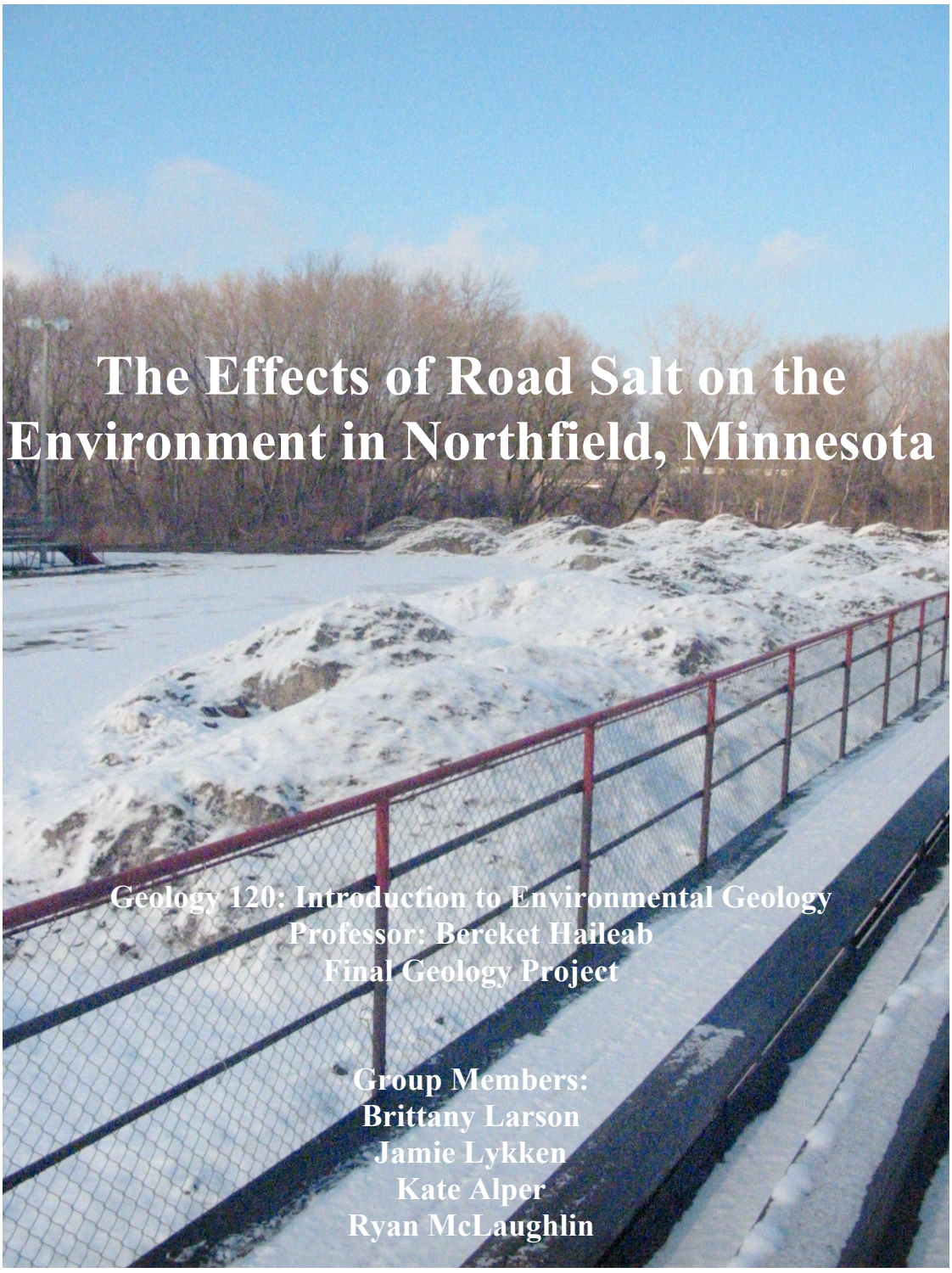

The Effects of Road Salt on the Environment in Northfield, Minnesota

Geology 120: Introduction to Environmental Geology
Professor: Bereket Haileab
Final Geology Project

