Alaska, low temperatures typically create unsuitable conditions for direct salt (NaCl) application and, other than as an additive in aggregate, chloride compounds are not applied in winter. The primary three deicing/anti-icing compounds used in Alaska are magnesium chloride ($MgCl_2$), sodium chloride (NaCl), and calcium chloride ($CaCl_2$). Magnesium chloride is typically used as a pre-wetting or anti-icing agent, while calcium and sodium chloride are applied both as particulate after snowfall accumulation and as an aggregate additive. Sodium and calcium chloride are mixed with aggregate to maintain friability at low temperatures.

General removal practices appear relatively uniform across the state. Snow plowed with graders forms windrows which either a snow blower or front-end loader places in dump trucks for transportation. Dump trucks then haul the snow to the nearest available disposal site where the snow may be placed, typically along one edge of the storage site. Front-end loaders or bulldozers groom the accumulated snow in the storage site to form taller snow piles. By leveling the top surface of the snow pile and applying water (in some cases), multiple lifts of snow can be created allowing accumulations to reach heights of 60 feet (Gonsioroski, 2003).

The AKDOT&PF Highway Maintenance and Operations Manual (AKDOT&PF, 1993) lacks instruction regarding snow removal after plowing, other than to recommend clearing shoulders after fully attending to road surfaces. In spite of a lack of general guidance, most maintenance regions reported hauling snow within 72 hours of plowing (Adams, 2003; Bottoms, 2003; Gonsioroski, 2003; Wright 2003). In areas with regular rain-on-snow events, snow may be left in-place after plowing, reducing haul volumes by as much as 50% (Wright, 2003). In the Anchorage area, contracted drivers transport snow collected from roads, while AKDOT&PF personnel perform the task in other regions.

Pollutant Characteristics

Urban snow accumulates pollutants from varied sources. Identified contaminant sources include atmospheric pollution, highway traffic, and highway maintenance activities; this combination of anthropomorphic sources creates regionally specific pollutant characteristics. Snow storage citing, design, and operation must consider maintenance materials and practices to effectively address contamination.

Several general trends have been observed which characterize pollutant accumulation in snow. Factors such as usage (commercial versus residential) (Zinger and Delisle, 1988; Viklander and Malmqvist, 1993) and residence time (Hay and Sullivan, 1985; Zinger and Delisle, 1988) on highways affect contaminant concentrations. Vegetation studies suggest contaminant concentrations decrease with increasing distance from roadways (Scott and Wylie, 1980).

The use of maintenance chemicals contributes to snow pollution. Specific practices vary regionally, but generally consist of the application of aggregate and salts to the roadway to improve traction on snow and ice. Additionally, the application of aggregates and chemicals varies annually depending upon precipitation frequency, intensity, and queuing (such as rain to snow events). Source control BMPs relating to material types as well as application rates and methods abound, but are outside the scope of this project.

The gross amounts of materials and contaminants delivered to storage sites are generally unknown. Mass balance estimates in Anchorage estimate, on average, 87% of applied chlorides are removed from the street drainage system (Rice et al., 1999). The high solubility of applied chloride compounds suggests that chlorides which do not reach street drainage are removed with snow. Of the amount removed from street drainage, the quantity detained in snow storage sites is largely unknown and likely variable; in Ontario and Alberta, only 10-15% of applied salts are found in storage sites (Hay and Sullivan, 1985). Likely causes of variations in site retention include relative amounts of side casting versus hauling and the number of rain and melt events within an accumulation season.

Pollutant discharge from storage sites varies spatially and temporally. Studies of the snowmelt process in Anchorage (Wheaton and Rice, 2003) have confirmed previous studies of preferential elution of pollutants from snowpacks (Novotny et al., 1999). As melting proceeds and the snowpack "ripens," impurities are forced to ice-crystal boundaries where they are acquired by percolating water and transported out of the snowpack (Novotny et al., 1999) while sediment accumulates on the outer surface (Wheaton and Rice, 2003). This process contributes to high chloride concentrations early in the melt season, which lowers the partition coefficient for metals and increases soluble metal concentrations (Novotny et al., 1999).

Analysis of snow contamination in Alaska has developed over several decades. One study (Cross and Little, 1989) tested snow, meltwater, and soil from storage sites in the Anchorage area. From this study, pollutants of concern in snow samples were Total Suspended Solids (TSS), metals (Cu, Pb, and Zn), chloride, and oil/grease. A more recent study (Merli et al., 1995), tested meltwater and snow samples from storage sites in Fairbanks and Anchorage for a variety of contaminants. This study found copper, iron, cadmium, lead, chloride, and oil/grease to be the primary pollutants of concern. Both studies (Cross and Little, 1985; Merli et al., 1995) are unspecific regarding the phase of melt in which they were conducted and conclusions without contextual information are tenuous. The MOA Watershed Management Section (WMS), as part of the Municipality's NPDES permit, has conducted multiyear studies of snow storage sites in Anchorage. From these studies, the MOA has found TSS, metals (Pb and Cu), and chloride to be contaminants of concern in snowmelt from the Anchorage area (Wheaton and Rice, 2003). Additional contaminants of concern in literature which have not been found problematic in Alaskan sampling include polychlorinated biphenyls (PCBs), free cyanide, and polynuclear aromatic hydrocarbons (PAHs) (Novotny et al., 1999). Chemical analyses of samples from other Alaskan locations could not be found.

Road salting has evolved over several decades. Traditional salting entailed applying sodium chloride (NaCl, "salt") to roads after a snowfall or mixing salt with sand to maintain friability while modern techniques incorporate alternative salts ($MgCl_2$, $CaCl_2$, and calcium magnesium acetate). Chloride concentrations in meltwater have been measured up to 10,000 mg/L in Anchorage storage site meltwater (Wheaton and Rice, 2003) and 4800 mg/L in Fairbanks (Merli et al., 1995). "First flush" effects are largely credited with high chloride concentrations which diminish after the snow pack ripens (Wheaton and Rice, 2003; Novotny et al., 1999). In lakes, high chloride concentrations may lead to stratification, low-temperature depression, and merimoxis (Environment Canada and Health Canada, 2000). Salt application, the assumed origin of chloride in storage sites, typically contributes greater concentrations of chloride than coupled cations (Mg, Ca, and Na) to groundwater due to percolation sorption and ionic transfer of the metals (Novotny et al., 1999).

Metals such as lead, cadmium, copper, and zinc may be contained in urban snow. Contaminants of this type are thought to come from vehicular traffic and road wear (Novotny et al., 1999), although applied aggregate may also supply metals (Oberts, 1986). High chloride concentrations in early snowmelt may contribute to increased metal solubility (Novotny et al., 1999), which decreases the fraction sorbed to sediment and increases meltwater concentrations. Pore water in lakes and wetlands is particularly susceptible to this effect and may impact benthic organisms (Environment Canada and Health Canada, 2000). For stormwater applications, sedimentation represents the most common, passive form of metals removal. Up to 50% of total metals in snowmelt are in the particulate phase or particle-sorbed (Viklander 1996).

Regulatory History

Historically, regulatory control over snow disposal in Alaska has been selectively applied. While direct disposal into waterbodies has been discontinued across the United States and Canada (except in emergency situations), the practice continues in some Alaskan coastal communities. In Juneau, AKDOT&PF, the City and Borough of Juneau, and private individuals transport and dispose of snow directly into the Gastineau Channel without permits. In Fairbanks, a permit application from the City of Fairbanks to place a snow disposal site on the Chena River was denied based upon solid waste regulations. A schism (possibly regional) exists between potential regulation and applied regulation.

A 1995 series of permit applications were submitted by the City of Fairbanks to place a storage site on and adjacent to the Chena River, a Tier II impaired water body (AKDEC, 1999). Permits were requested from agencies including the Alaska Department of Fish and Game (AKDF&G), AKDEC, and the United States Army Corps of Engineers (USACE); response varied from denial (AKDEC and AKDF&G) to non-involvement (USACE). The permit denials focus on the solid materials entrained in the snow and their classification as solid waste. By contrast, the USACE did not categorize the solids within the snow as subject to Corps permitting. An item of internal AKDEC discussion during this period was the direct disposal to the ocean practiced in Juneau and its applicability to the Chena River permit; no documentation was presented to justify the disposal in Juneau and the City of Fairbanks application for a solid waste disposal permit was denied (Stockard, 1995).

Regulation and permitting of conventional storage sites, when contrasted with surface water disposal sites, appears uniform. The meltwater discharge from storage sites may be classified as stormwater and falls under the purview of the NPDES Municipal Separate Storm Sewer System (MS4) permitting program. Until recently, the Municipality of Anchorage (MOA) was the only community in Alaska subject to NPDES MS4 permitting and snow dump management has been included in the Municipality's NPDES permit. The Fairbanks-Northstar Borough has recently been classified as an urban area and may begin to develop a stormwater management plan.

Regulation Review

Regulatory issues relating to snow disposal may be broadly separated into two categories: point and non-point discharge. Within these categories, the type of receiving body also dictates regulatory and permitting requirements.

Storage

AKDEC qualifies entrained material in urban snow as solid waste (Stockard, 1995). Under this classification, storage of urban snow also qualifies as solid waste storage. The Alaska Administrative Code (AAC) provides guidance regarding solid waste. Specifically, 18 AAC 60.010 states, "a person may not store accumulated solid waste in a manner that causes (1) a litter violation under 18 AAC 64.015; (2) the attraction or access of domestic animals, wildlife, or disease vectors; (3) a health hazard; or (4) polluted run-off water." (AKOLG, 2001). Further, Alaska Statute (AS) 46.06.080 states:

> (a) A person may not throw, drop, deposit, discard, or otherwise dispose of litter from a vehicle or otherwise, on public or private property in the state or in waters in the state or under state jurisdiction unless
>
> (1) the property is designated by a state agency or municipality as a site for the sanitary disposal of garbage or refuse, and the person is authorized to use the site for that purpose; or

(2) litter is placed in a litter receptacle so that the litter is prevented from being carried away or deposited by the elements upon public or private property or water in the state or under state jurisdiction.

These regulations require waste designations and authorizations (permits) for storage sites as well as litter retention devices for both land and water-based disposal.

Anchorage

The Anchorage Municipal Code (AMC) contains zoning and planning requirements for disposal sites. Specifically, AMC 21.50.270 addresses fourteen planning aspects for disposal sites including traffic access, landscaping, illumination, drainage facilities, signing, and noise levels. The AMC requires the service area, storage capacity, and footprint area of the site (see Figure 1) prior to development of the site. Although not explicitly addressed within the regulations, AMC 21.50.270 applies to sites used for direct application to waterbodies as well as conventional storage sites.

Figure 1 – Sign on Gate at Tudor Storage Site in Anchorage

Point Discharge

Title 40, Chapter 1, Part 122 of the Code of Federal Regulations, commonly known as the NPDES regulations, requires permits for stormwater discharges. Specifically, 40 CFR Part122.1(b)(1) states, “The NPDES program requires permits for the discharge of "pollutants" from any "point source" into "waters of the United States."” (USEPA, 2003a) Wording within the NPDES regulations is not explicit regarding requirements for snow storage and disposal sites.

Although not explicitly addressed by NPDES regulations, direct snow disposal may be evaluated by the basic definitions of “pollutants” and “point source.” Direct discharge of snow may constitute a pollutant discharge as 40 CFR 122.2 states, “*Discharge of a pollutant* means… discharges through… conveyances owned by a State, municipality, or other person which do not lead to a treatment works.” (USEPA, 2003a). Additionally, 40 CFR 122.2 defines a “point source” as “any discernible, confined, and discrete conveyance.” (USEPA, 2003a). Based upon these definitions, transporting snow for direct disposal constitutes a discrete conveyance in the form of a dump truck, front-end loader, or snow blower, and without on-site treatment, constitutes a pollutant discharge under NPDES regulations.

