The Effect of Road Salt On Urban Watersheds and Management Options

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I. Introduction

Thesis Statement

Although road salt is claimed to be the best option for safer road travel, and is applied liberally during inclement winter weather, consideration needs to be made as to how this is affecting the ecosystem of watersheds and the water quality of the waterbodies themselves. Runoff with road salt, and how this negatively impacts the ecosystem of the watershed, may need to be balanced with other management options for safe road travel and a healthy environment.

Purpose and Scope

This paper is intended to be an overview of the history of road salt use, and current concerns over its use. Sources of salts in waterbodies and their impacts are considered. Research by other agencies and municipalities of how and if road salt is impacting a watershed are brought into the fold, and hypotheses are formulated based upon their results. Also considered is the recent attention on the impacts of chloride by the U.S. Geological Survey, the state of Minnesota, and the city of Ann Arbor. Ann Arbor is attempting to lower their use of sodium chloride (the most used combination for road salt) and have better management practices, yet still maintain safety for drivers.

II. Background

Sources of Salts

Salts found in watersheds are either from natural or anthropogenic sources. Natural sources are those that already exist in or are created by the environment.

Natural sources of salts include oceans; weathering of soils, surface materials, and bedrock; saline groundwater (brines) or halite from geologic deposits; and volcanic activity. The majority of atmospheric deposition of sodium and chloride, especially along coastal areas, is from the ocean.

Sodium and chloride are the most abundant ions present in the atmosphere above the oceans, and atmospheric deposition of chloride and sodium from the oceans is highest along coastal areas.[1] The release of hydrogen chloride (HCl) during a volcanic eruption can also be a source of chloride in the atmosphere. Weathering is a process by which there is breaking down or dissolving of geologic materials. This process is usually slow because chlorine is present in many of these materials and there is release of chloride ions. There are geographical areas, such as Michigan, where salt deposits exist underground. These halite deposits are not believed to affect the quality of the shallow groundwater, as they are often too deep or at the downgradient ends of the water system. Another salinity source exists in sedimentary bedrock where there is water with high concentrations of dissolved solids. These halite deposits and brines may be a salinity source for groundwater in zones of flow convergence, where water of different ages and from different aquifers (surficial to deep bedrock) has mixed.[2]

Anthropogenic sources of salt are those which are due to human behavior or practices. These include deicing salt application, landfills, water and wastewater treatment, agriculture, and manufacturing.

Sodium chloride is the salt used for deicing because of its cost and abundance. The reason it works for deicing is because it allows for the lowering of the freezing point of water. Calcium and magnesium chloride are more expensive options, however they are sometimes used as a wetting agent for rock salt. Salt application for deicing of roadways is the focus of this paper, and more details and issues surrounding this will be further discussed. Landfills are sources of salts, as the leachate or in the groundwater beneath or downgradient contain high concentrations of chloride. Much of this is attributed to the high salt content of food, which is disposed of in the landfills. Other products containing salt which are put into landfills include paper products, metals, and rubber. Chloride contained in household items, food, and beverages that are disposed through septic systems and wastewater treatment facilities ends up in the environment. Water softeners, which treat hard water with processes using salt brine to displace calcium and magnesium, with the remaining brine being discharged to a dry well or wastewater system, where it can enter the environment. In agriculture, salt

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[1] Mullaney, John R. and David L. Lorenz, and Alan D. Arntson. "Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States". U.S. Department of the Interior, U.S. Geological Survey. PDF. 2009.

[2] Mullaney, John R. and David L. Lorenz, and Alan D. Arntson. "Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States". U.S. Department of the Interior, U.S. Geological Survey. PDF. 2009.

is used as a feed additive, as well as in fertilizers and pesticides. Additionally, irrigation from groundwater sources that are deep enough may contain salts. Other manufacturing, such as petroleum production, paper production, textiles and dyeing, and metal processing also use salts.

