Road Salt Runoff: Impervious Surface Area and Salt Concentrations in Urban Water Bodies

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Road Salt Runoff: Impervious Surface Area and Salt Concentrations in Urban Water Bodies

By:

Jordan Pharris

AN UNDERGRADUATE THESIS

Presented to the Faculty of
The Environmental Studies Program at the University of Nebraska – Lincoln

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For the Degree of Bachelor of Science in Natural Resources

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ABSTRACT

This experiment was designed to study the effects of one factor that may impact the quality of urban water bodies – the effects of impervious structure, such as roadways and other paved surfaces, on the concentration of salt in urban water bodies resulting from road salt application during winter months. The experiment included both field and laboratory research methods, as well as aerial imagery interpretation and literature review. The in-field research component was based at Holmes Lake, located in southwest Lincoln, Nebraska in an urban environment, where water samples from two tributary inputs were routinely collected over a 5 month period from November 2011 to March 2012. The water samples were then analyzed using laboratory equipment at the University of Nebraska - Lincoln’s Water Science Laboratory to detect for the presence of salt within the samples. Additional in-lab analyses included performing statistical calculations based on information obtained from the results of the laboratory studies, and making generalizations about impervious structure coverage surrounding the Holmes Lake watershed from current aerial photographs. The results of the analyses suggest that very little road salt runoff was received by the tributaries entering Holmes Lake, as significant (traceable) salt concentrations were only detected from four of the 20 collected water samples. The relatively low recordings of salt concentrations detected in the water samples may be due in part to winter conditions during the study and/or study parameters. Deductions on the impact of impervious structure on salt concentrations in Holmes Lake, from road salt application, from this experiment alone were, therefore, inconclusive. The author recommends study amendments to strengthen the research methodology, and insight as to how this type of experiment would be valuable for
municipalities to track the amount of road salt use and runoff that occurs in urban areas as a potential disturbance to urban water quality.
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I. INTRODUCTION

Water is such a simple molecule, made of two hydrogen atoms bonded to one oxygen atom; however, water is an essential element of life. Water can do amazing things like fuel our bodies, create energy, and even clean our cars. All living things on earth depend on water to survive, and therefore, the quality of our water is of vital importance.

The term “water quality,” is used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. Water that may be adequate for washing your car, for example, may not be suitable for human consumption. In most cases, the average person thinks about the quality of water in terms of its suitability for use, such as, is it good enough to drink? To swim in? To use for household chores? Or, is the quality of our natural waters suitable to support aquatic plants and animals? These questions can be used to categorize water quality for a number of different water uses, and assign an acceptable level of quality correlated to the use.

Water quality tests are usually run for the physical, biological, and chemical conditions of a water body or source. Physical tests can include turbidity (the clarity of the water), conductivity (the ability to conduct or transmit heat, electricity, or sound), color, taste and odor. Conductivity is highly dependent on the amount of dissolved solids in the water, such as salt. (UNICEF, 2010). Biological testing parameters consist of running test for microbiological contaminates that result from the environment in which the water bodies are located and the ecosystem that it provides. For instance, a decomposing animal can be host to millions of micro-biological contaminates and can compromise water quality if the host carcass comes in
contact with a water system. In most cases, we are most concerned about micro-biological pollutes that can be harmful if consumed by humans.

Harmful chemical compounds are also of concern and can include nitrate, iron, and cyanide. Harmful chemicals come from both “point” and “non-point” sources. Point sources are those that can be linked to a single source, such as a power plant or wastewater treatment facilities. Non-point sources are those that cannot be linked to any single source. For example, agriculture fields are a large contributor of non-point pollutants. Often times, fertilizers from agriculture runoff can increase the amount of nutrients in a water body and promote excessive growth of algae that can use all of the dissolved oxygen in a water body, causing eutrophication.

For this project I focused on one factor that may affect water quality of an urban water body, and how it can be handled by cities. Water quality of urban water bodies may be affected by many factors, and is important for municipalities for drinking purposes, aesthetics, urban recreation use, and many other ways in which a municipality utilizes water. The question I will attempt to address is, does the amount of impervious roadway surrounding a tributary have an effect on the amount of dissolved salts entering that water body due to the use of road salt during the winter months. I believe this is an important question because, as urban areas expand, the many factors that may affect the water quality of urban water bodies will become increasingly important to understand for municipalities that utilize these water bodies.