Group Members:
Brittany Larson
Jamie Lykken
Kate Alper
Ryan McLaughlin

Introduction

During Minnesota winters, snow affects the lives of all the citizens on a frequent basis. Because of the effects of snow and ice on the streets, local and state governments allocate significant amounts of funds towards road maintenance to provide safe driving conditions. Because of its effectiveness and relatively low cost, many cities treat the roads with pure NaCl. While sodium makes transportation much safer during the winter, it has been found to be harmful to the environment. In places where the winter season calls for frequent application of salt, such as in Minnesota, the impact of the deicing agent on the local water, plants, and animals should be researched to ensure that the use of sodium is not significantly detrimental to the environment.

The Northfield community piles approximately 1378 tons of snow twelve meters from the Cannon River creating an area with a high concentration of sodium chloride directly next to a main water source. In this project, we will study the effect of the salt on the Cannon River and the local environment. We are interested in just how much sodium is transferred from the city streets to the snow dumpsite. Further, we hope to understand where and to what degree the river and watershed is affected. The results of this study will suggest whether this site is a good location for this type of use, or if it has adverse effects on the environment.

Previous Literature

Although no similar studies have been done in Northfield or surrounding areas in the past, the effects of road salts in our lakes and rivers is apparent. This subject has been studied in many regions of North America, with various findings. Some researchers

found that NaCl, used during winter to melt snow on highways and roads, damaged the natural landscape, while other studies report that certain organisms go unaffected.

One study conducted by Forman and Deblinger (2000) found that woody vegetation was harmed by road treatments within ten meters of suburban highways in Massachusetts, and road salt also elevated the salt levels of local city drinking water. Another study by Leblanc (2000), found that plants were harmed within 50 meters of treated roadways. This study also reported that sodium chloride levels of 240 mg/L damage around 10% of aquatic animals, and that rainbow trout die after one week's exposure to 1000 mg/L of calcium chloride and sodium chloride. Miklovi and Galatowitsch (2005) measured the effects of NaCl on wetland plant life within the state of Minnesota and found that high concentrations of NaCl reduced the diversity of plant species. High chloride levels in lakes can also affect the distribution of oxygen and nutrients.

Benbow and Merritt (2004) reported that though road salt runoff makes its way into the watershed, the typical levels of sodium chloride in Michigan wetlands are not high enough to harm common macroinvertibrate species such as insects, snails, and crustaceans. They estimated the lethal dose of sodium chloride for macroinvertibrates at roughly 4,000 to 10,000 mg per liter over 96 hours of exposure time, while a lethal dose of chloride ranged from 3,000 to 5,000 mg per liter over the same time period. The chloride concentration in 43 Michigan Wetlands ranges from 18 to 2,700 mg per liter, which is lower than the lethal dose. Similarly, Blasius and Merritt (2002) found that there were no significant differences that could be attributed to road salt in the diversity and composition of invertebrate functional feeding groups.

City of Northfield Snow Removal Procedures

During a personal interview, Joel Walinski, the Operations Manager for the City of the Northfield, provided information essential for understanding the deicing procedures in Northfield and how they affect the local environment.

Northfield, Minnesota experiences an average of fourteen snow events each winter, during which time the maintenance department must treat the roads to make them safe and usable. When a storm is expected, the city pre-treats the roads with a solution that is composed of 23% salt and 77% water. When the storm hits, snowplows deploy throughout Northfield and administer treatment dependant upon the type of precipitation and the temperature.

In previous years, the City of Northfield used a salt and sand combination to de-ice the roads. However, they learned that sand traps car pollutants and when the sand sprays up onto nearby vegetation there is an adverse chemical reaction. Therefore, this sand/salt combination is no longer used on major Northfield roads.

