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FIELD DEMONSTRATION OF OIL AND GAS WELL BRINES IN LOCAL LEVEL ANTI-ICING PROGRAMS

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16. Abstract

Use of oil and gas well brines in anti-icing operations at the municipal government level was assessed through a one-winter field demonstration program in three West Virginia communities (Fairmont, Morgantown and Philippi). One truck in each community was outfitted with an on-board pre-wetting system consisting of one or two 25-gallon tanks, a 12-volt DC electric pump rated at up to 3 gallons per minute, spray nozzle and associated hardware. Natural brine was provided, at no cost, to the municipalities by an oil and gas producer who also provided (on a loan basis) one or two 4200-gallon brine storage tanks at each community's maintenance yard. During the winter of 1998-99, natural brine was sprayed, as a pre-wetting agent, on the rock salt and salt/abrasive mixtures at the rate of about 12 gallons per ton of material. Public works personnel in each community completed data forms which provided information on weather conditions, amount of materials placed, and an assessment of road surface condition.

Field test results showed that, in all three communities, brine was a valuable supplement to winter maintenance operations. In all three municipalities, better levels of service were provided to the traveling public; roads cleared more quickly than those treated by conventional techniques. The brine-enhanced mixtures worked well in temperatures as low as 3 degrees F and under a variety of winter storm conditions. Less material was used overall since the reduced bounce-off associated with pre-wetted materials kept more of the salt/abrasives in the travel lanes where it was needed. Where snow or ice had bonded to the pavement surface, brine-treated salt was able to break the bond in about one-half the time of conventional materials. Brine-enhanced mixtures showed considerable flexibility in the type and nature of application.

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Special appreciation is expressed to the communities of Fairmont, Morgantown, Philippi, and Weirton who were cooperating participants in the study. Public works department staff at these agencies, from the directors to the truck drivers contributed a great deal of time and effort in planning, implementing, and carrying out the research project. Their cooperation was essential to achieving project objectives.

Special appreciation is also expressed to Columbia Natural Resources and Hawg Hawling & Disposal, Inc.. They loaned storage tanks to three of the communities, provided technical assistance relative to constructing dikes around these tanks, and provided brine to the communities. In particular, Conrad Sansoucie of Columbia Natural Resources, Carl Starr, Bob Cayton, and David Gum of Hawg Hauling deserve special thanks for their efforts.

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EXECUTIVE SUMMARY

Research performed at West Virginia University during the 1980's demonstrated that West Virginia oil and gas well brines have the properties of freezing point depressants. Their effects on highway materials are essentially the same as conventional snow and ice control chemicals. Previous studies identified oil and gas fields in the state which produce brines suitable for roadway use. Thus, it was logical to formally assess the use of natural brines in anti-icing operations at the municipal government level. This was accomplished through a one-winter field demonstration program in three West Virginia communities (Fairmont, Morgantown and Philippi).

One truck in each community was outfitted with an on-board pre-wetting system consisting of one or two 25-gallon tanks, a 12-volt DC electric pump rated at up to 3 gallons per minute, spray nozzle and associated hardware. Natural brine was provided, at no cost, to the municipalities by an oil and gas producer who also provided (on a loan basis) one or two 4200-gallon brine storage tanks at each community's maintenance yard. During the winter of 1998-99, natural brine was sprayed, as a pre-wetting agent, on the rock salt and salt/abrasive mixtures at the rate of about 12 gallons per ton of material. Public works personnel in each community completed data forms which provided information on weather conditions, amount of materials placed, and an assessment of road surface condition.

Results of the field tests showed that, in all three communities, brine was a valuable supplement to winter maintenance operations. In all three municipalities, better levels of service were provided to the traveling public; roads cleared more quickly than those treated by conventional techniques. The brine-enhanced mixtures worked well in temperatures as low as 3 degrees F and under a variety of winter storm conditions. Less material was used overall since the reduced bounce-off associated with pre-wetted materials kept more of the salt/abrasives in the travel lanes where it was needed. Where snow or ice had bonded to the pavement surface, the brine-treated salt was able to break the bond in about one-half the time of conventional materials.

Brine-enhanced mixtures showed considerable flexibility in the type and nature of application. Due to positive comments received from citizens, the City of Fairmont expanded its use of brines beyond the single truck and sprayed the top of each truckload of material with brine before it left the maintenance yard. City crews also had success in hand application of brines to public sidewalks where they were beneficial in breaking up ice/snowpack. The City of Morgantown's experience demonstrated that the brine-treated mixes could be applied to the roadway before/early into the storm so that snow or ice was not able to bond to the roadway surface. This "bought" time for maintenance personnel.

It is recommended that West Virginia municipalities located in or near the oil and gas-producing regions of the state consider using natural brines as an addition to their snow removal and ice control programs. For relatively little cost, significant improvements in roadway levels of service can be obtained. When used as part of an anti-icing strategy, weather forecasts, road conditions and training for personnel need to be taken into account along with the material and equipment considerations discussed in the report. Preventive maintenance of equipment is especially important when using brines.

Brines are a variable material; a particular brine is not necessarily suitable for roadway applications. It is important that roadway agencies establish the quality of brine to be used on roads and streets and require that the supplier provide appropriate documentation attesting to the quality of each load of brine delivered to the agency.

A number of suggestions for implementing the results of this research are identified in the report. These include a brochure for distribution to municipalities, briefings to decision-makers and presentations at workshops and seminars.

CHAPTER 1
BACKGROUND AND INTRODUCTION

1.1 Introduction

In today's society, the motoring public expects an adequate level of service during all seasons. Providing this is difficult during winter months in northern climates when roads can be covered with snow and/or ice. Highway agency winter maintenance programs address this concern. Winter maintenance programs involve several aspects ranging from the application of chemicals and anti-skid materials for controlling snow and ice to repairing roadway damage incurred from winter weather.

To increase the level of service offered to the traveling public during a winter storm, two main approaches to snow and ice control have been identified. The first approach is deicing. A deicing program involves applying snow and ice control material after the storm has started, i.e. after snow and/or ice have accumulated on the pavement surface. Typically, this means that a bond has formed between the pavement and the snow and ice.

Snow and ice control material consists of either chemicals or abrasives. Abrasives are used to increase the friction between the snow-covered road and vehicle tires. Chemicals (typically of the dry solid variety) are used to melt the ice and break the bond between the road and the snow and ice. Breaking this bond requires application of large amounts of energy. Thus, this process is very inefficient.

The second and more recent approach is anti-icing. Anti-icing involves preventive winter maintenance operations to roadways such as applying chemicals to a pavement surface at or before the start of a winter storm. The chemicals inhibit the development of a bond between the snow/ice and the pavement surface. Periodic re-application of chemicals during the storm can continue this effect. Research done as part of the Strategic Highway Research Program (SHRP) program has clearly demonstrated the effectiveness of anti-icing programs (Blackburn, et al., 1994).

One of the key operational tools to support an anti-icing strategy is the use of liquid freezing-point depressants. The use of dry solid chemicals as an anti-icing treatment can be effective only when there is sufficient moisture available in the atmosphere or on the roadway. Moisture must be available to prevent the loss of material by bounce-off from a dry pavement and to trigger the dry solid chemical to go into a salt solution.

There are advantages to using small amounts of liquid chemicals to pre-wet solid chemicals and/or abrasives for particular conditions of pavement at temperatures of about -5° C and above. The advantages include the ability to place chemicals uniformly over the pavement at relatively fast spreading speeds and the ability to place chemical uniformly onto dry pavement as a pre-storm treatment to avoid delays in application which may lead to snow or ice bonding to the road surface.

The Federal Highway Administration (FHWA) Manual of Practice for an Effective Anti - Icing Program (Ketcham, et al., 1996) identifies five chemicals that have been used for liquid anti-icing treatments: sodium chloride, magnesium chloride, calcium chloride, calcium magnesium acetate, and potassium acetate. Table 1.1 shows the chemical composition, effective working temperature, environmental effects, and costs of each of these anti-icing agents.

Chemical	Composition	Eutectic Temperature /Composition	Lowest Effective Temperature	Environmental Effects	Cost ($/tn)
Sodium Chloride	NaCl	-21°C(-5.8°F) @ 23.3 wt%	-7°C(20°F)	High concentrations may cause plant stresses	20-35
Magnesium Chloride (Salt)	$MgCl_2$	-33°C(-27°F) @ 21.6 wt%	-23°C(-9°F)	Can contribute to accumulation of nutrients to bodies of water	50
Calcium Chloride	$CaCl_2$	-51°C(-60°F) @29.8 wt%	-29°C(-20°F)	Adds hardness to water	250-275
Calcium Magnesium Acetate (CMA)	$CaMg_2(CH_3COO_2)_6$	-27.5 C(-17.5 F) at 3:7 Ca:Mg ratio @32.5 wt%	-7°C(20°F)	Acetate ion my contribute to loss of oxygen in water bodies; difficult to produce in solution	650
Potassium Acetate (KAc)	CH_3COOK	-60°C(-76°F) @ 50 wt%	-25°C(-13°F)		

Table 1.1. Snow- and Ice-Related Characteristics of Five Anti-Icing Agents (Source: Minsk, 1998).

The FHWA manual (Ketcham, et al., 1996) discusses producing chemical solutions by dissolving solid agents in water. While these arrangements work well, they do require an input of energy to operate the pumps and mixers that comprise the mixing facility. Thus, although sodium chloride is relatively inexpensive, the actual costs will be higher due to mixing cost.

Some agencies have used liquid calcium chloride for snow removal and ice control applications. While very effective as a deicing or anti-icing agent, liquid calcium chloride suffers from the disadvantage of being relatively expensive. In view of these constraints, associated with common liquid chemicals, it would be desirable to utilize a low-cost "pre-mixed" solution that had minimum adverse environmental effect.

1.2 Background

In the early 1980's, the West Virginia Division of Highways (DOH) sponsored research which evaluated the use of West Virginia oil and gas well brines (salt water) as a roadway snow and ice control agent. These "natural brines" have the same advantages as the commercial solutions described above. Since the brines occur as a by-product of oil and gas production and West Virginia is a significant producer of oil and gas, there are substantial quantities of brine generated in West Virginia. The brines produced in West Virginia are difficult to dispose of in an environmentally acceptable manner since the brines are much more concentrated than seawater. There is at present no completely satisfactory and cost-effective method of waste brine disposal.

During the last 20 years, several research projects have been undertaken by the Department of Civil and Environmental Engineering at West Virginia University to address questions associated with the use of natural brine as a snow and ice control agent. The original project proposal indicated that the nature and magnitude of this research was substantial enough that the project was divided into 3 distinct phases. Phase I had a number of specific objectives including: 1) establishing state-of-the-art knowledge on the use of commercial salts and waste brines for snow and ice control, 2) sampling West Virginia brines and establishing their chemical composition, 3) evaluating the impact of brines on highway materials, 4) comparing effects of brines and commercial deicing agents on melting and skid resistance of actual roadways, 5) developing plans for collecting and storing brines and 6) estimating the costs of storing and handling brines.

Phase I research findings (Eck and Sack, 1984) indicated that use of natural brines as a highway deicing agent was technically feasible and cost-effective in a variety of situations. Thus, it seemed appropriate to proceed from the essentially laboratory and pilot scale research level to a larger scale use of brines as a deicing agent, i.e., Phase II.

Experience with two winters of field testing in Phase II confirmed the results of Phase I. As a result, in Phase II, a spray applicator was designed and tested and a model agreement relative to supplying brine to highway agencies was drafted.

At approximately the same time as the Phase II research was being conducted, a separate but related project was underway. The study investigated the feasibility of using brines as an additive to abrasive materials and salts. It was found (Eck, et al., 1986) that bottom ash, cinders, sand, and sawdust could be freeze-proofed effectively over a wide range of stockpile moisture contents and at temperatures as low as -12° C. Procedures for applying brine to the abrasive materials and salt were described and cost estimates provided.

The Phase II final report recommended that the DOH begin a larger scale use of natural brines for deicing purposes. Based on the information contained in the above-cited reports, the DOH had sufficient information to begin acquiring equipment, constructing facilities, and securing a supply of brine. The principal concern that remained was brine availability.

The Phase III research involved an in-depth evaluation of oil and gas brines on a statewide basis. Oil and gas fields producing brines suitable for highway applications were identified. Brine quality and quantity data were compiled in a brine availability database using groups of wells producing from a particular formation. The report (Eck and Sack, 1990) included samples of forms to be used for monitoring brine quantities and effectiveness.

Implementing this recommendation, the DOH pilot tested brines on a section of US Route 33 near Weston in Lewis County (DOH District 7). A brine tank and overhead spray arrangement was installed at the maintenance station and a pre-determined quantity of brine was sprayed on loads of salt/abrasives as trucks left the maintenance yard. During one particular storm, apparently a problem developed wherein the treated roads glazed over. Consequently, testing was discontinued. To our knowledge, no investigation was ever conducted to determine the cause of the problem.

In view of the current interest in anti-icing strategies, the potential benefits of brine usage, and the severe resource constraints faced by local road agencies, it is appropriate to investigate specifically how natural brines can be used to greatest advantage in anti-icing programs at the local level.

1.3 Objectives of the Study

The overall goal of the project was to assess the utility of oil and gas well brines (and related by-product brines) as a tool in local level anti-icing programs through a carefully planned one-winter field demonstration program in one or more West Virginia municipalities. To accomplish this goal, several specific objectives were established.

1. To update the literature reviews conducted as part of the original West Virginia brine research to include recent material on use of liquid chemicals in anti-icing programs generally and use of natural brines in winter maintenance in particular.

2. To identify oil and gas producers willing to cooperate in this study.
3. To select one or more communities willing to participate in the field testing program, based on characteristics of the local road system, equipment availability, and willingness to utilize anti-icing strategies.
4. Based on the characteristics of the community(ies) selected, to determine the anti-icing strategies to be used in the field-testing program.
5. Based on Objective #4, to make the necessary arrangements to support the field test program, including arranging for adequate brine supply, purchasing/fabricating the necessary application hardware such as spreaders or sprayers, personnel training, and other administrative issues.
6. To conduct, during one winter, a field test of the anti-icing strategies using the natural brines.
7. To document the effectiveness of the natural brine using both qualitative and quantitative measures.
8. To prepare a final technical report documenting the research procedures and results and outlining a plan to implement the results.

1.4 Organization of the Report

This report is divided into five chapters. Chapter 1 has presented background to the problem, the problem statement and the objectives of the project. Chapter 2 summarizes the results of the available literature related to anti-icing and the potential for using natural brines in anti-icing strategies. Chapter 3 describes the winter maintenance operations of the participating communities and the development and implementation of the anti-icing strategy used in this project. Chapter 4 discusses the results of the field-testing program. Chapter 5 presents conclusions and recommendations for using oil and gas brines in local level anti-icing programs. Implementation issues are also addressed.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

A thorough literature review was carried out to identify various issues related to anti-icing technology and materials. This chapter presents the results of the literature review, focusing on two main areas: 1) anti-icing material and technology and 2) experiences using brines (natural and man-made) as a winter maintenance agent.

2.2 Anti-Icing – Concept, Materials and Technology

Ketcham, et al. (1996) point out that application of a chemical freezing-point depressant onto a highway pavement at the start of a winter storm, or even prior to the beginning of precipitation, inhibits the development of a bond between the snow or ice and the pavement surface. Further, moderate and periodic reapplication of the chemical during the storm can continue this effect. Such preventive operations are at the heart of an anti-icing program.

Anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. According to Ketcham, et al. (1996), anti-icing allows maintenance personnel the ability to maintain roads in the best conditions possible during a winter storm and to do it in an efficient manner. Anti-icing offers the potential to provide the benefit of increased traffic safety at the lowest cost. However, to achieve this benefit, maintenance managers must adopt a systematic approach to snow and ice control and must ensure that the performance of the operations is consistent with the objective of preventing the formation or development of bonded snow and ice. Such an approach requires use of considerable judgment in making decisions, requires that available resources be utilized methodically, and requires that the operations be anticipatory or prompt in nature.

In contrast to anti-icing operations, a common procedure of traditional snow and ice control practice is to wait until an inch or more of snow accumulates on the pavement before beginning to plow and treat the roadway with chemicals or abrasives. This approach frequently leads to a compacted snow layer that is tightly bonded to the pavement surface. A subsequent "deicing" of the pavement is then necessary, usually resulting in a large quantity of chemical to work its way through the pack to reach the snow/pavement interface and destroy or weaken the bond. Because this operation is reactionary, it requires less judgment than anti-icing. Yet, due to its inherent delay, it often provides less safety, at higher cost, than anti-icing. In any event, the reactive technique of de-icing will remain important for snow and ice control, as there will always be lower priority service levels that preclude preventive operations.

Anti-icing is well-suited to routes with a higher level of service. Ketcham, et al. (1996) indicate that this is because the vigilance and timeliness of successful anti-icing operations are most compatible with service levels requiring earlier and higher frequency winter maintenance operations. In addition, the preventive nature of anti-icing can support higher service level objectives such as maintaining bare pavement throughout a storm or returning to bare pavement as soon as possible following pack formation.

Ketcham, et al. (1996) note that because of the requirements of higher service levels, many maintenance forces in the U.S. had instinctively implemented elements of anti-icing practices for years. However, the effectiveness of anti-icing had not been formally demonstrated until data were acquired as part of the Strategic Highway Research Program, also known as SHRP (Blackburn, et al., 1994).

