Optimization of Anti-Icing & Sanding Operations via Mobile Data Collection in Southeast Alaska

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Alaska Department of Transportation
Statewide Research Office
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## Optimization of Anti-Icing & Sanding Operations via Mobile Data Collection in Southeast Alaska

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### Abstract
The Alaska Department of Transportation and Public Facilities (AKDOT&PF) investigated the effectiveness of remote data collection technology to optimize the deicing and anti-icing material distribution methods in the Juneau, Alaska area. Researchers customized an in-vehicle remote data collection system provided by ThomTech Design, Inc. to collect objective data on meteorological conditions and deicing and anti-icing material distribution rates. The researchers also used an evaluation module of the remote data collection system to collect subjective data on the effectiveness of the snow/ice control treatments. The study team then analyzed this data with ArcVIEW GIS software to reveal opportunities to optimize the performance and cost effectiveness of AKDOT&PF’s regional snow and ice control program.

The study revealed that remote data collection technology promises to be an effective tool for optimizing the cost effectiveness of snow and ice control treatments in Juneau, Alaska. Additional data collection and analysis are necessary to more clearly establish performance and cost effectiveness of various treatments in Juneau’s variable winter climate.

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- Optimization
- Evaluation and assessment
- Magnesium chloride
- Sprayers
- Data collection
- Geographic information systems

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Alaska State Flag
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The Research Team Members

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ABSTRACT

The Alaska Department of Transportation and Public Facilities (AKDOT&PF) investigated the effectiveness of remote data collection technology to optimize the deicing and anti-icing material distribution methods in the Juneau, Alaska area. Researchers customized an in-vehicle remote data collection system provided by ThomTech Design, Inc. to collect objective data on meteorological conditions and deicing and anti-icing material distribution rates. The researchers also used an evaluation module of the remote data collection system to collect subjective data on the effectiveness of the snow/ice control treatments. The study team then analyzed this data with ArcVIEW GIS software to reveal opportunities to optimize the performance and cost effectiveness of AKDOT&PF’s regional snow and ice control program.

The study revealed that remote data collection technology promises to be an effective tool for optimizing the cost effectiveness of snow and ice control treatments in Juneau, Alaska. Additional data collection and analysis are necessary to more clearly establish performance and cost effectiveness of various treatments in Juneau’s variable winter climate. The researchers have recommended the following actions:

- Include the use of a road friction measuring device to eliminate subjectivity in evaluating performance of anti-icing and deicing treatments.

- Integrate the vehicle-borne sensors with AKDOT&PF’s future Road Weather Information System (RWIS).

- Prepare a detailed procedure roadmap that describes each step and method in the data collection process for the MgCl dispersion and the evaluation truck.

- Expand the evaluation runs to include pre-application and post-applications at sufficient intervals for as long as it takes to determine when the MgCl breaks the ice and how long it is effective.

- Record ancillary information such as weather prior to treatment, weather forecast, number of gallons used, number of miles the truck traveled, how the decision was made to treat the roadway, and other descriptions that may impact the collection of data for that treatment/evaluation period.

- Highlight the three parameters that seem to have the largest effect on the MgCl treatment, that is; weather, traffic, and application rate.

- Install state-of-the-art direct liquid dispensing equipment with data-enabled controller and equipment for more accurate and comprehensive recording of liquid treatment use.
SUMMARY OF FINDINGS

A. Findings.

1. Successful optimization of snow/ice control treatments requires a comprehensive understanding of the interaction between meteorological and treatment variables.

2. Several aspects of this study have never been attempted before. Many government agencies are struggling with evaluating level of service from the several methods of treatment. This study is the first of its kind to attempt to objectively and subjectively optimize a selected snow/ice control treatment (in this case MgCl) and then examine ways to improve effectiveness, increase efficiency, and reduce costs.

3. Results to date include limited evaluation over a single winter season. The mild winter, initial equipment problems, prevented collection of a comprehensive set of data from which to draw definitive conclusions. The researchers recommend ongoing data collection and analysis.

4. The data exists to make objective and subjective comparisons between treatments. The mapping and reporting power present in AK DOT/PF is extensive and the data manipulation skills are outstanding.

5. The evaluation data collected was smartly done and the data is valuable and useful. Great care was taken to ensure that the software and hardware worked to their satisfaction.

6. Greater communications between the research members would have been helpful earlier in the season, the process seemed to run smoothly only towards the end of the season.

7. The cost of the research was not in excess of the potential benefits. The resources required to collect and analyze data in the future are available, affordable, and practical.

8. The cost per snowplow for the data collection equipment is approximately $1850/plow. The cost for the evaluation equipment is $7500/truck (one per fleet). The analysis costs are difficult to assess, average cost in engineering/technical labor is approximately $800/storm.

9. A modest estimate of 10% reduction of Magnesium Chloride applied to the 21 lane-mile stretch of Highway 7 (Egan Road) in Juneau results in a savings of $8543/ year. This estimate does not include benefits from the improvement in safety (operator & motorist), reduced impact on the environment, increased efficiency by route, and decreased equipment maintenance and storage costs.
B. Recommendations.

1. Prepare a detailed procedure roadmap that describes each step and method in the data collection process for the MgCl dispersion and the evaluation truck. See Appendix C (User’s Manual).

2. Expand the evaluation runs to include pre-application and post-applications at sufficient intervals for as long as it takes to determine when the MgCl breaks the ice and how long it is effective.

3. Establish a logbook for recording ancillary information such as weather prior to treatment, weather forecast, number of gallons used, number of miles the truck traveled, how the decision was made to treat the roadway, and other descriptions that may impact the collection of data for that treatment/evaluation period.

4. Appoint a person to be in charge of the data collection effort that can assemble the data and examine the data set soon after the treatment/evaluation period. If a consultant is used, send data after each storm to team members to look for completeness, accuracy, and adjustments.

5. Continue this research for an additional season, anticipate a representative winter weather season, and incorporate the suggestions and recommendations from the research team members.

6. Highlight the three parameters that seem to have the largest effect on the MgCl treatment, that is; weather, traffic, and application rate. Include the time of day in relation to the temperature/dew point/pavement temperature for choosing “when to treat”.

7. Extend the study to other portions of the Southeast Region, and use the data collection equipment for summer maintenance activities.

8. Modify the evaluation software to include the run number and traffic flows.

9. Expand study to include granular material distribution and other routes within the Juneau area.

10. Replace the existing MgCl liquid dispensing equipment with data-enabled controller and equipment for more accurate and comprehensive recording of liquid treatment use.

11. Use a friction measuring device to improve evaluations of treatment effectiveness.
INTRODUCTION AND RESEARCH APPROACH

A. Problem Statement & Research Objective

The Alaska Department of Transportation and Public Facilities (AKDOT&PF) uses liquid magnesium chloride (MgCl) and other chemicals to maintain roads in a bare and wet condition. AKDOT&PF determines the timing of application and application rate of deicing and anti-icing chemicals by subjective judgment in response to many dynamic variables. Increased road maintenance needs in conjunction with stable or declining maintenance budgets have emphasized the need to optimize the cost effectiveness of anti-icing and deicing activities. AKDOT&PF believes that using subjective judgment may not lead to the most cost effective use of anti-icing and deicing chemicals.

Anti-icing and deicing operations in Southeast Alaska’s maritime climate are especially challenging given the extensive range of precipitation and temperature during the winter months. While strategically-placed road weather information systems (RWIS) can provide valuable information to road maintenance decision makers, this infrastructure is not yet in place in Southeast Alaska. In this region, AKDOT&PF maintenance forces use exclusively subjective criteria developed from operator experience to determine quantity and timing of chemical use for anti-icing activities.

While several dynamic variables impact the effectiveness of road treatment activities during the snow and ice season, this research effort seeks to examine the relative impact of the following variables.

- Type of chemical (i.e. Magnesium Chloride (MgCl), Calcium Chloride (CaCl), Sodium Chloride (NaCl), etc.).
- Amount of chemical used in each application (i.e. direct liquid of 35 gallons/lane-mile (gal/mi), granular of 300 pounds/lane-mile (lbs/mi), prewet of 20 gallons/ton (gal/ton), etc.).
- Type of snow & ice on roadway (i.e. packed snow, slush, black ice, etc.).
- Amount of traffic on Roadway (i.e. high, medium, low).
- Weather conditions (i.e. temperature, dew point, humidity, pavement temperature, precipitation, etc.).
- Timing (time of day, when evaluated, level of service achieved in certain number of hours, etc.)

The research sought to answer the following questions:

- Was the remote data collection technology useful for optimizing chemical usage? How?
- How cost effective was the technology for optimizing chemical use?
- How can AKDOT&PF use remote data collection technology to improve the effectiveness and economy of deicing/anti-icing operations?
• Other objective observations/recommendations to help AKDOT&PF’s Maintenance & Operations (M&O) decision makers decide whether or not to invest further in this technology.
• What operational/procedural improvements are necessary for successful implementation of remote data collection technology in Alaska.