Further provisions within the NPDES stipulate compliance with additional regulations. In particular, 40 CFR Part 122.4 states, "No permit may be issued:" … "(b) When the applicant is required to obtain a State or other appropriate certification under section 401 of CWA… and that certification has not been obtained or waived." (USEPA, 2003a). Section 401 Certification is required for federal permit applicants intending to discharge into navigable waters and entails certification from the state environmental agency where discharge may occur (in Alaska, AKDEC). The 401 Certification provides assurance of compliance with sections 301, 302, 303, 306, and 307 of the CWA. Certification under section 401 has been cited as an initial step for a federal permit application by the USACE (for general and special permits).

Direct Disposal to Surface Water

Deposition of urban snow, which commonly contains high concentrations of sediment, to navigable waters and wetlands may require a permit from the USACE under Section 404 of the CWA. Section 404 regulates "the discharge of dredged or fill material into the navigable waters [of the United States]." As a federal permitting program, permits under Section 404 (404 permits) require Section 401 certification from the state environmental agency (AKDEC) as discussed above. The USACE provides Nationwide Permits (NWPs) which are available for selected activities including Stormwater Treatment Facilities (NWP #43 in the 2002 NWP listings). Stormwater Treatment Facilities are defined as "those facilities, including but not limited to, stormwater retention and detention ponds and BMPs, which retain water for a period of time to control runoff and/or improve the quality… of stormwater runoff." (USACE, 2002) Under this definition, BMPs designed for meltwater are included in the NWP (provided they do not discharge into a non-tidal wetland adjacent to tidal waters), but direct disposal into a waterway is not and requires a specific 404 permit.

Sites located within or affecting Alaska's coastal zone must comply with the Alaska Coastal Management Plan (ACMP). Consistency determination with the ACMP functions as a pre-permitting process for state agencies. AKDEC, AKDF&G, and the Alaska Department of Natural Resources (AKDNR) use ACMP consistency review as a means of facilitating multi-agency management of coastal waters. The regulatory overlap associated with state-enforced federal permitting such as NPDES permits and the ACMP is not immediately clear. The approximate boundaries of Alaska's coastal zone (and the ACMP) are illustrated in Figure 2.

Ocean Disposal

Water-body classification plays an important role in determining appropriate regulatory controls. Beyond permitting and certification required under the CWA, NPDES regulations require adherence to additional laws and regulations. The Marine Protection

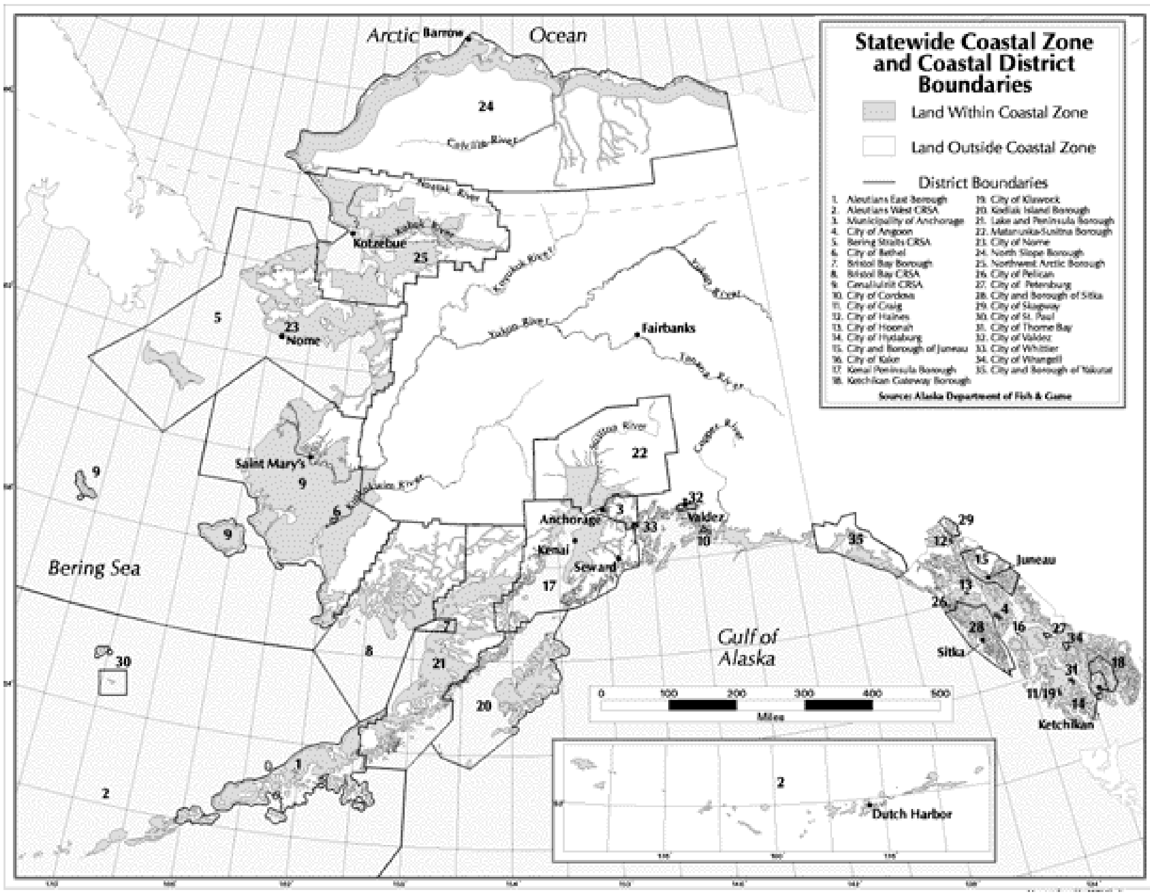

Figure 2 – Alaska Coastal Zone and Coastal District Boundaries (from AKDNR)

Research and Sanctuaries Act (MPRSA) outlines requirements for ocean dumping. Within the NPDES regulations, 40 CFR Part 122.21(f) states, "*Information requirements.* All applicants for NPDES permits, other than POTWs and other TWTDS, must provide the following information to the Director… (vii) Ocean dumping permits under the Marine Protection Research and Sanctuaries Act." (USEPA, 2003a) Regulations based upon the MPRSA are found in the Code of Federal Regulations, Title 40, Chapter 1, Subchapter H—Ocean Dumping. In particular, 40 CFR 220.1 states, "Except as may be authorized by a permit issued pursuant to this subchapter… in the case of a United States department, agency, or instrumentality, no person shall transport from any location any material for the purpose of dumping it into ocean waters." (USEPA, 2003a). For the purposes of Subchapter H, 40 CFR 220.2 defines the term "material" to include a number of constituents of urban snow including solid waste, garbage, rock, and sand (USEPA, 2003a). The Federal Water Pollution Control Act (FWPCA) supercedes the MPRSA and ocean dumping permits are not required for meltwater flows as they are addressed by NPDES regulations (the CWA and subsequently, the NDPES, are amendments to the FWPCA); 40 CFR 220.2 (e) states "*Dumping* means a disposition of material: *Provided,* That it does not mean a disposition of any effluent from any outfall structure to the extent that such disposition is regulated under the provisions of the FWPCA…" (USEPA, 2003a). Under this definition, failing to classify urban snow (and its entrained materials) as stormwater necessitates an MPRSA permit for direct disposal into the ocean.

Non-Point Discharge

For non-point discharges, such as meltwater infiltration or discharge to groundwater, NPDES regulations require MS4 permits for urbanized areas. Currently, the Municipality of Anchorage and the Fairbanks-Northstar Borough are the only designated urbanized areas in Alaska and accordingly, are the only communities required to submit MS4 stormwater permits. As mentioned previously, storage-site-management is included in the MOA's stormwater permit and the WMS is currently developing a series of guidelines for snow storage sites within the Municipality.

Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 requires states with coastal management plans create "coastal non-point pollution programs." The Alaska Coastal Clean Water Plan (ACCWP) fulfills this requirement and lists within its Goals and Action Plans a standard operating procedure with BMPs for "snow removal" and "snow dumping" (AKDNR, 1995). Oceanic discharge from non-point sources from disposal sites within is subject to the ACCWP.

Direct Disposal Options

A review of current disposal practices indicates a steady reduction in direct disposal to surface waters. Canadian guidelines recommend against/prohibit direct disposal to surface water or onto seasonally frozen waterbodies (Alberta Environmental Protection, 1994; Environment Quebec, 2002; New Brunswick Department of the Environment and Local Government, 2003; Ontario Ministry of the Environment, 1994). Recommendations from several states parallel the Canadian guidelines (Oberts and Rozumalski, 2001; Connecticut Department of Environmental Protection, 1998). Massachusetts guidelines warn of "ice block" formation (Massachusetts Bureau of Resource Protection, 2001), although City and Borough of Juneau (CBJ) personnel indicated that they have not observed any lasting, accumulated floating ice during their disposal operations. Guidance from New Hampshire advocates direct disposal to waterbodies when the chemical characteristics of the snow may threaten groundwater and further differentiates between aesthetic and chemical concerns regarding the disposed snow (New Hampshire Department of Environmental Services, 1992).

Ocean Disposal

Naturally high background chloride levels produce a favorable environment for the disposal of snow containing chloride-based de-icers ($MgCl_2$, $CaCl_2$, and NaCl most commonly); chloride concentrations in waste-snow meltwater, which may reach 10,000 mg/l (Wheaton and Rice, 2003), pale in comparison to those found in seawater, which can reach 35,000 mg/l in the open ocean (Wheaton, 1977).

Technical problems with marine disposal are largely aesthetic and relate to snow-entrained material. Disposed snow contains litter, grease, and oil, which have historically been observed in/on the water after dumping. In addition to this pollution and public relation issue, ocean-dumped snow can form "ice blocks" (Massachusetts Department of Environmental Protection, 2001) which create a visible sign of dumping and possibly a navigation hazard. Possible actions to prevent entrained garbage migration include placing trash racks around the disposal site or pre-sieving the material. Ice block mitigation could be accomplished by "blowing" the snow into the water with a snowblower, or by processing the snow through a Dögens-style auger system (described in Miscellaneous BMPs) to reduce snow particle size

The most common form of ocean disposal practiced in Alaska involves depositing collected snow below the tide line. Snow is entrained as the tide rises and carried away/dissolved as the tide declines. Concerns regarding this method include accelerated sedimentation, shoreline erosion, and garbage/debris accumulation.

Feasibility must be considered when evaluating ocean disposal sites. Few locations in Alaska have the necessary shoreline access to exclusively deposit into the ocean; transportation expenses are too great. In a "rough order-of-magnitude estimate", Rice et al estimated an annual transportation cost for ocean disposal in the Anchorage area at $20 million with the following assumptions: transport to a single ocean disposal site, a transport volume equal to the capacity of all Anchorage storage sites (2.8 million cubic yards), a transportation labor rate of $125 per hour, and an average transport speed of 25 mph (resulting in a cost of $5 per mile) (Rice et al, 1999). The 2002 maintenance and operations budget for all snow removal (streets, parks, and trails) in the municipality was $7.6 million (MOA Office of Management and Budget, 2002). Based upon this analysis, localized use of ocean disposal sites is not necessarily cost prohibitive, rather exclusive use of a single site is impractical and should not be considered for the MOA. Historically, direct ocean disposal has occurred in the Anchorage area, although the practice was discontinued due to concerns with snow-entrained material (Gonsioroski, 2003).

Ocean disposal site design is variable. In Juneau, snow is pushed from parking lots onto adjacent beaches or hauled to beaches and deposited below the tide line. Steeply cut topography such as cliffs are also desirable for disposal sites due to the rapid assimilation of deposited snow as well as the potential for rapid volumetric disposal rates (for high intensity storms). The use of sites such as docks for disposal as well as other activities such as boating is unadvisable as sediment and debris accumulation from dumping may interfere with the alternate functions. Mud flats and other areas with fine sediment beds should not be considered for dumping locations due to their potential for increased sedimentation as a result of snow input.

