Study of UBC's current snow removal practices, and their possible effects

Kathryn Choi, Solène Delumeau, Khris Liang, Lisa Xu

Course: ENVR 400

Date: April, 2020

Executive Summary

Introduction

This report details our team project in collaboration with UBC Building Operations and the SEEDS Program, from September 2019 to April 2020. Our project partners have expressed their desire to examine some ways to improve UBC's current methods of dealing with the snow seasons, particularly in the realm of reducing negative environmental impacts of snow and ice removal. The main aim of this project was to recommend changes in UBC's current snow removal practices by observing and documenting their existing protocols, and then exploring alternative methods that are used in other communities.

Methods

Our project had three main components; **(1)** soil collection and analysis, **(2)** surveying UBC patrons, and **(3)** documenting the current snow removal protocol.

Soil samples were collected from six different locations on campus, before and after salting. The samples were analysed for pH and salinity values at the UBC Soil Lab. This was done in order to discern a change in these parameters before and after a salting event.

A survey was conducted in order to investigate the views of the UBC public on Building Operations' snow response. This was approached by soliciting UBC patrons across the academic campus to complete a survey.

Several interviews with the Building Operations crew were conducted in order to gain a full understanding of the current protocol. We attended a snow response day in January 2020 to get a first-hand experience of snow removal with the Building Operations crew.

Findings & limitations

A statistical test suggests that the differences in soil pH and salinity were not statistically significant at the 0.05 significance level. However, the mean values of pH are visibly lower after salting, and those of salinity are higher after salting, as would be expected. The lack of statistical significance is likely due to the very small sample size, which was the main limitation of the soil collection design.

The survey results indicate an overall satisfaction of UBC patrons with the present snow removal response. They also point toward some “problem areas” on the campus which patrons found to be slippery. Participants generally reported feeling safer when walking rather than driving. The sample size of 100 people suggests that the survey results are not necessarily representative of a campus with over 70,000 patrons like UBC.

We estimated that UBC uses around 350 tonnes of salt in a standard snow season. This remains a very approximative number, as many assumptions were made and the raw numbers communicated to us by Building Operations were estimates themselves. By observing the snow response and interacting with crew members, we noted an area of improvement for the current snow removal method, specifically in terms of training crew members.

Conclusions

Despite a lack of statistical significance of the soil results, we cannot conclude that road salt poses no harm to the environment due to this study’s limitations. Many studies and observations point toward the various negative implications of road salt. Further studies should re-execute the soil collection and analysis with a larger sample size.

By surveying UBC patrons, we have learned that people are mostly satisfied by the speed and the efficacy of the work done by the Building Ops immediately following snow events.

Our personal observations and survey results suggest that there is variation in the level of salt application among crew members, which can sometimes result in unnecessary and excessive salt piles.

Recommendations

In consideration of the project findings, our team makes the following recommendations for UBC Building Operations:

- To develop a **training manual** for crew members which emphasizes a more conservative use of road salt, and avoiding unnecessary salting of roads.

- To begin testing an **organic based liquid de-icer** such as beet juice. The alternative de-icer should be used in conjunction with road salt, to try and limit the total amount of salt needed throughout the season.

Author Bios

Solene, Khris and Lisa are all Environmental Science students at UBC, specializing in Land, Air and Water. Kathryn is completing a double major in Environmental Sciences and Psychology.

Contents

Introduction

This project was driven by the following research question: ***can we make practical recommendations to improve the sustainability of UBC's snow removal protocol?***

The main reason snow and ice are removed is to reduce accidents, for both vehicles and pedestrians alike. However, the environmental impact of snow removal should be considered alongside road safety. Salt and brine are the most commonly used agents for snow and ice removal. Ideally, these should be applied to roads in predetermined optimal amounts based on the amount of snow and ice to remove, as well as the level of pedestrian and/or vehicle traffic experienced in the given zone. Salt and brine pose various negative environmental impacts, including roadside vegetation mortality (Liem et al., 1985), nearby forest mortality (Fan et al., 2013), and alters soil enzyme activities (Gutner & Wilke, 1983). Road salt, once applied, seeps into groundwater and makes its way into rivers (in the case of Vancouver, into the Georgia Strait). In the aquatic environment, these common de-icing salt compounds were found to have various negative impacts on fish, zooplankton, and amphibians (Hintz & Relyea, 2017). This fact is especially relevant in British Columbia, where salmonid fish species are of high economic and cultural importance. Aside from the environmental impact, the corrosive nature of salt causes damage to road surfaces (Fay & Shi, 2012) and vehicles (Ke et al., 2019). As such, limiting and mitigating the level of salting is preferable from various perspectives. UBC's current snow and ice removal practice has room for improvement on the environmental front. This project hopes to serve as a starting point in shifting the future of UBC's practices to be more environmentally conscious.

There are various other snow removal methods other than salt and brine. However, not all of them would be realistically suited for implementation at UBC. Therefore, improvements to UBC's snow response should include not only exploring alternative methods, but also potential areas in which the current methods can be more efficiently applied.

Methods

1. UBC's current snow removal practice

Because UBC's current snow and ice removal is not formally outlined, the first step was to investigate this in more detail. The information on page 9 was uncovered mainly by conducting unstructured interviews with crew members that directly carry out the snow removal process. This includes crew members from Streets and Operations Support, Soft Landscape, and other relevant staff from Building Operations. The crew have shared some common challenges faced in snow removal, such as notable 'problem areas' characterized by observed environmental damage. These areas were taken into consideration for soil testing.

In addition to the interviews, in order to experience the process first-hand, two of the authors physically attended a day of snow removal in January to make observations of the Building Operations staffs' duties.

Quantifying the total amount of salt used during the yearly snow season is important. However, as Building Operations does not keep detailed records of this information, an estimate was made by calculating the difference between the amount of salt ordered and the amount of salt leftover after the snow season.

2. Soil sampling & analysis

2.1 Soil Sampling

To observe possible effects of salting on the soil at UBC, soil samples were collected from the campus and analyzed. The parameters of interest were pH and salinity (measured as electrical conductivity), both of which are expected to change after the application of salt for snow removal due to the addition of ions present in salt (Kissel & Vendrell, 2012).

With the help of the Soft Landscape crew, six locations of interest were identified from which to collect soil samples. These locations include a mix of heavily salted areas (priority roads) and less salted areas (side roads). Figure 1 is a diagram of the soil sampling set-up, and Table 1 clarifies which sample relates to what distance from the roadside. Figure 2 indicates the location of sites, and Table 2 provides a general description of each site.

Table 1. Indication of the distances from the roadside at which samples were collected.

Sample	Distance from roadside
A	Directly adjacent
B	About 1 m
C	About 2 m

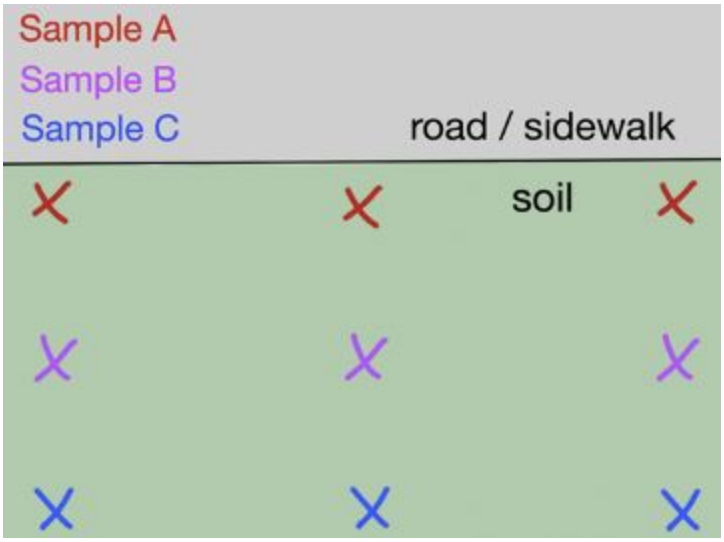


Figure 1. General set up of soil sampling for each site. Samples A, B and C are mixtures of 3 soil cores (drawn as X's in the diagram) taken from different respective distances from the road or sidewalk. Each site has a total of 3 samples, corresponding to different distances from the road/sidewalk. *Figure by Solene D.*

Samples were collected using a soil coring tool. For each of the samples A, B and C, three replicates were collected. The replicates were mixed together to provide a more representative soil sample at each distance from the roadside.

There were two rounds of soil sample collection:

1. November 29, 2019 → prior to salting
2. January 17, 2020 → after 2-3 days of salting

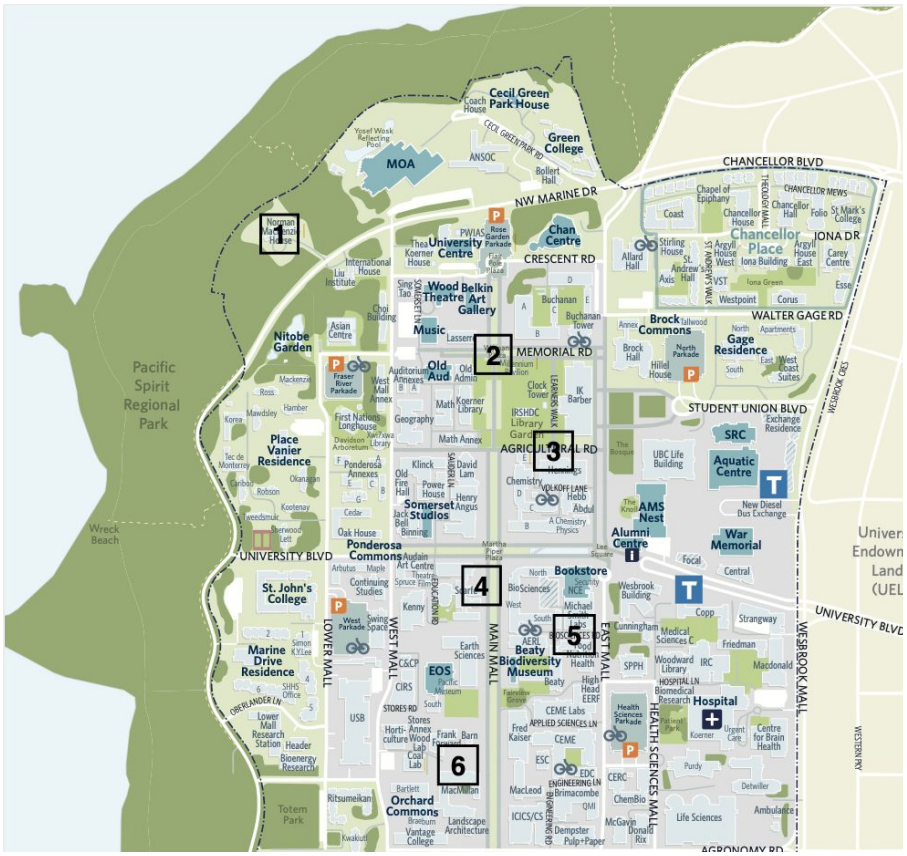


Figure 2. This is a partial map of the UBC Vancouver Campus. The numbers indicate the approximate locations where soil samples were collected. (UBC, n.d.)

Table 2. Overview of the six sites where soil samples were collected from.

Site	Location	Level of salting	Positioning
1	Norman MacKenzie House, flower bed	Heavy	Adjacent to UBC president's driveway
2	Wyman Plaza, flower bed	Heavy	Adjacent to main road
3	In front of Hennings Building	Heavy	Adjacent to main road
4	In front of Neville Scarfe Building	Heavy	Adjacent to main road
5	Behind Beaty Biodiversity Museum	Low / moderate	Adjacent to side road
6	Adjacent to MacMillan Building	Low / moderate	Adjacent to side road

Photos of each site can be found in the Appendix.

2.2 Soil Sample Analysis

Soil samples were analysed for pH and salinity at the UBC soil lab. Each sample was ground and sieved so that only particles ≤ 2 mm remained. For each soil sample, two duplicates were set aside, each weighing 10 g (+/- 0.05g). 20 mL of distilled water was added to each sample. To prepare for conductivity and pH testing, the contents were stirred and left to sit for 20 minutes and 1 hour respectively. For each sample, one duplicate was tested for pH, and the other for conductivity (salinity).

To test for conductivity, we used a Radiometer Copenhagen Conductivity Meter Type CDM 2e, shown in Figure 3. To test for pH, we used a Mettler Toledo SevenCompact, shown in Figure 4. Both meters were calibrated before use, and electrodes were rinsed with distilled water between each sample.

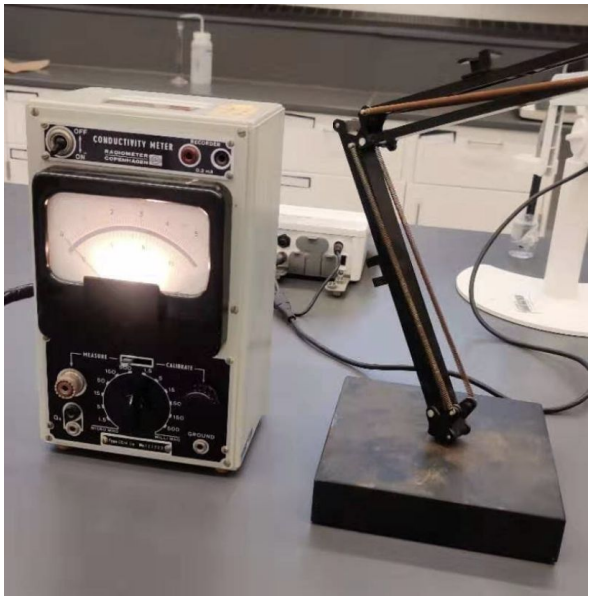


Figure 3. Radiometer Copenhagen Conductivity Meter, used for conductivity readings.
Photo by Khris L.

Figure 4. Mettler Toledo SevenCompact, used for pH readings.
Photo by Khris L.

3. Surveying UBC patrons

For a better understanding on how snow removal efficiency and efficacy are perceived by UBC patrons, and to use it to give feedback to UBC Building Operations, we conducted a survey and collected data from exactly 100 participants across UBC.

Prior to this survey data collection, the survey questions were first drafted in consultation with Calvin Cheung, Manager of Building Operations' Municipal Services, and an application to the Behavioural Research Ethics Board was submitted. After a few revisions, the final set of survey questions were approved to be administered (see Appendix for the full set of questions used in the survey).

Some of the questions consisted of general perceptions of safety while walking and/or driving on campus, as well as how participants perceived Building Operations' efficiency and efficacy. There were questions using a heat map feature which allowed us to visualize the frequently identified problem areas of either excessive or insufficient snow/ice removal. Lastly, participants were asked to provide basic demographic data in case further analysis was necessary.

On January 22nd, a few days after the snow day, we took some iPads and visited the Forest Sciences Centre, Earth Sciences Building, Henry Angus building, Irving K. Barber Learning Centre, and Buchanan A. These sites were chosen purposely, so that participants were more representative of the entire stretch of the campus. In total, we collected responses from 100 participants, who were invited to join a draw for a $25 UBC Bookstore gift card.

Results

1. UBC's current snow removal practice

The following information was gathered through interviews with Building Operations crew members and Calvin Cheung, Building Operations Manager. There are two divisions of Building Operations that deal with snow and ice removal; Streets and Operations Support (SOS) deals with main roads, while Soft Landscape (SL) deals with sidewalks. During a snow event, normal business hours will have around 70 crew members working on snow and ice removal; roughly 25 from SOS and 35 from SL. To increase snow removal efficiency, Building Operations staff can be expected to start as early as 3 AM to make sure snow and ice is cleared before campus activities begin. If conditions are severe, other teams may join to offer support.