Impacts of Salts

The impact of salt on the environment relates to how it is transported through the environment. The chloride ion migrates the same as water; however the sodium ion is affected by other elements in the soil, leading to the decrease of concentration in the groundwater. For example, sodium ions are exchanged with calcium adsorbed to clay-rich minerals, thereby decreasing the sodium ion concentrations within the infiltrating groundwater.[3] Most studies that look at the effects of road salt on watersheds focus on chloride for this reason. Chloride circulates through the hydrological cycle via mostly physical rather than chemical processes. The chloride ions pass readily through the soil, enter ground water and eventually drain into surface waters. Because chloride ions are persistent and are trapped in the hydrological cycle, all chloride ions applied to roadways as road salts or released from patrol yards or disposal sites ultimately reach surface water.[4] Salt is also transported through the environment via air currents. If there is not enough moisture to dissolve the salt, traffic motion will facilitate its movement, creating dust like particles in the air. It's also important to note that an anti-caking agent, which contains cyanide, is added to the salt which is applied to roadways. This is to prevent the salt from forming chunks making it difficult to spread on the roads. The cyanide is released into the environment when bacteria break it down, or when it photodegrades in sunlight. Anti-caking agents are not in salt that is purchased by the general public for use around their homes.

The application of road salt and movement of it through the environment can have ecological impacts. The sodium chloride which accumulates on foliage and water which has the dissolved ions is consumed by wildlife. Often birds think that road salt crystals are seeds and consume them. Excess consumption by wildlife can affect their health just as it does in humans. Birds are particularly vulnerable, especially terrestrial species, as their renal system is not able to deal with too much sodium in the same way mammals can. For aquatic organisms, chloride is required for maintenance of physiological functions. However these organisms adapt to their surroundings, and once they adapt to a certain level of chloride, the levels need to remain steady. If there is too much fluctuation, these

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[3, 4] Siegel, Lori, Ph.D., PE. "Hazard Identification for Human and Ecological Effects of Sodium Chloride Road Salt". State of New Hampshire, Department of Environmental Services, Water Division, Watershed Management Bureau. PDF. 6 July 2007.

organisms are susceptible to growth, reproduction, and survival risks. Interestingly, aquatic species may adapt to increased levels of chloride with time, such that surviving organisms may develop the means by which to handle the osmotic shock imposed by the excess chloride.[5] The impact of chloride may be affected by water chemistry, such as dissolved oxygen, temperature, and other contaminants. Chloride presence may decrease or increase toxicity of some contaminants. For vegetation, sodium chloride is considered an herbicide. In the soil, salts can cause an osmotic imbalance, stunting root growth and inhibiting water absorption, causing weakness. Leaves and shoots also deteriorate when salt directly accumulates. If vegetation is not strongly intact, this reduces the buffer and allows more run-off of contaminants to reach ground and surface water.

Figure 1 - Roadside grasses and other vegetation can be killed off by road salt. These plants are important for preventing soil erosion. All types of vegetation, even trees, can be killed off, or at least weakened, by road salt when they are coated in it due to spray from traffic, or by taking up salty snowmelt through their roots. Source: Sustainable Stormwater Management.

Road salt applications have resulted in the increase of sodium chloride in drinking water. The EPA has established a secondary maximum contaminant level (SMCL) for sodium at 250 mg/L. At this level, the taste of water is affected. EPA now, though, requires the monitoring of drinking water, and has a limit of 20 mg/L for sodium, and if above that, the public water systems must report to local health

[5] Siegel, Lori, Ph.D., PE. "Hazard Identification for Human and Ecological Effects of Sodium Chloride Road Salt". State of New Hampshire, Department of Environmental Services, Water Division, Watershed Management Bureau. PDF. 6 July 2007.

authorities what the concentration is. This is so those who are on sodium-restricted diets can adjust their drinking water usage habits. What determined this limit by the EPA was due to sodium's link to hypertension, which leads to many other health issues for people including renal disease, cardiac disease, eye damage, hardening of the arteries, and stroke. Chloride is not considered toxic to human health at reasonable exposures, however it can affect the taste. The potable limit for chloride, set by the EPA, is 250 mg/L. It is rare that concentrations of chloride exceed this, and if it does it is short-term. Relating to vegetation damage due to road salt, the increased run-off can also impact drinking water quality.

