PENNSTATE Harrisburg 1855

Salt Transport in a Bioretention Basin after Roadway Deicing Applications

Carrie Fischer[1], Shirley E Clark[2], Lauren McPhillips[3], Hong Wu[3], Sybil Gotsch[4]

[1]NTM Engineering, Inc., Dillsburg, PA, [2]Penn State Harrisburg, Middletown, PA, [3]Penn State University, University Park, PA, [4]Franklin and Marshall College, Lancaster, PA

Introduction

- In winter, the Mid-Atlantic region of the United States is subject to mixtures of snow, freezing rain, sleet, and rain – sometimes all in one storm event. This results in the need to clear streets and apply road salt for traffic safety.
- Melting of the snow occurs due to higher temperatures and/or rain falling on the snow, transporting the applied salt in the meltwater (Figure 1).
- This project investigated the impacts of this weather cycling on the salinity of the water entering and in the soil pores of a bioretention basin in the city of Lancaster, PA in the 3-month winter period of 2021.
- Multiple snow and wintry precipitation storm events occurred during this monitoring period, with three resulting in deicing salt application to the nearby roadway and sidewalk.

Figure 1. Salt accumulation in a campus parking lot over winter season.

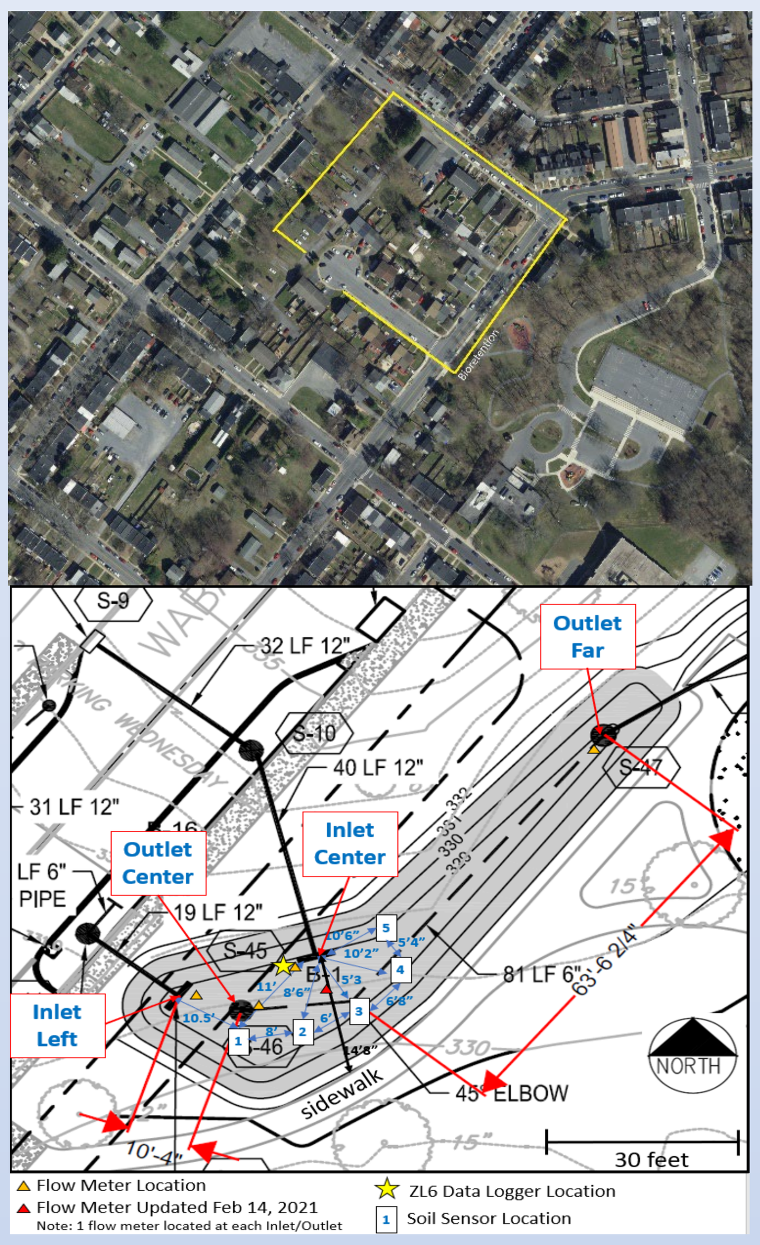

Figure 2. Top: Brandon Park bioretention drainage area outlined in yellow. Bottom: Sensor locations in basin.