Their main chemical methods are the use of road salt (NaCl) and brine, and physical methods include shovelling and plowing. Brine is a solution of salt in water (typically 22-24% of salt concentration), used as a preventative measure for ice formation. It is applied on to a dry road surface before anticipated snowfall or frost events. Once applied, it forms a film on pavement surfaces which can last for 2-3 days. Salt is applied once snowfall has already occurred to melt the remaining snow layer after plowing. Regular bulk salts are used, with no additives. Sand may be applied to facilitate traction of vehicles if the temperature drops below -7 degrees Celsius. However, it is hard to clean and becomes dusty in spring. Salt and brine are applied using Kubota tractors (shown in Figure 5), which also shovel and plow excess snow from roads and sidewalks before salting. Shoveling is done on narrow sidewalks and paths that plow vehicles cannot enter.

Figure 5.
Kubota tractor used for snow plowing and salt/brine application (Gifford, 2018).

Building Operations is responsible for clearing roads, sidewalks, plazas, and stairs. Salt is not directly applied to any vegetated areas, but inevitably reaches them during snowmelt, and when salty snow is shoveled into these areas. Shoveling and salting of snow around a 10-foot radius outside building doors is taken care of by UBC's custodial services. There are several areas of particular concern, including the main roads (Main Mall, West Mall, Agricultural Road) and sidewalks, and all roads and sidewalks in the Bus Loop area, which receive high daily pedestrian traffic. Such areas of concern will have much more salt applied to them to reduce the risk of accidents, compared to minor roads. UBC has a service that allows calling to report emergencies, as well as an online service request system in the case of problematic snow/ice conditions.

There were two periods of snowfall this season. They occurred in the second week of January, and the first week of February. Most salting and de-icing occurred during these times. Some salting also occurred outside of the main snow response periods, in order to prevent the freezing of roads.

We attempted to estimate the amount of road salt used in a typical snow season at UBC. Building Operations orders salt once a year from Mainroad (https://mainroad.ca/) a highway maintenance company in BC. When the first round of snow began (around January 10th), Building Operations was still using leftover salt from the previous year. An estimated 40 to 60 tonnes of salt was left over. On January 8th, a new order was placed for around 400 tonnes of salt (personal communication, January 10, 2020). Assuming that the same amount was ordered the previous year, then an estimated 340 to 360 tonnes of salt would have been used that season.

2. Soil sampling & analysis

The results of the soil analysis for pH and salinity (conductivity) are shown in the subsequent graphs. The raw data from pH and salinity testing can be found in the Appendix.

Figure 6 shows an overall comparison of soil pH of before and after salting. The mean value has shifted towards a lower pH after salting. Figure 9 shows the same information, but for conductivity (the proxy used for salinity). The values have shifted towards higher conductivity after salting. We note that for both pH and conductivity, the post-salting data has a wider range than the pre-salting data.

For both parameters of interest, the differences before and after salting were most notable for samples collected directly adjacent to the road. As seen in Figure 7, the largest pH decreases were observed closest to the roadside. As expected, Figure 10 shows that the largest conductivity increases were also closest to the roadside. A comparison of pre and post-salting data between the six sites are shown in Figure 8 and Figure 11, for pH and salinity respectively. From Figure 8 we can see that the largest pH decrease was observed at Site 3, which is located next to a heavily salted priority road.

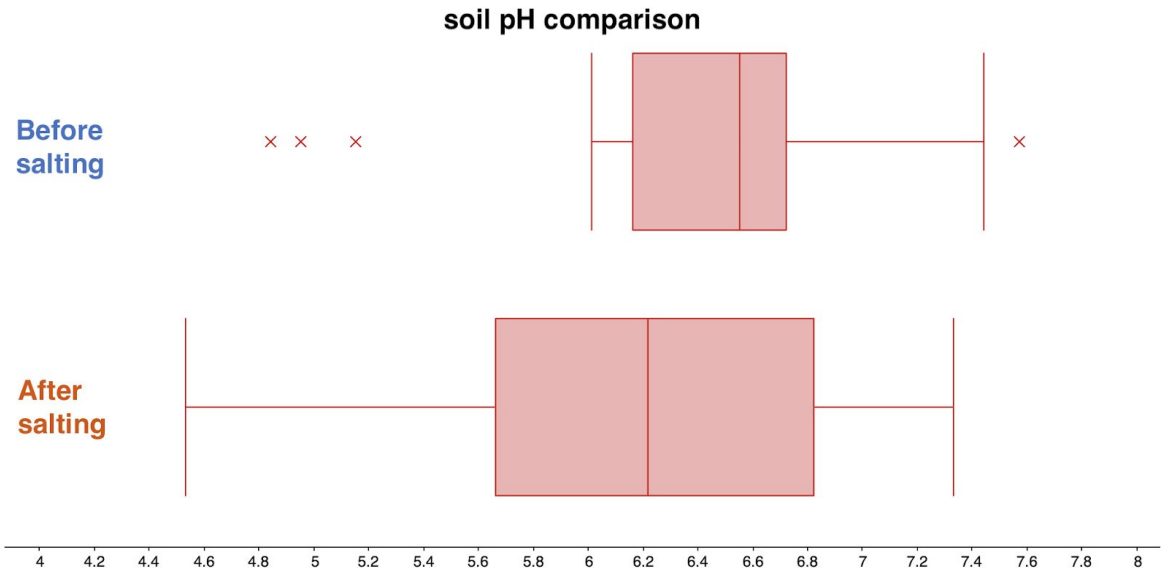


Figure 6. Box and whisker plots comparing soil pH before and after salting, across all sites and samples.

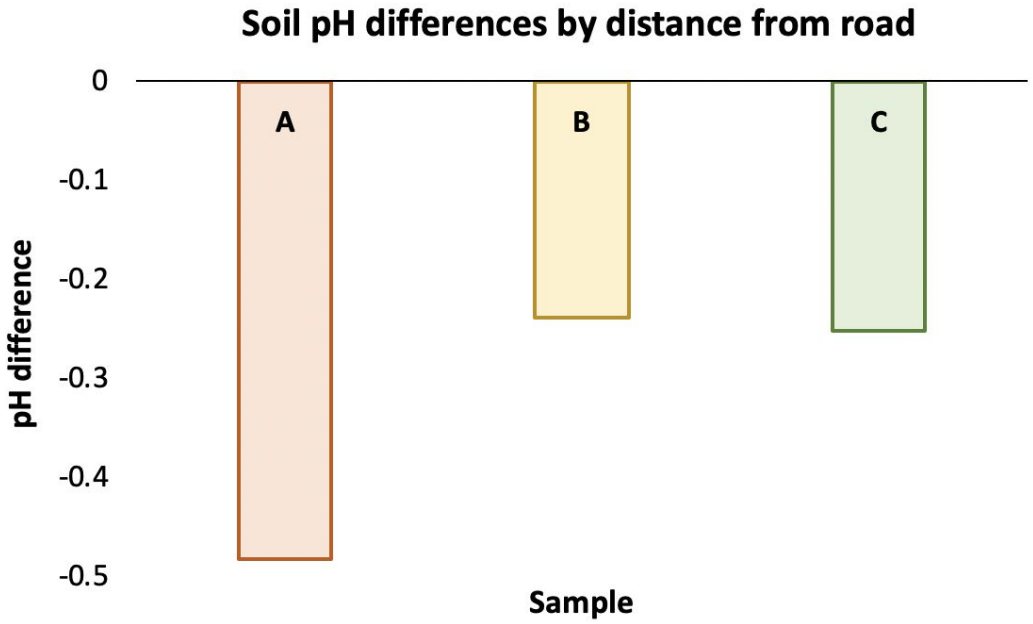


Figure 7. Bar graph showing mean differences in soil pH (across all 6 sites) before and after salting, at different distances from a salted roadside. Samples A were taken directly adjacent from the salted road. Samples B and C were taken about 1 and 2 meters away from the roadside, respectively.

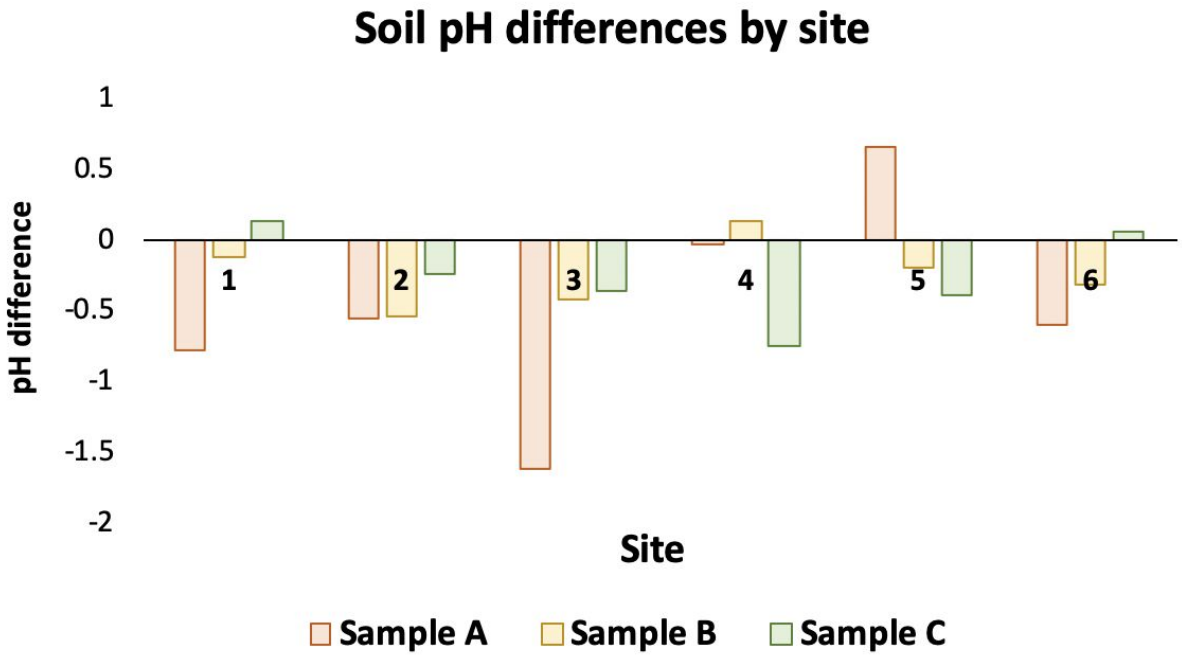


Figure 8. Bar graph showing differences in soil pH before and after salting, for each site and distance from the roadside.

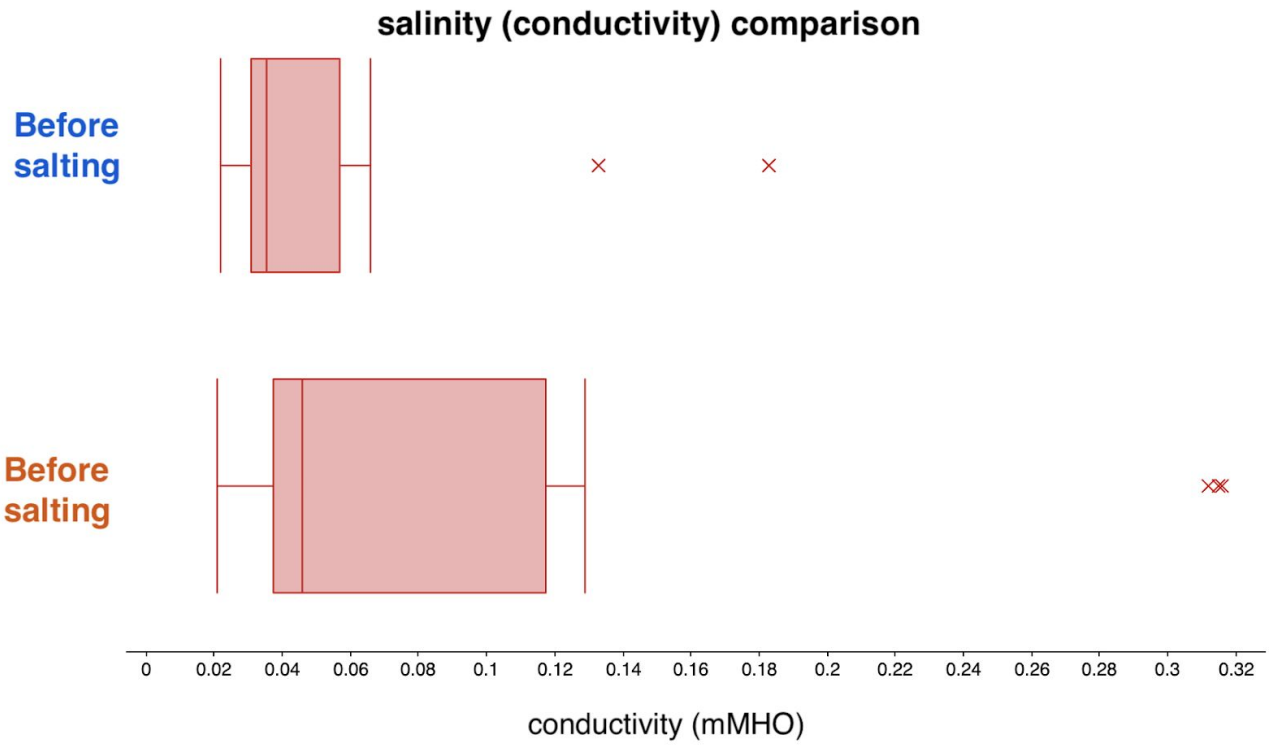


Figure 9. Box and whisker plots comparing soil salinity (measured as conductivity) before and after salting, which includes all sites and samples.

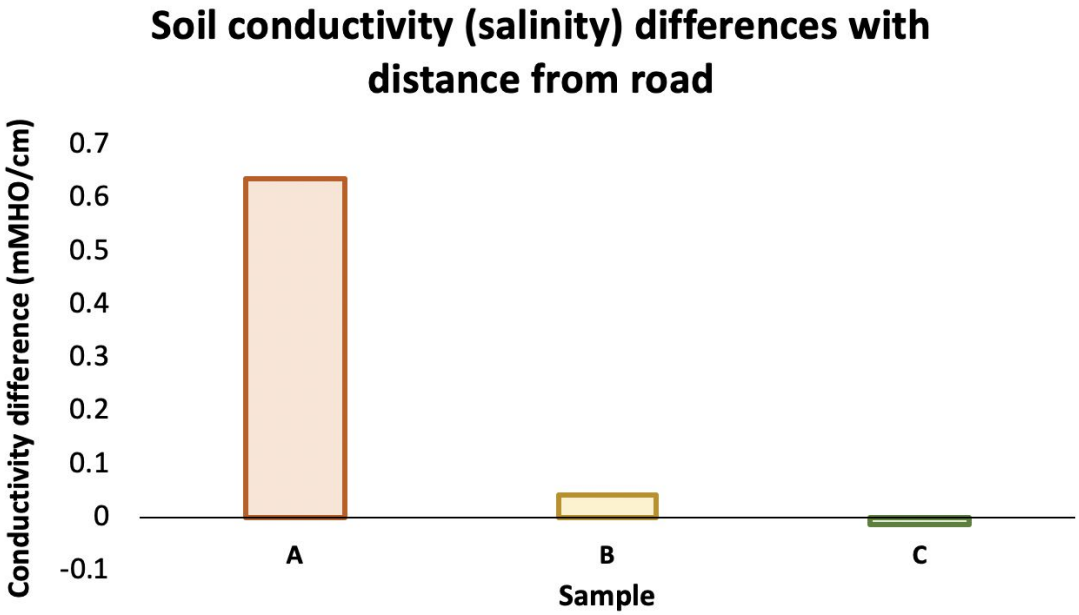


Figure 10. Bar graph showing mean differences in soil conductivity (a proxy for salinity) across all 6 sites, before and after salting.

