The Impact of Road Salt on Domestic Wells
in the North Road Area of Westfield, Massachusetts
II
December 19, 2005

Robert M. Newton
Department of Geology, Smith College

Introduction

This is an update to the report filed last February and includes results from a second round of samples collected in September. The purpose of this study is to survey the impact of road salt on domestic wells in the North Road area of Westfield and adjacent areas of Southampton. The project is sponsored by the Barnes Aquifer Protection Advisory Committee (BAPAC) in cooperation with the Westfield Health Department, Westfield Water Department, Southampton Water Department and Department of Geology at Smith College. In this second round of sampling water samples were collected from 24 domestic wells on September 21, 2005 (Figure 1). Eight of these samples were collected from wells along Rt 10 in Southampton, not sampled during phase 1 (December 19, 2004 sampling) while the remaining 16 were from re-sampled wells. All samples were analyzed at the Smith College Aqueous Geochemistry Lab for calcium, magnesium, sodium, potassium, lithium, fluoride, chloride, sulfate and nitrate using a Dionex model DX500 ion chromatograph.

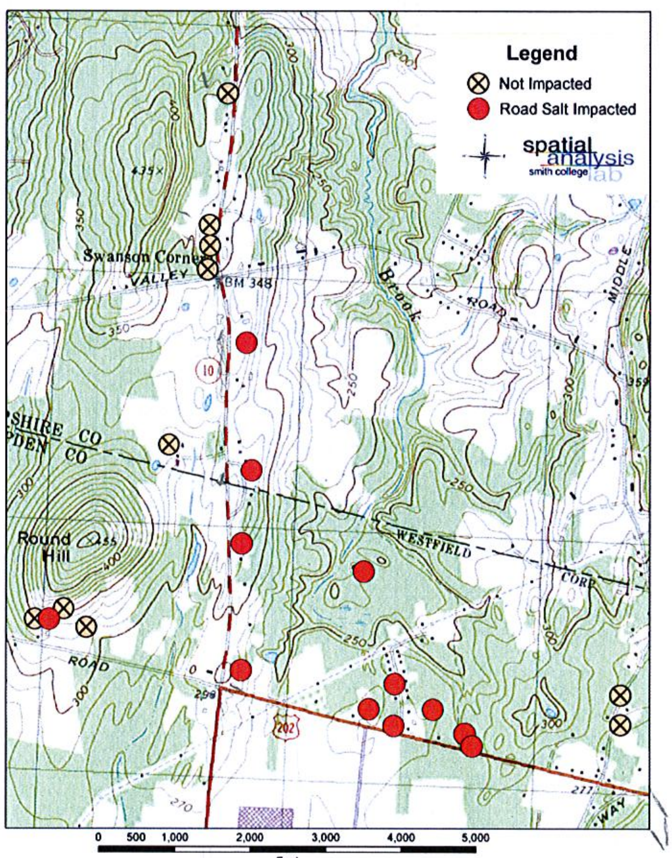

Figure 1. Map showing the location of wells impacted by road salt.

Background

Winter highway deicing is primarily accomplished through the use of road salt. Most of this salt is in the form of sodium chloride (NaCl), which is essentially common table salt. Calcium chloride (CaCl) is also sometimes used, as it is more effective at colder temperatures (< 10°F). In the United States, over 10 million tons of road salt are applied each year (Transportation Research Board, 1991). These salts are very soluble and are easily dissolved in the water that runs off the pavement. Runoff not captured by a storm runoff system, can infiltrate through permeable soils at the sides of the road causing, sodium and chloride contamination of the groundwater. The presence of permeable soils in aquifer recharge areas makes these areas particularly susceptible to contamination.

It is important to note that not all sodium found in groundwater comes from road salt. Minerals containing sodium are common in the rocks of the local area. Natural weathering of these rocks will also release sodium into the groundwater.

Dissolved sodium can potentially be a health hazard, especially for people suffering from high blood pressure and heart disease. The Massachusetts Office of Research and Standards Guideline (ORSG) has set the guideline for dissolved sodium at 20 mg/L. This is the concentration below which, adverse health affects are unlikely to occur. The guideline is set low enough to provide an adequate margin of safety so that exceeding the guideline would not necessarily lead to adverse health effects.