USGS Investigation

The U.S. Geological Survey (USGS) did an extensive study on chloride in the surface and groundwater in the northern United States which was released in 2009. Since, the 1950s, the use of salt in the United States has increased. In 1975 usage was at 42.9 million tons and in 2005 this rose to nearly 58.5 million tons. The chloralkali industry had been the largest user of salt; however in 2005 use of salt for deicing surpassed it. The USGS found that the largest chloride concentrations were in samples from shallow monitoring wells urban areas. Samples from agricultural areas followed in concentrations levels. November to April had chloride concentrations greater than 230 mg/L most frequently, showing a likely correlation to winter deicing practices.

> Long-term historical data and the literature on this subject suggest that chloride concentrations in streams are currently increasing in urbanized and urbanizing areas, potentially exceeding recommended criteria for aquatic life now or in the coming decades. Increases in chloride load over time generally can be attributed to changes in the application of deicing salt, the expansion of road networks and impervious areas that require deicing, increases in the number of septic systems, increases in the volume of wastewater discharge, and the arrival of saline groundwater plumes from landfills and salt-storage areas over time.[6]

The investigation by USGS reveals evidence that indicates the relationship between increased road salt use and the affect upon surface and groundwater.

Minnesota Groundwater Study

The Minnesota Pollution Control Agency, an agency of the State of Minnesota, released a report on the condition of Minnesota's groundwater. The analysis was done from 2007 through 2011, and chloride was among the topics covered. Chloride contamination to Minnesota groundwater is likely

[6] Mullaney, John R. and David L. Lorenz, and Alan D. Arntson. "Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States". U.S. Department of the Interior, U.S. Geological Survey. PDF. 2009.

attributed to the application of deicing salts to the roadways, according to the report. In 2010, about 70 percent of the salt which was distributed to Minnesota was rock salt used for the roads. The sand and gravel aquifers associated with urban use in the study showed high chloride concentrations. When compared to undeveloped areas, chloride concentrations were higher in urban areas. The most common source of chloride was found to be halite (commonly known as rock salt), likely derived from road salt. Minnesota purchased the majority of rock salt for the purpose of deicing.

III.Ann Arbor, MI

The city of Ann Arbor was selected as a case study due to personal interest, experience, and access to information. Also they are a community which has been concerned about the environment and potential effects of road salt since the 1970s.

Figure 2 – Ann Arbor skyline looking northeast from Michigan Stadium.

Source: Wikipedia.

Huron River Watershed Council

The Huron River is located in southeastern Michigan and flows more than 125 miles, with its headwaters at Big Lake, near Pontiac, and flows to its mouth at Lake Erie. The watershed covers more than 900 square miles of land area, and drains water through hundreds of tributary creeks and streams to the Huron River. The area includes seven counties (Oakland, Livingston, Ingham, Jackson, Washtenaw, Wayne, and Monroe), 63 municipal governments, and a half million residents. The Huron River Watershed Council (HRWC) was founded in 1965, it’s the oldest environmental organization dedicated to river protection in southeast Michigan, and is a nonprofit coalition of Huron Valley residents, businesses, and local governments. HRWC monitors the Huron River, its tributaries, lakes, and groundwater, and directs multiple programs addressing pollution prevention and abatement, wetland and floodplain protection, citizen education, and natural resource and land-use planning.[7]