Figure 2.1, taken from Ketcham, et al. (1996), depicts the components of an anti-icing program in the context of a winter maintenance program and roadway level of service assignments. The figure shows anti-icing as a support strategy for "bare pavement" service levels.

As can be seen from Figure 2.1, support of an anti-icing strategy is divided into "tools" and "operations". The supporting tools can be organized according to operations, decision-making, and personnel toolboxes which are further broken down according to capabilities, information sources, and procedures that may be available for a given operation. Operations are broken down into initial and subsequent operations in order to convey the importance of the initial chemical treatment in anti-icing operations, and to signal that subsequent operations throughout a storm or weather event should follow the anti-icing strategy as well.

Ketcham, et al. (1996) identify four major categories of operations tools needed to support an anti-icing program: solid chemical application, chemical solution (liquid) application, pre-wetted solid chemical application and plowing. The use of dry solid chemicals as an anti-icing treatment can be effective in many circumstances, but only those where there is sufficient moisture or accumulation on the pavement. Moisture must

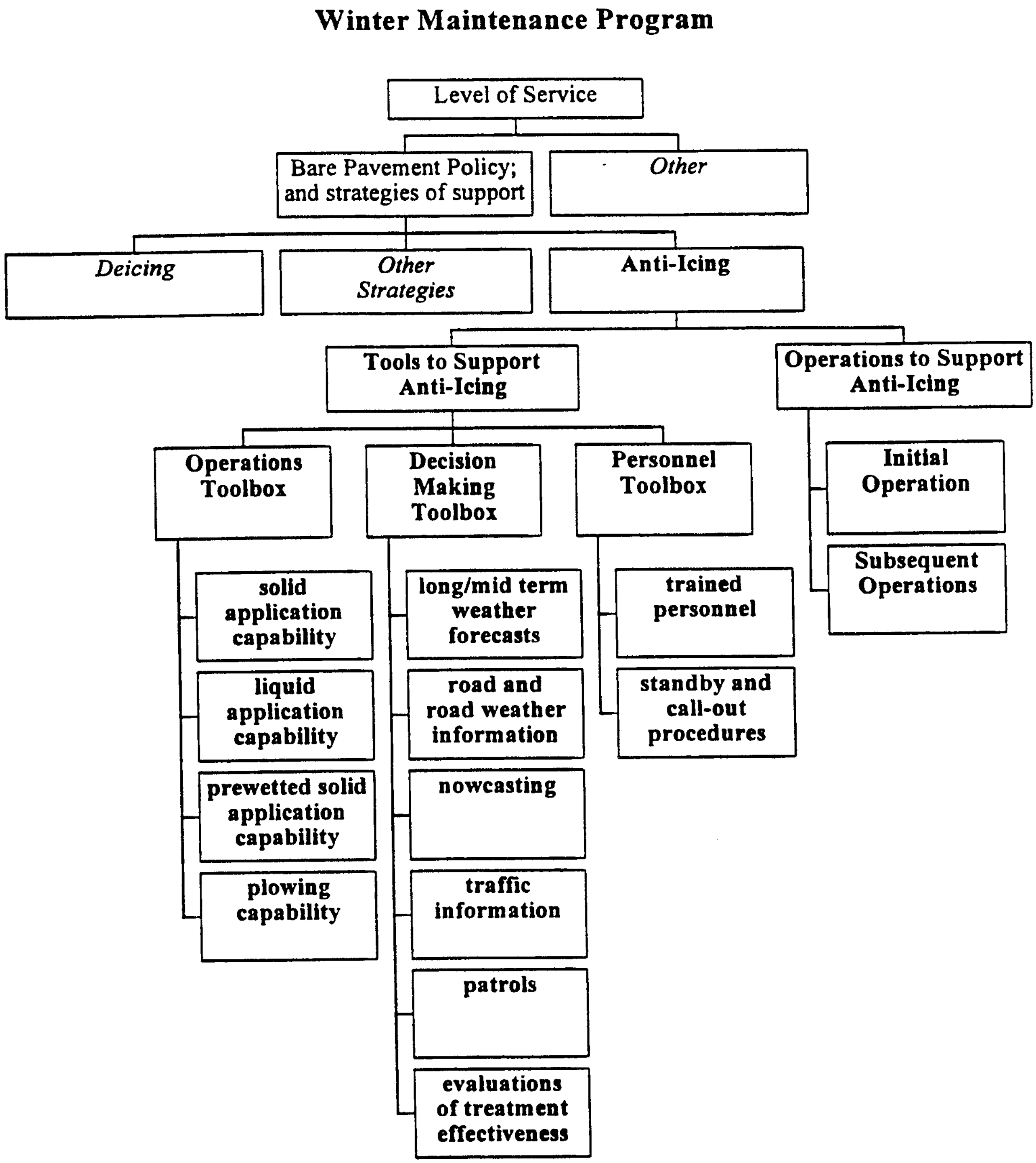

Figure 2.1. Outline of Components of an Anti-Icing Strategy in the Context of a Winter Maintenance Program (Source: Ketcham, et al., 1996).

be available for two reasons: to prevent loss of material off a dry pavement and to trigger the solution of the salt. For initial operations, solids will be effective when available resources allow the chemical to be applied as soon as possible after sufficient precipitation has fallen, but before the snowpack or ice bonds to the pavement. For subsequent operations, solid chemical treatments will usually be effective because there is typically adequate moisture or accumulation during later periods of storms.

When there is not enough moisture or accumulation on the pavement, there is likely to be loss of the chemical from the pavement. This may be caused by the blowing action of traffic, especially from high-speed and commercial vehicles, or by the bouncing of particles off the pavement during spreading. Ketcham, et al. (1996) report that it is not uncommon to see dry solid chemicals rebound up to 2 feet from a dry pavement after being distributed from a conventional spreader spinner.

The solid chemical most commonly used for anti-icing treatments is salt, or sodium chloride. A mix of solid sodium chloride and solid calcium chloride has been used by some agencies, and in some instances straight calcium chloride has been used. In fact, Ketcham, et al. (1996) point out that almost any solid chemical that has been used for deicing also can be used for anti-icing.

Dry chemicals are applied to the roadway by means of either a hopper type (or V-box) spreader (shown in Figure 2.2) or a dump body with an under-tailgate spreader (shown in Figure 2.3). These spreaders are capable of spreading free-flowing granular material from a minimum width of 3 feet to a maximum of 40 feet.

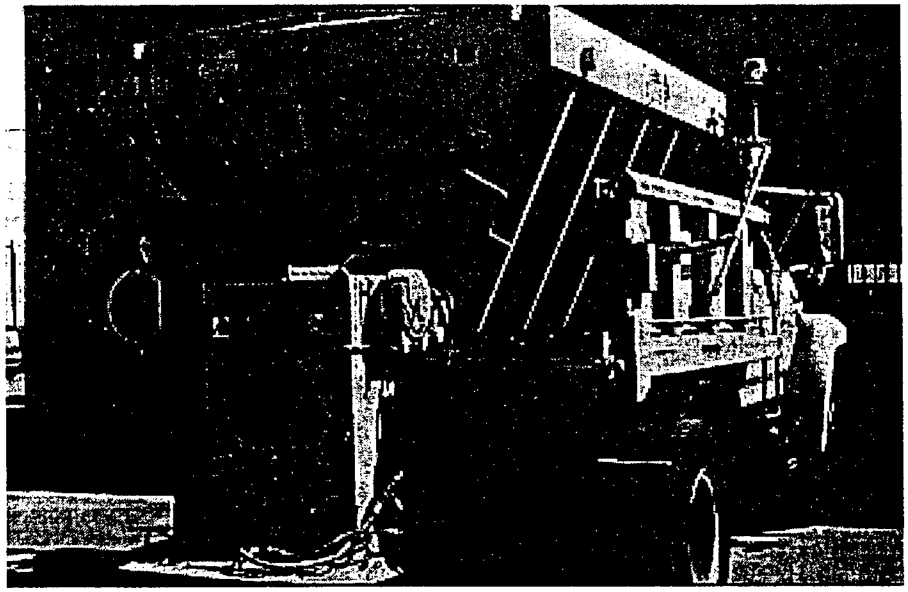

Figure 2.2. Typical V-Box Spreader (Source: Ketcham, et al., 1996).

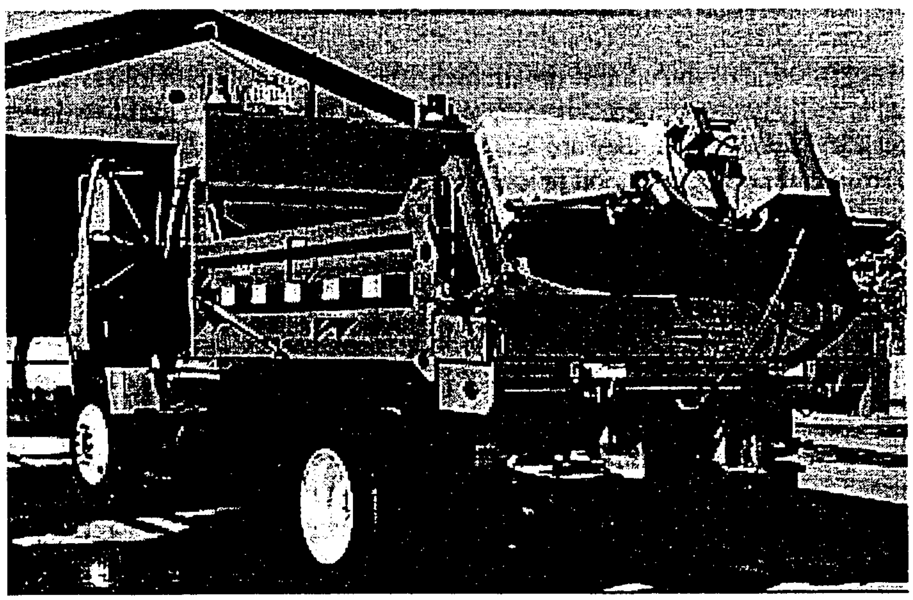

Figure 2.3. Under-Tailgate Spreader with Pre-Wetting Equipment (Source: Ketcham, et al., 1996).

The variables affecting application rate of a given material are 1) area of the gate opening on a hopper box or the opening in the bottom of the tailgate hopper, 2) feed-belt or auger speed, and truck speed. The gate opening height is an adjustment made at the time of calibration and generally is not changed during spreading operations. Thus, to control the actual spreading rate, the speed of the feed belt or auger needs to be considered along with truck speed. The methods that can be used to control the spreading rate of spreaders fall into three categories: 1) no control, 2) manual control, and 3) automatic control.

Solid chemicals should be stored under cover or inside a building. Chemicals stored in the open pick up moisture, produce leachate which drains into water sources, and develop a waste outer crust. When loaded into a spreader, the crust breaks into lumps that may clog the spreading equipment or will at least interrupt the feeding of the spinner.

Ketcham, et al. (1996) note that although solid or pre-wetted solid chemicals can be used as anti-icing treatments, there are advantages to use of liquids in small amounts for some conditions at pavement temperatures of about 23 degrees F and above. These include the ability to place chemical uniformly over the pavement at relatively fast spreading speeds and the ability to place chemical onto dry pavement as a pre-storm treatment to avert delays that may lead to bonded snow or ice. Five chemicals have been used for liquid anti-icing treatments: sodium chloride, magnesium chloride, calcium chloride, calcium magnesium acetate, and potassium acetate. Their characteristics were summarized in Table 1.1.

There are two principal types of liquid application equipment for highway use. One type uses spinners consisting of either multiple rotating disks or a single disk as shown in Figure 2.4. The other type uses nozzles on a distributor bar, as shown in Figure 2.5. Either spreader can be chassis-mounted, be a slip-in unit that can be placed temporarily in the bed of a dump truck, or it can be a trailer, or tow-behind unit.

With the use of salt brine or pre-wetted salt for anti-icing treatments, simple sodium chloride brine manufacturing plants became a necessity. Two types of manufacturing plants are currently in use for preparation of saturated brine: batch and continuous flow. Simple batch plants for temporary or small-scale production can be assembled using water tanks. Water passed through a bed of rock salt by gravity will produce a solution saturated at the water temperature. More efficient, continuous flow units, have been developed for high-capacity production. These plants force water under pressure through a bed of salt. The saturated solution then flows into a storage receptacle.

The wetting of a solid chemical prior to spreading can improve the effectiveness of the solid chemical in many situations. A solid chemical requires energy to go into solution and a dry solid chemical particle will remain inert until a liquid film forms. The process of going into solution will be accelerated if a liquid is added to the solid surface. Other advantages include: the solid chemical is spread more uniformly because of less waste from bouncing or traffic action; granules adhere to the road surface better; there is a faster and longer-lasting effect; spreading speed can be increase; and in some cases, the road surface dries more quickly. Ketcham, et al. (1996) conclude that the practical result

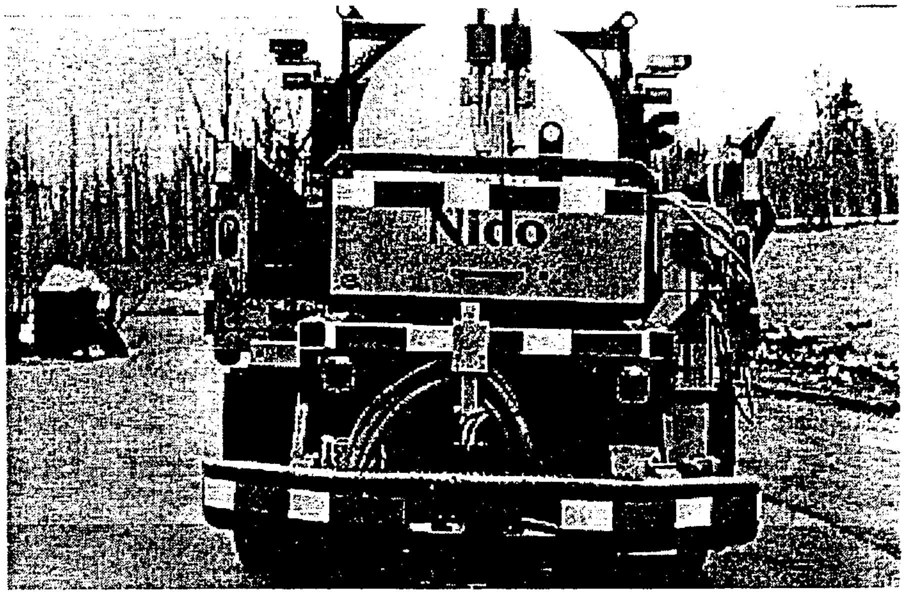

Figure 2.4. Typical Single Disk Liquid Spreader
(Source: Ketcham, et al., 1996).

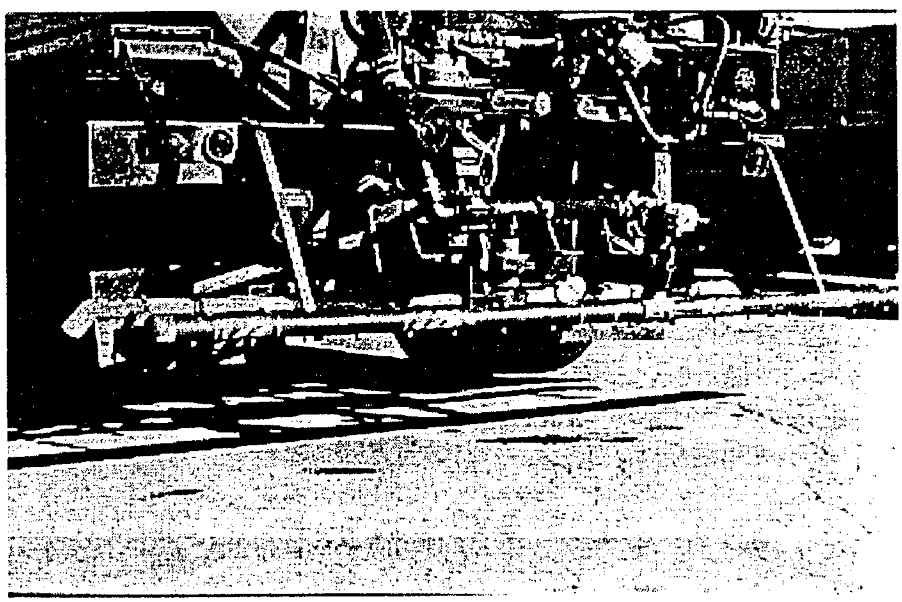

Figure 2.5. Liquid Spreader Using Distributor Bar with Nozzles (Source: Ketcham, et al., 1996).

is a reduction in the resources necessary for maintaining the highway since a lower application rate translates into a spreader load covering more area.

Pre-wetting can be accomplished by either of three methods. First, a pre-wetting chemical can be injected into the material stockpile at a specific dosage. Second, a liquid chemical can be sprayed onto a loaded spreader or on the material as it is being loaded into a spreader. Third, an on-board spray system mounted on the spreader and/or dump body can add a liquid chemical to the dry chemical at the time of spreading.