Methodology

- The study focuses on the upper basin in Brandon Park, Lancaster, PA. Drainage to the basin comes from Wabank Street and Brandon Court. The land use is high-density residential, with a recreation center and an elementary school (Figure 2).
- 5 TEROS 12 sensors (The METER Group) were installed in the bioretention basin and collected data continuously every 15 minutes. The five soil sensors were buried approximately 7.5- to 10-cm deep from the surface of the basin to ensure that they were installed in the top 20 cm of bioretention media. They measured the soil temperature (ºC), bulk saturation extract (mS/cm), and moisture content (m^3/m^3) of the soil. This study focused on Sensors 2 and 3, which were in the direct flowpath of water entering the basin from the Center Inlet.
- 4 Solinst Levellogger 5 meters were installed in the basin by the inlets and outlets. The loggers measure the temperature (ºC), conductivity (mS/cm), and depth (m) of the flow every 5 minutes. This study focuses on the Center Inlet flow meter.
- The temperature during the study period of mid-December 2020 through early March 2021 ranged from a minimum of -13.6 ºC to a maximum of 21.9 ºC.
- Hourly recorded weather data was obtained from Millersville University Climatology Center and the NOAA Weather Station at the Lancaster, PA airport. The Millersville University weather station is located approximately 5 km from Brandon Park and the Lancaster Airport is approximately 11 km from Brandon Park. The Millersville gage recorded the water-equivalent precipitation along with a description of the weather (fog, mist, light rain, rain, heavy rain, light snow, snow, heavy snow, freezing rain, sleet, etc.). The recorded precipitation acts as a general estimate for this study.

Results and Discussion

- Figure 3 shows the sensor setup on the center inlet between storms in January and immediately after a storm in February. Winter cycled between snow, rain, sleet, and dry periods above freezing.
- Figure 4 shows the results of the first road salt application (top) and the last road salt application of the season. Salt concentrations measured (as bulk electrical conductivity) in the soil and by the water logger show the increase in conductivity between the first and last storms.
  - The total salt application in the first storm was half as much as the last storm.
  - Even in a sandy bioretention soil, salinity/conductivity remained high between storms.
  - Salt was not transported until sufficient snow melted or rain occurred to transport the salt to the bioretention basin. In an urban area with concrete and asphalt drainage pathways, a light rain was sufficient to transport the salt.
- Soil conductivity did not return to background levels until June 2021, indicating potential salt retention during sensitive growth periods for bioretention vegetation.

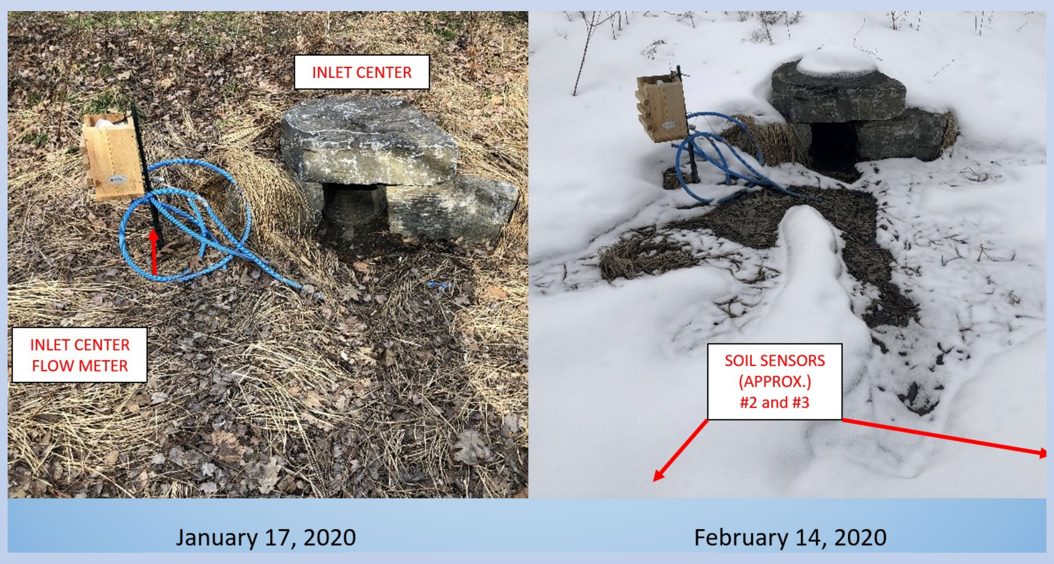

Figure 3. Installation during no-snow and snow periods.