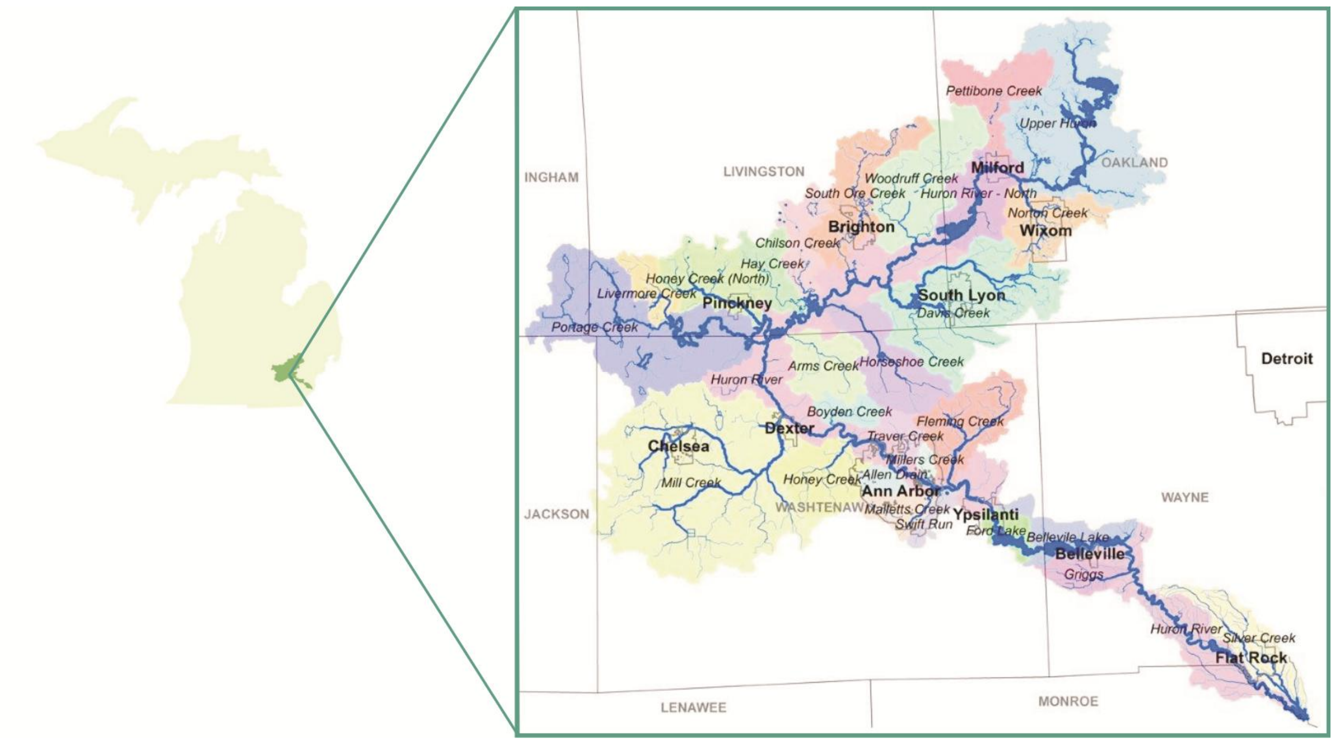

Figure 3 – Huron River Watershed. Source: HRWC

HRWC has taken an interest in the impact of road salt on the watershed. Conductivity readings have been taking in various sites throughout the watershed for the past several years. Conductivity is a measurement of water's ability to pass an electrical current. The presence of inorganic dissolved solids, such as chloride, affects conductivity. Ric Lawson, Watershed Planner at HRWC, hypothesized that there would be a correlation between conductivity and chloride, and in the spring of 2014 the water quality monitoring program at HRWC began taking chloride readings with a meter, as well as gather samples for lab analysis.   After the season, Lawson charted the data and found a compelling correlation, 90%, between conductivity and chloride, as illustrated in Figure 4. He stated that when looking at the correlation coefficient (aka R2) of Ln-transformed paired samples from a pooled dataset of samples from all sites, R2 = 0.8966. He then ran a regression of the 2 and got an adjusted R2 of 0.8019. The P-value of the regression residual ANOVA was << 0.01. This was how he found the 90% correlation. The red horizontal line in the chart is 230 ppm chloride which is the EPA standard.

