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Potential for Natural Brine for Anti-Icing and De-Icing

FINAL REPORT

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Submitted by

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16. Abstract (200 Words)

This project focused on the feasibility of the use of natural brine for anti-icing and pre-wetting in Onondaga County, Syracuse, New York. A thorough literature review was conducted on the use of brine as an anti-icing and pre-wetting agent both in the U.S. and abroad. The review indicated that the use of brine as an anti-icing and pre-wetting agent has gained popularity in most of the Departments of Transportation (DOT) in the U.S. and abroad over the years. Studies indicate that decreased applications of anti-icing chemicals lead to significant savings in material costs, reduced use of abrasives (rock salt and sand), better road conditions, lower accident rates, better environmental protection and lower costs for winter road maintenance. Costs analyses indicated that natural brine applications costs were comparable to commercial brine applications in the Onondaga County region. Deicing materials and accident data analyses for the Village of Fayetteville, Onondaga County and the NYSDOT Onondaga East Residency office indicated that

a) snow events are a significant contributor to winter road accidents
b) frequency of accidents go up immediately after a heavy precipitation
c) number of accidents in the 2010-2011 winter season when brine was applied was less than when rock salt was applied (2009-2010 winter season) even though the precipitation was greater in former case for I-81 and I-481.

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EXECUTIVE SUMMARY

Anti-icing, deicing and pre-wetting methods have become common for winter maintenance of roads. Brine (23%salt solution) is the most common material for anti-icing, deicing and pre-wetting processes. Typically brine is prepared from rock salt. There are very few studies that have investigated the use of naturally occurring brine for anti-icing and deicing. This study focused on the use of naturally occurring brine in the Syracuse, New York area for winter roadway maintenance. Participating agencies included the Village of Fayetteville, Onondaga County and the New York State Department of Transportation (NYSDOT) Onondaga East Residency office.

The major objective of this study was to determine the feasibility of the use of natural brine available in the Syracuse, New York area as a potential source for winter maintenance of roads. The study consisted of the following tasks:

- Conduct a thorough literature review of the status of brine use worldwide for winter road maintenance;
- Investigate the feasibility of natural brine use in the Syracuse, New York area;
- Investigate the relationship between material application during winter maintenance of roadways and accidents occurring during the application period in Syracuse, New York;
- Conduct interviews with the winter maintenance personnel from the participating agencies to determine the impact of natural brine use;
- Conduct a cost analyses to determine the cost effectiveness of the use of natural brine versus commercial brine; and to
- Develop a short brief operator's handbook on anti-icing and deicing techniques.

A thorough literature review was conducted on the potential of brine as an anti-icing and pre-wetting agent. The review indicated that brine applications in parts of Europe and other countries are more advanced than in the U.S. Anti-icing and pre-wetting lead to decreased applications of chemicals, reduced use of abrasives, improved road friction, lower costs and lower accident rates.

The chemicals cause less corrosion and environmental impacts to soil, water, and the atmosphere. Natural brine has great potential for use in roadway maintenance as evidenced by the operations of the Junex facility in Quebec, Canada and Syracuse, New York. Oil field brines are effective as conventional deicers. However, their use is limited because of high suspended solids, presence of trace metals and certain organic compounds. Anti-icing and pre-wetting programs are successful when combined with sophisticated weather forecasting technology and quality equipment for application of the chemical agents.

The study also investigated the relationship between material application during winter maintenance of roadways and accidents occurring in Syracuse, New York. Pre-wetted deicer and salt utilized by the Onondaga County DOT were evaluated and compared to study the impact on number of accidents and number of injuries. The conclusion drawn from the data analyses is that the material used (prewetted deicer versus salt) had more significant effect on the number of injuries than the amount of snowfall. Data analyses from the Village of Fayetteville indicated that the natural brine application data in the Village was highly variable. The data indicated that the frequency of accidents went up immediately after a heavy precipitation with either natural brine or rock salt application. The NYSDOT office data indicated that the number of accidents in the 2010-2011 winter season when brine was applied was less than when rock salt was applied during the 2009-2010 winter season, even though the precipitation was greater in the former case. It appears that brine was more effective in reducing the number of accidents at least on the roadways with similar characteristics such as I-81 and I-481.

Interviews with the winter road maintenance crew from the participating agencies indicated that the use of natural brine for both anti-icing and pre-wetting was beneficial for winter road maintenance. The crew indicated that quality equipment, accurate weather forecasting, good record keeping and overall quality management was needed for proper winter road maintenance.

Cost analyses of the use of natural brine from the NYSDOT groundwater well indicated that the costs for using commercial brine versus pumping natural brine from groundwater are comparable. Benefits of natural brine use include lesser material (salt) need and ease of mixing for preparation of the needed 23% brine for winter maintenance.

Part 1

LITERATURE REVIEW

STATUS OF THE USE OF BRINE IN ROADWAY MAINTENANCE

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LIST OF ACRONYMS

ADT: Average Daily Traffic

CMA: Calcium Magnesium Acetate

DOT: Department of Transportation

FAST: Fixed Automated Spray Technology

HITEC: Highway Innovative Technology Evaluation Center

LCS: Liquid Corn Substances

MCL: Maximum Contaminant Level

PNS: Pacific Northwestern Snow Fighters Association

RWIS: Road Weather Information System

USEPA: United States Environmental Protection Agency

Abstract

A thorough literature review was conducted on the use of brine as an anti-icing and pre-wetting agent both in the U.S. and abroad. The review indicated that the use of brine as an anti-icing and pre-wetting agent has gained popularity in most of the Departments of Transportation (DOT) in the U.S. and abroad over the years. The most common anti-icing chemicals include brine, calcium chloride, magnesium chloride, calcium magnesium acetate, potassium acetate, and agricultural byproducts, such as beet juice and molasses. European countries have mastered anti-icing techniques blended with sophisticated weather forecasting technology. Northern European countries also have access to advanced meteorological information as a result of formal arrangements made with various national meteorological agencies.

Studies indicate that increased applications of anti-icing chemicals lead to significant savings in material costs, reduced use of abrasives (typically sand), better road conditions, lower accident rates, and lower costs for winter road maintenance. Less use of anti-icing materials and abrasives has been shown to improve environmental protection. Anti-icing is currently recognized as a pro-active approach to winter driver safety by most transportation agencies. Pre-wetting has been shown to increase both the performance of solid chemicals and abrasives, as well as their longevity on the roadway surface, thereby reducing the amount of materials required. The disadvantages of anti-icing include the concerns for the chemicals refreezing if diluted, along with the rare development of slippery conditions in the absence of precipitation or freezing pavement temperature. The development of slippery conditions can be related to the combined effect of relative humidity, pavement temperature, and chemical type.

The choice of an anti-icing material is primarily a function of its freezing properties, corrosiveness, stability, material availability, impact to the environment, cost, and handling. The most popular anti-icing agent is brine with an average cost of 0.07 cents per gallon. Application and selection of an anti-icing chemical requires a full understanding of the phase diagram for the chemical and its eutectic point. The products that have a lower eutectic point, a flatter phase curve, and a higher concentration have the greatest potential to melt snow and ice.

The primary source of brine is rock salt or halite. Other sources of brine include naturally occurring brine and brine produced from oil/gas fields. Naturally occurring brine has great

potential for road maintenance as evidenced by the success of the Junex facility in Quebec, Canada. The natural brines used at this facility are as effective as conventional anti-icing agents and are cost effective. Oil/gas field brines are a byproduct and contain trace metals, organic compounds, and suspended solids. Therefore, their use has been limited and is subject to significant regulation and public scrutiny.

Salt brine is applied to roadways by slip/slide in application units, trailer brine application units, large tanker units, three legged applicators, bottom spray distributors, driver side sprays, and wheel path distributors. Best impacts can be obtained when anti-icing and pre-wetting are combined with sophisticated weather forecasting technology and quality equipment for application of brine. Trained personnel are also an integral part of the success of an anti-icing and pre-wetting program.

1.0 Introduction

Winter road clearance of snow and ice is essential to provide adequate safety for travel. Transportation agencies worldwide strive to keep their roadways open and safe during heavy snowfall, icy conditions, and low visibility conditions. State and local agencies in the U.S. spend $2.3 billion annually for removal of snow and ice.[1] Solid and liquid chemicals, as well as abrasives, are typically applied on winter highways to keep them clear of ice and snow. The use of abrasive material, typically sand, is the oldest form of snow maintenance. The main function of the abrasive is to increase the friction between the vehicles and the pavement. The material can be applied solely with a spreader (dry), or mixed with a salt chemical. Common chemicals used include sodium and calcium chloride, potassium acetate, calcium magnesium acetate, and agricultural byproducts. The overall efficiency of winter maintenance is limited without the complementary effect of utilizing both chemicals and abrasives. Winter maintenance strategies in North America traditionally focused on methods that allowed application of abrasives and chemicals after signs of snow and ice accumulation.[2] The use of chemicals and abrasives to remove snow and ice is known as *deicing*. In recent years, practice has shifted to applying chemicals before the accumulation of snow and ice. This practice is termed *pre-wetting* and *anti-icing*. A brief description of each process is provided below.

Deicing

This process entails the application of uniformly distributed salt across the width of the lane of the road. The salt (typically sodium chloride NaCl) mixes with water from the accumulating snow and forms brine. The primary function of rock salt is to lower the freezing point on the pavement. Deicing chemicals are frequently mixed with abrasives such as sand. The operations consist of plowing and applying the select materials to the pavement. Deicing operations are time consuming and costly. Large quantities of abrasives and salt are needed to increase traction levels and to disrupt the bonds between the compacted snow and pavement.

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[1] FHA, How do Weather Impact Roads? http://ops.fhwa.dot.gov/weather/weather_events/ snow_ice.htm [Accessed 11 Nov, 2009]

[2] O'Keefe, K., and Shi X. (2005) Synthesis of Information on Anti-icing and Pre-wetting for Winter Highway Maintenance Practices in North America. Final Report: Pacific Northwest Snow-fighters Association, Western Transportation Institute.

Anti-icing

Anti-icing is a more pro-active technique for winter road maintenance. A common practice is to spray pavement prior to a winter storm with a liquid ice-melting material such as brine, calcium chloride or magnesium chloride. The sprayed chemical forms a bond-breaking layer between the pavement and the falling snow. Effective anti-icing operations require accurate weather forecasting and timing of operations. Anti-icing operations require less materials and labor thereby reducing operational costs. If the roads are treated with anti-icing liquids prior to a predicted snow storm, but the storm arrives a few degrees warmer with rain instead of snow – the investment in anti-icing chemicals is washed off the road with no benefit. Alternatively, if temperatures unexpectedly rise during a snow event, anti-icing chemicals (calcium and magnesium chloride) may "slime" the road causing slippery and dangerous conditions.

Pre-wetting

Pre-wetting requires the addition of a liquid chemical (such as brine) to an abrasive such as sand or solid chemical before the material is applied to the roads. Pre-wetting usually takes place at the sand-salt stockpile or at the spreader. Pre-wetting of the solid rock salt and abrasives provides two major advantages. Wet material clings to roads better and prevents the dry materials from bouncing off roads or being swept away by winds. Pre-wetting also provides the moisture needed to melt the ice and snow and works faster at lower temperatures.

A study by Blackburn et al. [3] indicated that pre-wetting applications conducted in Europe in the 1960s and early 1970s appeared to be highly successful in cutting costs, providing safer roads and increasing environmental protection.

Anti-icing versus Deicing

Anti-icing prevents the snow and ice from bonding to the pavement and hastens achieving a bare pavement at the end of a storm.[4] Studies have shown that it takes four times more salt to deice

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[3] Blackburn, R.R., E.J. McGrane, C.C. Chappelow, D.W. Harwood, and E.J. Fleege. (1994) *Development of Anti-Icing Technology*. SHRP-H-385. Strategic Highway Research Program, National Research Council.

[4] http://cgs.rutgers.edu/public-works/documents/pw-sp10-1311a-brine.pdf [Accessed 6 May, 2010]

than to anti-ice. Anti-icing thus leads to a reduction in material costs and causes less harm to the environment. Anti-icing has been reported to provide a higher level of service throughout a winter storm in the ways listed below:[10]

- Keeps snow in a plowable condition
- Requires less chemical (e.g., salt, etc.)
- Improves roadway friction and lowers accident rates
- Can provide bare pavement for some events
- Reduces the need for abrasives
- Leads to faster cleanup after the storm has ended
- Reduces environmental impacts
- Reduces overtime usage

1.1 Materials Used for Winter Maintenance

This section provides a brief overview of properties sought in materials used in winter highway maintenance and description of the common materials used worldwide. Nixon and Williams (2001) [5] and Nixon et al., (2007)[6] indicated that the most important properties of materials used in highway maintenance during winter included the following:

a) *Freezing Point Depression*: A fundamental property of an anti-icing chemical when added to water is its ability to reduce the freezing point below the freezing point of water.
b) *Consistency*: An anti-icing chemical has to perform consistently from batch to batch over time.
c) *Environmental Impact:* Roadway maintenance chemicals can impact groundwater, roadside vegetation and surface water. As such the impact is measured using the presence of heavy metals, toxicity, nitrogen content, biological oxygen demand, and chemical oxygen demand of the chemical.

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[5] Nixon, W. A. and A.D. Williams (2001) A Guide for Selecting Anti-Icing Chemicals, IHRP Final Report # 420, A http://www.iihr.uiowa.edu/products/pubvid/pdf/IIHR420.pdf [Accessed 21 Jun, 2009]

[6] Nixon, W.A., G.Kochumman, Lin Qiu, Ju Qiu, and J. Xiong (2007) Evaluation of Using Non-corrosive Deicing Materials and Corrosion Reducing Treatments for Deicing Salts, IHRP Final Report # 463.

d) *Stability:* The chemical cannot be unstable and change properties over time.
e) *Corrosivity*: Chemicals used should not corrode equipment or structural materials, such as concrete and rebar.
f) *Handling*: Proper storage and ease of handling of the chemical is necessary.

Fay et al. (2007) [7] provided a thorough description of common materials used in winter road maintenance. These researchers also surveyed various states to provide their data on material use and their perspective on each material.

Traditional Materials

Traditional materials used in deicing, pre-wetting and anti-icing procedures include rock salt (sodium chloride, NaCl), magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), potassium chloride (KCl), calcium magnesium acetate (CMA) and potassium acetate (KAc). These chemicals primarily work by lowering the freezing point. Each chemical has its own working temperature range at a select concentration. CMA, KAc and KCl are much more expensive than the other salts and their use is primarily limited to high value locations such as airports and parking garages.

***Ag-Based Products*:** Recently, the use of beet juice, liquid corn salt, molasses and potato juice with salt brine have been demonstrated to be effective for anti-icing. Beet juice is a byproduct of the sugar beet process and has been reported to cost $1.05 per gallon. Adding carbohydrates can increase the adhesion properties of salt brine.[8] The beet brew is strongly adhesive, preventing ice from bonding with the roads. It is also biodegradable. The beet juice works well when mixed with either rock salt or liquid salt brine to keep ice from forming on the roads before a storm. When combined with salt, the beet juice freezes at a lower temperature than just salt alone, so it can be used when the weather is colder - even at temperatures well below zero. These organic materials also reduce the amount of corrosion from traditional salt; keep it working at lower temperatures and make the coating last longer.

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[7] Fay, L., Volke, K., Gallaway and C. Shi, X. (2008) Performance and Impacts of Current Deicing and Anti-icing Products: User Perspective versus Experimental Data", TRB,87th Annual Meeting.

[8] http://abcnews.go.com/US/keeping-winter-roads-ice-free-beet-juice/ [1 Feb, 2011]

Maryland DOT used a 85:15 solution of salt brine and beet molasses for the winter months of 2010 and 2011. Tennessee, Pennsylvania, Indiana, Virginia, Ohio, Iowa and Missouri DOTs have also successfully sprayed their highways with beet and potato juice during the 2010-2011 winter months.[9, 10] These DOTs indicate that beet juice can be a helpful aid for anti-icing and pre-wetting.

1.1.1. How Anti-icing Chemicals Work

In recent years there has been a growing transition from reactive strategies (deicing and sanding) to more proactive strategies (anti-icing and pre-wetting). Brine has the same melting characteristics of regular salt, but because it is already in liquid form, it can begin to work immediately. Brine provides improved road surface conditions and allows for safer travel. Liquid brine penetrates the ice pack faster and provides more uniform surface contact needed for the ice-road surface bond. The brine solution melts snow and ice that accumulates on roadways by lowering the freezing point of the water, thus minimizing the amount of snow and ice on the surface. [12]

A fundamental property for anti-icing chemicals is that they should have the ability to lower the freezing point of the mixture below the freezing point of water alone; a *eutectic system* is used to describe this phenomenon. A *eutectic system* is a mixture of chemical compounds or elements that has a single chemical composition that solidifies at a lower temperature than any other composition. This composition is known as the *eutectic composition* and the temperature is known as the *eutectic temperature*. On a phase diagram the intersection of the eutectic temperature and the eutectic composition gives the *eutectic point*.[11]

The eutectic point is the lowest possible freezing point for a particular anti-icing solution; every chemical used for anti-icing will have a different eutectic point. This can be seen in the phase diagram presented in Figure 1 for a salt-water system.[10] The Figure indicates that at 23.3

[9] http://www.usatoday.com/weather/research/2008-02-21-beeting-ice_N.htm [Accessed 12 Aug, 2009]

[10] http://www.washingtonpost.com/wp-dyn/content/article/2009/11/28/AR2009112801901.html [Accessed 15 Dec, 2010]

[11] http://www.science-dictionary.com/definition/eutectic-point.html [Accessed 15 Dec, 2010]

percent salt by weight the eutectic point is reached. The corresponding temperature is –21.1° C (-6.02° F).

The curved lines on the diagram separate the phases of the solution as follows:

- Above the curve—all liquid solution; melting action.
- Below the curve—mixture of solution and ice or salt; refreezing action.
- Below the eutectic point—solid ice.

The eutectic properties of the five most common anti-icing materials are presented in Table 1.

Three inorganic salts are commonly used to form salt brine with water, and their interactions with the environment are different if applied prematurely before a storm. Sodium chloride (NaCl) brine evaporates yielding salt residuals in the pavement and later dissolves back to brine with precipitation, whereas calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) attract moisture and continually wet the road until depleted.[5]

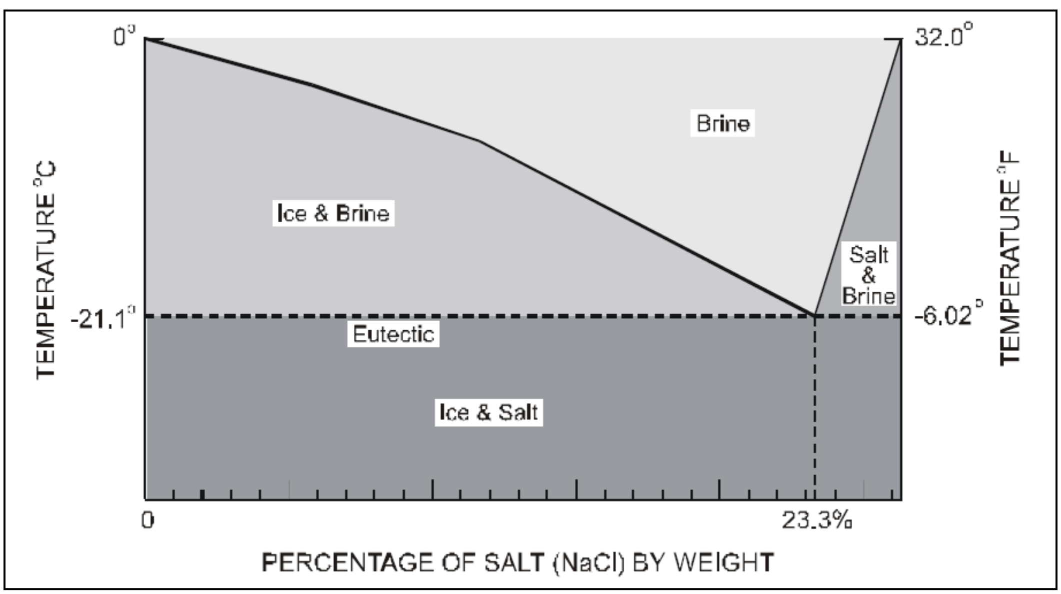

Figure 1: Phase Water Diagram for the Salt-Water System [5]

Table 1: Eutectic Temperatures for Common Anti-Icing Agents [12]

Chemical	Eutectic Temperature °C (°F)	Eutectic Concentration %
Calcium Chloride ($CaCl_2$)	-51 (-60)	29.8
Sodium Chloride (NaCl)	-21 (-5.8)	23.3
Magnesium Chloride ($MgCl_2$)	-33 (-28)	21.6
Calcium Magnesium Acetate (CMA)	-27.5 (-17.5)	32.5
Potassium Acetate (KAc)	-60 (-76)	49

1.1.2 Selecting an Anti-Icing Agent

Phase diagrams are useful when comparing and selecting various anti-icing agents. The products that have a lower eutectic point, a flatter phase curve and a higher concentration have the greatest potential to melt snow and ice. Products with steeper curves are susceptible to refreezing.[12] This is presented in the Figure 2(a) and 2(b) below.

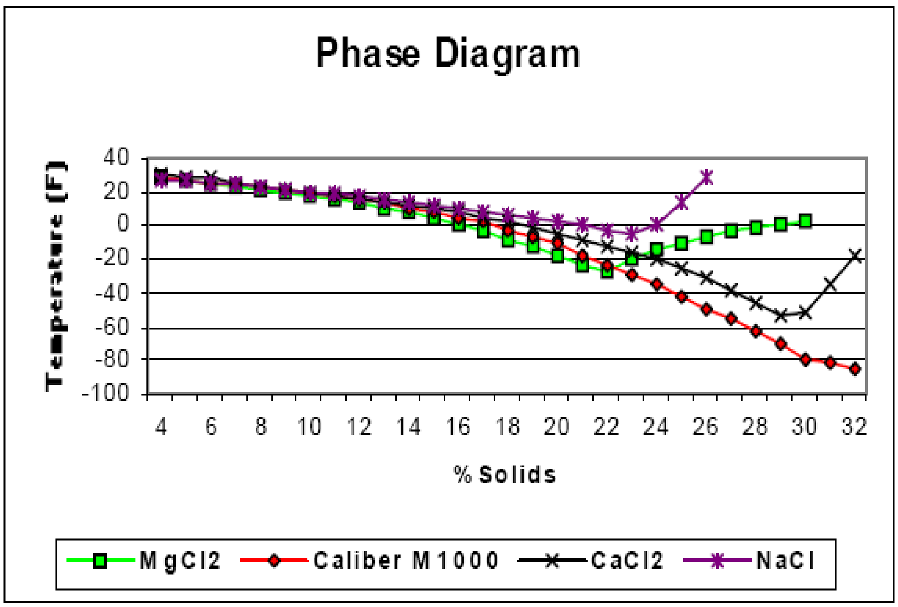

Figure 2(a): Phase Diagrams for Various Anti-icing Agents[12]

[12] http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm [Accessed 18 Mar, 2009]

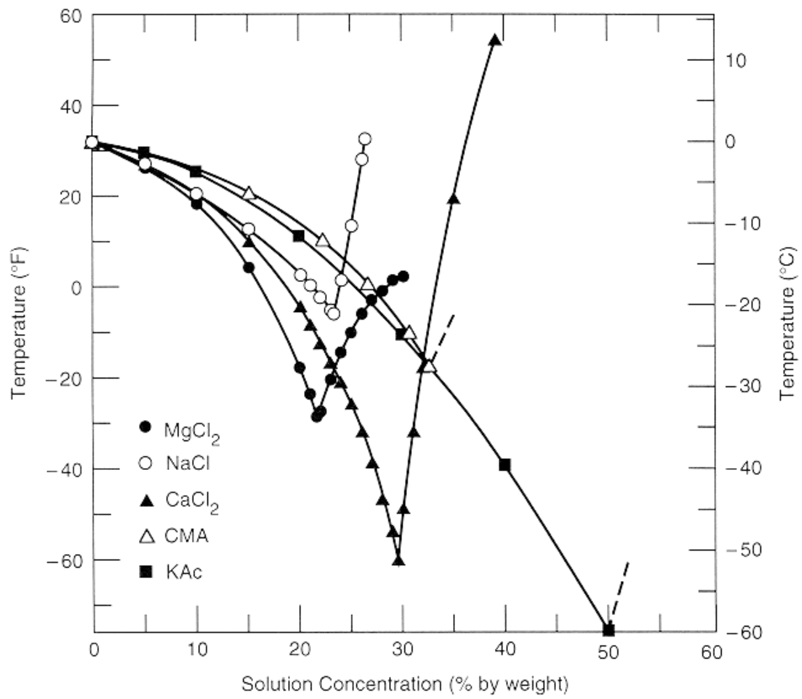

Figure 2(b): Phase Diagrams for Various Anti-icing Agents[12]

Data demonstrating the effectiveness of various anti-icing agents is presented in Table 2 and 3.

Table 2: Comparison of Anti-Icing Agents [5]

Anti-Icing Chemical Types						
Type	**Examples**	**Adhere**	**Suggested Min[1] (°F)**	**Practical Min[1] (°F)**	**Benefits**	**Cautions**
Basic	NaCl Salt Brine	No[5]	20°	15°	-Handles a high percentage of storm events over a typical season -Shorter road adherence, which can benefit areas prone to blowing snow	-Quality control (23.3% NaCl solution) -If no precipitation will "dry up" and blow off roadway
Adhering (Sticky)	LCS[2,4]	Yes	15°	10°	-Can adhere to roadway for multiple days if no precipitation	-Ensure concentration is correct (10% corn syrup, 90% NaCl)
Depresses Freezing Point	Blends[3]	No	10°	0°	-More effective at temperatures below 15°F	-Consider dilution, it is suggested to use 0°F as a general minimum
Adhering (Sticky) and Depressed Freezing Point	$MgCl_2$, $CaCl_2$, Blends[3,4]	Yes	10°	0°	-More effective at temperatures below 15°F -Can adhere to roadways for multiple days if no precipitation	-Do not apply if pavement temperature is above 32°F -Consider dilution, it is suggested to use 0°F as a general practical minimum -Blending $MgCl_2$ with salt brine has been reported to be problematic by some agencies

Table 3: Eutectic Temperatures and Chemical Concentrations[13]

Chemical	Practical/Effective Minimum	Eutectic Freezing Point (Lab Only)	Concentration
NaCl	15°F (20°F desired)	-6°F (-21°C)	23.3%
LCS	10°F (15F desired)		10% Liquid Corn and 90% NaCl
$MgCl_2$	0°F (10°F desired)	-28°F (-33°C)	21.6%
$CaCl_2$	0°F (10°F desired)	-60°F (-51°C)	29.8%
CMA	20°F	-17°F (-27°C)	32.5%
KA_c (Potassium Acetate)	0°F	-76°F (-60°C)	49%

The Minnesota DOT Anti-icing Committee has formulated a guideline on when and when not to apply anti-icing.[14] Table 4 summarizes these findings.

Table 4: Guidelines for Effective Anti-icing[14]

When to Apply	When not to Apply
Preferred times are during off peak hours	Prior to predicted rain
Apply on road with low pavement temperature and high traffic volume	During heavy snow (1inch/hour)
Apply on critical areas such as bridge, busy intersection prior to the storm	Under blowing or drifting snow conditions
Use different chemicals for different pavement temperature	After the bond between in the snow and the pavement has occurred

1.2 Anti-icing and Pre-wetting in the U.S. and Other Countries

Currently Departments of Transportation (DOT) in the U.S. and other countries use brine to provide safe transportation for travelers during the winter season. Brine is typically prepared from mined rock salt. Other sources include natural occurring brine in groundwater/surface water or from oil/gas fields.

[13] Pesti, G. and Y. Liu (2003) Abrasives and Salt Brine, NDOR Research Project Number SPR-P1(03) P557 Transportation Research Studies.

[14] http://www3.dot.state.mn.us/maint/research/chemical/Guidelines%20for%20Anti-icing%20-Public.pdf [Accessed 20 Apr, 2009]

1.2.1 Brine Use from Rock Salt (Halite)

There are hundreds of salt beds or domes (as they are sometimes known) across the world. Mines vary in depth from 100 meters or so, to a mile or more.[15]

In 2009, world salt production was estimated at 260 million metric tons. The top five producers (in million tons) reported were China (60.0), United States (46.0), Germany (16.5), India (15.8) and Canada (14.0).[16] Salt for highway deicing accounted for 43 percent of U.S. demand in 2009. The chemical industry consumed about 35 percent of total salt sales, with salt in brine representing about 90 percent of the type of salt used for feedstock. The chlorine and caustic soda manufacturing sector was the main consumer within the chemical industry. The remaining markets for salt, in declining order, were distributors, 8 percent; agricultural, 3 percent; food, 3 percent; general industrial, 3 percent; water treatment, 3 percent; and other combined with exports, 2 percent. The price for rock salt reported in the U.S. in 2009 was $35/ton and for brine $8/ton. [16]

1.2.2 Anti-icing and Pre-wetting in the U.S.

A thorough review of anti-icing and pre-wetting practices in the U.S. for winter road maintenance is presented in this section. An extensive nationwide survey of highway maintenance agencies to rank the advantages of specific deicers with respect to low cost per lane/mile, low effective temperature, high ice-melting capacity, ease of application, and overall safety benefits for winter roads based on field experience or research from the respondent's agency was conducted by Nixon et al (2007). [5] A total of 15 states in the U.S. participated in this study with an overall total of 24 deicer users. One user from New Zealand and one from Finland also participated in the study. The data collected is presented in Table 5 and indicates that rock salt is the most frequently used material followed by abrasives and then by magnesium chloride. Less than 25 percent of the survey respondents used alternative deicers such as potassium acetate, calcium magnesium acetate, sodium acetate, and potassium formate.

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[15] http://www.saltsense.co.uk/aboutsalt-prod03.htm [Accessed 12 June., 2010]

[16] http://minerals.usgs.gov/minerals/pubs/commodity/salt/mcs-2010-salt.pdf [Accessed 12 June., 2010]

Survey respondents were asked to rank the advantages of specific deicers with respect to low cost per lane/mile, low effective temperature, high ice-melting capacity, ease of application, and overall safety benefits for winter roads based on field experience or research on a scale of 1-5 with 1 being the least and 5 being the most advantageous. These results are presented in Figure 3. The average ranking results show that chloride based deicers are cost effective per lane/mile. Abrasives were indicated to be poor performers at low temperatures and were considered to have poor ice melting capacity. There was no perceived difference in the ease of application for all surveyed materials. Literature and experimental data indicated that the negative impacts of acetates and formates were greater than perceived by survey respondents, especially with respect to damage to pavement, structures and water quality.

O'Keefe and Shi [2005][2] also conducted an extensive study with fifteen state DOTs on their average percentage of anti-icing and pre-wetting agents utilized per year.

Table 5: Frequency of Deicers Used as Listed by Survey Respondents[5]

De/Anti-icers Listed	Abbreviation	Frequency (n)	Percent of Respondents (%)
Abrasives (sand)	sand	17	71
Sodium Chloride (solid)	NaCl (s)	20	83
Sodium Chloride (liquid brine)	NaCl (l)	4*	17
Sodium Chloride & Abrasives	NaCl & sand	3*	12
Magnesium Chloride	$MgCl_2$	14	58
Calcium Chloride	$CaCl_2$	11	46
Clearlane®	NaCl, $MgCl_2$	3	13
IceSlicer®	NaCl, KCl, $MgCl_2$	3	13
Calcium Magnesium Acetate	CMA	2	8
Potassium Acetate	K-acetate	6	25
Sodium Acetate	Na-acetate	2	8
Potassium Formate	K-formate	1	4
Agricultural Based	Ag-based	12[†]	50

* Only counted if specified use in survey.

[†] Ag based deicers include: Ice B'Gone® (n=2), Magic by Calibar® (n=1), beet and/or corn based (n=3), unspecified Ag-based as inhibitor mixed with $MgCl_2$ (n=2), unspecified Ag-based as inhibitor mixed with $CaCl_2$ and NaCl (l) (n=1), or an unspecified small amount of Ag-based listed generally as inhibitor (n=3), and Geomelt® (n=1).

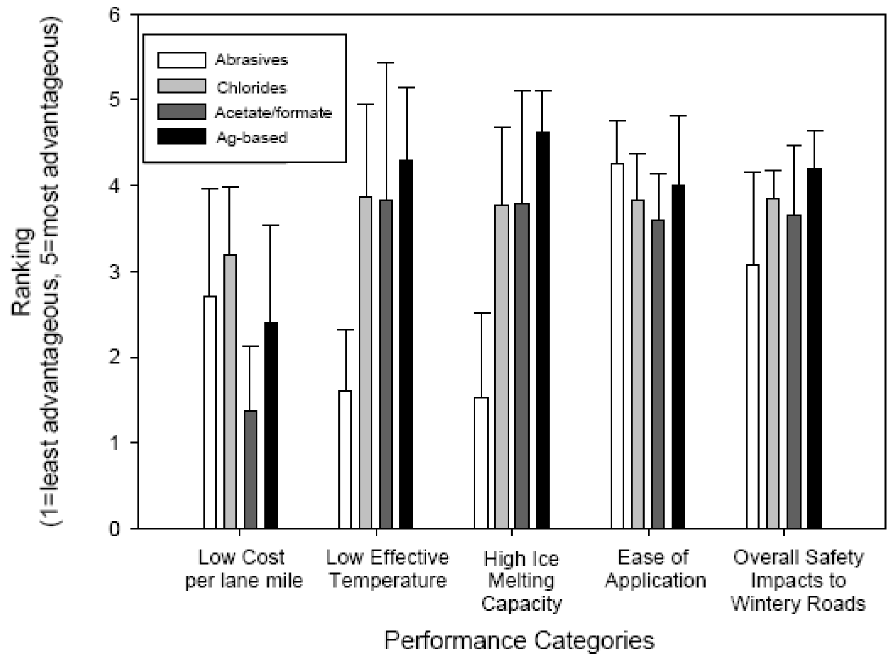

Figure 3: User Rankings for Deicers in Various Performance Categories[5]

Participating agencies included Alaska, Alberta, British Columbia, Colorado, Idaho, Minnesota, Missouri, Montana, Nevada, New York, Oregon, Vermont, Washington, Wisconsin, and Wyoming. The authors collated information from literature and agency surveys on the advantages and disadvantages of anti-icing and pre-wetting for winter highway maintenance. Concerns discussed included driver safety, human health, environmental stewardship, corrosion and costs. The research indicated that, compared with traditional methods for snow and ice control, anti-icing and pre-wetting lead to decreased applications of chemical products, reduced use of abrasives, decreased maintenance costs, improved roadway friction, and lower accident rates. Anti-icing was recognized as a pro-active approach to winter driver safety by most agencies. Pre-wetting was shown to increase the performance of solid chemicals or abrasives and their longevity on the roadway surface, thereby reducing the amount of materials required. These researchers included data obtained from the Pacific Northwest Snow Fighters Association (PNS) on brine use. The PNS was formed by technical experts from Idaho, Montana, Oregon, Washington, and British Columbia and later joined by Colorado to address the needs of winter highway maintenance with environmentally-friendly and fiscally-responsible solutions and to develop specifications for winter maintenance chemicals. Figures 4 and 5 indicate that the PNS states have a more even distribution of anti-icing and deicing applications. Eleven percent of non-PNS states used 90 percent-100 percent anti-icing material over other winter roadway practices. Results of this detailed study indicated that both PNS and non-PNS states unanimously indicated that anti-icing and pre-wetting improved winter road conditions and roadway safety.

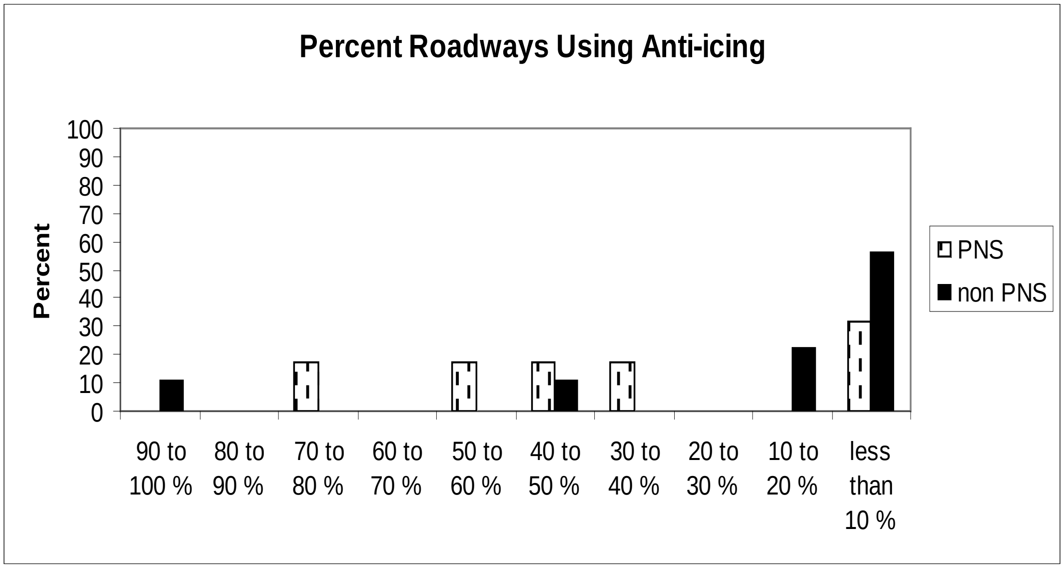

Figure 4: Percent Roadways Using Anti-icing [2]

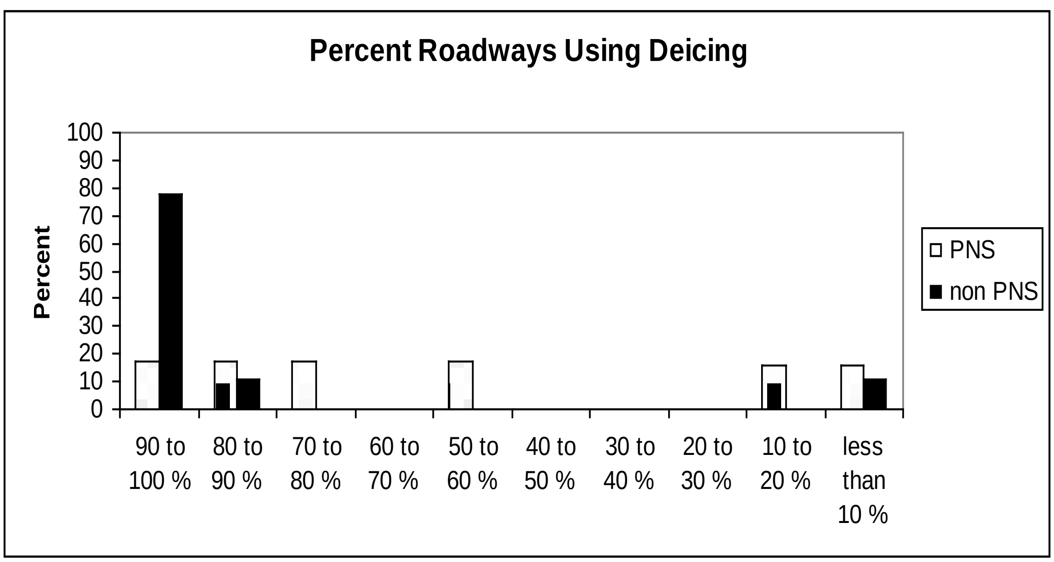

Figure 5: Percent Roadways Using Deicing [2]

In Washington State, the implementation of anti-icing in the North Central Region has resulted in an improved level-of-service at the same cost as previous maintenance practices.[17] Washington State DOT's (WSDOT) brine for anti-icing is a liquid compound consisting of salt, sugar, mineral and water. A 23.3 percent solution of salt makes up 75 percent of the compound. De-sugared molasses makes up 20 percent and calcium chloride 5 percent. WSDOT conducted a salt pilot project for evaluation of the performance of rock salt or brine on highways in comparison to other anti-icing chemicals that are used to control snow and ice on roadways. Some of the key findings of this study were:

- When comparing labor, materials and equipment, costs for snow and ice control were generally less for maintenance crews using salt than for crews using anti-icing chemicals,.
- Results of laboratory corrosion testing for anti-icers and the results seen in the field were significantly different. Field tests indicated a higher level of corrosion than the level that was produced in laboratory tests.
- Anti-icing chemicals generally appeared to be more corrosive on sheet and cast aluminum alloys than salt.

In Montana, benefits of anti-icing were witnessed during a winter storm that hit State Route 200 in December of 2000. [18] The crew responsible for the Plains section used anti-icing techniques, whereas the Thompson Falls crew implemented pre-wetting techniques. Of the two sections illustrated in Figure 6, the Plains section achieved bare pavement conditions while the Thompson Falls section remained snow packed.[4]

In Idaho, once anti-icing was implemented on U.S. 12 accidents were reduced by 83 percent compared to years before the start of the pilot program.[19] The study found significant benefits when traditional methods (i.e., deicing using NaCl and abrasive use) were replaced with liquid chemical anti-icing including salt brine. The area studied was on US 12 near Orofino in the

[17] Boon, C.B and C. Cluett (2002). Road Weather Information Systems: Enabling Proactive Maintenance Practices in Washington State. http://www.its.dot.gov/JPODOCS/REPTS_TE/13660.html [Accessed 12 Sept., 2009]

[18] Williams, D. and C. Linebarger (2000) Memorandum: Winter Maintenance in Thompson Falls. December, 29, 2000. http://www.wsdot.wa.gov/partners/pns/pdf/KalispellReview.pdf. [Accessed 12 Sept., 2009]

[19] Breen, B.D., 2001. Success of the Anti-icing Program in Idaho. <http://www2.state.id.us/ida-road/WinterMaint-AntiIcing.htm.> [Accessed 12 Sept., 2009]

winding Clearwater River canyon. Figure 7 shows the road after anti-icing. The results of three years of operations (1997 to 2000) for this study are presented in Table 6.

Figure 6: Montana State Route 200 at Select Sections[19]

Figure 7: U.S. 12 in. Idaho after Anti-icing Treatment Showing Frost on Edge of Roadway[19]

Table 6: Data for U.S. 12 in. Idaho[19]

Accidents	Avg. Labor Hours	Avg. Abrasives Used	Avg.
Before 1997(Pre anti-icing)	650	1475 cu. M	16.2
After 1997 (Since Anti-icing)	248	247 cu. M	2.7
Amount Reduced	402	1228 cu. M	13.5
Percent Reduction	62%	83%	83%

During a twelve-year study involving anti-icing strategies on the interstate system in the Denver metro area, Colorado saw an average of 14 decrease in snow and ice related crashes. [20]

Tennessee DOT[21] was one of the first states to use an ice and snow control solution using salt brine. The liquid salt brine solution helped prevent snow and ice from bonding to the road surface. The solution cost about $0.05 a gallon and used less salt, thus saving tax dollars and reducing the amount of sodium released into the environment.

Wisconsin DOT[22] has used pre-wetting with salt brine successfully. Faster melting action was seen due to the brine application. In addition, the wet salt was less likely to bounce or be blown off the road by traffic. This DOT recommends applications of 8-10 gallons of liquid per cubic yard of salt. The Iowa State DOT[23] used over 7,000,000 gallons of salt brine for snow and ice control in 2002-2003. The Department has equipped the entire fleet of 879 snow plow trucks with the ability to pre-wet all dry materials and has sufficient anti-icing equipment to anti-ice approximately 10,000 lane miles; including all of the Interstate. In Indiana, spraying liquid chemicals (specifically $MgCl_2$ and IceBan Magic) has helped to reduce accidents.[24] A study monitoring the number of accidents on U.S. 20 during the winter seasons of 1996/1997 when liquid chemicals were first introduced and 1997/1998 when anti-icing became more prevalent

[20] Colorado Department of Transportation. *Liquid Deicer Fact Sheet.* http://www.coloradodot.info/library/Brochures/DeicerFactSheet.pdf/view [Accessed June 13, 2012]

[21] http://www.tdot.state.tn.us/news/2005/120705.htm [Accessed Apr 20, 2009]

[22] http://epdfiles.engr.wisc.edu/pdf_web_files/tic/bulletins/Bltn_006_SaltNSand.pdf [Accessed 13 Mar, 2009]

[23] http://www.iowadot.gov/maintenance/pdf/4LiquidsAnti-icing.pdf [Accessed Nov 20, 2010]

[24] Highway Innovative Technology Evaluation Center, 1998. Evaluation Findings for IceBan. Prepared by HITEC and the Civil Engineering Research Foundation (CERF) http://www.bareground.com/bmwb/pdf/Bare_Ground_TestingIceBan1.pdf [Accessed 12 Mar, 2009]

showed a drastic decrease in accidents when anti-icing was implemented. The accident data results as reported by HITEC (Highway Innovative Technology Evaluation Center) are presented in Figure 8.