Wetting of stockpiled salt is performed in the late fall when the temperature of the stockpile drops to approximately 32 degrees F. The pre-wetting liquid is usually calcium chloride. One method uses a 42 or 45 percent solution liquid calcium chloride, heated to over 90 degrees F, hauled to the site by tanker truck and injected vertically into the stockpile at 1.5 to 2 foot spacing using special spray nozzles which penetrate deep into the pile. The recommended application rate is 8 gallons of liquid calcium chloride per ton of salt.

According to Ketcham, et al. (1996), this stockpile wetting is performed by the vendor of the liquid calcium chloride. The advantages of the method are 1) there is no spray equipment to maintain, 2) no installation of liquid storage tanks, and 3) no training of employees on application procedures. However, there are some disadvantages to this method of pre-wetting. Rain or snow on a wetted stockpile will dilute the calcium chloride and cause migration through the pile. Therefore, it is essential that stockpiles be covered and placed on impervious asphalt or concrete floors. Frequent working of the pile may be necessary to keep the pile manageable. The material cannot be readily carried through a warm season without the solution migrating from the pile.

The second method of pre-wetting consists of spraying liquid chemical onto a loaded spreader or on the material as it is loaded into the spreader. Application on the load is accomplished by an overhead sprayer with nozzles that dispense the liquid. A typical overhead spray system is shown in Figure 2.6. The driver pulls the truck loaded with dry chemical under a timer-controlled overhead spray bar system. A timer button activates a pump which sprays the truck with a solution. The recommended application rate for a 32 percent calcium chloride concentration is 12 gallons per ton of salt.

An important disadvantage of this method is that it has a very high corrosive effect on the truck equipment. Another drawback is the loaded material has to be completely discharged. The unused portion cannot be left in the truck box or mingled with non-pre-wetted material. Finally, it is very difficult to get uniform particle coating with this method. Liquid sometimes channels through the load to the truck bed without coating segments of the dry chemical. Other times, too much liquid is used in an attempt to achieve reasonable particle coating.

The most common method of pre-wetting is through the use of on-board spreader spray systems (shown in Figure 2.7). A spreader equipped for pre-wetting can apply liquids directly to the material being spread. The pre-wetting equipment can be an integral part of the spreader design or it can be a system that is added to an existing dry-material spreader. An existing spreader can be modified relatively simply and inexpensively. Both electric and hydraulic spray systems are used. An electric system

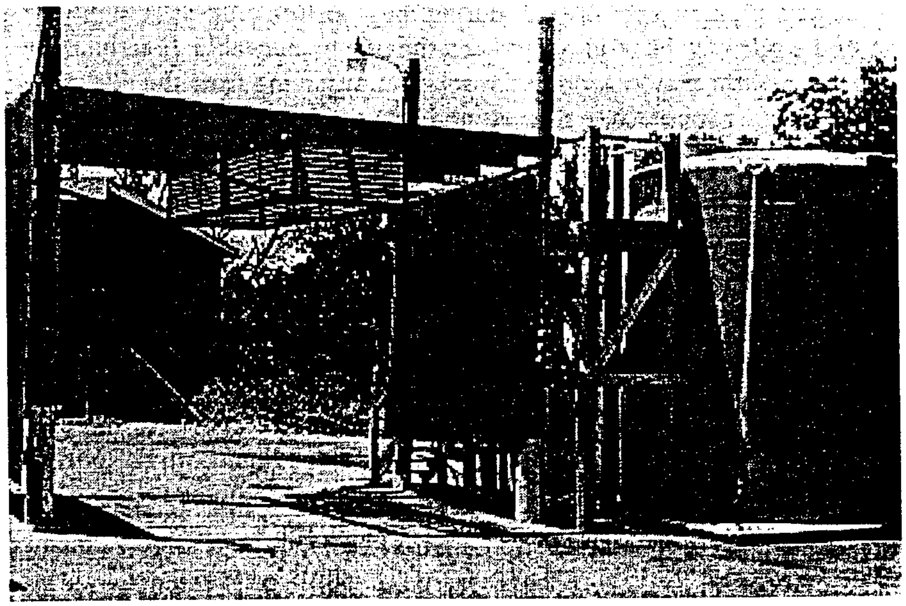

Figure 2.6. Typical Overhead Spray Arrangement for Pre-Wetting Material in Truck (Source: Ketcham, et al., 1996).

Figure 2.7. V-Box Spreader with Pre-Wetting Equipment.

consists of a 12-volt DC electric pump rated at up to 3 gallons per minute, in-cab controls, one or two nozzles, hoses, spray tank(s) and necessary fittings. The cab controls are generally of two types. The simple type has an on/off switch and a variable speed pump for increasing or decreasing the liquid material flow rate. Typically, this controller is not ground-speed oriented. The other type of controller monitors the amount of granular material being applied and automatically adjusts the liquid flow rate to maintain a constant gallons per ton ratio.

The hydraulic sprayer is in-line with the conveyor/auger motor which provides a constant relationship with the amount of material being spread. The system includes a liquid spray pump, hydraulic motor, cab controls, nozzle kit, spray tank(s), and necessary hoses and fittings. Generally, a small hydraulic motor is used to drive the product pump and is coupled in series with the conveyor/auger motor. An electrical solenoid valve built into the motor housing is connected to an on/off switch in the cab. An adjustable pressure regulator is located in-line between the pump and the nozzles to control the liquid flow rate.

Generally, the on-board spreader tanks are made of molded polyethylene and are provided with a replaceable output-line strainer and shut-off valves. Tank capacity is between 60 and 125 gallons.

The chemical solution production and storage facilities needed for pre-wetting operations are generally the same as those needed for liquid applications. However, smaller production/storage facilities may be adequate because of the smaller volumes of the chemical solution that will be required. Storage facilities for the solid chemicals are the same as those required for solid material applications.

Use of abrasives is common to many snow and ice control operations. Ketcham, et al. (1996) indicate that it is recognized that abrasives may be necessary when a rapid increase in friction coefficient is required. This is particularly important at temperatures so low that chemical action is slow, and in conditions where snow or ice is strongly bonded to the pavement and cannot easily be removed. These latter conditions are more likely to occur during a deicing operation. Abrasives are not ice-control chemicals, however, and will not support the objectives of either anti-icing or deicing. Their sole function is to increase the coefficient of friction. This increase may be short-lived, because traffic will rapidly disperse abrasives.

The routine use of abrasives in anti-icing operations generally yields no advantage. When anti-icing operations have successfully prevented or mitigated the hazards of packed snow, straight abrasive applications will provide no significant increase in friction or improvement in pavement condition. Because of the cost of application and clean-up of roads and drainage facilities, and because of the potential airborne dust problem accompanying their use, abrasives are not recommended as part of the routine operation of an anti-icing program.

The primary role of plowing in an anti-icing operation is to remove as much snow or loose ice as possible before applying chemicals in order that excessive dilution is avoided and the applied chemical can be effective. Because the initial chemical treatment should be placed before a significant accumulation, this is generally more important for subsequent operations. However, prior to liquid applications, it is essential that the pavement be cleared of as much snow or loose ice as possible, which may be important even for the initial operation. There are many types of snowplows. These include one-way front plows, reversible plows, deformable moldboard plows, underbody plows, side wings, and plows specifically designed for slush removal.

In the decision-making toolbox category, Ketcham, et al. (1996) include weather forecasting, traffic information, patrols, and evaluations of treatment effectiveness. The decision whether or not to initiate a treatment, when to start and what treatment to apply, can only be made if good weather information is available. This includes localized forecasts of when precipitation is expected to start, what form it will be, the probable air temperatures and the temperature trend during and after the storm, and the wind direction and speed. Ketcham, et al. (1996) recommend the use of meteorological forecasting services for anti-icing programs.

Ketcham, et al. (1996) also point out that real-time knowledge of the pavement surface is necessary for making an informed decision on treatment: the pavement temperature, whether it is wet or dry, and some indication of the concentration of a freezing point depressant. Pavement sensors accomplish this monitoring and warning function.

Road weather information systems are defined (Ketcham, et al., 1996) as networks of weather data-gathering and road condition monitoring systems and their associated communications, processing, and display facilities which provide decision information to maintenance managers. They point out that whoever makes the decisions for allocating resources for snow and ice control should have access to the latest weather and road information.

In spite of the technology available for collecting weather and pavement information, Ketcham, et al. (1996) emphasize that there is no substitute for visual observations of weather conditions and conditions of the pavement surface. Observations remain an important tool for making operational decisions even when an agency has access to and experience with new technology.

Vehicles can affect the pavement surface in several way: tires compact snow, abrade it, displace or disperse it; heat from tire friction, engine, and exhaust system can add measurable heat to the pavement surface. As noted previously, they can also result in applied chemical being blown from the pavement. As a consequence, they can influence, both positively and negatively, the effectiveness of anti-icing treatments, and should be considered in the decision-making process. Traffic information most important for making operational decisions is the variation of traffic flow throughout a 24 hour period.

Finally, as Ketcham, et al. (1996) note, it is essential for effective implementation of an anti-icing program that personnel be trained in the details of workings of the program. Anti-icing techniques and operations may be so foreign to many operators and managers that old ideas must be banished before a workable program can be started. An anti-icing program will necessitate more information for making an informed decision and may involve different methods and materials than do conventional methods. This will require an emphasis on training.

The FHWA Manual of Practice (Ketcham, et al.,1996) also recommends the type(s) of anti-icing operations for various winter weather conditions. Anti-icing operations consist of two major parts: (1) the initial operation and (2) subsequent operation. The goal of the initial operation is to place chemicals on the pavement before enough snow has accumulated to keep the chemical from reaching the pavement surface. However, before this action is taken, information about the nature and characteristics of the anticipated storm should be assembled and a decision made concerning the action.

Subsequent operations may not be necessary for some conditions and short duration events, but for major weather events, it is likely that further treatment will be necessary. In many cases, this does not differ from the initial treatment, although attention must be given to coordinating the application with plowing. It is important that roadway and weather conditions be closely monitored once the initial anti-icing operation has taken place.

2.3 Experience with Natural Brines

Although it is known that a number of jurisdictions in the northeastern and north central parts of the country have used natural brines for winter maintenance purposes, the only formal published material that could be located on the topic was that related to the work done at West Virginia University in the 1980's. Research activities on use of natural brines in winter maintenance started in the early 1980's with an assessment of the feasibility of using oil and gas well brines as highway deicing agents.

In the initial Phase I research project (Eck and Sack, 1984), in-depth laboratory research was completed along with a field-testing program. This was done to determine the chemical composition of the brines, the variability of brines from one well to another, and the freezing points of the brines compared to conventional deicing agents. In addition, testing was done to evaluate surface degradation of portland cement concrete and corrosion of steel.

To determine the chemical composition of the brines, forty-nine samples were taken from various wells around the state of West Virginia. Each sample was analyzed in four general components: (1) general parameters - total dissolved solids (TDS), conductivity, density, pH, and acidity; (2) major constituents - chloride, sodium, calcium, magnesium, and potassium; (3) minor constituents - iron, sulfate, barium, ammonia; (4) trace constituents - zinc, cadmium, arsenic, lead, and chromium. Some of these constituents can have negative effects on the environment; maximum toxicity levels were set under the Resource Conservation and Recovery Act (RCRA) of 1976, as can be seen in Table 2.1. Brines whose constituents exceeded these levels were excluded from further research.

Table 2.1. RCRA Limits of certain brine constituents (Source: Eck and Sack, 1984).

Constituent	Maximum Limit Under RCRA (mg/l)
Arsenic	5
Cadmium	1
Chromium	5
Lead	5

Brine variability was also examined. It was found that major variations in brine quality were not due to areal differences, but to formation and zone quality differences. This means that large variability in the quality of the brine can be found between geological formation. Brine composition varies with depth and the geological strata surrounding the brine.

The research found that certain weak brines froze at a lower temperature than a sodium chloride solution. It was concluded that this was probably due to the presence of calcium chloride in the natural brines. The sodium chloride solution was made by dissolving rock salt in water to form a solution of approximately 22 percent. This was attributed to the noticeable difference in eutectic temperature between sodium chloride, -6° F, and calcium chloride, -51°.

Lastly, natural brines were examined for their effects on highway materials, namely; asphalt concrete, portland cement concrete and steel. Samples of asphalt concrete were immersed in distilled water, natural brine, and sodium chloride solutions, and subjected to freeze-thaw cycles. It was found that no significant differences existed between the effects of natural brine and the rock salt samples. The effects of the brines on portland cement concrete were also evaluated. The specimens immersed in natural brines exhibited less surface scaling than those in rock salt.

The study also examined the amount of corrosion that natural brines and a sodium chloride solution caused to SAE 1010 steel (automobile steel) and A-36 steel (structural steel). Samples of SAE 1010 steel immersed in natural brine lost slightly less weight than those in sodium or calcium chloride. Samples of A-36 steel experienced a slightly greater weight loss when the samples were immersed in brine. The differences between the results of SAE 1010 and A-36 steel are likely due to the different chemical composition of the two steels.

After these lab tests concluded that use of natural brines was technically feasible, a high-pressure spray system was installed on a dual-axle dump truck. The unit consisted of a 1500-gallon fiberglass tank, a distributor bar and nozzles, a 25-hp gasoline engine, and a positive-displacement pump. Test sections consisted of both high and low volume roads.

As the field-testing progressed, it was found that corrosion products and other "dirt" typically found in brines tended to clog the small nozzle openings. Another drawback was the high initial cost of the unit. Examination of a simplified system seemed appropriate. The investigators (Eck and Sack, 1987) designed a system for tandem dump trucks that included a large steel tank, gravity feed system, and spray nozzles of the type used on liquid asphalt distributors.

The field testing showed that West Virginia oil and gas brines could be effective deicing agents over a wide variety of weather and pavement conditions. Visible melting began to occur almost immediately after the brine was applied and bare pavement was achieved rapidly. The high pressure spray unit was quite effective in cutting through packed snow and ice to create bare pavement. Gravity application of brines achieved rapid melt-off and bare pavement. The increased simplicity and lower equipment and maintenance costs made this system very attractive.

Results (Eck and Sack, 1987) showed that generally the brine performance was equal to that of traditional rock salt. Under light snow conditions, brine produced wet pavement immediately. However, under conditions where heavy snow continued after treatment, there was eventual snow accumulation on the pavement just as there was with rock salt-treated roadways.

In addition to evaluating the application of natural brine directly to the pavement surface, the feasibility of using brine as additive to abrasive materials and deicing salts was examined (Eck, et al., 1986). One issue addressed was the ability of the brine to freeze-proof material stockpiles. Brine was sprayed onto the material as it was placed into stockpiles, thus pre-wetting the material. Natural brine's ability to freeze-proof stockpiles of bottom ash, cinders, limestone, sand, and sawdust was studied. The study found that cinders and bottom ash in a relatively dry state could be easily freeze-proofed with the addition of brine. The ability to freeze-proof limestone chips depended on the moisture content. If the moisture content was equal to or less than three percent, the stockpile could be freeze-proofed. Thus, freeze-proofing of limestone stockpiles should be accomplished with conventional solid chemicals. Sawdust was freeze-proofed relatively easily because of the ability of sawdust to absorb the brine. Concern had been raised that the brine treated sawdust may be retained in the roadside vegetation and soil and cause significant problems.

The research (Eck, et al., 1986) concluded that spraying brine on abrasive materials as stockpiles are being formed, followed up by supplemental applications, would be the optimum procedure for freeze-proofing stockpiles. Results showed that the pre-wetted salt from the stockpile initiated slightly more rapid melting compared to dry salt. The salt also stayed closer the point of contact with the pavement, thereby reducing bounce-off.

For a number of years, several Pennsylvania Department of Transportation districts in the western parts of the state have been treating anti-skid piles with brine from oil and gas wells. It was reported (Ryan, 1988) that the brine treatment is effective in preventing freezing of anti-skid materials that are stockpiled each year over the fall and winter seasons. To control the application process, guidelines were developed for the treatment of anti-skid stockpiles with oil and gas brines.

Ryan (1988) notes that the usual rate of application for the season is 8 gallons per ton of anti-skid. However, a maximum rate of 12 to 15 gallons per ton per season may be needed for Type 3 and Type 5 anti-skid with finer materials. Brine should be applied at frequent intervals as the anti-skid pile is being constructed. Subsequent applications of brine after the initial construction of the pile, as the material is being used and portions of the pile are exposed, are acceptable as long as the approved rate is not exceeded.

The third and final phase of the comprehensive WVU research project (Eck and Sack, 1990) to determine the feasibility of West Virginia oil and gas field brines as highway-deicing agents concentrated on expanding the limited brine quality information collected in Phase I to include brine availability information (both quality and quantity) statewide. This involved development of a computer-based brine availability database.

According to the researchers' (Eck and Sack, 1990), the most important issues regarding brine's suitability for highway deicing were melting effectiveness and the level of potentially harmful constituents. The parameters evaluated included: total dissolved solids (TDS), chloride, sodium, calcium, pH, iron, sulfate, barium, led and oil/grease. Due to the low application rate of the brine, higher acceptable levels of iron, sulfate, barium, lead, and oil/grease were indicated for brine added to abrasives. It is worth noting that higher levels of barium could be found in dry deicing chemicals than may exist in many natural brines.

The database was capable of generating two types of reports. The first, which identified brine producers, was intended to be used at the managerial level at WVDOT Division of Highways district offices. The second, which identified specific brine sources, was intended for use by county maintenance personnel in making arrangements for acquiring specific brines.