[7] Huron River Watershed Council. *About The Huron River Watershed Council*. Web. 26 Mar 2015.

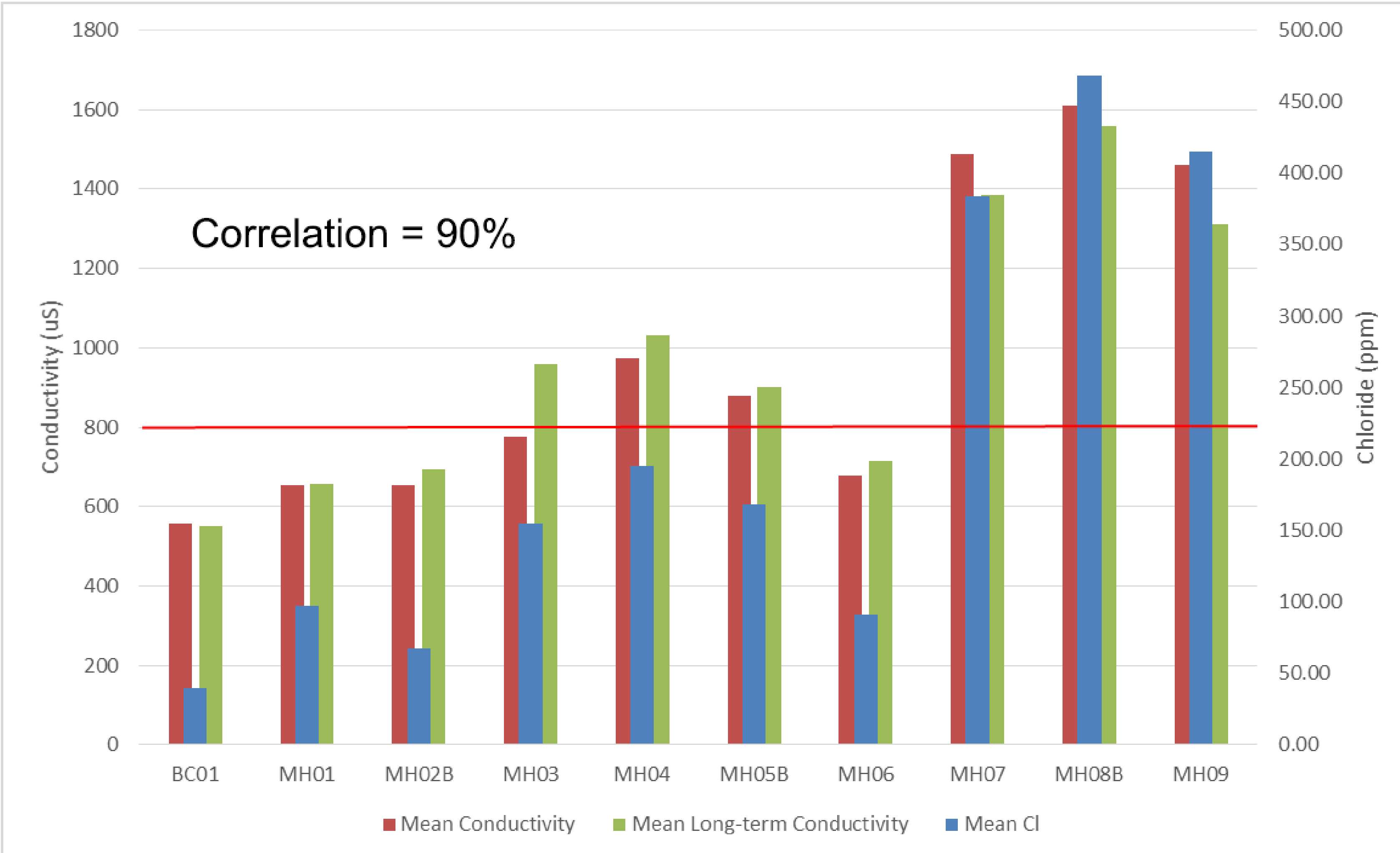

Figure 4 – Conductivity and chloride comparison. Source: HRWC

Site List: BCO1 - Boyden Creek (Huron River Drive), MH01 - Huron River (North Territorial Road), MH02B - Mill Creek (Parker Road), MH03 - Honey Creek (Wagner Road), MH04 - Allens Creek (Main Street), MH05B - Traver Creek (Broadway), MH06 - Fleming Creek (Geddes Road), MH07 - Malletts Creek (Chalmers Road), MH08B - Millers Creek (Huron Parkway), MH09 - Swift Run (Shetland Drive)

Huron River Watershed Council
Water Quality Monitoring - Conductivity and Chloride Sites