B. Scope of Study

There are several other factors that may contribute to the overall level of service achieved, such as weather forecast, equipment availability, time of day, etc. The number of combinations of variables can become quite cumbersome; however, by putting limits on the possible configurations, the study becomes manageable. The elements of each configuration consisted of: air temperature, pavement temperature, humidity, dew point, barometric pressure, GPS location data (latitude, longitude, speed, heading, date, time), and hydraulic controller information (plow up/down, material distribution rate).

The study also requires a control segment. This is a segment of road that is representative of the test roadway and is treated the same way each time.

The roadway study section was Egan Drive (State Highway 7) in Juneau, Alaska. The routes of interest for the evaluation are #296001 & #296002. This is the route that encompasses Egan Drive from Otter Way to the AML Road in Thane. This encompasses approximately 21 lane-miles of highway that is treated with Magnesium Chloride. See Figure 1.

![Figure 1: The Route (Egan Drive) of Interest for This Study](image-url)
The study was conducted during the winter season of 2002-2003. The weather was unusually mild and limited the number of days that data could be collected. Nevertheless, four days of complete data have been collected for the days – January 31, 2003; February 6, 2003; February 14, 2003; and February 17, 2003.

C. Equipment, Procedures, & Methodology

The project was subdivided into three parts. Table 1 illustrates the three sequential parts. The first part of the study defined the requirements, determined the method of data collection, and described the equipment and system parameters necessary to compare material distribution to level of service results. The second part of the study involved the system installation, data collection and recording, and level of service estimation. The final part of the study analyzes the results, and draws conclusions relative to the effectiveness of the snow and ice removal process.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Define Requirements &amp; Design Evaluation Criteria to Assess Distribution Methods</td>
<td>Install Equipment, Collect Material Distribution Data, Record Level of Service Obtained, &amp; Create Database</td>
<td>Map Distribution &amp; Level of Service Results to Evaluation Criteria and Draw Conclusions</td>
</tr>
</tbody>
</table>

*Table 1: Study Components*

The study was designed to be accomplished as a partnership between ThomTech Design, Inc. and AKDOT&PF. ThomTech accomplished the majority of the tasks, however AKDOT&PF Maintenance and Operations (M&O) personnel collected the actual data and prepared the level of service estimation. AKDOT&PF M&O selected five snowplows presently assigned to the Southeast Region in Juneau, AK. These snowplows were used to gather data about the snow and ice removal process.

AKDOT&PF M&O provided an additional vehicle for use in estimating the effectiveness of the snow and ice removal based on the material distributed on the route. ThomTech installed data collection equipment into the snow and ice removal vehicles to automatically record events (distribution rate) tagged with date/time and location information. While data was collected from other snowplows that were used for granular distribution, this document focuses on the truck that is dedicated to the distribution of MgCl on Egan Drive.

A complete description of the tasks and a summary of the work plan is included in Appendix A.

D. Routes and Evaluation Procedures

1. Routes. AKDOT&PF Coordinated Data System (CDS) routes in Juneau and their CDS route numbers are listed in Table 2. The routes evaluated under this study were #296001 & #296002. These routes encompass Egan Drive from Otter Way to the AML Road in Thane. Note that 296021 was used as the control route.
The complete list of maintenance routes that are maintained by the Southeast Region AKDOT&PF are shown in Table 3. “Category” defines the level of service where category 1 is highest.
<table>
<thead>
<tr>
<th>Juneau M&amp;O</th>
<th>Road Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter 2000-01</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Chemical-Sand Routes (Primary)</strong></td>
<td></td>
</tr>
<tr>
<td>Road Name</td>
<td>Route #</td>
</tr>
<tr>
<td>Thane Road</td>
<td>35296011</td>
</tr>
<tr>
<td>Douglas Hwy</td>
<td>35296000</td>
</tr>
<tr>
<td>Egan Drive</td>
<td>35296000</td>
</tr>
<tr>
<td>Egan Drive</td>
<td>35296000</td>
</tr>
<tr>
<td>Glacier Hwy</td>
<td>35296021</td>
</tr>
<tr>
<td>Glacier Hwy</td>
<td>35291119</td>
</tr>
<tr>
<td>Loop Road</td>
<td>35296028</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Chemical - Sand Routes (Secondary)</strong></td>
<td></td>
</tr>
<tr>
<td>Route Name</td>
<td>Route #</td>
</tr>
<tr>
<td>N. Douglas Hwy</td>
<td>35296010</td>
</tr>
<tr>
<td>Glacier Hwy</td>
<td>35296010</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>35296020</td>
</tr>
<tr>
<td>Glacier Hwy</td>
<td>35296000</td>
</tr>
<tr>
<td>Back Loop Road</td>
<td>35296028</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Plow -- Sand Routes (Category 1, 2, 3, &amp; 4)</strong></td>
<td></td>
</tr>
<tr>
<td>Route Name</td>
<td>Route #</td>
</tr>
<tr>
<td>Thane Road</td>
<td>35296011</td>
</tr>
<tr>
<td>N. Douglas Hwy</td>
<td>35296010</td>
</tr>
<tr>
<td>N. Douglas Hwy</td>
<td>35296010</td>
</tr>
<tr>
<td>Fish Creek Road</td>
<td>35296008</td>
</tr>
<tr>
<td>Nine Mile Creek</td>
<td>35296010</td>
</tr>
<tr>
<td>Marina Road</td>
<td>35291119</td>
</tr>
<tr>
<td>Sunny Point Road</td>
<td>35291119</td>
</tr>
<tr>
<td>Old Dairy Road</td>
<td>35291119</td>
</tr>
<tr>
<td>Old Glacier Hwy</td>
<td>35296021</td>
</tr>
<tr>
<td>Old Glacier Hwy</td>
<td>35291119</td>
</tr>
<tr>
<td>Mendenhall Glacier</td>
<td>35296028</td>
</tr>
<tr>
<td>Montana Creek</td>
<td>35296019</td>
</tr>
<tr>
<td>Engineers Cut Off</td>
<td>35296034</td>
</tr>
<tr>
<td>Fritz Cove Road</td>
<td>35296034</td>
</tr>
<tr>
<td>Auke Nu Drive</td>
<td>35291119</td>
</tr>
<tr>
<td>Otter Way</td>
<td>35291119</td>
</tr>
<tr>
<td>Indian Cove Loop</td>
<td>34101928</td>
</tr>
<tr>
<td>Glacier Hwy</td>
<td>35296000</td>
</tr>
<tr>
<td>Point Louisa</td>
<td>35291119</td>
</tr>
<tr>
<td>Lena Loop</td>
<td>35291119</td>
</tr>
<tr>
<td>Point Stevens</td>
<td>35291119</td>
</tr>
<tr>
<td>Tee Harbor Spur-2</td>
<td>35291119</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 3: SE Region Maintenance Routes and Lane Miles*
Table 4 provides material and/or chemical unit costs for the 2001-2002 season.

<table>
<thead>
<tr>
<th>Material</th>
<th>Units</th>
<th>price/p unit</th>
<th>cost/u unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>yards</td>
<td>$12.64</td>
<td>$126.40</td>
<td>load=10yards</td>
</tr>
<tr>
<td>Chips</td>
<td>yards</td>
<td>$18.50</td>
<td>$185.00</td>
<td>load=10yards</td>
</tr>
<tr>
<td>CG-90</td>
<td>tons</td>
<td>$210.38</td>
<td>$210.38</td>
<td>2500 lb bladders</td>
</tr>
<tr>
<td>CaCl</td>
<td>tons</td>
<td>$344.61</td>
<td>$13.78</td>
<td>80 lb bags@35bags/pallet</td>
</tr>
<tr>
<td>MgCl</td>
<td>gallons</td>
<td>$1.13</td>
<td>$1.13</td>
<td>4500 gal/tank, $204.79/ton</td>
</tr>
</tbody>
</table>

Legend

p unit = purchased unit the units that the material was purchased
u unit = used units the units that the material was used

Table 4: Material/Chemical Rate Information

Table 5 provides the amounts of materials used in the Juneau area during the 2001-02 winter season.

<table>
<thead>
<tr>
<th>Month</th>
<th>Sand</th>
<th>Chips</th>
<th>CG-90</th>
<th>CaCl</th>
<th>MgCl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>loads</td>
<td>loads</td>
<td>tons</td>
<td>#80lb bag</td>
<td>gallons</td>
</tr>
<tr>
<td>Oct-01</td>
<td>0.0</td>
<td>4.0</td>
<td>23.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Nov-01</td>
<td>8.0</td>
<td>0.0</td>
<td>9.0</td>
<td>10.0</td>
<td>6,614.0</td>
</tr>
<tr>
<td>Dec-01</td>
<td>217.0</td>
<td>24.5</td>
<td>47.0</td>
<td>13.0</td>
<td>32,737.0</td>
</tr>
<tr>
<td>Jan-02</td>
<td>112.5</td>
<td>33.0</td>
<td>18.0</td>
<td>0.0</td>
<td>13,833.0</td>
</tr>
<tr>
<td>Feb-02</td>
<td>271.0</td>
<td>43.0</td>
<td>49.0</td>
<td>12.0</td>
<td>15,057.0</td>
</tr>
<tr>
<td>Mar-02</td>
<td>35.5</td>
<td>13.5</td>
<td>6.0</td>
<td>19.0</td>
<td>10,142.0</td>
</tr>
<tr>
<td></td>
<td>644.0</td>
<td>118.0</td>
<td>152.0</td>
<td>54.0</td>
<td>78,383.0</td>
</tr>
</tbody>
</table>

Table 5: Amount of Material Used for 2001-2002 Season

Table 6 provides the total cost for the materials used in the Juneau area in 2001-2002 season.

