Beaver Brook/ Policy Brook I-93 Chloride TMDL

# Salt Loading Due to Private Winter Maintenance Practices

When the State of New Hampshire decided to widen its most important travel route, the New Hampshire Department of Environmental Services was called upon to address potential chloride increases from road salt. As part of the study, The Center for the Environment at Plymouth State University has performed the most thorough assessment of private salt loading of any chloride TMDL to date.

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**Submitted by:**
**Dari Sassan and Steve Kahl**

Plymouth State University
Center for the Environment
MSC 63 - 17 High Street
Plymouth, NH 03264

Phone: 603-535-3179
Fax: 603-535-3180
E-mail: dasassan@plymouth.edu

Plymouth State University
Center for the Environment

**Partnerships for a New Regional Perspective.**

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# Salt Loading Due to Private Winter Maintenance Practices

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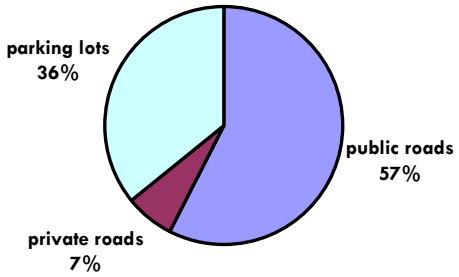
# Executive Summary

A chloride TMDL is currently being conducted in four southern New Hampshire watersheds which fall within the Interstate 93 corridor. Presently, seasonal variations in chloride are resulting in water quality violations under the federal Clean Water Act. The TMDL will guide scientists and policymakers in developing an implementation plan towards the end goal of attaining EPA compliance.

**Breakdown of Study Area Salt Loading from Vehicular Surface Deicing**




Road salt loading broken down by source, assuming a rate of 6.4 tons/acre/year is applied on parking lots and parking lot driveways and a rate of 17.8 tons/lane mile/year (average annual rate) is applied to public and private roads. Parking lot calculation includes associated driveways. Most residential driveways are excluded from this calculation.

As part of the TMDL study, an analysis of road salt use by maintainers of private roads and parking lots was conducted. Prior to the study, loading rates were hypothesized to be greater on parking lots than on roads. In actuality, the opposite was found to be true. A parking lot loading rate of between 5.7 - 6.4 tons/acre/year was established by our study. This loading rate for parking lots is significantly lower than the application rate to roads of 12.0 tons/lane mile/year (=8.3 tons/acre/year) derived from a state and municipal salt use tracking within the study area during winter 2006-7. The resultant breakdown of salt loading based on parking lot and road acreage attributes forty five percent of salt load from deicing to the private sector (see figure).

The parking lot loading rates described here are supported by findings of other private salt loading studies discussed in this report. Perceptions about parking lot load rates compared with road load rates are likely influenced by the perspective from which each are viewed. The lower rate for parking lots is explained here by the following factors:

- Parking lot and road geometry,
- traffic speed and flow,
- maintenance practices.

The solution to the chloride problem is likely to require multiple approaches. There is no known best-management practice for reducing salt flux to streams as there is for other water quality issues such as sediment or phosphorus. Therefore, a combination of legislative, managerial, and technological activities seem likely to be required in order to reduce salt loading to these and other New Hampshire watersheds. Education and social marketing geared toward changing the perceptions and winter behavior of the public will likely be required.

# Introduction

In recent decades, chloride contamination of surface and ground water resources in the northeast has become an increasingly prevalent environmental issue. (Kaushal *et al.* 2005, Rosfjord *et al.* 2007). Elevated chloride levels not only threaten aquatic organisms and ecosystems, but also human drinking water supplies (Transportation Research Board 1991, D'Itri 1992, Environment Canada 1999, Heisig 2000, Wegner and Yaggi 2001).

While multiple factors contribute to chloride concentrations, correlations drawn in previous studies point to deicing applications of sodium chloride (the most common deicer) on roads and parking lots as the leading cause of sharp upward trends in aquatic chloride concentrations detected in many northern US locations. (Jones *et al.* 1992, Godwin *et al.* 2003, Jackson and Jobbagy 2005, Kaushal *et al.* 2005)

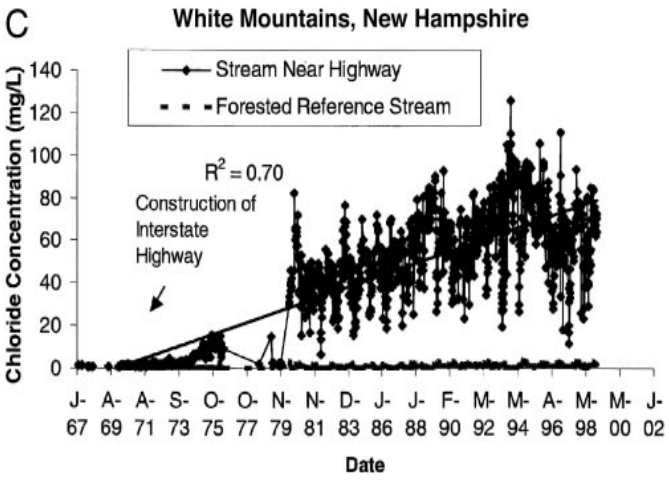



Figure 1. Comparison of chloride levels in a stream located near a highway and a stream in a forested area not receiving road runoff *(Kaushal et al. 2005)*

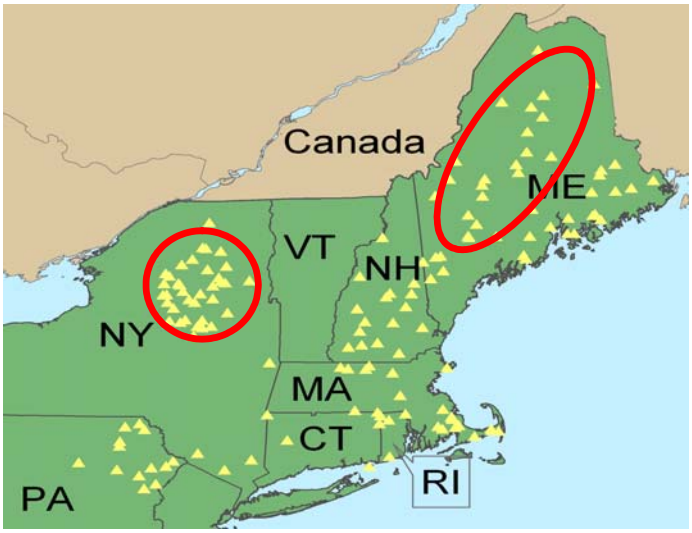



Figure 2. 1984 chloride levels in Northeast US were compared with levels reported in 2004. Yellow triangles show all sampling sites. Red circles generally indicate areas where chloride levels remained stable. These areas can be characterized as less urbanized, receiving little or no roadway runoff *(Kahl et al. 2007)*

At Hubbard Brook, NH a steady increase in chloride concentrations in the water of a stream located near Interstate 93 in New Hampshire contrasted with the unchanged concentrations in a nearby forested stream, illustrates a clear link between winter roadway maintenance and chloride contamination (Figure 1).

During a period from 1984 to 2004, Rosfjord et al. (2007) found increases in chloride in a significant portion of urbanized lakes in central and southern New England while remote, high elevation lakes receiving little or no roadway runoff in Maine and the Adirondacks, NY (Figures 2,3) showed no increase.

