I405: Sustainability Exchange

Deicing Impacts on the Danforth Campus

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Table of Contents

INTRODUCTION

Deicing is a practice utilized to remove snow or ice from a surface. Salts such as sodium chloride (NaCl) and magnesium chloride ($MgCl_2$) are commonly used as deicing materials because they lower the freezing point of water, thus allowing snow and ice to melt more easily. Chloride-based deicers are generally the least expensive and most common deicers on the market. NaCl is the material most often used for deicing in the United States, whereas $MgCl_2$ is generally more expensive and allows for an even lower practical melting temperature.[1]

It is crucial that deicing is conducted on Washington University's Danforth campus to prevent pedestrians from slipping and falling on walkways. Insufficient salting could create a public safety risk, but over-salting also has its drawbacks. Although deicing is necessary to maintain pedestrian safety, the salts used in deicers can lead to visible deterioration of the soil, killing grass and other foliage. One indicator of this damage is the soil's electrical conductivity, which is a measure of salt content; it can signify crop yield, plant nutrient availability, and general soil health. According to the USDA, increasing electrical conductivity has an inverse effect on soil microorganism activity, impacting a number of different soil processes including respiration, residue decomposition, nitrification, and denitrification.[2] Additionally, conductivity levels can indicate water and nutrient availability, which impacts the soil's needs and treatment methods. Thus, excessive salting not only can lead to inefficient spending and environmental damage, but also contributes indirect costs to the university such as those incurred by damaged property and plant material.

These consequences are some of the primary examples of the negative implications of under- and over-salting. Hence, the direct purpose of this project is to minimize these effects, ultimately working to strike a balance between maintaining public safety and respecting nature. Indirectly, these efforts also aim to encourage students and other passersby to become more conscious of how seemingly insignificant acts, such as straying from a walkway or shuffling to class in the snow, can have severe consequences on the environment. To achieve this goal, this project's principal objective was to collect samples at three different areas on Washington University's Danforth campus and compare their conductivity, pH, and temperature readings to a fourth, baseline location. In addition to this, a GIS application was further developed to facilitate reporting of over- and under-salting on campus. Finally, an experimental plan was established to evaluate the efficacy of select soil amendments and their ability to improve soil health. The main project objectives and associated plan of action can be found in Table 1.

Table 1 Project objectives and primary action taken to implement goals

Objective	Plan of Action
1. Analyze soil quality on campus	Measure conductivity, pH, and temperature of soil from 4 different locations on campus
2. Mitigate under-salting and over-salting on campus	Develop GIS application with crowd-sourcing feature
3. Improve soil health on campus	Investigate potential of certain soil amendments

METHODOLOGY

Soil samples were collected from Mudd Field, Oak Allée, and the East End of Washington University's Campus; these locations are marked on Figure 1. Given that certain areas of Brookings Quadrangle experience minimal foot traffic and no deicing, this location was used as a control or baseline site. These areas were chosen based on their varying soil types and levels of foot traffic.

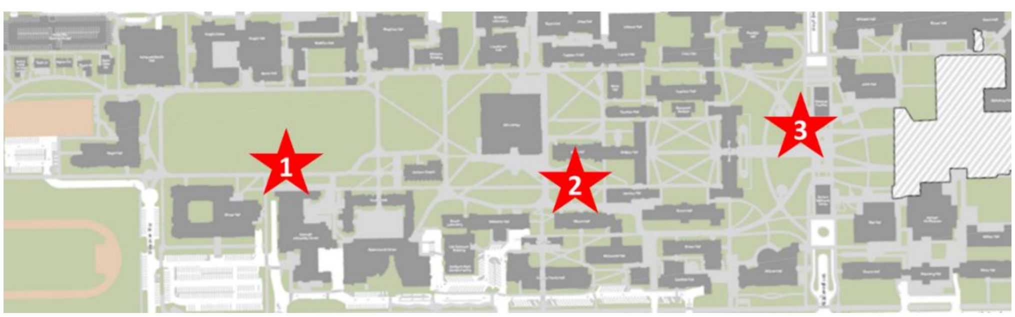

Fig. 1 Map of Danforth Campus containing sampling sites (1. Mudd Field, 2. Oak Allée, 3. East End) obtained from ArcGIS.