The roads of interest in this study are considered the "downtown streets" by the city (see Figure 1). It is from these roads that the city will occasionally remove the snow and dump it at the rodeo grounds (see Figure 2, location 1). On the downtown streets, the city uses only pure sodium chloride to treat the roads during and after winter storms. The decision to remove the snow from the streets is based on the amount of solid precipitation accumulated on the streets and the forecasted temperature. If the snow is predicted to melt within the next couple of days, the city will not spend the excess funds on removing and dumping the snow. However, if the snow is expected to sit and block the flow of traffic for an extended time period, the city will clear the streets of snow. Snow removal

occurs from about 12 am to 6 am the morning after a storm; therefore, the snow may sit on the curb for an entire day before it is removed.

During the current 2005-2006 snow season, there have been eighteen snow events, which is four above the average (as of March 1, 2006). Of these, only three have had conditions calling for removal. While the most cost-efficient dump site is the rodeo grounds, this site is not used if it is too muddy for the trucks to safely maneuver. Because of this, only two of this season's snow removals were dumped at the rodeo grounds, while the other was taken to Sechler Park (Figure 2, location 2).

While the Sechler Park dumpsite is located further from the river than the rodeo grounds, and thus may be the better location to dump sodium-rich snow, it is located further from the downtown streets. Therefore, to dump at Sechler Park the City has to hire more trucks to remove and dump all the snow during the six hour time frame. Each additional truck costs between $320 and $400, and a heavy snow requires three to four more trucks. Furthermore, Walinski explains that the dump location at Sechler Park is on an asphalt parking lot, which does not absorb and filter the snow and salt as the soil can at the rodeo grounds.

The 2005-2006 rodeo grounds snow dumps occurred on November 25, 2005 and December 15, 2005. These two snow dumps account for about 1837 cubic yards of snow at the rodeo site, which is nearly 1378 tons. During the November storm, a total of 41 tons of salt was used to deice all of Northfields roads, and during the December storm, 55 tons of salt was distributed. While we do not know the specific amount of salt sprayed on the downtown streets, these numbers give us a general idea of the deicing efforts of the

city during the storms of interest. See Appendix A and B for a detailed record of the storms and the subsequent road maintenance.