Both natural and anthropogenic (human induced) sources can contribute to salt concentrations in urban water bodies. Atmospheric deposition and rock weathering are natural sources of salt concentrations and are dependent on geographic location and geological setting.
Agricultural runoff, wastewater treatment plants, and septic systems can also attribute to salt accumulation in water bodies in highly urban areas. During winter months, de-icers are applied to impervious surfaces such as roads, walkways, and parking lots to keep these areas clear of ice and snow. There are many de-icers used around the country, but due to low cost and ease of use and storage, sodium chloride (NaCl), or rock salt is used most often (Gardner & Royer, 2010). Once temperatures reach above freezing snow and ice melt often facilitates the transportation of salt into streams, lakes, urban storm water runoff systems, and other water ways.

The accumulation of salt in water bodies is often an ongoing process. In most cases, salts are diluted by large water volumes, into non-harmful concentrations. These diluted concentrations then move through the water cycle and are transported elsewhere. However, when salts accumulate in a water system with low water volume, movement, or a combination of both, the concentration of salt can build to harmful levels. These less than desirable concentrations can cause an array of water quality problems that affect many different systems and compromise water use.

The effects on both aquatic and terrestrial ecosystems can include acidification of water bodies, mobilization of toxic metals through ion exchange or impurities in road salt, changes in mortality and reproduction of aquatic plants and animals, altered community composition of plants in riparian areas and wetlands, facilitation of saltwater species into previously freshwater ecosystems, and the interference with the natural mixing of lakes (Band et al., 2005). At relatively low concentrations, salts also have been shown to alter the structure of microbial
communities and inhibit de-nitrification, a process that is critical for removing nitrate and maintaining water quality in surface waters (Elshahed et al., 2004).

Humans are able to tolerate higher concentrations of salt much better than other species, but if these dissolved salts reach surface waters used for drinking water the effects can be noticed. Even when the water is purified it can leave a salty metallic taste and may have unpleasant odors. The water is safe for drinking purposes, but is often less thirst quenching than less salt-polluted sources of water.

Sodium chloride, commonly known as rock salt, is used all around the United States to aid in snow and ice removal. It is applied dry to impervious structures but does not truly begin its snow and ice fighting job until it dissolves into brine. Brine is water that is saturated or nearly saturated with salt. This brine lowers the temperature at which the resultant solution (saltwater) will freeze. For sodium chloride (NaCl) the temperature at which a solution of salt and water will freeze decreases as the concentration increases until the concentration reaches 23.3% (Principles of Road Salt, 2011). The application of road salt helps us get around during winter months when the weather brings snow and ice. Without this ability to lower the freezing point of water, snow and ice would persist until temperatures warm above the freezing point of freshwater (32°F). Without the use of an applicant such as road salt, the transport of goods, people, and services could be hindered for quite some time.
Dissolved salts in a water body can be measured in a variety of ways. We can measure salt by its concentration, which is the amount by weight of salt in water (measured in ppm), and the amount of chloride in water (measured in mg/liter). To obtain these measurements, gravimetric methods can be used which evaporate the liquid solvent (water) away leaving the particulate (salt) behind which can then be weighed. Electric conductivity can also be used to measures the amount of dissolved ionized solids that are closely related with salts (Bergman, 2001). These measurements are acceptable measures of salt concentrations depending on the task at hand and what needs to be measured, but what they cannot tell us is the origin of the dissolved solid.

Because water has a relatively low amount of dissolved solids it is useful to use chloride/bromide ratios to give us the amounts and sources from which these dissolved solids are coming from. For example, natural ground water has a mass ratio approximately 100-200:1, atmospheric precipitation approximately 50-100:1, domestic sewage approximately 300-600:1, summer runoff approximately 10-100:1, and water affected by the dissolution of salt approximately 1,000-10,000:1 (Davis et al., 1998). Using these approximate ratios as a baseline for source type ratios, a lab could analyze a sample of water and be able to determine not only the amount of dissolved solids in the sample, but also determine if the solids result from the dissolution of salts from road salt runoff or from other sources.

