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Operational Factors that Affect Road Salt Usage and the Effectiveness and Efficiency of Salt Spreading Operations and Equipment



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16. Abstract The Massachusetts Department of Transportation (MassDOT) conducted a three-year study to evaluate its Snow and Ice Control Program, identify measures that would improve the efficiency and effectiveness of its deicer material usage, and reduce material costs. Recommendations for improvement were developed based on: 1) feedback from a web-based employee survey; 2) over 500 hours of field observations that included monitoring operational activities and pavement conditions during snow events over two winter seasons; and 3) a regression analysis of material usage to Winter Severity Index (WSI) values over a ten-year (10) period. The recommendations focused on five key areas, including the material usage reporting procedures by route and event, employee and contractor training, equipment calibration, route optimization, and equipment and technology upgrades. Specific recommendations include increased use of GPS/AVL-enabled closed-loop controllers, installation of wireless data transfer stations, reduction or elimination of the use of sand in Reduced Salt Zone areas, increased training and coordination with state police personnel, and utilization of route optimization software to eliminate route overlaps and redundant treatment applications. Full integration of the recommended measures could result in a substantial cost savings and a major reduction in the amount of salt used each year.			
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Final Report

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Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of MassDOT or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Executive Summary

This study of the operational factors that affect road salt usage and the effectiveness and efficiency of salt spreading operations and equipment was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) Statewide Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

MassDOT's primary objective for its Snow and Ice Control Program is to provide reasonably safe travel conditions for its entire roadway network in a cost-effective and environmentally sensitive manner. Application of deicing chemicals, including road salt, is a necessary component of the snow and ice operations in order to ensure public safety. MassDOT currently conducts snow and ice operations during winter storm events on approximately 15,980 lane-miles of multidirectional roadway, including breakdown lanes and ramps, throughout the state. MassDOT utilizes hired equipment and labor to supplement state equipment and employees to perform winter maintenance operations. During a major snow event, up to 3,000 pieces of snow fighting equipment (e.g., spreaders, plows, loaders, etc.) and a similar number of equipment operators will be mobilized.

MassDOT's deicing material usage represents a significant cost component of its Snow and Ice Program in which its annual costs for road salt usage alone may range from \$10 million to \$30 million, depending on the severity of the winter. Additional costs are borne through its Salt Remediation Program in order to respond to and investigate contamination complaints for both private and public water supplies. Due to the increasing cost of deicing materials and the sensitivity of surface waters and groundwater supplies, MassDOT initiated a three-year study to evaluate its current snow and ice operations, operational procedures (e.g., use of weather data, application rate, equipment, etc.), and material usage, and to develop recommendations that would result in more effective and efficient use of deicer materials.

A major component of this study included compiling and summarizing feedback through a web-based survey of MassDOT snow and ice employees. A total of 174 MassDOT employees voluntarily participated in an online survey that consisted of 24 questions, including 14 multiple-choice and 10 requiring open-ended responses. The survey feedback provided valuable information and insight into the various challenges that MassDOT's snow and ice personnel face in performing their duties, including issues that relate to communications, chain of command, weather forecasting, the tools available to assist in the decision-making process, road pavement and drainage conditions, use of hired equipment, and equipment limitations, to name a few. Various suggestions and recommendations for improvement were also provided.

A comparative analysis of historical material usage on an annual basis to estimated Winter Severity Index (WSI) values over a ten-year period indicated that the variability in annual

salt usage was highly correlated to changes in winter severity from season to season. The WSI is based on the daily minimum, maximum, and average temperatures, and daily snowfall measured at selected weather stations. Daily snowfall accounts for approximately 35% of the WSI value. The method for estimating WSI is believed to have been originally developed by the State of Washington and more recently modified and utilized by the New Hampshire Department of Transportation. A regression analysis of annual salt use and WSI shows a correlation coefficient (R^2) value of 0.93, indicating a fairly strong correlation between the two variables. Given this ten-year baseline comparison, the regression equation can be used to compare the actual salt usage to that predicted in future years based on the WSI value. This is used first, to assess whether the annual salt usage is in line with the winter severity conditions; and second, to assess the performance of recently implemented salt application methods by determining whether the actual salt usage is less than anticipated given the severity of winter conditions. If the actual salt usage is lower than that predicted based on the WSI value, then this would suggest that any newly implemented equipment upgrades or enhanced application techniques are more efficient than previous methods, based on the ten-year historical relationship of annual salt usage and WSI values.

Another major study component involved field monitoring of the snow and ice operations and related pavement conditions in select locations during snow events over two winter seasons. In the 2009–2010 winter, approximately 210 hours of monitoring were performed at four locations over the course of the six storm events, averaging about 13 hours per storm and per location. In the 2010–2011 winter, over 300 hours of observation time were logged by field observers during ten winter storm events. The 2010–2011 winter was unusually severe, with numerous major snow events and long stretches of below-normal temperatures. Several operational activities were noted by the field observers that were either inconsistent with MassDOT policies and procedures or were likely to result in excess amounts of road salt being applied. The frequency of these activities varied from a one-time occurrence to observations on numerous occasions. Some of the specific observations included multiple trucks treating the same road segment (which typically occurs at the terminus of abutting spreader routes or interchange areas), limited use of liquid material for pre-wetting, excessive truck speeds, applying dry road salt to dry pavement, improper settings of gates and other spreader controls, and plowing too quickly after material applications. Spreader trucks treating the same roadway area due to route overlaps was one of the more frequent observations, although the length of these overlapping segments was typically less than a half-mile. Inconsistencies in reporting material usage by the operator and/or by the spreader controller was also noted on numerous occasions. These reporting inconsistencies produced a certain amount of uncertainty in the accuracy of the data.

Based on the data analysis and field observations, a number of Best Management Practices were recommended in five key areas, including the reporting procedures of material usage by route and event, enhancements to employee and contractor training, measures to improve or optimize spreader routes to eliminate or minimize overlaps in material applications, and equipment/technology upgrades that will improve application efficiency and material usage reporting. Specific recommendations included increased use of GPS/AVL-enabled closed-loop controllers, installation of wireless data transfer stations, reduction and/or elimination of the use of sand in Reduced Salt Zone areas, increased training/coordination with state police

personnel, and utilization of route optimization software to eliminate route overlaps and redundant treatment applications. Full integration of the recommended measures is expected to result in a potential cost savings of several million dollars per year and a significant reduction in the amount of salt used each year.

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1.0 Introduction

MassDOT's primary objective for its Snow and Ice Control Program is to provide reasonably safe travel conditions for the entire MassDOT roadway network in a cost-effective and environmentally sensitive manner. Application of deicing chemicals, including road salt, is a necessary component of MassDOT operations in order to ensure public safety. MassDOT currently conducts snow and ice operations during winter storm events on approximately 15,980 lane-miles of multidirectional roadway, including breakdown lanes and ramps, throughout the state. MassDOT utilizes hired equipment and labor to supplement state equipment and employees performing winter maintenance operations. During a major snow event, up to 3,000 pieces of snow fighting equipment (e.g., spreaders, plows, loaders, etc.) and a similar number of equipment operators will be mobilized.

The type of deicing material applied may vary depending on local environmental, roadway and weather conditions. For most multi-lane roadway sections and secondary roads, the primary deicing material consists of straight salt (sodium chloride, NaCl) or Pre-mix (a mixture of sodium chloride and calcium chloride at a 4:1 ratio). MassDOT also uses liquid calcium chloride (CaCl₂) and liquid magnesium chloride (MgCl₂) as either pre-wetting agents or for pre-treating pavement as direct applications prior to or early in the storm event. A mixture of sand and sodium chloride or Pre-mix is often used in reduced salt zones. Straight sand is rarely used due to the high clean up and disposal cost at the end of the season.

MassDOT's deicing material usage represents a significant cost component of its Snow and Ice Control Program, where the annual cost of road salt alone may range from \$10 to \$30 million, depending on the severity of the winter. Additional costs are borne through its Salt Remediation Program in order to respond and investigate contamination complaints for both private and public water supplies. Due to the increasing cost of deicing materials and the sensitivity of surface waters and groundwater supplies, MassDOT is interested in developing more effective and efficient Best Management Practices (BMPs) for its Snow and Ice operations. For this reason, MassDOT engaged the Project Team to undertake a three-year research project to evaluate MassDOT's current operations, operational procedures (i.e., use of weather data, application rate, equipment, etc.), and material usage.

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2.0 Project Objectives

The objectives of this research project were:

1. To evaluate and identify various critical factors associated with the current Snow and Ice Control Program operations, procedures, and technologies that may lead to inefficiencies and excess use of road salt and/or other materials.
2. Identify and recommend operational changes and/or Best Management Practices that would improve operations and increase the efficiency of material usage.

2.1 Project Approach

Consistent with tasks outlined by MassDOT, the project tasks were completed in the following phased approach.

Phase I: Evaluation of Existing Data

Task 1A: Data Collection

Task 1B: Survey of Snow and Ice Personnel

Task 2: GIS Map Development

Phase II: Observing Deicing Operations during Winter Storm Events

Task 1: Winter 2009–2010

Task 2: Winter 2010–2011

Phase I – Task 1A: Data Collection

Historical deicing material usage and related winter weather severity conditions were compiled for Maintenance Districts 3, 4, and 5 for the fiscal years 2002 through 2011. Specifically, available data on salt usage (in tons per year for each district), total lane-miles for each district, and calculated application rates (in tons per lane-mile) were provided by MassDOT. Data also included weather conditions, temperature, and snow accumulation amounts obtained for use in developing Winter Severity Index (WSI) values for each district, as discussed below. Graphs of salt usage versus WSI values for the ten-year period were generated to assess how the variability in annual salt usage compares to changes in winter severity from year to year. An interim technical memo was produced to present the results of this analysis (“MassDOT Historical Salt Usage for Districts 3, 4 and 5 plus the use of Winter Severity Index to Track Annual Salt Usage,” VHB, Inc., May 3, 2010)(see Appendix A).

It should be noted that following the completion of the Phase 1 task in 2010, salt usage and WSI data were collected throughout the 2011–2012 season. The development of the WSI value is based on an approach believed to be initially developed by the State of Washington

and more recently adopted and modified by the New Hampshire Department of Transportation. The WSI method provides a relative measure of the winter weather severity conditions from year to year and is based on daily minimum, maximum, and mean temperatures, and snowfall during the months of November through March. Depending on the strength of the correlation between seasonal WSI values and annual salt usage using a long-term data set (e.g., ten years or more), a WSI-to-salt use regression analysis can be used to evaluate the effects of proposed operational changes, salt reduction measures, and related efficiency measures on salt usage relative to the historical usage for the same roadway area.

It is important to point out that since the start of this project in 2009, MassDOT has reconfigured its district boundaries and has added a new District 6, which began snow and ice operations in the 2010–2011 winter season (see Figure 1). The district reconfiguration was largely prompted by the merger and inclusion of the former Massachusetts Turnpike Authority (MassPike) roadways in 2010, and approximately 2,118 lane-miles were added to the MassDOT roadway network at this time.

Figure 1: MassDOT Highway Districts

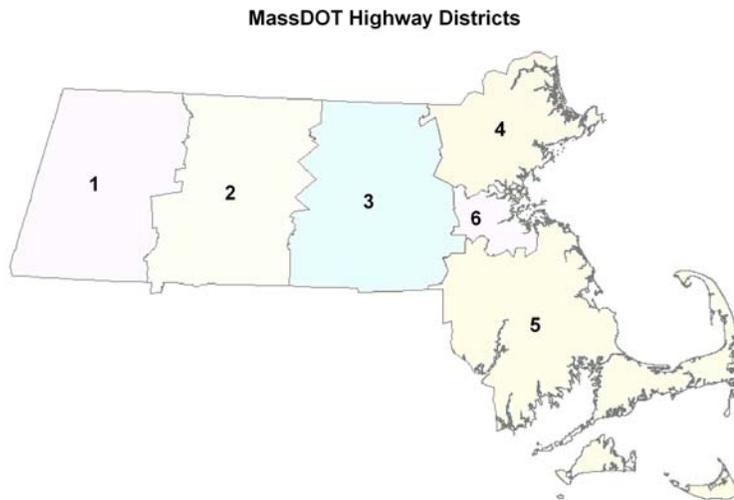


Table 1 provides a breakdown of the lane-mile totals for each district based on the MassDOT GIS roadway data prior to and after the district reconfiguration for the winter season of 2010–2011. Districts 3 and 5 had an increase in lane-mileage, while District 4 had a reduction in lane-mileage, as certain areas were shifted into the new District 6. This summary table includes MassPike roadways and the Massachusetts Department of Conservation and Recreation (DCR) roadways maintained by MassDOT for snow and ice purposes.

Table 1: Summary of the changes in MassDOT roadway lane-miles maintained by each district

District	Pre-2011	Post-2011	Gain/loss
1	827	1,269	442
2	1,868	2,241	373
3	3,097	3,306	209
4	4,457	3,384	(1,073)
5	3,612	4,219	607
6	--	1,560	1,560
Statewide	13,861	15,979	2,118

Phase I – Task 1B: Survey of Snow and Ice Personnel

Between September 3 and 17, 2009, a statewide web-based survey was conducted (Districts 1 through 5) for MassDOT Snow and Ice personnel. Participation in the survey was voluntary and anonymous, with 24 questions soliciting opinions and comments regarding the efficiency of Snow and Ice operations. Approximately 174 MassDOT employees from all five districts participated in the survey. The results of the survey are summarized in Appendix B and were originally presented in a technical memo entitled “Results of MassHighway Snow and Ice Employee Survey” (prepared by VHB, Inc.), dated October 8, 2009.

Phase I – Task 2: GIS Map Development

The project scope of work required the Project Team to produce statewide GIS mapping using the most current and relevant data layers available from the MassGIS database. The purpose was to display the major environmental resources and sensitive areas located within each district; including locations of public water supplies and Zone II areas, Areas of Critical Environmental Concerns (ACECs), Outstanding Resource Waters (ORWs), and Priority Habitat areas.

The statewide and district GIS maps were prepared and submitted in June 2010. In 2011, the statewide maps were revised and updated to include revised district boundaries (see attachment for CD). In addition to the statewide GIS maps, the Project Team developed updated GIS maps of the spreader routes in each of the selected study areas (see Appendix E.).

Phase II – Task 1: Winter 2009–2010

For the first winter, MassDOT selected spreader routes at four locations in Oxford, Westminster, Middleboro, and Lexington for observations. These locations were selected in order to have representative areas in each of three districts (Districts 3, 4, and 5) and to compare differences between Reduced Salt Zones (RSZs) and regular routes at each location. Prior to the start of monitoring, the Project Team members attended several training sessions led by MassDOT Snow and Ice personnel, where various operational activities, equipment settings, and pavement conditions that the field crews should try to observe and record within

each spreader route were outlined. The teams were directed to record pavement conditions and vehicle activity observations at designated safe locations along each route at regular intervals, while at the same time following spreader trucks at random intervals as time allowed during the storm. The general goals of the field effort were to document differences in pavement conditions between the routes and to note any operational activities that may lead to excess salt being applied. A summary of the routes, observation locations, and anticipated information to be gathered by the monitoring teams is presented in the “Data Collection Plan Meeting” notes, revised December 17, 2009 (see Appendix C).

To provide personnel coverage, three 2-person teams from each project consulting firm (GEOSPHERE, VHB, and Stacey DePasquale Inc. (SDE)) were established. GEOSPHERE and SDE were assigned Lexington and Middleboro depots respectively, while VHB was assigned to Oxford and Westminster, with each location to be covered on an alternating storm basis. Each team was furnished with a four-wheel drive vehicle equipped with the required safety lighting and reflective markings, a GPS data tablet, a camera, and a pavement temperature sensor to perform monitoring during storm events. Storms selected for monitoring were determined by MassDOT, and the first call-out began in January 2010. The teams were called out to arrive at the depot at least two hours ahead of the anticipated start of a snow event and to coincide with the typical call-out times for roadway maintenance crews. So as not to alert maintenance personnel that monitoring was occurring, MassDOT had instructed the project teams to observe operations in a discreet manner, to abstain from communication with depot personnel, and to stay off of depot grounds. The data was collected electronically and geo-referenced using the GPS-enabled tablet.

Each team was tasked to collect the following information at the designated locations through the entire storm, from the call-out time to the time that the roads were considered clear of snow and ice.

- General Information Data: Storm Beginning, Storm End, Roads Clear
- Station Observation Data (location / time)
- Precipitation Data (type, intensity, temperature, wind speed/direction, trend)
 - Treatment Data (type, plow timing, salt application timing)
 - Pavement Data (type, temperature, trend, lane conditions [snow/ice/wet])
 - Traffic Data (volume, speed)
- Vehicle Data (location / time): Vehicle type (MassDOT or contractor), activity, ID, location, spreader conditions/observations, approximate travel speed, plow conditions / observations)

The general approach for vehicle observations included the following:

- Follow randomly selected road salt application vehicles to inspect spreader equipment configuration, functioning, and ability to apply a uniform application rate.
- Verify through random observation if various equipment operators have valid calibration certificates and if the equipment appears to be adequately calibrated.

- Identify and document any observed operator practices that are not consistent with MassDOT’s Snow and Ice protocols, such as vehicles not adhering to their designated spreader route, operators overlapping spreader routes, spinning out excess material after covering their spreader route, spreading on dry roads, or applying materials in the breakdown or outside the proper travel lane for highway applications.
- Evaluate through random observations whether vehicles have properly functioning ground speed controllers.
- Evaluate and document any observed differences in the type of equipment and general operations between MassDOT equipment and hired equipment.

The first storm selected for monitoring by MassDOT occurred in January. Although the project work scope had targeted as many as ten storms to be monitored, only six monitoring events were completed in the first winter, due to a relatively mild stretch of weather that occurred in late February through March of that year. Despite the shortened season, approximately 210 hours of monitoring were completed for the four locations over the course of the six storm events, averaging about 13 hours per storm and per location.

Phase II – Task 2: Winter 2010–2011

During the second winter monitoring season, three 2-person teams were established for monitoring. To build on the results of the first monitoring season, MassDOT reduced the number of locations and focused on two primary locations maintained out of the Middleboro and Concord depots. These locations were selected because they provided nearly side-by-side spreader observations on similar road types, with one route serviced by a spreader with a closed-loop controller and the other with a controlled spreader with an open loop. This arrangement would allow a more direct comparison of the differences or effectiveness of a closed-loop controller versus an open-loop controller¹ in two separate locations. This information would help to address a separate objective of the study, which was to try and determine whether closed-loop (i.e., Cirus Controls SpreadSmartRX™) controllers were more efficient and used less salt as compared to conventional spreader units. In the first year of monitoring, similar information was attempted to be retrieved in Oxford, where one closed-loop controller was installed on a MassDOT spreader prior to the season. However, despite several inquiries to the Oxford timekeeper as well as the regional manufacturer representative (Cirus Controls, LLC), the Project Team was unable to retrieve any data from the controller.

On January 7, 2011, midway through the 2010–2011 monitoring season, a new closed-loop controller was installed on a MassDOT vehicle in Middleboro, which covers the Route 44 roadway from the Middleboro Route 28/44 rotary east to the Route 58 intersection. In Concord, one of the hired contractors was equipped with a closed-loop controller, which was matched up with a vehicle with an open-loop controller on the same route. The study objectives and selected routes were discussed with MassDOT personnel prior to the start of

¹ A closed-loop controller maintains a more consistent application rate than the more traditional open-loop controller because it has built-in mechanisms to automatically adjust the material output released from the spreader based on electronic feedback of the operations and efficiency of the mechanical components that move the material through the spreader system.

the monitoring season. In contrast to the previous season, the project teams were directed to maintain communications with district personnel throughout each event during the season to make sure the relevant data was collected.

In order to validate the reported material usage data for specific spreader trucks on each of the designated routes, the project teams were instructed to record material-loading (i.e., bucket loads) and vehicle spreader activity by following the relevant spreader truck throughout the storm. This process involved entering the maintenance depots to closely observe the MassDOT material-loading activities and closely monitor each individual application route in order to calculate application rates on a total lane-mile and per lane-mile basis for comparison to those reported by the operator or controller printout. Detailed spreadsheets were developed to record the number of buckets loaded, number of trips, total miles, and lane-miles traveled per route monitored. The loader bucket volumes and material weights used to calculate the amount of material applied were supplied by the facility timekeeper. The lane-mileage of each spreader route was determined based on the total length and pavement width using the MassDOT GIS roadway data layer included in the 2010 Roadway Inventory. The total number of lane-miles was estimated using the pavement width divided by 12 feet to approximate the numbers of lanes. The resulting number was multiplied times the length of the road to give total lane-miles. All turning lanes and shoulders were included in the calculation. An example of the “Loading and Application Rate Field Log” spreadsheet is provided in Appendix D.

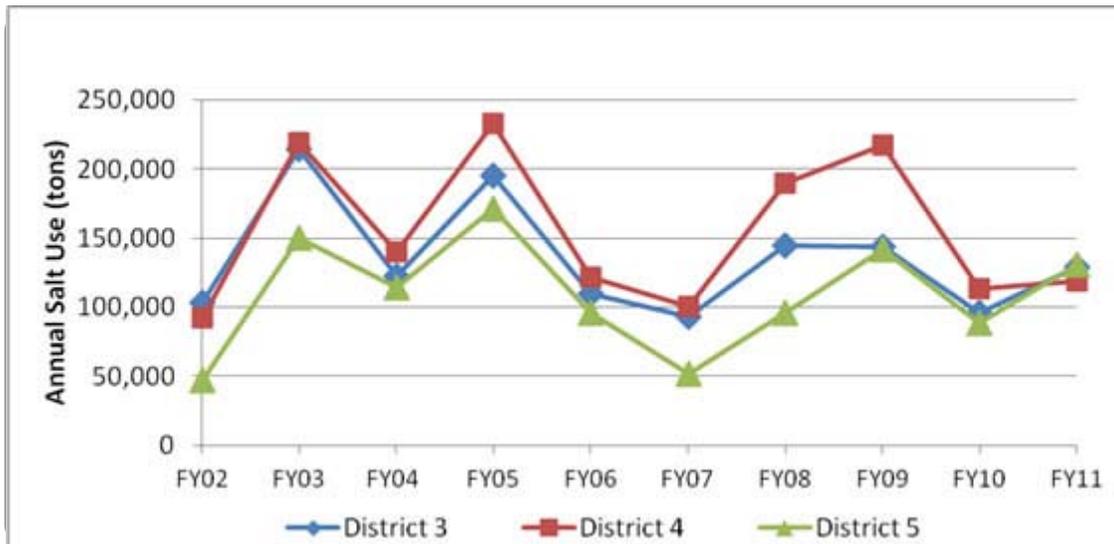
3.0 Results

3.1 Phase I – Task 1A: Data Collection

Historical Salt Usage by District

Figure 2 presents a comparison of the annual salt usage for Districts 3, 4, and 5 for fiscal years 2002 through 2011. As shown in Figure 2, prior to 2011, District 4 generally had the highest annual salt usage relative to the other two districts, and District 5 generally had the lowest annual salt usage. Depending on winter weather of each year, the annual salt usage generally ranged between 50,000 and 100,000 tons in all three districts during mild winters and from approximately 175,000 to 225,000 tons in each district during more severe winters. The difference in overall salt usage between districts is in part due to differences in the lane mileage maintained by each district. As noted earlier, up until 2010, District 4 had considerably more roadway lane-miles to maintain, and now after the district reconfiguration in 2011, District 5 has more roadway lane-miles.