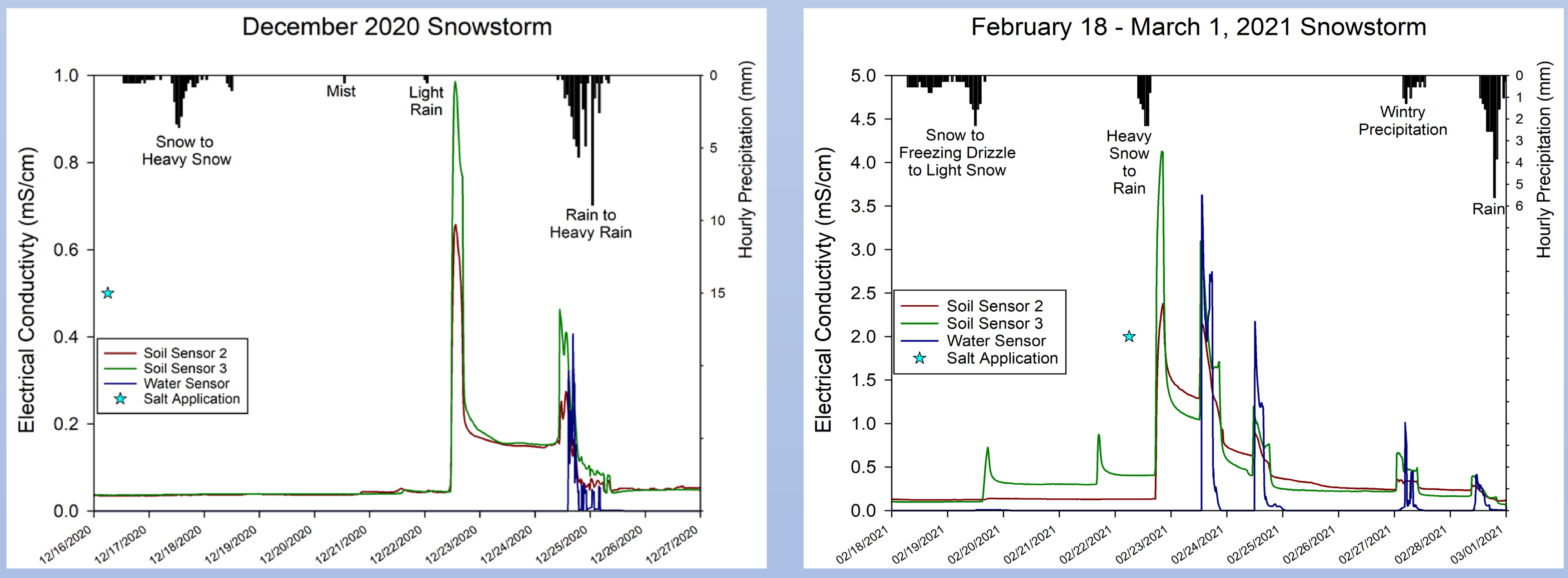

Figure 4. Winter 2020-21 season highlighting first (left) and last (right) storm and precipitation.

- To understand vertical salt migration, Sensors 1 and 2 were paired vertically prior to the Winter 2021-22 season, as were Sensors 3 and 4. These vertical pairings were installed where Sensors 2 and 3 were installed for Winter 2020-21. This put 1 sensor in the bioretention media and 1 in the sand underlayer.
  - Figure 5 compares Winter 2020-21 and Winter 2021-22. Winter 2021-22 had 50% of the snowfall, but the same number of salt applications. In Winter 2021-22, all three storms occurred within 1 month, reducing the time available for rain to flush salt through the basin prior to the next salt application. For the paired sensors, conductivity was slightly higher in the media layer compared to the sand layer, indicating that attenuation in the media was limited.