Though increases in paved surfaces have certainly led to intensified chloride contamination, road salt use over the past 25 years has inflated

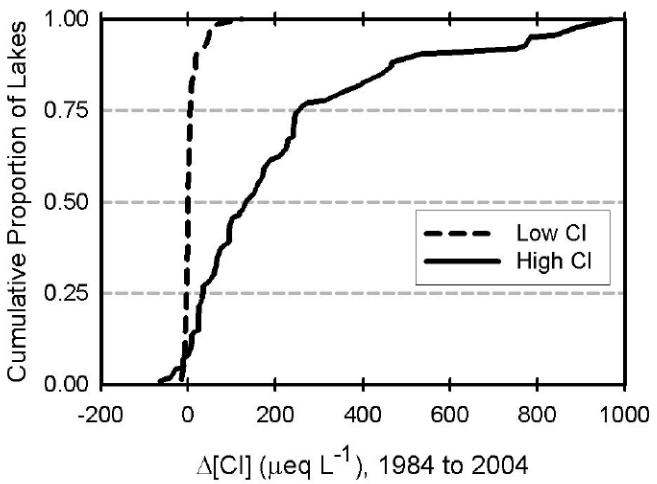



Figure 3. Change in chloride concentration among high and low chloride lakes (categorization based on 2004 levels). As indicated, the upper quartile of high chloride lakes experienced chloride increases ranging from approximately 250-1000 μeq/L *(Rosfjord et al. 2007)*.

by a much greater factor than have lane miles (Figure 4) (Bureau of Transportation Statistics 2007, Salt Institute 2007). This inference suggests that changing public expectations of post-storm road conditions are a major factor resulting in increased salt use.

The Transportation Research Board reports that New Hampshire was the first state to adopt a statewide salt-use policy, doing so in the winter of 1941-2. That winter, 5,000 tons were applied nationally. Widespread road salt use began in the 1960s (Transportation Research Board 1991). Today, twenty million tons is spread on paved surfaces in the US (Salt Institute 2004). In 2005 of 59.5 million tons of salt purchased in the US, 23.5 million tons was for ice removal/ stabilization (USGS 2007).

In some communities, consistent water quality violations could bring into question the watershed's ability to sustain increased development as more pavement equates to more salt applied. Planning boards, already facing conflict between sustainability and economic growth, face further challenges and legal issues. Mitigation of high chloride will require changes in development density, modification in the imperviousness characteristics of future development, altered winter maintenance, and/or new chemical approaches to ice control.

Over the past three winters, water quality monitoring has revealed water quality violations for chloride in four watersheds along the southern portion of the I-93 corridor in New Hampshire. Road maintenance practices are believed to be

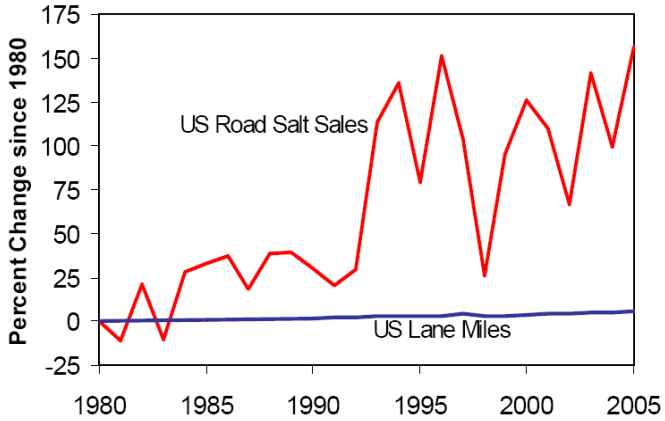



Figure 4. Comparison of percent increase in US lane miles (blue) to percent increase in salt use (red) since 1980. *(US Board of Transportation Statistics, Salt Institute)*

closely linked to the violations. A currently proposed I-93 widening project will impact the violating watersheds and increase their roadway lane miles requiring deicing treatment. As a resolution, the 401 Water Quality Certificate for the project has been held contingent upon the

completion of a TMDL for chloride to study the impacts and quantify the sources of chloride and permit acceptable allocations for the alleviation of excessive loads.

Over the past winter, as part of the southern NH chloride TMDL, we have compiled data on salt use in private deicing applications to compare to public applications.

Based on a review of other chloride studies and TMDLs from regions where road salt is a significant source, this study may represent the most exhaustive effort undertaken to place reality based parameters on the actual contribution from private deicing to the chloride budget. Studies conducted in Wisconsin (Bannerman, 2006) Minnesota (Wenck 2006, Fortin 2007) and Canada (Environment Canada 1999) are compared with the results of this study. An additional USGS report (USGS 2007) was referenced as a means of further analyzing the results. As an example of previous efforts, the 2006 Shingle Creek, MN TMDL addresses private de-icing practices in one brief paragraph:

> "Private contractors, industry, and agencies such as port authorities and airports use salt as a de-icer. Limited data were available for parking lots, industrial, commercial, and other private properties. Cheminfo (1999) estimated that commercial and industrial consumers represented approximately 5 to 10% of the road salt market. In quantifying total road salt application in Canada, Environment Canada used the midpoint of these data (7.5%) to represent commercial and industrial road salt application" (EC 1999)

(Wenck 2006).

The 2004 West Branch DuPage River, IL chloride TMDL makes no mention of parking lot de-icing but does take an interesting approach to quantifying salt-loading from road maintenance. The method involves applying an average annual salt-loading rate (calculated using 10 years worth of municipal and state salt-use data) and distributing that yearly application based on percentage of snow events occurring within each month. This method contains two inherent weaknesses 1.) it treats each snowfall event the same regardless of duration or severity and 2.) it discounts differences in year-to-year snowfall amount and year-to-year event counts). However, it does offer some direction in the development of a method for calculating salt-loading from private roads (CH2MHILL 2004).

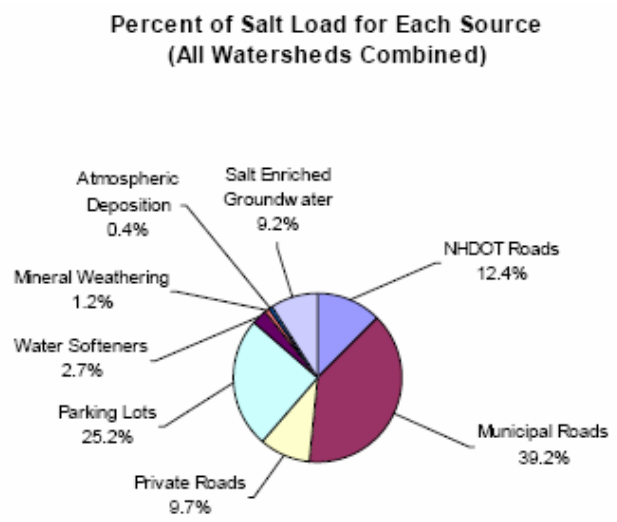



Figure 5. DES preliminary estimate on salt loading sources from within the TMDL study area *(NH DES 2006)*

### Sources of Chloride

Road salt has been recognized as the primary source of chloride in the environment in sites which experience winter weather requiring road maintenance. However, other sources do exist, include chloride introduced from water softening practices (a more significant concern in other regions), mineral weathering, reintroduction from

groundwater (e.g. base flow contribution) which mostly represents salt originally from deicing , and atmospheric deposition (airborne ocean water). Prior to the TMDL, NH DES provided a preliminary estimate of how these sources might break down in terms of percent contribution to the overall chloride load (Figure 5) (NH DES 2006). This study enhanced the accuracy of this original DES estimate of salt source loading.