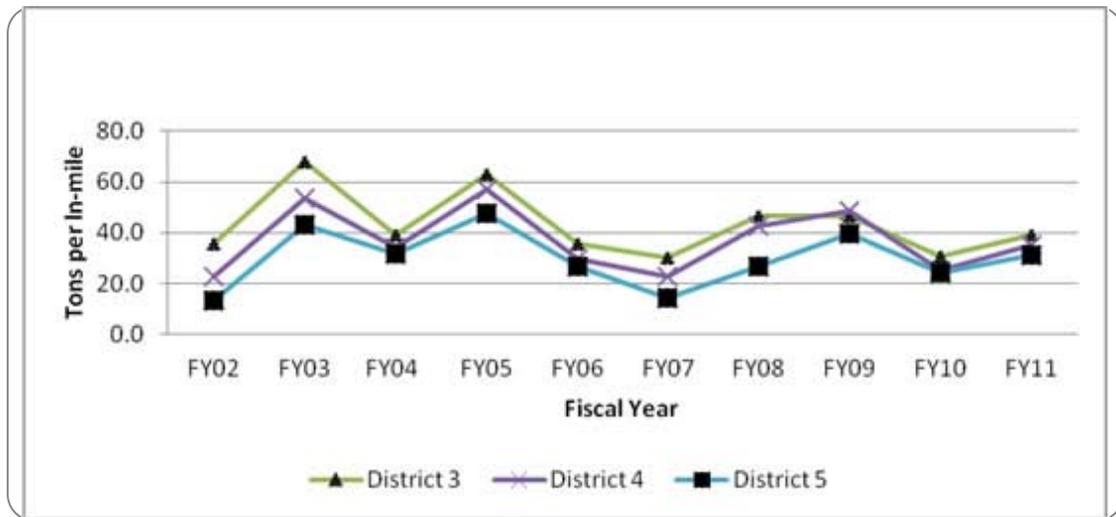
Figure 2: Comparison of salt usage for Districts 3, 4, and 5 for Fiscal Years 2002–2011



Historic Annual Salt Usage by Lane-Miles

Figure 3 presents a comparison of annual ton per lane-mile salt usage for each district. District 3 generally had the highest annual salt usage from year to year, followed by District 4 and then 5. On an average annual basis, it appears that District 3 typically applied approximately 35 to 50 tons of salt per lane-mile per year, while Districts 4 and 5 typically utilized roughly 25 to 50 tons and 20 to 40 tons of salt per lane-mile respectively. In the last two seasons studied, the variability between districts had decreased.

Figure 3: Comparison of annual salt usage on tons per lane-mile basis for Districts 3, 4, and 5 for Fiscal Years 2002–2011



Comparison of the Average Annual Statewide Salt Usage to the Winter Severity Index for Fiscal Years 2001–2011

Figure 4 presents a comparison of the annual statewide salt usage to the annual statewide WSI value averaged over each of the districts. As discussed earlier, the WSI value provides a relative measure of the winter weather severity conditions. The method for estimating WSI is believed to have been originally developed by the State of Wisconsin and more recently modified and utilized by the New Hampshire Department of Transportation. The WSI is based on the daily minimum, maximum, and average temperatures, and daily snowfall measured at selected weather stations. Daily snowfall accounts for approximately 35% of the WSI value. The figure shows that annual salt usage fluctuates very closely with changes in WSI values from year to year. As the WSI value becomes more negative, indicating more severe conditions, the annual salt usage generally increases. During some of the more severe winters such as Fiscal Year 2003 and Fiscal Year 2005, the statewide salt usage is close to 700,000 tons or more, while in the mildest winters, such as in Fiscal Year 2002 and Fiscal Year 2007, the statewide salt usage is closer to 300,000 tons.

Figure 4: Comparison of statewide salt usage (tons) to average statewide Winter Severity Index (WSI) value

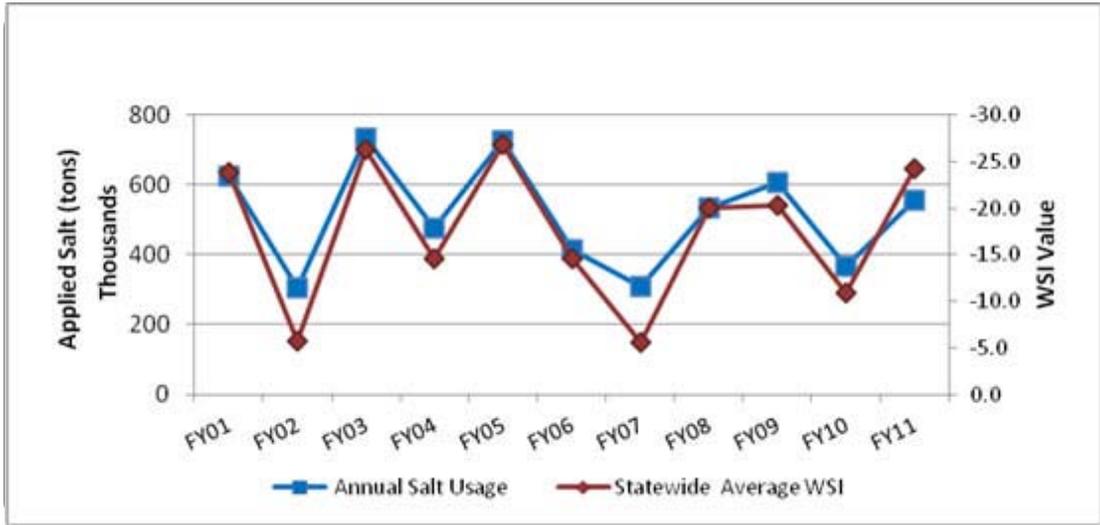
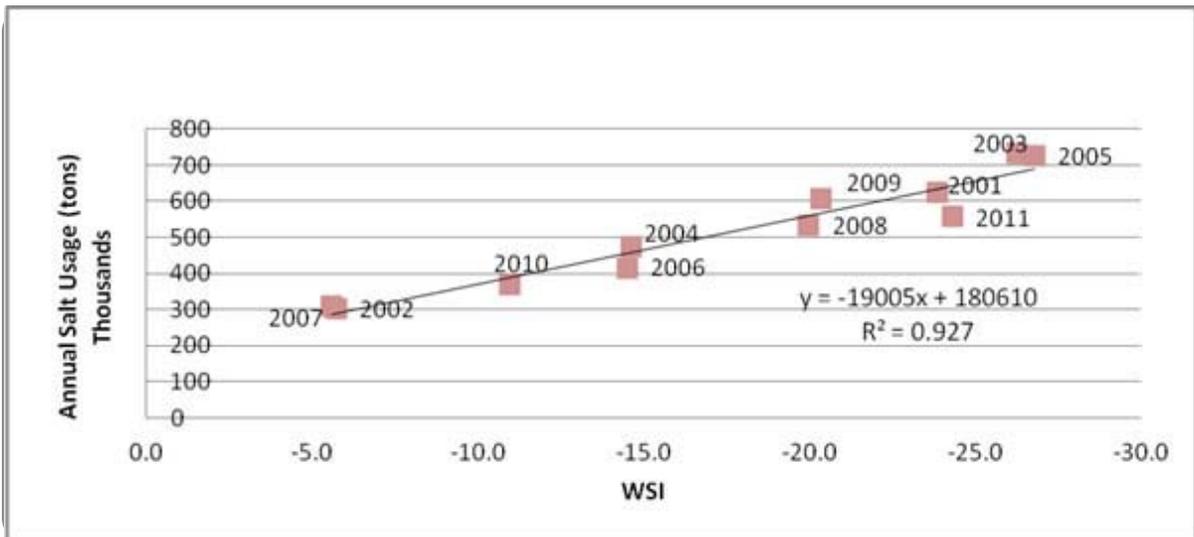


Figure 4 also shows that in Fiscal Year 2011, the statewide salt usage for the first time in the 11-year history was lower than the estimated WSI. In all other years, the salt usage was just above or very similar to the WSI value on the Y-axis. This result may suggest that the development and implementation of BMPs on a statewide basis, such as increased annual training, pre-wetting, pre-treatment, additional closed-loop controllers, etc., are having a positive effect and have increased the efficiency and effectiveness of MassDOT’s Snow and Ice operations.

Figure 5 shows a best-fit regression line with annual statewide salt usage plotted against the average annual statewide WSI for fiscal years 2001 to 2011.

Figure 5: Comparison of statewide salt usage to the statewide average monthly WSI (Fiscal Year 2001–Fiscal Year 2011)



The result of this regression analysis shows a correlation coefficient (R^2) value of 0.93, indicating a fairly strong correlation between the two variables. The strong correlation is also indicated by the paired values of salt usage and WSI for each year being very close, if not directly on the regression line. The regression equation itself can be used to predict the future annual salt usage based on the average annual WSI value. Given this ten-year baseline comparison, the regression equation can be used to compare the actual salt usage to that predicted in future years based on the WSI value to assess whether the annual salt usage is, first, in line with the winter severity conditions, and second, to assess the performance of recently implemented salt application methods by determining whether the actual salt usage is less than anticipated, given the severity of winter conditions. If the actual salt usage is lower than that predicted based on the WSI value, then this would suggest that any newly implemented equipment upgrade or enhanced application technique is more efficient (i.e., less salt used) as compared to the previous methods based on the ten-year historical relationship of annual salt usage and WSI values. This method is most useful in comparing salt use and WSI values on a statewide data basis. Recent changes in roadway lane-miles in certain districts after the district reconfiguration in 2010 resulted in some discrepancy in comparing recent annual salt usage to historical usage in some areas. These changes have less of an impact on the statewide lane-mileage and salt use and, thus, could still be used to assess the effectiveness of salt reduction and efficiency measures as well as other operational changes in the future.

An interim technical memo was produced to present the results of this comparison (“MassDOT Historical Salt Usage for Districts 3, 4 and 5 plus the use of Winter Severity Index to track Annual Salt Usage,” VHB, Inc., May 3, 2010)(see Appendix A).

3.2 Phase I – Task 1B: Survey of Snow and Ice Personnel

A voluntary online survey was conducted using the web-based service Zoomerang™ during the period of September 3 to September 17, 2009. A total of 174 MassDOT employees anonymously participated in this survey. The survey consisted of 24 questions, with 14 multiple choice and 10 requiring open-ended responses. A previously prepared Technical Memo summarizing the results of the *MassHighway Snow and Ice Employee Survey* can be found in Appendix B.

The following provides a general summary of the survey results:

- Level of Experience of Respondents:
 - 71 of the 174 respondents (41%) had 0–4 years of experience with Snow and Ice Program.
 - 29 respondents (17%) had more than 20 years of experience.
 - 61 respondents (34%) had 5–14 years of experience.

- Role/Responsibility of Respondents:
 - The majority of the respondents (61%) were either plow chasers or timekeepers.
 - 29 respondents (17%) were supervisors; 32 (18%) were depot foremen; 9 (5%) were equipment operators; and 11 (6%) were management.

- In Your Position, What Are Greatest Challenges to Performing Duties?
 - 104 respondents (61%) said motorists drive too fast.
 - 95 (56%) said not being called out early enough before an event.
 - 60 (35%) said working the long hours with little to no sleep.
 - 43 (25%) said mobilizing enough personnel and equipment.
 - 29 (17%) said working and coordinating with hired contractors.

- List in Order of Preference the Top Three Tools or Data Sources that are Relied on in Determining When Applications Are Needed:
 - Out of 100 responses, 53 respondents (53%) listed patrol observations as their number one means for determining when material applications are needed.
 - 44 respondents (44%) listed roadway or air temperatures as the primary or secondary method.
 - 18 respondents (18%) identified local weather forecast information from local television and radio reports as their primary method.
 - 15 (15%) listed pavement temperatures as their third choice or priority (Note: in the open comment section were a number of requests for additional mobile pavement temperature sensors).
 - 7 listed MassDOT's Road Weather Information System (RWIS) as one of their three methods.
 - 4 listed complaints or calls from police as one of the three methods.
 - 4 listed conversations with hired contractors as one of the three methods.
 - 3 or 4 listed instructions from supervisors or headquarters.

- Do You Think Message Signs are Useful or Could Be Useful in Modifying the Driving Behavior of the Traveling Public?
 - 139 respondents (82%) indicated that they thought message signs would be helpful in modifying driving behavior.

- What Road Conditions (e.g., slope, curve, pavement type, drainage) Present the Greatest Challenge to Maintaining Proper Road Conditions in Your Area?
 - 54 respondents (40%) said pavement type or open graded friction course overlays presented one of the biggest challenges.
 - 40 respondents (30%) said poor drainage conditions, including poor sub-base and clogged catch basins.
 - 12 respondents (9%) said steep slopes and nine (7%) said curves presented challenges.
 - 7 respondents (5%) said high traffic volumes posed their greatest challenge.

- What are the Biggest Difference(s) in the Level of Effort Needed to Maintain Reduced Salt Zones Versus Regular Spreader Routes?
 - More plowing time is needed with more frequent passes to prevent snow pack.
 - Greater application frequency is needed and perhaps more overall material needs to be applied.
 - More time patrolling roads is needed.
- In Your Experience, Do You Feel that Reduced Salt Zones are Effective in Reducing Overall Salt Use?
 - 43 (26%) responded that Reduced Salt Zones are effective in reducing the overall use of road salt as compared to a similar roadway.
 - 58 (35%) thought that RSZs are not effective.
 - 64 (39%) were not sure or did not have an RSZ in their service area.
- How Often Do You See Spreader Trucks “Spinning off” Excess Salt at the End of a Run on the Way Back to the Shed?
 - 99 respondents (58%) indicated that they seldom see trucks “spinning off” excess salt.
 - 41 respondents (24%) that they have occasionally seen it.
 - 8 (5%) said they see “spinning off” quite often and five (3%) said they often see trucks “spinning off.”
- In Your Experience, How Often Does Hired Equipment Generally Follow the MassDOT Policies and Procedures?
 - 153 respondents (89%) indicated that hired equipment often or most often follows the policies and procedures of MassDOT.
 - 18 respondents (10%) indicated that hired equipment only seldom or occasionally follows MassDOT policies and procedures.
- What are the Most Frequent Problems or Greatest Challenges in Snow and Ice Control?
 - There were 127 open-ended responses on a wide-variety of topics. The most common issues reported were that the call-outs are not early enough, and not having enough time to coordinate.
 - The fact that decisions were being made by headquarters and/or at the district level rather than by people in the field was also reported as an issue.
 - Not having enough or more up-to-date equipment was another more common issue.
- Does the MassDOT Snow and Ice Operations Manual prescribe “black and wet” as the desired pavement condition for high-volume roadways?
 - Out of 160 responses, 80 (50%) said Yes and 81 (50%) said No.
- When asked what can MassDOT do to make their job easier, the following summarizes the top three responses for each of eight major categories:

- Communications (53 responses): 29 suggested they need to be called out earlier in an event; 8 suggested they need direct communication ability with hired equipment and MassDOT personnel; 5 suggested better and more communication between management and district personnel.
- Operations (53 responses): 25 or about 50% suggested letting the Depot Foreman have more control in decision making and less micro-management from management; other suggestions included having operational meetings with state police, using state police in convoys, having more control over hired help and deciding who gets called in, having one-year contracts, pre-treating with anti-icing chemicals, and having more supervision on the roads and relying less on hired equipment.
- Policies (50 responses): 20 comments or 40% of the responses suggested that the rest break policy be changed to get rid of the two-hour mandatory break, while others suggested having more rest on the longer storm events; pay for the break time; pay for meals and more relief during longer storms; 8 comments suggested updating policies to require hired equipment to have better equipment and direct communication capabilities; have state calibrate hired equipment; limit the number of equipment from each contractor. Other suggestions include: eliminate the black and wet curb-to-curb policy; keep MassDOT personnel closer to home; keep drivers who know each other together; improve relations with DCR; reduce levels of service; and educate the public.
- Personnel (38 responses): 24 of the 38 comments suggested needing more personnel, with 3 suggesting more chasers, 2 for more timekeepers; others suggested needing more qualified personnel; requiring English-speaking hired contractors; having the ability to fire problem contractors; utilizing state personnel first; having backup people for time keeping.
- Equipment (29 responses): 9 people suggested needing laptops, Wi-Fi connections, and Nextel phones with trucks. Another 9 people said they needed more trucks; others suggested having pre-wetting equipment, GPS equipment, better maintenance of state equipment, have a loader and sander in each pit, provide a signature pad for invoices.
- Vehicles (16 responses): 12 of the 16 comments suggested needing more or better vehicles; with 3 comments related to having dedicated vehicles for plow chasers; 4 comments requested trucks in better condition, functioning properly with a working horn, and better tires; 2 comments indicated a need for 4 wheel-drive trucks; one suggested improving interior lighting; one suggested acquiring more MassDOT combos; and another suggested having Supervisors be able to take trucks home in order to have a faster response time.
- Training (4 responses): The 4 comments related to training included 2 suggesting more training should be provided; 1 suggesting sharing the results of this survey; and 1 suggesting lowering the levels of service on the roads and educating the public and police.
- Weather (4 responses): 2 comments suggested having better and/or more frequent weather report updates; 1 general comment pertained to having better

forecasting; and 1 suggested having laptops in trucks for more up-to-date weather information.

- Additional open-ended suggestions and comments were solicited by the respondents. Many of the comments and suggestions were quite detailed and poignant and can be found in Appendix B.

3.3 Phase I – Task 2: GIS Map Development

In 2010, consistent with the project RFR scope, the Project Team produced detailed GIS maps for all five districts to show the MassDOT roadway network relative to the major environmental resources included in the MASSGIS database. Separate maps were produced for each major environmentally sensitive area or resource, including locations of public water supplies and Zone II areas, Areas of Critical Environmental Concerns (ACECs), Outstanding Resource Waters (ORWs), Impaired Waters, and Priority Habitat areas. These maps were submitted to MassDOT in June 2010.

The Project Team also produced statewide GIS mapping of similar relevant environmental resource data, which were updated again in 2011 following the district reconfiguration. These were submitted to MassDOT in June 2011 (see attachment for CD containing updated maps). In addition, the Project Team developed updated GIS maps of the spreader routes in each of the selected monitoring areas (see Appendices E and G).

3.4 Phase II – Tasks 1 and 2: Winter 2009–2010 and Winter 2010–2011

Summary of Observed Operations and Reporting Practices

First Monitoring Season, 2009–2010

During the first 2009–2010 winter season, MassDOT initiated the first monitoring event call-out in January 2010. Six monitoring events were conducted between January and March. Because of a stretch of relatively mild weather, not all of the intended ten events were completed. Nonetheless, a total of approximately 210 observation hours were logged by the three teams during the six events at the four locations. The duration of monitoring events ranged from 3 to 21.5 hours, with an overall average monitoring period per event of approximately 13 hours. The largest snow event occurred on January 17, 2010, with 10–12 inches of snow recorded.

During the six events, over 400 vehicle observations were logged at the four locations. More than half of these observations were related to chute flap positions and gate openings on the spreader apparatus. Of these 400 observations, only 27 involved operations or activities that were considered inconsistent or “out of spec” with MassDOT policies and procedures and

could lead to inefficient, if not, excessive material usage. Most of these “out of spec” practices related to spreader trucks traveling at relatively high speeds, plow trucks plowing too soon after material was applied, and multiple trucks treating the same roadway due to route overlaps, especially where routes terminated in the same area or required trucks to travel through the same road section. In one case, a truck was overloaded, which led to some minor spillage, and in another case, the spreader spinner was still spinning while the truck was stopped. These observations are summarized in Appendix E.

Second Monitoring Season, 2010–2011

During the second winter season, the study approach was modified slightly to focus on specific spreader routes at the Concord and Middleboro maintenance depots. Focusing on fewer depots allowed for more intense route coverage and expanded observation and data collection roles at each of depots. Unlike the first winter, the observation crews were asked to enter the depots, consult with the depot foremen at the onset of the storm, and closely monitor and record material loading and application activity for specific spreader trucks on designated spreader routes. The designated routes were selected to enable detailed comparison of material usage between closed- and open-loop controllers as well as an evaluation as to how material was being accounted for and reported at the route and depot level. This enabled observations to be made on a variety of other operations and practices that were not necessarily observed in the first winter. A summary of observations made during the second winter season are included in Appendix F.

Over 300 hours of observation were recorded during ten winter storm events in the second monitoring season, with approximately 150 hours logged at each of the depots. Overall, the average observation time per storm event was 15 hours, but for three events, field crews monitored operations for more than 18 hours and up to 24 hours on one occasion. There were three major snow events where more than 10 inches of snow accumulation was recorded. The 2010–2011 winter was unusually severe, with numerous snow events and long stretches of below-normal temperatures. Pavement temperatures below 20° F were frequently reported by the observation crews using temperature sensors. During these cold periods, ice and snow “hard pack” was observed bonding to the pavement, despite the more frequent applications.

Similar to the first monitoring season, several operational activities were occasionally observed that were considered inconsistent or “out of spec” with MassDOT policies and procedures. These operational activities as noted over the two seasons are summarized in Table 2. The observations are not listed in any order of importance or frequency of occurrence, as they occurred at various locations and times. Each incident or activity by itself did not appear to result in a major release or overly excessive use of salt but, cumulatively across the state and perhaps over time, could lead to a more significant overuse of road salt. It is difficult to predict how often and how widespread these practices and activities may occur on a statewide basis, since the observations were made in select areas and only for a relative small segment of the overall winter season. Nonetheless, the list highlights several operational activities that could be focused on as part of future training

topics to improve the Snow and Ice Program efficiency and increase the overall material usage effectiveness.

Table 2: General observations of practices/activities that contribute to excess material usage or reporting deficiencies

Observed Practice	Location	Notes
Overlapping spreading routes	Oxford	During 2009–2010, a town truck was observed applying salt on same Route 12 being treated by MassDOT.
	Westminster	Spreaders from adjoining routes were overlapping applications along Route 2 by more than one exit.
	Lexington	Spreaders from three separate depots were applying material on same stretch of roadway between exits along Routes 128/95.
	Concord	The Route 2 section thru Route 128 interchange was often treated by spreaders from both Concord and Lexington depots as trucks passed through same area. Route 2 traffic circle was also treated by unknown vehicles passing through.
	Middleboro	Rotary at Routes 44/28 was often treated by spreaders treating different routes terminating at rotary—also, town truck observed occasionally treating Route 28 section. Route 495 ramps were also treated by overlapping trucks, or treated by private/town equipment.
Application to dry pavement	All Locations	Although infrequent, application of dry salt to dry pavement with subsequent “bounce and scatter” was observed on occasion at each observation location. A photograph of this type of event was captured outside the study area to show a typical event (see Attachment 2 of Appendix F).
Reduced Salt Zones receiving similar or more salt than regular spreader routes	Oxford/ Middleboro	Based on reported data, it appears that the amount of salt being applied in RSZ was similar if not greater than that in regular adjacent route during multiple storm events. In Oxford, reported material usage was much higher in RSZ, but the entire travel distance could not be confirmed as it was outside observation route. On several occasions, straight salt applications were required in RSZ, as hard-pack was forming on road.
Applying without liquid to pre-wet salt	Concord/ Middleboro	Most operators reported using liquids for pre-wetting, but it was often difficult to discern; During one storm in Middleboro, an operator had little to no change in liquid level in saddle tanks; in Concord, one case where pre-wetting equipment not fully functioning and one MassDOT spreader had no pre-wet equipment.
Gate openings	Concord/ Middleboro	Oftentimes, operators reported using gate openings of 3 to 4 instead of 2 to 2.5; appears inconsistent with MassDOT policy.
Application settings	Concord/ Middleboro	Similarly, operators often reported setting their controllers to an application rate of 300#, 400#, or 480#, instead of 240# per lane-mile.
Plowing Immediately After Material Application	Lexington/ Oxford/ Westminster	On several occasions during 2009–2010, plow batteries were observed plowing relatively soon after material application (e.g., < 30 minutes). This was not observed in 2010–2011, most likely due to policy change in sending out plow and spreader together in combos instead of separately.
Material applications made at relatively high truck speeds	Concord/ Lexington/ Middleboro	On several occasions, excessive bounce and scatter observed with spreaders applying at high speeds (> 40 mph).
Inaccurate or inconsistent application rate data on Cirus Controller reporting forms	Concord	The reported application rate on Cirus Controller vendor form did not match with the amount of material used divided by total miles, whereas on Component Tech controllers, the application rate matched with miles and material used. The use of applied versus total mileage did not seem to matter; see copies of report forms in Attachment 3 of Appendix F.

Observed Practice	Location	Notes
Inaccurate or inconsistent data on controller reporting forms	Middleboro	In Middleboro, it was unclear as to whether application rate was based on applied or total miles. Also, at times, different materials were reported on loader sheet versus Vendor Form. Example: Feb. 21st loader sheet for Route 28 says 17.4 tons of salt and 5.0 tons of sand/salt mix, Vendor Form says 17.3 tons of 50:50 sand/salt mix and no salt; it is unclear whether vendor form or loader sheet is rolled up into the district material usage records. These reporting discrepancies were noted on several events.
Various material conversion factors for loader information	Concord/ Middleboro	Middleboro uses a conversion rate of yards to tons of 1.15 for salt, while Concord assumes 1.0 ton per yard. Also, bucket load sizes vary considerably, depending on which loader used and amount filled.
Inconsistent reporting between loader sheet and timekeeper material usage sheet	Concord/ Middleboro	Occasionally, timekeeper info does not match with loader sheet, or timekeeper reports loads in yards per bucket and other times tons per bucket without indicating units.
Sand: salt mix appeared ineffective in RSZ at cold temps—use of straight salt	Middleboro	In Middleboro, in particular, during three to four storms, the operator switched to straight salt because the sand/salt mix was not effective with cold pavement temperatures.
Multiple consecutive applications on same route; unclear if these applications were directed by Depot Foreman	Concord/ Middleboro	During several events, spreader operators were observed performing multiple consecutive applications on same route until truck was emptied; field observers were not sure if this was standard protocol for storm pre-treatment directed by depot personnel or based on operator judgment. This observation occurred primarily during cold temperature periods, when applications were marginally preventing hard-pack conditions.
Spinning off excess material on roads on way back to shed	N/A	This practice was not observed at any of the locations during either season; spinning off of material was observed within the sheds.