<table>
<thead>
<tr>
<th>Material</th>
<th>Sand</th>
<th>Chips</th>
<th>CG-90</th>
<th>CaCl</th>
<th>MgCl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>loads</td>
<td>loads</td>
<td>tons</td>
<td>#80lb bag</td>
<td>gallons</td>
</tr>
<tr>
<td>Oct-01</td>
<td>$0.00</td>
<td>$74.00</td>
<td>$4,838.74</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>Nov-01</td>
<td>$101.12</td>
<td>$0.00</td>
<td>$1,893.42</td>
<td>$3,446.10</td>
<td>$7,473.82</td>
</tr>
<tr>
<td>Dec-01</td>
<td>$2,742.88</td>
<td>$453.25</td>
<td>$9,887.86</td>
<td>$4,479.93</td>
<td>$36,992.81</td>
</tr>
<tr>
<td>Jan-02</td>
<td>$1,422.00</td>
<td>$610.50</td>
<td>$3,786.84</td>
<td>$0.00</td>
<td>$15,631.29</td>
</tr>
<tr>
<td>Feb-02</td>
<td>$3,425.44</td>
<td>$795.50</td>
<td>$10,308.62</td>
<td>$4,135.32</td>
<td>$17,014.41</td>
</tr>
<tr>
<td>Mar-02</td>
<td>$448.72</td>
<td>$249.75</td>
<td>$1,262.28</td>
<td>$6,547.59</td>
<td>$11,460.46</td>
</tr>
<tr>
<td>totals</td>
<td>$8,140.16</td>
<td>$2,183.00</td>
<td>$31,977.76</td>
<td>$18,608.94</td>
<td>$88,572.79</td>
</tr>
</tbody>
</table>

Table 6: Material Costs for 2001-2002 Season

8
2. Evaluation Criteria. The evaluation criteria that were used to measure the effectiveness of the material distribution are consistent with the chart that AKDOT&PF M&O has used in previous seasons. Table 7 provides a listing of the roadway surface descriptions, abbreviations, and names.

<table>
<thead>
<tr>
<th>Abbrev</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>Snow Cover</td>
<td>Snow present, vehicles haven’t driven over the roadway</td>
</tr>
<tr>
<td>CS</td>
<td>Compact Snow</td>
<td>Snow present, vehicles have packed the snow</td>
</tr>
<tr>
<td>I</td>
<td>Ice on Surface</td>
<td>Visible ice on the road surface</td>
</tr>
<tr>
<td>BW</td>
<td>Bare &amp; Wet</td>
<td>Pavement is bare but wet</td>
</tr>
<tr>
<td>SL</td>
<td>Slush on Surface</td>
<td>Pavement is covered with slush of snow, ice, &amp; water</td>
</tr>
<tr>
<td>BWt</td>
<td>Bare &amp; Wet tracks</td>
<td>Snow present, however tracks on pavement are bare/wet</td>
</tr>
<tr>
<td>BI</td>
<td>Black Ice</td>
<td>Ice on pavement, invisible or difficult to detect</td>
</tr>
<tr>
<td>FD</td>
<td>Freeze Dried</td>
<td>Pavement is dry, surface temperature is below freezing</td>
</tr>
<tr>
<td>O</td>
<td>Other</td>
<td>Other descriptions not consistent with above criteria</td>
</tr>
</tbody>
</table>

Table 7: Evaluation Criteria of Roadway Surface after Material Application

E. Evaluation Tools

1. Route Evaluation Software. The route evaluation software has been developed for this project. Its function is to be a tool for the route evaluation team in determining the effectiveness of the material (MgCl & sand) distribution on selected roadways in southeast Alaska. The purpose is to develop a tool that makes the evaluation process as objective as possible, thereby, providing a clearer comparison of the material distribution process between seasons, roadways, type of material, when material applied, and amount of material. Figure 3 provides a screen shot of the evaluation software application package. Figure 4 illustrates the snapshot feature that records a snapshot of the road surface and stores it in the database.
2. Report Generator. The report generation software provides the evaluator with report preparation options that include material usage and equipment usage reporting. The reports have a standard format or can be tailored. Each report can be created by truck, start and end time, or sensor information.

3. Mapping Display Software. The data files recorded by the evaluation truck and the mobile data collection (distribution) trucks are comma delimited ASCII text. As such, they can be imported into most mapping display software packages. The examples in Appendix C use Microsoft’s MapPoint software. However, the data is best displayed using ArcView 3.2. AK DOT&PF’s Mapping Section has provided the road data for mapping and the additional shape files are available on the AK DOT&PF Mapping Section web site.
Each data field can be displayed on a digital map, such as plow up/down, speed, road temperature, and material used, etc. ThomTech has provided a copy of Microsoft MapPoint software for this purpose. ArcView 3.2 is a more capable software application package that is compatible with the data collection formats. Personnel from AKDOT&PF’s Mapping Section used ArcView 3.2 for analysis for this phase of the project.
FINDINGS

A. General.

The weather was unusually mild and limited the number of days that data could be collected. Nevertheless, four days of complete data were collected for the days – January 31, 2003; February 6, 2003; February 14, 2003; and February 17, 2003.

B. Results.

The results of the study are illustrated best by viewing the data collected graphically displayed as layers on the road map.

An ideal data set will reflect pre-application conditions, that is, prior to the MgCl truck going out to distribute material on Egan Drive. Next we would see the route with the results of the material distribution. Last, we would see the route with the post-application results. There may be more than one post application analysis (for example, 2 hours, 4 hours, and/or 6 hours after application). For the days indicated, the data collected is reflected in Table 8.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-application</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Distribution</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Post-application 1</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Post-application 2</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Post-application 3</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Results of Data Collected

C. Display Results on Map.

The data collected can use any one of the fields (dew point, speed, road condition, etc.) to display the route, color coded by unique value to illustrate various segments of the road. Figures 5-10 illustrate various parameters from the data sets listed above displayed as a layer over the road grid centered around Egan Drive in Juneau, AK.
Figure 5: Road Condition from Evaluation Data of 2/14/03

Figure 6: Road Temperature from Evaluation Data of 2/17/03
Figure 7: Speed (mph) of MgCl Truck from Distribution Data of 2/14/03

Distribution speed - 2/14/03
brick = 0 - 6
red = 7 - 19
pink = 20 - 32
gray/blue = 33 - 41
blue = 42 - 52

Figure 8: Speed (mph) of MgCl Truck from Distribution Data of 2/17/03

Distribution Speed - 2/17/2003
pink = 0 - 11
orange = 12 - 24
red = 25-35
brown = 36 - 43
black = 44 - 56
Figure 9: Traffic Flow (observed by Evaluator) from Evaluation Data of 2/6/03

Figure 10: Dew Point (°F) of Road Segment of Evaluation Data of 1/31/03

Dew Point - 1/31/03
pink = 38.138 - 38.352
orange = 38.354 - 38.50
red = 38.507 - 38.803
brown = 38.804 - 39.163
dark brown = 39.164 - 39.43
D. Lessons Learned.

The lessons learned were gathered from interviews of the research team. Each team member was asked the following questions:

1. What outcomes are you expecting from this project?

2. What are the lessons learned from your point of view with regards to this project? For example, training issues, documentation, ease of use, data structure, others, etc.

3. What recommendations do you have for this project if it is extended for 1-2 years? For example, change spread rate, change material, suggest new evaluation truck rates, or use additional sensors, others, etc.

4. Is there any other information that you would like to add, that was not covered in the questions above?

Research team member responses to these questions appear in Appendix B.

E. Assessments.

ThomTech Design, Inc. provides the following assessments of the first year of research based on the following five questions.

1. Was the technology useful for optimizing chemical usage? How?

Yes, the equipment that is installed on the MgCl truck and the evaluation truck is sufficient for collecting the data necessary for the first phase. Additional software development and data manipulation is necessary to add the features that have been suggested in this document, such as traffic volumes, segments, weather conditions and forecasts, charts by temperature, etc. The hardware (mobile data computers & sensors) appear to have held up through the winter. There were no failures reported. The data collection equipment on the granular distribution trucks was not used for this first season, there is some doubt as to whether it will be used next year.