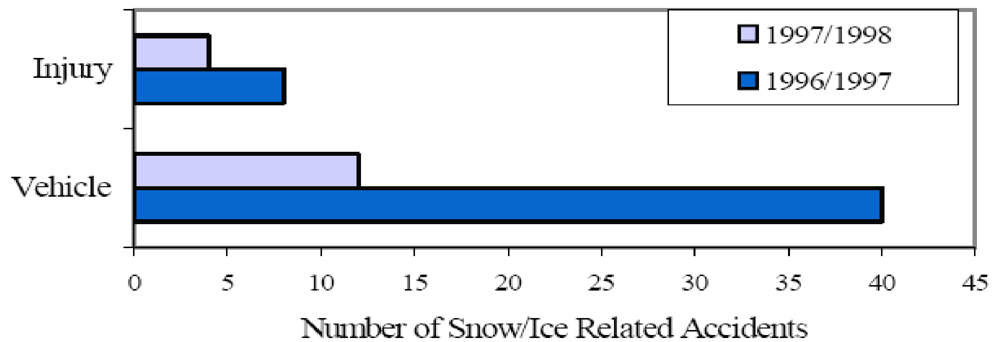

Figure 8: Accident Rate on U.S. 20 in Indiana during the Winters of 96/97 and 97/98[24]

The city of Denver, Colorado conducted a 12 year study involving anti-icing strategies on the interstate system. An average of 14 percent decrease in snow and ice related crashes, and a more than 23 percent increase in traffic volume, was observed. Colorado DOT (CDOT) maintenance personnel utilize two primary compounds for anti-icing and deicing operations, NaCl mixed with sand and $MgCl_2$ liquid deicer.[25] In addition, another liquid deicer used by CDOT is $MgCl_2$ with corn-based agricultural additives to enhance its performance. According to the field experience of CDOT personnel, $MgCl_2$ outperformed the salt-sand mixture as a deicer. Compared to the salt sand mixture, $MgCl_2$ proved to be more effective, less toxic and less corrosive. It also significantly decreased the amount of sediment entering Colorado's streams and particulates entering its air. CDOT has thus shifted from using primarily NaCl and sand to using $MgCl_2$ liquid deicers for wintertime operation and maintenance of state and national highway systems over the past several years.

Nevada DOT[26] began experimenting with anti-icing technologies in 1991, when it started using RWIS (Road Weather Information System), a technology evaluated as part of the Strategic Highway Research Program (SHRP). The RWIS data shows the DOT when and where to send

[25] Colorado DOT. 2006. Evaluation of Alternate Anti-icing and Deicing Compounds Using Sodium Chloride and Magnesium Chloride as Baseline Deicers. Proposal No: HAA 05-06/BL.

[26] http://www.fhwa.dot.gov/publications/focus/96may/56nevada.cfm [Accessed 15 July, 2009]

crews to apply liquid deicing chemicals before an approaching storm. By implementing anti-icing strategies, Nevada DOT uses considerably less deicing material than with conventional deicing strategies. Nevada has cut its use of road salt in half and its use of sand by 70 percent which means significantly less salt and sand end up in the Lake Tahoe watershed.

The Vermont Transportation Agency research team recommends the use of salt brine above when conditions are above 15°F. They also recommend and a mixture of 70 percent salt brine and 30 percent Ice-B-Gone when conditions are between 15 and 5°F.[27] It was determined that the use of sand could be eliminated when temperatures are above 5°F. This project had a salt savings of 30 percent and a cost savings of 24 percent over conventional methods. There was also a 27 percent reduction in the number of miles driven by the operators in order to clear the road.

In a survey of the snow removal practices in Virginia, it was found that 52 divisions of the Virginia DOT were using pre-wetting techniques with pre-wetting being conducted at the point of discharge.[28] The divisions were primarily using magnesium chloride.

Missouri uses a commercial product GeoMelt as an additive to salt brine.[29] GeoMelt is a byproduct from the production of sugar from sugar beets. In other publications by the Missouri DOT it is referred to as beet juice. GeoMelt decreases the temperature that salt brines are effective at and also reduces corrosion.

The Minnesota DOT (MnDOT) uses both magnesium chloride and brine for anti-icing.[30] Anti-icing can be applied before the storm or in the early storm period. Scheduled applications are

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[27] Newbury Gil, and C. Jason (2009) Vermont Agency of Transportation. "Salt Brine, Salt Brine Blends And Application Technologies During the 2008 – 2009 Winter Maintenance Season". Report No. 2009-9. , [Accessed 7 July, 2010]

[28] Roosevelt, D.S. (1997) *A Survey of Anti-Icing Practice in Virginia*. VTRC 98-R19. Virginia Transportation Research Council, Charlottesville, 1997. http://www.virginiadot.org/vtrc/main/online_reports/pdf/98-r19.pdf [Accessed 7 July, 2010]

[29] Organizational Results Division Missouri Department of Transportation, "Snow Plowing Best Practices" 2008, <http://library.modot.mo.gov/RDT/reports/ad09077/orb09003.pdf> [Accessed 7 Aug, 2010]

[30] Minnesota Department of Transportation, "Guidelines for the Use of Anti-icing". May 2005. http://rebar.ecn.purdue.edu/snownice/documents/Guidelines%20for%20Anti-icing.pdf [Accessed 3 Aug, 2010]

made on bridge decks and other critical areas and the chemical may have a residual effect for five days. MnDOT recommends that anti-icing should not be applied before rain, during heavy snow, after a bond has formed between snow and pavement, or when there is blowing or drifting snow. It is also cautioned that under some temperatures and humidity conditions magnesium and calcium chloride will become slippery. There is also the potential for slippery conditions if there is a build-up of oil and rubber residue on the road. The benefits to anti-icing in Minnesota are a reduction in accidents, deicing material and residue, labor including clean-up work and cost. It was also reported that the accumulation of sand in drainage structures and under guide rails are reduced and road conditions are returned more rapidly to bare pavement. The Minnesota DOT prepared a comprehensive report titled "Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice".[31] This report provides detailed research to identify existing anti-icing practices, field strategies and procedures, and application rates. A total of 12 transportation agencies' anti-icing guidelines were reviewed to prepare procedures to identify current patterns of practice.

A detailed qualitative survey of 20 local and highway superintendents in the U.S. was conducted to gauge the type and amount of deicing chemicals applied to roads and highways via a 2009 USGS study.[32] Results are presented in Appendix A. Respondents were asked to describe the type and amount of deicing chemical used, and the number of lane/road miles serviced. Deicing application rates in units of tons per road or lane mile were calculated from the results of the survey. Sodium chloride rock salt was the most common de-icing agent. Average rates ranged from 10 to 30 tons per lane mile for the USGS study. Heisig (2000)[33] reported application rates per lane per mile ranging from less than 1 ton per mile road in Washington State to 74.5 tons per lane mile for Interstate 84 in New York.

[31] Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice TRS 092 (2009) http://www.lrrb.org/pdf/trs0902.pdf [Accessed 3 Aug, 2010]

[32] Mullaney, J.R., Lorenz, D.L., Arntson, A.D., 2009, Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States: U.S. Geological Survey Scientific Investigations Report 2009–5086, 41 p.

[33] Heisig, (2000) Effects of residential and agricultural land use on the chemical quality of baseflow of small streams in the Croton watershed, southeastern New York: U.S. Geological Survey Water-Resources Investigations Report, 99–4173, 15 p.

1.2.3 Brine Use Outside the U.S.

Europe, in regards to winter highway maintenance, is ahead of the United States. Since the European Union placed an order to have a concentration of any pollutant in groundwater identified or reversed by 2015, European countries have either implemented new practices or conducted pilot studies on environmentally friendly snow removal applications. In Northern Europe, which suffers from harsh winter seasons, winter maintenance routines are crucial in maintaining safe travel. For example, specific maintenance routines and technologies in Sweden, Denmark, Norway, Belgium, and Germany are necessary for daily commute and travel. All of these countries have implemented RWIS technologies to assist them in winter roadway maintenance. In fact, with the exception of Belgium, these countries have been using RWIS technologies for over 15 years. Through the use of RWIS, and the latest innovative means of snow and ice control, these countries have achieved increased: safety, traffic movement, cost optimization, awareness, and environmental protection.

The deicing agents used in Sweden, Denmark, Norway, Belgium, Finland and Germany are nearly the same agents utilized in the U.S.[34] Commonly used deicing agents include: sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), urea, alcohols and various magnesium acetate solutions. The agents are applied dry or in a wetted solution. Deicing agents are used to prevent or combat poor road conditions. The differences in winter roadway maintenance routines used in the U.S. compared to Northern European countries occur in the processes implemented to determine proper roadway treatments. The processes include the use of winter indexes that are prepared by using data provided by RWIS and FAST systems.

Finland uses salt brine and prewetted salt.[34] The brine is 23 percent sodium chloride and is used to pre-wet the rock salt. If the pre-wetting at 30 percent brine by weight is used, this mixture has the consistency of oatmeal. This consistency ensures that the mixture stays on the road. It was concluded that brine application was the most effective action against black ice and as a preventative measure in the spring and fall seasons.

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[34] Blackburn Robert R., McGrane Erin J., Chappelow Cecil C. , Harwood Douglas W., Fleege Edward J. (1994) Development of Anti-Icing Technology" SHRP-H-**3**85. http://onlinepubs.trb.org/onlinepubs/shrp/SHRP-H-385.pdf [Accessed 4 Aug, 2010]

Denmark uses both salt brine and pre-wetted salt.[22] Additionally, Denmark makes heavy use of road weather stations and short-term forecasts.[37] Salt brine is applied two hours before a storm at a rate between 130 and 325 pounds per lane mile. No chemicals are applied during a storm.

The Netherlands uses pre-wetting and dry salt.[35] The main concern is ice from wet roadways, condensation, or frozen fog. The salt is pre-wetted with either 16 percent calcium chloride or 20 percent sodium chloride. When snow is predicted, anti-icing takes place using pre-wetted salt. After plowing, dry salt is reapplied.

Studies conducted in Germany and Finland [34] used a brine solution to pre-wet their sodium chloride and experienced success keeping more of the materials on the road surface than with dry materials. A study conducted during the winters of 2000-2001 and 2001-2002 concluded that using straight salt brine for frost conditions is better than pre-wet salt. The study found a salt saving of 30 percent using brine for frost events. Denmark is also extensively using RWIS and Vinterman systems to increase the efficiency of their maintenance operations. Also being investigated is the use of GPS-controlled spreading technology.

Sweden uses salt brine and pre-wetted salt. [34] The salt brine is best used for anti-icing to prevent black ice and on roads with over 6000 ADT. For the pre-wetted salt, 30 percent brine by weight is applied at the spinner. Sweden has implemented the MINSALT project to investigate whether the negative effect of using salt in winter maintenance can be reduced, without compromising safety.

While there are no European standards for winter roadway maintenance, there is structure present in most countries. For instance, in Sweden, maintenance organization is prepared regionally. In other countries such as Belgium and Germany, maintenance is organized through a political structure. Roadway importance and traffic volume are used to determine policies that are implemented to regulate road treatment.[34]

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[35] Knudsen Freddy (2004) Quality improvement of winter service in Denmark. Snow 04-052. Sixth international symposium on snow removal and ice control technology. Transportation research circular e-c063: snow and ice control technology. June 2004. Pp. 179-189 <http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf> [accessed 21 July, 2010]

Deicing agents are regulated in all of these countries. Sweden requires that only NaCl be used and specifies that the salt is fine graded (0-4 mm). Norway regulations include salt content and size. Denmark requires a minimum salt content in brine solutions (greater than 70 percent salt). Belgium regulates salt type and chloride concentration. The only chemicals permitted in Belgium are NaCl and $CaCl_2$. Furthermore, these countries have regulations on equipment used for snow removal and salt application, as well as manpower restrictions.[34]

The Northern European countries also have advanced ways of acquiring meteorological information. In most cases, formal arrangements are made with the various national meteorological agencies.[34] Additionally, road weather station data is collected through phone lines, wireless and fiber optic technology. This data is often collected by a central agency that distributes this information to the smaller maintenance operations. Although some sensors collect data throughout the year, most sensors are only active during the winter season. Data collected from RWIS systems is crucial for smaller maintenance operations, because it allows them to determine what type of treatment is necessary under certain conditions. RWIS stations are typically spaced approximately 30 km apart. Germany contains over 600 RWIS stations to help monitor and collect necessary data.[34]

New technologies that are currently in use throughout the Northern European countries include thermal mapping, as well as sensors to determine roadway surface friction coefficient and temperature. Thermal mapping is achieved by measuring radiated or reflected heat. These measurements are then used to create real-time images of roadways. Thus, the images provide a considerable amount of information for maintenance facilities. Sensors that calculate the roadway friction coefficient are now being implemented on maintenance vehicles. This data is significant because having the roadways friction coefficient allows maintenance operations to develop a strategy for roadway treatment. Consequently, the friction coefficient sensors can make operations much more efficient. Sensors that measure surface temperature of the roadway are also being used on maintenance vehicles. In addition to these advances, GPS technology is being used by maintenance facilities throughout Northern European countries, resulting in a more smooth and efficient operation. [34]

Canada has also made major progress in the use of anti-icing.[36] Anti-icing in British Columbia began as early as 1995 with liquid magnesium chloride. Results indicated a reduction in accidents and windshield damage caused by solid sand and salt. Subsequently, other regions also initiated anti-icing strategies. The Transportation Agency of Canada conducted a survey in 2000 of 10 provinces and one territory to determine anti-icing usage data. The results from the survey are indicated on Table 7.

In the winter of 2003-2004, the Nova Scotia Department of Transportation & Public Works (NSTPW) in Canada conducted a liquid anti-icing trial by equipping a truck with a brine concentration of 23% for pre-wetting. The reduction of salt usage from previous snow-removal practices to the addition of salt brine is depicted in Figure 9.[37]

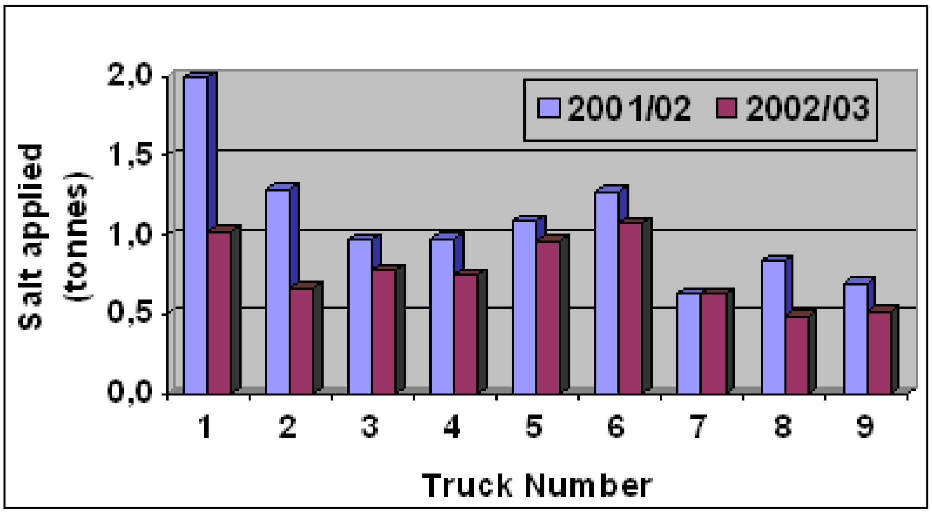

Figure 9: Salt Use Reduction by Units Retrofitted for Pre-wetting [37]

Results indicated that sodium chloride followed by magnesium chloride was mainly used in solid, pre-wet and liquid brine forms. Canada is aggressively implementing anti-icing with RWIS and thermal mapping technology.

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[36] http://www.cshrp.org/products/brief-20.pdf [Accessed 7 Jul, 2009]

[37] Utilizing Technological Advances in the Management of Road Salt Usage in Nova Scotia (2000). http://www.ec.gc.ca/nopp/roadsalt/cStudies/en/index.cfm [Accessed June 13, 2012].

Table 7: Anti-Icing Usage in Canada[36]

Province or Territory	Agency	Total Lane Km Maintained	Lane Km Treated with Anti-icing	Primary Anti-icing Chemicals	Applied in What Form?	Experience with Anti-icing
Northwest Territories	Department of Transportation	2200	700	Sodium	Solid	Over 2 years
British Columbia	City of Vancouver	1400	500	Sodium Chloride	Liquid	Over 2 years
	City of Kamloops	1500	610	Magnesium Chloride	Liquid	Over 2 years
	Insurance Corporation of British Columbia (ICBC) Anti-Icing Pilot Project*	>50000	5000 (approximate)	Magnesium Chloride and Sodium Chloride	Liquid and Prewet Solid	1-2 years
	Emcon Services (Ministry contractor)	13894	550	Magnesium Chloride	Liquid	2 years
	Main Road Mid-Island Contracting (Ministry contractor)	2056	1303	Sodium Chloride	Liquid and Prewet Solid	Over 2 years
Alberta	Alberta Infrastructure	Trials scheduled for 2000/2001				
	City of Calgary	7000	10	Calcium Chloride	Liquid	1 year
Saskatchewan	Highways and Transportation	32600	20 (Trial)	Sodium Chloride		Trial this Winter
Manitoba	Public Works	4208	1080	Sodium Chloride	Liquid	Over 2 years
Ontario	Ministry of Transportation			Sodium Chloride Prewet with Magnesium Chloride		2 years
	Region of Ottawa-Carleton	3200	30-40	Sodium Chloride	Liquid	First Season
	City of Ottawa	875	875	Sodium Chloride Prewet with Calcium Chloride		Over 2 years
	McCormick Rankin Corp. (Ministry contractor)	5000	2500	Sodium Chloride	Solid	Over 2 years
Ontario and New Brunswick	Integrated Maintenance & Operations Services Inc. (Ministry contractor)	3000	300	Sodium Chloride	Liquid	Over 2 years
New Brunswick	Department of Transportation	35200	Variable	Sodium Chloride	Solid	Over 2 years
Prince Edward Island	Transportation and Public Works	5800	300	Sodium Chloride	Solid	Over 2 years

* the ICBC Anti-Icing Pilot Program consists of 17 municipalities and 4 highway contractors

Due to environmental concerns, salt has not been used in New Zealand since the late 1970's.[38] However, increased traffic since the 1970's has caused a demand for better road conditions than the sole use of sand treatment would allow. New Zealand was very concerned about possible environmental damages. Therefore, calcium magnesium acetate (CMA) was chosen due to its low environmental impact. Throughout the course of the study, the dissolved oxygen (DO) in streams around the test sites were monitored. Little change in the DO levels was observed. Soil tests and vegetation monitoring also showed little change. New Zealand therefore decided to use CMA as an anti-icier/deicer. However, due to the high cost, it is only being used on high volume tourist routes and state highways.

Japan has made successful strides in technological developments for anti-icing pavements.[39] The anti-icing pavements used in Japan are classified as chemical or physical type pavements. Chemical-type pavements use the depression of freezing point to release the anti-icing chemicals to the pavements. On physical-type pavements, ice layers on the road surface are destroyed and removed when elastic materials placed in or on the surface of the pavements are deformed under traffic loads.

China faces some interesting winter weather challenges.[40] In addition to snow and ice, avalanche, landslides, and super cooled fog are also concerns. Winter maintenance is fairly new in China. A study conducted in 2007 by Xiancai and Pei[40] identified obstacles to effective winter maintenance. The obstacles included poor communication between organizations and decreased emergency services in poor weather. Three areas were identified for winter weather management. These were informing the public about weather and road conditions, increasing traffic control by closing roads and adjusting signals, and snow and ice management and removal.[40] For snow, the maintenance actions are to plow, use salt and sand, and the possible use of anti-icing chemicals. For avalanches or landslides, the road is closed and the avalanche or

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[38] Burkett, A. and N. Gurr (2004) Icy Road Management with Calcium Magnesium Acetate to Meet Environmental and Customer Expectations in New Zealand". SNOW04-050. Sixth International Symposium on Snow Removal and Ice Control Technology. Transportation Research Circular E-C063: Snow and Ice Control Technology.

[39] Hara, T., Sakata, K. and Kano, T. (2002**)** Present Status and Evaluation of Anti-Icing Pavements in Japan, New Challenges for Winter Road Service. XIth International Winter Road Congress, Sapporo, Japan.

[40] Xiancai, Jian and Yulong Pei (2007) Analysis of the Characters and Strategies of Road Transportation Safety in the Cold Region of China". J Transpn Sys Eng & IT, 7(4), 82–89.

landslide is triggered. The road is cleaned before reopening. For super cooled fog, liquid carbon dioxide is sprayed into the fog while anti-icing agents are used on the road. The suggestions in this study were implemented over a group of roads. Before the changes were executed, there were 26 accidents including one serious injury and one fatality. After the changes, there were only 3 minor accidents.

Worldwide, the use of brine from rock salt has gained momentum and popularity.

1.2.4 Natural Brine

Besides rock salt, there are two other sources of brine that can be used for winter maintenance of roadways. These include natural brine and brine as a byproduct from oil/gas fields. Occurrences of natural brines are not bound to geological horizons, but are associated with the strata's porosity.

The Junex Company in Canada is located in the Appalachian basin in the province of Quebec. It has exploration rights on more than 6 million acres of land for oil, gas and natural brine.[41] The natural brine produced by Junex is naturally occurring, extremely salty water, and buried deep underground for the last 400 million years. This clear and odorless liquid contains several valuable ingredients including calcium, magnesium, sodium and potassium. Its main characteristic, however, is its total dissolved solids concentration varying between 200 grams per liter to 360 grams per liter, representing a salinity degree up 10-12 times superior to sea water. This natural brine is used as a deicing product and a dust control agent on unpaved roads. This is the only natural brine produced in Quebec and is commercially known as Solnat. A pilot project was initiated in 2001-2002, and the product is being marketed both in Canada and the North Eastern U.S. Junex performed prolonged productivity tests on the Bécancour well. The results indicated that the Bécancour well could sustain a continuous production of natural brine. The possible reserves in place of natural brine, as evaluated by the French firm Géostock, are at over four billion liters. Junex currently operates three production well sites of natural brine in the Bécancour area. These three wells have a combined annual production capacity of more than 25 million liters of brine. The well productivity is shown in Table 8.

[41] http://www.junex.ca/en/index.php [Accessed 4 Mar, 2009]

Table 8: Natural Brine Production at Junex [41]

JUNEX PRODUCING WELLS - SOLNAT (GROSS)		
Name	Production Capacity per Day (L)	Production Capacity Annually (L)*
Husky-Bruyère No 1	11,000	3,300,000
Soquip Pétrofina Bécancour No 2	50,000	15,000,000
Junex Bécancour No 3	30,000	9,000,000
Total	91,000 Liters	27,300,000 Liters

* Based on 300 days

In the winter season, Solnat is mostly used as a complement to calcium chloride. The pulverization of liquid Solnat on deicing salt just before its application on the road is a simple process (pre-wetting) which greatly optimizes the efficiency of deicing salts on the road. This process helps to significantly reduce application rates of salts. Solnat is also used for winter stockpile treatments (sand or gravel) which are spread on roads during very cold periods. Several reservoirs for natural brine are also installed on these sites to permit storage all year long. Therefore, the brine can be resold during the high periods of use during the dust control season, which is mostly concentrated between May and July. The natural brine sales of Junex have totaled $515,207 in 2005, a 116 percent growth in comparison to the 2002 sales when the production had first started. The Junex facility results indicate that natural brine can be a major source for deicing for winter road maintenance.

Abundant amounts of natural brines are located under states such as Pennsylvania, Ohio, New York, West Virginia, and Michigan. Michigan extracts natural $CaCl_2$ brine from deep wells for anti-icing and salt manufacturing.[42] Various geological formations and depths of the central Appalachian region for natural brine were investigated by Sack and Eck (1985).[43] Major findings from the analytical tests run on collected samples indicated that the use of natural brines over conventional agents was more beneficial. Stability tests showed that natural brines did not form crystals in closed storage tanks, and natural brine constituents were lower in chrome and

[42] Turrentine, J.W., Merz, A.R., Gardner, R.F. (1912) Composition of the Salines of the United States: Natural (Subterranean) Brines and Mother Liquors from Natural Brines. *I&EC* **1912**, *December*, pp 885.

[43] Sack, W.A. and Eck, R.W. (1985) Potential for Use of Natural Brines in Highway Applications. *TRB* **985**, *1019*, pp 1-8.

cadmium than conventional agents. It was concluded that there are significant quantities of natural brines from the central Appalachian region that are suitable for highway applications.

Halite brine ranging from 45 to 85 percent has also been identified in the Onondaga trough, a bedrock valley near Syracuse, New York.[44] The brine originates from halite beds of the Salina group shales of central New York. Geochemical modeling studies indicate that the most concentrated brine occupies the northern end of the trough and was formed through dissolution of halite by glacial melt water about 16,500 years ago. The halite brine covers an area of 26 square kilometers and the brine pool is confined beneath Onondaga Lake. Measured brine densities currently range from 1.09 to 0.16 g/m^3, corresponding to salt saturations of 45 to 80 percent. The mass of halite pool is estimated to be 45 million megagrams. This huge reserve of halite brine could be a significant source of anti-icing materials similar to the Canadian brine solvent, discussed earlier.

1.2.5 Oil/Gas Field Brine

Another source of salt brine in winter ice control applications is the use of brine generated during oil and gas well drilling and production operations; however, this form is less commonly used in practice. Oil-field brine is a waste product produced along with oil and gas. The brine is separated from the oil settling to the bottom of a tank. Oil-field brine is in a liquid state and can act faster than road salt, which must dissolve before it can melt ice. It is a natural solution containing sodium and calcium chloride, thus combining the benefits of both deicing agents. Oil field brine costs are less than solid road salt. These brines can have elevated metal and suspended solid concentrations that can limit their use for roadway maintenance.

The Ohio DOT has a comprehensive report on the use of oil-field brine for dust and ice control. Chloride, sodium and calcium are the primary constituents of Ohio brines; comprising 95 percent of all dissolved solids.[45,46] Certain dissolved metals and organic compounds are also present in

[44] Yager, R.M., Kappel, W.M., and Plummer, L.N.(2007) Origin of halite brine in the Onondaga Trough near Syracuse, New York State, USA: modeling geochemistry and variable-density flow: *Hydrogeology Journal*, v. 15, p. 1321-1339.

[45] http://www.dnr.state.oh.us/Portals/11/publications/pdf/Brine.pdf

the oil brines. Brines generated during drilling operations can also contain chemical additives such as biodegradable industrial detergents, caustic soda and soda ash. Brine generated during production operations can also contain polymers and spent acid. Trace metals, including heavy metals, have also been detected in the Ohio brines. The ranges of trace metal concentrations for Ohio production brines are presented in Table 9 below.

Table 9: Trace Metal Concentrations in Ohio Oil-field Brine [46]

Trace Element	Range in Ohio Brines	MCL for Drinking Water P-Primary S-Secondary
Barium	0.1-255 mg/L	2 mg/L (P)
Zinc	0.05-4.1 mg/L	5 mg/L (S)
Cadmium	0.4-181 µg/L	5 µg/L (P)
Chromium	0.6-644 µg/L	100 µg/L (P)
Cobalt	0.4-155 µg/L	-----
Copper	0.3-220 µg/L	1mg/L (S)
Lead	5 – 1300 µg/L	50 µg/L (P)
Mercury	0.915-0.70 µg/L	2 µg/L (P)
Molybdenum	4-51 µg/L	-----
Nickel	0.7-637 µg/L	-----
Vanadium	0.6-30 µg/L	-----

The last column of Table 9 represents the USEPA MCL (Maximum Contaminant Level) for public drinking water. Some trace metals exceed the standards for drinking water. Dilution with snow and ice melt reduce these concentrations below the MCLs before the brine leaves the roadways. Brine spreading studies[45,46] indicate, that under careful spreading practices, the metals can be diluted or absorbed by clay particles and do not reach fresh ground water. Barium can be an exception to this, as cation exchange between soils and brine can release barium into the solution. If dilution and re-absorption to soils does not occur before the brine runoff water reaches a well, barium can pose health risk problems if it exceeds the MCL. It is to be noted that this problem can also occur during applications with rock salt.

According to the Ohio DOT report, typical road salt application rates range from 150 to 350 pounds per lane mile. Table 10 indicates the quantity of salt, in pounds per lane mile, that would be applied to a road surface at the maximum spreading rate allowed by Ohio DOT for brine, ranging from 30,000 to 225,000 mg/L chloride.

[46] Knapp, N. F. and Stith, D. A. (1989) "Characterization of trace metals in Ohio brines" Geological Survey Divn., Ohio Department of Natural Resources, Open File Report 89-2.

Table 10: Ohio DOT Quantity of Salt/Lane Miles at Varying Application Rates for Brines with Selected Salinities [46]

Brine Salinity (mg/l Chloride)	Pounds of Salt Per Lane Mile
30,000	751
50,000	1,252
75,000	1,877
100,000	2,503
125,000	3,129
150,000	3,755
175,000	4,301
200,000	5,007
220,000	5,507

Salinity ranges for Ohio oil-field brine range from 70,000 to 200,000 mg/L of chloride. Oil field brine was indicated to have similar effects on cement concrete and metallic corrosion, as conventional deicing agents.

Every 36 months, the North Dakota DOT requires pH, specific conductivity, major ions (including iron and manganese), total dissolved solids, alkalinity, oil and grease and trace elements to be monitored for oil-field brines used for ice control.[47] The produced brine is also required to meet hydrogen sulfide concentrations that do not constitute a hazard. A comparison of typical oil-field brine to a conventional deicer is presented in Table 11.

Table 11: Comparison of Oil-field Brine Composition with a Conventional Deicer[46]

Mg/L	Typical Oil-field Brine	Conventional De-Icer from the Salina Formation
Chloride	150,000	150,000
Sodium	42,800	107,300
Calcium	36,200	1,400
Magnesium	6,190	19.1
Potassium	1,460	45.2
Strontium	1,070	9.2
Manganese	14	0.41
Sulfate	229	2,300

[47] http://www.ndhealth.gov/wq/gw/pubs/IceDustControlUsingOilfieldBrine.pdf [Accessed 3 Aug, 2009]

Calcium is the most important ion in oil-field brine because it must be added to rock salt to enhance its melting characteristics.

The Michigan DOT attempted to phase out the use of oil field brines for dust control in Michigan altogether because of environmental concerns regarding the presence of pollutants. The primary concern was for aromatic hydrocarbons, especially benzene, a known human carcinogen.[48] This measure was contested in a lawsuit by some county road commissions who found the product to be useful and economical. The use of oil field brine for dust and ice control is currently allowed in Michigan but only in accordance with a groundwater discharge permit. To qualify for this permit, a county road commission (or other applicant) must, among other things, certify that the brine is from an approved source (i.e., the brine has been tested for certain chemical contaminants in accordance with the Supervisor of Wells law) and that the applicant will follow all applicable rules.

Most production brine in New York comes either from shallow oil wells or from deep gas wells.[49] There are about 5,500 active gas wells and 3,800 oil wells in New York State. The oil wells are present in the Allegheny and Cattaraugus counties while the gas fields are located in the Chautauqua County. The volume of brine generated from these sites was reported to be 12.6 and 88.2 million from gas and oil fields respectively. Brine disposal methods include road spreading for deicing, dust control for unpaved roads, discharge to surface water via permits and underground injection. The characteristics of the brines from gas and oil producing areas vary significantly as indicated in Table 12. The differences are primarily in the chloride and total dissolved solids (TDS) content. The shallow oil production waters allow for dilution, resulting in lower chloride concentrations in comparison to deep gas wells.

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[48] http://www.michigan.gov/documents/deq/wb-groundwater-generalpermit-Rule2215-O5-5FieldBrine_206269_7.pdf [Accessed 3 Aug, 2009]

[49] Matsumoto, M.R., Atkinson, J.F. Bunn, M.D. and Hodge, D.S. (1992) Disposal/Recovery Options for Brine Waters from Oil and Gas Production in New York. NYSERDA Report 1591-ERER-RIER-91.

Table 12: Brine Quality Data from New York's Gas and Oil Producing Zones[49]

Parameter mg/l	Potsdam/Theresa	Queenston	Medina	Oriskany	Bass Island	Upper Devonian Oil Zones
Sodium (Na)	76,172	73,500	69,893	45,457	60,750	36,367
Calcium (Ca)	31,256	36,603	37,124	33,684	56,400	16,467
Magnesium Mg)	4,499	2,887	2,766	5,168	3,160	2,733
Strontium (Sr)	---	0	---	---	---	107
Barium (Ba)	750	0	---	---	---	8
Potassium (K)	3,367	1,124	---	1,307	---	71
Iron (Fe)	17	195	676	215	18	189
Manganese (Mn)	0	---	84	---	0	7
Chloride (Cl)	183,701	187,418	181,298	145,442	203,000	92,167
Bromide Br)	1,417	1,120	1,721	1,687	---	860
Sulfate (SO4)	18	---	736	57	180	619
Bicarbonate (HCO3)	89	---	25	203	50	0
Iodine (I)	9	11	18	10	---	200
Lithium (Li)	54	---	---	---	---	---
Trace Metals	---	---	---	---	---	1
Hydrocarbons	---	---	---	---	---	108
Measured TDS	300,763	298,358	292,121	231,836	323,500	156,267
Calculated TDS	299,187	302,869	282,727	232,743	323,558	149,582
Ionic Ratios						
Na/Ca	2.40	2.01	1.89	1.42	1.08	2.24
Ca/Mg	9.75	12.76	15.90	6.93	34.17	6.04
Mg/K	1.07	2.64	---	4.00	---	47.03
Cl/Br	142.84	255.07	102.49	104.86	---	104.60
# of samples	9	2	8	4	2	3
Na/Cl	0.415	0.392	0.386	0.312	0.299	0.394

A composite brine sample from the Medina gas wells was used for analyses of total solids (TS), total dissolved solids (TDS) and total suspended solids (TSS). This data is presented in Table 13. The pH, density, turbidity and chloride concentrations are presented in Table 14. It is clear that the brine has very high solid content with TDS, contributing to 91 percent of the total solids.

An acidic pH of 3.0 indicates that heavy metals are likely to be dissolved in the brine if they are present in the gas wells.

An estimated 90 percent of deep gas well production brine in New York is hauled offsite and spread over roads for dust and ice control. Hauling of the brines in New York is regulated by the DEC Division of Solid and Hazardous Waste (DSHW) under 6 NYCRR Part 364. Oil and gas drilling production brines are considered industrial waste and as such are subject to requirements of Part 364 for transportation and use.

Table 13: Brine Water Solids Analysis[49]

	Medina Brine	
Parameter	**Composite**	**Individual Well**
Total Solids (TS) mg/L	270,400	276,250
Volatile Solids (VS) mg/L	36,400	16,000
Filtered Solids (FS) mg/L	233,600	260,250
VS/TS Ratio (%)	13.1	5.7
Total Dissolved Solids (TDS) mg/L	245,800	282,500
Volatile Dissolved Solids (VDS) mg/L	18,400	10,000
Filtered Dissolved Solids (FDS) mg/l	229,000	282,500
VDS/TDS Ratio (%)	6.9	3.4
Total Suspended Solids (TSS) mg/L	174	64
Volatile Suspended Solids (VSS) mg/L	64	34
Filtered Suspended Solids (FSS) mg/L	110	28
VSS/TSS Ratio (%)	37.2	55.2
TS calculated mg/L	245,960	282,580

Table 14: Brine Water Characterization for Medina Brine [49]

Parameter	Composite	Individual Well
pH	2.7	3.7
Density (kg/L)	1.17	1.18
Turbidity (NTU)	190	62
Chloride mg/L	141,700	161,700

Metals analyses for the Medina well is presented in Table 15. As expected, sodium and calcium are high followed by magnesium, strontium and potassium. Nickel, lead, zinc and copper concentrations are low.

Table 15: Metal Content in Medina Brine [49]

	Medina Brine	Medina Brine
Parameter mg/L	**Composite**	**Individual Well**
Sodium	58,800	66,800
Calcium	21,000	23,200
Magnesium	3,000	3,360
Strontium	1,760	1,780
Potassium	1,080	1,040
Iron	130	129
Manganese	70	85
Nickel	3.6	3.1
Lead	2.5	2.2
Zinc	1.2	0.6
Copper	0.6	0.6

Approximately 30 percent of the oil/gas brine in New York state is disposed via road spreading. Deep gas wells are the primary source of the brine. Since the disposal is weather dependent, storage of the brine poses a problem for the state.

A study conducted by the Pennsylvania DOT compared the different types of oil brine to conventional road salt.[50] The data indicated that the deep gas well oil brine was similar to conventional road salt, thus making this oil brine attractive for ice control. Another factor stimulating interest of use of oil brine is the associated costs for application for ice and dust control.

West Virginia has considered oil field brines for road maintenance.[51] The West Virginia Department of Environmental Protection has entered an agreement with the state Division of Highways setting standards for natural gas well brines used for winter road safety. The

[50] www.penndot.gov [Accessed 12 Mar, 2009]

[51] http://statejournal.com/story.cfm?func=viewstory&storyid=84327 [Accessed 3 Dec, 2010]

agreement sets maximum concentration levels for chloride and sodium and a minimum level for the combination of those salts and calcium - all related to the brine's freezing temperature. With regard to other aspects of natural gas well brine, the memo establishes levels for pH, iron, barium, lead, oil and grease, benzene and ethylbenzene.

1.3 Equipment for Brine Application

A review of brine application methods indicates that small scale batch production units, along with a variety of application vehicles, are popular. Two types of liquid applicators are the most common: spinners consisting of either multiple rotating disks or a single disk and nozzles on a distributor bar. A brief description of brine production and application is provided below.

Production Facility

Brine production plants have been designed through the collaboration of DOTs and private companies in the U.S. These facilities use batch or continuous flow systems. For small scale production, batch units are assembled using small tanks where water passes through a bed of rock salt to produce a saturated solution. The brine is then pumped through a 10 µm filter into a storage tank or a spreader truck. The plant used by Kansas DOT, shown in Figure 10, produces salt brine at low rates around 600gal/hr.[52] High capacity production of salt brine requires continuous flow plants. A saturated solution of brine is pumped into a storage tank after water has been forced through a bed of salt.

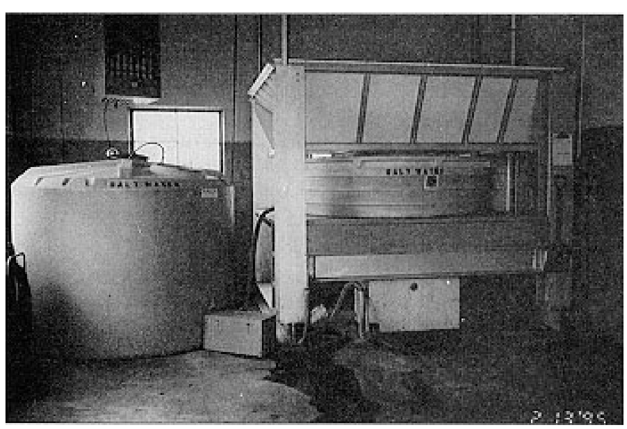

Figure 10: Brine Production Facility[12]

[52] Ketcham, S. A., Minsk, L.D., Blackburn, R.R. , Fleege, E.J. "Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel" F*HWA* **1996**, *RD-95-202*, pp 1.

Dultmeier Sales has a patent pending Brine Production System as shown in Figure 11.[53]

Figure 11: Du BPS3000 Brine Production System[53]

The Du BPS 3000 is a self-contained hydraulic control system that funnels all of the debris into the buck, which allows for easy cleaning. The system is also corrosion-resistant and constructed of heavy duty stainless steel. AccuBrine has a new remote fill product, which enables the operator to fill a truck automatically with the push of a button as shown in Figure 12.[54]

Figure 12: AccuBrine Brine Maker[54]

53 http://www.dultmeier.com/literature/brine.asp [Accessed 5 Apr, 2010]

54 http://www.accubrine.com/how_faq.html [Accessed 5 Apr, 2010]

The system uses a pump and actuated valves to divert flow and decrease the chance of spilling the anti- or deicing material. Furthermore, the apparatus produces larger volumes of brine efficiently and offers a bottom-down water flow design.

Liquid Application

Each State DOT typically produces a 23 percent salt brine solution using a purchased brine maker. The brine solution is then transferred to the salt brine applicators. Each state primarily uses the same type of equipment when applying brine to roadways. The equipment spans from homemade units to units manufactured by mass production companies. These units are mounted on existing trucks or trailers to allow for easy application. Large tankers can also be used for a more extensive application of brine. Liquid applicators include spinners or nozzles. Either spreader may be chassis mounted or a "slip-in" unit that can be placed in a dump truck or in a trailer. The Iowa State Department of Transportation website has an extensive list of equipment used in the application of salt brine.[55] An example of each unit is shown in Figures 13-15.

Figure 13: Slip-in Brine Application Units[55]

[55] http://www.iowadot.gov/maintenance/materials.html [Accessed 4 Feb, 2010]

Figure 14: Trailer Brine Application Units[55]

Figure 15: Large Tanker Unit[55]

The volumetric capacity can vary from 140 gallon tankers to as large as 5000 gallon tankers. The appropriate size and type is used for specific roadway applications. Smaller trucks are typically used for rural areas while larger tankers are used for interstate highways. Typical brine distributors are shown in Figures 16-19.

Figure 16: Three Legged Applicator[55]

Figure 17: Bottom Spray Distributors[55]

Figure 18: Driver Side Spray[55]

Figure 19: Wheel Path Distributor[55]

Each distribution unit is used for a specific application purpose. The three-legged and driver side sprayers are typically used for a large area of application, while the bottom spray is used for a smaller area of application. The Wheel Path Distributor is used to concentrate the brine in the wheel path of the roadway, making the application more efficient. Each unit can apply approximately 15 – 50 gallons of brine per lane mile of roadway and the selected roadway speed is based on the calibration of the spreader.

Another method gaining momentum for liquid application is FAST (Fixed Automated Spray Technology).[56] This is a stationary system used in rural areas where ice and snow greatly impacts road conditions and is also popular for use in bridge structures. It is suitable for use in roads that face high traffic volumes and congestion and cannot allow regular maintenance vehicles to clean the roads in a reasonable manner. It is also suitable for road sections that are prone to winter accidents. FAST continually senses weather conditions onsite and detects when ice and frost conditions are imminent. The FAST system discharges a liquid chemical deicing agent from a spray nozzle upon icing conditions and, therefore, prevents inclement road conditions. This is presented in Figure 20. FAST is designed to reduce the number of accidents in rural regions and improve commuter safety. The technology was installed in Ontario in the fall of 2000 on a newly constructed bridge. During the first winter that the bridge was in service, there were a number of accidents caused by dangerous road conditions. After the FAST system was installed, the rural bridge did not experience any accidents during the winter (2000-2001).[64]

Figure 20: FAST and RWIS Systems by Boschung America LLCsystem[57]

[56] Anti-icing and RWIS Technology in Canada. (2000) C-SHRP technical Brief # 20.

[57] http://www.boschungamerica.com/pages/FAST.php

The FAST system typically employs the use of a RWIS detection to determine exactly when dangerous driving conditions could occur. The detection system consists of pavement sensors and meteorological sensors. A remote processing unit is contained within the system to process the raw data received from these sensors and react to such conditions that may suggest icing. The pavement sensors measure surface temperatures, subsurface temperatures, dangerous pavement conditions, concentration of anti-icing chemicals on the pavement surface, and the calculated freezing point of the liquid on the road surface. Additionally, the meteorological sensor detects air temperature, wind speed and direction, precipitation, relative humidity, and the dew point calculated based on these conditions.

RWIS technology has become an integral part of anti-icing and most states in the U.S. and countries around the world are embracing this technology.

Many states that do not have RWIS technology use truck mounted thermometers that allow the truck driver to know the road surface temperature as it is vital to pre-wetting techniques and helps maximize efficiency. In fact, the temperature of the road's surface is more essential than the air temperature. The thermometers may also be used to warn the operator when the road surface ahead is frozen. However, the device can measure different temperature values depending on the particular pavement type. A typical truck-mounted system is shown in Figure 21.

Figure 21: Truck Mounted Thermometer[53]

1.4 Environmental Impacts of Brine Use

Many studies have focused on the environmental impacts of materials used in winter maintenance of roads. Winter maintenance chemicals may have detrimental effects on the receiving soil, vegetation, and water bodies once the concentration reaches excessive levels. While sodium chloride is relatively harmless in small amounts; the quantities applied for winter maintenance may kill vegetation near the roadway and increase chloride concentrations in the waterways. The accumulation of road salt can be detrimental to the surrounding vegetation. Environment Canada reported that many woody plant species exposed to road salt had vanished from Canadian roadsides.[58] Based on the finding of this study, the Canadian Environmental Protection Act declared road salt as "toxic" and in 2001 declared all chlorides as toxic; however, the act acknowledged the importance of chloride's role in providing safe roads. Salt consists of a sodium ion (Na^{+}) and a chloride ion (Cl^{-}) which both may be toxic to vegetation when excessive accumulation occurs in the soil. Tolerance to NaCl for some vegetation, specifically pine seedlings, is as low as 67.5 ppm in soils. For seed germination and root growth to occur for grasses and wildflowers, the NaCl concentration in soil should be less than 100 ppm.[59] Runoff to surface waters and percolation to groundwater are the most common mechanisms for road salts to enter water supplies, while infiltration is more common for groundwater-based supplies.[60] In the New York City watersheds, groundwater is a major contributor to streams. Groundwater discharge accounts for at least 60 percent of total annual stream flow in the Croton watershed. Chloride concentration in groundwater supplies exhibits a relatively linear relation to road-salt application rates or two-lane road density throughout the year.[61] In surface-water supplies, chloride concentration depends on salting intensity, soil type, climate, topography, and

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[58] Environment Canada. *Priority Substances Assessment Report: Road Salts.* *www.ec.gc.ca/cceb1/eng/public/road_salts.html.* 2000.

[59] Hofstra, G. and D.W. Smith. "The effects of road deicing salt on the levels of ions in roadside soils in southern Ontario." *Journal of Environmental Management.* 19:261-271. 1984.

[60] Heisig, P.M. *Effects of Residential and Agricultural Land Uses on the Chemical Quality of Baseflow of Small Streams in the Croton Watershed, Southeastern New York.* US Geological Survey Water-Resources Investigations Report 99-4173. *http://ny.usgs.gov/projects/misc/WRIR99-4173.pdf.* March 2000.

water volume, with larger water bodies exhibiting lower concentrations through the process of dilution.

A thorough study on the occurrence of chloride in groundwater and surface water in areas underlain by the glacial aquifer system in the Northern U.S. was funded by USGS.[62] As shown in Figure 22, the study indicated that the second highest consumption of salt was for deicing of roads.

