Draft

Low Salt Design Guidance

Minnesota Stormwater Manual

Low Salt Solutions

Real People. Real Solutions.

Submitted by:
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Contents

Why Low Salt Design

Winter Safety! Snow and ice create unsafe conditions for driving and walking. These unsafe conditions are addressed by using plows, shovels, blowers, deicers, and sometimes closures. Deicers create a host of expensive and long-term problems for the state of Minnesota, its communities, property owners and taxpayers. Deicers damage expensive infrastructure and permanently change freshwater chemistry.

Low Salt Design elevates the responsibility for winter safety into design. Solving a safety problem in design is much more cost effective than continually reacting to a safety problem over the life of that infrastructure.

Requirements for Low Salt Design

Permits

Designs must meet existing local, state, and federal requirements. At this time, we are unaware of permits or requirements to use Low Salt Design.

Performance standards

No winter performance standards exist at this time at the state level. Currently, rate and volume control of meltwater is considered but that does not do enough to improve winter safety.

Definition of terms

Critical Area: Area that requires excellent winter friction. Examples of critical areas are front steps, high traffic sidewalks, braking zones, bridges, underpasses, ramps, curves, hills, and ADA routes. The volume of traffic and speed of traffic influence what is deemed as a critical area.

Fetch: The distance wind blows across water or open land without impedance. For Low Salt Design, look at the prevailing winter wind direction to calculate fetch.

Horizontal drainage is the near lateral movement of meltwater (meltwater running across a highway ramp) whereas **vertical drainage** has a more extreme elevation change (i.e., Roof to sidewalk).

Low Salt Design: A series of design concepts aimed to create safer winter surfaces by improving pavement recovery and reducing the re-entry of snow and meltwater onto saltable surfaces. Safer surfaces reduce the need for salt.

Meltwater footprint: The wet surface area created on a dry pavement from the movement of snowmelt water.

Meltwater sprawl: The movement of snowmelt onto saltable surfaces.

Pavement Recovery: The time it takes after snow removal for the pavement to regain traction that meets user expectations. Several of the Low Salt Design strategies help here. This could also refer to the time it takes after a freezing rain event to regain traction that meets user expectations. Only a few of the Low Salt Design Strategies help here.

Plowability: A way to rate the site for ease or difficulty of motorized snow removal

Plowshed: Delineated surface from where snow is pushed into a snow pile.

Precision Winter Maintenance: Winter maintenance strategies that minimize the amount of salt to meet the level of service targets. Precision agricultural practices are quite common, but precision winter maintenance practices are still developing. Many factors are involved in "more than needed" salt use such as the fear of safety, not wanting to pay overtime, not understanding how much salt is needed, lower performing equipment, shortage of crew, long route cycle times and/or lawsuits just to name a few, drive the over application of salt.

Salt: Generic term that represents chloride-based deicers.

Saltable surfaces: Includes sidewalks, parking lots, roads, trails, bridges, ramps, and steps, most outdoor hard surfaces that are used for walking or driving in cold climates.

Low Salt Design Goals

The goal of Low Salt Design is to improve winter performance of saltable surfaces for safety and to reduce the need for salt.

- Low Salt Design takes some pressure off of winter maintenance
    - Creating cost savings across the board
        - In winter operations
        - In sustainability of:
            - Soil
            - Vegetation
            - Wildlife
            - Water
            - Infrastructure

There are two basic strategies in Low Salt Design.

1. Increase the speed of pavement recovery (before the use of chemicals).
2. Control the repeat offenders. Repeat offenders are the reentry of blowing snow and meltwater onto saltable surfaces.

Snow that falls from the sky will be managed through winter maintenance efforts. This falls into a smart salting strategy.

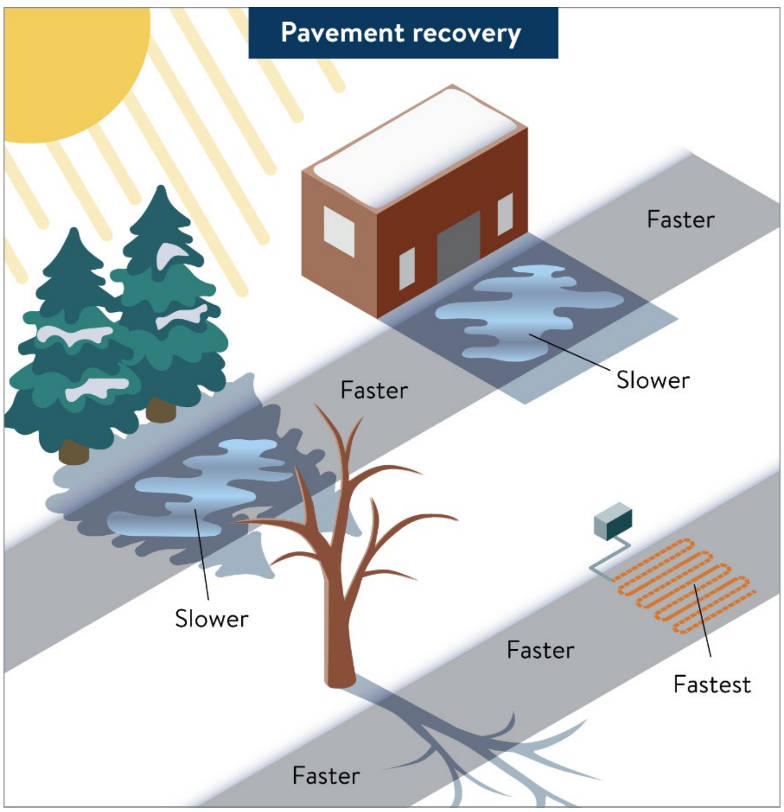
Snow that comes to rest after winter maintenance operations or snow that is not involved in winter maintenance operations (i.e. snow on the roof, snow on the lawn, snow in the right-of-way) can be managed through infrastructure design so as to speed up pavement recovery or reduce its movement onto saltable surfaces.

Most important to use Low Salt Design strategies to protect **critical areas**

Speed Up Pavement Recovery

Low Salt Design speeds up pavement recovery from snow or ice-covered surfaces to clear, higher friction pavement. Faster pavement recovery through design reduces the window of winter danger for the travelling public and drives down the need for salt.

Key Low Salt Design concepts to speed up pavement recovery:



Heat on saltable surfaces speeds up pavement recovery. Image source: MPCA.

Control Repeat Offenders

Low Salt Design strives to reduce the frequency and/or footprint of blowing snow and meltwater sprawl onto saltable surfaces. Many of the risky winter travel situations are the result of repeat offenders. Reduced winter safety is often followed by a callout of winter maintenance crews and the use of deicers. Low Salt Design aims to reduce the footprint and frequency of these problems.

Key Low Salt Design concepts that control repeat offenders are:

Blowing snow (repeat offender)

Blowing and drifting snow control begins by understanding the winter wind angle and snow transport and deposition concepts. In Minnesota, the number of hours where the wind is strong enough to move snow at rest varies greatly. In windy regions blowing snow control should be elevated as a top design criteria.

Snow deposits from wind onto the sidewalk. Image courtesy of Bolton & Menk.

Meltwater sprawl (repeat offender)

Meltwater sprawl is the process of turning a dry pavement wet by the melting of snow and ice and its movement onto a saltable surface. Meltwater sprawl is a phenomenon that can be controlled through design. This differs from the melting of residual snow/ice on a pavement after a snow event.

Meltwater Sprawl	Not Meltwater Sprawl

Left: Meltwater sprawl. Snowmelt moves onto the pavement after pavement is dry. This CAN be controlled through design. Image courtesy of Bolton & Menk.

Right: Not meltwater sprawl. The pavement is wet because of a snow event. This CANNOT be controlled through design. Image courtesy of Bolton & Menk.

Prioritization

Critical Areas

Critical areas are smaller components of the larger transportation system that require excellent winter friction. Examples of critical areas are front steps, high traffic sidewalks, braking zones, bridges, underpasses, ramps, curves, hills, and ADA routes. The volume of traffic and speed of traffic influence what is deemed a critical area. For parking lots and sidewalks, critical area examples include building entrances, steps, high foot traffic areas, ramps, ADA parking spaces, and intersections.

- Critical areas should be identified in each design. Low Salt Design strategies that can be integrated into winter critical areas will provide the best return on investment.

Site Specific Influences

Although it would be nice to say one design element is more important than another design element, the truth is it will depend on your site. For example, much of Minnesota will benefit from improved control of the meltwater sprawl (horizontal and vertical drainage) but if you are in a windy part of the state where winter road closures are common, outsmarting the wind may move to your top Low Salt Design strategy. If you are designing a year-round functional loading dock, you are likely to prioritize locating that feature in the sun.

Low Salt Design Implementation

Low Salt Design will be a new concept for many people involved in constructing and maintaining infrastructure and buildings.

Construction: Low Salt Design features should be made known to construction project representatives. Some designs may not make sense to those who are not familiar with the purpose of these design features, and they may revert to what they are used to seeing in designs (e.g., change in curb type).

Maintenance: Inform maintenance leadership on specially designed snow storage areas. If the maintenance crew is not aware of these low salt design features (for example specially designed snow storage areas), they may not take advantage of them.

For a retrofit situation, inform maintenance crews of the changes that should result in lower salt use, so they do not continue to salt those areas as they always have in the past.

Low Salt Design Strategies and Details

Ten design strategies were developed (Bolton & Menk, 2024) to create safer winter surfaces and prevent or lessen the need for salt use. There is no priority to this list as all could greatly improve winter performance. As for frequency of use, the bolded items come into play in almost every design. This section provides details on each of these design strategies. Integrate these strategies into your designs to improve winter performance of saltable surfaces and reduce salt use.

Low Salt Design Strategies

- **Use the sun**
- **Outsmart the wind**
- **Horizontal drainage (stop meltwater sprawl)**
- **Vertical drainage (stop meltwater sprawl)**
- **Snow removal made easy (plow access)**
- **Snow storage**
- **Salt storage**
- **Minimize footprint of salted surfaces**
- **Pavement alternatives**
- **Vegetation in design summary**

When to Use Low Salt Design Strategies

- Low Salt Design strategies should be considered in every cold climate design.
- Low Salt Design considerations may compete with other design considerations.
  - Low Salt Design should not be forced into the design, rather the designer should integrate Low Salt Design concepts where it shows the best overall results and omit Low Salt Design concepts where other performance criteria offer better net performance.

    - Low Salt Design (at the time of publication) is not a required design element, it serves as a tool for the designer to use where appropriate to add winter safety, cost savings and sustainability into projects.
- For climate action plans, managing meltwater sprawl (which lead to ice and salting) will serve you well as the trend in most of Minnesota shows an increase in the number of thaw/freeze cycles.

Conflicts with Low Salt Design

Within Design

As Low Salt Design strategies are considered, they bump into other design objectives. Low Salt Design considerations may be more valuable in some areas and less valuable in others. This is not unusual as designers wrestle with budget constraints, client specific criteria, etc. Bringing Low Salt Design into all design charrettes will ultimately produce a better four-season design strategy.

- An example of conflict between design concepts may be the desire to have high density of trees on site which conflicts with a snow storage sizing estimate of about 20% of the plow shed, snow storage areas should not have trees. The designer will have to consider the pros and cons of both concepts and decide the best overall approach for the site.

With Policy

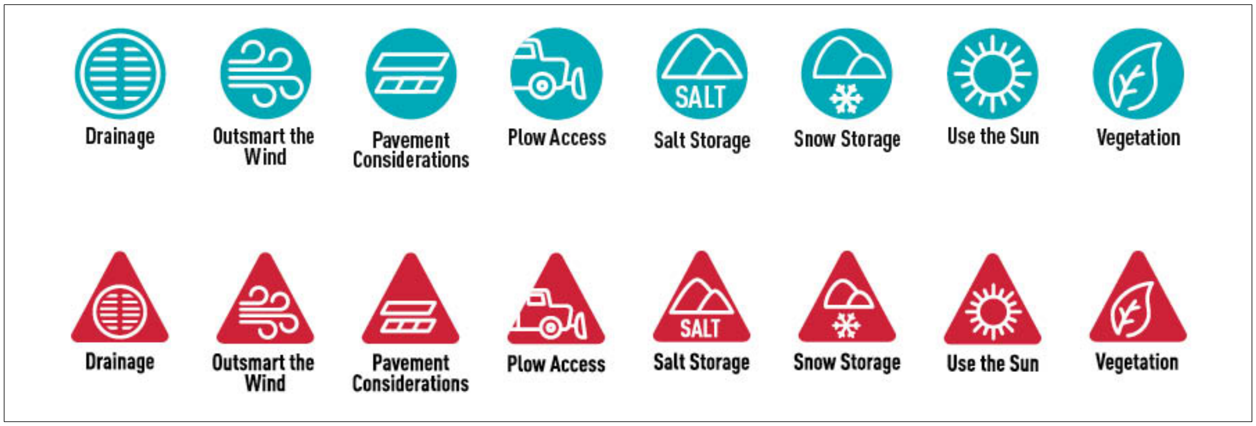
As Low Salt Design strategies are considered, they may conflict with policy/standards written without winter considerations. If this conflict is brought to the organization's attention, they have the potential to review and update policy/standards to optimize four-season benefits.

- An example of conflict between winter design and policy are requirements for parking lot islands. These islands offer benefits such as traffic calming, beauty, and summer shading. However, in winter design they are a plow obstacle and a source of meltwater sprawl, both leading to increased salting and short life expectancy for the vegetation.

Icons

Blue Icons are used to indicate areas where Low Salt Design concepts are integrated into the project. Blue Icons can also be useful in PowerPoint presentations, word documents or other ways to initiate discussion surrounding Low Salt Design.

Red Icons are used to indicate winter problem areas in design. As design considerations and requirements are many, not all can be met. By using a red icon in areas where there are anticipated winter problems, it informs the client, and it manages expectations. These areas are not oversights they are areas where winter performance was deemed less important than other design considerations.



Blue and red Low Salt Design Icons. Graphics courtesy of Bolton & Menk.

Checklists

Checklists are an easy way to remind designers and plan reviewers to consider winter. Checklists can be very detailed, or very simple, and can emphasize any number of Low Salt Design concepts that are of interest to the organization in charge.

Below is an example from the City of Hopkins. This example integrates custom snow storage sizing and winter wind direction for their city, but most of the concepts apply generally to any city across Minnesota.

City of Hopkins: Factsheet for Developers

Why Low Salt Design?

Low Salt Design strategies help infrastructure perform better in the winter. They increase safety and drive down the need for salt. The use of salt has economic, environmental, and societal costs:

- Degrades infrastructure including concrete, pavement, metal fixtures, and exterior and interior of buildings (Every 50 lb. bag of salt causes $40-$400 in infrastructure damage)
- Damages vegetation and soil
- Pollutes drinking water, lakes, rivers & wetlands
- Harms fish, fish eggs and other aquatic life

Low Salt Design Examples

Outsmart the Wind
Hopkins' prevailing winter wind is NNW. Anticipate blowing/drifting areas and design to shelter your critical traffic areas.

Use the Sun
Less salt is used where the sun shines. Evaluate where shadows will be on a project site to help place critical areas in the sun.

Snow Storage
Designs must include snow storage with meltwater control. **About 18% of plowshed needed** for snow storage in average snow winter. Snow hauling plan needed if storage is undersized.

Drainage
Route meltwater away from salted surfaces. Consider downspouts, snow storage areas, and snow melt from lawn/landscape areas. Reduce meltwater footprint onto saltable surfaces.

Plow Access
Plan for width of snow removal equipment. Avoid acute angles and curved surfaces. Design for easy push to snow storage. Limit need for back up maneuvers.