The soil on Mudd Field is dry and clay-like and experiences heavy foot traffic during the school year. Oak Allée is more of a "classic" soil and is located near a drain. The East End, meanwhile, has relatively healthy, sandy soil. Sampling days were chosen based on weather events, as rain, snow, and lack thereof can have varying effects on the soil's properties. The samples were taken in 30-centimeter increments starting from the edge of the sidewalk and moving outwards, which allowed soil properties to be analyzed at different distances from primary walkways. Given that people kick salt onto the grass and soil when they utilize these sidewalks, it is expected that salt concentration and conductivity will decrease with increasing distance from the walkways.

Once the samples were obtained from the field, they were taken for analysis in the laboratory. These results will reflect how soil properties such as pH and conductivity change based on location and weather events, which can be compared to findings from previous semesters.

Fig. 2 Images of sampling sites at the beginning of the Fall 2020 semester; from left to right: Mudd Field, Oak Allée, and the East End

Procedure

At each of the three sampling sites, the Soil Testing Kit was inserted into the soil, where the pH reading was given 5-10 minutes to stabilize; the resulting pH was recorded (Appendix A). During this time, an auger was used to collect roughly 20 grams of soil at 0, 30, and 60 cm from the edge of the sidewalk. Using the same process, a soil sample was also collected from the control site (Brookings) at an arbitrary distance from the sidewalk.

Once these samples were collected from the field, they were analyzed in the laboratory. 20 grams of a given soil sample were added to a clean beaker with 40 mL of reverse osmosis (RO) water. The mixture was stirred for 5 minutes using a stir plate and magnetic stir bar. After mixing, the beaker was removed from the plate and left to settle for 2 minutes. Then, a calibrated pH probe was used to measure the pH of each mixture, while the conductivity and temperature values were recorded using a handheld meter. The resulting data (Appendix A) was then analyzed and compared to previous semesters.

RESULTS

The conductivity of each soil sample was measured in the lab and compared to that of Brookings Quadrangle, which experiences limited deicing and foot traffic. Measurements were taken three times throughout the Fall 2020 semester, two of which were on dry, sunny days. The conductivities from these dry days were averaged and are displayed in Fig. 3. Mudd Field appears to experience the highest conductivity levels, which decrease with increasing distance from the sidewalk. The East End and Oak Allée do not display a consistent trend; however, it is likely that a pattern would arise if more measurements were taken throughout the semester. With the exception of 30 cm from the East End's walkway, all sites experience higher conductivity levels than those of Brookings Quad.