Previous studies have been performed linking the amount of impervious structure to increased amounts of salt from road salt runoff within surface waters. Most studies have been concerned with increased amounts of salt within our stream systems because of the lower
water volumes and because streams are often the first point at which the salts begin to affect water quality.

One such study was performed using stream channels in Baltimore City, Maryland. The study was used to research the relationship between the amounts of impervious surface coverage and the amount of salt entering streams. Concentrations of chloride within the system were measured weekly from 1998 to 2002 without regard to flow conditions - meaning there was no bias toward storm flow vs. base flow. The samples were filtered in the field and analyzed for chloride using a Dionex LC20 series chromatograph, a machine used to determine the concentration of chloride within the solution. After the study was complete the findings were analyzed and it was found that the mean annual concentration of chloride in Baltimore streams increased as the relative amount of impervious surface increased. In developed areas with over 40% impervious surface coverage, mean annual concentrations of chloride exceeded the thresholds of tolerance for sensitive taxa of fresh water life. The concentration of chloride remained elevated throughout the spring, summer, and autumn and were reported up to 100 times greater than concentrations found in streams draining forest and agriculture watersheds without impervious structure (Band et al., 2005).

Site Description

The field research was conducted at Holmes Lake, located in the southeast portion of the City of Lincoln, Lancaster County, Nebraska. More specifically, Holmes Lake is located on 70th Street between East Van Dorn Street (to the north) and Pioneers Boulevard (to the south). The lake is within the Holmes Lake watershed that lies within the larger Middle Salt Creek watershed.
Holmes Lake was originally constructed in 1972 for flood retention and control purposes; however, the lake provides additional recreational benefits for Lincoln residents including boating, fishing, and hiking. The lake is sustained by two stream channels, Antelope Creek and an unnamed tributary, which enter the lake from the south and southeast, respectively. The two streams share the same watershed with land use consisting primarily of residential and commercial properties. A golf course also surrounds the southeast corner of the lake. I chose Holmes Lake for the site of my research study because of the two streams that contribute to the lake. By analyzing water samples taken near the inlets of each stream, I will be able to draw some conclusions about the amount of salt detected within the samples, whether the salt concentrations come from road salts or other sources, and if the amount of impervious roadway surrounding the two streams contributes to the amount of salt from road salt use found within the samples.
Figure 3
II. MATERIALS AND METHODS

Materials

- Waterproof, chest-high waders
- Garmin GPS unit
- Ice auger
- Log book
- Sharpie
- Pen/pencil
- Camera
- Water thermometer
- Measuring stick – PVC pipe marked to four and a half feet in inch increments
- Approximately 20 – 250-ml Nalgene sampling jars with labels
- Dionex ICS-90 chromatograph (lab use only)
- Syringe with filter
- 4 ml. laboratory sample tubes (for use in chromatograph)

In-Field Methods

Water samples were taken at the inlet of each stream in 2 week increments, beginning November 6, 2011, and ending March 11, 2012. A Garmin GPS unit was used to mark way points at the sample locations. At each location, waterproof, chest-high waders were used to wade out into the water to the approximate middle of the stream inlet (at its confluence with Holmes Lake), using the GPS to find the previously recorded way point. When the lake Surface froze over during the sampling months, an ice auger was used to create an opening in the ice at the sampling locations.

At the sample location, a measuring stick was used to record the depth of the water from the water’s surface to the lake bottom and was recorded in a log book along with other information discussed below. The samples were collected in 250-ml Nalgene sampling jars with labels to record sample date, time, number, and location. The jars were first rinsed out using lake water to rid them of any unwanted contaminates. The jars were then flipped upside down
(above water) and inserted into the water at a depth of approximately 1 foot, then flipped right-side up for water intake. This is done because the air trapped within the jar when held upside down will help to displace any water until the jar can be lowered to the correct sampling depth of approximately 1 foot below the water’s surface. The jars containing the water samples were secured with a lid and stored in a dark, refrigerated place until they were ready to be taken to the lab for anion testing. Anions are relatively stable and will keep for some time if the water is kept cool in a refrigerator. This makes analyzing the samples easier as they do not need to be taken to the lab right away, but can sit in the refrigerator until a convenient time for lab work.