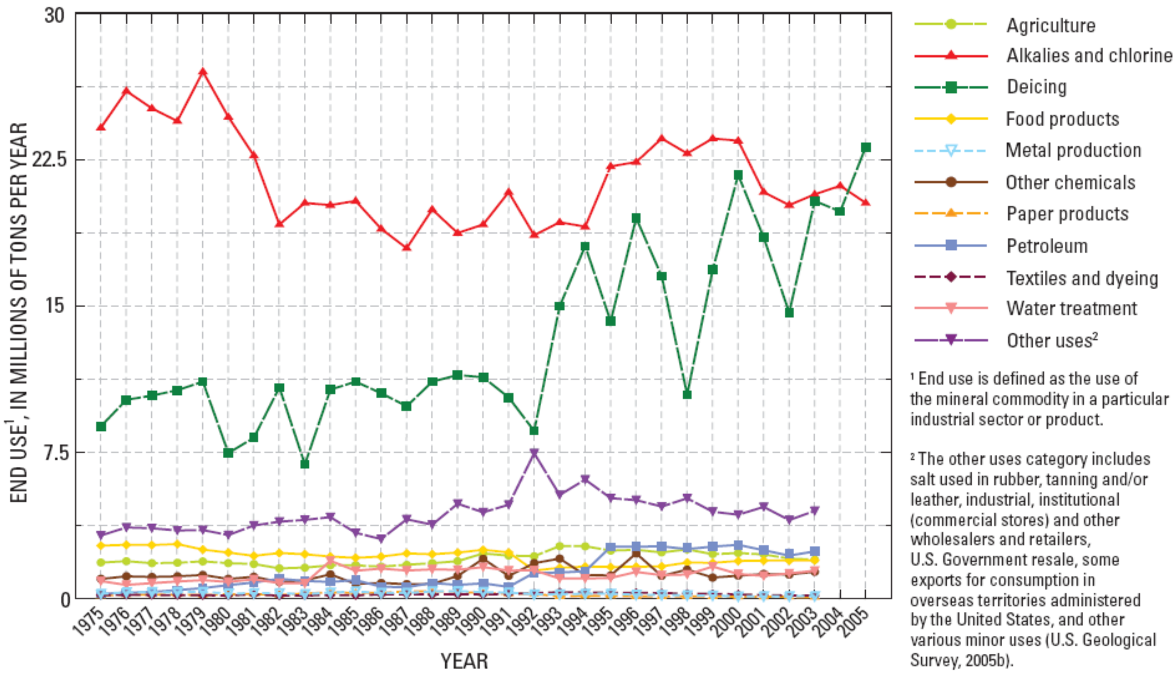

Figure 22: Salt Consumption by Use or Industry in the U.S.[62]

Water quality analyses of shallow monitoring wells and drinking water supply wells indicated that chloride concentrations exceeded the USEPA limit of 250 mg/L in 2.5 percent of shallow wells and 1.7 percent in the drinking water wells. Upward trends in chloride loads were apparent in several watersheds and were attributed to increases in road deicing, wastewater-septic discharges, landfill leachate and salt storage areas. Samples with chloride concentrations greater than 230 mg/L were noted primarily during the months of November through April and were attributed to winter deicing activity.

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[61] http://www.newyorkwater.org/downloadedArticles/ENVIRONMENTANIMPACT.cfm [Accessed 3 May, 2010]

[62] Mullaney, J.R., Lorenz, D.L., Arntson, A.D., 2009, Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States: U.S. Geological Survey Scientific Investigations Report 2009–5086, 41 p.

A summary of the winter maintenance materials and their environmental impacts were summarized by Fischel et al. (2001) and is presented in Table 16. [63]

Table 16: Summary of Current Winter Maintenance Materials[63]

		Abrasives	Sodium Chloride	Calcium Chloride	Magnesium Chloride	Calcium Magnesium Acetate	Potassium Acetate
Performance	Eutectic Temperature	N/A	-21°C @ 23%	-51°C @ 29.8%	-33C @ 21.6%	-27C @ 21.6%	-60C @ 49%
	General	<11°C	Effectively depresses the freeze point of water	Effective at low temperatures; melts ice faster than NaCl	Effective at low temperature; melts ice faster than NaCl	Effective as a liquid anti-icer; melts longer than NaCl	Effective as a liquid anti-icer; Effective at low temperature
Corrosion Impacts	Highway Structure	Non-corrosive	Corrosive	Moderately corrosive	Moderately corrosive	Non-corrosive	Moderately corrosive
	Asphalt Concrete	Non-corrosive	Slightly corrosive	Slightly corrosive	Slightly corrosive	Moderately corrosive	Moderately corrosive
Environmental Impacts	Air Quality	Fine particulate material increases air pollution	Net decrease in air pollution from reduction in use of abrasives	Net decrease in air pollution from reduction in use of abrasives	Net decrease in air pollution from reduction in use of abrasives	Net decrease in air pollution from reduction in use of abrasives	Net decrease in air pollution from reduction in use of abrasives
	Vegetation	Can smother roadside vegetation causing mortality	Inhibits water and nutrient uptake; vegetation and damage mortality	Inhibits water and nutrient uptake; vegetation and damage mortality	Inhibits water and nutrient uptake; vegetation and damage mortality	Potential mortality from oxygen depletion in soil	Potential mortality from oxygen depletion in soil
	Soil	Little effect on soil expected	Increases soil salinity; decreases soil stability and permeability	Increases soil salinity; improves soil structure	Increases soil salinity; improves soil structure and permeability	Potential oxygen depletion from break down of acetate; improves soil structure	Potential oxygen depletion from break down of acetate
	Surface/ Ground Water	Increases turbidity, photosynthesis in aquatic plants	Potential increase in water salinity; slight increase in metals	Potential increase in water salinity; slight increase in metals	Potential increase in water salinity; slight increase in metals	Potential oxygen depletion	Potential oxygen depletion
Cost	Initial	Low cost	Low cost	Relatively low cost	Relatively low cost	High Cost	High Cost
	Associated	High Cost	High Cost	High Cost	High Cost	Low cost	Low cost

[63] Fischel, M. (2001). Evaluation of Selected Deicers Based on a Review of the Literature. The SeaCrest Group. Louisville, CO. Report Number CDOT-DTD-R-2001-15.

1.5 Economic Impacts of Salt Brine Use

Countries around the world using anti-icing and pre-wetting for winter road maintenance have indicated that there are significant cost savings in a number of categories. Both anti-icing and pre-wetting reduce labor hours and material usage while providing a safer roadway, leading to cost savings. In one study, Colorado, Kansas, Oregon, Washington and the Insurance Corporation of British Columbia (ICBC) were asked to state any cost savings from anti-icing.[64] Table 17 includes their responses. Specifically, Colorado saw an overall cost savings of 52 percent while Oregon saw a cost savings of 75 percent for freezing rain events. It was concluded that anti-icing could provide a 10-20 percent cost savings in snow and ice control budgets, and possibly result in a 50 percent reduction in cost per lane mile. The survey conducted by O' Keefe and Shi (2005)[2] also confirmed that agencies saw significant cost savings when using anti-icing and pre-wetting techniques during winter storms.[2] Less material was applied and roads were cleared faster. Reduction in material use led to less environmental impacts.

Table 17: Cost Savings Reported by Select DOTs[64]

Agency	Cost Savings
Colorado DOT	Sand use decreased by 55% Winter operations cost $2,500 per lane mile versus $5,200 previously
Kansas DOT	Saved $12,700 in labor and materials at one location in the first eight responses using an anti- icing strategy.
Oregon DOT	Reduced costs for snow and ice control from $96 per lane mile to $24 per lane mile in freezing rain events.
Washington DOT	Save $7,000 in labor and chemicals for three test locations.
ICBC (Insurance Corporation of British Columbia)	1. Accident claims reduced 8% on snow days in Kamloops, BC: estimated savings to ICBC $350,000-$750,000 in Kamloops 2. Potential annual savings of up to $6 million with reduced windshield damage.

[64] Boselly, S.E. (2001) Benefit/Cost Study of RWIS and Anti-Icing Technologies. Report 20-7-117 NCHRP. http://www.transportation.org/sites/sicop/docs/NCHRP20-7(117).pdf [Accessed 8 May, 2009]

The North Central Region (NCR) of the Washington DOT embarked on an expansive anti-icing program with liquid chemicals in 1991-2000.[65] The NCR reported their savings from the anti-icing program. Table 18 provides documented savings identified by separate area superintendents and shed supervisors for pretreatment anti-icing activities.

Table 18: Cost Savings Reported by Washington DOT[65]

Location	Saving
Wenatchee	Used 64% more liquid but 70% less sand compared to the 3-years average. $23,000 savings on the books.
Leavenworth	1. Blewett Pass shed: Reduced sand usage from 12,000 yd average to 4,000 yd. Also less accidents, less overtime. 2. Scenic shed: 5,000 yd sand cut down to 2,600 yd. 3. Stevens Pass shed: Less tort claims, less guardrail damage. 4. Leavenworth shed: Eliminated need to clean up sand; removed impact on salmon
Moses Lake	1. Moses Lake Area; Able to use contingency shifts with four 10-hr shifts. Eliminated weekend work and overtime and freed personnel to do other highway maintenance. Less facility damage repair. 2. Moses Lake and Othello sheds; Lowest cost per lane mile for snow and ice control in Eastern Washington. Accident rates way down.
Omak	1. Okanogan shed: Less sand used, accident rates way down. 2. Township shed: Cut sand usage by 1/3; reduced tort claims. 3. Electric City; Saved call out and overtime during weekends and the holidays.

The Montana DOT reported 37 percent reduction in costs per lane mile for US Route 200 when compared with the Thompson Falls section that only received pre-wetting.[66] An annual material use and cost for various materials used was reported. This is presented in Table 19.

[65] Ikiz, Nida (2004) FIELD INVESTIGATION OF ANTI-ICING / PRETREATMENT. Ohio University. http://etd.ohiolink.edu/send-pdf.cgi/Ikiz%20Nida.pdf?ohiou1176405449 [Accessed 15 July, 2010]

[66] Goodwin, L.C. (2003) Best Practices for Road Weather Management. Office of Transportation Operations, FHA Report # FHWA-OP-03-081.

Table 19: Montana DOT Winter Maintenance Performance Measures[66]
(Annual Averages)

	Thompson Falls Section	Plains Section	Percent Difference
Sand Quantities	73 cubic yards (56 cubic meters)	43 cubic yards (33 cubic meters)	41%
Sand Costs per lane mile	$724	$407	44%
MgCl Costs per lane mile	$136	$233	N/A
Material Costs per lane mile	$860	$640	26%
Equipment Costs per lane mile	$327	$182	44%
Labor Costs per lane mile	$564	$273	52%
Total Costs per lane mile	**$1,750**	**$1,095**	**37%**

A number of studies have reported on the prices of anti-icing chemicals. The costs reported are comparable. Results from studies reviewed indicate the following average costs for various anti-icing agents:

Table 20: Costs for Common Anti-Icing Chemicals

Chemical	Average Cost/Gallon
23% Brine	$0.07
28% $CaCl_2$ or $MgCl_2$	$0.80
Potassium Acetate	$7.00
Agricultural Products	$1-$2

Another study reported the following costs and comparison of the anti-icing chemicals.[67]

[67] http://www.epa.state.il.us/water/tmdl/implementation/dupage-river/drscw-chloride-study-phase2.pdf [accessed 17 Jan, 2009]

Table 21: Chemical Anti-Icing and Deicing Products with Costs[67]

Product	Estimated Cost[1]	CT by mass	Eutectic Temperature[2]	Other Characteristics
Rock Salt (NaCl)	\$20-40/ton or \$0.03-0.10/gal	61%	-6°F	Very corrosive; harmful to vegetation; can attract wildlife
Calcium Chloride ($CaCl_2$)	\$200-340/ton	64%	-60°F	Extremely corrosive; exothermic melting; dissolves in atmospheric moisture; harmful to vegetation
Magnesium Chloride ($MgCl_2$)	\$260-780/ton	75%	-27°F	Corrosive; can attack concrete
Potassium Chloride (KCl)	\$240/ton	48%	12°F	Corrosive
Calcium Magnesium Acetate (CMA)	\$650-2,000/ton	0%	-18°F	Low toxicity; non-corrosive; can cause 0_2 depletion
Potassium Acetate (CF7®)	\$2.60-3.90/gal or \$600/ton	0%	-76°F	Non-corrosive; can cause 0_2 depletion
Urea	\$280/ton	0%	10°F	Endothermic; degrade to ammonia, then nitrate; working temperature same as CMA
Ice Slicer®	\$58-64/ton	Some	-6°F	Granular and reddish, with naturally occurring complex chlorides (Mg, Ca, Na and K chlorides); 20-70% less corrosive than rock salt; harmful to vegetation

A study by Nevada Department of Roads compared the cost of brine to liquid corn salt (LCS).[4] The study reported the cost of liquid brine to be \$0.05/gallon and \$0.20/gallon for LCS. An analysis by the Texas Transportation Institute found that highway crews could save more than twice the estimated start-up costs if they were fully geared-up for anti-icing operations. The savings would be in addition to the estimated annual collision cost savings of \$228 million to \$447 million that would be saved by the accidents prevented if roads were made less slippery. A 1994 study in Glenwood Canyon, Colorado using magnesium chloride allowed the community to reduce the amount of sand used to only 600 tons in comparison to the 7000 tons of sand used in the absence of anti-icing.[68] Another pilot study conducted in Michigan indicated significant cost savings when they applied anti-icing chemicals to the roads.[69] The study was conducted along parts of US-31 and US-12 in Berrien County, with anti-icing liquid application rates at 40 gallons per lane mile. Both test sections and control sections covered thirty-two lane miles, with the control section using rock salt only. Results indicated that anti-icing material cost savings averaged $2.58 per lane mile. Table 22 summarizes anti-icing and deicing use by date for each major route. A 28 percent reduction in salt use was also observed due to anti-icing.

Table 22: Cost Summary for Michigan Study [69]

Us-31	**Southbound-Test Section**		**Northbound-Control Section**	**Cost Per Lane-Mile ($)**	
Application Dates	**Total Gallons anti-icing**	**Total Tons rock salt**	**Total Tons rock salt**	**Test**	**Control**
11/29/99	200	0	0	$7.00	$0.00
12/15-17/99	0	28	34	$21.88	$26.56
12/20-24/99	300	50	78	$49.56	$60.94
12/27-29/99	900	42	35	$64.31	$27.34
1/16-19/00	800	26	45	$48.31	$35.16
1/19-24/00	1,100	47	76	$75.22	$59.38
1/25-28/00	1,100	17	67	$51.78	$52.34
1/28-2/14/00	1,050	71	110	$92.22	$85.94
2/17-19/00	1,000	44	91	$69.38	$71.09
US-12 – includes nb and sb routes, no control section.					
12/20-21/99	50	4	--	$4.88	$0.00
1/19-24/00	700	49	--	$62.78	$0.00
Totals	7,200	378	536	$49.76 (avg.)	$52.34 (avg.)

68 *Manual of Practice for an Effective De-Icing Program: A Guide for Highway Winter Maintenance Personnel.* United States Department of Transportation, Federal Highway Administration, 1996. www.fhwa.dot.gov/reports/mopeap/eapcov.htm [Accessed 15 Mar, 2009]

69 http://www.michigan.gov/documents/mdot/MDOT_Research_Report_R1418_245018_7.pdf[Accessed 15 Mar, 2009]

The Iowa DOT indicates the following as a guide for costs to produce brine and also for calculating cost savings.[70]

Annual cost to produce 100,000 gallons of salt brine	
Assume 2,500 gallons per hour	
Labor @ $22 per hour	$860
Building*	$886
Water	$750
Salt	$795
Electricity	$750
Storage tanks*	$60
Brine maker*	$650
Total annual cost for 100,000 gallons of salt brine	$4,751
Cost per gallon	$0.00475

Expected Cost Savings from Pre-wetting

Assumptions	
Salt	$45 per ton
50/50 salt/sand mix	$26 per ton
Brine	$0.09 per gallon
Prewet at 15 gallons per ton of dry material	
50/50 salt/sand mix applied at 300 pounds per lane-mile on a 40-lane-mile route	
Without pre-wetting	
6 tons of material at $26/ton	$156
With pre-wetting assuming application rate is reduced by 25 percent (225 pounds per lane-mile)	
4.5 tons of dry material at $26 per ton	$117.00
68 gallons of brine at $0.09 per gallon	$6.12
Total costs	$123.12
Total savings	$32.88
Straight salt applied at 200 pounds per lane-mile on a 40-lane-mile route	
Without pre-wetting	
4 tons of material used at $45 per ton	$180
With pre-wetting assuming application rate is reduced by 25 percent (150 pounds per lane-mile)	
3 tons of dry material at $45 per ton	$135.00
45 gallons of brine at $0.09 per gallon	$4.05
Total costs	$139.05
Total Savings $40.95	

[70] http://www.iowadot.gov/maintenance/materials.html [Accessed 15 Sept, 2010]

In their Anti-Icing guide the Minnesota DOT provided the following visual (Figure 23) to describe the dramatic impact of anti-icing in terms of cost, road coverage and material savings.[71]

Illustration of Anti-Icing Coverage
Compare "Roadway Lane-Miles Treated" for 10 tons of salt

Type	Roadway Lane-Miles Treated	Example of Distance
Liquids @ 20 gal/lane-mile (20 gal/ln-mi = 45.44 lb/ln-mi)	440 miles	Austin, MN to Thunder Bay, Canada
Granular @ 300 lb/lane-mile	67 miles	Austin, MN to Faribault, MN

Graphic to Illustrate Anti-Icing Coverage
Compare "Roadway Lane-Miles Treated" for 10 tons of salt

Note that that the above illustration assumes continuous roadway anti-icing. Targeted anti-icing (trouble-spot) will provide even more coverage.

Figure 23: Anti-Icing Coverage Advantage [71]

Overall, pilot scale studies and real applications indicate that the application of brine or other chemicals results in significant cost savings, which stem from the use of less salt and less accidents. Less use of salt also results in better environmental protection.

[71] http://www.dot.state.mn.us/maintenance/docs/Training/Anti%20Icing%20Guide%208%20Full.pdf

1.6 Summary and Conclusions

A thorough literature review was conducted on the potential of brine as an anti-icing and pre-wetting agent. The review studied states in the U.S. and other countries with harsh winter weather road conditions. Anti-icing and pre-wetting have become popular techniques for winter road maintenance throughout the world. Many states in the U.S. and European countries have adopted anti-icing and pre-wetting as a standard practice for winter road maintenance. The shift from the application of solid materials such as rock salt and sand to liquids results from the vast benefits of the use of liquid chemicals. Anti-icing and pre-wetting allow for cost savings, cause less harm to the environment, and lead to safer roads.

The most common chemical used for anti-icing and pre-wetting is brine (liquid salt). Other popular chemicals include calcium and magnesium chloride, calcium magnesium acetate and potassium acetate. Organic compounds, such as liquid corn substances, molasses and beet juice are also gaining momentum. The major source of brine is commercial production from rock salt and water. The average price of commercial brine has been reported at 0.07 cents per gallon. Natural brine use is limited; the only country that currently uses natural brine is Canada and Syracuse, New York. Brine generated at oil and gas field sites has limited use and is subject to strict regulatory oversight. This stems from the presence of metals, organic compounds, and high amounts of suspended and dissolved solids.

Anti-icing and pre-wetting techniques are extremely effective when coupled with sophisticated weather forecasting technologies and sophisticated equipment for applying the chemicals. Proper training of personnel on preparation/application of the liquid chemicals, maintenance of equipment, collection of field data, and good coordination with weather forecasting personnel is necessary for successful anti-icing and pre-wetting programs.

The following conclusions can be made from this study:

a) Salt brine applications in parts of Europe and other countries are more advanced than in the U.S.
b) Salt brine applications are being adopted by more states in the U.S. and other advanced countries of the world

c) Anti-icing and pre-wetting lead to decreased applications of chemicals, reduced use of abrasives, improved road friction, and lower accident rates

d) Maintenance material costs are significantly reduced when using anti-icing agents

e) Safer traveling conditions are provided by anti-icing and pre-wetting

f) Chemicals cause less corrosion and environmental impacts to soil, water, and the atmosphere

g) Brine is the cheapest of the anti-icing agents at an average cost of $0.07/gallon

h) Natural brine has great potential for use in roadway maintenance as evidenced by the operations of the Junex facility in Quebec, Canada

i) Oil field brines are effective as conventional deicers. However, their use is limited because of high suspended solids, presence of trace metals and certain organic compounds.

j) Anti-icing and pre-wetting programs are successful when combined with sophisticated weather forecasting technology and quality equipment for application of the chemical agents. Trained personnel and good field data record keeping are also essential for the success of these program

APPENDIX A

State DOT Brine Applications

Selected annual application rates of deicing chemicals on State and local roads in the glacier aquifer system, northern U.S.[40]

State, municipality, or region	State	Road miles managed	Lane miles managed	Deicing chemical	Total amount of deicing salt used (tons)	Average use per lane mile (tons)	Average use per road mile (tons)	Source
Columbus	IN			Sodium chloride	2,000		8.5	Steven Brown, City of Columbus, Indiana, Public Works, oral commun., 2006
Indianapolis Department of Transportation	IN	7,329	4,000	Cargill ClearLane (treated sodium chloride) liquid calcium chloride, magnesium chloride, and brine also used	48,000	12.0	6.5	John Burkhardt, City of Indianapolis, Department of Public Works, oral commun., 2006
State of Michigan Department of Transportation	MI			Sodium chloride		12.9		Transportation Research Board, 1991
Brighton	MI	25	50	Sodium chloride	1,505	21.0	42.0	Matthew J. Schindewolf, Director of Public Services, Brighton, Michigan, oral commun., 2006
Farmington Hills	MI	301		Sodium chloride	6,500		21.6	Daniel Rooney, Division of Public Works, Farmington Hills, Michigan, oral commun., 2006
Rochester Hills	MI		506	Sodium chloride	4,270	8.4	16.9	Roger Rousse, Department of Public Service, Rochester Hills, Michigan, oral commun., 2006
Wolverine Lake	MI	20		Sodium chloride	750		37.5	Andy Stone, Department of Public Serivce, Wolverine Lake, Michigan, oral commun., 2006
Minnesota Department of Transportation	MN	12,000		Sodium chloride	233,434 & 2.3 Mgal of brine		19.5	Minnesota Department of Transportation, 2006
Twin Cities Metro Area	MN		5,900	Sodium chloride	103,000	17.5		Minnesota Department of Transportation, 2006
Brooklyn Center	MN		139	Sodium chloride		27.0		Wenck Associates, Inc., 2004
Brooklyn Park	MN		243	Sodium chloride		27.0		Wenck Associates, Inc., 2004
Crystal	MN		112	Sodium chloride		3.0		Wenck Associates, Inc., 2004
Robbinsdale	MN		88	Sodium chloride		12.0		Wenck Associates, Inc., 2004

State, municipality, or region	State	Road miles managed	Lane miles managed	Deicing chemical	Total amount of deicing salt used (tons)	Average use per lane mile (tons)	Average use per road mile (tons)	Source
Connecticut Department of Transportation	CT	3,276		Sodium chloride	101,947		31.1	Pat Rodgers, Connecticut DOT, oral commun., 2006
Manchester	CT	200		Sodium chloride	2,500		12.5	Kenneth Longo, Manchester Department of Public Works, oral commun., 2006
Woodbury	CT	86		Sodium chloride	900		10.5	Woodbury Department of Public Works, oral commun., 2006
Scituate Reservoir drainage basin–State Roads	RI	90	191	Sodium chloride	611	3.2	6.8	Nimiroski and Waldron, 2002, note that estimated sodium chloride reported based on calcium chloride/sodium chloride mixture
Scituate Reservoir drainage basin–Local Roads	RI	139	277	Sodium chloride	2,784	10.1	20.1	Nimiroski and Waldron, 2002
Iowa Department of Transportation–State Roads	IA			Sodium chloride		3.8		Transportation Research Board, 1991
Ames	IA	230		Sodium chloride	2,000		8.7	John Joiner, Director, Ames Iowa, Department of Public Works, oral commun., 2006
Cedar Rapids	IA		720	Sodium chloride	7,500	10.4		Department of Street Maintenance, oral commun., 2006
Waverly	IA	75		Sodium chloride	500		6.7	Brian Sullivan, Superintendent, Division of Streets, Public Works Department, Waverly, IA, oral commun., 2006
Illinois Department of Transportation	IL			Sodium chloride		6.6		Transportation Research Board, 1991
Elgin	IL	312		Sodium chloride, some calcium chloride liquid	6,000		19.2	City of Elgin, Illinois, Web page at *http://www.cityofelgin.org/index.asp?NID=180*
Gurnee	IL		210	Sodium chloride		14.3		City of Gurnee, Illinois, Web page at *http://www.gurnee.il.us/public_works/about.html#streetdivision*
Indiana Department of Transportation	IN			Sodium chloride	335,137			Indiana Department of Transporatation, 2004, Web page at *http://www.in.gov/dot/div/communications/2004annualreport/Safety.pdf*
Indiana Department of Transportation	IN			Sodium chloride		9.0		Transportation Research Board, 1991

State, municipality, or region	State	Road miles managed	Lane miles managed	Deicing chemical	Total amount of deicing salt used (tons)	Average use per lane mile (tons)	Average use per road mile (tons)	Source
New Hampshire Department of Transportation, Interstate 93	NH		111	Sodium chloride	2,762	24.9		Phil Trowbridge, New Hampshire Department of Environmental Services, written commun., 2006
New York, Croton Watershed–Interstate 84	NY			Sodium chloride		74.5	298.0	Heisig, 2000
New York, Croton Watershed–Taconic Parkway	NY			Sodium chloride		18.8	75.0	Heisig, 2000
New York, Croton Watershed Local Roads	NY			Sodium chloride		9.3	37.0	Heisig, 2000
Colonie Village	NY	35		Sodium chloride	1,500		43.5	Carl Fleshman, Superintendent of Public Works, Colonie Village, NY, oral commun., 2006
Ohio Department of Transportation	OH			Sodium chloride, calcium chloride also used		9.7		Kunze and Sroka, 2004 (for selected counties)
Harrison	OH		100	Sodium chloride, calcium chloride	600, 1,000 gal.	6.0		James Leslie, Director of Public Works, Harrison, OH, oral commun., 2006
West Carrollton	OH	300		Sodium chloride, calcium chloride	800		0.4	
Lacey City	WA		25	Sodium chloride	10	0.4		Dennis Ritter, Public Works Department, Lacey, WA, oral commun., 2006
Olympia	WA	200		Calcium magnesium acetate, some sodium chloride	5		0.03	Randy Stewart, Department of Transportation, Lacey, Washington, oral commun., 2006
Brookfield	WI		482	Sodium chloride	4,400	9.1	17.2	Terry Starns, Department of Public Works, Brookfield, Wisconsin, oral commun., 2006
Lake Geneva	WI		300	Sodium chloride	300	7.5		Lynn Allen, Department of Public Works, City of Lake Geneva, Wisconsin, oral commun., 2006
Milwaukee	WI		7,112	Sodium chloride	50,000	7.0		Hintz and others, 2001
Sussex	WI		45	Sodium chloride	1,500	33.3		Jeremy Smith, Department of Public Works, Sussex, Wisconsin, oral commun., 2006

Survey of DOT websites for Anti-Icing Information

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristics	Method of Application
Alaska	**> 50"**	**Pilot Study**	**Anti-icing: $MgCl_2$ and Potassium Acetate** **$MgCl_2$ \$1.11 per gallon; 50 gallons per lane mile** **Potassium Acetate \$4 to \$5 per gallon** **Deicing: $MgCl_2$** **Pre-wetting: Wetting sand with $MgCl_2$(Traction Sand) Contains 5% salt. Promote melting with temps above 15° F 9 gallons of $MgCl_2$ per cubic yard of sand. 3.2 % by weight** **Abrasives: Sand and Aggregate** **Aggregate is similiar in composition to pea gravel Uses an average of approximately 19,000 tons of clean (less than 2% silt content) washed sand per year** **GPS Data Collection: Mount a GPS in one of the sanders to collect inventory information as to how much sand/liquid $MgCl_2$ is applied and where**	**Anti-icing/Pre-wetting/Abrasives: All of the Anchorage and Girdwood sanders are equipped with twin 70-gallon saddle tanks for pre-wetting the traction sand with liquid $MgCl_2$. A couple of 2,000-gallon direct application trucks and a single 1,800-gallon truck. All three of these vehicles have "ground speed controls" capable of maintaining a uniform predetermined application rate of MgCl2 over** **one, two, or three lanes of pavement at varying speeds from a dead stop to 50 mph.**
Arizona	< 10"	Unknown	**Road Salts:** NaCl or MgCl **Anti-icing:** Liquid MgCl is used as an anti-icing additive **Deicing:** MgCl, NaCl, or complex chlorides **Pre-wetting:** Liquid MgCl, salt brine, liquid $CaCl_2$, or other liquid chemical to wet the granular chemical addictive before it is applied to the road **Abrasives:** Volcanic cinders, Sand, Washed sand, and decomposed granite. Chemical additives, such as NaCl or complex chlorides, may be added to abrasives to increase effectiveness	**Anti-icing:** applying chemical additives to a highway surface prior to snow or ice accumulation Applied using computer controlled mechanical spreaders **Deicing:** Liquids are applied using spray or tank trucks Granular additives are applied using trucks equipped with spreader units **Pre-wetting:** injecting pre-wetting chemical onto

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
			Cinders: sieve size 1/2", percent passing 100% sieve size #8, percent passing 5-25% sieve size No. 4, percent passing 100% sieve size No. 200, percent passing 2-8%	a loaded spreader or onto material as it is being loaded **Abrasives:** Applied during and after winter storm by trucks with mechanical spreaders
California	3" - 10"	Unknown	**Anti-icer:** Salt, Salt Brine, CMA, Liquid Potassium Acetate or Liquid $MgCl_2$ **Deicer:** Salt, Salt Brine, CMA, Liquid Potassium Acetate or Liquid $MgCl_2$ **Abrasives:** Salt; Salt Brine is made when dry salt is added to water to create a 25% solution Abrasives will ordinarily be applied at 1,000 lbs. or less per lane mile. Up to 2,000 lbs. per lane mile	**Abrasives:** Trucks with spreaders
Colorado	> 50"	Pilot Study	Salt Brine - 23% mixture of salt & water	spray trucks (did not specify)
Connecticut	30" - 45''	Real Study		Specially equipped tank truck that will spray pre-wetting applications with sodium chloride & liquid calcium chloride up to 5 days in advance so that the liquid will dry, leaving a salt residue on the pavement
Idaho	36" - 48"	Real Study	**Anti-icing:** Liquid $CaCl_2$ and MgCl MgCl should not be applied if the air temperature is above 40^o F with relative humidity 0f 45-50% **Deicing:** Liquid $CaCl_2$ and MgCl **Pre-wetting:** Liquid $CaCl_2$, MgCl, and sand	**Anti-icing:** Liquids are sprayed on roads before a storm hits Currently, monitoring is reqiured if application rates of 20-30 gallons per lane mile are exceeded. Other states have an application range from 15 to 50 gallon per lane mile **Deicing:** Liquid applied to remove a thin layer of snowpack already on the road **Pre-wetting:** Wetting sands with

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
				Anti-icing liquids and applying to snow covered roads
Illinois	24" - 36"	Unknown	Anti-icing: Apply salt before storm Deicing/Pre-wetting: NaCl, CaCl, MgCl	full-width spreading pattern: good for multiple lane highways Windrow spreading: applied in a 4-8 foot strip along the centerline and is effective for two-lane roadways
Indiana	24" - 36"	Real Study	When the temperature is above 25 degrees, salt is used to melt snow and ice and prevent the bonding of compacted snow to the pavement's surface. Once the temperature falls below 25 degrees, INDOT adds a small amount of liquid, usually calcium chloride or magnesium chloride, to increase the salt's effectiveness. 335,147 tons/year NaCl	
Iowa	24" - 36"	Real	23.3% solution	slip ins, trailers, tankers
Kansas	6" - 12"	Unknown	Salt Brine - 23% mixture of salt & water	spray trucks (did not specify)
Maine	60" - 90"	Real Study Pilot Study	**Salt Application Rates:** (above 32^o)F, use pre-wet system (25^o-32^o)F, pre-wet at 6 gal's per ton (20^o-25^o)F, pre-wet at 8 gal's per ton (15^o-20^o)F, pre-wet at 10 gal's per ton (15^o or below)F, apply sand & plow if needed, monitor pavement temperature & switch to salt if temperature rises above 15^o Liquid Calcium - 32% Salt Brine - 23% mixture of salt & water	pre-wetting with materials listed granular materials applied through use of spreader
Maryland	12" - 24"	Real Study		550 truck-mounted saddle tanks 80 wing plows 11 truck-mounted liquid applicator spray tanks
Massachusetts	25" - 50"	Unknown		**rock salt** (calcium chloride) sand **premix** (calcium chloride/sodium chloride blend)

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
				quid calcium chloride **magnesium chloride**
Michigan	> 50"	Real Study	Small quantity of calcium chloride, predominantly to add to sand piles to prevent freezing at low temperatures. Also, calcium chloride sometimes is mixed with sand to facilitate its flow through spreaders at low temperatures• 426,000 tons/yr of NaCl **Anti-icing:** Te first inch of snow in a storm bonds to the pavement and requires the most effort to remove. Anti-icing with calcium chloride has made clean up significantly easier in Mason county which receives 60-90 inches of mostly lake effect snow per year. Resulting in saving in their labor cost. **Pre-wetting:** Mason County also prewets their salt-sand mixture wit 10 gallons per ton, and is able to reduce their application rates by 50-75 lbs per lane-mile.	Controlling the spread of road salt by equipping its trucks with flow valves and calibration system
Minnesota	> 50"	Pilot Study	23% mixed w/ sugar beet byproduct **Anti-icing:** Uses magnesium chloride and salt brine for anti-icing. In addition to applying before a storm, scheduled applications are made to bridges and other critical areas, with the residual chemical having an effect for up to 5 days. Minnesota warns that under some temperature and humidity conditions magnesium and calcium chlorides can become slippery, the road may also become slippery if there is a build up of rubber and oil on the road surface before anti-icing is applied.	spray trucks (did not specify)
Missouri	6" - 12"	Unknown	**Anti-icing:** Uses salt brine with an agricultural byproduct, Geomelt, added. The Geomelt decreases the temperature that the brine is effective at, and also reduces corrosion.	
Montana	> 50"	Pilot Study	**Anti-icing:** Liquid temperature suppressant chemicals (salt brines, acetates, chloride and non-chloride solutions) Application rates: 10-30 gallons per lane mile	

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
			Abrasives: Sanding Material NaCl (Rock Salt) Rock salt has been typically mixed at a rate of up to 5% by volume **Deicing:** Solid or liquid	
Nevada	25" - 50"	Unknown	**Road Salts:** Road Brine and Salt, NaCl(salt, rock salt or road salt) Brine is 10% salt and 90% sand blend **Anti-icing/Deicing:** $MgCl_2$ **Deicer:** Brown sugar-like mineralized mixed with sand Can melt ice at temps to 5º F **Abrasives:** Sand and Cinders	**Road Salts:** Trucks with mechanical spreaders **Anti-icing:** Solution is sprayed from six 1,800-gallon truck bed tanks. Product applied to the road before a storm to reduce the buildup of snow and ice **Deicing:** Product applied to a layer of ice or snow to assist in melting **Pre-wetting:** Product is mixed into sand to help material stick to the ice or snow, and help to prevent traffic from blowing the sanding material off the road
New Hampshire	> 50"	Unknown	2.2 lb's of salt per gallon of water 32% calcium chloride strength	3000g tanks attached to back of trucks that dispense salt brine calibrated at 30-35 mph
New Jersey	15" - 30"		112,000 tons of salt 551,000 gallons of liquid calcium per year	skid resistant overlay granular spreaders on trucks liquid potassium acetate sprayers brine solution (salt & water)
New York	> 50"	Unknown		1 million tons of salt 75,000 tons of treated salt 52,000 tons of liquid calcium 343,000 gallons of liquid magnesium chloride 15,000 gallons of Liquids/aggriculture

				Abrasives (sand) < 15,000
State	**Average Annual Snowfall**	**Nature of Study**	**Salt-Brine Application Characteristic**	**Method of Application**
North Dakota	35" - 50"	Unknown	**FAST system:** Installed two FAST systems one of which is shared with Minnesota. The FAST systems were found to be 95% effective. The total net economic benefit was over 1.9 million. There was a 75% reduction in accidents on one of the bridges and a 50% reduction on the other.	
Ohio	24" - 36"	Real Study	416,000 tons/year NaCl 825 gal/year Calcium Chloride	
Oregon	> 50"	Pilot Study	**Pre-wet Sand:** Sand wet with MgCl **Anti-icing/Deicing:** MgCl or Calcium magnesium acetate Anti-icing: applied to lower freezing temp of water to prevent ice and snow from forming a bond to the road surface Deicing: applied to layer of snow or ice to assist melting process Calcium magnesium acetate: Acetic acid(strong vinegar) mixed with lime **Abrasives:** Sanding (various sizes of gravel and cinder) Road Salt: NaCl	**Anti-icing/Deicing:** Trucks equipped with tanks, pumps, and spray bars and nozzles. Product application rates typically range from 15 to 50 gallons per lane mile. A computer inside the truck controls these rates
Pennsylvania	24" - 36"	Unknown	**Anti-icing:** Uses salt brine. **Abrasives:** Uses sandstone and limestone anti-skid material. **Pre-wetting:** Pre-wetting is done with salt brine; it helps minimize lost material from the roadway.	2,250 trucks with plows and salt spreaders, 527front end loaders, 180 anti-icing units, and 15 snow blowers
Rhode Island	34" - 36"	Unknown		pre-wetting of roadways
South Dakota	35" - 50"	Unknown		
Tennessee	10”-15”	Unknown	**Anti-icing:** Uses 23% salt brine. **Pre-wetting:** Pre-wetting is done with beet & potato juice	Salt trucks, salt-brine spreader trucks, snow plows 36 RWIS stations

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
Utah	36" - 48"	Unknown	**Road Salt:** Most of the salt is made by drying the water from the Great Salt Lake and some comes from a saltmine. Amount of salt applied is equal to two pieces of salt in the sample per square foot tons of Salt used in an average year - 211,000 (based on last three-years average) **Anti-icing/Deicing:** MgCl and Liquid Salt Brine (Liquid NaCl) Salt content - 23% by weight Salt Brine used - 1,820,000 gallons CaCl: 32% by weight **Abrasives:** Grit or crushed rock (Sand or Volcanic). Not used to melt snow or ice but to give cars better traction **Deslicking Grit used** - 117,000 tons **FAST system:** Installed a FAST system on the Northbound lanes of one bridge and left the Southbound lanes with out a FAST system as a control. The level of service was continually improved on the test section, however when there was heavy snow fall the FAST system could not maintain bare pavement conditions.	**Road Salts:** Trucks with salt/sand spreaders **Anti-icing/Deicing:** Trucks equipped with tanks
Vermont	> 50"	Pilot Study	**Anti-icing:** Salt brine (23%), and Ice-B-Gone **Deicing:** Rock salt, and oatmeal (70% salt and 30% brine) 75,000 tons of salt used per year **Abrasives:** Sand uses 21,000 tons per year, with the use of brines sand use could be eliminated above 5°F	**Anti-icing/deicing:** STRATOS spreaders
Virginia	12" - 24"	Unknown	**Anti-icing**: 4 of 52 divisions are using anti-icing with liquid calcium or magnesium chloride **Pre-wetting:** 9 of 52 divisions are pre-wetting with liquid calcium or magnesium chloride at the point of discharge **Brine from runoff:** Virginia DOT's over 300 facilities generate and capture large amounts of runoff if this runoff was recycled into brine Virginia would save 3	

State	Average Annual Snowfall	Nature of Study	Salt-Brine Application Characteristic	Method of Application
			million dollars a year if the brine was used for pre-wetting. 6.5 milllion dollars would be saved if the brine was used for both pre-wetting and anti-icing. **FAST system:** The use of FAST systems was investigated, as many Virginia bridges are due to be widened increasing slippery conditions due to increased shading. It was determined that it would cost 33 dollars to have a truck apply 25 cents of liquid sodium chloride, while a FAST system could apply 1.81 dollars worth of magnesium chloride, and has low maintenance cost compared to the capital cost.	
Washington	> 50"	Pilot Study	**Anti-icing:** Liquid Calcium Magnesium Acetate Applied to roadway before weather events occur to prevent ice crystals from bonding to the pavement **Deicing:** $CaCl_2$ is most used. $MgCl_2$ and $NaCl_2$ are also used $NaCl_2$ is table salt mixed with water to produce a brine Use less chloride because of milder climate **Pre-wetting:** Mix Deicing liquid with salt **Rock Salt:** $NaCl_2$ solid salt used in brine. Not as refined as brining salt. Has some clay content **Abrasives:** Sand	**Deicing:** 150 vehicles with liquid sprayers **Rock Salt:** Snow plows with road sanders
West Virginia	12" - 24"	Real Study	At full capacity, WVDOT stockpiles hold about 73,000 tons of salt. This amount may be adequate for a very mild winter. During the average winter, however, around 100,000 tons will be used. A severe winter, such as 1993-94, can require the use of 140,000 tons or more. For deicing use during extremely cold periods, the state also keeps approximately 40,000 bags of calcium chloride on hand. In addition, over 100,000 tons of anti-skid materials (sand, crushed stone and cinders) are stockpiled	

Wisconsin	36" - 48"	Unknown	23.3wt% mixture of Salt and Water Pre-wetting liquids include salt brine, calcium chloride, and magnesium chloride. Some liquid pre-wetting chemicals may contain additives to inhibit corrosion. Applications of 8-10 gallons of liquid per cubic yard of salt are recommended	The spreader with a spinner to apply deicers. 25 MPH or greater spread speed
Wyoming	> 50"	Unknown	**Road Salt:** Salt/Sand mixture **Snow fences:** Snow fences are used since Wyoming often has blowing snow, the frequency with which Wyoming has blowing snow also makes anti-icing highly ineffective in this state.	**Road Salt:** Plow trucks

PART 2

IMPACT OF PRE-WETTED DEICER AND SALT ON ACCIDENTS AND INJURIES

ANALYSIS OF THE VILLAGE OF FAYETTEVILLE DATA FOR NATURAL BRINE AND "COMBINATION OF SALT/PRE-WET/DEICING" APPLICATIONS

ANALYSIS OF NYSDOT (EAST ONONDAGA RESIDENCY OFFICE) I-81/I-481 DATA WITH AND WITHOUT BRINE

SUMMARY OF RESPONSES TO QUESTIONS AFTER MEETING WITH OPERATORS AND DRIVERS FROM VILLAGE OF FAYETTEVILLE AND NYSDOT ONONDAGA EAST RESIDENCY OFFICE

COST ANALYSIS FOR NATURAL BRINE APPLICATION FOR ANTI-ICING IN THE SYRACUSE AREA

ANTI-ICING OPERATORS GUIDE

Abstract

This part of the report investigates the relationship between material application during winter maintenance of roadways and accidents occurring during that time period in Syracuse, New York. Data was obtained from three agencies: the Village of Fayetteville, Onondaga County and the New York State Department of Transportation (NYSDOT) Onondaga East Residency office. Data collected from these agencies included materials application, miles covered by the material, weather conditions and accident data.

The report also provides a summary of the responses received from interviews conducted with the winter maintenance personnel from the participating agencies mentioned above. A cost analyses of natural brine application in the Syracuse area using the NYSDOT groundwater well located at Van Rensselaer Street (next to I-690) in Syracuse, New York is also included. A simple operator's manual for brine application is also presented at the end of the report.

A thorough literature review on the impact of winter road maintenance on accidents was conducted. The review indicated that anti-icing and pre-wetting practices using brine had a major impact on winter road conditions leading to reduced number of accidents and a lesser number of fatal crashes. This was attributed to better road conditions and reduced vehicle speed during the winter season.

Pre-wetted deicer and salt utilized by the Onondaga County DOT were evaluated and compared to study the impact on number of accidents and number of injuries. The data was evaluated using Pareto charts. The dependent variables were materials and snowfall in inches; the response variables were number of accidents and number of injuries. The conclusion drawn from the data analyses is that the material used (prewetted deicer versus salt) had more significant effect on the number of injuries than the amount of snowfall. Data analyses from the Village of Fayetteville indicated that the natural brine application data in the Village was highly variable. The data indicated that the frequency of accidents went up immediately after a heavy precipitation with either natural brine or rock salt application. Therefore, it appears that both applications may not be as effective when there is heavy precipitation. The NYSDOT office data indicated that the number of accidents in the 2010-2011 winter season when brine was applied was less than when rock salt was applied during the 2009-2010 winter season, even though the precipitation was greater in the former case. It appears that brine was more effective in reducing the number of accidents at least on the roadways with similar characteristics such as I-81 and I-481.

Interviews with the winter road maintenance crew from the participating agencies indicated that the use of brine for both anti-icing and pre-wetting was beneficial for winter road maintenance. The crew indicated that quality equipment, accurate weather forecasting, good record keeping and overall quality management was needed for proper winter road maintenance.

Cost analyses of the use of natural brine from the NYSDOT groundwater well indicated that the costs for using commercial brine versus pumping natural brine from groundwater are comparable. Benefits of natural brine use include lesser material (salt) need and ease of mixing for preparation of the needed 23% brine for winter maintenance.