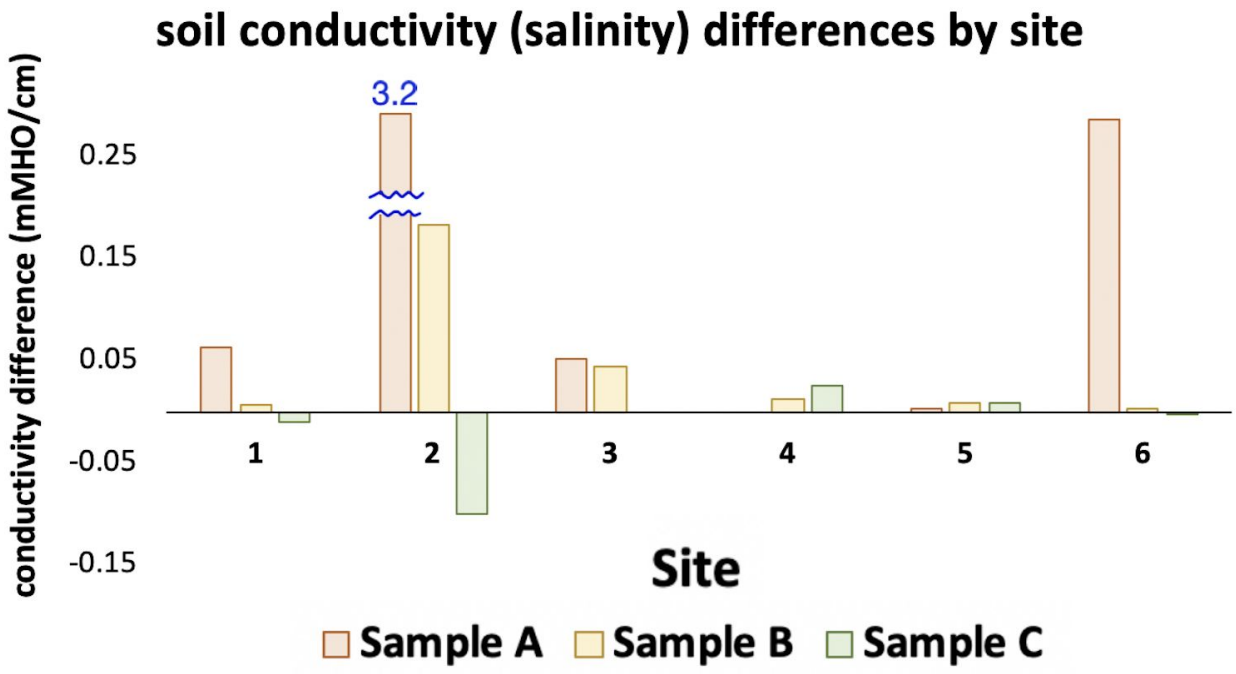


Figure 11. Bar graph showing differences in soil conductivity (a proxy for salinity) before and after salting, for each site and distance from the roadside. The value for sample 2A was disproportionately large; its real value is shown by the number on top of the bar.

As shown in Figure 11 above, sample A from site 2 seems to be an outlier, with a disproportionately high conductivity value. This was noted in the lab, so we repeated the conductivity test in case of an error. However, the repeat gave the same conductivity reading, so we assume that this is the correct value. It is worth noting that site 2 was a flower bed at the intersection of two main roads, so this high value may not be so surprising.

3. Survey results

The results collected from the survey are generally more positive than we anticipated in terms of UBC patrons' ratings on the speed and efficiency of snow removal done immediately after the snow events (detailed results can be found in Appendix). From the survey comments regarding problems due to insufficient salting, many people mentioned that sidewalks,slopes and stairs are usually slippery, icy and slushy in mornings, as shown in Figure 12. Also in Figure 13, problems areas due to insufficient snow or ice removal identified by participants are generally along the Main mall and Buchanan area, specific buildings such as ESB, BUCH, IKB are also identified and mentioned both on maps and in comments. In addition, the survey results also showed rankings of different categories of concerns in Table 2, public safety is ranked as the most concerning, accessibility as second and damage to personal items as third. Our project is trying to find a sustainable solution to the current snow removal methods, however, results suggest environmental impacts by de-icing salts is least concerning to UBC patrons.

Figure 12. A word cloud composed of relevant words from the survey comments regarding problems due to insufficient salting. Larger words indicate greater frequency.

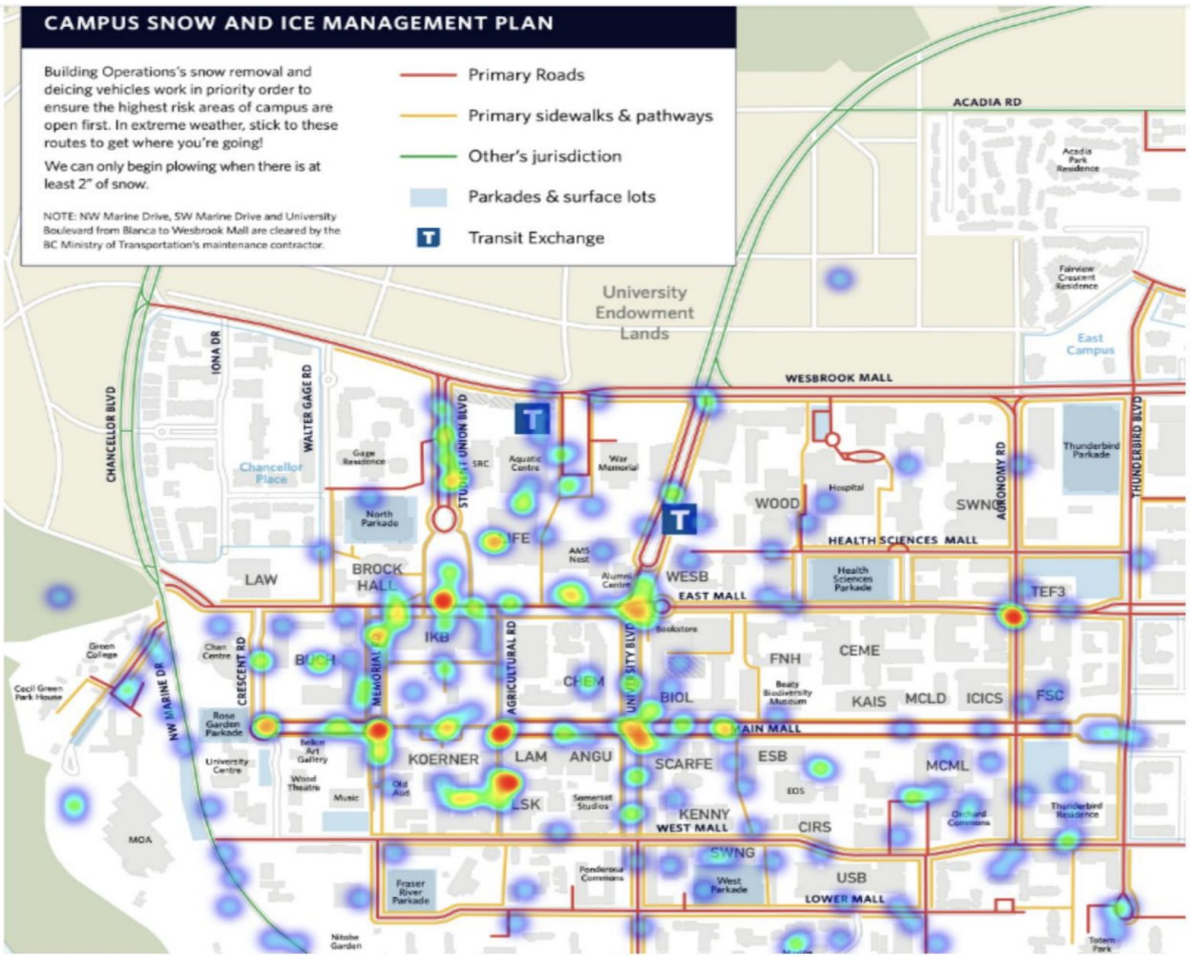


Figure 13. Heat map showing all the problems areas due to insufficient snow or ice removal identified by participants, the warmer color dots indicate that those areas have been identified more frequently.

Table 3. Table summarizing the relevant areas of concern ranked in order from most concerning (1) to least concerning (7). Percentages are shown in gray, and actual counts in black. The top two concerns were public safety and accessibility.

#	Field	1		2		3		4		5		6		7		Total
1	Public safety (e.g. making sure sidewalks and roads are not slippery)	75.58%	65	20.93%	18	2.33%	2	1.16%	1	0.00%	0	0.00%	0	0.00%	0	86
2	Accessibility (e.g. ease of transportation for people with mobility impairments)	20.93%	18	62.79%	54	6.98%	6	4.65%	4	2.33%	2	2.33%	2	0.00%	0	86
3	Damage to grasses & plants (soft landscape)	3.49%	3	3.49%	3	19.77%	17	36.05%	31	29.07%	25	6.98%	6	1.16%	1	86
4	Damage to pavement (hard landscape)	0.00%	0	1.16%	1	6.98%	6	24.42%	21	32.56%	28	34.88%	30	0.00%	0	86
5	Damage to personal items (e.g. footwear, tires)	0.00%	0	6.98%	6	40.70%	35	12.79%	11	22.09%	19	17.44%	15	0.00%	0	86
6	Broader environmental implications (e.g. fish, groundwater)	0.00%	0	4.65%	4	23.26%	20	20.93%	18	13.95%	12	37.21%	32	0.00%	0	86
7	Other (If applicable):	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	1.16%	1	98.84%	85	86

Discussion

1. UBC's current snow removal practice

In January, we observed Building Operations' snow response firsthand. We noted that some areas had piles of salt that were clearly in excess. A crew member explained that some (crew members) don't necessarily turn the salting mechanism off when they are driving on roads that have already been dealt with (personal communication, January 10, 2020). This implies there is no specific part of the training that encourages crew members to be conservative in their use of salt.

From the interactions with several Building Operations crew members, it became clear to us that liability plays a big part in snow removal. If patrons slip and get injured on campus due to improper de-icing, they are able to sue the university. In order to avoid this, Building Operations tends to use an excess of salt to be on the safe side (personal communication, January 10, 2020).

2.1 Soil sampling & analysis

As seen in Figures 7 and 8, pH values were generally lower after salting, with a few exceptions. A one-way ANOVA test concluded that the differences in soil pH before and after salting are not statistically significant at a significance level of 0.05. However, even a small change in pH may be significant for some plants and soil enzymes. According to the University of Vermont, most plants are suited for a pH range of 5.5 - 7.0 (Perry, 2003). This is a generalisation as each plant has a specific suitable pH range. Among the data, drops in pH out of this range have been observed, such as in Site 3.

Salinity (measured as conductivity) was higher after salting, for most instances. However, a one-way ANOVA test concluded that again, the differences are not statistically significant at a significance level of 0.05. According to the FAO, a salinity range of 0 - 4.5 mMHOs/cm refers to a non-saline soil (FAO, n.d.). All of the measured salinity values, both before and after salting, are below 4.5 mMHOs/cm, which would indicate that the soils are still not considered saline even after salting. However, this does not mean that the plants growing are not affected by an increase in salinity. As salt concentration in the soil increases, water uptake is reduced due to the interference of ions (FAO, n.d.). Some particularly sensitive plants can be hindered by salinity levels in the upper range of "non-saline" soil (FAO, n.d.).

Although statistical tests conclude that the differences in conductivity and pH are not of statistical significance, this should not be interpreted as “UBC’s salting activities are not harmful to the environment”. Statistical tests do not dictate what is actually harmful or not for the soil and plants. Site 3, which was a heavily salted priority road, experienced the largest pH decrease of over 1.5 adjacent to the road. Even a smaller change in pH than this could be consequential for plants and bacteria in the soil. The same reasoning applies to changes in salinity. Since UBC Soft Landscape has observed plant mortality near heavily salted roads in the past (personal communication, November 2019), we can speculate that changes in pH and/or salinity are notable enough to be harmful to the environment- at least in some parts of campus.

2.2 Limitations of soil sampling

Soil samples were collected at two intervals; before any salting had occurred (November) and after a major snow event (January). The number of samples collected was clearly limited by personnel and time constraints. Had there been more support, it would have been worthwhile to increase the number of sites to collect samples from, and to collect more replicates at each site. The small sample size was a clear limitation of the project, and could be a main reason for the results not being statistically significant. Therefore, we recommend that future studies increase the number of samples collected.

In addition, soil types were not taken into account due to time constraints. It was clear that some sites had differing soil types, which may have impacted properties such as permeability and sensitivity to pH and/or salinity changes. For instance, salt can accumulate near the surface or travel further down depending on the soil type (FAO, n.d.). Thus, in future investigations it would be worthwhile to identify soil types and account for this in the results of the data.

The second round of samples was collected while there was still snow cover over the soil. When taking samples, the snow was pushed aside so that only soil was collected. This meant there was surely some salt contained within the snow cover that was not accounted for. Normally, the snow would have melted, and percolated through the soil along with the ions from the salt. There is a high chance that the samples collected after salting were not truly representative of how much salt would have entered the soil after salting. Perhaps collecting the samples right after snowmelt would have produced a more representative data set.

3. Survey Results

We can learn from the data summarized in Table 3 that most people are not deeply concerned about the negative effects of salt on the environment. Rather, public safety and accessibility are of greatest concern. When given the opportunity to provide a comment, many participants noted observing excessive salt on sidewalks and roads. From the word cloud (Figure 12), the words that stand out seem to spell out the fact that sidewalks, entrances, and stairs are slippery and slushy in the mornings, and that the Bus Loop, Totem Park Residence, Buchanan, Main Mall, and ESB are areas of concern. This feedback can be delivered to the Building Operations crew so that they can investigate further in preparation for next winter.

In terms of how people view Building Operations' performance on snow and ice removal, the results were generally positive. On a scale of 1 to 5 (1 being the lowest), about 50% of participants rated the speed of snow removal as 4/5 and the same score was given to efficacy by 36% of participants. In addition, when asked how comfortable they felt when walking or driving around campus, results indicate people were less comfortable with driving than they were with walking. This suggests that perhaps more attention should be directed to the main driving roads. More figures and raw data from the survey results can be found in the Appendix.

UBC is a large university hosting over 60,000 students and 16,000 employees. Our sample size of 100 cannot possibly be representative of all UBC patrons, especially given that most of our respondents were students. As most students have similar daily routines and tend to visit the same high-occupancy buildings, the results may be incomplete. In addition, when approaching potential participants, we identified ourselves as Environmental Sciences students which may have affected the responses to certain sustainability-related questions. Furthermore, as these surveys were conducted in-person and in the presence of the researchers, the respondents may have answered according to what is socially acceptable (response bias).

Recommendations

As many studies have suggested, excess salting has various environmental implications. With this in mind, we recommend that UBC Building Operations crew try to incorporate an organic-based liquid de-icer into the snow removal protocol. A common example of an organic de-icer is beet juice, a byproduct of beet sugar production. Beet juice was adopted by Michigan State University (MSU) as a de-icer. The university claims that beet juice was able to effectively melt snow and ice, even at lower temperatures. MSU covers 5,300 acres of land (MSU, n.d.), while UBC only covers 988 acres (UBC, n.d.). Considering the size difference, it is conceivable for UBC to incorporate beet juice successfully if MSU has done so.