The means of snow application are also somewhat variable; if feasible, trucks can dump in-place, otherwise a bulldozer or front-end loader must be used to place the snow. If beach access is available, snow may be placed below the tide line and carried away with the tide, this process is temporally limited by tidal influence, although snow may be stored above the tide line and moved after subsidence of the water; sites without beach access must extend beyond the tide line. Snowblowers could be used to apply snow to the water, however this adds another degree of complexity to the site as temporary snow storage and increased equipment and personnel would become necessary.

Costs associated with ocean disposal are highly uncertain. In Juneau, transportation costs are low owing to the close proximity of disposal sites to the service area; also frequent rain-on-snow events allow as much as 40-60% of Juneau's snowfall to melt in place. If new infrastructure is required, initial outlays may be lower than for land-based disposal sites of larger area, however this is not guaranteed: market desirability for ocean-front property coupled with a potential dearth of appropriate sites may complicate site acquisition. As with land disposal sites, high volumes of truck traffic must reach the disposal site and infrastructure development, in terms of roadway improvement and lighting, may be required to facilitate efficient and safe disposal. Currently, AKDEC does not regulate ocean disposal in Alaska, however the potential for regulation and permitting is high. Permit maintenance, accomplished through site monitoring and periodic renewals, will contribute significantly to the cost of ocean disposal. Provided appropriate sites are available, transportation and permitting costs constitute the largest potential costs for direct ocean disposal.

Maintenance of sites may entail periodic dredging of sediment and collection of large, accumulated debris. Sites which deposit snow directly into the ocean, rather than onto a beach, may require more sophisticated debris removal efforts if the area is not immediately accessible to land-based removal equipment. Beach erosion has been cited as a possible impact of disposal (Massachusetts Bureau of Resource Protection, 2001) and frequently traveled surfaces may require armoring.

Fluvial Disposal

Fluvial disposal entails placing collected snow directly into/onto flowing, channelized bodies of water. Direct disposal to rivers and streams has been widely discontinued in Canada and the United States (Massachusetts Bureau of Resource Protection, 2001; Szewczykowski, 1990; Alberta Environmental Protection, 1994; Environment Quebec, 2002; New Brunswick Department of the Environment and Local Government, 2003), except in emergency situations (as recently as the winter of 2002-2003) (MacDonald, 2003). As mentioned previously, in 1995 a permit was denied to the City of Fairbanks to place snow on the Chena River, essentially a secondary form of direct fluvial disposal.

A lack of tidal influence requires snow be placed directly onto the water and eliminates the option of passive application such as beach placement. Snow may be stored on a frozen river, although this method allows the snowpack to ripen atop the river ice and may concentrate pollutants released during the early stages of melt; unlike ocean disposal which purges snow on a daily basis, snow stored on river ice accumulates over the entire collection season and is introduced to the river at a rapid rate. Additionally, placement on river ice requires either sufficient ice thickness to allow equipment to traverse the ice or another conveyance (such as a snow blower) to place the snow.

Disposal points should place snow in swift flow to prevent local sedimentation and promote rapid dispersal of the snow. Disposal into high flow bodies is preferred to those with lower flows (Hay and Sullivan, 1985); in Anchorage, meltwater discharge to streams with winter base-flows below 3 cubic feet per second is not recommended (Rice and Wheaton, 2001), although acceptable minimum base-flows will vary regionally. Fluvial discharge is not recommended to water bodies prone to ice jams or alternate forms of spring flooding as the snow influx may aggravate channel restriction.

Costs associated with fluvial disposal are similar to those for ocean disposal. Site development may be necessary, particularly with respect to lighting. Bridges may be used as application sites, but will likely conflict with traffic passage. Snow-blowers may be used to apply the snow, but require additional storage space on-site as well as additional equipment and personnel expenditures. Dump truck application requires the site possess a steeply inclined interface with the water to maximize transport rates and ensure snow is applied to a high flow region; steep-walled sites will likely be too vertical to riprap and will require a more costly retention/protection plan if construction is required. Potential drinking water classification coupled with Alaska's anti-degradation policy create the possibility of more stringent permitting criteria for fluvial disposal compared to permitting for salt-water bodies.

Maintenance costs, again, parallel those for ocean disposal. Periodic removal of accumulated debris and dredging of accumulated sediment may be required at the application site. Rivers with recreational access and/or narrow widths may require more frequent material removal as debris will more readily form hazards in the channel.

Lake and Pond Disposal

The impacts of direct disposal to lakes or ponds vary from those of disposal to rivers and oceans. Like rivers, lakes and ponds typically possess low chloride concentrations and are sensitive to chloride influx. Hydraulic residence time in lakes and ponds is far greater than in rivers, which creates a higher potential for pollutant accumulation. Sedimentation near disposal sites will likely be greater in lakes and ponds than in rivers or oceans due to decreased local flow. Similar to rivers, larger bodies of water are more desirable for dilution purposes as they are less likely to develop "global" impacts than smaller bodies; closed basin lakes and wetlands should not be considered as disposal sites (Rice and Wheaton, 2001) due to their propensity to accumulate pollutants.

Chloride exposure can alter the circulation patterns of lakes and ponds and prevent seasonal mixing (Environment Canada and Health Canada, 2000). Currently, there is no evidence of altered circulation in Alaskan lakes due to snow storage operations. Seven lakes in Anchorage were tested over 5 years to assess their degrees of density stratification with conductivity measurements; no increase in stratification was evident (DHHS, 1992).

Costs of lake disposal are similar to those of ocean and river disposal. Site development may be necessary, particularly in the form of infrastructure improvements for access. A site with a steep interface with the water is desirable, as shallow-sloped sites will not facilitate dump truck application.

BMP Listing

Structural BMPs include engineered or constructed systems that are designed to improve water quality of meltwater runoff. Operational BMPs are institutional, education or pollution prevention practices designed to reduce pollution.

Structural BMPs

Infiltration

An infiltration BMP is designed to detain a volume of runoff and infiltrate the volume into the ground over time. Contaminant removal is accomplished through adsorption and solids removal; biological degradation of contaminants may also occur. Infiltration rates will likely be reduced in cold climates; the equilibrium infiltration rate of Fairbanks Silt is reduced by as much as two orders of magnitude after freezing (Kane and Chaco, 1990). In addition, infiltration BMPs may experience reduced infiltrative capacity and even clogging due to excessive sediment accumulation (Oberts and Rozamalski, 2001). Oberts (1994) reports infiltration at the bottom of snowpacks and cites studies which have found “substantial” infiltration into clay and loam soils; soil saturation is seen as the primary barrier to low-temperature infiltration. Underdrain systems have been recommended as a means of optimizing infiltration-based BMPs through seasonal soil draining (Oberts, 1994a); however underdrain systems are not recommended for snow storage sites in Alaska due to frost susceptibility, requisite seasonal maintenance, and potentially costly long term maintenance (Wheaton, 2003a). In permafrost areas, infiltration is not recommended as it may degrade the permafrost and permafrost soils typically exhibit low infiltration rates (Caraco and Clayter, 1997). Further, infiltration may aggravate frost heave in nearby soils; Caraco and Clayter (1997) recommend a 20 ft setback distance between roads and infiltration locations where frost depth exceeds 3 ft to prevent heave damage (Caraco and Clayter, 1997).

Infiltration of runoff containing chlorides is also discouraged (Caraco and Claytor, 1997), however this suitability criterion may not be uniformly applicable: ponds utilized at storage sites in the MOA function as chloride dilution reservoirs and dry ponds (Rice and Wheaton, 2001). Provided chloride dilution is attained and potable aquifers are not threatened, infiltration of chloride-contaminated waters is feasible.

Infiltration is best used as a secondary measure in-line with a sediment reducing measure. While maximizing on-pad infiltration reduces run-off volume and promotes meltwater dilution, the sensitivity of infiltration rates to soil conditions inhibits practical use. The accumulation of sodium in storage site soils and soil compaction from snow and equipment surcharges (Scott and Wylie, 1980) coupled with basal ice formation

(Wheaton, 2003a) negatively impact on-pad infiltration severely. Off-pad infiltration with sediment pretreatment is the most effective means of infiltrating meltwater.

A reduction in required permitting is one of the primary benefits of infiltration practices. Provided infiltration is the sole method of discharge for a site, an NPDES permit is not required for discharge as the NPDES generally applies to surface waters (excluding MS4 permitting). Areas with potential for high chloride concentrations should still monitor chloride levels to ensure sufficient dilution is attained.

Stormwater experience with infiltration practices in the Puget Sound area has shown annual maintenance expenses from $525-$1050 (updated from 2000 dollars; dollar values are given in 2002 USD, details on conversion are given in Appendix E) per year and a propensity for reductions in infiltration rate over time (Hilding, 2000). While these failures were mostly in quantity control applications, they are indicative of operation and maintenance challenges associated with infiltration use.

Filtration

Filtration removes pollutants and treats runoff as it flows through a filtering medium, such as sand or an organic material (Caraco and Claytor, 1997). Filtration has not been widely applied in cold climate regions but has the potential to be a valuable BMP type in these areas. Unlike sedimentation basins, filtration systems remove fine sediment (reduce turbidity) when designed for removal of a specific sediment size. Most notably, a filter composed of non-woven geotextile fabric and 2" washed rock has been used by the city of Jackson Hole, Wyoming as intermediate treatment for snowmelt from a snow storage site and is reported to remove particles larger than 0.0056 inches in diameter (USEPA, 2003b). The overall system cost for the 6.2 acre, 120,000 cubic yard capacity site was $16,400 (adjusted from 1998 dollars) (USEPA, 2003b).

While the Jackson Hole filter has not required annual replacement of filter media (the original fabric and rock was left in place for the 1999 and 2000 runoff seasons), Alaskan experience has differed; clogging of geotextile in filtration applications presents a persistent maintenance problem and has been observed in Anchorage tests. System reliability, as a maintenance issue, could substantially increase the cost of operating a filtration system. As shown by the Jackson Hole system costs, construction and materials for filtration units may be low, however, maintenance and operation of such units for snow storage applications may be significant.

In application, filtration systems function optimally as a secondary treatment measure; pre-treatment to remove larger sediment particles will extend the service intervals for the filter. Operation of filtration systems requires regular monitoring while in service (during the melt period) to ensure filtration occurs. Redundant treatment may be advisable on a bypass if high sediment loading or short maintenance intervals are expected.

Filter Strips

AKDEC guidance lists "vegetated buffer zones" between storage sites and surface water among best management practices (AKDEC, 2001). Such an area functions as a filter strip which uses vegetation to remove sediment from runoff. To function properly, flow must be spread over filter strips to prevent runnel or channel formation. Infiltration may occur in filter strips, however, infiltration rates will likely be reduced during early melt. Filter strip slopes may be varied from 2-6% (Caraco and Claytor, 1997), although greater slopes will minimize ice development on the strip and shallow slopes will promote infiltration. Filter strips will likely be most effective during the late-season sediment discharge from storage sites.

Incorporation of filter strips on storage pads may cause decreased contaminant removal early in the melt season. Basal ice (Wheaton and Rice, 2003) impedes the sediment removal function of filter strips and allows meltwater to bypass the treatment functions of filter strips. On-pad vegetation may aid non-winter sediment retention and prevent runnel formation during rainfall events.

Filter strip costs are generally low. Planting may require initial capital outlay, but species selection will likely affect the cost to a greater extent; vegetation must be selected based upon regional suitability, salt sensitivity, and growth characteristics (required growing season, required precipitation, drought sensitivity, etc.). Maintenance is generally not required to maintain proper function, but mowing may enhance site aesthetics.

Ponds

For stormwater applications, ponds are the most highly recommended BMP in cold regions (Caraco and Claytor, 1997). For snow storage areas, ponds have been used in the Anchorage area for sediment removal and dilution.