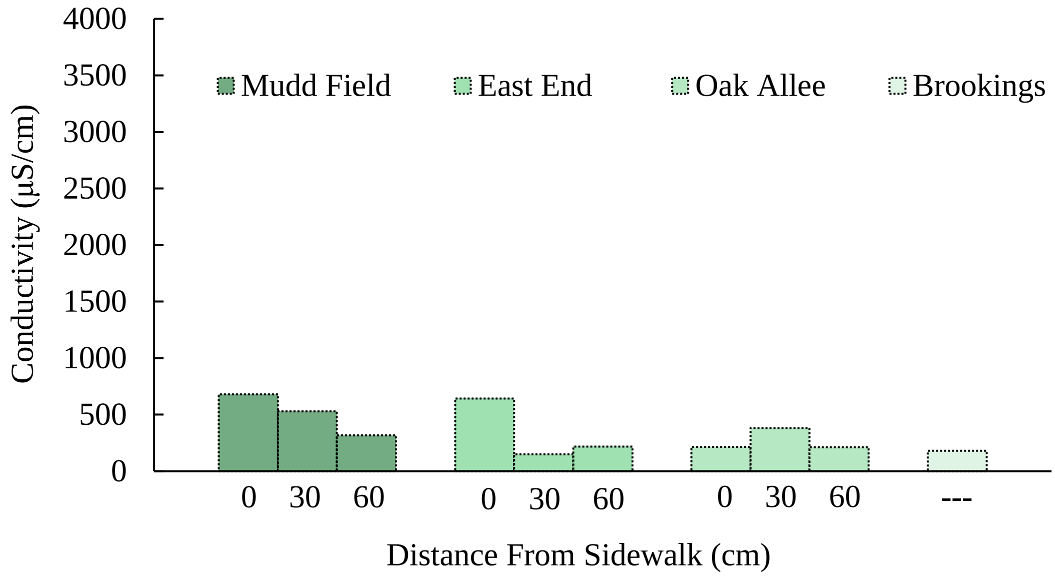

Fig. 3 Conductivity (µS/cm) of the soil relative to distance from the sidewalk (cm) at three different locations on Washington University's Danforth campus during dry days in Fall 2020. One sample was taken at Brookings Quad as a control.

Figure 4 displays the conductivities of these sites following rainfall. In general, the conductivities appear lower than those measured on dry fall days (Fig. 3) and follow similar trends. The East End's soil does experience a spike in conductivity at 0 cm from the sidewalk; however, these measurements represent only a single weather event, and further analysis should be conducted to see how additional weather events affect conductivity.

Figure 5 shows conductivity levels measured after deicing events in Fall 2019 and Spring 2020. A large spike in conductivity can be observed, particularly in comparison to the low levels depicted in Fig. 6, which displays the average conductivity following rainfall in previous semesters. As observed in the Fall 2020 semester, Mudd Field appears to have the highest conductivity of the locations analyzed.

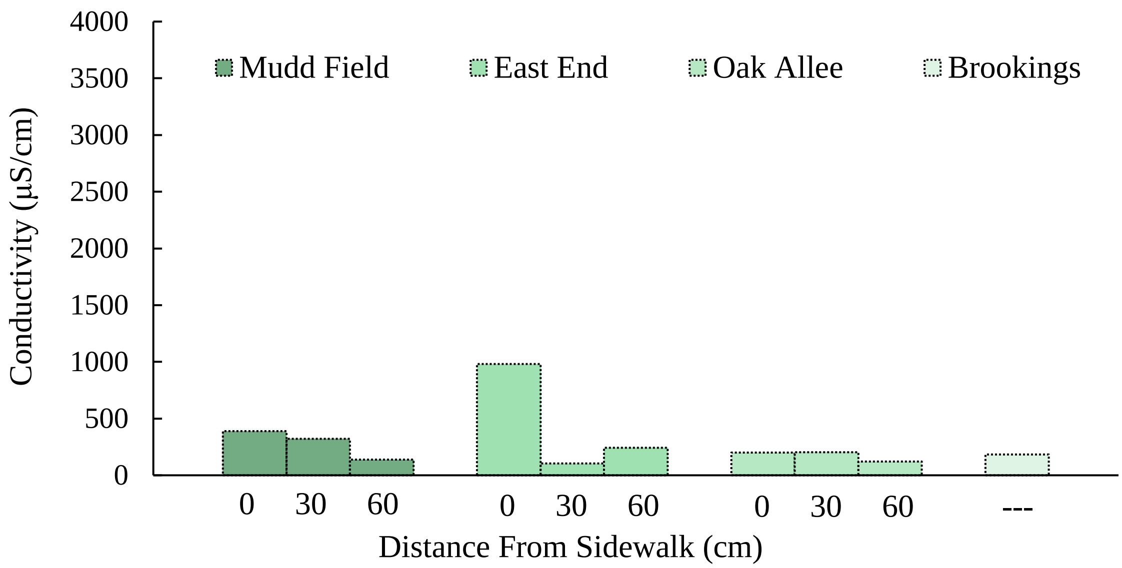

Fig. 4 Soil conductivity relative to distance from the sidewalk at three different locations on Washington University's Danforth campus following rainfall in Fall 2020. One sample was taken at Brookings Quad as a control.