During the second winter season, in addition to observing general operations, the field crews focused on verifying the material usage being recorded by the closed-loop controllers by counting every bucket of material that was loaded into the spreader truck, and recorded every vehicle lane-mile that the spreader traveled to apply material on each trip throughout the storm. As mentioned earlier, the purpose of this effort was to provide an independent means of recording the material usage by closed-loop controllers and to compare that being reported by the operators or closed-loop controller printouts.

Inconsistencies in the material usage quantities were often noted in terms of the amount of material that was observed by the field observers and the amount of material reported to have been used based on post-storm reports provided by the operators of the same truck. For some events, the observed data and the reported data for the same truck were fairly close, but for other events, there were considerable differences (e.g., 80% to 100% difference) between the two sources of information. The field observers relied on counting loader buckets of material being loaded into the truck and tracking the number of trips and lane-mileage for each application, while the operators submitted post-storm material usage and vehicle miles data based on the controller readout, which was typically handwritten on the MassDOT Vendor Closed-Loop Report Summary. As discussed in more detail below, there were a number of factors and possible sources of error that could contribute to these inconsistencies.

As mentioned earlier, the observed material usage data is based on the number of bucket loads of material that were loaded into the spreader and the number of lane-miles treated for each application that was observed for the same spreader truck using a closed-loop controller. The field crews were on hand at the beginning and end of nearly every event to record buckets of material being loaded and vehicle miles traveled for each application. The lane-miles for each route were based on GIS roadway data and were consistent with odometer readings.

Some of this discrepancy could be in part due to the potential errors that are inherent to counting bucket loads and the rounding that may occur with volume and material weight calculations when converting bucket loads to material weight. The bucket volume (e.g., 3.0 cubic yards in Concord versus 2.6 cubic yards in Middleboro) and material weight information was supplied by the depot timekeeper at the beginning of the season. The volume of each bucket load was multiplied by the estimated weight of material to determine the number of tons of material applied. The detailed calculations associated with converting bucket loads to weight of material applied, along with the observed data details including the number of lane-miles per application, are summarized in the summary.

Another possible source of error relates to whether or not each bucket consisted of a full or partial bucket load. Observers were instructed to note whether the buckets appeared to be full (i.e., “heaping”) or partially full. In the end, this appeared to be of little consequence, since most of the buckets appeared as full buckets, especially for the mid-storm loading, when multiple applications were being done and trucks were returning to be filled. For most storm events, there were less than ten loader buckets of material that were loaded into the observed spreaders over the course of the storm. Observers were limited in their ability to visually determine if there was any residual material left in the truck after the storm. However, observers were typically on hand for the entire storm duration, with the exception of one or two events, such that they would see if the operators “spun-off” any excess material at the end of the storm. Again, since a large majority of the observed applications occurred during the storm when trucks returned empty or nearly empty only to be filled again, this is considered to be a very minor potential source of error in the material load calculations. In fact, the potential combined effect of these possible sources of error associated with the observed loader bucket counts and result calculations is not likely to fully explain the relatively large discrepancies between the observed material usage data and that recorded by the closed-loop controllers or operators.

The amount and type of data reported on the Vendor Closed Loop Ground Speed Report Summary submitted by the operators were also very inconsistent from event to event for the same spreader route. Following several events, it was difficult to determine how the reported application rate was derived, since it did not correspond to either the total amount of material applied or the number of miles traveled. In other words, dividing the reported total tons of material applied by either the total miles or even the applied miles did not result in the same application rate that was listed on the usage sheets (see Appendix F). For some events, the numbers did correspond, but the method varied, as sometimes the reported application rate was based on the total miles and other times it was based on applied miles. Use of applied miles was considered the most appropriate method for deriving application rate. For those

events where total miles were used, the reported application rate was lower than would have otherwise been reported if applied miles were used. It is unclear why the basis for application rate was derived differently from one event to the next. For several events, the application rate did not correspond to the total miles or applied miles, even though it was the same truck and operator for most events. These inconsistencies were observed both in Concord and Middleboro and raise some questions about the validity and accuracy of the reported data.

In any event, the observed findings suggest that the Vendor Closed Loop Ground Speed Report Summary forms should be revised and updated to require additional data to be reported, such as number of applications, odometer readings, and number of lanes treated, to allow greater verification of the reported application and mileage information. The installation of wireless data transfer stations at each depot would also help to minimize the data transcription errors or errors related to missing data. These stations could also provide near real-time access to data during storm events. It may also be beneficial to perform detailed field calibration procedures for the various types of spreader controllers currently being used, to ensure that material output is consistent with the various controller settings.

In Concord, observations indicated that the operator was setting the controller to 480 lbs/ lane-mile, suggesting that he was treating both lanes at 240 lbs/ lane-mile, even though there were two spreader trucks that were treating one of the two west- and east-bound lanes of Route 2. These spreaders often operated either side by side or traveled in same direction treating the same lanes within 15 minutes of each other, such that there was essentially one spreader for each travel lane.

During a training session on January 4, the Cirus Controls, LLC representative stated that application rates would be affected by both the application setting and the spinner rate, such that if the application rate was set at 240 lbs/ lane-mile and the spinner rate was set at 2, the resulting output on display would be 480 lbs/ lane-mile (see Attachment 3 to the October 14, 2011, Technical Memo, Appendix F). The operator in Concord with the closed-loop controller was reported to have set application rate at 480 lbs/ lane-mile, but it is unclear what spinner rate was used. The Cirus Controls, LLC representative also said that the Middleboro controller was set to be "locked in" at 240 lbs/ lane-mile, and only the spinner could be adjusted. This may explain why the Middleboro data appeared to be closer to the target 240 lbs/ lane-mile for most events. However, the reported application rate in Middleboro was based on total miles rather than applied miles.

With respect to liquid material usage, in general, it appeared most operators were using liquids for pre-wetting purposes at reported rates of 2 to 10 gallons per ton, and more often in the range of 6 to 8 gallons per ton. On several occasions, liquid usage was not reported on the vendor material usage sheets. On one occasion in Middleboro, it was noted the hired contractor appeared to be not using his pre-wetting equipment, but it was difficult to definitively verify. There was, however, no noticeable change in the fluid level in the saddle tanks throughout the 12+ hours of monitoring, and no tank filling was observed. In Concord, it was reported that one MassDOT spreader was not equipped to pre-wet equipment, and one vendor reported having problems with the dispensing pump.

With regard to Reduced Salt Zones, it was apparent during several snow storms, especially in Middleboro, that the 50:50 sand/salt mix had limited effectiveness in preventing hard-pack from forming on the road surface during cold temperatures (18–22° F) in January 2011. On several occasions, the operators switched to straight salt mid-storm and appeared to be using nearly as much or even more salt than on the regular routes. The reported material usage for the RSZ route in Oxford in the first winter also suggested that more salt may have been used in the RSZ route. However, the length of the overall route was not confirmed, such that the application rate could not be verified. In Concord, the operators relied on a 50:50 mix of premix and sand and on several occasions needed to rely on straight pre-mix applications. On one occasion, straight salt was used. The material usage policies for Reduced Salt Zones, in terms of types of materials and their potential effectiveness at cold temperatures, should be revisited. Specifically, the use of sand appears to offer minimal, if any, benefit in maintaining reasonably safe road surfaces, particularly at cold temperatures, and may even result in greater salt usage, as more frequent applications are made to “catch up” once hard-pack begins to form on the road.

4.0 Discussion

Overall, the information and observations compiled over the two winter seasons by the field crews suggest that the MassDOT snow and ice control activities were generally done in a systematic manner in the areas monitored and were consistent with the overall Snow and Ice Program policies and procedures, with a few exceptions as noted herein. Potential areas of improvement were noted with various recommendations provided in the next section. Material usage reporting data and route optimization represent two notable areas in need of improvement. As discussed below, route optimization and communication between depots have the potential to result in substantial cost savings both in reduced material and fuel usage. Increased use of liquid materials especially for pretreatment applications was also an area that deserves some attention. In selected study areas, there appeared to be very few, if any, pretreatment applications. The winter operational monitoring also revealed that the use of the 50:50 salt/sand mixture used in Reduced Salt Zone areas was not very effective in preventing snow and ice from bonding to the pavement during very cold temperatures. During some events, it may even resulted in greater salt usage as compared to a conventionally treated roadway because it appeared that Depot personnel had to apply more frequent straight salt applications once the bonding or “hard-pack” began to form to prevent further ice bond formation. During the periods of cold pavement temperatures and moderate to high snowfall intensities (especially during the second winter events), it was generally observed that an “all hands on deck” approach was needed and reliance on good professional judgment from everyone involved was required to keep the roads reasonably safe.

Overlapping routes or situations where more than one truck would travel through and apply materials to the same roadway segment was observed in several locations and is likely to lead to an over-application of materials. In most cases, the roadway segments that received multiple applications from different trucks were relatively small and usually less than 0.5 mile but in some cases such as in Westminster as much as 1.0 mile of roadway was observed being “treated” by multiple spreaders due to overlapping adjacent routes. The route overlap extended beyond one interchange on an east-west route. According to the MassDOT Director of the Snow and Ice Control Program, there are more than 700 spreader routes throughout the state. Each of these routes could have some potential overlap with adjacent routes, such that there could be tens if not hundreds of roadway miles that could be receiving multiple applications during each storm event. For discussion purposes, if we assume that approximately 10% of the roughly 16,000 lane-miles currently maintained by MassDOT are part of a route overlap and each overlapping spreader applies to these roadway segments, then approximately 1,600 lane-miles are receiving excess deicing materials. Using a seasonal application rate of roughly 20-30 tons/lane-mile, these overlaps could potentially translate to an extra 32,000 to 48,000 tons of salt used unnecessarily due to route overlaps. This is likely to be a conservative estimate of the amount of overlapping routes statewide. At an approximate cost of \$50 per ton for salt, potentially reducing 40,000 tons of salt usage by avoiding route overlaps could result in \$2 million of savings in annual material costs. MassDOT should consider the use of route optimization to software to evaluate the current

spreader routes to minimize overlaps or at the very least have adjacent depots coordinate to determine which spreader will be responsible for overlapping road segments and which spreaders should turn off their units as they pass through these sections.

On a related issue, the route overlaps also appear to be created by certain spreaders being designated to treat ramps only while other spreaders are designated to treat the mainline. For certain interchanges, it appeared that the two spreaders were treating the same interchange roadway miles. Perhaps route optimization and increased communications and equipment coordination may be helpful between adjacent depots and especially those that exist along district boundaries may be in order to help avoid and reduce the number of spreaders and route overlaps associated with ramps and roadways.

With respect to comparing the performance of closed-loop versus open-loop controllers, field observers did note that the material applications behind closed-loop controller-equipped spreaders visually appeared more uniform and well distributed across the pavement surface. The reported material usage data for the closed-loop controllers was often much less and as much as 50% less than that used with open-loop controllers. However, as discussed above, the observed material usage and mileage data recorded by field crews very rarely matched what was reported on the vendor forms for the exact same truck. In most instances, the estimated application rate based on the bucket loads loaded into the truck and the lane-miles traveled was much higher than that reported on vendor form. In Concord, in particular, the reported application rate on the vendor forms for the closed-loop controller did not match well with the overall material usage and miles traveled. The source of this error is unknown.

The inconsistencies and discrepancies on the loader sheets and vendor reporting forms as discussed earlier in the previous section need to be evaluated. On several events, there were differences in the type of materials and quantities reported on the loader sheet versus that reported on Vendor forms. In addition, the reported quantities on the timekeeper material usage sheets also varied at times from yards, buckets and tons per load, which can be confusing and/or lead to inaccurate reports. Given that there are at least three different sources of usage data from various personnel including the loader operator, the timekeeper and the spreader operator, there is considerable potential for errors and discrepancies due to issues with the timing of observation and recording, interpretation, transcription errors and overall reliance on memory and judgment. Again, it is unclear as to which source of data is used in the annual reporting or developing storm event summaries and whether these discrepancies have any impact on the end of year or event summaries. Perhaps at the very least, the reporting procedures could be a topic of discussion during the training sessions, if they are not already.

Recommendations geared towards improving operations and increasing the efficiency and effectiveness of material used are provided in the next section. These recommendations generally fall into five (5) categories including reporting procedures, personnel training, calibration, route optimization and material usage/equipment upgrades. An implementation plan was developed to outline a proposed timeline for implementation for each of the recommendations based on anticipated priorities, level of effort required to implement and the potential capital costs required to implement. The less costly and least complicated

recommendations were generally considered that they could be implemented in the next 6 to 12 months while the more complicated and perhaps more costly recommendations were targeted for a 3 to 5 year implementation schedule.

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5.0 Recommendations

The following recommendations are based primarily on the observations from two winter seasons and are geared toward improving the efficiency and effectiveness of the MassDOT Snow and Ice Control Program. The recommendations generally fall into five major categories, including material usage reporting, personnel training, improved calibration/equipment settings, equipment enhancements, and route optimization/coordination. It is important to note that the suggestions and recommendations that were provided by MassDOT employees as part of the earlier survey are not included in the list below, as they represent opinions and information held by others and were not based on the observations or data collected by the project team. These other suggestions should be reviewed as part of the survey results that were previously presented, and perhaps incorporated into the implementation plan.

5.1 Recommendations on Material Usage Reporting

- Install wireless data transfer stations in each depot to allow data transfer from closed-loop controllers after each event. Wireless data transfer stations would, most importantly, allow direct access to material usage data but would also minimize human reporting and transcription errors that occur when reporting data from controller readouts. This would also reduce the time involved with compiling and inputting data.
- MassDOT should transition to greater use of AVL/GPS-equipped spreader units to electronically record where and when applications are made and the amount of material used. The use of ESRI ARcINFO software or other proprietary software to compile and display material usage data should be considered. The use of GIS software and equipment tracking would greatly benefit the route optimization process.
- MassDOT Vendor Closed-Loop Ground Speed Control Report Form:
 - Consider requiring that pre-storm and post-storm odometer or controller mileage readings be provided to insure pre-storm mileage is zeroed-out and add space to record number of trips, mileage per trip, etc.
 - Add space on form to report controller application rate setting, e.g., target application rate, number of lane-miles, spinner setting, etc.
 - Drivers should also report their spreader route, number of applications, number of miles driven, and amount of material used (including pre- and post-storm liquid tank levels).
- Loader bucket sizes and weights for various materials should be standardized, as there seems to be differences in the factors used at different depots. Having variable-sized loaders at same depots also adds potential error to material usage.

5.2 Recommendations on Personnel Training

- Consider implementation of a Certification Training Program for MassDOT and hired contractors using recently developed online training modules.
- Incorporate a training segment on reporting protocols in annual training to improve consistency in units and data.
- Add at least one training session at each depot with closed-loop controller representatives for both hired contractors and depot personnel; perhaps break out in smaller groups to get more hands-on training and rotate to various stations, focusing on certain key issues.
- Reiterate the importance of compliance with MassDOT policies and procedures (e.g., proper truck speeds, pre-wetting, etc.) and possible disciplinary actions for non-compliance. Perhaps revisit disciplinary policy for hired contractors to develop a tiered policy imposing greater disciplinary action or demerits for more egregious actions (e.g., applications of dry salt to dry pavement).
- Consider annual training/coordination sessions with state police and other emergency personnel to discuss roadway conditions, communications, sign messaging, and vehicle speed control methods during winter storm events.

5.3 Recommendations on Calibration

- Review policy for setting controller settings with depot personnel for routes using multiple spreaders covering same lane-mileage. Material output should be set for 240 lbs/lane-mile when multiple trucks are treating multiple lanes on same roadway.
- Develop a pilot program to conduct actual field calibration/testing at depots where known quantities of material are loaded into spreader units and the amount and rate of material released are then measured as the spreader is operated at various controllers and gate settings to verify material output at each setting; consider using different materials as well.
- Coordinate and conduct periodic random audits of third-party contractors that are used by vendors to certify equipment calibration.
- Roll out statewide field calibration program to conduct field calibration on certain percentage of state and hired equipment spreader units in each district on a rotating basis.

5.4 Recommendations on Route Optimization/Coordination

- Coordinate with district personnel to evaluate spreader routes, and identify ways to reduce route overlaps; designate who is responsible for treatment when overlaps cannot be avoided, and optimize the treatment of ramps versus mainline roadway.

- As part of the route evaluation, identify opportunities to utilize the most efficient equipment (e.g., closed-loop controllers, pretreatment, advanced plow blades, etc.) and the best operators in known environmentally sensitive areas.
- Research and consider the use of Route Optimization software to revise spreader routes, starting with a pilot program in a selected area. Route optimization would likely result in significant cost savings in reduced material usage and reduced fuel costs.

5.5 Recommendations on Equipment/Material Usage

- Develop a statewide database that provides an inventory of equipment availability and capabilities for each depot and route, with respect to spreader controller type, pre-wetting equipment, plows, and direct pre-storm liquid applications.
- Increase use of pavement temperature and weather data for decision making and material selection/application rate.
- Enhance/develop process for reporting when and where pre-treatment applications are performed. In addition, develop process for recording pre-wetting liquid levels before and after storms for providing total quantities used.
- Reduce and/or eliminate the use of sand in Reduced Salt Zones through other sand:salt ratios and/or use of other materials or more advanced equipment.
- Evaluate use of newer technology and equipment BMPs to control overall material usage in lieu of designated RSZ, which may be causing overall increases in salt use.
- Review and re-evaluate whether the prescribed pre-wetting liquid application rates should be increased to a range of 8 to 12 gallons per ton or more.
- Initiate a pilot program to integrate the use of GPS/GIS software to program spreader controllers through the use of geo-fencing where spreaders are to automatically shut off or adjust applications in selected areas such as overlapping routes.

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6.0 Appendices

6.1 Appendix A

MassDOT Historical Salt Usage for Districts 3, 4, and 5, plus the use of Winter Severity Index to track Annual Salt Usage, VHB, Inc., May 3, 2010



Memorandum

To: Paul Brown, MassDOT
David Blodgett, MassDOT
Patrick McMahon, MassDOT

Date: May 3, 2010

Cc; Dave Niemeyer, Geosphere

Project No.: 52011.00

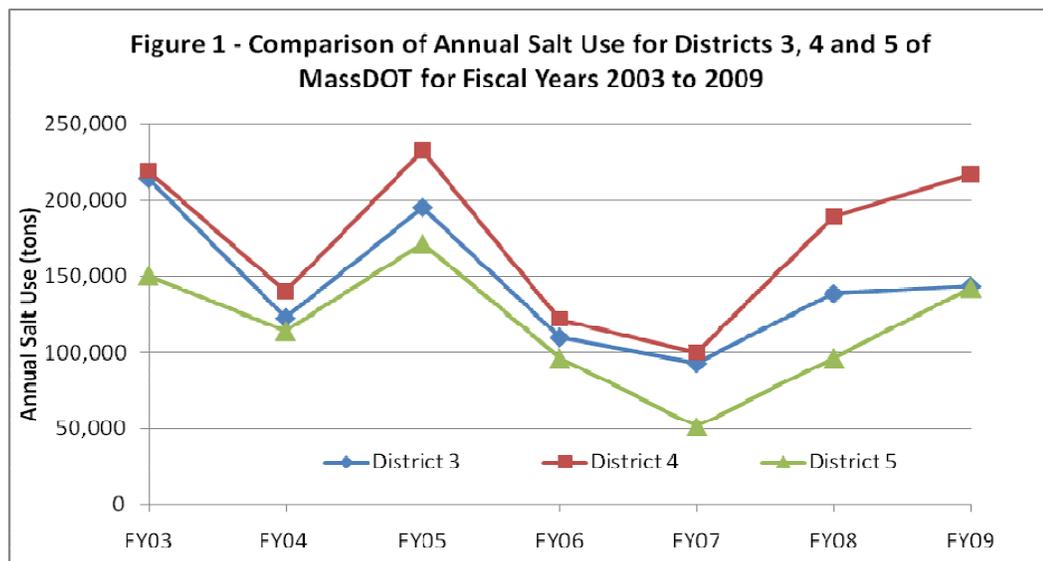
From: Bill Arcieri

Re: MassDOT Historical Salt Usage for
Districts 3, 4 and 5 plus the use of Winter
Severity Index to track Annual Salt Usage

The following provides a summary of the historical salt usage each year within Districts 3, 4 and 5 for the last seven years starting in FY 2003 through FY 2009, consistent with the study RFR and project proposal.

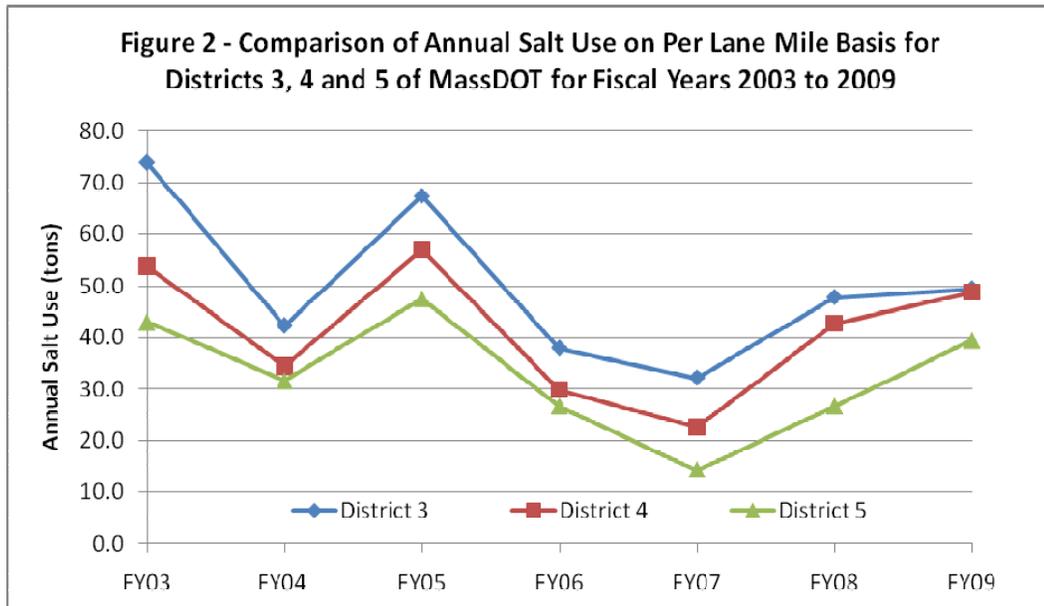
1.0 Historical Salt Usage by District

Figure 1 below presents the overall annual salt usage by district between fiscal years 2003 and 2009. District 4 consistently had the highest annual salt usage relative to the other two districts and District 5 consistently had the least amount of annual salt usage. The annual salt usage in District 4 generally ranged between 100,000 and 230,000 tons per year whereas in District 5, the annual salt usage ranged from 50,000 and 170,000 tons per year and the usage for District 3 was consistently somewhere in between the two districts. District 4 also has the most roadway lane miles to maintain which explains the higher salt usage. The difference in overall salt usage between districts is in part due to differences in the lane mileage maintained by each district. District 4 also has the greatest number of roadway lane miles. A more meaningful means of comparing salt usage is on a per lane mile basis.



2.0 Historical Annual Salt Use by Lane-Miles

Figure 2 presents the annual salt usage for each district expressed in tons of salt used per lane mile. On a per lane-mile basis, District 3 had the highest annual salt usage from year to year followed by Districts 4 and then 5. The higher per lane mile usage for District 3 is most likely due to a greater number of snow events and colder temperatures in the higher elevations in the hills around the Worcester area requiring a greater number of applications relative to the other two districts. On an average annual basis, it appears that District 3 typically applies approximately 35 to 65 tons of salt per year per lane mile. While District 5 typically utilizes roughly 20 to 40 tons of salt per lane mile and District 4 utilizes roughly 25 to 50 tons of salt per lane mile.