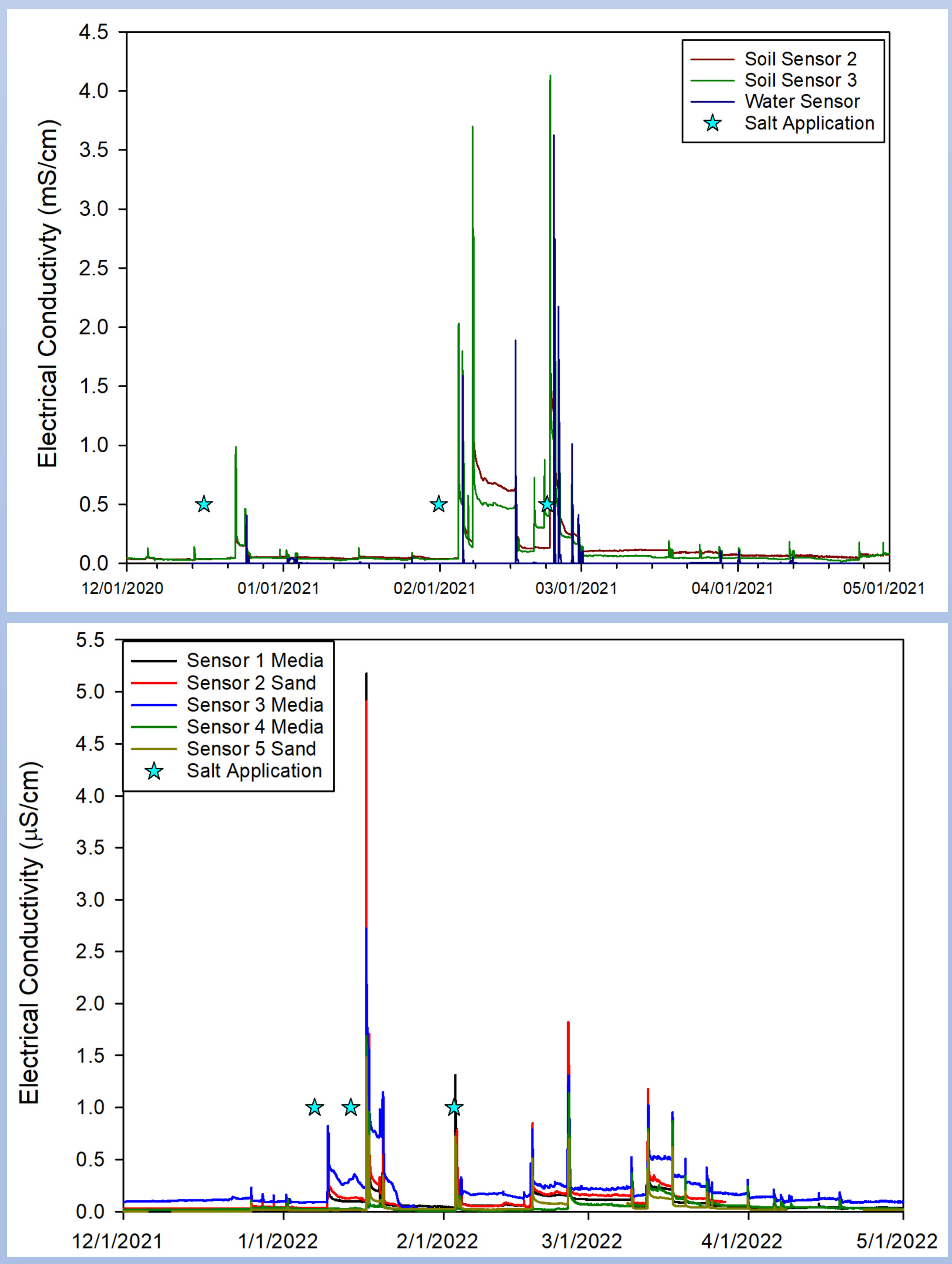

Figure 5. Top: Winter 2020-21 season and sensor responses. Bottom: Winter 2021-22 season and sensor responses.

Conclusions to Date

- During snow and/or cold, no measurable water entered the basin and no change in soil electrical conductivity.
- When rain followed salt, soil conductivity increased and then rapidly decreased to above baseline, before slowly decreasing as more flow entered the basin.
- Conductivity concentrations in soil and water increased after every de-icing salt application.
  - Response time to peak conductivity decreased as the rain intensity and/or air temperature increased.
  - Winter 2022 was warmer than 2021, resulting in more rapid flushing of the system.
  - Little salt attenuation in engineered media, indicating that salt would transport to downstream waterbodies.
- At the end of winter, soil conductivity took at least 60 days after last recorded salt application to decrease to baseline.

Acknowledgments

1. The City of Lancaster (Kate Austin and Angela Brackbill) has partnered on this project and others to allow for these detailed studies of bioretention system behavior in winter.
2. Initial funding from Penn State Strategic Planning grants (PI: Wu).
3. Current funding from the Chesapeake Bay Trust (PI: McPhillips).