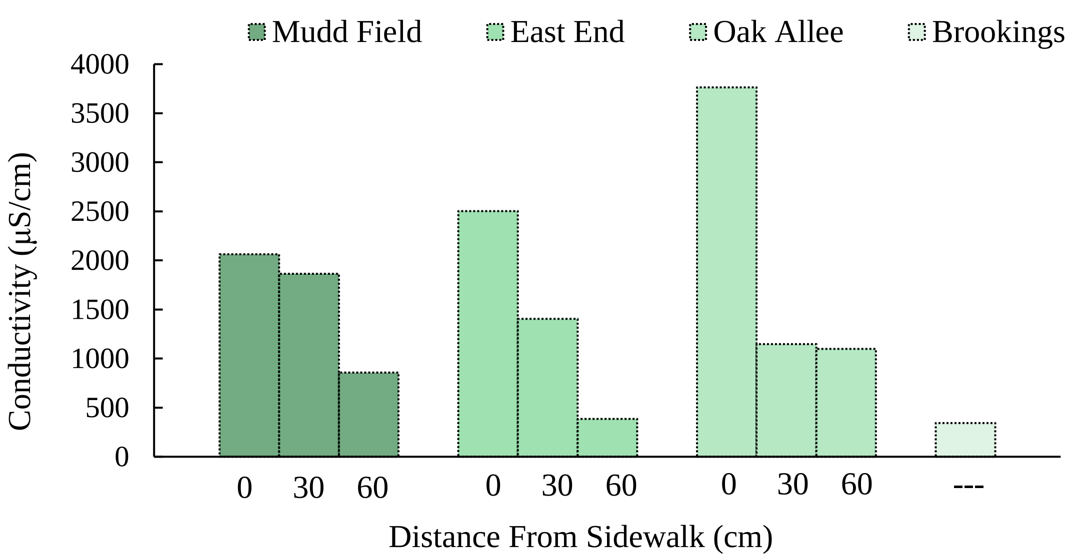

Fig. 5 Soil conductivity relative to distance from the sidewalk at three different locations on Washington University's Danforth campus in Fall 2019 and Spring 2020 after snow and deicing had recently occurred. One sample was taken at Brookings Quad as a control.

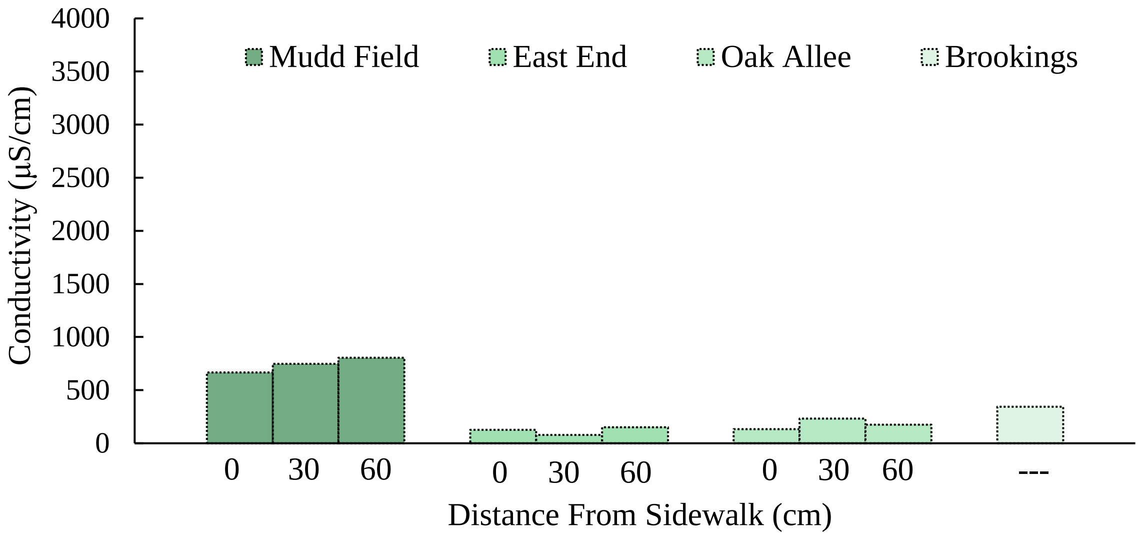

Fig. 6 Soil conductivity relative to distance from the sidewalk at three different locations on Washington University's Danforth campus following rainfall in Fall 2019 and Spring 2020. One sample was taken at Brookings Quad as a control.