3.0 Comparison of Average Annual Salt Usage on per lane Mile Basis from Fiscal Years 1993-2002 and from Fiscal Years 2003-2009

Table 1.0 below provides a comparison of the average annual salt usage on a per lane mile basis between FY 2003 to 2009 and the previous 10 years including FY 1993 to 2002. Based on this comparison, the average annual usage for the last seven years appears to be considerably higher than the annual average for the previous ten years. This increase may in part be due the fact that the total lane mileage maintained in each district has increased but has not been updated in recent years. The increase may also due to an increase the severity of the winters within the last seven years as compared to the previous ten years between 1993 and 2002 (See analyses on WSI below). It may also due in part to a greater reliance on road salt and an increase in the number of applications to maintain safe roads given higher expectations of the traveling public and increased traffic volumes. From both an environmental and financial perspective, this trend of increased annual salt usage is not likely to be sustainable. It will be important to reverse this trend though additional measures to increase efficiency and effectiveness of road salt.

Table 1.0 – Comparison of Long-term Average Annual Salt Usage from Fiscal Years 1993-2002 and FY 2003-2009

District	FY 1993 to 2002		FY 2003-09		% Diff in Salt Usage
	Ln-miles	Salt Usage tons/ln-mi	Ln-miles	Salt Usage tons/ln-mi	
Three	2905*	29	2905*	50	72%
Four	4082	24	4,457	41	71%
Five	3506	21	3,612	33	55%

Notes: * no recent data was available on lane mileage for District 3

3.0 Comparison of Annual Salt Usage vs. Weather Severity Index in District 4

Figure 3 shows a comparison of the annual salt usage in District 4 from 1995 to 2009 to the computed Weather Severity Index (WSI) based on weather data recorded at the Hanscom Airport. Between the years 1995 and 2000, the two variables do not appear to be closely correlated but after 2000 the annual salt usage appears to track closely to the estimated WSI.

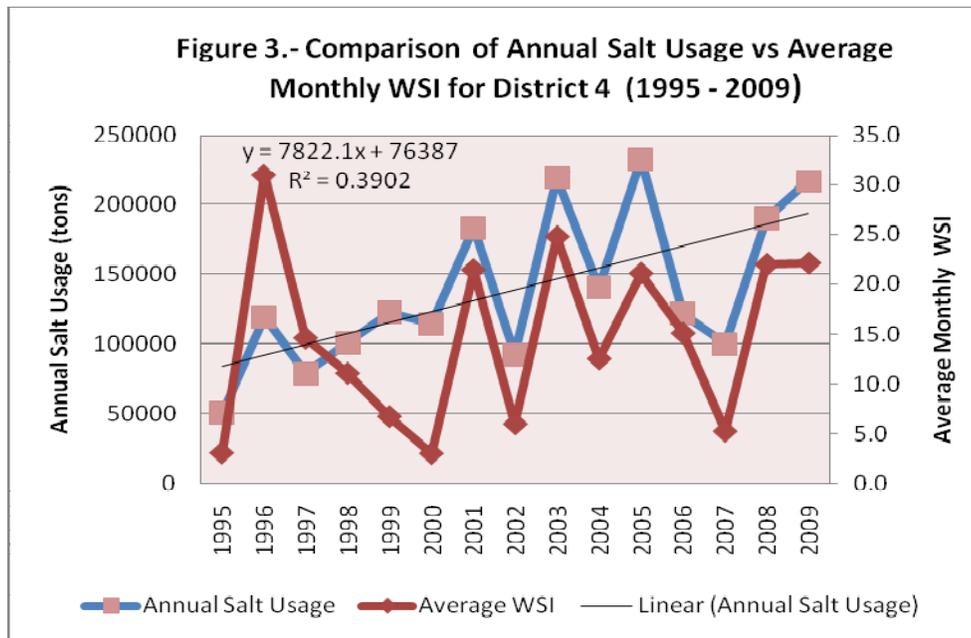
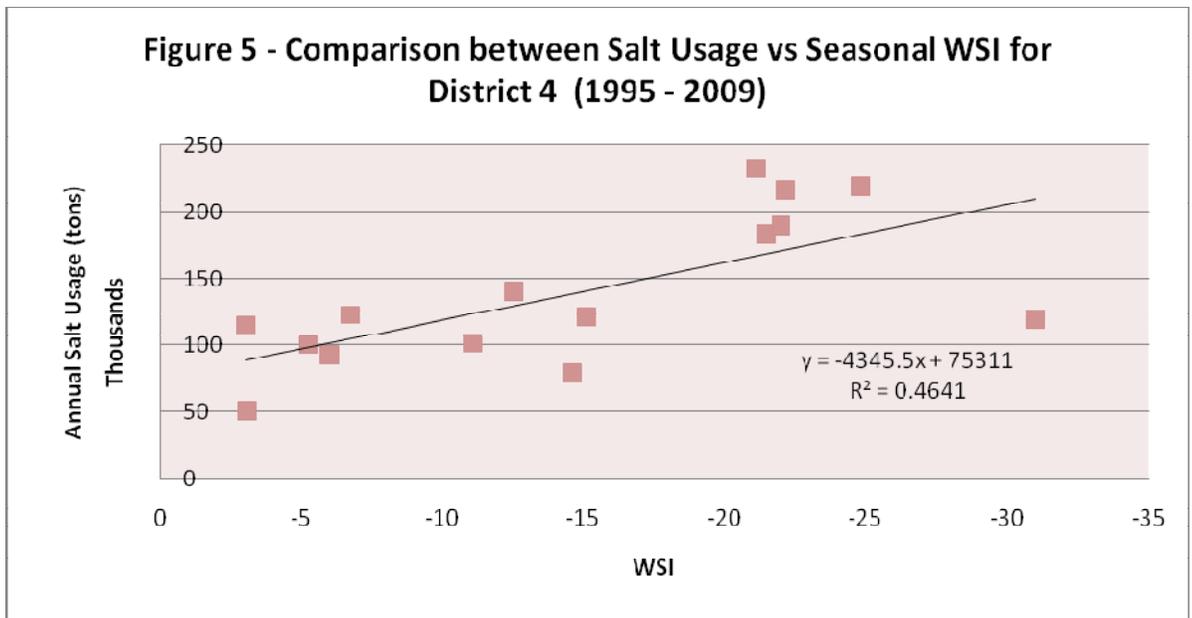
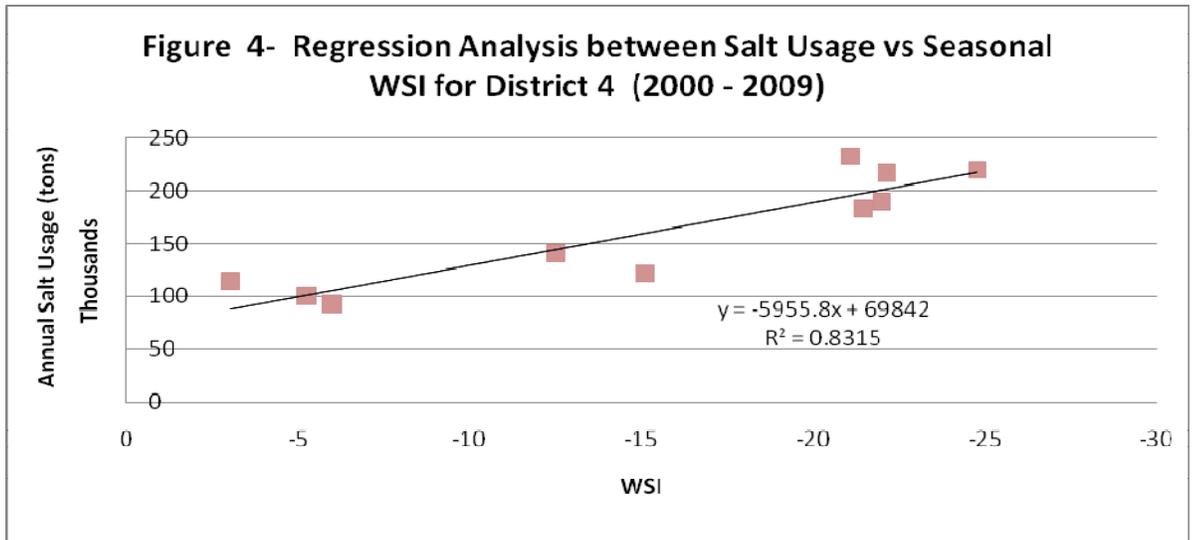


Figure 4 below shows the annual salt usage plotted against the WSI for the years 2000 through 2009, and the linear regression equation and correlation coefficient (R^2) value of 0.83 indicating fairly strong correlation between the two variables. Figure 5 shows the results of the same analysis but with the extended time period between 1995 and 2009. The correlation coefficient values (R^2) is much lower at 0.46 indicating a weaker correlation between the two variables and reaffirms that prior to the year 2000 the annual salt use did not track well with the WSI. These results indicate going forward that the use of the WSI could be a useful tool for tracking the year to year variability in annual salt usage. It could also be used to measure the effectiveness of reducing salt usage in the future as more and newer efficiency practices are implemented.



6.2 Appendix B

Results of MassHighway Snow and Ice Employee Survey, VHB, Inc., October 8, 2009



Vanasse Hangen Brustlin, Inc.

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Memorandum

To: Paul Brown
David White
Catherine Brown

Date: October 8, 2009

Cc; Dave Niemeyer, GEOSPHERE

Project No.: 52011.00

From: Bill Arcieri

Re: Results of the MassHighway Snow and
Ice Employee Survey

The following summarizes the results of the MassHighway employee online survey regarding the Snow and Ice Control Program. The primary goals of the survey included the following:

- 1) To identify the biggest limitations and difficulties that snow and ice personnel face in performing their jobs;
- 2) To identify ways to improve operations and make the job duties for snow and ice control personnel easier;
- 3) To identify ways to improve the efficiency of salt use and eliminate or change practices that use road salt less efficiently.

The survey was conducted online using the Zoomerang™ web based service during the period of Sept. 3rd to 17th, 2009. A total of 174 employees participated on a voluntary basis. The survey consisted of 24 questions with 14 multiple choice questions and 10 questions that involved open-ended responses. The following provides a detailed summary of the various responses for each question:

Q1: How long have you worked in MassHighway's Snow & Ice Control Program?

Response: 41% of the responders had 0-4 years of experience with S & I Program; 17% had more than 20 years of experience; 34% had between 5 and 14 years of experience.

Q2: For snow and ice control operations, what are your primary duties?

Response: There were 211 responses, so some respondents selected more than one duty:

- The majority or roughly 61% were either plow chasers or time keepers,
- There were 29 supervisors representing 17% of the total,
- There were 32 depot foremen representing 18% of the total,
- There were only 9 (5%) equipment operators,
- There were 11 (6%) listed as management.

Q3: In your position, what are the greatest challenges or difficulties in performing your duties?
(Select or add top 3 challenges).

Response: Top 3 choices: 1) Motorists driving too fast; 61%
2) Not being called out early enough before an event; 56%*
3) Working the long hours with little to no sleep; 35%.*

* the issues of not being called out early enough and the long hours and rest periods were

common themes in the open-ended comments and responses in the later Questions 20 & 22.

The remaining results for Question 3 include:

4th place: mobilizing enough personnel & equipment; 25%

5th place: coordinating with the privatized force; 17%

6th place: keeping track of hired equipment; 13%

7th place: knowing when to apply materials; 8%

There were also 25 open-ended comments provided:

5 comments related to not having enough personnel or adequate equipment;

7 comments related to management and the decision-making process; some commented on there being too much micro-managing or decisions being made from the office not the field, one comment referred to a hostile working environment being an issue;

4 comments were critical of the 2-hour break policy and suggested it was not needed or they should be paid for the mandatory break time;

3 comments were related to communications and the difficulties of deciding when to call in equipment given forecast info, not being called out early enough, or calling hired help all at once.

Q4: What tools are available to you in determining when deicing applications are needed?
(check all those that apply)

Response: Listed in Order of Preference:

- 1) Patrol Road Observations; 68%
- 2) Local weather forecast info from local TV or radio; 49%
- 3) Mobile Pavement Temperature Sensors; 48%
- 4) RWIS Data; 40%
- 5) Weather forecast from Contracted Weather Service; 35%
- 6) Special Internet Weather Web sites – please specify; 15%

Summary: Field observations and pavement temperature sensors appear to be the primary tools along with mobile temperature sensors. There were a number of requests for additional mobile pavement temperature sensors in the responses to Q6 below. Local TV and radio sources seem to be used much more than the contracted weather service - RWIS appears to be useful but not a dominant resource for weather information. Other sources or web sites mentioned include NOAA web site, IntelliCast, Doppler Radar, weather underground, weather channel, etc.

Q5: Please specify what are the top three tools or methods that you rely on to decide when deicing applications are needed (please list in order of effectiveness, leave blank if not part of your job duties).

Response: There were 100 responses:

- 53 responders listed road or patrol observations was the No. 1 method or tool for deciding when applications were needed;
- 44 listed roadway or air temperatures as the primary or secondary method;
- 18 responders listed weather forecast or current weather conditions as the primary method for deciding on application timing;
- 15 listed pavement temps as the 3rd choice for deciding on applications;
- 12 listed time of day or traffic volume as a 2nd or 3rd factor;
- 7 listed RWIS data as one of the three choices;
- 4 listed complaints or police calls as one of the 3 methods;
- 4 listed conversations with hired contractors as one of the 3 methods;
- 3 or 4 listed instructions from supervisors or headquarters.

Q6: What equipment or tools would you like to have to improve your decision making process?
Please describe: (Leave blank if not sure or not part of your job duties).

Response: There were 51 responses.

- 13 respondents listed having more or better mobile pavement temperature sensors;

- Some elaborated needing temperature sensors for plows or spreaders and hired equipment;
- 5 listed having laptops in the trucks would be helpful to monitor weather/ RWIS;
- Other equipment requests included having Nextel DC capability with equipment, closed loop controllers for spreaders, a web cam and a scanner to monitor police and MassHighway communications;
- 4 listed having more or better trucks and perhaps the ability to take pickup truck home during winter events;
- 6 listed needing better weather forecast information or sources;
- On the Operations side, four suggested letting the foreman make the decisions (this is repeated in response to Question 22);
- Others suggested more training for patrollers and hired personnel.

Q7: How often do local and state police or other emergency personnel influence your application timing and protocols?

Response: There were 172 responses with 28 or 16% stating not sure or was not part of job duties.

- 86 respondents or approx. 50 % said either Very seldom or only Occasionally - this represents 60% of the respondents who felt it was part of their job duties;
- 58 respondents or approx. 34% said Often (>5 times per season) or Nearly Every Event - this represents 40% of the respondents who felt it was part of their job duties;
- 26 respondents or approx. 18% indicated that local or state police influence their application timing and protocols on Nearly Every Event.

Q8: Do you think Message Signs are useful or could be useful in modifying the driving behavior of the traveling public?

Response: 82% or 139 respondents said yes – they thought message signs would be helpful in modifying driving behavior;
18% or 31 respondents said no.

Q9: What road conditions (i.e. slope, curve, pavement type, drainage) present the greatest challenge to maintaining proper road conditions in your specific area?

Response: Open-ended question with 133 responses.

- 54 respondents said pavement type or open graded friction course overlays presented one of the biggest challenges;
- 40 respondents said poor drainage conditions including poor sub-base, clogged catch basins were the biggest challenges;
- 12 respondents said steep slopes;
- 9 respondents said curves presented challenges;
- 7 respondents said high traffic volumes;
- 7 respondents said poor pavement conditions due to pot holes, wheel ruts, etc.;
- 6 respondents said shaded areas with poor sunlight;
- 1 or 2 said low salt areas were the biggest challenge.

Q10: If you have a Reduced Salt Zone in your area, in your experience, what do you see as the biggest difference in the level of effort needed to maintain a Reduced Salt Zone vs. a typical roadway? (Leave blank if not sure)

Response: Open-ended question with 66 responses.

- 21 respondents said more plowing time was needed with more frequent passes to prevent snow pack, which requires more labor time and equipment and one mentioned more post-storm clean-up or need for heavier plows;
- 14 respondents indicated that a greater application frequency was needed and perhaps more overall material needed to be applied - some suggested pre-mix and

sand was less effective (although at least one said pre-mix was more effective – see below);

- 12 respondents said that more time patrolling roads was biggest difference;
- 5 respondents indicated that there was little or no difference in the effort to maintain a RSZ and one respondent suggested that low salt roads typically had better conditions because pre-mix works better.

Other comments included:

- 5 respondents suggested that maintaining RSZ's required dedicated equipment;
- 3 respondents suggested that greater understanding by police was needed;
- 3 respondents indicated the difference depended on whether liquid chemicals are available or not;
- 2 respondents mentioned the Spring cleanup of the add'l sand is also a major effort.

Q11: In your experience, do you feel Reduced Salt Zones are effective in reducing the overall use of road salt as compared to a similar roadway? (yes or no question)

Response: 165 responses with 64 responding Not Sure or Do Not Have Reduced Salt Zone In Area

Of the other 101 respondents:

- 43 or 43% said Yes;
- 58 or 57% said No.

Given the added effort typically required to maintain a RSZ (as noted above in Q10) and the add'l related costs, these results may suggest that the use of RSZ's are ineffective or at least not cost-effective where additional money is being spent on a measure that is or is perceived to be ineffective.

Q12: How often do you see spreader trucks "spinning off" excess salt at the end of a run on the way back to the shed?

Response: 172 responses with 19 or 11% indicated not sure or not part of my job duties.

- A large majority or 140 respondents (91%) indicated that "spinning off" Seldom or only Occasionally occurs;
- Only 13 respondents or less than 10% indicated that spinning off occurs Often or Quite Often.

These results are perhaps a surprise and suggest that "spinning off" excess salt on the way back to the shed is not a prevalent problem.

Q13: Do you have suggestions for handling excess salt and preventing the practice of "spinning off" salt on roadways?

Response: 144 responses, with 74 open-ended comments

- 60 % or 86 respondents said No;
- 40% or 58 respondents said Yes.

There was a wide range of responses with most indicating that excess salt was or should be spun off within the shed. There were a few comments suggested that operators were concerned about being paid for the extra time need to spin off salt in shed after reporting into the Depot, some suggested add'l training especially hired operators would help, others suggested fining or "benching" hired operators who are repeat offenders, some indicated that the decision for a final application should be left to depot foreman.

Q14: How often are orders given "to put the road to bed" at the end of the storm event?

Response: 171 responses; 33 responses said Not Sure or Not Part of My Job Duties; the other 138 responses were essentially equally divided from Seldom to Almost Every Event; there was no response that had a majority - no clear trend here.

- 26% or 36 respondents stated that put to bed orders were Seldom given;
- 27% or 38 respondents stated that put to bed orders were given Occasionally;

- 20% or 28 respondents stated that put to bed orders were Often given;
- 26% or 36 respondents stated that put to bed orders are given Nearly Every Event.

Q15: In your experience, how often does hired equipment generally follow the MassHighway policies and procedures?

Responses: 172 responses with only 1 respondent indicating Not Sure or Not Part of my Job Duties.

- Large majority or 153 respondents (89%) indicated hired equipment follow the policies and procedures Often or Most Often;
- 17 respondents or 10% indicating that it occurs only Occasionally;
- Only 1 respondent or < 1 % indicating that they Seldom follow policies and procedures.

These results strongly suggest that hired equipment often follow policies and procedures but these results are somewhat in conflict with the responses in the next Question 16.

Q16: Please describe the greatest difficulties in utilizing hired equipment?

Response: 127 Open-Ended Responses, Some respondents listed multiple issues or problems.

- 29 respondents suggested that the initial coordination, call-outs and getting them to respond in a timely manner is the biggest problem: A few suggested that the foreman should have the authority to “weed out” or “bench” the chronic poor performers; one respondent said it was difficult to coordinate when the hired equipment are called out earlier than they are;
- 27 respondents indicated that not having the ability to communicate and keep track of them during operations is the biggest problem;
- 24 respondents indicated that outdated equipment, mechanical breakdowns and lack of equipment upkeep with hired contractors is the biggest problem;
- 21 respondents indicating that general poor performance of some and the add’l time and personnel needed to make sure they are doing what they were supposed to do is the biggest problem;
- 14 respondents said that having inexperienced operators or vendors who change operators frequently and operators with language barriers are the biggest problems;
- 13 respondents said just getting them to follow protocols or do what they are told are the biggest problems;
- 14 respondents said having to deal with or adhere the rotation schedule was the biggest problem;
- 8 respondents said they had no problems with hired equipment and one said that he found “that the ‘hireds’ are more reliable than the state employees”; another one said that “it is tough to maintain cooperation when we don’t pay on a regular basis”.

Q17: How much control do you have on hired equipment?

Response: 173 responses;

- More than 50% or 101 respondents said they had a Great Deal of Control or control nearly all of the time;
- 50 or 29% of the respondents said they had Some Control of Hired Equipment;
- 22 or 13% of the respondents said they had Very Little control.

Again, these responses are somewhat in conflict with the responses provided for Question 16.

Q18: Does the MassHighway Snow and Ice Operations Manual prescribe “black and wet” as the desired pavement condition for high volume roadway?

Response: 161 Responses: there was nearly a 50:50 split on this answer; with 80 respondents or 49% said Yes and 81 respondents or 51% said No.

Q19: Do you feel that the annual training is adequate for understanding for policies, procedures and

expectations that MassHighway has for its snow and ice control program?

Response: 165 Responses: 140 Respondents or 85% said Yes and 25 respondents or 15% said No. There were also 32 open-ended responses. The comments on the open-ended responses were wide ranging with very few similarities or common themes. The following provides a summary of the most relevant or useful suggestions:

- At least four respondents suggested that the hired contractors should attend the training;
- Several suggested that there were some inconsistencies in the training vs what actually happens primarily since the major decisions about when and how much equipment needs to be called in is decided by district or headquarter staff rather than depot foreman; several suggested that either depot foreman should make these decisions or at least provide input in the decisions;
- Several suggested that specific training should be geared toward the timekeepers and plow chasers rather than just foreman;
- Two suggested that additional training on how to communicate within the various roles the responsibilities everyone has should be provided – too much disrespect and “bad-mouthing” between MHD personnel and between MHD and vendors;
- One suggested too much time is spent on materials and not enough on operations and vendors;
- One suggested that there should be a mid-winter training course to go over issues that have come up;
- One suggested that there should be a mentoring program encouraged to pass down the experience from seasoned employees to the newer employees;
- Another suggested that perhaps the DVD video of the Do’s and Don’ts should be available to view on individual or small group basis back at Depot.

Q20: What are the most frequent problems or greatest challenges in dealing with S&I Control?

Response: There were 127 Open-ended Responses. The responses had a few common themes as listed below:

- There was a tie for the two most common problems or challenges reported:
- 24 respondents indicated that not having early enough call-outs was the biggest challenge;
- Another 24 respondents suggested that management and/or the fact that decisions were made at the district level or higher rather than people in the field was the biggest challenge.
- The second most common problem or challenge related to the traveling public driving too fast and/or traffic volumes as reported by 23 respondents;
- 11 respondents listed not having enough personnel or dealing with difficult personnel as the biggest challenge;
- 10 respondents stated that weather forecasting or just dealing with ever changing weather especially icing conditions was the biggest challenge;
- 8 respondents stated that the long hours, lack of sleep and dealing with the rest policy was the biggest challenge;
- 5 respondents stated that dealing with the hired contractors was the biggest problem;
- 5 respondent stated that poor equipment or not having enough equipment was the biggest problem;
- 4 respondents said coordinating amongst the various operators during an event was the biggest challenge;
- 3 listed pavement type especially OGFC was a big problem;
- 2 listed maintaining “black and wet” conditions was the biggest problem.

Q21: Overall, how do you feel that the MassHighway S & I Control Program has changed in the last few years? 162 responses,

- 46 respondents or 28% said much better;
- 76 respondents or 47% said slightly better;

- 32 respondents or 20% said there was no change;
- 9 respondents or 6 % said things have gotten worse.

Q22: What can MassHighway do to make your job easier? (List up to three suggestions).