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IMPACT OF PRE-WETTED DEICER AND SALT ON ACCIDENTS AND INJURIES

Abstract

Winter road accidents are a major contributor to the annual accident rates in the northern part of the U.S. and Canada. Snowfall and ice are the two main causes of winter accidents. Various road maintenance techniques and materials are utilized by the Departments of Transportation to provide an optimum road condition for travelers. The accident data, the weather information during the accident, and the material application data for Onondaga County, New York were investigated to determine the effect of different materials on the accident rate. Salt and pre-wetted deicers were compared. The deicer contains 4.1% pre-wetting agents and 95.9% salt by weight. It was found that the material applied did not have a significant effect on the accident rate. However, the number of injuries was greater when pre-wetted deicer was applied. In addition, the accident rate during a snow event was significantly higher when compared to non-snow days.

Keywords: pre-wetted deicer, winter accident, accident analysis, anti-icing, de-icing

2.1 Background

Onondaga County is located in the Central New York region and stands at the northeast of the Finger Lakes. The county has a land area of 793.5 square miles and is approximately 35 miles in length and 30 miles in width. As of the 2010, the U.S. Census showed a population of 467,026 for Onondaga County, which included a population of 145,170 for the City of Syracuse. Onondaga County is a part of the Syracuse Metropolitan Statistical Area which also includes the counties of Oswego and Madison. The Onondaga County seat is Syracuse.

Onondaga County is known for its harsh winters and heavy snowfall. With an average snowfall of 115.6 inches in Syracuse, the Syracuse metropolitan area receives more snow on average than any other metropolitan city in the U.S. Elevated snowfall in Onondaga County is due to its geographic location. Onondaga County receives both lake-effect snow from the Great Lakes regions, particularly Lake Ontario, and the northeastern snow. Lake-effect snow is produced when cold winds sweep over a large body of water and pick up vapors. As a result, clouds build over the lake and eventually develop into snow showers on the windward shores.

In the case of Onondaga County, arctic cold air moves across the Great Lakes picking up water vapor. As moist air reaches land, water vapor is deposited onto the land in forms of snow or rain depending on the temperature. As a result, it is common for Onondaga County to receive more than one inch of snow on a daily basis. Northeastern snow is another major snowfall contributor in Onondaga County. Northeastern snow storms are usually formed over the Gulf of Mexico and move towards the northeast. The areas affected by northeastern snow range from Virginia to the New England coast.

2.2 Weather Induced Accidents during Winter

In the northern states of the U.S. and Canada, a considerable portion of road accidents occur in the winter. Adverse weather has been identified as a primary or contributing cause (Thordarson and Olafsson 2008). Gusty winds, snow, ice, and sleet are characteristics of adverse weather. Transportation agencies face a difficult challenge to keep roadways open and safe during these adverse conditions. National Oceanic and Atmospheric Administration (NOAA) has found that for all injuries due to ice and snow, about 70% result from vehicle accidents (NOAA, 2001).

A study was conducted by the European Transportation Research Arena on weather induced road accidents in Iceland. It was found that a large portion of road accidents in the winter have reduced winter road surface friction and strong winds as contributing factors (Thordarson and Olafsson 2008). The study also revealed that a higher proportion of winter accidents happened during night due to lower visibility and lower temperatures.

The effect of weather on road surface and impaired visibility due to adverse weather conditions are a well understood phenomenon (Andrey et al. 2001). With detailed information, road surface friction can be predicted with a fair degree of accuracy. The factors that affect driver visibility are well identified in literature. However, modeling weather induced accident risk is a difficult task due to the stochastic nature of collisions and heterogeneity of driver response (Andrey et al. 2001).

A number of studies provide empirical estimates on weather induced accident risk. Generally, accident rates increase during precipitation (Edward, 1996). There is considerable evidence that snowfall has a greater effect on accident rates than rainfall. However, snowfall related accidents tend to be less serious, possibly due to slower traffic speed during snow events. Overall, freezing rain and sleet have the greatest effect on accident rates.

2.3 Problem Statement

Due to the elevated snowfall in Onondaga County, New York, winter road maintenance is essential in providing safe road conditions for residents and commuters in the area. Onondaga County is responsible for snow removal and ice control on 304 miles of county roads and 220 miles of state roads within the county limits. Plowing and salt application to prevent freezing are the two traditional operations employed by the county. The constituents present, as well the abundance of natural brine in the area, makes natural brine an ideal winter road maintenance material.

Anti-icing is a proactive strategy to winter roadway maintenance that applies liquid chemicals to prevent the formation of frost or the bonding of snow or ice to pavement. Another proactive operation is pre-wetting. Pre-wetting is the process of adding liquids to solid stockpiles before applying it on the roadway. Compared to the traditional reactive winter roadway maintenance, the combination of both anti-icing and pre-wetting practice has several advantages. Some of the advantages are listed below:

1. Reduced snow and ice bonding
2. Reduced accidents
3. Reduced number of road closures
4. Reduced de-icing material, labor, and de-icing residue
5. Reduced winter maintenance work and cost

Traditionally, calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) are used as anti-icing and deicing agents. Natural brine has gained attention as an alternative to traditional anti-icing agents. Natural brines are waters with high concentration of dissolved constituents. Natural brine typically contains about 8-16% of $CaCl_2$, 3-4% of $MgCl_2$, 8-16% of NaCl, 1-2% of KCl, and 0.1-0.3% of bromide (Mavity, 1978). The purpose of the accident analysis is to investigate the impact of different winter road maintenance operations on road accidents.

2.4 Literature Review

2.4.1 Effect of Road and Weather Conditions on Accident Rates

The relationship between adverse weather and accident rates has been well studied in Transportation Engineering, particularly during winter. Rain, snow, sleet, and gusting winds are identified as adverse weather in these studies. Rain and snow may freeze on the roadways which can drastically decrease the friction on the roadways. Norman et al. (2000) identified that the highest number of accidents occurred during snowfall. Proper anti-icing and deicing operations are essential in providing safe driving conditions.

Andrey and Olley (1990) indicated that approximately 40% of winter accidents occurred on roads with ice, snow, or rain. The study suggested that accident rates increased as roadways became wet or covered by snow or ice. However, the statistical significance on the increase in rates of accident occurrences varied among different studies. Variations may be due to differences in methodology, weather conditions, or geographic locations. Two studies conducted by the Swedish Road and Traffic Research Institute have found that accident rates can be several times greater when roads are covered with snow or ice than roads under normal conditions (Savenhed 1994 and Scharsching 1996).

A detailed study on winter accidents due to slippery winter road surfaces was conducted by Thordarson and Olafsson (2008). Reykjanebraut Road, which connects the capital city of Iceland to the airport, was chosen for accident analysis. On Reykjanebraut Road, 53 accidents were registered for the observation period from September 2004 to April 2005 and from September 2005 to March 2006. Out of 53 accidents, 35 accidents had road conditions that were described as slippery, icy, or with snow. Also from the study, it was found that 23% of accidents occurred during the night (24:00-07:00). It was noted that 10% of the daily winter traffic on the study site was during the night. Typically, accident rates have a potential to increase during night time.

One challenge with comparative winter accident analysis is the variation in traffic volume. The daily traffic volume can be significantly different between weekdays and weekends. Also, winter storms have shown to reduce the traffic volume. Hanbali and Kuemmel (1993) studied the effect of winter storms on traffic volume reduction and found that the reduction ranged from

7% to 56% depending on the severity of the winter storm. The reduction in traffic volume accompanied by higher accident occurrence during adverse winter weather may suggest a greater risk of accident than the apparent risk indicated by literature.

Khattak et al. (2000) compared accident rates on interstate highways when the snowfall was more than 0.2 inches per day versus when the weather was clear. This comparison was conducted using the same month, day, and time of day. The goal of this comparison was to normalize the seasonal and weekly variation in the traffic volume. It was found that during the winter storms, the accident rate was 5.86 accidents per million vehicle-km compared to 0.41 accidents per million vehicle-km during non-storm period.

Although there is a consensus that adverse weather has a statistically significant effect on winter accidents, the severity of accidents due to adverse weather varied among literature reviewed. There is substantial evidence that snow has a greater effect on accident rates when compared to rain. Studies in the UK have found that total injuries and fatalities increased by 25% on snowy days, and the rate of injuries and fatality increased by 100% (Perry and Symons 1991). However, other studies found that crashes during winter storms were less serious (less fatal crashes) when compared to clear conditions (Bass and Brown 1997). The reduction in relative rate of fatal crashes is due to reduced vehicle speed during snow events. The literature previously presented describes the relationship between adverse weather and accident occurrence. These studies do not account for the effect of winter road maintenance operations on accident rates.

2.4.2 Effect of Maintenance Practices on Accident Rates

Approximately $2 billion is spent annually in the U.S. on winter road maintenance (O’Keefe and Shi, 2005). The assumed benefits from winter road maintenance operation are recognized by researchers and maintenance workers. However, upon examination of literature, the degree of accident rates reduced by winter road maintenance is unclear. The amount of studies in assessing the effect of winter road maintenance and accident rates in the U.S. is deficient.

A comparative study on the relationship between road maintenance operations and accidents was presented by Thordarson and Olafsson (2008). Figure 2.1 shows a direct correlation between the timeline of maintenance activity and accidents. In the diagram, the red and yellow dots represent snow plowing and deicing operations. The time of accident is marked with a blue triangle. The timeline indicates that accidents tend to happen moments before maintenance operations. The comparison of the road surface condition before and after the maintenance operation shows that the road surface condition is significantly better after the maintenance operation. This finding points to road surface condition as a big contributing factor to winter road accidents.

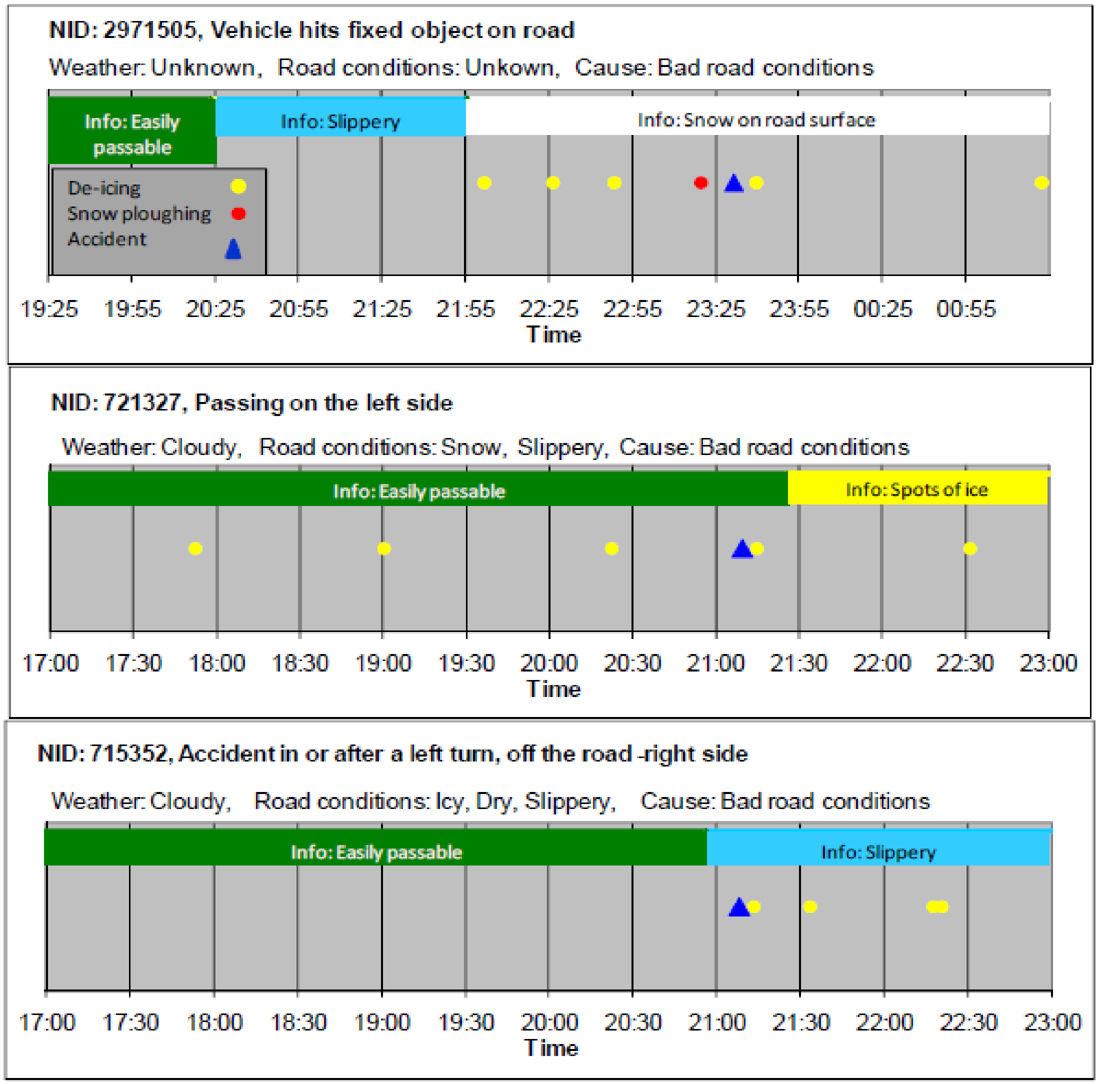

Figure 2.1: Timeline Diagrams Showing Winter Maintenance Activity and Time of Accident (Thordarson and Olafsson 2008)

There are few published studies that have assessed the safety benefits of winter road maintenance operations, particularly on salted versus unsalted roads. The Norwegian Directorate of Public Works compared the accident occurrence before and after a road is salted. An 11% accident reduction was reported after the road was salted. A similar study conducted in Finland found that the accident rate increased (30-40%) when amount of salt applied onto the roadway was decreased (10 tons/km to 1-2 tons/km).

A network of two-lane undivided and divided highways of approximately 520 miles and 50 miles were selected for winter accident analysis (Kuemmel and Hanbali, 1992). An Automatic Traffic Recorder (ATR) was used to measure the hourly traffic volume. The hourly traffic volume was then converted to Million Miles Vehicle Travel (MMVT) providing the highway length. The accident data were provided by the participating DOTs. The salt application timeline was also provided. The statistical analysis (the Poisson's Method and the "Paired T-Test") was conducted on the accident rate before and after salt application. The test showed a significant difference between before and after the accidents. The finding of this study is illustrated in Figure 2.2. The following conclusions were determined from this study:

- Before deicing, the accident rate is eight times higher on a two-lane roadway (4.5 times higher for multi-lane freeways);
- The fatal accident rate is nine times higher before application (seven times higher for multilane freeways); and
- Total accidents are reduced from 23 to 16 (approximately 30%) within the first hour after application of road salt.

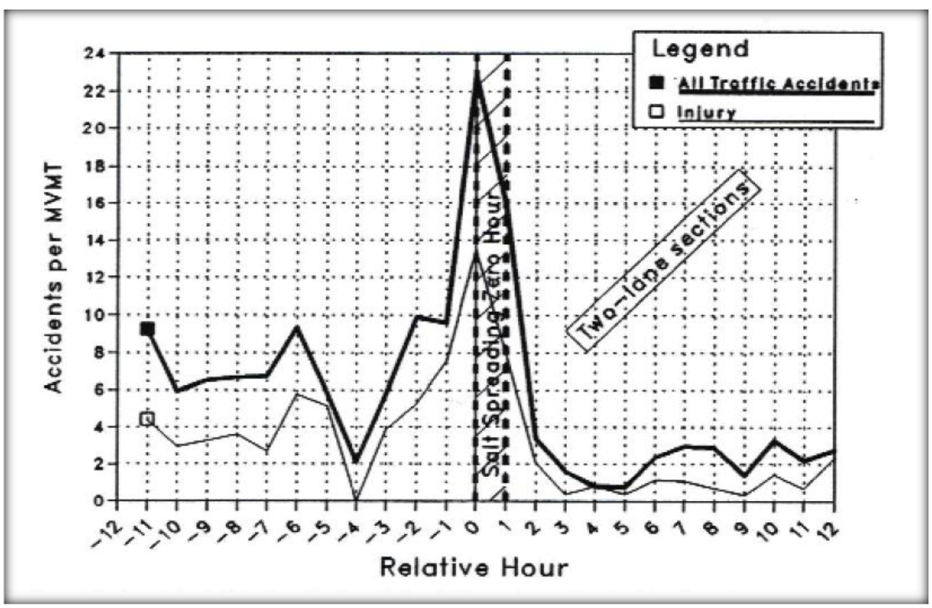

Figure 2.2: Traffic Accidents Before and After Salt Application (Kuemmel and Hanbali 1992)

Researchers and government agencies in the U.S. are continuously refining winter road maintenance operations. The benefits of anti-icing and pre-wetting have been discussed in details in Section 1. The benefits of anti-icing and pre-wetting on accidents rates will specifically be addressed in the following section.

2.4.3 Impact of Anti-icing on Accident Rates

In Idaho, once anti-icing was implemented on U.S. 20, accidents were reduced by 83% each year compared to years before the start of the pilot program (Breen, 2001). During a twelve-year study involving anti-icing strategies on the interstate system in the Denver metropolitan area, Colorado saw an average of 14% decrease in snow and ice related crashes (Colorado DOT 2008).

A study in Indiana on U.S. 20 showed a drastic decrease in accidents when anti-icing was implemented (Highway Innovative Technology Evaluation Center, 1998). In this study, anti-icing consisted of spraying liquid chemicals ($MgCl_2$ and IceBan MagicTM). Figure 2.3 depicts the detailed number of snow and ice related accidents during the study period.

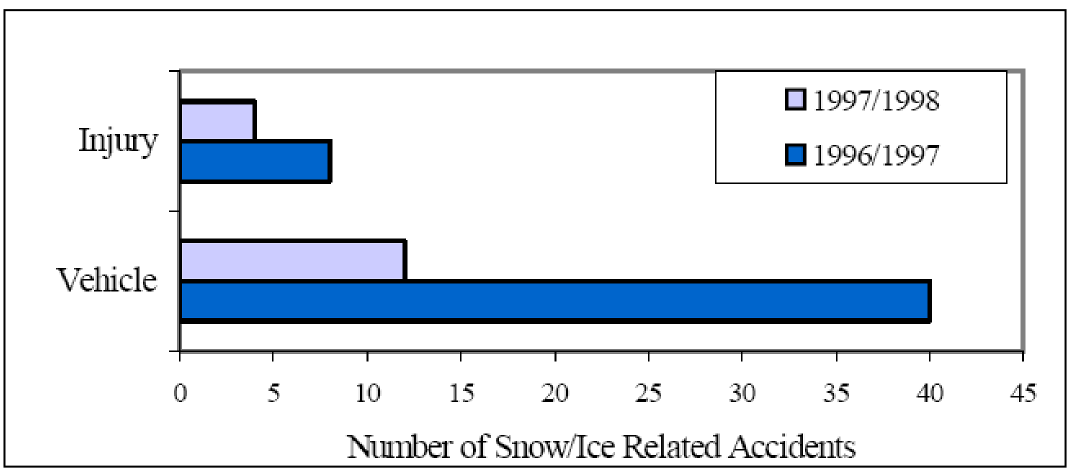

Figure 2.3: Accident Rates on U.S. 20 in Indiana during the Winters of 96/97 and 97/98

Colorado found that during the course of two storms, the test section that utilized $MgCl_2$ for anti-icing had higher friction values throughout the duration of the storm than the control section that was sanded (Highway Innovative Technology Evaluation Center, 1998). In Nevada, anti-icing was used for conditions such as light snowfall, short duration weather events, and temperatures just below freezing. This measure was successful in preventing ice bonds during these select weather conditions. Anti-icing has also been successful in Wisconsin where treatments of 100 pounds of $MgCl_2$ per lane mile (28 kg/lane km) slowed down the reduction in friction and provided greater frictional resistance during periods of heavy snowfall. In California, however, results were mixed. The test section consisting of an application of $MgCl_2$, road salt, and abrasives lessened the effects of bonded snow and ice, but did not prevent an ice bond to the pavement. Therefore, the treatment was not effective as a means of anti-icing (Highway Innovative Technology Evaluation Center, 1998).

As discussed in the previous sections, the goal of winter road maintenance is to provide safe road conditions for travelers. Besides environmental impact and cost, accident is another variable considered when measuring the effectiveness of maintenance materials. However, it is extremely difficult to evaluate and compare winter road maintenance materials (MnDOT 2005). It is also difficult to normalize the data so that the variations in traffic volume, weather conditions, road characteristics, and material application rates are minimized. Limited information was available in literature that evaluates the performance of pre-wetted deicer. A detailed composition of pre-wetting agents is presented in Table 2.1.

Table 2.1: Chemical Analysis of Pre-wetting Agent

Component	Unit	Typical
Magnesium Chloride	%	29
Triethanolamine	%	0.6
Coloring Agent	%	0.25
Proprietary Performance Enhancing Additive	%	0.4
pH		8.6

Minnesota DOT conducted a field test for pre-wetted deicer in Montevideo, Minnesota. Nine snow events were encountered during the field test. Seven events were below 20°F surface temperature and two were 20°F or above. The average application rate was 667 pounds per two lane miles. It was found that pre-wetted deicer worked twice as fast when compared to salt. It was also concluded that pre-wetted deicer is more effective in colder temperatures where sodium chloride becomes ineffective. The residue of pre-wetted deicer is also a good anti-icing agent.

2.5 Data

2.5.1 Road Section

The Onondaga County Department of Transportation plows roads in 19 towns, two villages, and certain county roads in Cayuga County. Onondaga County DOT is also contracted by the State of New York to maintain 220 miles of State roads within Onondaga County. The areas covered by Onondaga DOT can be broken down into four sections. These four sections are Jamesville, North Area, Camillus, and Marcellus. The detail mileage data covered by each section are presented in Table 2.2.

Table 2.2: Onondaga DOT Snow Removal Program Mileage Coverage by Sections

Section Number	Name	County Road (miles)	State Routes (miles)
Section I	Jamesville	110.19	102.07
Section II	North Area	137.27	0
Section III	Camillus	120.19	32.77
Section IV	Marcellus	141.03	74.02

2.5.2 Time of Salt/Pre-wetted Deicer Application

Participating areas in Onondaga County have been using salt as the deicing material. Another material that is being used is pre-wetted deicer. Pre-wetted deicers are bulk deicing salt pre-mixed with pre-wetting agents. The county is also investigating the use of natural brine as a pre-wetting material.

In Onondaga County, keeping a record of each snow and ice control maintenance operation is part of the highway maintenance work activities. A copy of the winter road maintenance schedule, which contains information such as route number, miles driven, number of trips, amount of materials, and type of materials used, was provided. The weather information, such as snowfall, is also included in this schedule. A typical dataset is shown in Table 2.3.

Table 2.3: A Typical Salt/Deicing Solution Application Data

Date	Truck #	Route #	Dickey-John Rate Setting	Spreader Miles Beginning	Spreader Miles Ending	Spreader Tons Beginning	Spreader Tons Ending	Material Type	Rate per Miles in lb
01/14/09	139	night	300	1,702.50	1,714.00	445.12	447.12	salt	347.83
01/14/09	57	1	450	1,052.00	1,084.00	212.53	219.59	deicing solution	441.25
01/14/09	139	10	350	1,685.00	1,702.50	442.00	445.12	deicing solution	356.57
01/14/09	191	2	350-450	565.60	639.50	110.03	125.61	deicing solution	421.65
01/14/09	187	3	400-450	283.10	350.10	58.59	71.50	deicing solution	385.37
01/14/09	166	4	300-400	0.00	56.00			deicing solution	0.00
01/14/09	184	5	450-500	0.00	101.70	0.00	24.20	deicing solution	475.91
01/14/09	159	6	450	0.00	39.00	0.00	8.40	deicing solution	430.77
01/14/09	162	7	400-450	0.00	71.00	0.00	14.40	deicing solution	405.63
01/14/09	147	8	350-450	554.10	604.20	114.96	125.57	deicing solution	423.55
01/14/09	136	9	450	304.10	360.60	52.78	64.71	deicing solution	422.30
01/14/09	54	10	300-450	514.20	582.70	105.92	121.07	deicing solution	442.34
01/14/09	144	12	400-450	313.40	368.60	65.74	77.69	deicing solution	432.97
01/14/09	117	13	350-700	448.20	496.30	120.67	133.66	deicing solution	540.12
01/14/09	63	10		0.00	32.00	0.00	10.00	deicing solution	625.00

2.5.3 Accident Data

A database of all accidents within Onondaga County from January 2007 to December 2009 was provided by the NYSDOT Office of Modal Safety and Security Safety and Security Planning and Development Bureau. The database contains information, such as date and time of the accident, as well the geographic and weather information during the accident. Accidents that occurred during the days with snow were analyzed. The weather information available in the database is used to evaluate the atmospheric conditions during the accident. The database also provided the longitude and latitude of the location of the accident. The GPS location was converted to street information using Google Earth™. The street information was matched to the salt and brine application schedule to identify whether road maintenance was conducted and what material was used. A typical dataset is shown in Table 2.4.1. The coded values used for weather and road surface conditions are also explained in Table 2.4.2. Road alignment, accident type and lighting conditions are not included in this table. This data can be found in the police reports. Due to the nature of study, weather and road surface conditions are the main focus of this accident analysis.

Table 2.4: A Typical Format of Accident Information from Database Provided by NYSDOT

Date	# of Fatalities	# of Injuries	# of Vehicle	Weather	Road Surface Condition	Time	Location of Accident
11/20/2008	0	0	1	2	2	17:15	W. Seymour Street or Route 31
12/16/2008	0	0	2	4	2	10:40	Inter State 81
12/21/2008	0	0	1	2	5	11:53	Inter State 81
12/31/2008	0	0	2	4	2	14:58	Inter State 481
1/8/2009	0	1	1	4	5	15:33	Inter State 481
1/24/2009	0	0	2	2	4	13:20	Inter State 481
2/13/2009	0	0	1	1	4	7:48	Inter State 481
2/20/2009	0	0	2	4	4	18:50	Inter State 481
12/26/2008	0	0	2	4	4	13:06	Great Northern Mall
12/30/2008	0	0	2	4	4	9:50	Great Northern Mall Parking Lot
1/24/2009	0	0	2	4	4	17:20	Great Northern Mall Parking Lot
10/28/2008	0	0	2	3	2	12:03	Great Northern Mall Drive way

Date	# of Fatalities	# of Injuries	# of Vehicle	Weather	Road Surface Condition	Time	Location of Accident
12/17/2008	0	1	2	2	2	17:20	Euclid Road or Route 31
12/21/2008	0	0	2	1	2	13:50	Caughdenoy Rd (8288)
11/26/2008	0	0	2	3	2	11:00	Brewerton Rd or Route 11

Coded Values Provided by the NYSDOT Office of Modal Safety and Security Safety and Security Planning and Development Bureau

WEATHER	Weather condition at the time of the accident.	0 – OTHER; 1 – CLEAR; 2 – CLOUDY; 3 – RAIN; 4 – SNOW 5 - SLEET/HAIL/FREEZING RAIN; 6 - FOG/SMOG/SMOKE ? - INVALID CODE; X - NOT ENTERED; Z - NOT REPORTED
ROAD_SURF_COND	Road surface condition at the time of the accident.	0 – OTHER; 1 – DRY; 2 – WET; 3 – MUDDY; 4 - SNOW/ICE 5 – SLUSH; 6 - FLOODED WATER; ? - INVALID CODE X - NOT ENTERED; Y - NOT APPLICABLE Z - UNKNOWN

2.5.4 Weather Information

The latitude and longitude data in the accident database was utilized to obtain the relevant weather information such as temperature, snowfall, visibility, and gusting winds during the time of accident from the closest weather station. The accident database and salt application schedule also have weather information on the day of the accident.

2.6 Accident Analysis

2.6.1 Pre-wetted Deicer versus Salt

Onondaga County DOT also uses pre-wetted deicer as one of its winter maintenance materials. Due to the budget constraints, pre-wetted deicer is only used when the temperature drops below 20°F. The analysis presented here compared the accident occurrence when salt and pre-wetted deicers were used during the 2008/2009 winter season in the North Area. The North Area was selected due to its higher traffic volume, which results in higher accident occurrence. The North Area also utilized different materials.

Tables 2.5 and 2.6 show the date when only pre-wetted deicer and salt were applied, respectively. The inches of snowfall, number of accidents, and number of injuries on each day are included in the tables. The snowfall information was available in the salt and pre-wetted deicer application data provided by Onondaga DOT. The snowfall data was determined from the local weather station. The number of accidents and injuries were obtained from the accident database provided by NYSDOT.

Table 2.5: Accident Data When Deicing Solution is Applied (Numbers inside the parenthesis are multi-car accidents.)

Date	Snowfall (inch)	Number of Accidents	Number of Injuries
12-21-08	5.5	4 (2)	0
1-11-09	2.2	0	0
1-14-09	0.7	4 (4)	0
1-15-09	0.3	3 (3)	2
1-16-09	0.7	4 (3)	2
1-17-09	0.5	1	1
1-18-09	4.4	4 (2)	5
1-21-09	2.1	0	0
2-1-09	0	0	0
2-20-09	9.5	10 (5)	2
Total:	**25.9**	**30**	**12**

Table 2.6: Accident Data When Salt is Applied

Date	Snowfall (inch)	Number of Accidents	Number of Injuries
12-9-08	1.8	6 (2)	0
12-26-08	1	3 (3)	1
12-30-08	2.6	4 (3)	3
1-2-09	0.4	1 (1)	0
1-3-09	3.2	0	0
1-4-09	0	2 (2)	0
1-5-09	0	0	0
1-6-09	0.6	1	0
1-7-09	0.5	1	3
1-8-09	9	1	1
1-9-09	1.1	6 (4)	1
1-10-09	2.6	2 (1)	0
1-19-09	0.7	1 (1)	1
1-24-09	1.3	7 (6)	2
1-26-09	0	0	0

Date	Snowfall (inch)	Number of Accidents	Number of Injuries
1-27-09	0.2	1 (1)	0
1-28-09	9.3	7 (2)	2
1-29-09	1.5	3 (2)	1
2-19-09	0	0	0
Total	**35.8**	**46**	**15**

Accident data analyzed was limited to accidents occurring during snow events. To normalize the variation in traffic volume, it was assumed that the reduction in traffic volume due to snow events was similar for all roads. Since the accident analysis also covered a large area, the localized effects, such as the road surface profile, road alignment, and intersection, were also normalized. Two local extremes of the snowfall (>9 inches) data were not included in the analysis since they had a dominant effect on the accident rate, and therefore, skewed the analysis.

A factorial experimental analysis was designed to analyze the data. The coded value for each variable (materials and snowfall) is presented in Table 2.7. Statgraphic™ was used to analyze the significance of the variables to the number of accidents.

Table 2.7: Coded Value Used for Statistical Significance Analysis

Material	Code	Snowfall (inches)	Code
Deicing solution	1	0 - 1	-1
Salt	-1	1 - 3	0
		3 - 6	1

A standardized Pareto chart was plotted and is shown in Figure 2.4. A standardized Pareto chart shows the significance of a fixed factor on a dependent variable. In this case, materials was the fixed factor and number of accidents was the dependent variable. If the standardized effect is greater than 2.1, the fixed factor has a significant effect on accident rate. It was found that during a snow event, both the amount of snowfall and materials applied and their interaction did not have a significant effect on the number of accidents. A similar analysis was conducted to determine effect of snowfall and material on injuries (Figure 2.5). It was observed that the amount of snowfall and materials applied and their interaction did not have a significant effect on the number of injuries.

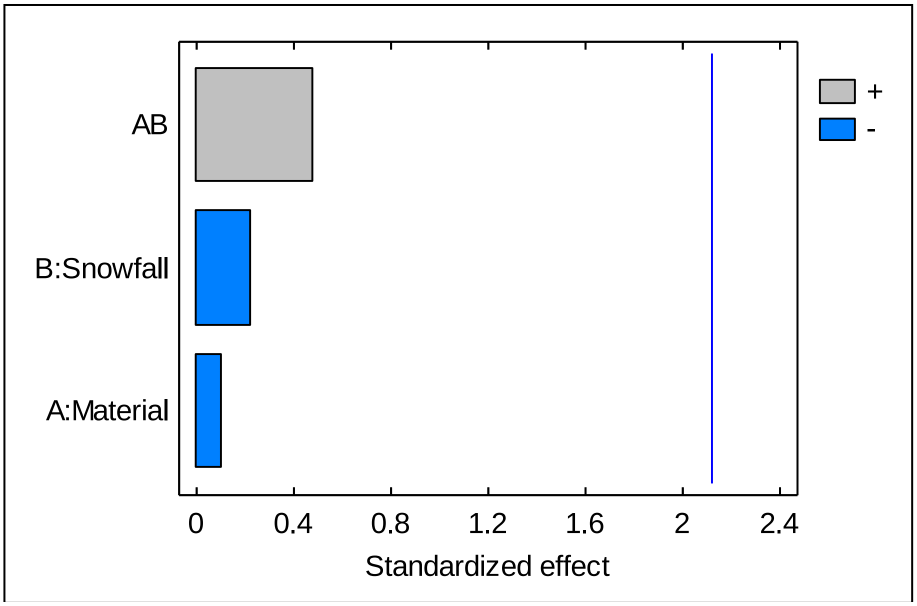

Figure 2.4: Standardized Pareto Chart for Accidents

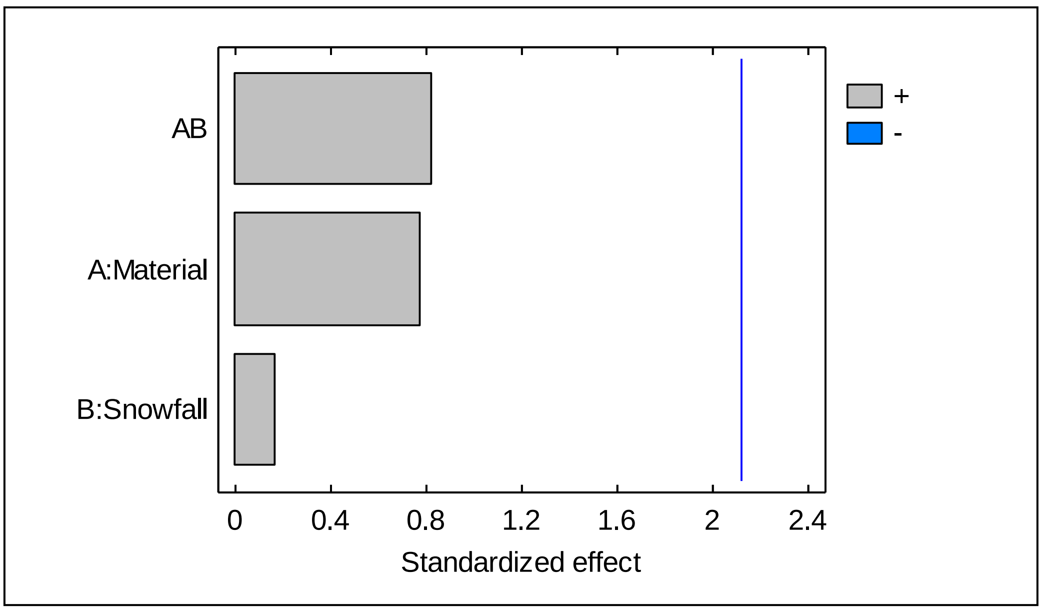

Figure 2.5: Standardized Pareto Chart for Number of Injuries

In addition, an analysis of variance for accidents was also performed to test the statistical significance of each variable by comparing the mean square against an estimated experimental error. Both variables have a P-value greater than 0.05, indicating that they have no significant effect on accidents at the 95% confidence level. Details of the statistical values obtained is presented in Table 2.8. The interaction of snowfall and materials are also found to have no significant effect on the number of accidents.

Table 2.8: Variance Analysis for Accidents

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Material	0.054	1	0.054	0.01	0.92
B:Snowfall	0.27	1	0.272	0.05	0.82
AB	1.22	1	1.22	0.23	0.64
Total error	83.48	16	5.22		
Total (corr.)	85.75	19			

A similar analysis was performed for the number of injuries using the same coded variables shown in Table 2.5. The objective of this analysis was to determine the effect of materials and snowfall on the severity of the accident. Although it was determined that materials and snowfall have no significant effect on the number of injuries, it appears that the material used has a greater effect on the number of injuries when compared to snowfall. Since pre-wetted deicers clear the roads faster than sodium chloride, vehicles may travel at a faster speed on the roadway, resulting in more severe accidents. However, speed data is not available to prove this hypothesis.

2.6.2. Accident Analysis during a Snow Event

Khattak et al. (2000) compared accident rates on interstate highways for periods on a day when snowfall was more than 0.2 inches per day to the accident rates during the same time period on the same day of the week during the same month when the weather was clear. However, in this study, the research team compared the accident rates during a heavy snow event to the non-snow or light snow days. This analysis used the entire pool of accident data in Onondaga County from 2007-2009. A total of 45,002 accidents were recorded in Onondaga County during the study period. Out of these 45,002 accidents, 37% of the total accidents occurred during the winter months (November, December, January, and February).

The goal of this comparison was to normalize the seasonal and weekly variation on the traffic volume. On February 20, 2009, 9.5 inches of snowfall was recorded by the Syracuse Airport Weather Station in Onondaga County. One hundred and five accidents were registered in the database on that day. The study compared the accident occurrence on the same weekday in the same month of two previous years. Table 2.9 shows the snowfall and number of accidents for the two previous years. It was found that the accidents doubled during heavy snowfall (9.5 inches).

Table 2.9: Number of Accident during Same Weekday of the Year

Weekday	Date	Snowfall (inches)	Number of Accidents
Friday	2-20-2009	9.5	105
Friday	2-22-2008	0.7	48
Friday	2-23-2007	0.7	54

A duplicate analysis was conducted for January 28, 2009, when 9.3 inches of snowfall was recorded. The results of this study are presented in Table 2.10. These two analyses produced similar results. It is clear that accident rates increase during snow events even though the traffic volume is reduced.

Table 2.10: Duplicated Study Showing the Accident Occurrence Increase with Snowfall

Weekday	Date	Snowfall (inches)	Number of Accidents
Wednesday	1-28-2009	9.5	94
Wednesday	1-30-2008	0	32
Wednesday	1-31-2007	3.1	61

2.7 Conclusions

The conclusions based on the extensive synthesis of literature published on the impact of winter maintenance on accidents are as follows:

1) The weather-induced vehicle accident analysis remains a challenge for researchers. The fact that a snow event is a significant contributor to winter road accidents is consistent with literature. However, the level of contribution a snow event has on the overall accident rate varied among studies.
2) The accident rate found in literature ranged from as little as 25% to as high as 1,300% when compared to normal road conditions (Perry et. al 1991; Giese et al. 2000). The variations in studies are due to differences in methodology, weather conditions, traffic volume, and road alignments.

3) The reduction in accidents due to winter road maintenance operations is recognized by researchers and maintenance workers. Studies in the UK have found that the rate of injuries and fatality increased by 100% during snow days. Conversely, other studies found that crashes during winter storms had less serious injuries (less fatal crashes) when compared to clear conditions. Lesser number of fatal crashes during a snow event is due to reduced driving speed. Kuemmel and Hanbali (1992) determined that the occurrences of fatal accidents are nine times higher before salt application and accident severity is reduced by 30% one hour after salt application.

Pre-wetted deicer and salt utilized by the Onondaga County DOT were evaluated and compared to study the impact on the number of accidents and the number of injuries. The data was evaluated using Pareto charts. The dependent variables were materials and snowfall in inches; the response variables were number of accidents and number of injuries. The conclusion drawn from the data analyses is that the material used (prewetted deicer versus salt) had more significant effect on the number of injuries than the amount of snowfall.

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ANALYSIS OF THE VILLAGE OF FAYETTEVILLE DATA FOR NATURAL BRINE AND "COMBINATION OF SALT/PRE-WET/DEICING" APPLICATIONS

3.0 Introduction

Natural brine application data for the roads of the Village of Fayetteville in New York for the 2008-2009 and 2009-2010 winter seasons were obtained. Data for the 2010-2011winter season included a combination of rock salt, pre-wetting and deicing The detailed roadway and mile information for brine application was unavailable. However, the Village of Fayetteville Department of Public Works[1] (DPW) indicated that brine was applied on all 26 center lane miles within the Village. The map of the Village of Fayetteville is presented in Figure 3.1

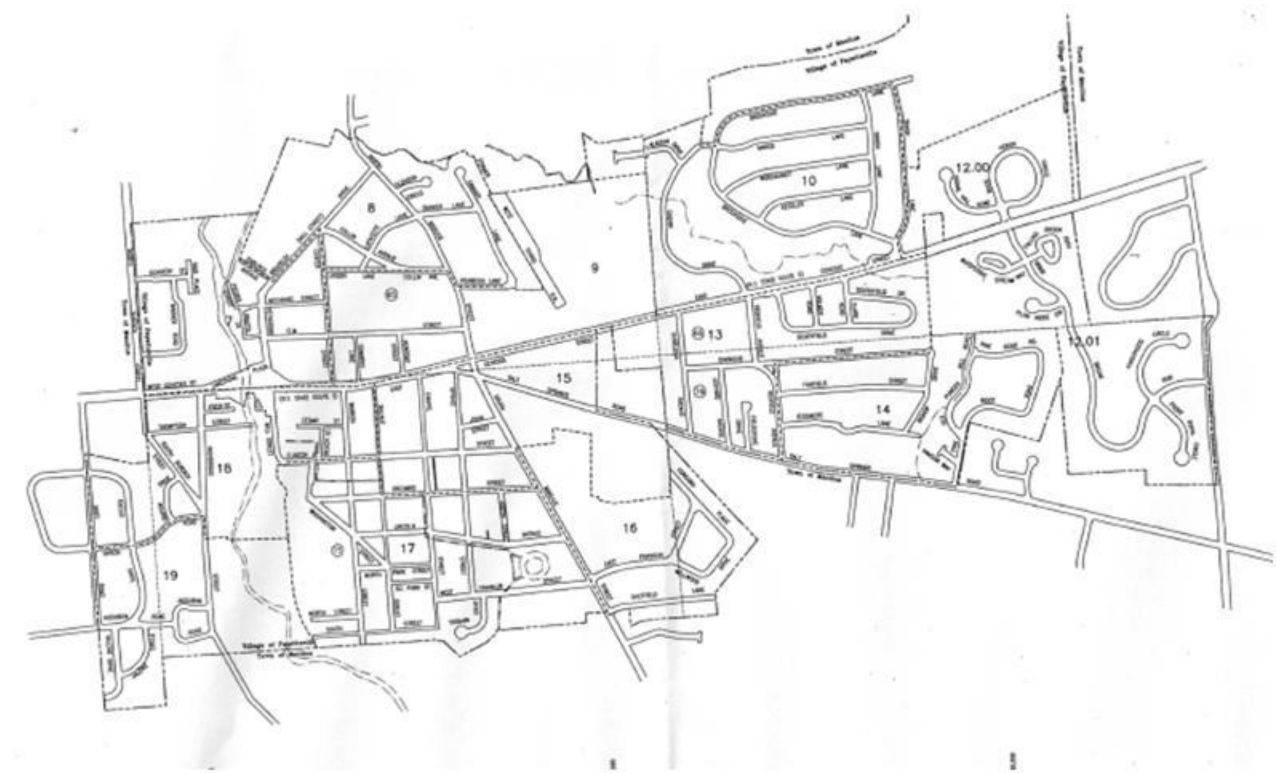


Figure 3.1: Map of the Village of Fayetteville

Accident data was obtained from the Bureau of Safety and Security Planning and Development of the New York State Office of Modal Safety and Security (OMSS). This office posts accident data for a region 8-10 months after the occurrence of the accident. With the available data, the objectives of the analysis were to:

[1] James Craw DPW Superintendent, Village of Fayetteville, New York

1. Quantify the brine application for the Village of Fayetteville;
2. Get a better understanding on whether the application rate correlated with snowfall; and
3. Determine if the brine application is related to the accident data.

3.1 Brine Application

Table 3.1 shows the descriptive statistics of brine application. Each case in Table 3.1 represents how the brine application rate was calculated.

Table 3.1: Descriptive Statistics of Brine Application

Case	Average brine application	Standard deviation of brine application	units	Remark
1	44.5	64.4	gals/mile	Average of gallons per mile for every roadway
2	32.5	-	Average gals/ average miles	Average number of gals divided by average number of miles
3	31.0	26.3	Average gals/26 center miles	Average number of gals divided by 26 center lane miles

The Village of Fayetteville, DPW, also indicated that approximately 30 gallons of brine/mile of roadway is applied on an average during the winter season. This number was consistent with the average calculated under Case 2 and Case 3 shown in Table 3.1.

However, a major concern was the large variation in application rates as indicated by the standard deviation of the brine application. A large discrepancy of the average brine application rate between Case 1 and the other two cases was supported by the fact that some brine application data points were unusually high (>100 gal/mile). These high values of application rates could be due to error in data collection, such as misreading the odometer in inclement weather or an actually high field application of brine. In either case, the research team decided to determine if brine application had any correlation with snowfall. The results are presented in the following sections.

3.2 Correlation between Brine Application and Snowfall

The snowfall and precipitation for the dates when brine application data was available were obtained from the Weather Underground website[2]. This brine application data was plotted against the precipitation data and is presented in Figures 3.2 and 3.3.