2. How cost effective was the technology for optimizing chemical use?

The rates for magnesium chloride for the 2001-2002 winter season were $1.13/gallon and 78,383 gallons were used for a total of $88,573. If the rate was thirty gallons per lane mile, then 2,613 lane miles were treated with MgCl. If the average route was 21 lane miles long, then approximately 124 treatments occurred for the Egan Drive during the 2001-2002 winter season. If two thirds of the each route (approximately 14 lane miles) were treated at twenty gallons per mile, then there would be a cost savings of $19,676 for those 124 treatments. This figure is for comparison only as it doesn’t reflect latest prices for MgCl and assumes that 20 gallons/mile in the high traffic areas would be sufficient. However, it does illustrate
that the successful determination of the proper rate for each type of treatment (weather, traffic, and time of day) may save the cost of the research and equipment.

The cost of research equipment is listed below.

- **Snowplow:** estimated at $1,850 (includes MDC, plow/up down sensor, temperature sensor, etc.)
- **Evaluation Truck:** estimated at $7,500 (includes TB CF-28, weather station, camera, etc.)
- **Analysis:** estimated at $800/storm (one day of data collection and analyst)

3. What are your recommendations for improving cost effectiveness of AKOT&PF deicing/anti-icing operations?

- If the focus of the research continues to be MgCl and Egan Drive, then the trucks that are fitted for granular material distribution do not need to be instrumented. Thus, some cost and time savings could be realized.
- The effectiveness of the research would be better served if the data collected was examined after every treatment and storm day.
- One person should be placed in charge of the study and be responsible for collecting the data from the MgCl truck and the evaluation truck.
- A detailed procedure needs to be published to ensure that data is collected the same way each run.
- A control segment should be established that can be treated with the standard rate and is representative of the Egan Drive route.
- As each successful complete data set is collected, a short description of available items should be recorded as a running log. Items such as weather forecasts, decision process to treat, the number of gallons used and miles traveled down.
- Traffic flows should be recorded and if feasible divide the Egan Drive route into three segments based on level of traffic (high, medium, low).

4. Other objective observations/recommendations to help M&O decision makers decide whether or not to invest further in this technology.

- The data exists to make objective and subjective comparisons between treatments. The mapping and reporting power present in AK DOT/PF is extensive and the data manipulation skills are outstanding.
The evaluation data collected was smartly done and the data is valuable and useful. Great care was taken to ensure that the software and hardware worked to their satisfaction.

Greater communications between the research members would have been helpful earlier in the season, the process seemed to run smoothly only towards the end of the season.

5. Operational/procedural recommendations. These are provided in Chapter 3.

F. Summary of Dispersion Data Collected.

Table 9 provides a summary of the MgCl dispersion data collected for the four days of interest.

<table>
<thead>
<tr>
<th>Item</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Count</td>
<td>1/31/2003</td>
</tr>
<tr>
<td>Total Distance in miles</td>
<td>2/6/2003</td>
</tr>
<tr>
<td>Operational Distance in miles</td>
<td>2/14/2003</td>
</tr>
<tr>
<td>Deadhead Distance in miles</td>
<td>2/17/2003</td>
</tr>
<tr>
<td>Gallons per Route - op miles X 30 gal/mi</td>
<td>48.758</td>
</tr>
<tr>
<td></td>
<td>70.591</td>
</tr>
<tr>
<td></td>
<td>160,696</td>
</tr>
<tr>
<td></td>
<td>71,044</td>
</tr>
<tr>
<td></td>
<td>25.27</td>
</tr>
<tr>
<td></td>
<td>26.27</td>
</tr>
<tr>
<td></td>
<td>76.22</td>
</tr>
<tr>
<td></td>
<td>21.57</td>
</tr>
<tr>
<td></td>
<td>16.05</td>
</tr>
<tr>
<td></td>
<td>23.31</td>
</tr>
<tr>
<td></td>
<td>45.97</td>
</tr>
<tr>
<td></td>
<td>21.57</td>
</tr>
<tr>
<td></td>
<td>9.22</td>
</tr>
<tr>
<td></td>
<td>2.95</td>
</tr>
<tr>
<td></td>
<td>30.25</td>
</tr>
<tr>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Percent Operational - op distance/total</td>
<td>63.5%</td>
</tr>
<tr>
<td>Gallons per Route - op miles X 30 gal/mi</td>
<td>481.5</td>
</tr>
<tr>
<td></td>
<td>699.3</td>
</tr>
<tr>
<td></td>
<td>1379.1</td>
</tr>
<tr>
<td></td>
<td>647.2</td>
</tr>
</tbody>
</table>

Table 9: Summary Dispersion Data

The results from Table 9 are valuable only if compared to actual data and conditions before and after the material has been distributed onto the roadway. For the MgCl totals, the data is based on the pulse count from the flow meter at the rear of the truck. As the liquid MgCl is dispersed out of the truck, the flow meter rotates, thereby generating pulses which are counted by a pulse counter. The pulses are translated to gallons/mile. Unless a rigorous procedural method is used, the pulse counts can lead to false interpretation. For example, an event is generated, whereby the pulse count is recorded every 10 seconds, during that 10 seconds the flow meter could have been on for only 2 of the seconds, thereby generating pulses for one fifth of the time. However the distance would be measured for a full ten seconds. Upon calculation this would result in a material rate of one fifth of the actual rate. The same is true of the deadhead versus operational hours, if the data collection unit is turned off at the end of material distribution, then deadhead miles and time are not counted.

The data needs to be examined soon after the route has been treated to determine that the data collected makes sense and that data was collected for the entire route. The data reflected in Table 9 shows that the routes are inconsistent and that the data collected for each treatment is not similar. Part of this inconsistency can be corrected by examining the data at the end of each route and determining the feasibility of using it as a candidate run for comparison with other routes.

Pulse counts are used for determining the rate of distribution. In order to make an accurate calculation based on the pulse counts, another sensor would be useful that would sense flow meter on/off. Thereby, a more accurate operational versus deadhead ratio can be calculated.
Another solution is to install a new liquid dispensing system with the data enabled controller that would create events whenever the rate is changed or the blast button is pressed.

In Table 9, the number of gallons per route was calculated by multiplying the operational miles times thirty gallons per mile. An improvement on the accuracy of this figure can be made by making consistent runs and calibrating the calculation algorithm to the actual number of gallons dispensed at the end of the run.

INTERPRETATION, APPRAISAL, & APPLICATIONS

A. General Recommendations.

The following general recommendations are provided for review.

- Prepare a detailed procedure roadmap that describes each step and method in the data collection process for the MgCl dispersion and the evaluation truck.

- Expand the evaluation runs to include pre-application and post-application runs at one hour intervals for as long as it takes to determine when the MgCl breaks the ice and how long it is effective.

- Establish a logbook for recording ancillary information such as weather prior to treatment, weather forecast, number of gallons used, number of miles the truck traveled, how the decision was made to treat the roadway, and other descriptions that may impact the collection of data for that treatment/evaluation period.

- Appoint a person to be in charge of the data collection effort that can assemble the data and examine the data set soon after the treatment/evaluation period. If a consultant is used, send data after each storm to team members to look for completeness, accuracy, and adjustments.

- Continue this research for an additional season, anticipate a representative winter weather season, and incorporate the suggestions and recommendations from the research team members.

- Highlight the three parameters that seem to have the largest effect on the MgCl treatment, that is; weather, traffic, and application rate. Another suggested parameter is time of day in relation to the temperature/dew point/pavement temperature for choosing “when to treat”.

- If funding allows, extend the study to other portions of the Southeast Region, if necessary, use the data collection equipment for summer maintenance activities.

- If funding allows, modify the evaluation software to include the run number, existing weather conditions, and traffic flows.
If funding allows, expand study to include granular material distribution and other routes within the Juneau area.

If funding allows, replace the Spraytronics MgCl liquid dispensing equipment with data-enabled controller and equipment for more accurate and comprehensive recording of liquid treatment use.

B. Interpretations.

The data needs to be interpreted and graphically displayed in several forms in order to be valuable as a decision tool.

CONCLUSIONS & SUGGESTED RESEARCH

A. Conclusions.

1. The research for this first season was successful in limiting the scope of the study, determining the equipment capabilities, and adjusting the learning curve of what data should be collected and how it should be evaluated.

2. Several aspects of this study have never been attempted before. Many government agencies are struggling with evaluating level of service from the several methods of treatment. This study is the first of its kind to attempt to objectively and subjectively seek the breaking point of a selected treatment (in this case MgCl) and then examine ways to approach this threshold (not exceed) in order to improve effectiveness, increase efficiency, and reduce costs.

3. The mild winter, initial equipment problems, and understanding all of the variables that make up this research project, prevented the collection of a clear set of data from which comprehensive conclusions can be drawn.

4. The data from this first season indicates substantial progress in attaining the goals next season and illustrates the potential benefits of additional research.