Vegetation
Keep trees and shrubs out of snow storage. Use salt tolerant species in islands. Limit winter shadows in safety zones through species selection and placement

For more information, contact the City Engineer, Eric Klingbeil: eklingbeil@hopkinsmn.com

More information on Low Salt Design including a Low Salt Design Best Practices checklist: https://www.hopkinsmn.com/1196/Hopkins-Sustainable-Building-Policy

City of Hopkins

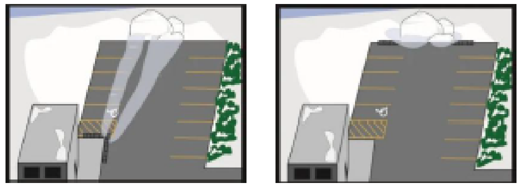
Produced by Bolton & Menk, Inc. for the City of Hopkins

Example page 1 of City of Hopkins Low Salt Design Fact sheet. Used with permission from the City of Hopkins MN

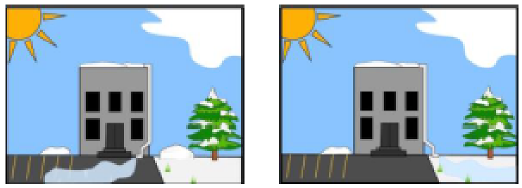
Low Salt Design Examples

Poor Winter Performance | **Proactive Winter Performance**

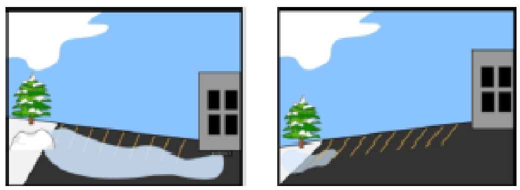
Design for snow storage:
- Size snow storage area at ~18% of plowed area
- Keep snow storage areas free of trees and other obstacles
- Control meltwater sprawl



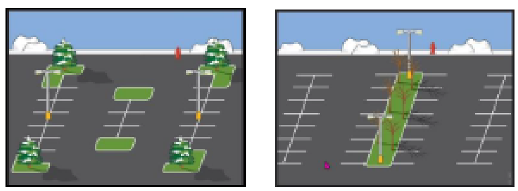
Control vertical drainage:
- Drain snowmelt from (roofs, decks, awnings away from saltable surfaces
- Reduce meltwater sprawl



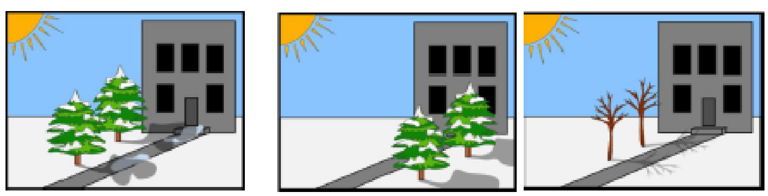
Manage horizontal drainage:
- Store snow on low side of pavement
- Direct perimeter meltwater away from saltable surfaces



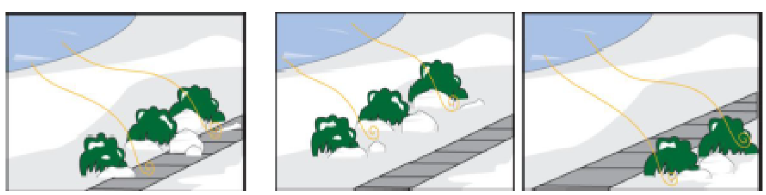
Make it easy to plow:
- Reduce obstacles
- Create easy push to snow storage
- Limit plow back up maneuvers



Direct sunlight to critical areas (front steps, braking zones):
- Select deciduous vegetation
- Control shadows of conifers
- Consider building orientation



Manage the NNW winter Wind:
- Create snow drop zones before or after the saltable surface.
- Eliminate snow drop zones on saltable surfaces



Produced by Bolton & Menk, Inc. for the City of Hopkins

Example page 2 of City of Hopkins Low Salt Design Fact sheet. Used with permission from the City of Hopkins MN

Use the Sun

Overview

Pavement recovery is fastest when pavement is in the sun, winter shaded surfaces are slower to melt. Consider the areas of greatest need for pavement friction (i.e., front steps, braking zones) and optimize them to receive winter sun. Trees, fences, and buildings are all items to consider in neighboring infrastructure and in proposed design.

Problem to be solved

Shade creates slower winter pavement recovery. Shades influence on slow pavement recovery can be compounded with other considerations (meltwater sprawl, blowing snow) to make a dangerous scenario for the travelling public (thus a higher salt zone).

The left side has faster pavement recovery. The right side has slower pavement recovery. Image courtesy of Bolton & Menk.

Benefits and Limitations

Making use of the sun to speed up pavement recovery can be free or can be expensive. However, if you have this as a design consideration from the start of your project, you are more likely to be able to capitalize on this free element in design.

Design Criteria and Considerations

Put the sun into your CAD system. Evaluate the angle of the sun on the shortest day of the year; identify the orientation of the sun and hours of sunlight. It will remind you to take advantage of this free resource for melting snow and speeding up pavement recovery.

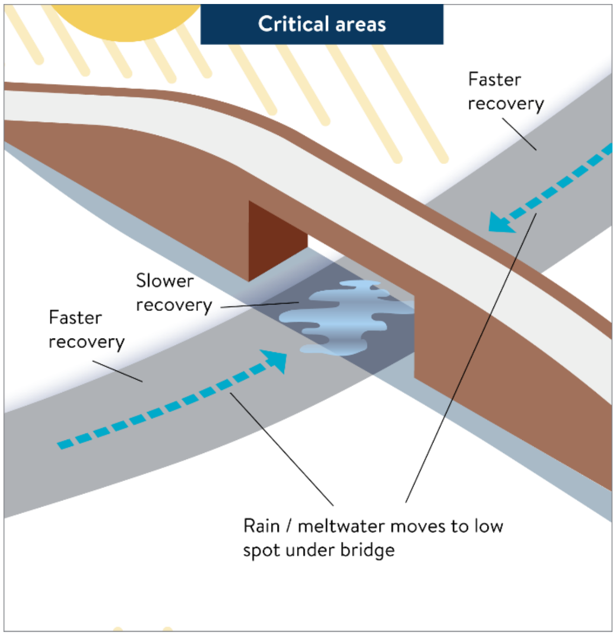
Albedo is a measurement of how much light a surface reflects or absorbs. Darks surfaces, such as asphalt, have a low albedo leading to a warming effect while white surfaces such as snow or concrete have a higher albedo.

The Use the Sun strategy should be considered for critical areas such as building entrances, braking zones, and any area where winter pavement friction is critical.

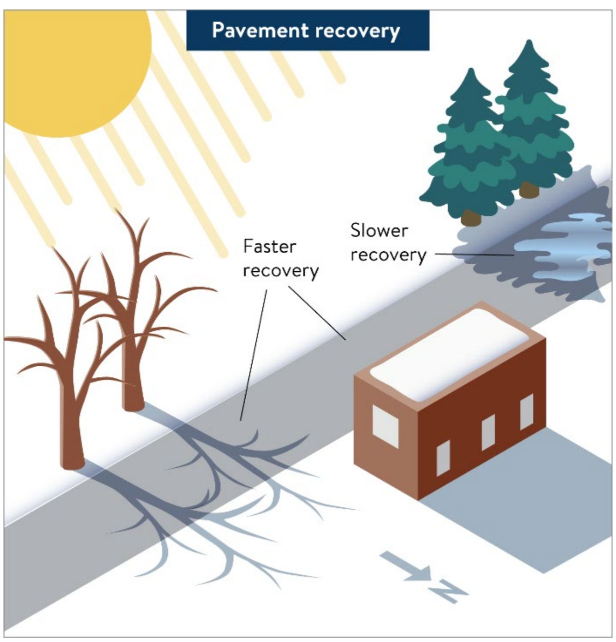
To take advantage of the sun, consider:

- Building placement/rotation
- Other structure placement (i.e., noise walls, fences)
- Vegetation selection and placement
- Vegetation management

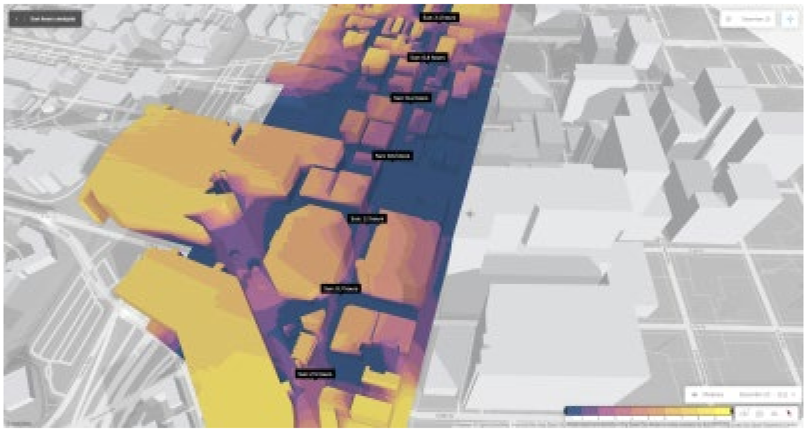
Diagrams/Infographics



Double negative shadow in the low spot. Image source: MPCA.



Shadows delay pavement recovery and promote repeat salting events. Image source: MPCA.



Example of sunlight analysis, dark color represents persistent winter shade. Image courtesy of Bolton & Menk.

Shaded areas can be identified using sun analysis software such as Autodesk Forma. If designing for the dark purple zones, there is no help from the sun and a serious winter challenge. Consider pavement innovation for help in retrofits. If there is new construction, move the pieces around. Try and optimize the location of critical areas into the yellow zone (braking zone, front doors, hills, sharp curves, crosswalks, high traffic areas). Using the sun is free and one of several strategies to speed up winter pavement recovery.

Retrofit Suitability

High: Vegetation management via removal of trees and replacement with shorter vegetation or replacing coniferous trees with deciduous trees is an easily implemented retrofit opportunity to reduce shade.

Low: Rotate building, remove adjacent property features casting shade.

Permits/Regulations

Some cities have ordinances that restrict tree removal. Some urban designs require shade cast analysis.

Potential Conflicts

Climate change: If warming up winter pavement would contribute to climate change, how does that impact compare to the extra danger for the traveling public, and salt loading on a colder pavement?

Research Needed

How many hours of sunlight exposure per day are needed to improve winter performance?

What is the optimal air and/or pavement temperature required to increase performance (based on pavement type, and on pavement with a layer of residual snow).

References and Additional Resources

Autodesk Forma. Design software.

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Outsmart the Wind

Overview

Blowing and drifting snow can create hazardous conditions on roads and other saltable surfaces. With proper design and placement, a variety of snow fence types can be used to create a snow drop area that is not on a critical paved surface and prevent blowing and drifting on roads. Likewise, placement of berm structures and vegetation without consideration of wind effects on snow drop can create unintentional snow drop areas and create hazardous conditions that require a lot of maintenance and use of deicers.

Problem to be solved

Blowing snow causes reduced visibility and repeated drifting. This is different than the snow that falls from the sky. The blowing snow that can be outsmart though design is the snow that is already on the ground. It can be picked up by the wind and moved laterally unless we anticipate this and design to control it.

Blowing snow can be controlled through design. Image courtesy of Bolton & Menk.

Snow falling from the sky cannot be controlled through design. Image courtesy of Bolton & Menk.

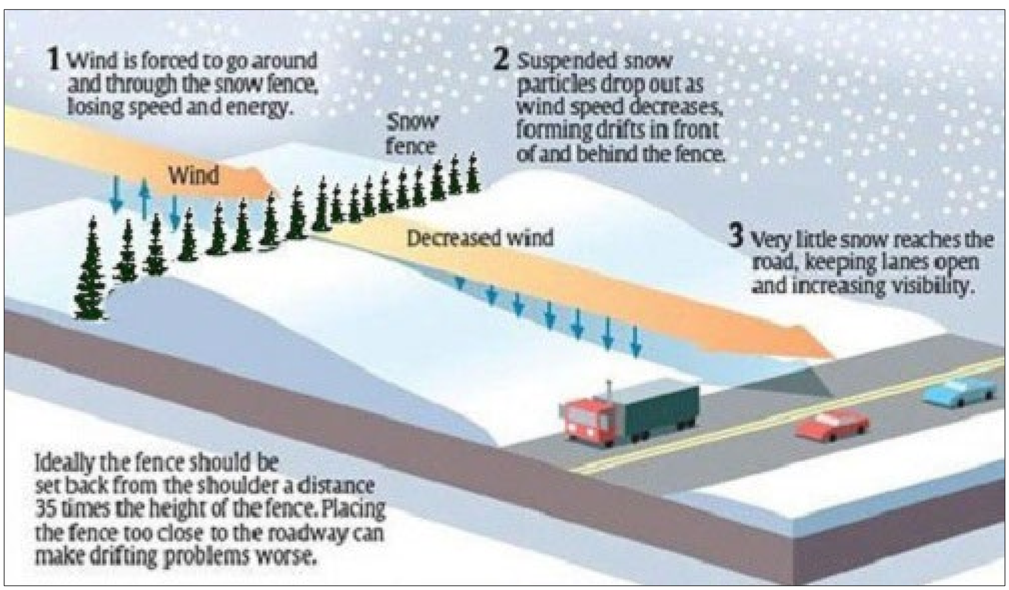
Benefits and Limitations

The University of Minnesota, with funding from the Minnesota Department of Transportation, developed a cost-benefit tool to estimate return on investment for implementing blowing snow control practices. MnDOT found that snow fencing provides a return on investment of $14 for every $1 spent (Current, 2017).

Design Criteria and Considerations

Three approaches to outsmart the wind:

1. Install snow fences – traditionally associated with corridor protection but offers equal benefits for site protection.
    a. Snow fencing can be a built structure such as a snow fence or berm, or a living structure such as a wall of vegetation, standing row crops, or a row of large hay bales. The angle, porosity, height and setback from the saltable surface are key to success. MnDOT and the University of Minnesota have tools and instructional videos to help with this design.
        i. MnDOT Living Snow Fences
        ii. UMN Blowing Snow Control Design Tool
    b. Understanding basic snow fence dynamics is important. Realize the snow drop happens as the wind crosses over the snow fence (and loses speed) and deposits snow after (not before) it hits the fence: Proper set back allows for snow drop before the saltable surface.



Proper snow fence installation and function.

Image: With permission from Wisconsin Department of Transportation (WisDOT), Living snow fence, https://wisconsindot.gov/Pages/doing-bus/local-gov/hwy-mnt/winter-maintenance/living-snow-fence.aspx. Accessed 11/20/2025.

Success! Effective sequence from left to right: wind, snow fence, snow drop zone, protected road. Image courtesy of Bolton & Menk.

2. Remove unintentional snow fences

An unintentional snow fence is anything that is placed in the path of the winter wind that causes a reduction in wind speed resulting in a snow drop. This could be park benches, landscaping, decorative fencing, sports field fencing, and other structures.

Failure! Ineffective sequence from left to right: wind, unintentional snow fence, drop zone on top of path. Image courtesy of Bolton & Menk.

3. Drift free road and ditch design

Drift free road and ditch design considers road elevation compared to windward elevation, ditch shape and geometry to store and manage snow before it becomes a problem on the roadway, http://www.dot.state.mn.us/project-development/subject-guidance/snow-blowing-drifting-control/process.html.

Design Tools

University of Minnesota/MnDOT Design tool

The University of Minnesota Center for Transportation Studies, with funding from MnDOT, developed a Blowing Snow Control Tools website that includes tools for designing snow fences, and road design that promotes deposition of snow in roadside ditches rather than on the road. Link: Design Tool | Blowing Snow Control Tools.

The Minnesota Drift-Free Roads Design Tool can be used to design a snow fence for a specific site. After entering a location on a map, the tool provides the following calculations (some are based on data within the tool and others are site specific entries) and leads to snow fence design.