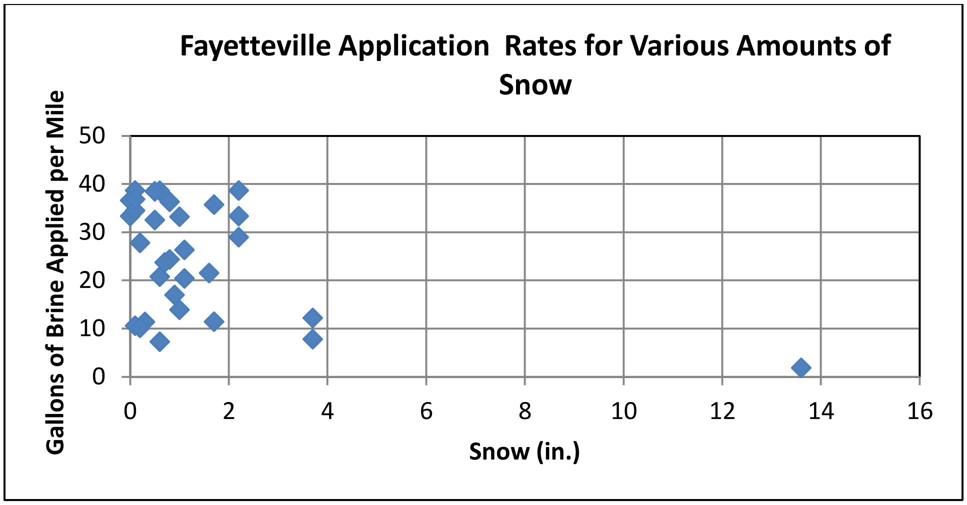


Figure 3.2: Brine Applied from 12/19/2008 to 2/25/2010 by the Village of Fayetteville DPW, Based on Snowfall

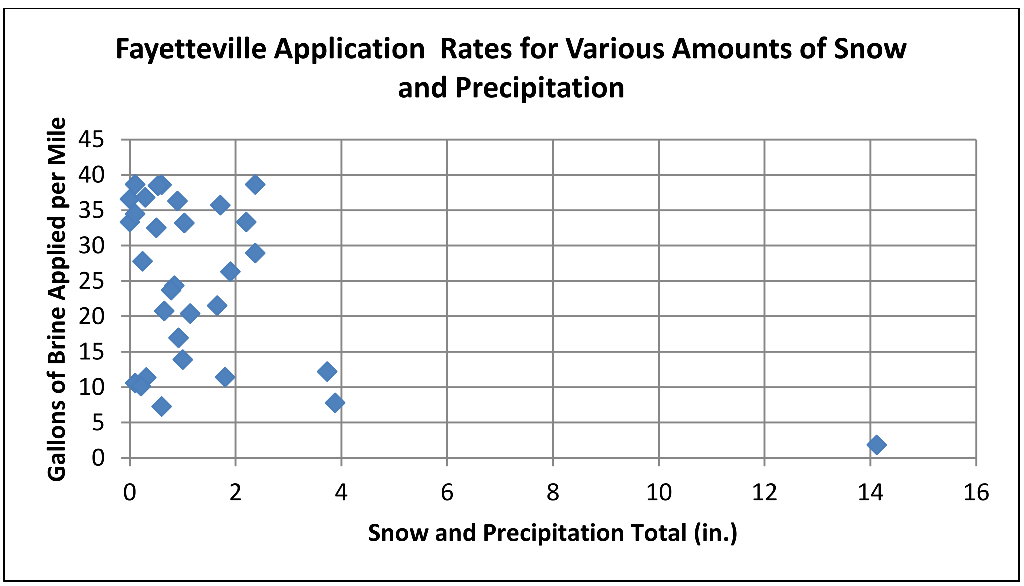


Figure 3.3: Brine Application from 12/19/2008 to 2/25/2010 by the Village of Fayetteville DPW, Based on Total Precipitation Including Snow

[2] www.wunderground.com/history/airport/KSYR/2010/2/25/dailyhistory.html

The figures indicate that in the majority of instances when brine was applied, there were two inches or less of precipitation and the application rates were less than 40 gallons per mile. However, there were 13 out of 44 data points that exceeded 40 gallons per mile. There appeared to be no correlation between snowfall and application rate. The above analysis reinforced the possibility that some of the high brine application rates may be due to error in data collection.

3.3 Accident Data (December 19 2008-December 31 2009)

Accident data up to December 2009 was used in these analyses. Only the accidents that occurred under non-dry road surface condition with some form of precipitation were included. This was the only way to exclude accidents that could have potentially occurred due to conditions other than inclement weather or slippery surface. The accident database does not mention the cause of the accident. If there is a fatality during an accident, the cause can be determined from the USDOT maintained Fatal Accidents Recording System (FARS) database. There were 13 accidents during the winter months spanning from December18, 2008 to December 31, 2009. Out of these thirteen accidents, there were seven accidents that were within a day of the brine application date. The characteristics of the seven accidents are mentioned below:

1) All seven accidents involved two cars.
2) Two accidents had “possible” injuries.
3) All seven accidents were on straight stretches of roads.
4) Three of these seven accidents were on some form of an intersection.

3.3.1 Summary of Findings

1) Brine application data in the Village of Fayetteville was highly variable. This may be primarily due to errors in data collection.
2) It is premature to make any definitive conclusions based on this accident analysis. However, the relatively low number of accidents over the two-year time frame of brine application indicates that this could be a promising alternative to other pre-wetting agents.

3.4 Accident Data from January 1, 2010-February 28, 2010

Accident data for the 2010-2011 winter season was obtained from the USDOT FARS database and analyzed. Once again, only those accidents that had non-dry surface road conditions were selected. If the condition of the road was designated as "unknown" it was included in the analysis. In this time frame, there were twenty-one accidents, with no fatalities and no injuries. No injuries and no fatalities could imply that the speeds may have been relatively low, but there is no independent data to confirm this implication. Fourteen of the 21 accidents were within a day of the brine application. The characteristics of the fourteen accidents (Table 3.2.) were as follows:

Table 3.2: Accident Characteristics

Collision Type		Road Characteristics		Traffic control	
Rear End	2	Straight and level	12	No Traffic control	9
Side swipe	1			Traffic signal	3
Left (turn) another car	1				
Right angle	1				
Other	8				
Unknown	1	Unknown	2	Unknown	2

There were almost 14 inches of total precipitation on February 25, 2010. There was one accident on February 25, 2010 and three accidents on February 26, 2010.

3.4.1 Summary

During the 2010-2011 winter season, there were a total of 21 accidents within a day of application of brine. It appears that during heavy precipitation the number of accidents increased (four accidents within a day of 14 inch precipitation). There were two possible injuries among those 21 accidents.

3.5 Application of a "Combination of Salt/Pre-wet/Deicing" for Winter Season 2010-2011

During the 2010-2011 winter season (December 1, 2010 to February 9, 2011) a combination of applications (Salt/Pre-wet/Deicing) were applied. The summary of operator log is shown in the

Appendix. The details of the applications are provided for certain dates, however the specific route names are not provided. Hence, the accident data on a given route could not be correlated with the specific application.

3.5.1 Total Precipitation

The total precipitation, which is a combination of rain and snow data, is summarized below (Table 3.3). Based on the number of precipitation days greater than 1 inch, the winter of 2010-2011 was almost 4 times severe than the previous two winters. The threshold precipitation of 1 inch was arbitrarily selected. If the threshold was 2 inches, the winter of 2010-2011 would be approximately 3 times severe as that of the previous winters. The calculations are not presented, but the concept is the same.

Table 3.3: Total Precipitation Data

	Total precipitation, inches	
Application	**Brine**	**Combination of Salt/Pre-wet/Deicing**
Date	December 19th 2008 to February 26th 2010	December 1st 2010 to Feb 09th 2011
Months included	From Dec 19th 2008, Jan 2009, Feb 2009, Dec 2009, Jan 2010, Feb 2010	Dec 2010, Jan 2011, up to Feb 09th 2011
Minimum	0	0
Average	2.30	1.39
Maximum	14.12	9.36
Number of days with total precipitation greater than 1 inch (Row 1)	20 days	36 days
Total number of days evaluated (Row 2)	161 days	72 days
Ratio [(Row 1)/(Row 2)]	0.124	0.500
A measure of severity of Winter 2010-2011 (0.500 divided by 0.124)		4.05

The accident data was analyzed from December 1, 2010 to February 17, 2011. There were twenty-eight accidents during the above mentioned time frame which had a surface condition of non-dry or “unknown”. None of them had fatalities. Twenty-two accidents were within a day of application of the “Combination of Salt/Pre-Wet/Deicing”. Among the twenty-two, two accidents incurred injuries. The extent of injuries was not provided. The characteristics of the accidents are explained in Table 3.4. The total precipitation of 9.36 inches was on December 6, 2010. Two accidents occurred on December 7 and two on December 8, 2010. A similar spike in accidents was not observed when there was around 6 inches of precipitation.

Table 3.4: Accident Characteristics

Collision Type		Road characteristics		Traffic control	
Collision with curbing	1	Straight and level	14	No Traffic control	14
Collision with other	2	Straight and grade	6	Traffic signal	5
Collision with motor vehicle	17	Curve and grade	1	Stop sign	1
Collision with deer	2			Yield	1
Unknown	0	Unknown	1	Unknown	1

3.5.2 Summary

As mentioned above, the winter of 2010 -2011 was more severe than the previous two winters. It could be quantified as 3 or 4 times more severe depending on the threshold precipitation selected. At the same time, it also appears that the number of accidents in 2010-2011 (22 accidents) within a day of application was similar to that of the previous two winter seasons combined (2008-2010 seasons were 21 accidents).

3.6 Conclusions

Based on the application and precipitation data available and the overall comparison of accident data, we cannot definitively conclude which application may lead to more accidents. However, it appears that the frequency of accidents go up immediately after a heavy precipitation with either application. This trend was observed in the 2008-2010, when there was 14.12 inches of precipitation, and in the 2010-2011 season when there was 9.36 inches of precipitation. Therefore, it appears that both applications may not be as effective when there is heavy precipitation.

ANALYSIS OF NYSDOT (EAST ONONDAGA RESIDENCY OFFICE) I-81/I-481 DATA WITH AND WITHOUT BRINE

4.1 Brine Application Data Analysis for I-81 and I-481

Natural brine was applied on a stretch of NYSDOT I-81 and I-481 from November 26, 2010 to January 20, 2011 during the 2010-2011 winter season by the NYSDOT East Onondaga Residency Office. Data for brine applications, odometer readings and roadway miles were obtained from this office. This data is summarized in Table 4.1 below.

Table 4.1: Summary of Natural brine application on I-81 by the NYSDOT Onondaga East Residency Office

Date	Route	Time Start	Time End	Odometer	Liquid Gallons Applied	DJ* Miles	Comment
11/26/2010	I81 &I 481	7:30	20:00	203	1400	25	Bridge decks
12/2/2010	I81	12:00	16:30	111	4720	109	
12/11/2010	I81	15:15	19:00	99	1609	48	I81 in City
12/13/2010	I81 &I 481	1:40	4:50	104	750	11	left lane only
12/21/2010	I81	1:00	2:00	36	598	32	left lane only in city
12/22/2010	I81			122	1824	55	Bridge parapet walls only
12/28/2010	I81	12:00	18:00	115	2524	104	left and center lanes all I81
1/3/2011	I81	15:00	18:00	70	1711	43.7	
1/3/2011	I81	15:00	20:00	88	2282		I81 NB and SB
1/5/2011	I81	12:30	16:30	65	2093	21	
1/7/2011	I81	12:30	5:00	120	3410	99.2	City and northend of county
1/19/2011	I81	17:30	23:30	75	2122	21.9	Bridge parapet walls only
1/20/2011	I81	15:20	17:00	45.9	1561	35.6	left lane only
1/20/2011	I81			15	201	2	Bridge parapet walls right side only

*Dickey John

Inconsistencies were observed between odometer readings, liquid gallons applied and the reported DJ miles. The data analysis was thus based on aggregate numbers to avoid the above mentioned inconsistencies. The summary of the application rate is indicated in Table 4.2. The table does not include data which involved applying brine to the parapet walls. As expected, the brine application rate (based on spread miles) on parapet walls was very high, as more brine was used per mile. It appears that on an average the calculated application rate based on odometer data was almost 45% lower than the calculated application rate based on spread miles.

Table 4.2: Summary of Application Rate

	Application Rate (gal/mile)	
	Based on odometer data	**Based on spread miles (DJ miles)**
Minimum	7.1	24.4
Average	22.9	41.7
Maximum	42.5	68.2
Median	25.2	41.2

4.1.1 Precipitation Data 2010-2011

The total precipitation data was obtained from the NOAA website. The precipitation within a day of the application was included in the analysis. Figure 4.1 shows the total precipitation versus the application rate based on spread miles. Overall, there was an increase in the application rate with precipitation rates. However, no clear trend was observed.

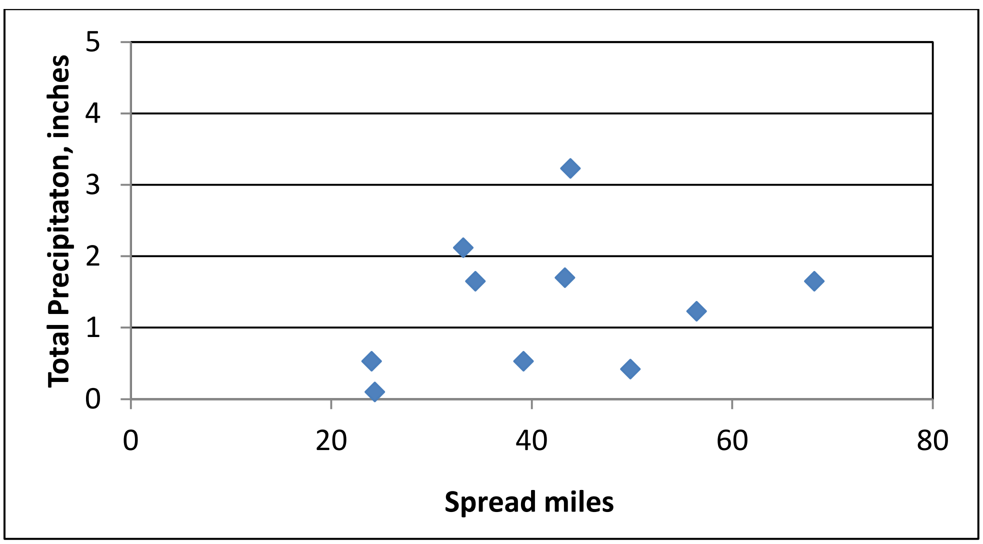


Figure 4.1: Total Precipitation versus Spread Miles

4.1.2. Accident Rate

4.1.2.1 Winter Season 2010-2011

The accident data for the 2010-2011 winter season was analyzed for the village of North Syracuse. Only accidents that occurred on the interstate were selected, since all applications were in I-81/I-481. During the specific dates indicated in Table 4.1 (including a day before and after), there were no accidents on the thruways with a non-dry surface road in the village of North Syracuse.

4.2 Comparison with 2009-2010 Winter Season

In order to evaluate the effectiveness of brine applications, it was assumed that only rock salt was applied to the same roadways during the 2009-2010 winter season.

4.2.1 Winter Season 2009-2010

The accident data was analyzed during a similar time frame, but for a year earlier. The same criteria for selection of accident data were used. The criteria included that the accident occur in the village of N. Syracuse on an interstate or thruway with a non-dry surface. There were five accidents with no injuries and fatalities meeting the above criteria. The accident characteristics are shown in Table 4.3. One of the accidents was an explosion. The cause of the explosion was not provided.

Table 4.3: Accident Characteristics

Collision Type		Road Characteristics	
Collision with another motor vehicle	3	Straight and level	3
Explosion	1	Curve and level	1
Collision with snow embankment	1	Curve and grade	1

4.2.2 Precipitation 2009-2010

The individual analysis of the precipitation was not conducted, because specific application data was unknown for the 2009 -2010 winter season. However, it is known from the analysis conducted for the Village of Fayetteville data, that the overall winter of 2010-2011 was more severe than the 2009-2010 winter season.

4.3 Conclusions

The number of accidents in the 2010-2011 winter season when brine was applied, was less than when rock salt was applied (2009-2010 seasons) even though the precipitation was greater in the former case. It appears that brine is more effective in reducing the number of accidents at least on the roadways with similar characteristics as I-81 and I-481.

SUMMARY OF RESPONSES TO QUESTIONS AFTER MEETING WITH OPERATORS AND DRIVERS FROM VILLAGE OF FAYETTEVILLE AND NYSDOT ONONDAGA EAST RESIDENCY OFFICE

5.0 Introduction

The advantages and disadvantages of natural brine operations in the Syracuse area during the winter months were documented after meeting with the equipment operators and drivers of the winter road maintenance operations. Interviews were conducted with the crew of the Village of Fayetteville and the NYSDOT (Onondaga East Residency) office on March 14, 2011. NYSDOT meetings were conducted with the morning and noon shift crews. The following questionnaire was prepared with consent of the Technical Working Group for this project and was used to obtain information.

Potential for Natural brine for Anti-Icing and De-Icing RFP Number C-06-07

Questions for Meeting with Operators and Drivers

1. What are the positives/negatives that you observe during liquid brine application?

    Ease of application using the provided equipment

    Better road conditions such as "Less/More Bonding of Snow/Ice to Pavement Surface"

    Less equipment problems

    Easy/Difficult equipment maintenance

    Less/More time for application

    Less/More weather impacts such as drifting snow etc.

    More/Lesser use of other chemicals or rock salt or sand

    More/Less Prone to Re-Freeze

    More/Less Man power

2. Personal thoughts on this type of application that you would like to share

3. Any issues that come up and are not documented in the forms.

5.1 Village of Fayetteville Responses

The Village of Fayetteville winter maintenance crew had very positive feedback in response to the questionnaire. The crew indicated that they had sophisticated equipment that allowed for ease of natural brine application. It was pointed out that natural brine from the NYSDOT well allowed faster mixing with rock salt addition to achieve the required salt percentage of 23% by weight. An average of 30 miles per gallon was achieved for the 26 miles of roadways winterized for the village.

The crew indicated the following advantages in using natural brine for deicing:

a) Savings on use of rock salt

b) Less rock salt leads to better environmental protection and less environmental impact

c) Less time (almost 50%) needed to prepare the brine solution when using well water with natural brine

d) Easier to apply

e) Less man power needed for applying brine

f) More lane miles covered with brine

g) Spraying before a storm event provided better road conditions

h) Faster application possible with sprayer equipment

i) Sprayer equipment less susceptible to clogging and as such needed less cleaning time

j) Refreezing was not a concern

k) Temperature was noted as a major factor for application decisions

The staff did not indicate any disadvantages or negatives associated with the application of natural brine.

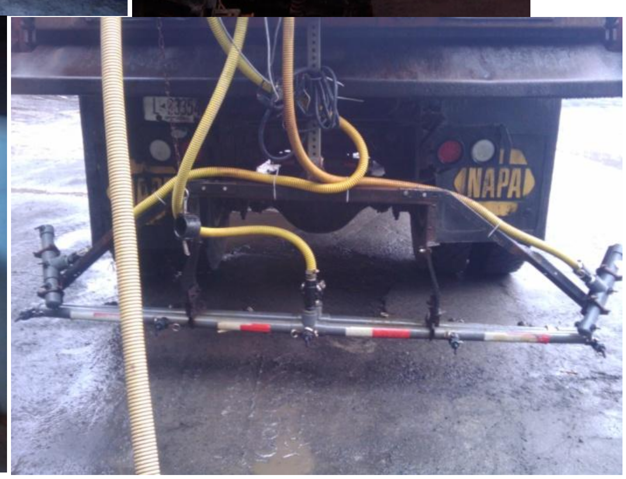
The staff indicated that with proper equipment and technology, brine applications should be integrated by all DOTs as a winter anti-icing tool. No other concerns were voiced by the crew. The crew indicated that their operations ran smoothly and they had access to quality equipment.

It was pointed out that the onsite facilities for brine preparation allowed for greater ease of operations.

5.2 Equipment at the Village of Fayetteville





5.3 NYSDOT Office Responses

The responses from the NYSDOT Onondaga East Residency office were less positive in comparison to the Village of Fayetteville crew.

The following concerns were voiced by the morning and noon shift crews:

a) Inadequate equipment (spray trucks) for brine application operations (the crew indicated that slide in trucks did not work well)

b) Need for state of the art technology for both brine application and weather forecasting

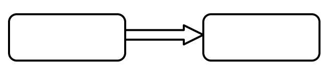
c) Pumps on the trucks get corroded with salt and are subject to clogging. As such, time is needed for cleaning and de-clogging operations

d) Need better temperature guidelines for brine applications

e) Refreezing problems after brine application if not enough traffic on roadways

f) Major time (about 3 hours) is lost by hauling natural brine to the Village of Fayetteville brine site for rock salt addition and returning with the 23% brine for roadway application

g) Current configuration of the brine tank (two tanks in series) requires about 1.5 hours for filling. The configuration of the tanks is such that the first tank fills up and drains into the second tank. Once the second tank is full, the first tank then fills up.



h) The well site is unsafe and should be better maintained. There is a leak in the hose for collecting natural brine and better maintenance of the three phase circuit breakers needs to be in place.

i) Brine applications do not work during heavy snowfall events and need to be applied before storms.

j) Better guidance on route identification and time of application for anti-icing are necessary to provide safer and cleaner roads.

The crew shared the following information in regards to their experiences in brine application:

a) Liquid brine works better with 5% $MgCl_2$ for the interstate roadways

b) Pre-wetting rock salt with liquid brine works better during heavy traffic in the Syracuse Interstate roadways

Personnel from both agencies indicated that anti-icing and pre-wetting were definitely better options for winter road maintenance.

5.4 Equipment at the NYSDOT Onondaga East Residency Office

COST ANALYSIS FOR NATURAL BRINE APPLICATION FOR ANTI-ICING IN THE SYRACUSE AREA

6.0 Introduction

Many studies in the U.S. and developed countries with heavy snowfall have already indicated that brine applications for anti-icing and pre-wetting are the preferred method for winter road maintenance. Section 1.5 from Section 1 of this report provided a thorough literature review on the cost savings associated with liquid brine applications in comparison to traditional sand and rock salt applications. The studies indicated that there is significant cost savings in materials and labor, along with safer roads, more roadway lane miles treated, and less environmental damage.

This section investigates the costs associated with the use of natural brine in the Syracuse area for anti-icing. The high salt concentrations present in the Onondaga trough in the Syracuse area have been discussed in Section 1.3.

The NYSDOT is investigating the use of natural brine from a groundwater well located on one of their salt barn sites on Van Rensselaer Street (next to I-690) in Syracuse, New York. Natural brine is pumped from a six-inch diameter, 170 feet deep well via a Grundfos submersible pump to a brine truck. Once the truck is full, the brine is hauled to the Village of Fayetteville's brine maker (Accubrine™) for processing. The existing brine concentration from the well water is approximately 15% by weight. This natural brine is then processed at the Fayetteville facility and boosted to the 23% by weight concentration necessary for anti-icing.

6.1 Cost Analysis

A cost analysis was performed to assess the cost-effectiveness of using natural brine in comparison to use of brine prepared from commercial salt in the Syracuse area. Data used for this analysis was provided by the Village of Fayetteville and the NYSDOT staff. Costs were divided into the following categories:

- Labor
- Transportation
- Materials
- Electricity
- Operations and Maintenance

Table 6.1 provides the data used in the cost analyses. Appendix C contains information relevant to the data used. This data was provided by the NYSDOT.

Table 6.1: Cost Data Used for Cost Analyses

Item	Unit Price	Comment
Materials		
Salt	$42.41/ton	Data supplied by NYSDOT (presented in Appendix B)
OCMA Water	$3.50/1,000 gallon	Website (presented in Appendix B)
Total Volume of Brine Used in 2010-2011 in Onondaga County	22,000 Gallons	Supplied by Village of Fayetteville
Labor		
Salary for Truck Operator		Supplied by State Salary ranges for HWM1 and HWM2 (presented in Appendix B)
Transportation		
Distance	30 miles each way from well to Fayetteville Brine facility	Data supplied by NYSDOT brine truck operators during interview conducted on March 24, 2011
Time for travel (Roundtrip)	3.0 hours	
Diesel	$4.00/gallon	
Brine Truck mpg	5 miles/gallon	
Brine Truck volume	4,000 Gallons	
Operation of Well Facility		
Energy Use at well site	$515.55/year	Obtained from National Grid records for electricity use at well site (presented in Appendix B)
Time for Brine Pumping into truck	1.5 hours	Data supplied by NYSDOT brine truck operators during interview conducted on March 24, 2011

The above data was used to calculate costs associated with:

a) Salt addition at Fayetteville to make 23% brine using the 15% natural brine;
b) Pumping of natural brine at well facility; and
c) Hauling of natural brine to the Village of Fayetteville brine making facility and bringing back the prepared brine to the NYSDOT facility.

Capital and operation and maintenance costs for the well facility and the brine truck were not taken into account for the cost analyses. Costs of labor and utilities incurred at the Village of

Fayetteville were not taken into account as this cost would be common for both natural brine and commercial brine mixing.

6.2 Cost Analyses for Natural Brine Use

Material Costs:

Rock salt has to be added to the 15% natural brine obtained from the Van Rensselaer facility in the 4,000 gallon brine truck to make up the brine concentration to 23%.

Calculation for rock salt to be added in pounds per 1,000 gallon is presented below:

$$\frac{(23-15)\ gram}{100\ mL} * \frac{lb}{454\ gram} * \frac{1000\ mL}{L} * \frac{3.78\ L}{gallon} * 1{,}000 = 666 \text{ lbs/1,000 gallons}$$

Cost of rock salt added:

$$\frac{\$42.41}{ton} * \frac{ton}{2{,}000\ lbs} * \frac{666 lbs}{1{,}000\ gallon} = \$\mathbf{14.12/1{,}000\ Gallon}$$

Utility Costs:

$515.55/year for producing 22,000 gallons of brine.

Therefore, $515.55/22 = **$23.43/1,000 gallons**

Transportation Costs:

Costs for hauling 4,000 gallons of natural brine from well to Fayetteville and back:

Diesel Costs:

$$\frac{\$4.00}{gallon\ diesel} * \frac{30\ miles\ (roundtrip)}{5\ miles/gallon} = \$24.00$$

Therefore, diesel cost per 1,000 gallon= $24/4 = **$6/1,000 gallon**

Brine Truck Driver Labor Costs:

Gross Salary $32,000 for 40 hours/week for = $16/hour

Duration of collecting brine at site + driving time (roundtrip NYSDOT to Fayetteville) = 3 hours

Cost $16*3 = $48 for transporting 4,000 gallons or **$12/1,000 gallon**

Item	Cost ($/1,000 gallon)
Material	14.00
Utility	23.00
Diesel	6.00
Labor	12.00
Total	**$55.00**

6.3 Cost Analyses for Commercial Brine Use

Costs were calculated for preparing 23% brine on site at Fayetteville.

$$\frac{(23)\text{ gram}}{100\text{ mL}} * \frac{\text{lb}}{454\text{ gram}} * \frac{1000\text{ mL}}{\text{L}} * \frac{3.78\text{ L}}{\text{gallon}} * 1{,}000 = 1{,}915\text{ lbs/1,000 gallon}$$

Cost of rock salt added:

$$\frac{\$42.41}{ton} * \frac{ton}{2{,}000\ lbs} * \frac{1{,}915 lbs}{1{,}000\ gallon} = \$\mathbf{40.6/1,000}\ \boldsymbol{Gallon}$$

Cost of OCWA water for making brine = **$3.50/1,000 gallon**

Total material cost = $43.50/1,000 gallon

The following is evident from the above analysis:

a) The costs for using commercial brine versus pumping natural brine from groundwater are comparable.

b) Only 600 lbs of salt/1,000 gallons of water needs to be added to the natural 15% brine to obtain the desired 23%, whereas 1,915 lbs of salt/1,000 gallons is needed to make the 23% commercial brine. As such, the cost of purchasing 1,400 lbs of salt/1,000 gallons is saved when natural brine is used.

c) The major expense occurs from filling the natural brine truck at the well facility. The cost is primarily from the use of electricity for pumping the natural brine. Utility costs can be reduced by using a solar or a more efficient pump.

d) It was pointed out during the NYSDOT operator interview that the time to fill the natural brine truck was a lengthy process due to the design of the tanks in the truck. Costs can also be reduced by decreasing fill time for the truck. Investing in a brine maker on site at the well facility can also enhance brine applications and provide ease of operations for the NYSDOT East Onondaga Residency Office.

ANTI-ICING OPERATORS GUIDE

7.1 Definition of Anti-icing

Anti-icing is the application of liquid chemicals to prevent the formation of frost or the bonding of snow or ice to pavement. Applications are typically made either as a pre-treatment in advance of a snow storm or as an early storm period treatment.

7.2 Why Anti-ice

- Anti-icing requires ten times less energy than deicing after a storm.
- Ant-icing can last for several days
- Anti-icing reduces material and labor costs
- Anti-icing leads to better pavement conditions and reduces number of accidents
- Applications can be made during regular working hours
- More roadway miles can be treated with anti-icing
- Anti-icing is an environmentally friendly process as it uses less salt and eliminates the use of sand that can contaminate water ways

7.3 When to Anti-Ice

- Anti-icing should be conducted 12 to 18 hours prior to forecasts for frost, freezing precipitation or black ice events.
- Anti-icing may also be conducted prior to light sleet (less than 5 inches/hour) or moderate (0.5 inches-1.0 inches/hour) snow events.
- Bridge decks, troubled pavement spots, ramps, intersections, curves, and hills should be treated.
- Anti-icing should be conducted when the pavement temperature is at or above 23^{o}F. Anti-icing can also be initiated if forecasts predict the pavement temperature will rise or stay at 23^{o}F.
- Anti-icing should be conducted during normal low traffic volume. A following vehicle for traffic control may be needed during high traffic volumes.

7.4 When Not to Anti-ice

- If rain is predicted anti-icing should be avoided.
- Anti-icing should be avoided during heavy snowfall, gusty winds leading to blowing or drifting snow.
- Anti-icing should be avoided when the bond between the snow and pavement has formed.

7.5 Chemicals for Anti-icing

Chemicals used for anti-icing include solutions made with water and sodium chloride, calcium chloride or magnesium chloride.

7.5.1 Advantages of Using Liquid Chemicals

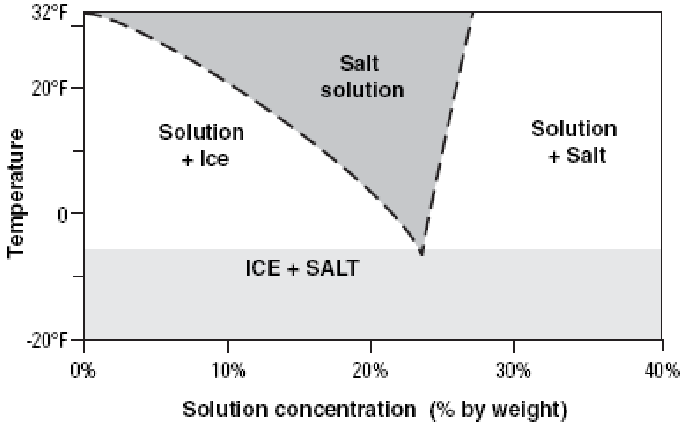
Use of liquid ensures instantaneous melting action. Brine (liquid sodium chloride) can easily be made at local highway stations with costs as low as 5 cents/gallon. Corrosion can also be inhibited by adding select chemicals to the liquid anti-icing agent.

7.5.2 Disadvantages of Using Liquid Chemicals

Liquid chemicals can become diluted and can refreeze more quickly than solid road maintenance materials. Transportation of liquid chemicals can be more expensive. The use of these chemicals is limited to pavement temperatures above 20^{o}F. Special equipment for brine storage, pumping and application is required.

7.5.3 How Anti-icing Chemicals Work

Anti-icing chemicals, like other solid chemicals, work by reducing or depressing the freezing point of the pavement. Phase diagrams can be used to explain how the chemical works. Figure 7.1 depicts a phase diagram of salt.



Area above the curved lines-all liquid is in solution-MELTING ACTION

Below the curve-mixture of ice and salt-REFREEZING ACTION

Below the eutectic point-SOLID ICE

Figure 7.1: Phase Diagram of Salt

The plot shows that as the freezing point decreases, the salt concentration increases to a certain point known as the eutectic point. This point occurs at -6^{o}F and a salt concentration of 23% by weight. The freezing point of the salt solution increases sharply beyond the eutectic point (or higher concentrations). The products that have a lower eutectic point, a flatter phase curve, and a higher concentration have the greatest potential to melt snow and ice. It is important to understand this diagram in order to use liquid chemicals effectively. Table 7.1 provides eutectic temperatures for typical anti-icing agents.

Table 7.1: Eutectic Temperatures for Common Anti-Icing Agents

Chemical	Eutectic Temperature ^{o}C (°F)	Eutectic Concentration % by weight
Calcium Chloride ($CaCl_2$)	-51 (-60)	29.8
Sodium Chloride (NaCl)	-21 (-5.8)	23.3
Magnesium Chloride ($MgCl_2$)	-33 (-28)	21.6
Calcium Magnesium Acetate (CMA)	-27.5 (-17.5)	32.5
Potassium Acetate (KAc)	-60 (-76)	49

7.6 Application

Typical brine application rates are in the range of 25-50 gallons per lane mile (equivalent to 60-120 pounds per lane mile of dry chemical). Table 7.2 provides a comparison of equivalent application rates for select chemicals.

Table 7.2: Equivalent application rates for select chemicals

Temperature	Salt		Calcium Chloride		Magnesium Chloride	
Degrees F	Solid *lb/lane*	Liquid *gal/lane mile*	Solid *lb/lane*	Liquid *gal/lane mile*	Solid *lb/lane*	Liquid *gal/lane mile*
31	100	44	111	32	94	33
25	100	44	102	29	86	30
21	100	44	89	25	74	26

Special equipment is needed for anti-icing applications. The size of the tanks on the application vehicles depends on the size of the roadway system. Streamer nozzles are preferred to fan nozzles. Applications can be conducted at speeds of 25 to 55 miles per hours.

Use of computer controlled equipment such as pavement temperature sensors are encouraged.

Accurate weather prediction is necessary to avoid refreezing, slippery conditions and waste of chemicals.

Evaluation of field performance should be an integral part of anti-icing operations. A TAPER (**T**emperature, **A**pplication, **P**roduct, **E**vent, **R**esults) form is recommended for collection of roadway performance information.

7.7 Safety and Precautions

- Higher application rates need extra caution
- Bridge decks and pavement surfaces can refreeze if the applied chemical is significantly diluted
- Familiarity with the phase diagram of chemicals is useful to determine freezing point depression
- Slippery conditions can occur for magnesium and calcium chloride when temperatures are above 30^{o}F and humidity levels are greater than 40%
- Corrosion inhibitors that reduce material corrosion to 70% less than sodium chloride should be used with magnesium and calcium chloride
- Liquid anti-icing chemicals may enhance build-up of oils and rubber residues on pavement surfaces and bridge decks
- Anti-icing is not recommended during blowing or drifting snow

7.8 References

http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm [Accessed 18 Mar, 2009]

Transportation Research Center Circular E-C063: Snow and Ice Control Technology, Page 48.

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Agricultural By-products for Anti-Icing and Deicing Use in Michigan, December 2002, Michigan Department of Transportation, Research Report R1418.

Field Trials of Pre-wetted Salt and Sand with MgCl2 and CaCl2 Brines: Efficiency and Effects, September 1994, Province of British Columbia, Ministry of Transportation and Highways, Project No. 09455.

Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel, June 1996, Federal Highway Administration. FHWA-RD-95-202.

APPENDIX B

RELEVANT RAW DATA RECEIVED FROM NYSDOT, ONONDAGA COUNTY, AND VILLAGE OF FAYETTEVILLE (PARTS 2.0, 3.0, 4.0)

Date received	File name	Remarks	Notes from Ed Reichert regarding the data
August 2009	Namf.xls	**Used data in Part 1.0 of the report (Included in Appendix)**	1. The data are from 2008. The program consisted of an 1050 gallon brine tank in the back of a 6 wheel dump truck. The object was to be a test of brine use on 14 bridges in the North Area. It was the best negotiation I could make, but I lacked any control over training and orientation over the program and it was run without my input. Drivers were not instructed on what to do when the pump stopped working, the crews neglected to top off the tank after use; those involved lost interest, and the program was allowed to cease. So there was no route, just hopping around to different sites to squirt onto various bridges when they got to the right locations. There was no feedback as to how well the brine worked. I sent you this spreadsheet for the salt application data, so you'd have an idea from one year to the next about the salt application program. My hope in sending

Date received	File name	Remarks	Notes from Ed Reichert regarding the data
			it was that we WOULD get a brine pre-wetting program running, and you might see a change in salt use because of pre-wetting. 2. There will be discrepancies in route mileage because the reported mileage comes from the dickey-john devices. Sometimes snow does not cover the entire route, or the crews are plowing wind spots. In these cases, they may drive along clear, dry roads and only drop the blade and turn on the dickey-john as needed, usually just before and just after driving over the snow spot.
Jan 2010	Onondaga 2009-2010.mdb	**Used data in Part 1.0, 2.0 and 3.0** Accident data up to December 2009 (file too big to attach).	
Feb 2010	Jamesville 2009-2010.xls Jamesville Plow routes.xls	**Did not use /not included in Appendix** **Did not use /not included in Appendix**	Each spreadsheet contains data for only one truck. Each is a plow truck. The information sent earlier is for salt trucks. If Clearlane™ was used, it should be readily indicated on the spreadsheet. Tate information was the best up to date information I could obtain

Date received	File name	Remarks	Notes from Ed Reichert regarding the data
	North Area Plow routes.xls Section 4 Marcellus Plow RTS2009-2010.doc	**Used data in Part 1.0 of the report (Included in Appendix)** **Did not use /not included in Appendix**	about our program, salting or brining. We have also noted the inconsistencies. We have yet to account for them. They may be human errors, being the case where someone thinks he can remember the numbers as he makes his way indoors from his truck cab, visits the restroom, grabs a hot drink, and writes his report. The data sent yesterday is taken directly from the website that services our GPS Vehicle System. "Liquid" does refer to brine. I was hoping your students could match the truck number to the routes plowed using the information sent earlier. Please let me know if this is not adequate. Otherwise, the data must be averaged over the entire route.

March 2010	Worksheet196-Jamesville.xls Worksheet197-north area		I can make no excuses for my crews. The files below represent the best information available. These 2 files show the only participation I can present to this study:
		Did not use /not included in Appendix **Used data in Part 1.0 of the report (Included in Appendix)**	Data was gathered by a GPS system. Information was gathered from December 1, 2009 to the last snowfall before March 21, 2010.
October 2010	Fayetteville_October_2010.xlsx	**Used data in Part 2.0 of the report (Included in Appendix)** No specific route information was provided.	

Date received	File name	Remarks	Notes from Ed Reichert regarding the data
		Brine applied on all 26 center miles. Accident data could only be analyzed for the entire village. It could not be correlated for a specific roadway.	
Feb 2011	Fayetteville_Feb22.xlsx	**Used data in Part 2.0 of the report (Included in Appendix)** No specific route/roadway information provided. Data is currently being analyzed.	
Mar 2011		**Used data in Part 3.0 of the report (Included in Appendix)** I-81/I-481	
November 2011	Onondaga2010-2011.mdb	**Used data in Part 1.0, 2.0 and 3.0 of the report (Included in Appendix)** Accident data up from January 201 to February 2011 (file too big to attach).	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
10/28/08	136	var	1	350	3,181.00	3,243.50	649.76	661.38	Clearlane
10/28/08	147	var	1	300					
11/17/08	63	1	1	350	0.00	24.90	0.00	4.43	
11/17/08	147	2	1	350					
11/17/08	177	3	1	350					
11/17/08	144	4	1	350					
11/17/08	187	5	1	350	0.00	29.30	0.00	5.07	
11/17/08	130	6	1	350					
11/17/08	191	7	1	350	0.00	29.60	0.00	5.14	
11/17/08	117	8	1	350	0.00	21.90	0.00	3.89	
11/17/08	136	9	1	350	0.00	19.70	0.00	3.97	
11/17/08	139	10	1	350	0.00	19.70	0.00	3.18	
11/17/08	54	11	1	350	0.00	18.80	0.00	3.54	
11/17/08	57	12	1	350	0.00	14.30	0.00	3.17	
11/17/08	144	13	1	350					
11/17/08	144	night	1	350					
11/18/08	63	1	1	350-500	24.90	60.80	4.43	11.23	
11/18/08	147	2	2	350-500					
11/18/08	177	3	2	350					
11/18/08	181	4	2	350-400	0.00	41.10	0.00	8.50	
11/18/08	187	5	2	350-450	29.30	38.70	5.07	7.61	
11/18/08	130	6 7	2	350	0.00	50.70	0.00	6.50	
11/18/08	191	7	1	350-450	29.60	83.80	5.14	16.88	
11/18/08	117	8	1	350-400	21.90	43.20	3.89	8.36	
11/18/08	136	9 10	1	350	19.70	80.90	3.97	14.56	
11/18/08	139	10	2	350-400	19.70	98.70	3.18	18.14	
11/18/08	54	11	1	350	18.80	39.60	3.54	7.50	
11/18/08	57	12	1	350-400	20.40	43.40	5.25	10.25	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
11/18/08	144	13	1	350					
11/18/08	136	night	1	350-400	80.90	129.50	14.56	23.65	
11/19/08	136	9	1	450	129.50	171.40	23.65	31.25	
11/19/08	117	8	1		43.20	70.20	8.36	14.35	
11/19/08	144	13	1	manual					
11/19/08	181	4	1	350	0.00	31.10	0.00	4.80	
11/19/08	130	6	1	350	0.00	24.40	0.00	5.30	
11/20/08	63	night	1		87.60	103.70	16.01	18.40	
11/20/08	63	1	1	350	60.80	87.60	11.23	16.00	
11/20/08	147	2	1	manual					
11/20/08	177	3	1	350					
11/20/08	181	4	1	350	0.00	22.00	0.00	4.10	
11/20/08	184	5	1	400	0.00	30.30	0.00	6.40	
11/20/08	130	6	1	350	0.00	24.80	0.00	4.40	
11/20/08	191	7	1		83.80	113.50	16.88	22.13	
11/20/08	117	8	1	400	70.20	86.70	14.35	17.74	
11/20/08	136	9	1	350	171.10	203.60	31.25	36.88	
11/20/08	139	10	1	350	98.70	138.30	18.14	26.25	
11/20/08	54	11	1		39.60	61.60	7.51	11.97	
11/20/08	187	12	1		65.00	78.40	13.16	16.21	
11/20/08	144	13	1	manual					
11/21/08	136	night	1		278.40	307.60	52.24	57.25	
11/21/08	117	night	1		143.40	184.90	30.00	37.49	
11/21/08	57	1 12	2	350-400	0.00	73.20	0.00	13.86	
11/21/08	147	2	2	400-500	0.00	84.00	0.00	18.94	
11/21/08	187	3	2	400	78.40	152.00	16.21	31.49	
11/21/08	181	4	2	400	0.00	78.00	0.00	15.80	
11/21/08	184	5	1	400	0.00	37.50	0.00	7.90	
11/21/08	184	5	1	400-500	0.00	38.60	0.00	8.60	
11/21/08	130	6	2	350-400	0.00	65.40	0.00	13.40	
11/21/08	191	7	2	400	113.50	179.90	22.13	35.13	
11/21/08	117	8	2	400	86.70	143.40	17.74	30.00	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
11/21/08	136	9	2	400	203.60	279.40	36.88	52.24	
11/21/08	139	10	2	450	138.30	244.20	26.25	51.73	
11/21/08	54	11	2	400	61.50	130.40	11.97	25.32	
11/21/08	63	12	1	400	103.70	129.10	18.40	23.75	
11/21/08	144	144	2	400	43.90	99.60	4.71	16.39	
11/22/08	136	night	2		381.40	424.40	72.11	80.99	
11/22/08	177	night	2		86.10	168.90	18.40	31.11	
11/22/08	57	1	2	400	73.20	153.00	13.86	29.19	
11/22/08	147	2	2	400-450	84.00	161.10	18.94	35.52	
11/22/08	177	3	2	400	2.00	86.10	2.00	18.40	
11/22/08	181	4	3	400	0.00	85.00	0.00	16.20	
11/22/08	184	5	3	400	0.00	74.50	0.00	15.30	
11/22/08	130	6	2	400-450	0.00	69.80	0.00	13.70	
11/22/08	191	7	2		179.90	288.30	35.13	56.23	
11/22/08	117	8	2	400-500	184.90	247.80	37.49	51.92	
11/22/08	139	10	3	400-450	244.20	336.80	51.73	75.47	
11/22/08	136	9	2	400	304.60	381.40	57.25	72.11	
11/22/08	54	11 6	3	400	130.40	198.10	25.32	37.57	
11/22/08	63	63	2	400	129.10	186.50	23.75	35.27	
11/22/08	144	13	2	350	99.60	155.80	16.39	26.37	
11/23/08	57	1	2	300-400	153.00	195.60	29.19	37.09	
11/23/08	147	2	2	400-450	161.10	222.70	35.52	48.29	
11/23/08	177	3	2	400	168.90	230.20	31.11	43.70	
11/23/08	181	4	2	300-400	0.00	57.20	0.00	10.00	
11/23/08	184	5	2	400	0.00	60.60	0.00	14.90	
11/23/08	130	6	2	400	0.00	49.40	0.00	10.70	
11/23/08	191	7	2	400	288.30	358.90	56.23	70.99	
11/23/08	117	8	2	400	247.80	283.90	51.92	61.56	
11/23/08	130	9	2	400	424.40	477.70	80.94	91.52	
11/23/08	139	10	2	450	336.80	395.90	75.47	88.06	
11/23/08	54	11	2	400	198.10	248.80	37.57	48.07	
11/23/08	63	12	2	400	129.10	162.20	23.75	31.54	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
11/23/08	144	13	2	350-400	155.80	201.30	26.37	35.75	
11/24/08	117	night	1		283.90	331.60	61.56	68.81	
11/24/08	136	night	1		477.70	490.70	91.52	93.69	
11/24/08	54	night	1		252.28	258.60	49.27	50.16	
11/25/08	147	2	1	350	222.70	254.20	48.29	53.32	
11/25/08	181	3	1	350	0.00	19.80	0.00	3.10	
11/25/08	184	5	1	400	0.00	24.10	0.00	4.70	
11/25/08	191	7	1		358.90	371.90	70.99	74.20	
11/25/08	187	10	1	350	152.00	165.60	31.49	33.94	
11/25/08	117	night	1		331.60	385.90	68.81	78.06	
11/25/08	136	night	1		490.40	527.90	93.69	101.11	
11/26/08	139	night	1	350	395.90	402.80	88.06	89.28	
11/26/08	63	night	1		184.20	197.90	35.97	39.34	
11/26/08	136	night	1		548.00	548.80	105.00	105.80	
11/26/08	57	1	1	400	195.60	217.70	37.09	41.52	
11/26/08	147	2	1	400	254.20	263.50	53.32	55.20	
11/26/08	177	3	1	400	230.20	252.00	43.70	47.63	
11/26/08	181	4	1	350-400	0.00	22.20	0.00	3.90	
11/26/08	184	5	1	400	0.00	22.20	0.00	4.50	
11/26/08	191	7	1	400	371.90	401.40	74.20	79.80	
11/26/08	117	8	1		385.90	398.10	78.06	80.50	
11/26/08	136	9	1	400	527.90	548.00	101.11	105.00	
11/26/08	187	10	1	350	165.60	189.50	33.94	37.97	
11/26/08	54	6 11	1	350	258.60	282.40	50.16	54.38	
11/26/08	63	12	1	400	162.20	184.20	31.54	35.97	
11/26/08	144	13	1	400	201.30	216.90	35.75	39.01	
11/30/08	63	12	2	500	199.90	239.60	39.34	48.45	
11/30/08	136	night	1	400	576.30	606.50	109.72	115.49	
11/30/08	139	night	1		402.80	409.90	89.28	91.00	
11/30/08	63	night	1		239.60	250.30	48.45	50.20	
11/30/08	57	1	2	400-500	217.70	271.10	41.52	53.81	
11/30/08	147	2	2	450-500	263.50	318.60	55.20	67.39	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
11/30/08	177	3	2	400-450	252.00	309.70	47.63	60.10	
11/30/08	181	4	2	450-500	0.00	56.00	0.00	9.80	
11/30/08	184	5	2	450	0.00	68.80	0.00	14.80	
11/30/08	130	6	2	400-450	0.00	43.90	0.00	9.80	
11/30/08	191	7	2		401.40	473.40	79.80	95.74	
11/30/08	117	8	2	450	398.10	444.40	80.50	90.55	
11/30/08	136	9	2	400-450	548.80	576.30	105.08	109.72	
11/30/08	186	10	2	300-450	189.50	260.20	37.97	52.47	
11/30/08	54	11	2	450	282.40	340.00	54.38	64.86	
11/30/08	144	13	2	400-450	216.90	263.60	39.01	49.99	
12/02/08	63	1	1	350-400	246.30	264.90	49.59	53.11	
12/02/08	147	2	1	400-450	318.60	350.80	67.39	73.47	
12/02/08	177	3	1	400	309.70	337.50	60.10	65.45	
12/02/08	117	4	1	300-450	444.40	463.50	90.55	94.35	
12/02/08	184	5	1	400	0.00	11.70	0.00	2.30	
12/02/08	130	6	1	400	0.00	18.60	0.00	3.80	
12/02/08	191	7	1	350-450	473.40	504.30	95.74	102.39	
12/02/08	181	8	1	350-400	0.00	16.00	0.00	3.00	
12/02/08	136	9	1	350	606.50	645.00	115.49	122.11	
12/02/08	187	10	1	400	260.20	291.90	52.47	59.32	
12/02/08	54	11	1	300-400	340.00	360.40	64.86	68.60	
12/02/08	57	1	1	450	271.10	286.70	53.81	58.13	
12/02/08	144	12	1	300-350	263.60	288.90	49.99	54.38	
02/06/08	184	night	1		3,541.60	3,590.90	862.90	872.80	
12/06/08	139	night	1		409.90	462.39	91.00	103.39	
12/06/08	136	night	1		645.00	684.90	122.11	129.77	
12/06/08	63	night	1		264.90	298.30	53.11	62.38	
12/07/08	63	1	1	400	264.90	290.20	53.11	57.71	
12/07/08	57	1a	1	400	286.70	311.80	58.13	63.47	
12/07/08	147	2	1		350.80	384.10	73.47	80.47	
12/07/08	177	3	1	400	337.50	375.10	65.45	72.30	
12/07/08	181	4	1	300-400	0.00	10.00	0.00	1.70	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/07/08	184	5	1	400	0.00	8.60	0.00	1.70	
12/07/08	181	4	1	350-400	0.00	28.90	0.00	5.40	
12/07/08	130	5	1	400	0.00	18.90	0.00	4.40	
12/07/08	130	6	1	400	0.00	24.10	0.00	5.30	
12/07/08	191	7	1	400-500	504.30	553.80	102.39	112.60	
12/07/08	117	8	1	450	463.50	488.50	94.35	100.47	
12/07/08	136	9	1	400	684.90	730.40	129.70	137.41	
12/07/08	139	`10	1	450	462.00	498.70	103.39	111.57	
12/07/08	54	11	1	300-450	360.40	381.80	68.60	72.47	
12/07/08	144	12	1	350-400	288.90	313.30	54.38	59.22	
12/07/08	181	night	1	400	348.40	399.20	64.90	75.00	
12/07/08	136	night	1	400	794.40	834.10	148.41	155.88	
12/07/08	63	1	2	400	290.20	347.50	57.71	68.52	
12/07/08	57	1a`	2	400	311.68	336.90	63.47	68.72	
12/07/08	147	2	2	400-450	384.10	433.20	80.47	92.35	
12/07/08	177	3	2	400	375.10	443.00	72.30	86.83	
12/07/08	181	4	1	350	0.00	22.90	0.00	4.60	
12/07/08	187	5	2	400-450	291.90	356.30	59.32	73.60	
12/07/08	130	6	2		0.00	36.90	0.00	9.30	
12/07/08	191	7	2	400-500	553.80	632.80	112.60	128.33	
12/07/08	117	8	2		488.50	540.50	100.47	112.89	
12/07/08	136	9	2	350-400	730.40	794.40	137.41	148.41	
12/07/08	139	10	2	450	498.70	578.00	111.57	133.25	
12/07/08	54	11	2	300-400	381.80	438.10	72.47	82.22	
12/07/08	144	12	2	350-400	313.30	357.50	59.22	67.89	
12/08/08	136	night			0.00	10.50	0.00	2.22	
12/08/08	63	1	1	400	0.00	34.50	0.00	6.33	
12/08/08	57	1	1	400	336.90	359.00	68.72	73.25	
12/08/08	147	2	1	400-500	0.00	45.30	0.00	9.39	
12/08/08	177	3	1	400	0.00	36.40	0.00	7.41	
12/08/08	181	4	2	400	0.00	10.50	0.00	2.20	
12/08/08	187	5	2	400	0.00	28.20	0.00	5.55	