**How Road Salt is Transported**

Langen et al. effectively summarize the various ways in which applied road salt is initially introduced into the environment from roads as "scatter" during initial application of rock salt, flow away from roadway in melt water, splash from vehicular travel, splash from plowing, or aerosolized mist mobilized by vehicles or directly from the road by wind "transported as a fine spray by wind currents". Langen indicates that the influence of each of these "mechanisms" is impacted by deicer type and application method, road characteristics, traffic patterns, and environmental conditions including slope, soil type, vegetation, and climate (Langen *et al.* 2006).

In a 1991 publication, the Transportation Research Board simplified the various ways that salt enters the environment and linked each conduit with its associated potential impacts (Figure 6).

**Impacts of Road Salt**

Chloride, which makes up about 60% of NaCl by weight, has been found to have certain negative impacts on the natural environment, highway and municipal infrastructure and on drinking water supplies. Bridges, roads, masonry, machinery and vehicles are all subject to corrosion caused by salt (Transportation Research Board 1991). Some road salt alternatives have been found to be less corrosive (Transportation Research Board 1991, Fischel 2001) but at the present time, with NaCl as the prevalent deicer, corrosion is a significant concern. The only major building material not affected by salt is wood, hence the movement toward a return to wood and wood-composite bridges in New England.

Chloride is generally considered to be a "conservative" element in the environment. Meaning, except in a strict biogeochemical sense, as it passes through the landscape, it is not taken up or sequestered to any significant degree (Effler *et al.* 1984, Öberg and Sandén 2005). In the most general terms, any chloride that is applied (via water softening, deicing or other) eventually makes it into a water source. As a result, in watersheds where increased development and maintenance activity has led to increased chloride use, lakes, streams, and aquifers are receiving inputs with increased chloride levels.

A study released in 1975 by Hall shed light on the impacts that increased chloride inputs were having on groundwater in New Hampshire. Long term (1920-1970) chloride data from seven well sites around the state (Colebrook, Derry. Dover, Hampton, Laconia, Portsmouth and Whitefield) was analyzed. Hall concluded that despite very "slight" evidence of chloride increases prior to 1945, all sites began to show increases. Hall writes, "This essentially coincides with the beginning of increased road deicing salt applications" (Hall 1975).

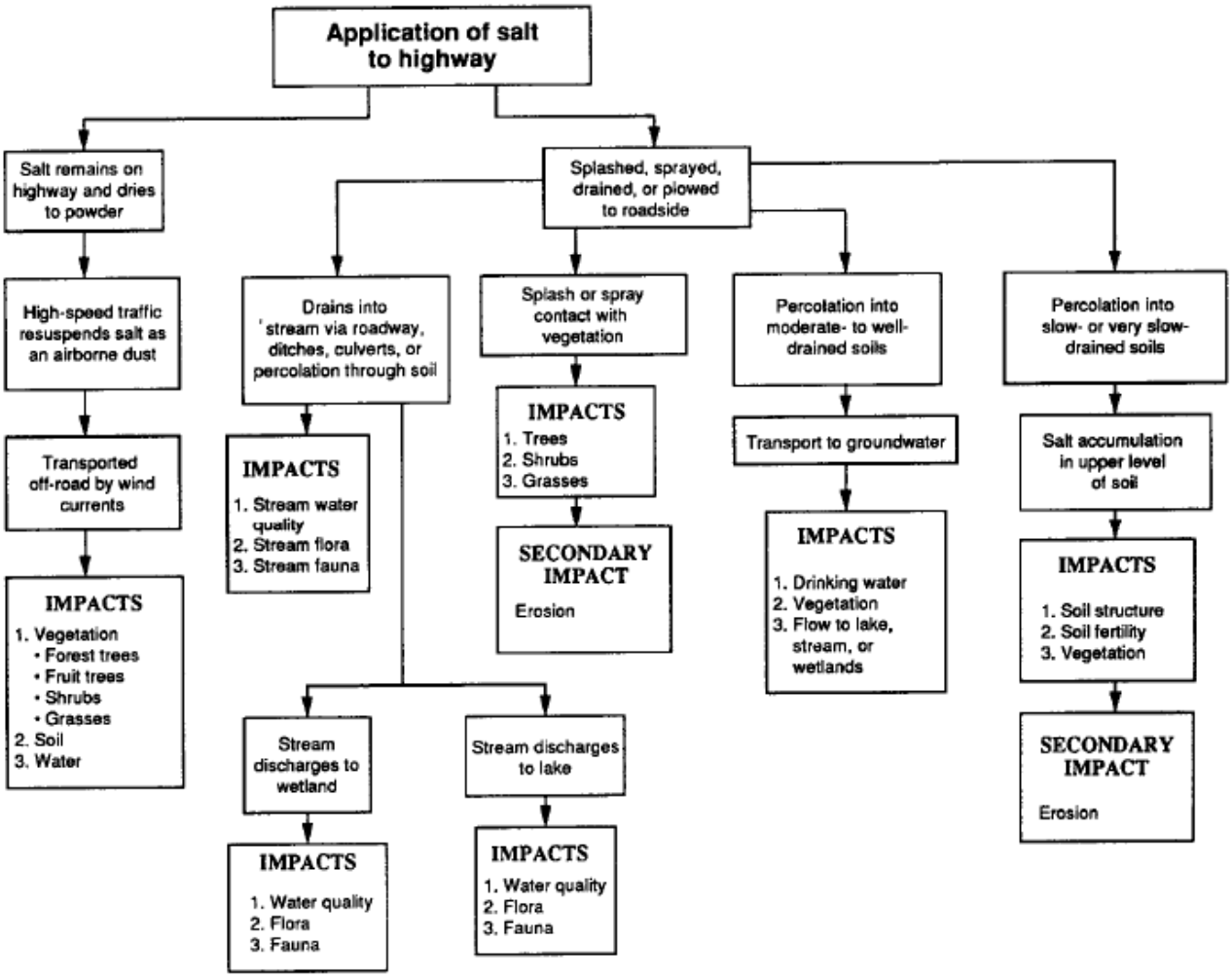



Figure 6. From the point of initial application, salt enters the environment through various paths, each with associated environmental impacts (Transportation Research Board 1991)

EPA has set a maximum level of 250 mg/L (recommended drinking water chloride standard of 25 mg/L) and a drinking water sodium standard of 20 mg/L. While the chloride drinking water standard is based on aesthetics (taste) the sodium standard is intended to reduce any contribution to hypertension (US EPA 2007).

Perhaps the most readily apparent and obviously linked impact of the chloride in road salt is the effect it has on roadside vegetation. In New Hampshire salt intolerant trees such as White Pine, *Pinus Strobus*, Canadian Hemlock, *Tsuga Canadensis*, Sugar Maple, *Acer Sacharum*, and Red Maple, *Acer Rubrum* commonly show salt damage in the late winter and spring . Airborne

Figure 7. Chloride is mobilized by vehicle traffic in the form of airborne spray which can cause extensive foliar damage as can be seen on these white pines.

*(http://www.gtcd.org/photos/WinterSaltDamageWeb.JPG)*

salt, in the form of an aerosol spray, accumulates on the foliage of roadside vegetation causing health impairments ranging from leaf damage (Figure 7) to mortality (Lumis *et al.* 1975, Transportation Association of Canada 2003).

Another way in which road salt impacts vegetation is through soil contamination. Impacts vary in severity depending on factors including drainage, slope, proximity to a contamination source, and, of course, level of application. Chloride inhibits the uptake not only of water, but also of nutrients like potassium and phosphorus. (Lumis *et al.* 1975, Environment Canada 1999, Wegner and Yaggi 2001). In soils receiving elevated levels of road-salt-laden runoff, metals and other contaminants may be mobilized with increased NaCl concentrations (Amrhein *et al.* 1992).

Organisms other than plants are also impacted by chloride, including not only those living in contaminated water bodies, but also terrestrial organisms. For example, salt use has been correlated with a decline in habitat for soil bacteria and earthworms. Ingestion of salt has been linked to bird mortality and increased road kills from animals feeding on the salt on roadsides (Environment Canada 1999, Wegner and Yaggi 2001).

**The Chloride Standard for Aquatic Life**

The EPA chloride is based on an aquatic life criteria and establishes that "freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of dissolved chloride, when associated with sodium, does not exceed 230 mg/L more than once every three years on the average and if the one-hour average concentration does not exceed 860 mg/L more than once every three years on the average" (US EPA 1988).

**Why a chloride TMDL in southern NH?**

A TMDL, or Total Maximum Daily Load is the mechanism established by EPA to address water quality violations to meet the requirements of the federal Clean Water Act. TMDLs are typically done for waters on the state 303(d) list, which identifies all waterbodies whose water quality is in violation of any state or federal water quality standard (US EPA 2007). In New Hampshire, 85% of exceedances are for mercury. Though pH related water quality violations come in a distant second at 5% all pending TMDLs, roughly 3/4 of approved TMDLs in the state have been for pH (EPA 2007).

The chloride TMDL currently being conducted in southern NH is not only in response to recorded water quality violations in four heavily-developed watersheds (Figure 8), but also in

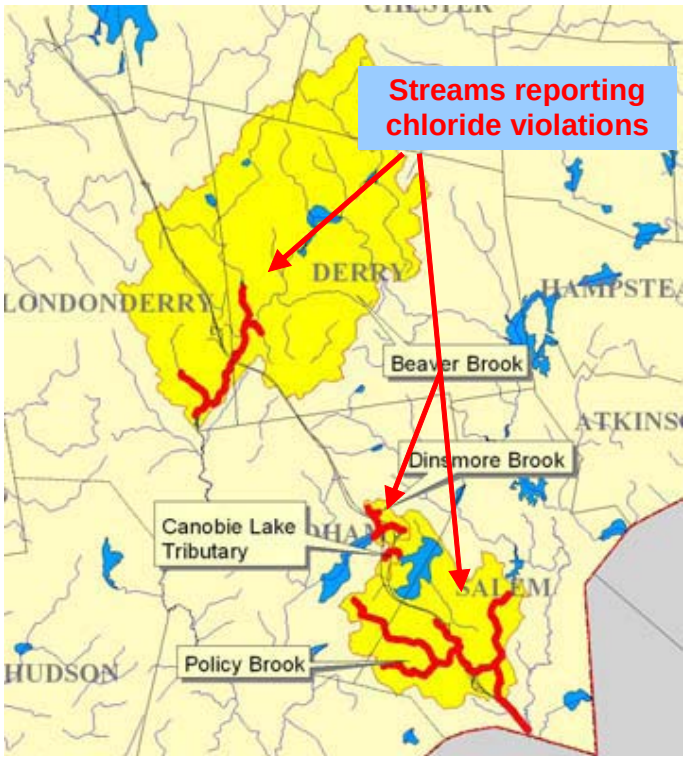



Figure 8. The southern NH chloride TMDL study area (yellow) and *(NH DES 2006)*

preparation for a proposed expansion of Interstate 93 and additional associated salt loading .

### The Study Area

The four southern New Hampshire watersheds showing chloride violations are named Beaver Brook (19,447 acres, 30 $mi^2$), Policy Brook (6,530 acres, 10 $mi^2$), Dinsmore (381 acres, 0.6 $mi^2$), and North Tributary to Canobie Lake (128 acres, 0.2 $mi^2$). As a subwatershed of Policy Brook watershed, North Tributary to Canobie Lake feeds Canobie Lake whose outlet(s) flow south through Policy Brook watershed.

The New Hampshire towns which intersect the study area include Auburn, Chester, Derry, Londonderry, Pelham, Salem, and Windham (Table 1). Derry comprises nearly half of the study area. The watersheds can be characterized as mostly urbanized. Appendix F provides some statistics about the percent of land covered by paved surfaces for vehicular use (excluding most residential driveways). Overall, more than six percent of the study area is paved and it is likely that a complete analysis of impervious surface would find the study area to be above the ten percent threshold at which adverse impacts including flashy hydrographic conditions, reduced infiltration and polluted runoff begin to rapidly accelerate (Deacon *et al.* 2005, Ballestero *et al.* 2006, Kahl *et al.* 2007).

### Road Salt Alternatives

Parking lot and roadway managers are generally familiar with sodium chloride and comfortable using it. Salt is readily available for purchase in large quantities all over the world and it is relatively inexpensive. Though the negative impacts of road salt use have long been relatively well known among scientists (Hanes *et al.* 1970), the true costs of salt use are just recently being realized by policy makers.

As federal, state and municipal legislators, administrators and managers seek ways to lessen the environmental impact of deicing while continuing to keep roads safe, various alternative deicers have been used or investigated. While some alternatives have environmental costs of their own, others are expensive, and others simply do not work as well as salt. In 2001, Fischel researched various deicers for Colorado Department of Transportation and assessed environmental impacts of each (Appendix C). He found

| | total town acres | acres within study area | percentage of town in study area | percent of total study area | study watershed(s) which share land with the town | town population (2005)* | town population density (people/ square mile) |
|---|---|---|---|---|---|---|---|
| **Auburn** | 18472.6 | 132.5 | 0.7 | 0.5 | Beaver Brook | 5122 | 178 |
| **Chester** | 16749.2 | 1789.2 | 10.7 | 6.8 | Beaver Brook | 4636 | 177 |
| **Derry** | 23269.3 | 12242.5 | 52.6 | 46.4 | Beaver Brook | 34290 | 945 |
| **Londonderry** | 27008.8 | 5282.7 | 19.6 | 20.0 | Beaver Brook | 24837 | 590 |
| **Pelham** | 17183.6 | 0.8 | 0.0 | 0.0 | Policy Brook | 12474 | 465 |
| **Salem** | 16600.5 | 4903.6 | 29.5 | 18.6 | Policy Brook | 29558 | 1142 |
| **Windham** | 17805.7 | 2006.1 | 11.3 | 7.6 | Policy Brook, North Tributary to Canobie, Dinsmore | 12721 | 458 |

Table 1. Makeup of the TMDL study area broken down by town. **(US Census Bureau)*

that between all chloride-based and acetate-based deicers, each has associated adverse environmental impacts (Fischel 2001).

Magnesium and calcium salts have been used widely and are a common ingredient in brine. Like NaCl, they introduce chloride into the environment.

Calcium Magnesium Acetate (CMA) has received considerable attention as a less corrosive, chloride free salt substitute. CMA however, comes with its own set of negative impacts including a high energy production cost and a purchase cost that has proven prohibitive in most cases. Additionally it has been linked to oxygen depletion and eutrophication (Fishel 2001). CMA is also less effective at low temperatures.

A product that has received considerable attention recently is a salt additive that is a bi-product of food processing and distillation processes. It has been marketed under the trade names Ice Ban and Magic Salt. Referred to by many private contractors as "molasses", the sticky brown substance is sprayed over salt piles prior to use and

is said to reduce salt use by twenty percent and to negate some of salt's corrosive effects. Negatives associated with this additive is that it introduces a source of phosphorous into roadway runoff and can contribute to increased biological oxygen demand. In New Hampshire all three state colleges and universities as well as the city of Keene have experimented with this product. While reviews are mixed as to whether it has resulted in lower costs, users agree that the product does reduce salt use.

# Materials and Methods

The scope of work for this project, as requested by DES, included the following major components:

- Identify the party responsible for winter maintenance of parking lots and private roads in the study watersheds.
- Contact the party responsible for winter maintenance at parking lots and private roads to obtain estimates of the chloride loading rate for winter deicing.
- Reconnoiter the study area to identify all parking lots and private roads and accurately represent them in GIS format.
- Compile parking lot areas and salt loading rate information in a spreadsheet.

In the early stages of research, it became evident that gathering comprehensive data from the private sector would be difficult, a finding reported by other similar studies and reported anecdotally (Wenck 2006, Bannerman 2006). Initial attempts to contact owners and managers of large parking lots and learn the name of their maintainer proved inefficient as most were unwilling to provide information upon learning the purpose of the study. Attempts to speak with owners and managers without indicating a purpose were perceived as an attempt to take over the winter maintenance contract for the property and also received unfavorable response. Eventually, a few lot managers did provide important data.

Attempts to directly contact winter maintenance contractors in the region, including sending letters (Appendix A), making several rounds of phone calls and faxing surveys (Appendix B) were also generally unsuccessful. In time, however, several contractors including RG Carr of Windham, NH and Freshwater Farms of Atkinson, NH, provided a wealth of valuable data and guidance.

Accurately representing all parking lots in the study area and attributing area, occupant name, use type, and owner name (Appendix D, J) involved a multi-step process. Initially, use of aerial photos provided by New Hampshire Depart-

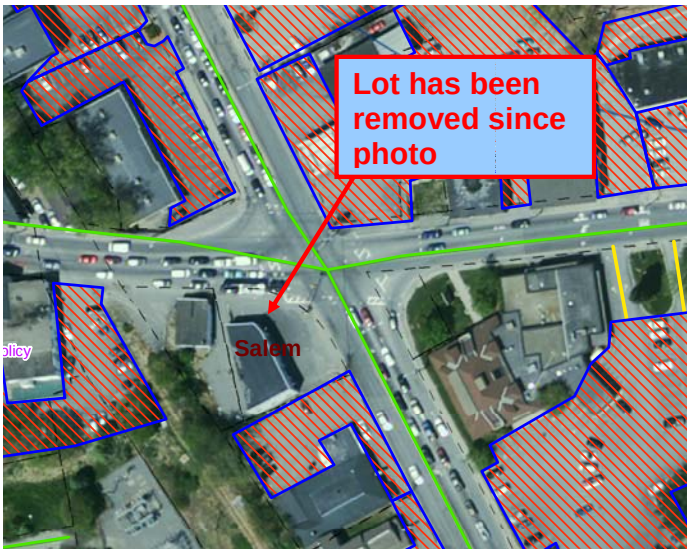



Figure 9. A lot that had been removed and replaced with topsoil and vegetation prior to winter 2006-7.

ment of Transportation, taken between April 22 and May 15, 2005, allowed for generation of digitized parking lot and parking lot driveway features. Following this process, visits to each lot

Figure 10. A lot that had been altered since the 2005 aerial photo was taken, adding to overall parking lot acreage receiving winter maintenance.

allowed for an association/occupant name and use type to be generated. A total of 30 visits to the region were made to gather this information. We compiled data on a laptop computer using ArcView 9.1 (ESRI) and DNRGarmin 5.1.1 (Minnesota Department of Natural Resources) software and a Garmin ETrex Legend GPS unit with PC connectivity.

During these trips, the study area was also surveyed for unrepresented lots or changes made in lots since the time of the 2005 aerial photo fly-

Figure 11. Lots that had been added since the 2005 aerial photo was taken.

over. In some cases, previously existing lots had been removed (Figure 9) or changed (Figure 10) and in other cases, new lots had been added since the photos were taken (Figure 11). For newly added lots, a GPS unit was used establish general lot dimensions.

To ensure full representation of all private roads, a DOT roads layer was overlaid on a GIS map of the study area and cross referenced with a DES

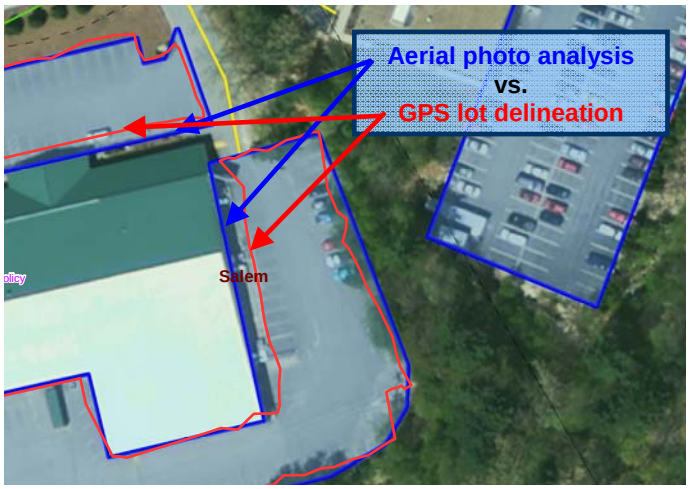



Figure 12. Example of a lot delineated 1. by tracing the boundaries of the aerial imagery (blue line) and 2. by walking the perimeter of the lot with a GPS unit. Obvious trajectory errors are apparent in the GPS generated polygon.

private roads layer. This combined coverage was augmented using aerial photo analysis; roads that were visible in the aerial photos but not represented as state, federal, or municipal by the DOT GIS layer were incorporated into either the digitized private roads layer or the parking lot driveways layer.

Local Municipal GIS managers provided invaluable assistance for identifying parking lot owners. Parcel data provided by the towns of Derry, Londonderry and Salem was clipped to the boundaries of the watersheds. For the town of Windham, an internet based GIS map of the town was referenced to determine ownership of parking lots within the town.

Each parking lot was drawn or reshaped individually based on aerial imagery, field observations, and/or local GIS updates. Simultaneously, ownership was established by determining the particular parcel which occupied the largest portion of the lot (according to the GIS parcel features, some lots overlapped two or more parcels).

Follow-up field work was conducted to evaluate the accuracy of delineation via aerial photos. We walked the boundaries of 50 parking lots within the study area and, using a sub-meter GPS unit, recorded and transformed these boundaries into GIS polygons. Figure 12 shows a drawn lot (blue) and a GPS generated lot (red) atop an aerial photo. Based on the trajectory errors of the GPS generated boundary line, we determined that drawing lots by tracing aerial photo features was a more accurate and efficient way of delineating parking lots.

To validate the salt loading estimates for the study area, colleges and universities around the state were contacted to provide salt loading data. These sources tend to be highly documented and presumably more consistently accurate than many other sources of loading data. Delineation of parking lots and maintained roads of participating colleges and universities allowed for their salt use numbers to be translated into a per-acre application rate.

# Results and Discussion

**Parking Lots**

A total of 1,111 parking lots were delineated within the four study watersheds (Appendix D, J), including 361 more lots than originally listed for the region by DES. Total area of parking lots within the study area equaled 763 acres, 325 acres more than initially catalogued by DES.

Calculations on paved area were made using the assumption that all private roads and parking lot driveways were an average of two lanes wide. Public road mileage was calculated by clipping all state and local roads as identified by DOT roads GIS layer to the watershed boundaries and multiplying each segment length by the number of lanes per segment. All lanes were assumed to be 12 feet wide based on the most common listed lane width in the DOT roads GIS layer.

Parking lots account for forty-seven percent of total paved acreage, private roads accounted for five percent, and parking lot driveways account for five percent (Figure 13). Thus, a total of fifty-seven percent of the total regional paved area is under private management, underscoring the importance of road salt loading estimates for the TMDL. The area of all four study watersheds combined equals 26,485 acres. Total paved acreage for vehicular travel and parking equaled 1,651 acres, 6.3 percent of the land area (Policy Brook, 9.5% [North Tributary to Canobie, 11.2%]; Beaver Brook, 5.2%, Dinsmore, 7.0%) (Appendix F).

Salt loading data were collected from 31 separate sites totaling 338 lots, 108 of which were within or immediately outlying the study area (Appendix E). Loading data were collected for 270 acres (35% of study area parking lot acreage), 142 of which were within or immediately outlying the study area. Salt use was presumed to have been applied equally over parking lots and associated driveways, an unavoidable assumption.

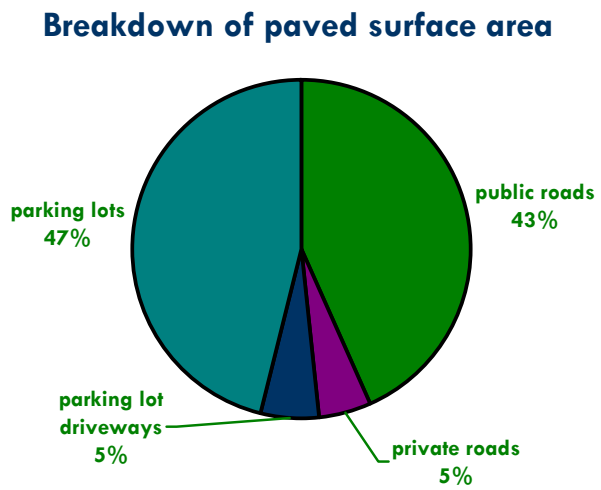



Figure 13. Breakdown of paved surface for vehicular use (most residential driveways excluded, all watersheds combined)

For all sites reporting, average salt application rate was **4.8** tons NaCl/acre/year (Appendix E). No significant correlation existed between total site lot size and loading rate ($R^2$=0.05, Figure 14) and therefore average loading rate was based on a per-lot average as opposed to a per-acre average. Wide ranges of were seen in reported application rates (0.38 - 20.08 tons NaCl/yr).

The frequency distribution (Figure 15a) indicates that the data were not normally distributed. When lots maintained by the same contractor are averaged and entered as one unit, the sample size is reduced to 10 and the distribution becomes normal to facilitate an estimation of confidence (Figure 15b). Under these conditions, the mean loading rate becomes **5.7** tons NaCl/acre/year with a 95% confidence interval of +/- 2.95.

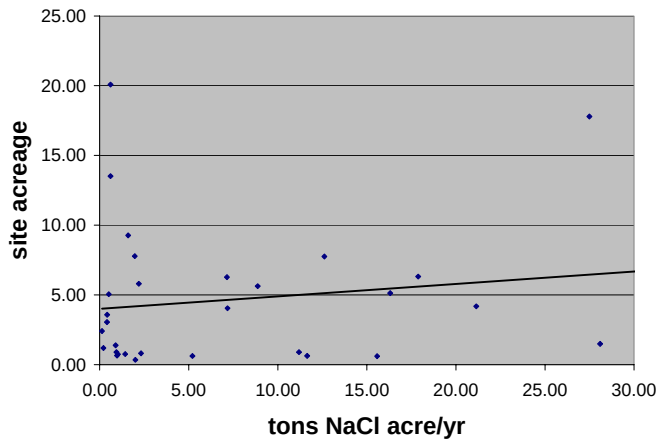
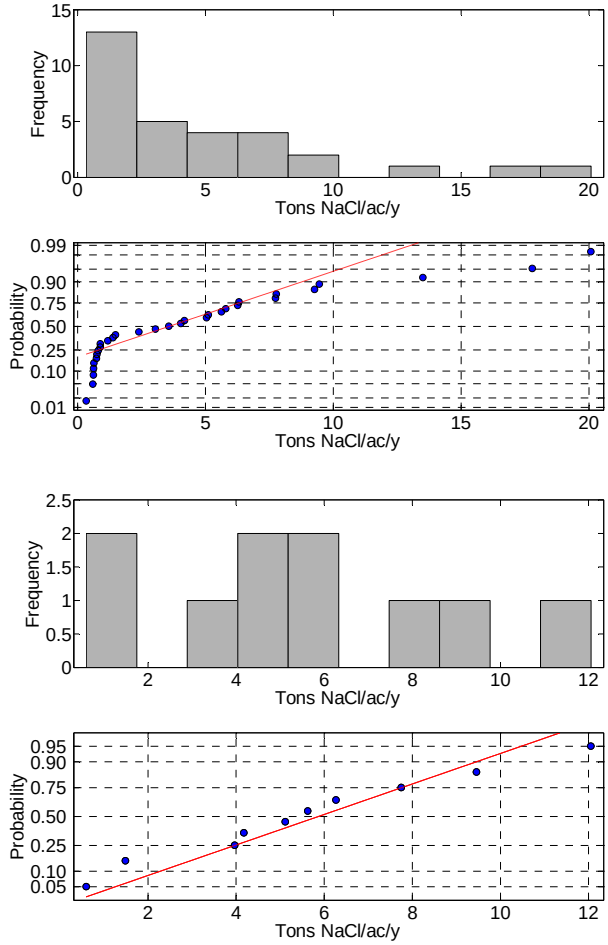



Figure 14. No significant correlation exists between parking lot size and application rate ($R^2$=0.05)

Data from high school, college and university sites maintained by staff members was expected to be particularly valuable because good records were kept of salt purchases, and the area to which salt was applied was clearly defined. Conversely, private contractors kept varying levels of purchase records, and the list of clients receiving salt applications is ever-changing, making an exact area difficult to pinpoint. When the staff-maintained educational sites (five colleges and one high school) were isolated, the mean application rate equaled **6.4** tons NaCl/acre/year (Appendix E).




Figures 15a & 15b. Frequency distribution and probability plot of each of 31 parking lot sites entered individually (a) and of parking sites maintained by the same entity averaged and entered as one data point (b).

In Wisconsin, Bannerman (2006) collected data from the private sector and arrived at a private sector application rate of between **2.6 – 6.0** tons NaCl/acre/year, consistent with the loading rate we established in this report.

Fortin Consulting of Minnesota conducted work-

**Breakdown of Study Area Salt Loading from Vehicular Surface Deicing**

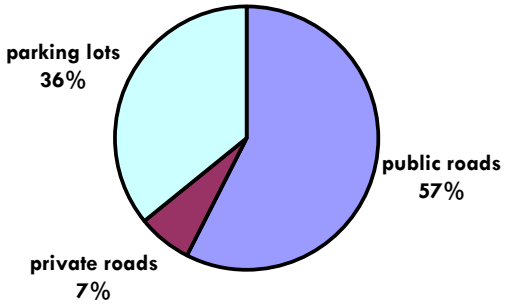



Figure 16. Road salt loading broken down by source, assuming a rate of 6.4 tons/acre/year is applied on parking lots and parking lot driveways and a rate of 17.8 tons/lane mile/year is applied to public and private roads. Parking lot calculation includes associated driveways. Most residential driveways are excluded from this calculation.

shops for snow and ice removal contractors following the Shingle Creek, MN Chloride TMDL. Contractors who completed Fortin's training program were awarded a certificate indicating their knowledge of appropriate salt application levels. As part of the workshop, representatives from Fortin collected surveys from 74 contractors at five separate workshops who underwent training. The survey included an inquiry into how much salt use reduction participants could achieve by adhering to application rates recommended by Fortin. These recommended rates range from no salt to 3 pounds/1000 $ft^2$ (Appendix G).

Fortin shared this expected reduction data with us. The data was presented in pounds of salt used before the workshop, pounds of salt expected to be used after the workshop and the resultant percent reduction. Although no application area was associated with each poundage, using Appendix F, we calculated recommended salt use/acre/year by assuming that 20 events requiring deicing were experienced in a year and applied the following simple equation:

**recommended rate * 100 ÷ (100 - percent salt reduction anticipated) = application rate prior to training**

When recommended rate was entered as the average of the various recommended salt application rates given for various storm conditions (1.83 pounds/1000 $ft^2$ = 79.6 pounds/acre) the average application rate prior to training came out to be **3.9** tons NaCl acre/year. When the recommended rate was entered as 3 pounds/1000 $ft^2$ (2,614 pounds/acre, the highest rate on Appendix F), average application rate prior to training equaled **6.4** tons NaCl/acre/year. This rate exactly matches the average application rate of the six New Hampshire colleges, universities and high schools maintained by staff members which provided salt loading data.

**Private Roads**

Salt use was tracked for a five year period from the winter of 2002 through the winter of 2006 in the study area by NH DOT. Averaging all annual application rates on a per-maintenance unit basis (i.e. municipality, precinct) gives a lane-mile/year rate of 17.8 tons NaCl (12.2 tons NaCl/acre/year). Assuming this application rate is consistently applied over all private and public roads in the study area, we arrive at a breakdown of salt application in the study area (Figure 16). Public roads occupy forty-three percent of the

study area paved surface. Initial DES estimates projected salt use for state and municipal road maintenance to account for fifty-two percent of total salt load and sixty percent of salt load from deicing operations. Our findings indicate the public sector contribution (public road maintenance) to be fifty-seven percent of salt load from deicing operations, slightly less than originally estimated.

**Results Analysis**

Prior to starting this research, it was broadly hypothesized that loading rates on parking lots are higher than those on roads. Much of this perception was likely based on visual evidence. Most people can easily call to mind an instance of walking through a parking lot where salt had visibly been applied excessively and large salt crystals persisted on areas where no snow or ice remained.

Our data, however, contrast this hypothesis. Certain differences between the way parking lots and roads are configured, utilized and maintained may explain these discrepancies.

First, it is worthwhile to point out that the perspective one gets while walking or slowly driving through a parking lot offers a better opportunity to observe excessive salt use than when driving down a road at normal travel speed. Secondly, it is important to consider that of all the things most people have to keep track of in the course of a day, it is unlikely that one's attention would be drawn to salt application rates in any situation other than an instance of over-application.

In terms of the way salt is applied, it is put down on roads over the same pathway in a consistent manner. Parking lots are not salted consistently in twelve foot swaths and oftentimes access is limited by parked cars so that even at double or triple the spreader setting, overall salt per area may be less.

Once applied, salt undergoes different dispersal patterns on roads than it does on parking lots. On roads, traffic moves at a higher speed over a more concentrated area than in parking lots. In lots, speeds are slow and travel patterns are irregular. Another important difference is that in lots, dispersed salt is often cast to another portion of the lot as opposed to away from the paved area. Chunks of salt are more likely to stay intact on a parking lot and transport via spray is less likely. Lastly, subsequent maintenance procedures likely result in the removal of salt from roads as snow is plowed off to the sides at normal travel speeds. In parking lots, however, snow is pushed a greater distance at slower speeds; as a consequence, more salt is potentially redistributed upon the lot.

In its 2005 Minerals Yearbook, USGS indicates that of all imported and domestic salt which had an end use of "ice control and/or stabilization", only 11 percent went to the private sector (USGS 2007). Additionally, Environment Canada (1999) and the Shingle Creek, Minnesota TMDL (Wenck, 2006) referred to salt sales data and assumed the private sector to contribute only 7.5% of the salt load from deicing. Our estimate for the southern NH study area is that forty-five percent of salt is applied by the private sector, at a rate of approximately 6.4 tons/acre/year, a rate consistent with estimates in other studies.

Despite perceptions that parking lot salt loading rates are greater than road application rates, all evidence from within and outside the study area suggests the opposite.

# Conclusions

Findings of this study have generated research-based parameters on the acreage of private paved surfaces and on parking lot loading rates in the study area. This evaluation of private sector maintenance practices, conducted from the ground level, represents an opposite approach to other comparisons of private and public salt loading which focused primarily on mass-generated salt allocation statistics. Private sector loading rates determined from this study were similar to loading rates found in other studies in which private contractors were actually polled.

Despite finding that salt application rates are lower on parking lots than on roads, we found that a high percentage of total paved surface was represented by parking lots, associated driveways and private roads (fifty-seven percent). Ultimately, the percentage of salt load from the private sector represented a greater portion of total salt load from deicing than originally forecasted.

USGS estimates that eleven percent of salt sold for deicing and road stabilization goes to the private sector (USGS 2007). Cheminfo (1999) reported that five to ten percent of deicing salt is purchased in the private sector Our findings suggest that in the study area, the private sector applies (and assumedly purchases) approximately forty-five percent of deicing salt. While the southern NH study area likely has an above-average parking lot-to-road ratio, the USGS and Cheminfo numbers suggest our reported private sector loading rate may be approaching an upper bound.

The adverse environmental impacts associated with increased percent impervious cover of watersheds have recently received significant attention. Urbanization has been linked to drastic changes in watershed hydrology, affecting not only the hydrographic characteristics of stormwater entering receiving water bodies, but also the quality of runoff, including chloride contamination. To address these issues, advances are being made in low impact development strategies, nutrient buffering BMPs, and shoreline protection legislation. Yet the problem of chloride contamination due to increased road salt use has proven more difficult to solve and to this point, has not been met with any silver bullets.

Redefining the perceived costs and benefits of salt use in the minds of citizens, including homeowners, retailers, property managers, maintenance contractors, road agents, and policy makers is likely an important and challenging part of an overall solution.

# References


Amrhein, C., J.E. Strong, P.A. Mosher. 1992. Effect of deicing salts on metal and organic matter mobilization in roadside soils. Environmental Science and Technology. 26:703-709.

Ballestero, T.P., R.M. Roseen, J.P. Houle. Personal Communications. December, 2006.

Bannerman, Roger. 2006. Report of the Salt Use Subcommittee to the Commission on the Environment on Road Salt Use and Recommendations. City of Madison Wisconsin.

Bureau of Transportation Statistics. Estimated U.S. Roadway Lane-Miles by Functional System. Accessed March 2007. <http://www.bts.gov/publications/national_transportation_statistics/html/table_01_06.html>

CH2MHILL. 2004. "Total Maximum Daily Loads for West Branch DuPage River, Illinois".<http://www.epa.state.il.us/water/tmdl/report/dupage/west-branch-dupage.pdf>.

Cheminfo. 1999. Socio-economic background and options study on the Canadian salt industry. Report prepared by Cheminfo, Toronto, Ontario, for Regulatory and Assessment Branch, Environment Canada, Hull, Quebec.

D'Itri, F.M. 1992. Chemical Deicers and the Environment. Lewis Publishers, Boca Raton, Florida.

Deacon, J.R., S.A. Soule, and T.E. Smith, 2005. Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03, U.S. Geological Survey Scientific Investigations Report 2005-5103, November 15, 2005.

Effler, S.W., M. G. Perkins, S.D. Field. 1984. Onondaga Lake and the Dynamics of chloride in the Oswego River. Water, Air & Soil Pollution. 23/1: 69-80.

Environment Canada. 1999 "Priority Substances List, Assessment Report: Road Salts". <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/road_salt_sels_voirie_e.pdf>

EPA, US (US Environmental Protection Agency). 1988. Ambient Aquatic Life. Water Quality Criteria for Chloride. Office of Research and Development, Environmental Research Laboratory, Duluth, Minnesota. EPA 440/5-88-001.

EPA, US. 2007. Total Maximum Daily Loads. Accessed June 2007. <http://www.epa.gov/owow/tmdl/>

Fischel, M. 2001. Evaluation of Selected Deicers Based on a Review of the Literature. Colorado Department of Transportation Research Branch, CDOT-DTD-R-2001-15.

Fortin Consulting. 2006. Winter Parking Lot and Sidewalk Maintenance Manual. <http://www.pca.state.mn.us/publications/parkinglotmanual-june06.pdf>.

Godwin, K.S., S.D. Hafner, M.F. Buff. 2003. Long-term trends in sodium and chloride in the Mo-

hawk River, New York: the effect of fifty years of road-salt application. Environmental Pollution. 124:273-81.

Hall, F.J. 1975. Chloride in Natural Waters of New Hampshire: New Hampshire Agricultural Experiment Station Bulletin 504, University of New Hampshire, Durham.

Hanes, R.E., L.W. Zelazny, R.E. Blaser. 1970. Effects of deicing salts on water quality an biota. Literature review and recommended research. National Cooperative Research Program Report 91. Transportation Research Board.

Heisig, P.M. 2000.Effects of Residential and Agricultural Land Uses on the Chemical Quality of Baseflow of Small Streams in the Croton Watershed, Southeastern New York. US Geological Survey Water-Resources Investigations Report 99-4173.

Jackson, R.B., E.G. Jobbagy. 2005. From icy roads to salty streams. Proceedings of the National Academy of Science, USA 41:14487-14488.

Jones, P.H., B.A. Jeffrey, P.K. Watler, H. Hutchon. 1992. Environmental impact of road salting. Pages 1-116 in Chemical Deicers and the Environment (F.M. D'Itri, ed.). Lewis Publishers, Boca Raton, Florida.

Kahl, J.S., K. Webster, D. Sassan, C. Rosfjord, S. Nelson, M. Greenawalt-Yelle. 2007. Increasing Cl in Northeastern Surface Waters: an indicator of increasing development pressure. Presentation at the Maine Water Conference. <http://www.cutler.maine.edu/waterresearch/mwc/pdfs/07/Kahl%20MWC%202007%20ELS-III%20Cl.pdf>

Kaushal, S.S., P.M. Groffman, G.E. Likens, K.T. Belt, W.P. Stack, V.R. Kelly, L.E. Band, G.T. Fisher. 2005. Increased salinization of fresh water on the northeastern United States. Proceedings of the National Academy of Science, USA 102:13517-13520.

Langen, T.A., M. Twiss, T. Young, K. Janoyan, J.C. Stager, J. Osso Jr., H. Prutzman, Ben Green. 2006. Environmental Impacts of Winter Road Management at the Cascade Lakes and Chapel Pond: Report #1. Clarkson Center for the Environment.

Lumis G.P., G. Hofstra, R. Hall. 1975. Salt Damage to Roadside Plants. Journal of Arboriculture. 1: 14-16.

New Hampshire Department of Environmental Services (NH DES). 2006. "Total Maximum Daily Loads for Chloride for Waterbodies in the Vicinity of the I-93 Corridor From Massachusetts to Manchester, NH Quality Assurance Plan".

Öberg, G. and P. Sandén. 2005. Retention of chloride in soil and cycling of organic matter-bound chlorine. Hydrological Processes. 19: 2123-2136.

Rosfjord, C. H., K. E. Webster, J. S. Kahl, S. A. Norton, I. J. Fernandez, A. T. Herlihy. 2007. Anthropogenically-driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acid deposition. Environmental Science and Technology, In Press.

Salt Institute. U.S. SALT SALES. Accessed March 2007. <http://www.saltinstitute.org/33.html>

Transportation Association of Canada. 2003. Synthesis of Best Practices Road Salt Management. 6.0 Vegetation Management. <http://www.tac-atc.ca/english/pdf/vegetation.PDF>.

Transportation Research Board. 1991. Special Report 235: Highway deicing – comparing salt and calcium magnesium acetate. National Research Council Washington, D.C.

USGS (United States Geologic Survey). 2007. "Minerals Yearbook: Salt". <http://minerals.usgs.gov/minerals/pubs/commodity/salt/salt_myb05.pdf>

Wegner, W., and M. Yaggi. 2001. Environmental Impacts of Road Salt and Alternatives in the New York City Watershed. Stormwater. 2: 1-22.

Wenck Associates Inc. 2006. "Chloride TMDL Report". <http://www.pca.state.mn.us/publications/reports/tmdl-shinglecreekchloride.pdf>

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