B. Suggested Research.

- Continue this study for another season as modified by the suggestions and recommendations from the research team members.
- Suggest that ThomTech prepare a detailed guide for the next phase of research.
- If successful, expand the study to include the other routes that are treated with granular material.
REFERENCES


APPENDICES

Appendix A – Project work flow, research tasks, and work plan summary.
Appendix B – Team member observations.
Appendix C – User’s Manual
APPENDIX

A. WORK FLOW, RESEARCH TASKS, AND WORK PLAN SUMMARY
WORK FLOW, RESEARCH TASKS, AND WORK PLAN SUMMARY

Work Flow. The project work flow, research tasks, and equipment summary and a description of the project procedures is included below.

Project Flow Chart. Figure 11 provides a block diagram of the project flow. The first two blocks (green in color) denote the two tasks for part one of the study. The sand colored blocks illustrate the tasks for part two. The blue blocks highlight the tasks of part three of the study.

Part 1 – Data Needs Assessment
Part 2 – Equipment Installation and Data Collection
Part 3 – Analysis of Effectiveness

The three parts of the study overlap each other in schedule and scope of services, however, they do represent three distinct phases of the project. ThomTech has the lead responsibility in each of the tasks except the data collection and the roadway evaluation. These tasks are accomplished by the AKDOT&PF personnel from the southeast Region with assistance from ThomTech.

Figure 11: Project Flow Chart
**Tasks.** Table 10 provides a task list and short description of each task. The left hand column lists the task, the center column provides a brief description and the right hand column lists the responsibility for task completion.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1 – Data Needs Assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Define Detailed Requirements &amp; Design Criteria</td>
<td>Establish the baseline parameters of the study by gathering information about how the snow and ice removal process is presently employed. This includes routes, material used, effectiveness, costs, personnel requirements. Design a system of evaluation criteria and procedures that the research team will use to accurately assess the level of service provided during the snow &amp; ice removal process. Also determine the parameters that will be varied during the study to determine their effectiveness. Such as material amount, type of material, when applied, where applied, and type of equipment.</td>
<td>ThomTech In consultation with AKDOT&amp;PF</td>
</tr>
<tr>
<td>2. Prepare Comprehensive Work Plan</td>
<td>Develop a detailed work plan to accomplish the goals and objectives of the study. The purpose of the work plan is to assign tasks, schedule installation, and describe how data is collected, recorded, and stored.</td>
<td>ThomTech With AKDOT&amp;PF review</td>
</tr>
<tr>
<td><strong>Part 2 – Equipment Installation and Data Collection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Implement Work Plan</td>
<td>ThomTech’s research team begins executing the work plan. This task includes hardware and software design and testing.</td>
<td>ThomTech</td>
</tr>
<tr>
<td>4. Install Equipment &amp; Conduct System Test</td>
<td>ThomTech will install new equipment on the snowplows. This includes new controllers that accurately log snow and ice removal events such as salter on/off, pounds per lane mile, gallons per ton, and many others. In addition, a mobile data computer with embedded GPS receiver will record the events and tag them with date/time and location information. The events will be stored on a PCMCIA card and downloaded after the storm.</td>
<td>ThomTech With AKDOT&amp;PF (M&amp;O) oversight &amp; assistance (AKDOT&amp;PF M&amp;O driver needed.)</td>
</tr>
<tr>
<td>5. Integrate Systems &amp; Evaluation Procedures</td>
<td>Ensure that the installed equipment and subsystems are successfully working and the evaluation procedures (for estimating the level of service) are collecting the information necessary to complete the analysis.</td>
<td>ThomTech In consultation with AKDOT&amp;PF M&amp;O</td>
</tr>
<tr>
<td>Task</td>
<td>Description</td>
<td>Responsibility</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>6. Conduct Evaluation &amp; Investigation</td>
<td>Observe the effectiveness of the snow and ice removal material by driving the route at selected periods after the material has been distributed. The methods for completing this are determined in Task 1. An accurate method of determining the level of service through observation is required.</td>
<td>AKDOT&amp;PF M&amp;O with Assistance from ThomTech</td>
</tr>
<tr>
<td>(Effectiveness evaluation.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Collect Data &amp; Record Results</td>
<td>Actual collection of the detailed data from the snowplows during the snow and ice removal procedures. Data is downloaded periodically and stored in a database.</td>
<td>AKDOT&amp;PF M&amp;O with Assistance from ThomTech</td>
</tr>
<tr>
<td>8. Analyze Data &amp; Map to Evaluation Criteria</td>
<td>Conduct an analysis of the snow and ice process by evaluating the results of the data as they pertain the level of service estimation.</td>
<td>ThomTech With assistance from AKDOT&amp;PF M&amp;O</td>
</tr>
<tr>
<td>9. Prepare Final Report</td>
<td>Prepare a written report that comprehensively documents the study, draws conclusions, and provides suggestions and recommendations. The report will include as an Appendix, a Reference guide and Manual for AKDOT&amp;PF M&amp;O personnel use.</td>
<td>ThomTech With AKDOT&amp;PF review and approval</td>
</tr>
</tbody>
</table>

**Table 10: Project Tasks**

**Equipment.**

1. For GRS32 (sander) and Spratronics (sprayer) snowplows. The collection of material usage and equipment usage data is provided by a mobile data computer (MDC) and several sensors. Figure 12 provides an illustration of the MDC and maximum number of sensors that the MDC can accommodate. For the sander and sprayer trucks, only the front or main plow, the salter/controller, air/pavement temperature sensors, and GPS receiver were used. The data was recorded and stored to an embedded PCMCIA card. This card is removed at the end of day, end of shift, end of week, or end of storm. The data is downloaded to a database on a desktop PC. ThomTech installed an MDC, plow sensor, pavement/air temperature sensor, and the SSC 5100 controller into four snowplows & a pulse counter for the MgCl truck. ThomTech provided detailed instructions and interface connections in the Comprehensive Work Plan. The data file consisted of records (a recording of each event) and each record will consist of several data fields. Of the six possible I/Os, only the sensor for main plow up/down and ignition will be used for this project.
A list of components for the in-vehicle equipment for the snowplows is provided below:

- Mobile data computer & PCMCIA data collection card
- GPS receiver & antenna
- Sprague infrared air/pavement temperature sensor
- Proximity sensor for main plow
- Force America SSC5100 controller

2. For Level of Service Evaluation Vehicle. The level of service evaluator was provided with a laptop computer, GPS receiver, humidity sensor, and pavement temperature sensor. The laptop computer software application was tailored to meet the data collection needs of the evaluator. The software application assisted the evaluator by providing menu choices and definitions of pavement and roadway observations made by the evaluator. The in-vehicle laptop was a ruggedized Panasonic tough book with a touch screen capability. Thus, the route evaluator had several items of data collected automatically that support the subjective portions of the evaluation. As much of the evaluation data collection effort was instrumented as possible. Initially, the evaluator is required to provide a subjective evaluation of the effect of the material distribution.
A list of components for the service evaluation vehicle equipment is provided below, see Figure 13 for an illustration of the MgCl truck and snowplow prior to installation:

- Laptop computer (Panasonic Toughbook) with touch screen
- GPS receiver & antenna
- Sprague infrared air/pavement temperature sensor
- Humidity/dew point sensor
- Barometric pressure sensor
- Report generator software (SnowOwl)
- Route evaluation software package
- Camera

Figure 13: Photographs of the Two Types of Truck Before Installation
APPENDIX

B. TEAM MEMBER OBSERVATIONS
TEAM MEMBER OBSERVATIONS

The following comments from the research members illustrate the successes and limitations from this first season of research.

A. What outcomes are you expecting from this project?

1. The mild winter resulted in not as many opportunities to collect data from Egan Drive route.

2. The learning curve for the equipment was approximately one month, hampered somewhat by equipment problems, mild winter in the November – December 2002 timeframe and personnel assignments.

3. Based on the mild winter and the data collection opportunities there may not be sufficient data to draw conclusions from during this first season.

4. It is possible that during high ADT (average daily traffic) segments or time periods less magnesium chloride (20 gal/mi) would be required to break the ice, whereas during low ADTs an application rate of 40 gal/mi would be required.

5. It was even suggested that where there is very low ADT, MgCl might not be the chemical of choice.

6. Magnesium chloride applied to low ADT is useless with no traffic. It takes too long to break for traffic to use the road.

7. Several research team members suggested that at least one more season is required to get meaningful data to make decisions on chemical distribution.

8. The data manipulation power and mapping display capability is excellent within AK DOT/PF.

9. The data, as collected, required manipulation and formatting in order to be useful in a mapping and display screen shot. Some more software development to improve the software output would be helpful.

B. What are the lessons learned from your point of view with regards to this project? For example, training issues, documentation, ease of use, data structure, others, etc.

1. A control segment of the road was needed, where this portion of the route on Egan Drive (or representative of Egan Drive) would be treated the same each time and the same from previous years. Thus, the data collected for the test segment could be compared to the data collected for the control segment.