Discussion

Comparing the results in Fig. 5 to the data collected on days not following a deicing event, it is clear that the soil's conductivity levels increase following deicing events. This can be expected, as the primary deicing materials used on campus have a high salt content and will naturally give rise to higher conductivity levels. Both Fig. 4 and 6 show that rainfall has the opposite effect on conductivity, with levels decreasing even lower than those observed on dry days. This trend can be attributed to the fact that salts move with water, meaning that rain will carry soluble salts deeper into the soil or into nearby drains, thus lowering the conductivity.

Regardless of weather conditions, Mudd Field most often displays the highest conductivity of the sites measured. This could be for a variety of reasons, one of which may be the soil type itself. Clay soils typically give rise to higher conductivity than other soil textures, and so Mudd Field may naturally retain greater salt content.[3] Furthermore, it is likely that Mudd Field experiences the most foot traffic of the locations considered, and more people will trek deicers onto the grass and soil as a result. While no deicing events were observed in the Fall 2020 semester, it could be valuable to see how this trend may change in Spring 2021; given that COVID testing now occurs on Mudd Field, more pedestrians will be drawn to this site than other areas of campus. In contrast, the East End encounters the least amount of foot traffic of the three primary locations, which may explain its relatively low conductivity levels.

Soil Amendments

Although deicers cause significant damage to soil, adding soil amendments can help restore the soil's nutrients. Currently, Focal Pointe applies gypsum to the campus soil annually; while gypsum does help aerate the soil and retain its moisture, it is not the only option that does so. This semester, biochar, sphagnum peat moss, and lime were investigated as possible amendments of interest. Biochar can potentially lower salinity and improve soil health; similarly, sphagnum peat lowers pH and holds moisture in the soil. Lime can also be used to adjust soil pH, and although it is slightly less promising than the others, experimentation would still provide valuable information on its effects.[4] Unfortunately, time did not permit for these effects to be tested. A preliminary procedure (Appendix B) was developed to provide a starting point for future groups that may wish to pursue this research. By conducting these experiments and analyzing the results, future groups could provide useful recommendations to Focal Pointe regarding the use of soil amendments.

GIS Development

Building off the progress made in Spring 2020, the trajectory of the GIS component of this project was altered during the Fall 2020 semester. The purpose of this project was to utilize feedback from the WashU community to determine where there may be over- or under-salting on the Danforth campus. As previously discussed, there are dangers to both over- and under-salting; too much can be hazardous to the soil, but too little increases the likelihood of pedestrians injuring themselves. The creation of a GIS application could allow these deicing techniques to be monitored. In the previous semester, the app consisted of a survey that students and staff could complete upon noticing either inadequate or extreme salting. This semester, the app was enhanced and based off a crowdsourcing application consisting of a map of the Danforth Campus; this allows for WashU students and staff to pinpoint the exact location of the observed discrepancy. Using QR codes that will be placed throughout campus, the WashU community can report on any questionable salting they encounter. This data will be accessible to Focal Pointe and enable them to monitor and adjust their salting practices. Unfortunately, due to time constraints and other roadblocks, the app is not yet at a working stage. The same goes with the establishment of the QR codes, but more time and effort, it should be up and running by next semester if the incoming group chooses to further its development. A preliminary procedure detailing the app's progress and future steps can be found in Appendix C.