There were 245 separate suggestions from 120 Respondents. The suggestions were grouped into 8 major categories including Communications, Equipment, Operations, Personnel, Policies, Training, Vehicles and Weather Forecasting. The following provides a breakdown of the total number of suggestions in each Category and the top 3 most common suggestions:

- Communications (53): 29 suggested they need to be called out earlier in an event;
8 suggested they need direct communication abilities with hired equipment and MassHighway personnel;
5 suggested better and more communication b/n mgt and district personnel.
- Operations (53) 25 or about 50% suggested letting Foreman have more control in decision making less micro-management from top;
Other suggestions were wide ranging included having operational mtgs with state police, use state police in convoys, having more control over hired help and deciding who gets called in, have one year contracts, pre-treat with anti-icing chemicals, have more supervision on the roads and rely less on hired equipment;
- Polices (50): 20 comments or 40% related to the rest break policy with many suggesting to get rid of 2 hr mandatory break while others suggesting have more rest on the longer storm events; pay for the break time; pay for meals and more relief during longer storms; 8 comments suggested updating policies to require hired equipment to have better equipment and direct communication capabilities; have state calibrate hired equipment; limit the number of equipment from each contractor.
Other suggestions include: eliminate black and wet curb to curb policy; keep MassHighway personnel closer to home; keep drivers who know each other together; improve relations with DCR; reduce levels of service and educate public.
- Personnel (38): 24 of the 38 comments suggested needing more personnel, with 3 suggesting more chasers, 2 for more time keepers, others suggested needed more qualified personnel; require English speaking hired contractors; have ability to fire problem contractors; utilize state personnel first; have backup people for time keeping.
- Equipment (29): 9 people suggested needing laptops, wifi connections and Nextel DC with trucks. Another 9 people said they needed more trucks; others suggested having pre-wetting equipment, GPS equipment, better maintenance of state equipment; have a loader and sander in each pit; provide a signature pad for invoices.
- Vehicles (16): 12 of the 16 comments suggested needing more or better vehicles; with 3 comments related to having dedicated vehicles for plow chasers; 4 comments pertained to have trucks in better condition or functioning properly with a working horn or better tires; 2 comments indicated a need for 4wd trucks; one suggested improving interior lighting; one suggested acquiring more MHD combos; and another suggested having Supervisors be able to take trucks home in order to have a faster response time.
- Training (4): The 4 comments related to training included two suggesting more training should

be provided; one suggesting sharing the results of this survey; and another suggesting lowering the levels of service on the roads and educating the public and police.

Weather (4): 2 comments suggested have better and/or more frequent weather report updates; one general comment pertained to having better forecasting; and one suggested having laptops in trucks for more up to date weather information.

Q23: Please feel free to provided additional comments or suggestions in space below.

(45 Responses); Overall, many of the comments and suggestions provided here are the most detailed and poignant relative to those from other questions. Rather than summarize or paraphrase, the following represent the most relevant and informative comments for each major Category:

Communications

1. I'd like more freedom on determining when to call my equipment in. Typically speaking, 1 hour lead time for the spreaders; 1.5 hours for the plows, and 2 for the loaders or similar.
2. I think it would help if the pit foreman could make the call when to call in and how much equipment to call in, also when to release the equipment.
3. Listen to the foreman's, don't try to run every pit from the main district office, don't try to make cuts in amount of hired equipment.
4. Calling MHD personnel out consistently, not an hour before storm, then next storm after there is an inch of snow on ground, etc. I like to be ready and be able to respond quickly but sometimes you wait and wait and do not get a call. A "heads up", especially if not getting called would be helpful so one can plan other things.
5. Without question in my opinion the biggest waste of resources comes at the end of an event. We have waited in the pit with a full crew for hours on end waiting for someone from the district to give us the go ahead to hit it one more time then go home. I mean it's sunny with rising temps and we're waiting around for hours. If there was some way to give the pit Foreman more responsibility to make the "no brainer decisions" on when to knock off. If there's a band of flurries coming through thirty miles to the north we will be on hold until it passes. Sometimes it just makes you scratch your head.
6. Stop the favoritism and actually call in the time keepers and chasers to do their job.

Operations

1. The state depends too much on hired equipment and is spending money in this area that would better serve the Commonwealth if it were done in house, or at least reduce the numbers of hired equipment. Every cost estimate ever done proves this, but we continue to waste money on a one time service that does nothing for the rest of the maintenance year.
2. The time and personnel required to address administrative issues has increased significantly. The goal of effective S&I control is being lost in the process.
3. The department should start thinking about snow and ice and setting up meetings with supervisors earlier to get them thinking snow and ice.
4. There should be down time and active times for payment. Require certified payrolls to eliminate tax cheats. [Have] age limits for equipment or rolling pay for age of equipment. Eliminate pit boundary's to aid in storm fighting. Rates for what you do in the event..no wing rate for sanding minor snow event. State [should] verify calibration not members of snow fighters association. Minor storms should not require full force.
5. Don't tell us [there is] no more black and wet if managers are still insisting on it. It only confuses things. I think they hate live trees and unpolluted wells.
6. All drainage structures should be clearly mark[ed] with a flag pole identifying the location of such structures to allow the structures to be cleaned during and after a storm event. These flag poles could be placed behind a guard rail and off the shoulder side so that they will not

be destroyed by the plows. These will be placed before the ground freezes and removed after the season is over.

Rotation Policy

1. The "Rotation" of equipment (although fair to the vendors) does not put the best truck or driver on the road. Helpful vendors should be used more (a reward based system), then they would do better. Too much money is wasted on "early signup bonuses". Cheaper might be a flat fee incentive.
2. I believe some sort of "rotation" is necessary but we should also be able to incorporate the quality of work being performed when deciding what contractors to utilize.
3. Every depot may have a problem vendor. We should be allowed to trade them like an NFL draft.
4. [Be helpful if we could] Email w/ contractors.

Storage Facilities

1. I work out of a DCR facility and am very concerned that the salt is uncovered. This is not only hazardous for the environment, but when it rains some salt disintegrates (increases cost) and you get an awful crusty and clumpy top layer that cannot be used in spreaders without the loader operator crushing it with the bucket and/or driving over them.

Vehicles

1. The depot foreman had 4x4 pickup and was working with the hired equip. they took then away and gave then 2 wheel drive and now we get to do nothing and get tired real fast in a bad snow storm. Sometime we are short equipment or get called out for a car that has gone off road and can't come out to do the job cause the foreman don't have the pickup with the plow to do it. The foreman SHOULD have a 4x4 pickup.
2. My biggest problem is driving an old, unsafe vehicle to chase with. I feel not safe and in these conditions it isn't worth my life.
3. 4wd pickups with more safety lighting
4. Chaser's should have 4x4 trucks
5. Need more six wheelers less pickups.

Equipment

1. More video cameras on roadways and selective areas were observation of on going operations may be viewed and taped.
2. MassHighway needs to add more pavement temperature sensors.
3. Addition of message boards to slow motorists will reduce accidents

Rest Policy

1. I believe it is not right to deduct 2 hours for 'rest' when you are too far from home to go there and have to stay on site for the entire time.
2. I think the MassHighway Dept, has been lucky till now that no employees have been hurt or killed do to the fatigue from too many hours at work during S/I Operations
3. During storms over 36 hours allow personnel to use overtime for at least 4 hours comp. time after storm to make up on time lost out of work such as sleep.
4. Mandatory breaks to be taken at specific times is a joke. In this field of work you take breaks when possible. In addition, to hold some workers to breaks and not others is just wrong. PS: May quit snow & Ice due to this nonproductive policy.
5. After working 12 to 18 hours straight you should have proper time to rest and still get paid for it. We are putting our lives on the line every snow storm when we are on the road!!!!!!
6. Pay us for all the unpaid breaks we are forced to show on our timesheets. The contractors get paid 24 hours w/o breaks and I believe other Districts (I work in District 5) don't "show" a mandatory 2 hr break after working 16 hrs. We rarely take these breaks as they are too

short to go anywhere so if we stay in the depots we're still answering phones, getting interruptions, etc when we're supposedly off the clock.

7. It would be nice to take those 1/2, 2hr, 4 hrs breaks that are mandatory on the timecard.
8. It's a real stinger to have to go off the payroll after 16 hrs. The people in maintenance go back to his / her regular rate.

Training and Educational Outreach

1. The local News media has provided the traveling motorist with constant updates on road conditions, closures, accidents, etc. An educational program advising of the dangers of winter driving would assist in constantly reminding of expected unsafe conditions.
2. Tell the State Police every time their crown vic's slide, doesn't mean the road needs treatment, same w/ every accident, the roads have been black & wet for so long nobody knows how drive in the winter.
3. Make use of message boards "Do Not Pass Snow Equipment".

Positive Feedback/Praise

1. I have been impressed by this excellent public/private partnership. Contractors and employees exhibit pride in their work and genuinely care about public safety. This message needs to get to the public!
2. Re: Q21 - The program has not changed much since I began working snow and ice, but it seems to be improving.
3. I think MHD does an excellent job clearing the roads.

Q24: Please indicate which District that you work in (Optional). (134 responses)

Of the 134 responders that indicated their District location,
52 were from District 5
38 were from District 4
30 were from District 3
4 were from District 2
9 were from District 1

1 was from the Boston headquarters

Ultimately, it is anticipated that the information obtained from this survey will be used in developing the recommendations that are to be included in the Final Study Report regarding possible measures to improve the efficiency and effectiveness of the MassHighway Snow and Ice Program. There are perhaps a number of common themes or "take away" messages included in these Survey results. It is anticipated that these results will be discussed with the Project Team members prior to developing the list of recommendations. For purposes of the Final Report, the results for a select number of multiple choice questions could be presented in a graphical format such as a pie chart for greater effect. We would be happy to discuss the results of this survey at a time of your convenience.

6.3 Appendix C

Data Collection Plan

MassDOT Salt Research Project – Contract 55354

WINTER MONITORING 2009/2010
 Data Collection Plan Meeting – December 14, 2009
 Revised December 17, 2009

Summary of Routes

District	Depot Location	Route	Extents	Distance mi. (approx)	Company	Observation Points
3	A - Westminster	2	Exit 21 (Rte 101) – Exit 28 (Rte 31)	11	VHB	1. Mobil Station (Wachusett Village Inn Rd) 2. Exit 22 Bridge Deck 3. Templeton Rest Area
	B - Oxford	12	Route 20 – Connecticut State Line	11	VHB	1. Rite Aid (near Fire Station) 2. Fire Station 2 / Little League(656 Main St) 3. Fitness club near Common
4	Lexington	128	Exit 20 – Exit 33	14	GEOSPHERE	1. Exit 21A SB – Rest Area 2. Exit 30 NB – Rest Area 3. Exit 33A – Phoenix University 4. Exit 28 – Tracer Lane/Reservoir Place
5	Middleboro	28	Route 44 – Route 495	13	SDE	1. Lorenzo’s Restaurant (Route 28)
		495	Exit 2 (Route 58) – Exit 6 (Route 44)	13	SDE	2. Rest Areas (NB or SB) 3. Exit 3 – Mobil Station

Maps of Routes and Observation Points

(See attached Routes for Districts 4 and 5, only)

Data Collection Plan

See attached Field Observation Data Sheet (double sided)

General Information Data: Storm Beginning, Storm End, Roads Clear

Station Observation Data (location / time):

Precipitation Data (type, intensity, temperature, wind speed/direction, trend)

Treatment Data (type, plow timing, salt application timing)

Pavement Data (type, temperature, trend, lane conditions[snow/ice/wet])

Traffic Data (volume, speed)

Vehicle Data (location / time):

(vehicle [MassDOT/private], type, action, ID, location, spreader conditions/observations, plow conditions/observations)

- Follow randomly selected road salt application vehicles to inspect spreader equipment configuration, functioning, and ability to apply a uniform application rate.
- Verify through random observation if various equipment operators have valid calibration certificates and if the equipment appears to be adequately calibrated.
- Identify and document any observed operator practices that are not consistent with MassHighway's Snow and Ice protocols such as vehicles not adhering to their designated spreader route, operators overlapping spreader routes, spinning out excess material after covering their spreader route, spreading on dry roads or applying materials in the breakdown or outside the proper travel lane for highway applications.
- Evaluate through random observations whether vehicles have properly functioning ground speed controllers.
- Evaluate and document any observed differences in the type of equipment and general operations between MassHighway equipment and hired equipment.

Communications Plan

Initial Call: Patrick McMahan to call David Niemeyer: 1) as soon as possible once decision is made to monitor storm; 2) a minimum of 1.5 hours in advance of confirmed start time (one-hour prior to storm?)

Depot Notifications: Crews to call depot liaison (foreman) at start of monitoring, and at end of monitoring

Post Storm: Contact liaison (foreman/time keeper/Snow and Ice Engineer) for salt usage data

Following each monitoring event, a brief field report will be prepared to summarize the observations, weather conditions, monitoring locations, storm duration, specific findings, recommendations for changes and any unusual issues or conditions that need to be resolved before the next event. The field reports will be submitted by the Project Manager within one week following each monitoring event.

6.4 Appendix D

Material Loading and Application Rate Field Log

6.5 Appendix E

**Summary of First Year Winter Observations and Recommendations for Next Season,
GEOSPHERE, June 11, 2010**

Memorandum

To: Paul Brown, MassDOT
Dave Blodgett, MassDOT
David White, MassDOT
Patrick McMahon, MassDOT

From: David Niemeyer, GEOSPHERE
Bill Arcieri, VHB

Date: June 11, 2010

Re: Summary of First Year Winter Observations and Recommendations for Next Season

This memo provides a summary of the first year observations of winter deicing operations in Districts 3, 4 and 5 as well as recommendations for the next winter season as part of the MassDOT Road Salt Effectiveness and Efficiency Research Study (RFR 05_24EOTSALT, Contract 55354). In addition to the information described below, the following attachments are included with this memorandum:

1. Summary reports for each of the four observation locations within the 3 monitored Districts, as prepared by each observation team.
2. Figures showing the monitored observation routes, observation locations, and the estimated overall lane mileage within each route, including reduced salt zones and ramps within each route.
3. Spreadsheet of the relevant weather, pavement and salt usage information for each of the monitoring events.
4. A summary memorandum describing the historical annual usage for each of Districts for the years 2003 to 2009 and an analysis as to how annual salt usage compares to the estimated Weather Severity Index (WSI) using District 4 data.

General Summary of Winter Deicing Observations Results

Overall, fewer than six deicing events were observed at each of the four locations and only two or three of these events had moderate snowfall amounts (i.e., > 6 inches). This was a relatively mild winter in terms of overall snowfall totals and number of snow events, particularly in the latter part of February and most of March. Perhaps the biggest benefit of this winter's observations is having a much greater understanding as to what needs to be done for next season to collect data that will be more consistent with the projects goals. Specifically, in order to be able to assess the effectiveness and benefits of the Cirrus "SpreadSmart Rx" Controllers as

compared to the conventional open-loop controllers, the observation study plan will need to be revised as suggested in our recommendations below. During this past winter, the operations, communications and reporting system was not sufficiently aligned to be able to compare and assess the differences between the two types of spreader controllers. We present the recommendations below for discussion purposes as a starting point to improve the ability to compare the efficiencies between the two types of equipment but there may be other ideas that MassDOT personnel would have to further enhance the outcome of this study.

A couple of other secondary items were noted this past winter that may relate to improving salt usage efficiency and are worth mentioning for discussion purposes. First, it was noted that at the boundaries of abutting spreader routes there appears to be an overlap in salt applications between the two maintenance gangs or depots. These overlaps may extend for several miles and between multiple interchanges as was observed in Westminster. Although it is recognized that deicing operations may vary from storm to storm and adjustments are frequently made in the field due to prevailing storm conditions and the availability of equipment and personnel, perhaps the protocols for handling transition areas between abutting spreader routes should be revisited and/or enhanced to provide a more consistent approach to address these areas as it may present an opportunity to reduce the overall salt usage statewide. Perhaps protocols are already in place but as a possible suggestion, maybe the primary responsibility for maintaining transition areas between spreader routes should be designated to one of the adjacent maintenance gangs such as the more easterly or northerly gang to provide consistency and reduce duplication of efforts.

The other item of note was that the reported salt usage data did not provide a breakdown as to how much salt was being used in the reduced salt zones (RSZs) vs. regular spreader routes. The information that was provided, particularly in Oxford, seemed to suggest that as much salt was being used in the RSZ as that used in regularly maintained roadways. The breakdown of salt usage data for the RSZs and the regular spreader routes as well as for ramps and mainline areas can hopefully be improved for next year. This may warrant further discussion as to how the salt usage data is being tracked and reported statewide for RSZs and whether this needs to be improved or are the tracking procedures already in place.

Recommendations for Next Season

1. In order to develop a more “apple to apple” comparison, it is recommended that a side by side comparison be set up in each district where dedicated spreader(s) equipped with Cirrus Controllers would be assigned to treat either a northbound or eastbound section of a roadway and dedicated spreader(s) with a conventional open loop controller would be assigned to treat the opposing southbound or eastbound barrel of nearly equal distance.
2. The designated routes could be abutting each other to allow for out and back spreader route but they should be of nearly equal distance on the same type of roadway with similar traffic volumes, pavement conditions, drainage conditions and whether or not it is a reduced salt zone.
3. To minimize variability, ramps should be avoided in the comparison test and should include only MassDOT spreaders as contractors tend to move around and are not necessarily reliable in terms of being in same location for each storm event.

4. The salt usage data for each participating spreader truck must be tracked individually by the time keeper and reported separately from the rest of the fleet. This will need to be coordinated with time keeper, depot foreman and perhaps salt loader or spreader operator.
5. Ideally, this comparison would be done in a “blind” manner such that the operators of each vehicle are not aware of the comparison test but it is understood that this may be difficult to maintain.
6. Selection of appropriate road sections may need to be coordinated with District personnel to find existing spreader routes that may be most appropriate or require the least modification. Using two lane or single lane roadways may be better than 4-lane roadways. For District 3, a section of the Route 2 in Westminster area may be a good location. In District 4, perhaps a two-lane barrel such as Route 2 or 2A may be ideal. In District 5, the 2-lane sections of Rte 495 could work or perhaps another appropriate roadway.

MassDOT Summary of Winter Maintenance Observations (District 3) First Winter Season 2009-2010; Observed by VHB personnel

Oxford/Westminster Locations

Storm Information

- Four observation events were conducted between Jan. 8th and March 3rd, 2010. VHB was called out for a 5th event on Feb 27th in Westminster but no appreciable precipitation occurred and no MassDOT personnel were called out. Two observation events occurred in Oxford and two were conducted in Westminster.
- The two Oxford events occurred on Sunday, Jan 17th and Wednesday, Feb 10th with 10-12-inches of snow in the 1st event over a 15-hour period and the 2nd event had only 2 to 2.5" of snow over a 14-hour period.
- The two Westminster events occurred on Friday, Jan. 8th and Tuesday, Feb. 16th with 3 to 4" of snow in the 1st event over a 5.5 hour period and 6 to 8 inches in the 2nd event over a 21.5 hour period.
- Total winter observation hours were 30 hours for Oxford and 27 hours in Westminster.

Oxford

Operations

- The winter maintenance observation route consisted of a 12.1 mile stretch of Route 12 from Route 20 in the north to the Connecticut line in the south. A total of 24.2 lane miles. The Reduced Salt section is from Route 20 to the Sunoco station (near Oxford Town Common-South); total length= 4.05+/- miles or 8.1 lane-miles. The remainder of the route is considered to be 8.05 +/- miles or 16.1 lane-miles.
- Three observations points along Route 12 were chosen at the start of winter, which included Rite-Aid in the south, Town Common (Medical office parking lot) and Oxford Fire Station #2-north (**See Map**).
- The actual road segment observed was 6.1 miles from Rte 20 (Wal-mart) to the South End Fire Station/LL Field due the length and ability to maintain the desired half-hour observation intervals.
- Material used in Reduced Salt area was primarily a 50:50, Sand/Salt Mix (not sure if Pre-Mix is used). During the Feb.16/17th event, however, straight salt was used in southern half of LS Area from Dept Rd to Sunoco due to lack of equipment.
- All MassDOT spreader trucks in this Depot were assumed to be equipped with closed-loop Cirrus Controllers. There were no open-loop spreaders for comparison.
- During the 2nd event, a Town truck was observed applying material and plowing on a portion of the Low Salt area just north of Sunoco.

Salt Usage

- For 1st event, two contractor trucks assisted (Latour and Charlton Welding) Latour was plowing and Charlton Welding (CW) was plowing and applying material. CW applied 28.8 tons of 50:50 sand/salt mix from Route 20 to the Sunoco Station (~1.7 tons salt/ ln-mi) and 19.2 tons of straight salt for remainder of route (~ 1.2 tons/ ln-mi). MassDOT truck applied 25.2 tons of sand/salt mix from Rte 20 to Depot Rd (3.8 lane-miles or 3.3 tons salt/ln-mile).

- **Appears that the reduced salt area was being treated with more salt than that used on regular route (~1.7 tons/ln-mile (contractor) plus 3.3 tons/ln-mile (MassDOT) vs ~1.2 tons per ln-mile).** *It is possible that the MassDOT truck was applying material to Worcester town line which would be approx. 22.4 ln-miles, which results in 1.3 tons of mix per ln-mile.*
- For the 2nd event, no contractor trucks were observed, one MassDOT truck applied 29 tons of a 50:50 Sand/Salt mix from Depot Road to Route 20 (29 tons / 3.8 ln-mi = 7.6 tons of 50:50 mix/ln-mi or 3.8 tons of salt /ln-mi). *Again, the time keeper did not indicate this but it is possible that the MassDOT was applying material beyond Rte 20 to Worcester town line.* The 2nd MassDOT truck applied 27 tons of straight salt from Depot Road south to the Conn. Line (20.4 ln-miles or 1.3 tons salt/ ln-mi). The straight salt application though low salt area (Depot Rd to Sunoco) was due to lack of trucks/personnel.
- **Again, it is difficult to say but given information provided by time keeper it appears that the reduced salt area could be treated with same or more salt than rest of route.**
- **There were no opportunities to compare salt usage between open-loop vs closed loop spreader equipment.**

Westminster Operations

- Winter maintenance operations were observed along a 20 mile stretch of Route 2 from Exits 21 to 28 with an estimated total of 43.7 lane miles of mainline road and 12.2 lane-miles of ramps.
- This route was selected for observation to compare salt usage with conventional open loop spreaders with closed loop Cirrus Controllers used by contractor “Bennett”. There is no reduced salt area within this observation route.
- Three (3) observation locations were used, the Irving Station at Village Inn Road-east end; the bridge deck at Exit 22-west end and the median crossover near Exit 24.
- For both events, material applications were primarily performed by two contractors, A. Jandris and G. Streeter. A. Jandris trucks were applying on the mainline both EB and WB and the G. Streeter trucks were applying on the ramps including the two rotaries on Exit 22 and 23. It is assumed that these trucks were equipped with open loop spreaders.
- The contractor, “Bennett” did not participate in the operations during either of the two observation events. Thus, there was no data collected for the Cirrus Controller spreaders.
- Spreader trucks from the adjacent Fitchburg crew were observed to be overlapping the road section between Exits 25 to 28 and the Gardner crew overlapped from Exits 21 to 22. As a result, there may be excess material being applied on these sections of road. This was somewhat evident between Exits 25 and 28 where the pavement was consistently black and wet with running water off pavement where in the none-overlapped sections, the pavement fluctuated between slush-covered and black and wet.

Salt usage

- For the Jan 8th event, only the mainline treatment by A. Jandris trucks were reported with a total 19.5 tons applied or roughly 0.5 tons per ln-mi. This was a 5 hour event.
- For the Feb 16/17th event, a total of 283 tons of salt were applied over storm duration of approx. 22 hours, which translates to approx 6.5 tons per lane-mile. **This salt usage does not include the additional salt applied by adjacent crews on overlapped road sections.**
- **There were no opportunities to compare differences between open-loop vs closed loop spreader equipment.**

MassDOT Summary of Winter Maintenance Observations (District 4) First Winter Season 2009-2010: Observations by GEOSPHERE personnel

Lexington Depot Location – Route 128/95 between Exits 20 and 33

Storm Information

- Six storm observation events were conducted in Lexington by GEOSPHERE personnel between Jan. 8th and March 3rd, 2010.
- The storm events occurred on Friday Jan. 8th, Sunday, Jan. 17th, Wednesday, Feb. 10th, Tuesday, Feb. 16th, Monday Mar. 1st, and Wednesday Mar. 3rd. Snowfall amounts for the six storms were < ½-inch, 10-12 inches, < 1 inch, 6 inches, trace and trace, respectively.
- Total winter observation hours were 81 hours (per person) for Lexington.

Operations

- The winter maintenance observation route consisted of a 14.75 mile stretch of Route 128/95 from Exit 20 (Route 9, Needham) in the south to Exit 33 (Route 3A, Burlington to the north). The mainline road accounts for 118.4 lane miles plus 35.3 ln-miles in ramps.
- Four observations points along Route 128 were chosen: the Exit 30 Rest Area on Route 128 NB in Lexington; the Exit 21A Rest Area on Route 128 SB in Newton; Phoenix University parking lot adjacent to Route 128 NB near Exit 33A; and Tracer Lane along Route 128 SB near Exit 28 (**See Map**).
- The reduced salt section is considered to be from Exit 20 to Exit 31 (Route 4, Lexington) total length = 11.9 miles or 95.2 lane-miles, based on MassDOT reduced salt zone maps. There is an estimated 19.4 lane miles associated with ramps within the reduced salt zone.
- Identifying Spreader Trucks (MassDOT or Private) was difficult in the field due to highway congestion/speed and observation location distances.