In addition to the information recorded on the sampling jar labels, a log book was kept to record the following information at each sample location, for each sample, at the time of the sampling: air temperature, water temperature, precipitation accumulation within the past 24 hours and 48 hours (or if no precipitation fell within the last 48 hours, the time of the last precipitation event will be recorded instead), depth of water at the sample location, and any other relevant visual lake conditions (ex. ice or snow cover, waterfowl or animal use, surrounding vegetation, etc.). This process was completed at each sample location at the date/time of each sample.
Figure 5
In-Lab Methods

All samples were stored and refrigerated to preserve anions until the testing date. Once taken to the lab all samples were filtered to remove any particles that can skew the result of the test. Filtration was done by using a filter attached to a syringe. Filtered samples were then placed into 4ml laboratory test tubes. Two random samples were selected from the twenty samples to be used as a control to ensure accuracy. From here all samples were given to Dr. Snow’s laboratory technician, Jesse Voelker, to run through the Dionex ICS-90. The chromatographer is able to determine the amounts of chloride, bromide, fluoride, nitrate, nitrite, orthophosphate, and sulfate within given samples. All results of the Dionex ICS-90 tests were analyzed by Jesse and Dr. Snow to determine the exact concentration of anions. These results were then given to me (see Appendix A) and I preformed the chloride to bromide ratio by simply dividing the amount of chloride by the amount of bromide in solution which will help us to determine the origin of the anions.

Part of my research question involves making some assumptions about how the general amount of impervious roadway surrounding a tributary affects the amount of salt concentration that enters an urban water body. The Holmes Lake location is ideal for looking at this issue as the lake is fed by two individual tributaries which are surrounded by different amounts of impervious roadway. The amount of impervious roadway surrounding the two tributaries was generalized using aerial imagery; aerial photographs were reviewed visually to make these determinations.
III. RESULTS

As mentioned above, the results of Dr. Snow and his lab technician’s analysis of the Dionex ICS-90 tests were provided to me following analysis of all samples. These results are provided in Appendix A and important information is summarized in the tables below.

The following table (Table 1) summarizes the reported bromide and chloride concentrations obtained from the collected samples, as reported by the chromatographer and analyzed by Dr. Snow, for each sampling location (Antelope Creek and the unnamed tributary) for each sampling date. As mentioned in the introduction, salts can be measured as concentrations which refer to the amount of substance – in this case either bromide or chloride – by weight in water, and is typically measured in units of milligrams per liter (mg/L). The chromatographer has a reporting limit of 0.10 (mg/L) for bromide and chloride, and therefore, any samples with traces of either element below this reporting limit are treated as having no significant concentrations and are denoted by a “NO TRACE” in the table. Any sample with traces of either element greater than or equal to the reporting limit are denoted by the concentration reported (mg/L) in the table.
Table 1. Bromide and Chloride Concentrations

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Sampling Location</th>
<th>Bromide Concentration* (mg/L)</th>
<th>Chloride Concentration* (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/6/2011</td>
<td>Antelope Creek</td>
<td>0.23</td>
<td>38.9</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>20.7</td>
</tr>
<tr>
<td>11/20/2011</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>26.1</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>18.5</td>
</tr>
<tr>
<td>12/4/2011</td>
<td>Antelope Creek</td>
<td>0.15</td>
<td>64.2</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>17.4</td>
</tr>
<tr>
<td>12/18/2011</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>34.1</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>22.0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>Antelope Creek</td>
<td>0.13</td>
<td>47.2</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>29.7</td>
</tr>
<tr>
<td>1/15/2012</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>32.7</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>27.9</td>
</tr>
<tr>
<td>1/29/2012</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>29.7</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>26.1</td>
</tr>
<tr>
<td>2/12/2012</td>
<td>Antelope Creek</td>
<td>0.12</td>
<td>61.4</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>39.4</td>
</tr>
<tr>
<td>2/26/2012</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>57.7</td>
</tr>
<tr>
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<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>41.9</td>
</tr>
<tr>
<td>3/11/2012</td>
<td>Antelope Creek</td>
<td>NO TRACE</td>
<td>34.6</td>
</tr>
<tr>
<td></td>
<td>Unnamed Tributary</td>
<td>NO TRACE</td>
<td>45.6</td>
</tr>
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</table>