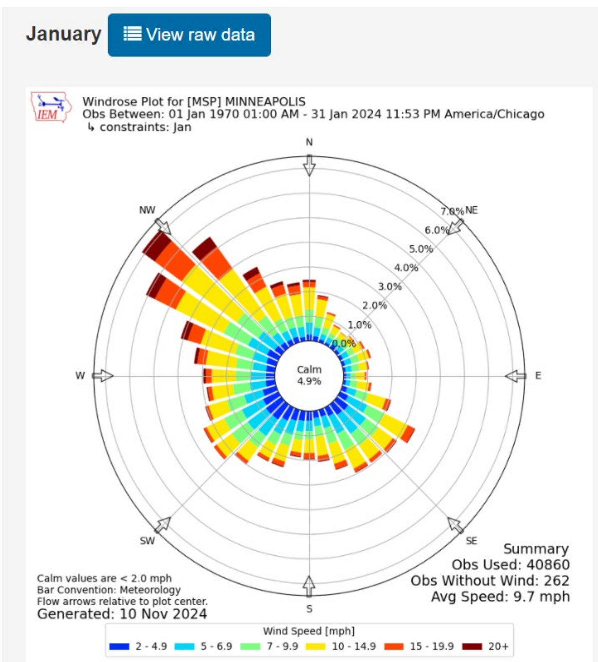
- Snowfall data
  - Mean snowfall accumulation- used in mean seasonal transport calculation
  - Mean snow water equivalent ratio- used in mean seasonal transport calculation
  - Relocation Coefficient- used in mean seasonal transport calculation
- Site Conditions
  - Wind direction of greatest snow transport- needed to help determine the attack angle
  - Fetch distance- used in mean seasonal transport calculation to find ideal snow fence setback
  - Mean snow transport- used to determine height and setback of snow fence
- Fence design
  - Porosity- porosity of structural or living fence type (examples provided)
  - Fence height- calculates minimum fence height needed to capture the calculated snow transport
  - Attack angle- the angle between the prevailing snow transport wind direction and alignment of the road or site. Attack angle is used to determine fence setback.
  - Fence setback- calculated from fence porosity, height and attack angle.
  - Fence extension- fence length needed to account for variations in wind direction and the end effect. To avoid creating dangerous transitions:
    - Tie fence into natural features
    - Fill in gaps between fence systems
    - Taper out protection by reducing fence height or increasing porosity near the ends.

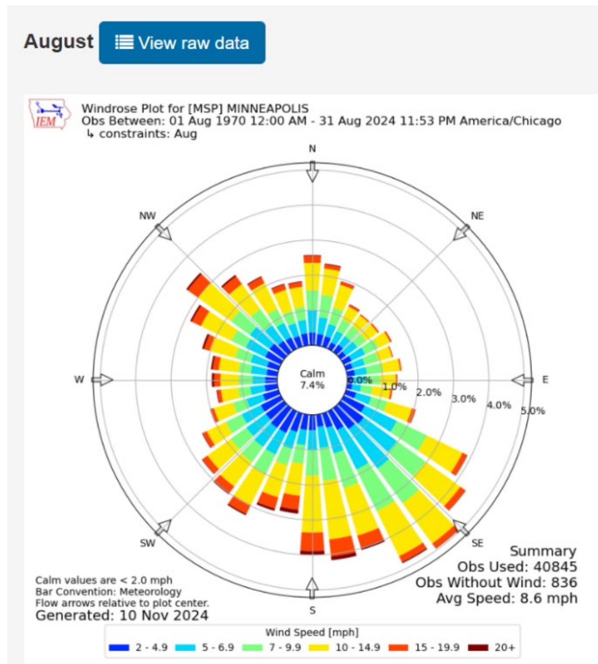
Wind Rose

The prevailing winter wind direction should be documented for your project site. Focus on winter wind direction, not a composite of 12 months.
https://www.dnr.state.mn.us/climate/summaries_and_publications/wind.html

How to read a wind rose: The largest bars are the most frequent winds. The design site location is in the circle center of these charts. Imagine that the wind is blowing towards the center of the chart from the largest of the sectors. This is the force you need to control in design.

These wind roses for Minneapolis show the prevailing January wind will come from the northwest but August shows a different trend.



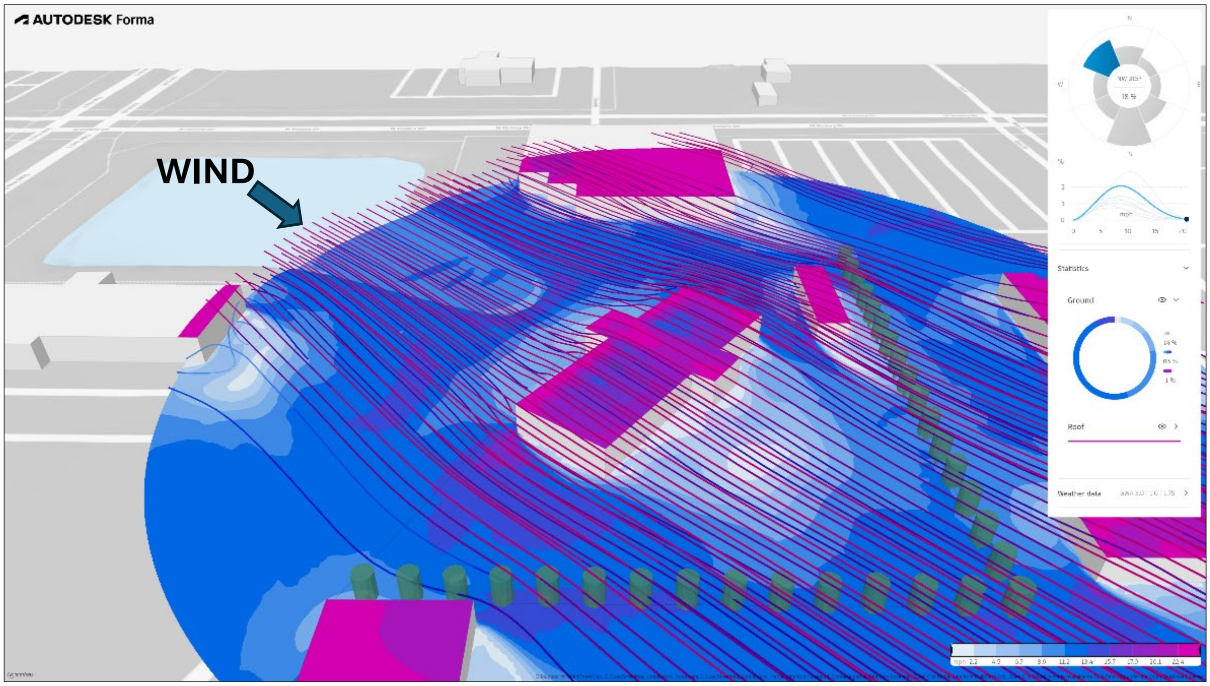


January wind rose for Minneapolis, MN. Image courtesy of Iowa State University.	*August wind rose for Minneapolis, MN. Images courtesy of Iowa State University.*

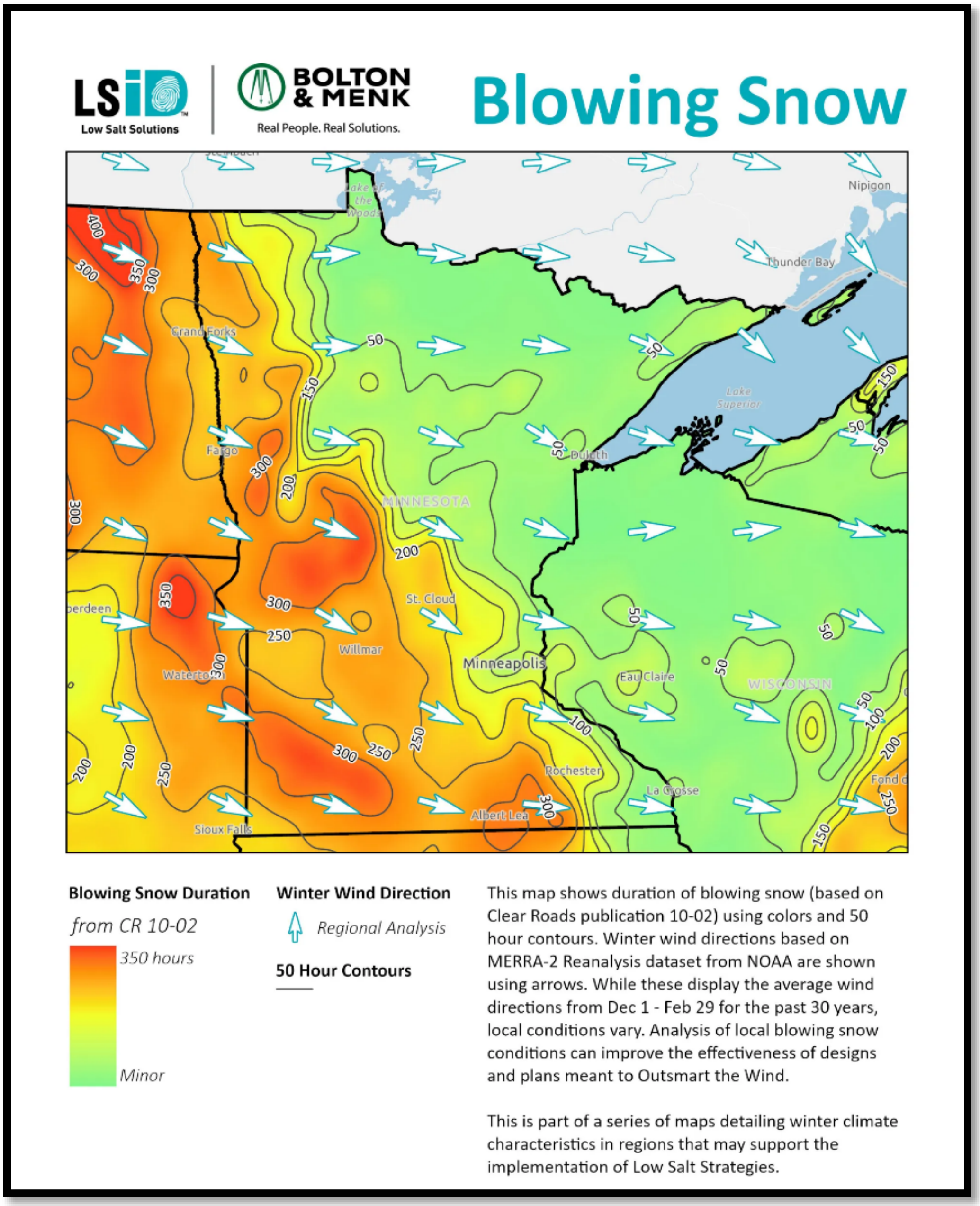
Wind modeling software

Determine the prevailing winter wind direction and blowing snow duration. In this example, the lighter colors and white areas indicate lower velocity areas where snow deposition is anticipated.

If you are designing within a part of the state with frequent strong winter winds, prioritize consideration of blowing and drifting snow in your design.



Wind speed model. Low wind velocity zones are shown in white. These are potential snow drop areas. Image courtesy Bolton & Menk.

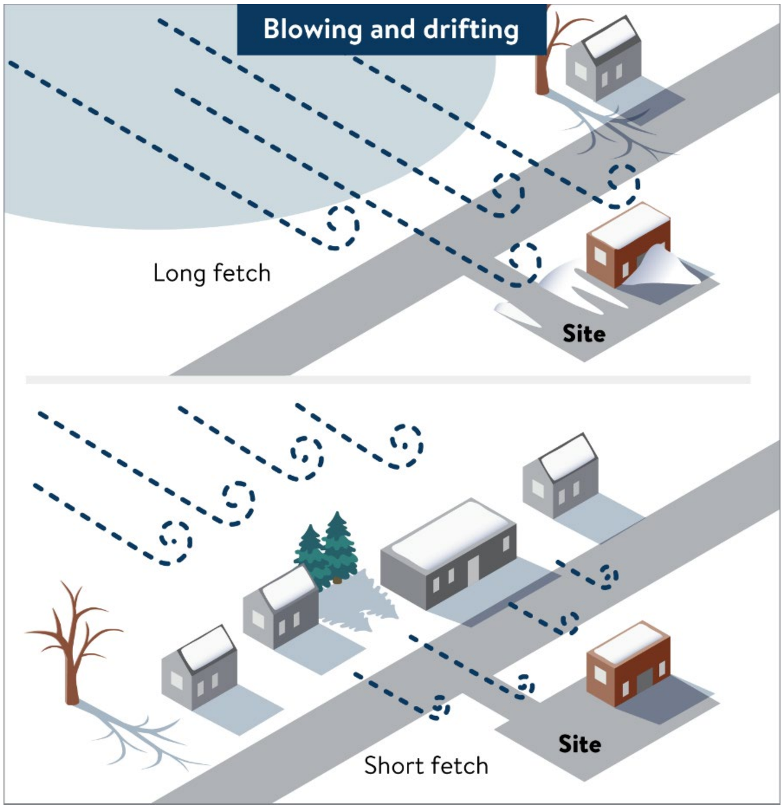


Winter prevailing winter wind direction and frequency of strong winter winds. Image courtesy of Bolton & Menk.

Fetch

Determine the fetch (distance of unimpeded winter wind). Fetch can be used to calculate the mean seasonal snow transport to determine ideal snow fence setback. It is one of the calculations in the Minnesota Drift-Free Roads Design Tool.

- The longer the fetch the more likely there will be a blowing and drifting snow problem



The longer the wind can travel unimpeded (fetch) to a site, the more likely it will have a blowing and drifting snow problem. Image source: MPCA.

- For more complicated blowing snow such as in downtown areas, modelling is recommended to understand velocity shifts and snow drop areas.

Strong wind is a simple term to introduce a more complex subject. The threshold friction velocity determines when snow at rest can move. Dry, fluffy, less dense snow may require a wind speed of 10-15 mph to move it laterally, whereas a higher wind speed is required to move wet, compacted, or icy snow. Terrain roughness also comes into this calculation.

Retrofit Suitability

High: Intentional and unintentional snow fences

- May require adjustments on adjacent property.
- Structural or living snow fences can be added to a site if there is enough space. If not, it may require working with adjacent properties. For roadways, the right-of-way is often not enough space. MnDOT has been successful in working with and providing payment to farmers and other landowners to leave corn rows or hay bales in place through the winter, plant living snow fences, or allow MnDOT to install structural snow fences. Urban and suburban sites would be more difficult to understand for outsmarting the wind, and it may be difficult to alter locations of landscaping features and benches.

Permits/Regulations

Coordinating the installation of snow fences along roadways involves cooperation with local agencies and property owners. If private property owners are involved, payment, contracts, and easements may be needed.

Permits/Regulation concerns

Future considerations: Is it ok for a design to create a snowdrop onto a public road, sidewalk, or adjacent property? Is it ok to remove an unintentional snow fence that decreases public safety? Should blowing snow analysis be required in designs of the future in the windy areas of the state? Blowing/drifting snow decreases public safety.

Potential Conflicts

One of the best ways to outsmart the wind is the installation of "snow fences." These must be set back from the "saltable" surface to create a drop zone not on a "saltable" surface. Depending on the size of the site, this may involve working with property owners adjacent to the site you are developing or managing.

Case Studies

1. Minnesota found that snow fences reduced crashes on super elevated curves by 40% (Wyatt et al, 2015) and save the state thousands of dollars in reduced costs for winter maintenance (Wyatt, et al. 2012).
2. North Dakota snow fence/solar fence provides dual benefit of blowing snow control and power generation (Yang et al. 2021).

Research Needed

Linear playground or decorative structures that also serve as snow fences for sites in open areas such highway rest stops or in/near parks, sport fields, lakes, golf courses, and prairies.

How to obtain more interest and implementation of snow fences and outsmart the wind strategies.

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Horizontal Drainage

Overview

Snow falls across an entire landscape filled with roads, buildings, parking lots, sidewalks, lawns, fields, gardens, sport fields and it all melts. The meltwater must go somewhere, and the saltable surface should be protected from meltwater intrusion. Wet pavement turns to icy winter pavement. By restricting the entry of snowmelt onto saltable surfaces, a safer winter surface emerges. Unless you are in a very windy area, this is likely to be the single most important concept in low salt design.