Incorporating an organic-based de-icer does not mean getting rid of road salt completely. Beer juice is usually used in conjunction with road salt, to help reduce the total amount of salt used throughout the season. For example, the city of Merritt, BC, reduced its road salt use by 40% by incorporating beet juice (Hume, 2014). Therefore, we recommend that UBC starts testing out beet juice by incorporating it progressively.

Besides beet juice, the Minnesota Department of Transportation has listed alternatives to chloride deicers, and their trade-offs. This information is shown in **Table A3** of the Appendix. UBC Building Operations could consider some of the alternative de-icers listed, along with their trade-offs.

Another recommendation is for Building Operations to develop a training manual for its crew which emphasises a more conservative use of road salt. We observed first-hand that not all crew members turn off the salting mechanism when they are driving on roads that have already been salted. This results in piles of excess salt in some locations, which was also noted in some of the survey comments. Even if there is no economical motivation to limit salt use, we would recommend that all crew members are trained to conserve salt. Specifically, by turning off the salting mechanism of vehicles when driving in areas that are not target roads in need of salting.

Conclusions

Snowy and icy roads are often a cause of inconvenience and can be dangerous for people during their everyday travels. Salting is an effective snow and ice management method which is used to reduce the incidence of people getting injured or otherwise inconvenienced. Despite its effectiveness, road salts impact natural environments and should be considered in the context of both safety and sustainability.

After comparing pH and salinity in soil samples collected before and after salting, it was found that the soil adjacent to the road exhibited the greatest difference as opposed to soils further from the road. Although these results were not statistically significant, it is not enough to conclude road salts pose no harm to the environment due to this study's limitations. Further studies should take in consideration of soil types and characteristics when analysing soil samples, as well as re-execute this study with a larger sample size.

Through surveying UBC patrons, we have learned that people are mostly satisfied by the speed and the efficacy of the work done by the Building Ops immediately following snow events. However, participants generally reported feeling safer when walking rather than driving, suggesting that more work may need to be directed to main roads and parkades. Based on the written comments, stairs, sidewalks, and slopes are usually slushy, icy and slippery in mornings. Most participants also indicated areas around BUCH (Buchanan), ESB (Earth Science Building), IKBLC (Irving K. Barber Learning Centre), and BIOL (Biological Sciences Building) as lacking sufficient salt application. Other areas have similarly been indicated as having been over-salted. In a ranking question, sustainability and environmental impacts of the current snow removal method were ranked to be less of a concern than safety and accessibility.

In conclusion, to transition UBC's snow response towards a more sustainable practice, our major recommendation is that the Building Operations' crew should collectively receive training guidelines to promote more conservative salting. Our personal observations and survey results suggest that there is variation in the level of conservation in salt spreading among crews, which can sometimes result in unnecessary and excessive salt piles. To reduce the potential damage to natural landscapes due to road salts, alternative agents can be considered. Beet juice is an alternative product that is more environmentally-friendly and easily applied, but the feasibility of these types of products should be tested in following years to see how they perform compared to conventional methods.

Acknowledgements

We would like to give a special thanks the following people who helped us throughout the project:

- Calvin Cheung from Building Operations (project partner)
- David Gill from SEEDS (project partner)
- Christopher Langford from Soft Landscape
- Dale Low from Soft Landscape
- Lewis Fausak from the UBC soil lab
- Michael Lipsen (faculty supervisor) from EOAS
- Tara Ivanochko (faculty supervisor) from EOAS
- Ross, Jaz, Bob and the rest of the Building Operations crew

References

Boeckmann, C. (2019). Optimum soil pH levels for trees, shrubs, vegetables and flowers. Retrieved from https://www.almanac.com/plant-ph

Crop Nutrition. (N.d.) Soil pH: Soil acidity. Retrieved from https://www.cropnutrition.com/nutrient-management/soil-ph

Fan, Y., Weisberg, P.J., & Nowak, R.S. (2013). Spatio-Temporal Analysis of Remotely-Sensed Forest Mortality Associated with De-icing Salts. *Science of the Total Environment, 472,* 929-938.

FAO. (N.d.) *Chapter 7- Salty soils.* Retrieved from http://www.fao.org/3/r4082e/r4082e08.htm

FAO. (N.d.) *Chapter 3- Saline soils and their management.* Retrieved from http://www.fao.org/3/x5871e/x5871e04.htm

Fay, L., & Shi, X. (2012). Environmental Impacts of Chemicals for Snow and Ice Control: State of the Knowledge. *Water, Air, & Soil Pollution*, *223*(5), 2751–2770. doi: 10.1007/s11270-011-1064-6

Geisberg, B. (2019). *UBC Cancels February 12 classes as transit to campus hits major delays.* [Online image]. Retrieved from https://ubyssey.storage.googleapis.com/media/images/2016/12/20161205-2.jpg

Gifford, R. (2018). *Kubota Utility Vehicle.* [Online image].
Retrieved from: https://compactequip.com/utility-vehicles/truckin-tool-carriers/

Hintz, W. D., & Relyea, R. A. (2017). Impacts of road deicing salts on the early-life growth and development of a stream salmonid: Salt type matters. *Environmental Pollution, 223*, 409-415. doi: 10.1016/j.envpol.2017.01.040

Hume, M. (2014). BC town uses beet juice on snowy roads. Retrieved from https://www.theglobeandmail.com/news/british-columbia/bc-town-uses-beet-juice-on-snowy-roads/article16274717/

Jin, Z. Q., Zhao, T. J., Gao, S., & Zhang, S. Y. (2014). Ice-Formation Expansion of Salt Solution and its Effect on Frost Damage of Concrete. *Key Engineering Materials*, *633*, 281–285. doi: 10.4028/www.scientific.net/kem.633.281

Ke, G., Zhang, J., & Tian, B. (2019). Evaluation and Selection of De-Icing Salt Based on Multi-Factor. *Materials, 12*(6), 912. https://doi.org/10.3390/ma12060912

Kissel, D. & Vendrell, P. (2012). *Soil Testing: Soil pH and Salt Concentration.* Retrieved from https://extension.uga.edu/publications/detail.html?number=C875

Liem, A. S. N., Hendriks, A., Kraal, H., & Loenen, M. (1985) Effects of De-icing Salt on Roadside Grasses and Herbs. *Plant and Soil, 84*, 299-310.

MSU. (n.d.). Improving snow removal operations with sustainable practices. Retrieved from https://sustainability.msu.edu/get-involved/staff-resources/improving-snow-removal.html

MSU. (n.d.). MSU Facts. Retrieved from https://msu.edu/about/thisismsu/facts.php

Pearson, K. E. (n.d.). Basics of Salinity and Sodicity Effects on Soil Physical Properties. Retrieved November 23, 2019, from http://waterquality.montana.edu/energy/cbm/background/soil-prop.html.

Perry, L. (2003). pH for the garden. Retrieved from http://pss.uvm.edu/ppp/pubs/oh34.htm

Rocha, R. (2015). A look at the alternatives to rock salt for de-icing roads. Montreal Gazette. Retrieved November 28, 2019, from: https://montrealgazette.com/news/local-news/a-look-at-the-alternatives-to-rock-salt-for-de-icing-roads

SCU, & The University of the West of England, Bristol. (Eds.). (2017). Additives used in alternative road salts may affect aquatic ecosystems. Retrieved November 28, 2019, from: https://ec.europa.eu/environment/integration/research/newsalert/pdf/additives_in_alternative_road_salts_affect_aquatic_ecosystems_496na1_en.pdf.

UBC. (n.d.). UBC Vancouver Campus. Retrieved from https://www.ubc.ca/our-campuses/vancouver/

Wahlin, J., & Klein-Paste, A. (2014). The effect of common de-icing chemicals on the hardness of compacted snow. *Cold Regions Science and Technology, 109*, 28-32.

Warrence, N. J., Pearson, K. E., & Bauder, J. W. (2003). Basics of Salinity and Sodicity Effects on Soil Physical Properties. Retrieved from http://waterquality.montana.edu/energy/cbm/background/soil-prop.html#Texture

Western Transportation Institute. (2017). *Field Usage of Alternative Deicers for Snow and Ice Control*. Minnesota Department of Transportation. Retrieved from http://dot.state.mn.us/research/TRS/2017/TRS1706.pdf

Woodrow, P. (2011). Salinity Stress and Salt Tolerance. *Abiotic Stress in Plants: Mechanisms and Adaptations.* Retrieved from https://www.intechopen.com/books/abiotic-stress-in-plants-mechanisms-and-adaptations/salinity-stress-and-salt-tolerance

Tait, C. (2018). Sand, salt and beet juice: How Canada wages war against ice and snow. Retrieved from https://www.theglobeandmail.com/news/national/salt-sand-and-beet-juice-how-canada-wages-war-against-ice-and-snow/article37673031/

Tayag, Y. (2017). Chemistry explains how beet juice makes ice and snow melt. Retrieved from https://www.inverse.com/article/39632-beet-juice-melt-snow-ice

Appendix

Photos of the sites where soil samples were collected.

Figure A1. (left) Photo of Site 1. Photo by Khris L.

Figure A2. (right) Photo of Site 2. Photo by Khris L.

Figure A3. (left) Photo of Site 3. Source: Google Maps, street view (2020).

Figure A4. (left) Photo of Site 4. Source: Google Maps, street view (2020).

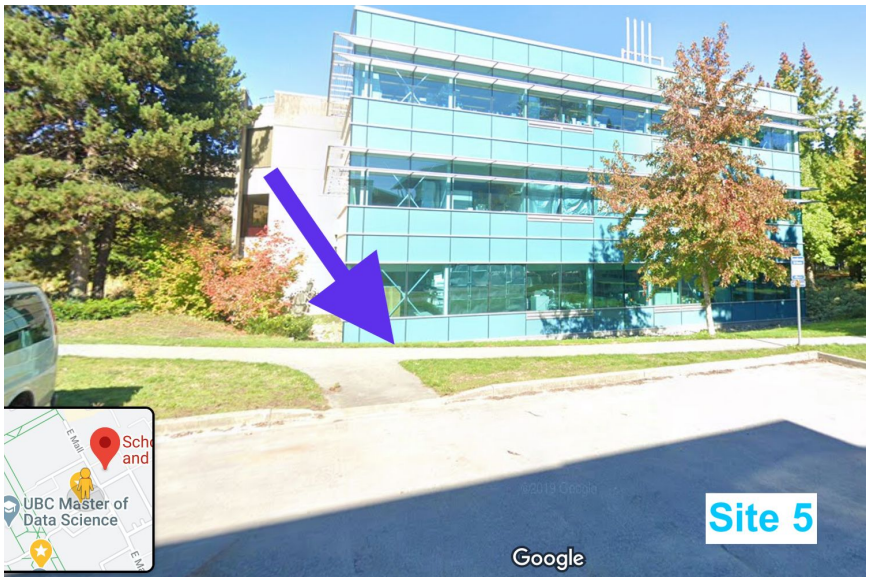


Figure A5. (left) Photo of Site 5. Source: Google Maps, street view (2020).

Figure A6. (left) Photo of Site 6. Source: Google Maps, street view (2020).

Raw data from the soil sample analysis:

Table A1-1 Raw data values of the soil pH, **before** salting.

Sample	1	2	3	4	5	6
A	6.68	6.41	6.72	6.38	6.16	5.15
B	7.04	7.44	6.49	6.29	6.66	4.84
C	6.69	7.57	6.01	6.61	7.04	4.95

Table A1-2 Raw data values of the soil pH, **after** salting.

Sample	1	2	3	4	5	6
A	5.91	5.86	5.11	6.35	6.82	4.56
B	6.92	6.90	6.08	6.43	6.57	4.53
C	6.83	7.33	5.66	5.87	6.66	5.01

Table A2-1 Raw data values of the soil conductivity (in mMHOs/cm), **before** salting.

Sample	1	2	3	4	5	6
A	0.065	0.061	0.053	0.032	0.030	0.028
B	0.035	0.132	0.056	0.029	0.033	0.027
C	0.040	0.182	0.045	0.034	0.032	0.021

Table A2-2 Raw data values of the soil conductivity (in mMHOs/cm), **after** salting.

Sample	1	2	3	4	5	6
A	0.128	3.2	0.105	0.311	0.033	0.314
B	0.041	0.315	0.101	0.041	0.042	0.029
C	0.029	0.081	0.045	0.06	0.04	0.02

Summary of alternative de-icing chemicals from the Minnesota Department of Transportation:

Table A3 Summary of non-chloride deicer working temperature range, relative cost and toxicity, key environmental impacts, and known impacts to infrastructure. Boxes highlighted in orange are rated high which in this case is negative. (Direct quote from Western Transportation Institute, 2017)

Deicer Type	Lower Functional Temperature	Relative Cost	Relative Toxicity	Environmental Impacts	Infrastructure Impacts
Chlorides	NaCl: 15°F MgCl2: -5°F CaCl2: -15°F	Low	High	Accumulate in the environment. Impact water quality, aquatic and terrestrial flora and fauna.	Pavements and metals
Acetates	KAc: -26°F NaAc: 0°F CMA: 0°F	Moderate	Moderate	Moderate Biochemical Oxygen Demand	Pavements and galvanized steel
Formates	NaFm: 0°F KFm: -20°F	High	Moderate	Moderate Biochemical Oxygen Demand	Pavements and galvanized steel
Glycols	-20°F	Moderate	High	High Biochemical Oxygen Demand	Limited
Succinates	-4°F (unknown)	High (Unknown)	Moderate	Moderate Biochemical Oxygen Demand	None known

Survey questions and results begin on the next page.

ENVR 400 Snow Removal

Survey Flow

Block: Start page (1 Question)
Standard: Main questions (11 Questions)
Standard: Demographic (5 Questions)

Page Break

This is the consent page. Participants are agreeing to participate in this study once they click next.

Start of Block: Start page

Consent

Study: **IDENTIFYING AREAS OF FEASIBLE IMPROVEMENTS TO THE SUSTAINABILITY OF SNOW REMOVAL AT UBC**

Primary Investigator: Dr. Tara Ivanochko, *tivanoch@eoas.ubc.ca*

Primary Contact: Kathryn Choi, *kathryn@alumni.ubc.ca*

Co-Investigators: Michael Lipsen, mlipsen@eoas.ubc.ca; Solene Delumeau, solene.delumeau@alumni.ubc.ca; Lisheng Xu, lisheng.xu@alumni.ubc.ca; Shu Ying Liang, cliang1997@alumni.ubc.ca

Introduction and Purpose of the Study: The purpose of this study is to collect qualitative data on how UBC students, staff, and faculty feel about snow removal processes at UBC. The summarized data will be used to develop a Recommendations Report for UBC Building Operations which may be available publicly.

Study Procedures: You will be asked to complete a 5-10-minute survey on your perceptions of effectiveness and efficacy of snow removal by UBC Building Operations. We will ask you to think about your travels around the Academic Core of the Vancouver Campus during the snow season. There will be no personally identifying information in the survey.

Confidentiality: All of the information you provide will be kept strictly confidential. Your data will be combined with other participants' data and summarized in your peers' research reports. These reports may be made public (with the paper author's permission). Once the data are downloaded, these files will be stored in a locked location in the Primary Investigator's office or locked storage room in the EOS-South Building for 5 years following the end of this study. At that time, all data will be destroyed.

Remuneration: Participants will be offered a chance to enter a draw for a $25 gift card to the UBC Bookstore at the end of the survey. Providing an email address is optional, and will be collected separately from the survey responses. Participants will be offered the chance to enter the draw regardless of whether they have fully or partially completed the survey.