* Reporting Limit = 0.10 mg/L

Table 2 (below) summarizes the chloride to bromide mass ratios that I calculated based on the concentration reported by the chromatographer. Ratios are given for each sample location, for each sampling date. As mentioned earlier in this report, chloride: bromide ratios are commonly used to determine the source of salt in a water body. Approximate known ratios are available for natural ground water, atmospheric precipitation, domestic sewage, summer runoff, and water affected by the dissolution of salt, and these ratios are provided in the table as “Reference Ratios.” Reference ratios are helpful because they allow data interpreters to make assumptions about the source of salt within a water body.
### Table 2. Chloride: Bromide Ratios

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Sampling Location</th>
<th>Chloride: Bromide Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/6/2011</td>
<td>Antelope Creek</td>
<td>169.13:1</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>11/20/2011</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>12/4/2011</td>
<td>Antelope Creek</td>
<td>428:1</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>12/18/2011</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>Antelope Creek</td>
<td>363.08:1</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>1/15/2012</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>1/29/2012</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>2/12/2012</td>
<td>Antelope Creek</td>
<td>511.67:1</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>2/26/2012</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
<tr>
<td>3/11/2012</td>
<td>Antelope Creek</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>unnamed tributary</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Reference Ratio:**
- Natural Ground Water  100-200:1
- Atmospheric Precipitation  50-100:1
- Domestic Sewage  300-600:1
- Summer Runoff  10-100:1
- Dissolved Salt  1,000-10,000:1

Graph 1 (below) shows chloride concentrations from the inlet of location 1 over the sampling period. Chloride concentrations are labeled on the y-axis in mg/L with the sampling dates labeled on the x-axis. The graph shows that chloride concentrations were found between 26.1 mg/L and 64.2 mg/L. A trend line was put in to show the general direction of the time series data. The trend line at this location shows that over time the average concentration of chloride remained steady.
Graph 2 (below) shows the chloride concentration at location 2 over the sampling period. Chloride concentrations are labeled on the y-axis with sampling dates labeled on the x-axis. The graph shows that chloride concentrations ranged from 17.4 mg/L to 45.6 mg/L over the sampling period. A trend line was also put into this time series data. The trend line at this location shows that over time the average chloride concentration increased progressively.
IV. DISCUSSION

Before starting this experiment, hypotheses were made that the results of the experiment would show strong evidence of salt pollution from road salt runoff contributing to increased salt concentrations at both Holmes Lake and the incoming tributaries. The Holmes lake watershed is a highly developed area with a complex road system connecting the residents that live around the lake to the amenities of Lincoln. A golf course and dog park are also in the area, bringing additional traffic to the area. Road salt must be applied to these roads during winter snow and ice events so residents can maneuver the streets safely. When the snow melts, the runoff enters Holmes Lake via the tributaries, and should, in effect, increase the salt concentration of both the tributaries and the lake.

Of the twenty samples taken, only four had bromide levels above the reporting limit. This means Chloride: Bromide ratios could only be performed on these four samples, thus the
determination of the salts origin can only be found in these samples. None of the samples with applicable ratios were reported to be from road salt runoff (dissolved salt), according to reference ratios. One sample had a ratio that lies within the levels of natural ground water using the reference rations given by Davis, Martin, and Whittemore; and, more importantly very close to the ratio of natural salt springs, which have a ratio around 164:1. The remaining three recordable ratios were found to be from domestic sewage. All recordable Chloride:Bromide ratios were found at location 1, the inlet from Antelope Creek. Because Antelope Creek is a larger watershed with greater volume and flow it can carry more dissolved solids. When increased runoff events occur even more dissolved solids are put into the system contributing to bromide levels that are of a significant level and can be used to form Chloride:Bromide ratios.