Unlike sodium, minerals containing chloride are not usually found in local area rocks, so most of the chloride observed in groundwater is associated with some form of contamination. A very small amount is natural, coming from sea spray that has been transported inland. Although there are no negative health effects for low concentrations of chloride, both the State of Massachusetts and the U.S. Environmental Protection Agency have set a Secondary Maximum Contaminant Level (SMCL) of 250 mg/l for dissolved chloride. This standard was developed to protect the aesthetic quality of drinking water and is not health based nor is it legally enforceable.

In this study, wells are classified as "salt-impacted" if the chloride concentration exceeds a critical value of 30.8 mg/L. This critical value is based on the concentration of chloride that would result if enough salt were dissolved to increase the sodium concentration by 20 mg/L (the ORSG guideline maximum allowable sodium concentration). It is better to use chloride for the critical value to assess salt-impact as, unlike sodium, there are no natural sources of chloride in the local rocks.

Results

The phase I sampling (December, 2004) identified 11 wells that were impacted by road salt. Ten of the 11 impacted wells from the phase I study were re-sampled during phase II (September, 2005). Of these, 9 were found to have increased concentrations of both sodium and chloride (Figures 2 and 3). Four of the non-salt-impacted re-sampled wells showed increased sodium concentrations while 3 of these also increased in chloride. One of the wells classified as non-salt-impacted in the Phase I sampling, was re-classified as salt-impacted in Phase II. Three of the 8 new wells sampled in Southampton as part of Phase II, were found to be salt-impacted. Two of these had very high concentrations of both sodium and chloride.

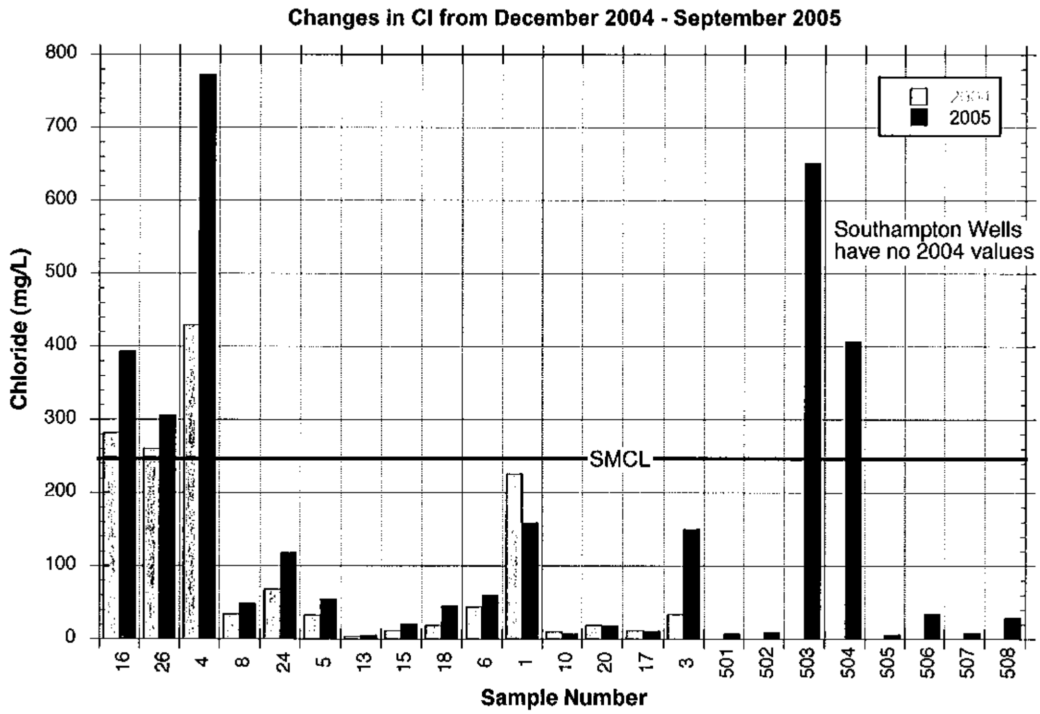

Figure 2. Chloride concentrations in wells. SMCL represents the secondary maximum contaminant level for chloride (250 mg/L).