It is clear from the earlier West Virginia University work that natural brines are liquids that have the properties of freezing point depressants. It is also apparent that this work addressed anti-icing aspects of natural brines, although that particular terminology had not yet been recognized. Furthermore, the literature on anti-icing technology and materials has focused on state-level applications. There is no published record of experiences at the municipal government level. Thus, it appears appropriate to assess the feasibility of using natural brines in local level anti-icing applications.

CHAPTER 3
METHODOLOGY

3.1 Introduction

In performing this research, several activities had to be completed before the field testing of brines could begin. Communities willing to cooperate in the project had been identified during the proposal stage. A source of brine had to be located for the selected communities. Anti-icing strategies had to be selected for each of the communities based on their particular characteristics. Then the appropriate application rates and study roadway sections had to be identified. Each of these issues is addressed in this chapter.

3.2 Participating Communities

Selection of the communities to participate in this project was made during the proposal preparation stage and relied heavily on the local level contacts made via the activities of the West Virginia Transportation Technology Transfer Center (LTAP Center) at West Virginia University. The communities of Fairmont, Morgantown and Philippi, WV were selected due to their proximity to major oil/gas fields in north central West Virginia and to the University. The city of Weirton, WV was also selected as a study site because of its proximity to New Cumberland, WV where an industrial by-product was available (as will be described later). Figure 3.1 shows the locations of four communities in West Virginia. All four communities have progressive public works departments and good working relationships with the Technology Transfer Center. The research team visited each community shortly after the project started to discuss the project, examine

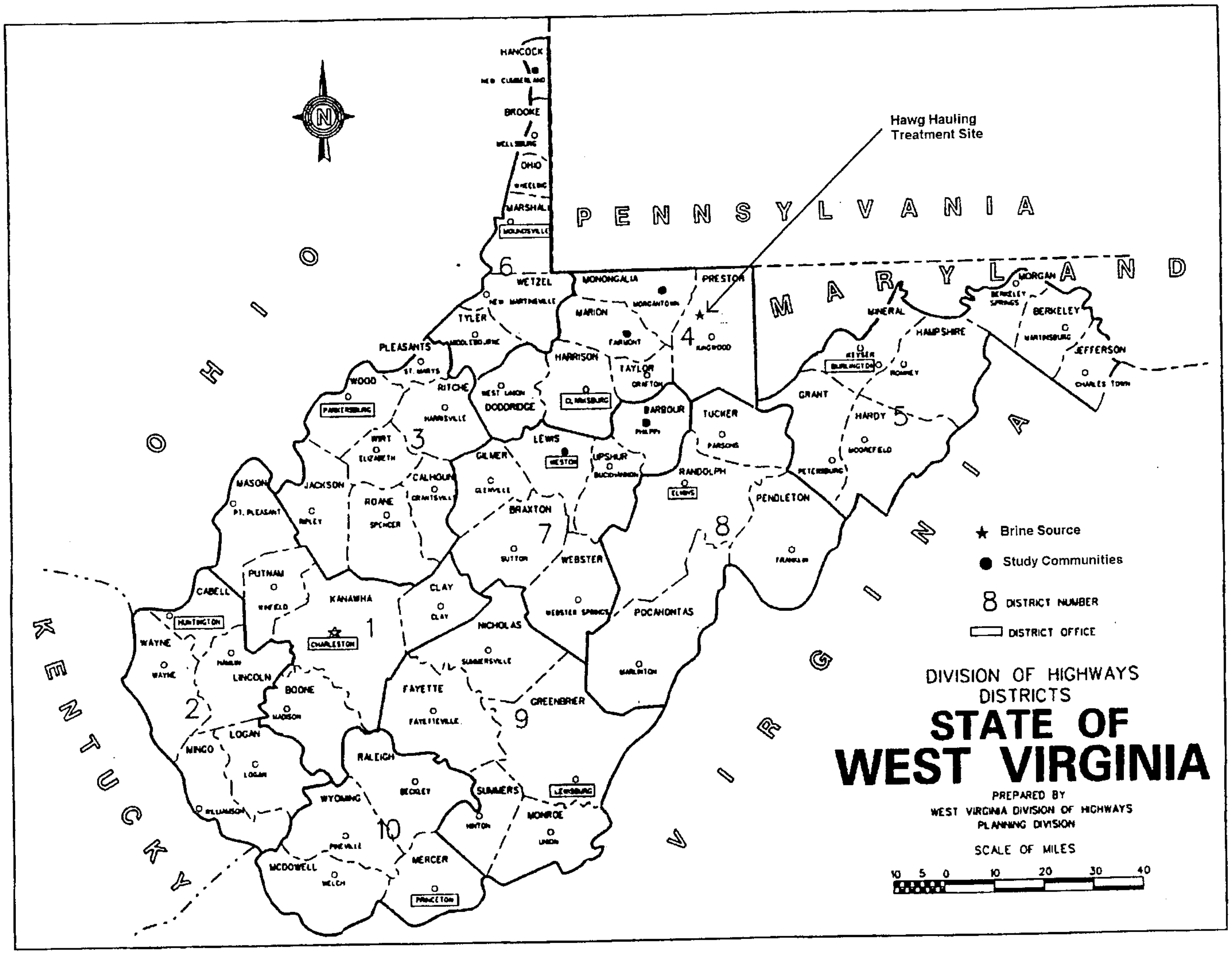

Figure 3.1. Locations of Brine Source and Study Communities.

available equipment and to identify potential test routes. Brief descriptions of the communities and their winter maintenance activities are presented below.

3.2.1 Fairmont, WV

The city of Fairmont, WV, with a population of approximately 20,000 people, is located in north central West Virginia where the West Fork and Tygart Rivers join to form the Monongahela River. Originally settled as a mining community, it has since grown to a manufacturing area that includes aluminum, glass, and mine machinery. The City Public Works Department is responsible for about 110 lane-miles of road.

Fairmont receives weather and road condition information from several sources. For current local weather conditions and radar, "The Weather Channel" (homepage and cable station) is utilized. Road condition reports come from city road crews, local police agencies and state road officials.

Typically, Fairmont applied a combination of rock salt and bottom ash (cinders). They were mixed at an outdoor storage area in ratios ranging from 1:1 to 3:1, cinders to salt. Maintenance personnel determine the ratio used in a particular situation based on weather conditions.

Mr. Michael DeMary, Director of Public Works, stated that he would like to spread chemicals only, but cannot obtain the funding needed to start such an operation. He hoped that the use of brine would reduce the amount of abrasive material used and, consequently, the amount to be removed from roads and drainage facilities in storm clean-up.

Fairmont's winter maintenance equipment consisted of two (2) one-ton pickup trucks with dump beds, four (4) three-quarter ton pickup trucks and two (2) single-axle dump trucks. Each of the trucks can be equipped with a front-mounted snowplow. To apply abrasives or salt, two (2) one and one-half cubic yard V-box spreaders for the one-ton trucks and two (2) two and one- half cubic yard V-box spreaders for the dump trucks are used.

3.2.2 Morgantown, WV

The City of Morgantown, WV is home to West Virginia University. The city is located on the Monongahela River approximately sixty miles south of Pittsburgh, PA. The community developed around the vast coal mines in the area. At present, the city's economy is growing with the aid of the health care facilities and pharmaceutical and manufacturing industry.

During the school year, the population of the town grows from about 35,000 to 60,000. Maintaining the road and street system during the winter months is made difficult by the topography and the nature of roads in Morgantown. The city has a large number of long, steep hills and many of the roads are very narrow. A network of this type would benefit from implementation of an anti-icing program.

Weather conditions are obtained from local radio stations. The Police Department dispatches winter maintenance crews when public works officials are not on duty.

Morgantown, uses rock salt as its chemical agent and bottom ash as an abrasive. The two are mixed in a ratio of 2:1 to 3:1, cinders to salt. The city's rock salt is stored inside a salt shed.

The city maintains a fleet of maintenance equipment consisting of four (4) one-ton pickup trucks and three (3) single-axle dump trucks. All trucks can be equipped with front-mounted snowplows. For application of salt or abrasives, three (3) one and one-half cubic yard V-box spreaders are placed on the bed of the pickup trucks and three (3) two and one-half cubic yard V-box spreaders are used on the dump trucks.

3.2.3 Philippi, WV

The town of Philippi is a historic community with a population of 3,100 people located in the foothills of north central West Virginia. Philippi was originally settled as a mining community, but is trying to be reborn as a industrial area. The Town of Philippi provides several unique services to the public. Besides supplying the community with the typical water and sewer utilities, they also furnish electricity and cable television to residents.

Typically, Philippi performs limited snow or ice control activities due to the relatively level terrain and the relatively short street system for which it is responsible. To determine local weather conditions, Philippi maintenance crews listen to local radio and conduct road surveys to evaluate road conditions. The public works department normally applies chemicals and abrasives only to intersections and to specific critical areas, e.g., hills and curves. Philippi applies a combination of rock salt and wood chips to roadways. The wood chips are mixed with the rock salt at a rate of approximately ½ ton of chips to 2 to 3 tons of rock salt. For plowing and salting operations, the city has one (1) three-quarter ton pickup and one (1) three-quarter ton pickup with a flat bed on it. Both trucks are equipped with snow plows and one and one-half (1.5) cubic yard V-box spreaders.

3.2.4 Weirton, WV

The city of Weirton, WV, with a population of 22,000 people, is located on the Ohio River in the northern panhandle of West Virginia. In the early 20th century, an integrated steel plant was established there. Steel manufacturing is still the principal industry, but building materials, chemicals, and lubricants are also produced.

The city of Weirton applies rock salt mixed with bottom ash. The two materials are mixed in various proportions depending on the type of winter storm event. At the time this project started, the rock salt and bottom ash were stored outside on a concrete slab. This practice created runoff that killed the vegetation downgrade from the storage area. To eliminate this practice, the city constructed a new barn-type facility to store both the bottom ash and rock salt.

City officials receive weather information from a Pittsburgh-based weather service. The service faxes weather bulletins periodically and whenever weather warnings are issued. Public work officials make periodic road surveys to assess the current conditions.

Weirton's public works department has a large indoor facility for the maintenance and storage of trucks and equipment. The department has three (3) single-axle dump trucks. Each truck is equipped with a two cubic yard V-box spreader and a plow. At some time in the past, pre-wetting systems were installed on the trucks. However, the systems were no longer functional at the time this project was initiated. Weirton also has a three-quarter ton pickup truck with a one and one-half cubic yard spreader box and plow installed on it. This pickup is used to clear and salt narrow roadways and alleys.

3.3 Anti -Icing Strategies

As described in the previous chapter, a number of anti-icing strategies are available. As a liquid, one of the obvious strategies to utilize brines would be to apply them directly to the roadway. However, this strategy was rejected for two principal reasons. First, to implement this option would require a large tank and spray bar and nozzle arrangement on each truck. The issues of initial costs and problems with orienting field personnel to a new system were of such a magnitude that this strategy was viewed as not feasible for small municipalities. The typical municipality utilizes its equipment for a variety of purposes. It would be difficult to justify dedicating a piece of equipment to only one task, i.e., application of liquid chemicals. Secondly, based on prior research with West Virginia brines, it was understood that slight variations in brine quality occur from time to time. Unless carefully monitored, it is possible that weaker brine could be acquired that would freeze upon direct application to a cold road surface.

For these reasons, anti-icing strategies considered by the researchers centered around one of the forms of pre-wetting salt and abrasives. Pre-wetting can be accomplished by one of three methods. First, the pre-wetting chemical can be injected into the salt stockpile at a specified dosage. Second, the pre-wetting chemical can be sprayed onto a loaded spreader box or on the material as it is being loaded into the spreader box. Third, a system mounted on the spreader and/or dump body of the truck can spray the liquid chemical on the dry material(s) at the time of application to the roadway.

After an evaluation of available anti-icing strategies and discussions with public works officials in each of the communities, it was decided that the best approach would be to install on-board pre-wetting systems, such as that shown in Figure 2.7, on the municipal maintenance trucks. Several factors affected this decision. First, it was believed that pre-wetting either the stockpile or the load would not provide uniform treatment of the dry material. Second, there would be increased risk of environmental degradation with this approach. Furthermore, the overhead spray units used to pre-wet an entire load would accelerate corrosion of the bed and box of the truck. It was thought that the on-board system would be the most cost-beneficial system because of the particular size and nature (i.e., a municipal environment) of this project and because the spreaders could be modified relatively simply.

An off-the-shelf, on-board pre-wetting system typically consists of a 12-V DC electric pump rated at up to 3 gal/min, in-cab controls, two to four spray nozzles, hoses, various size spray tank(s) and necessary fittings. In-cab controls can be one of two types. The simple type has an on/off switch and may have a control for a variable speed pump. The other type monitors and displays overall total gallons of liquid pumped and tons of granular material spread per trip. The spray nozzles are positioned so that they spray either down onto the spinner or in the chute. The on-board spray tanks are generally made of molded polyethylene specifically designed to fit with the spreader box in the dump body of the truck and are provided with a replaceable output-line screen strainer and shut-off valves. An off-the-shelf system like that described can be purchased from a variety of outlets. Alternatively, it is not difficult to build a system from scratch, as the components are relatively easy to obtain.

For Fairmont and Philippi, the complete on-board systems had to be purchased. The project team and the communities decided that it would be best to equip the towns' pickup trucks with units designed to work on a pick-up truck chassis. For Morgantown, a larger unit was needed because it would be placed on a single-axle dump truck.

It was necessary to determine the size and type of unit to be purchased for each city. Considering the density of the brine (9.75 lb/gal) and the size of spreader to be used in each community, it was determined that each of the pick-up truck units needed to carry about 50 gallons of brine; the dump truck unit needed to carry about 70 gallons of brine. This would allow the trucks to make approximately two runs without having to refill the tanks and, at the same time, would not overload the trucks.

The investigators discussed whether to purchase units with a variable speed on-board pump. The team decided that Fairmont would receive a unit with variable speed pump and that Philippi would get a unit with an in-cab on/off switch. This was done for several reasons. First, Philippi does not apply as much salt as Fairmont. A second reason was economic concerns given the budget constraints of the project.

Morgantown became involved in the project at some time after the other communities. At this point, project funds were not available to purchase the necessary equipment. However, Morgantown still wanted to participate. Consequently, the research team assisted them in selecting equipment and designing and fabricating a low-cost system. The system was designed to be installed on one of the city's single-axle dump trucks.

Since Weirton's vehicles were already equipped with pre-wetting systems, they needed only the equipment necessary to outfit one of the single-axle dump truck units, i.e., a 12 - volt pump and a set of new nozzles.

The on-board pre-wetting systems and accessories were obtained from Snow Equipment Sales, Inc. of Dayton, Ohio. Appendix A contains the specifications for the on-board systems as furnished by Snow Equipment. Also included is a list of the equipment provided to each municipality, along with the associated cost.

3.4 Brine Supply

Preliminary calculations (shown in Appendix B) indicated that for the anti-icing strategy selected, the participating communities would need between 1900 gallons

(Philippi) and 4200 gallons (Morgantown) of brine during a typical winter. In identifying available brine sources, factors such as well or storage facility location, brine quality, and the quantity of brine available had to be considered. The previously established Brine Availability Database (Eck and Sack, 1990) provided assistance in this regard. The database contains information such as supplier, well group location, quantity produced, and quality parameters.

The researchers contacted several oil and gas companies operating in north-central West Virginia about providing the indicated quantities of brine. Columbia Natural Resources (CNR) responded enthusiastically about involvement with the project. CNR indicated that one of their subsidiaries, Hawg Hauling & Disposal Inc., handles disposal of much of the brine from natural gas and oil operations in north-central West Virginia. Hawg Hauling disposes of approximately 10 million gallons of brine each year. Of these 10 million gallons, approximately 2.5 million gallons originate from CNR wells. This brine is normally put back into the ground via injection wells at one of the company's three treatment and injection facilities. For purposes of this research, it was decided to use only brines from CNR wells. The brine used was a combination of several wells from the Oriskany formation. Samples of the brine were obtained and analyzed and found to be acceptable for project purposes. Table 3.1 presents the constituents of the brine used in the field tests. A copy of the Material Safety Data Sheet (MSDS) for this particular brine, which was furnished by Hawg Hauling to the participating municipalities, is included as Appendix C.

Table 3.1. Composition of Brine Used in Field Tests and Comparison with Other West Virginia Brines.