The sample shown to be from natural salt springs is a definite possibility for a source of salt entering Holmes Lake because Lincoln has natural salt springs within its urban development. Lincoln is underlined by Dakota sandstone, which is a porous material that allows ground water to seep up through the rock via capillary action creating surface salt springs. These springs then contribute salt into Holmes Lake. Ratios in the range of domestic sewage are also another viable source of salt contribution. Holmes Lake is surrounded by residential housing that is connected to a sewer system. If any sewage leaks from these sewers it can be deposited into the lake. A dog park also surrounds Antelope Creek directly before it enters Holmes Lake. Salts from the dog urine and waste can be running off into Antelope Creek and entering Holmes Lake.
Although I was not able to determine if the salt entering Holmes Lake was that from road salt runoff, I was able to see a difference in chloride concentrations at both locations. Antelope Creek contributed a higher concentration of chloride throughout the sampling period, ranging from 26.6 to 64.2 mg/L, but the average change in chloride concentrations over time was fairly steady. I think this is again due to the fact that Antelope Creek has a greater volume and flow so more dissolved solids will be in this tributary, thus leading to higher concentrations from this tributary. Also because Antelope Creek is sparsely surrounded by impervious roadway smaller contributions of salt from road salt runoff were occurring. So with greater flow, volume, and less salt entering from road salt runoff concentrations of salt were not able to accumulate to higher levels.

The unnamed tributary had chloride concentrations ranging from 17.4 to 45.6 mg/L. The average change in chloride concentration grew throughout the sampling period. I believe this was because the unnamed tributary was densely surrounded by impervious roadway coupled with the fact that this tributary has a smaller volume and flow. The combination of these three factors helped contribute to chloride concentrations increasing throughout the sampling period.

V. CONCLUSION

No previous salt studies have been done at Holmes Lake, therefore, it is hard to accurately assess if the amount of impervious roadway has an effect on the amount of salt that enters the lake. However, I still feel that the amount of impervious roadway likely has an effect on the amount of salt entering urban water bodies from road salt application, but to make a solid conclusion, based on this study alone, is not possible. Therefore, to strengthen this type
of research to where an acceptable conclusion could be made, I make the following recommendations.

More intensive in-field and in-lab studies should be performed. A sampling period consisting of longer than five months would be preferred to demonstrate the true effects the amount of impervious roadway surrounding a tributary has on salt concentration entering the lake. It is recommended that future sampling be done over a multi-year period, testing once a week throughout the year. The multi-year study would negate years in which precipitation patterns deviate from normal. By sampling once a week you decrease the risk of missing runoff events as the lag time between precipitation events and actual inflow into the lake is compensated for. Samples taken over the summer months would give a good baseline during months that road salt is not applied. Using this baseline will help to rule out salt concentration reports due to other factors.

A quantitative approach for assessing the amount of impervious roadway would also be recommended to show more accurate results on the effect different amounts of impervious roadway have on salt contribution from road salt runoff to an urban water body. Because some constitutes from road salt runoff are better traced than others it is suggested that using ratios from other anions to chloride be performed to help narrow the source of salt contamination. For instance, Howard and Beck used the ratios of fluoride to chloride to differentiate between de-icing chemicals and saline bedrock water (Granato, 1996).

These studies are important because this is one area in which municipalities can control the amount of salt pollution entering an urban water body. By knowing what effect the amount of impervious roadway has on salt concentrations from road salt runoff cities can manage the
amounts of road salt applied. Also, further methods to control this runoff can be applied such as diverting runoff to other locations. For these reasons road salt runoff and the amounts of impervious roadway surrounding tributaries should be analyzed further to help control salt pollution, a common urban water quality factor.
LITERATURE CITED:


**FIGURE REFERENCES:**

1.) Truck applying road salt. Downloaded from http://www.mychamplain.net/forum/winter-manure-spreading-road-salt-updates-vermont-impacts-lake-champlain

2.) Picture of Holmes Lake. Photo by author.

3.) Aerial map of Holmes Lake. Created by author.

4.) Photo of Jordan Pharris sampling water at Holmes Lake. Photo by author.

5.) Aerial map of Holmes Lake. Created by author.