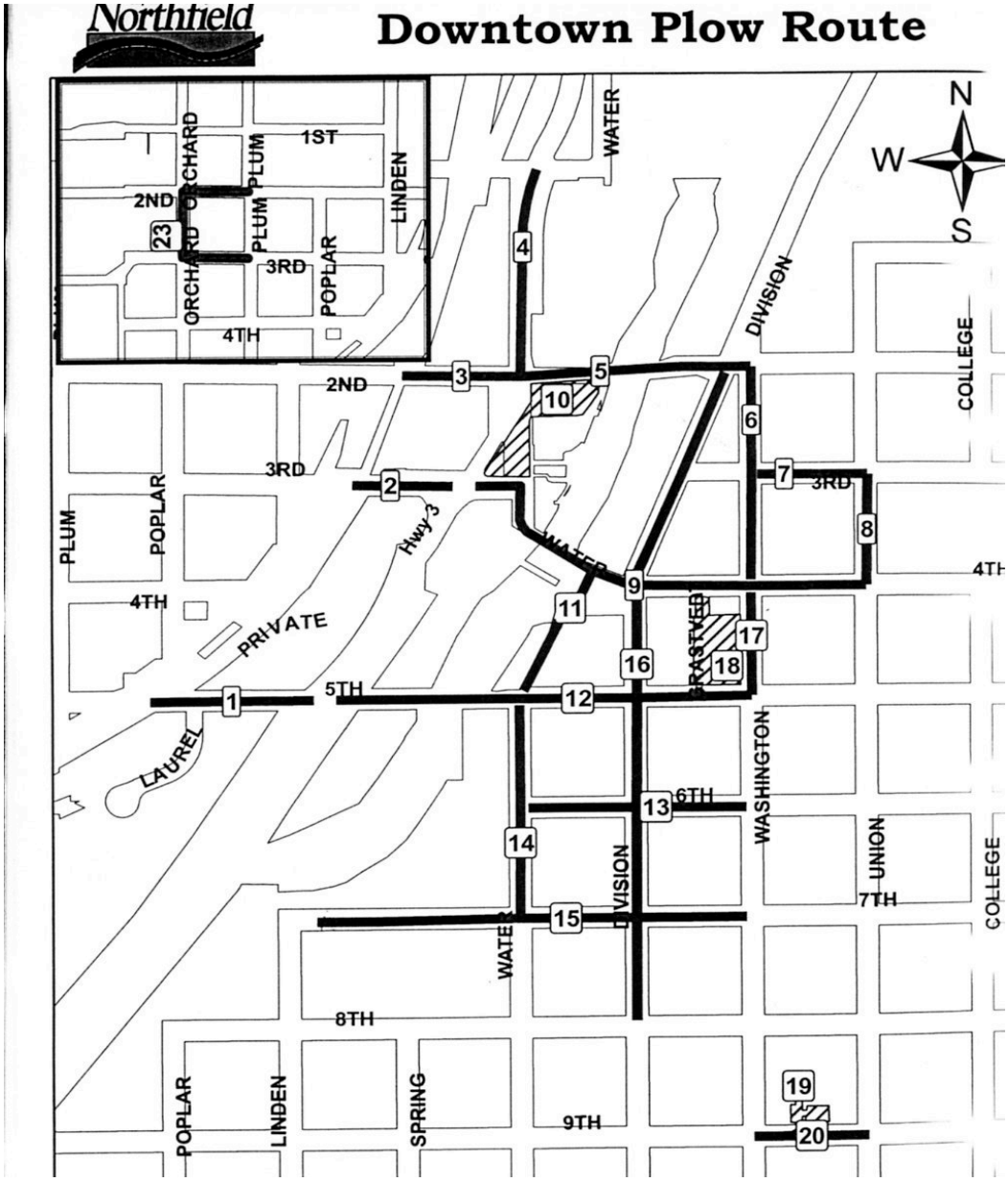

Figure 1: City of Northfield showing plow route of downtown area, from which snow for the rodeo dumpsite is gathered. Map was contributed by Joel Walinski.

Figure 2. Aerial Map of the Cannon River in Northfield, MN. From Carleton Biology department website.

Methods

Multiple snow samples were collected from the rodeo grounds dumpsite on February 7 and 14, between 2:00 and 4:00 pm. The dump site is approximately 50m in length and 25m in width and snow was relatively even distributed in dome-like masses approximately 3 cubic meters in volume. Samples were taken from various piles by chipping away the 10 cm of the outer shell (further access was impeded by impenetrably

compacted ice). Sealed in a sample container, the snow was melted and tested with an ion chromatograph in the lab.

Given ion chromatography's success in analyzing aqueous samples in parts-per-million (ppm) of common anions and cations, it was the instrument of choice for the present project. The Carleton Geology Department's ion chromatograph was used for the analysis of various organic cations and anions including: sodium, calcium, potassium, magnesium, ammonium, and lithium.

To conduct a comparative analysis, we needed to also find the sodium content of both fresh snow and the Cannon River water downstream from the dumpsite. Because our peers studied fresh snow and the cannon river, we were able to collaborate and share data. To measure the sodium in snow that is not near any streets, and thus likely clear of road salt, we used the 2006 data that Bloom et al. collected at the Hill of Three Oaks on the Carleton College campus. The snow was gathered at this isolated location during three different dates. For our study, we took an average of the sodium findings from these three days to compare to the NaCl found in the dumped snow.

For the Cannon River analysis, we used the 2006 data collected by Dana et al. Two samples were taken on different days from the Cannon River just downstream from the rodeo grounds (see Figure 2, location 3). We averaged these two findings to compare to the sodium level of the dumped snow.