RECOMMENDATIONS & CONCLUSION

In nearly all sampling cases, an expected decrease in soil conductivity with increasing distance from the sidewalk was observed. This trend becomes most evident following snow and subsequent deicing events, as pedestrians track salt onto the grass when they utilize freshly treated walkways. Following rainfall, however, conductivity levels decrease dramatically, as water travels through the soil and carries soluble ions away from sampling sites. It is recommended that future groups investigate ways to mitigate the resulting soil damage through the exploration of soil amendments, which would involve laboratory tests and a cost-benefit analysis. Furthermore, the groundwork has been laid for the development of a GIS app that will allow members of the WashU community to report on over-salting and under-salting on the Danforth campus. While the application is not currently operable, future groups can work to enhance its robustness so that it can be implemented and utilized by Focal Pointe. It is the hope that with these recommendations, future groups can find further success in not only minimizing the campus's costs and soil damage, but also making it a safer and more flourishing environment.

References

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(4) Preparing Soil for Planting. https://www.almanac.com/preparing-soil-planting (accessed Dec 14, 2020)

(5) Salinity Conversion Calculator. https://www.hamzasreef.com/Contents/Calculators/SalinityConversion.php (accessed Dec. 14, 2020).

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APPENDICES

The following appendices include raw data from the lab experiments and field measurements, a procedure for soil amendment experiments to be performed in the future, and a detailed description of the next steps for the GIS application development.

Appendix A: Raw Data Collection

Tables A1-A3 display the values measured (temperature, pH, and conductivity) for each sample in the lab in addition to calculated values (total dissolved solids and salinity). The total dissolved solids (TDS) values were calculated as follows:

$$\text{TDS} = 0.64\sigma$$

where TDS represents the total dissolved solids in the soil (ppm) and σ represents the electrical conductivity of the soil (μS). The salinity values (ppt) were calculated from the conductivities using an online conversion tool.[5] Tables A4-A6, meanwhile, display the raw data from field testing at each of the soil sites.

Table A1 Sampling data from 10/08/2020, including distance from the sidewalk (cm), temperature (°C), pH, conductivity (μS), TDS (ppm), and salinity (ppt). In addition to the three main locations, one sample was also taken at Brookings Quadrangle as a control.

Location	Distance (cm)	Temperature (°C)	pH	Conductivity (μS)	TDS (ppm)	Salinity (ppt)
East End	0	22.8	7.57	305.0	195.2	0.15
	30	22.0	7.62	197.2	126.2	0.10
	60	21.9	7.50	193.1	123.6	0.09
Oak Allee	0	21.7	8.29	230.0	147.2	0.11
	30	21.5	7.71	561.0	359.0	0.27
	60	21.7	7.05	303.0	193.9	0.15
Mudd Field	0	21.2	8.46	968.0	619.5	0.48
	30	22.3	7.85	738.0	472.3	0.36
	60	21.2	7.11	496.0	317.4	0.24
Brookings	-	21.7	7.06	182.5	116.8	0.09

Table A2 Sampling data from 10/22/2020, including distance from the sidewalk (cm), temperature (°C), pH, conductivity (µS), TDS (ppm), and salinity (ppt).

Location	Distance (cm)	Temperature (°C)	pH	Conductivity (µS)	TDS (ppm)	Salinity (ppt)
East End	0	22.5	7.74	980.0	627.2	0.48
	30	22.4	7.61	105.6	67.6	0.05
	60	21.9	7.62	244.0	156.2	0.12
Oak Allee	0	22.0	7.88	200.0	128.0	0.10
	30	21.8	7.66	203.0	129.9	0.10
	60	21.8	7.94	120.3	77.0	0.06
Mudd Field	0	21.8	8.34	390.0	249.6	0.19
	30	21.7	7.93	322.0	206.1	0.16
	60	21.8	7.58	139.4	89.2	0.07

Table A3 Sampling data from 11/05/2020, including distance from the sidewalk (cm), temperature (°C), pH, conductivity (µS), TDS (ppm), and salinity (ppt).