Contact Information: Any questions about the details of the study or interview process can be directed to the researchers using the contact information listed above. If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604.822.8598, or if long distance email RSIL@ors.ubc.ca or call toll free 1.877.822.8598.

Consent: Participation is entirely voluntary, so you may withdraw your consent for any reason. However, please note that once your survey is submitted, your data cannot be withdrawn from the data pool due to the anonymous nature of the platform. Partially completed surveys will be discarded from analysis. Whether or not you take part in and complete the project has no bearing whatsoever on your treatment or academic standing.

By clicking through the first page of the survey, you are indicating that you are releasing your data to be used in the study and that you have received a copy of this consent form. *Human Ethics H19-03681*

End of Block: Start page

Start of Block: Main questions

Q1 **Please ensure that your responses pertain to only the academic core of the campus (i.e. excluding the University Neighbourhood Association/Residential areas).**

Q2 I feel comfortable walking around campus during and immediately after snow events.

- Always (1)
- Most of the time (2)
- About half the time (3)
- Sometimes (4)
- Never (5)

The following questions are asked in order to understand how UBC students, staff, and faculty perceive the effectiveness of snow removal and snow management on campus. The results will be incorporated into our final recommendations report.

Q3 I feel comfortable driving around campus during and immediately after snow events.

- ○ Always (1)
- ○ Most of the time (2)
- ○ About half the time (3)
- ○ Sometimes (4)
- ○ Never (5)
- ○ Not applicable (6)

Q5 On a scale of 1-5, how would you rate the UBC Building Operations staff in their response to snowfall with regards to...

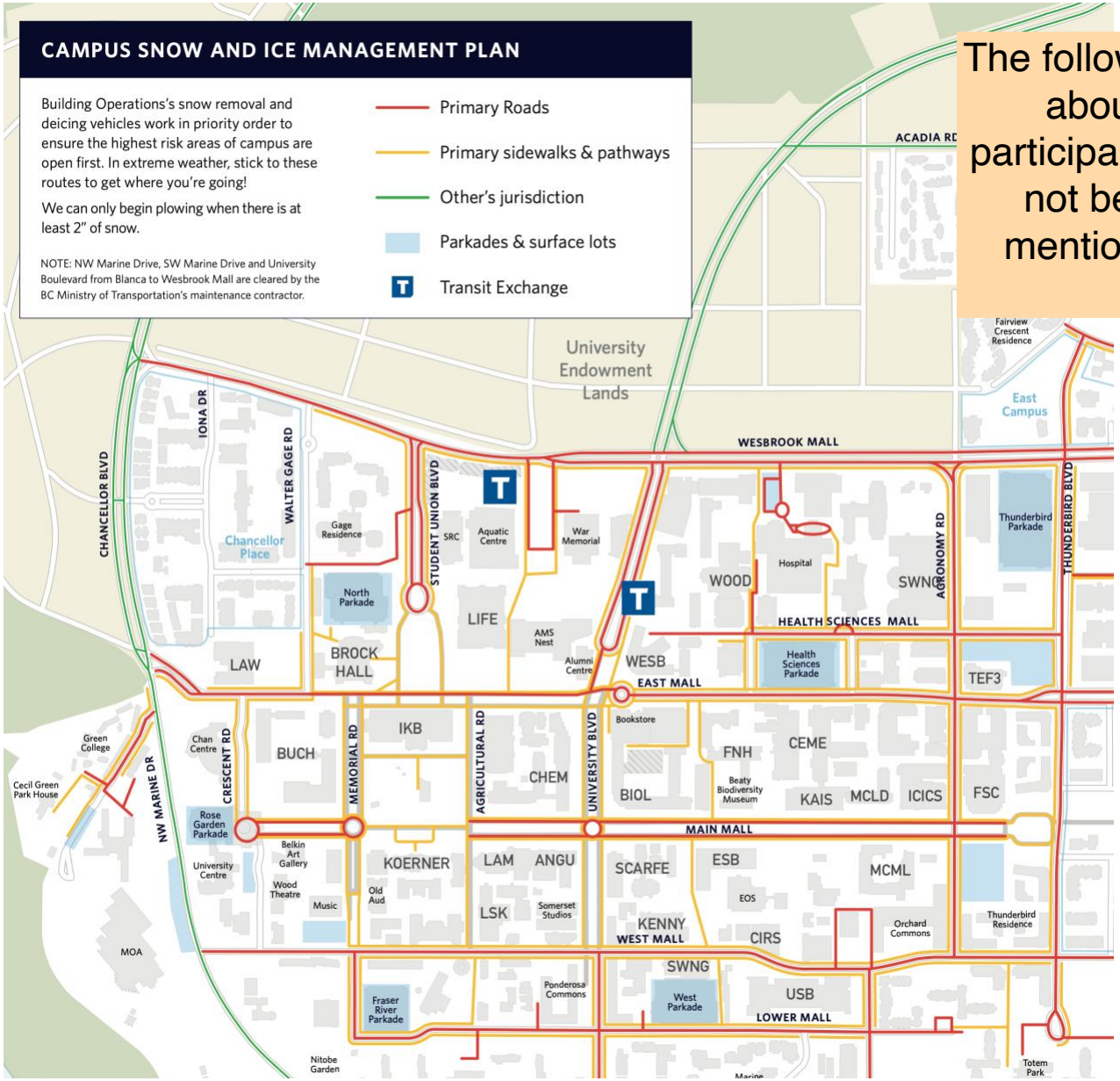
	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)
Speed (e.g. how fast they clear snow) (1)	○	○	○	○	○
Efficacy (e.g. how well they clear snow) (2)	○	○	○	○	○

Q6 My major areas of concern relating to snow removal/management are (please **drag** to rank in order from most to least concerning):

_____ Public safety (e.g. making sure sidewalks and roads are not slippery) (1)
_____ Accessibility (e.g. ease of transportation for people with mobility impairments) (2)
_____ Damage to grasses & plants (soft landscape) (3)
_____ Damage to pavement (hard landscape) (4)
_____ Damage to personal items (e.g. footwear, tires) (5)
_____ Broader environmental implications (e.g. fish, groundwater) (6)
_____ Other (if applicable): (7)

This question informs us about what values are most important to UBC students, staff, and faculty regarding snow removal operations. We can assess how high of a priority sustainability is among UBC patrons.

Q7 Please click on any areas on campus that you have experienced or noticed problems with due to insufficient snow or ice management (up to 10 clicks). Examples include areas that are slippery or have snow piled up due to insufficient salting or plowing.

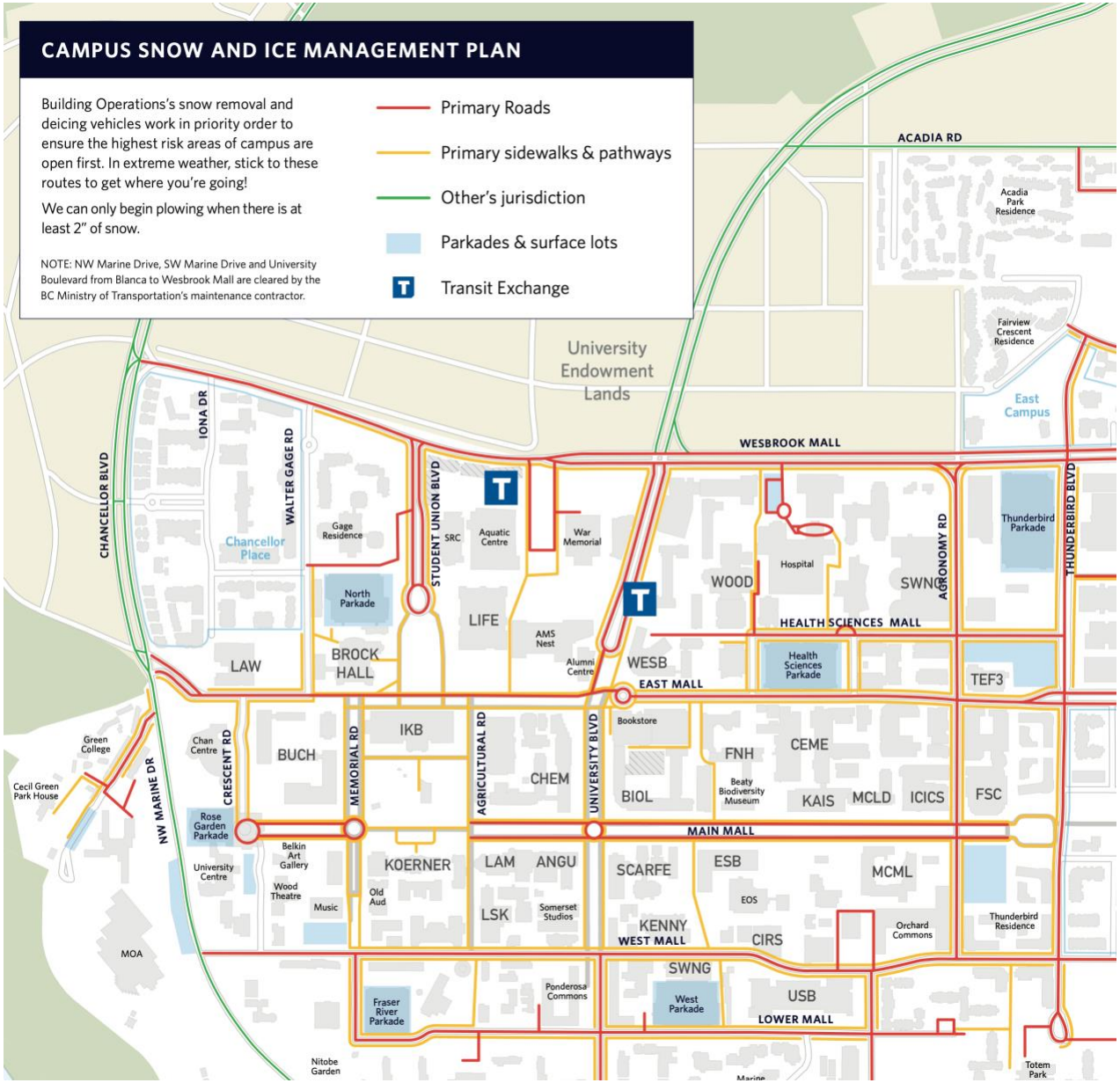


The following questions give us information about the problem areas noted by participants that Building Operations might not be aware of. These areas will be mentioned in our final report for further investigation.

Q8
Please describe the areas you clicked on in further detail. Details such as time of observance, whether the problem was noted at a sidewalk or a street, etc. would be helpful for our analysis.

Examples:
1. Bus Loop: slippery sidewalk in the mornings
2. Sidewalk outside IKB: icy sidewalk during the afternoon

Q9 Please click on any areas on campus that you have experienced or noticed problems with due to excessive snow or ice management (up to 10 clicks). Examples include excessive salting and plowing causing damage to plants, grasses, shrubs, roads, sidewalks, etc. as a result.



Q10
Please describe the areas you clicked on in further detail. Details such as time of observance, whether the problem was noted at a sidewalk or a street, etc. would be helpful for our analysis.

Example:
1. Bus Loop: too much salt on sidewalk in the evenings

_____

Q11 How has this year's snow response to date compared to previous years (if applicable)?

- ○ Much worse (47)
- ○ Somewhat worse (48)
- ○ About the same (49)
- ○ Somewhat better (50)
- ○ Much better (51)
- ○ Not applicable (52)

This question will be used to gauge whether there are noticeable changes between different years - this question can be re-used in follow up studies when actual alternatives are being implemented.

Q12
Please provide any additional comments, questions, or feedback you have regarding snow removal practices on campus. Constructive feedback will be passed on to UBC Building Operations as recommendations to improve on current practices.

Please also feel free to use this space to expand on your answers to previous questions.

_____

End of Block: Main questions

Start of Block: Demographic

Q13 Please select all that apply:

The following questions will be used to classify the data during analysis.

- ☐ I am a UBC student (1)
- ☐ I work at UBC (2)
- ☐ I live on campus (UNA) (6)
- ☐ I live on campus (student housing) (3)
- ☐ I frequently drive to campus during snow events (4)
- ☐ I frequently ride a bicycle or skateboard on campus during snow events (5)

Q14 If you drive, which parkade(s) do you use on campus? Please skip this question if not applicable.

- [ ] North (1)
- [ ] West (2)
- [ ] Rose Garden (3)
- [ ] Health Sciences (4)
- [ ] Fraser (5)
- [ ] Thunderbird (6)

Display This Question:

If Please select all that apply: != I live on campus (student housing)

Or Please select all that apply: != I live on campus (UNA)

These questions will give us insight into whether there are any time slots that require more attention. Results will be used to form recommendations.

Q15 Around what time do you typically get to/leave campus?

- ○ I arrive on campus around (e.g. 10:30am) (1) _____
- ○ I leave campus around (e.g. 5:45pm) (2) _____

Display This Question:

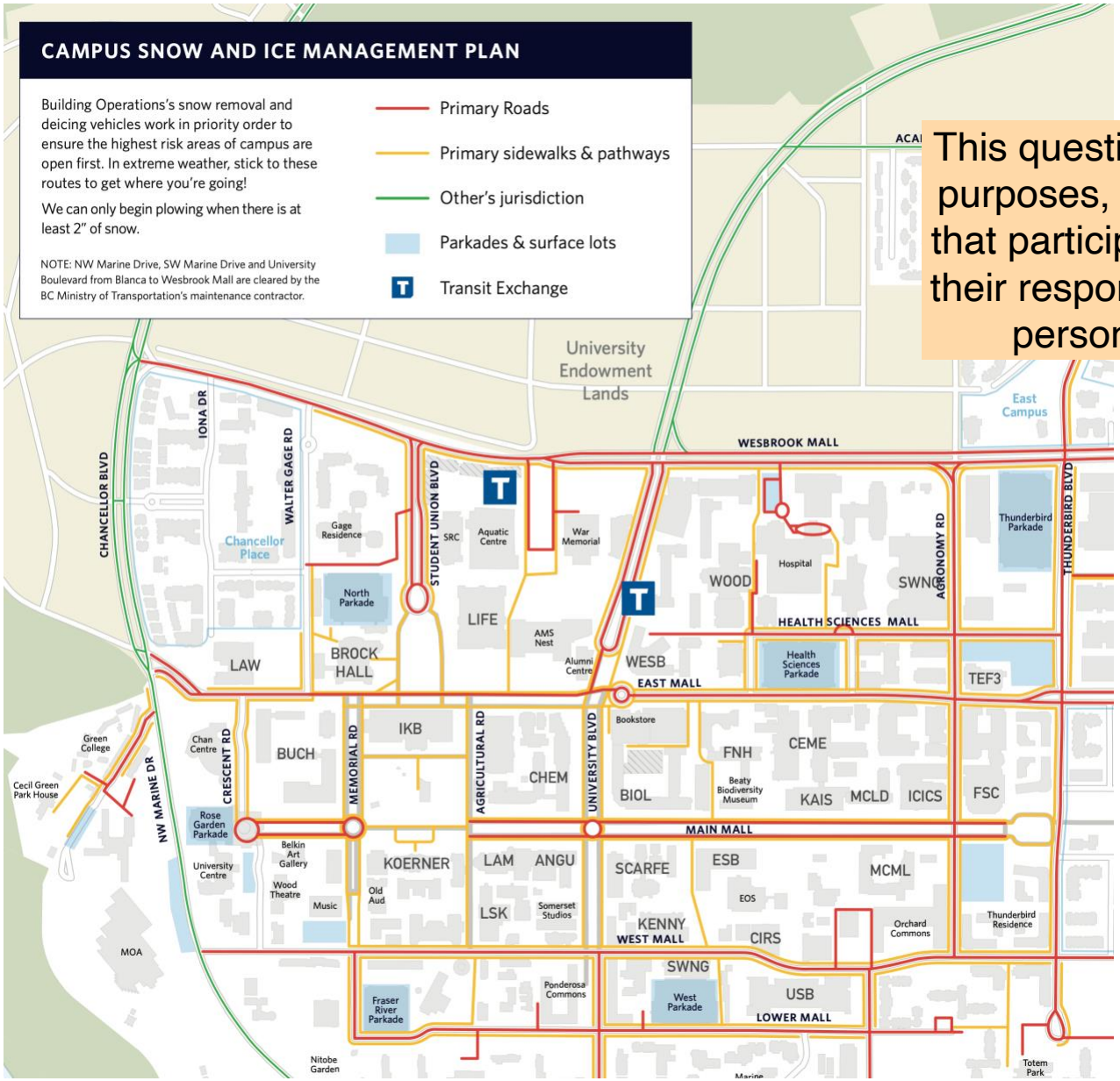
If Please select all that apply: = I live on campus (student housing)

Or Please select all that apply: = I live on campus (UNA)

Q22 Around what times do you typically travel around campus?