Constituent	Level of Project Brines	Range of Previous Brines Studied	Average of Previous Brines Studied
TDS (mg/l)	289,440	90,420 - 323,700	218,600
Conductivity (micromhos/cm)	432,000	200,000 - 605,000	413,600
Density (lb/gal)	1.17	9.191 - 10.129	9.774
pH	8.74	2.72 - 6.14	4.3
Acidity	Neg	80 - 227	276
Chlorine	173,000	57,510 - 192,420	128,600
Sodium	82,400	29,130 - 82,420	52,740
Calcium	34,230	5,470 - 57,900	31,310
Magnesium	2,924	645 - 4,950	3,200
Potassium	2,100	30 - 3,310	590
Iron	84.58	28 - 750	276
Sulfate	3,372.13	<5 - 547	163
Barium	196.5	1.3 - 2,500	545
TOC	NA	6 - 45	29
Ammonia	218.97	11 - 386	51
Cadmium	0.1007	<0.01 - 1,627	0.365
Chromium	<0.1	<0.06	<0.06
Hexavalent Chromium	0.5	NA	NA
Arsenic	1.62	0.138 - 0.457	0.263
Lead	1.102	1.583 - 6.100	3
Zinc	0.2518	0.212 - 1,739	0.619
Fluoride	<0.1	NA	NA
Nitrate	0.5127	NA	NA
Total Cyanide	<0.005	NA	NA
Ammonia Nitrogen	NA	NA	NA
Chemical Oxygen Demand	NA	NA	NA
Aluminum	444.1	NA	NA
Vanadium	0.1447	NA	NA
Copper	0.3106	NA	NA
Mercury	62.7	NA	NA
Manganese	1.709	NA	NA
Nickel	0.4148	NA	NA
Selenium	1.53	NA	NA
Beryllium	0.0125	NA	NA

NA = Not Available

Hawg Hauling's base of operation is Buckhannon, WV. It operates three brine treatment and injection facilities in north-central West Virginia. One facility is near Weston, WV and the other two are near Morgantown, WV. The location of the facility supplying brines for this study is shown in Figure 3.1. Hawg Hauling's treatment facility locations were convenient to the participating municipalities since all municipalities except Weirton, WV were within 30 miles of one of the brine treatment facilities. Hawg Hauling agreed to provide brine storage tanks and the required diking for Fairmont, Morgantown and Philippi. Fiberglass storage tanks of 4200- and 8400-gallon capacity were erected at the maintenance yards in Fairmont and Morgantown, respectively. A 1400-gallon fiberglass tank was erected at Philippi. All storage tanks had to have a dike that surrounded them, that would hold up to one and one-half times the volume contained in the tank. All dikes were made out of earth with dimensions appropriate to the site.

After the project started, the investigators became aware of a brine produced by CM Tech, Inc. of New Cumberland, WV. CM Tech, Inc. is located on the banks of the Ohio River approximately ten miles north of Weirton, WV. The company generates a calcium chloride brine as a by-product of a potassium titanium fluoride recovery operation. From samples taken at the plant, it was determined that the constituents of the brine were within acceptable levels, as identified in previous brine-related research. It is important to note that production brines, from oil and gas wells, are excluded from regulations under the Resource Conservation and Recovery Act (RCRA) but brines such as produced by CM Tech are not excluded. This brine contained several elements not typically found in oil and gas wells brines, namely, nitrate, cyanide, aluminum, titanium, vanadium, copper, and ammonia nitrogen. After it was determined that the brine met project requirements, approval was sought from the West Virginia Department of Environmental Protection (WVDEP) to apply the brine in this pilot application.

CM Tech, Inc. was not able to supply the City of Weirton with an on-site storage tank. For this reason, the project furnished a 1,400-gallon polyethylene storage tank to the city. Weirton maintenance personnel constructed the earth dike. The City of Weirton and CM Tech, Inc. made a delivery arrangement. When City public works personnel felt that the storage tank needed to be refilled, they would call CM Tech, Inc for brine delivery.

3.5 Selection of Test Routes and Data to be Collected

The research team visited each community to identify appropriate test routes for the project. Through these discussions it was found that Weirton and Philippi used similar strategies to maximize use of their maintenance equipment. Both communities divided their streets into sections and assigned a truck to each section. Each section contained both major arterial and residential streets. Thus, for Weirton and Philippi a section of the road system was used as a test route and the other sections were used as control sections.

Morgantown and Fairmont do not divide their system into clearly defined sections. Each truck is assigned a major arterial street that they maintain initially. As the main arterial are treated and cleared, then the tucks move to the minor and residential streets. Test routes for these communities were selected on the basis of past winter maintenance experience.

Morgantown selected as test sections two bituminous surface major arterial streets, which had a tendency to have a low level of service during snow/ice events. These routes had lengths ranging from 1.5 to 2.5 miles and pavements widths ranging from 21 to 30 feet. As shown in Figure 3.2 and 3.3, each test section starts near downtown Morgantown and terminated at the Morgantown City limits. Starting from the city limits the roadways are classified as state routes. The West Virginia Division of Highways treated the roads using a traditional deicing approach. These were considered to be the control sections.

Fairmont used an approach similar to Morgantown to select test streets. Instead of using major arterial streets, Fairmont, selected several of their bituminous surface collector roads that service higher volume routes and have steep hills. Control sections were major arterial streets and collector roads that were not part of the test routes.

During the community visits, samples of rock salt and anti-skid material were obtained. Gradations were then taken on each of the samples. The gradation of each sample was nearly the same, the average of the three rock salt samples is presented in Figure 3.4. As the graph shows, the average gradation fell within ASTM specification D 632 for type 1 salt. A similar analysis was done for bottom ash, some of the material was smaller than 75 micrometers in diameter, as shown in Figure 3.4. Anti-skid material that is smaller than 75 micrometers tends to make an icy surface even more slippery because of the particle size (Minsk, 1998).

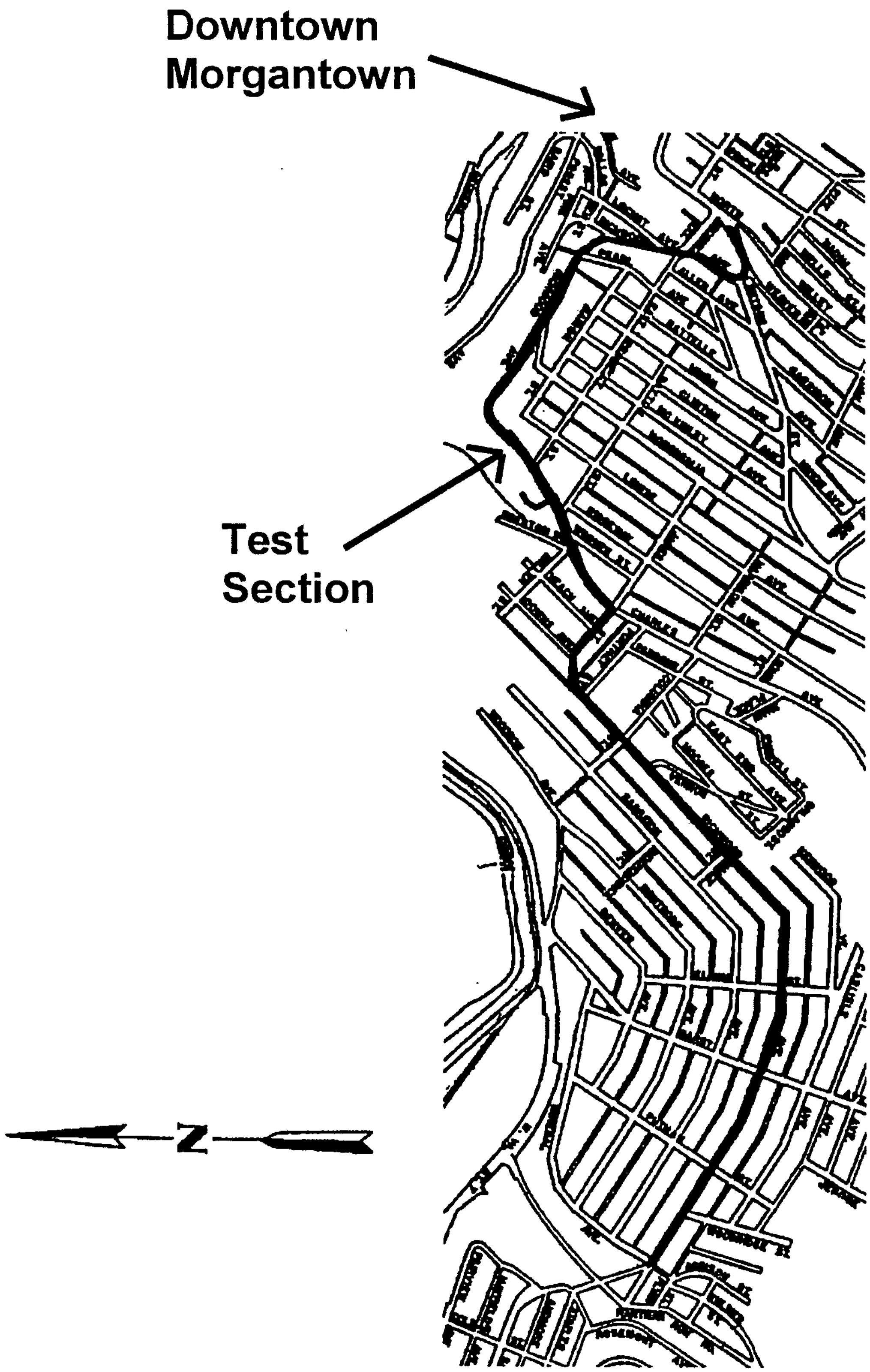

Figure 3.2. Vicinity Map of Richwood Avenue Test Section in Morgantown, WV.

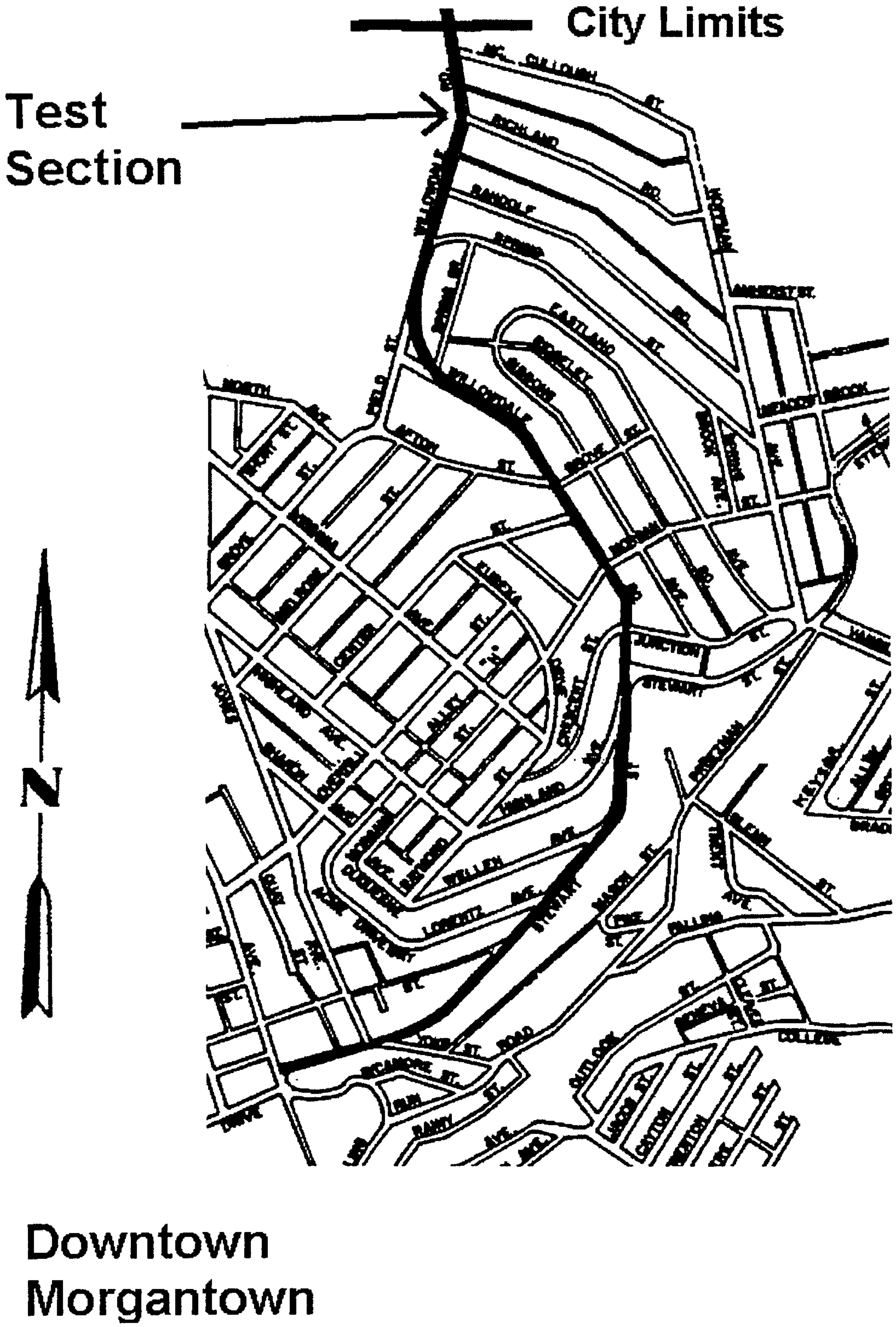

Figure 3.3. Vicinity Map of Stewart Street-Willowdale Road Test Section in Morgantown, WV.

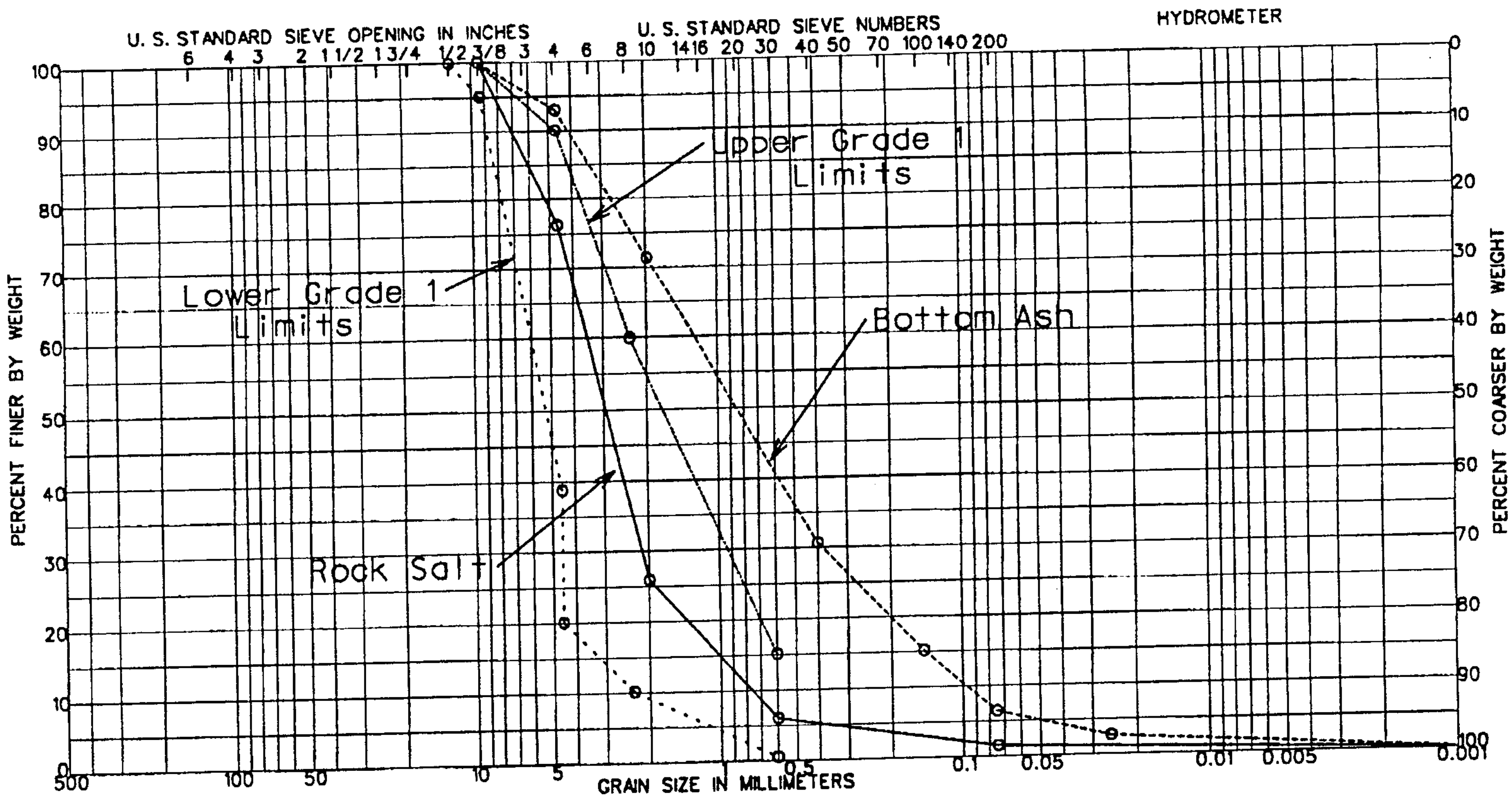

Figure 3.4. Gradations of Rock Salt and Bottom Ash Obtained from Participating Communities.

The researchers also wanted to verify that if brine was combined with rock salt and abrasive material that the combination would not "clump" in such a way that it would jam the spreader or clump on the roadway. A test was conducted by mixing the rock salt and cinders together in ratios of 1:1, 2:1, 3:1; anti-skid to salt. The sample was then saturated to see if any adhesion would occur between the rock salt and anti-skid. No particle adhesion was found to occur.

