# ROAD SALT

## Possible Alternatives to Road Salt as a De-Icing Agent at the University of Utah

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# INTRODUCTION & BACKGROUND

Deicing agents are necessary to ensure safe conditions on the University of Utah campus during snowy winter months. However, current research suggests that road salt, the deicer widely applied by the U, has severe ecosystem impacts. This project aims to assess road salt's current application and environmental impact on campus. We aim to achieve the following objectives:

## KEY OBJECTIVES

1. Improve the campus' understanding of its deicing program to assess the potential for implementing non-salt alternatives.
2. Review previous research on road salts' environmental impacts to assess potential issues on the U's campus and provide a better understanding to campus staff and policymakers about the impacts of road salt.
3. Identify potential alternatives and understand the associated impacts to provide a better understanding to campus staff about what alternatives to road salt exist.
4. Create an organizational chart so that separate depts with significant overlap can better understand deicer practices, policies, etc. This will help improve understanding of the campus facilities hierarchy.
5. Improve understanding of the challenges within current practices.
6. Create an experimental design to establish a baseline of current environmental conditions and assess an alternative solution if implemented.

# LITERATURE REVIEW

Roads are de-iced by melting snow using salt. It works by decreasing the vapor pressure of the solvent (snow) and reducing the freezing point. The effectiveness of road salt, as well as its relative affordability, means that as much as four million tonnes may be applied annually in Canada for deicing (Lembcke et al., 2017), and in the United States, this rate has increased from 1 to 2 million tonnes to 10-20 million tonnes in 2014 (Kelly et al., 2010; Bolen 2014). Road salt, most commonly sodium chloride (NaCL), calcium chloride (CaCl2), or magnesium chloride (MgCl2), is a deicing agent applied to roads during the winter season (Evans and Frick, 2001; Hintz et al., 2021). It was first used as a deicing agent on roads in New Hampshire in 1938; by the early 1940s, more than 5,000 tons of road salt was applied to roads and highways annually (Road Salt: Moving Toward the Solution). More recently, an estimated 20 million metric tons of road salt are applied across the United States annually, with exceptionally high concentrations in snow-dominated states. Despite reducing winter traffic accidents by 78 - 87% (Kuemmel and Hanbali, 1992), studies since the 1970s have shown road salt use's adverse economic, health, and environmental impacts (Hintz et al., 2021). Here, we examine the effects of road salt application on sensitive ecosystems and recommend alternative practices.

Urban streams and water tables are critical elements of a balanced and resilient ecosystem. Ecosystem services provided by urban streams and water tables include nutrient recycling, stormwater management, contamination reduction, increased biodiversity levels, and many other benefits (Coles et al., 2012). However, with increasing levels of urbanization and continued use of deicing agents (amongst other pollutants), urban water bodies and their ecosystem services are negatively impacted. Road salt can significantly alter the health of these water bodies and organisms that rely upon them for habitat.

Chloride concentrations from road salt vary with the seasons, but winter typically sees higher concentrations and then tapers off in the summer (Novotny et al., 2007). However, this is beginning to change as higher chloride concentrations are observed even during summer (Kincaid et al., 2009). This increased chloride retention in streams year-round is quite concerning (Findlay et al., 2011). This trend has driven certain legislative bodies, such as the Minnesota Legislature, to set acute and chronic standards for chloride pollution. According to Minnesota chapters 7050 and 7052, "The chronic chloride pollution standard has been set at 230 mg/L and the acute standard at 860 mg/L". Levels above "230 mg/L are deemed harmful to aquatic life, and concentrations above the acute standard being lethal and sub-lethal to aquatic plants and invertebrates."

Chloride concentrations impact salinity levels which in turn have massive impacts on water quality and aquatic life. We can view and forecast the impacts of salinity on organisms by using key indicator species such as macroinvertebrates. Macroinvertebrates help indicate water quality as some species are resilient to pollution/rapid change while others are inept to these elements (Lenat, 1988). Common macroinvertebrates tracked for these studies include worms, stonefly nymphs, mayfly nymphs, caddisfly larvae, leeches, blackfly larvae, midges, and many others.

One can create a quick snapshot of environmental conditions by using macroinvertebrates to help analyze water quality and health. Should any sensitive macroinvertebrate species be found in the water samples, we can determine that there is a healthy and functioning ecosystem. However, should only hardy macroinvertebrates be observed, we can infer that water quality is poor. The impacts of salinity touch even the smallest of organisms. Observing the impact on smaller organisms scaling up and observing the impacts on larger species typically results in similar findings. This is why macroinvertebrate studies can be so crucial in understanding ecosystem health.