- I leave my room around (e.g. 10:30am) (1) _____
- I return to my room for the day around (e.g. 5:45pm) (2) _____

Q14 Please click on the buildings that you have most frequently visited during the snow season (up to 10 clicks):



This question will be used for classification purposes, to understand the typical routes that participants take and compare them to their responses. This data won't reveal any personally identifying information.

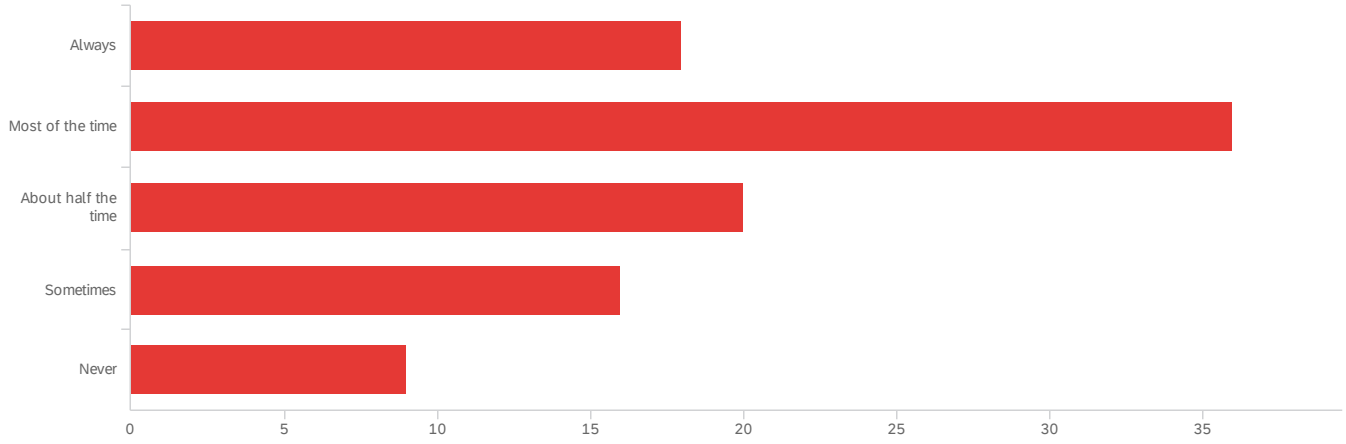
End of Block: Demographic

Default Report

ENVR 400 Snow Removal

January 30, 2020 9:19 AM MST

Q2 - I feel comfortable walking around campus during and immediately after snow events.

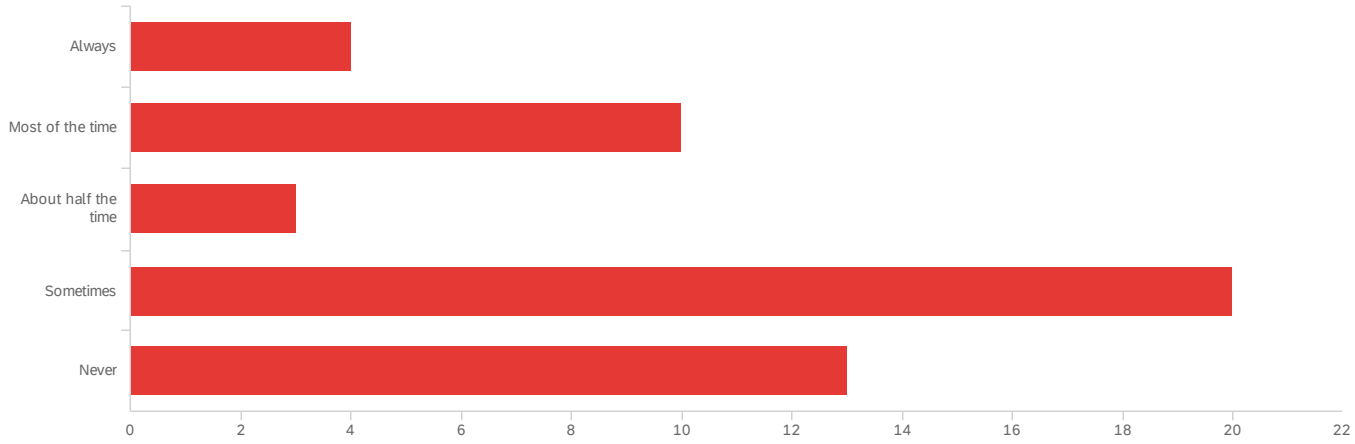


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	I feel comfortable walking around campus during and immediately after snow events.	1.00	5.00	2.62	1.21	1.47	99

#	Field		Choice Count
1	Always	18.18%	18
2	Most of the time	36.36%	36
3	About half the time	20.20%	20
4	Sometimes	16.16%	16
5	Never	9.09%	9
			99

Showing rows 1 - 6 of 6

Q3 - I feel comfortable driving around campus during and immediately after snow events.

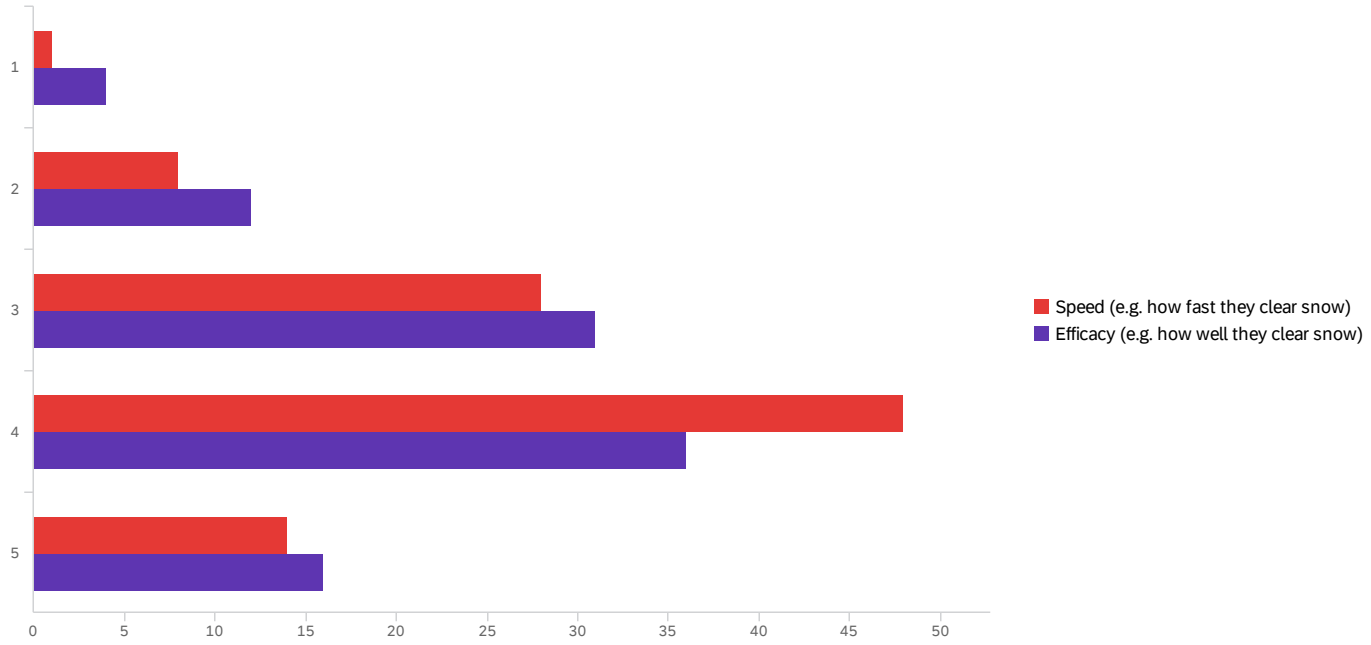


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	I feel comfortable driving around campus during and immediately after snow events.	1.00	5.00	3.56	1.28	1.65	50

#	Field		Choice Count
1	Always	8.00%	4
2	Most of the time	20.00%	10
3	About half the time	6.00%	3
4	Sometimes	40.00%	20
5	Never	26.00%	13
			50

Showing rows 1 - 6 of 6

Q5 - On a scale of 1-5 (1=low, 5=high), how would you rate the UBC Building Operations staff in their response to snowfall with regards to...

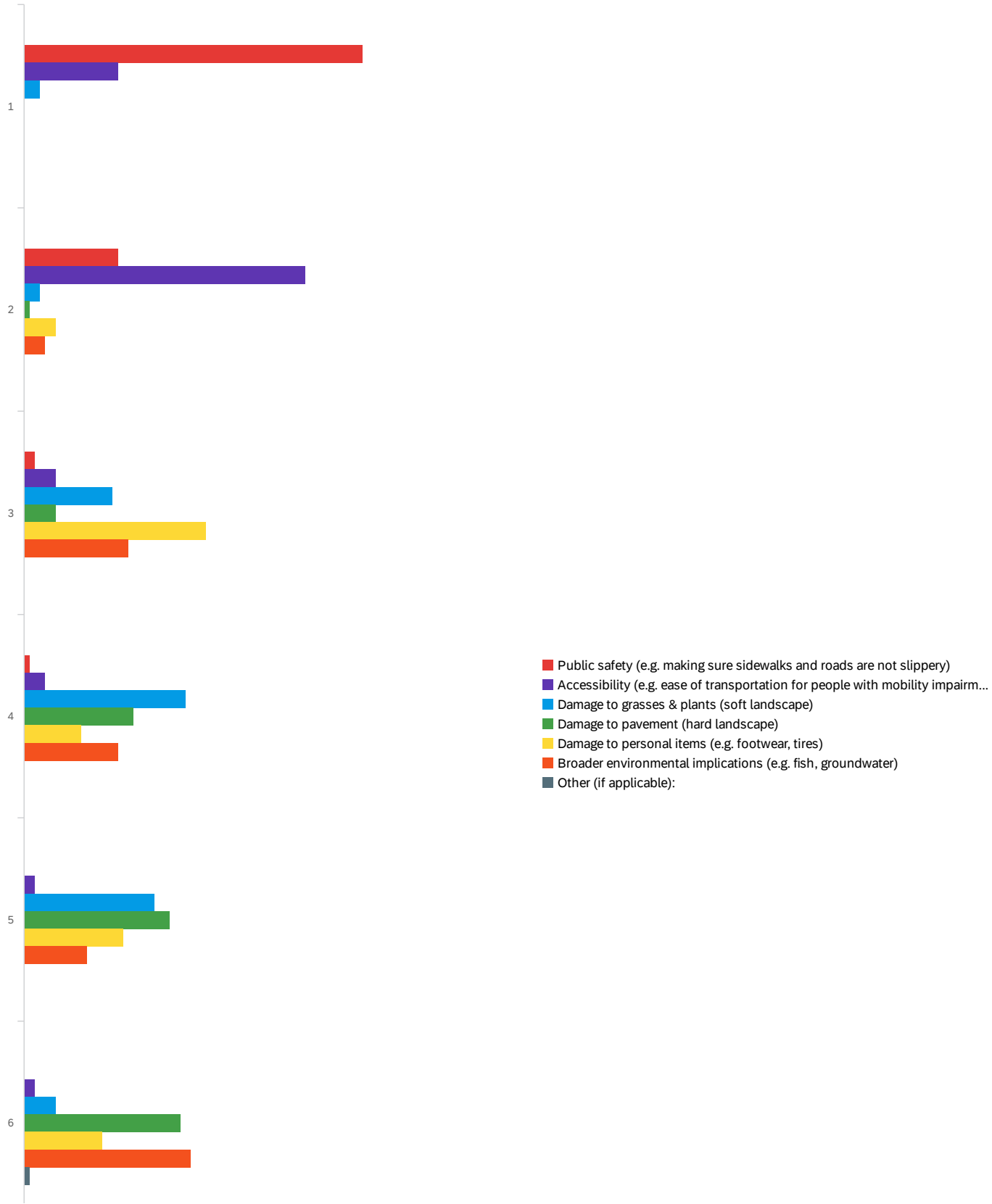


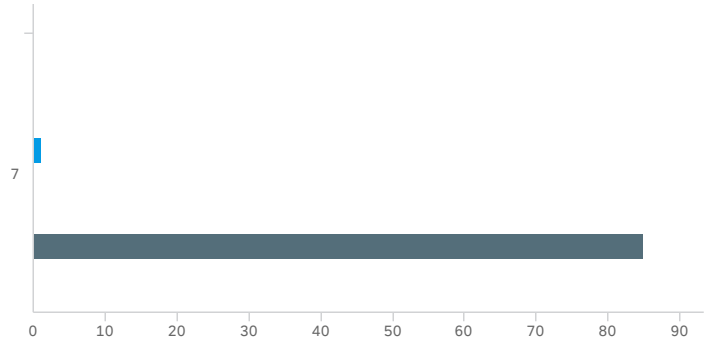
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Speed (e.g. how fast they clear snow)	1.00	5.00	3.67	0.85	0.73	99
2	Efficacy (e.g. how well they clear snow)	1.00	5.00	3.48	1.03	1.06	99

#	Field	1		2		3		4		5		Total
1	Speed (e.g. how fast they clear snow)	1.01%	1	8.08%	8	28.28%	28	48.48%	48	14.14%	14	99
2	Efficacy (e.g. how well they clear snow)	4.04%	4	12.12%	12	31.31%	31	36.36%	36	16.16%	16	99

Showing rows 1 - 2 of 2

Q6 - My major areas of concern relating to snow removal/management are (please drag to rank in order from most to least concerning):