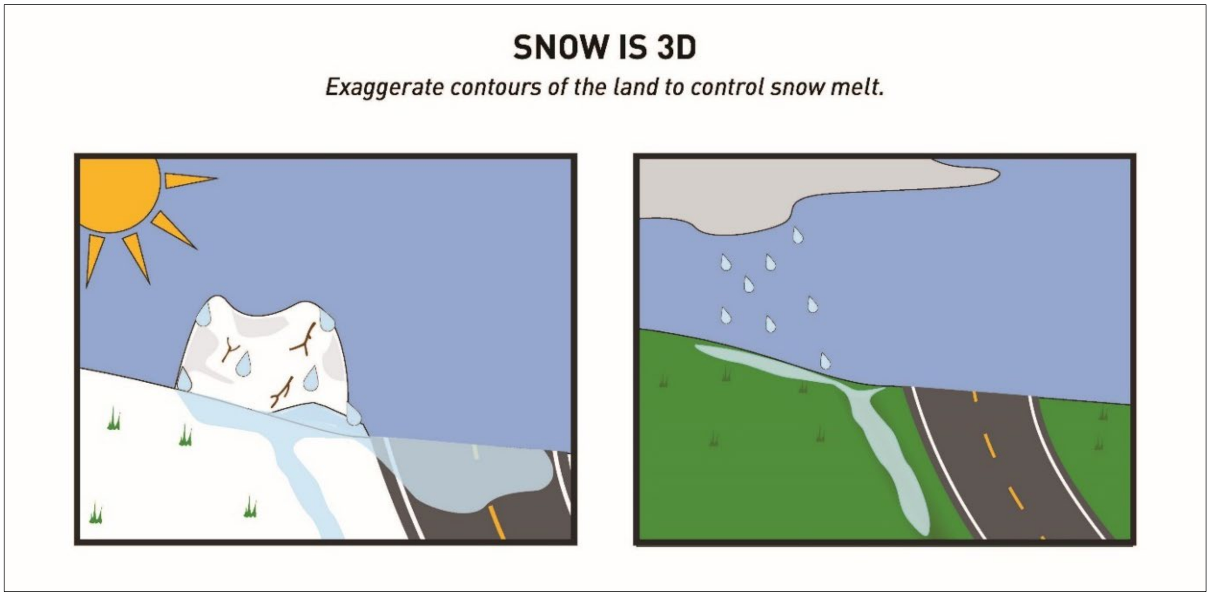
Horizontal drainage is the near lateral movement of meltwater, while vertical drainage has a more extreme elevation change (i.e., roof to sidewalk).

Problem to be solved

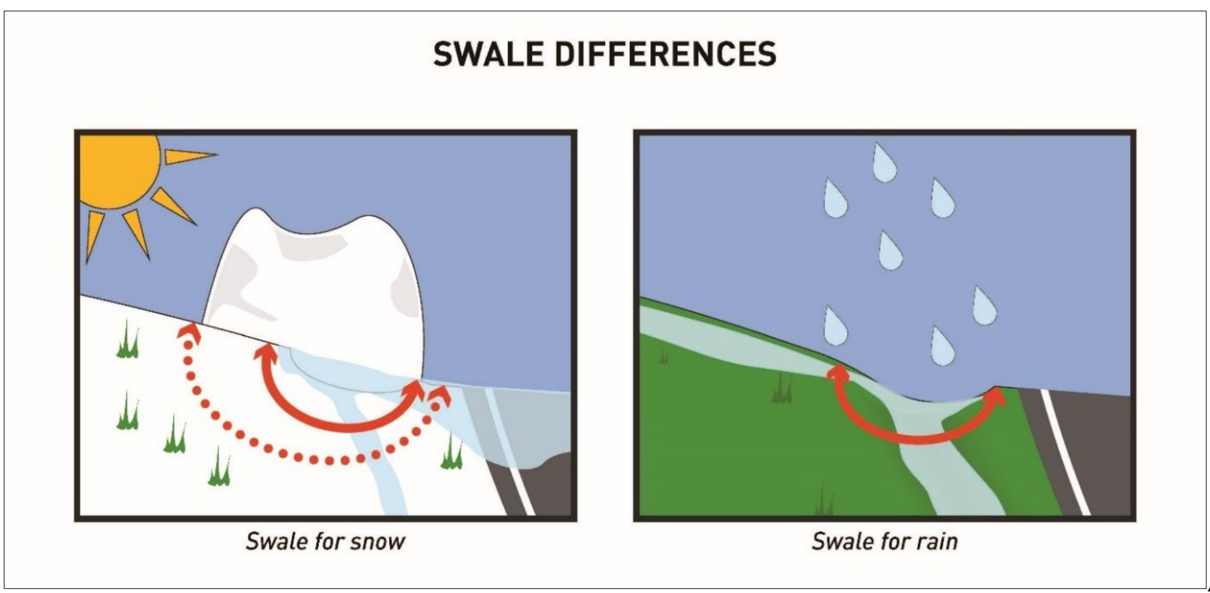
Reduce meltwater sprawl from snow rest zones onto saltable surfaces.

1. Conditions for problem

   a. Dry winter pavement
   b. Snow adjacent to saltable surface
   c. Temperatures above 32°F long enough so that the snow starts melting
2. Problem
   a. Snow melt moves downhill and often spreads across saltable surfaces.
   b. Wet pavements freeze as temperatures drop, become ice covered, unsafe and often get salted.



Winter meltwater will move across surfaces such as a snow-filled land contour compared to rain that fills and follows the contours. Graphic courtesy of Bolton & Menk.



A

Swale adequate for rain may not be adequate to accommodate winter snow with meltwater management. Graphic courtesy of Bolton & Menk.

Contours of the land should be exaggerated (swale or ditch deeper and/or wider) in order to control the movement of meltwater. The lower layers of snow may fill in and block a swale and the snowmelt will not follow its contours.

To manage rain, it is often captured or controlled at the low spot. However, for snow melt control the meltwater must be intercepted before it starts crossing the pavement, add meltwater control at the higher elevations.

Snow melt and sprawl problem that can be controlled in design. Image courtesy of Bolton & Menk.

Wet pavement from a winter rain event: This cannot be controlled in design to prevent a sheet of ice unless more drastic measures are employed such as heated pavement or covered surfaces. Image courtesy of Bolton & Menk.

Benefits and Limitations

Every inch of meltwater sprawl onto saltable surfaces threatens public safety, drives up salt use, and shortens the lifespan of infrastructure.

To get the best return on investment, restrict meltwater sprawl in critical areas (if you are unsure what a critical area is, follow the maintenance crew. Wherever they make repeated visits to an area to ensure safety, that is a critical area. You see the bucket of salt by a door; this is a critical area. You see repeated salting passes on the cloverleaf; this is a critical area).

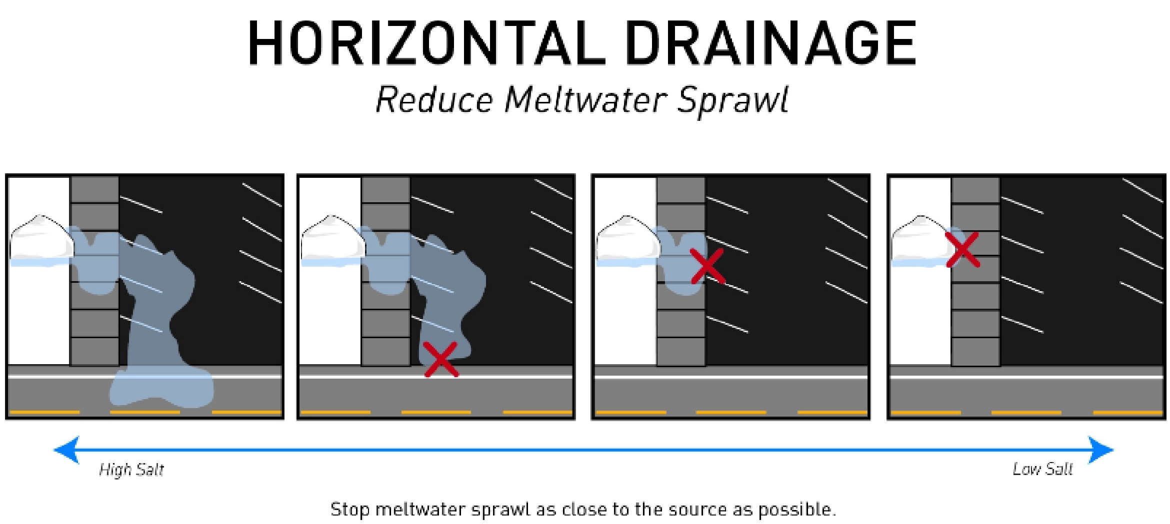
Wherever meltwater sprawl is eliminated, there are benefits to:

- The users of the pavement (safer),
- The maintenance crews (less work, less salt, less cost)
- The property owners (less infrastructure damage, less vegetation damage)
- The next generations (less water pollution)

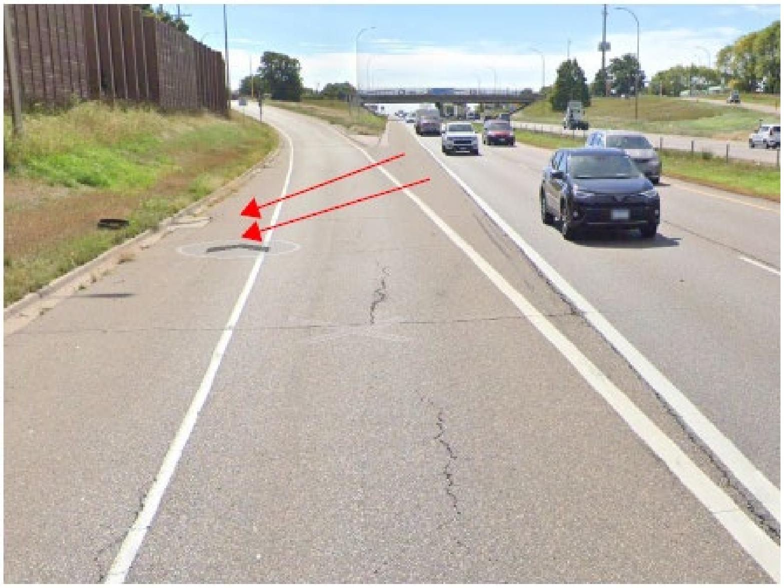
Design Criteria and Considerations

- Understand where the snow will fall
  - Lawn, landscape, natural areas, unplowed areas, saltable surfaces
- Understand where the snow will be pushed to
  - Along the perimeter of saltable surfaces
  - Roads, parking lots, sidewalks, trails, ramps
- Design the snow melt path so it avoids reentry onto saltable surfaces
- No storm drain or curb cut in ADA parking spot.
- Avoid routing meltwater across ADA zone (i.e., crosswalk)

Diagrams/Infographics



Horizontal drainage: stop meltwater sprawl as close to the source as possible. Graphic courtesy of Bolton & Menk.



Critical acceleration lane in cross slope, gore collects snow and drains across acceleration lane. Image courtesy of Bolton & Menk.

Superelevated surfaces have a high risk of meltwater sprawl. Image courtesy of Bolton & Menk.

Retrofit Suitability

High likelihood that retrofits can reduce meltwater sprawl.

Permits/Regulation concerns

Currently there are no requirements to design for winter performance beyond that of summer performance. It is logical that controlling/reducing/eliminating meltwater sprawl will be a future performance standard especially in critical pavement friction areas.

Potential Conflicts

Winter design considerations versus summer design considerations can create conflict. Both must be considered to move ahead with the most optimal four-season design.

Winter design: Key objective is to reduce melt water sprawl.

- Once the surface recovers from a snow event (plowed/shoveled), do not let the meltwater sprawl across impervious surfaces, thus reducing the need to apply salt.
- Snow on the perimeter of a paved surface (parking lot, sidewalk, etc.) encounters above freezing temperatures long enough so that the snow starts melting.
- Snow meltwater drains downhill and often cascades across impervious surfaces.
- These wet pavements freeze as temperatures drop, become ice covered, unsafe and often get salted.
- A key strategy in winter design and safety is to keep the pavement dry.

Summer design: Key objective is to meet requirements for stormwater management (volume and rate).

- Spreading runoff over the pavement is a strategy that distributes the volume across a greater surface area and is less costly to build with a lower infrastructure investment.
- There is little concern about wet pavement as long as water does not pool since the pavement will drain to the nearest curb/catch basin, ditch, or turf/planting area.
- Temperatures are not cold, so there is no concern about ice.

Summer/Winter Design conflict:

- Meltwater sprawl must be minimized in winter to prevent a sheet of ice from forming.
- Sheet flow of stormwater in the summer is a design strategy that may reduce infrastructure installation costs (i.e., additional storm drains, curb and gutter, etc.).
- Ignoring winter performance is shortsighted, it creates safety risks and increases the need for salt.
    - Salt accelerates infrastructure deterioration and shortens its useful lifespan, thus increasing maintenance, repairs, and replacement costs.
    - Erosion of infrastructure is a disaster that can be reduced using low salt design.

Research Needed

- Study and document the average meltwater sprawl of current designs. This will inform design goals for the future to reduce meltwater sprawl and deicer use.
- Meltwater sprawl research should be split between critical area meltwater sprawl and standard area meltwater sprawl.
- Tool to predict/measure meltwater sprawl of designs.

Vertical Drainage

Overview

Snow that falls from the sky lands on surfaces of all heights. Elevated surfaces are generally not cleared of snow. As the snow melts, elevated surfaces create an avalanche of snow, dripping meltwater, and/or a stream of meltwater. Any of it discharged to saltable surfaces creates unsafe winter conditions and increases the need for salt.

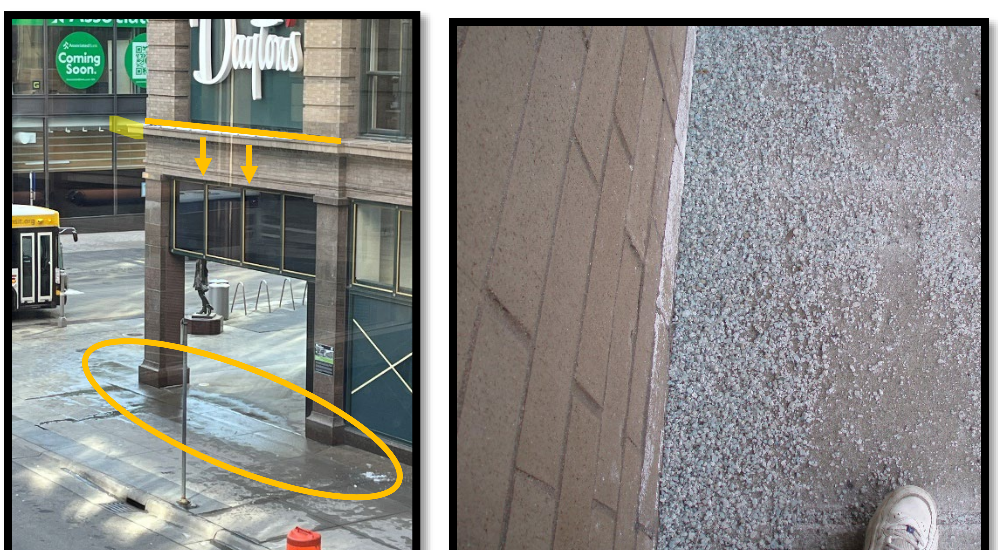
Vertical snowmelt is commonly associated with structures, trees, bridges, awnings, and other elevated surfaces can direct meltwater to sidewalks, steps, and ramps, creating unsafe conditions, accelerating the need for salt and increasing infrastructure damage.

Icicles are an example of vertical drainage. Image courtesy of Bolton & Menk.

Infrastructure damage due to salt. Image courtesy of Nick Queensland.

Problem to be solved

Direct snowmelt from higher elevations to lower elevations without it landing on saltable surfaces.