6.) Picture of Dionex ICS-90. Downloaded from http://www.instrument.com.cn
APPENDIX A

Chromatographer Results (text format only – PDF original)
Water Sciences Laboratory - Analytical Report

202 Water Sciences Laboratory University of Nebraska Lincoln, NE 68583-0844 ph.402-472-7539 fax.402-472-9599

Results Reported To: Project: PHARRIS ANIONS IC - ANIONS
Jordan Pharris Ion Chromatography - Major Anions EPA 300.0
Sampled By: Jordan Pharris
4854 Holdrege St Received: 15-Mar-12
Lincoln, NE 68504 Received By: Jesse Voelker
308-627-1602 Batch: W12064

*** Results of Analysis *** IC - ANIONS

Lab ID Sample ID Collection Date Analysis Date Bromide
(mg/L) Chloride
(mg/L) Fluoride
(mg/L) Nitrate-N
(mg/L) Nitrite-N
(mg/L) Orthophosphate-P
(mg/L) Sulfate
(mg/L)
12-369 BASELINE 1 11/06/2011 03/15/2012 0.23 38.9 0.37 0.18 0.00* 0.20 42.0
12-370 BASELINE 2 11/06/2011 03/15/2012 0.00* 20.7 0.19 0.24 0.00* 0.04* 20.8
12-371 #2 SUR 1 11/20/2011 03/15/2012 0.07* 26.1 0.27 0.17 0.00* 0.04* 29.5
12-372 #2 SUR 2 11/20/2011 03/15/2012 0.00* 18.5 0.27 0.25 0.00* 0.00* 23.8
12-373 #3 SUR 1 12/04/2011 03/15/2012 0.15 64.2 0.31 0.18 0.00* 0.11 32.9
12-374 #3 SUR 2 12/04/2011 03/15/2012 0.00* 17.4 0.22 0.19 0.00* 0.00* 22.9
12-375 #4 SUR 1 12/18/2011 03/15/2012 0.09* 34.1 0.26 0.31 0.00* 0.10* 29.5
12-376 #4 SUR 2 12/18/2011 03/15/2012 0.00* 22.0 0.25 0.45 0.00* 0.10* 19.2
12-377 #5 SUR 1 01/01/2012 03/15/2012 0.13 47.2 0.18 0.13 0.00* 0.10 33.0
12-378 #5 SUR 2 01/01/2012 03/15/2012 0.03* 29.7 0.26 0.14 0.00* 0.00* 24.5
12-380 #6 SUR 1 01/15/2012 03/15/2012 0.00* 32.7 0.25 0.01* 0.00* 0.03* 28.8
12-381 #6 SUR 2 01/15/2012 03/15/2012 0.00* 27.9 0.15 0.00* 0.00* 0.00* 24.8
12-382 # 7 SUR 1 01/29/2012 03/15/2012 0.06* 29.7 0.22 0.01* 0.00* 0.00* 25.0
12-383 #7 SUR 2 01/29/2012 03/15/2012 0.06* 26.1 0.21 0.00* 0.00* 0.01* 23.3
12-384 #8 SUR 1 02/12/2012 03/15/2012 0.12 61.4 0.52 0.00* 0.00* 0.00* 32.1
12-386 #8 SUR 2 02/12/2012 03/15/2012 0.00* 39.4 0.22 0.00* 0.00* 0.00* 30.4
12-387 #9 SUR 1 02/26/2012 03/15/2012 0.00* 57.7 0.30 0.00* 0.00* 0.05* 36.6
12-388 #9 SUR 2 02/26/2012 03/15/2012 0.00* 41.9 0.22 0.00* 0.00* 0.00* 24.8
12-389 #10 SUR 1 03/11/2012 03/15/2012 0.00* 34.6 0.38 0.00* 0.00* 0.00* 31.5
12-390 #10 SUR 2 03/11/2012 03/15/2012 0.07* 45.6 0.22 0.01* 0.00* 0.00* 27.0

Reporting Limit: 0.10 0.10 0.10 0.10 0.10 0.10 0.10

0.10

Results Approved: 3/21/2012 Daniel D. Snow, Laboratory Manager

"*" - Indicates value below reporting limit