Results

	Sodium Concentration (mg/L)
Fresh Snow 1 (Jan. 7)	16.95
Fresh Snow 2 (Jan. 29)	3.03
Fresh Snow 3 (Feb. 9)	1.04
Average Fresh Snow	7.01
Cannon River 1 (Feb. 8)	27.4
Cannon River 2 (Feb. 25)	11.4
Average Cannon River	19.4
Dumped Snow	47.47

Chart 1: Sodium concentrations

The plowed and discarded snow we gathered from the rodeo dumpsite has considerably higher sodium content than both the fresh snow and the Cannon River.

The ion chromatograph measured 47.47 mg/L of sodium in the dumped snow, which means that about five percent of the snow piles is sodium. Therefore, the 1378 tons of snow at the rodeo grounds this winter is made up of about 70 tons of salt.

Discussion

To account for the 70 tons of salt, we should consider the City of Northfield's snow treatment process: pre-treatment, salt application, and occasional removal. During the two snow events that merited removal, the roads were treated with 96 tons of salt. However, an accumulative amount of 145.75 tons of salt was applied to the roads during the previous six snow events. Because the city only removes the snow and salt from the street on certain occasions, we can assume that a large quantity of the 145.75 tons of salt remained on the streets prior to the removal dates. Under this assumption, the 70 tons at the rodeo site accounts for 48% of all salt applied before the final snow removal under study, on December 15.

While the 70 tons of salt that we found may not be enough to harm the environment, it is important to keep in mind that this amount only accounts for two snow removal dates. During a winter when there are many large snow falls and lower temperatures, more salt will be applied to the roads and more will need to be removed and dumped near the river.

Through a comparative analysis, we found that the snow dumped at the rodeo grounds has more than twenty five times the sodium content as fresh snow in Minnesota. Insofar as the sodium-saturated snow will eventually melt and run-off into the river, this poses an environmental concern.

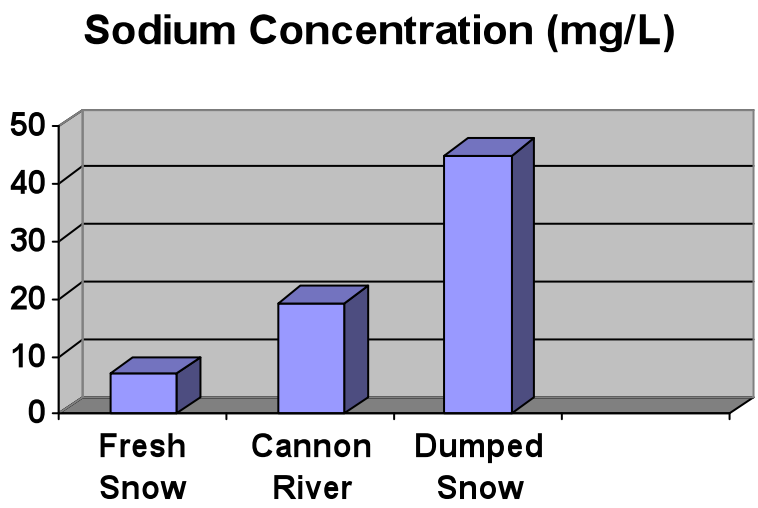

Figure 4

While the sodium content of the dumped snow has the potential of being harmful to the environment, the frozen nature of the snow piles during our study prevented run-off, which would lead to high sodium levels in the Cannon River. In fact, we found that the sodium concentration downstream from the snow dump site is lower that of the dumped snow. While this could be evidence against the hypothesis that the sodium-rich snow at the dump site runs-off into the river, it is probably a result of the low

temperatures during the time of the study. The average temperature in Northfield, as reported by The Weather Channel, is 10.6 degrees Fahrenheit between November and February. Consequently, it has not been warm enough for the snow in this location to melt off. We speculate that when this snow does melt it will flow into the Cannon River, carrying the road salt with it and thus raising the levels of sodium found in the river. A study on this effect in the spring would provide a more detailed understanding of how the snow dump affects the river.

While the sodium content of the dumped snow is much higher than the fresh snow, we had expected it find an even higher sodium concentration. These findings may be reflective of the samples studied. Because of the freezing temperatures during the study, the mounds of dumped snow froze, making sample collecting very difficult. We were unable to sample from the inner core of the snow piles, where the salt may have percolated during the warmer days of the winter. Also, as fresh snow fell upon these snow mounds, the outer layers of snow may have become more diluted with water.