The image on the left reflects the problem caused by dripping snowmelt. The image on the right shows excessive salt use near the building where vertical drainage is a problem. Image courtesy of Bolton & Menk (Left) and Jenny Winkleman (Right).

Downspout directing roof melt to sidewalk creating unsafe conditions and the excessive use of salt. Images courtesy of Bolton & Menk.

Benefits and Limitations

Benefit: Meltwater routed away from saltable surfaces increases public safety since it prevents formation of ice.

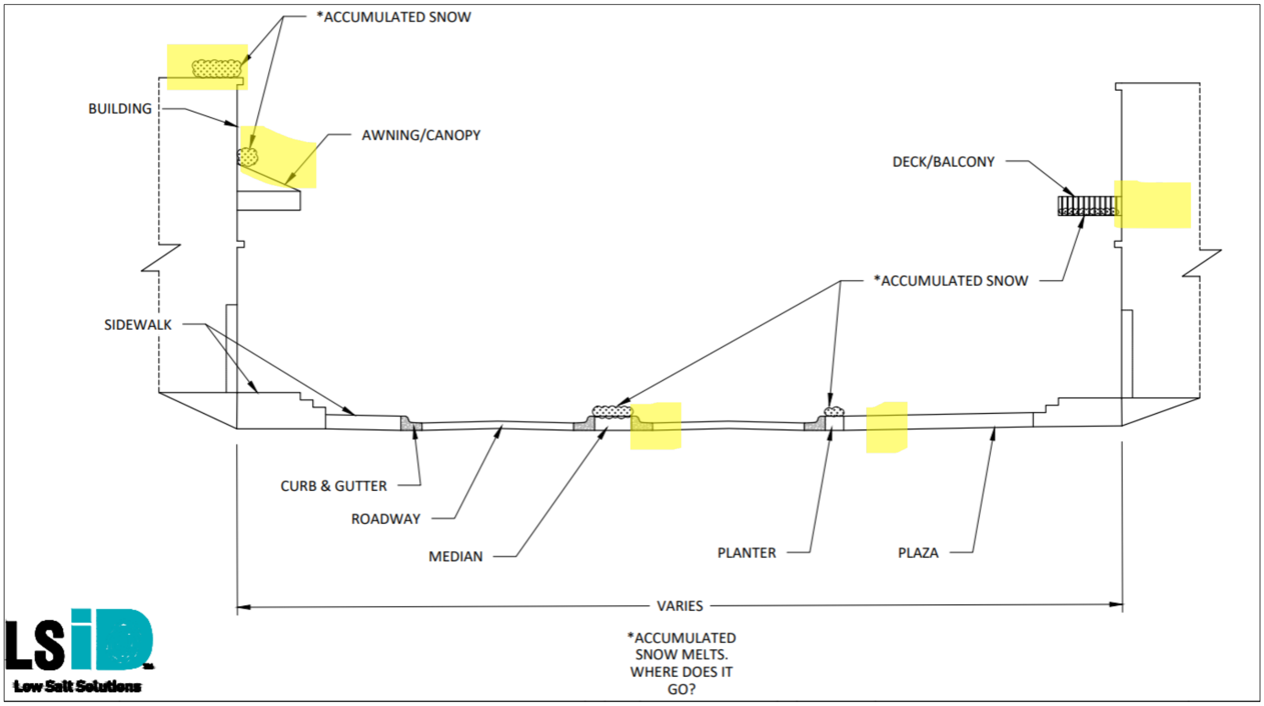
Limitation: It is difficult to collect runoff from some vertical snow catch areas so that it can be routed to a safer area. For example, awnings lining a high traffic sidewalk are installed at a variety of depths and heights. Seldom is there an area to route the meltwater that is not a saltable surface.

Design Criteria and Considerations

Look up! Look at the entire site/corridor for vertical snow catches. Map out where the snowmelt will drain. Intercept the melt and route it away from saltable surfaces.

For snow catches like decks, avoid placing steps, sidewalks or parking lots under them. If sidewalks must run under decks, capture the meltwater and convey it away from a saltable surface.

Diagrams/Infographics



Areas where snow will accumulate. Graphic courtesy of Bolton & Menk.

Retrofit Suitability

- High

Permits/Regulations

- Check local regulations about connecting downspouts into stormwater system.

Potential Conflicts

Awnings – It is difficult to control meltwater from awnings. Awnings are often placed in critical areas such as high use doorways and sidewalks. Awnings add beauty to the building facade but create winter danger and extra salting. Awnings on a stretch of sidewalk vary in height from the building down to the sidewalk, making a system-wide awning catch/retrofit nearly impossible to install.

- If awnings are low enough to be reached by maintenance staff, the snow should be removed from the awning during the sidewalk snow removal process.
- Possible, but likely unpopular, ideas:
  - Restrict awning use in critical areas
    - Awnings for three-season use, retract/remove in winter
    - Capture meltwater and route away from saltable surface (vegetation, drain)
    - Standardize awning depth, create a linear sidewalk dripline catch area (planting zone, linear drain…)

Case Studies

Maintenance leaders from Edina, Minnesota brought attention to the icy sidewalk created from awning meltwater.

Snow accumulated on the awnings. When it is released, it will create a safety problem and likely a reapplication of salt. Image courtesy of 50Th & France Business Association

Snow released from awnings post storm onto dry pavement. The release of snow from awnings creates a new safety concern and often a new application of salt. Notice accumulation of salt near doorway. Image courtesy of Bolton & Menk.

Research Needed

- How to solve awning meltwater management
- What percentage of repeat salting events come from vertical drainage?

Easy to Plow

Overview

Design surfaces for the ease of snow removal. The quicker and more thorough snow can be removed, the sooner the surface can recover friction.

Most snow removal is done on motorized equipment with a rigid blade. Design with the width and contour of the plow in mind. If it isn't plowable, then hand removal will be required, and this often lags behind plowing and/or is ignored unless it is in a critical area. The fewer obstacles to plow around, the better the snow removal process.

Snow left in uncleared patches creates unsafe conditions as it melts, sprawls, and refreezes. Segmented cutting edges/live edge blades are used on some plows and can clear uneven surfaces such as wheel tracks in roads better than straight edges but don't improve clearing when there are larger differences in pavement height or narrow indents in pavement.

- Snowplows move most efficiently in straight lines.
- Back up maneuvers are more dangerous for the plow, traveling public and infrastructure.
- Plows cannot clear snow out of acute angles.
- Plows cannot clear snow from surface undulations that occur under the width of the blade.
- Plows leave patches of snow when they maneuver around obstacles.

Problem to be solved

- Design saltable surfaces so that snow removal is easy with a wide rigid blade. This includes roadways, parking lots, sidewalks, trails, ramps, bridges, and plazas.
  Consider:
    - Turning radius
    - Rigid and wide plow blades
        - Cannot clear snow out of swales, divots, undulating surfaces.
        - Cannot reach into acute angles (<90°).
    - Consider blade width and design with it in mind (e.g., City of Crystal Minnesota commonly uses UTV blade 6', parking lot plow 9'2", street plow 12', could have a wing plow that makes it wider, box plow 12') (B. Fortin, 4/9/25).
    - Snow push/deposit areas should align with plowing pattern.
    - Straight ahead pushes are the fastest and easiest for the plow.
        - Reduce the need for back dragging snow.
        - Avoid having to move the same snow multiple times to get it to a snow storage location.

Benefits and Limitations

Benefits: Faster recovery of pavement, less meltwater sprawl from patches of unplowed snow, safer winter navigation of pedestrian ramps in a shorter timeline, lower potential for icy conditions.

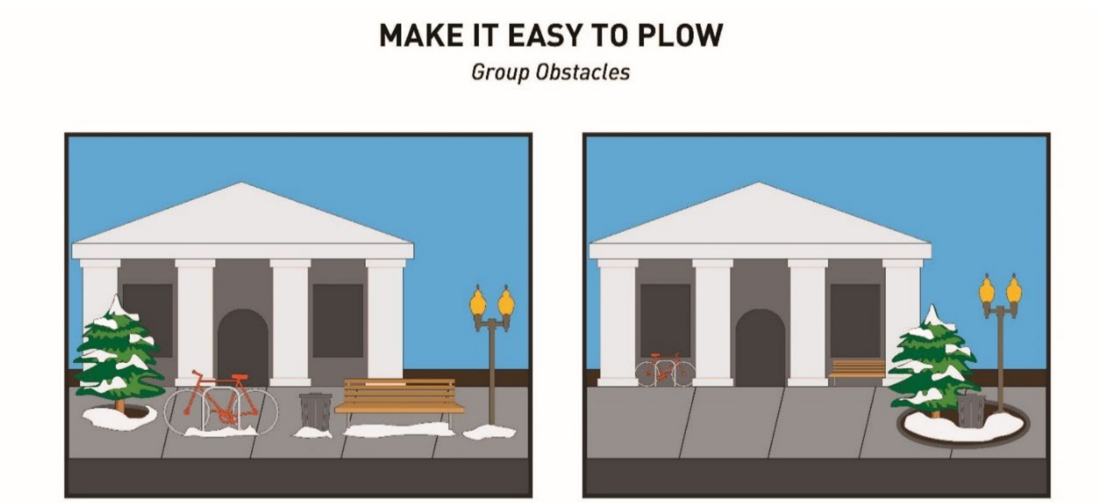
Limitations: Width and rigidity of plow blade

- Conflicts between the recommended/required placement of infrastructure and the ability to plow (i.e., crosswalk buttons, handrails, signposts, mailboxes, gores, fire hydrants, etc.). All have their own criteria, and it may conflict with the ease and effectiveness of plowing the site.
- Lack of space

Design Criteria and Considerations

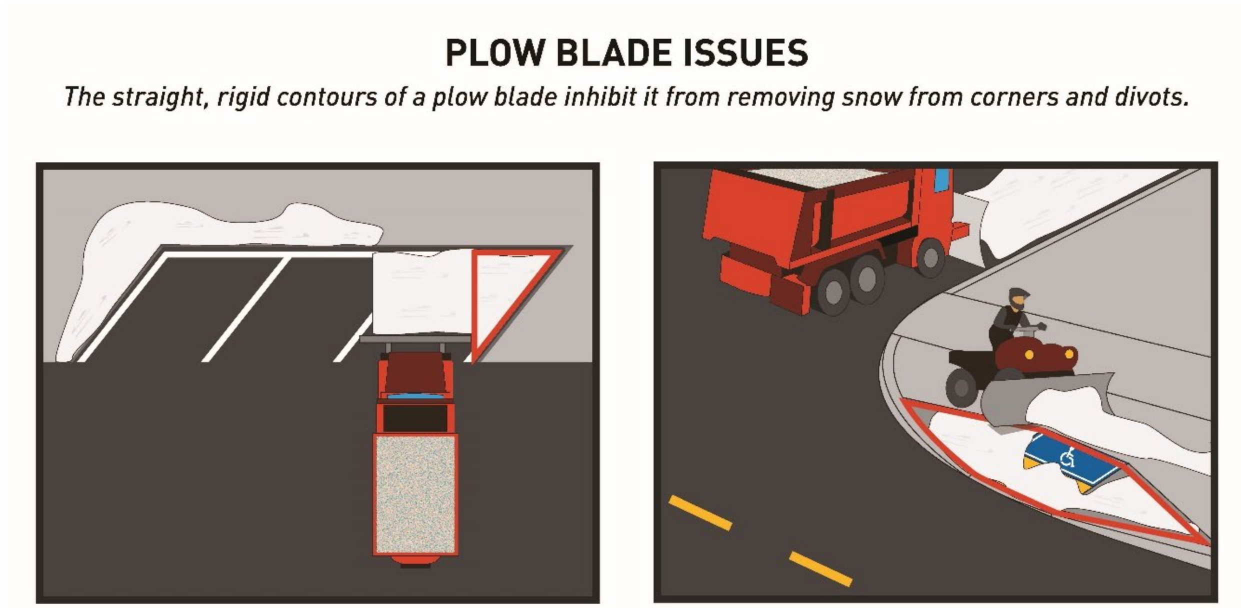
Research the plow width to be used to maintain the sidewalk/plaza you are designing. This should influence the spacing of benches, trees, posts, and other plowing obstacles. It will inform pavement contours on ramps as well. A common blade is 60 inches, a V plow is a minimum of 55 inches, and some specialty equipment supports a 48-inch blade. A site may be maintained using a power broom or blower. Seek out this information to help inform your design.

Group obstacles (fire hydrant, light pole, mailbox, sign pole, benches, flower boxes, crosswalk buttons, trash cans, etc.) wherever possible to create a plowable circumference.

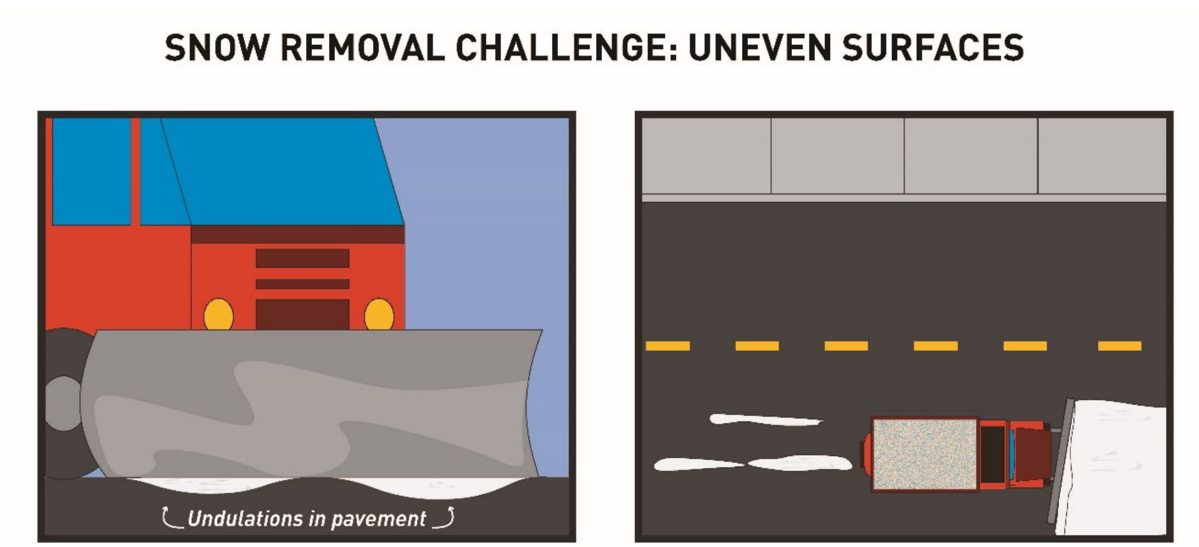


Left image, difficult to plow, right image easier to plow. Graphic courtesy of Bolton & Menk.

Poor winter design, no place to push the snow. Image purchased through iStock Images.



Blades cannot clear snow out of acute angles or swales. Improving plowability through design, improves speed of pavement recovery and public safety. Graphic courtesy of Bolton & Menk.



Pavements must be level under the entire width of the blade for good snow removal. Graphic courtesy of MPCA.

Retrofit Suitability

High

Permits/Regulations

State and other ADA requirements.

Local ordinances for parking lots.

Potential Conflicts

The following are examples of regulations or requirements that often result in making sidewalks and parking lots difficult to plow which leads to increased salt use.

1. Parking lot island standards https://stormwater.pca.state.mn.us/index.php/Residential_streets_and_parking_lot_checklist
2. Requirements for placement of light poles, fire hydrants, mailboxes, handrails, crosswalk buttons, signs, etc., may restrict the grouping or placement of items for plowability.
3. ADA requirements

Case Studies

City of New Brighton Parking lot code standards

The City of New Brighton changed City requirements for parking lot islands after considering low salt design as well as other factors. The requirement for parking lot islands may be waived if the parking lot design achieves all of the following (City of New Brighton, 2024):

1. Consolidates landscape and stormwater management areas into large medians
2. Demonstrates adequate traffic calming
3. Implements design techniques for using less salt in winter conditions Section 11-020 (13)
4. Medians can function as adequate snow storage as part of a snow storage plan

The City also incorporated other Low Salt Design such as requiring trees planted on the south side or within the parking areas to be deciduous to improve sunlight reaching pavement in the winter, and snow and snowmelt management.