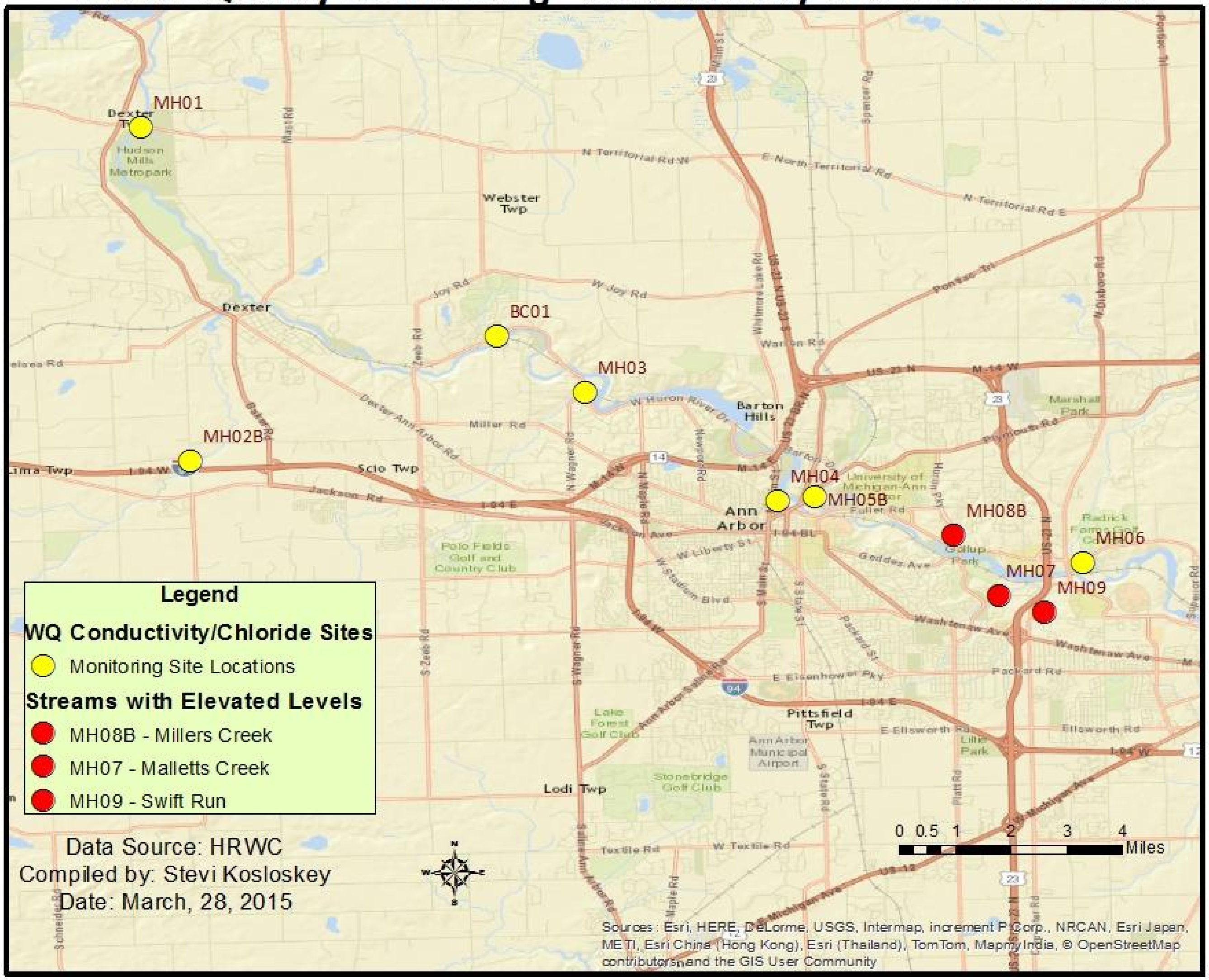

Figure 5 – Sites that were monitored for conductivity and chloride. Red points indicate those with elevated levels.

The creek sites in the most urban areas had the highest levels of conductivity and chloride. HRWC will be continuing to monitor the chloride levels at sites within the Middle Huron (Washtenaw County) during the spring and summer. Also some year around sampling is being considered during thaw events, rain events, and after roads are salted. The Ann Arbor Water Treatment Plant had expressed interest in a road salt sampling program, and collaborating with HRWC on this effort, however their involvement been put on hold at this time.

Ann Arbor Road Salt Practices

The City of Ann Arbor began considering the effects of road salt as early as 1970. On November 16, 1970, City Council approved the annual salt purchase, however they would not allow the use of salt until a report was completed on its environmental and infrastructure impacts, and alternatives solutions on how to reduce them. It is thought that this directive was brought about due to a study done in the Sister Lakes area of the city. John Judd, a researcher from University of Wisconsin, was working on his Ph.D. thesis several years prior and focused on the first Sister Lake. Judd concluded that 75-80% of the salt in the lake came from road salt use. Now the neighborhood is a low salt use area. Judd also said that 22% of the chlorides in the Huron River were from street run-off.

The impact report was given to the council in mid-December, 1970. Infrastructure impacts, automobile corrosion, traffic safety, vegetation impacts, and water quality were covered in this report. Based upon this information, the council recommended continuing the use of salt, but on a reduced basis. Controls and monitoring would be implemented, new equipment would be adopted, and staff as well as the public would be educated about road salt practices.