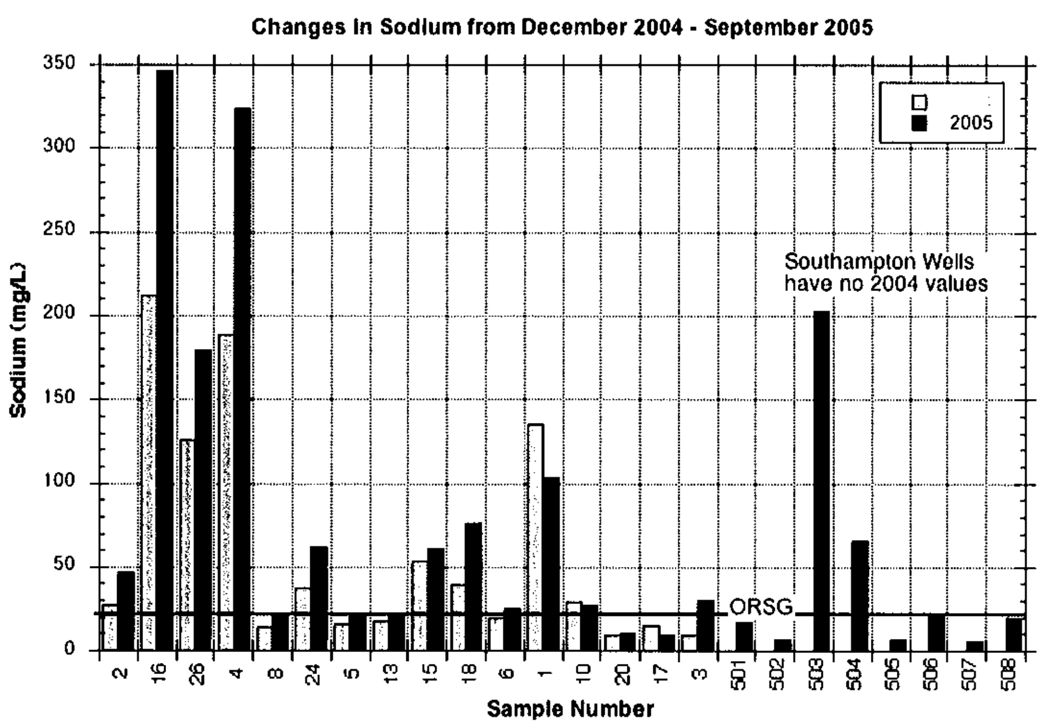

Figure 3. Sodium concentrations in wells. ORSG represents recommended maximum sodium concentration (20 mg/L).

Table 1. Average concentration in milligrams per liter

Class	#	Sodium		Chloride		Calcium		Nitrate	
Salt-Impacted	15	94.0	*83.7*	192.4	*203.1*	69.9	*83.7*	5.1	*4.7*
High Chloride	5	205.7	*93.0*	437.8	*182.7*	139.9	*117.0*	5.6	*5.1*
Natural Sodium	6	37.1	*14.2*	16.4	*9.3*	16.5	*8.8*	3.7	*4.0*
Un-Impacted	17	8.7	*6.0*	12.3	*8.4*	35.2	*24.6*	7.9	*6.4*

refers to the number of wells in each class. *Italics* = standard deviation of the mean

The general increase in salt concentrations, between the two sampling periods, is of some concern. However, it should be noted that many other constituents also increased in concentration from Phase I to Phase II and this could indicate that the phase I samples were more diluted, perhaps by a precipitation event prior to sample collection. More sampling is needed to establish if there is a long-term trend toward increasing salt contamination.

The salt-impacted wells predominantly occur in the area north and east of the intersection of North Road and Route 10 (Figure 4). They are characterized by high sodium and chloride concentrations. The average sodium concentration (94 mg/L) is more than 4 times higher than the 20 mg/L recommended by the ORSG. Chloride concentrations average 192 mg/L, which is less than the 250 mg/L SMCL for chloride. However, 5 of the salt-impacted wells had chloride concentrations above the SMCL. These represent the most grossly contaminated wells and all occur on either the east side of Rt 10 or the north side of North Road (Figure 5). The average sodium concentration in these wells (206 mg/L) is more than 10 times the recommended maximum value and over 20 times the background value found in nearby uncontaminated wells (Table 1). People suffering from high blood pressure or heart disease should not use water from these wells.