Conclusion

The City of Northfield's Environmental Protection Goals indicate the intent "to protect the environment and preserve clean water and clean air," and "to preserve the scenic and environmental qualities of the Cannon River Valley and its tributaries" (See Appendix B). Our study questions whether or not dumping sodium-rich snow adjacent to the Cannon River complies with these environmental goals.

While the cold temperatures during the study did not allow us to directly test how the snow piles run-off, and whether they contaminate the Cannon River, we are certain that a good amount of sodium is transferred to the dumpsite. While we found that the salt

levels of Cannon River are not high enough during the winter to cause damage, the long term effects of dumping sodium-rich snow at the rodeo dump site has the potential to harm the plants, animals, and ecosystem of the surrounding area. Thus, the City of Northfield should take steps to dump contaminated snow further away from the Cannon River, if economically viable.

The average monthly temperature in Northfield during December, January, and February is lower than thirty degrees Fahrenheit, which is not cold enough for the snow to melt, and the sodium chloride to dissolve and seep into the water table. When the temperature rises in March to an average of forty degrees Fahrenheit, the salt will be released into the environment. Our results did not indicate that the levels of sodium chloride in the Cannon River were elevated by the presence of the salt at the rodeo site. However, we recommend an additional study be completed during the spring at higher average monthly temperatures.

Forman and Deblinger's (2000) study indicated that road salt affected the area up to 300 meters away from suburban highways. The rodeo salt dump is only 12 meters away from the Cannon River. The city of Northfield should undertake an environmental cost/benefit analysis of their snow removal procedures. If economically possible, they should dump the snow from the downtown area at a more isolated location, further away from the Cannon River. Further study on the run-off effects at Sechler Park would help determine if this may be a more environmentally friendly, and economically feasible, dump location.

Studies indicated that the sodium chloride levels from road salt in wetlands in Minnesota and Wisconsin, though higher than natural levels, were not high enough to

harm macroinvertibrates. Our results indicate that the sodium chloride levels in the Cannon River during the winter months are 27 mg/L, which is about 400 times lower than the lethal dose for crustaceans. The plant community is more vulnerable than animals, however, and it is possible that the sodium chloride levels are high even to harm the vegetation around the rodeo site.

Another important issue raised in our study was the effect of sodium chloride in the Cannon on drinking water. According to the City of Northfield Water Division, the City supplies its water from a groundwater source from 4 wells ranging from 365 to 410 feet that draw water from the Multiple and Jordan-St. Lawrence aquifers. It is highly unlikely that the road salt from the rodeo site is contaminating drinking water for the city of Northfield. However, the road salt most likely affects the groundwater below the rodeo site.

The low sodium content of our snow samples could be explained by the fact that the salt was concentrated in the center of the piles, below where we collected. A study conducted at warmer temperatures would explain what happens to the 70 tons of sodium chloride estimated to be at the rodeo site. The salt could be seeping into the groundwater or the river, at levels above or below the lethal levels for plants and animals. The city of Northfield should take such considerations into account when formulating their snow removal policy.

Acknowledgements

This project would not be possible without the generosity of many people who deserve recognition. We would like to thank Professor Bereket Haileab, for his time and guidance in the many stages of this research and project development, and the Carleton

College Department of Geology for the use of lab machinery and field equipment. This project would not have been possible without the assistance of the City of Northfield, particularly the Operations Manager, Joel Walinski. We are also appreciative of the Geology T.A.'s, Nick Riordan and Kelsey Dyck, for their enthusiasm and reassurance that everything would be okay. And lastly, we would like to thank our fellow classmates, for sharing their research and making Geology an awesome experience.

Works Cited

Benbow, ME and RW Merritt. "Road-Salt Toxicity of Select Michigan Wetland Macroinvertebrates Under Different Testing Conditions." Wetlands. Vol. 24, no. 1, pp. 68-76. Mar 2004.