Salt usage (data provided by time keeper)

- For the Jan. 8th event, a total 60 tons of 50:50 mix (assume Pre-mix/salt) was applied. This was a 5-hour event with trace snow accumulation.
- For the Jan. 17th event, 98 tons of salt, 175 tons of sand, and 76 tons of 50:50 mix were applied. This was an 18-hour event with significant rain, sleet, freezing rain and snow accumulation (10-12 inches).
- For the Feb. 10th event, 170 tons of salt, 84 tons of sand, and 205 tons of 50:50 mix were applied. This was a 14-hour event with little (< 1 inch) snow accumulation.
- For the Feb. 16th event, 75 tons of salt, 192 tons of sand, and 57 tons of 50:50 mix were applied. This was a 19-hour event with 6-inches of sleet and snow accumulation.
- For the Mar. 1st event, 23 tons of salt, 67 tons of sand, and 26 tons of 50:50 mix were applied. This was a 7-hour event with trace rain/snow accumulation.
- For the Mar. 3rd event, no material was applied. This was a 17-hour event with trace rain/snow accumulation.
- **A breakdown of salt usage by truck (private or MassDOT) or by ramp vs mainline road was not provided. In addition, a breakdown by Reduced Salt vs Regular road sections was not provided.**
- **Data was not available to compare differences in salt usage between open-loop vs closed loop (Cirrus Controllers) spreader equipment.**

MassDOT Summary of Winter Maintenance Observations; (District 5) First Winter Season 2009-2010; Observations by SDE personnel

Middleboro Route – Route 495 N/S between Exits 3 and 6, Route 28 N/S between Exits 2 and 6 of Route 495.

Storm Information

- Five storm observation events were conducted in Middleboro by SDE personnel between Jan. 8th and March 3rd, 2010.
- The storm events occurred on Friday Jan. 8th, Wednesday, Feb. 10th, Tuesday, Feb. 16th, Monday Mar. 1st, and Wednesday Mar. 3rd. Snowfall amounts for these five storms were trace (< ½ inch), < 1 inch, 8 inches, trace and < 1 inch, respectively.
- Total winter observation hours were 69.5 hours (per person) for Middleboro.

Operations

- The winter maintenance observation route consisted of a 11.8 mile stretch of Route 495 from Exit 2 (Route 58, Wareham) in the south to Exit 6 (Route 44, Middleboro) to the north, and a 12.5 mile stretch of Route 28, also between Exits 2 and 6 (Route 495). The Route 495 section has total of 47.4 lane miles of mainline and 8.8 lane-miles of ramps (**See Map**). The Route 28 section has an estimated 25.9 lane-miles of mainline and no ramps.
- Three observations points were chosen: the Rest Area on Route 495 SB between Exits 3 and 4, Lorenzo's Restaurant on Route 28, ½-mile from Exit 6 on Route 495, and a Mobil Station on Route 28 adjacent to Exit 3 on Route 495.
- The Reduced Salt sections for both highways are located between Exits 3 and 6, which is approximately 7 miles in length and 27.4 ln-mi on Rte 495 and 14 ln-mi on Rte 28.

Salt usage (data provided by timekeeper)

- For the Jan 8th event, 7 tons of salt were applied to Route 495, and 5 tons of salt to Route 28. This was a 4.5-hour event with trace snow accumulation.
- For the Feb. 10th event, 87 tons of salt, 43 tons of sand, and 55 tons of 50:50 mix were applied to Route 495. For Route 28, 40 tons of salt, 20 tons of sand, and 15 tons of 50:50 mix were applied. This was a 19-hour event with < 1 inch of snow accumulation.
- For the Feb. 16th event, 85 tons of salt and 35 tons of sand were applied to Route 495. For Route 28, 34 tons of salt and 21 tons of sand were applied. This was a 21.5-hour event with 8 inches of rain/snow accumulation.
- For the Mar. 1st event, 63 tons of salt and 28 tons of sand were applied to Route 495. For Route 28, 37 tons of salt and 19 tons of sand were applied. This was an 11-hour event with trace rain/snow accumulation.
- For the Mar. 3rd event, 63 tons of salt and 28 tons of sand were applied to Route 495. For Route 28, 37 tons of salt and 19 tons of sand were applied. This was a 13.5-hour event with trace snow accumulation.
- **The salt usage provided did not include a breakdown for Reduced Salt Zone vs Regular roadway routes or for mainline vs ramp area treated.**
- **There was no data available to compare differences in salt usage between open-loop vs closed loop spreader equipment.**



Memorandum

To: Paul Brown, MassDOT
David Blodgett, MassDOT
David White, MassDOT
Patrick McMahon, MassDOT

Date: June 11, 2010

Cc; Dave Niemeyer, Geosphere

Project No.: 52011.00

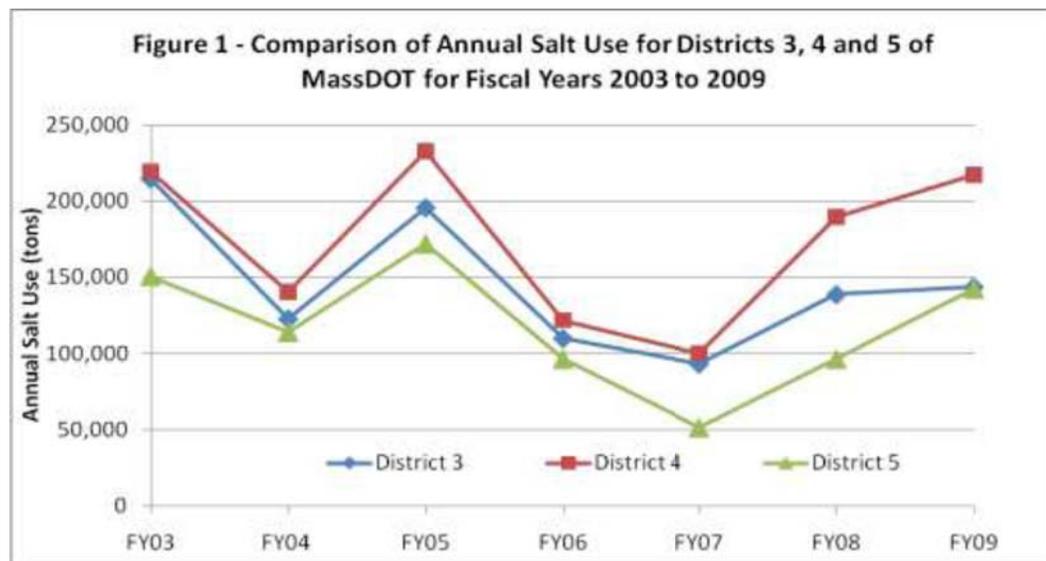
From: Bill Arcieri

Re: MassDOT Historical Salt Usage for Districts 3, 4 and 5 plus the use of Winter Severity Index to track Annual Salt Usage

The following provides a summary of the historical salt usage each year within Districts 3, 4 and 5 for the last seven years starting in FY 2003 through FY 2009, consistent with the project RFR.

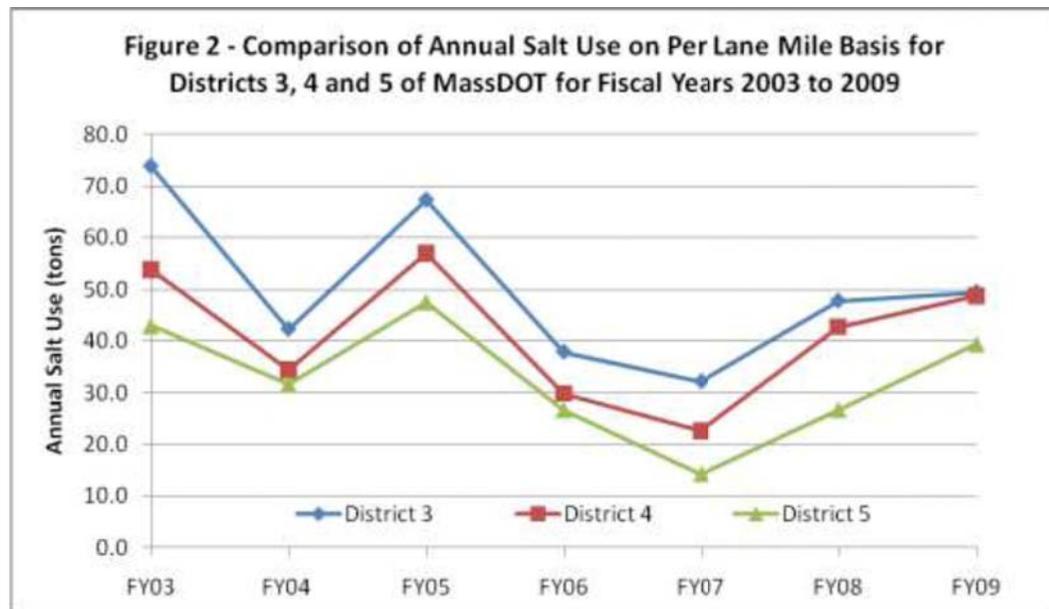
1.0 Annual Salt Usage by District

Figure 1 below presents the overall annual salt usage by district between fiscal years 2003 and 2009. District 4 consistently had the highest annual salt usage relative to the other two districts and District 5 consistently had the least amount of annual salt usage. The annual salt usage in District 4 generally ranged between 100,000 and 230,000 tons per year while in District 5, the annual salt usage ranged from 50,000 and 170,000 tons per year and for District 3, the annual usage generally ranged between 100,000 and 200,000 tons per year. The difference in overall salt usage between districts is due in large part to differences in the lane mileage maintained by each district. District 4 has the greatest number of roadway lane miles at an estimated 4457 lane-miles compared to an estimated 3,097 and 3,612 lane miles maintained by Districts 3 and 5, respectively. Thus, comparing salt usage on a per lane mile basis provides a more meaningful and direct comparison, as discussed below.



2.0 Comparison of Annual Salt Usage by Lane-Miles

Figure 2 presents the annual salt usage for each district expressed in tons of salt used per lane mile. On a per lane-mile basis, District 3 had the highest annual salt usage from year to year followed by Districts 4 and then 5. The higher per lane mile usage for District 3 is most likely due to a greater number of snow events and colder temperatures in the higher elevations in the hills around the Worcester area requiring a greater number of applications relative to the other two districts. On an average annual basis, it appears that District 3 typically applies approximately 35 to 60 tons of salt per year per lane mile. While District 5 typically utilizes roughly 20 to 40 tons of salt per lane mile and District 4 utilizes roughly 25 to 50 tons of salt per lane mile.



3.0 Historical Comparison of Average Annual Salt Usage on per lane Mile Basis from Fiscal Years 1993-2003 and from Fiscal Years 2004-2009

Table 1.0 below provides a comparison of the average annual salt usage on a per lane mile basis between FY 2004 to 2009 and the previous 11 years including FY 1993 to 2003. Based on this comparison, the average annual usage for the last six years appears to be somewhat higher than the annual average salt usage for the previous eleven years. The amount of salt used in each of the three Districts in the last six years on a per lane mile basis is approximately 24 to 37% higher than that estimated for the years 1993 to 2003. This increase may in part be due the fact that each district may be maintaining more roadway lane miles but the total lane mileage recorded for each District may not been updated in recent years. The increase may also due to a greater number of more severe winters in the last seven years as compared to the previous ten years between 1993 and 2002 (See analyses on WSI below). There may also be a greater reliance on road salt as opposed to other materials such as sand or premix as there has been a growing demand for higher levels of treatment by the traveling public and public safety officials to maintain bare pavement roads to minimize vehicle accidents and maintain higher levels of vehicle speeds. From both an environmental and financial perspective, this trend in increased annual salt usage is not likely to be sustainable. It will be important to modify and/ or reverse this trend though additional measures to increase efficiency and effectiveness of road salt.

Table 1.0 – Comparison of Long-Term Average Annual Salt Usage from Fiscal Years 1993-2003 and FY 2004-2009

District	FY 1993 to 2003*			FY 2004-09			% Difference in Salt Usage per Ln-mile
	Ln-miles	Ave. Annual Salt Usage (tons)	Salt Usage tons/ln-mi	Ln-miles	Ave. Annual Salt Usage (tons)	Salt Usage tons/ln-mi	
Three	2905	103,352	35	3097	135,045	43	24%
Four	4082	116,999	29	4457	166,935	39	37%
Five	3506	85,923	25	3612	111,996	31	27%

Notes: * data prior to 2002 was included in the 2006 Snow and Ice Control GEIR

3.0 Comparison of Annual Salt Usage vs. Weather Severity Index

Figure 3 shows a comparison of the annual salt usage in District 4 from 1995 to 2009 to the computed Weather Severity Index (WSI) based on weather data recorded at the Hanscom Airport. Between the years 1995 and 2000, the two variables do not appear to be closely correlated but after 2000 the annual salt usage appears to track closely to the estimated WSI.

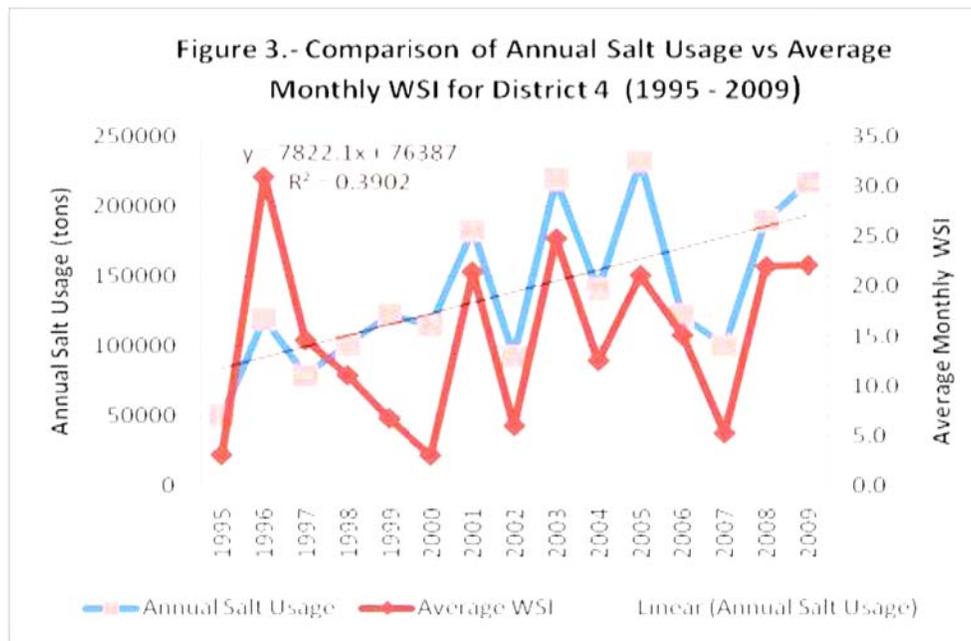
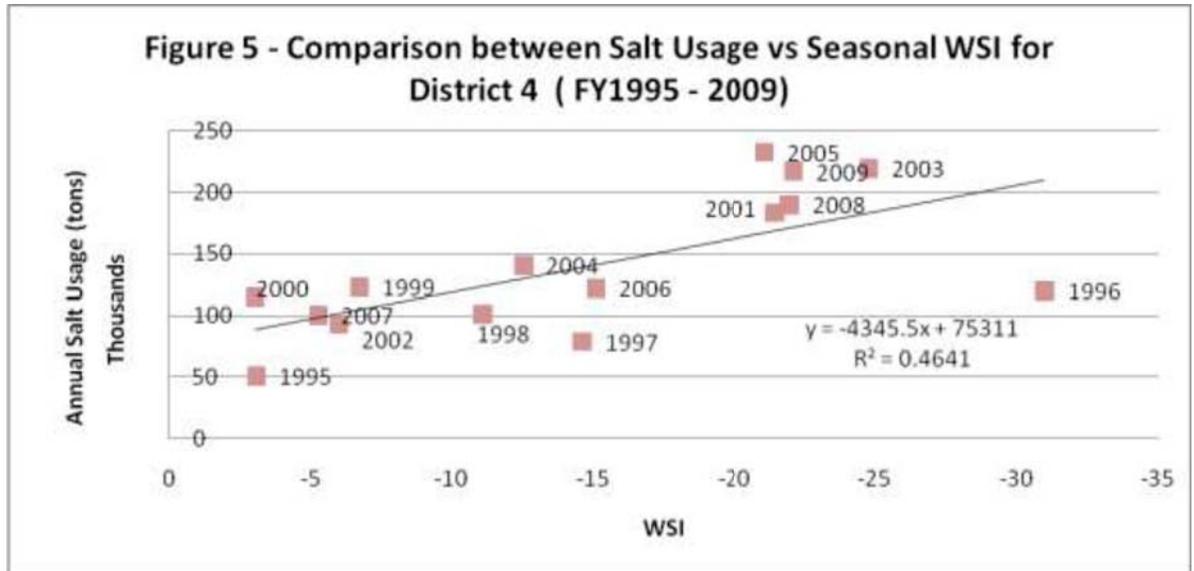
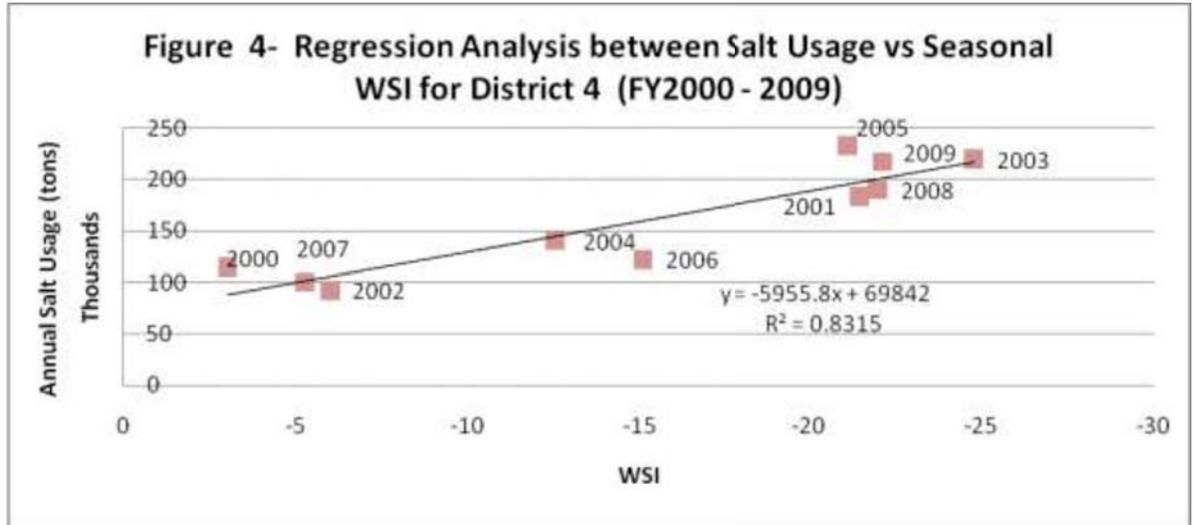


Figure 4 below shows the annual salt usage plotted against the WSI for the years 2000 through 2009, and the linear regression equation and correlation coefficient (R^2) value of 0.83 indicating fairly strong correlation between WSI and Annual Salt Use. Figure 5 shows the results of the same analysis but with the extended time period between 1995 and 2009. The correlation coefficient values (R^2) is much lower at 0.46 indicating a weaker correlation between the two variables and suggests that prior to 2000, the annual salt use did not track as well with the WSI. For three years in a row, prior 2000, including 1995, 1996 and 1997, the annual salt usage was much less than what would have been predicted (i.e., well below the trend line) if based on the WSI value. It is unknown

at this time, if there was a change in operations during this three year period that would have resulted in less overall salt usage as compared to other previous and subsequent years. The more recent results showing a strong correlation indicate that going forward the use of the WSI could be a useful tool for tracking the year to year variability in annual salt usage. It could also be used to measure the effectiveness of reducing salt usage in the future as more and newer efficiency practices are implemented.



6.6 Appendix F

Technical Memo - MassDOT S&I Research Project: Second Annual Report of Observations and Recommendations, VHB and GEOSPHERE, October 14, 2011

**Technical
Memorandum**

To: Paul Brown, MassDOT
David White, MassDOT
Patrick McMahon, MassDOT

Date: October 14, 2011

Project No: 52011.00

From: David Niemeyer, GEOSPHERE
Bill Arcieri, VHB

Re: MassDOT S&I Research Project: Second
Annual Report of Observations and
Recommendations

The following represents an Annual Summary Report summarizing the project goals, the activities conducted, the observations recorded and a list of recommendations based on the observations made during the past two winter seasons as part of the MassDOT Road Salt Efficiency Research Study. Consistent with the project RFP, the draft list of recommendations are geared toward increasing the effectiveness and efficiencies of the Snow and Ice Control Program. It is anticipated that upon review and with acceptance by MassDOT personnel, these recommendations would be included in the future Implementation Plan and possibly evaluated in the field on a trial basis as part of this Project.

Project Goals

Consistent with the Project RFP, the following describes the primary goals of the project:

1. To evaluate and identify various critical factors associated with the current S&I Control operations, procedures and technologies that may lead to inefficiencies and the use of excess road salt and other materials.
2. Identify and recommend operational changes and/or Best Management Practices that would improve operations and increase the efficiency of material usage.
3. Evaluate the effectiveness of closed-loop controllers in reducing material usage and recording usage data as compared to conventional open-loop controllers.

Project Activities Completed

1. Completed Statewide Survey of MassDOT S&I personnel to obtain employee feedback on the current status of the S&I Control Program, the challenges involved in performing their duties and ideas that could improve the program (Tech. Memo submitted on Oct. 8th, 2009).
2. Compiled annual salt usage data for Districts 3, 4 & 5 for last 5 years and compared salt use to Winter Severity Index calculated for District 4 (Tech. Memo submitted on June 11, 2010).
3. Prepared GIS Maps of mapped statewide environmental resources based on MassGIS data (Submitted June 2010).
4. Prepared GIS Maps of Spreader Routes for the Concord and Middleboro Depots.
5. Conducted over 220 hours of field monitoring of operation at various depots during winter storm events over the past two winters of 2009/10 and 2010/11.
6. Prepared first Annual Summary Report summarizing first winter observations (Tech. memo with attached spreadsheets of observations submitted June 2010).
7. Attendance of various Training Sessions and Project Coordination Meetings in Boston and each depot location targeted for monitoring.
8. Prepared Summary of 2nd Season Observations in PowerPoint slides for June 22, 2011 meeting and a follow-up Draft Summary Memo (Sept 2011).

Methodology for Operational Observations

Field observations were conducted over two winter periods of 2009/10 and 2010/11. Three teams of 2-person crews were established to respond to specific locations during winter storms to observe S&I Control operations along predetermined spreader routes. The specific depots and routes were selected by MassDOT based on the availability of certain equipment (e.g. closed loop controllers) and other specific operations of interest (e.g., Reduced Salt Zones). The storms selected for monitoring were also determined by MassDOT personnel. Prior to start of the monitoring season, the field crews attended training sessions at the Boston central office as well as at selected depots to review observation protocols and MassDOT operational policies and procedures.

During each event, the field crews recorded weather and road surface conditions at specific intervals and locations throughout the storm. Observations of material applications and plowing operations were also made along specific routes. The field observation locations were geo-referenced, time stamped and digitally recorded using Trimble ProXT GPS-enabled tablets or computer laptops loaded with GIS-enabled ArcPad™ software. Where field and safety conditions allowed, digital photos were occasionally collected. During the first winter season, material usage data for specific spreader routes was obtained from district personnel following the storm event. This was generally sufficient to compare total material usage between routes for the entire storm but was not sufficient to confirm/verify application rates for each route as the number of trips or total mileage for each spreader was not available. In the first winter, MassDOT had decided it was best if field crews did not enter the Depot yard during winter operations so as to not bias the observations or interfere with operations. Observations were generally made from stationary locations along the route or by occasionally driving through the designated route. Using the stationary locations, however, it was often difficult to see the finer details of spreader operations when observing from a distance. In terms of specific equipment, there was only one MassDOT truck that was equipped with a closed-loop controller. The controller data could not be retrieved, however, as the software was not available. The first winter observations were done along designated spreader routes in Oxford, Westminster, Lexington and Middleboro.