Unlike the Phase I sampling when four of the wells, classified as salt-impacted, did not actually have sodium concentrations higher than the 20 mg/l threshold, all of the Phase II salt-impacted wells had sodium concentrations above the threshold. High chloride without high sodium can be explained by two possible hypotheses. The first is that not all of the chloride was derived from sodium chloride. As noted earlier, calcium chloride is also used as a highway deicer. Dissolution of calcium chloride will raise chloride concentrations without increasing sodium. The second hypothesis involves exchange reactions in the soils and aquifer. The sodium in the salt contaminated runoff can exchange with other cations, such as calcium, that are loosely bound to soil and mineral particles. This lowers the sodium concentrations in the groundwater. The higher concentrations observed in the Phase II samples lessened the impact of these two effects and thus all salt-impacted wells also had high sodium.

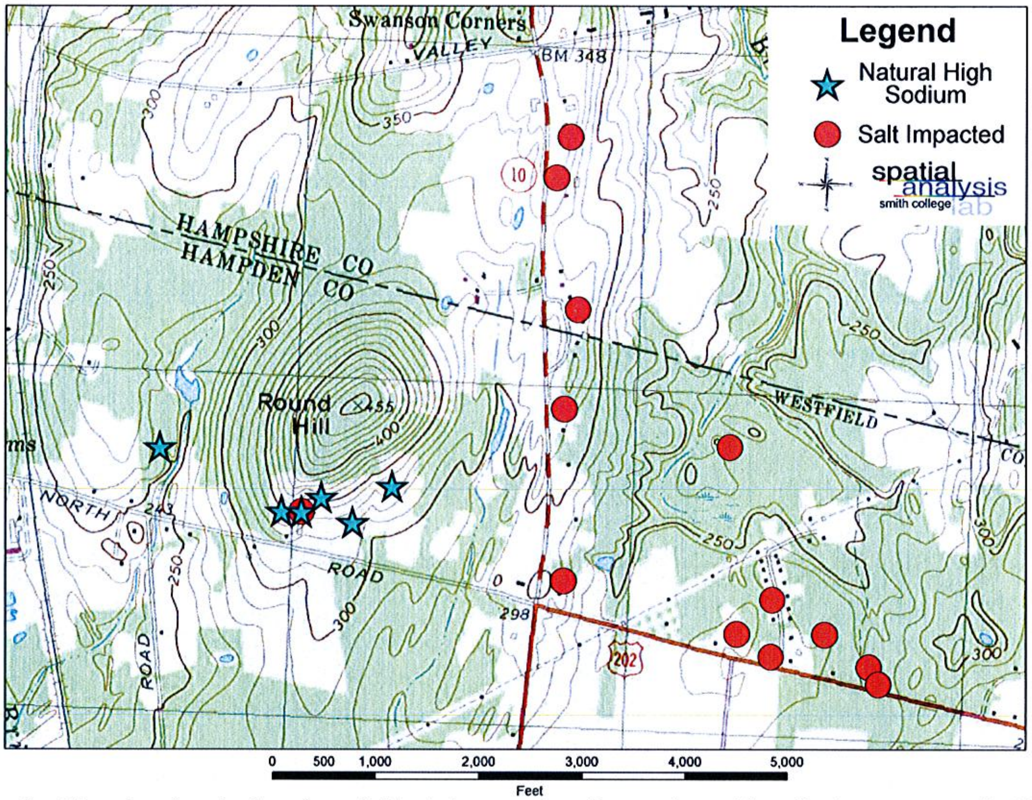

Figure 4. Map showing the location of all salt-impacted wells together with wells that are naturally high in sodium.