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/08/08	130	6	1	450	0.00	34.80	0.00	7.80	
12/08/08	191	7	1	400-500	0.00	48.60	0.00	9.84	
12/08/08	117	8	1	400	0.00	43.70	0.00	13.02	
12/08/08	136	9	1	400	834.10	884.40	155.88	164.50	
12/08/08	139	10	1	450	0.00	43.00	0.00	11.64	
12/08/08	54	11	1	350-450	0.00	33.90	0.00	7.26	
12/08/08	144	12	1	350-450	357.50	395.30	67.89	75.44	
12/09/08	63	1	1	400	347.50	421.50	68.52	82.50	salt
12/09/08	63	1	1	400	347.50	421.50	68.52	82.50	salt
12/09/08	57	1	2	350-400	359.00	401.70	73.25	82.02	salt
12/09/08	147	2	2	300-500	433.20	520.50	92.35	109.55	salt
12/09/08	177	3	2	400	443.00	516.30	86.83	101.45	salt
12/09/08	181	4	2	400-450	0.00	72.20	0.00	15.10	salt
12/09/08	187	5	1	400	28.20	63.40	5.55	12.90	clearlane
12/09/08	187	5	1	400	356.30	385.50	73.16	79.61	salt
12/09/08	130	6	2	400	0.00	60.30	0.00	11.90	salt
12/09/08	191	7	1	400-500	48.60	94.70	9.84	19.22	clearlane
12/09/08	191	7	1	400	632.80	668.80	128.33	135.50	salt
12/09/08	117	8	2	450	540.50	598.10	112.89	127.89	salt
12/09/08	136	9	2	350-400	889.40	964.30	164.50	178.13	salt
12/09/08	139	10	2	450	43.00	120.50	11.64	32.93	clearlane
12/09/08	54	11	2	400	438.10	504.30	82.22	94.05	salt
12/09/08	144	12	1	350-450	395.30	424.80	75.44	81.69	salt
12/09/08	144	12	1	350-450	0.00	29.10	0.00	6.19	clearlane
12/11/08	177	night	1		539.70	582.00	105.55	113.69	salt
12/11/08	147	night	1		544.08	567.10	113.69	118.35	salt
12/11/08	139	night	1		152.90	212.90	39.49	53.67	salt
12/11/08	136	night	1		983.80	1,027.00	181.53	188.72	salt
12/12/08	136	night	1		129.90	150.70	206.69	209.81	clearlane
12/12/08	147	night	1		689.50	710.90	144.50	148.91	salt
12/12/08	63	night	1		406.30	416.80	80.25	82.03	salt
12/12/08	139	night	1		212.90	243.20	53.67	60.89	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/12/08	177	night	1		705.00	751.30	138.00	145.75	salt
12/12/08	57	1	3						
12/12/08	63	1	1	400	347.50	406.30	68.52	80.25	
12/12/08	147	2	2	300-450	618.10	689.10	130.27	144.50	
12/12/08	177	3	3	350-450	592.10	705.00	113.71	138.00	
12/12/08	181	4	3	400	0.00	104.10	0.00	17.90	
12/12/08	184	5	3	350-450	0.00	100.20	0.00	21.30	
12/12/08	130	6	3	300-450	0.00	88.90	0.00	17.60	
12/12/08	191	7	3	300-450	697.80	827.90	140.53	167.85	
12/12/08	117	8	3	450	606.30	700.60	129.77	151.91	
12/12/08	136	9	3	300-450	1,027.00	1,129.90	188.72	206.69	
12/12/08	147	10	1	450	567.10	618.10	118.35	130.27	
12/12/08	187	10	2	400-450	385.50	459.90	76.61	95.02	
12/12/08	54	11	3	300-400	521.90	624.00	97.22	114.49	
12/12/08	144	12	3	300-450	444.80	529.60	85.19	100.75	
12/13/08	63	1	1	400	406.30	434.10	80.25	85.97	
12/13/08	57	1a	1	manual					
12/13/08	147	2	1	400-500	710.90	757.30	148.91	159.57	
12/13/08	177	3	1	400	751.30	778.40	145.75	151.63	
12/13/08	181	4	1	400	0.00	30.50	0.00	6.10	
12/13/08	184	5	1	400	0.00	30.10	0.00	6.50	
12/13/08	130	6	1	450	0.00	20.80	0.00	4.70	
12/13/08	191	7	1`	400	827.90	857.90	167.85	173.82	
12/13/08	117	8	1	450	700.60	725.90	151.91	157.69	
12/13/08	136	9	1	400	1,150.70	1,175.50	209.81	214.56	
12/13/08	139	10	1	400	243.00	280.00	60.89	71.28	
12/13/08	54	11	1	400	624.00	646.30	114.40	118.74	
12/13/08	144	12	1	400-450	529.60	558.00	100.75	107.74	
12/16/08	177	night	1		793.40	817.90	154.44	159.38	
12/16/08	63	night	1		461.30	480.50	90.42	94.80	
12/16/08	139	night	1		280.10	319.40	71.28	82.08	
12/16/08	136	night	1		1,214.00	1,253.40	220.53	227.13	

NAMF - Daily Depar Dickey-John Detail

Date	Truck #	Route #	# of Trips	Dickey-John Rate Setting	Spreader Miles Beginning	Spreader Miles Ending	Spreader Tons Beginning	Spreader Tons Ending	Material Type
12/16/08	63	1 1a	1	300	434.10	461.30	85.92	90.42	
12/16/08	57	1a	1	300	414.70	414.90	84.67	84.69	
12/16/08	147	2	1	300-400	757.30	778.10	159.57	163.07	
12/16/08	177	3	1	350	778.60	793.40	151.69	154.44	
12/16/08	181	4	2	300-400	0.00	38.40	0.00	6.50	
12/16/08	184	5	2`	300-400	0.00	44.30	0.00	8.80	
12/16/08	130	6	1	350	0.00	13.20	0.00	2.70	
12/16/08	191	7	1	350-400	857.90	908.50	173.82	182.69	
12/16/08	117	8	1	350	725.80	740.40	157.69	160.75	
12/16/08	136	9	2	400	1,175.50	1,214.00	214.56	220.55	
12/16/08	187	10	1	400	459.90	478.30	95.02	98.63	
12/16/08	54	11	1	350-400	646.30	665.60	118.74	122.35	
12/16/08	144	12	1	350	558.00	577.60	107.74	111.38	
12/17/08	63	1	1	400	480.50	515.30	94.80	101.03	
12/17/08	57	1 1A	2	350					
12/17/08	147	2 10	1	400-450	778.10	878.00	163.07	183.78	
12/17/08	177	3	3	350-450	817.90	907.80	159.38	179.03	
12/17/08	181	4	2	400-450	0.00	73.60	0.00	14.30	
12/17/08	184	5	2	400-450	0.00	66.00	0.00	13.70	
12/17/08	130	6	1	400-450	0.00	26.00	0.00	5.40	
12/17/08	130	6	1	400					
12/17/08	191	7	2	400	908.50	1,010.40	182.69	203.91	
12/17/08	117	8	2	450	740.40	805.60	160.75	178.63	
12/17/08	136	9	2	136	1,253.40	1,326.80	227.30	240.22	
12/17/08	139	10	3	450	319.40	392.70	82.08	100.80	
12/17/08	54	11	1	350-450	665.60	735.30	122.35	134.82	
12/17/08	144	12	2	350-400	577.60	640.70	111.38	123.17	
12/19/08	136	night	2		1,379.50	1,452.80	249.19	261.38	
12/19/08	139	night	2		477.00	570.00	124.05	143.57	
12/19/08	63	1	2						
12/19/08	57	1	2						
12/19/08	147	2	2	400	878.00	924.40	183.78	194.10	

NAMF - Daily Depar Dickey-John Detail

Date	Truck #	Route #	# of Trips	Dickey-John Rate Setting	Spreader Miles Beginning	Spreader Miles Ending	Spreader Tons Beginning	Spreader Tons Ending	Material Type
12/19/08	177	3	3	400-450	907.80	983.30	179.03	195.88	
12/19/08	181	4	2	250-400	0.00	80.20	0.00	14.40	
12/19/08	184	5	3	400	0.00	81.20	0.00	15.70	
12/19/08	130	6	3	250-450	0.00	50.80	0.00	8.60	
12/19/08	191	7	3	400-500	1,010.40	1,067.30	203.91	215.66	
12/19/08	117	8	2	400-450	805.60	848.90	178.03	190.00	
12/19/08	136	9	2	350	1,326.80	1,379.19	240.22	249.19	
12/19/08	139	10	3	450-500	392.70	477.00	100.80	124.05	
12/19/08	54	11	2	350-400	735.30	860.60	134.82	147.41	
12/19/08	144	12	2	350	640.70	693.50	123.17	132.38	
12/20/08	57	1	3	400-450	415.00	602.00	84.69	121.78	clearlane
12/20/08	63	1`	1						clearlane
12/20/08	147	2	2	400-500	45.30	121.70	9.39	26.55	clearlane
12/20/08	177	3	1	450	983.30	1,024.40	195.88	205.34	salt
12/20/08	177	3	1	450	36.40	79.60	7.41	17.89	clearlane
12/20/08	181	4	1	400	0.00	41.10	0.00	8.10	salt
12/20/08	181	4	1	400	0.00	42.50	0.00	8.00	clearlane
12/20/08	184	5	1	400-450	0.00	32.60	0.00	7.30	salt
12/20/08	184	5	1	400-450	0.00	46.90	0.00	10.40	clearlane
12/20/08	130	6	2	450	0.00	55.20	0.00	11.80	clearlane
12/20/08	191	7	1	450	1,067.30	1,090.50	215.66	221.00	salt
12/20/08	191	7	1	450	94.70	157.30	19.22	34.00	clearlane
12/20/08	117	8	1	500	848.90	881.30	190.00	199.28	salt
12/20/08	117	8	1	400	43.70	73.20	13.02	21.62	clearlane
12/20/08	136	9	2	400-450	1,452.80	1,533.80	143.57	158.16	salt
12/20/08	139	10	2	400-500	577.70	640.00	143.57	167.47	salt
12/20/08	54	11	1	450-500	800.60	853.00	147.41	160.28	salt
12/20/08	54	11	1	300-400	33.90	57.40	7.26	11.90	clearlane
12/20/08	144	12	1	400	693.50	726.30	132.38	139.03	salt
12/20/08	144	12	1	400-450	29.10	53.70	6.19	11.93	clearlane
12/21/08	187	night	1		149.80	190.70	33.07	39.31	salt
12/21/08	139	night	2		692.30	735.30	180.53	189.63	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/21/08	136	night	1	300	1,621.30	1,634.80	291.94	293.94	salt
12/21/08	63	night	1		515.30	546.50	101.30	108.38	clearlane
12/21/08	63	1	3	350-400	515.30	552.50	101.03	110.45	clearlane
12/21/08	57	1	3	450	…..				clearlane
12/21/08	147	2	3	400-450	121.70	227.30	26.55	48.73	clearlane
12/21/08	177	3	3	450	79.60	181.40	17.89	42.25	clearlane
12/21/08	181	4	3	300-400	0.00	102.00	0.00	16.10	clearlane
12/21/08	184	5	3	450	0.00	97.20	0.00	21.80	clearlane
12/21/08	130	6	3	400					clearlane
12/21/08	191	7	3	350-450	157.30	287.70	34.00	57.40	clearlane
12/21/08	117	8	3	500	73.20	150.50	21.62	42.07	clearlane
12/21/08	136	9	3	400-450	1,533.80	1,621.30	276.88	291.94	clearlane
12/21/08	139	10	3	400-500	640.10	692.30	167.47	180.53	clearlane
12/21/08	187	11	3	400-450	63.40	149.80	12.90	33.04	clearlane
12/21/08	144	12	3	350-450	53.70	127.60	11.93	27.05	salt
12/22/08	136	night			109.30	130.90	17.44	20.79	salt
12/22/08	139	night			766.10	783.50	228.09	231.19	salt
12/22/08	63	1	2	400	546.50	595.00	108.38	119.47	clearlane
12/22/08	57	1	4	400					clearlane
12/22/08	147	2	4	400	227.30	286.90	48.73	61.02	clearlane
12/22/08	177	3	2	400	181.40	298.90	42.25	66.97	clearlane
12/22/08	177	3	2	400	1,024.40	1,048.70	205.34	210.78	salt
12/22/08	181	4	4	400	0.00	132.70	0.00	20.00	clearlane
12/22/08	184	5	4	400-450	0.00	146.10	0.00	32.70	clearlane
12/22/08	130	6	4	450	0.00	63.60	0.00	15.00	clearlane
12/22/08	191	7	4	300-400	287.70	365.40	57.40	70.35	clearlane
12/22/08	117	8	3	400-500	150.50	235.70	42.07	67.43	clearlane
12/22/08	117	8	1	400	881.40	887.60	199.32	201.07	salt
12/22/08	136	9	3	400	10.50	109.30	2.22	17.44	clearlane
12/22/08	136	9	1	400	735.30		189.63		salt
12/22/08	139	10	4		735.30	866.00	189.63	228.09	
12/22/08	54	11	4	350	57.40	128.80	11.90	24.38	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/22/08	144	12	4	400	127.60	213.40	27.05	44.47	clearlane
12/23/08	177	night	1		1,116.20	1,137.50	225.34	228.59	salt
12/23/08	139	night	1	450	907.00	919.50	234.97	237.91	salt
12/23/08	57	1	3						salt
12/23/08	63	1	3	400	595.00	660.40	119.47	132.06	salt
12/23/08	147	2 10	2	350-450	286.90	373.40	61.02	78.30	clearlane
12/23/08	177	3	3	400-450	1,048.70	1,116.20	210.78	225.34	salt
12/23/08	181	4	1	400	419.20	455.20	97.20	102.60	salt
12/23/08	184	5	3	400-450	0.00	80.60	0.00	18.50	clearlane
12/23/08	130	6	2	450	0.00	50.70	0.00	10.70	salt
12/23/08	191	7	2	300-400	365.20	450.20	70.35	84.86	clearlane
12/23/08	117	8	2	400-500	887.60	948.90	201.07	217.28	salt
12/23/08	136	9	2	350-450	130.90	198.00	20.79	32.67	clearlane
12/23/08	54	11	3	350-450	128.80	186.30	31.34	35.49	clearlane
12/23/08	144	12	3	350	213.40	279.70	44.47	58.63	clearlane
12/24/08	63	1	1	400	660.40	696.90	132.60	139.16	salt
12/24/08	57	1	1	400					salt
12/24/08	147	2	1	400-500	373.40	411.20	78.30	86.31	clearlane
12/24/08	177	3	1	350-400	1,137.50	1,179.00	228.59	237.25	salt
12/24/08	181	4	1	400	0.00	44.30	0.00	8.50	clearlane
12/24/08	184	5	2	400	0.00	65.90	0.00	13.80	salt
12/24/08	130	6	1	450	0.00	33.50	0.00	6.70	salt
12/24/08	191	7	1	400	450.20	480.60	84.86	90.94	clearlane
12/24/08	191	7	1	400	1,090.50	1,117.70	221.00	225.88	salt
12/24/08	117	8	1	500	948.90	990.90	217.28	228.50	salt
12/24/08	136	9	1	400	1,634.80	1,667.00	293.94	299.44	salt
12/24/08	139	10	1	400					
12/24/08	54	11	1	400	186.30	225.30	35.49	42.54	clearlane
12/24/08	144	12	1	400-450	726.30	755.00	139.03	145.72	salt
12/25/08	181	5	1	400	0.00	17.70	0.00	3.60	salt
12/26/08	181	night	1	350	442.90	456.60	82.20	87.60	clearlane
12/26/08	139	night	1	350	1,006.80	1,024.80	261.00	264.38	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/26/08	147	night	1	350	960.60	968.60	200.41	201.85	salt
12/26/08	177	1	1	400	1,179.00	1,197.30	237.25	241.00	salt
12/26/08	147	2	1	300-400	0.00	26.30	0.00	4.81	salt
12/26/08	63	1	1	400	696.90	708.00	139.16	140.50	salt
12/26/08	181	5	1	400-450	0.00	29.90	0.00	6.40	salt
12/26/08	181	5	1	450	0.00	4.50	0.00	1.01	salt
12/26/08	130	6	1	400	0.00	25.40	0.00	5.20	salt
12/26/08	191	7	1	400	1,117.70	1,148.30	225.88	232.19	salt
12/26/08	117	8	1	350	990.90	1,023.30	228.50	234.38	salt
12/26/08	136	3 9	1	400	1,667.00	1,699.00	299.44	304.50	salt
12/26/08	139	10	1	400	972.00	1,006.00	251.00	261.00	salt
12/26/08	54	11	1	350	225.30	248.10	42.54	46.13	salt
12/26/08	144	4 12	1	350-450	755.00	782.10	145.72	151.00	salt
12/30/08	`147	night	1	350	1,028.50	1,054.00	213.66	218.53	salt
12/30/08	63	night	1		741.30	758.60	146.07	150.13	salt
12/30/08	139	night	2	350	1,081.30	1,178.20	280.50	302.75	salt
12/30/08	136	night	2	300	1,765.30	1,830.50	316.25	326.28	salt
12/30/08	177	night	2	350	1,257.00	1,315.50	252.00	263.20	salt
12/30/08	57	1 1a	2	400	415.10	456.20	84.69	92.86	salt
12/30/08	63	1 1a	1	350	708.00	741.30	140.50	146.07	salt
12/30/08	147	2	2	350-400	968.60	1,028.50	201.85	213.66	salt
12/30/08	177	3	2	400	1,197.50	1,257.20	241.06	252.91	salt
12/30/08	181	4	1	350-400	0.00	28.90	0.00	5.30	salt
12/30/08	181	4	1	350	0.00	31.60	0.00	5.70	salt
12/30/08	166	4	1	350	0.00	13.90	0.00	2.60	salt
12/30/08	184	5	3	400-450	0.00	90.40	0.00	19.60	salt
12/30/08	130	6	2	400-450	0.00	42.00	0.00	8.70	salt
12/30/08	191	7	3	350-400	1,148.30	1,226.20	232.19	248.25	salt
12/30/08	117	8	2	450	1,023.40	1,067.40	234.41	245.69	salt
12/30/08	136	9	3	400	1,699.30	1,765.30	304.50	316.25	salt
12/30/08	139	10	2	400-450	1,024.00	1,081.00	264.00	280.00	salt
12/30/08	54	11	2	350-450	853.00	903.50	160.28	169.69	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
12/30/08	144	12	2	350-400	782.10	829.00	151.00	160.38	salt
12/31/08	147	night	2						salt
12/31/08	139	night	1	350	1,333.30	1,366.80	345.06	350.88	clearlane
12/31/08	63	1 1A 8	3	400	741.30	798.10	146.07	156.66	salt
12/31/08	57	1 1A	2	400	456.20	531.00	92.86	108.74	salt
12/31/08	147	2	1	450					salt
12/31/08	187	2	1	350-450	…..	511.40	98.63	104.94	salt
12/31/08	187	2	2	350-400	190.70	240.10	39.31	48.84	clearlane
12/31/08	177	3	2	450	1,315.50	1,401.80	263.19	282.69	salt
12/31/08	177	3	2	400-450	298.90	373.90	66.97	82.70	clearlane
12/31/08	166	4	2	350					salt
12/31/08	166	4	2	350	0.00	120.80	0.00	14.00	clearlane
12/31/08	184	5	4	450	0.00	141.00	0.00	31.20	salt
12/31/08	159	6	2	400-450	0.00	73.70	0.00	15.20	salt
12/31/08	159	6	2	450	0.00	45.50	0.00	9.90	clearlane
12/31/08	191	7	2	400	1,226.20	1,306.70	248.25	266.31	salt
12/31/08	162	7	2	400	0.00	70.30	0.00	10.20	clearlane
12/31/08	117	8	4	450	1,067.40	1,144.00	245.69	265.13	salt
12/31/08	136	9	4	400	1,830.50	1,968.50	326.38	353.38	salt
12/31/08	139	10	4	400	1,178.00	1,333.00	302.00	345.00	clearlane
12/31/08	54	11	4	400	903.50	1,024.90	169.69	195.44	salt
12/31/08	144	12	4	350-400	829.00	912.80	160.38	177.00	salt
01/01/09	139	night	1		1,417.00	1,469.00	366.13	373.97	salt
01/01/09	`117	night	1	400	274.70	338.40	75.85	87.83	salt
01/01/09	191	night	1		1,306.70	1,368.80	266.31	281.56	salt
01/01/09	57	1		400					clearlane
01/01/09	63	1a	1	400	798.50		156.75		salt
01/01/09	187	2	1	450	240.10	283.10	48.84	58.59	clearlane
01/01/09	177	3	1	450	373.90	415.30	82.70	92.58	clearlane
01/01/09	166	4	1	400	0.00	28.70	0.00	5.70	clearlane
01/01/09	184	5	1	450	0.00	50.00	0.00	12.20	clearlane
01/01/09	159	6	1	450	0.00	33.60	0.00	7.70	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/01/09	162	7	1	450	0.00	47.60	0.00	11.10	clearlane
01/01/09	117	8	1	400-800	235.70	274.70	62.43	75.85	clearlane
01/01/09	136	9	1	450	198.00	236.80	32.67	40.70	clearlane
01/01/09	139	10	1	450	1,366.00	1,417.00	350.00	366.00	clearlane
01/01/09	54	11	1	400	248.10	283.30	46.13	56.27	clearlane
01/01/09	144	12	1	400-450	279.70	313.40	58.63	65.74	clearlane
01/02/09	63	night	2		798.50	868.90	156.75	162.78	salt
01/02/09	147	night	2	400	1,054.00	1,122.50	218.53	232.34	salt
01/02/09	139	night	2	400	1,465.00	1,534.50	373.94	394.25	salt
01/02/09	136	night	1	350	236.50	278.50	40.70	47.88	salt
01/02/09	187	2 7 10	1		511.40	525.90	104.94	107.24	salt
01/02/09	184	5	1	400	0.00	20.40	0.00	4.50	clearlane
01/03/09	57	1	2	400					salt
01/03/09	147	2	2	400	1,122.50	`1207.5	232.34	250.28	salt
01/03/09	191	3	2	400	1,368.80	1,446.50	281.56	296.88	salt
01/03/09	166	4	3	400	0.00	74.60	0.00	14.90	salt
01/03/09	184	5	3	400	0.00	93.00	0.00	19.60	salt
01/03/09	159	6	2	450	0.00	70.70	0.00	14.20	salt
01/03/09	162	7	2	400	0.00	90.50	0.00	17.20	salt
01/03/09	63	8	1	400	868.90	905.30	167.19	174.47	salt
01/03/09	117	8	1	500	1,203.50	1,235.70	278.94	286.06	salt
01/03/09	136	9	2	400	1,968.50	2,051.00	353.75	368.69	salt
01/03/09	139	10	3	400-450	1,534.00	1,625.00	394.00	418.00	salt
01/03/09	54	11	2	350-450	283.30	364.00	56.27	72.88	salt
01/03/09	144	12	2	350-400	912.80	975.30	177.00	188.91	salt
01/03/09	117	13	2	400-450	1,144.00	1,203.50	265.13	278.94	salt
01/04/09	63	1	1	450	905.60	936.10	174.53	181.44	salt
01/04/09	191	3	1	450	1,446.50	1,476.30	296.88	304.00	salt
01/04/09	166	4	1	450-500	0.00	34.60	0.00	8.40	salt
01/04/09	184	5	1	450	0.00	37.00	0.00	8.40	salt
01/04/09	159	6	1	450	0.00	23.70	0.00	6.50	salt
01/04/09	162	7	1	450	0.00	32.10	0.00	7.70	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/04/09	57	8	1	450	604.50	630.10	123.91	130.12	salt
01/04/09	136	9	1	450	2,051.00	2,080.00	368.69	374.63	salt
01/04/09	139	10	1	450	1,625.00	1,636.00	418.00	423.00	salt
01/04/09	54	11	1	450	364.00	405.10	72.88	82.42	salt
01/04/09	139	7	1	450	1,636.00	1,666.50	423.62	436.18	salt
01/04/09	144	12	1	450	975.30	1,008.00	188.91	197.10	salt
01/04/09	136	12	1	450	2,080.30	2,090.00	374.63	376.88	salt
01/04/09	117	3 13	1	450	1,235.70	1,277.50	286.06	295.50	salt
01/04/09	147	2 6	1	450	1,207.50	1,262.00	250.28	263.56	salt
01/05/09	57	1	1	400	630.10	657.40	130.12	135.75	salt
01/05/09	147	2	1	400	1,262.00	1,294.40	263.56	270.25	salt
01/05/09	166	3	1	350	0.00	31.20	0.00	3.60	salt
01/05/09	184	4	1	450	0.00	33.90	0.00	7.70	salt
01/05/09	63	8	1	300-500	936.10	964.00	181.44	187.41	salt
01/05/09	136	9	1	400	2,090.00	2,117.50	376.88	382.06	salt
01/05/09	139	10 7	1	400	578.00	609.50	133.25	140.10	salt
01/05/09	54	11 7	1	350-450	405.10	438.10	82.42	88.92	clearlane
01/05/09	187	13	1	450-800	525.90	554.50	107.24	115.30	
01/06/09	166	night	1	400	232.10	256.30	44.20	48.70	salt
01/06/09	139	night	1		609.50	655.30	140.10	155.10	salt
01/06/09	147	night	1	400	1,294.70	1,345.00	270.25	280.75	salt
01/06/09	136	night	1		2,117.50	2,150.80	382.06	387.19	salt
01/07/09	187	8	1	450	554.50	585.70	115.30	122.19	salt
01/07/09	57	1	3	400-450	657.40	736.90	135.75	152.72	salt
01/07/09	147	2	3	400-450	1,345.00	1,449.00	280.75	301.81	salt
01/07/09	191	3	3	400-450	1,476.30	1,567.30	304.00	322.30	salt
01/07/09	166	4	3	450	0.00	92.00	0.00	16.80	salt
01/07/09	184	5	5	400-450	0.00	154.90	0.00	35.20	salt
01/07/09	159	6	3	350-450	0.00	82.00	0.00	16.90	salt
01/07/09	162	7	4	400-450	0.00	149.60	0.00	32.10	salt
01/07/09	187	8	1	400	618.50	634.90	129.56	133.32	salt
01/07/09	136	9	3	400-450	2,150.80	2,253.30	387.19	405.50	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/07/09	139	10	3	400	655.00	729.00	155.00	175.00	salt
01/07/09	54	11	3	400-450	1,024.90	1,113.30	195.44	212.47	salt
01/07/09	144	12	3	350-400	1,008.00	1,070.00	197.10	209.41	salt
01/07/09	117	13	3	400-450	1,277.70	1,360.00	295.56	314.13	salt
01/07/09	147	night	1		1,449.00	1,514.00	301.81	314.19	salt
01/07/09	166	night	1		348.30	392.00	65.20	71.30	salt
01/07/09	136	night	1	450	2,253.30	2,291.50	405.55	412.18	salt
01/07/09	139	night	1		729.00	805.90	175.85	196.47	salt
01/08/09	57	1	4	300-400	736.90	848.10	152.72	172.35	salt
01/08/09	147	2	4	350-450	1,514.00	1,643.50	314.19	338.75	salt
01/08/09	191	3 12	4	400-450	1,567.30	1,708.30	322.31	351.56	salt
01/08/09	166	4	3	400	0.00	95.40	0.00	18.30	salt
01/08/09	166	4	1	350	0.00	18.80	0.00	3.40	salt
01/08/09	184	5	4	400-450	0.00	152.50	0.00	33.20	salt
01/08/09	159	6	1	350	0.00	26.10	0.00	4.60	salt
01/08/09	159	6	2	450	0.00	62.30	0.00	13.60	salt
01/08/09	162	7	4	350-450	0.00	146.60	0.00	27.10	salt
01/08/09	187	8	4	450	634.90	755.00	133.32	159.41	salt
01/08/09	136	9	3	400-450	2,291.50	2,401.30	412.18	431.76	salt
01/08/09	139	10	4		805.00	908.60	196.00	222.31	salt
01/08/09	54	11	4	350-450	1,113.30	1,231.00	212.47	236.94	salt
01/08/09	144	12	4	350-400	1,070.00	1,160.30	209.44	226.94	salt
01/08/09	117	13	4	400	1,360.00	1,464.80	314.13	336.56	salt
01/08/09	139	night	1	400	908.60	942.60	222.31	229.41	salt
01/08/09	136	night	1	400	2,401.30	2,452.80	431.75	440.26	salt
01/08/09	117	night	1	400	1,464.50	1,522.30	336.56	347.88	salt
01/09/09	57	1	2	300-450	848.10	905.80	172.35	183.72	salt
01/09/09	63	2	1	350-400	964.80	1,005.40	187.63	194.57	salt
01/09/09	191	3	2	450	1,708.30	1,755.00	351.56	361.31	salt
01/09/09	166	4	2	350					
01/09/09	184	5	2	450	0.00	73.90	0.00	16.00	salt
01/09/09	159	6	2	300-350	0.00	51.30	0.00	10.00	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/09/09	162	7	2	200-450	0.00	75.30	0.00	15.60	salt
01/09/09	187	8	2	400	755.00	786.00	159.41	166.16	salt
01/09/09	136	9	2	400-450	2,402.80	2,519.50	440.26	452.68	salt
01/09/09	139	10	2	400-450	942.00	1,020.00	229.00	250.00	salt
01/09/09	54	11	2	350-400	1,231.00	1,294.30	236.94	249.19	salt
01/09/09	144	12	2	350-450	1,160.30	1,217.50	226.94	238.41	salt
01/09/09	117	13	2	350-450	1,522.30	1,580.80	347.88	360.44	salt
01/10/09	57	1	1	450	905.80	923.30	183.72	187.66	salt
01/10/09	`191	2	1	450	1,755.00	1,792.00	361.31	369.81	salt
01/10/09	166	3	1	400					
01/10/09	184	5	1	450	0.00	35.90	0.00	8.00	salt
01/10/09	159	6	1	450	0.00	13.10	0.00	4.80	salt
01/10/09	162	7	1	450	0.00	34.50	0.00	7.90	salt
01/10/09	187	8	1	350-450	813.90	841.10	171.60	176.10	salt
01/10/09	136	9+	2	450	2,519.50	2,563.00	452.68	461.00	salt
01/10/09	139	10	1	450	1,020.00	1,040.00	250.00	255.00	salt
01/10/09	54	11	1	450	1,294.30	1,319.50	249.19	254.38	salt
01/10/09	117	13	1	350-400	1,580.00	1,608.00	360.44	366.25	salt
01/10/09	166	night	1	450					`
01/10/09	139	night	1	450	1,040.70	1,061.20	255.47	260.10	salt
01/10/09	147	2+	1	400-450	1,644.30	1,708.80	338.88	351.75	salt
01/10/09	159	6	1	450	410.80	450.10	86.00	94.80	clearlane
01/11/09	57	1	2	350-450	923.30	990.10	187.66	200.94	salt
01/11/09	147	2	2	350-450	411.20	497.50	86.31	102.38	clearlane
01/11/09	191	3	2	450	480.60	565.60	90.94	110.03	clearlane
01/11/09	166	4	2	400	0.00	33.00			clearlane
01/11/09	184	5	3	450-500	0.00	106.80	0.00	25.90	clearlane
01/11/09	159	6	1	350-500	0.00	6.60	0.00	31.60	clearlane
01/11/09	162	7	2	400-450	0.00	97.80	0.00	21.20	clearlane
01/11/09	187	8	2	450	0.00	59.10	0.00	13.70	clearlane
01/11/09	136	9	1	450	2,563.00	2,605.80	461.00	470.94	salt
01/11/09	139	10	1	450	1,061.20	1,094.00	260.00	268.00	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/11/09	139	10	1	450	1,094.00	1,127.00	268.00	276.00	salt
01/11/09	54	11	2	400	438.10	514.20	88.92	105.92	clearlane
01/11/09	144	12	2	400-450	1,217.50	1,285.00	238.41	253.28	salt
01/11/09	117	13	2	500-700	338.50	410.60	87.83	112.67	clearlane
01/12/09	147	night	1		1,763.00	1,764.00	361.88	362.31	salt
01/12/09	57	1, 10	2	400	990.10	1,052.20	200.94	212.53	clearlane
01/12/09	147	2	2	350-400	1,708.80	1,762.30	351.75	361.75	salt
01/12/09	191	3	2	400	1,792.00	1,846.30	369.81	380.88	salt
01/12/09	166	4	2	350					salt
01/12/09	184	5	2	450	0.00	66.50	0.00	15.10	salt
01/12/09	159	6	2	350	0.00	44.70	0.00	8.40	salt
01/12/09	162	7	2	400	0.00	70.40	0.00	14.40	salt
01/12/09	187	8	2	450					
01/12/09	136	9	2	400	2,635.80	3,664.50	470.94	481.94	salt
01/12/09	139	10	2		1,127.00	1,685.00	27.60	44.20	clearlane
01/12/09	54	11	2	400	1,319.50	1,371.00	254.38	264.88	salt
01/12/09	144	12	2	400-450	1,285.00	1,331.50	253.28	264.31	salt
01/12/09	117	13	2	400-450	20.00	1,667.30	366.25	380.50	salt
01/13/09	166	night	1	400	684.60	721.20	94.60	94.60	salt
01/13/09	117	night	1	400	410.60	448.20	112.67	120.67	clearlane
01/13/09	147	night	1	400	497.50	554.10	102.38	114.96	clearlane
10/13/09	136	night	1	400	278.50	304.10	47.88	52.78	clearlane
01/14/09	139	night	1	300	1,702.50	1,714.00	445.12	447.12	salt
01/14/09	57	1	1	450	1,052.00	1,084.00	212.53	219.59	clearlane
01/14/09	139	1 10	1	350	1,685.00	1,702.50	442.00	445.12	clearlane
01/14/09	191	2	2	350-450	565.60	639.50	110.03	125.61	clearlane
01/14/09	187	3	2	400-450	283.10	350.10	58.59	71.50	clearlane
01/14/09	166	4	2	300-400	0.00	56.00			clearlane
01/14/09	184	5	3	450-500	0.00	101.70	0.00	24.20	clearlane
01/14/09	159	6	2	450	0.00	39.00	0.00	8.40	clearlane
01/14/09	162	7	2	400-450	0.00	71.00	0.00	14.40	clearlane
01/14/09	147	8	2	350-450	554.10	604.20	114.96	125.57	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/14/09	136	9	2	450	304.10	360.60	52.78	64.71	clearlane
01/14/09	54	10	2	300-450	514.20	582.70	105.92	121.07	clearlane
01/14/09	144	12	2	400-450	313.40	368.60	65.74	77.69	clearlane
01/14/09	117	13	2	350-700	448.20	496.30	120.67	133.66	clearlane
01/14/09	63	10	1		0.00	32.00	0.00	10.00	clearlane
01/15/09	57	1	1	450	1,084.00	1,114.90	215.59	226.34	clearlane
01/15/09	191	2	1	450	639.50	678.60	125.61	134.88	clearlane
01/15/09	187	3	1	450	350.10	394.80	71.50	80.88	clearlane
01/15/09	166	4	1	450					clearlane
01/15/09	184	5	1	450	0.00	43.50	0.00	10.80	clearlane
01/15/09	159	6	1	450	0.00	23.60	0.00	5.40	clearlane
01/15/09	162	7	1	450	0.00	34.60	0.00	8.50	clearlane
01/15/09	147	8	1	450	604.20	629.40	125.57	130.62	clearlane
01/15/09	139	9	1	450	1,714.00	1,881.50	447.00	486.94	clearlane
01/15/09	63	10	1	450					
01/15/09	54	11	1	450	582.70	619.90	121.07	130.15	clearlane
01/15/09	144	12	1	450	368.60	397.60	77.69	84.20	clearlane
01/15/09	117	13	1	450	496.30	527.10	133.60	143.50	clearlane
01/16/09	136	night	1	450	360.70	399.60	64.71	72.28	clearlane
01/16/09	147	night	1		693.00	747.90	146.22	158.69	clearlane
01/16/09	191	night	1		775.90	785.10	158.47	160.60	clearlane
01/16/09	117	night	1	450	529.60	538.80	144.53	146.85	clearlane
01/16/09	139	night	1	450	1,881.50	1,911.50	486.94	497.44	clearlane
01/16/09	57	1	3	300-450	1,114.90	1,196.90	226.34	242.38	clearlane
01/16/09	191	2	4	350-500	678.60	775.90	134.88	158.47	clearlane
01/16/09	187	3	3	400-450	394.80	479.90	80.88	99.14	clearlane
01/16/09	166	4	3	300-450	0.00	66.80	0.00	17.80	salt
01/16/09	184	5	4	400-500	0.00	106.20	0.00	27.90	clearlane
01/16/09	159	6	3	450	0.00	44.10	0.00	10.50	clearlane
01/16/09	162	7	4	450	0.00	74.00	0.00	12.60	clearlane
01/16/09	63	8	5	450					
01/16/09	147	8	2	400-450	659.00	693.00	139.22	146.22	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/16/09	139	9	3	450		1,881.50		486.94	clearlane
01/16/09	147	10	1		629.00	659.00	130.00	139.00	clearlane
01/16/09	54	11	3	300-450	619.90	695.00	130.15	146.57	clearlane
01/16/09	144	12	4	400-450	397.60	463.90	84.20	98.77	clearlane
01/16/09	117	13	1	500	527.10	529.60	143.50	144.53	clearlane
01/17/09	184	5	1	450	0.00	9.00	0.00	2.80	clearlane
01/17/09	136	9	1	450	399.00	417.30	72.28	77.17	clearlane
01/17/09	166	4	1	350	0.00	17.70	0.00	3.60	clearlane
01/17/09	162	7	1	450	0.00	7.60	0.00	2.60	clearlane
01/18/09	57	1	2	450	1,196.90	1,207.50	242.38	244.41	clearlane
01/18/09	191	2	2	350-500	785.10	873.90	160.60	181.25	clearlane
01/18/09	187	3	2	450	479.90	570.30	99.14	118.57	clearlane
01/18/09	166	4	2	400	0.00	74.50	0.00	14.10	salt
01/18/09	184	5	2	350-500	0.00	95.00	0.00	21.60	clearlane
01/18/09	159	6	2	350-450	0.00	72.10	0.00	13.00	clearlane
01/18/09	179	7	1		0.00	14.50	0.00	3.10	clearlane
01/18/09	147	8	2	400-450	747.90	799.80	158.69	170.03	clearlane
01/18/09	136	9	2	450	417.40	506.00	77.19	95.53	clearlane
01/18/09	139	10	2		1,911.00	1,980.00	497.00	518.00	clearlane
01/18/09	54	11	2	350-450	695.00	768.50	146.57	161.44	clearlane
01/18/09	144	12	2	400-450	463.90	522.50	98.77	111.28	clearlane
01/18/09	117	13	2	600-700	538.80	627.00	146.85	176.97	clearlane
01/19/09	57	1	1	450	1,207.50	1,223.50	244.41	247.84	clearlane
01/19/09	191	2	1	400	1,846.30	1,886.50	380.88	390.38	salt
01/19/09	187	3	1	450	887.60	943.90	183.60	193.38	salt
01/19/09	166	4	1	400	0.00	35.30	0.00	6.90	salt
01/19/09	184	5	1	450	0.00	39.70	0.00	9.40	salt
01/19/09	159	6	1	450	0.00	38.50	0.00	8.00	salt
01/19/09	179	7	1	450-500	0.00	48.90	0.00	12.70	salt
01/19/09	147	8	2	350-450	1,746.80	1,806.30	362.31	370.81	salt
01/19/09	136	9	1	450	2,664.50	2,704.00	481.94	490.82	salt
01/19/09	139	10	1	450	1,980.00	2,009.00	518.00	527.00	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/19/09	155	11	1	450	0.00	40.20	0.00	3.80	salt
01/19/09	144	12	1	400-450	1,331.50	1,360.30	264.31	270.88	salt
01/19/09	117	13	1	450	1,667.50	1,697.00	380.56	388.25	salt
01/20/09	136	night	1	300-400	532.80	538.80	101.24	102.28	clearlane
01/20/09	139	night	1	400	2,031.50	2,048.80	534.50	539.76	salt
01/20/09	57	1	1	400	168.30	187.80	40.63	44.64	clearlane
01/20/09	187	3	1	400	570.30	595.40	118.57	123.00	clearlane
01/20/09	187	3	1	350	27.90	29.20	6.50	6.90	salt
01/20/09	166	4	1	400-450	0.00	18.90	0.00	4.10	salt
01/20/09	184	5	2	350-450	0.00	32.40	0.00	7.20	clearlane
01/20/09	159	6	1	450	0.00	15.30	0.00	3.70	clearlane
01/20/09	179	7	1	400-450	0.00	27.90	0.00	6.50	clearlane
01/20/09	147	8	2	350-400	799.80	819.30	170.03	173.83	clearlane
01/20/09	136	9	1	400	506.00	532.80	95.53	101.24	clearlane
01/20/09	139	10	1	450	2,009.00	2,031.00	527.00	534.00	salt
01/20/09	155	11	1	400	0.00	21.00	0.00	4.70	salt
01/20/09	144	12	2	350-400	522.00	538.10	111.28	114.44	clearlane
01/20/09	117	2 13	2	400	627.00	657.10	176.97	183.57	clearlane
01/21/09	57	1	1	450	188.00	220.20	44.71	51.89	clearlane
01/21/09	191	2	1	500	873.90	911.40	181.25	190.60	clearlane
01/21/09	187	3	2	400-450	595.40	639.10	123.00	132.63	clearlane
01/21/09	166	4	2	400	0.00	35.00	0.00	6.80	clearlane
01/21/09	184	5	2	450	0.00	55.10	0.00	13.00	clearlane
01/21/09	159	6	1	450	0.00	36.30	0.00	8.30	clearlane
01/21/09	179	7	1	450	1.40	49.10	0.40	12.30	clearlane
01/21/09	147	8	1	450	819.30	846.30	173.82	179.14	clearlane
01/21/09	136	9	1	450	538.80	574.80	102.28	109.59	clearlane
01/21/09	139	10	1	450	2,048.00	2,078.00	539.76	550.00	clearlane
01/21/09	54	11	1	450	0.00	32.70	0.00	8.80	clearlane
01/21/09	144	12	1	400	538.10	567.90	114.44	121.24	clearlane
01/21/09	117	13	2	500	657.10	693.80	183.57	195.75	clearlane
01/22/09	184	5	1	500	0.00	1.50	0.00	0.60	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/24/09	191	night	1		988.80	990.80	208.87	208.97	clearlane
01/24/09	139	night	1		0.00	0.00	0.00	0.00	
01/24/09	57	1	1	350	220.20	223.70	51.89	54.53	salt
01/24/09	57	1	1	350	1,225.50	1,239.80	247.84	251.38	clearlane
01/24/09	191	2	2	400-500	911.60	989.80	190.63	208.84	salt
01/24/09	179	3	2	400	0.00	60.30	0.00	12.40	salt
01/24/09	166	4	3	400	0.00	66.00	0.00	13.00	salt
01/24/09	184	5	3	400	0.00	84.70	0.00	16.90	salt
01/24/09	117	5	5	400	1,753.80	1,763.80	402.44	404.44	salt
01/24/09	159	6	3	400	0.00	33.40	0.00	7.80	salt
01/24/09	155	9	1	400	0.00	6.10	0.00	2.10	salt
01/24/09	159	7	1	400	0.00	3.40	0.00	1.10	salt
01/24/09	117	13	3	400-450	1,697.00	1,753.80	388.25	402.44	salt
01/24/09	162	7	2						salt
01/24/09	147	8	1	400	1,806.30	1,833.00	370.81	376.06	salt
01/24/09	136	9	2	400					salt
01/24/09	155	11	2		0.00	55.70	0.00	11.90	salt
01/24/09	144	12	2	350-400	1,360.30	1,396.30	270.88	278.50	salt
01/24/09	139	10	1		1,127.00	1,149.00	276.00	281.00	salt
01/26/09	166	4	1		0.00	1.70	0.00	0.40	salt
01/26/09	117	5	1	400	1,763.80	1,788.30	404.44	409.62	salt
01/26/09	184	5	1	400	0.00	1.40	0.00	0.50	salt
01/27/09	139	9	1	350	1,149.70	1,156.70	281.63	283.00	salt
01/27/09	144	12	1	350	1,396.30	1,397.00	278.50	278.63	salt
01/27/09	184	5	1	500	0.00	14.60	0.00	3.60	salt
01/28/09	57	1	4	350-400	1,239.00	1,320.00	251.44	267.19	salt
01/28/09	191	2	4	300-400	1,886.50	1,986.30	390.38	412.12	salt
01/28/09	179	3	4	300-450	0.00	97.20	0.00	18.60	salt
01/28/09	166	4	4	350-450	0.00	117.70	0.00	21.40	salt
01/28/09	184	5	4	300-450	0.00	120.20	0.00	24.70	salt
01/28/09	159	6	4	350-450	0.00	107.10	0.00	15.60	salt
01/28/09	162	7	1	300	0.00	47.90	0.00	7.80	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/28/09	162	7	3	450	0.00	58.80	0.00	12.20	salt
01/28/09	147	8	4	300-450	1,833.00	1,914.80	376.06	390.69	salt
01/28/09	136	9	4	300-450	2,772.00	2,870.00	503.76	519.96	salt
01/28/09	139	10	4	300-450	1,156.00	1,248.00	283.00	307.00	salt
01/28/09	155	11	4	300-450	0.00	114.00	0.00	21.50	salt
01/28/09	144	12	4	350-400	1,397.00	1,475.80	278.63	293.44	salt
01/28/09	117	13	4	300-450	1,788.30	1,877.30	409.62	429.88	salt
01/28/09	139	night	1	400	1,244.80	1,254.40	307.19	309.56	salt
01/28/09	191	night	1		1,986.30	1,993.00	412.12	413.50	salt
01/28/09	147	night	1	400	1,914.80	1,941.30	390.69	396.31	salt
01/28/09	136	night	1	400	2,870.00	2,877.00	519.96	521.38	salt
01/29/09	57	1	3	350-450	1,320.80	1,372.00	267.19	276.63	salt
01/29/09	191	2	2	350-450	1,993.00	2,073.80	413.50	429.76	salt
01/29/09	179	3	2	400-450	0.00	60.90	0.00	12.50	salt
01/29/09	166	4	2	300-400	0.00	67.90	0.00	11.90	salt
01/29/09	187	5	1	450	943.90	982.10	193.38	201.60	salt
01/29/09	184	5	1	400	0.00	27.60	0.00	5.70	salt
01/29/09	159	6	2	350-400	0.00	55.00	0.00	12.50	salt
01/29/09	162	7	2	450	0.00	51.20	0.00	10.30	salt
01/29/09	147	8	1	400	1,914.80	1,941.30	396.31	401.50	salt
01/29/09	147	8	1	350	1,968.50	1,989.30	401.50	405.00	salt
01/29/09	136	9	2	350-450	2,877.00	2,952.00	521.38	535.38	salt
01/29/09	139	10	2	450-	1,254.00	1,305.00	309.00	321.00	salt
01/29/09	155	11	2	350-450	0.00	67.50	0.00	14.50	salt
01/29/09	144	12	3	350-450	1,475.80	1,525.80	293.44	303.81	salt
01/29/09	117	13	3	450	1,877.30	1,940.30	429.88	443.44	salt
01/30/09	147	night	1		1,970.00	2,000.00	405.00	407.00	salt
01/31/09	63	1	1	400					salt
01/31/09	117	1	1	400	1,940.30	1,953.30	443.44	446.26	salt
01/31/09	117	1	1	400	14.00	29.60	2.26	5.79	clearlane
01/31/09	57	1	1	400	1,372.00	1,381.30	276.63	278.44	salt
01/31/09	`191	2	2	350	2,073.80	2,137.80	429.76	442.44	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
01/31/09	177	3	3	350-400	0.00	85.40	0.00	17.00	salt
01/31/09	166	4	1	400	0.00	35.10	0.00	6.80	salt
01/31/09	166	4	2	300-400	0.00	44.90	0.00	8.90	clearlane
01/31/09	184	5	2	300-400	0.00	76.40	0.00	16.20	salt
01/31/09	184	5	1	500	0.00	37.70	0.00	7.90	clearlane
01/31/09	159	6	2	400	0.00	37.30	0.00	6.90	salt
01/31/09	159	6	1	400	0.00	19.00	0.00	3.90	clearlane
01/31/09	162	7	3	400	0.30	93.20	0.10	19.90	salt
01/31/09	147	8	2	350-400	2,000.50	2,071.30	407.00	420.82	salt
01/31/09	136	9	3	350-400	2,952.00	3,056.00	535.38	554.76	salt
01/31/09	139	10	1		1,305.00	1,340.00	321.00	330.00	salt
01/31/09	139	10	2		2,080.00	2,132.00	551.00	564.00	clearlane
01/31/09	155	11	2	400	0.00	74.10	0.00	16.20	salt
01/31/09	144	12	2	350-400	1,528.00	1,585.30	304.44	316.44	salt
02/01/09	57	1	1	400	1,381.30	1,403.50	278.44	282.88	clearlane
02/01/09	191	2	1	350	2,137.00	2,170.50	442.44	448.32	salt
02/01/09	179	3	1	350	0.00	30.50	0.00	5.00	clearlane
02/01/09	166	4	1	400	44.90	78.00	8.90	14.60	clearlane
02/01/09	184	5	1	400	0.00	33.50	0.00	8.10	clearlane
02/01/09	159	6	1	400	0.00	4.70	0.00	1.20	clearlane
02/01/09	187	6	1	400	639.10	645.80	132.63	134.57	clearlane
02/01/09	162	7	1	400	0.00	28.40	0.00	6.40	clearlane
02/01/09	136	9	1	400	575.00	606.00	109.61	115.13	clearlane
02/01/09	139	10	1	400	2,132.00	2,146.00	564.00	567.00	clearlane
02/01/09	155	11 8	1	400	0.00	35.30	0.00	7.50	clearlane
02/01/09	144	12	1	400	1,585.30	1,607.50	316.44	320.75	salt
02/01/09	117	13	1	400	30.80	50.30	6.08	10.47	clearlane
02/06/09	136			350	17.40	18.50	5.22	5.60	salt
02/09/09	63			500	1,005.10	1,005.40	194.57	194.57	
02/12/09	136	night	1		18.50	46.20	5.60	14.96	mix
02/12/09	191	night	1		1,047.30	1,088.50	218.16	228.41	mix
02/13/09	54	2	1						mix

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
02/13/09	54	1	1	350					clearlane
02/13/09	63	2	1						mix
02/13/09	63	2	1						clearlane
02/13/09	179	3	1	600	0.00	46.70	0.00	14.10	mix
02/13/09	179	3	1	350	0.00	39.70	0.00	8.20	clearlane
02/13/09	166	4	1	600	0.00	37.40	0.00	10.80	mix
02/13/09	166	4	1	350	0.00	42.70	0.00	9.10	clearlane
02/13/09	184	5	1	600	0.00	40.10	0.00	10.20	mix
02/13/09	159	6	1	600	0.00	33.80	0.00	11.40	mix
02/13/09	159	6	1	350	0.00	31.40	0.00	9.20	clearlane
02/13/09	162	7	1	600	0.00	69.10	0.00	22.20	mix
02/13/09	162	7	1		0.00	35.30	0.00	12.70	clearlane
02/13/09	147	8	1		0.00	29.40	0.00	8.78	mix
02/13/09	147	8	1	350	853.50	886.10	181.22	188.03	clearlane
02/13/09	136	9	1	600	46.20	82.40	14.96	23.56	mix
02/13/09	136	9	1	450	606.00	653.60	115.13	125.50	clearlane
02/13/09	187	10	2		0.00	134.00	0.00	38.00	mix
02/13/09	155	11	1	600	0.00	46.60	0.00	15.40	mix
02/13/09	155	11	1	350	0.00	38.50	0.00	8.20	clearlane
02/13/09	144	12	1	600	0.00	5.70	0.00	1.69	mix
02/13/09	144	12	1	400	567.90	577.10	121.24	123.25	clearlane
02/13/09	117	13	1	600	693.80	743.50	195.75	210.81	mix
02/13/09	117	13	2	500	50.30	78.60	10.47	18.92	clearlane
02/18/09	136	night	1	350	653.60	695.80	125.50	132.53	salt
02/18/09	136	night	1	600	82.40	119.30	23.56	35.83	mix
02/18/09	184	night	1		5,263.00	5,344.90	123.30	127.70	salt
02/18/09	139	night	1		2,146.00		567.76		salt
02/18/09	117	night	1	350	1,961.30	2,011.00	448.12	456.94	salt
02/18/09	147	night	1	350	2,071.30	2,112.80	420.82	428.94	salt
02/19/09	117	night	1		2,038.80	2,062.50	463.38	468.32	salt
02/19/09	147	night	1		433.56	434.06	214.03	214.05	salt
02/19/09	184	night	1		5,378.40	5,387.10	1,248.30	1,250.60	salt

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
02/19/09	57	1	1	350	1,403.50	1,430.00	282.88	287.13	salt
02/19/09	54	2	1	350					salt
02/19/09	179	3	1	350					salt
02/19/09	166	4	1	350	0.00	35.90	0.00	6.10	salt
02/19/09	184	5	1	350	0.00	33.40	0.00	6.90	salt
02/19/09	159	6	1	350	0.00	28.20	0.00	4.60	salt
02/19/09	162	7	1	350	0.00	41.50	0.00	7.10	salt
02/19/09	147	8	1	350	2,112.80	2,140.30	428.94	433.56	salt
02/19/09	136	9	1	350	3,056.00	3,093.00	554.76	561.25	salt
02/19/09	139	10	1	350					salt
02/19/09	155	11	1	350	0.00	35.60	0.00	6.10	salt
02/19/09	144	12	1	350	1,607.50	1,635.30	320.75	325.81	salt
02/19/09	117	13	1	350	2,011.00	2,038.80	456.94	463.38	salt
02/20/09	147	night	1	350	971.00	990.00	202.28	206.59	clearlane
02/20/09	184	night	1		1,277.10	1,323.00	280.60	295.50	salt
02/20/09	136	night	1	350	821.10	860.90	155.28	161.82	clearlane
02/20/09	147	night	1		990.00	1,025.00	206.99	214.47	salt
02/20/09	139	night	1	350	2,194.00	2,217.50	580.50	584.62	clearlane
02/20/09	57	1	2	350	233.70	301.00	54.53	66.10	clearlane
02/20/09	54	1	1	350					clearlane
02/20/09	54	2	1						salt
02/20/09	179	3	1	350	0.00	33.20	0.00	6.20	clearlane
02/20/09	179	3	2	350	0.00	73.70	0.00	12.70	clearlane
02/20/09	166	4	3	350	0.00	91.30	0.00	16.30	clearlane
02/20/09	184	5	4	350	0.00	163.10	0.00	27.80	clearlane
02/20/09	159	6	3	350	0.00	59.30	0.00	4.50	clearlane
02/20/09	162	7	3	350	0.00	110.20	0.00	22.30	clearlane
02/20/09	162	7	1	350	0.00	5.10	0.00	1.00	clearlane
02/20/09	147	8	3	350	886.00	971.00	188.03	202.88	clearlane
02/20/09	136	9	3	350-400	695.80	821.10	132.53	155.28	clearlane
02/20/09	63	10	1	350					clearlane
02/20/09	139	10	1	350	2,146.00	2,194.00	567.00	580.00	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
02/20/09	155	11	3	350	0.00	35.70	0.00	16.10	clearlane
02/20/09	144	12	3	350-400	577.10	656.10	123.25	137.72	clearlane
02/20/09	117	13	1	400	2,062.50	2,081.00	468.32	473.44	salt
02/20/09	117	13	2	400	78.60	161.50	18.92	38.62	clearlane
02/21/09	57	1	1	350	301.00	333.30	66.10	72.05	clearlane
02/21/09	54	1	1	350					clearlane
02/21/09	54	2	1	350					clearlane
02/21/09	179	3	2	350	0.00	64.50	0.00	11.30	clearlane
02/21/09	166	4	2	350	0.00	56.30	0.00	10.00	clearlane
02/21/09	184	5	2	350	0.00	69.60	0.00	14.70	clearlane
02/21/09	159	6	2	350	0.00	53.30	0.00	10.60	clearlane
02/21/09	162	7	2	350	0.00	86.60	0.00	16.60	clearlane
02/21/09	147	8	2	350	1,025.00	1,070.50	214.47	222.75	clearlane
02/21/09	136	9	2	350-400	860.91	942.26	161.82	177.66	clearlane
02/21/09	139	10	2	400	2,217.00	2,282.00	584.00	600.00	clearlane
02/21/09	155	11	2	350	0.00	62.90	0.00	11.80	clearlane
02/21/09	144	12	2	350-400	656.10	704.10	137.72	147.28	clearlane
02/21/09	117	13	2	450	161.50	211.90	38.62	50.44	clearlane
02/22/09	166	4	1	200-300	0.00	11.20	0.00	1.07	clearlane
02/22/09	184	5	1	350	0.00	21.30	0.00	3.90	clearlane
02/22/09	117	13	1	350	211.90	213.60	50.44	50.73	clearlane
02/23/09	63	1	2						clearlane
02/23/09	54	1	1	350					clearlane
02/23/09	54	2	1	350					clearlane
02/23/09	117	2	1	350	2,081.00	2,136.80	473.44	483.38	clearlane
02/23/09	147	2	1	450	1,070.50	1,101.20	222.75	229.47	clearlane
02/23/09	179	3	2	350	0.00	75.90	0.00	13.00	clearlane
02/23/09	179	3	1	350	0.00	25.50	0.00	4.70	clearlane
02/23/09	166	4	3	350	0.00	105.20	0.00	18.30	clearlane
02/23/09	184	5	3	350	0.00	135.10	0.00	25.30	clearlane
02/23/09	159	6	3	350	0.00	76.10	0.00	16.80	clearlane
02/23/09	162	7	3	350	0.00	113.90	0.00	20.50	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
02/23/09	187	8	3	350	645.90	724.50	134.57	149.75	clearlane
02/23/09	136	9	1	350	942.60	1,040.70	177.66	194.53	clearlane
02/23/09	139	10	3	350	2,282.00	2,366.00	600.00	622.00	clearlane
02/23/09	155	11	2	350	0.00	74.20	0.00	14.60	clearlane
02/23/09	155	11	1	350	0.00	17.30	0.00	3.50	clearlane
02/23/09	144	12	3	350	704.10	787.50	147.28	163.10	clearlane
02/23/09	117	13	2	350	213.60	275.60	50.73	64.28	clearlane
02/23/09	139	night	1	350	2,366.00	2,402.00	622.00	628.00	clearlane
02/23/09	147	night	1	350	1,101.20	1,139.90	229.47	236.40	clearlane
02/23/09	136	night	1	350	1,040.70	1,071.80	194.53	199.60	clearlane
02/23/09	184	night	1	350	1,549.00	1,562.00	339.30	341.50	clearlane
02/24/09	54	1	2	300-350					clearlane
02/24/09	147	2	1	450	1,139.90	1,180.90	236.34	245.97	clearlane
02/24/09	179	3	1	350					clearlane
02/24/09	166	4	2	350	0.00	36.30	0.00	6.30	clearlane
02/24/09	184	5	2	350-450	0.00	47.70	0.00	10.50	clearlane
02/24/09	159	6	1	350	0.00	23.90	0.00	5.60	clearlane
02/24/09	162	7	1	350	0.00	47.10	0.00	9.60	clearlane
02/24/09	187	8	1	350	724.50	757.30	149.75	156.88	clearlane
02/24/09	136	9	1	350	1,071.80	1,106.90	199.60	205.53	clearlane
02/24/09	139	10	1	350	2,402.00	2,442.00	628.00	640.00	clearlane
02/24/09	155	11	1	350-400	0.00	41.50	0.00	8.00	clearlane
02/24/09	144	12	1	350	787.50	816.40	163.10	169.19	clearlane
02/24/09	117	13	1	400	275.60	304.70	64.28	71.03	clearlane
02/28/09	63	1	1	350					clearlane
02/28/09	191	2 10	1	350	1,088.50	1,128.20	228.41	234.97	clearlane
02/28/09	179	3	1	350					clearlane
02/28/09	166	4	1	350	0.00	39.70	0.00	6.40	clearlane
02/28/09	184	5	1	350	0.00	49.80	0.00	10.40	clearlane
02/28/09	162	6	1	350					clearlane
02/28/09	159	7	1	350	0.00	27.70	0.00	6.8`c	
02/28/09	187	8	1	350	757.30	786.40	156.88	162.78	clearlane

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
Date	#	#	Trips	Setting	Beginning	Ending	Beginning	Ending	Type
02/28/09	136	9	1	400	1,106.80	1,178.90	205.53	215.59	clearlane
02/28/09	155	11	1	350	0.00	36.60	0.00	6.60	clearlane
02/28/09	144	12	1	350	816.40	844.10	169.19	174.88	clearlane
02/28/09	117	13 10	1	350	304.70	324.90	71.03	74.67	clearlane
03/02/09	139	night	ice		2,442.00	2,442.50	640.00	640.50	clearlane
03/03/09	136	night			1,148.90	1,176.00	215.59	220.72	clearlane
03/03/09	187	night			1,660.40	1,670.60	362.40	364.40	clearlane
03/03/09	139	night		350	2,442.50	2,460.30	640.50	645.12	clearlane
03/03/09	184	5	1	450	0.00	6.60	0.00	3.30	sand
03/03/09	191	13	1	350	1,128.20	1,133.80	234.97	236.06	clearlane
03/04/09	57	1	1	350	333.30	354.60	72.05	75.27	clearlane
03/04/09	191	2	1	350	1,133.80	1,150.70	236.06	238.97	clearlane
03/04/09	179	3	1	350	0.00	27.80	0.00	4.50	clearlane
03/04/09	166	4	2	300-200	0.00	31.20	0.00	4.10	clearlane
03/04/09	184	5	2	350	0.00	29.00	0.00	5.50	clearlane
03/04/09	159	6	1	350	0.00	23.70	0.00	5.30	clearlane
03/04/09	162	7	1	350					clearlane
03/04/09	63	8	1	350					clearlane
03/04/09	136	9	1	350	1,176.00	1,203.90	220.72	225.31	clearlane
03/04/09	139	10	2	350	2,460.00	2,472.00	645.00	647.00	clearlane
03/04/09	155	11	1	350	0.00	22.10	0.00	3.80	clearlane
03/04/09	144	12	1	350	1,635.30	1,664.00	325.81	331.50	salt
03/04/09	117	13 2	2	350	324.90	331.30	74.67	75.92	clearlane
03/12/09	63	1	1	300					clearlane
03/12/09	191	2	1	300	1,150.70	1,170.50	238.97	242.19	clearlane
03/12/09	187	3 8	1	300	786.40	804.40	162.78	165.69	clearlane
03/12/09	166	4	1	300	0.00	9.20	0.00	1.30	clearlane
03/12/09	184	5	1	350	0.00	16.20	0.00	3.40	clearlane
03/12/09	159	6	1	300	0.00	20.80	0.00	3.30	clearlane
03/12/09	162	7	1	300	0.00	9.80	0.00	1.40	clearlane
03/12/09	147	9	1	350	1,180.90	1,194.20	245.97	248.31	clearlane
03/12/09	139	10	1						

NAMF - Daily Depar Dickey-John Detail									
				Dickey-John	Spreader	Spreader	Spreader	Spreader	
	Truck	Route	# of	Rate	Miles	Miles	Tons	Tons	Material
03/12/09	155	11	1	300	0.00	25.10	0.00	4.20	clearlane
03/12/09	144	12	1	300	844.10	862.10	174.88	178.03	clearlane
03/12/09	117	13	1	300					clearlane

North area plow routes

	2009--2010		ROUTE MILEAGE SHEET	
TRUCK 57 NERI / MCCAFFREY	**RTE 1**		**TRUCK 147 R OCONNELL /R BAXTER**	**RTE 8**
MOLLOY RD.	1.9		W TAFT (RT11-- HENRY CLAY BLVD	2.2
TOWN LINE RD.	0.6		VINE ST	1.5
THOMPSON RD.	0.7		WETZEL (HENRY CLAY--RT 57)	2.1
KINNE ST	1.4			**5.8**
JAMES ST	0.5		**TRUCK 136 P DAVIS / N AZZERELLO**	**RTE 9**
EXETER ST	0.7		MORGAN RD (TULIP--WETZEL)	2.5
FRANKLIN PARK DR.	0.9		HENRY CLAY (W TAFT-- WETZEL)	2.2
FLY RD. (KIRKVILLE-VILLAGE LINE)	1.5		LIVERPOOL BY-PASS	0.5
	8.2		TULIP ST	0.9
TRUCK 191 S BOVALINO OPP	**RTE 2**			**7.1**
FLY RD (E TAFT -- KIRKVILLE)	3.1		**TRUCK 139 L NORTON /C DANIELS**	**RTE10**
FREMONT RD (E TAFT-- KIRKVILLE)	3.1		KIRKVILLE RD (FREMONT-- KINNE)	2.5
E TAFT (NORTHERN --298)	3.1		NEW VENTURE GEAR	1.1
	9.3		FREMONT (KIRKVILLE-- RT290)	1.1
TRUCK 177 D GULLOTTO /D CORSARO	**RTE 3**		FREMONT SPUR	0.3
E. TAFT (NORTHERN -- RT 11)	3.3		KIRKVILLE SPUR ?	0.4
SOUTH BAY (RT 11 --THOMPSON	1.4			**5.4**
	4.7		**TRUCK 155 T HOPKINS / R COLE**	**RTE 11**
TRUCK 181 M SCHINTO OPP	**RTE 4**		BEAR RD (RT11-- TAFT)	3.5
HENRY CLAY (WETZEL -- OAK ORCHARD	4.4		ALLEN RD	1.3
WETZEL (RT 57-- BUCKLEY)	1.3		CHESTNUT (ALLEN--VILLAGE)	0.5

North area plow routes				
MORGAN RD (WETZEL-OAK ORCHARD)	4		BUCKLEY RD. (TAFT ROAD-HENRY CLAY)	2.2
GRANGE	0.9		WETZEL (BUCKLEY - HENRY CLAY)	1.4
	10.6			**8.9**
TRUCK 184 M MURPHY OPP	**RTE 5**		**TRUCK 144 S ZYGMONT / C HILLS**	**RTE 12**
CAUGHDENOY RD	11		JOHN GLENN BLVD (BUCKLEY-- RT57)	2.1
OAK ORCHARD	2.2		AIRPORT	0.8
MAPLE RD	**2.3**		ELECTRONICS	1.8
	15.5		BUCKLEY RD (henry clay Blvd.--John Glenn)	1.1
TRUCK 130 S DELELLO /L SALANGER	**RTE 6**			5.8
7TH NORTH (CITYLINE--ELECTRONICS	1.9			
BUCKLEY RD (W TAFT-- OLD L POOL0)	3.1		**TRUCK 117 C SMITH OPP**	**RTE 13**
OLD LIVERPOOL	2		KIRKVILLE RD (FREMONT-N KIRKVILLE)	4.2
LEMOYNE AVE	1		N KIRKVILLE	2
	8		N MANLIUS RD	2.8
TRUCK 162 D WRIGHT /C KRAUS	**RTE 7**		SCHEPPS RD (RT298- KIRKVILLE)	1.9
NORTHERN BLVD	3.9		MINOA RD (KIRKVILLE--RT 290	2.4
THOMPSON RD (TAFT--NORTHERN)	1.7		EASTERN RESEVIOR	0.3
THOMPSON RD (NORTHERN-- RT 31)	1.7			**13.8**
SOUTH BAY (THOMPSON --LAKESHORE)	3		**NIGHTS** / ODONNELL, BODLEY	
	10.3		DIAS , MCALLISTER	
NIGHT RIDER - CUMMINS			**LOADER**-FARRELL	
			LABORER-COWMEADOW	

Worksheet197-north area

Winter Operations Report - Onondaga County							
Date	Spreading	Plow	Dead Heading	Total Operational	Salt Used	Liquid Used	
D M Y	Distance(Miles)	Distance(Miles)	Distance(Miles)	Distance(Miles)	lb.	gal	gal / ton
11/12/2009	0	0.18	15.55	15.55	0	0	
13/12/2009	0	0.18	39.52	39.52	0	0	
14/12/2009	0	0.2	43.55	43.55	0	0	
16/12/2009	0	0.05	87.76	87.76	0	0	
17/12/2009	0	0.16	41.87	41.87	0	0	
21/12/2009	0	0	44.31	44.31	0	0	
23/12/2009	0	0.27	130.28	130.28	0	0	
25/12/2009	0	0.16	77.08	77.08	0	0	
26/12/2009	0	0.17	77.05	77.05	0	0	
27/12/2009	0	0.45	33.03	33.03	0	0	
28/12/2009	0	0.6	124.99	124.99	0	0	
29/12/2009	0	0.63	165.93	165.93	0	0	
30/12/2009	0	0.55	82.3	82.3	0	0	
1/1/2010	0	0.43	46.35	46.35	0	0	
2/1/2010	0	0.83	185.98	185.98	0	0	
3/1/2010	0	1.27	198.72	198.72	0	0	
4/1/2010	0	0.6	122.82	122.82	0	0	
5/1/2010	0	0.43	89.54	89.54	0	0	
6/1/2010	0	0.61	179.18	179.18	0	0	
7/1/2010	0	0.44	97.8	97.8	0	0	
8/1/2010	41.83	0.88	38.86	80.69	7.6	0	
9/1/2010	83.83	0.4	59.13	142.96	15.9	0	
12/2/2010	33.92	0.38	17.29	51.22	5.1	0	
13/02/2010	24.31	0.03	28.18	52.49	5	0	
14/02/2010	123.38	1.55	98.39	221.76	25.8	0	

Worksheet197-north area							
15/02/2010	66.38	0.49	59.49	125.87	11.9	0	
16/02/2010	48.06	1.17	61.6	109.66	8.3	0	
17/02/2010	84.23	0.79	100.57	184.8	18.9	0	
18/02/2010	85.83	0.75	60.78	146.61	16	0	
19/02/2010	16.24	0	36	52.24	2.5	0	
20/02/2010	22.06	0.06	14.19	36.25	4.4	0	
22/02/2010	38.14	0.2	8.96	47.1	6.4	0	
23/02/2010	104.54	0.35	28.36	132.9	18.6	0	
24/02/2010	100.64	0.05	31.63	132.27	18.1	0	
25/02/2010	5.68	0.17	6.18	11.85	1.3	0	
26/02/2010	43	1.18	62.12	105.12	8.5	0	
27/02/2010	29.38	0.63	14.75	44.12	5.6	0	
28/02/2010	36.81	0.05	39.19	76	7.9	0	
1/3/2010	11.64	0.23	37.93	49.57	0.3	0	
2/3/2010	0	0	5.7	5.7	0	0	
3/3/2010	0	0	7.44	7.44	0	0	
12/1/2010	75.56	0.69	65.95	141.51	5.8	0	
13/01/2010	1.16	0	25.93	27.09	0.3	0	
18/01/2010	18.26	0.26	15.19	33.45	3.2	0	
19/01/2010	40.19	0.49	29.6	69.78	5.8	0	
20/01/2010	68.22	0.76	64.45	132.66	12.3	0	
21/01/2010	0	0	37.74	37.74	0	0	
25/01/2010	0	0	5.79	5.79	0	0	
27/01/2010	18.57	0.5	15.59	34.17	3.2	0	
28/01/2010	103.94	0.83	82.66	186.6	20.2	114.3	5.7
29/01/2010	129.97	2.15	97.31	227.28	27.1	29	1.1
30/01/2010	67.73	0.52	27.7	95.43	12.4	0	
1/2/2010	37.66	0.61	21.56	59.23	6.3	0	
3/2/2010	90.03	0.52	69.72	159.74	18.4	0	

Worksheet197-north area							
4/2/2010	85.39	1.28	67.14	152.53	14.9	0	
5/2/2010	0	0.25	23.9	23.9	0	0	
8/2/2010	56.07	0.23	23.8	79.88	11.4	0	
					329.4	143.3	

Fayetteville_October_2010.xlsx

date	time	St. mile	end mile	brine gal
12/19/2008	11:00:00 AM	38250	38270	2550
12/20/2008	7:19:00 AM	38270	38306	1700
12/20/2008	5:00:00 AM	856	877	500
12/29/2008	10:00:00 AM	995	1011	4500
12/29/2008	9:00:00 AM	38306	38333	800
12/30/2008	1:30:00 PM	1024	1035	1000
1/5/2009	7:00:00 AM	4720	4722	850
1/5/2009	8:00:00 AM	1103	1122	2000
1/8/2009	1:00:00 PM	38493	38523	1700
1/9/2009	12:30:00 PM	1242	1264	500
1/9/2009	12:30:00 PM	38523	38544	400
1/11/2009	8:30:00 AM	38544	38566	850
1/12/2009	2:00:00 PM	38592	38604	100
1/12/2009	9:30:00 AM	38566	38592	1000
1/13/2009	12:30:00 PM	38604	38628	800
1/20/2009	9:00:00 PM	38651	38690	1600
2/18/2009	7:00:00 AM	38781	38798	850
2/19/2009	5:00:00 AM	1613	1629	848
2/20/2009	7:15:00 AM	38798	38818	850
2/20/2009	7:00:00 AM	1642	1659	1000
2/23/2009	7:30:00 AM	38819	38835	850
2/23/2009	9:30:00 AM	38833	38852	850
2/23/2009	1:35:00 PM	38852	38870	850
2/23/2009	7:00:00 AM	1701	1715	176
2/23/2009	10:00:00 AM	1715	1733	500
2/23/2009	1:30:00 PM	1733	1746	500
12/7/2009	12:00 PM	2451	2490	1500
12/10/2009	10:30 AM	2528	2569	1500

Fayetteville_October_2010.xlsx				
date	**time**	**St. mile**	**end mile**	**brine gal**
12/11/2009	7:00 AM	2575	2605	1000
12/15/2009	10:00 AM	2605	2641	1000
12/17/2009	9:00 AM	2701	2730	1000
12/21/2009	7:00 AM	15567	15609	792
12/21/2009	7:00 AM	2730	2773	750
12/22/2009	7:00 AM	15609	15628	394
12/22/2009	7:00 AM	2773	2795	750
12/23/2009	5:00 AM	2795	2811	210
12/28/2009	12:30 PM	2877	2904	500
12/31/2009	10:00 AM	2963	2982	500
1/5/2010	12:30 PM	3135	3176	500
1/7/2010	4:00 AM	25300	25323	300
1/7/2010	9:00 AM	3199	3220	773.5
1/8/2010	12:30 AM	3273	3287	500
1/9/2010	7:30 AM	3287	3323	500
1/19/2010	12:30 PM	3385	3401	332.2
1/20/2010	12:30 PM	3432	3447	365
1/26/2010	7:00 AM	3447	3466	630.7
1/27/2010	7:00 AM	3466	3479	422.7
1/28/2010	7:00 AM	3479	3490	481.7
1/29/2010	4:00 AM	3534	3602	493.7
1/30/2010	5:00 AM	3602	3645	454.7
2/8/2010	7:00 AM	3707	3729	373.3
2/9/2010	1:00 PM	3729	3770	415.8
2/16/2010	7:30 AM	3933	3954	428.3
2/17/2010	6:00 PM	3976	3992	344.3
2/18/2010	1:50 PM	4014	4031	403

Fayetteville_October_2010.xlsx				
date	**time**	**St. mile**	**end mile**	**brine gal**
2/19/2010	4:00 AM	4031	4072	467.8
2/22/2010	12:30 PM	4088	4101	478.6
2/25/2010	4:00 AM	4142	4214	132

Fayetteville_Feb22.xlsx

Superintendent Log

Date	**Time**	**Time since application**	**Surf Temp**	**Product**	**inches**	**Results**	**Temp**	**Comments**
		hours					**Thru storm**	
12/4/2010	6.00 am		27	Rock	1	Bare/wet pavement	30/27/27	
12/5/2010	4.00 am	24		Rock/brine	2	Bare/ wet tracks		Lake effect-heavy at times
12/5/2010	2.00 pm	10		Rock/brine	6	Bare/ wet tracks		Lake effect-heavy at times
12/6/2010	4.00 am	16	27	Rock/brine	4	Bare/wet pavement		
12/7/2010	3.00 am	8	20	Rock/brine	10	Bare/wet pavement	20/22	Snowed hard/road wet
12/7/2010	8.00 am	5	19	Rock/brine	3	Bare/wet pavement		
12/7/2010	2.00 pm	6	24	Rock/brine	4	Bare/wet pavement		
12/7/2010	6.00 pm	4	22	Rock/brine		Bare/wet pavement		
12/8/2010	4.00 am	12	10	Salt/hot mix	2	Bare/wet pavement	12	Some compacting where no traffic
12/8/2010	9.00 am	2	14	Salt/hot mix		Bare/wet pavement	12	Cleanup
12/9/2010	4.00 am	6	16	Rock/brine	8		16/25	Road wet under snow/no ice condition

Date	Time	Time since application hrs	Surf Temp	Product	inches	Results	Temp	Comments
12/9/2010	8.00 am	4	22	Rock/brine	3			
12/9/2010	2.00 pm	6	24	Rock/brine	4			
12/10/2010	4.00 am		24	Hot mix		Bare/wet pavement		Anti-ice
12/11/2010	4.00 am	24	29	Hot mix	Freezing rain			Freezing rain/app led to prevent freezing roads
1/11/2011	4.00 pm	24	20	Rock/brine	3	Bare/wet pavement	22/24	Freezing mist
1/11/2011	7.00 am	26	22	Hot mix	Mist	Bare/wet pavement		
1/11/2011	1.00 pm	26	24	Hot mix		Bare/wet pavement		
1/12/2011	4.00 am	16	16	Rock	4	Bare/wet pavement		
1/12/2011	9.30 am	4	18		1		19/19	Plow to keep clear/no salt cue to high humidity
1/12/2011	11.00 am	4	21	Rock	2	Bare/wet pavement		Hard lake effect
1/12/2011	4.00 pm	3	17	Rock	2	Bare/wet pavement		Lake effect-heavy at times
1/13/2011	4.00 am	12	12	Rock	3	Bare/wet pavement		
1/13/2011	9.00 am	5	10	Hot mix				Anti-ice
1/13/2011	12.30 pm	4	14	Hot mix				

Date	Time	Time since application	Surf Temp	Product	inches	Results	Temp	Comments
		hours					Thru storm	
1/14/2011	1.00 pm	10	21	Hot mix				
1/17/2011	4.00 am	48	12	Rock	12	Bare/wet tracks		
1/17/2011	9.00 am	2	5	Hot mix		Bare/wet pavement	17/-1/12	Sprayed after storm/ on some bad spots
1/18/2011	4.00 am	16	17	Rock	Dusting	Bare/wet pavement	24/29	Light snow changing to rain
1/18/2011	7.00 am	18	18	Hot mix	Freezing rain	Bare/wet pavement		
1/19/2011	4.00 am	24	18	Rock/ P wet	1	Bare/wet pavement	22/21	Anti-ice
1/20/2011	4.00 am	18	12	Rock	Dusting	Bare/wet pavement	16/14	
1/21/2011	4.00 am	24	15	Rock	Dusting	Bare/wet pavement	20/17	
1/21/2011	1.00 pm	9	19	Hot mix				
1/31/2011	4.00 am		18	Rock	Dusting	Bare/wet pavement	Jan-00	Anti-ice forecast for heavy wet snow
1/31/2011	10.00 am		6	Hot mix				
2/1/2011	6.00 am		12	Rock	2	Ice or compact	13/	
2/1/2011	10.00 am	2	12	Rock	3			
2/1/2011	2.00 pm	4	19	Hot mix				
2/2/2011	4.00 am	16	9	Rock	3			Heavy snow

Date	Time	Time since application	Surf Temp	Product	inches	Results	Temp	Comments
		hours					Thru storm	
2/2/2011	1.00 pm	5	19	Hot mix		Bare/wet pavement	15/1	
2/3/2011	4.00 am	15	14	Rock	3	Bare/wet pavement		
2/5/2011	1.00 pm	5	20	Hot mix		Bare/wet pavement	30/31	
2/5/2011	5.00 pm		19	Rock	ice	ice or compact		Freezing rain to snow
2/5/2011	5.00 pm			Rock			30/28	Freezing rain
2/5/2011	7.00 pm			Rock				Rain to snow
2/6/2011	4.00 am	12	19	Rock	8		30/30	
2/6/2011	7.00 am	3	18	Rock	Clean up	Bare/wet pavement		Cleanup
2/6/2011	4.00 am	6	20	Rock	6	Bare/wet pavement	28/20	Wet heavy snow
2/6/2011	9.00 am	2	10	Rock	8	Bare/wet tracks		
2/7/2011	4.00 am	20		Hot mix		Bare/wet tracks	32/16	Anti-ice
2/8/2011	4.00 am	24	28	Rock	2	Bare/wet tracks		
2/9/2011	4.00 am	20	8	Rock	3	Bare/wet tracks		Pre-wet
2/9/2011	10.00 am	8	6	Hot mix		Bare/wet tracks	8 to 6	

Fayetteville_Feb22.xlsx
Operator Log

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fu el	Salt	Result	Fuel	Salt	
12/1/2010	8	12.30 pm	4.30 pm	4731				A			
12/1/2010	6	12.30 pm	2.30 pm	1771	1801		2 loads	A		2 loads	
12/4/2010	17	7.00 am	9.20 am	26129	26145			A	7.6 G	X	
12/4/2010	8	7.15 am	9.15 am	4803	4822						
12/5/2010	17	5.30 am	8.00 am	26145	26164			C	4 G	X	
12/5/2010	17	3.00 pm	5.30 pm	26164	26186			A		X	
12/5/2010	8	6.00 am	8.00 am	4822	4841			A		1 load	
12/5/2010	8	3.00 pm	5.00 pm					A		1 load	
12/6/2010	17	4.00 am	8.30 am	26186	26223						
12/6/2010	17	6.00 pm	8.30 pm	26223	26242					X	Deicing
12/6/2010	8	4.00 am	7.00 am	4861	4883			A	1 G	1 load	
12/7/2010	17	4.00 am	7.30 am	26242	26267						
	17	12.30 pm	3.00 pm	26267	26288					X	
12/9/2010	4	4.00 am	8.00 am	2533	2614			A	16 G	1 load	

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fuel	Salt	Result	Fuel	Salt	
12/9/2010	8	4.00 am	7.30 am	4907	4929				17.9 G	X	
12/16/2010	17	4.00 am	7.00 am	26448	26473					X	
12/17/2010	8			4982	5010			C	9.4 G	5 yds.	
12/20/2010	8	7.00 am	8.30 am	5010	5023			E		1 load	
12/21/2010	8	1.30 pm		5023	5040			A			
12/22/2010	8	12.30 pm	3.00 pm	5050	5058			A			Anti-ice
12/22/2010	8	5.00 am	7.00 am	5028	5076			E	20 G		
12/23/2010	17	5.00 am	7.00 am	26509	26528						
12/24/2010	17	7.00 am	3.30 pm	26528	26547					X	
12/27/2010	8	2.00 pm		5093	5110			A			Anti-ice
12/28/2010	8	7.00 am	9.00 am	5110	5128			A	16.8 G		
12/28/2010	4	7.00 am	9.00 am	2802	2817						Salt
1/4/2011	8	7.00 am	9.00 am	5130	5149				7.3 G		Anti-ice
1/5/2011	8	4.00 am	7.00 am	5149	5171			C		1 load	Salt/pre-wet
1/5/2011	6	4.00 am	7.10 am	2233	2255			A	4 G		Anti/Ice-deice

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fu el	Salt	Result	Fuel	Salt	
1/5/2011	17	4.00 am	7.00 am	26547	26572				9G		Salt/hot mix
1/6/2011	17	5.00 am	7.00 am	26572	26593				6 G		Salt/hot mix
1/6/2011	8	5.00 am	7.30 am	5171	5190			A	20 G		Salt/pre-wet
1/7/2011	8	7.00 am	8.30 am	5190	5204			A		30g/ mi	Anti-ice
1/7/2011	17	12.30 pm	2.30 pm	26593	36613				6 G		Salt/hot mix
1/7/2011	8	12.30 pm	3.00 pm	5204	5221			A	10 G		Salt/pre-wet
1/9/2011	8	5.00 am	7.00 am	5221	5242			C			Salt/pre-wet
1/9/2011	8	12.00 pm	2.00 pm	5242	5261		150G/mi	E			Salt/pre-wet
1/9/2011	17	5.00 am	7.15 am	26613	26634				5 G		Salt/hot mix
1/9/2011	17	12.00 pm	2.00 pm	26634	26654						Salt/hot mix
1/10/2011	17	4.00 am		26654	26678				12 G		Salt/hot mix
1/10/2011	8	9.00 am	12.00 pm	5283	5302						Salt/pre-wet
1/10/2011	8	4.00 am	7.00 am	5261	5283			C	30 G		Salt/pre-wet
1/10/2011	4	4.00 am	7.00 am	2942	2979		2 yds.	E			Salt
1/10/2011	4	9.30 am	11.30 am				1yd	A			Salt