2. The main question for this phase is determining the usefulness of the technology.
3. The evaluation team noticed that the traffic played a central part into the success of the Magnesium Chloride treatments. Where the traffic thinned out, the chemical was not as effective in breaking down the ice.

4. There are three issues that are apparent from this initial data collection; 1) the application never changed, 2) there is no yardstick with which to use as a baseline, and 3) the traffic volume energized the magnesium chloride.

5. During the middle of the test, it we noted that traffic volume played a large part in the effectiveness of the magnesium chloride, thus, about the end of January 2003, the evaluator was able to record the traffic volume as high or low.

6. Weather conditions need to be recorded and received from the same source each time.

7. A method to enter the total gallons used for each application should be developed for the evaluation software.

C. What recommendations do you have for this project if it is extended for 1-2 years? For example, change spread rate, change material, suggest new evaluation truck rates, or use additional sensors, others, etc.

1. It would be useful to collect daily traffic counts for the dates and times that magnesium chloride was used for anti-icing or de-icing.

2. A manual for a step by step process on how to use the equipment would be useful. Especially, when substitute personnel were used for chemical distribution or pre/post application evaluations.

3. Data needs to be collected as part of set for each storm or application, that is; pre-application, chemical distribution, post application #1 (one hour), post application (two hours), post application (three hour), … , post application (nth hour, until MgCl breaks).

4. The data can then be compared in one graphic by overlaying the data from pre-application, application, and post application.

5. A yardstick needs to be established where the route (Egan Drive) is divided into three seven mile segments (approximately). The three segments are divided essentially by three different traffic volumes.

6. The application needs to be varied, some examples of rates are: 20 gal/mi, 25 gal/mi, 30 gal/mi, 35 gal/mi, and 40 gal/mi.

7. Evaluations should be collected every hour after application not every two hours.
8. Use 5 gal/mi increments for the levels of chemical distribution.


10. The data collection needs to be coordinated to make sure that a plan is presented that ensures that the evaluation team actually collects data where the chemical is applied and that everyone knows the rate, traffic volume, time of day, and weather parameters prior to treating/evaluating the route.

11. It is strongly suggested that the team establish a procedure, application rate levels, and a yard stick (control segment).

12. A question to ask is, where and when was the breaking power of the MgCl. This needs to be analyzed on an hourly basis, not two hours.

13. Daily weather information should be logged for each day data is collected. That way, it would allow an evaluator to go back and get a clear picture of what happened during that storm event.

14. The project should be narrowed down to just Egan Drive and segmented based on traffic volumes and include a control segment.

15. An area where no MgCl is applied is needed as a control segment. Perhaps parallel to Egan Drive, this needs to be thought out very carefully.

16. Communications between the various players needs to be nailed down better, often times the distribution truck didn’t want or couldn’t wait for the evaluation truck to do a pre-application run.

17. Procedures and a decision tree needs to be established and published prior to the next season.

18. The 2-4-6 hour post-application evaluations were part of the plan, but that is not long enough, we need to keep going, perhaps as long as twelve hours at one hour intervals.

19. A sensor that detects the controller on/off would be useful.

20. The data should be examined soon after the runs are made to ensure that the runs are interpreted and parsed correctly. Most of the data was assembled at the end of the season for the 2002-03 winter season.

21. Additional feedback from the drivers and participants is necessary to get proper calibration and determine the accuracy of the data collected.
D. Is there any other information that you would like to add, that was not covered in the questions above?

1. It was also found to beneficial to collect data on a pre-application run prior to the deployment of the MgCl truck and the material distribution. This was only accomplished a few times towards the end of the season. Thereby, the data collected as part of the post-application phase could be compared to the data collected from the pre-application phase.

2. The application rate was not changed for this phase of the research.

3. The operation needs to be evaluated using three variables: weather, traffic, and application rate.

4. During this first season of the research, two of the three (weather, traffic, and application) never changed, that is, application rate and traffic.

5. We know that 30 gal/mi will break up the ice, but we don’t know if 20 gal/mi will also do it.

6. A goal would be to know where the limit is based on weather, application rate, and traffic volume.

7. Most of the data collected is good, reasonable, and accurate, but it is fragmented, not collected the same for each storm event, and consistency is lacking.

8. The traffic volumes for the Egan Drive route would be valuable. Suggested volume break points would be 20,000 vehicles/day, 25,000 vehicles/day, and 30,000 vehicles/day.

9. In low ADT areas, MgCl application of 30-40 gal/mi is necessary, however in high ADT areas, 20 gal/mi might be sufficient.

10. MgCl is a very good treatment, it works well in the Juneau climate, but it is more effective in high volume traffic areas, it is not worth it in low volume areas.

11. The vehicle drivers were confused about the operation and the value of collecting the data. The training and guidance were not sufficient according to the drivers. Some drivers did not cooperate.

12. There did not seem to be a reason to collect the data from the other trucks that were not using MgCl or treating Egan Drive.

13. The data quickly became extensive and the data archiving became confusing. The afternoon and evening shifts were not up to speed on the data collection procedures.
14. There was some confusion in understanding the technology and the project leadership. The drivers weren’t sure of their role in this project and the importance of following standard data collection procedures.

15. Because the application rate never changed, the dispersion or distribution data was the same every time, it never varied. The hardware and software equipment installations were accomplished and worked fine.

16. The project was weak on methodology and procedures.

17. The pre-application run is critical.

18. As far as outcomes go, we know that MgCl is effective, but there is a lot we don’t know.

19. MgCl works well in the Juneau environment where it is very wet, rain turning to snow, little warmer than elsewhere.

20. It is essential to get the MgCl down at a time where it can be effective. Optimum timing of the application in various weather conditions is essential.

21. Another item to determine is the length of effectiveness in varying weather conditions, sometimes it is effective for twelve hours, other times it is necessary to retreat after three hours.

22. Next year, the application rate should be adjusted to determine if the MgCl would be effective at a lesser application rate. There were not enough instances this winter.

23. The testing process, training, and equipment installation and operation took longer than expected.

24. One way to approach the problem is make divisions from intersection to intersection on Egan Drive. Call each one of them a segment and evaluate them as segments.

25. Once the chemical broke, what was the event that broke it? Traffic?, Chemical?, Temperature?, Dew Point?, Time of day?, etc. We need to determine this.

26. The procedures and parameters that surround the decision to apply the MgCl need to be written down, so that the procedure is the same each time and there’s enough time to call in the evaluation team to do the pre-application run.

27. The crew was not involved as much as was needed to understand what the research was trying to do.

28. By entering the weather, a clear picture of how the decision to apply before and after is recorded, which affects the application rate, time of day, etc. For example, if the
temperature is 34 degrees and clear, then drops to 27 degrees, there will be ice on the roads, time to apply. The conditions might be different the next time the decision to apply is made.

29. The data collection and passing of data files between research team members was somewhat disjointed at first.

30. The data collected for each run is different from other runs, sometimes markedly. The data is not consistent from treatment to treatment. For example, the evaluation runs do not follow the dispersion runs so that a direct overlay can be made.
APPENDIX

C. USER’S MANUAL
I. UNDERSTANDING

A. Purpose. The purpose of the user’s manual is to provide a set of procedures and descriptions for the collection, distribution, and manipulation of snow and ice removal data. Ultimately, this data can be used to assist highway maintenance personnel as part of a larger decision support system to improve efficiency, reduce costs, and increase the safety of the motoring public.

B. Introduction. The AKDOT&PF uses liquid magnesium chloride (MgCl) and other chemicals to maintain roads in a bare and wet condition. AKDOT&PF determines the timing of application and application rate of de-icing and anti-icing chemicals by subjective judgment in response to many dynamic variables.

C. Background. Research has shown that gathering information through the use of sensor data collection techniques can improve the snow and ice removal process efficiency by maintaining or increasing performance and minimizing costs. This manual provides generalized procedures to that end. Specific procedures may vary but will follow the same logic.

D. General. The User’s Manual is composed of four parts. The first part consists of the procedures for the vehicle operator. The second part includes the procedures for the supervisor. The third part involves the database management for interpreting the data and using it for assisting highway maintenance decisions pertaining to snow and ice removal. The fourth part pertains to the roadway evaluation truck that follows the route at intervals after the anti/de-icing materials are applied to the roadway.
II. PART ONE – Collecting Data from the Snowplow

A. Description. Each vehicle has a mobile data computer (MDC) installed as the main data collector. Its function is to collect data from the sensors (plow up/down, temperature, and the spreader).

In addition it tags each sensor event with location, speed, heading, date, and time from a GPS receiver. A block diagram of the MDC and sensor interfaces is shown in Figure 14 to the right. It then records that data to a PCMCIA memory card. The card can record approximately 3 days of continuous snowplow operations.

The PCMCIA card must be reformatted (erased) before use, after the data has been downloaded by the supervisor.