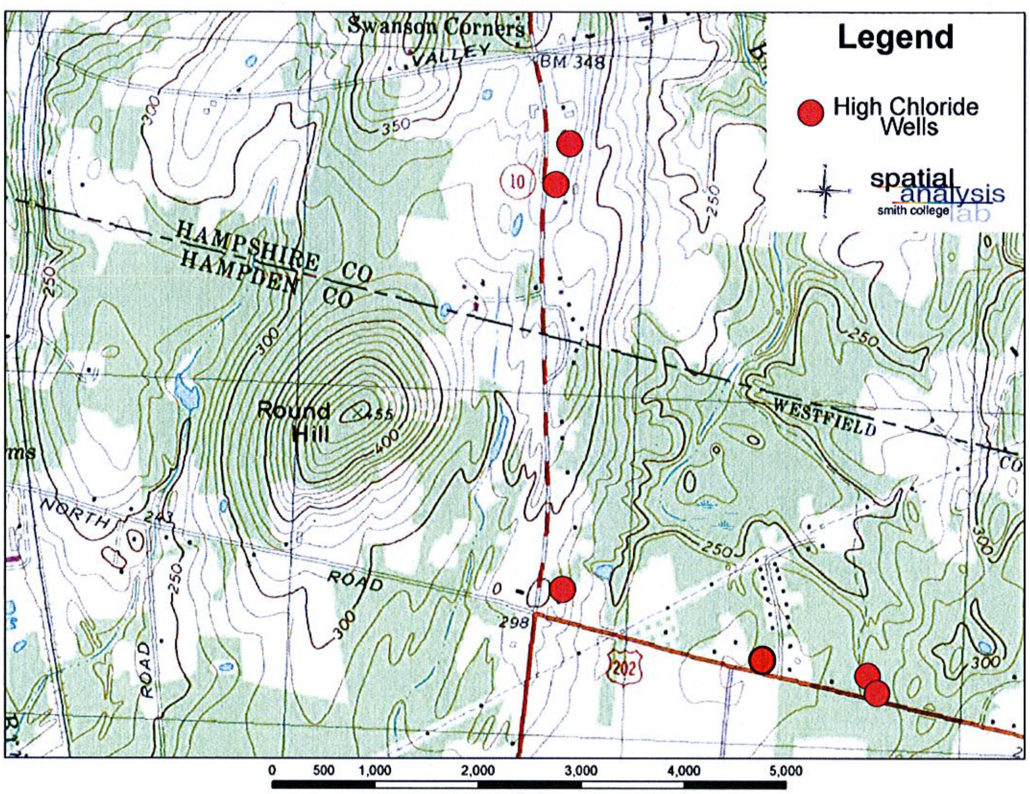

Figure 5. Map showing the location of highly contaminated wells where chloride concentrations exceed the 250 mg/L MCL.

Not all high sodium concentrations were the result of road salt contamination. Samples from some wells were observed to have high sodium concentrations without associated high chloride. (Figure 6) This is most likely due to the release of sodium from the natural weathering of minerals in the underlying bedrock. In the Phase I sampling, 5 wells were found to have sodium concentrations above 20 mg/L and chloride concentrations below the threshold salt-impacted value (30.8 mg/L). In the Phase II sampling, 3 of these wells were re-sampled and one was re-classified as salt-impacted due to an increase in the chloride concentration. The other two remained high in sodium and low in chloride. In addition, one well not previously classified as high sodium shifted to the high sodium class in the phase 2 sampling (Figure 3). All of these wells are found in the North Road area west of Rt 10 (Figure 4). Although these wells have sodium concentrations above the ORSG threshold, as a group, their sodium concentrations are much lower than those observed in salt-impacted wells (Table 1). The high natural background concentration of sodium makes this area particularly susceptible to road salt contamination as any additional sodium drives the concentration further above the recommended maximum concentration.