References and Additional Resources

City of New Brighton, 2024. Zoning Code Chapter 11 Parking Standards, Chapter-11---Parking-Standards-PDF.

Fortin, Brad. 4/9/25. City of Crystal, Superintendent of Parks and Facilities. Email correspondence.

Snow Storage

Overview

Snow storage may be the most complicated and least understood area in Low Salt Design.

In cold and snowy Minnesota there is a lack of understanding and guidance on snow storage.

In the literature there is very little guidance on how much space is needed for snow storage and no reference to Minnesota snow storage specifications. Some Minnesota communities require snow storage in their designs but without performance standards (sizing, location criteria, reality check to see if a plow would be capable of pushing snow into the snow storage location, snow storage on a plan sheet could overlap with obstacles like trees and utilities that make stockpiling snow difficult).

We have long designed for rain (i.e., 2-year, 10-year, 100-year) storm events but not for snow, other than to ensure snow melt fits into the rain criteria for rate/volume.

In snow storage design, many criteria come into play and for most we have no research to guide us. This opens up a new era in Minnesota for research that can influence future design standards. All of which could improve winter safety and sustainability. In this section we will lay out criteria that should be considered in snow storage design.

Sample: Minnesota Snow Metrics

Annual Average snowfall (50%)

Ely (77")

Duluth (64")

Minneapolis (40")

Rochester (46")

The range of snowfall at each location varies on a yearly basis.

Duluth (10% 39", 90% 90")

Minneapolis (10% 23", 90% 68")

Most snow in one season

Pigeon River (170")

Problems to be solved

How to design snow storage for winter safety.

How to design snow storage areas that are practical for the maintenance crew to use.

How to design snow storage that does create problems for the infrastructure, plants, soil, and maintenance crews in the summer months.

Design Criteria and Considerations

In 2022, Bolton & Menk began looking at winter weather metrics including snowfall statistics and thaw-to-freeze cycles for each community to help guide design for snow storage. We studied the way plow drivers push the snow to locate optimal snow storage sites, and we delineate the plowsheds to determine snow storage sizing. We started paying attention to the size of plowsheds and the footprint of the snow piles they produced. We recognized that winter use for snow storage damaged the summer use of these same locations. We observed safety problems from meltwater sprawl and obstructed site lines. We began to realize the many criteria that should be considered in snow storage to provide a better four-season outcome.

Our tiny snow storage sizing data set is the start of a much longer investigation/investment needed to improve design.

Sizing

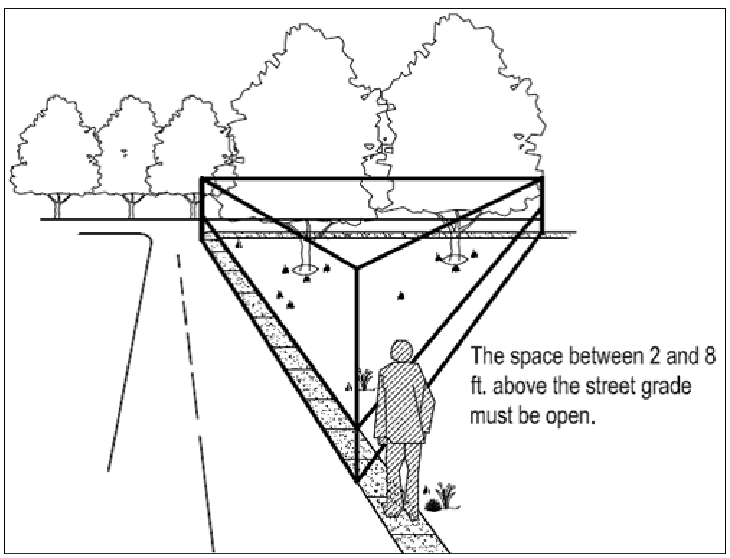
More research is needed to inform snow storage sizing. Bolton & Menk is researching sizing, but the data set is small, 30 observations of the relationship between plowshed, snowfall, and snow pile footprint. This is not enough data to have confidence in snow pile footprint sizing, but it is more data than what was found through a literature search. Additional work will be conducted to better define snow storage needs. The first research funds directed to snow storage sizing will be contributed by the MN stormwater research council in 2025.

Plowshed is the surface area that contributes snow to a snow pile.

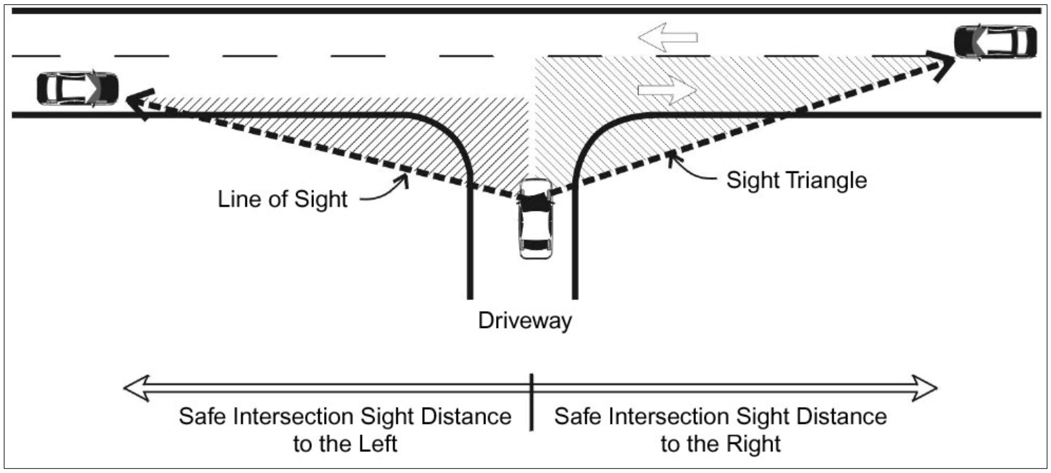
Based on this tiny data set, the snow storage footprint across Minnesota for sites (not corridors) for an average snow winter would range from 10 to 30% of the plowshed, with the population's centers in the Twin Cities & Rochester ranging from 15 – 20 % based on a tiny set of observations. There is no data for lake effect snow areas, but the snow storage footprint is expected to be larger.

Sight Lines

Snow is three dimensional. What looks like a suitable location for snow storage on a plan sheet should be examined for sight lines and clearance. Both pedestrian and vehicular traffic are safer if they can see around the snow pile.



Snowbanks should not obscure site clearance lines. Image source: City of Redmond, WA, Municipal Code, Item 21.52.040.

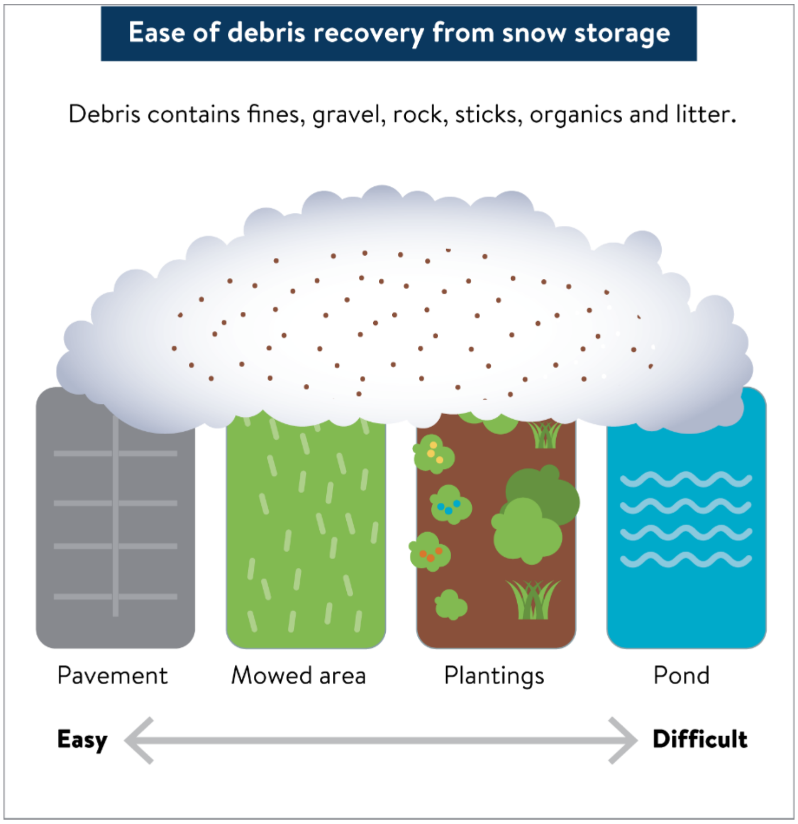


Snow storage can obscure site lines. Image Source: Figure 3.21, MnDOT Access Management Manual, January 2008.


Snow piles restrict sight lines for vehicles and pedestrians. Images courtesy of Bolton & Menk.

Debris Recovery

Snow storage contains debris. The amount of debris will vary depending on the land use. If snow storage is on hard surfaces, it is easy to recover the debris (i.e., sand, cigarettes, bottles, car parts). Debris recovery gets more difficult on grass, even more difficult in plantings, and nearly impossible in ponds. Beware that as the snow pile melts, the light debris will blow off site in the windward direction.



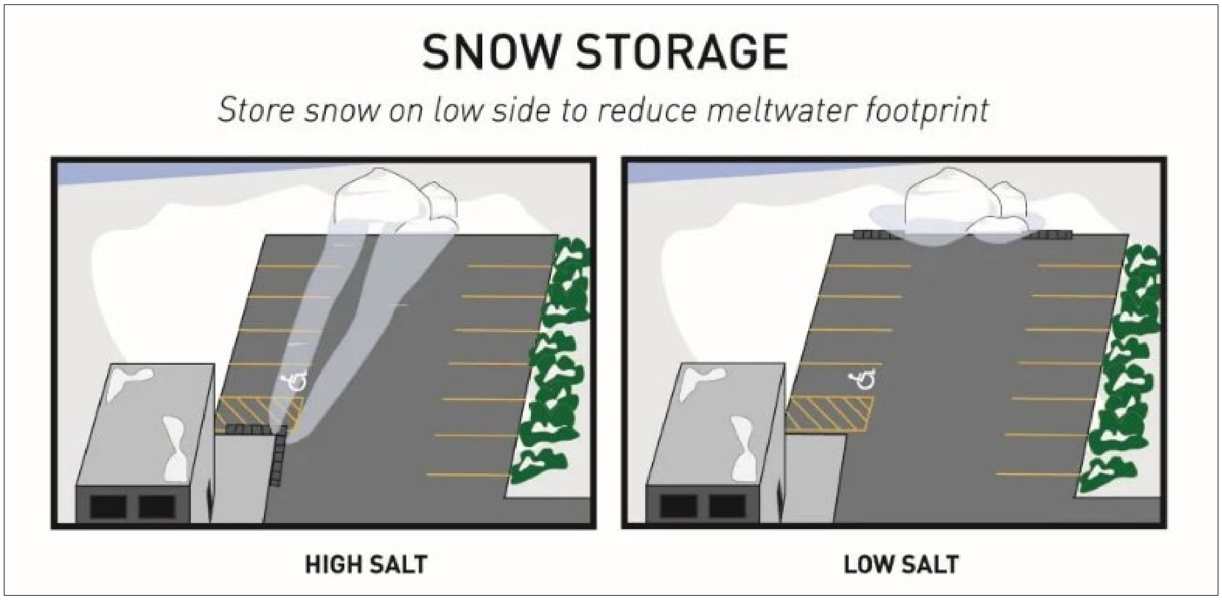
Debris contains fines, gravel, rock, sticks, organics & litter. Image source: MPCA.

For permanent snow dump areas, design perimeter control to direct meltwater and reduce the transport of sediment.

Meltwater Control

This is the #1 consideration in snow storage.

- Most efficient meltwater control happens if snow storage is designed on the low end of the plowshed.
- For snow dumps, ensure meltwater cannot migrate onto saltable surfaces that are in use during winter months. (i.e., U of MN uses state fairgrounds as a snow dump. This section of the fairgrounds pavement is not used in the winter, so meltwater sprawl is of less concern)
- Wherever snow is stored, design the contours so meltwater is contained or directed away from saltable surfaces
    - If this is not possible, intercept the meltwater
        - Curb in vs curb out
        - A strip of permeable pavement on the leading edge of the snow storage area



Store snow on the low side or intercept it before it sprawls. Graphic courtesy of Bolton & Menk.

Salt Tolerance

If snow is stored on vegetation, salt tolerant species are recommended. With the prevention of meltwater sprawl, less salt will be used so less salt will be deposited on the vegetated areas during plowing and eventually a wider range of plants will be able to survive.

Meanwhile to reduce the need for replanting, select from a variety of more salt tolerant species. MnDOT has more salt-tolerant Northern and Southern Boulevard Mixes for turfgrass along urban roadsides and boulevards along with a complete plant selector that allows salt as a selection criteria. https://plantp.dot.state.mn.us/plant/

Practical Access

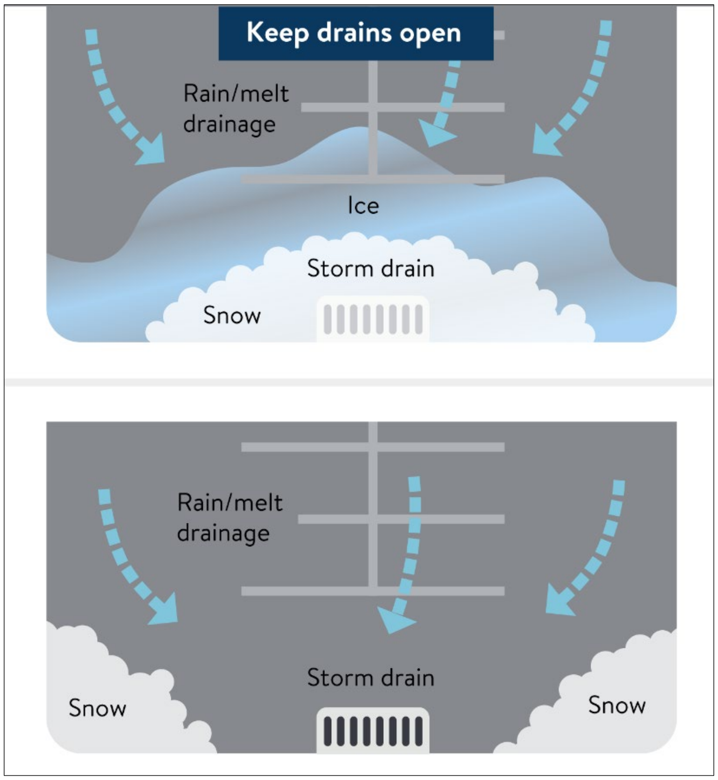
Snow storage should be designed for easy to access by the plows and make sense with their plowing pattern. For sites, if snow storage is not on the pavement, use surmountable curb for easier push onto the storage area. (see ease of plowing section)

Attracts people for play

Large snow piles are magnets for children. When designing snow storage in areas with high density of children (apartments, schools…) consider the attraction to these areas and the risk of mixing children with vehicles, open water, and other hazards.

Does not block drainage

Snow storage should not cover storm drain catch basins or block drainage. Snow storage should be on the low side of saltable surfaces but should not block the conveyance. Consider the early spring rain fighting with residual snow storage in design.



Keep drainage open for meltwater and rain. Image source: MPCA.

Permits/Regulations

Snow storage is not allowed in the waters of the state. Minnesota Rule 7050.0210 regulates discharge of pollutants to waters of the state. This includes lakes, rivers, and wetlands. Snow storage is allowed in rain gardens, holding ponds, and detention basins, but can block infiltration and add sediment and debris to them.