Several pond types are commonly used for stormwater applications; pond type determination stems from pool permanence and treatment time scale. Wet ponds retain a permanent pool which is displaced by incoming flows. Wet ponds are generally not recommended for snow storage applications because the pond level must be maintained: periodic (i.e. spring/summer) discharge from storage sites cannot solely maintain the required water volume in a conventional wet pond design. Pools interfacing with shallow groundwater could maintain water levels, however this practice would encourage direct interaction between the meltwater and groundwater. Also, wet ponds form an ice cover in winter months and may concentrate pollutants such as dissolved solids and organics in the remaining water, which may leach or infiltrate. Oberts (1994a) proposed a seasonal drainage procedure to empty the pond prior to winter using underdrains or bypasses, however this type of practice is maintenance intensive. Rather than attempting to seasonally varying the pond type between wet and dry, dry ponds are recommended.

Dry ponds provide the same treatment benefits as wet ponds, but typically infiltrate or drain between storm events. For snow storage applications, dry ponds infiltrate the detention volume seasonally. In regions with high fall precipitation and low infiltration rates, sizing of dry ponds may depend upon run-off infiltration capacity rather than snowmelt. Dry ponds do not suffer from the impairments of wet ponds: a lack of permanent pool prevents large-scale ice buildup (some volume reduction due to ice formation should still be considered), water is infiltrated while diluted, and groundwater interaction occurs after dilution and percolation. In Anchorage, at least one storage-site pond serendipitously functions as a dry pond (Wheaton, 2003a).

Dilution capacity makes detention ponds ideal for mitigating periodic spiking of contaminant concentrations from snow meltwater. Initially high chloride concentrations from snowmelt, as mentioned previously, can increase the soluble metal fraction and reduce the treatment efficiency of BMPs designed to remove metals. Chloride treatment is difficult due to chloride's high solubility and low affinity for chemical bonding, and dilution is the recommended means of mitigation (Wheaton and Rice, 2003;). While not found to be a problem in Alaska, PAH discharge typically occurs at the end of snowmelt (Oberts and Rozumalski, 2001; Novotny et al., 1999) and also benefits from dilution.

Sedimentation efficiency in ponds will be reduced during snowmelt (Caraco and Clayter, 1997; Oberts and Rozumalski, 2001). Viscosity increases with decreased temperature causing reduced settling velocities and necessitating ponds with a larger footprint to achieve sediment removal efficiencies equal to those found in warmer seasons. At the beginning of snowmelt, ice will likely occupy a portion of the pond volume (Caraco and Clayter, 1997; Oberts and Rozumalski, 2001). As meltwater enters the pond, it can flow over or under the ice: flow above the ice surface may "short-circuit" the sedimentation process and discharge untreated, while flows below the ice may create increased scour of bottom sediments (Caraco and Clayter, 1997; Oberts and Rozumalski, 2001). In regions with rain-on-snow events, ponds require extended detention volume to accommodate periodically high flows which may contain elevated sediment loads.

Due to their popularity, costs for pond construction have been extensively studied. For stormwater applications, ponds represent the most economical BMP for water quality and quantity control (Brown and Schueler, 2000). Additionally, pond costs exhibit an economy of scale with larger ponds costing less per cubic foot of storage than smaller ponds (Brown and Schueler, 2000). Permitting, design complexity, and inlet/outlet controls will affect the cost of individual ponds. Brown and Schueler (2000) found costs outside of construction expenses (design, permitting, erosion control, landscaping, etc.) accounted for 32% of pond construction and 37% if the pond was located near a wetland or stream. The specific applicability of these values to Alaska is tentative considering the study area was predominantly in the mid-Atlantic region, however a rough estimate of cost scales may be extracted.

Maintenance and operation expenses for ponds will vary with sediment loading, inlet and outlet controls, and pond size. Pre-treatment for sediment will lengthen dredging intervals required to maintain treatment volumes. Armoring near inlets and outlets prevents local scouring of sediments which may alter performance and require corrective action over time. Inlet and outlet structures must accommodate or prevent icing effects. Popular types are oversized culverts and weir structures (Oberts and Rozumalski, 2001).

Wetlands

Wetlands function similarly to ponds in terms of sedimentation, but provide additional contaminant removal through chemical and biological processes. Additional pollutant removal in wetlands can occur through an array of mechanisms including filtration, microbial decomposition, sorption, and plant uptake (Davis, 1995). Wetlands are dynamic systems with complex interactions between flora, bacteria, and water. The complexity of wetland systems results in a variety of observed effects: generally, water quality is improved after flow through wetlands (constructed and natural), although leeching of persistent contaminants may also occur if sorption sites are saturated (Davis, 1995). A number of design variations are possible with wetlands including deep versus shallow pools, surface and subsurface flow, and constructed versus natural wetlands.

The incorporation of pools in wetland design provides saturated conditions required for some wetland vegetation and sediment removal through settlement. As with ponds, pollutant removal is accomplished through sedimentation of solids with sorbed contaminants.

Vegetation provides additional sediment removal capability (McLean 2000; Oberts and Rozumalski, 2001). Several studies (McLean, 2000) assert plants acquire contaminants from soil rather than the water column, where roots promote pollutant assimilation through oxidation and microbial action. In terms of pollutant removal capacity, the utility of plant uptake is questionable as particle-sorbed contaminants are generally considered "biologically unavailable" (Novotny et al., 1999) and once sorbed and the particulate settled, considered treated. Pollutant uptake varies among species and pollutant type. The fate of contaminants in vegetation after decomposition is largely unknown and seasonal die-back and biological litter may transport contaminants off-site. For snow storage applications, aquatic vegetation may be difficult to maintain without an auxiliary water source as discharge from storage sites will vary both diurnally and seasonally.

Constructed wetlands optimize site hydraulics for water quality, while natural wetlands are typically used for convenience. Normal constructed wetland design incorporates multiple pools with flow and level control structures and landscaping which spreads flow across a planted area to achieve further sediment removal (this refers to surface flow wetlands; subsurface variations may be prone to seasonal freezing and sediment clogging and are generally not recommended). Natural wetlands provide sorptive and digestive benefits which may aid in contaminant removal. A 2001 study in Anchorage compared vegetation in a natural wetland which has received discharge from a snow storage site for over 20 years to that of a nearby site without snowmelt influence; the study found, relative to the control site, greater numbers of graminoids and forbs, fewer shrubs, retarded willow growth early in the growth season, and more dead trees in the site receiving melt water (Hansen 2001). From these findings, long-term exposure to snow storage meltwater likely alters plant communities in natural wetlands and should be anticipated in receiving wetlands (Wheaton, 2003a). Guidance from several sources recommends against disposing of snow into wetlands (AKDEC, 2001; Connecticut Department of Environmental Protection, 1998; Massachusetts Bureau of Resource Protection, 2001; Oberts and Rozumalski, 2001); no attempts have been made to monitor changes in species diversity in natural wetlands receiving treated/indirect meltwater versus direct snow application.

A constructed wetland site in Anchorage receives meltwater from a storage site and a storm sewer outlet (see Figure 3). Although some sources recommend against modifying natural wetlands to constructed wetlands (Michigan Department of Environmental Quality, 1997), the MOA transplanted peat blocks from future pond locations to form constructed wetlands elsewhere on-site (Jokela and Pinks, 1999). The site provides turbidity control and the combination of flow sources eliminates drying concerns associated with the periodic nature of discharge from storage sites. Site construction utilized innovative techniques such as the cutting and transplant of frozen peat blocks and a winter construction schedule which relied upon freezing of the work-site to limit environmental impacts and facilitate construction (Jokela and Pinks, 1999).

Figure 3 – Constructed Wetland at 97th and C Street site in Anchorage (From MOA WMS)

Concerns with wetlands relate to seasonal suitability and consistency. Pollutant uptake in vegetation varies with both vegetation and pollutant type (McLean, 2000). Further, vegetation may make pollutants more bio-available through uptake and subsequent decay or ingestion, while particle-sorbed pollutants are generally considered biologically unavailable (Novotny et al., 1999). Vegetation, while effective at physically removing sediment, decreases in utility during early snowmelt as it is likely dormant (Oberts, 1994a), although precise information regarding dormancy's affect on treatment is lacking. Additionally, changes in vegetation and reduced biodiversity (Hansen, 2001) may further alter the treatment capabilities of wetlands. Other biological processes involved in wetland treatment will also be reduced and, with ice formation, dissolved solids and organics in pools may be increased early in the melt season (Oberts, 1994a). Additionally, pollutants may accumulate in wetlands and after reaching a critical concentration, the wetland may leech persistent contaminants (Davis, 1995).

Costs for wetland treatment options vary with design and location; generally, construction costs will be greater than for other structural BMPs (Oberts and Rozumalski, 2001). Submerged vegetation limits pool depths and may cause wetlands to occupy more area than other BMPs to achieve the same volume. Constructed wetland systems, due to vegetation requirements, will cost more than sedimentation ponds; engineer's estimates for the constructed wetland site in Anchorage show vegetation costs as almost 25% of the site development budget (MWH, 1996).

Snow Storage Pads

Studies have recognized snow-entrained sediment as a significant source of meltwater pollution and advocated immobilizing sediment on-site (Viklander, 1996; Wheaton and Rice, 2003). Solids removal on storage pads can be optimized through site sloping and orientation as well as operational measures relating to snow placement. A subset of storage pad design, piers have been used as storage pads to allow rapid assimilation of meltwater into a diluting water body (MacDonald, 2003).

As melting progresses, a sediment crust accumulates on the snow surface and may be retained on the pad surface (after melting of the snow beneath) by allowing melt to progress from high to low elevation; meltwater flows are limited to the down-gradient, snow covered portion of the site (Wheaton and Rice, 2003). In Alaska, southerly solar azimuths prescribe a preferential site-aspect for the majority of the melt season, although local shading may alter the optimal aspect orientation for some sites. The highest point on a site should correspond to the optimal aspect orientation. Pad slopes should be minimized to prevent erosion of deposited sediments by storm and melt events.

In regions with significant numbers of rain-on-snow events, storage pad improvements perform poorly due to surface rinsing and the formation of multiple ice layers within the pack (Oberts, 1994b). Rain-on-snow events may further erode on-pad sediments through increased run-off due to saturated, frozen soils which inhibit infiltration (Oberts, 1994b).

Experience in Anchorage suggests that little or no infiltration occurs under the snowpack (Wheaton and Rice, 2003), while Oberts (1994) states, "Infiltration can occur at the bottom of a snowpack even into frozen or partially frozen soils." Disparities in infiltration observation require additional study to determine whether infiltration basins may function as snow storage pads and vice-versa. Observational differences likely owe to different site designs, with the MOA's focusing on runoff through the snowpack via site sloping, while those of Oberts likely involved directly placing snow within a basin or pond where infiltration represented the optimal flow path. The magnitude of infiltration which may occur on a storage pad remains nebulous and warrants consideration given the large pad area relative to BMP structure area at most sites.

Vegetation pad surfaces aids in sediment removal. Similar in function to grass swales, pad vegetation provides additional late-season sediment removal and possible pollutant uptake in plant tissues. Maintaining vegetation on the pad surface may become difficult due to high sodium and chloride concentrations, or if large amounts of sediment deposition occur on the pad; the MOA is currently preparing to study the suitability of a series of plants as pad vegetation (Wheaton, 2003a). Anchorage results may be useful in selecting optimal vegetation varieties for other Alaskan regions. In areas with prolonged

Figure 4 – Perimeter Berms and Channel at Tudor Storage Site in Anchorage

melting periods and short growing seasons, vegetation of pad surfaces may not be practical.

To prevent damage to on-pad features, snow poles should be placed near all structures on the pad, which are not designed for storage. MOA criteria recommend placing poles 10 feet from perimeter structures and 5 feet from structures within the site (Rice and Wheaton, 2001).

Berms

Figure 5 – Berm Channel at Tudor Storage Site in Anchorage (From MOA WMS)

Berms composed of native material or imported fill may be used to direct flows from the snowmass. Although not independently a BMP, berms augment the performance of other BMPs, effectively reducing pollutant loads. Cross and Little (1989) tested water quality adjacent to an Anchorage snow disposal site following improper snow placement which exceeded the confines of a containment berm and found elevated levels of oil/grease, TSS, Na, Cl, Ca, and TDS. When used to define a flow channel, the channel should be over-sized to accommodate ice-formation within the channel; channels should be designed such that velocities are maximized to prevent large-scale ice-formation. Figures 4 and 5 show a bermed channel at the Tudor Storage Site in Anchorage. In situations where berms form channels, surface armoring is vital to prevent erosion. Under Draft MOA criteria, perimeter berms stand three feet tall with 2:1 (27^o) side slopes and one foot crests. Berms used to form channels must accommodate peak flows from the storage site and ice storage. Open channels are not recommended in permafrost areas. Permafrost degradation may accelerate as a result of channel use and thawing permafrost could negatively affect channel function (Caraco and Clayter, 1997).