In addition to negatively impacting water quality, road salt application affects soil and vegetation health. Predictably, road salt increases the salinity level of soils (Fay and Shi, 2012), which disrupts the osmotic diffusion, ionic toxicity, and nutrient uptake of vegetation (Munns and Tester, 2008). Road salt has also significantly impacted soil nitrogen cycling (Green et al., 2012), impacting plant growth as nitrogen is a limiting nutrient. Additionally, road salt decreases the water permeability of the soil, raises the pH, and promotes poor aeration, producing unfavorable growing conditions for plants (Fay and Shi, 2012). As a result of salty soils, plants may experience reduced growth rates, needle and leaf scorch, desiccation, nutrient imbalances, and high stress, which overall increases plant mortality (Green et a., 2012).

Given the well-documented impacts of road salt on soil and vegetation health, it is essential to monitor high-risk ecosystems (i.e., regions with significant snowfall and road salt use) and continue to improve our understanding of road salt use with additional data sets. We recommend collecting soil samples from the University of Utah campus and analyzing health indicators. Additional research will focus on identifying fundamental analyses, which will be discussed later in this document. This study is recommended to span multiple seasons, primarily if alternative solutions are pursued.

Alternatives to road salt have been assumed to be less harmful to infrastructure and vegetation (Lembcke et al., 2017). These alternatives can include the use and application of other snow-melting agents (e.g., Szklarek et al., 2022), the use of more efficient mechanical methods (e.g., Guan et al., 2003), and thermal snow-melting techniques along with pavements' chemical modifications (ASHRAE, 1985). Even though each method has its advantages and disadvantages, we intend to examine each method in light of economic factors and environmental mitigation in the spirit of Table 1. Our main objective is to offer at least one recommendation for alternative practices that can be successfully applied at the University of Utah.

# EXISTING CONDITIONS

According to John Walker, the department supervisor of Landscape Facilities at the University of Utah, there is an understanding among landscape maintenance employees that salt application can cause damage to campus landscaping. Challenges can arise not only when facilities workers apply salt themselves but also from salt being pushed in from the parking lots onto park strips while parking lots are plowed. However, as this section will address, there are significant obstacles to simply switching off the application of deicing salts. First and foremost, the University of Utah has ADA obligations that it must meet concerning snow removal, particularly on key walking paths and at the entrances of buildings, meaning that not removing the snow and waiting for it to melt is simply not an option. There is also a risk that ice presents to people walking, around the medical campus, with slip and fall claims against the university resulting in between $150,000 and $175,000 in damages, based on purchase records from 2022 and 2023. Thus there is physical and financial danger of spotty snow removal for people on campus and the university.

The material costs of salt for facilities alone can be quite steep, especially with the historic snowfall that has taken place in the winter of 2022-23. John Walker estimates that by the end of this snowfall season, the campus facilities will have used 9,000 bags of salt, which equates to 450,000 pounds of salt and at the cost of nearly $50,000. However, even in less historic snowfall seasons, Walker estimates that facilities use 5,000 and 6,000 bags, equivalent to 250,000 and 300,000 pounds of salt. These numbers account for facilities' salt usage and exclude what is likely hundreds of thousands of pounds more salt used by the streets division. Todd Ryan of Road Maintenance estimated his department had used over 1000 tonnes of Road Salt this winter and projected an additional 200-400 tonnes would be needed by the end of the winter season. Yet, as the section will explore further, it is worth considering how these costs would stack up against any proposed alternative requiring switching to new equipment, training employees on its use, and the cost of the material itself.

Sue Pope, in Landscape Planning, provided insights into the limitations of some alternatives to road salt. According to Pope, sidewalk sand was initially used on walkways, and a mix of sand and salt on roads for traction. However, it could have been more effective at melting ice quickly and caused issues for custodial staff (i.e., scratching wooden floors and generally harder to clean up). Sand also accumulated and caused other issues, such as clogging sprinkler heads and dulling mower blades.

According to Pope, de-icing materials were later used to melt ice and prevent refreezing quickly. Liquid brine was tried but had downsides, such as needing appropriate timing and equipment changes and needing to be more costly to convert and store equipment. On the upside, de-icing material showed minimal damage to concrete and plants if applied accurately and removed quickly. However, Pope says balancing environmental impacts with safety concerns is essential, making liquid brine a less attractive alternative.