3.6 Data Collection

To collect data on the effectiveness of the brine and to compare test sections to the control sections, data collection sheets were developed for use by maintenance personnel. The data collection sheet, as shown in Figure 3.5, is designed around a TAPER (Temperature Application Product Event Result) data collection plan (Gesford, 1997). This approach was implemented because of the amount of useful data that is collected. Each of the variables allows the researchers to know the conditions that were present during application and the results of the type of material applied and the application rate. Both the air temperature and pavement temperature at time of application were desired. To find the pavement temperature, communities used a digital infra-red thermometer. All communities but Philippi possessed such a device. Under “type of weather event” the driver recorded the current type of winter weather that caused maintenance operations to be performed. All communities mixed rock salt in various amounts with anti-skid material. The research team felt that knowing this ratio was very important in evaluating the effectiveness of the treatment. With drivers able to apply the mixture at various rates, City of ______________ Streets/Routes Treated: ____________________

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		

D - Dry W - Wet Sn - Snow Sl - Slush

Figure 3.5. Abbreviated Version of Field Data Collection Form Used by Field Personnel

both liquid and solid applications rate had to be recorded. Finally, the drivers initial were recorded so that they could be contacted if any questions arose later. The sheet was designed so that the driver would fill out everything, except the results, on the initial application run. On the return trip to the section of roadway, the results from the previous application would be noted in the appropriate column.

CHAPTER 4
RESULTS

4.1 Introduction

During winter of 1998–99, public works personnel of the participating communities applied brines as a pre-wetting agent to rock salt and abrasive mixtures. Members of the research team performed periodic monitoring. Along with the periodic monitoring done by the research team, the communities' maintenance supervisors and truck drivers completed data forms and informed the team of their subjective assessment.

The winter of 1998-99 was generally warmer than average for north central West Virginia. The first significant snowfall did not occur until December 30, 1998. This was followed by about six more storms in January that required winter maintenance activities. The test communities received all forms of winter weather conditions, including snow, ice, and sleet. Note that additional heavy snow fell in mid-March. Although the communities successfully used brines in treating these snows, no data are available since the research team had notified the communities that no data would be collected after February.

4.2 Fairmont, WV

Although Fairmont and Morgantown are located relatively close to one another, during winter storms it was not easy for the researchers to travel to Fairmont to evaluate the results brine application. In order to have a photographic record data of before and after road conditions, maintenance crews were provided with disposal cameras. However, this effort was not successful because either the timing of the storms did not permit photographs to be taken or crews forgot that they had the cameras. For these reasons, no photographic or videotape records were obtained in Fairmont. The maintenance crews supplied daily dairy entries that consisted of detailed notes on date and times of applications, location of treatments, and application rates. Due to their completeness and excellent detail, the complete set of notes and data forms from Fairmont has been included as Appendix D.

Fairmont applied brine during seven winter storms. There were more than seven winter storms, but conditions during several of them called for treatments other than applying salt or cinders to the roadway, e. g., plowing or do nothing. In fighting these seven storms, Fairmont used approximately 4200 gallons of brine in various ways.

Except for two instances, brine was applied to a mixture of 3 parts cinders to 1 part salt. The material was pre-wetted with brine at an application rate of approximately 20 gallons per ton of material as it came out of the spreader box and fell onto the spinner. This rate was much higher than both that determined by the investigators and that called for by Ketcham, et al. (1996) because the Public Works Department staff wanted to start off at a high application rate then slowly reduce the rate with experience. This was never accomplished because of the nature of the 1998–99 winter season.

Fairmont applied brine in temperatures ranging from 3° to 19° F; higher temperatures where not encountered during the winter storms when the brine was applied. At no time did the brine in the storage tank show any tendency to freeze.

Based on initial success with the brine pre-wetting; the Public Works Department utilized brines in ways other than described in Chapter 3 to assist them with maintenance operations. Although, as described in the previous chapter, only one truck was equipped with brine pre-wetting equipment, the benefits of brine were extended to other trucks by spraying each load with a pre-determined quantity of brine before it left the maintenance yard. Figure 4.1 shows that the treatment involved using a hose to spray the top of the spreader box. Note that material treated in this manner was applied to streets other than the test sections.

When the entire load was pre-wetted at one time, brine was applied at a rate of about 10 to 11.5 gallons per ton of material. Maintenance crews calibrated the supply tank pump and found that it pumped approximately 20 gallons per minute. This was then equated to the application rates presented by Ketcham, et al. (1996) and the amount of time required to spray each load, approximately 90 to 120 seconds, was determined. Crews sprayed each truckload for at least this amount of time, i.e., about 30 to 40 gallons per truckload. In some instances, the application rate may have been higher than what was reported to the researchers. The application of rate of 10 to 11.5 gallons is slightly less than the range stated by Ketcham, et al. (1996) and represents the lower range of what the application could have been. This is due to the techniques that were employed to pre-wet the entire load.

In a different application, on one occasion, the city used brine on the sidewalks of a bridge to aid in the removal of ice. On January 5, 1999, the sidewalks of the Mid-City Bridge, were covered by ice from material thrown on them from snowplows. The weather was cold and sunny with an air temperature of 3° F. Sidewalks were treated at 8:30 am by applying salt to them by hand. Since by 10:00 am, the ice showed no signs of melting, maintenance personnel sprayed the sidewalk with brine using a 3-gallon hand sprayer. By 11:30 am, the sidewalks showed signs of melting. At 12:30 pm, there was water running on the sidewalks and the ice was

Figure 4.1. City of Fairmont Crew Member Using Hose to Pre-Wet Entire Truck Load with Brine.

breaking up. This occurred with very little foot traffic on the sidewalk. City personnel were very pleased with the results which suggest another potential application of the brine.

Fairmont public works personnel felt that the brine-treated roadways provided a better level of service to the motoring public. For instance, on December 30, 1998, the test section was treated at 8:30 am using the truck equipped with the pre-wetting equipment. The test section was snow-covered with icepack under the snow. By 9:30 am, the snow and ice on the road surface had started to melt. By 10:30 am, the roadway was slush-covered. At 11:30 am, the roadway had water running on it. By 11:30 am, the control section, which had also been treated at 8:30 am, was still snow- and ice-covered. Clearly, this represents an improvement in the level of service and should be safer for the traveling public.

Maintenance personnel indicated that they saw the same results when brine was sprayed on top of the loads. They felt that the brine reduced the clearing time by about one-half compared to the clearing time associated with the material not treated with brine.

The city also applied straight cinders prewetted with brine. Crews reported that this method showed signs of melting the snow and ice, but took much longer to do so. The main benefit associated with this approach was that it reduced bounce–off of abrasive material.

Fairmont's Public Works supervisors felt that the brine resulted in roadways that were responding to treatment in about one-half the time of conventional deicing operations, resulting in safer road conditions for the citizens of Fairmont. Supervisors also reported that many citizens called to thank the city for clearing their streets faster. Lastly, they felt that brine was a worthwhile product to aid in fighting snow and ice on roadways and sidewalks. Supervisors planned to continue using the brine as long as it is cost-effective alternative for them.

4.3 Morgantown, WV

Since the research team was located in Morgantown, they were able to evaluate the performance of the brine firsthand. This was accomplished visually via drive-throughs, photographs, and videotape. During several storms, the researchers traveled the control and test sections evaluating the condition of the roadway surface after treatment. City of Morgantown truck drivers also kept records of temperature, precipitation and materials usage. A sample of these data sheets is included as Appendix E.

Morgantown used approximately 2700 gallons of brine for winter maintenance operations in combating the seven winter storms. In general, significant differences were noted between the conditions of the test and control sections. Typically, snow and ice had bonded to the pavement on the control sections, as shown in Figure 4.2. This condition adversely affected the level of service and safety of the roadway.

The conditions of the test sections were typically just the opposite. Test section pavements were either nearly clear or slush-covered, as shown in Figures 4.3 and 4.4. Such conditions allowed motorist to travel at higher speeds and to maintain better control of their vehicles.

After it was evident that brine could be used effectively as an anti-icing agent, the street department of Morgantown decided expand the use of the brine. Test sections were expanded to street types ranging from high volume arterial roads to low volume collector streets. All roadways had a posted speed limit of 25 mph. Morgantown crews applied brine-treated

Figure 4.2. Snow/Ice Bonded to Roadway Surface on Control Section in City of Morgantown.

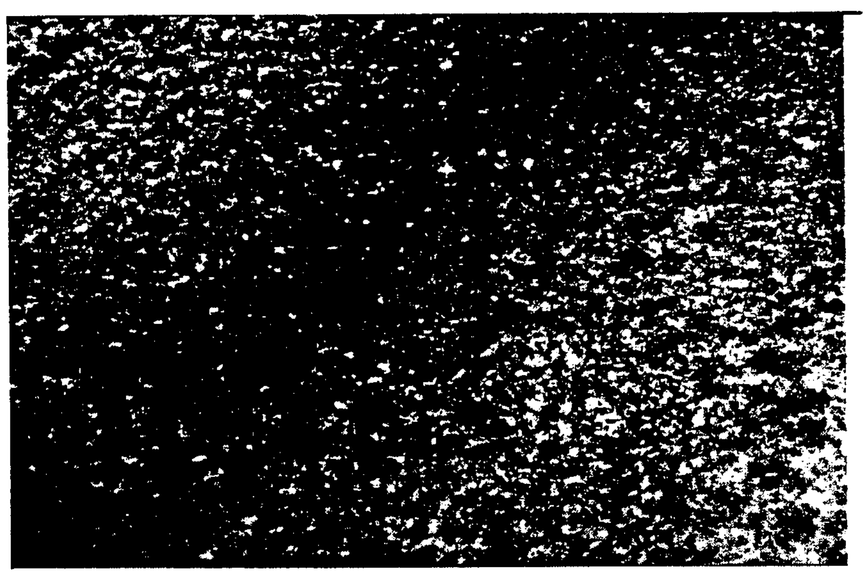

Figure 4.3. Close-Up View of Pavement Surface Condition on Richwood Avenue Test Section in City of Morgantown.

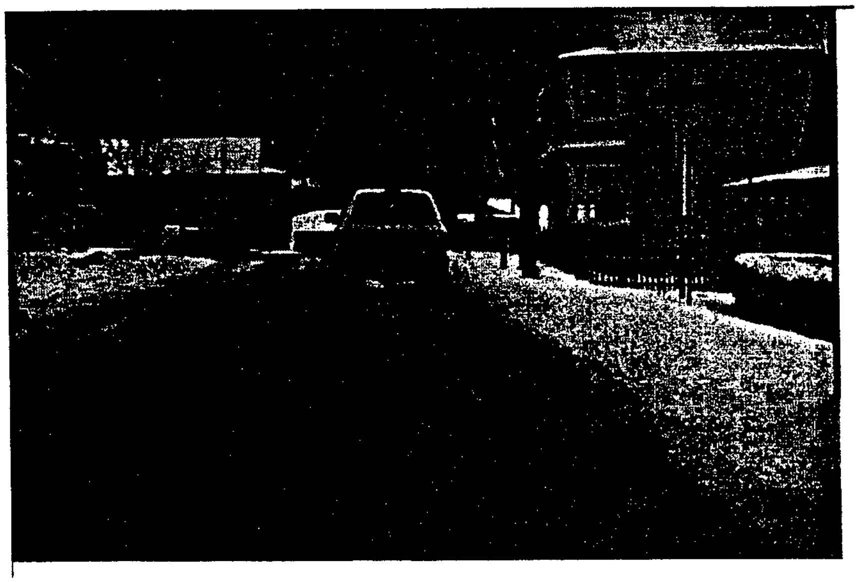

Figure 4.4. Driver's Eye View of Slush on Richwood Avenue Test Section in Morgantown.

materials at various times during storm events depending on the temperature and the local weather forecast.

On one occasion, brine-treated material was applied before precipitation started in an effort to pre-treat the roadways. This was done when the temperature was low and the local weather forecast called for some form of winter precipitation. Main roads were pretreated with pre-wetted salt and cinders at a ratio of 1:3; the material was applied at various levels ranging from approximately 1200 to 2000 pounds per lane-mile. While the application rate was very high, only one-fourth of the material was salt. Thus, the City applied approximately 300 to 500 pounds of salt per lane-mile. This pre-treatment was done shortly before the daytime crews went off duty, i.e. 2:00 to 3:00 pm and allowed a delayed reaction by maintenance crews. The mainline routes that were pre-treated stayed clear or slush-covered while non-treated roads experienced snow and ice bonding to the pavement. The Public Works Department deemed this approach a success. One drawback was that the Police Department responded later than normal in calling out the maintenance crews since the main streets were in relatively good condition. Streets that were not pre-treated had significant accumulation on them by the time maintenance crews were called out.

Most Street Department personnel had a positive reaction to the use of brine. They felt that pre-wetting the salt and cinder mixture with brine alleviated the tendency of the dry material to bounce off the pavement. Maintenance personnel felt that pre-wetting with brine provided a higher level of service on treated roads by preventing the snow and ice from bonding to the pavement. Test sections of road were kept mainly in a slushy condition. The investigators and maintenance supervisors agreed that roads in such condition are not a major problem for motorists to negotiate. Field personnel also thought that in those instances where a bond had formed, the brine-pre-wetted mixture caused the condition to break up more easily and more quickly. This was expected since, with the application of brine, rock salt has moisture available to commence work immediately on breaking the bond.

The Public Works Director felt that brines improved the level of service supplied to motorist. This was done by preventing snow or ice from bonding to the pavement surface. At the present time, the City of Morgantown is exploring options to expand the use of the brine to all trucks used in winter maintenance operations. Funds to purchase on-board pre-wetting units for all City trucks have been requested for the upcoming year.

4.4 Philippi, WV

Since the City of Philippi operates only two trucks equipped with plows and spreader boxes, each of the trucks covers one-half of the roads. Both trucks are equipped with the same type and size of spreader; both spreaders were also set to the same application rate. Maintenance crews started the winter pre-wetting the loads by hosing the entire load once at the same rate as Fairmont. Initially, they could not utilize their on-board system because several parts were either lost or not delivered. Since Philippi applied relatively very little salt and wood chip mixture, only limited results were obtained. About 1100 gallons of brine were utilized during the winter. Even though limited applications were made, maintenance personnel reacted positively to the use of brine to enhance winter maintenance operations. Personnel felt that brine sprayed on the salt and wood chip mixture made the materials stick to the road surface more readily. It was their opinion that roads treated with brine did not experience bonding between the snow/ice and the road surface. Crews felt that the wood chips absorbed some of the brine allowing the brine to last longer on the pavement. The wood chips apparently absorbed some of the brine, leaving a residue on the pavement surface. The residue prevents the formation of bond between the road surface and snow/ice.

4.5 Weirton, WV

As described in Chapter 3, Weirton planned to use an industrial by-product brine. Apparently due to a recent re-start of the plant, the brine supplied to Weirton was not of the same quality as that tested earlier in the project. The lower quality of the brine resulted in it freezing in the Weirton Public Works storage tank at a relatively warm temperature, i.e. around 28° F. Since the by-product brine was not consistent in quality, the decision was made not to use the brine as an anti-icing agent.

The research team attempted to switch the city of Weirton to oil and gas well brines being provided by Hawg Hauling. Unfortunately, Hawg Hauling was not able to provide brine to Weirton.

The City of Weirton purchased liquid calcium chloride and added it to the CMTech brine to "sweeten" the material. The material no longer solidified in the tank during cold temperatures. City crews used the on-board spray equipment to pre-wet the chemical/abrasive mixtures. However, since the pre-wetting agent used was not a by-product brine, the research team did not monitor the results of these applications.

4.6 Concluding Remarks

The researchers found that brines enhanced winter maintenance operations in several ways. Less material was used overall since reduced bounce-off kept the material in the travel lanes where it was needed. The brine-treated salt could be applied to the roadway before/early into the storm so that snow or ice was not able to bond to the roadway surface. This "bought time" for maintenance personnel allowing them to prepare better for the upcoming storm. Where snow or ice had bonded to the pavement surface, the brine-treated salt was able to break the bond in about one-half the time of conventional materials.

Data and reports from maintenance personnel show that the brine works well in temperatures as low 3° F and should continue to work well in temperatures below that. The brine also worked well on all types of winter storms and conditions even the most extreme types, such as very cold temperatures with little to no traffic on the treated surface. Field personnel reported that no conditions were found where the use of brine was unacceptable. Some personnel reported that the brine cause increased rusting of their equipment, this was not reported by all participating communities. This should not be a problem if preventive maintenance is done on equipment such as washing equipment down after each storm and painting all bare metal so that the salt does not come into direct contact with the metal.

As a liquid, the brine showed considerable flexibility in the type and nature of applications. The material could be sprayed, via on-board equipment, directly onto material as it fell on the spinner. Alternatively, the brine could be applied to the top of the spreader box, before the truck left the yard, to pre-wet the load in that manner. Finally using hand-held sprayers, brines were successfully applied to public sidewalks where they were beneficial in breaking up ice/snow pack.

CHAPTER 5
CONCLUSIONS, RECOMMENDATIONS AND IMPLEMENTATION

5.1. Introduction

The research described in this report represents a field testing program to assess the feasibility of using West Virginia oil and gas brines in municipal-level anti-icing applications. Previous research had demonstrated that brines were feasible to use in a number of situations. However, no formal assessment had been made either of using brines in anti-icing strategies or at the community level. Such an assessment was the primary objective of this study.

Several conclusions have been drawn and recommendations made as a result of the research effort. Conclusions are presented first, followed by recommendations and implementation of research results.