Costs for berm construction vary with site size, peak meltwater flows, and material type. Larger storage sites will require longer channels with larger flow capacities. Imported fill may be necessary if native material is unsuitable. Greater site capacities and slopes will require larger material to armor channels and prevent erosion.

Operational BMPs

Management

Agency Cooperation
Site management plans should be developed for each storage site. Cooperative site usage in Alaskan communities necessitates multi-agency cooperation to develop and implement management plans; treatment benefits of many BMPs diminish with improper site use and snow placement. The cooperative use of sites simplifies operational logistics and potentially decreases transportation costs, however inconsistent use of sites may mitigate BMP benefits (Gonsiorski, 2003; Wheaton, 2003b).

Costs to accomplish this task vary with the number of cooperatively managed sites, type of treatment employed at each site, and mode of communication. A memorandum distributed by supervisors, or an overview at a weekly shop meeting may suffice. Ideally, maintenance personnel could communicate directly how best to implement site operation guidelines, which could require a joint-agency meeting. Site management complexity will dictate the duration of any meeting, and in practice, maintenance foremen and site administrators are the only individuals who need to attend interagency meetings.

Snow Placement
Snow placement significantly affects runoff turbidity (Wheaton and Rice, 2003). Studies in Anchorage (Wheaton et al., 1998; Rice et al., 1999; Rice, 2000; Rice and Wheaton, 2001) suggest turbidity in meltwater flows from snowpacks may be reduced by proper placement of snow within a storage site. As snow melts, sediment collects on the surface of the pack, forming a sediment “crust” (Wheaton and Rice, 2003). On sloped pads, meltwater flows should travel through existing snowpack, which requires snow placement begin at the downslope portion of the site and progress uphill. Incorporation of V-swales in the pad design can provide more defined storage areas and further direct meltwater flows and increase sediment removal from the meltwater (Wheaton and Rice, 2003).

Larger snow piles with longer melt periods also decrease meltwater turbidity. Snow pile geometry does not affect concentrations of any other contaminants (excluding those associated with turbidity) (Viklander and Malmqvist, 1993). Care must be taken in northern locations not to create multi-year snow accumulations.

Optimally, storage sites should not be located near utility poles. If snow storage near utilities cannot be avoided, minimum separation distances, as recommended by the utility, must be maintained to protect personnel and pedestrians. Scott and Wylie (1980) indicate children standing on snow piles have been seen striking conductors on electrical utility poles with sticks.

Costs to optimize snow placement will generally be low. If current site access prevents beneficial placement, new access or re-routing may become necessary.

Administrative

Alaskan storage sites without administrative controls have been subjected to illegal dumping of both snow and garbage (Gonsioroski, 2003; Bottoms, 2003). Locked access-road gates provide a convenient means of excluding unauthorized personnel and dumping.

Depending upon the nature of site access, a fence may also be required to prevent unauthorized access. In an Anchorage site, geotextile fabric has been placed against fences to provide additional removal of sediment. If fences are to be used, snow poles must be placed so as to create an offset between the snow pile and fence; direct dumping of the snow onto the fence may damage fence posts and render the fence ineffective (See Figure 6)

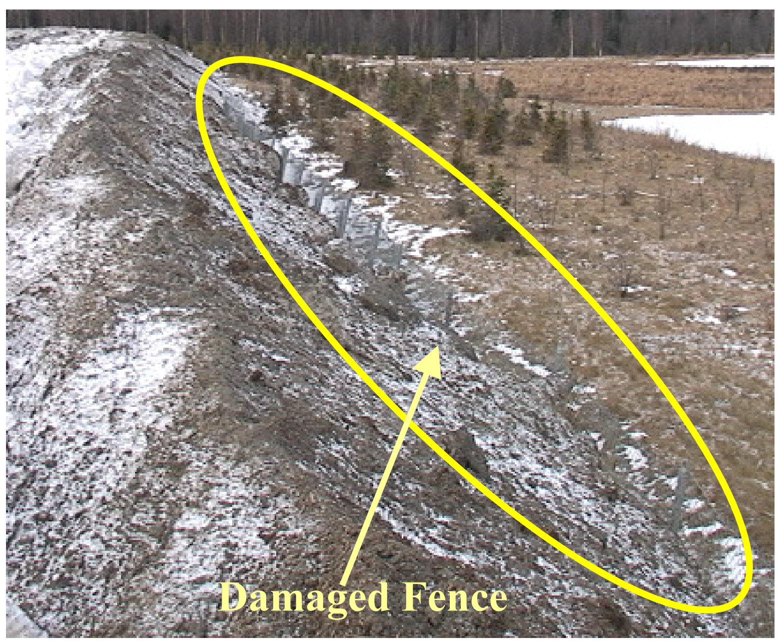

Figure 6 – Storage Site Fence with Improper Setback

Cost varies according to site perimeter and number of entrances. In Fairbanks, damaged streetlight poles are recycled as gates (See Figure 7), effectively limiting materials costs. From previous site investigations, fencing and gate material costs are low relative to other storage site features. Lightpole gates likely incur a lesser initial cost, but appear to require more frequent maintenance than other gate types. Fencing costs will vary with site perimeter, but maintenance, excluding damage or vandalims, is minimal.

Maintenance

Due to entrained solids within collected snow, storage sites accumulate a variety of solid debris, and trash. After melting, these items are deposited upon the pad and should be removed. Trash should be removed annually to prevent migration off-site. Rotary snow blowers handle the majority of snow in Alaskan storage sites, which effectively limits debris size and weight. Site clean-up may be performed by volunteer labor, although hazardous objects may be deposited at the site (Gonsiorski, 2003) and agency supervision should be provided.

Figure 7 – Lightpole Gate at S. Cushman Site in Fairbanks

Long-term maintenance may include sediment removal and re-grading. Generally, grading of sites is discouraged (Rice and Wheaton, 2001), but sediment accumulation may require periodic surface alterations or removal, particularly if accumulations hinder winter-operations.

Composite BMPs

MOA Draft Criteria for Snow Storage Sites

The MOA WMS, through studies of the snowmelt process in the Anchorage area, have developed draft criteria for snow disposal site design (Wheaton and Rice, 2003). The Draft Snow Disposal Site Design Criteria are comprehensive in coverage of storage area siting, design, and operation.

Siting considerations evaluate local suitability for application of the prescribed treatment measures; rather than selecting treatment measures to accommodate available sites, MOA criteria advocates selecting sites which facilitate the application of designated treatment options.

Sediment removal and immobilization represent the primary pollutant removal mechanisms incorporated in the MOA criteria. On-pad structures coupled with snow placement procedures retain sediment from the snow pack on the pad, while meltwater is directed to a detention area to ensure dilution. V-swale design reduces turbidity, in most cases in Anchorage, to a seasonal average of 50 nephelometric turbidity units (NTU) (Rice and Wheaton, 2001). Additional features such as perimeter berms, channel armoring, and pad vegetation encourage on-pad sediment retention.

As a system incorporating multiple BMPs, the MOA Draft Criteria have been experimentally implemented with positive results (Rice and Wheaton, 2003). Costs associated with application of the criteria vary with site characteristics. Siting guidelines restrict sites and application may require acquisition of additional right-of-way. Construction of multiple BMPs may reduce mobilization costs when compared to those for individual BMP construction.

MOA Draft Criteria are designed for the Anchorage-area and wholesale application elsewhere remains tentative.

Miscellaneous BMPs

The inclusion or exclusion of any product or brand in this report does not constitute an endorsement or condemnation of the product.

Snow Melting

The practice of snow melting has gained prominence internationally and domestically. Most melting operations are confined to airports and urban areas where storage space is limited or cost-prohibitive. Snow melting facilities use an energy source to melt deposited snow; the energy source may be incidental or generated specifically for melting. Sources of energy include domestic sewage (Takamatsu et al., 2002), geothermal energy (natural) (Tanaka et al., 2002), combustion (natural gas, diesel, jet fuel) (Trecan Combustion Limited, 2001), and waste-heat from industrial applications (Takamatsu et al, 2002). The primary source of concern with incidental energy sources is their ability to process high-intensity loading.

Melting reduces the snow’s exposure to precipitation and additional features may be included in melting systems to remove pollutants from the meltwater. Snow is typically loaded into a pit filled with water or a melting tank with an applied heat source. The primary function of melting is to convert snow to meltwater, after which it may be treated as stormwater.

Trecan-brand snowmelters have gas, oil, or jet-fuel fired burners. Available sizes for stationary melters are 20, 40, and 60 tons/hr or any multiple thereof. Portable snowmelters are generally loaded with a front-end loader and have their own melting tank, burner fuel supply, and electrical power supply. Trecan’s available sizes for portable models are 20, 40, 60, 100, 135, 350, and 500 tons/hr.

Trecan snowmelters are used at airports in Canada and the United States, including Elmendorf Air Force Base in Anchorage (see Figure 8). The city of Toronto also uses five custom Trecan 150 MetroMelt melters which are self-propelled and self-feeding. The city of New York operates snow melters which discharge into storm sewers to streamline winter snow removal operations.

The city of Sapporo, Japan utilizes a number of stationary snowmelting tanks with varying heat sources (Takamatsu et al., 2002). Incidental energy sources such as sewage, geothermal energy, and waste-heat are particularly attractive for melting as operational expenses for petroleum fuel-based systems fluctuate with fuel prices and may become unfeasible; Montreal, Quebec has ceased use of petroleum systems due to high costs (Environment Canada and Health Canada, 2000). Geothermal energy has been used for road heating in Japan (Takamatsu et al., 2002) and may be viable for larger scale operations.

Figure 8 - Trecan 100 PD Snowmelter at Elmendorf Air Force Base (Trecan Combustion Limited, 2001)

Costs associated with snow melting vary with transportation distance, type of melter (portable versus stationary), energy source, snow quality (temperature, water content, and density), and meltwater receptor. Initial capital outlays for small Trecan-brand snowmelters are from $130,000-140,000 (Trecan is a Canadian company and these values are sensitive to US-Canadian exchange rates) for a 20 ton/hr melter and $650,000-700,000 for a 500 ton/hr melter; this pricing suggests, for initial expense, there is a significant economy of scale for snow melters. The City of Philadelphia's lease of two 80 ton/hr portable snow melters for $120,000 (Blanchard, 2003) and the City of Toronto's estimate of $515,000 (from 2002 Canadian Dollars) for a 300 ton/hr snow melter (Kaufman and Gutteridge, 2002) indicate a significant amount of variation in initial expense exists for melters. Maintenance and operation estimates for the 300 ton/hr snow melter were $6,400 (from 2002 Canadian Dollars) per year for minor maintenance and set-up costs (Kaufman and Gutteridge, 2002). In three years of operation, Elmendorf Air Force Base's snow melter has required service from a company representative several times.

Assuming fuel prices near $1/gal (No. 1 Diesel), Trecan data (135 ton/hr model taken as average) estimates $0.25-$0.50 in fuel expense per cubic yard for melting, depending upon snow density. Additional costs for stationary melters include site preparation, snow melter purchase, transportation to the site, additional fuel for snow at temperatures less than 32° F (0° C), a full-time operator, removal of accumulated sediment, and maintenance. Portable melters do not require site development and can reduce transportation distance, but still require a suitable location to discharge meltwater and incur additional fuel expenses for transportation.