Blassius, B.J. and Marriot, R.W. "Field and laboratory investigations of the effects of road salt (NaCl) on stream macroinvertebrate." Environmental Pollution 120

Bloom, Nicky, Tim Singer, Ben Barclay, and Rachel Samuels. 2006 Carleton College Environmental Geology Report.

Carleton Biology Website. Feb 28, 2006. www.carleton.edu/curricular/BIOL/resources/musselpage/aerphoto.html

City of Northfield Comprehensive Plan. Chapter 10 Environmental Protection. 2001. http://www.ci.northfield.mn.us/housing/planningandzoning/comprehensiveplan

City of Northfield Water Division. "2004 Annual Report to Consumers on Water Quality."

Dana, Juliet, Matthew Cole, Blake Nicholson, and Leena Odeh. 2006 Carleton College Environmental Geology Report.

Guy L. Leblanc. "Assessment Report on the Toxicity of Road Salt." Winsor Salt, The Canadian Salt Company Limited (2000).

Miklovic, S and SM Galatowitsch. "Effect of NaCl and Typha Angustifolia L. on Marsh Community Establishment: A Greenhouse Study." Wetlands. Vol. 25, no. 2, pp. 420-429. Jun 2005.

Monthly Averages for Northfield, MN. 2006. The Weather Channel. 4 Mar. 2004 <http://www.weather.com/activities/other/other/weather/climo-monthly-graph.html?locid=USMN0552&from=36hr_bottomnav_undeclared>.

Walinski, Joel. Personal Interview. Feb 22 & March 2, 2006.

Appendix A. Records of the Two Snow Removal/Dump Events of 2006

STORM RECORD REPORT

DATE: Nov 25,26,2005		STORM No: 2	
1. TIME	**AM**	**PM**	**Day of Week**
Storm Started	**4:00**		**Nov 25,2005**
Storm Cleared		**3:00**	**Nov25, 2005**
Roads Cleared		**10:00**	**Nov 26,2005**

2. Description

Snow Type	Amount	Temperature		Wind	
Dry Snow	4"	Max: 18	Min: 12	Direction: ESE	Velocity: 11mph
Wet Snow		**Road Temperature**			
Sleet		Loc.1:	+8 hr: 19 21	Loc.3:	+8 hr: 21 22
Freezing Rain		Loc.2:	+8 hr: 22 25	Loc.4:	+8 hr: 20 24

			Loc.5:	+8 hr: 20 24
			Loc.6:	+8 hr: 20 22

3. Procedures

	No. Of Apps.	Amount
Pre-treatment	**11,22,05 1000**	Gals.
Plowing	**6**	Hrs.
Salt	**41**	Tons
Salt/Sand	**18**	Tons

4. Results

	Excellent	Good	Poor
Pre-treatment		**X**	
Plowing		**X**	**X**
Salt		**X**	**X**
Salt/Sand		**X**	**X**

5. Labor, Equipment

Personnel	Hours				Downtown Hours			Start Time: / Finish Time:	
	Reg.	OT	Total	Equip. Type	Reg.	OT	Total	Equip.	**Snow Hauling**
Lenny		18	18	LT, SDMP					
Tom		13	13.5	LT					**Company:**
Steve P.		17	17.75	SDMP, FL		**6**	**6**	**MG**	**Owatonna, Theile**
Steve M.		17	17.75	SDMP		**4.5**	**4.5**	**FL**	**Truck Type:**
Bryan		17	1705	SDMP, FL		**6**	**6**	**FL**	**4 triaxles**
Jeremy		0	0						**2 end dumps**
Chris		17	17.75	SDMP					**Amount Hauled:**
Ryan		11	11.25	SDMP					**4 loads each**
Sean		11	11.5	FL					
Dan P.		0	0						
Mike A.		11	11.5	TC, JDT					**Dump Location:**
									Rodeo grds