Snow and ice control operations for the city of Ann Arbor fall under the jurisdiction of the Public Services, Field Operations Unit. Field Operations will take the lead as it pertains to establishing and implementing the snow and ice control operations and is responsible for the overall city-wide coordination and strategy. Field Operations does coordinate with AATA, public schools, local police agencies and the Michigan State police.[8] Salting routes and practices are based upon several factors. High volume roads are important for community mobility and emergency services; also roads with accident history or topography that is of concern. All other roads and residential areas have a 95% sand and 5% salt mixture. Only enough salt is used to prevent sand clumping and easier spreading. Also

[8] City of Ann Arbor Street Snow Maintenance Procedures

focus is mostly on intersections, hills, and curves to limit the need for sweeping and cleaning drains. In a further effort to reduce salt, the city has an agreement with the County Road Commission and their trucks operating within the city. Annual salt tonnage [in Ann Arbor] has remained consistent even with increase in lane miles. Fluctuations in annual use are attributable to winter severity (season heating degrees, event count and snow accumulation).[9]

Winter Season	salted lane miles	Tons Salt Used	Annual Inches Snowfall	Annual Days w/ snowfall >0.1	Mean Temp Jan	January Snowfall	Snow Season (7/1 -6/31) Heating degree days base 65 at KARB	SEMCOG All Crashes Jan 6a-9a	SEMCOG All Crashes July 6a-9a
14/15	345.975	0							
13/14	345.975	7582	97.1	72	17	37.81	7782	68	32
12/13	345.975	6083	66.5	56	28.7	15.67	6676	55	26
11/12	345.975	3594	40	43	30.2	13.9	5635	39	31
10/11	0	7011	68.2	56	22.1	20.89	6929	54	14
9/10	344.33	4882	56	45	24.6	10.54	6449	30	14
08/09	343.525	6632	79.3	52	17.9	27.04	7130	45	20
07/08	0	8500	89.8	63	28	22.81	6793	42	13
72/73	261	6100	50.5	31	29.2				
70/71		7300	38.4	47	20.7				

Table 1 – Statistics from city of Ann Arbor. Tons of salt used corresponds with inches of snowfall.