B. Components. A list of components for the in-vehicle equipment for the snowplows is provided below:

- Mobile data computer
- PCMCIA data collection card
- GPS receiver & antenna
- Sprague infrared air/pavement temperature sensor
- Proximity sensor for main plow
- Force America SSC5100 controller

C. Procedures. The procedures listed below are from the quick reference guide for vehicle operators and they provide a step by step procedure for collecting data during the snowplow operation.

INTRODUCTION: The mobile data computer (MDC) is an event logging device that collects information from sensors located on the snowplow. A GPS receiver is embedded into the MDC and it records the latitude, longitude, speed, direction, date, and time. An event occurs every ten seconds or every thousand yards, each time a sensor input is changed from the salter or the plow.
**OPERATION:** Before starting, ensure that a PCMCIA memory card is inserted in the bottom left hand side of the MDC. After starting the snowplow using the ignition, turn the MDC on by pressing the on/off button in the upper left hand corner of the MDC. The MDC will “boot up” by displaying a splash screen and then asking for the vehicle ID #. At this time enter the four digit number “1234.” Then hit the enter key. The enter key is the button in the lower right hand portion of the MDC that looks like a right angle arrow pointing to the left. The screen will display the first of four screens. At this time, nothing further needs to be done by the operator.

**ERASE THE CARD:** If the information on the card has been downloaded into the desktop in the office, then clear the card in the following way. Hit the number “1” key and another menu appears with the word “FORMAT” next to the first green hot key on the left hand side of the MDC. Press the FORMAT green key. The MDC asked the question for a password. Type in the password to erase the card “4321.” The screen then asked if you are sure. If yes, press the enter key, if no, press the “X” key. If the enter key (YES) is pressed, the card will indicate that the format was successful. Then press the “X” key to return to the main menu. Now begin snowplow operation. The bottom line of the screen indicated the card status: in, out, 25% left.

**FRONT VIEW:** A figure of the front panel of the MDC is shown below.

The four green buttons on the left hand side are the means to record manual events. Press the “hwytype”, “activity”, or “incident” to view the detailed menu of manual events in these categories. The “X” button is used to return to the previous screen, it also is used for a “no” or “not sure” answer. The red button is not used for this application.

**SCROLLING:** If the operator would like to view the data collected, use the double arrow (Up/Down) key at the bottom of the screen to page up or page down. The single arrow (Up/Down) key is used to scroll the manual event choices after one of the green hot keys are pressed. See the caption at the left of the figure of the front view of the MDC.

**SHUTDOWN:** To turn the MDC off, turn off the ignition or press the on/off button in the upper left hand corner of the MDC. Remove the card from the bottom slot and download the data to the desktop PC in the office.

**TROUBLESHOOTING:** First step, turn the unit off then on. Second, ensure that the power connector and the GPS antenna cable are connected on the back of the MDC. If not corrected call repairman.
D. Events. Events are generated by several methods. The MDC seeks to record changes in snowplow activity and mark these changes (or tag them) with GPS information. An event is generated each time one of the following occurs:

1. An input/output (I/O) changes state (for example the main plow is changed from up to down, underbody blade up/down, salter on/off, etc.).
2. The SSC5100 Spreader provides a data set, this occurs if the rate changes, spreader turned on/off, blast button on/off, warning/error message, change for granular to liquid, or prewet on/off.
3. The unit travels 1000 feet or operates for 10 seconds.
4. Manual event is inputted by the operator, change highway type, record an activity, or mark an incident (such as downed light pole, drainage problem, pot hole, etc.).

E. Technical & Performance Specifications. The technical and performance specifications are listed below.

Display: Backlit LCD, 8mm characters
Discrete Interface: A minimum of 6 channels
Serial Interface: A minimum of 1 interface (RS-232, SAE-J1708 multi-inputs)
Power: Filtered 12 volts vehicles power form a cigarette lighter outlet
Drain: A maximum of 2 amps during transmission
GPS Channels: A minimum of 8 channel differential capabilities
GPS Accuracy: 100 meters uncorrected; 5 meters corrected
Position Update Rate: A minimum of 1 per every 2 seconds
Transmission Rate: A minimum of every 2 seconds, store and forward capability, user definable
Operating Temperature: 0°F
Storage Temperature: -40°F
Supply voltage: .......................................................... 9 - 18 volts
Current consumption:
Typical (LCD heater off, medium backlight): .................................................................
0.22 amps
• Maximum (LCD heater on, full backlight): 1.29 amps

Temperature range:
• Operating: -22 to +149°F
• Storage: -22 to +176°F

Approximate Size (W x D x H): 8.5 x 2 x 3.5 in.

Weight: 1 pound

Interfaces: 2 RS-232, 6 I/Os, wireless modem

III. PART TWO – Downloading Snowplow Data to the Desktop

A. General. The following portion of the User’s Manual pertains to the equipment and procedures for downloading the PCMCIA card collected data as a file onto the AKDOT&PF supervisor’s desktop computer.

Equipment list for the PC Card Reader:

• SolidState Data Drive with RS232 interface (SDDR) serial port
• Interface cable, six foot DB9 connector serial cable
• AC wall adapter power supply
• Software diskette
• Installation Manual

B. Specifications. The specifications for the PC Card Reader are listed below.

• Card Types PC Card ATA Flash, SRAM, linear Flash, Compact Flash with Adapter
• Indicators BATT LED: Indicates when SRAM battery is low or dead
• BUSY LED: Indicates accesses to the memory card
• Interface SDDR: DB9 connects to PC’s serial port (COM)
• Supported baud rates: 2400, 9600, 38400, 57600, 115200
• Power Adapter AC wall adapter supplying 15V DC @ 300 mA (plug is center positive)

C. Procedures. The following procedures are used for installing and operating the Adtron SDDR PC Card Reader.
1. Connect the Interface Cable - Locate a serial port on the rear of the computer (it may be labeled COM1 or COM2). Connect the cable to the serial port and secure the thumb screws.

2. Connect the other end of the cable to the SDDR and secure the thumb screws.

3. Connect the Power Supply - The SDDR uses a standard AC wall adapter power supply. Plug the unit into a wall outlet and plug the other end of the power cable into the SDDR. There is no power switch on the SDDR - power is on once the cable is connected.

4. Once power is applied, the BATT LED on the front of the SDDR/SDDL should blink GREEN-RED-GREEN-RED and then go out. This is a power-on self-test and indicates that the unit is working properly.

5. If you do not see the sequence, make sure the wall adapter is plugged in and has power. If you see a different sequence, the unit may be faulty.

D. Download Software & Driver. The software application and drivers to run the PC Card Reader are loaded onto the supervisor’s desktop PC. The application is opened by double clicking the PC Card Reader icon on the computer screen. Follow the prompts on the screen for inserting the card and downloading the data from the card. The card cannot be erased at the desktop computer, it can only be erased in the vehicle. This prevents the data from being lost inadvertently. The file is stored as an ASCII, comma delimited, text file that can be imported into most spreadsheet and database applications (i.e. MS Excel, MS Access, Foxpro, Lotus123, etc.). See Figure 17.
IV. PART 3 – Using the MgCl Application Data

A. General. The data can be displayed on a digital map the route data collected from the ASCII, comma delimited text file that is directly downloaded from the vehicle using the PCMCIA Card Reader.

B. MapPoint from Microsoft. One of the mapping programs that is straight forward to use (it is also less capable and less expensive) is Microsoft’s MapPoint. Figure 18 and Figure 19 illustrate examples of MapPoint output. Procedures for importing data onto a MapPoint map follow.

![Figure 18: Example Route Mapping for Snowplow (02/14/2003).](image)
C. MapPoint procedures.
1. Open MS MapPoint and navigate to the City of Juneau, AK. This is done by drawing a box around Juneau with the click and drag option of the mouse and then clicking inside the box.
2. Once the area desired is centered on the map, use the pan and zoom in/out buttons to get the correct view.
3. Open the “Data Import Wizard” by clicking on the pull down menu called “Data.” Navigate to the directory where the data files are stored. The data files are named by truck number and date. Click on the desired file and then click OPEN. The file will be imported and proceed through the import wizard. Ensure that the “First row contains column headings” box is checked. The wizard will find latitude and longitude on its own.
4. Then click FINISH until the wizard displays the data.
5. If you want to change the data, colors, or other features, double click on the legend and the options will appear for modification.
6. If you want to print, copy, or paste the image, right click on the map and select desired action.
D. Photos of Sensors & In-Vehicle Equipment. See Figures 20, 21, and 22.