Straight road salt and Redmond products are used for melting ice on roadways and parking lots, which aligns with information collected from Todd Ryan in Road Maintenance. According to Pope and the official product website, Redmond, which may have a clay component to activate it, melts ice three and a half times faster and can prevent ice from reforming down to 0° F. As safety concerns for people traveling on campus are the main priority, it is seen as the best de-icing option available to the campus to mitigate those concerns. However, salt ends up in storm drains and piles around trees and landscapes, persisting in areas with water restrictions, which has damaging environmental effects that the university is supposed to lessen.

Moreover, according to Environment & Health Safety Department employees Michael Brehm and Tyler Fresdall, the University of Utah's permit addresses stormwater quality and volume for the entire campus, with one-third to one-half of the water draining to Red Butte and the rest to Salt Lake City, both of which flow into the Jordan River. The state and federal governments have established water quality standards for the Jordan River and require permittees to protect it. Since roughly 30% of the campus is impervious, road salt application is well-structured, with the number of trucks, timing, and salt purchases being meticulously tracked. According to Brehm, there is a scientific approach to snow removal, with efforts to minimize costs and impact.

However, a large part of this effort falls on other departments, emphasizing the coordination that needs to take place. Todd Ryan, in Roads Maintenance, manages salt truck purchasing, storing, filling, and distribution. Brehm has some theories about changing the protocol of salt distribution to prevent accidental piles, whose effects could be measured by a future class, as well as measuring what comes out of uncovered cache piles for buildings in Research Park (e.g., dentistry building).

From the interviews conducted for the road salt project, there appears to be a degree of isolation among individuals in departments that would otherwise logically have significant crossover. For instance, individuals in the Environmental Health & Safety, the department responsible for ensuring the campus adheres to environmental quality regulations, needed to gain more knowledge of the responsibilities, policies, or decision-makers in the Grounds or Road Maintenance departments. This observation reinforces the concept discussed earlier this semester: a lack of interdepartmental collaboration can lead to miscommunication, mismatched policies, or harmful practices, which, overall, can inhibit the successful implementation of forward-thinking initiatives. As a practical example, this was evident when the Road Maintenance department staff needed to be made aware of the type of salt used by the Grounds department to clear sidewalks on campus. The Environmental Health & Safety department was contacted to provide information on this, but their response directed us back to the Road Maintenance department.

While questions remain about the viability of alternatives to using salt for deicing, campus facilities have taken some steps to at least reduce the quantity of salt currently being used. Firstly, they recently switched from broadcast spreaders to brush spreaders, allowing them to deliberately and concentratedly apply salt. Secondly, they have started to close portions of stairwells to avoid having to deice an entire stairwell. Finally, they have also tried to better coordinate with the custodial staff of buildings (as they often handle deicing building entrances) to ensure less salt is used where possible. These measures offer another tool for combatting the ill effects of salt usage on campus: using less salt.

# OPPORTUNITIES & RECOMMENDATIONS

## 1. Better Coordination Between Departments

As noted in our existing conditions analysis, there needs to be more coordination between departments. This can sometimes present challenges to providing any comprehensive overhaul of campus policy regarding deicing; for example, road maintenance and the campus grounds crew must be made aware of what each is doing regarding deicing campus. Better coordination between them may open up opportunities for departments to collaborate and, at the very least, use less salt overall for deicing. In addition, if in the future there is a significant change in policy regarding deicing on campus, be it timing, locations where it is carried out, or the materials and equipment used, it will be necessary for it to be implemented across departments for it to be effective.

One challenge with this recommendation is determining what the actual mechanics of better coordination will look like. Heads of respective departments are already busy, particularly during the winter, so simply asking them to take more time to work with each other may not be feasible. Bringing on a new employee for coordination is another possibility, but this is subject to budget considerations and opens up the possibility for self-defeating bureaucratic entanglements.

## 2. Obtain a Better Picture of the Impacts of Deicing Salts

Our literature review shows extensive research on the impacts of deicing salts on water and soil quality. Still, it would be essential to establish better the impacts in the specific University of Utah campus environment. This will enable policymakers at the university to determine their next course of action better and potentially provide more substantial justification for changing the methods of deicing campus. The next section of this report will outline a more specific experimental proposal for testing the impacts of deicing salts on campus.

## 3. Deicing Alternatives Pilot Program

Given the sheer scale of the campus and its deicing program, a total shift to a different deicing method will require a significant investment of time and financial resources. Convincing the campus policymakers to approve such a shift will be easier with better context-specific data. The study above will help fill this gap, but a pilot program testing other deicing methods would be another way to better understand the challenges and opportunities of different deicing methods. A particular section of campus could be chosen where alternative methods, such as beet juice, could be applied instead of traditional deicing salts. This would provide an opportunity to not only test the real-world efficacy of different deicing methods but it would also serve as a chance to understand better the logistical challenges for campus maintenance crews to switch over to and apply different deicing methods. This program would likely be eligible to apply for a Sustainable Campus Initiative Fund (SCIF) grant.