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fu el	Salt	Result	Fuel	Salt	
1/11/2011	8	7.00 am	8.30 am	5302	5317		30G/mi	A			Ant-ice
1/11/2011	8	1.30 pm	3.00 pm	5317	5332		30G/mi	A			Ant-ice
1/12/2011	8	4.00 am	7.00 am	5332	5353		150G/mi	E			Pre-wet
1/12/2011	8	12.30 pm		5353	5371		200G/mi	E	70.2 G		Salt/pre-wet
1/12/2011	8	4.00 am	6.30 am	5372	5385		30G/mi	E			Salt
1/12/2011	17	4.00 am	7.00 am	26697	26724						Salt/hot mix
1/12/2011	17	12.30 pm	6.30 pm	26724	26776						Salt/hot mix
1/13/2011	8	4.00 am	7.00 am	5388	5410		250G/mi	E	32G		Salt
1/13/2011	8	9.00 am	12.00 pm	5410	5444		30G/mi	E			Anti-ice
1/13/2011	17	4.00 am	7.00 am	26776	26789						Salt/hot mix
1/14/2011	17	4.00 am	7.00 am	26789	26811						Salt/hot mix
1/14/2011	8	4.00 am	7.00 am	5444	5466		250G/mi	C	166.1		Salt
1/14/2011	10	1.00 pm	2.30 pm	41250	41271			A			Hot-mix
1/14/2011	8	12.30 pm		5466	5482		30G/mi	C			Anti-ice
1/15/2011	8	2.30 pm		5482	5500		150G/mi	E			Salt

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fu el	Salt	Result	Fuel	Salt	
1/15/2011	17	2.00 pm	4.30 pm	26811							Salt/hot mix
1/16/2011	17	5.00 am	11.30 pm	26830	26874						Salt/hot mix
1/16/2011	17	1.00 pm	3.30 pm	26874	26896						
1/16/2011	8	5.00 am	3.15 pm	5500	5565				60 G		Salt
1/17/2011	8	4.00 am	7.00 am	5565	5586		250G/mi	E			Salt
1/17/2011	17	4.00 am		26896	26902						
1/18/2011	8	5.00 am	7.00 am	5586	5601		150G/mi				Salt
1/18/2011	8	9.30 pm	11.00 pm	5601	5617	15 G					Anti-ice
1/19/2011	8	4.00 am	7.00 am	5617	5638		150G/mi	C			Salt
1/19/2011	8	12.30 pm	3.30 pm	5638	5655	32 G	200G/mi	C			Salt and pre-wet
1/19/2011	17	4.00 am	7.00 am	26902	26926	26 G					salt / hot mix
1/20/2011	8	5.00 pm	7.00 pm	5655	5673	10 G	200G/mi	C			salt and prewet
1/21/2011	8	4.00 am	7.00 am	5673	5695		200G/mi	E			salt and prewet
1/21/2011	8	12.30 pm		5695	5714		200G/mi	A			salt and prewet
1/28/2011	17	5.00 am	7.00 am	26996	27017						salt/hot mix

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fuel	Salt	Result	Fuel	Salt	
1/29/2011	17	5.00 am	7.00 am	27017	27037						salt
1/31/2011	17	5.00 am	7.00 am	27037	27057	16 G					salt/hot mix
1/31/2011	8	12.30 pm	2.30 pm	5809	5826	30 G					anti-ice
2/1/2011	8	7.00 am	9.30am	5829	5865	19 G	200G/mi	E			
2/1/2011	8	5.00 pm	7.15 pm	5865			200G/mi	E			salt and prewet
2/3/2011	4	4.00 am	7.00 am	3425	3438		2 yds.	C			salt
2/3/2011	8	4.00 am	7.00 am	5587	5910	23 G	200 G/mi	E			salt and prewet
2/4/2011	8	12.30 pm	3.00 pm	5910	5935	5G	30 G/mi	A			anti-ice
2/5/2011	8	5.15 pm	8.00 pm	5935	5954		250 G	E			salt and prewet
2/5/2011	17	5.30 pm	8.00 pm	27147	27166						salt/hot mix
2/6/2011	8	4.00 am	10.00 am	5955	5996	27 G	250 G	A			salt and pre-wet
2/6/2011	17	4.00 am	11.00 am	27166	27213						salt/hot mix
2/7/2011	8	5.00 am	7.00 am	5996	6019	8G	30G	C			anti-ice
2/7/2011	29	5.00 am	7.00 am	21067	21085			C			anti-ice
2/8/2011	8	5.00 am	7.15 am	6019	6041		250G	E			salt and prewet

Start Date	Truck	Start time	End time	Start Mileage	End mileage	Fu el	Salt	Result	Fuel	Salt	
2/8/2011	8	9.00 am	12.00 pm	6041	6064	21 G	250G	E			salt and prewet
2/9/2011	17	4.00 am	7.00 am	6093	6114	17 G		C			salt and prewet

NYSDOT I-81/I-481 Data

Date	Truck ID	Remarks	Beat ID	start odometer	end odometer	Distance	Total miles	liquid material (Start)	liquid material (End)	Gallons	Gallons	Spread miles (start)	Spread miles (end)	Spread miles (based on DJ miles)	Spread mles	Application rate (Gal/mile based on odometer reading)	Application rate (Gal/mile based on spread miles)	Comments
11/26/2010	915035																	
11/26/2010	915035		Bridge decks (I81/I481)	27082	27279	197		2000	600	1400						7.1		Truck Not in Snow Mat
11/26/2010	915035		Bridge decks (I81/I481)															
11/26/2010	915035		Bridge decks (I81/I481)															
12/2/2010	915035		RI-81	37314	37425	111		151870	156590	4720		2852	2961	109		42.5	43.3	Truck Not in Snow Mat
				37702	37728	26		155797	157830	2033		2962	2980	18				
12/11/2010	915035		I-81 in city	37728	37801	73	99	157830	158506	676	2709	2980	3010	30	48	27.4	56.4	
12/13/2010	915035	Most likely left lane	I-81 and I-481	37792	37896	104		158606	159356	750		3010	3021	11		7.2	68.2	
				37993	38003	10		161180	161453	273		3042	3048	6				
12/21/2010	905035	Most likely left lane (north of city)	I-81	38003	38029	26	36	161453	161778	325	598	3048	3054	6	12	12.5	49.8	
12/27/2010	915035		I-81 bridge walls	38029	38151	122		161782	163606	1824		3055	3110	55		15.0	33.2	
12/28/2010	915035	Left and center lanes	I-81	38183	38298	115		163606.7	166130.8	2524.1		3110.6	3214.3	103.7		21.9	24.3	
1/3/2011	115029		I-81 N and S	7234	7304	70		0	1711.8	1711.8		0	43.7	43.7		24.5	39.2	Anti-ice
1/3/2011	115038		I-81 N and S	7704	7792	88		1823	4105	2282		2074	2095	95		25.9	24.0	
1/5/2011	915035		I-81	38418	38483	65		166193.2	168286.2	2093		3214.4	3235.4	21		32.2	99.7	Spray all of 81 walls from brighton to 481 N/S/ left and right lanes
1/7/2011	915035	City and northern end	I-81	38531	38651	120		168287	171697	3410		3235.4	3334.6	99.2		28.4	34.4	
1/9/2011	915035		I-81 walls	38811	38886	75		172004.2	174126.5	2122.3		3335.6	3357.5	21.9		28.3	96.9	I-81 park street bridge parapet walls
1/20/2011	115029			70024.2	70070.1	45.9		0	1561.2	1561.2		0	35.6	35.6		34.0	43.9	Anti ice
1/20/2011	915035		I-81 bridge walls	38886	38901	15		174126.5	174327.5	201		3357.5	3359.5	2		13.4	100.5	Bridge parapets, right side only

RELEVANT RAW DATA RECEIVED FROM NYSDOT FOR COST ANALYSES FOR THE USE OF NATURAL BRINE

Documents Provided for Cost of Rock Salt

New York State Office Of General Services
Procurement Services Group
Corning Tower Building
Empire State Plaza
Albany, New York 12242
http://www.ogs.state.ny.us

PURCHASING MEMORANDUM

CONTRACT AWARD NOTIFICATION UPDATE

AWARD NUMBER: 20883
21344
21749

DATE: March 8, 2011

GROUP: 01800 - ROAD SALT
(All State Agencies & Political Subdivisions)

CONTRACT PERIOD: September 1, 2010 through
August 31, 2011

CONTRACTORS/
CONTRACT NOS.: ***SEE BELOW**

PLEASE ADDRESS INQUIRIES TO:
STATE AGENCIES & CONTRACTORS
Beverly L. Moore
Purchasing Officer I
(518) 474-7273
beverly.moore@ogs.state.ny.us

OTHER AUTHORIZED USERS
Customer Services
(518) 474-6717

*AWARD #	CONTRACTOR	CONTRACT#
20883	American Rock Salt	PC63267
20883	Cargill Inc. Deicing Technology	PC63269
21344	American Rock Salt	PC64066
21344	Atlantic Salt, Inc.	PC64067
21344	Cargill Inc. Deicing Technology	PC64068
21344	International Salt Co.	PC64069
21749	Cargill Inc. Deicing Technology	PC64740

SUBJECT: **FUEL PRICE ADJUSTMENT FOR ALL COUNTIES FOR THE WEEK OF MARCH 14, 2011 THROUGH MARCH 20, 2011**

TO ALL STATE AGENCIES AND OTHERS AUTHORIZED TO USE THE ABOVE REFERENCED CONTRACTS:

In accordance with the terms of the contract, we are implementing a fuel price adjustment on a weekly basis beginning September 1, 2010. **This Purchasing Memorandum applies to ALL counties.**

Please see following pages for the fuel price adjustment in each county.

(continued)

FUEL PRICE ADJUSTMENT FOR ALL COUNTIES FOR THE WEEK OF MARCH 14, 2011 THROUGH MARCH 20, 2011: (Cont'd)

COUNTY	CONTRACTOR	CONTRACT PRICE PER TON	FUEL PRICE ADJUSTMENT	PRICE PER TON INCLUDING FUEL PRICE ADJUSTMENT
ALBANY	American Rock	$52.43	$1.01	$53.44
ALLEGANY	American Rock	$40.44	$1.01	$41.45
BRONX	Atlantic	$67.67	$1.01	$68.68
BROOME	Cargill	$40.23	$1.01	$41.24
CATTARAUGUS	American Rock	$40.78	$1.01	$41.79
CAYUGA	Cargill	$36.72	$1.01	$37.73
CHAUTAUQUA	American Rock	$48.61	$1.01	$49.62
CHEMUNG	Cargill	$40.00	$1.01	$41.01
CHENANGO	Cargill	$44.80	$1.01	$45.81
CLINTON	American Rock	$62.00	$1.01	$63.01
COLUMBIA	Cargill	$55.24	$1.01	$56.25
CORTLAND	Cargill	$36.76	$1.01	$37.77
DELAWARE	Cargill	$52.12	$1.01	$53.13
DUTCHESS	International	$64.10	$1.01	$65.11
ERIE	American Rock	$40.52	$1.01	$41.53
ESSEX	American Rock	$68.00	$1.01	$69.01
FRANKLIN	American Rock	$62.00	$1.01	$63.01
FULTON	Cargill	$51.39	$1.01	$52.40
GENESEE	American Rock	$38.76	$1.01	$39.77
GREENE	Cargill	$57.43	$1.01	$58.44
HAMILTON	Cargill	$62.27	$1.01	$63.28
HERKIMER	Cargill	$48.28	$1.01	$49.29
JEFFERSON	American Rock	$57.41	$1.01	$58.42
KINGS	Atlantic	$67.67	$1.01	$68.68
LEWIS	American Rock	$59.88	$1.01	$60.89
LIVINGSTON	American Rock	$38.89	$1.01	$39.90
MADISON	Cargill	$46.01	$1.01	$47.02
MONROE	American Rock	$40.13	$1.01	$41.14
MONTGOMERY	Cargill	$51.39	$1.01	$52.40
NASSAU	Atlantic	$66.20	$1.01	$67.21
NEW YORK	Atlantic	$67.67	$1.01	$68.68
NIAGARA	American Rock	$43.49	$1.01	$44.50
ONEIDA	Cargill	$44.98	$1.01	$45.99
ONONDAGA	Cargill	$41.23	$1.01	$42.24
ONTARIO	American Rock	$35.12	$1.01	$36.13
ORANGE	Cargill	$55.26	$1.01	$56.27
ORLEANS	American Rock	$38.76	$1.01	$39.77
OSWEGO	American Rock	$46.34	$1.01	$47.35

(continued)

Electricity Use at Van Rensselaer Street Natural Brine Site (Records from National Grid Used for preparation of Table)

Dates	Total Cost	Costs for Power	KWh
3/9/10-4/8/10	$123.57	$38.69	99
4/8/10-5/10/10	$113.88	$37.63	96
5/10/10-6/8/10	$149.34	$35.46	82
6/8/10-7/12/10	$187.60	$38.26	93
7/12/10-8/9/10	$186.50	$36.46	80
8/9/10-9/9/10	$113.41	$37.63	88
9/9/10-10/6/10	$172.82	$59.41	237
10/6/10-11/5/10	$173.76	$39.20	105
11/5/10-12/8/10	$183.51	$46.21	151
12/8/10-1/7/11	$194.26	$48.38	160
1/7/11-2/7/11	$194.39	$60.60	227
2/7/11-3/8/11	$192.81	$37.62	93
	Total	**$515.55**	

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SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Mar 9, 2010 to Apr 8, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	May 6, 2010	$ 123.57

www.nationalgridus.com

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Apr 12, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Apr 09	268	Nov 09	230
May 09	233	Dec 09	201
Jun 09	218	Jan 10	131
Jul 09	236	Feb 10	140
Aug 09	207	Mar 10	90
Sep 09	210	Apr 10	99
Oct 09	261		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	129.61
Payment Received on MAR 18 (*Check*)	- 44.73
Balance Forward	**84.88**
Current Charges	+ 38.69
Amount Due ▶	**$ 123.57**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	33.59	5.10	38.69
Total Current Charges	**$ 33.59**	**$ 5.10**	**$ 38.69**

PAYMENT CONCERNS?: We're here to help you. We have several plans that can help you manage your energy bills. Go to www.nationalgridus.com/paymentoptions to find out more or call us at the number on your bill.

GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE: Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .

★ **WILL WE BE ABLE TO REACH YOU DURING A POWER OUTAGE?:** During a power outage, phones with a direct link to a local phone line are able to operate. Phones that are not directly linked (for example, wireless phones with answering machines) need electricity to make/receive calls. If you would like to register another phone number, such as a cell phone, as your account's primary phone number, please go to www.nationalgridus.com/myaccount to update your information so that we may be able to reach you with important information during power outages.

KEEP THIS PORTION FOR YOUR RECORDS

RETURN THIS PORTION WITH YOUR PAYMENT

nationalgrid

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	May 6, 2010	$ 123.57 *includes amount past due*

▶ DID YOU FORGET ? ◀

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 05544
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003869 382639313440000123571 26

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Mar 9, 2010 to Apr 8, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	May 6, 2010	$ 123.57

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice.

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5048 *Actual*	4949 *Actual*	99	1	99 kWh
				Total Energy Usage	**99 kWh**
				Billed Energy Usage	**99 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE May 10
SERVICE PERIOD Mar 9 - Apr 8 NUMBER OF DAYS IN PERIOD 30
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06615	x 99 kWh	6.55
Delivery Adjustment	0.02072	x 99 kWh	2.05
SBC/RPS	0.00565932	x 99 kWh	0.56
Incr State Assessment	0.00403	x 99 kWh	0.40
Transmission Rev Adj	0.00215	x 99 kWh	0.21
Tariff Surcharge	1.0101 %		0.31
Sales Tax	8.0 %		2.49
	Total Delivery Services		**$ 33.59**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.04716	x 99 kWh	4.67
Tariff Surcharge	1.0101 %		0.05
Sales Tax	8.0 %		0.38
	Total Supply Services		**$ 5.10**

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www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Apr 8, 2010 to May 10, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jun 4, 2010	$ 113.88

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
May 11, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
May 09	233	Dec 09	201
Jun 09	218	Jan 10	131
Jul 09	236	Feb 10	149
Aug 09	207	Mar 10	90
Sep 09	210	Apr 10	89
Oct 09	261	May 10	96
Nov 09	230		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	123.57
Payment Received on MAY 10 (*Check*)	- 47.32
Balance Forward	76.25
Current Charges	+ 37.63
Amount Due ▶	**$ 113.88**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	31.85	5.78	37.63
Total Current Charges	**$ 31.85**	**$ 5.78**	**$ 37.63**

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GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE: Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .

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RETURN THIS PORTION WITH YOUR PAYMENT

nationalgrid

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jun 4, 2010	$ 113.88 *includes amount past due*

▶ DID YOU FORGET ? ◀

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$ ______

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 06425
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003763 3826393134800001138815 5

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Apr 8, 2010 to May 10, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jun 4, 2010	$ 113.88

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5144 *Actual*	5048 *Actual*	96	1	96 kWh
				Total Energy Usage	**96 kWh**
				Billed Energy Usage	**96 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Jun 8
SERVICE PERIOD Apr 8 - May 10 NUMBER OF DAYS IN PERIOD 32
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06615	x 96 kWh	6.36
Delivery Adjustment	0.0098	x 96 kWh	0.94
SBC/RPS	0.005927	x 96 kWh	0.56
Incr State Assessment	0.00403	x 96 kWh	0.39
Transmission Rev Adj	-0.00077	x 96 kWh	-0.07
Tariff Surcharge	1.0101 %		0.29
Sales Tax	8.0 %		2.36
	Total Delivery Services		**$ 31.85**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.05516	x 96 kWh	5.30
Tariff Surcharge	1.0101 %		0.05
Sales Tax	8.0 %		0.43
	Total Supply Services		**$ 5.78**

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD		PAGE 1 of 4
May 10, 2010 to Jun 8, 2010		
ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jul 3, 2010	$ 149.34

www.nationalgridus.com

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Jun 9, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Jun 09	218	Jan 10	131
Jul 09	236	Feb 10	149
Aug 09	207	Mar 10	90
Sep 09	210	Apr 10	99
Oct 09	261	May 10	96
Nov 09	230	Jun 10	82
Dec 09	201		

ACCOUNT BALANCE

Previous Balance		113.88
Payment Received	*No payments have been received during this billing period*	- 0.00
Balance Forward		**113.88**
Current Charges		+ 35.46
	Amount Due ▶	**$ 149.34**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	30.07	5.39	35.46
Total Current Charges	**$ 30.07**	**$ 5.39**	**$ 35.46**

NOTICE: In compliance with an update provided in the rate plan approved May 2009, new gas delivery pricing will take effect on May 20, 2010. These new gas delivery rates will be posted on www.nationalgrid.com/rates. Questions? Please call 1-800-642-4272.

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jul 3, 2010	$ 149.34

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739

05836

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003546 38263931341000014934184

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD		PAGE 2 of 4
May 10, 2010 to Jun 8, 2010		
ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jul 3, 2010	$ 149.34

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5226 *Actual*	5144 *Actual*	82	1	82 kWh
				Total Energy Usage	**82 kWh**
				Billed Energy Usage	**82 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Jul 9
SERVICE PERIOD May 10 - Jun 8 NUMBER OF DAYS IN PERIOD 29
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer		21.02
Delivery	0.06615 x 82 kWh	5.43
Delivery Adjustment	0.00658 x 82 kWh	0.54
SBC/RPS	0.005927 x 82 kWh	0.49
Incr State Assessment	0.00403 x 82 kWh	0.33
Transmission Rev Adj	-0.00303 x 82 kWh	-0.25
Tariff Surcharge	1.0101 %	0.28
Sales Tax	8.0 %	2.23
	Total Delivery Services	**$ 30.07**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.06029 x 82 kWh	4.94
Tariff Surcharge	1.0101 %	0.05
Sales Tax	8.0 %	0.40
	Total Supply Services	**$ 5.39**

nationalgrid

SERVICE FOR (240006 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jun 8, 2010 to Jul 12, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Aug 5, 2010	$ 187.60

www.nationalgridus.com

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Jul 12, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Jul 09	236	Feb 10	149
Aug 09	207	Mar 10	90
Sep 09	210	Apr 10	99
Oct 09	261	May 10	96
Nov 09	230	Jun 10	82
Dec 09	201	Jul 10	93
Jan 10	131		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance		149.34
Payment Received	*No payments have been received during this billing period*	- 0.00
Balance Forward		**149.34**
Current Charges		+ 38.26
	Amount Due ▶	**$ 187.60**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	31.19	7.07	38.26
Total Current Charges	**$ 31.19**	**$ 7.07**	**$ 38.26**

NOTICE: In compliance with an update provided in the rate plan approved May 2009, new gas delivery pricing will take effect on May 29, 2010. These new gas delivery rates will be posted on www.nationalgrid.com/rates. Questions? Please call 1-800-642-4272 .

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300 Erie Blvd West
Syracuse NY 13202-0960

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Aug 5, 2010	$ 187.60 *includes amount past due*

▶ DID YOU FORGET ? ◀

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 05828
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003826 38263931349000018760217

nationalgrid

SERVICE FOR (240006 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jun 8, 2010 to Jul 12, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Aug 5, 2010	$ 187.60

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	5319 *Actual*		5226 *Actual*		93		1		93 kWh
							Total Energy Usage		**93 kWh**
							Billed Energy Usage		**93 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Aug 10
SERVICE PERIOD Jun 8 - Jul 12 NUMBER OF DAYS IN PERIOD 34
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06615	x 93 kWh	6.15
Delivery Adjustment	0.00575	x 93 kWh	0.54
SBC/RPS	0.00603817	x 93 kWh	0.56
Incr State Assessment	0.00403	x 93 kWh	0.37
Transmission Rev Adj	-0.00051	x 93 kWh	-0.05
Tariff Surcharge	1.0101 %		0.29
Sales Tax	8.0 %		2.31
	Total Delivery Services		**$ 31.19**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.06964	x 93 kWh	6.48
Tariff Surcharge	1.0101 %		0.07
Sales Tax	8.0 %		0.52
	Total Supply Services		**$ 7.07**

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www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jul 12, 2010 to Aug 9, 2010

PAGE 1 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Sep 3, 2010	$ 186.50

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Aug 10, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Aug 09	207	Mar 10	90
Sep 09	210	Apr 10	99
Oct 09	261	May 10	96
Nov 09	230	Jun 10	82
Dec 09	201	Jul 10	93
Jan 10	131	Aug 10	80
Feb 10	149		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	187.60
Payment Received on JUL 19 (*Check*)	- 37.56
Balance Forward	**150.04**
Current Charges	+ 36.46
Amount Due ▶	**$ 186.50**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	29.67	6.79	36.46
Total Current Charges	**$ 29.67**	**$ 6.79**	**$ 36.46**

NOTICE: In compliance with an update provided in the rate plan approved May 2009, new gas delivery pricing will take effect on May 29, 2010. These new gas delivery rates will be posted on www.nationalgrid.com/rates. Questions? Please call 1-800-642-4272.

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	**Sep 3, 2010**	**$ 186.50** *includes amount past due*

300 Erie Blvd West
Syracuse NY 13202-0960

▶ DID YOU FORGET ? ◀

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739 01897

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003646 382639313410000186502466

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jul 12, 2010 to Aug 9, 2010

PAGE 2 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Sep 3, 2010	$ 186.50

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	=	Total Usage
Energy	5399 *Actual*	5319 *Actual*	80	1		80 kWh
				Total Energy Usage		**80 kWh**
				Billed Energy Usage		**80 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Sep 9
SERVICE PERIOD Jul 12 - Aug 9 NUMBER OF DAYS IN PERIOD 28
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer		21.02
Delivery	0.06615 x 80 kWh	5.29
Delivery Adjustment	0.00187 x 80 kWh	0.15
SBC/RPS	0.006242 x 80 kWh	0.50
Incr State Assessment	0.00403 x 80 kWh	0.32
Transmission Rev Adj	-0.00097 x 80 kWh	-0.08
Tariff Surcharge	1.0101 %	0.27
Sales Tax	8.0 %	2.20
	Total Delivery Services	**$ 29.67**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.07786 x 80 kWh	6.23
Tariff Surcharge	1.0101 %	0.06
Sales Tax	8.0 %	0.50
	Total Supply Services	**$ 6.79**

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www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Aug 9, 2010 to Sep 9, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Oct 6, 2010	$ 113.41

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Sep 10, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Sep 09	210	Apr 10	99
Oct 09	261	May 10	96
Nov 09	230	Jun 10	82
Dec 09	201	Jul 10	93
Jan 10	131	Aug 10	80
Feb 10	149	Sep 10	88
Mar 10	90		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	186.50
Payment Received on AUG 23 (*Check*)	- 35.46
Payment Received on AUG 23 (*Check*)	- 37.63
Payment Received on AUG 23 (*Check*)	- 37.63
Balance Forward	**75.78**
Current Charges	+ 37.63
Amount Due ▶	**$ 113.41**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	31.02	6.61	37.63
Total Current Charges	**$ 31.02**	**$ 6.61**	**$ 37.63**

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Oct 6, 2010	$ 113.41 *includes amount past due*

▶ DID YOU FORGET ? ◀

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739

06301

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000003763 38263931342000011341279

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Aug 9, 2010 to Sep 9, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Oct 6, 2010	$ 113.41

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	5487 *Actual*		5399 *Actual*		88		1		88 kWh
							Total Energy Usage		**88 kWh**
							Billed Energy Usage		**88 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Oct 7
SERVICE PERIOD Aug 9 - Sep 9 NUMBER OF DAYS IN PERIOD 31
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer				21.02
Delivery	0.06615	x	88 kWh	5.82
Delivery Adjustment	0.00922	x	88 kWh	0.82
SBC/RPS	0.006242	x	88 kWh	0.55
Incr State Assessment	0.00403	x	88 kWh	0.35
Transmission Rev Adj	-0.00151	x	88 kWh	-0.13
Tariff Surcharge	1.0101 %			0.29
Sales Tax	8.0 %			2.30
	Total Delivery Services			**$ 31.02**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.06881	x	88 kWh	6.06
Tariff Surcharge	1.0101 %			0.06
Sales Tax	8.0 %			0.49
	Total Supply Services			**$ 6.61**

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www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Sep 9, 2010 to Oct 6, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Nov 3, 2010	$ 172.82

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Oct 8, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Oct 09	261	May 10	96
Nov 09	230	Jun 10	82
Dec 09	201	Jul 10	93
Jan 10	131	Aug 10	80
Feb 10	149	Sep 10	88
Mar 10	90	Oct 10	237
Apr 10	99		

ACCOUNT BALANCE

Previous Balance		113.41
Payment Received	*No payments have been received during this billing period*	- 0.00
Balance Forward		**113.41**
Current Charges		+ 59.41
	Amount Due ▶	**$ 172.82**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	43.93	15.48	59.41
Total Current Charges	**$ 43.93**	**$ 15.48**	**$ 59.41**

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KEEP THIS PORTION FOR YOUR RECORDS

RETURN THIS PORTION WITH YOUR PAYMENT

nationalgrid

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	**Nov 3, 2010**	**$ 172.82**

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 06507
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 1303
BUFFALO NY 14240

000005941 382639313490000172823O7

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Sep 9, 2010 to Oct 6, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Nov 3, 2010	$ 172.82

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DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5724 *Actual*	5487 *Actual*	237	1	237 kWh
				Total Energy Usage	**237 kWh**
				Billed Energy Usage	**237 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Nov 5
SERVICE PERIOD Sep 9 - Oct 6 NUMBER OF DAYS IN PERIOD 27
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer				21.02
Delivery	0.06615	x	237 kWh	15.68
Delivery Adjustment	0.00652	x	237 kWh	1.55
SBC/RPS	0.00636865	x	237 kWh	1.52
Incr State Assessment	0.00403	x	237 kWh	0.96
Transmission Rev Adj	-0.00193	x	237 kWh	-0.46
Tariff Surcharge	1.0101 %			0.41
Sales Tax	8.0 %			3.25
			Total Delivery Services	**$ 43.93**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.05989	x	237 kWh	14.19
Tariff Surcharge	1.0101 %			0.14
Sales Tax	8.0 %			1.15
			Total Supply Services	**$ 15.48**

nationalgrid

www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Oct 6, 2010 to Nov 5, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Dec 2, 2010	$ 173.76

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Nov 8, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Nov 09	230	Jun 10	82
Dec 09	201	Jul 10	93
Jan 10	131	Aug 10	80
Feb 10	149	Sep 10	88
Mar 10	90	Oct 10	237
Apr 10	99	Nov 10	105
May 10	96		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	172.82
Payment Received on NOV 8 (*Check*)	- 38.26
Balance Forward	**134.56**
Current Charges	+ 39.20
Amount Due ▶	**$ 173.76**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	33.38	5.82	39.20
Total Current Charges	**$ 33.38**	**$ 5.82**	**$ 39.20**

- **NOTICE:** Important notice with your bill regarding a new payment address beginning 10/20/10. For more information, please go to www.nationalgridus.com.
- **PAYMENT CONCERNS?:** We're here to help you. We have several plans that can help you manage your energy bills. Go to www.nationalgridus.com/paymentoptions to find out more or call us at the number on your bill .
- **GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE:** Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .
- ★ **WILL WE BE ABLE TO REACH YOU DURING A POWER OUTAGE?:** During a power outage, phones with a direct link to a local phone line are able to operate. Phones that are **not** directly linked (for example, wireless phones with answering machines) need electricity to make/receive calls. If you would like to register another phone number, such as a cell phone, as your account's primary phone number, please go to www.nationalgridus.com/myaccount to update your information so that we may be able to reach you with important information during power outages.

KEEP THIS PORTION FOR YOUR RECORDS

RETURN THIS PORTION WITH YOUR PAYMENT

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Dec 2, 2010	$ 173.76 *includes amount past due*

300 Erie Blvd West
Syracuse NY 13202-0960

▶ DID YOU FORGET ? ◀

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 06936
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 11742
NEWARK NJ 07101-4742

000003920 38263931345000017376336

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Oct 6, 2010 to Nov 5, 2010

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Dec 2, 2010	$ 173.76

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5829 *Actual*	5724 *Actual*	105	1	105 kWh
				Total Energy Usage	**105 kWh**
				Billed Energy Usage	**105 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Dec 8
SERVICE PERIOD Oct 6 - Nov 5 NUMBER OF DAYS IN PERIOD 30
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06615	x 105 kWh	6.94
Delivery Adjustment	0.01584	x 105 kWh	1.66
SBC/RPS	0.006812	x 105 kWh	0.71
Incr State Assessment	0.00403	x 105 kWh	0.42
Transmission Rev Adj	-0.00139	x 105 kWh	-0.15
Tariff Surcharge	1.0101 %		0.31
Sales Tax	8.0 %		2.47
		Total Delivery Services	**$ 33.38**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.05085	x 105 kWh	5.34
Tariff Surcharge	1.0101 %		0.05
Sales Tax	8.0 %		0.43
		Total Supply Services	**$ 5.82**

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SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Nov 5, 2010 to Dec 8, 2010

PAGE 1 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jan 2, 2011	$ 183.51

C & I BUSINESS TEAM M-F 8-6
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS OR ELECTRIC EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

POWER OUTAGE OR DOWNED LINE
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Dec 9, 2010

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Dec 09	201	Jul 10	93
Jan 10	131	Aug 10	80
Feb 10	149	Sep 10	88
Mar 10	90	Oct 10	237
Apr 10	99	Nov 10	108
May 10	96	Dec 10	151
Jun 10	82		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	173.76
Payment Received on NOV 12 (*Check*)	- 36.46
Balance Forward	**137.30**
Current Charges	+ 46.21
Amount Due ▶	**$ 183.51**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	37.98	8.23	46.21
Total Current Charges	**$ 37.98**	**$ 8.23**	**$ 46.21**

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GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE: Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .

★ **WILL WE BE ABLE TO REACH YOU DURING A POWER OUTAGE?:** During a power outage, phones with a direct link to a local phone line are able to operate. Phones that are **not** directly linked (for example, wireless phones with answering machines) need electricity to make/receive calls. If you would like to register another phone number, such as a cell phone, as your account's primary phone number, please go to www.nationalgridus.com/myaccount to update your information so that we may be able to reach you with important information during power outages.

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nationalgrid

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jan 2, 2011	$ 183.51 *includes amount past due*

▶ DID YOU FORGET ? ◀

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739

05910

NATIONAL GRID
PO BOX 11742
NEWARK NJ 07101-4742

000004621 38263931340000018351002

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Nov 5, 2010 to Dec 8, 2010

PAGE 2 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Jan 2, 2011	$ 183.51

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	5980 *Actual*	5829 *Actual*	151	1	151 kWh
				Total Energy Usage	**151 kWh**
				Billed Energy Usage	**151 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Jan 7
SERVICE PERIOD Nov 5 - Dec 8 NUMBER OF DAYS IN PERIOD 33
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06615	x 151 kWh	9.99
Delivery Adjustment	0.01528	x 151 kWh	2.31
SBC/RPS	0.006812	x 151 kWh	1.03
Incr State Assessment	0.00403	x 151 kWh	0.61
Transmission Rev Adj	-0.00094	x 151 kWh	-0.14
Tariff Surcharge	1.0101 %		0.35
Sales Tax	8.0 %		2.81
		Total Delivery Services	**$ 37.98**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.04992	x 151 kWh	7.54
Tariff Surcharge	1.0101 %		0.08
Sales Tax	8.0 %		0.61
		Total Supply Services	**$ 8.23**

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Dec 8, 2010 to Jan 7, 2011

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Feb 3, 2011	$ 194.26

www.nationalgridus.com

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

OUTAGE AND ELECTRIC EMERGENCIES
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Jan 10, 2011

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Jan 10	131	Aug 10	60
Feb 10	149	Sep 10	68
Mar 10	90	Oct 10	237
Apr 10	99	Nov 10	105
May 10	98	Dec 10	151
Jun 10	82	Jan 11	160
Jul 10	93		

ACCOUNT BALANCE

Previous Balance	183.51
Payment Received on DEC 29 (*Check*)	- 37.63
Balance Forward	**145.88**
Current Charges	+ 48.38
Amount Due ▶	**$ 194.26**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	38.38	10.00	48.38
Total Current Charges	**$ 38.38**	**$ 10.00**	**$ 48.38**

PAYMENT CONCERNS?: We're here to help you. We have several plans that can help you manage your energy bills. Go to www.nationalgridus.com/paymentoptions to find out more or call us at 1-800-443-1837 .

GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE: Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .

★ **WILL WE BE ABLE TO REACH YOU DURING A POWER OUTAGE?:** During a power outage, phones with a direct link to a local phone line are able to operate. Phones that are **not** directly linked (for example, wireless phones with answering machines) need electricity to make/receive calls. If you would like to register another phone number, such as a cell phone, as your account's primary phone number, please go to www.nationalgridus.com/myaccount to update your information so that we may be able to reach you with important information during power outages.

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Feb 3, 2011	$ 194.26

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739

06808

NATIONAL GRID
PO BOX 11742
NEWARK NJ 07101-4742

000004838 382639313420000194260034

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Dec 8, 2010 to Jan 7, 2011

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Feb 3, 2011	$ 194.26

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	6140 *Actual*	5980 *Actual*	160	1	160 kWh
				Total Energy Usage	**160 kWh**
				Billed Energy Usage	**160 kWh**

METER NUMBER 05518945 — NEXT SCHEDULED READ DATE Feb 7
SERVICE PERIOD Dec 8 - Jan 7 — NUMBER OF DAYS IN PERIOD 30
RATE Electric SC2 — VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06614997	x 160 kWh	10.58
Delivery Adjustment	0.01102	x 160 kWh	1.76
SBC/RPS	0.00680731	x 160 kWh	1.09
Incr State Assessment	0.00403	x 160 kWh	0.64
Transmission Rev Adj	0.00055	x 160 kWh	0.09
Tariff Surcharge	1.0101 %		0.36
Sales Tax	8.0 %		2.84
		Total Delivery Services	**$ 38.38**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.0573	x 160 kWh	9.17
Tariff Surcharge	1.0101 %		0.09
Sales Tax	8.0 %		0.74
		Total Supply Services	**$ 10.00**

nationalgrid

www.nationalgridus.com

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jan 7, 2011 to Feb 7, 2011

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Mar 4, 2011	$ 194.39

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

OUTAGE AND ELECTRIC EMERGENCIES
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Feb 8, 2011

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Feb 10	149	Sep 10	88
Mar 10	90	Oct 10	237
Apr 10	99	Nov 10	108
May 10	96	Dec 10	151
Jun 10	82	Jan 11	160
Jul 10	93	Feb 11	227
Aug 10	80		

▶ DID YOU FORGET? ◀

The total amount due includes an unpaid balance from a previous bill. If you have already paid this balance, please disregard this message. Thank You.

ACCOUNT BALANCE

Previous Balance	194.26
Payment Received on JAN 26 (*Check*)	- 60.47
Balance Forward	**133.79**
Current Charges	+ 60.60
Amount Due ▶	**$ 194.39**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	43.71	16.89	60.60
Total Current Charges	**$ 43.71**	**$ 16.89**	**$ 60.60**

- **IMPORTANT NOTICE:** In compliance with the order issued in the Niagara Mohawk d/b/a National Grid rate case, new electric delivery service pricing will take effect on February 1, 2011. The new electric delivery rates will be posted on www.nationalgridus.com/niagaramohawk. If you have questions, please call 1-800-642-4272.
- **GO PAPERLESS. RECEIVE AND PAY YOUR BILLS ONLINE:** Help improve the environment by managing your bills online. Get started today - go to www.nationalgridus.com/gopaperless .
- **PAYMENT CONCERNS?:** We're here to help you. We have several plans that can help you manage your energy bills. Go to www.nationalgridus.com/paymentoptions to find out more or call us at 1-800-443-1837 .

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ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Mar 4, 2011	$ 194.39 *includes amount past due*

▶ DID YOU FORGET ? ◀

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$ ____________

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD
NORTH SYRACUSE NY 13212-3739 05654

NATIONAL GRID
PO BOX 11742
NEWARK NJ 07101-4742

000006060 382639313460000194390б3

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Jan 7, 2011 to Feb 7, 2011

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Mar 4, 2011	$ 194.39

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	- Previous Reading	= Difference	x Meter Multiplier	= Total Usage
Energy	6367 *Actual*	6140 *Actual*	227	1	227 kWh
				Total Energy Usage	**227 kWh**
				Billed Energy Usage	**227 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Mar 8
SERVICE PERIOD Jan 7 - Feb 7 NUMBER OF DAYS IN PERIOD 31
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06577286	x 227 kWh	14.93
Delivery Adjustment	0.00619	x 227 kWh	1.40
SBC/RPS	0.00642663	x 227 kWh	1.46
Incr State Assessment	0.00403	x 227 kWh	0.91
Transmission Rev Adj	0.00156	x 227 kWh	0.35
Tariff Surcharge	1.0101 %		0.40
Sales Tax	8.0 %		3.24
	Total Delivery Services		**$ 43.71**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.06763	x 227 kWh	15.35
Merchant Function	0.00054435	x 227 kWh	0.13
Tariff Surcharge	1.0101 %		0.16
Sales Tax	8.0 %		1.25
	Total Supply Services		**$ 16.89**

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SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Feb 7, 2011 to Mar 8, 2011

PAGE 1 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Apr 2, 2011	$ 192.81

C & I BUSINESS TEAM M-F 8-5
1-800-664-6729

AUTOMATED SERVICES
1-888-932-0301

GAS EMERGENCIES
1-800-892-2345
(Does not replace 911 emergency medical service)

OUTAGE AND ELECTRIC EMERGENCIES
1-800-867-5222

CORRESPONDENCE ADDRESS
300 Erie Blvd West
Syracuse, NY 13202

DATE BILL ISSUED
Mar 9, 2011

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone Central
Acct No: 38263-93134 Cycle: 7, NYS

Electric Usage History

Month	kWh	Month	kWh
Mar 10	90	Oct 10	237
Apr 10	99	Nov 10	105
May 10	96	Dec 10	161
Jun 10	82	Jan 11	160
Jul 10	93	Feb 11	227
Aug 10	80	Mar 11	93
Sep 10	88		

ACCOUNT BALANCE

Previous Balance	194.39
Payment Received on FEB 11 (*Check*)	- 39.20
Balance Forward	**155.19**
Current Charges	+ 37.62
Amount Due ▶	**$ 192.81**

SUMMARY OF CURRENT CHARGES

	DELIVERY SERVICES	SUPPLY SERVICES	TOTAL
Electric Service	32.39	5.23	37.62
Total Current Charges	**$ 32.39**	**$ 5.23**	**$ 37.62**

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- ★ **WILL WE BE ABLE TO REACH YOU DURING A POWER OUTAGE?:** During a power outage, phones with a direct link to a local phone line are able to operate. Phones that are **not** directly linked (for example, wireless phones with answering machines) need electricity to make/receive calls. If you would like to register another phone number, such as a cell phone, as your account's primary phone number, please go to www.nationalgridus.com/myaccount to update your information so that we may be able to reach you with important information during power outages.

KEEP THIS PORTION FOR YOUR RECORDS.

RETURN THIS PORTION WITH YOUR PAYMENT

nationalgrid

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	**Apr 2, 2011**	**$ 192.81**

300 Erie Blvd West
Syracuse NY 13202-0960

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

***AUTO**SCH 3-DIGIT 130
NYS DOT
5430 S BAY RD 06407
NORTH SYRACUSE NY 13212-3739

NATIONAL GRID
PO BOX 11742
NEWARK NJ 07101-4742

000003762 38263931344000019281092

nationalgrid

SERVICE FOR (240008 EL)
NYS DOT
VAN RENSSELAER ST
SYRACUSE NY 13204

BILLING PERIOD
Feb 7, 2011 to Mar 8, 2011

PAGE 2 of 4

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
38263-93134	Apr 2, 2011	$ 192.81

Choosing an Energy Supplier You can choose who supplies your energy. No matter which energy supplier you choose, National Grid will continue to deliver energy to you safely, efficiently and reliably. We will also continue to provide your customer service, including emergency response and storm restoration. National Grid is dedicated to creating an open energy market that lets you choose from a variety of competitive energy suppliers, who may offer different pricing options. For information on authorized energy suppliers and how to choose, please visit us online at www.nationalgridus.com/energychoice

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	6460 *Actual*		6367 *Actual*		93		1		*93 kWh*
							Total Energy Usage		**93 kWh**
							Billed Energy Usage		**93 kWh**

METER NUMBER 05518945 NEXT SCHEDULED READ DATE Apr 7
SERVICE PERIOD Feb 7 - Mar 8 NUMBER OF DAYS IN PERIOD 29
RATE Electric SC2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer			21.02
Delivery	0.06448	x 93 kWh	5.99
Delivery Adjustment	0.01703	x 93 kWh	1.58
SBC/RPS	0.005211	x 93 kWh	0.48
Incr State Assessment	0.00403	x 93 kWh	0.37
Transmission Rev Adj	0.00265	x 93 kWh	0.25
Tariff Surcharge	1.0101 %		0.30
Sales Tax	8.0 %		2.40
	Total Delivery Services		**$ 32.39**

Supply Services

SUPPLIER National Grid

Electricity Supply	0.04949	x 93 kWh	4.60
Merchant Function	0.00203279	x 93 kWh	0.19
Tariff Surcharge	1.0101 %		0.05
Sales Tax	8.0 %		0.39
	Total Supply Services		**$ 5.23**

Labor Calculations for Brine Truck Operators

OFFICE OF THE STATE COMPTROLLER
BUREAU OF PAYROLL AUDIT-SALARY DETERMINATION SECTION
SALARY GRADE SCHEDULE FOR CSEA UNITS (02, 03, 04, AND 47)
EFFECTIVE MARCH 25, 2010 (INST)
EFFECTIVE APRIL 1, 2010 (ADMIN)

SG	HR	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	JR	Incr
1	22041	22785	23529	24273	25017	25761	26505	27249	744
2	22883	23663	24443	25223	26003	26783	27563	28343	780
3	24025	24840	25655	26470	27285	28100	28915	29730	815
4	25074	25937	26800	27663	28526	29389	30252	31115	863
5	26274	27178	28082	28986	29890	30794	31698	32602	904
6	27744	28683	29622	30561	31500	32439	33378	34317	939
7	29278	30263	31248	32233	33218	34203	35188	36173	985
HMW1 * → 8	30928	31951	32974	33997	35020	36043	37066	38089	1023
9	32653	33722	34791	35860	36929	37998	39067	40136	1069
HMW2 → 10	34521	35642	36763	37884	39005	40126	41247	42368	1121
11	36523	37700	38877	40054	41231	42408	43585	44762	1177
12	38612	39830	41048	42266	43484	44702	45920	47138	1218
13	40903	42177	43451	44725	45999	47273	48547	49821	1274
14	43270	44596	45922	47248	48574	49900	51226	52552	1326
15	45781	47163	48545	49927	51309	52691	54073	55455	1382
16	48346	49792	51238	52684	54130	55576	57022	58468	1446
17	51067	52595	54123	55651	57179	58707	60235	61763	1528
18	54018	55614	57210	58806	60402	61998	63594	65190	1596
19	56912	58587	60262	61937	63612	65287	66962	68637	1675
20	59889	61630	63371	65112	66853	68594	70335	72076	1741
21	63101	64924	66747	68570	70393	72216	74039	75862	1823
22	66484	68389	70294	72199	74104	76009	77914	79819	1905
23	70038	72026	74014	76002	77990	79978	81966	83954	1988
24	73850	75908	77966	80024	82082	84140	86198	88256	2058
25	77931	80080	82229	84378	86527	88676	90825	92974	2149