For the 2nd winter season, the monitoring approach was modified under MassDOT's direction to allow the field crews to interact with the spreader operators and district personnel and directly record the amount of material being loaded in each spreader and the mileage of each material application by following specific spreaders. These direct observations would not allow comparisons between separate routes utilizing closed-loop and open-loop controllers but differences between routes designated as RSZs and regular spreader routes as well. These direct observations would also theoretically allow verification of reported application rates being reported by the operator. The observations during the second winter were obtained by shadowing certain spreaders during the entire event on specific spreader routes in the Towns of Concord and Middleboro.

The data associated with the Cirrus Controls "SpreadSmart RX™" controller in Middleboro was provided directly from the Controller, whereas in Concord the data was manually reported by the drivers and submitted to the Timekeeper on MassDOT forms.

Summary of Observed Operations and Reporting Practices

In general, the information and observations compiled by the field crews suggest that the MassDOT S&I Control activities in the areas monitored are being done in a systematic manner and are generally consistent with the overall Program policies and procedures, as we understand them. It appeared that the activities were principally directed by the depot foreman with assistance from the plow chasers, although the field crews were not privy to the communications between operators and depot personnel done by two-way radio. When material applications were made, it appeared warranted by the weather and road surface conditions, with a few exceptions as noted below.

During the 2009/10 season, over 400 observations were logged with regard to vehicle operations in the four monitoring locations. More than half of these observations pertained to chute flap positions and gate openings on the spreader apparatus. Of these 400 observations, only twenty-seven (27) involved operations or reporting practices that were considered inconsistent with MassDOT policies and procedures or would appear to lead to

excessive material usage. Most of these practices related to spreader trucks traveling at relatively high speeds, plow trucks plowing too soon after material was applied, multiple trucks treating same roadway due to route overlaps, in one case the truck was overloaded leading to some minor spillage and another case the spreader spinner was still spinning while truck was stopped. These are summarized in detail below. During the second winter season, the change in study approach, as noted above, allowed the field crews to focus more on evaluating differences in spreader apparatus, specifically closed and open loop controllers as well as how material was being accounted for and reported at the route and depot level. This enabled observations to be made on a variety of other operations and practices that were not necessarily observed in the first winter. A summary of observations made during the second winter season are included in Attachment 1.

The following table presents a summary of the observations for the two seasons focusing on the various operations and practices that were likely to contribute to excess deicing material usage and/or inaccurate or inconsistent reporting information. These observations are not listed in any order of importance or frequency of occurrence as they occurred at various locations and times. It is difficult to predict how often and how widespread these practices and activities may occur on a statewide basis, since the observations were made in select areas and only for a relative small segment of the overall winter season. Nonetheless, the list highlights several important operational issues that could be modified to improve the Program efficiency and perhaps reduce overall material usage in the future. The feedback received by MassDOT employees as part of the employee survey is not included here as this information was reported in an earlier report.

General Observations of Practices/ Activities that Contribute to Excess Material Usage or Reporting Deficiencies

Observed Practice	Location	Notes
Overlapping Spreading Routes	Oxford	During 2009/10, a Town truck was observed applying salt on same Rte 12 being treated by MassDOT
	Westminster	Spreaders from adjoining routes were overlapping applications along Rte 2 by more than one exit
	Lexington	Spreaders from three separate depots were applying material on same stretch of roadway between Exits along Rte 128/95
	Concord	The Rte 2 section thru Rte 128 interchange was often treated by spreaders from both Concord and Lexington depots as trucks passed through same area. Rte 2 traffic circle was also treated by unknown vehicles passing through.
	Middleboro	Rotary at 44/28 was often treated by spreaders treating different routes terminating at rotary – also, Town truck observed occasionally treating Rte 28 section. Rte 495 ramps were also treated by overlapping trucks, or treated by private / Town equipment
Application to Dry Pavement	Rte 495 - Andover	Traveling NB on I-495 in Andover area on Jan 28, 2010; one vendor spreader was applying dry salt to dry pavement in center travel lane with extensive material bounce and scatter; Although an approaching cold front was forecasted for later in the evening, it is likely that most of this material was blown off pavement- see photo in Attachment 2.
Reduced Salt Zones receiving similar or more salt than regular spreader routes	Oxford/ Middleboro	Based on reported data, it appears that the amount of salt being applied in RSZ was similar if not greater than that in regular adjacent route during multiple storm events. In Oxford, reported material usage was much higher in RSZ but the entire travel distance could not be confirmed as it was outside observation route. On several occasions, straight salt applications were required in RSZ as hardpack was forming on road
Applying without Liquid to Pre-wet Salt	Concord / Middleboro	Most operators reported using liquids for pre-wetting but it was often difficult to discern; In more than one event in Middleboro, no pre-wetting of salt was occurring; in Concord, there was one case where pre-

		wetting equipment not fully functioning and one MassDOT spreader had no pre-wet equipment
Gate Openings	Concord/ Middleboro	Often times, operators reported using gate openings of 3 to 4 instead of 2 to 2.5, appears inconsistent with MassDOT policy
Application Settings	Concord/ Middleboro	Similarly, operators often reported setting their controllers to an application rate of 300#, 400# or 480# instead of 240# per lane mile
Plowing Immediately After Material Application	Lexington / Oxford / Westminster	On several occasions during 2009/2010, plow batteries were observed plowing relatively soon after material application (e.g., < 30 minutes). This was not observed in 2010/2011, most likely due to policy change in going to combos instead of separate plows and spreaders
Material Applications made at relatively high truck speeds	Concord / Lexington / Middleboro	On several occasions excessive bounce and scatter observed with spreaders applying at high speeds (> 40 mph)
Inaccurate or Inconsistent Application Rate Data on Cirus Controller Reporting Forms	Concord	The reported application rate on Cirus controller vendor form did not match with the amount of material used divided by total miles – whereas on Component Tech controllers the application rate matched with miles and material used - the use of applied vs total mileage did not seem to matter – see copies of report forms in Attachment 3.
Inaccurate or Inconsistent Data on Controller Reporting Forms	Middleboro	In Middleboro, it was unclear as to whether application rate based on applied or total miles (see Attachment 3), Also, material usage on loader sheet were different than that reported on Vendor Form; Ex. Feb 21 st loader sheet for Rte 28 says 17.4 tons of <u>salt</u> and 5.0 tons of sand/salt mix, Vendor form says 17.3 tons of 50:50 <u>sand/salt mix</u> and no salt, it is unclear whether vendor form or loader sheet is rolled up into the district material usage records. These type of discrepancies were noted on several events.
Various material conversion factors for loader information	Concord/ Middleboro	Concord uses a conversion rate of yards to tons of 1.15 for salt while Middleboro assumes 1.0 ton per yard; Also, bucket load sizes vary considerably depending on which loader used and amount filled
Inconsistent reporting between loader sheet and time keeper material usage sheet	Concord/ Middleboro	Occasionally time keeper info does not match with loader sheet or time keeper reports loads in yards per bucket and other times tons per bucket without indicating units
Sand:salt mix appeared ineffective in RSZ at cold temps- use of straight salt	Middleboro	In Middleboro, in particular, during 3 to 4 storms the operator switched to straight salt because the sand/salt mix was not effective with cold pavement temperatures
Multiple consecutive applications on same route; unclear if these applic. were directed by Depot Foreman	Concord/ Middleboro	During several events, spreader operators were observed performing multiple consecutive applications on same route until truck was emptied; field observers were not sure if this was standard protocol for storm pre-treatment directed by depot personnel or based on operator judgment
Spinning off excess material on roads on way back to shed	NA	This practice was not observed at any of the locations during either season; Spinning off of material was observed within the sheds

Discussion

Overlapping routes or routes with more than one truck treating the same roadway was frequently observed and this could lead to an over-application of materials. In most areas, the amount of roadway receiving applications from multiple trucks was less than 0.5 mile but in some cases such as in Westminster as much as 1.0 mile of roadway was estimated as being “treated” by multiple spreaders due to overlapping adjacent routes. The route overlap extended beyond one interchange on an east-west route. Given that there are perhaps hundreds of spreader routes throughout the state that overlap to some degree, there could be tens if not hundreds of roadway miles that may be receiving excess applications during each storm event. For discussion purposes, if we assume that

approximately 10% of the roughly 14,000 lane-miles currently maintained by MassDOT are part of a route overlap and each overlapping spreader applies to these roadway segments, then approximately 140 lane-miles are receiving excess deicing materials. This is likely to be a conservative estimate of the amount of overlapping routes statewide. MassDOT should re-evaluate the current spreader routes to minimize overlaps or at the very least have adjacent depots coordinate to determine which spreader will be responsible for overlapping road segments and which spreaders should turn off their units as they pass through these sections.

On a related issue, overlaps are also likely due to certain spreaders being designated only to treat ramps while other spreaders are designated to treat the mainline. For most interchanges, it appears that both spreaders are treating the interchange roadway miles. Perhaps a route optimization exercise may be in order to avoid having separate spreaders for ramps and roadways and the overlapping applications.

On roads with multiple travel lanes, there was often more than one spreader used to treat the various lanes. In Concord, for instance, on Route 2 there were often two spreader combos treating the two travel lanes going west and these trucks were often operating side by side or traveling in same direction within 15 minutes of each other. It was observed that for at least one of these trucks, the operator set the controller setting at 480# suggesting that he was treating both lanes at once resulting in an application rate of 240 lbs/lane-mile. But with two spreader combos treating this road, it would seem more appropriate to have the controller settings at 240 bs/ln-mile. Otherwise, if both trucks are applying at rate of 480#, this would result in twice the targeted application rate.

During the 2nd winter monitoring season, much of the reported and observed application rate data indicates that material applications were done at rates greater than the target rate of 240 lbs/lane-mile set by MassDOT Policy. This is based on the data reported on vendor forms as well as that tallied through bucket counts and observed miles. The typical application rate ranged between 300 and 600 lbs/ln-mile. Reported application rates for Route 44 in Middleboro appeared to be the most consistent to the target rate. After January 7th, the MassDOT spreader truck was equipped with a Cirus™ closed-loop controller and had reported application rates close to 240 lbs/ln-mile for most events but the reported application rate was generally based on total miles and not applied miles. Use of applied miles on at least one occasion would have resulted in a higher reported application rate.

On January 28th, 2010, a pre-storm or an apparent preventative application was observed on Route 495 northbound in the Andover area (see photo in Attachment 1). This observance occurred outside of a scheduled monitoring event. In this instance, a vendor truck was applying what appeared to be dry salt to dry pavement at a relatively high speed that resulted in extensive scatter or bounce of material. A majority of the material appeared to be bouncing off the roadway and would likely result in wasted material. Presumably this application was being made as a preventative measure prior to a pending cold front that eventually produced severe snow squall conditions later that evening. It would be difficult to speculate if other similar applications were made that afternoon on other routes, but it is likely that most of the applied material was lost off the roadway before it had a chance to have an effect. A direct, liquid application or at least pre-wetted salt may have been more effective.

With respect to liquid material usage, for the most part it appeared most operators were using liquids for pre-wetting purposes but the pre-wetting rates may have been on the low side. Liquid usage was not always reported but when it was it generally at a rate of 2 to 10 gallons per ton and most often in the range of 6 to 8 gallons per ton. There were no observations or reported data received for pre-storm, direct liquid applications. The crews generally did not encounter any pre-storm direct applications even though on several occasions the crews arrived at depots well before the onset of precipitation. On more than one occasion in Middleboro, it was noted that the contractor appeared to be not using his pre-wetting equipment; this was based on no noticeable change in the fluid level in the saddle tanks throughout the 12+ hours of monitoring and no tank filling was observed. Also, in Storm #4, the Cirus controller report on Rte 44 indicated no pre-wetting. In Concord, it was reported that one MassDOT spreader was not equipped to pre-wet equipment and one vendor reported having problems with the tank pump.

As far as observations made in Reduced Salt Zones, it was apparent during several snow storms especially in Middleboro that the 50:50 sand/salt mix had limited effectiveness in preventing hard pack from forming on the road surface during cold temperatures (18-22°F) in January 2011. On several occasions, the operators switched to straight salt mid-storm and based on the reported material usage data were often using nearly as much or even

more salt than on the regular routes. The reported material usage for the RSZ route in Oxford also suggested that more salt may have been used in the RSZ route, however, the length of the overall route was not confirmed such that the application rate could not be verified. In Concord, the operators relied on 50:50 mix of premix and sand but on several occasions needed to rely on straight pre-mix applications. On one occasion, straight salt was used.

With respect to comparing the performance of closed-loop vs. open-loop controllers, field observers did note that the material applications behind closed-loop controller-equipped spreaders visually appeared more uniform and well distributed across the pavement surface. The reported material usage data for the closed loop controllers was often much less and as much as 50% less than that used with open-loop controllers. However, the material usage and mileage data recorded by field crews rarely matched what was being reported by the vendor for the same truck. In Concord and Middleboro, the reported application rate on the vendor forms for the Cirus controller did not match with the overall material usage and miles traveled. The source of this error is unknown. Whereas the reported application rate for the Component Tech controller did seem to match with material used and miles (see Attachment 3). During a training session on Jan. 4th, the Cirus representative stated that the resulting application rate will be affected by both the application setting and the spinner rate such that if the application rate is set at 240 lbs /ln-mi and the spinner rate is set at 2, the resulting output on display will be 480 lbs/ln-mi (see memo in Attachment 3). The operator in Concord with the Cirus controller was reported to have set the application rate at 480# but it is unclear what spinner rate was used. The Cirus representative also said that the Middleboro controller was set to be “locked in” at 240# and only the spinner could be adjusted. This may explain why the Middleboro data appeared to be closer to 240# for most events. However, the application rate in Middleboro did not match with the total miles or applied miles for most events (see Attachment #3). It would seem that applied miles would be more appropriate but this would result in a higher application rate.

It is uncertain as to how critical these reporting issues may be in terms of the data that is rolled up into the Depot summaries of material usage by event and on a seasonal basis. In any event, it would seem important to have greater confidence and understanding of the data that is being reported by these controllers for specific routes. To address this issue, MassDOT should rely on calibration testing of the controllers using known quantities and various controller settings to gain a sufficient level of confidence in the data rather than rely on observations during winter events. Additional hands-on training at each depot with Cirus representatives and perhaps other manufacturers may be helpful.

Discrepancies in the loader sheets and vendor reporting forms were also observed on multiple occasions. On several events, there were differences in the type of materials and quantities reported on the loader sheet versus that reported on Vendor forms. The reported quantities on the Timekeeper material usage sheets also varied at times from yards, buckets and tons per load, which can be confusing or lead to inaccurate reports. Again, it is unclear as to which source of data is used in the annual reporting or developing storm event summaries and whether these discrepancies have any ramifications to the end of year or event summaries. Perhaps at the very least, the reporting procedures could be a topic of discussion during the training sessions, if they are not already.

In summary, although several practices and activities as discussed above could certainly be improved with a variety of measures, it appears in general, based on the limited observations conducted to date, that the overall S&I operations and activities are being carried out consistent with the MassDOT S&I policies and procedures.

Recommendations

Reporting

- Revise the MassDOT Vendor Closed-Loop Ground Speed Control Report Form:
 - Consider adding space for pre-storm and post-storm mileage readouts to ensure pre-storm mileage is zeroed-out and add space to record # of trips, mileage per trip, etc.
 - Add space to report controller application rate setting,
 - Drivers should also report their spreader route, number of applications, number of miles driven, and amount of material used.
 - Alternatively, use of GPS-enabled equipment would help to report mileage & trip information.
- Add at least one training session at each depot with closed-loop controller representatives for vendors and depot personnel;
- Install wireless data download stations in depot to allow data transfer after each event;
- Loader bucket sizes and weights for various materials should be standardized as there seems to be differences in the factors used at different depots. Having variable sized loaders at same depots also adds potential error to material usage.
- Reporting protocols should be highlighted in annual training to improve consistency in units and data.

Calibration/Equipment Settings

- Conduct actual field calibration/testing at depots using controllers at various gate settings and other controller settings to quantify and verify material output; consider using different materials as well;
- Review policy for setting controller settings with depot personnel for routes using multiple spreaders covering same lane-mileage; It would seem output should be set for 240 lbs/lm-mi when more than one truck is treating same roadway.
- Coordinate and conduct periodic random audits of third-party contractors that are used by vendors to certify equipment calibration.

Route Optimization /Coordination with Plows

- Coordinate with District personnel to evaluate spreader routes and identify ways to reduce route overlaps, designate who is responsible for treatment when overlaps cannot be avoided and optimize the treatment of ramps vs. mainline roadway.
- As part of the route evaluation, identify opportunities to utilize the most efficient equipment (i.e., closed loop controllers, direct liquid applicators, etc.) and the best operators in known environmental sensitive areas.
- As a long term goal, the integrated use of GPS/GIS software with the spreader controllers would allow the use of geo-fencing where spreaders would automatically shut-off or adjust applications in selected areas such as overlapping routes.

Equipment/ Material Usage

- Develop a statewide inventory database of equipment availability and capabilities for each depot and route, with respect to spreader controller type, pre-wetting equipment, plows and direct pre-storm liquid applications.
- Reduce the use of sand in Reduced Salt Zones through other sand/salt ratios and/or use of other materials.
- Perhaps the pre-wetting liquid application rates should be increased to be in the range of 10 to 12 gallons per ton or more.

Attachment 1:

Summary of Second Winter Season Observations Recorded In Concord and Middleboro

The following presents a summary of observer notes that were recorded during various storms at specific depot location during the 2011 monitoring season. This is not a complete list but a summary of some of the more frequent practices and/or significant issues noted.

CONCORD DEPOT:

- Truck (K Carroll) straddled the skip lane in order to treat both left and right lanes.
Storm 1: 12-22-2010
- Treatment was ceased during periods of intense snowfall. During this time only plowing of the roads was completed due to rapid accumulation rates.
Storm 2: 12-26-2010
Storm 5: 1-11-2011
Storm 7: 1-21-2011
Storm 8: 1-26-2011
- Truck Driver (Lalicatta) informed crew that saddle tanks are set to only pre-wet material if the setting is 5 or higher on the controller. Pumps will not kick on if the dial is set to anything under 5.
Storm 2: 12-26-2010
Storm 5: 1-11-2011
- A calibration inspector from the state came to Concord depot and changed Lalicatta's gate opening from 2.25'' to 3''.
Storm 2: 12-26-2010
- The open loop trucks were observed having the output of materials sputter on and off at an irregular pattern in regards to truck speed. The auger is always spinning at the same speed and the material is dropped into the auger at the driver's control. Pre wetting liquid observed leaking out when truck comes to a stop.
Storm 6: 1-18-2011
Storm 8: 1-26-2011
- When only one spreader treats loop, only shoulder and ½ of the right lane are being treated (observed that treatment does not seem necessary).
Storm 6: 1-18-2011
- While on Route KSC ran out of salt, auger still spinning, no material available.
Storm 6: 1-18-2011
Storm 7: 1-21-2011
- Plow battery plowed road less than 30 minutes after treatment.
Storm 6: 1-18-2011 (twice)

- Truck (KC) was loaded with straight salt and told to treat low salt area and “where ever else he was directed to go”. Observed that treating low salt area with straight salt may be due to dangerous conditions.
Storm 6: 1-18-2011
- Road was treated during normal rain storm.
Storm 6: 1-18-2011
- Route was treated by both trucks applying material three times at the beginning of the storm when roads were still black and wet. Over treatment? One hour after this occurrence, after some snow had accumulated on the road, a plow battery plowed the road and a pretreatment liquid truck applied liquid treatment on the route. Over treatment or not proper use of pretreatment liquid material?
Storm 7: 1-21-2011
Storm 8: 1-26-2011
- Excessive bouncing of salt off the roadway due to lack of pre-wetting and truck speeds greater than or equal to 40 mph.
Storm 5: 1-11-2011
Storm 8: 1-26-2011
- Cirrus controller not turned on and truck still spreading material.
Storm 8: 1-26-2011
- Cirrus controller truck observed to be treating roadway much more evenly when traveling a slower speeds.
Storm 8: 1-26-2011
- Trucks observed to be “hitting it hard” before a storm was about to hit. This caused confusion and many trucks treating same roadway where others had already treated.
Storm 9: 2-1-2011
- Salt observed to be non-effective by timekeeper because roadway temperatures were too cold for the salt to be effective.

The following /observations were pulled from Arc Pad data recorded during the 2011 monitoring season

CONCORD DEPOT:

- Storm 5: GEOSPHERE Vehicle Observation: additional unknown vehicle treated traffic circle.
- Storm 5: VHB Station Observation: Last application inconsistent.
- Storm 5: VHB Vehicle observation: Jim informed VHB of spreader issue at Tracy’s corner of inconsistent spreader function.
- Storm 5: VHB Vehicle Observation: Conveyor did not stop while at full stop at Tracy’s corner.
- Storm 5: VHB Vehicle Observation: Traveling at excessive speed. Out of material at Rt-128 (1 full route completed).

- Storm 6: GEOSPHERE Vehicle Observation: KSC set at 480lbs/ln mile. No change in spreader speed with truck speed (i.e. ramps loaded up).
- Storm 7: GEOSPHERE Vehicle Observation: snow falling too hard to treat.

MIDDLEBORO DEPOT:

- Storm 1: SDE Vehicle Observation: no pre-wetting, lots of bounce and scatter off road about 6pm.
- Storm 1: SDE Vehicle Observation: double treated several ramps. No pre-wetting.
- Storm 1: SDE Vehicle Observation: Gate opening measured 3.5 inches in, at times speed up to 38 MPH, higher volume spread on intersections/bridges.
- Storm 2: SDE Station Observation: MassDOT 1252 has not plowed route but it appears to have been plowed by someone else.
- Storm 4: SDE Vehicle Observation: not pre-wetting.
- Storm 4: SDE Vehicle Observation: driver dropped pile of excess salt onto road after completing run of 44EB, created a pile of salt. After application the plow battery plowed the road on route and the spreader followed again, used 1.5 tons of salt.
- Storm 4: SDE Vehicle Observation: Driver did not stop applying material between Route 58 and spring street so extra lane miles treated.
- Storm 4: SDE not pre-wetting, some bounce and scatter off shoulder.
- Storm 5: SDE Vehicle Observation: suspect calibration of Cirrus control not correct for different material.
- Storm 5: SDE Vehicle Observation: Spreading CaCl Cirrus controller not calibrated for CaCl running on salt settings, pre-wet at 6 MgCl per lane mile.
- Storm 6: SDE Station Observation: snow has bonded to parts of rt 28 roadway, likely due to cold pavement temps.
- Storm 7: SDE Vehicle Observation: some bouncing salt travelled into shoulder and left lane.
- Storm 7: SDE Vehicle Observation: Issue with pre-wetting equipment.
- Storm 7: SDE Vehicle Observation: roads not in great condition so gate set to 3 inches.
- Storm 7: SDE Vehicle Observation: Salt appeared to get bound up in truck for a short while, spinner was spreading but no salt being applied.
- Storm 9: SDE Storm Summary: State truck 1252 cirrus controller malfunction.
- Storm 9: SDE Vehicle Observation: State truck 1252 not working properly, some bounce and scatter occurring, spinner belt set just under 2.