![Photo of MDC](image1)

**Figure 20: Photo of MDC**

![Photo of Spreader](image2)

**Figure 21: Photo of Spreader**

![Sprague Infrared Temperature Sensor](image3)

**Figure 22: Sprague Infrared Temperature Sensor**

V. PART FOUR – Evaluation Truck Data, Collection, and Employment

A. For Level of Service Evaluation Vehicle. The level of service evaluator is provided with a laptop computer, GPS receiver, humidity sensor, and pavement temperature sensor. The laptop computer has a software application tailored to meet the data collection needs of the evaluator. The software application assists the evaluator by providing menu choices and definitions of pavement and roadway observations made by the evaluator. The in-vehicle laptop is a ruggedized Panasonic Toughbook (CF-28) with a touch screen capability. Thus, the route evaluator has several items of data collected automatically that support the subjective portions of the evaluation. Much of the evaluation data collection effort is instrumented with the onboard sensors, as possible. Initially, the evaluator is required to provide a subjective evaluation of the effect of the material distribution by selecting from nine different road conditions (e.g. black ice).
B. Components. A list of components for the service evaluation vehicle equipment is provided below:

- Laptop computer (Panasonic Toughbook, CF-28) with touch screen
- GPS receiver & antenna
- Sprague infrared air/pavement temperature sensor
- Humidity/dew point sensor
- Barometric pressure sensor
- Camera, Logitech video camera, mounted on dashboard
- Mount, cables, power cords

C. Route Evaluation Software. The route evaluation software has been developed for this project. Its function is to be a tool for the route evaluation team in determining the effectiveness of the material (MgCl & sand) distribution on selected roadways in southeast Alaska. The purpose is develop a tool that makes the evaluation process as objective as possible, thereby providing a clearer comparison of the material distribution process between seasons, roadways, type of material, when material applied, and amount of material. Figure 23 provides a screen shot of the evaluation package. One addition is the dew point calculation which will be calculated and provide a warning to the driver of “fronts danger.”
The software is intuitive to use for the road surface evaluator. The application is activated by double clicking the “evaltruck” icon. The screen above (Figure 23) will appear on the computer screen. The software will now collect data from the sensors without any operator intervention. The data is collected in a series of events where each event is described by a collection of data fields (such as, road temperature, dewpoint, barometric pressure, etc.). Each event is also tagged with date, time, latitude, longitude, speed, and heading by the GPS receiver. The operator can view the weather information and the progress on the map of the evaluation effort. At pre-selected points (i.e. beginning of the route, key intersections, or appropriate events), the operator can designate the road condition by pressing one of the road condition buttons (e.g. black ice, wet pavement, etc.). When the operator presses one of the road condition buttons, the video camera takes a snapshot of the road surface as a jpeg file and puts it in the database.

D. Evaluation Criteria. The evaluation criteria that will be used to measure the effectiveness of the material distribution are consistent with the chart that has been used in previous seasons. Table 11 provides a listing of the roadway surface descriptions, abbreviations, and names.

<table>
<thead>
<tr>
<th>Abbrev</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>Snow Cover</td>
<td>Snow present, vehicles haven’t driven over the roadway</td>
</tr>
<tr>
<td>CS</td>
<td>Compact Snow</td>
<td>Snow present, vehicles have packed the snow</td>
</tr>
<tr>
<td>I</td>
<td>Ice on Surface</td>
<td>Visible ice on the road surface</td>
</tr>
<tr>
<td>BW</td>
<td>Bare &amp; Wet</td>
<td>Pavement is bare but wet</td>
</tr>
<tr>
<td>SL</td>
<td>Slush on Surface</td>
<td>Pavement is covered with slush of snow, ice, &amp; water</td>
</tr>
<tr>
<td>BWt</td>
<td>Bare &amp; Wet tracks</td>
<td>Snow present, however tracks on pavement are bare/wet</td>
</tr>
<tr>
<td>BI</td>
<td>Black Ice</td>
<td>Ice on pavement, invisible or difficult to detect</td>
</tr>
<tr>
<td>FD</td>
<td>Freeze Dried</td>
<td>Pavement is dry, surface temperature is below freezing</td>
</tr>
<tr>
<td>O</td>
<td>Other</td>
<td>Other descriptions not consistent with above criteria</td>
</tr>
</tbody>
</table>

*Table 11: Evaluation Criteria of Roadway Surface after Material Application*
E. Weather Station Data Fields. Table 12 provides the weather station data fields and their data type for manipulation when importing the evaluation data into the ArcView mapping software.

<table>
<thead>
<tr>
<th>Original Field Name</th>
<th>Original Data Type</th>
<th>New Field Name</th>
<th>New Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp(F)</td>
<td>Text</td>
<td>Temp_F</td>
<td>N, single</td>
</tr>
<tr>
<td>Humidity(%)</td>
<td>Text</td>
<td>Humidity</td>
<td>N, single</td>
</tr>
<tr>
<td>Barometer (in)</td>
<td>Text</td>
<td>Barom_in</td>
<td>N, single</td>
</tr>
<tr>
<td>DewPoint(C)</td>
<td>Text</td>
<td>Dew_pt</td>
<td>N, single</td>
</tr>
<tr>
<td>WholeWeatherString</td>
<td>Text</td>
<td>WWS</td>
<td>T, 100</td>
</tr>
<tr>
<td>RoadTemp(F)</td>
<td>Text</td>
<td>Rd_temp</td>
<td>N, integer</td>
</tr>
<tr>
<td>AirTemp(F)</td>
<td>Text</td>
<td>Air_temp</td>
<td>N, integer</td>
</tr>
<tr>
<td>GpsDateTime</td>
<td>Text</td>
<td>Gps_d_t</td>
<td>N, integer</td>
</tr>
<tr>
<td>GpsLat</td>
<td>Text</td>
<td>Gps_lat</td>
<td>N, long integer</td>
</tr>
<tr>
<td>GpsLon</td>
<td>Text</td>
<td>Gps_lon</td>
<td>N, long integer</td>
</tr>
<tr>
<td>GpsSpeed(mph)</td>
<td>Text</td>
<td>Gps_spd</td>
<td>N, long integer</td>
</tr>
<tr>
<td>GpsHeading</td>
<td>Text</td>
<td>Gps_head</td>
<td>N, integer</td>
</tr>
<tr>
<td>GpsAge</td>
<td>Text</td>
<td>Gps_age</td>
<td>N, integer</td>
</tr>
<tr>
<td>GpsAltitude(ft)</td>
<td>Text</td>
<td>Gps_alt</td>
<td>N, integer</td>
</tr>
<tr>
<td>RoadCondition</td>
<td>Text</td>
<td>Rd_cond</td>
<td>T, 30</td>
</tr>
<tr>
<td>PrePostRunStatus</td>
<td>Text</td>
<td>Pre_post</td>
<td>T, 10</td>
</tr>
<tr>
<td>TrafficStatus</td>
<td>Text</td>
<td>Traffic</td>
<td>T, 10</td>
</tr>
<tr>
<td>WeatherForecast</td>
<td>Text</td>
<td>Weather</td>
<td>T, 255</td>
</tr>
<tr>
<td>PicPath</td>
<td>Text</td>
<td>Pic_path</td>
<td>T, 100</td>
</tr>
<tr>
<td>Date</td>
<td>Text</td>
<td>Date</td>
<td>T, 10</td>
</tr>
<tr>
<td>Time</td>
<td>Text</td>
<td>Time</td>
<td>T, 15</td>
</tr>
</tbody>
</table>

Table 12: Weather Station Data Field Names & Data Types

F. Mapping Display Software. The data files recorded by the evaluation truck and the mobile data collection (distribution) trucks is comma delimited, ASCII text. As such, it can be imported into most mapping display software packages. However, the data is best displayed using ArcView 3.X or ArcView 8.X. AK DOT&PF has provided the road data for mapping and the additional shape files are available on the AK state web site.
G. Raw Data Example. An ASCII, comma delimited text file is provided below as an example of how the data is presented. The data can be imported into an ArcView project for displaying key elements – color coded to assist in decision making. Mapping examples are provided in the next section (H). The data fields are described as follows: Barometer(in.), Humidity(%), Temperature(ºF), Dewpoint(ºC), Weatherstring(Text), RoadTemperature(ºF), AirTemperature(ºF), GPSdate/time(seconds), GPSlatitude(decimal degrees), GPSlongitude(decimal degrees), GPSspeed(mph), GPSheading(0-360), GPSage(seconds), RoadCondition(nine types), PrePostRunStatus(Pre-App,Post-App), TrafficStatus(High/Low), WeatherForecast(Text), ComputerDate(DD/MM/YY), ComputerTime(HH:MM:SS)

99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:36:57 AM"
99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:00 AM"
99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:03 AM"
99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:06 AM"
99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","35 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:09 AM"
99.10,39.00,"29.59","3.75","!!00000080018600002725039203DF----0004057600000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:12 AM"
98.90,39.10,"29.59","3.78","!!00000080018700002724039503DD----0004057700000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:15 AM"
98.90,39.10,"29.59","3.78","!!00000080018700002724039503DD----0004057700000000 ","34 F","36 F","63162","+5835986","-13452650","000","136","1","11","","PRE-App.","LOW","","1/31/2003","9:37:18 AM"

H. Map Examples. Map examples of the evaluation data displayed as a function of the road conditions or others is provided in Figures 24, 25, and 26. There are several other examples possible.
Figure 24: Digital Map Example 1

Figure 25: Digital Map Example 2
Figure 26: Digital Map Example 3