Comments: Started to snow on 11,25,05 & also ended on same day. 1st full plowing on 11,26,05. 2nd night the downtown was removed without any problems. Overall everything went great. No troubles to be said

Completed By: __ T.J. Heinricy_____

Temp Locations:

Loc. #1: Bridge Deck 4th Street
Loc. #2: Asphalt Protected 3rd & Maple
Loc. #3: Asphalt Open Jeff. Pkwy. & Maple
Loc. #4: Concrete Protected Division & 3rd.
Loc. #5: Concrete Open Division & 6th
Loc. #6: North Avenue by Hospital

8.STORM RECORD REPORT

DATE: Dec 15,2005		STORM No: 8	
1. TIME	**AM**	**PM**	**Day of Week**
Storm Started	3:00 to 4:00		Dec 14,2005
Storm Cleared		6:00 to 8:00	Dec 14,2005
Roads Cleared	8:00 to 9:00		Dec 15,2005

2. Description

Snow Type	Amount	Temperature		Wind	
Dry Snow		Max: 24	Min: 20	Direction S to WSW	Velocity: 7 mph
Wet Snow	4 to 6 total	**Road Temperature**			
Sleet		Loc.1: +8 25,21,13	Loc.3: +8 hr: 26,20,11	Loc.5:	+8 hr: 26,23,13
Freezing Rain		Loc.2: +8 26,21,14	Loc.4: +8 hr: 27,20,14	Loc.6:	+8 hr: 25,19,11

3. Procedures

	No. Of Apps.	Amount
Pre-treatment		Gals.
Plowing	9	Hrs.
Salt	55	Tons
Salt/Sand	30	Tons.

4. Results

	Excellent	Good	Poor
Pre-treatment			
Plowing		X	
Salt	**X**	X	
Salt/Sand	**X**	X	

5. Labor, Equipment

Personnel	Hours				Downtown Hours				Start Time: 12:00 & 2:00 Finish Time: 6:30
	Reg.	OT	Total	Equip. Type	Reg.	OT	Total	Equip.	**Snow Hauling**
Lenny	8	5	13	SDMP					
Tom	8	7	15	LT					**Company:**
Steve P.	8	3	11	FL	**8.25**			MG	**Thiele trucking**
Steve M.	8	5	13	SDMP	**8**			FL	**Truck Type:**
Bryan	8	3	11	FL	**8.25**			FL	**5 end dump truck**
Jeremy	8	2	10	MG					
Chris	8	5	13	SDMP	**2**			SDMP	**Amount Hauled:**
Ryan	8	5	13	SDMP					**53 loads**
Sean	8	2	10	FL					**20 to 28 tons**
Dan P.	8	2	10	TC, JDT					**Per load**
Mike A.	2.5		2.5	JDT	**8**		8	SDMP	**Dump Location:**
								&FL	**Rodeo Grds**

Comments: Snowed ended the night before. Did a full plowing of the town, streets, and walks. Warmer when plowing started became colder as the day went on. Streets got icy. There will be a 2nd night removal

Completed By: __ T.J. Heinricy_____

Temp Locations:

Loc. #1: Bridge Deck 4th Street
Loc. #2: Asphalt Protected 3rd & Maple
Loc. #3: Asphalt Open Jeff. Pkwy. & Maple
Loc. #4: Concrete Protected Division & 3rd.
Loc. #5: Concrete Open Division & 6th
Loc. #6: North Avenue by Hospital

Appendix B.

From the City of Northfield's Comprehensive Plan:

Environmental Protection Goals

The City of Northfield's goals related to environmental protection and enhancement include:

1. To protect the environment and preserve clean water and clean air.
2. To preserve the scenic and environmental qualities of the Cannon River Valley and its tributaries.
3. To protect the existence of Spring Brook as a cold water trout stream.
4. To preserve sufficient natural open space in order to provide habitat for wildlife and provide scenic and recreational qualities for the community.
5. To guide development and redevelopment in a manner that protects and enhances the air, water and land resources in the City.

Appendix C.

Photo taken of the rodeo snow dump site: