

**Implementation Plan to
Increase the Efficiency and
Effectiveness of Road Salt Use**

**To Meet
Total Maximum Daily Load For Chloride**

In Water Bodies Along the I-93 Corridor
From Salem to Manchester, NH:

Beaver Brook
Dinsmore Brook
North Tributary to Canobie Lake
Porcupine-Policy Brook



STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION

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Executive Summary

In 2008, the New Hampshire Department of Environmental Services (DES) completed Total Maximum Daily Load (TMDL) studies for four streams along the I-93 roadway corridor from Salem to Manchester considered to be impaired due to violations of the water quality standards for chloride. These streams include Beaver Brook located primarily in the Towns of Derry and Londonderry, Dinsmore Brook in the Town of Windham, the northern tributary to Canobie Lake in the Town of Salem and the Porcupine and Policy Brook watershed located primarily in the Towns of Pelham and Salem. As a result of these studies, DES has established a maximum allowable chloride load on an annual basis for each water body that would theoretically allow water quality standards to be met for all designated uses in all areas of the watershed.

The TMDL studies estimated that more than 90% of the chloride load in each of the watersheds was attributable to road salt usage for winter maintenance on roadways and parking lots. In the two largest watersheds, namely the Beaver Brook and the Policy-Porcupine Brook watersheds, nearly 50% of the total annual load was attributed to road salt used on private parking lots, while roughly 30% was attributable to municipal roads and another 9 to 11% of the annual load was associated with the NH Department of Transportation's ("Department") road salt usage. In the Dinsmore Brook and north tributary to Canobie Lake watersheds, the Department's annual usage was estimated to contribute as much as 50% and 84% of the total annual load, respectively.

The TMDL studies suggest that each of the major road salt users or sectors will need to reduce their annual road salt usage by roughly 24 to 28%, depending on the watershed, in order to meet the allowable annual chloride loads established by DES. To achieve these reductions, each sector including municipalities, private parking lots and privately maintained roads as well as the Department will need to implement equipment upgrades and perhaps change their application practices to reduce their annual road salt usage. The extent of the measures needed, the associated costs and the level of difficulty in achieving these reductions will vary greatly for each of the major sectors and will depend upon on their current winter maintenance practices, the measures currently utilized to use salt in an efficient manner and the inherent flexibility to modify practices within each sector to still maintain reasonable safe roadway surfaces or an acceptable level of service for the traveling public.

The Department faces a much greater challenge and will require far greater resources to achieve the desired salt reductions as compared to the other sectors for a number of reasons but primarily due to the fact that the are high speed, high volume interstates are very labor and equipment intensive and demand a high level of service. Additionally, the Department has already incorporated numerous technologies, equipment upgrades, training and other practices in its Snow and Ice Control Program to utilize salt in a highly efficient manner. To achieve even greater reductions will require much more sophisticated and more costly technologies and equipment as well as possibly the use of more costly alternative deicers. The Department's current winter maintenance practices are already operating at a minimum threshold necessary to maintain at an "anti-icing" condition (i.e. avoidance of snow pack and ice formation). The Department cannot implement any measure that would place the traveling public at greater risk.

Second, since I-93 is major high volume roadway averaging over 100,000 vehicles per day and up to 3,600 vehicles per hour on both the northbound and southbound lanes at relatively high speeds, it requires much more vigilance and timeliness to maintain consistent and reasonably safe conditions for the entire length of roadway essentially 24 hours a day, 7 days a week. To provide this vigilance and timeliness requires a great deal more equipment and personnel to be on hand, as compared to the other sectors. The parking lots in particular have much greater flexibility in timing their operations and arguably have far less equipment and maintenance needs during the non-business hours of each day. Municipalities, although they may have more roadway miles to maintain, they also have greater inherent flexibility in prioritizing which roadways will receive higher levels of service than others during winter storm events to lessen their equipment needs and application frequency. There is minimal margin for error in maintaining consistent and reasonably safe travel conditions on the I-93 roadway, the application frequency and timing must be “spot-on” or the pavement and travel conditions can change dramatically in a matter of minutes as the vehicle volume begins to compact and bond accumulating snow to the pavement. Just last winter, two major, multi-car accidents occurred on this stretch of the I-93 during winter storm events that resulted in, extensive vehicle damage and numerous personal injuries. Moreover, fatal accidents also occurred in recent years on this same stretch of roadway that has resulted in lawsuits against the Department contending our winter maintenance practices are not aggressive enough and the Department should be applying more salt to protect life and property.

Lastly, the I-93 roadway is a major “cog in the engine” that supports both the local and regional economy. Maintaining reasonably safe travel conditions on this roadway is essential to the economic vitality of businesses in southern NH and the surrounding region. One traffic backup and/or accident can have major socio-economic impacts as tens of thousands of commuters could be delayed or miss work, a similar number of consumers and tourists may not reach their various destinations and the shipments and deliveries to the region’s businesses can be seriously delayed.

In addition to the factors above, the Department must also account for the future road salt needs associated with the proposed I-93 widening. The proposed widening is needed to accommodate the ever-increasing traffic volumes and the future traffic needs as documented in various studies and reports. The frequency and amount of property damage, loss of life and traffic congestion that currently occurs can be expected to worsen without the widening, not only in the winter months but also year-round. To meet DES’ suggested draft sector allocations (which assumes each sector achieves a similar 24 to 28% reduction), the Department would need to reduce their annual road salt usage by approximately 63 percent in the Policy Brook watershed and roughly 30 and 50 percent in the Beaver Brook and Dinsmore Brook watersheds, respectively, to accommodate the proposed expanded I-93 roadway. To achieve these higher percent reductions would require either a dramatic change in the level of service or roadway conditions that are maintained on the I-93 roadway or a complete conversion to using a non-chloride based deicer. A dramatic change in the level of service would have substantial implications to both the traveling public and the regional and local economy. This would also be in conflict with the State’s Legislative Mandate, which is to “maintain a state transportation road network that will provide safe and convenient movement of people and goods”.

The Department does recognize that there are a number of newer tools and technologies that it can use to increase the efficiency and effectiveness of road salt. Contrary to public belief, reducing salt use is not as simple as just reducing the application rate by 50 % or whatever the targeted reduction may be. The primary purpose for using road salt or any other deicer is to lower the freezing temperature of water to prevent snow and ice from freezing and bonding to the pavement. To be effective, an adequate amount of material must be applied to achieve an appropriate concentration to lower the temperature at which water freezes. The appropriate application rate must account for the amount of pavement area to be treated, the precipitation rate and volume, the pavement temperature, the air temperature trend and the typical duration between applications. Using too low of an application rate can be as wasteful as using a very high application rate, since it can be completely ineffective in lowering the freezing temperature. Recent research has shown that the greatest potential for reducing the overall road salt use is not so much in varying the application rate but by reducing the application frequency by using better forecasting tools to know more accurately when applications are needed and by increasing the effectiveness by reducing scatter during application and keeping the deicer in the travel lanes.

With respect to forecasting tools, the Department has incorporated the use of various measures at PS 528 shed in Derry including truck mounted pavement temperature sensors, road weather information systems (RWIS) and the use of a Maintenance Decision Support System (MDSS), which is a computer software application that integrates pavement condition and weather forecasting data to provide real-time guidance on application timing and application rates. The Department has been utilizing this software over the last couple of years and has it found to be most useful in determining when applications may be necessary. In terms of equipment an upgrade, the Department has been experimenting with the use of liquid brine applications using tanker trucks, pre-wetting apparatus on spreaders, ground speed computer controllers and under-belly plows. Additional operator training is another measure that the Department has employed at the PS 528 shed. The Department has observed that the most notable effect of these measures is in reducing the overall number of applications over the course of the season rather than the application rate. The biggest gains in efficiency appear to be related to the use of the ground speed controllers and pre-wetting equipment and which better regulates how much deicer is applied and reduces scatter thus keeps the deicer in the travel lane where it is most effective.

Based on a three-year comparison study, the Department has determined that it can potentially reduce its annual salt use by approximately 20 percent by incorporating these more recent application technologies and forecasting tools into its winter maintenance program. The three-year study was conducted by comparing the annual salt usage in the PS 528 maintenance district utilizing the more recent tools and technologies to the annual salt used at a Merrimack district shed that was maintaining a similar amount of high volume roadway (Everett Turnpike) using the more conventional methods. The Department suspects that the reason that greater reductions or differences were not observed between the two maintenance areas was most likely due to fact that the current application methods used in Merrimack are already operating in highly efficient manner.

To fully implement these technologies throughout the TMDL watersheds including I-93, the Department has estimated that it will cost approximately \$3 million just to purchase equipment. This includes the purchase of additional storage tanks and brine making equipment for four different maintenance sheds as well as the purchase of the thirteen (13) new spreader trucks fully

equipped with pre-wetting apparatus as well as GPS enabled computer controllers. The added trucks are needed to replace the use of rented trucks that have traditionally been equipped with older less efficient salt spreaders. There will also be another \$3 million capitol expenditure for infrastructure to house and maintain this equipment

The results of comparative study reinforce the fact that achieving the estimated 50 to 63 % reductions in the Department's annual salt use needed in the Dinsmore and Policy Brook watersheds to accommodate the proposed widened I-93 roadway (based on DES's suggested allocations) would be nearly impossible considering that fully implementing the latest and greatest application technologies evaluated in the 3-year study is only expected to achieve a 20% reduction. A 50 to 63% reduction would require either a dramatic change in the level of service maintained on the State roadways, or a complete change to using an alternative deicer. Based on the suppliers' information, the material costs for a non-chloride based deicer such as calcium magnesium acetate is roughly 30 times greater than road salt (i.e., \$1,800 per ton vs. \$60 per ton), which would increase the winter maintenance costs just for the I-93 roadway sections by approximately \$2.0 million per year. In addition, acetate-based products have their own environmental concerns, specifically the potential for oxygen-depletion due to the biodegradation of the acetate components, which would be a major concern for the two principal lakes in the study area, namely Canobie Lake and Cobbett's Pond.

The Federal Highway Administration (FHWA) through the Department has allocated approximately \$2.5 million to assist municipalities in purchasing and implementing their own salt reduction measures. The Department realized that to achieve overall TMDL allocation in each watershed, the municipalities, private parking lots and private roads must participate in the process by implementing their own salt reduction measures. It was then decided to use the funds to help reduce the cost burdens of the municipalities and incentivize participation through a competitive grant application process similar to the municipal-managed bridge project program, where 80% of the project cost would be funded by the Department and 20% of the project cost would be funded by a local match. A Salt Reduction Workgroup Committee has been established to review and select grant applications based on established selection criteria. Preference will be given to those projects that have identified measures with the greatest potential for annual salt reductions for the least amount of money.

A portion of the total funds have also been allocated to help municipalities conduct planning studies to identify a list of potential measures and evaluate the cost-benefit factors of each salt reduction measure. Since the municipalities and the private contractors that are hired to maintain private parking lots are not typically utilizing the latest and greatest in application equipment and forecasting tools for weather/road pavement conditions, the potential for substantial salt reductions may be relatively high with various equipment upgrades as well as increased operator training. Based on the Department's experience, the biggest "bang for the buck" in achieving salt reductions may be in equipping spreader trucks with pre-wetting apparatus and ground speed computer controllers. Increased operator training and the use of the forecasting tools such as pavement temperature sensors were also found to be effective for relatively low costs.

For parking lots, the use of liquid brine applications may be an effective tool to be considered since the applications could be done ahead of a storm event and during non-business hours to prevent ice pack from bonding to the pavement, which is enhanced by vehicle traffic. Once ice

bonds occur, it generally requires numerous subsequent salt applications to break up or melt the ice bond formation. With approximately \$2.5 million available, it is anticipated that a fair amount of equipment upgrades can be implemented at the municipal and private contractor level and substantial amount of annual salt use can be reduced in each of the watersheds. In fact, with the use of pre-wetting equipment and/or ground speed controllers on their spreaders alone, the municipalities are likely to achieve better than 30% reductions from their current annual salt usage. Studies have shown that pre-wetting retains more salt on the pavement by eliminating the scatter from particle bounce and vehicle wind effects that typically results in about 30 % of the applied “dry” salt ending up in the roadway shoulder. Eliminating this loss and increasing the efficiency of each application can ultimately reduce the number of applications needed per storm and over the course of the winter season.

If the municipalities and parking lots were to achieve a 35% to 40 % reduction in their annual salt usage, the overall watershed allocations for both Beaver Brook and Policy Brook could be achieved even with the proposed widened I-93 roadway in place. This is based on the FY05 salt usage data for Beaver Brook and the FY07 salt usage data for Policy Brook, consistent with the TMDL study reports.

When comparing the amount of annual salt used by each sector with vehicle usage, the amount of vehicle miles traveled within each sector on an average daily basis, the Department uses much less salt relative to the amount of vehicles it services or the vehicle-miles traveled as compared to the municipal or private sectors. For instance, in the Policy Brook watershed, approximately 48 % of the average daily vehicle miles traveled in the entire watershed area are on state-maintained roads but the Department utilizes only 11% of the overall salt whereas the parking lot sector is servicing 36% of the estimated average daily vehicle trips and contributes 56% of the estimated total chloride load. The difference is most likely attributable to the existing controls and procedures that are part of the Department’s existing Winter Maintenance Snow Removal and Ice Control Policy. Similar findings are observed in the Beaver Brook watershed as well, where the parking lots contribute the largest share of the annual salt load but are not necessarily servicing the largest percentage of the average daily vehicle trips. In Dinsmore Brook, the Department is servicing approximately 95% of the estimated average daily vehicle usage in the watershed but is estimated to contribute only 50% of the annual salt load.

1.0 INTRODUCTION

In 2006, the NH Department of Environmental Services (NHDES) had listed four streams along the I-93 roadway corridor in southern New Hampshire on the 303(d) list of impaired water bodies due to violations of the water quality standard for chloride. These streams are Beaver Brook located primarily in the Towns of Derry and Londonderry, Dinsmore Brook in the Town of Windham, the northern tributary to Canobie Lake in the Town of Salem and the Porcupine and Policy Brook watershed located primarily in the Towns of Pelham and Salem. In 2008, NHDES completed Total Maximum Daily Load (TMDL) studies for each of the four streams and their associated watersheds. In January 2009, the TMDL studies were approved by the US Environmental Protection Agency. As a result of these studies, NHDES has estimated a total allowable chloride load on an annual basis for each water body that would theoretically allow water quality standards to be met for all designated uses in all areas of the watershed.

The TMDL studies indicated that more than 90% of the chloride load in each of the watersheds was associated with road salt used for winter maintenance on roadways and parking lots. In order to meet the maximum allowable loads for each watershed, each of the major sources or users of road salt will need to reduce their current usage through various equipment upgrades, changes in application practices and other technological advances geared toward to using less road salt for winter maintenance of roadway and parking lots. The suggested sector allocations presented in the TMDL studies assumed each sector should achieve an equal percentage reduction from their estimated existing loads. These suggested allocations do not account for any previous efficiency measures used to date nor do they account for the constraints and challenges posed by the specific roadway conditions and number of vehicles served by each of the sectors. NHDOT believes that a number of key factors need to be considered in finalizing the load allocations including the future road salt usage needed to accommodate the I-93 roadway expansion, which is of vital interest to the region and the state. A more equitable allocation alternative is to base the sector allocations by the intensity of vehicle usage for the various roadways and pavement areas maintained by each sector as described herein.

Table 1-1 provides a summary breakdown of the estimated total road salt usage in the winter of 2006/07 and the percent contribution of the total salt load from each of the major sources within each of the watersheds. The source contributions vary from watershed to watershed and this will be an important factor in identifying the appropriate measures necessary to meet the desired load allocations.

Table 1-1 – Summary of the Estimated Percentage of the Total Road Salt Contributions Associated with the Major Sources within Each of the TMDL Watersheds.

Watershed	Parking Lots	State Roads	Municipal Roads	Private Roads	% of Total
Beaver Brook	2,956 tons 47%	669 tons 11%	1,901 tons 30%	336 tons 5%	5,862 tons 94%
Dinsmore Brook	43 tons 26%	82 tons 50%	4 tons 2%	34 tons 21%	163 tons 98%
N.Tributary to Canobie Lake*	2 tons 5%	39 tons 84%	4 tons 9%	0 tons 0%	46 tons 98%
Porcupine-Policy Brook	2,426 tons 50%	456 tons 9%	1,306 tons 27%	125 tons 3%	4,313 tons 89%

Source: NHDES Data Report, September 2007.

Notes: *the north tributary to Canobie Lake is within the Porcupine – Policy Brook watershed.

2.0 IMPLEMENTATION PLAN DEVELOPMENT

2.1 Plan Development Process

The development of this Implementation Plan is the result of a collaborative effort amongst the Department's Bureau of Environment, Bureau of Road Maintenance, and the Commissioner's Office. The plan strives to balance the current responsibilities of the Department for maintaining reasonably safe roadway conditions during winter weather conditions as well as meeting our legislative mandate¹ while addressing the need for reduced salt use within the TMDL watersheds.

This Plan is based on the Department's extensive knowledge and experience gained through its own testing of protocols and equipment to improve salt use efficiency as well as the findings of other relevant research conducted elsewhere in this country. The Department's Maintenance Personnel have a thorough understanding of the benefits and limitations of the various methods and technologies that have been developed in recent years, not only from their own experiences but from the wealth of information that has been published and exchanged with other state transportation personnel in the New England states and throughout the country. The Department considers winter maintenance operations as a very serious matter and has always strived to perform these operations in an environmentally sound manner and at the same time balance the socio-economic and safety considerations involved with maintaining reasonably safe travel conditions on roadways during winter weather conditions.

This Plan describes the procedures, capabilities and challenges associated with the Department's winter maintenance operations and the critical factors that were considered in developing this implementation. The Department has thoroughly evaluated various alternatives, technologies and operational practices to reduce annual salt usage and improve efficiency of use and has determined that the anticipated reduction proposed in this Plan represents the maximum extent practicable.

2.2 Critical Factors Considered Essential to Developing an Effective Implementation Plan

The Department strongly believes that in order to improve probability of success in meeting the allowable chloride load in each watershed, several critical factors need to be considered in developing appropriate allocations for each of the major sources. The proposed allocations and the associated actions needed to achieve them must be flexible, adaptive, measurable, practical, consider safety of the traveling public of foremost importance and recognize the socio-economic benefits that are linked to winter maintenance operations. The relative importance of these factors is discussed below.

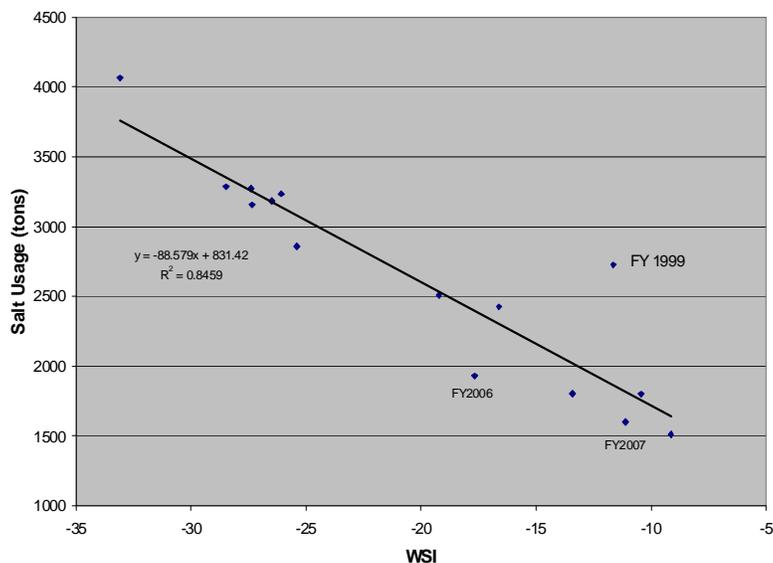
Flexibility: The plan needs to be flexible to allow the Department to respond to vast array of winter weather conditions. As such, the Department concurs with NHDES that the annual

¹According to Chapter 21-L-2, the primary legislative mandate of the Department includes planning, developing and maintaining a state transportation network which will provide safe and convenient movement of people and goods throughout the state by means of a system of highways, railroads, air service, mass transit and other practicable modes of transportation, in order to support state growth and economic development and promote the general welfare of the citizens of the state.

allowable salt use threshold should be tied to the Winter Severity Index (WSI). As shown in the adjacent figure, and demonstrated previously as part of NHDOT’s Memorandum of Agreement (MOA) with NHDES, the Department’s annual road salt usage for the last 15 years, going back to 1993, is highly correlated (correlation coefficient: $R^2 = 0.85$, with exception of 1999) to the severity of winter weather conditions. The WSI accounts for a number of winter weather conditions including total snowfall, number of storms, storm hours, air temperatures and heating degree-days, to name a few that describe the relative severity of the winter season. The Department’s records of annual road salt usage clearly show that the amount of road salt used during mild winters is considerably less than that used during the more severe winters. Establishing a “one size fits all” annual limit on road salt use regardless of winter weather conditions would not be feasible and could potentially put the safety of the traveling public at considerable risk.

The fact that the Department’s salt usage on the I-93 roadway south of Manchester has been shown to be highly correlated to the WSI, going back nearly 15 years, demonstrates, in contrast to popular belief, that the Department’s road salt usage has not continually increased over the years and that its maintenance policies and procedures are closely tied to the severity of winter weather conditions. The Department uses considerably less salt in milder winters and more salt in more severe winters. The tight relationship between WSI and salt use also indicates that there are tight controls on how much salt is applied during a given winter season.

Annual Salt Use vs. Winter Severity Index (WSI)



Adaptive: Achieving the desired targeted allocation will require an adaptive approach of phased implementation where the more practical, easiest to implement and least costly measures are initiated first and the more challenging, more costly and least practical measures are phased in over time depending on the observed results of the initial measures. Even though there has been an explosion in the research associated with winter maintenance activities in recent years, many of newer innovations and practices have not been fully tested, developed or are only appropriate for certain site specific conditions. With this in mind, the Department anticipates that newer and more effective Best Management Practices (BMP) will be added to the program and less effective ones will be phased out.

Measurable: Simply put, the goals of an effective Implementation Plan must be measurable to determine if the planned action steps are having the desired effect. In order for the goals to be measurable, there must be reasonable accurate baseline data to establish the existing usage from each of the major sources. This baseline data must also account for the year-to-year variability

for each major source. Without having reasonably accurate baseline data, it will be extremely difficult to measure whether any future improvements within a particular sector or source are having a meaningful effect in reducing road salt usage within a given watershed. It is here that the Department believes that it has a distinct advantage of having reasonably accurate baseline data from which to assess the salt reduction benefits of any proposed BMP since the Department has good long-term records of annual salt use going back more than 15 years. As discussed earlier, the fact that the Department's annual usage data has been shown to be closely correlated with the WSI, further supports the conclusion that the Department will have a reasonably accurate means to measure the amount of salt use reduction that results from future implementation.

Safety: The safety of the traveling public has to be the most important factor and must be addressed at all junctures in the decision matrix for this plan. The Department cannot implement any measure that would place the traveling public at greater risk. Therefore, each new measure considered must be evaluated in context with the desired environmental benefits and providing a reasonably safe transportation system. The Department maintains records of the number of accidents that occur on all highways. The records contain information on road conditions which include snow and slush, and ice. The Department will continue to evaluate this data to determine if there is a substantial increase in accidents. The I-93 roadway is one of the highest traffic volume roadways in the State on a per lane mile basis and, as such, can be very challenging in maintaining reasonably safe travel conditions. On average, more than 100,000 vehicles per day travel on the southern stretch of I-93 and during peak hours, there are more than 1,800 vehicles per hour are passing through on each travel lane².

Socio-Economic Benefits: The I-93 roadway is also major "cog in the engine" that supports both the local and regional economy. Maintaining reasonably safe travel conditions on the major roadways is essential to the economic vitality of businesses in southern NH and the surrounding region. Prolonged traffic congestion due to poor roadway conditions during winter weather can have a major impact on the economic activity due to either disruptions in shipping and deliveries or fewer consumer visits and purchases. There is also a greater likelihood for employee tardiness and absenteeism, which can also adversely affect business productivity, revenues and business-to-business activity. Reducing the level of service to a point where it delays the delivery of goods or significantly impedes the ability of commuters to get to work can have a huge impact on local businesses. Each Best Management Practice needs to be evaluated to determine its affect on roadway conditions and traffic mobility.

A 1998 Standard & Poor's study, commissioned by the Salt Institute, evaluated the economic impact of a major snow event that affected many of the mid-Atlantic and northeast states in 1996 (referred to as the "Blizzard of 1996"), and concluded that for every working day that goods and services could not be provided due to poor roadway conditions resulted in an estimated financial loss of \$4.8 to \$5.6 billion to the region. The same study estimated that \$526.4 million a day would be lost in federal, state and local tax revenues if roadways were impassable in twelve mid-Atlantic and mid-western states, including Illinois, Indiana, Iowa, Wisconsin, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, New Jersey, New York and Virginia. This one day

² Based on automatic traffic recorder data for June 2007 for the I-93 segment at Windham/Derry town line between Exits 3 and 4

loss in tax revenues is more than the \$518.7 million estimated to be spent by all twelve states for the entire winter season on snow and ice control (**Salt Institute, January 2000**).

Another study conducted by the Marquette University's Civil and Environmental Engineering Department, which focused on evaluating how deicing applications tended reduce the number of vehicle accidents during winter storms found that during the first four hours after a salt application, the direct road user benefits were estimated to be approximately \$6.50 for every \$1.00 spent on direct roadway maintenance costs. The direct benefits related to the reduced number of accidents and the avoided costs associated with property damage, medical expenses, emergency services, workplace costs, travel delays, legal and other administrative expenses (Kuemmel and Hanabali, 1992).

Practical and Cost-Effective: In the larger watersheds, such as in the Porcupine-Policy Brook and the Beaver Brook watersheds, the estimated road salt contributions from parking lots and municipal roadways represent a much a larger share of the overall salt usage amongst the various sources. The potential benefits for the various remedial measures available for each of the sources must be weighed against the potential costs and the potential reductions that may be gained by using a similar amount of money to implement measures for another source. For example, it would not seem to make sense to have one source spend \$2 million to potentially reduce their usage by 200 tons per year if another source within same watershed could potentially reduce their usage by say 400 or 800 tons/ year with the same amount of money or possibly even a smaller investment.

The Department also strongly believes that it would be impractical and very unsafe to switch from one type of deicing material to another along the I-93 mainline as a means to achieving a potentially greater chloride reduction in one area versus another. Implementing a complete overall change to a non-chloride based deicing alternative in the southern half of I-93 would also be hugely expensive as the non-chloride alternatives are generally up to 30 times more expensive than regular road salt. For instance, Calcium Magnesium Acetate (CMA), one of the leading non-chloride deicer alternatives, costs approximately \$1,800 per ton as compared to approximately \$60 per ton for road salt (based on recent correspondence from Cryotech Deicing Technology, a supplier of deicing materials).

3.0 EXISTING ROAD SALT MAINTENANCE PRACTICES

3.1 The Department's Winter Maintenance Road Network, Facilities and Historical Road Salt Usage along the I-93 Corridor and Within the TMDL Watersheds

Within the TMDL watersheds, there are five patrol sheds that perform winter maintenance operations on state roadways. Patrol Shed (PS) 528 in Derry is responsible for much of the I-93 mainline from Manchester to Salem while the other four sheds are primarily responsible for maintaining other state roads such as Routes 28, 102, 111 and 111A. Table 3.1 provides a summary of the number of lane-miles currently being maintained by each of the patrol sheds within each of the major TMDL watersheds.

Table 3-1 - Number of Existing NHDOT Roadway Lane-Miles Associated with Each Patrol Shed within Each Major TMDL Watershed.

Patrol Shed	Beaver Brook	Dinsmore Brook	Policy Brook
PS 508	3.80	-	-
PS 512	12.14	-	-
PS 513	8.26	-	-
PS 514	4.80	1.90	6.11
PS 528	21.70	4.59	24.92
Totals	50.70	6.49	31.03

As discussed earlier, the annual salt usage for PS 528 has been shown to be highly correlated to the weather severity index (WSI). The WSI is a relative measure of the winter severity and is based on a number of factors including snow depth, number of storms, storm duration, average daily temperatures and number of heating degree days. Similar close correlations were also found for the other patrol sheds based on a comparison of 10 years of annual salt usage with the annual WSI (see Appendix B for regression analyses figures for each patrol shed). The close correlations indicate the Department's road salt usage has been very much regulated to the needs based on winter weather conditions.

Contrary to the general popular belief, reducing salt use is not as simple as just reducing the application rate. In fact, there is minimal margin of opportunity to reduce application rates as a means of reducing the overall salt use. Applications of deicing materials are specifically geared toward lowering the freezing temperature of water to prevent snow and ice from freezing and bonding to the pavement. To be effective, an adequate amount of material must be applied to achieve the appropriate concentration to keep snow and water from freezing. The application rate must account for the amount of pavement area to be treated, the precipitation rate and volume, the pavement temperature, the temperature trend and the typical duration between applications. Using a lower application rate that is ineffective in changing the freezing temperature can be as wasteful as using a very high application rate.

The greatest potential for reducing the overall road salt usage is not so much in varying the application rate but by reducing the total number of applications by using better forecasting tools to know more accurately when applications are needed and by increasing the effectiveness by better regulating the amount of deicer through ground orientation and reducing scatter and keeping the deicer in the travel lanes with the use of pre-wetting. This is where the Department

has focused its efforts in recent years and the various tools utilized to modify the application frequency are discussed further in the next section.

The suggested allocations included in the TMDL studies were based on the salt usage during the 2006/07 season, which was a relatively mild winter. As shown in Table 3-2, in comparing the annual salt usage in 2006/07 to the historical average annual road salt usage over the last 10 years for each watershed, the historical average annual usage amounts are considerably higher. Essentially, the Department’s historical average annual salt use is approximately 42% to 69% higher than the estimated salt usage for the 2006/07 season. This means that the percent reductions needed to meet the suggested TMDL load allocations are actually much greater than that when based on the 2006/07 season usage amounts.

Table 3-2 Comparison of the Department’s Historical Average Annual Salt Use vs. 2006/07 Winter Season Usage Data within Each of the TMDL Watersheds

Watershed	2006/07 Annual Usage (tons/yr)	Historical Annual Average (tons/yr)	Percent Difference
Beaver Brook	669	949	+ 42%
Dinsmore Brook	82	139	+ 69%
Policy-Porcupine Brook	456	676	+ 48%
Total	1,207	1,764	+ 46%

3.2 The Department’s Use of Newer Application Technology and Road Weather Information Systems

Well before the TMDL studies were initiated, the Department has experimented with and has incorporated various methods and measures to improve road salt use efficiency. Over the years, the Department has transformed from a deicing approach to an anti-icing approach. Recently, the Department has incorporated the use of liquid brine at the Patrol Shed 528 in Derry for pre-storm, anti-icing applications on the I-93 roadway and has already expanded the use to the secondary state roadways in Derry, Londonderry, Windham and Salem. Anti-icing applications have been shown to be much more effective in preventing ice-bonds with the pavement and, therefore, can reduce the amount of subsequent salt applications that may be needed to “break up” ice-bond formations that develop later in the storm. The Department has incorporated other equipment improvements such as ground speed controllers, pre-wetting spreaders, under-belly plows and the use of the Road Weather Information Systems (RWIS) coupled with the Maintenance Decision Support System (MDSS). The MDSS is a computer software package that utilizes road weather and pavement condition data provided by RWIS sensors and weather forecast information to assist maintenance personnel in determining appropriate application rates and timing to maintain a pre-determined level of service or road pavement condition.

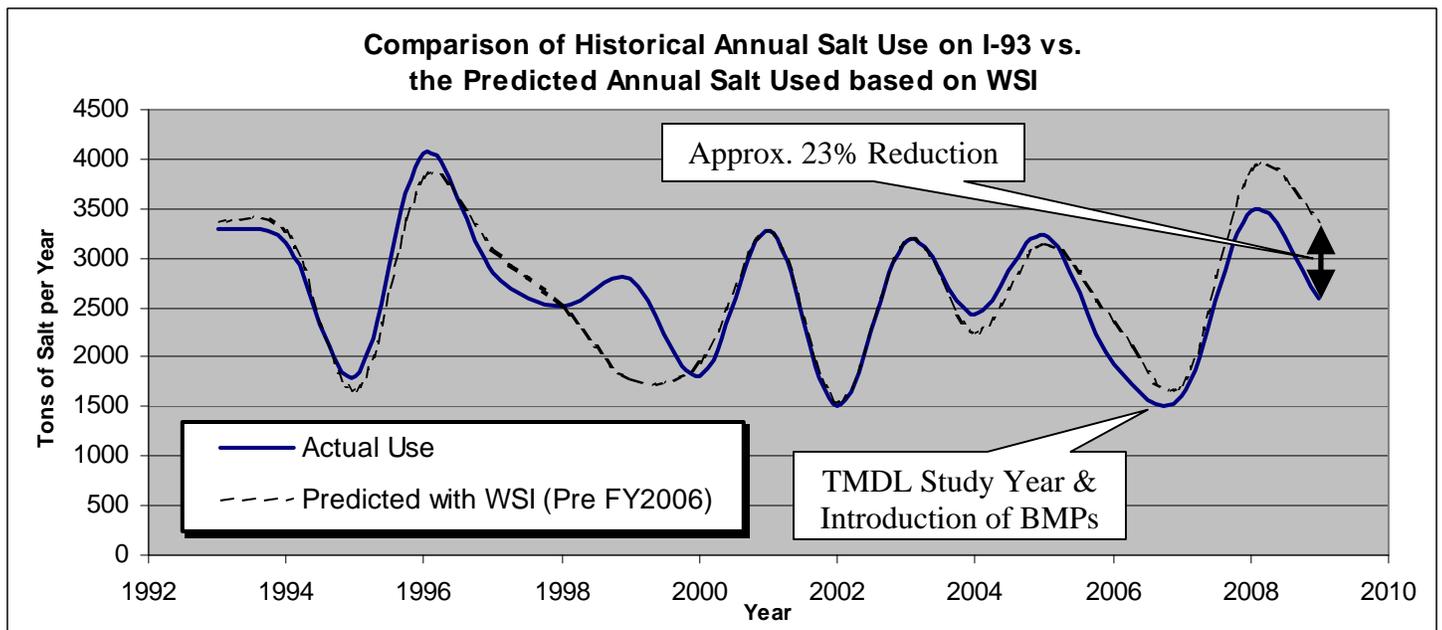
Appendix A contains a more detailed discussion of the research findings and the demonstrated benefits of the various technologies and equipment upgrades recently used by the Department. Most of these equipment upgrades and newer technologies have already been tested at the Patrol Shed 528. It is important to point out that not all of the maintenance trucks used at Shed 528 are equipped with these recent improvements. The private contractor trucks rented during major snow events are not typically equipped with the newer technologies such as ground oriented spreaders and pre-wetting equipment. The Department plans to purchase new spreader trucks

with the latest equipment technology to avoid having to utilize private contractors that generally do not have the latest equipment.

3.3 The Department Anticipates a Potential 20% Reduction in Salt Use with Full Implementation of Various Application Technologies and Other Best Management Practices (BMPs)

Over the last two years, the Department has incorporated a number of the latest technologies and equipment upgrades into the maintenance program at Patrol Shed 528 located in Derry, which maintains most of the mainline of I-93 from Londonderry to Salem. The new equipment included brine trucks for “pre-storm” brine applications, pre-wetting apparatus on spreaders, ground speed computer controllers, pavement temperature sensors, under-belly plows, enhanced operator training and the use of Maintenance Decision Support System MDSS/RWIS computer applications. The winter season of FY09 was the first full season that these BMPs were fully implemented.

The figure below shows the effect of the various BMPs based on a comparison of the actual annual salt usage for the PS 528 shed over the last 15 years in comparison to the predicted annual salt use based on the WSI correlation. As discussed earlier, there is a very close correlation between the actual and predicted usage for most years. In FY09, the first full year that the BMPs were implemented, the actual salt usage was approximately 23% less than that predicted indicating that the BMPs led to a net reduction in salt use relative to historical practices.



In addition to the year to year comparison at PS 528 with new measures in place, the Department also conducted a comparison study to compare the annual salt usage at PS 528 with that used at the Merrimack shed, which maintains a similar amount of lane-miles of a high volume roadway (Everett Turnpike). The results of this comparison also show that the PS 528 used approximately 20 percent less on annual tons per lane-mile basis with the BMPs in place as compared to that used at the Merrimack shed.

Based on these recent results for PS 528, the Department anticipates that a 20% reduction in the annual salt use can be achieved in all the TMDL watersheds if the same equipment upgrades and technologies were incorporated in the four other patrol sheds that maintain state roads in the I-93 corridor. The fact that larger a difference or larger salt use reduction was not observed is believed to be due to the fact that even the conventional maintenance practices already utilized salt in a relatively efficient manner. In other words, despite of the all of the new measures utilized, including liquid brine applications, pre-wetting equipment, computerized spreader controllers, etc., the actual margin of opportunity for improvement is relatively modest. Again, the net effect of the measures primarily relate to a reduction in the number of applications that were needed over the course of season rather than the rate of application. Overall, the 20% decrease represents an annual reduction of approximately 620 tons compared to the predicted annual usage in the PS 528 maintenance area.

The maintenance personnel in Derry believe that the biggest reductions were mostly attributable to the use of pre-wetting equipment on the spreader trucks, the use of ground speed, computer controllers, followed by the increased operator training and the MDSS/RWIS support system. These four measures generally helped to improve the efficiency of each salt application either by retaining more salt on the roads (pre-wetting), improving the accuracy of the application rate (computer controllers) and/or helped to more accurately determine when applications were needed through the use of the enhanced road surface and weather information.

As discussed further in Appendix A, pre-wetting alone can eliminate the typical 30% loss of salt that occurs as “dry” salt is blown or bounces off the pavement. Retaining more salt in the travel lanes through pre-wetting can result in fewer applications needed over the course of a storm or winter period. The use of mobile pavement temperature sensors and liquid brine applications also helped in this regard but to a lesser degree. Under-belly plows are really only effective in breaking up ice bonds and snow pack formation on pavement and thus they are useful only under special circumstances.

The Department has estimated that to incorporate the suite of BMPs, described above, into the other four patrol sheds will result in upfront costs of approximately \$6.0 million with about \$3 million in equipment and technology upgrades and another \$3 million in support infrastructure (i.e., shed additions for storage). These estimated equipment costs include the following items:

- Purchase of brine making equipment and storage tanks for four maintenance sheds.-
- Purchase of thirteen (13) new spreader/plow trucks that are fully equipped with pre-wetting apparatus, GPS enabled computer controllers and pavement temperature sensors.
- Additional computer networking and communications equipment to operate the MDSS/RWIS software as well as download and record salt usage data from the spreader trucks.

The primary reason for purchasing the additional trucks is to avoid having to rely on rented spreader equipment coverage during peak periods. Rented equipment generally does not have the latest spreader technology and therefore cannot be relied upon to apply road salt in the most efficient manner. The proposed implementation time frame is discussed later in this document.

4.0 EVALUATION OF EXISTING AND FUTURE SALT USE IN COMPARSION TO THE DES PROPOSED ALLOCATIONS IN EACH WATERSHED

4.1 Existing and Proposed Annual Road Salt Usage on the Department's Roadways

The TMDL studies prepared by DES suggested that each of the major sectors would need to reduce their annual salt usage by roughly 24 to 28 percent in order to meet the overall annual salt load in each watershed. The estimated 24 % reduction was for the Policy–Porcupine Brook watershed based on the annual salt usage for the 2006/07 winter season, whereas the estimated 28% reduction was for the Beaver Brook watershed based on the annual salt usage during the 2004/05 winter season, which was a much more severe winter relative to the 2006/07 season. There were no violations of the chloride water quality standard in the Beaver Brook during the 2006/07-winter season. For Dinsmore Brook, the estimated percent reduction needed for each sector was 25% based again on the 2006/07-winter season.

The DES suggested allocations do not include the anticipated salt needs for the proposed expanded I-93 roadway. The proposed expansion will nearly double the number of lane-miles as the mainline is increased from four to eight travel lanes and some of secondary roads and ramps will also be widened to provide turning lanes and other traffic management improvements as part of the interchange upgrades. This additional roadway lane mileage will become part of the winter maintenance operations for each of the respective patrol sheds. The total amount of road salt used each year will increase to maintain reasonably safe travel conditions on these roadway lane miles.

Table 4-1 presents the estimated future annual salt usage on I-93 in comparison to the existing average annual usage within each watershed (i.e., based on 10-years of records) with the anticipated 20% reduction from full implementation of BMPs and the estimated future average annual usage with the expanded roadway area and full implementation of the BMPs.

Table 4-1 - Estimated Existing and Future Average Annual Road Salt Usage on NHDOT Maintained Roadways in Comparison to the DES Suggested TMDL Allocation

Watershed	Existing	Existing Est.	Estimated Future	DES Suggested Allocation	
	Estimated Average Annual Use ¹ (tons/yr)	Average Annual Use w/ BMPs ² (tons/yr)	Average Annual w/ I-93 Expansion and BMPs (tons/yr)	Tons/yr	% decrease needed to meet allocation
Beaver Brook	949	759	1,158	814	30%
Dinsmore Brook	139	111	125	62	50%
Policy Brook	676	545	1,002	365	63%

Notes: ¹ Existing Average Annual Usage is based on historical records for a 10-year period. ² Existing Ave. Annual Usage assumes a 20% reduction due to efficiency improvements with full implementation with BMPs.

To meet the DES suggested allocation for the Department with the proposed I-93 expansion, the estimated future annual salt usage would need to be reduced by 30 % in the Beaver Brook watershed and by 50 and 63 % in the Dinsmore Brook and Policy Brook watersheds, respectively. These potential reductions would be extremely difficult to meet without resulting in a substantial reduction in the level of service and safety provided on the state roadways given that the recent experimentation with the numerous BMPs, discussed earlier, produced approximately a 20 % reduction compared to the current annual usage.

The potential change in level of service or road conditions that would result by adhering to DES suggested salt reductions are likely to put the traveling public at a considerably greater risk and may lead to increased traffic congestion and accidents due to poor road conditions. The poorer road conditions would likely result in increased travel delays that would have an impact on the local and regional economy due to delayed shipments, increased employees tardiness and absenteeism and fewer consumer and tourism visits.

The only foreseeable means of achieving annual salt reductions of 50 to 63 percent would be to fully convert to a non-chloride based deicer alternative. Non-chloride based deicers generally consist of either potassium acetate or calcium magnesium acetate. Both compounds present their own relatively significant environmental concerns. The acetate component of both these compounds can generate a substantial biological oxygen demand as it degrades in the environment, which can present even greater aquatic life impacts in streams and rivers than chloride. The high biological oxygen demand and resulting low dissolved oxygen could have major impacts on Canobie Lake and Cobbett's Pond, the two major lakes within the project corridor. In addition, since these acetates are typically produced from an organic plant source such as corn or sugar cane, they generally have a high nutrient content, which can lead to increased eutrophication in nearby streams, lakes and ponds.

Along with the environmental concerns, recent price information from a deicer supplier indicated that the bulk cost for CMA was approximately \$1,800 per ton or roughly 30 times greater than the cost of road salt at approximately \$60 per ton. Similar higher costs were provided for potassium acetate as well. Assuming that the Department's average annual salt usage in the I-93 corridor was approximately 2,500 tons, the additional material costs per year would increase from approximately \$150,000 to \$4,500,000 if the Department were to completely switch to using CMA instead of road salt. If the Department were to use a mix of 60% CMA and 40% road salt to achieve a 60% reduction in chloride, the net increase in material costs per year would be approximately \$2.6 million. This compares to the one time, up-front costs of \$3.0 million for the equipment upgrades and added technology BMPs discussed earlier. Given the added substantial annual costs and the potential for other environmental issues associated with these compounds, the Department feels that converting to non-chloride deicers is not a practical alternative.

The Department also strongly believes that switching from one type of deicer to another along the same roadway is not an acceptable practice as it may result in hazardous road conditions since the various deicers behave differently at various temperatures. Abrupt changes in road conditions or the Level of Service along the same stretch of roadway would present a major safety issue. The Department will continue to evaluate the development of other potentially environmentally safe and less costly deicing alternatives but at this time feels that the acetate based, non-chloride alternatives area are not practical as the primary deicer for State highways.

4.2 Evaluation of Vehicle Usage as a Basis for Determining Sector Allocations

The Department believes that the sector allocations should account for the differences in traffic volumes and typical vehicle speeds on the various roadways within each sector since the use of road salt is primarily for the purposes of maintaining reasonably safe travel conditions. The

considerably greater traffic volumes and vehicle speeds on the I-93 roadways as compared to municipal roadways and parking lots requires a much higher level of service (road surface with minimal ice and snow pack) to prevent vehicle accidents and a major disruption to the regional economy. As discussed earlier in Section 2.0, one vehicle accident on the I-93 roadway can have a “ripple effect” on the employee tardiness, absenteeism, delivery of goods, consumer visits, and tourism. Preventing ice, and snow pack to form on the road surface can also be much more difficult when high traffic volumes can be as high as 3,600 vehicles per hour and spreader and plow trucks need to account for longer travel times and longer return cycles due to the number of vehicles on the roads. The section below provides a different perspective of what the potential sector allocations would be if they were based on the amount of pavement (i.e., roadway lane – miles) and the average daily traffic volumes for each roadway mile serviced by each of the major sectors including the Department, the municipalities and the parking lot contractors.

The Department has conducted an analysis to quantify the amount of vehicle usage (i.e., average daily traffic volumes (ADTs)) and amount of roadway mileage for each of the various roadway maintenance sectors (i.e., state, local, and private) as well as the commercial parking lots within each of the major TMDL watersheds including Beaver Brook, Dinsmore Brook and Policy Brook. The traffic data estimates and roadway miles for the north tributary to Canobie Lake are included in the Policy Brook watershed analysis. The purpose of this analysis was to provide a relative comparison of the average daily traffic volumes and number of lane miles that are within each roadway maintenance jurisdiction. The total number of vehicles estimated to travel within each of the roadway maintenance jurisdictions is based on estimates of ADT’s for each roadway segment multiplied by the number of miles for that segment and then divided by the number of lanes. The product of this calculation for each roadway segment is referred to as the Vehicle Lane Miles (VLM), which represents a measure of the average daily vehicle usage for each road. In the end, the sum total of Vehicle Lane Miles (VLM) for all the roadway segments were provided for each maintenance jurisdiction. The total allowable allocation of road salt for each watershed can then be apportioned to each of the sectors based on average daily vehicle usage.

The methods used to develop ADT estimates for each of the roadway segments are described in the summary memo contained in Appendix C. With the exception of the Dinsmore Brook watershed, only parking lots greater than or equal to 1.0 acre in size were included this analysis. According to NHDES’s GIS land coverage data, the number of parking lots in the Policy Brook and Beaver Brook watersheds is estimated to be approximately 425 and 870 lots, respectively. Small parking lots less than 1.0 acre in size account for more than 80 percent of the total number of parking lots. However, in terms of overall parking lot area, parking lots greater than or equal to 1.0 acre in size account for roughly 64 and 68 percent of the total estimated parking lot area in the Beaver Brook and Policy Brook watersheds, respectively. With nearly two-thirds of the parking lot area accounted for in both the Policy Brook and Beaver Brook watersheds, the results of this analysis are considered sufficient to conduct relative comparisons to the roadway maintenance jurisdictions discussed above. However, it should be noted that the total VLM estimates for parking lots in the Beaver Brook and Policy Brook might be underestimated given the number of smaller parking lots that were not included in this analysis. A much greater effort would have been required to generate traffic volume estimates for the hundreds of small parking lots in each of the larger watersheds. All of the parking lots in the Dinsmore Brook watershed were accounted for since there were fewer than 20 parking lots in this watershed.

Parking Lot Lane-Mileage

The parking lot lane-miles were calculated based on the following assumptions:

Typical Parking Space = 9'x18'

Typical Drive Aisle = 24'

Typical parking plus drive aisle = (18'+12') x 9'=270 sf, say 300 sf

Number of spaces per acre of Parking = 43,560 sf / 300 sf = 145 spaces per acre

Drive Aisle length for 145 spaces = 145 spaces/2 (double sided parking aisle) x 9' = 650 LF of drive aisle per acre

Assume 650 LF/0.9 (layout efficiency factor) = 725 LF of drive aisle x 2 drive aisles (double sided parking aisle) = 1,450 LF

Assume 1,450 LF / 5,280 LF per mile = 0.28 lane miles per acre of parking lot

Use multiplier of 0.28 lane-miles for each acre of parking lot to determine lane mileage*.

Note: *Assumes salt is only applied to travel lane portion of parking lot. The amount of travel lanes will vary greatly for each parking lot depending on layout and length of access and connecting roads. For some parking lots, the amount of travel lanes relative to the amount of parking spaces could be much higher.

Table 4-2 provides a summary of the estimated roadway miles, lane miles and vehicle-lane mileage for each roadway maintenance jurisdiction (i.e., state, local, and private) and parking lots. In general, the results show that NHDOT's road network has the highest amount of vehicle usage on a daily basis in each of the three watersheds as compared to the other maintenance jurisdictions. In the Beaver Brook watershed, NHDOT has nearly twice as many vehicle lane-miles traveled on an average daily basis compared to the local road maintenance jurisdictions, even though under local maintenance there are nearly six times as many lane miles. For Dinsmore Brook, the number of VLM's within NHDOT's jurisdiction is far greater than that estimated for any of the road maintenance jurisdiction because of the traffic volumes utilizing the Exit 3 Interchange, the I-93 mainline as well as Route 111 and Route 111A. For Policy Brook, again, even though there are a far greater number of lane miles under local jurisdiction, the estimated VLM, which is indicative of the amount of vehicle usage, is much higher for the roads under NHDOT jurisdiction as compared to the local or privately maintained roads.

Table 4-2 Estimated Number of Roadway Miles, Parking Lot Area and Average Daily Vehicle Lane Miles (VLM) for State, Local and Private Jurisdiction in Each Watershed

Watershed	Jurisdiction	Road Miles (miles) or Parking Area (acres)	Lane-Miles	Percent of Vehicle Usage	Average Daily Vehicle Lane Miles (VLM) ²
<i>Beaver Brook</i>	State	27.9	53.2	47%	273,317
	Local	147.5	295.0	23%	133,213
	Private	23.1	44.3	29%	6,673
	Parking Lots	296 ac (64% of total) ¹	82.9	1%	171,209
	Total ²	--	475.4	100%	584,412
<i>Dinsmore Brook</i>	State	4.0	6.5	95%	40,018
	Local	0.5	1.0	<1%	39
	Private	2.3	4.4	5%	89
	Parking Lots	7.5 ac (100% of total) ¹	2.1	<1%	2,100
	Total ²	--	14.0	100%	42,246
<i>Policy Brook</i>	State	17.8	32.1	48%	237,375
	Local	55.6	116.0	16%	79,750
	Private	8.2	16.4	36%	1,870
	Parking Lots	260 ac (68% of total) ¹	72.7	<1%	177,267
	Total ²	--	237.2	100%	494,427

Notes: ¹percentage of total refers to percentage of all parking lots identified in the watershed. ² Vehicle usage per lane mile is based on an analysis of Average Daily Traffic Volumes Data for State Roads and Estimated Average Daily Trips for local roads and parking lots based on either number of homes and/or the extent and type of commercial development associated with each road using trip generation rates published by the Institute of Transportation Engineers (ITE), Trip Generation 7th Edition, 2003.

In comparing the amount of vehicle usage to the amount of annual salt used by each sector and within each watershed, the results indicate that the Department is using much less salt relative to amount of vehicles it is servicing on a vehicle lane mile basis as compared to the municipal or private sector. For instance, in the Policy Brook watershed, approximately 48 % of the total average daily vehicle trips occur on state-maintained roads and, yet, the Department is contributing only 11% of the total salt whereas the parking lot sector is servicing 36% of the estimated average daily vehicle trips and contributes 56% of the estimated total chloride load. The difference is most likely attributable to the existing controls and procedures that are part of the Department’s existing Winter Maintenance Snow Removal and Ice Control Policy. Similar findings are observed in the Beaver Brook watershed as well, where the parking lots contribute the largest share of the annual salt load but are not necessarily servicing the largest percentage of the average daily vehicle trips. In Dinsmore Brook, the Department is servicing approximately 95% of the estimated average daily vehicle usage in the watershed but is estimated to contribute only 50% of the annual salt load.

The relatively high percentage of road salt use estimated for parking lots compared to the estimated vehicle usage suggests that there may be greater opportunities to improve the efficiency of use and reduce the overall salt load associated with parking lots as compared to the State and even municipal roads. This is not particularly surprising since there are few incentives, if any, for private contractors to use less salt rather than more salt while maintaining parking lots. Nor are there any regulatory mechanisms or controls in place to limit salt use on parking lots despite the fact that commercial development and the associated impervious area has arguably

been the largest increased source of road salt over the last decade or two. A new regulatory approach will be essential to address salt use on both existing and future parking lots in order for the targeted chloride allocations to be achieved, particularly in the Policy and Beaver Brook watersheds. However, basing the allocations on an equal percentage reduction from existing loads rewards users that may have been less efficient or prudent in their salt usage in the past and punishes those who have already taken steps to improve their salt use efficiency.

Table 4-3 provides a comparison of existing salt use, estimated percent of vehicle usage and the potential vehicle based allocation for each sector within each of the major watersheds.

Table 4-3 - Comparison of Existing Salt Use vs. Vehicle Usage and Proposed Vehicle Based Allocations for Each Sector Along with Estimated Future Annual Road Salt Use on the Expanded I-93 Roadway.

Watershed	Sector	Percent of Total Load	Existing FY07 Usage ¹ (tons/yr)	DES Suggested Allocation (tons/yr)	Percent of Vehicle Usage	Potential Vehicle Based Allocation ² (tons/yr)
<i>Beaver Brook</i>	State	11%	669	814	47%	3,566
	Municipal	32%	1,901	2,966	23%	1,745
	Parking Lots	50%	2,936	3,472	29%	2,200
	Private	6%	336	336	1%	77
	Total	99%	5,842	7,588	100%	7,588
<i>Dinsmore Brook</i>	State	50%	82	62	95%	116
	Municipal	2%	4	3	<1%	1
	Parking Lots	26%	43	33	5%	6
	Private	21%	34	26	<1%	1
	Total	99%	166	124	100%	124
<i>Policy Brook</i>	State	11%	456	365	48%	1,650
	Municipal	30%	1,306	1,044	16%	552
	Parking Lots	56%	2,426	1,940	36%	1,242
	Private	3%	125	100	<1%	5
	Total	100%	4,313	3,449	100%	3,449

NOTES: ¹ Existing Salt Usage is based on salt used in the 2006/07 winter season ² The potential vehicle based allocation is calculated by multiplying the percentage of the total vehicle usage by the total DES suggested road salt allocation.

4.3 Proposed NHDOT Allocation with Expanded I-93 Roadway

The proposed I-93 expansion and the average annual salt use associated with this expansion will need to be incorporated into the TMDL allocations. As discussed earlier, the Department has estimated the future average annual use based on the roadway lane miles and the historical average usage per lane mile correlated to the weather severity index (WSI). The future use accounts for the implementation of Best Management Practices (BMPs) utilized in Patrol Section 528 to the remaining patrol sections operating within the TMDL watersheds. The overall future increase in salt use is less than what would have otherwise occurred if not for the improved efficiency and effectiveness gained by the full implementation of BMPs. To achieve full implementation of the BMPs will require a fairly substantial capital investment in new equipment and equipment upgrades, as discussed earlier in this document.

Table 4-4 presents a comparison of NHDOT’s estimated future average annual road salt use needs with the proposed I-93 expansion to the proposed vehicle usage based allocation. Based on this comparison, the Department would only be using 33 to 62 percent of the estimated vehicle based allocation in the Beaver Brook and Policy Brook watershed, respectively. The remaining portions of the vehicle usage based allocation could then be redistributed to the municipal and parking lot sectors.

In the Dinsmore Brook watershed, however, the Department would need slightly more or roughly 108 percent of the proposed vehicle usage based allocation. There will be proportionally a greater amount of new state roadway in the Dinsmore Brook watershed due to the Exit 3 improvements and the additional travel lanes on Route 111. The total salt allocation for Dinsmore Brook is estimated to be 125 tons/year, which means that the Department would essentially utilize the entire allocation for this watershed in order to maintain the same level of service on State highways.

Table 4-4 – NHDOT’s Estimated Future Average Annual Road Salt Usage in Comparison with the DES Suggested TMDL Allocation and the Vehicle Usage Based Allocation

Watershed	Existing Estimated Annual Average (tons/yr)	Existing Est. Annual Average w/ BMPs (tons/yr)	Estimated Future Average Annual w/ I-93 Expansion and BMPs (tons/yr)	Vehicle Usage Based Allocation Tons/yr	Future Use vs Vehicle Based Allocation (%)
Beaver Brook	949	759	1,158	3,566	33%
Dinsmore Brook	139	111	125	116	108%
Policy Brook	676	545	1,002	1,613	62%

It is possible that with the full BMPs in place and with a better geometric design of the Exit 3 Ramps, that even greater salt reductions might result and the Department would utilize less of the overall allocation for Dinsmore Brook. Again, because of the historical records and the close correlation with WSI, the Department has the ability to monitor usage and estimate the amount of salt use reduced with the BMPs in place.

Table 4-5 presents a comparison of the existing salt usage, the DES suggested TMDL allocation, the estimated future usage on the expanded I-93 with BMPs in place, and a proposed vehicle based adjusted allocation for each of the sectors in each watershed. Since the future estimated usage with the expanded I-93 roadway is less than the estimated vehicle based allocation, the surplus vehicle based allocation can be redistributed to the other three sectors. In the Beaver Brook watershed, there is a considerable surplus of 2,400 tons/year that can be redistributed. The proposed allocation adjustments or redistributions presented below are for illustrative purposes only. Essentially, with the adjustments, the proposed allocations for the municipal and parking lot sectors would be roughly 4 to 5 percent less than the DES suggested allocations. The adjustment shown for the private road sector represents a 21 percent difference from the DES suggested allocation. The potential adjustments to each sector allocation will need to be finalized through a more formal process coordinated by NHDES with the various implementation plans developed by each municipality.

Table 4-5 – Comparison of Existing Salt Use, DES Suggested TMDL Allocation and Adjusted Potential Vehicle Based Allocation for Each Sector

Watershed	Sector	Existing FY07 Usage ¹ (tons/yr)	DES Suggested Allocation (tons/yr)	Estimated Future Average Annual w/ I-93 Expansion and BMPs (tons/yr)	Potential Vehicle Based Allocation (tons/yr)	Adjusted Potential Vehicle Based Allocation (tons/yr)
<i>Beaver Brook</i>	State	669	814	1,158	3,593 (2435) ²	1,158 (+344) ⁴
	Municipal	1,901	2,966	--	1,758 (+1100) ³	2,858 (-108)
	Parking Lots	2,936	3,472	--	2,217(+1100)	3,317 (-155)
	Private	336	393	--	77(+235)	312 (- 81)
	Total	5,842	7,645	--	7,645	7,645
<i>Dinsmore Brook</i>	State	82	62	125	116 (-9) ²	124 (62) ⁴
	Municipal	4	3	--	0.5 (-0.5) ³	0 (-3)
	Parking Lots	43	33	--	6 (-6.0)	0 (-33)
	Private	34	26	--	1.5 (-1.5)	0 (-26)
	Total	166	124	--	124	124
<i>Policy Brook</i>	State	456	365	1,002	1,650 (648) ²	1,002 (+637) ⁴
	Municipal	1,306	1,044	--	552 (+284) ³	836 (-208)
	Parking Lots	2,426	1,940	--	1,242 (+284)	1,526 (-414)
	Private	125	100	--	5 (+80)	85 (-15)
	Total	4,313	3,449	--	3,449	3,449

Notes: ¹Existing Usage is based on estimated usage in the winter of 2006/07. ² Values in parenthesis represent the estimated surplus or deficit allocation for NHDOT based on the estimated future needs on I-93 relative to the vehicle based allocation. ³Values in parenthesis represent the potential redistribution of the surplus or deficit associated with the vehicle based allocation relative to the estimated future needs for the expanded I-93 roadway. ⁴ Values in parenthesis represents the difference between the DES suggested allocation and the proposed adjusted vehicle based allocation.

For Policy Brook, there is less of a surplus between the future estimated needs for I-93 and the calculated vehicle based allocation. The proposed adjusted allocations for the municipal and parking lot sector represent approximately a 20 to 21 percent difference from the DES suggested allocation. The adjusted allocation for the private road sector represents roughly a 15 percent difference from the DES suggested allocation. If the municipalities and parking lots were to achieve a reduction of 35% to 40 % from their current estimate annual salt usage, the overall watershed allocations for both Beaver Brook and Policy Brook could be achieved even with the proposed widened I-93 roadway in place. This is based on the FY05 salt usage data for Beaver Brook and the FY07 salt usage data for Policy Brook, consistent with the TMDL study reports.

For Dinsmore Brook, there is essentially no surplus and the estimated future needs to accommodate the proposed I-93 expansion would utilize both the vehicle based and the DES suggested allocation for the entire watershed. This is primarily due to the fact there is a disproportional amount of state roadway within this small watershed with the Exit 3 interchange and NH Route 111. The pre-TMDL specific conductance monitoring also showed that there was a fairly substantial upstream source as specific conductance and chlorides were quite elevated above the existing I-93 roadway as well. Perhaps there may be opportunity as a collaborative effort with DES and other stakeholders to investigate and rectify the source of the elevated upstream levels, which would allow for greater allocations of chloride and road salt downstream.

MDSS/RWIS MODELING

The Department has also conducted a modeling exercise to evaluate how the DES suggested allocation for the Department's annual salt use might impact road conditions with the proposed roadway expansion. The modeling was done using the Maintenance Decision Support System (MDSS) software and previously recorded weather and road pavement condition data. Typically, the MDSS software is used to estimate what type of application rate may be needed to prevent pavement ice bonds from forming or some other predefined undesirable road condition based on real-time weather and pavement conditions. The modeling software can also be used in a reverse manner to evaluate what type of road conditions may result if certain application treatment is applied under the same weather and pavement conditions. This provides a useful tool to evaluate how various changes in application techniques or the amount of material applied can change road conditions.

The Department ran simulations utilizing the weather data from FY 2000 through FY 2006 to estimate the potential changes in road conditions or Level of Service that may occur with potential salt reductions of 40 and 60 percent. This percent reduction is roughly what would be needed to meet the DES suggested Load Based Allocations in the Policy Brook watershed under existing and proposed conditions if the suggested vehicle based allocation adjustments were not utilized. These estimated reductions do not include a 20% reduction anticipated with the various proposed BMPs because the software was calibrated to conventional treatment options. The MDSS was used to predict and categorize the number of hours that certain road conditions may occur under the following categories: Good, Poor and Bad. The Good condition represents an ice free condition; the Poor condition represent snow covered but no snow or ice pack on the roadway; and the Bad condition represents packed and bonded snow or glare ice.

The modeling results showed that the Department is already operating at the threshold where poor and bad road conditions can occasionally occur under severe weather and the current application practices. Under existing conditions, represented by zero percent reductions, the model predicts that as much as 15 hours of bad road conditions (ice pack and snow bonding to the road) may occur along with approximately 50 hours of poor road conditions (snow covered but not necessarily an ice pack bond). With a potential 40% reduction in salt use, the predicted number of hours for bad road conditions increases to approximately 25 hours and the number of hours with poor road conditions is predicted to increase to approximately 70 hours. With a potential 60+% reduction in salt use, the potential number of hours with bad road conditions essentially doubles relative to existing conditions. Similarly, the potential number of hours with poor road conditions increases to roughly 80 hours. The 60+% reduction represents what the Department would need to achieve with proposed I-93 expansion and still meet the DES suggested load based allocations in the Dinsmore and Policy Brook watershed.

The results also show that the 60%-plus reduction threshold appears to be a tipping point at which road conditions appear to deteriorate more rapidly. Also, the predicted variability tends to increase as less and less salt is applied. During a severe winter, the model suggests that up to 100 hours of bad road conditions may be possible with a 60%-plus salt reduction. The model does not account for the timing of the events, which play a critical role in both the effectiveness

of the treatment and potential consequences with poor road conditions. Obviously, during peak travel periods, the ability to maintain reasonably safe travel conditions can become more challenging and the potential consequences of vehicle accidents due to poor road conditions increases. In summary, it is safe to say that any further reductions in salt use beyond what we can achieve with more efficient application will reduce the level of service currently provided by the winter maintenance program and will increase the likelihood for longer periods of bad and poor roadway conditions. This will likely have a substantial negative impact on commuter travel and economic activity for the region and the state.

5.0 FUTURE IMPLEMENTATION OF BMPS TO OTHER PATROL SECTIONS

There are five patrol sections in the TMDL watersheds. The plan currently involves maximizing the use of the BMPS from Patrol Section 528 to the other patrol sheds maintaining roadways in the TMDL watershed. Most of the Department owned trucks are equipped with ground speed oriented spreaders but only few have pre-wetting equipment. None of the rented trucks that spread salt have ground-oriented spreaders and do not have pre-wetting equipment. There are four brine tanker trucks that have been used to apply pre-storm anti-icing applications on State highways. These tankers are also equipped with under belly plows. There are two other trucks that operate with under belly plows on I-93.

The current target date to begin operating the 4th lane between Exits 2 and 3 is the fall of 2013. The Department plans to begin implementation of the various Best Management Practices over the next five years with full implementation to occur by the end of 2013. These BMPs include use of ground speed oriented spreaders, pre-wetting materials and equipment, pre-storm brine applications, use of the Maintenance Decision Support system and increased personnel training. The Department also plans to eliminate the use of rented salt spreading trucks within the TMDL watersheds, which will require the purchase of additional trucks to replace them. The acquisition of new trucks equipped with the computer controllers, ground oriented spreaders, and pre-wetting equipment will require a major capital investment.

The following presents the proposed timeline to achieve deployment of these various BMPs in the TMDL watersheds:

- 2009 - Brine applications will be expanded to all state highway in the TMDL watersheds
- 2010 - All operators will be required to attend Snow and Ice training each year
- 2012 - All trucks will be equipped with pre-wetting equipment
 - All trucks will be equipped with Ground Oriented spreaders
 - MDSS/RWIS will be expanded to all Patrol Sections
- 2013 - All trucks will be equipped with GPS enabled Computer Controllers (see below)

6.0 FUTURE MONITORING TO VERIFY EFFECTIVENESS

6.1 Use of GPS enabled Computer Controllers to Monitor Salt Use

Tracking the amount of salt applied to the highway has been traditionally completed through weekly patrol section salt shed inventory. This method is adequate for tracking inventory and was acceptable for estimating the amount for the TMDL study, but lacks the resolution to evaluate the effectiveness of the proposed best management practices. To better measure and evaluate the application of salt, the Department has received a \$75K grant to instrument a number of state owned plow trucks with Global Positioning Systems (GPS) enabled computer controllers that will automatically record where, when and how much salt is applied after the truck leaves the patrol shed. This equipment will be downloaded each time the trucks return to their respective shed and will be post processed into a single geographic database. Once a viable system for transferring the onboard controller data is established, the goal would be to equip all plow and spreader trucks in the watersheds with this GPS equipment. This will provide reasonably accurate data on how much salt has been applied in the watershed, and on which roads and by a particular truck. Until that point in time the Department will continue to track salt use through these weekly inventories. The practice will likely continue after the GPS system is fully implemented to verify salt usage on a patrol section basis. Due to the substantial costs involved and the budget constraints and current economic conditions, the implementation of these GPS enabled controllers will be phased in over the next few years. It is anticipated that full implementation of these controllers on all trucks applying deicers in the TMDL watersheds will be completed by 2013.

6.2 Using the Winter Severity Index to Verify Anticipated Reductions

The Winter Severity Index (WSI) allows the Department to evaluate its salt use from year to year independently of the weather. In other words, since the historical annual usage over the last 15 years has been shown to be highly correlated to the computed WSI for each season, the Department can predict reasonably accurately what its annual usage would be based on the WSI alone. This correlation will be used to demonstrate that the TMDL allocation or the anticipated 20% reduction has been met by comparing the predicted salt usage with actual usage tracked at the individual sheds. The Department is already seeing quantifiable results from the partial deployment of the BMPs at the 528 Patrol Shed and expect to see similar result when the BMPs are introduced to the remaining four Patrol Sheds operating in the TMDL watersheds.

7.0 DISCUSSION

The Department believes that the proposed measures outlined in this implementation plan represent substantial commitment on the Department's part to reduce the "State's" share of the chloride contributions in the TMDL watersheds. The overall cost to implement these measures is currently estimated to be approximate \$6 million, \$3 million for equipment and \$3 million for support infrastructure. This is in addition to the funds already provided to advance the TMDL studies, provide assistance in monitoring in the TMDL streams, purchase new brine tanker trucks and salt spreaders for I-93, install RWIS towers and pool fund the MDSS. The equipment upgrades and the use of newer technologies proposed in this document are anticipated to result in at least a 20 percent reduction in the annual salt use relative to existing conditions. The Department will continue its efforts to investigate and utilize other newer Best Management Practices (BMPs) as they become available.

The Department believes that the vehicle based allocations proposed in this Plan represent the more equitable means of distributing the total watershed allocation amongst the various road and parking lot maintenance sectors, since road salt is primarily used for maintaining safe travel conditions for vehicles. Utilizing the Load Based Allocations, as proposed by NHDES in the TMDL studies, is highly inequitable because it rewards those users or sectors that previously used the most salt and have not incorporated any efficiency measures to date. The Department has demonstrated through its comparison of annual road salt usage with the Weather Severity Index, that its annual salt usage for more than 15 years has been highly correlated to winter severity.

Maintaining reasonably safe travel conditions on the I-93 and other State highways is essential to the economic vitality of businesses in southern NH and the surrounding region. Many local and regional businesses rely on the I-93 and other State highway for shipment of good, and to support tourism and consumer travel. The I-93 supports over a 100,000 vehicles per day with large percentage of the vehicle trips consisting of commuters traveling to the workplace. Deteriorating road conditions during winter weather can have major impact on the local and regional economic activity and increase the likelihood for employee tardiness and absenteeism. Reducing the annual salt use beyond the anticipated 20 percent reduction proposed with the various BMPs in place, would result in a decrease in the current level of service provided on the I-93 and area State Highways and will result in an increased safety risk to the traveling public.

Ultimately, driving behavior and expectations may need to change and adjust to the possibility of longer periods of poor road conditions during winter weather, especially during severe winter weather. The Department believes that its planned Intelligent Travel System (ITS) for the I-93 corridor will also help to deliver real-time information to drivers about road conditions and to promote lower vehicle speeds and encourage safer driving habits during winter weather. It will take several years to construct this ITS infrastructure and additional educational outreach efforts will be needed before notable changes in driving habits and expectations are realized. To that end, DOT is currently funded a DES Public Education initiative to better inform and encourage safer driving habits during winter weather.

The Dinsmore Brook watershed represents the greatest challenge in trying to meet the proposed TMDL allocation. Under the proposed I-93 expansion, the Department will essentially need the

entire watershed allocation to maintain its roadway network without substantially altering its current level of service. This is primarily due to the fact there is a disproportional amount of state roadway within this small watershed with the Exit 3 interchange and the NH Route 111 roadway, both of which will be widened under proposed conditions. Since the watershed ultimately drains to Cobbett's Pond downstream, using an organic-based, non-chloride deicer alternative would not be appropriate, as it would only exacerbate existing low dissolved oxygen and nutrient enrichment problems within the pond. However, the Department will continue to research other technological advances, as they are developed to obtain even greater efficiencies.

The pre-TMDL water quality monitoring also showed that the specific conductance and chloride levels were fairly elevated upstream of the existing I-93 roadway as well. Perhaps there may be opportunity as a collaborative effort with DES and other stakeholders to investigate and rectify the source of the elevated upstream levels, which would allow for some flexibility in sharing the chloride allocations to the other sources downstream. The elevated upstream levels might also suggest that a Use Attainability study may be an appropriate course of action to determine if the designated water quality uses can reasonably be attained and the potential socio-economic costs that may be involved with achieving full support of the designated uses.

An added benefit to the various equipment upgrades that the Department is planning to implement is that it will make it easier to experiment with other alternative deicers by allowing the application of solids, liquids or slurry mixtures. The new GPS computer controllers are also anticipated to provide tracking of road salt usage on a roadway segment by segment basis and on a storm by storm basis. This will allow for an increased understanding of the weather and road related factors that are inherent to the deicing application decisions and allow for fine-tuning to improve delivery and applications of deicer. The activities of the Salt Reduction Workgroup will continue to benefit the Department and other stakeholders by educating the public of environmental consequences of chloride based deicers, promoting changes in expectations during and after winter weather events and increasing the available education opportunities for all those involved with winter maintenance activities.

The Department has allocated approximately \$2.5 million to assist municipalities and other sectors in purchasing and implementing their own salt reduction measures. Initially, these funds were targeted by the Department to implement their own salt reduction measures, however, following the release of the TMDL studies, the Department realized that to achieve overall TMDL allocation in each watershed, the municipalities, private parking lots and private roads must participate in the process by implementing their own salt reduction measures. It was then decided to use the funds to help reduce the cost burdens of the other sectors and incentivize participation through a competitive grant application process similar to the municipal-managed bridge project program, where the Department will fund 80% of the project cost and 20% of the project cost would be funded by a local match. A Salt Reduction Workgroup Committee has been established to review and select grant applications based on established selection criteria. Preference will be given to those projects that have identified measures with the greatest potential for annual salt reductions for the least amount of money.

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APPENDIX A

SUMMARY OF EXISTING NHDOT'S
SNOW AND ICE CONTROL PRACTICES and BMPs

ANTI-ICING VS. DE-ICING

Anti-icing practices are designed to prevent the formation or development of a bond between snow/ice and the roadway surface. It involves the timely application of a deicing agent often well before the storm commences that depresses the freezing-point of water. As such, anti-icing is often considered a preventive or proactive approach to winter maintenance as the initial actions of the maintenance crew (including the application of deicing chemicals) can greatly affect the amount of deicing chemical needed over the duration of a storm. The chemical applied from this early treatment remains on the roadway surface ready to begin working when the precipitation begins thus keeping compaction and adhesion from occurring. If the prevention of the bond is successful, the subsequent accumulated snow can typically be removed by mechanical means (plowing) and often reduces the number of additional applications of deicing chemicals. It is important to point out that the effectiveness of anti-icing practices in preventing ice-bonds to the pavement can be depend on numerous factors including pavement temperatures, precipitation type and intensity and traffic volumes. Heavy traffic volumes alone can be a major factor in the promoting an ice bond to pavement as snow is compacted more quickly in the wheel path as snow continues to accumulate and when temperatures are conducive to ice formation. This is just one of several reasons why the heavy traffic volumes typical of Interstate highway make winter maintenance operations on major highways more challenging.

Additionally, since the application timing is critical to the success of anti-icing techniques, a dependable, accurate weather forecast is essential to implementing this technique. A forecast that accurately predict when a storm will commence and the type of precipitation that will fall will allow the maintenance crew time to make appropriate application of deicing chemical to the bare roadway surface prior to or just after the commencement of precipitation and to make timely applications during the storm to prevent snow and ice from forming solid pack and refreezing to the pavement.

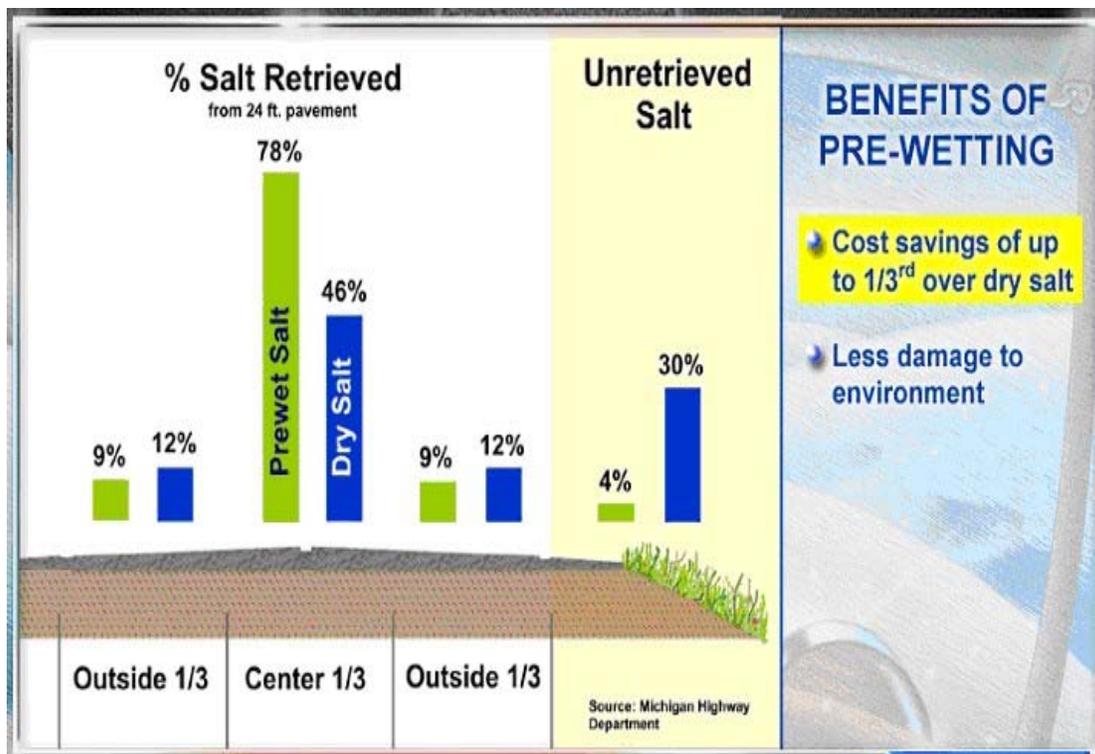
Ground Speed Oriented Spreaders

When a plow truck operator or the supervisor determines a desired salt application rate, the next requirement is to have equipment that has the ability to dispense that amount of material. The quantity of salt dispensed is dependent on three factors. The first is the gate opening thru which the salt emerges from the spreader. As the gate opening is increased the amount of salt dispensed increases. The opening is generally set at the patrol shed and not changed during any salt run. The next variable is the speed of the spreader belt that revolves in the bottom of the spreader and transports material to the rear of the truck to be discharged out the gate opening. By alternating the belt speed the operator is able to change the amount of material that is forced thru the gate opening thus varying the quantity of salt dispensed. The final variable in the determination of how much material is dropped onto the roadway is the speed of the truck itself. If belt speed and gate opening are held constant then more material will be spread per mile at 10 MPH than at 30 MPH. This can waste salt so to be efficient spreader manufacturers have devised a way of varying the belt speed in the spreader with a corresponding truck speed. This permits for the constant application of a specific quantity of deicing material regardless of the speed the truck is traveling. When the truck stops the belt stops and no material is dispensed. This equipment is known as being ground speed orientated controls and is essential in keeping salt applications to a

specified amount and no more. All trucks owned by NHDOT have ground orientated spreader controls while few private trucks working for NHDOT have invested in them.

Pre-Wetting Spreaders

When dry salt is applied as solid pellets for snow and ice control purposes, it must first dissolve through the adsorption of moisture from the air or snow before it can be effective in melting snow or preventing ice bonds. Dry salt applied to dry pavement also often results in much of salt either “bouncing” or being blown off the pavement by wind. Pre-wetting road salt with a liquid deicer at the time of application speeds up the reaction/melting process and has the added advantage of “sticking” the solid material to the roadway. The pre-wetting application is typically done by equipping spreader trucks with saddle tanks and spray nozzles that apply approximately 8-10 gallons of a liquid calcium chloride or salt brine per ton of solid deicer as salt passes through the spreader chute. Pre-wetting has been shown to increase the effectiveness of the solid salt and allows for reduced application rates. Studies done for the Michigan Highway Department indicate a savings of up to 33% percent when the salt is pre-wetted in this manner. The following figure illustrates the previous findings.



To expand pre-wetting capabilities for the Department’s fleet of plow and spreader trucks would require a significant investment to purchase the saddle tanks, pumps and nozzles that are capable of applying a liquid at the spreader’s spinner. This effort should also include all the private trucks that dispense salt.

Underbelly Plows

At the end of a storm the NHDOT's standard procedure is to plow the roadway clear of as much snow as possible and then apply a light application of salt to bare up the pavement. As the amount of salt required is directly proportioned to the depth of snow on the roadway, the more snow scraped off the smaller the quantity of salt needed on the final salt run. Underbody plows function similar to a grader scrapper cleaning the roadways that have a uniform cross section and a minimum accumulation of snow. Therefore, if plow trucks could be equipped with these plows and run just prior to the final salt run then the minimum quantity of salt would be needed to remove any remaining snow, slush or ice on the roadway surface. The underbody plows are not restricted to end of the storm use and can be used throughout a storm event to remove as much accumulated snow as possible. They are used in conjunction with the front plow and a trailing wing that moves the snow windrow off the traveled way and away from traffic. The use of the underbody plow is restricted to those roadways that are relatively smooth and of a constant cross section as heaved, broken pavement will catch on the blade, creating hazard for the truck, operator and other users of the highway.

Maintenance Decision Support System and Roadway Weather Information Systems

Road weather information systems (RWIS) consist of a suite of atmospheric and pavement-monitoring sensors that continuously collect real time site condition data and distribute it to maintenance personnel. These instruments are mounted on or beside a 30' tower alongside various roadways and transmit data every 7 minutes to a central sever that processes the data and displays it along with all the other sites in an easily understood format. Maintenance crews can tell at a glance what weather conditions are occurring across the state and prepare to take the appropriate action. The data also provides valuable information for meteorologists under contract with NHDOT in providing weather forecasts for maintenance operations. Chemical treatments can often be carried out in a more efficient manner if the start or end times of storms are forecasted in advance. Additionally, the RWIS reports on the chemical concentration that is present on the roadway surface and predicts a freeze point for that location, which allows the patrol foreman to determine if additional deicing chemical treatments are necessary at any particular time.

In an effort to assist these frontline managers the Federal Highway Administration (FHWA) established a Road Weather Management Program with a strategic goals of minimizing the adverse effects that weather has highway maintenance. The objectives of the program were to reduce accidents attributed to inclement weather, maintain the traveling public mobility, reduce roadway congestion, minimize the impact that adverse weather has on the roadway movement of goods and services, minimize the impacts of road treatments that impact air, soil and water quality. The FHWA studied the problem and concluded that what was needed was a needed was a way for field managers to link all the information available from RWIS, weather forecasts, and traffic monitoring equipment and to their standard operating procedures. Given certain weather conditions and a weather forecast the program will recommend certain actions to be taken and predict what the outcome will be if the recommendations are followed. For example, a foreman will respond to a pending storm with a site-specific weather forecast. The program will take this information, look at the real time pavement conditions and then suggest an application of deicing

material, when to apply the chemical, when to plow and predicts what the end of the storm conditions will be.

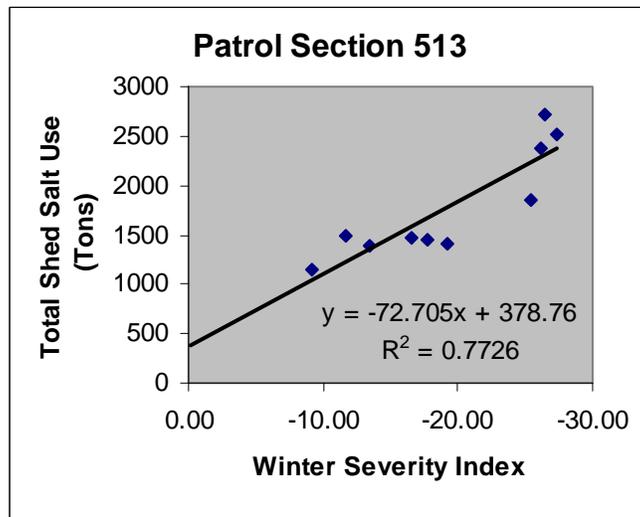
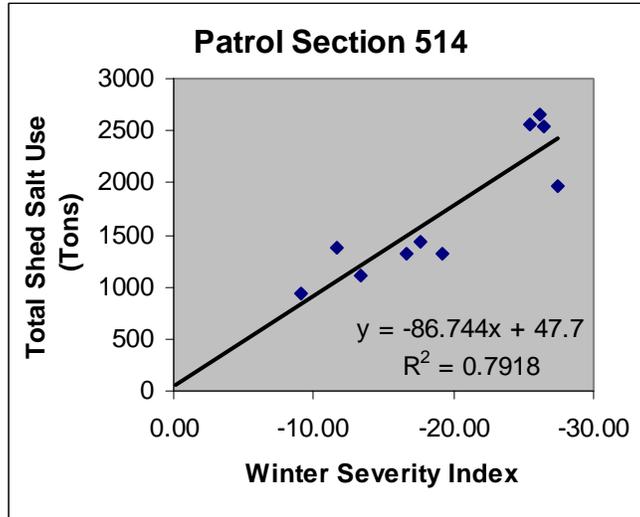
Training

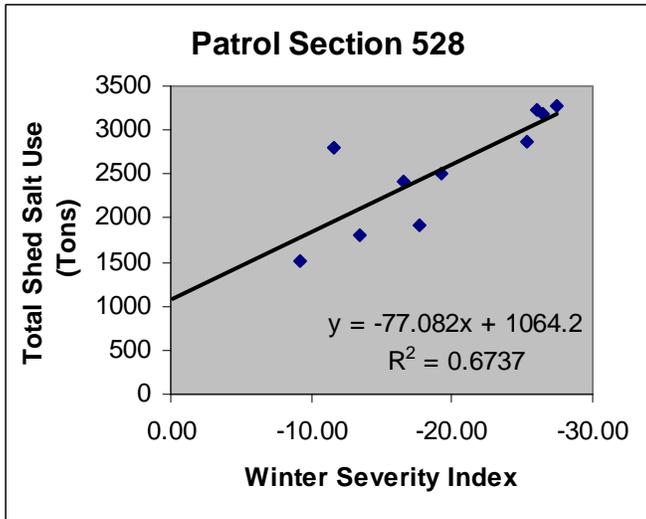
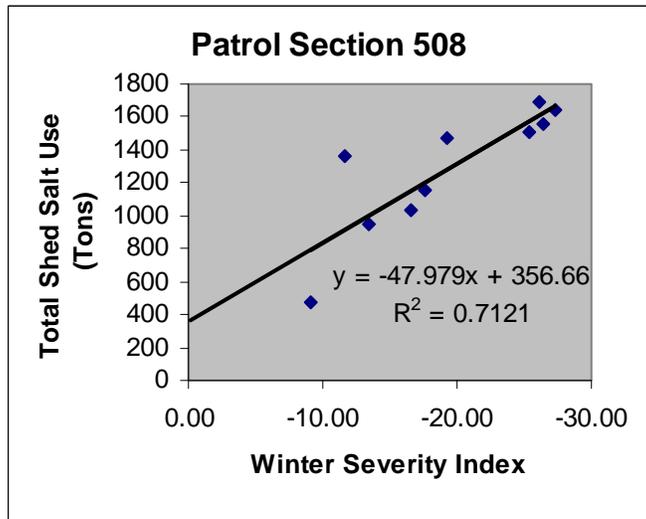
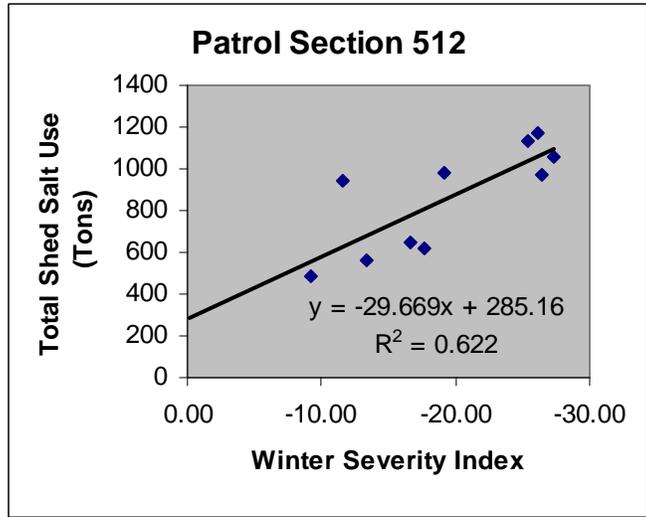
The Bureau of Highway Maintenance has developed an eight-hour training course in snow and ice control operations that has been given to most maintenance employees. The course stresses the importance of applying deicing chemicals in the most efficient manner and the tools and methods that are available to do the job. The course covers proper techniques for plowing, sanding and the application of chlorides. It is anticipated that the course will continue to be offered each year and that operators of private equipment will also be given the opportunity to attend the course. The Department feels quite strongly that educated employees who are given the necessary equipment represent the best possible method of insuring that the minimum salt needed is actually dispensed within the corridor. The Department recognizes the importance of training as the practice of snow and ice control has become increasingly more complex and new information is generated each year.

Appendix B
Figures of Historical Annual Usage vs. WSI
for the Five DOT Patrol Sheds

The following are linear relationships for salt use by Patrol Section based on the WSI from November to April:

Total Patrol Section Salt Usage = Slope * WSI + Intercept





APPENDIX C
Summary Memo of the Vehicle Usage and Roadway Lane Miles
Analyses in Each of the TMDL Watersheds



Memorandum

To: Mark Hemmerlein
Water Quality Program Manager

Date: May 19, 2008; rev. June 5, 2008

Project No.: 51738.00

From: Bill Arcieri
Senior Water Quality Scientist

Re: I-93 TMDL Watershed Comparison of
Estimated Road Mileage and Average
Daily Traffic Volumes -DRAFT

The following provides an update to the methodology and results of the comparative analysis of roadway mileage and vehicle usage (i.e. Average Daily Traffic Volumes) for the various roadway maintenance jurisdictions (i.e. local, state and private) as well as the paved parking lots within each of the major chloride-TMDL watersheds including Beaver Brook, Dinsmore Brook and Policy Brook. The traffic data estimates and roadway miles for the north tributary to Canobie Lake were included in the Policy Brook watershed due to the relatively small size of the north tributary watershed. The purpose of this analysis was to provide a relative comparison of the average daily traffic volumes and number of lane miles that are within each roadway maintenance jurisdiction. The total number of vehicles estimated to travel within each of the roadway maintenance jurisdictions is based on estimates of ADT's for each roadway segment multiplied by the number of miles for that segment divided by the number of lanes. The product of this calculation for each roadway segment is referred to as the Vehicle Lane Miles (VLM). In the end, the sum total of Vehicle Lane Miles (VLM) for all the roadway segments were provided for each maintenance jurisdiction. The methods used to develop ADT estimates for each of the roadway segments are described in more detail below. The estimates are considered sufficient for relative comparisons between the different roadway maintenance jurisdictions but should not be utilized for traffic planning or other purposes aside from the intended use of this analysis.

With the exception of the Dinsmore Brook watershed, only parking lots greater or equal to 1.0 acre in size were included this analysis. According to NHDES' GIS land coverage data, the number of parking lots in the Policy Brook and Beaver Brook watersheds is estimated to be approximately 425 and 870 lots, respectively. Small parking lots less than 1.0 acre in size account for more than 80 percent of the total number of parking lots. However, in terms of overall parking lot area, parking lots greater than or equal to 1.0 acre in size account for roughly 64 and 68 percent of the total estimated parking lot area in the Beaver Brook and Policy Brook watersheds, respectively. With nearly two-thirds of the parking lot area accounted for in both the Policy Brook and Beaver Brook watersheds, the results of this analysis are considered sufficient to conduct relative comparisons to the roadway maintenance jurisdictions discussed above. However, it should be noted that the total VLM estimates for parking lots in the Beaver Brook and Policy Brook may be underestimated given the number of smaller parking lots that were not included in this analysis. A much greater effort would have been required to generate traffic volume estimates for the hundreds of small parking lots in each of the larger watersheds. All of the parking lots in the Dinsmore Brook watershed were accounted for since there were fewer than 20 parking lots in this watershed.

Traffic Comparison Results in TMDL Watersheds- June 2008.doc

Methodology

Watershed boundaries, road mileage, maintenance jurisdiction and parking lot areas were included in the GIS data layers and associated attribute tables developed by NHDES as part of the overall TMDL study. This GIS data included roadway length and parking lot sizes for the parking lots identified. The estimates of Average Daily Traffic ADTs volumes for each of the roadways were compiled and/ or developed from the following combination of methods or sources.

1. Existing Published ADT volumes: Some of the ADT volumes were included in the GIS data layers as provided by traffic count data collected by the New Hampshire Department of Transportation (NHDOT), the Southern New Hampshire Planning Commission (SNHPC), and the Rockingham Planning Commission (RPC). Some modifications or updates were included where more recent traffic count data was available.
2. Where only peak hour traffic counts were available, ADT volume estimates were developed with the use of K-Factors derived from various sources (i.e. Traffic Impact Studies, Environmental Impact Studies, etc.). A K-Factor (expressed as a percentage) is the ratio of peak hour traffic to the average daily traffic. K-Factors were developed from certain locations that had both a daily and hourly count data and were applied to surrounding locations with only peak hour counts to estimate the daily volume.
3. Where traffic count data were not available, trip generation estimates (i.e. ADT volumes) were generated based on trip generation rates published by the Institute of Transportation Engineers (ITE) in Trip Generation¹. These estimated traffic volumes included traffic generated by the various land uses on that particular section of roadway, as well as traffic generated on adjacent roadways that would feed onto or cut-through that particular section of roadway.

Adjustments were made to produce a reasonably balanced network of traffic volumes for connector and main arterial roads using the existing ADT volumes combined with the new volume estimates generated with the above-noted methodologies. Lastly, ADT volumes for roadways were rounded to the nearest 25 vehicles for minor local roadways and to the nearest 100 vehicles for major highways and freeways.

Parking Lot Lane-Mileage

The parking lot lane-miles were calculated based on the following assumptions:

Typical Parking Space = 9'x18'

Typical Drive Aisle = 24'

Typical parking plus drive aisle = (18'+12') x 9'=270 sf, say 300 sf

Number of spaces per acre of Parking = 43,560 sf / 300 sf = 145 spaces per acre

Drive Aisle length for 145 spaces = 145 spaces / 2 (double sided parking aisle) x 9' = 650 LF of drive aisle per acre

Assume 650 LF / 0.9 (layout efficiency factor) = 725 LF of drive aisle x 2 drive aisles (double sided parking aisle) = 1,450 LF

Assume 1,450 LF / 5,280 LF per mile = 0.28 lane miles per acre of parking lot

Use multiplier of 0.28 lane-miles for each acre of parking lot to determine lane mileage.

Note: Assumes salt is only applied to travel lane portion of parking lot. The amount of travel lanes will vary greatly for each parking lot depending on layout and length of access and connecting roads. For some parking lots, the amount of travel lanes relative to the amount of parking spaces could be much higher.

¹ Trip Generation Seventh Edition, Institute of Transportation Engineers, Washington, D The summary provides a relative comparison of the average number of vehicles that travel (VLM) within each maintenance jurisdiction as well as the number of lane miles that need to be maintained on a daily basis..C., 2003.

Results

The following tables provide a summary of the estimated roadway miles, lane miles and vehicle-lane mileage for each roadway maintenance jurisdiction (i.e., state, local, and private) and parking lots. In general, the results show that NHDOT's road network has the highest amount of vehicle usage on a daily basis in each of the three watersheds as compared to the other maintenance jurisdictions. In the Beaver Brook watershed, NHDOT has nearly twice as many vehicle lane-miles traveled on an average daily basis compared to the local road maintenance jurisdictions, even though under local maintenance there are nearly six times as many lane miles. For Dinsmore Brook, the number of VLM's within NHDOT's jurisdiction is far greater than that estimated for any of the road maintenance jurisdiction because of the traffic volumes utilizing the Exit 3 Interchange, the I-93 mainline as well as Route 111 and Route 111A. For Policy Brook, again, even though there are a far greater number of lane miles under local jurisdiction, the estimated VLM, which is indicative of the amount of vehicle usage, is much higher for the roads under NHDOT jurisdiction as compared to the local or privately maintained roads. With regard to parking lots, the estimated amount of vehicle usage (VLM) is again much less than that estimated for NHDOT roads and somewhere between that estimated for state and local road jurisdictions, which makes sense since traffic is utilizing both state and locals roads to get to parking lot destinations. The parking lot VLM estimates are much higher than that estimated for local roadways, especially in the Policy Brook watershed. Although the smaller parking lots (i.e., < 1.0 acre) were not included, it is not likely that even if they were that the estimated vehicle usage would surpass that estimated for NHDOT roads.

Beaver Brook			
Jurisdiction	Road Miles (miles) or Parking Area (acres)	Lane-Miles	Vehicle - Lane Miles (VLM)
State (NHDOT)	27.9	53.2	273,317
Local	147.5	295.0	133,213
Private	23.1	44.3	6673
Parking Lots	296 (64%)*	82.9	171,209

Dinsmore Brook			
Jurisdiction	Road Mileage (miles) or Parking Lot (acres)	Lane -Miles	Vehicle - Lane Miles (VLM)
State (NHDOT)	4.0	6.5	40,018
Local	0.5	1.0	39
Private	2.3	4.4	89
Parking Lots	7.5 ac	2.1	2100

Policy Brook			
Jurisdiction	Road Mileage (miles) or Parking Lot (acres)	Lane -Miles	Vehicle - Lane Miles (VLM)
State (NHDOT)	17.8	32.1	237,375
Local	55.6	116.0	79,750
Private	8.2	16.4	1,870
Parking Lots	260 (68%)*	72.7	177,267

Notes: * Values in parentheses represent the percentage of the total parking lot acreage estimated to be within the watershed according to DES' estimates of parking lot area contained in Table 26 of the TMDL Data Report dated December 2007.

In general, the results of this analysis provides information to help assess the differences in the overall road salt needs or usage on a seasonal basis between the various roadway maintenance jurisdictions and parking lots. In addition to the winter inclement weather, traffic volumes and roadway lane mileage are two principal factors that affect the amount of road salt used each year. It is fairly well understood that as the number of roadway lane miles increases, the amount of road salt used each year will also increase. The effect that traffic volumes have on road salt usage may be less obvious. Higher traffic volumes tend to require more frequent applications due to the greater likelihood for snowpack to form and bond to the road. Snow pack forms as vehicles travel over accumulating snow compressing the snow into a hard pack squeezing out moisture that bonds to the pavement under the right temperature conditions. This frozen snowpack is what makes road surface conditions more treacherous and requires a great deal more salt to break or melt the bond from the pavement. Snow pack is less likely to form on a less traveled road since there are fewer vehicle trips and less snow compaction occurring. Less frequent applications can be afforded on roads with less traffic. As you know, these are just some of the factors that maintenance personnel must consider on daily basis depending on the time of day and day of the week (i.e., weekday vs. weekend) in determining when to initiate, the frequency and the amount of road salt application needed to maintain reasonably safe travel conditions.