5.1. Conclusions

It is clear from the research performed at West Virginia University during the 1980's that natural brines found in West Virginia are liquids that have the properties of freezing point depressants. Laboratory and field testing showed that their effects on highway materials were essentially the same as conventional snow and ice control materials. The research identified oil and gas fields in West Virginia which produce brines suitable for roadway use. Based on the literature review performed as part of this study, it is apparent that the brine-related research performed in the 1980's addressed certain anti-icing aspects of natural brines, although that particular terminology had not yet been recognized nor was that a focus of the research. Therefore, it was logical to formally explore the use of natural brines in anti-icing operations.

Experiences, at least as reflected in the published literature on anti-icing technology and materials, have focused on state highway agency level applications. There is no published record of experiences at the municipal government level. Thus, it was appropriate to assess the feasibility of using natural brines in local level anti-icing applications.

The three communities that participated in the field tests (Fairmont, Morgantown, and Philippi) provided a good range of conditions, in terms of personnel, equipment, roadway geometry, traffic characteristics, and agency organizational structure, under which to evaluate the use of brines in anti-icing applications. However, due to their geographic proximity, they all faced essentially the same weather conditions. In retrospect, a community in mountainous terrain with heavier snowfall and colder temperatures should have been included in the field test program.

For municipalities considering the use of West Virginia brines, application of this liquid as a pre-wetting agent to rock salt and rock salt/abrasive mixtures, as opposed to direct liquid application to the roadway, is the most appropriate technique. Direct liquid application requires specialized equipment. In addition, there is concern that, due to the variability in brines, there is the potential for the material to freeze on the road surface.

There is sufficient suitable oil and gas brine produced in West Virginia to support the use of brines in local level anti-icing initiatives. During this project, the oil and gas producer delivered brines at no cost to the participating communities and, in fact, loaned tanks to all three communities. However, as the utility of the product is demonstrated, oil and gas producers may begin charging for brines.

Results of the one winter field testing program in three north central West Virginia municipalities showed that in each case, brines enhanced winter maintenance operations. Perhaps most importantly, a better level of service was provided to the traveling public. Roads cleared more quickly than those treated by conventional techniques. Personnel from all three public works departments commented on this result. In Fairmont, this attribute was recognized by citizens who passed on compliments to city officials. In addition, less material was used overall since reduced bounce-off kept more of the material in the travel lanes where it was needed. Although not noted in any of the formal feedback, it is logical to conclude that if there is less material bouncing off the roads and streets there will be less damage to the lawns, shrubs, and concrete driveways and sidewalks of residents and business establishments.

The City of Morgantown's experience demonstrated that brine-treated mixes could be applied to the roadway before/early into the storm so that snow or ice was not able to bond to the roadway surface. This "bought time" for maintenance personnel allowing them to prepare better for the upcoming storm. Where snow or ice had bonded to the pavement surface, the brine-treated salt was able to break the bond in about one-half the time of conventional materials.

Data and reports from maintenance personnel indicated that the brine-enhanced mixtures worked well in temperatures as low 3° F. The brine also worked well on all types of winter storms and conditions even the most extreme types, such as very cold temperatures with little to no traffic on the treated surface. Field personnel reported that no conditions were found where the use of brine was unacceptable.

Some field personnel reported that the brine cause increased rusting of their equipment; however, this was not reported by all participating communities. This should not be a problem if preventive maintenance is done on equipment such as washing equipment down after each storm and painting all bare metal so that the salt does not come into direct contact with the metal.

As a liquid, the brine showed considerable flexibility in the type and nature of applications. The material could be sprayed, via on-board equipment, directly onto material as it fell on the spinner. Alternatively, the brine could be applied to the top of the spreader box, before the truck left the yard, to pre-wet the load in that manner. Finally using hand-held sprayers, brines were successfully applied to public sidewalks where they were beneficial in breaking up ice/snow pack.

5.3. Recommendations

Two types of recommendations are made in this section. The first set is aimed at municipalities considering the use of brines in anti-icing applications. The second set represents follow-on research needed to address several issues either left unanswered or which were identified by this research effort.

It is recommended that West Virginia municipalities located in or near the oil and gas producing regions of the state consider using natural brines as an addition to their snow removal and ice control programs. For relatively little cost, significant improvements in roadway levels of service can be obtained. When used as part of an anti-icing strategy, weather forecasts, road conditions and training for personnel need to be taken into account along with the material and equipment considerations. Preventive maintenance of equipment is especially important when using brines.

It must be recognized that natural brines are a variable material. A particular brine is not necessarily suitable for roadway applications. It is important that roadway agencies establish the quality of the brine to be used on roads and streets and require that the supplier provide appropriate documentation attesting to the quality of each load of brine delivered to the agency.

With respect to ideas for follow-on research, several suggestions are presented below. While a variety of weather conditions were evaluated during the winter of 1998-99, the winter was not particularly severe from the standpoint of temperature and precipitation. Brine usage in anti-icing applications should be evaluated in the mountainous regions of West Virginia where heavy snowfall and low temperatures are a normal occurrence.

Results of the field tests demonstrated that technically the use of brine in anti-icing applications is feasible. However, this project did not examine the economics of brine usage. Additional data are needed in this regard. In particular, it would be desirable to quantify the reductions in the amounts of conventional materials used and to translate these into cost savings for the municipalities. In addition, an understanding of the economics from a brine producer's standpoint would also be appropriate. This includes quantifying transportation costs, maximum haul distances, and related parameters.

Other municipal uses of brines, notably application to sidewalks and stairs, should be further evaluated in terms of application rates and frequencies. Improved levels of service for pedestrians appear possible without some of the drawbacks of conventional snow and ice materials.

5.4. Implementation

As noted in the Conclusions, the field testing program demonstrated that West Virginia oil and gas brines are viable additions to local level winter maintenance programs. Municipalities can begin implementing this approach immediately. In fact, both Fairmont and Morgantown expanded their use of brines after the formal research was conducted during the winter of 1998-1999.

Using city crews to fabricate the units, Morgantown equipped all of its trucks with on-board pre-wetting equipment. Pre-wetting salt/abrasive mixes with natural brines is now a routine part of the City's winter maintenance program.

In addition, they converted a "retired" 1978 GMC pumper fire truck into a brine tanker for roadway pre-wetting applications. After stripping the vehicle, city crews modified the truck so it would accept a 500-gallon polyethylene tank and the necessary pumps to apply brine, through a spray bar, directly to the roadway.

The City of Fairmont continues to use natural brines, although it has opted to pre-wet each load prior to the truck leaving the yard, rather than use on-board equipment. So that personnel do not have to climb on top of the truck to accomplish the pre-wetting, a wooden platform was constructed for this purpose. This has improved the safety of the operation.

As noted earlier, Fairmont had good success with using brines to treat the several miles of sidewalks (including 5 bridges) for which it is responsible. For two winters, this was done by crews on foot with a hand-held spray unit. During the winter of 2000-2001, the City purchased an ATV for winter maintenance of sidewalks and equipped it with a polyethylene tank, handwand, plow, spreader box and brine spray unit. The tank and handwand allow the operator to pre-treat sidewalks. The ATV has made the job of snow removal and ice control on sidewalks easier and more cost-effective.

To encourage additional communities to use brine, local-level decision-makers need information on the advantages of using brines, the type and cost of equipment needed to apply brines, and the availability of brines in their geographic area. This implies an information program to be carried out by the West Virginia Transportation Technology Transfer Center (T-Square Center).

In addition, Columbia Natural Resources, the supplier of the brine used in this project, has expressed an interest in helping municipalities interested in using brines to get started by providing storage tanks and brine and offering technical assistance. Storage tanks have been delivered to the cities of Clarksburg and Weston, West Virginia. Their use of brines as a pre-wetting agent has not been reported. The Town of Glenville is also considering the use of brines.

The primary mission of the T-Square Center is to get technical information on roads and streets into the hands of public works officials. The Center has taken a multi-faceted approach to disseminate information on using brines in anti-icing applications.

These efforts are on-going. In March 1999, Dr. Eck presented an overview of the project at a session on anti-icing at the annual Roadway Management Conference in Dover, Delaware. Over 100 local officials from the region encompassed by former FHWA Region 3 (Delaware, Maryland, Pennsylvania, Virginia, and West Virginia) were in attendance at the session. At the 2001 Roadway Management Conference in Ocean City, Maryland, Mike DeMary and Terry Hough, Public Works Directors for Fairmont and Morgantown, respectively, provided an update on brine usage in their communities. This included a discussion of the equipment just mentioned.

Each fall, the Center hosts a one-day workshop on snow and ice control at the Jacksons Mill Conference Center. The program for the fall 1999 workshop featured use of natural brines in anti-icing applications. The program at the 2000 workshop included an update on brine use among West Virginia public works agencies. Another update, including equipment display, will be provided at the fall 2001 workshop.

An attractive brochure highlighting the advantages of using brines, identifying the type and cost of equipment needed to apply brines, and indicating the availability of brines in the state was prepared as West Virginia T-Square Center Bulletin No. 1 (included as Appendix F). This has been distributed at snow and ice workshops, at the Roadway Management Conference, at the Roads Scholar winter training sessions and at other venues to provide another source of information.

The investigators are available for briefings with highway agencies so that the advantages and costs of using brines can be described succinctly for decision-makers. The public works directors for Fairmont and Morgantown have volunteered to accompany the researchers to these sessions to provide the viewpoint of an operating agency that has used brines successfully. As an example, the Delaware Department of Transportation and its Federal Highway Administration Division office hosted a one-half-day session on the topic of brines in anti-icing in Dover, Delaware in April 2000. A representative of Columbia Natural Resources has also volunteered to participate in similar sessions to address the brine supply issue. All parties stand ready to offer technical assistance and advice to those municipalities requesting it.

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APPENDIX A

SPECIFICATIONS FOR ON-BOARD PRE-WETTING SYSTEM
AND
LIST OF EQUIPMENT PROVIDED TO EACH COMMUNITY

CTM-E (or EVS) - SPT TRUCK MOUNT SYSTEMS
SPECIFICATIONS

The CTM-E-PU truck mount prewet systems are designed for use on one ton pick up trucks or smaller. The components consist of liquid tank, electric pump, cab controls, and all plumbing, hoses, and spray nozzle needed to make a working system. Systems are available for V box hopper and tailgate type spreader. Mounting brackets have to be fabricated by customer to meet individual needs of the truck and spreader.

TANK:
Tank sizes available: 12, 14, 20, and 25 gallon. Configuration of the spreader equipment generally dictates the size and mounting location of the tank or tanks. All tanks are rotationally molded, UV stabilized, polyethylene with 5" top fill openings and bottom outlets of ½".
The tank can be fitted with an ***optional*** float switch which will shut down the pump when the tank is empty.

ELECTRIC PUMP:
The electric pump is flow rated at 3 gpm at 45psi. It is a positive displacement 3 chamber pump with check valve to prevent reverse flow. It requires 12 volt power for operation. Adjustable pressure switch has range of 30-50 psi. Ports are ½".

PUMP ENCLOSURE:
The enclosure dimensions are 18"wide x 7" deep x 12" long. It is made of molded polyethylene with a removable cover held in place by two rubber pull latches. The latches are mounted with stainless steel fasteners. With the enclosure is a T strainer coupled in line to the suction side of the pump.

CAB CONTROL:
The cab mounted control box contains a lighted "on / off" rocker switch to control the pump's operation. It also has the capability for low tank level warning (light and audible buzzer) as an option. It comes with mounting hardware and a complete wiring harness for easy installation. An ***optional*** variable speed controller is available which allows the operator to vary the pump's output.

SPRAY NOZZLE:
A single brass spray nozzle and body are included. The spray pattern provides for a 120 degree fan pattern to cover salt at the spinner.

PLUMBING CONPONENTS:
All hose is ½" nylon reinforced polyethylene. All valves and fittings are polypropylene. Hose clamps are stainless steel.

Effective 7-99
Replaces 7-97

EQUIPMENT PROVIDED TO EACH COMMUNITY

City of Fairmont

1 On-Board System for Pick-Up Truck	$676.00
1 Second Tank and Control System	$350.00
Subtotal	$1026.00

City of Philippi

1 On-Board System for Pick-Up Truck	$676.00
1 Second Tank	$114.00
Subtotal	$790.00

City of Weirton

2 On-Board Electric Pumps	$245.40
3 Brass Spray Nozzles	$74.25
3 In-Cab Control Systems	$1311.00
Subtotal	$1630.65

Storage Tanks

1 1300 Gallon Tank for Weirton	$807.00
1 1100 Gallon Tank for Fairmont	$870.00
3 PK-1 Pump Kits to Load Trucks	$2025.00
Subtotal	$3702.00

APPENDIX B

ESTIMATES OF BRINE QUANTITIES

Relating Brine Concentration to Field Application Rates:

$$\text{Brine Application Rate} = \frac{\dfrac{6955 \text{ g/lb of rock salt}}{\text{brine concentration (g/l)}}}{3.78 \text{ l/gal}}$$

Application rates for various brine concentrations are shown in the table below:

Concentration (mg/L)	Application Rate (gal/ton)
150000	12.3
175000	10.5
200000	9.2
225000	8.2
250000	7.4
275000	6.7
300000	6.1

Determining quantity of brine needed for typical winter:

Assume, based on historical data from earlier brine-related research, that there are 15 storms per year in north central West Virginia and that the average truck makes 7 trips per storm:

For Morgantown:

15 storms/year X 3.33 tons/trip X 12 gal brine/ton X 7 trips/storm = 4200 gal/year

APPENDIX C

MATERIAL SAFETY DATA SHEET
FOR
BRINE USED IN FIELD TEST PROGRAM

Date: 05/29/98

BRINE SOLUTIONS
MATERIAL SAFETY DATA SHEET

ALAMCO
BUCKHANNON WEST VIRGINIA 26201

EMERGENCY TELEPHONE: 1 - 800 - 873 - 2526
AFTER HOURS: 1 - 304 - 361 - 1764

SECTION I - PRODUCT DESCRIPTION

Chemical Code: Brine Solutions
Package Qty: Bulk
Application: Dust control, ice control.

SECTION II - COMPONENT INFORMATION

MATERIAL		PERCENT	COMPONENT TLV
Sodium Chloride	7647-14-5	1-50	10 mg/m^3
Calcium Chloride	10043-52-4	1-30	10 mg/m^3
Magnesium Chloride	7791-18-6	1-10	10 mg/m^3
Barium Chloride	10326-26-9	< .1	10 mg/m^3
Other Chlorides	NA	< 1	10 mg/m^3

OSHA EXPOSURE LIMITS

Peak Exposure - Limit (STEL) Not Est.
Ceiling Exposure - Limit (CEL) Not Est.

Component Toxicity Data

	NaCl	$CaCl_2$	MgCl	BaCl
PEL	15mg/m^3	Not Est.	Not Est.	0.5 mg/m^3
IRR SKN-RBT	500 mg/24H MLD	50 mg/24H MLD	Not Known	Not Known
IRR EYE RBT	100 mg/24H MLD	100 mg/24H SEV	Not Known	Not Known
TOX ORL-HMN TDLO:	Not Known	12357 mg/kg/23D-C	Not Known	Not Known
TOX ORL-RAT LD50:	3 g/kg	3000 mg/kg	8100 mg/kg	Not Known
TOX ORL-MUS LD50:	4g/kg	4000 mg/kg	7600 mg/kg	Not Known

SECTION III - PHYSICAL DATA

Property	Measurement
Appearance	Clear Liquid
Odor	Odorless
Specific Gravity (H_2O=1)	1.10 to 1.25
Bulk Density	9 to 10 lbs/gal
pH	5.0 to 7.0
Solubility in Water	
20 Deg C. gms/100ml H_2O	Soluble
Biodegradability	N/D
Percent Volatiles	N/D
Evaporation Rate (Butyl Acetate=1)	N/D
Vapor Density	N/D

SECTION IV - FIRE AND EXPLOSION DATA

Flash Point	None
Auto-ignition Temperature	Not Determined
Flammable Limits (Oz. Per Cu. Ft.)	Not Determined
Extinguishing Media	Use media appropriate for surrounding Materials
Special Fire Fighting Procedures	Not Applicable
Unusual Fire and Explosion Hazards	Not Applicable

The product is mostly water with less than 25 % solids. All of the solids are essentially non flammable in solution.

SECTION V - HEALTH HAZARD DATA

Carcinogenic Toxicity Data:	Product or Product Components are not Regulated as a potential carcinogen, According to: "NTP, IARC, OSHA, ACIGH".
Product Toxicity Data:	See OSHA Exposure Limits listed under Section II
Over Exposure	Primary routes of exposure: Eye or skin contact, inhalation, or ingestion.

Inhalation: Irritates the respiratory tract. May produce sore throat, coughing and labored breathing.

Ingestion: May cause severe gastroenteritis, including abdominal pain, vomiting and diarrhea. May cause tremors, faintness, paralysis of arms and legs, and slow or irregular heartbeat. Severe cases may produce collapse and death on respirator failure.

Skin contact: May cause redness or irritation with prolonged contact.

Eye contact: May cause redness, pain or blurred vision.

Chronic Exposure: No information found.