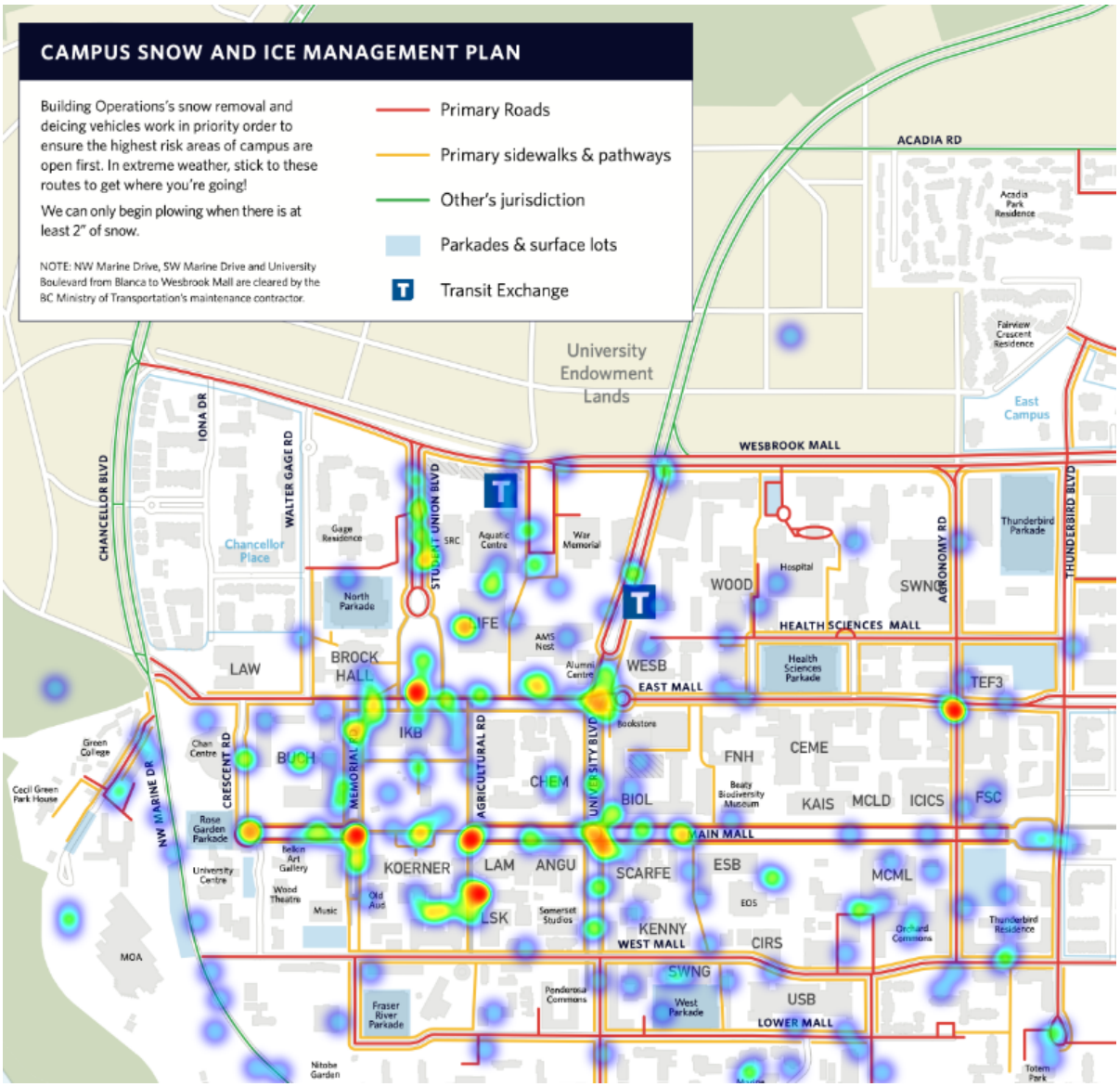
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Public safety (e.g. making sure sidewalks and roads are not slippery)	1.00	4.00	1.29	0.57	0.32	86
2	Accessibility (e.g. ease of transportation for people with mobility impairments)	1.00	6.00	2.12	1.02	1.03	86
3	Damage to grasses & plants (soft landscape)	1.00	7.00	4.09	1.15	1.32	86
4	Damage to pavement (hard landscape)	2.00	6.00	4.93	0.99	0.97	86
5	Damage to personal items (e.g. footwear, tires)	2.00	6.00	4.02	1.27	1.60	86
6	Broader environmental implications (e.g. fish, groundwater)	2.00	6.00	4.56	1.32	1.73	86
7	Other (if applicable):	6.00	7.00	6.99	0.11	0.01	86

#	Field	1		2		3		4		5		6		7	
1	Public safety (e.g. making sure sidewalks and roads are not slippery)	75.58%	65	20.93%	18	2.33%	2	1.16%	1	0.00%	0	0.00%	0	0.00%	0
2	Accessibility (e.g. ease of transportation for people with mobility impairments)	20.93%	18	62.79%	54	6.98%	6	4.65%	4	2.33%	2	2.33%	2	0.00%	0
3	Damage to grasses & plants (soft landscape)	3.49%	3	3.49%	3	19.77%	17	36.05%	31	29.07%	25	6.98%	6	1.16%	1
4	Damage to pavement (hard landscape)	0.00%	0	1.16%	1	6.98%	6	24.42%	21	32.56%	28	34.88%	30	0.00%	0
5	Damage to personal items (e.g. footwear, tires)	0.00%	0	6.98%	6	40.70%	35	12.79%	11	22.09%	19	17.44%	15	0.00%	0

#	Field	1		2		3		4		5		6		7	
6	Broader environmental implications (e.g. fish, groundwater)	0.00%	0	4.65%	4	23.26%	20	20.93%	18	13.95%	12	37.21%	32	0.00%	0
7	Other (if applicable):	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	1.16%	1	98.84%	85

Showing rows 1 - 7 of 7

Q7 - Please click on any areas on campus that you have experienced or noticed problems with due to insufficient snow or ice management (up to 10 clicks). Examples include areas that are slippery or have snow piled up due to insufficient salting or plowing.



Q8 - Please describe the areas you clicked on in further detail. Details such as time of observance, whether the problem was noted at a sidewalk or a street, etc. would be helpful for our analysis. Examples: 1. Bus Loop: slippery sidewalk in the mornings 2. Sidewalk outside IKB: icy sidewalk during the afternoon

Please describe the areas you clicked on in further detail. Details such as...
Unpaved walkways
icy during the morning
Snow accumulation on grass is not removed, the road track is covered by the snow.
Bus loop: slipper always Sidewalk all over cmapus: icy
1. BIOL: slippery sidewalk in the mornings 2. GEOG: snow not cleared in the X-shape crosswalk behind the building during the day
2nd last stop 99: North sidewalk slippery. Between aquatic and old sub: wet and slushy South side of woodward: slushy East of Allard Law: wet and slippery
The areas I clicked are largely sidewalks that were very slippery. The area indicated right outside the Biology building was covered in black ice that was unnoticeable. Many students fell prey to that area.
sidewalk at the back of geog building was not cleared or salted.
university Boulevard near Ponderosa is very slippery especially there's a slope
1. ANSO: some areas of the stars weren't cleared off at all 2. Main mall: the shortcuts wrre so slippery
Slippery stairs covered in snow that turns into ice. Bus loop wasn't cleared immediately.
Stairs outside LIFE building（and most outdoor stairs in general) get VERY slippery
1. path from ESB to swng: steep slope and no ice cleared
Bus loop slush was difficult to get around
1. Old Auditorium：snow not cleared （ramp slippery） 2. Indoor stairs and sidewalk：people falling
mornings and afternoons on the sidewalk towards music building
Long lineup for busses

Please describe the areas you clicked on in further detail. Details such as...

roads were very icy very dangerous to drive

Snowy walkways around totem

1. bus loop 2. sidewalk along the boulevard

1. Diagonal path from Buch to IKB: still cover in snow all day 2. Sidewalk around Fraser river parkade: icy sidewalk at night

The bricks outside the building get very slippery whenever wet.

the front door of LSK: slippery sidewalk

IKB super slippery Bus loop no salt on side walk Old auditorium no snow removal

1. Main entrance to Vanier in the mornings, hard to go through 2. Sidewalk towards ESB side entrance, slippery in the mornings

sidewalk outside LSK: icy sidewalk in the mornings

none

All highlighted areas are super slippery and icy, especially during morning classes.

main mall is one of the busier streets and there are a lot of icy patches that are dangerous to students and occasional cars that go by.

slippery and icy stairs

outside totem:very icy in the mornings bus loop:never usually sanded pretty icy road from West mall to main mall: stairs never usually cleared or sanded

1. sidewalk between ikb and life usually has a lot of wet snow 2. exiting rose garden parkade is sometimes difficult

streets a bit slippery

Slushy ice

Snow is not cleared at the rose garden in the morning

near pharmacy and orchard, slippery sidewalks

Walking street: Downward slope

icy and choppy frozen terrain

BUCH:slippery in the morning

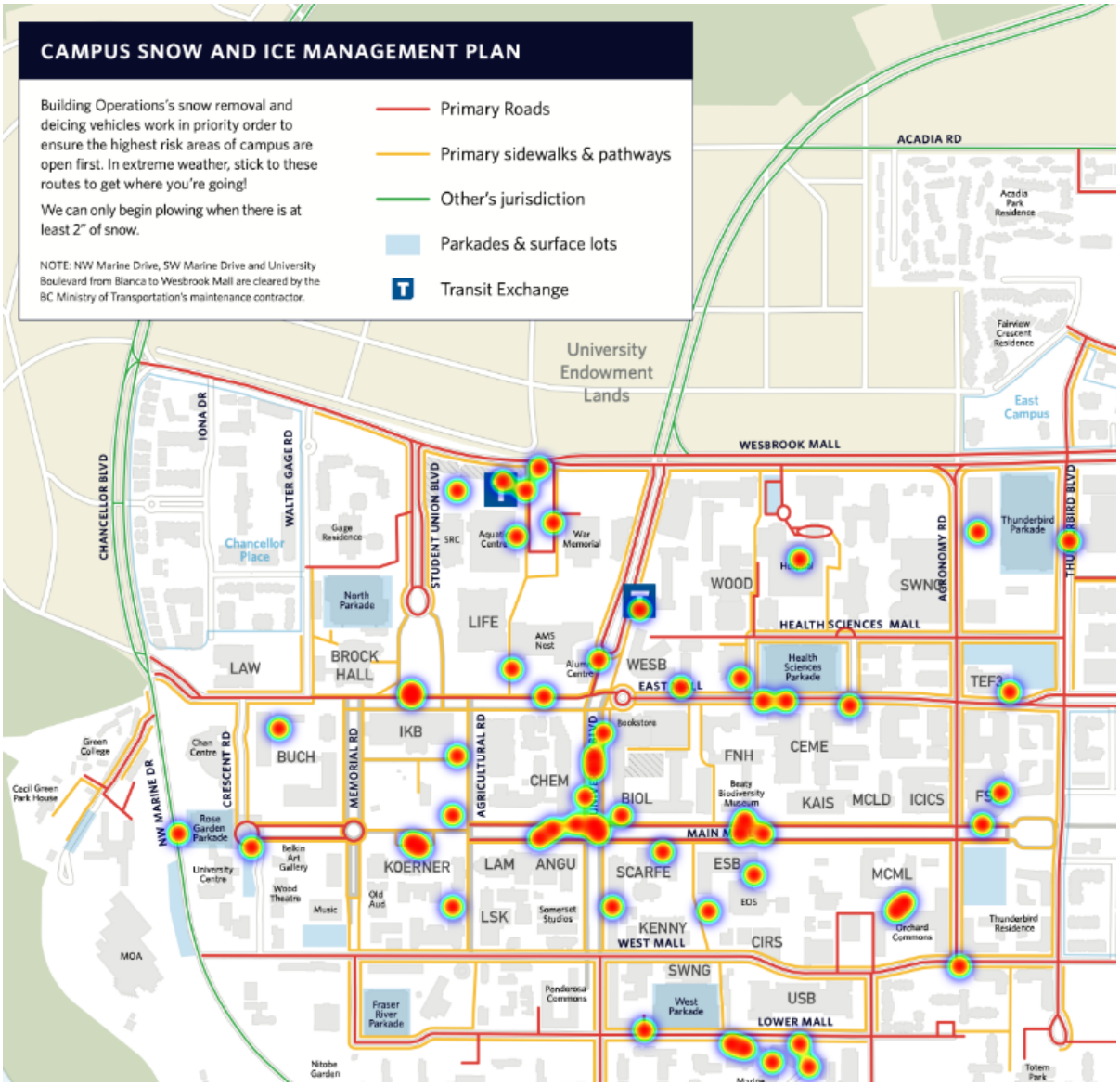
Residences - extremely slushy and slippery

n/a

Please describe the areas you clicked on in further detail. Details such as...

Fair view student housing: hard to walk in the morning Life building: wet shoes
very wet and slushy outside math building and just inside the entrance
Muddy after snow
around the chem building/ fountain area: slippery and icy
There was snow on the path
slippery sidewalk
Street: too slippery
hard to walk and too wet
orchard commons: stairs are icy and half filled with snow
Totem small roads have slippery surfaces because of the snow being crushed underfoot. It was there for a long time.
sidewalk: not fully cleared and lots of slush
BUCH the floor is very very very slipery!
1. between Life building and aquatic centre; 2. path toward WOOD
Bus loop to Lasserre Building via east mall and memorial road slippery in mornings.
N/a
the path is very slushy
slippery sidewalk to the parkade
Side walk outside North parkade: slippery in the morning
Buch and law: too much snow - difficult to access; ikb and sauder: a bit slippery
sidewalk outside Buchanan : icy sidewalk during the afternoon
Too much snow outside of the Chem building, hard to elf. Same for ESB
road between Scarfe and Angu: there is a big slope, which is very slippery after snowing.
In front of library Koerner: Large packs of snow below some trees that were icy due to w recent warming weather.

Q9 - Please click on any areas on campus that you have experienced or noticed problems with due to excessive snow or ice management (up to 10 clicks). Examples include excessive salting and plowing causing damage to plants, grasses, shrubs, roads, sidewalks, etc. as a result.



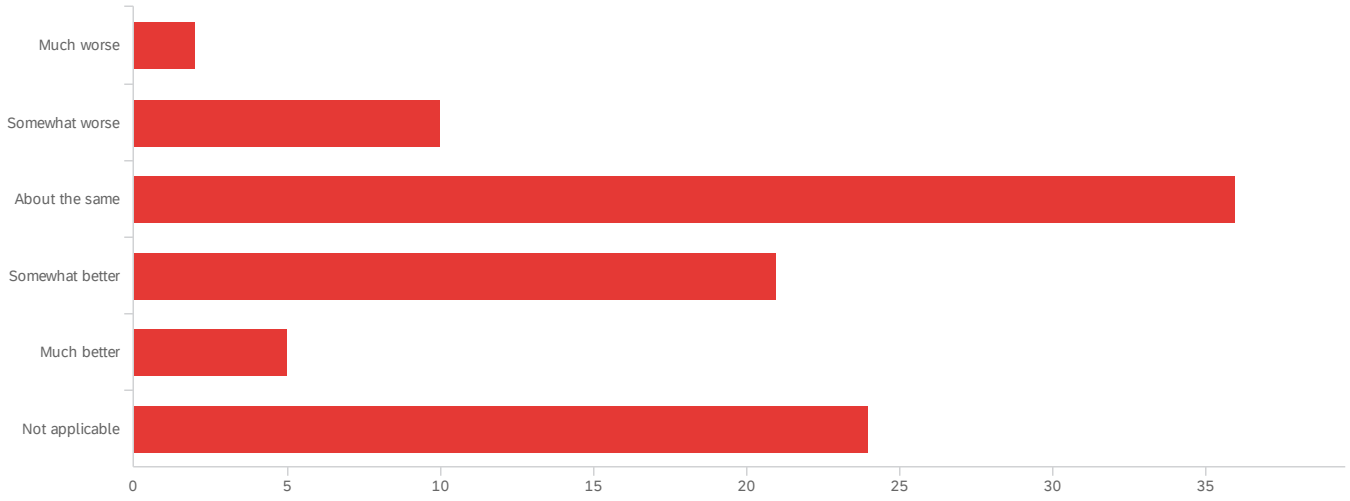
Q10 - Please describe the areas you clicked on in further detail. Details such as time of observance, whether the problem was noted at a sidewalk or a street, etc. would be helpful for our analysis. Example: 1. Bus Loop: too much salt on sidewalk in the evenings

Please describe the areas you clicked on in further detail. Details such as...
N/A
Rather poor spreading of salt around Marine; piling up in specific spots
too much salt
1. Main Mall: too much salt on sidewalk during the day
n/a
too much salt
1. rose garden: there was so much salt
The shrubs by the totem pole only ever look good for 1 month per year. Usually dead and brown
Uphill towards fountain and other steep areas felt slippery
didn't notice
Too much salt
No noticeable damage
Busloop： 痛哦牧场sa'l'tsalt
ploud grass instead
bus loop too much salt rather than removing snow
main mall right in front of Keorner library has too much salt
none
a lot of salt near chem building
too much salt at the nest throughout the day

Please describe the areas you clicked on in further detail. Details such as...