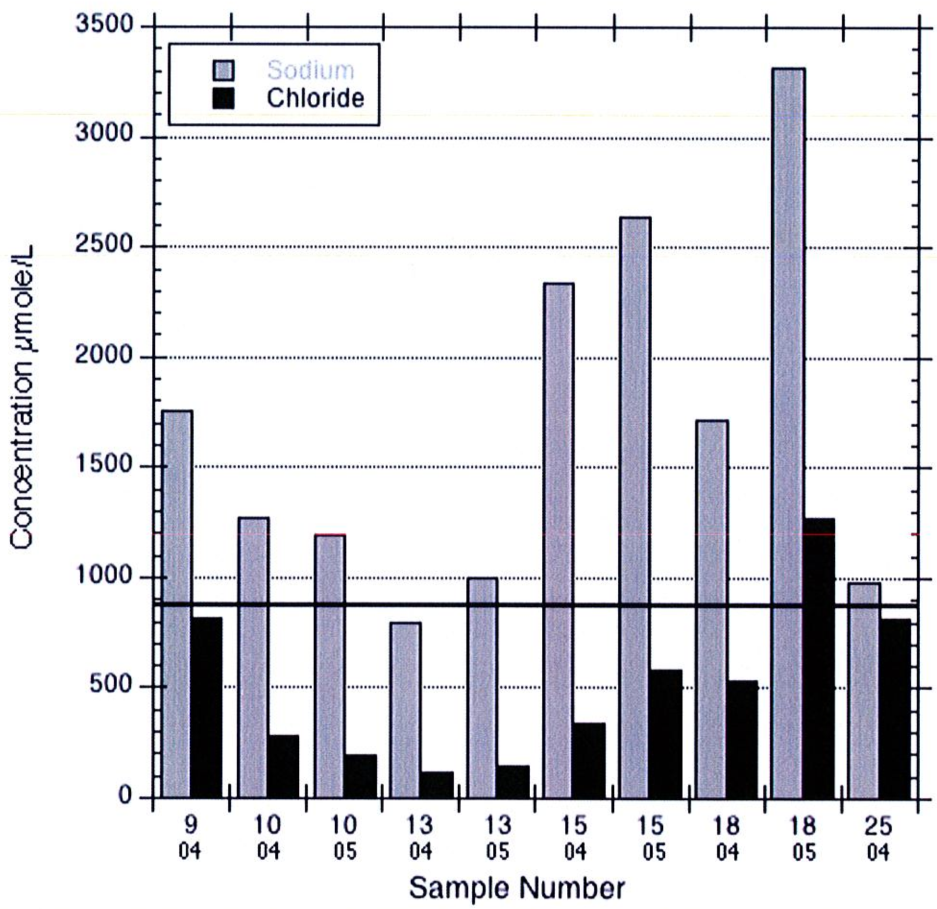

Figure 6. Concentration of sodium and chloride in wells that have high sodium without associated high chloride. Sodium would equal chloride if all the sodium came from road salt.

Other results of interest include the finding that some of the wells have relatively high concentrations of fluoride while others have higher than expected concentrations of lithium. Small amounts of fluoride are beneficial to health, helping to prevent tooth decay. However, high concentrations are harmful, causing skeletal fluorosis that leads to bone degradation. Generally, fluoride concentrations in drinking water should be lower than 1.0 to 1.5 mg/l. The EPA has set the Maximum Contaminant Level for fluoride at 4.0 mg/l. In this study, fluoride concentration range from below detection limits to as high as 1.0 mg/l. These concentrations are well within the recommended zone, however, children drinking water from the well with the maximum fluoride concentration should not be given supplemental fluoride. The highest fluoride concentrations were found in the wells that had the highest natural sodium concentrations lending support to the hypothesis that both the sodium and the fluoride are derived from weathering of the underlying bedrock.

The presence of lithium in some of the well water samples is somewhat of a surprise. Lithium is a fairly common trace element that, at low concentrations, causes no serious adverse health effects. It is routinely used as a drug for clinical depression. While there is no current federal standard for lithium in drinking water, the EPA estimates that concentrations should not exceed 0.70 mg/l. Lithium was detected in 20 out of the 35 wells sampled in this study and concentrations ranged up to 0.99 mg/l. There is a statistically significant positive correlation between lithium and sodium suggesting that they may have a common source. It is also possible that the lithium could be derived from contaminants associated with the road salt.

Water hardness is a term associated with the tendency of a water to consume soap and also to form scale. Total water hardness can be calculated from the measured calcium and magnesium concentrations. Hardness can be reported as the concentration of an equivalent amount of dissolved calcium carbonate ($CaCO_3$) in mg/l. Waters are classified according to the scheme shown in Table 2. Most groundwaters in the area are classified as soft or moderately hard, however, some of the wells sampled during this survey were classified as hard or very hard. A total of 21 wells had water that was classified as hard or very hard during either Phase I or Phase II sampling. This includes all the wells along Rt 10 as well as a number north of North Road (Figure 7). The distribution of hard water in this area suggests limestone bearing bedrock underlies part of the study area.

Table 2. Classification of water hardness.

Hardness $CaCO_3$ (mg/l)	Classification
0 – 60	Soft
61 – 120	Moderately Hard
121 – 180	Hard
> 180	Very Hard

There are no health concerns associated with water hardness but hard water does react with soap inhibiting the formation of soapsuds. It also tends to leave mineral deposits in sinks and other plumbing fixtures. At least one of the homeowners participating in this study had installed a water softener. Water softeners remove calcium and magnesium through an exchange process that replaces the calcium and magnesium with sodium. Care should be exercised in the use of this type of system as these water softeners can raise sodium concentrations to potentially hazardous levels. To prevent this, some newer systems use potassium as the replacing ion.