Ann Arbor has kept their road salt use fairly steady even with increased lane miles. This is a result of their management practices.

The City of Ann Arbor has shown commitment to having best management practices for road salt for several decades. The city works to educate their staff and the public, and welcomes feedback as well.

IV. Alternatives to Road Salt – What is being considered?

As the public is becoming more aware of the damage that road salt can do, and with the increasing costs of road salt, alternatives are being considered. One alternative is from sugar beets. Beet Heet is a product derived from molasses from sugar beet processing. Salt treated with Beet Heet, a creation of K-Tech Specialty Coatings in Indiana, is effective at colder temperatures and lowers the freezing

[9] Pennington, Kirk. Field Operations Supervisor IV - Infrastructure Systems, City of Ann Arbor. “City of Ann Arbor Increasing Public Awareness while Decreasing Salt.” Ann Arbor, Michigan. 2015. Presentation.

point of rock salt. Increased performance reduces the amount of salt needed. It also can be used to pre-treat roads before a storm.[10] Tomato juice, ash, and volcanic rock are also being considered. Xianming Shi, Washington State University associate professor in civil and environmental engineering, has developed a mixture composed of leftover barley residue from vodka distilleries as an ice-melt. However he says that chlorides are blended in even with the green products before they are used.

Russ Alger, director of the Institute of Snow Research at Michigan Technological University, says some of the alternatives to salt there also pose environmental concerns. Beet juice, for example, may deplete oxygen in waterways. According to Alger:

> "When you look at all the options, a lot of time road salt turns out to be pretty good. So we keep coming back to road salt. Cost-wise, efficiency-wise, availability-wise, it's just the best answer. I don't see it getting replaced for a long, long time, if ever."[11]

Each winter Minnesota's Department of Transportation averages about 225,000 tons of salt on state roads. They have found a way to make barriers made of trees, shrubs, and native grasses to prevent snow from drifting on the roads. These "living snow fences" is a unique way to deal with drifting snow, and minimizing the need for road salt.

With winters being colder and snowier the past few years, municipalities have encountered rock salt shortages. This shortage may be a blessing, a motivating factor to find alternatives, and an indication that it may be time for eco-friendly deicing agents to be seriously looked at as an option.

V. Conclusion

Road salt has been used for several decades. In many municipalities, road salt use has been on the rise, although some are looking at other options. Road safety is extremely important; however there are ways that can balance safety with less damage to our watersheds. These alternatives may be able to actually save costs, especially when long-term costs, environmental and infrastructure, are considered as part of those costs. Good management practices – being thoughtful about how road salt is applied, and where, can help. Ann Arbor is a good example of this. Although there is still evidence of elevated levels of chloride in the urban streams, this may be due to county salt applications, or residential use. And if Ann Arbor did not implement these practices, chloride levels could be much

[10] Post, Rachel. "The alternatives to salt for battling ice: cheese, beets and ash." The Guardian. Web. 3 Mar 2014.

[11] Copeland, Larry. "Communities seek a substitute for road salt." USA Today. Web. 23 Feb. 2013.

higher. The Huron River Watershed Council will be continuing to look at chloride in the watershed to monitor its level and impact.

With municipalities being encouraged to look at alternatives, either by the public or due to the increasing cost of road salt, eco-friendly alternatives are ripe for consideration. These application alternatives may need to be mixed with chloride; however any sort of reduction may be helpful. If municipalities consider alternatives to road salt, including incorporating best management practices, it will be a positive step towards the reduction of road salt use.

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