Near ikb: too much salt after evening class
Too much salt down university blvd
too much salt on stairs to wood processing
N/A
Nigh
N/A
excessive salt
Roads: too much salt
Too much salt on main path
Grasses were plowed over
N/a
Too much salt
Tbf everything is okay
sidewalk to ESB : pigeon eating salt on the sidewalk
Orchard commons residence and areas near Maths building: plants dying from cold snow.

Q11 - How has this year's snow response to date compared to previous years (if applicable)?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How has this year's snow response to date compared to previous years (if applicable)?	47.00	52.00	49.91	1.41	1.98	98

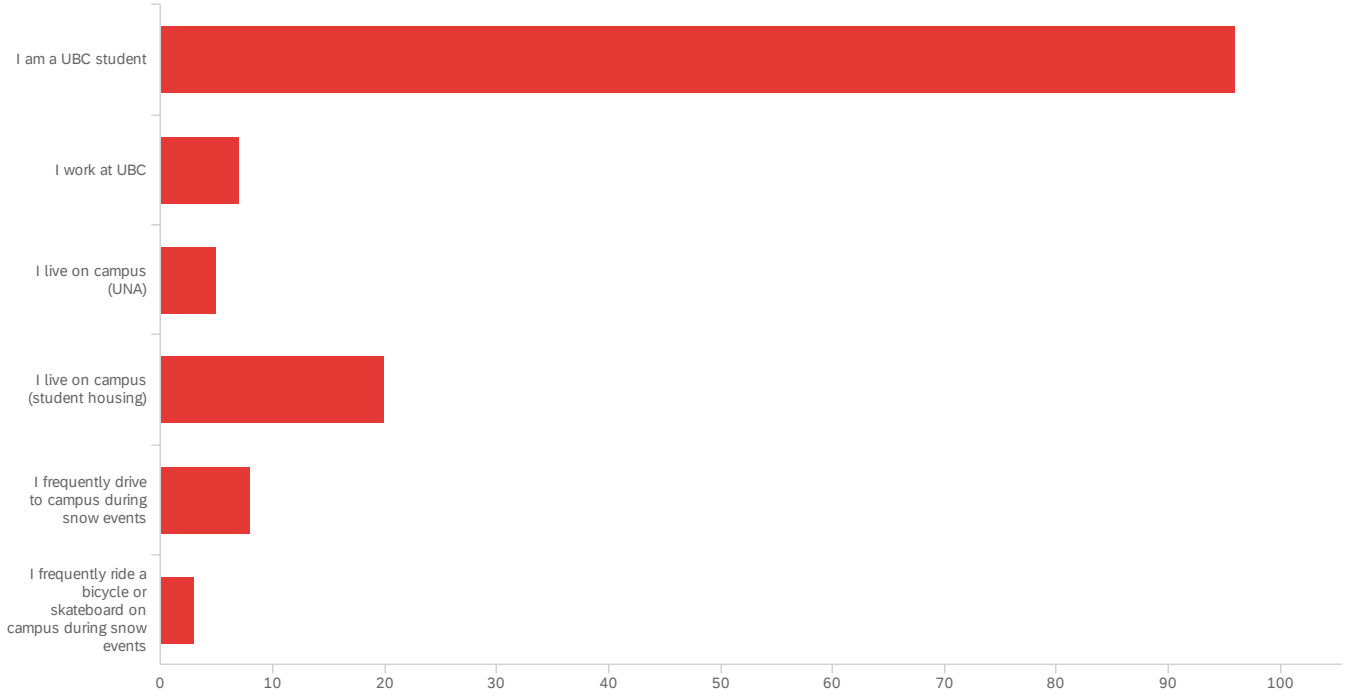
#	Field		Choice Count
47	Much worse	2.04%	2
48	Somewhat worse	10.20%	10
49	About the same	36.73%	36
50	Somewhat better	21.43%	21
51	Much better	5.10%	5
52	Not applicable	24.49%	24
			98

Showing rows 1 - 7 of 7

Q12 - Please provide any additional comments, questions, or feedback you have regarding snow removal practices on campus. Constructive feedback will be passed on to UBC Building Operations as recommendations to improve on current practices. Please also feel free to use this space to expand on your answers to previous questions.

Please provide any additional comments, questions, or feedback you have reg...
I don't really notice much because I'm from a place with a lot of snow so I don't care lol
I didn't notice anything in particular with regards to how they handled the snow this year. It felt the same as it always has. The routes were slippery as usual.
The snow response was about the same as the previous year, but in the previous year it was good. The only thing that bothers me about UBC snow removal is the amount of salt entering water/soil every time it snows.
the day after a snow day should be better managed since all the sidewalks and roads are still relatively full of snow.
UBC is much more better regarding snow removal
Everything goes well this year.
n/a
need to remove snow and ice faster
I feel the removal of snow is really quick
I'm pretty satisfied with it!

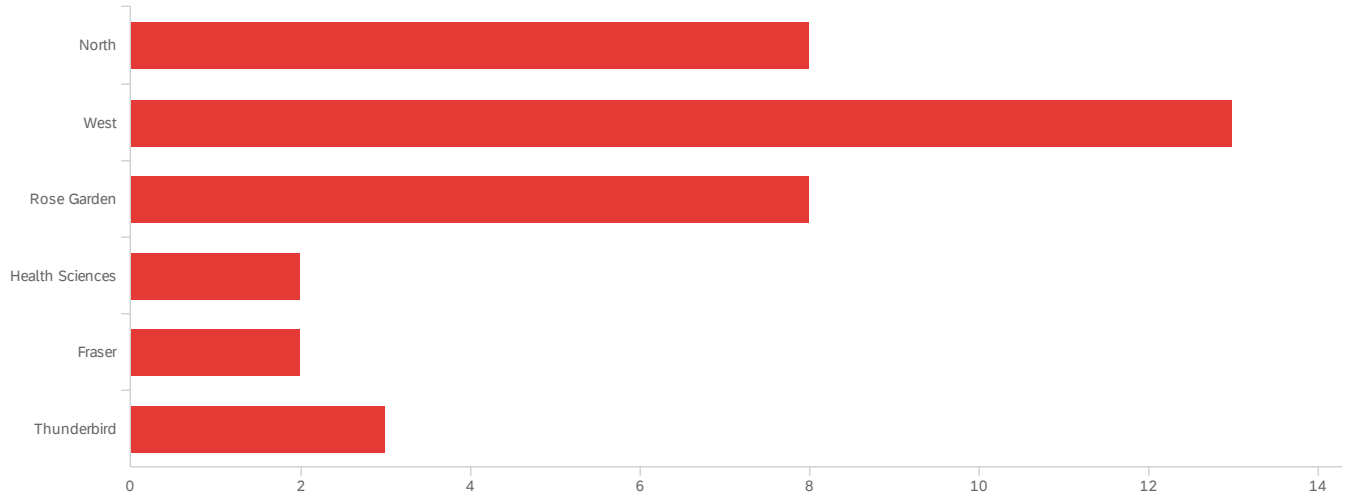
Q13 - Please select all that apply:



#	Field	Choice Count	
1	I am a UBC student	69.06%	96
2	I work at UBC	5.04%	7
6	I live on campus (UNA)	3.60%	5
3	I live on campus (student housing)	14.39%	20
4	I frequently drive to campus during snow events	5.76%	8
5	I frequently ride a bicycle or skateboard on campus during snow events	2.16%	3
			139

Showing rows 1 - 7 of 7

Q14 - If you drive, which parkade(s) do you use on campus? Please skip this question if not applicable.



#	Field		Choice Count
1	North	22.22%	8
2	West	36.11%	13
3	Rose Garden	22.22%	8
4	Health Sciences	5.56%	2
5	Fraser	5.56%	2
6	Thunderbird	8.33%	3
			36

Showing rows 1 - 7 of 7

Q15 - Around what time do you typically get to/leave campus?

I arrive on campus around (e.g. 10:30am)	I leave campus around (e.g. 5:45pm)
9:00am	5pm
9 am	5
9am	4pm
11:00am	4:00pm
10 am	7 pm
10	4pm
10	5:30
9am	6pm
9:30am	4pm
8:30am	5:00pm
2:00pm	5:00pm
9.30	17.00
10	6pm
11:30	7:30
7:40am	10pm
10:30am	6:00pm
10:00am	6:00pm
8:20 am	3:00 pm
8:30am	3pm
9 : 50am	2 : 00pm
845 am	4 pm
9:30	6:30

I arrive on campus around (e.g. 10:30am)	I leave campus around (e.g. 5:45pm)
11	4
11	4
9:30	7:30
9:30am	7:00pm
12p'm	5p'mpm
8:50am	9:00
8am	7pm
8:00am	1:00pm
9:20am	2pm
9:00am	6:00pm
9:30 am	2:00 pm
9:50am	4:00pm
9:30	6:30
8:30am	3:30pm
8:30am	5-7pm
11:00am	5:00pm
9am	2pm
9am	7pm
8 : 00 AM	5 : 00 pm
9am	5pm
945am	7pm
8:30am	5 pm
9	4
arrive around 9 am	leave around 5pm

I arrive on campus around (e.g. 10:30am)	I leave campus around (e.g. 5:45pm)
1030	600
9	2
9.00 am	7.00 pm
8:00am	5:00
8:30am	4:00pm
9am	3pm
9:00am	7:00pm
10	4
9am	6pm
9am	5pm
8:00 am	8:00pm
8 am	4pm
8am	6pm
9am	8:30pm
7:30 am	6:30 pm
8 : 00	6 : 00
8:00AM	7:00PM
8:00am	7:00pm
7 : 30	17 : 00
On Residence	On residence
9am	6pm
8:40am	8pm
8am	3pm
6:30am	10:00pm

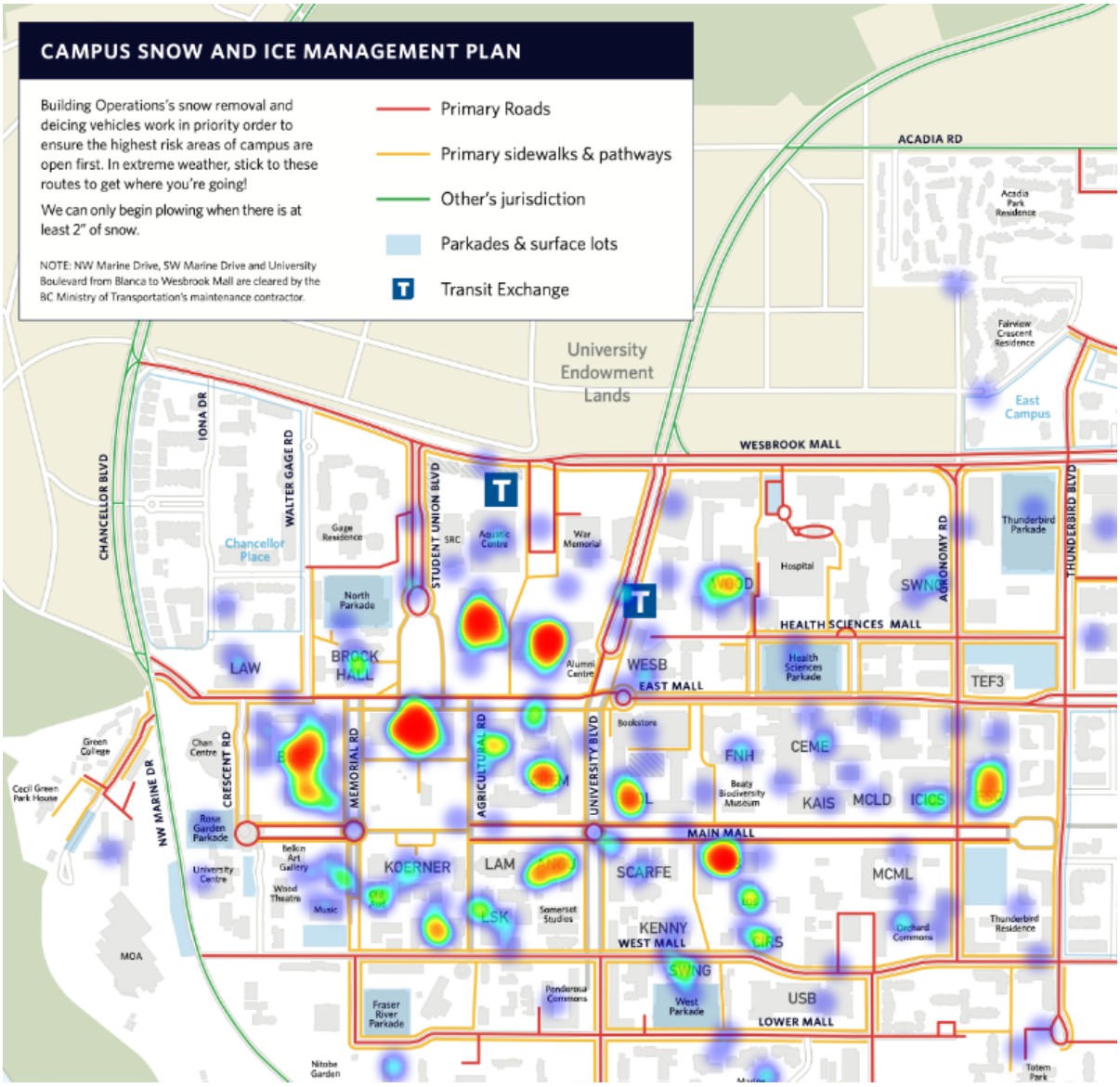
I arrive on campus around (e.g. 10:30am)	I leave campus around (e.g. 5:45pm)
9:30am	7pm
10am	6pm
9:30am	3:30pm
10:00am	3:00pm
9:30	3:30
9:20am	3:00pm
9am	5pm
9am	4pm
11am	5pm
11:30	5:30
3:00pm	7:00pm
9:00 am	2:00 pm
10:00am	5:00pm
10:00am	17:00

Q22 - Around what times do you typically travel around campus?

I leave my room around (e.g. 10:30am)	I return to my room for the day around (e.g. 5:45pm)
8:30am	3:30pm
8:50	5:00
3	7
8.30am	5pm
8 am	3-5pm
10:30am	6:00pm
11	4
8 am	5:15 pm
9:20	6:40
8:30	5:00
9am	7pm
7:30 am	6 pm
8am	5:45pm
8;30am	4;00pm
9am	5pm
7:30am	4:30pm
10	5
7 : 40am	6 : 00 pm
7	6
9am	6pm
12 pm	8 pm
9am	4pm

I leave my room around (e.g. 10:30am)	I return to my room for the day around (e.g. 5:45pm)
11am	5pm

Q14 - Please click on the buildings that you have most frequently visited during the snow season (up to 10 clicks):



End of Report