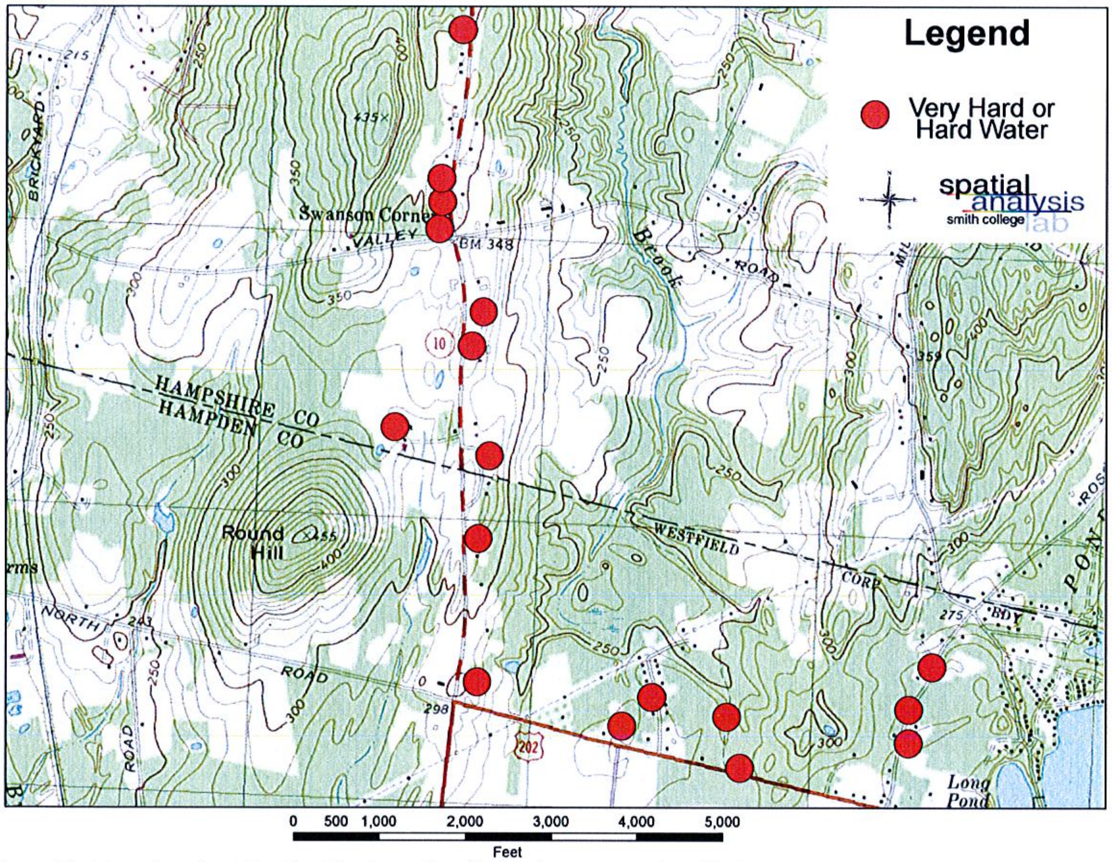

Figure 7. Map showing the distribution of wells having water classified as either "hard" or "very hard".

Conclusion

Fifteen out of 35 domestic wells sampled during either the Phase I or Phase II sampling were found to be salt-impacted. Five of the 15 are classified as high chloride, having concentrations above the SMCL (250mg/L). All of the salt-impacted wells had sodium concentrations above the 20 mg/L limit set by the ORSG. In addition, 6 wells, not impacted by road salt, were found to have sodium concentrations above the ORSG threshold. These wells are all found in the area just west of the intersection of Rt 10 and North Road and their high sodium appears to be the result of natural weathering of minerals in the underlying bedrock.

This study clearly shows that domestic wells along Rt 10 and along North Road, east of Rt 10 are being negatively impacted by the application of road salt. Steps should be taken to reduce the amount of salt applied to roads in this area. Although only a few of the wells east of the Rt 10 are currently salt contaminated, the high natural background sodium concentrations make this area particularly susceptible.

Salt concentrations in samples collected during the Phase II sampling were almost always higher than those observed in the Phase I sampling. While this is not, by itself, conclusive evidence that salt contamination is increasing, it does suggest that this is a distinct possibility and more monitoring over a longer period of time is needed.

Phase III Amendment (January 2008)

A phase III sampling of domestic wells was done on March 30, 2006. At this time 33 wells were sampled including 9 new sites. Eleven wells were sampled during all three phases. The well with the highest salt contamination showed the most significant increase in concentration through time (Figure 9).