Of course, before carrying out such a program, it would be essential to understand what has been tried before in this regard. As noted in the existing conditions section, some alternatives (liquid brine and sand) have already been tried on campus and have run into significant hurdles.

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## 4. Identify Areas on Campus Where Salt Usage can be Reduced

As mentioned in the previous section, campus facilities have already taken steps to reduce their salt usage, including updating their equipment and closing off select stairwells during the snow season. One possible alternative is to continue exploring ways to reduce the quantity of deicing salt used on campus. Facilities have already identified stairwells that can be closed during the snow season, and the possibility may exist for closing other areas of campus as well or designating them as areas where shovels or plows will only remove snow. This would require an extensive analysis of existing snow routes (routes that facilities prioritize keeping clear) and an understanding where ADA requirements must be met. GIS analysis of some kind may be used in this regard.

## 5. Case Studies of Dicing Programs at Similar Universities

While this report has covered in-depth the status of the University of Utah's campus deicing program, the U is far from the only campus located in an environment that receives much snow in the winter, nor is it the only one that serves significant other purposes besides education and research (the hospital system). There are likely many opportunities to conduct case studies of other universities and learn how they have approached deicing and to what extent they have dabbled with alternatives to traditional deicing methods. This could be a project that students in a future campus as a living lab workshops take on in conjunction with some of the aforementioned opportunities and recommendations

# PROPOSED ALTERNATIVE SOLUTIONS

| TECHNIQUE TYPE | SALT NAME | CHEMICAL FORMULA | ADVANTAGES | DISADVANTAGES | PRICE (50 LB) | TESTED BY U | BRAND |
|---|---|---|---|---|---|---|---|
| Shoveling, Snowplowing | | | - Clear snow from storefronts<br>- Inexpensive<br>- Exercise<br>- Perfect for light snowfall | - Quick snow removal (no need to wait for ice melting)<br>- Not practical for large areas<br>- Machines can be costly<br>- Frequent maintenance | $50 | X | |
| Chlorides | Sodium Chloride | NaCl | - Cheapest salt<br>- Non-toxic (when applied) | - Corrosion of vehicles and infrastructure<br>- Damage and staining to the interior and exterior of buildings<br>- Impacts on roadside vegetation, soils, and freshwater<br>- Decreases its effectiveness under very low T (15 F) | $12-60 (solid) | X | Snow Plo |
| | Calcium Choride | CaCl2 | - Effective under low temperatures -20F<br>- Less harmful to infrastructure than salt<br>- Faster than other salts | - Possible irritation to the skin/eyes and toxic if inhaled<br>- Dangerous to pets<br>- Increase moisture of roads<br>- Corrosive for infrastructure and vegetation<br>- Once incorporated into water, it isn't easy to re-establish Cl- water levels | $17-30 | | Safe Step |
| | Magnesium Chloride | MgCl2 | - Effective under low temperatures -10F | - It needs to be reapplied frequently<br>- Mild temperatures (0F)<br>- Reduce soil fertility due to metal remobilization | $35-78 | | Safe step, Skilcraft |

| TECHNIQUE TYPE | SALT NAME | CHEMICAL FORMULA | ADVANTAGES | DISADVANTAGES | PRICE (50 LB) | TESTED BY U | BRAND |
|---|---|---|---|---|---|---|---|
| | Potassium Chloride | KCl | - Less toxic compared to ordinary salt.<br>- Safer for pets than salt<br>- Reduce water hardness | - Melts ice slower than other chlorides<br>- Ineffective below 12 F<br>- Commonly mixed with other agents<br>- Reduce soil fertility due to metal remobilization | $20-50 | | Diamond crystal, Xynyth Mountain Organic Natural Ice Melter |
| Acetates | Potassium Acetate | Ch3COOK (solid/ liquid) | - Non-corrosive<br>- Last-longing effect<br>- Biodegradable<br>- Effective under low temperatures -26F<br>- No abrasives are needed | - When solid: negative impact on concrete durability<br>- Reduce water oxygen levels<br>- Highly corrosive due to it's conductivity | $18-87 | | Viper Elite |
| | Calcium Magnesium Acetate | Ca-Mg (CMA) | - Effective under low temperatures 20F | - Possibly skin irritant<br>- Highly corrosive due to its conductivity<br>- Reduce soil fertility due to metal remobilization | $26-72 | | Xynyth, SnowJoe |
| | Chromogenic Snow Melt | NA | - Not hazardous to plants<br>- Color scale help to apply the necessary amount | - Limited information available | NA | | NA |
| Abrasives | Sand | NA | - Creates friction = significant reduction of accidents<br>- Reduce the surface area of the snow, keeping the top layer of ice warmer and preventing it from freezing further.<br>- No significant environmental impact | - Retains moisture<br>- No deicing/de-icing agent | $10-40 | | Traction Sand |

| TECHNIQUE TYPE | SALT NAME | CHEMICAL FORMULA | ADVANTAGES | DISADVANTAGES | PRICE (50 LB) | TESTED BY U | BRAND |
|---|---|---|---|---|---|---|---|
| | Volcanic Mineral | NA | - Adds traction, reducing slippery accidents<br>- "Volcanic natural" granulates = increasing minerals to vegetation<br>- Improve moisture of the grass and plants<br>- No damage<br>- Reusable (lower rates of dissolution compared to salt) | - No deicing/de-icing agent<br>- High caloric capacity means it doesn't help avoid further freezing on the ice layer | $31 | | Ecotraction |
| Carbohydrates | Beet, Leftover Beer, Molasses | Usually Beet + Brine | - Doesn't freeze at cold temperatures and reduces the freezing point<br>- Reusable<br>- Less corrosive<br>- Biodegradable<br>- Effective under low temperatures 15 F<br>- Not "tasty" for animals | - Harmful to water-dwelling insects and aerobic animals<br>- Increase the rate of aerobic germs<br>- Eutrophication of waterways resulting in increasing algae blooms<br>- Bad odors<br>- Red-brown roadways<br>- Limited information available | $10-29 per gallon (com-mercial) | | K-Tech Specialty Coatings -Beet Heet |
| | Corn | Wet Milling of Corn | - Doesn't freeze at cold temperatures and reduces the freezing point<br>- Less corrosive compared to salt | - Limited information available | NA | | Ice Ban |
| | Pickle Brine | NA | - "Works as saltwater"<br>- Effective under low temperatures -6F<br>- Prevents ice bonding with pavements | - Limited information available | NA | | |
| | Cheese Brine | NA | - Effective under low temperatures -21F | -"Stinky cheese" odor | NA | | |

*Table 1. Summary of properties, advantages, disadvantages, price, and mechanical and chemical deicing agent brands. Modified Local Road Research Board, 2012, Ketcham et al., 1996 and Levelton Consultants Ltd., 2008., and references in this work.*

# PROPOSED STUDY DESIGN

Here, we recommend a targeted soil health study on the U's campus to (1) establish a baseline of current soil conditions, (2) assess the environmental impacts of alternative solutions and/or continued monitoring of road salt application. First, we recognize shortcomings in the experimental design arising from the difficulty of directly attributing soil conditions to deicing techniques. However, if nothing else, establishing a baseline is critical for long-term assessment, which is necessary to truly understand the impact of road salt application. Additionally, we recommend a soil assessment rather than a water quality assessment given that (1) current research suggests road salt significantly impacts soil conditions and (2) ease of sampling. The recommended measurements were selected as important indicators of soil health that can be easily measured in the field.

## RECOMMENDED ANALYSES:

### pH Test

Numerous studies suggest road salts increase soil pH (e.g., Green et al., 2008; Equiza et al., 2017), which is concerning given that soil bacteria and vegetation thrive at 6.0 - 6.5 (Boom et al., 2002). We recommend measuring soil pH with an electrical sensor at the sites described below (e.g., GroLine Soil pH Tester). This measurement is time efficient and can be taken during routine maintenance. The sensor is user-friendly and inexpensive if the purchase is needed. We anticipate that sites nearest road salt application hot spots will show the highest pH measurements, and years with the highest road salt application will yield the highest pH measurements.

### Electrical Conductivity (Salinity)

Due to the composition of road salt (primarily NaCl), the application is expected to increase soil salinity. High salinity can limit water uptake potential for plants and result in heavy metal accumulation (Kotuby et al., 2000); therefore, high salinity is often a limiting factor for plant growth and overall soil health. Soil salinity is commonly measured as soil electrical conductivity (EC), which can be obtained with a handheld sensor (e.g., Direct Soil Conductivity Meter). We expect sites nearest road salt application hot spots will show the highest salinity (EC) measurements, and years with the highest road salt application will yield the highest salinity (EC) measurements.

# Soil Moisture

A prolonged accumulation of salinity leads to less moisture retention (Siegel, 2007). With a reduction in moisture levels, many impacts on vegetation and soil composition follow. Reduction in moisture within soils can lead to issues with soil erosion. The moisture in soils helps retain structural integrity.

The use of various soil moisture testing tools can examine this. All are straightforward in their use and can be done by maintenance teams in the field. (e.g., TEROS 12 Advanced Soil Moisture Senor + Temperature and EC) Other more economical versions exist, which are often used within greenhouses to measure moisture content in root levels for plants. The university may already have these tools at its disposal. We expect sites nearest road salt application hot spots will show the lowest soil moisture measurements, and years with the highest road salt application will yield the lowest moisture measurements.

# Soil Aeration (Oxygen Diffusion Rate)

Road salt decreases the water permeability of the soil and promotes poor aeration, producing unfavorable growing conditions for plants (Fay & Shi, 2012). The low levels of oxygen diffusion due to high salinity may impact more than vegetation, micro-biomes, and smaller organisms. This can be examined with portable tools (e.g., Ohaus Starter 300D Portable DO Meters). Some training will be required for ground crews/students sampling oxygen diffusion rates.

# Soil Density

The sodium ion within road salts removes and replaces potassium and phosphorus within the soil. Potassium, phosphorous, and other suspended particles help increase soil percolation; however, percolation levels are altered when removed. This often decreases soil permeability, and as a result, it increases soil density and compaction rates. Exact results and intensity of compaction vary depending on soil type, with clay soils being the most susceptible.

This can be examined through the sand-cone test within the field. This test requires a few tools: mallets, scoops, chisels, and sample bags. The rubber balloon test can also be used should environmental conditions dictate that this is a more optimal method. More training and briefing would need to occur to execute these tests properly.

# Vegetation Impacts

Salt burns are obvious within plants. Excessive salt can hinder water absorption and thus stagnate vegetation growth within the area. Visual signs of this are most typically seen as yellowed/browned leaves at the tips and margins of the leaf. Vegetation experiencing salt damage has also been noted to have thicker leaves and stunted growth (Department of Primary Industries and Regional Development, 2014). Minimal training would be required for this field test.

# SAMPLING SITES

To avoid human injuries due to the composition of road salt (primarily NaCl) and prevent traffic increases, de-icing roads with salt has been applied in the US and worldwide (Yu et al., 2014). The effectiveness of salt application has been amply studied. However, the disadvantages of using salt and other de- or un-icing agents on roads have been proven to damage the infrastructure and the abutting scenery. At the University of Utah, the Facilities Management Department has developed a protocol to prioritize spaces due to the high traffic and mean usage. Those areas are primary or high roads, sidewalks, and secondary or low-traffic paths.

## Landscapes Adjacent to High/Primary Traffic Roads

The University of Utah snow removal's priority is on the roadways that lead to the University of Utah hospital. Here, snow removal and salt applications are monitored 24 hours a day, seven days a week. Thus, we suggest monitoring soil outside the main entrances of the University hospital facilities and the School of Medicine. Overall, we expect to observe the highest salinity levels within soils adjacent to the North Campus Dr, Mario Capecchi Dr, the School of Medicine, and all the North Campus structures (Fig. 1a).

## Landscapes Adjacent to Low/Secondary Traffic Roads

Without considering the University of Utah hospital facilities, the main campus's most used areas are close to the J. Willard Marriott Library and the Presidents Circle Road. These "secondary" spaces coincide with the main sidewalk paths. Thus, we expect to find lower levels of salinity relative to the priority Facilities management designated areas but still with a salinity baseline higher than the published by the State of Utah permit: UT0000647. We recommend testing soil properties on green spaces next to President Circle Road, Union Building, and Marriott Plaza (Fig. 1b).

## Landscapes Adjacent to Roads of Snow Shoveling

The University of Utah has spaces in which snow removal is preferred instead of applying salt. Examples of these zones comprise parking lot pedestrian entrances, building entrances (in some buildings), and on-campus housing facilities. Here we propose quantifying salt concentration in shrub soils found in traffic islands within the parking lots or in front of the University's village buildings. We suspect salinity levels are not comparable to those registered along primary or secondary salt application paths (Fig. 1c).

## Environmental Impact on Green Keypoint Areas

According to the Snow Removal routes map, contiguous green areas with the University of Utah have no salt application. Examples of these areas include Red Butte Creek, The Living Room Trailhead, or The Red Butte Garden. Some of them may have Snow shoveling treatment. However, due to the closeness to the University's main salty roads, we suggest tracking the soil's salinity on these critical points. The impacts of salt usage may be affecting the soil even if they are not filtering salt directly.

Furthermore, points of interest in this study may include highly transited spaces. Such areas comprehend main entrances to the University campus at the U Kennecott Building, U Presidents' Circle Stop B, Stadium Bus Station, and U Museum of Fine Arts (Fig. 1d).

## Areas with No Salt or De-Icing Agents

As part of the goals of this proposal, evaluating the current conditions of salinity and the health of soils is imperative. Thus, we propose assessing green spaces adjacent to pathways and roads where salt is not applied. Some of them will serve as the calibration parameter for further studies. These areas may include the Amphitheater of the Lassonde Studios building and green islands between the engineering buildings South Campus.

# TIMELINE CHART

Based on our research and snow availability, we suggest monitoring soil salt concentration according to Table 2. Phase 1 consists of registering the baseline with the current conditions of soil properties. Moreover, testing within the next winter will provide soil infiltration and permeability constraints. Recommended steps in Phase 2 comprise comparative analysis if an alternative solution is pursued or continued monitoring if no change is made.

| | Phase 1 | | | | | | | Phase 2 (Alternative) | | | | | | Phase 2 (Better Practice) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Months | MAY | OCT | NOV | DEC | JAN | FEB | MAY | JUN | OCT | NOV | DEC | JAN | MAY | JUN | OCT | NOV | DEC | JAN | MAY |
| Baseline | X | X | | | | | | | | | | | | | | | | | |
| First Salt Application | | ? | ? | | | | | | | | | | | | | | | | |
| Sampling and Measurement | | | X | X | X | X | | | | | | | | | | | | | |
| Final Test and Comparison | | | | | | | X | | | | | | | | | | | | |
| Delayed Effect | | | | | | | X | | | | | | | | | | | | |
| First Alternative Application | | | | | | | | | ? | ? | | | | | ? | ? | | | |
| Support Test | | | | | | | | | X | X | X | X | | | X | X | X | X | |
| Measurement and Comparison | | | | | | | | | | | | | X | | | | | | X |

*Table 2. Time suggestion form. Red cross on Phase 1 indicates the baseline for taking into account in Phase 2.*

# IMPLEMENTATION

One key issue within longer-living experimental designs is the sustainability of the staff who will carry out the study. To make this study as feasible as possible with limited staff bandwidth, we have only recommended inexpensive analyses in the field, requiring little to no training. Implementation of this project will require support from maintenance crews, ground crews, and students to carry it for the entire duration of our proposed timeline. If the proposed study design detailed above is adopted and carried out, the most likely department to help spearhead and conduct the analysis will be Grounds.

Grounds crews are already responsible for the salting of sidewalks, so they are excellent staff to take readings. Most sites that are ideal for testing require travel by foot or some other compact means of travel. Grounds will likely be either on their feet or in smaller, maneuverable vehicles applying salt, making it easier for them to perform this study. Many tools used to measure pH, salinity, moisture, oxygen diffusion rate, soil density, and vegetation impacts are user-friendly. This is ideal due to the need for more departmental bandwidth. The grounds crew could undergo training on using the aforementioned field devices to ensure quality data. This same training can be given to students in upcoming semesters to alleviate some work pressures for grounds & maintenance.

Phase 1 will establish baseline conditions. The first set of road salt data will be completed only after the winter season. Students can then analyze this data to observe the impacts of road salt on the soil. Phase 2 will begin next winter season and will test alternatives to road salt. During Phase 2, road salts can be used in specific sites while alternatives are tested simultaneously in different areas. The same protocols, tests, and analyses will be completed with the alternatives. Once the first year of Phase 2 is complete, w,e can compare it to Phase 1 analysis and results. However, to further improve the quality of data, Phase 2 will be repeated during the following winter.

Data obtained from Phases 1 and 2 can now be compared to observe any significant impacts on soil conditions. Evaluation methods for alternatives to road salt field assessments should be conducted to expand the effectiveness. Visual assessments to determine if ice has been melted using alternatives are the most time-efficient and simple assessment which can be conducted.

Creating a standard scale for evaluating the efficiency of road salt alternatives will also prove helpful moving forward. For example, a Likert scale ranging from 1-5 to create a standard evaluation process. 1 could represent absolutely no efficiency in melting. Five could represent the complete melting of the ice on site. This Likert scale can be applied to the ease of application for grounds crews. Labor and intensity of application will be critical for the sustainable use of road salt alternatives. If an alternative is effective but too difficult to apply, other alternatives may be worth exploring.