Location	Distance (cm)	Temperature (°C)	pH	Conductivity (µS)	TDS (ppm)	Salinity (ppt)
East End	0	21.8	7.51	277.0	177.3	0.13
	30	21.8	7.69	134.1	85.8	0.07
	60	21.2	7.67	318.0	203.5	0.15
Oak Allee	0	22.1	7.18	612.0	391.7	0.30
	30	21.5	7.54	214.0	137.0	0.10
	60	21.9	7.93	192.2	123.0	0.09
Mudd Field	0	22.0	8.64	520.0	332.8	0.25
	30	21.6	8.22	1112.0	711.7	0.55
	60	21.4	8.06	329.0	210.6	0.16

Table A4 Sampling data from field tests on 10/08/2020, including temperature (°C), pH, and fertility.

Location	Temperature (°C)	pH	Fertility
East End	24.4	7	1
Oak Allee	27.2	7	6
Mudd Field	27.8	7	0

Table A5 **Sampling data from field tests on 10/22/2020, including temperature (°C), pH, and fertility.**

Location	Temperature (°C)	pH	Fertility
East End	25.6	1	7
Oak Allee	22.8	5	5.9
Mudd Field	30.0	4	7

Table A6 **Sampling data from field tests on 11/05/2020, including temperature (°C), pH, and fertility.**

Location	Temperature (°C)	pH	Fertility
East End	16.1	0	7
Oak Allee	19.4	5	7
Mudd Field	20.6	0	7

Appendix B: Soil Amendments Procedure

To test the effect of soil amendments on soil health, future groups should consider using a procedure similar to that utilized for soil sampling. While any of the sampling sites can be used as the soil base, it is recommended that samples from Mudd Field be chosen, as this clay-like soil's health has the most room for improvement. 20 grams of this soil should be added to a beaker with the corresponding amount of amendment listed in Table A7. After adding 40 mL of RO water to the mixture, the solution should be mixed for 5 minutes with a stir plate and magnetic stir bar. After this, it should be removed from the stir plate and given 2 minutes to rest. Once the solution has settled, the pH, temperature, and conductivity of the mixture can be measured, and this process should be repeated for each amendment listed in Table A7. By comparing these results to the control sample, recommendations can be made about the potential of soil amendments investigated in this experiment.

Table A7 **Amounts of soil and soil amendment to be mixed in a 100 mL beaker with 40 mL of RO water**

Amendment	g of Amendment Added	g of Soil Added
None (Control)	0	20
Biochar [6]	10	10
Sphagnum Peat [7]	5	15
Lime [8] *units must be converted	300-400	*Per 1 m^2 of soil

Appendix C: Description of GIS Trajectory

The development of the GIS application commenced with researching different foundations that could be used for the application itself. After conducting preliminary research and contacting the head of the GIS department, Bill Winston, the team was directed toward a crowdsourcing app through ArcGIS Online called Crowdsource Reporter. A key feature of Crowdsource Reporter is a program called Citizen Problem Reporter. Lessons are provided that allow users to become familiar with how to use the app. After attempting to follow along with these lessons, the team encountered technical difficulties on ESRI's end, the company that houses ArcGIS and its online applications, and received limited assistance from their IT department.

Should future deicing teams choose to continue with the GIS app, there would need to be a transfer of information and access so that the next group can retrieve the information necessary to complete the app. For the project to be successful, contact should be maintained with Bill Winston, along with Genna Torgan, the team member in charge of the app implementation in Fall 2020. An initial meeting, at the very least, will help ensure a smooth transition. Additional resources that will be helpful in learning how to use the application and ArcGIS Online can be found in Table A8. The hope is that next semester's team will be able to complete the app in its entirety so that it can be deployed in the Wash U community, which will allow Focal Pointe to further inform their deicing practices.

Table A8 Useful resources that will help future groups become familiar with ArcGIS and enable them to bring the GIS application to completion. The links are provided in the right-hand column.

Source Description	Link
ArcGIS Online (AGOL) – GIS (Geographic Information Systems) – Research Guides at Washington University in St. Louis	Research Guides
Washington University in St. Louis ArcGIS Access	ArcGIS Access
Map-Making Workshop	Workshop
Introduction to ArcGIS Online	Tutorial