Attachment 2:

Photo of Pre-storm Application on Rte 495 in Andover on January 28, 2010

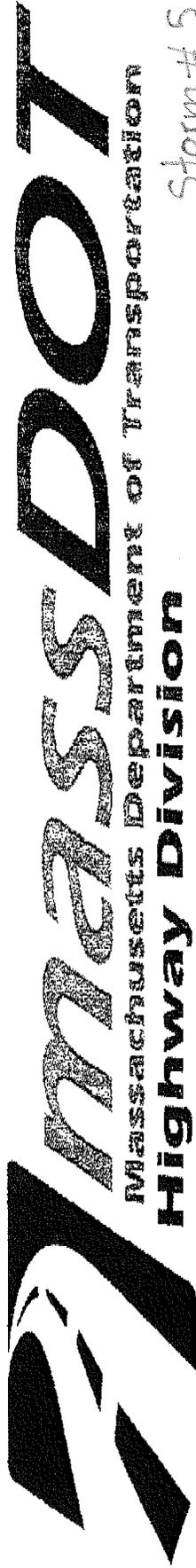


Attachment # 3

Copies of Concord Vendor Controller Report Forms for Storms 5 thru 10

Copies of Middleboro Vendor Controller Report Forms Storms 4 thru 8

Meeting Notes from Cirus Training Session on Jan 4th in Raynham, Mass



Storm # 5

Vendor Closed Loop Ground Speed Control Report Summary

Date	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1-11-12	4711	03152	KEITH CARROLL			CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
(3)	SALT	52859	56	419.6	2	481
Reset	SAND	6726.4 tons				
After Spinning	PRE-MIX			52859 / 419.6 mi		= 126.165 / mi
Off	LIQUIDS					
	50/50					
Comments:						
Timekeeper <i>[Signature]</i>						
Time Worked 23,90 hours						

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Vendor Closed Loop Ground Speed Control Report Summary

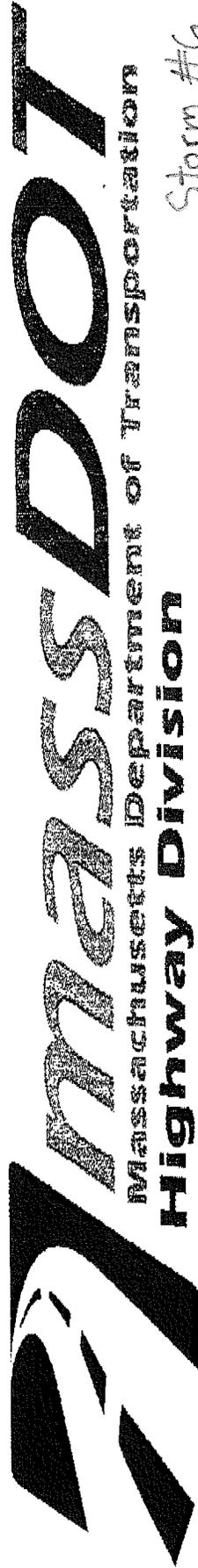
Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1-11-12	4711	02673	K. M. CARROL			COMPONENT TECH
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
	SALT	47943		955	2	502
Reset	SAND	φ → 240 tons				
After Spinning	PRE-MIX	φ	47,743 lbs	95.5 km	=	502 ✓
Off	LIQUIDS		360			
	50/50	φ				

Comments:

Timekeeper

Time Worked

Instructions for Closed Loop Ground Speed Control Report Summary: This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
	4711	03152	KEITH CARROLL			CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
3	SALT	93691	96 ≈ 2 gal/ton	194.9	2	495.3 ←
Reset	SAND	16,8 tons	Salt miles -	117.9		
After	PRE-MIX		93,691 / Total miles	194.9	=	480.7 lbs/ln-mi
Spinning	LIQUIDS		93,691 lbs / supplied miles	117.9	=	795 lbs/ln-mi
Off	50/50					

Comments: 35 Ton. of Pre mix? 1 yard spread out.

Timekeeper: *[Signature]*

Time Worked: 25.80 Hours

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Stovun * Co

Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1/8-1/9	4711	02673	K. M. CARROL			COMPONENT TECH
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
	SALT	97604		187.7	2	520 lbs/mile
Reset	SAND	Ø 48.8 tons				
After	PRE-MIX	Ø	97604 lbs	187.7 miles	=	520 lbs/mile
Spinning	LIQUIDS		(355)			
Off	50/50	Ø				

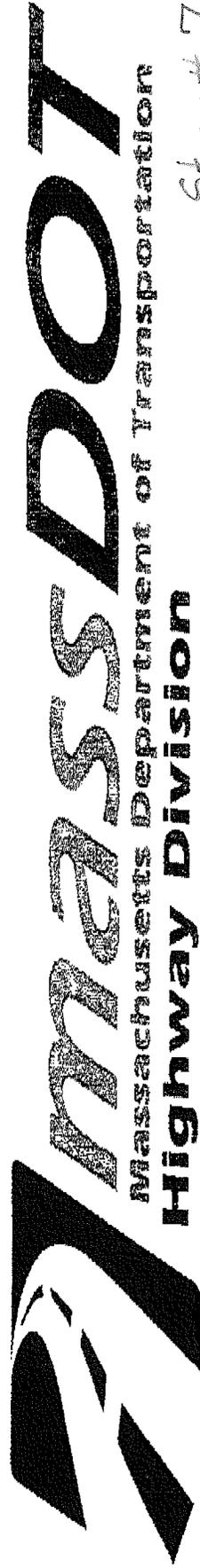
Comments: System Doesn't Do Over All Miles. 1/2 Yard Spined out.

[Signature]

25.93 Hours

Timekeeper
Time Worked

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Storm # 7

Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
11-21-11	4711	03152	KEITH CARROLL			CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
4	SALT			104.6		
Reset	SAND	(AAT)	Salt	46.1		
After	PRE-MIX	39802	0	150.6	2	490.8
Spinning	LIQUIDS		39,802 lbs	104.6 total		380.5 lbs/in-mi
Off	50/50		39,802 lbs	46.1 applied mi		86.34 lbs/in-mi

No match

Comments:	27 Ton. of Pre mix from Lex. Spined out 1 yard					
Timekeeper	<i>[Signature]</i>					
Time Worked	13.57 Hours					

Instructions for Closed Loop Ground Speed Control Report Summary. This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1-21-11	4711	02673	K. M. CARROL			COMPONENT TECH
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
2.75	SALT	28256 (41131)		57.3	2	493 ✓
Reset	SAND	∅				
After	PRE-MIX	∅				
Spinning	LIQUIDS		420			
Off	50/50	∅				

Comments: unload 1.5 yards

Timekeeper: *[Signature]*

Time Worked: 13.92 Hours

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



MassDOT
 Massachusetts Department of Transportation
Highway Division

Storm #8

Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1-24-27-11	4711	03152	KEITH CARROLL	3:12 PM		CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
(4)	SALT	32,746	30 ≈ 2.0 gallons per ton	149.3	2	413.2
Reset	SAND	16.4 tons	salt	56.5		
After	PRE-MIX			(79.2)?		No match
Spinning	LIQUIDS		Applic. Rate 32,746 lbs	149.3 mi	219.3	lbs/mi
Off	50/50		32,746 lbs	56.5 mi	579.5	lbs/mi

Comments: unload 1.5 yards 32,746 lbs / 413.2 lbs-mi = 79.2 miles

[Signature]

Timekeeper
 Time Worked 22.62 Hours

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



MassDOT

Massachusetts Department of Transportation
Highway Division

Form # 8

Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
1-26-27-28	4711	02673	K. M. CARROL	3:48 PM	1:41 PM	COMPONENT TECH
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
	SALT	64661		134.6	2	480
Reset	SAND	Ø 32.3 tons		64.66116 / 134.6 mi	=	480 ✓
After	PRE-MIX	Ø				
Spinning	LIQUIDS		350			
Off	50/50	Ø				

Comments: un load 2 yds Loader Sheet says
 Timekeeper: *[Signature]* 27.6 tons salt
 Time Worked: 21.53 hours

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.

COMBO MATERIAL SHEET

WINTER 10-11

DISTRICT FOUR

CONCORD

RJ #

DAD

START DATE

1-26-11

SALT

FINISH DATE

1-27-11

PAGE #

Storm # 8

K. CARROLL		K. CARROLL		KM CARROLL		LALICATA		STATE		VAIL	
#	BUCKETS / TIME	#	BUCKETS / TIME	#	BUCKETS / TIME						
2 1/2	- 355	2 1/2	- 432	2	- 355	1	- 114	2	- 535		-
2	- 535	2	- 828	2	- 844		-	2	- 828		-
2	- 828	2	- 1141	2	- 252		-	2	- 959		-
2	- 959	2	- 514	1	- 710		-	2	- 1102		-
2	- 1141	2	- 816	1	- 959		-	2	- 514		-
2	- 200		-		-		-	1	- 636		-
2	- 732		-		-	8' buckets		2	- 737		-
2 1/2	- 814		-		-	24 yds		1	- 816		-
	-		-		-	2 3/4 tons		1 1/2	- 959		-
	-		-		-				-		-
	-		-		-				-		-

SAND 50/50

K. CARROLL		K. CARROLL		KM CARROLL		LALICATA		STATE		VAIL	
#	BUCKETS / TIME	#	BUCKETS / TIME	#	BUCKETS / TIME	#	BUCKETS / TIME	#	BUCKETS / TIME	#	BUCKETS / TIME
	-		-		-		-		-		-
	-		-		-		-		-		-
	-		-		-		-		-		-
	-		-		-		-		-		-



Storm # 9

Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
2/1/11	4711	03152	KEITH CARROLL			CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
4	SALT	62,250	93 ≈ 3 gal per ton	98.4	2	500.4
Reset	SAND	31.12 tons	salt	78.7	- assume applied miles	
After	PRE-MIX	Application Rate Calc	Straight Mileage	98.4 mi	=	632.6 lbs/mi
Spinning	LIQUIDS	Assume twice Applied m.	2x(Applied m)	157.4 mi		395.5 lbs/mi
Off	50/50	Assume twice total mileage	2x(Total m)	196.8 mi		316.3 lbs/mi

Comments: 4 y and on Truck NO match to 500.4 lbs/mi

Timekeeper: [Signature]

Time Worked: 12.30 hrs

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Vendor Closed Loop Ground Speed Control Report Summary

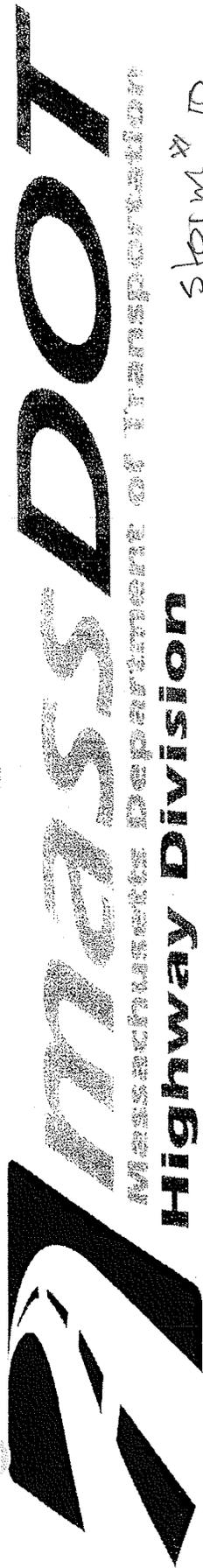
Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
2-21-11	4711	03152	KEITH CARROLL			CIRUS
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
3	SALT	19347		29	2	513?
Reset	SAND	9.67 tons	salt	26		
After	PRE-MIX					
Spinning	LIQUIDS		Applic Rate	19347 lbs / 29 mi =		667 lbs/m-m.
Off	50/50			19347 lbs / 58 mi =		333 lbs/m-m.

Comments: Can load 77 subs 1

Timekeeper: *[Signature]*

Time Worked: ~~8.0~~ Hours worked

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.



Vendor Closed Loop Ground Speed Control Report Summary

Date:	Depot	Equipment No.	Contractor	Start Time	End Time	Manufacturer
2-21-4	4711	02673	K. M. CARROL			COMPONENT TECH
Gate Setting	Material	Pounds	Gallons	Total Miles	Lanes Spread	Avg. Application Rate
	SALT	23598		46	2	513 ✓
Reset	SAND	∅				
After	PRE-MIX	∅				
Spinning	LIQUIDS		∅			
Off	50/50	∅				

Comments: *unloaded 3 yards*

Timekeeper: *[Signature]*

Time Worked: *8.5 hours*

Instructions for Closed Loop Ground Speed Control Report Summary This form is to be filled out by the contractor and given to the timekeeper at the end of each storm period for every piece of equipment that has a closed loop ground speed control unit. Failure by the contractor to submit this form at the end of each storm period may result in the incentive hourly rate not being applied.

Information from Cirrus controller at end of storm event.
1/8 to 1/9

Middleboro State Truck

Total mi	270.6
Average MPH	18
Salt mi	171.7
Salt hrs	7.4
Salt lbs	44582
Average Salt lbs per mi	259.6
Brine mi	171.7
Brine hrs	7.4
Brine gal	0

} based on applied miles

} prewetting was not used during this storm

Storm #5

01/19/2011 10:32

(FAX)

P.011/014

Middleboro
State Truck
Ate 44

Cirus information from Storm 1/12-1/13

Total Miles	478.8
Average MPH	16.9
Salt Miles	307
Salt Hrs	13.3
Salt lbs	116445
Average lbs per Inmi	244.2
Brine Miles	307
Brine Hrs	13.3
Brine Gal	347
Average Brine gal per ton	5.9

Based on
Total Miles

379.3 lbs/in-mi
based Salt Miles

Storm # 6
Middleboro
State Truck

Cirrus information from Storm 1/18

Total Miles	134.4
Average MPH	16.3
Salt Miles	93.8
Salt Hrs	3.4
Salt lbs	36447
Average lbs per Inmi	241.6
Brine Miles	93.8
Brine Hrs	3.4
Brine Gal	61
Average Brine gal per ton	3.3

← does not match to total or applied miles
 ↳ rate = 388.5 lbs based on applied
 ↳ 271 lbs/in-m based on total

↳ seems low

NOTE

Totals as of 1 pm 1/18. More treatments expected to have taken place

Storm # 7

Cirrus information from Storm 1/21

Total Miles	175.7
Average MPH	14.4
Salt Miles	115.6
Salt Hrs	4.7
Salt lbs	49986
Average lbs per Inmi	237.1
Brine Miles	115.6
Brine Hrs	4.7
Brine Gal	148
Average Brine gal per ton	5.9

← does not match
to total or salt
miles

→ 284.5 lbs/ln-mi
based on total

→ 432.4 lbs/ln-mi
based on Salt
miles

Storm #8
middleboro

Cirrus information from Storm 1/26-1/27

Total Miles	330
Average MPH	14
Salt Miles	194.3
Salt Hrs	9.1
Salt lbs	97348
Average lbs per Inmi	241.7
Brine Miles	177
Brine Hrs	8.5
Brine Gal	266
Average Brine gal per ton	5.9

— does not match
to total or salt
miles
→ 295 lbs/In-mi
based on total
→ 501 lbs/In-mi
based on
Salt miles

This is just for Rt 44 State sander 1252



Vanasse Hangen Brustlin, Inc.

101 Walnut Street
P. O. Box 9151
Watertown, MA 02471-9151
617 924 1770
FAX 617 924 2286

Memorandum

To: Bill Arcieri
Kristen Bean
Dale Abbott

Date: January 4, 2011

Project No.: 52011.00

From: Jonathan S. Gould, PE

Re: MassDOT - Winter Monitoring Program
Cirrus Controller Demonstration

On January 4, 2011, Jonathan S. Gould from VHB and Lucas Chapman of SDE participated in a Cirrus controller demonstration at MassDOT's maintenance facility in Raynham, MA. In attendance were Rick Fisher and Joe Brill of Cirrus Controls and included MassDOT Snow & Ice personnel Dave Blodgett, Laurene Poland, area foreman, depot foreman, and operators from District 4 & 5.

Joe Brill – Local Representative (Dudley, MA – cell: 207-522-7131)

The demonstration began with a projector demonstration of the Cirrus controller operation, an overview of components and their operation and configuration. Rick Fisher demonstrated the controller box with toggle switches for solid application, Brine application, and liquid application. He also showed the display unit.

MassDOT has directed Cirrus to set-up the graphics to display the material application rate in LBS/LN-MI for the "Salt Conveyor". Most have been set to intervals of 240, 480, and 720 LB/LN-MI for use by the operator to toggle through. The operator also controls the number of lanes on the "Salt Spinner". To increase the amount of material applied the operator can increase the spinner speed from 0.5, 1, 2, 3, etc... depending on number of lanes. The operator can also increase the LB/LN-MI from 240 to 480 or 720.

IF the operator increases both controls, as is allowed in the current set-up, they would be placing 240 LB/LN-MI times 2 LN-MI totaling 480 LB/LN-MI, or even worse $480 \times 2 = 860$ LB/LN-MI. The display however will display 240 or 480 the entire time unless a max flow situation occurs at which time the unit will alarm.

The Middleboro State truck (Rte 44) has been uniquely configured by Cirrus to only allow application rate changes by utilizing the spinner control. The LBS/LN-MI will always read 240 and will be multiplied by the spinner value. The usual operator was in attendance and is aware of the configuration.

The Brine controls are set for 6 gal/ton; however on state trucks with Pro-line systems (Fixed non-variable motors) at speeds less than 20 mph do not produce enough hydraulic pressure for them to activate. The data collection is based on the solid application so

amount of Brine will always be high and cannot be relied upon. Most private trucks have variable speed pumps which should operate correctly. The operator needs to physically "Fill" the Brine in the controller MENU each time he fills up too.

The control MENU also allows the operator to change Material Types. Up to 10 Material types could be set-up in each truck and will provide storm and season totals individually and cumulatively for each of these.

I.e. - SALT 1	SAND
SALT 2	PREMIX
SALT 3	SAND-SALT 50/50
	SAND-PREMIX 33/66

The calibration information of the first material will be carried through for each additional material or can be calibrated separately if desired. It is assumed that the SALT 1 calibration data would be used for all and a multiplier would be used to when post processing the LBS/LN-MI.

Questions:

Q: Trucks have had the incorrect time and date.

A: This should only occur if they have been RESET to factory defaults or not set-up. A processor battery should last 5 years before needing replacement. The time may be off 1 hr due to daylight savings time.

Q: Is there subtraction for Spin-Off.

A: At 0 speed, all material used is logged as a positive but under material type "OTHER".

Q: Can the operator switch Mix types during a storm event.

A: Yes, any time by going into the MENU and changing materials.

Q: Is the Season data available if the Storm data has been downloaded which erases it.

A: No, the storm totals and season totals are independent of the log file data. By downloading the log file, it does not reset the storm or season totals; likewise if you reset the storm totals it does not delete the log file.

Q: Can MassDOT and Research project both download the Log file.

A: No, once it is downloaded it erases the log data from the SD card. However, the two log files can be combined later on in a directory (assuming they have different filenames or dates). Data is in CSV raw format.

Q: Can we still get data off the Oxford Trucks.

A: Yes, (assuming MassDOT has not downloaded the log file and hopefully the operator changed material types each time he changed materials or it'll all be lumped into one material). The Oxford trucks also should have GPS data associated with them.

Q: What is Blast.

A: Blast has been set to 1200 LBS/LN-MI and comes on for 10 seconds, displayed on the screen for the operator to see. % Blast and QTY Blast are quantified in the reports.

Q: It has been seen that the miles on MassDOT forms are often recorded as total miles driven, and not miles driven while applying.

A: This shows up in the Cirus data correctly with LBS/LN-MI since the data file includes time/miles in "PASS" mode which is when the conveyor is off.

Q: Who will make sure the STORM Totals are reset prior to a storm.

A: MassDOT wants to place the onus for this and total reporting on the contractor.

Lucas and I discussed and will try and remind the contractor prior to a storm starting, but if it was not reset or we arrive late we will record totals "as is" at the beginning and end of shift. Relying on Log files to capture the rest.

DATA DOWNLOAD INFORMATION -----

COMPUTER CONFIGURATION:

Network Connections → Local Area Connection
Internet Protocol (TCP/IP) → Properties
Alternate Configuration → User Configured

IP – 192.168.97.51
Subnet – 255.255.240.0

WIRELESS CONFIGURATION:

Typically use DLINK access points but Linksys or Belkin, etc would also work.
Connect the AP directly to the computer to set-up manually (no internet connected).
Default setting to connect prior to changing the IP are: Start/run: //192.168.0.50

<u>Wireless Configuration:</u>	<u>Lan Configuration:</u>
Band-IEEE802.11g	Get - Static
Mode-Access Point	IP – 192.168.97.124
SSID-DRIVEBYDOWNLOAD	Subnet – 255.255.240.0
SSID Broadcast-enable	Default Gateway – 192.168.1.1
Channel-11	
Open Authentication- enable	
Key Type-HEX 64 Bit	
Validation-First Key	
Key-8B0EA37480	

DATA MINER CONFIGURATION:

None

In the software, a vehicle list needs to be set-up in each download program. Each vehicle's controller and Bridge have unique IP addresses which need to be entered before a download can occur.

The Log Files are saved as:

010111P01.log	- vehicle 1 in the data miner list, day 1
010111P02.log	- vehicle 2 in the data miner list, day 1
010111P03.log	- vehicle 3 in the data miner list, day 1
010211P01.log	- vehicle 1 in the data miner list, day 2
010211P02.log	- vehicle 2 in the data miner list, day 2
010211P03.log	- vehicle 3 in the data miner list, day 2

The "performance report" software looks in the directory:

C:\Program Files\Cirus Controller\Data\

And mines the data based on the dates specified and vehicle id which is located in the log files. Technically I think it would be ok if P04 files were dumped into the same directory and would be combined in a search with the P01 files if the same Truck IP address was found in the log file.

I assume that each download of the log file APPENDS data to the end of the log file until the next date places it into a new file.

DO NOT delete the file: TRUCK.CFG

CONTROLLER CONFIGURATION:

From the MENU: toggle the AUGER and PREWET down at the same time.
Password: 9000

** allows for material types to be added.

6.7 Appendix G

Phase III – Proposed Implementation Plan

General Frame	Time	Area of Improvement	Recommendation	Responsibility
Near Term – FY13 or next 6 to 12 months	Reporting	1:	Install Wireless Data Transfer Equipment in a select pilot study location.	Boston/District
		3:	Revise Vendor Material Usage Form to require more information to validate usage data.	Boston/District
		4:	Review/standardize loader bucket volumes and weights for various materials in each district.	District/Boston
	Training	1:	Consider implementation of Certification Training Program for MassDOT and hired contractors using recent developed online training modules.	Boston/District
		2:	Incorporate a training segment on reporting protocols in annual training to improve consistency in units and data.	Boston/District
		3:	Add at least one training session in each district with controller representative.	Boston/District
		4:	Reiterate the importance of compliance with MassDOT policies and procedures (e.g., truck speeds, pre-wetting, etc.) and possible actions for non-compliance. Perhaps revisit policy to assess performance of hired contractors, and use contractors with good performance history more frequently than others.	Boston/District
	Calibration	1:	Review policy for setting controller settings with depot personnel for routes using multiple spreaders covering same lane-mileage.	Boston/District
	Route Optimization	2:	Identify opportunities to use the most efficient equipment (e.g., closed-loop controllers, pre-treatment applicators, etc.) and best operators in known environmentally sensitive areas.	District
	Equipment/ Material Usage	1:	Develop a statewide database that provides an inventory of equipment availability and capabilities for each depot and route (e.g., spreader controller type, pre-wetting equipment, plows, and direct pre-storm liquid applications).	Boston/District
		2:	Increase use of pavement temperature and weather data for decision making and material selection/application rate.	District
		3:	Enhance/develop process for reporting when and where pre-treatment applications are performed, and recording pre-wetting liquid volumes before and after storms to present total liquid quantities used.	District
	Mid-Term: FY14 or next 1 to 2 years	Training	5:	Consider annual training/coordination sessions with state police and other emergency personnel to discuss roadway conditions, communications, sign messaging, and vehicle speed control methods during winter storm events.

General Frame	Time	Area of Improvement	Recommendation	Responsibility		
		Calibration	2: Develop a pilot program to conduct actual field calibration/testing at a selected depot using known quantities of material, and measure output at various controller and gate settings.	Boston/District		
			3: Coordinate and conduct periodic random audits of third-party contractors that are used by vendors to certify equipment calibration.	Boston/District		
		Route Optimization	1: Coordinate with District personnel to evaluate spreader routes and identify ways to reduce route overlaps, designate who is responsible for treatment when overlaps.	Boston/District		
			3: Integrate use of GPS/GIS software to program spreaders to allow use of geo-fencing to shut off or adjust applications in selected areas such as overlapping routes.	Boston/District		
		Equipment/ Material Usage	4: Reduce the use of sand in Reduced Salt Zones through other sand:salt ratios and/or use of other materials.	Boston/District		
			5: Evaluate use of newer technology and equipment BMPs to control overall material usage in lieu of designated RSZ, which may be causing overall increases in salt use.	Boston/District		
			6: Review and re-evaluate whether the prescribed pre-wetting liquid application rates should be increased to a range of 8 to 12 gallons per ton or more.	District		
		Long-Term – next 3 to 5 years		Reporting	2: Transition to greater use of AVL/GPS-equipped spreader units to electronically record where and when applications are made, along with the amount of material used.	Boston/District
				Calibration	4: Roll out statewide field calibration program to conduct field calibration on certain percentage of state and hired equipment spreader units in each district on a rotating basis.	Boston/District
Equipment/ Material Usage	7: Initiate a pilot program to integrate the use of GPS/GIS software to program spreader controllers through the use of geo-fencing where spreaders to automatically shut off or adjust applications in selected areas such as overlapping routes.			Boston/District		