Measuring melting points and other factors could help inform the efficacy of road salt alternatives. This information could determine the extent of each alternative efficiency in melting ice. Some training would be required to measure this properly, but it can be done in the field during regular crew maintenance. Also, much more preferable than slip tests.

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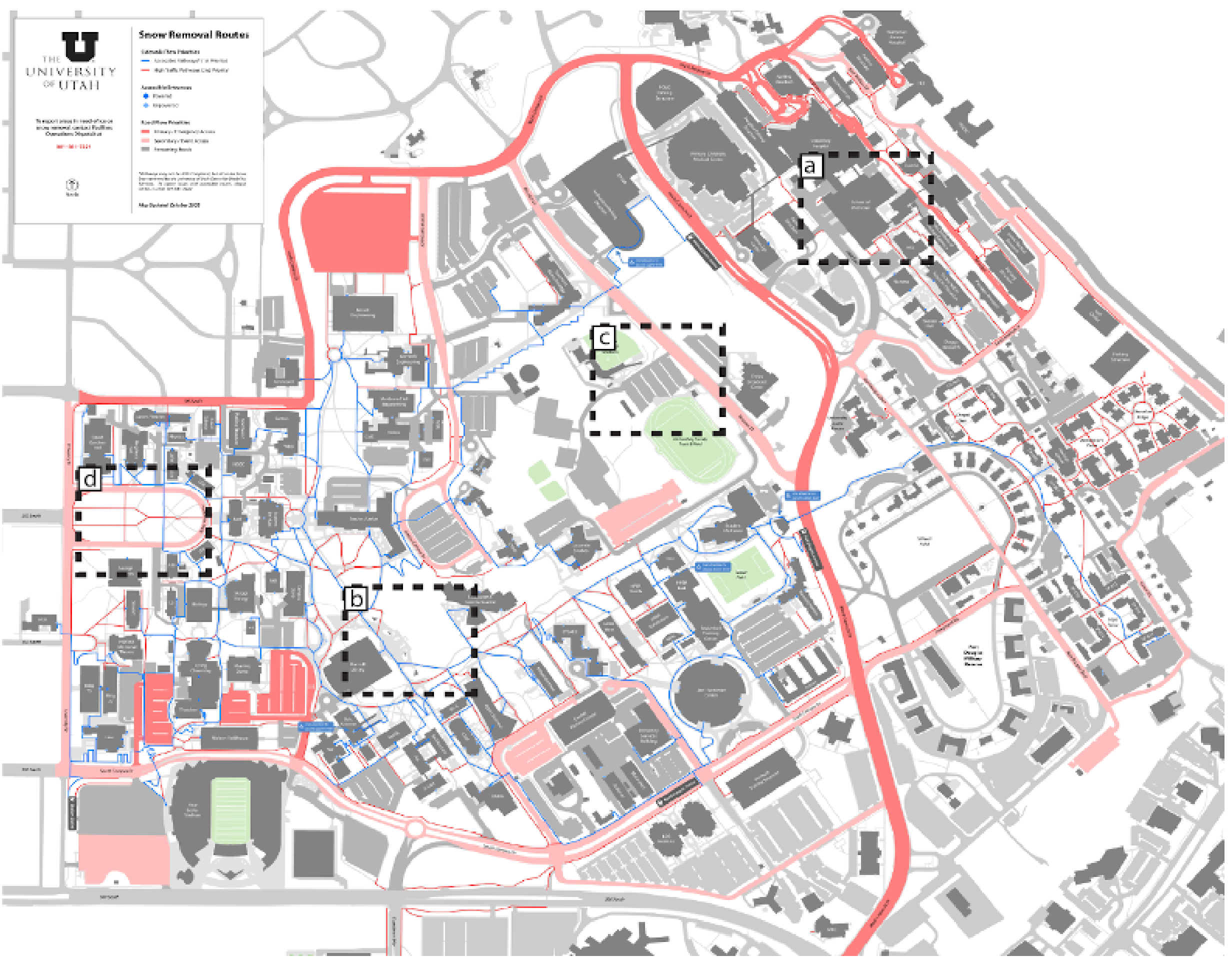


*Figure 1. Map of Snow Removal Routes. Dashed boxes indicate examples of suggested sampling sites. Modified after The University of Utah, Facilities website (https://facilities.utah.edu/landscape/snow-removal/index.php).*