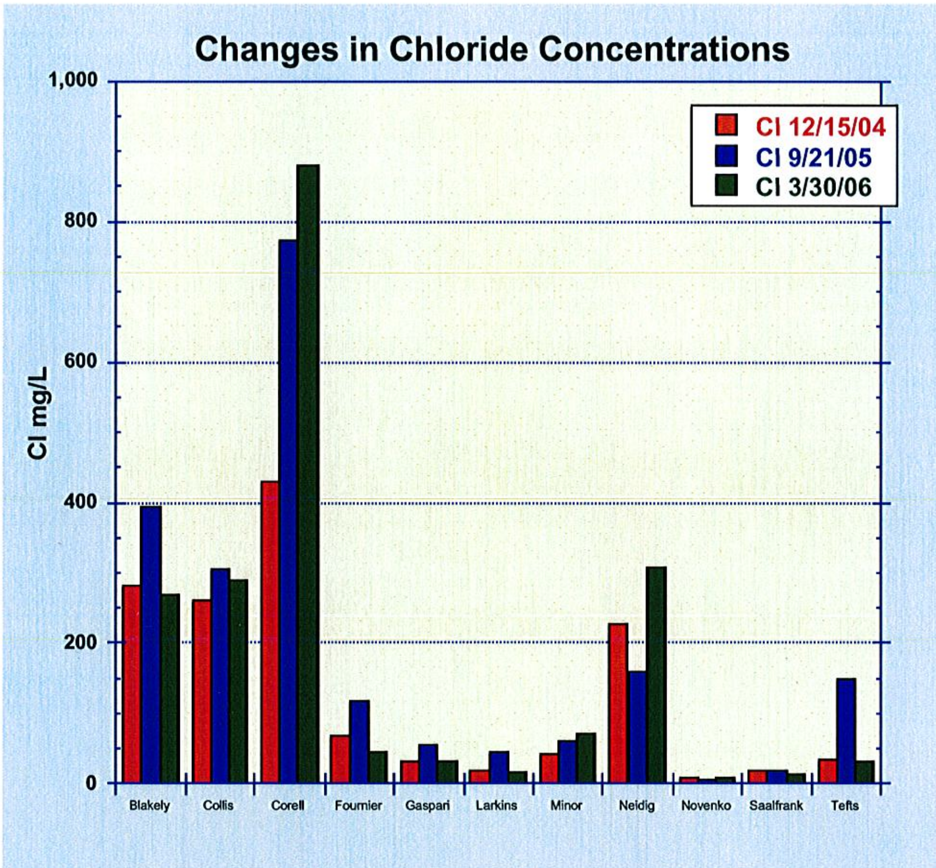

Figure 9. Changes in chloride concentration in wells sampled during all 3 phases of the study.

A total of 5 domestic wells were found to be highly contaminated, having chloride concentrations in excess of 250 mg/L in all samples.

Name	Address	Average Cl (mg/L)	#
Blakely	752 North Rd	315	3
Boden	415 College Highway	380	2
Collis	758 North Rd	286	3
Corell	1277 Southampton Rd	694	3
Wing	407 College Highway	651	2

One well (Neidig) had chloride concentrations below 250 mg/L during the first two sample intervals but increased to 308 mg/L during the March 2006 sampling.

Summary of Results

Phase I

27 samples collected December 15, 2004.

Location of samples: Westfield=26, Holyoke=1

Salt-Impacted 41% (11)

	Average	Maximum
Sodium	75.12	212.45
Chloride	138.92	429.68

Concentrations in mg/L

Not-Impacted 59% (16)

	Average	Maximum
Sodium	17.13	53.76
Chloride	15.13	28.99

Concentrations in mg/L

Phase II

24 samples collected September 21, 2005.

Location of samples: Westfield=16, Southampton=7, Holyoke=1

Salt-Impacted 58% (14)

	Average	Maximum
Sodium	108.89	346.06
Chloride	234.38	772.67

Concentrations in mg/L

Not-Impacted 59% (16)

	Average	Maximum
Sodium	18.75	60.75
Chloride	12.26	29.35

Concentrations in mg/L

Phase III

34 samples collected March 30, 2005.

Location of samples: Westfield=22, Southampton=8, Holyoke=4

Salt-Impacted 47% (16)

	Average	Maximum
Sodium	66.18	244.52
Chloride	210.49	878.83

Concentrations in mg/L

Not-Impacted 53% (16)

	Average	Maximum
Sodium	14.59	44.83
Chloride	12.77	22.67

Concentrations in mg/L