Regional differences affect the economics of snowmelting. Northern Alaska, where temperatures during snow events may be significantly lower than 32° F (0° C), would suffer from increased fuel costs to account for sensible heating of the snow. Water content and density of snow also vary across the state and could influence the operational expenses of melting. Disposal of meltwater also poses a problem in areas without convenient stormsewer access or where stormsewers operate seasonally. Output to a waterbody may be attractive in these instances.

Operationally, portable snow melters allow greater disposal flexibility and remove the need for additional right-of-way for snow disposal. The incorporation of sediment and trash removing mechanisms (Trecan offers a sediment removal package as an optional accessory) may permit more flexible disposal options, such as discharge to rivers. Because snow is not preferentially melted in snow melters, pollutant dynamics observed in storage sites do not develop to the same extent and a reduction in peak contaminant concentrations results.

Dögens© Snow Disposal System (John Meunier/US Filter, 2003)

The Dögens© is a mechanized snow disposal system controlled by the thermal capacity of melting water in the sewer or by the hydraulic removal capacity of the sewage waters. This system is used at several locations in the city of Saint-Laurent, Quebec.

Figure 9 illustrates the Dögens© system: a frame or receiving box is built on a sewer shaft head and inserted into the Dögens©. The snow is unloaded into the loading chamber and the machine automatically controls the balance of the snow disposal process. To avoid pile-up and plugging problems in the pipes, the snow is pulverized by an auger system. To control the quantity of snow sent to the sewer, either the thermal capacity of melted waters in the sewer or the hydraulic removal capacity of the snow present in the sewer can be selected by the user.

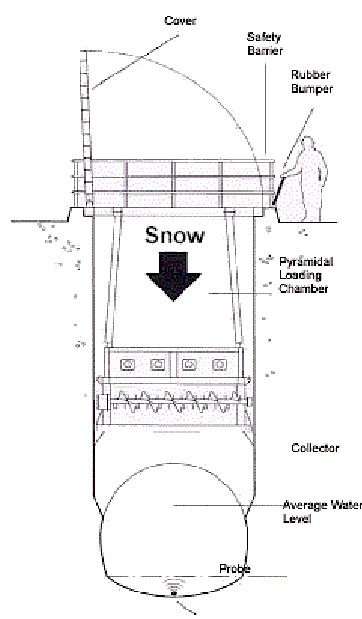

Figure 9 - Schematic © Dögens (John Meunier/US Filter, 2003)

The system has a nominal capacity of 5 m^3/minute (6.5 yd^3/min or 165 ton/hr) or a 1-truck/5 minutes with an average snow density of 500 kg/m^3. A maximum capacity of 15 m^3/minute or 3 trucks/5 minutes can be achieved.

Sensible heat considerations make this system impractical for continuous use in colder climates such as Fairbanks or Nome. Seasonal (i.e. spring) use of the system would require intensive man-hours to load the device and would effectively eliminate the benefit of storage-area reduction normally afforded by the device. Shock loading to the sewer system in the form of rapid and prolonged dilution as well as the presence of chloride, sediment, and metals could negatively impact the operation of the sewage treatment facility. Additionally, implementation of a sanitary sewer discharge system contradicts an effort to phase-out combined sewer systems throughout Alaska.

Areas with year-round stormwater flows could benefit from the device, although installation on a stormsewer system removes many of the thermal benefits of installation on a combined sewer. Snow with temperatures below 32^{o} F (0^{o} C) could severely limit the system's processing capacity.

Costs for the system include construction of a sewer access point and yard (assuming right-of-way exists), purchase of the device, transportation to the device, a qualified employee to operate the device during use, power consumption, and maintenance.

Chapter 4 - Conclusions and Suggested Research

Conclusions

A number of technologies and practices can reduce the contaminant output of centralized snow storage sites in Alaska. Specific applications of each option depend upon local management methods and local/regional differences. BMP suitability hinges upon local weather events, temperature, infrastructure development, maintenance practices, and hydrogeology. Beyond regional and environmental suitability, economic analysis further dictates the relative suitability of certain management procedures.

Regulatory considerations restrict the use of direct disposal to surface water. Of the three types of waterbodies considered; marine areas, rivers, and lakes; marine areas are preferable due to their high chloride tolerance and lack of a drinking water standard. Rivers represent the next most suitable option, followed by lakes. All forms of direct disposal potentially violate state and federal regulations as entrained solids are directly placed into/onto waterbodies. A schism exists between regulation and enforcement for Alaskan communities practicing direct disposal and the practice has been widely discontinued outside of the state except in emergency situations.

Suggested research

The long-term impacts of storage site use have not been widely investigated. The Tudor storage site in Anchorage has been the subject of a vegetation study to investigate the impacts of meltwater exposure on natural wetlands (Hansen, 2001), otherwise, few impact studies have been conducted. Due to varied soil mineralogy, soil impact studies require baseline monitoring to establish initial conditions; existing studies investigating contaminant concentrations in storage site soils lack control samples for comparison (Vicklander and Malmqvist, 1993; Cross and Little, 1989). Trends of interest include contaminant concentration as a function of depth and chloride variation with season and depth. Studies suggest seasonal chloride variations may affect a site's potential for groundwater contamination regardless of discharge concentration (Scott and Wylie, 1980). Additionally, peak chloride concentrations in waters adjacent to storage sites have been observed after complete melting of the snow pack (Scott and Wylie, 1980).

As discussed in Chapter 3, observations of on-pad infiltration are in confliction. While observations of infiltration modifiers suggest a reduction in infiltration rate, significant infiltration has been observed under stored snow (Oberts, 1994b). The practicality of on-pad infiltration could affect conventional storage site design as delayed infiltration can function as detention, effectively mitigating the effects of favorable elution.

While effective at removing a variety of contaminants and reducing turbidity, the ultimate fate of pollutants in wetlands remains unknown. For example, plant uptake may ultimately reintroduce persistent pollutants such as metals into the environment through seasonal littering and ingestion: plants which store contaminants predominantly in their roots may be preferable to those with stalk and leaf uptake behavior.

Generally, Alaskan BMP experience for the development of guidelines to operate snow storage areas has been concentrated in the Anchorage area and application of practices elsewhere is experimental. Information from BMP implementation elsewhere in the state will improve the knowledge-base regarding the suitability of BMPs across climatological zones.

To determine optimal disposal logistics and disposal types, operational analysis must be performed for each maintenance region. Varied labor practices and nonspecific billing procedures complicate this procedure. Currently, costs for AKDOT&PF snow disposal are not known on a unit basis (cost per cubic foot of snow). Without unit disposal costs, disposal site management options cannot be fully assessed. Unconventional disposal options such as snow melting, sewer discharge, and direct disposal to surface waters require analysis of this type to determine economic suitability.

Habitat and community benefits of storage sites have been largely overlooked. Off-pad treatment creates the potential for parks, ponds, and other enhancement features. Storage pads can function as limited habitat as seen in Figure 10.

Direct Disposal to Surface Water

Potential barriers to marine disposal are largely regulatory. Illustration of the effects of direct disposal on marine ecosystems may ease regulatory restrictions. Aesthetic concerns with any form of direct disposal must be addressed before large-scale implementation can occur; trash and debris must be contained to prevent visual impacts.

Figure 10 – Mallard at Johansen Expressway. Site in Fairbanks

The effects of fluvial

disposal on biotic communities are not well understood. Specifically, temporal trends in contaminant release and subsequent effects on organisms during the meltperiod remain largely unknown.

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Appendices

Appendix A: Abbreviations/Acronyms

AAC – Alaska Administrative Code
ACCWP – Alaska Coastal Clean Water Plan
ACMP – Alaska Coastal Management Plan
AKDEC – Alaska Department of Environmental Conservation
AKDF&G – Alaska Department of Fish and Game
AKDOT&PF – Alaska Department of Transportation and Public Facilities
AKDNR – Alaska Department of Natural Resources
AKOLG – Alaska Office of the Lieutenant Governor
AMC – Anchorage Municipal Code
AS – Alaska Statute
BMP(s) – Best Management Practice(s)
CBJ – City and Borough of Juneau
CFR – Code of Federal Regulations
CWA – Clean Water Act
CZARA – Coastal Zone Act Reauthorization Amendments
DHHS – Department of Health and Human Services
FWPCA – Federal Water Pollution Control Act
MOA – Municipality of Anchorage
MPRSA – Marine Protection Research and Sanctuaries Act
MS4 – Municipal Separate Storm Sewer System
MWH – Montgomery Watson-Harza
NPDES – National Pollutant Discharge Elimination System
NWP – Nationwide Permit
PAH – Poly-nuclear Aromatic Hydrocarbon
PCB – Polychlorinated Biphenyl
POTWS – Publicly Owned Treatment Works
TDS – Total Dissolved Solids
TSS – Total Suspended Solids
TWTDS – Treatment Works Treating Domestic Sewage
USACE – United States Army Corps of Engineers
USEPA – United States Environmental Protection Agency

Appendix B: Glossary of Terms

Direct Disposal – the placement of snow in a location where melting is expedited: placement of snow in a location not intended for storage.

Favorable Elution – the time-varied discharge of pollutants from a snow pack. Soluble pollutants elute early in the melt-phase, while insoluble pollutants are concentrated near the end of the melt.

First Flush – the initial meltwater which typically contains high concentrations of soluble pollutants.

Snow Disposal Site – a site where snow is transported for disposal. Differs from a snow storage site in purpose: snow is converted to meltwater without long-term storage at disposal sites (i.e. introduced to the receiving body).

Snow Plowing – removal of snow with a grader or other piece of equipment. Plowing differs from snow removal in that plowing does not entail the placement of snow in a vehicle for transport off-site.

Snow Removal – the process of transporting plowed snow from its original plowed location.

Snow Storage Site – a land-based site where snow is stored until melting.

Appendix C: Regulation Decision Tree

State/National Permitting:

-Point Discharge
- -Meltwater
  - NPDES Permit (USEPA)
    - 401 Certification (AKDEC)
  - Solid Waste Permit (AKDEC)
- -Direct Dumping
  - -Into River or Lake
    - NPDES Permit (USEPA)
      - 401 Certification (AKDEC)
    - 404 Permit (USACE)
      - 401 Certification (concurrent, AKDEC)
  - -Into the Ocean
    - NPDES Permit (USEPA)
      - 401 Certification (AKDEC)
    - 404 Permit (USACE)
      - 401 Certification (concurrent, AKDEC)
    - MPRSA Permit (USEPA)
      - 401 Certification (concurrent, AKDEC)
    - ACMP Consistency Determination (AKDNR)

-Non-Point Discharge
- - Outside of a Coastal Area
  - Solid Waste Permit (AKDEC)
- - Within a Coastal Area
  - Solid Waste Permit (AKDEC)
  - ACCWP Compliance (AKDNR)

Local Permitting:

Anchorage

Anchorage Municipal Code – Contact MOAWMS for more information

Appendix D: Literature Search Results

Search Details:

A survey of currently available literature was accomplished through several search mediums. Searches were made of the Online Computer Library Center First Search databases including WorldCat and Article First. WorldCat searches 21,000 libraries including those of the University of Alaska Anchorage, University of Alaska Fairbanks, Alaska State Library, Colorado State University, and the Transportation Institute of the University of California; the results of these searches comprised predominantly of published research reports, including several from Anchorage-based engineering firms.

Following the Statement of Services, websites of the Federal Highways Administration, Transportation Research Board, Center for Transportation and the Environment, National Transportation Library, Transportation Research Information Service, Transportation Association of Canada, and the United States Environmental Protection Agency were visited and searched for relevant information. Additional organization websites reviewed include the Metropolitan Council of the Twin Cities, the Center for Watershed Protection, the Municipality of Anchorage, and Ted Stevens International Airport. 27 State web sites (www.state.**.gov) were also searched to probe for published snow storage/disposal guidelines and BMPs.

Internet searches using a combination of terms yielded a range of results. Terms such as “snow,” “storage,” “regulations,” “reg,” “meltwater,” “solid,” “stormwater,” “bmp,” “treatment,” “urban,” “disposal,” “dump,” and “ocean” were searched for in a variety of combinations. Commonly, websites for local public works departments would register with descriptions of the services they provide.