Potential Conflicts

Bioretention parking lot islands- are these being used for snow storage, see if plowing is possible and how it interacts with these designs.
(https://stormwater.pca.state.mn.us/index.php?title=File:Bioretention_parking_lot_island.jpg)

Investigate programs to see what tree density is required (i.e., B3, Tree City, Greensteps cities…). If the density does not allow for adequate snow storage, the tree requirement should be revisited to include more suitable species in snow storage zones. These requirements could also be reviewed in the light of winter shading, blowing snow control where species selection and location are critical.

Research Needed

Snow storage needs

Bolton & Menk is at a starting point designing for the annual average snowfall.

Snow storage sizing influences

- For corridors, as the plow casts the snow in a broader pattern than site plowing
  - Footprint needed for snow storage
    - Speed of plow
    - Angle of blade
- Site
  - Footprint needed for snow storage
    - With plow
    - With loader
- What amount of predicted snow should be used in the calculations? Average annual snowfall? 25%, 75%, largest snowfall on record?
- How do thaw/freeze cycles influence optimal snow pile footprint?

Storing snow in rain gardens or ponds

Research is needed to identify the year-round advantages or disadvantages of storing snow in rain gardens or ponds when considering the salt reduction strategy of meltwater control. In addition, we should study the quantity of debris that gets translocated via snow deposit directly into rain gardens/ponds vs. transport via the storm sewer system. Research could be expanded to include public safety benefits of reducing meltwater sprawl.

1. Meltwater sprawl reduction = salt savings
2. Snow storage in rain gardens/ponds = meltwater sprawl reduction
3. Snow storage in rain gardens/ponds = advantage in tight spaces where there is no proper amount of space for snow storage with meltwater control.
4. Snow storage in rain gardens/ponds = more sediment and debris in them, but how much more?
   a. Maybe only the large items that would not have fit through the storm drain
   b. If rigorous sweeping regime, then more fines would have been pushed into the pond
5. All of the salt we apply ends up in surface or groundwater
6. Does reducing the salt load supply more ecosystem benefits than losses?

Guidance has long been not to store snow in rain gardens or holding ponds. This guidance was meant to decrease maintenance costs of these features. If we can reduce/eliminate meltwater sprawl and re-salting events, this guidance may be adjusted if solids can be captured. Reducing salt load extends the life of infrastructure and costs to the community. The rain garden/pond will also receive less salt. These winter considerations were not included in previous research. More comprehensive research and modelling to better understand the net benefit/penalty of storing snow in rain gardens and ponds is needed.

References and Additional Resources

- Alaska Department of Environmental Conservation, Division of Water. Snow Disposal Site Selection, Preparation and Maintenance. Website last updated 4/30/2024.

Salt Storage

Overview

Salt storage areas are a hot spot for groundwater contamination. The runoff chloride load from the stockpile and loading areas are also a threat to any receiving water. Stormwater ponds, rain gardens and other biofiltration and infiltration basins and other interventions do not remove or treat the salt; the chloride will pass through them. Storage areas are fully under our control and should be designed and managed with care.

Problems to be solved

Salt storage should be designed so that it is not a source or is a very limited source of chloride to ground or surface water.

When granular salt is loaded and unloaded from the plow trucks, salt is spilled. If outside of the salt shed, it becomes a potential source of chloride pollution.

Design Criteria and Considerations

For information on salt storage visit MPCA Smart Salting Refresher Training and look for the refresher training on "Salt and Snow Storage".

- Soil and ground water vulnerability should be considered before building salt storage areas.
- Runoff from improperly stored salt is harmful to receiving waters.
- High salt exposure from salt loading zones and salt spilling from overloaded vehicles occurs at or near salt storage locations. These should not be located near high value lakes, streams, rivers and wetlands.

To control the negative effects of salt storage, basic considerations include:

- Design site for permanent salt storage (e.g., city, DOT, winter maintenance contractor)
    - Locate storage on high spot or protect from meltwater sprawl
        - Snow storage at a lower elevation
- Design site for temporary salt storage (i.e., shopping mall, large parking lots).
    - Locate storage on high spot or protect from meltwater sprawl
        - Snow storage at a lower elevation
- Design of permanent and temporary salt storage structures.
    - Salt storage areas must be covered
    - Pavement contours inside of salt shed designed to prevent discharge of salty water
    - Pavement contours to prevent water flowing into storage area
    - Protect salt from wind, rain, meltwater
    - Indoor loading reduces chloride pollution
    - Face storage shed away from prevailing winter winds
    - Consider runoff capture, filter, reuse in brine making
    - Impermeable floor

Evaluate potential storage locations

Storage site selection should include an evaluation of groundwater susceptibility, location of drinking water sources, and proximity to surface waters. There are several sources of data that can be used to evaluate the site.

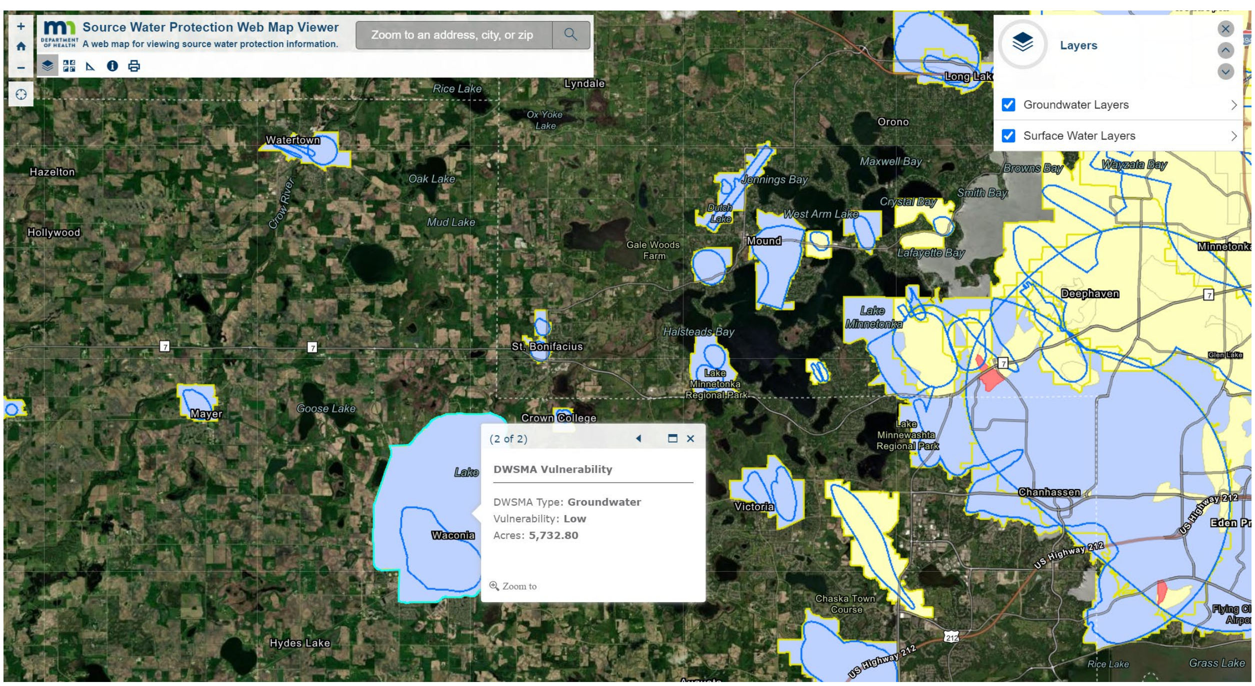
Wellhead protection areas

Wellhead Protection Areas (WHPAs) are areas surrounding public water supply wells that contribute groundwater to the well. In these areas, contamination on the land surface or in water can affect the drinking water supply. Ideally, salt storage should be located outside of WHPAs to reduce the risk of salt contamination to the public water supply. Contact the Minnesota Department of Health (MDH) to determine the location of the wellhead protection area.

Drinking Water Supply Management Area

Drinking Water Supply Management Areas (DWSMAs) are designated by the MDH as geographic areas vulnerable to contamination that could affect the public water supply well. DWSMA boundaries include WHPAs and are defined by identifiable physical features, landmarks, and boundaries including highways, property lines, and landmarks. Potential sources of contamination within a DWSMA can include surface runoff from surrounding land uses and accidental spills that contaminate the surface and ground waters in the designated area. The MDH assesses the vulnerability of DWSMAs to contamination, determining how likely it is that a contaminant could reach the public water supply. Evaluate potential locations for salt storage to avoid placement in these areas.

Use MDH's [Source Water Protection Web Map Viewer] to determine boundaries of DWSMAs. This interactive map shows the location of DWSMAs in Minnesota and the level of vulnerability for contamination to the water source in that area. Search for a specific address or zoom into a general area. Click onto the site on the map to see details of the DWSMA and vulnerability.



Minnesota Source Water Protection Web Map Viewer. Image courtesy of Minnesota Department of Health.

Soils

- Site selection for salt storage informed by (soils/groundwater vulnerability) to minimize ground water contamination.
    - Part B groundwater atlas
        - Groundwater is most sensitive to salt pollution in places where aquifers are near the land surface or not covered by thick aquitards. Aquitards or confining layers are composed of fine-grained materials, such as clay, that slow the flow of water and any associated pollutants from reaching the underlying groundwater.
        - In these maps, the uppermost aquifers are called the "near-surface materials," and aquifers rated with a high sensitivity to pollution are shown in an orange or red color.
    - Surficial geology map (Plate 3)
        - If the DNR pollution sensitivity map is not available, use the surficial geology map to get an idea of where the surficial groundwater would be most sensitive to pollution. The most vulnerable areas are "sand" or "sand to gravelly sand."

Permits/Regulations

MS4 General Permit salt storage requirements

MPCA Liquid salt storage guidance and regulations

Potential Conflicts

Site selection is based on either property available, or to optimize salt delivery and speed up operations. This may conflict with sustainability aspects.

References and Additional Resources

MPCA. MS4 fact sheet- Winter Roads Materials Management.

Minnesota Department of Health. Accessed April 2025. Source Water Protection web pages.

Minnesota Department of Health. Accessed April 2025. Source Water Protection Web Map Viewer.

Minnesota Department of Natural Resources. Accessed April 2025. County Geologic Atlas (CGA) Series.

Pavement Reduction

Overview

Regarding improved winter safety and chloride pollution reduction: the less surface area to maintain, the less salt needed. Consider pavement reduction possibilities in design. This is not new to stormwater management considerations and has been discussed in Low Impact Design for many years.

Problem to be solved

All pavements used in the winter are likely to be salted. Less pavement should translate into less salt.

Benefits and Limitations

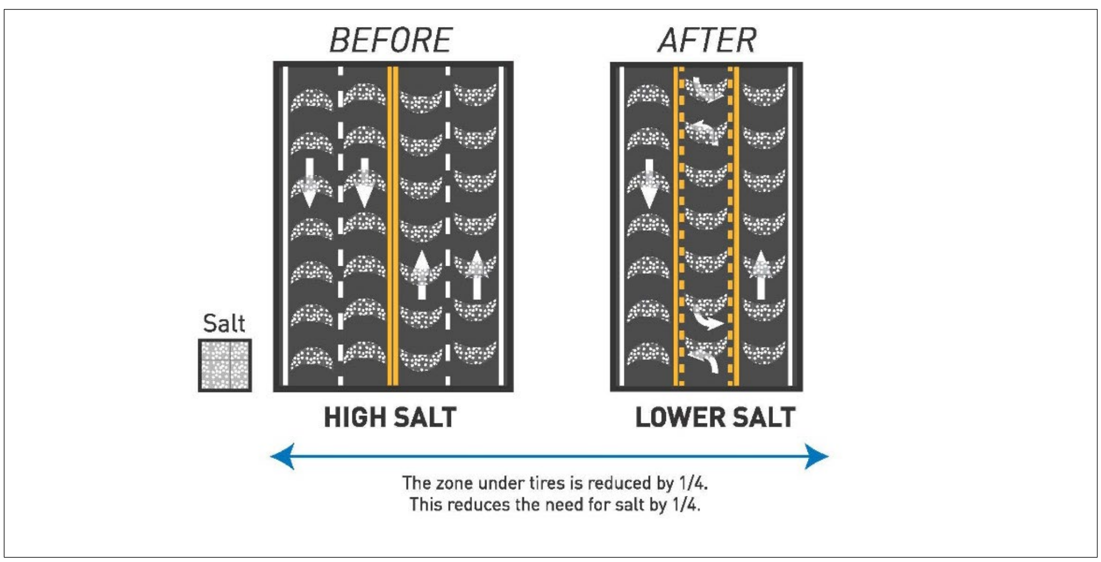
With less pavement, less runoff will be generated. Salt reductions will be dependent on how the perimeter space is redesignated. If a removed road lane transitions to a sidewalk or bike lane, salt reduction will likely not be achieved. If the perimeter space is allocated for snow storage or green space, a large salt savings is likely.

Design Criteria and Considerations

Pavement reduction can be part of an initial plan or retrofit.

For example, Road Diets may be implemented for a number of reason including a low salt design strategy.

Road diets have been encouraged for many reasons (MnDOT, March 2025). As a chloride reduction strategy, there is less tire contact area, so less salt is needed on three lanes versus four lanes. This should offer an approximate 25% salt reduction unless the repurposed lane becomes a different type of saltalbe surface (i.e. sidewalk).



Road diet: reducing a lane needed for salting by ¼, reduces the salt use by ¼. Graphic courtesy of Bolton & Menk.

References and Additional Resources

MPCA. Accessed March 2025. MS4 Fact Sheet – Reducing Impervious Surfaces. Minnesota Stormwater Manual.

Minnesota Department of Transportation, Accessed March 2025. Four to Three-Lane Conversion/Road Diet Summary.

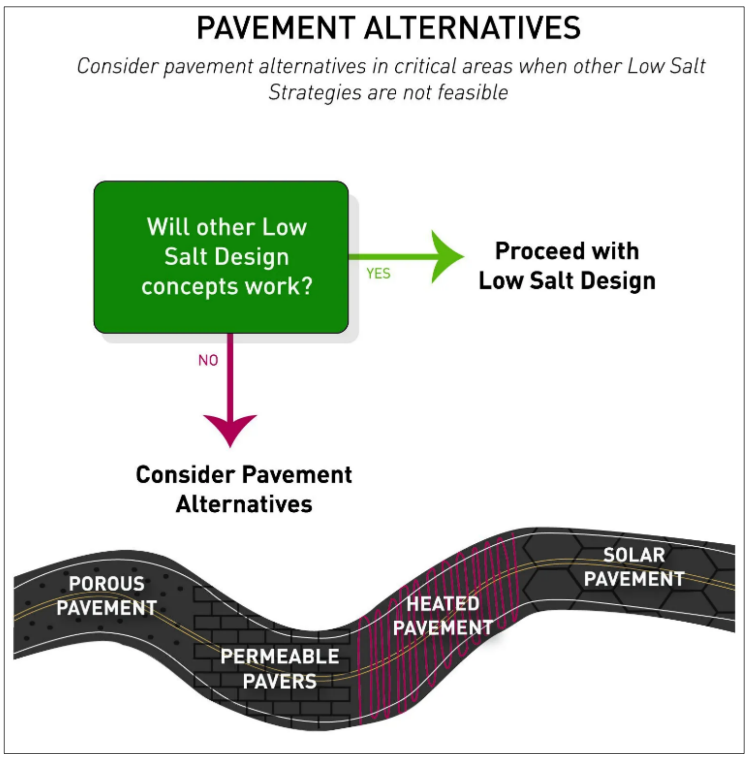
Pavement Alternatives

Overview

Traditional pavement selections such as concrete and asphalt work well for the majority of our surfaces. However, these may not be the safest or most cost-effective option considering winter challenges.

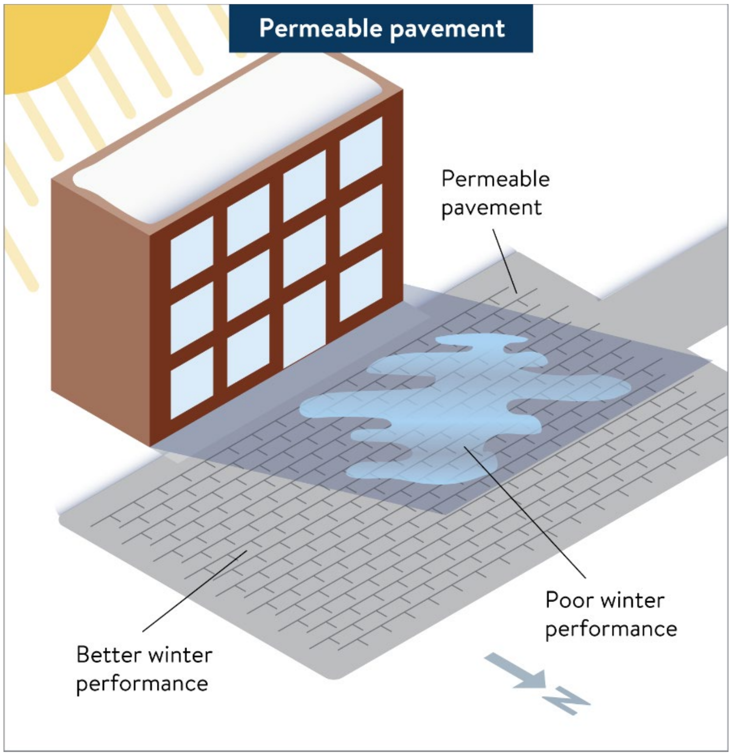
Problem to be solved

In Low Salt Design, as we become aware of the sun, the wind, the meltwater sprawl and how these intersect with critical areas (braking zones, front steps, emergency vehicle entrances, etc.) we better see where our designs shine or fall short. With many competing factors in design, we may discover a future winter performance problem in a critical area. That is the perfect time to consider alternative pavements.



Overcome winter hazard areas in your design by considering alternative pavements. Graphic courtesy of Bolton & Menk.

In areas where we are already specifying alternative pavements to solve other design problems (i.e., permeable pavers to increase stormwater infiltration) such as rainwater management, a look at where they are located and how those locations might be optimized to include a winter benefit. Permeable surfaces located in the sun provide year-round benefits. Permeable surfaces in the shade will have much more limited winter benefits.



Permeable pavement provides more winter benefit if placed in the sun. Image source: MPCA.

Benefits and Limitations

Permeable Surfaces

Permeable surfaces can increase their usefulness in the winter if placed in the sun. In this image, the permeable pavers on the left are in the sun and perform well in winter. Pavers on the right are in the shade and have reduced winter performance.

Permeable pavers placed in the sun provide winter benefit in addition to summer benefit. Permeable pavers in the shade show reduced winter benefit. Image courtesy of Google Earth.

Heated Surfaces

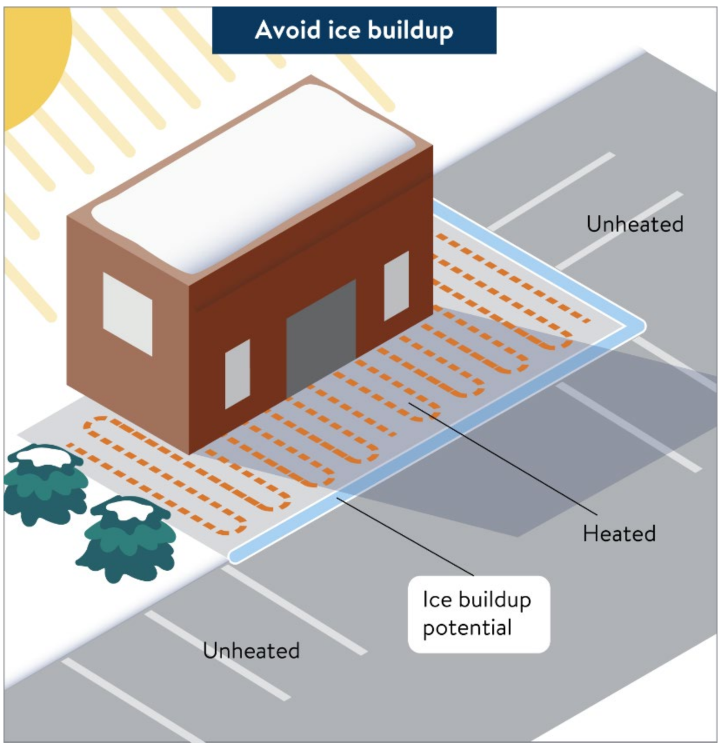
Heated pavements can drive up energy use. Yet heated pavements can drive up safety, reduce the need for salt use, and reduce salt tracking into buildings. They may be a consideration for critical areas such as main entrances of buildings.

Small scale research has been conducted on the use of heated surfaces such as conductive concrete and solar panels for road and sidewalk surfaces.

Design Criteria and Considerations

Optimize four-season use of permeable surfaces by installing them in sunny areas.

For heated pavements, pay attention to the heated/unheated interface when it occurs on saltable surfaces. Design a route for meltwater to flow to avoid creating an ice dam at the interface



Design interface of heated and unheated pavement to avoid ice build-up. Image source: MPCA.

Maintenance crews should be informed not to use deicers on heated pavement which may be damaged by the salts.

Maintenance crews should be informed not to use abrasives on permeable surfaces to reduce clogging.

Retrofit Suitability

Small-scale retrofits of existing surfaces such as high use building entrances, loading ramps, underground parking ramps, or first responder exits/entrances with heated pavement would improve safety and may provide a good return on investment, especially on the north side of a building and in the low spots.

Consider the shortened life of infrastructure that experience high salt use, the indoor tracking of salt, and the maintenance worry of these winter safety problems.

Potential Conflicts

Heated pavements can create higher energy use. Whenever possible consider using waste heat for heated pavements. Heated pavements can drive up safety, reduce salt tracking into buildings and drive down the need for salt.

Newer technologies in heated pavements have had less use, less testing, and many unknowns compared to traditional asphalt and concrete. The installation and testing of heated pavements would help to increase familiarity, better understand potential solutions, and to continue to push forward to a better winter solution.

Permeable surfaces designed for summer stormwater management do not consider sun exposure; they are places for optimal efficiency. By relocating permeable surfaces to areas in the winter sun, the design for precipitation/stormwater management may become more complicated. Four-season considerations for the installation of permeable surfaces should become standard practice. Permeable surfaces may be used for summer stormwater management and/or for meltwater management and might not offer a four-season benefit.

Case Studies

- Reuse of heat for heated streets
  City of Holland Michigan, reuse of waste heat for heated pavements.
  https://www.cityofholland.com/879/Snowmelt-System
- Solar panels as pavers for roadway/sidewalks
  https://solarroadways.com/
- Self-heating electrically conductive concrete
  https://prosper.intrans.iastate.edu/research/completed/self-heating-electrically-conductive-concrete-demonstration-project/
- Conductive Asphalt
  https://www.asme.org/topics-resources/content/conductive-asphalt-deices-itself

Research Needed

What winter performance boost is expected if permeable surfaces are in the sun versus shade? This should be measured by how many hours in the winter they are slippery (measure the hours of slipperiness in both the sun and shade sections. Do not allow salt on either section during the study. Do not allow cars to park on these surfaces or drive over them as both parking and driving distribute salt and change the slippery factor we are trying to measure). Slippery surfaces drive the need for salt.

References and Additional Resources

Minnesota Department of Transportation, Accessed March 2025. Four to Three-Lane Conversion/Road Diet Summary.

Vegetation

Overview

Vegetation plays a significant role in Low Salt Design. It provides more than habitat or aesthetics. It is truly a force of nature that changes blowing snow characteristics and alters the speed of pavement recovery due to the shade it casts. Vegetation must be thoughtfully selected and placed to make room for winter storage and must be more salt-tolerant to survive the heavy salt load it often receives. If properly designed and installed, vegetation can be used as a snow fence to improve pavement recovery.

Problem to be solved

Shade caused by vegetation, especially trees, extends the time it takes for snow and ice to melt and decreases winter safety on roads and walkable surfaces such as parking lots and sidewalks.

Improperly placed vegetation can function as an unintentional snow fence, directing blowing snow onto paved surfaces that require winter maintenance.

Vegetation may conflict with the area needed for snow storage, resulting in more snow stored on or melting across paved surfaces.

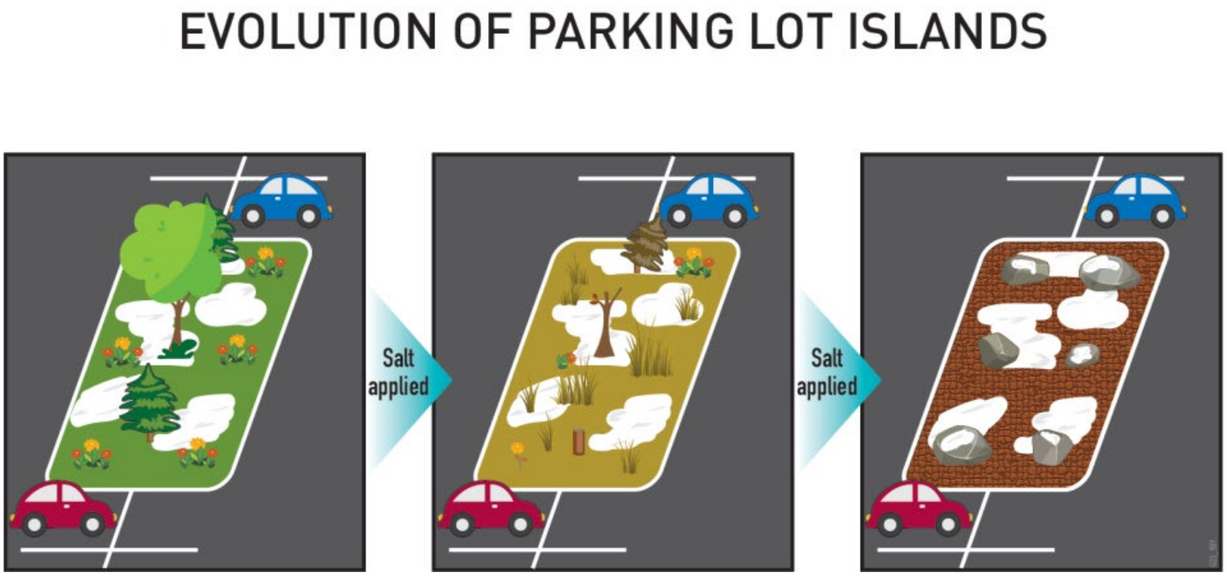
Vegetation is injured, dies or cannot reproduce due to salt loading.

Benefits and Limitations

The designer should take salt loading into consideration and select species accordingly. For environmental benefits, native plants, those that attract pollinators, and higher plant diversity are recommended in landscape plans, but these as well as some desired non-native plants may or may not work in an area used for salt storage or an area that receives salt spray or salty runoff. Consider the plant salt tolerance when designing the site or right of way. This will limit species selection and diversity. There are two options to manage vegetation.

- Option 1: Change vegetation to survive the high salt demands of a site
- Option 2: Change site design to perform better in winter and require less salt. More species will survive in this environment, but they may not be placed in the same locations we are planting them in current designs.

Parking lot islands are one of the most difficult areas to establish plants, and it may be argued that plants on the perimeter versus in islands offer more beauty and ecosystem benefits 5+ years after construction when many parking lot islands have dead or dying trees and weeds instead of the selected plants.



The length of time between phases (blue arrows) expands as we design parking lots for easy plowing and manage meltwater sprawl from raised islands. Graphic courtesy of Bolton & Menk.

Design Criteria and Consideration

Shade

Shaded winter surfaces are slow to recover, less safe, and need more salt (see use the sun section). Placement and species selection of vegetation can increase or decrease hours of sunlight on winter pavements and affect safety and how quickly the pavement will recover.

- Conifers offer four season shade
- Deciduous trees offer three season shade

Snow Storage

Snow storage areas are often planted with vegetation designed for spring, summer and fall, and not considered for winter snow storage. Trees and shrubs conflict with snow storage and are often damaged by the plow or the snow push, or use space needed for snow storage. Consider vegetation that can be covered with heavy snow that leaves space for snow storage, and that can withstand the salt and debris (see snow storage section).

Snow Fences

Snow fences (intentional or unintentional) can be comprised of plants. The selection and placement of these plants can help or hinder blowing and drifting snow (see outsmart the wind section).

Salt Tolerance

Salt tolerant species are advised for spaces adjacent to critical winter safety areas (ramps, front steps, high volume sidewalks, etc.). Wherever there is high salt use, the plants will suffer, and although our goal is to reduce the need for salt, salt tolerant plants are still a smart option for Minnesota, a huge importer of rock salt and deicers.

Design Tools

For a list of salt tolerant plants:

MnDOT plant selector- Allows salt as a criteria
https://www.dot.state.mn.us/roadsides/plantselector/index.html

MPCA stormwater manual plant selector - Allows salt as a criteria
https://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists

Research Needs

1. Understand the average meltwater footprint (surface area not depth) of traditional infrastructure design
    a. This will help establish future performance criteria for low salt design
    b. Research should include understanding meltwater footprint in critical areas vs standard areas
    c. Research should separate site and corridor design
2. Gather insight into snow storage sizing
    a. Should it be based on average snow year
    b. How do thaw/freeze cycles affect snow storage sizing
    c. Relate plow shed to snow storage sizing
    d. Understand speed of plow, cast of snow and its impact on snow storage sizing
    e. This will build towards performance standards in design with “right sized” snow storage
3. Itemize the conflicts in current stormwater manual guidance with the new guidance in Low Salt Design.
    a. For example, don’t push snow into rain garden
    b. For example, don’t push snow into stormwater pond

Additional Low Salt Design Resources

Low Salt Design Podcasts

- Episode 72: Designing in salt reduction. AASHTO. https://sicop.transportation.org/episode-72-designing-in-salt-reduction/
- Episode 3: Innovating Winter Maintenance: Reducing Salt Use and Protecting the Environment with Connie Fortin. The Public Works Nerds. https://www.buzzsprout.com/2197993/12998912-innovating-winter-maintenance-reducing-salt-use-and-protecting-the-environment-with-connie-fortin
- Episode 6: Designing for a Low-Salt Future with Connie Fortin. River of Ideas. Mississippi Watershed Management Organization.
  - Video: https://www.youtube.com/watch?v=OHsYCMN2qlw
  - Audio: https://riverofideas.buzzsprout.com/2340313/15651039-designing-for-a-low-salt-future-with-connie-fortin-river-of-ideas-episode-06

Low Salt Design Articles

- Low Salt Design. ASCE Journal of Cold Regions engineering. Journal of Cold Regions Engineering | ASCE Library
- Designing to Achieve a Lower Salt future. Environmental Connection. IECA. https://associationpublications.com/flipbook/ieca/2024/Quarter1/14/index.html
- Site Design: Rethinking infrastructure performance to reduce salt use. Snow Business Magazine. SIMA. https://www.sima.snowbusinessmagazine.com/snowbusiness/september_2023/MobilePagedReplica.action?pm=2&folio=44#pg51
- On the Road to Less Salt Use in Minnesota Cities. Minnesota Cities Magazine. League of Minnesota Cities. https://www.lmc.org/news-publications/magazine/mar-apr-2023/less-road-salt/
- Designing a Low Salt Future. Roads & Bridges. https://www.roadsbridges.com/winter-maintenance/article/33009904/designing-a-low-salt-future
- Designing a Lower Salt Future. Stormwater Solutions. https://www.stormwater.com/home/article/33043034/designing-a-lower-salt-future
- How Rethinking Design Could Reduce the Need for Salt. MPR News. https://www.mprnews.org/story/2024/01/31/how-rethinking-design-could-reduce-the-need-for-road-salt

Low Salt Design Videos

- Bolton & Menk – Low Salt Design, Corridor Consideration (youtube.com)

Low Salt Design Guide

- https://www.bolton-menk.com/real-solutions/low-salt-solutions/