Literature review will continue throughout the project as additional BMP information is found.

Literature Summary

Currently available literature generally consists of three types, stormwater treatment methods, snowmelt pollution characteristics, and various state environmental agency best management practices (BMPs). Other than material from the Municipality of Anchorage (MOA) Watershed Management Group, little specific information directly pertaining to snow storage practices is available. With studies of snow pollution characteristics, descriptions of likely pollution sources are also available; a great deal of material is available on source control for common snow storage pollutants, however research and development for these control methods are ongoing and BMPs relating to these may be of limited use at the present time.

Several groups have compiled information on cold region best management practices as they apply to storm/meltwater. Vladimir Novotny et al (1999) have compiled a thorough, detailed report on highway snowmelt with pollutant descriptions and management suggestions; Thomas Schueler and Heather Holland (2000) have compiled a set of BMP articles, several of which address cold regions; and another publication from the Center for Watershed Protection (1997) addresses BMP design in cold regions. These sources represent the most applicable information for snow storage best management practices, although the majority of the information focuses on structural BMPs and source control, largely ignoring other non-strucutural BMPs.

State and provincial environmental agency BMPs typically consist of general site placement guidance. Currently, published BMPs from AK, CA, CT, MA, NH, PA, SD, AB, and New Brunswick environmental agencies with application to snow storage areas have been collected.

Literature Review

1. **Urban and Highway Snowmelt: Minimizing the Impact on Receiving Water**

Water Environment Research Foundation. Project 94-IRM-2, 1999. 267 pg.

Authors: Vladimir Novotny, Daniel W. Smith, David A. Kuemmel, Joseph Mastriano, Alena Bartošová

From Source:

This report outlines sources and causes of winter snowmelt pollution, addresses the environmental impact of snowmelt, and provides guidelines to reduce adverse effects of winter snowmelt/runoff on receiving waters.

Note: *Urban and Highway Snowmelt* describes broadly and in-depth the factors currently known to affect snow and snowmelt water quality. A section on snow BMPs is also included, although the majority of the BMPs are targeted at de/anti-icer reduction.

2. **Stormwater BMP Design: Supplement for Cold Climates**

Center for Watershed Protection, 1997. 43 pg.

Authors: Deborah Caraco, Richard Clayter

From source:

Many communities nationwide have adopted urban stormwater quality requirements, resulting in the need to implement stormwater best management practices (BMPs) under many different physical and climatic conditions. The engineering community has expressed concern over how these structures perform in cold or snowy climates. This manual addresses some of the unique challenges in cold climates and makes design recommendations for BMPs to make them more effective in cold regions.

Note: Performance of various BMPs are discussed as well as parameters for application. Other than a design example listed in Appendix C, this source does not explicitly address snow storage.

3. **Minimizing the Environmental Impact of the Disposal of Snow from Urban Areas: Proceedings of Workshop Held in Montreal, Quebec, June 11-12, 1984**

Environment Canada, Environmental Protection Service. 1985, 125 pg.

Editors: David J Hay; Richard H Sullivan

Note: A transcript of a conference held in Montreal in 1984 attended predominantly by Canadian provincial representatives. Most of the material is general in nature, but describes costs for measures as well as some "innovative" treatment options such as the use of quarries for snow dumps in Quebec.

4. **Practice of Watershed Protection**

Center for Watershed Protection. Elicott City, MD: 2000

Editors: Thomas R. Schueler and Heather K. Holland

Abstract: *The Practice of Watershed Protection* is a comprehensive compilation of articles from all past issues of the Center for Watershed Protection's technical journal, *Watershed Protection Techniques.*

Note: Several articles, "Influence of Snowmelt Dynamics on Stormwater Runoff Quality," "The Economics of Stormwater Treatment," and "Performance of a Gravel-based Wetland in a Cold, High Altitude Region," apply well to snow storage BMPs and provide general guidance with regard to trends in BMP expenses over time.

5. **Environmentally Sound Snow Management and Disposal**

Pennsylvania Department of Environmental Protection, 1994. 2 pg.

Note: Contains general guidelines for snow disposal in Pennsylvania. Addresses salt storage and recommended separation distances for storage sites.

6. **Minimizing the Environmental Impacts from Snow Disposal: Guidance for Municipalities**

South Dakota Department of Water and Natural Resources, 1990. 8 pg.

Author: Paul Szewczykowski

Note: A moderately detailed set of recommendations for snow storage site design published by the Non-Point Source Program of the Division of Water Resources of the State of South Dakota. Details on the effects of salt are listed as well as a review of alternate deicers.

7. **Snow Disposal Site Design Criteria**

Municipality of Anchorage Watershed Management Section, 11 pg.

Note: A detailed set of design criteria and practices assembled by MOA's Watershed Management Section for snow storage sites in Anchorage. Contains local statutory references and an assortment of non-structural management practices.

8. **Best Management Practices for Snow Storage Sites**

Alaska Department of Environmental Conservation, 1 pg.

Note: Although much less detailed than the MOA's design criteria, the document addresses AKDEC's primary regulatory concerns for snow storage sites. The three topics addressed are general site selection to prevent groundwater contamination, runoff treatment (NPDES), and debris accumulation (solid waste regulations).

9. **Evaluation of the Environmental Impacts of Snow Disposal Activities within the Municipality of Anchorage, Alaska**

Ground Water: Alaska's Hidden Resource, Proceedings, Fairbanks, Alaska. March 16-17, 1989, pg. 43-54.

Authors: James E. Cross, Marc P. Little

Note: In this study, various water quality indicators were measured in meltwater, snow, and soil samples from two snow storage sites in Anchorage, AK. Additionally, samples were collected and analyzed from nearby receiving bodies (one lake and one stream). Water samples were temporally varied, and trends monitored. The effects of improperly stored snow were measured as the site was filled to capacity and operators placed excess snow outside the confines of the site's berm. During the period in which the excess snow melted, significantly higher contaminant levels (TSS, Na, Cl, Ca, TDS, and Oil and Grease) were measured in the receiving stream.

10. **Water Quality Effects of Snow Storage Areas**

Transportation Research Center. Report No. INE/TRC 95.06, SPR-UAF-94-14, 64 pg.

Authors: Jean-Marie Merli, Robert F. Carlson, Christina Behr-Andres

Note: A study of meltwater pollution in Fairbanks and Anchorage coupled with attempts to test catch basins at both locations. The conclusion contains suggestions for "Best Management Plans" for storage sites including a skimming weir and a sorptive media to remove further contaminants.

11. **Snow Disposal Guidelines**

New Hampshire Department of Environmental Services. WD-SWQB-6, 1992

Note: A brief and general listing of suggested placement and management practices including separation distances and litter and sediment control.

12. **Bureau of Resource Protection Snow Disposal Guidelines**

Massachusetts Department of Environmental Protection. BRPG01-01, 2001. 5 pg.

Note: A moderately detailed set of disposal criteria. Direct disposal into a waterbody is discouraged except under extreme circumstances in which case disposal to salt marshes, wetlands, and low flow areas are discouraged; formation of "ice blocks" from direct, open water disposal is mentioned.

Appendix E: Construction Cost Index Values

All costs included in this report have been updated to 2002 dollars using the following adjustment factors. 2003 and 2002 dollars are assumed to be similar in value. Canadian dollars were converted using historical conversion values from the Bank of Canada.

Values are from the Engineering News-Record

Year	Construction Costs Relative Annual Increase	Annual Factor	Cum. Update Factor
1981	9.21%	1.09	2.020
1982	8.20%	1.08	1.850
1983	6.30%	1.06	1.709
1984	1.97%	1.02	1.608
1985	1.18%	1.01	1.577
1986	2.38%	1.02	1.559
1987	2.58%	1.03	1.522
1988	2.56%	1.03	1.484
1989	2.12%	1.02	1.447
1990	2.54%	1.03	1.417
1991	2.18%	1.02	1.382
1992	3.10%	1.03	1.352
1993	4.51%	1.05	1.312
1994	3.80%	1.04	1.255
1995	1.16%	1.01	1.209
1996	2.72%	1.03	1.195
1997	3.67%	1.04	1.163
1998	1.61%	1.02	1.122
1999	2.35%	1.02	1.104
2000	2.67%	1.03	1.079
2001	1.82%	1.02	1.051
2002	3.22%	1.03	1.032

Appendix F: Guidance for Maintenance Personnel

General environmental guidance for snow storage sites include:

- The longer snow stays near the roadway, the more polluted it becomes.
- Snow from high traffic areas becomes more polluted than snow from low traffic areas.
- Placing snow on the downhill portion of storage sites and working uphill reduces meltwater pollution.
- Placing snow in a single larger pile, rather than multiple small piles, reduces meltwater pollution.
- Annual clean-up of trash and debris reduces chances of trash complaints.
- Driving (and turning sharply with equipment) on pad surfaces can cause increased pollution in meltwater. Impacts are lessened when the ground is frozen.
- If a site has pollution-reducing features (ponds, berms, etc), a management plan should be made for the site.

For sites with surface drainage:

- Site grading can agitate deposited sediment and pollute runoff. Avoid grading unless hazards or large channels develop on the pad

Appendix G: BEST MANAGEMENT PRACTICES FOR SNOW STORAGE SITES (AKDEC, 2001)

BEST MANAGEMENT PRACTICES FOR SNOW STORAGE SITES

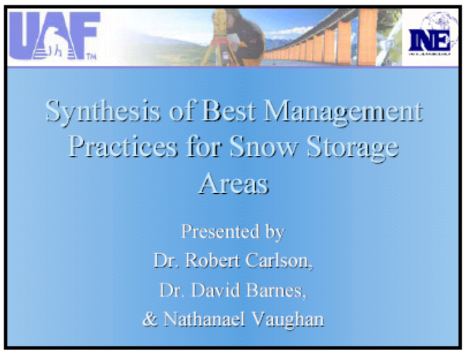
Why is anyone concerned about the storage of snow that is cleaned from a community's streets? First of all, the snows that accumulate on the roadways and side streets of a city are not just the clean, white fluffy frozen water crystals that float down from the sky in Alaska from October to April. Snow that collects on roads is likely to contain pollutants such as salt, sand and gravel, other suspended or dissolved solids, oil and grease, antifreeze, heavy metals, and other trace elements from vehicle traffic and automobile engine emissions. Snow collected from roadways often contains incidental trash, broken pavement, and other road debris. Some of these pollutants become diluted as the snow melts, but others can accumulate in the area where the snow is dumped or downstream from areas where snow is dumped into surface water.

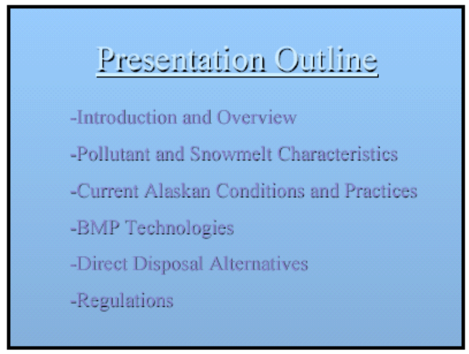
Communities need to do some planning for their snow storage areas that include the consideration of the sizes of sites needed, distances and driving time for trucks hauling removed snow, access control of the site for public safety, distance of storage area to any surface water bodies, and plans for site maintenance during both the winter months and summer growing seasons. Below are some best management practices that communities should consider when planning for snow storage areas:

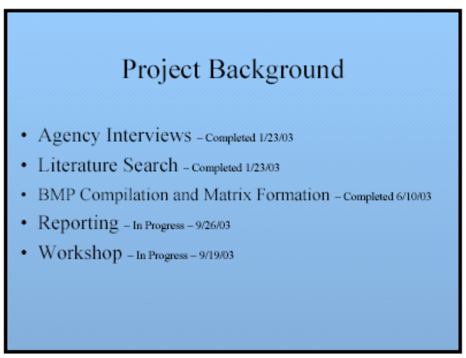
1. Avoid placing snow that has been scraped off of city streets into sensitive areas such as wetlands, aquifer recharge areas such as gravel pits, and wellhead protection areas. This snow often has accumulated trash, litter, debris, road salts (if used in your area), and automotive fluids (e.g., gasoline, diesel, lubricating oils, antifreeze) incorporated into it which have the potential for contaminating surface water or shallow groundwater in an area.
2. A minimum 50 foot wide, vegetated buffer zone should be maintained between a snow storage areas and any surface water bodies (streams, creeks, rivers, lakes, ponds). This distance could be decreased if adequate stormwater/sediment catchment basins, coarse gravel berms, or sediment traps/barriers/filters are built to reduce impacts on surface water bodies that potential run off form these sites may have. Run off from snow storage areas should not exceed State Water Quality Standards (18 AAC 70) when discharged into surface water.
3. Accumulated trash and debris need to be removed from the storage area in the spring as they become visible when the snow melts. This may need to be done several times over the course of the summer as the snow pile continues to melt. Wastes and littler that become uncovered as the snow melts need to be picked up before off-site migration of the waste becomes a problem. Heavy equipment may need to be brought into a site to push the snow piles around and enhance the melting process. Sites that are littered with trash tend to act as magnets for additional unpermitted dumping of wastes.

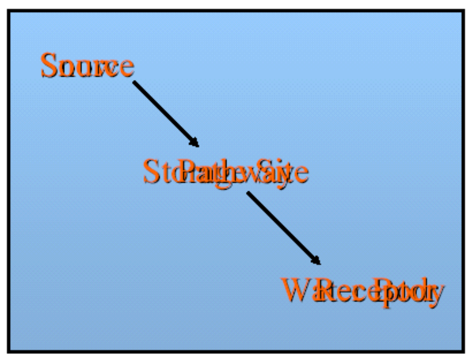
Appendix H: Workshop 9/19/03

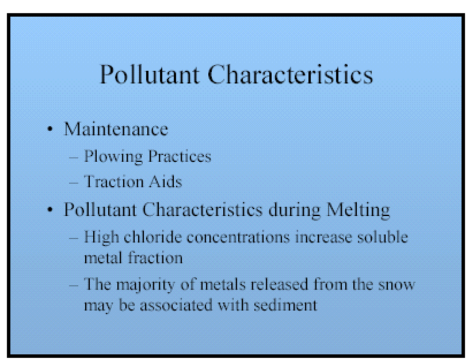
A video-conference workshop was held on 9/19/03 with participants in Anchorage, Fairbanks, Nome, and Juneau. AKDOT&PF attendance included (from Anchorage) Clint Adler, Gerry Reed, Chris Keplar, (from Juneau) Greg Otto, (from Fairbanks) Jay Bottoms, Dave Waldo, (from Nome) James Adams, Richard Barengo, Pat Kelliher, and Jerry Oliver (participants in Nome were connected via telephone). UAF attendence included Dr. Robert Carlson, Dr. David Barnes, Anna Forsstrom, and Nathanael Vaughan. Additional participants included Chris Haigh with the City of Fairbanks, Dan Jordan with the Fairbanks-Northstar Borough, and Mike Scott with the City and Borough of Juneau Public Works Department. The following slides were shown during the workshop.











Alaskan Conditions and Practices

- Southeast
  - CG-90 (predominantly NaCl), $MgCl_2$
  - Aggregates
- Southcentral
  - NaCl, $MgCl_2$
  - Aggregates
- Central
  - NaCl (as additive in aggregate)
  - Aggregates
- Western
  - $CaCl_2$
  - Aggregates

Fairbanks Chip

Snow Storage Considerations

- Siting
- Design
- Operation

BMPs

- BMP definition: "a BMP is any procedure or technology which
  - Reduces use of pollutants that may cause an impact.
  - Reduces exposure of a pollutant to precipitation.
  - Removes a pollutant from a runoff stream by natural or man-made treatment."

•Structural
•Operational
•Composite
•Miscellaneous

Structural BMPs

- Infiltration
- Filtration
- Filter Strips
- Ponds
- Wetlands
- Storage Pads

Structural BMPs

Infiltration

Description:

Discharges meltwater through soil contact; encourages interaction with groundwater

Pros:

- Does not constitute point source discharge

Cons:

- Undesirable in presence of shallow, potable aquifers
- Higher typical maintenance cost than other options

Structural BMPs

Filtration

Description:

Pollutants are removed as meltwater passes through a filter media

Pros:

- Inexpensive means of removing particulate

Cons:

- Filter media must be replaced periodically
- Reduced function at low temperatures

Structural BMPs

Filter Strips

Description:

Vegetated land serves as a physical filter for overland flow; recommended as a site "buffer"

Pros:

- Removes sediment and trash

Cons:

- Reduces available pad area (buffer use only)
- May suffer from reduced effectiveness due to icing

Structural BMPs

Ponds

Description:

Reservoir which dilutes inflows and settles particulate

Pros:

- Inexpensive means of removing sediment
- Provides early-season detention and dilution
- May provide infiltration

Cons:

- Occupies area otherwise available for storage

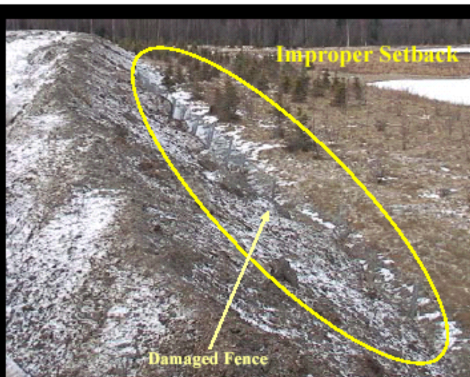
Structural BMPs

Wetlands

- Natural Wetlands are not recommended
  - If used, wetland function will be altered
- Constructed Wetlands
  - Storage site input is not sufficient to solely maintain wetland year-round
  - Effective in removing nutrients, solids, and reducing turbidity
  - Typically more costly than ponds


Image Courtesy of MOA WMS


Johansen Expy Storage Site, Fairbanks



Operational BMPs

- Management
- Administration
- Snow Placement
- Maintenance

Management

- Agency Cooperation
  - Shared sites are common in Alaska (private use is generally discouraged)
  - Develop Site Management Plans
  - Schedule Annual Coordination Meetings

Administration

- Fencing/Gates
  - Sites have been subject to unauthorized snow and waste disposal
  - Gates discourage access from highway vehicles
  - Fences discourage access by other means

Snow Placement

- Place snow on downhill side first
- When oriented properly, melt progresses from uphill to downhill
- Snow pack acts as filter media
- Generally, melt progresses from South to North

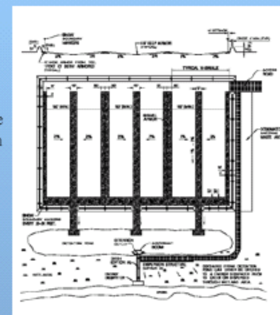
Operational BMPs

Maintenance

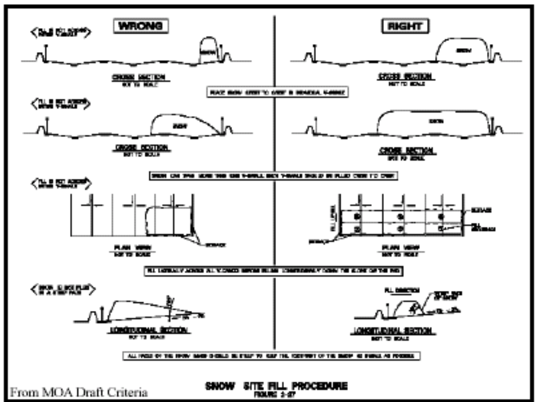
- Litter Clean-Up
  - Perform annually to prevent waste migration
  - Permanent storage may qualify site as a solid waste disposal site (additional permitting)
  - Supervised clean-up (i.e. volunteers with DOT supervision) is recommended

Composite BMPs

- MOA Draft Criteria
  - Addresses Siting, Design, and Operation
  - Provides specific guidance regarding site construction and operation
  - Under continual development
  - Wholesale use outside of the MOA is tentative and should be considered experimental



Draft Site Layout Courtesy of MOA WMS



From MOA Draft Criteria

SNOW SITE FILL PROCEDURE

Miscellaneous BMPs

- Sewer Inlets
- Snow Melting

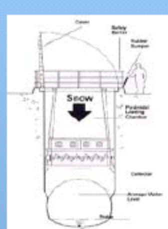
Miscellaneous BMPs

Sewer Inlets

Description:
- Snow is dumped at the inlet and assimilated into the wastewater flow

Pros:
- Requires little land area (little to no storage)

Cons:
- Not well suited for separate sewers
- Sensible heating effects will restrict melting capacity
- Wastewater must still be treated elsewhere



Schematic © Dilgrass (John Meunier US Filter, 2003)

Miscellaneous BMPs

Snow Melting

Description:
Snow is placed in a melting apparatus and disposed as meltwater

Pros:
- Reduced land area
- May be portable
- Sediment removal capability

Cons:
- Providing heat may be expensive
- Efficiency varies with sensible heat considerations
- Providing maintenance can be difficult/costly

Trecan 100 PD Snowmelter at Elmendorf Air Force Base (Courtesy of Trecan Combustion Limited)

Snow Melting Tank Demonstration from PIARC 2002

Direct Disposal Options

- Rivers
- Lakes
- Marine Waters

Snow Dumping in the St. Lawrence River

Direct Disposal History

- 1970's – Anchorage Discontinues Ocean Disposal
- 1995 – AKDEC denies permit to the City of Fairbanks to place a storage site on the Chena River
- Present Day – Ocean disposal continues in Alaskan coastal communities

Direct Disposal

Rivers

Pros:

- Turbulent flow provides rapid mixing
- High velocities promote rapid melting of snow

Cons:

- Sensitive to chloride influx
- Subject to drinking water standard
- Alter sedimentation and erosion

Direct Disposal

Lakes

Pros:

- Potentially large dilution reservoir

Cons:

- Sensitive to chloride influx
- Subject to drinking water standard
- Increased sedimentation potential
- Potential salt-induced stratification

Direct Disposal

Marine Waters

Pros:

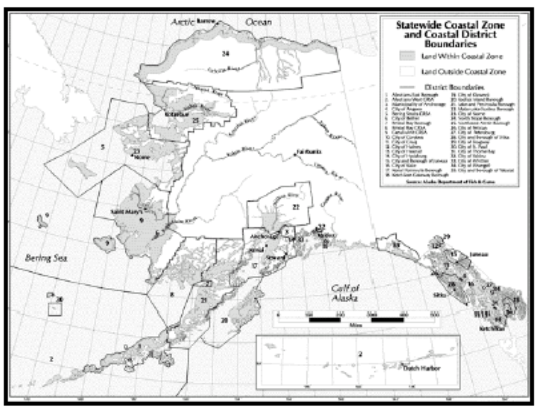
- Tidal action inhibits local sedimentation
- Rapid assimilation of snow mass
- High ambient chloride levels
- No drinking water standard

Cons:

- Increased regulatory considerations

Regulations

Conventional Storage
Direct Disposal



Regulations

Direct Disposal

- NPDES (USEPA)
- Clean Water Act Section 404 (USACE)
- Marine Protection Research and Sanctuaries Act (marine only) (EPA)
- Alaska Coastal Management Plan Consistency (if within coastal management zone) (AKDNR)

+ Applicable Local Regulations

Acknowledgements

This research was funded by the Alaska Department of Transportation and Public Facilities under Project No. FHWA-AK-RD-01-33.

Thanks to:

- Clint Adler, AKDOT&PF Research, for project management and review
- Jimmy Adams, Jay Bottoms, Alan Gonsioroski, Greg Patz, Gerry Reed, and Kerby Wright, AKDOT&PF Maintenance, for service and background information
- Scott Wheaton, MOA WMS, and Bill Rice, Montgomery Watson-Harza, for project review and background material and studies.

"Arctic Man" Sapporo from PIARC 2002

Comments

- Please submit comments regarding the final report by 9/26/03 via e-mail to:

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