First Aid	Inhalation: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician. Ingestion: If swallowed, induce vomiting immediately by giving two glasses of water and stitching finger down the throat. Never give anything by mouth to any unconscious person. Call physician immediately. Skin Exposure: Remove any contaminated clothing. Wash skin with plenty of water for at least 15 minutes. If irritation develops, get medical attention. Eye Exposure: Wash eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.
Toxicity Data	If Barium Chloride is present in the brine. Oral Rat LD50: 118mg/kg. Reproductive effects cited.

SECTION VI - REACTIVITY DATA

Stability	Stable

Conditions To Avoid	**Not Applicable**
Incompatibility (Materials to Avoid)	**Not Applicable**
Hazardous Decomposition Products	**Not Applicable**
Hazard Polymerization **Conditions to Avoid**	**Won't Occur** **Not Applicable**

SECTION VIII - SPILL AND LEAK PROCEDURES

Steps to be taken if material is Released or Spilled	**Use protective equipment. Isolate spilled material and stop leak where safe. Pump spilled material back into bulk container where possible, absorb remainder of spilled material with an inert material. Scoop up, remove and place material in an approved landfill.**
Waste Disposal Method	**Receive approval from landfill operator and transport absorbed material to sanitary landfill.**

SECTION IX - SPECIAL PRECAUTIONS

Precautionary Labeling Brine Solution	CAUTION! MAY CAUSE IRRITAION TO THE EYES, SKIN OR RESPIRATORY SYSTEM. FOR PRECAUTIONARY STATEMENTS, REFER TO SECTIONS IV - VIII
Other Handling and Storage Conditions	STORE IN A COOL WELL VENTILATED LOCATION.
Container Disposition	CONTAINER SHOULD BE TRANSPORTED WITH ALL CLOSURES IN PLACE AND RETURNED FOR REUSE.

SECTION X - TRANSPORTATION INFORMATION

DOT SHIPPING DESCRIPTION: NOT RESTRICTED

IATA/CAO SHIPPING DESCRIPTION: NOT RESTRICTED

IMO SHIPPING DESCRIPTION: NOT RESTRICTED

ADR SHIPPING DESCRIPTION: NOT RESTRICTED

CUSTOMS DESCRIPTION: SALT WATER

U.S. DEPT. OF COMMERCE SCHEDULE B NO. 433.1095

BTN NUMBER:	CONTAINER SPECIFICAITON:
38.19A	NONE

SECTION XI - ENVIRONMENTAL EVALUATION

EPA SUPERFUND (SARA) TITLE III - HAZARD CLASSIFICATION & ASSOCIATED INFOMATION:

Fire Hazard	No
Pressure Hazard	No
Reaction Hazard	No
Acute (Immediate) Hazard	Yes
Chronic (Delayed) Hazard	No
Mixture or Pure Material	Mix
Extremely Hazardous List	No
EPA - Reportable Spill Quantity	N/A

The information which is contained in this document is based on available data and believed to be correct. However, as such has been obtained from various sources, including the manufacturer and independent laboratories, it is given without warranty or representation that it is complete, accurate and can be relied upon. Alamco has not attempted to conceal in any way the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, as Alamco cannot anticipate nor control the many situations in which the listed product or this information may be used by our customer, there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole

responsibility of each user of the listed product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

APPENDIX D

NOTES AND FIELD DATA FORMS FOR BRINES USED IN FAIRMONT, WEST VIRGINIA

Salt Brine Project

December 30, 1998

The test road was Big Tree Drive from Franklin Court to Joy Street.

We used a 3 to 1 mix of cinders and salt. That being 3 parts cinders to 1 part salt. The salt brine used was 5.5 gallons per mile and 406 lbs of abrasives' per mile.

The weather was cloudy, no wind, snow flurries. The roadway was snow covered with ice under the snow. The air temp. was 17 and the road temp. was 19.

We started treating the roadway at 8:30 a.m. by 9:30 a.m. the snow and ice were starting to melt. Then at 10:30 a.m. the roadway was turning into slush from the melting snow and ice. Then at 11:30 a.m. the roadway had water running on it.

The roadway had a very low traffic count of 20 cars per hour.

The rest of the roadway was treated at the same time using a 3 to 1 mix without salt brine. The roadway at 11:30 a.m. was still snow covered compared to the section of roadway which we used salt brine, at 11:30 it was melting.

Salt Brine Project

December 31, 1998

The test road was Big Tree Drive.

We used a 3 to 1 mix of cinders and salt. That being 3 parts cinders to 1 part salt.

The weather was cold, with light snow and no wind. The air temp. was 16 and the road temp. was 17.

We started treating the roadway at 7 a.m. by 8:45 a.m. the snow was melting and caking up.

The roadway had a traffic count of 25 cars per hour.

The roadway that was not treated with salt brine showed no signs of melting at 8:45 a.m.

City of Fairmont Streets/Routes Applied to: Big Tree Dr. Franklin St. to Joy Lane

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
12/30/98	9:30	17°	19°	cloudy, no wind flurries	2 cinders to 1 salt	5.5 gal	400 lb.	In 1/2 the time Roadway was clearing	JC

D - Dry W - Wet Sn - Snow Sl - Slush

Franklin Ct. to Joy Lane

City of Fairmont Streets/Routes Applied to: Big Tree Dr.

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
12/31/98	7:00 AM	16°	17°	Windy, cloudy light snow	3 cinders to 1 salt	5.5 gal	406 lbs	45 min. snow was melting & clearing	JC

D - Dry W - Wet Sn - Snow Sl - Slush

Salt Brine Project

January 4, 1999

We expanded the test area of the project to encompass the city streets in Fairmont.

We used a mixture of 3 parts cinders to 1 part salt. This was achieved by pumping 25 to 30 gallons of salt brine on top of loaded cinder trucks.

The weather was cloudy, with snow flurries and no wind. The air temp. was 13 and the roadway temp. was 15.

The roads in Fairmont were icy with a snow cover.

The results of the expanded test area are as follows. The driver's reported that using this method had cut the clearing off time to about half the time of the salt and cinder method. They also reported that the cinders did not fly off the roadways like they do when applied dry, and the mixture seems to track further on the roadway resulting in a more even melting pattern of the roadway.

Salt Brine Project

January 5, 1999

The test area was the city streets that encompassed in the city of Fairmont.

We used plain cinders with 25 to 30 gallons of salt brine pumped over loaded cinder trucks.

The weather was sunny and cold, with no wind. The air temp. was 3 and the road temp. was 7.

We started treating the streets at 7 a.m. using this method. We found the streets did not respond as fast as they do when we use the cinders and salt, with the salt brine. This method showed signs of melting after 1 hour. This method also took a lot longer. The one thing with the salt brine use it helps to keep the cinders down on the roadways and helps track the cinders further down the roadway.

Salt Brine Project

January 5, 1999

The test area was the Mid-City Parking Lot.

We used plain cinders and salt brine at a rate of 10.5 gallons lane mile.

The weather was sunny and cold. The air temp. was 3 and the road temp. was 8.

We started treating the lot at 7:30 a.m. Then at 9 a.m. with the air temp. up to 4 degrees the parking lot was showing signs of melting. Then at 11:30 a.m. the parking lot had water running off from the melting ice.

Salt Brine Project

January 5, 1999

The test area was the sidewalks on the Mid-City Bridge.

We used salt on the sidewalk. Then we went back and used salt brine.

The weather was sunny and cold. The air temp. was 3 and the sidewalk temp. was 4.

We started treating the sidewalks at 8:30 a.m. by throwing salt by hand on them. Then at 10 a.m. with the air temp. up to 6 the ice on the sidewalks was not showing any signs of melting. Then at 10:30 a.m. we sprayed salt brine from a 3 gallon hand sprayer. Then at 11:30 a.m. the sidewalks were showing signs of of melting. Then at 12:30 p.m. with an air temp. of 10 the sidewalks had water running off and ice breaking up. Then at 3:30 p.m. with an air temp. of 13 the sidewalks were pretty well clear of ice.

City of Fairmont Streets/Routes Applied to: City Wide

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature Air	Temperature Pavement	Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate Liquid gal/ln-mi	Application Rate Solid lb/ln-mi	Results	Driver Initials
1-4-99	7:30 Am	13°	16°	Clear - cold	3 cinder - 1 salt	5.5 gal	406 LB.	After about 1 hr Roadway was melting	JC
1-5-99	7:30 am	3°	7°	clear - cold	STRAIGHT	5.5 gal	406 LB	After about 3 hrs Roadway was melting	JC
Parking Lot 1-5-99	7:00 Am	3°	7°	clear cold	3 cinder 1 salt	5.5 gal	406 LB	2 hrs. ice was melting	JC

D - Dry W - Wet Sn - Snow Sl - Slush

Salt Brine Project

January 7, 1999

The city was divided into two test areas, the east and west sides of town. The West side of the city was treated with salt and cinders and salt brine. The East side of the city was treated with salt and cinders.

The rate of salt brine applied was 3.5 gallons per lane mile with three parts cinders and one part salt. The treatment was started at 7 a.m.

The weather was partly cloudy and windy. The air temp. was 13. The street temp. was 11. There was 3 inches of snow.

The city streets were snow covered.

The West side of the city the streets were melting and had water running at 9 a.m. The East side city streets were not showing any signs of melting at 9 a.m.

Then at 12 p.m. the West side streets were clearing off and the East side streets were just starting to show signs of melting.

City of Fairmont Streets/Routes Applied to: City wide

Road Surface Condition at Application:
D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
1/7/99	7 Am	13°	11°	Snow	1 To 3	3 gal	406 lb	See Report	JC

D - Dry W - Wet Sn - Snow Sl - Slush

Salt Brine Project

January 8, 1999

The test area was expanded to encompass all the streets in the city.

We used a 3 to 1 mixture, 3 parts cinders to 1 part salt, with salt brine pumped over the salt and cinders in the loaded trucks.

The weather conditions were snow, sleet, and freezing rain. The air temp. was 20. The street temp. was 18.

We started treating the streets at 7 a.m. The drivers reported that at 9 a.m. the streets were melting and traffic was flowing at a normal rate of speed.

City of Fairmont Streets/Routes Applied to: City Wide

Road Surface Condition at Application:
D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
1/8/97	7 am	20°	18°	Snow	3 cinders 1 salt	3 gal	4/06 [illegible]	see report	JC

D - Dry W - Wet Sn - Snow Sl - Slush

Salt Brine Project

January 15, 1999

The test area was all the city streets in Fairmont.

We used a 3 to 1 mixture of, 3 parts cinders to 1 part salt, with a lower rate of salt brine, 1 gallon per lane mile.

The weather conditions were snowing and cold. The air temp. was 22. The road temp. was 25.

The roadways were icy and snow covered. We started treating the roads at 7 a.m. One hour later the streets were melting with the new formulation of salt brine mixture.

We found the same results of the ice and snow melting with this smaller application of salt brine mixture as when we use the 3.5 gallons per lane mile. So the 1 gallon per lane mile works as well as the 3.5 gallons per lane mile.

City of *Fairmont* Streets/Routes Applied to: *City Wide*

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
1/15/99	7 AM	22°	25°	snow ice	3 cinder 1 salt	1 gal	406.40	See Report	JC

D - Dry W - Wet Sn - Snow Sl - Slush

To Whom It May Concern,

I have ran the "Salt Brine Project" for the "City of Fairmont" during the winter of 98/99.

We have used the salt brine with a mixture of salt and cinders. In using the salt brine we have observed that the results are that the roadway's were responding in half the time, resulting in safer road conditions for the citizens and the general public of Fairmont.

We also had alot of citizens call and respond that their streets were clearing faster and thanking us for the service.

We feel this is a worthwhile product to aid in fighting snow and ice on roadways and sidewalks. Which make for safer driving and walking conditions for everyone.

Thank You,

John Caston

John Caston
"City of Fairmont"
Asst. Street Superintendent

APPENDIX E

SAMPLE FIELD DATA FORMS FOR TEST SECTIONS IN MORGANTOWN, WEST VIRGINIA

City of ______ Streets/Routes Applied to: ______

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
1-8-99				W-SN	1 TO 3	10	4 TON	—	OS
1-8-99				W-SN	1 TO 3	10	4 TON	—	OS
1-8-99				W-SN	1 TO 3	10	4 TON		OS
1-8-99				W-SN	1 TO 3	10	4 TON		OS
1-8-99				W-SN	1 TO 3	10	4 TON		OS
"	9:00AM	22	24	W-SR	1 TO 3	10	4 TON	Grant	
"	9:10AM	"	"	W-SN	1 TO 3	10	4 TON	Univ. ave	
	11:00	27	26	W. SN	1 to 3	10	4 to	Richwood Av	

D - Dry W - Wet Sn - Snow Sl - Slush

City of Morgantown Streets/Routes Applied to: See below

Road Surface Condition at Application:

D W Sn Sl Ice

Date	PM Time of Application	Temperature Air	Temperature Pavement	Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate Liquid gal/ln-mi	Application Rate Solid lb/ln-mi	Where Temp was Taken	Driver Initials
1-9-99	3:31 UNiV AV	12	30	W-SL	1 to 3	10 gal	4 Ton	UNiV + Willey	OJ
1-9-99	3:33 Stewart	16	26	W-SL	1 to 3			Stewart + UNiV	OJ
1-9-99	3:35 Willowdale	17	23	W-SL	1 to 3			Willowdale + Stewart	OJ
1-9-99	3:45 UNiV AV	18	24	W-SL	1 to 3			UNiV + Stewart	OJ
1-9-99	3:50 Jacobs Dr	17	23	SN	1 to 3			Jacobs + UNiV	OJ
1-9-99	4:35 Dorsey	19	22	SN-ICE	1 to 3	10 gal	4 Ton	Dorsey + South U	OJ
1-9-99	4:55 Grand ST	18	17	SN-Ice	1 to 3			Grand + Ross	OJ
1-9-99	5:20 Ross St	13	21	SN-Ice	1 to 3	10 gal	4 Ton	Ross + Dorsey	OJ
1-9-99	5:34 Falling Run	19	11	SN-Ice	1 to 3			Falling Run + UNiV	OJ
1-9-99	5:38 Protzman	20	11	Ice	1 to 3			Falling Run + Protzman	OJ
1-9-99	5:39 Amhurst	18	22	Ice	1 to 3			Amhurst + Hoffman	OJ
1-9-99	5:40 Hoffman	30	12	Ice	1 to 3			Hoffman + Amhurst	OJ
1-9-99	5:50 McCullough	12	21	SN-Ice	1 to 3			Hoffman + McCullough	OJ
1-9-99	6:10 8th St	13	20	SN-Ice	1 to 3			Eight + UNiV	OJ
1-9-99	8:05 Richwood	11	5	SN-ICE	1 to 3	10 gal	4 Ton	Richwood + Sab AV	OJ
1-9-99	8:35 Sabraton AV	11	7	SN-Ice	1 to 3			Sab AV + Richwood	OJ

D - Dry W - Wet Sn - Snow Sl - Slush

City of ____________ Streets/Routes Applied to: ____________

Road Surface Condition at Application:

D W Sn Sl Ice

Date	Time of Application	Temperature		Type of Weather Event	Salt to Anti-Skid Ratio	Application Rate		Results	Driver Initials
		Air	Pavement			Liquid gal/ln-mi	Solid lb/ln-mi		
1-14-99	3:45	34	022	clear	3X1	25 gal	4 TON	Junction/US	SD
1-14-99	4:00		022	clear	3X1		~~[illegible]~~	Braddock	SD
1-14-99	6:10	21	018	clear	3X1	26 gal	4 ton	Park	SD
1-14-99	7:45	21	019	clear	3X1	12	4 to	University Av	SD
1-14-99	9:00	21	024	clear	3X1	20	4 Ton	Richwood	SD
1-14-99	10:00	21	020	clear	3X1	25 gal	4 Ton	Hayds	SD
1-16-99	11:45	22	14	Clear	3x1	22	4 Ton	Jacob	DD
1-16-99	1:30	20	14	Clear	3x1	23	4 ton	university	CG
1-16-99	3:40	17	9	Clear	3x1	25	4 Ton	Rotary	CG
1-16-99	4:30	19	13	Clear	3x1	24	4 Ton	Rolling run	DD
1-16-99	6:30	20	14	Clear	3x1	22	4 Ton	Valley View	DD

D - Dry W - Wet Sn - Snow Sl - Slush

APPENDIX F

T-SQUARE CENTER BULLETIN HIGHLIGHTING USE OF NATURAL BRINES IN WINTER MAINTENANCE

Study Demonstrates Effectiveness of Natural Brines in Snow Removal and Ice Control Operations

Mike Blankenship * Brad Pittsnogle

WV T² Center Bulletin

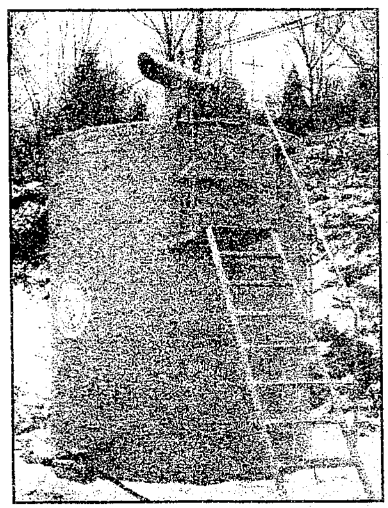
West Virginia University

Providing the level of service expected by the motoring public is difficult during the winter months when roads can be covered with snow and/or ice. A number of agencies around the world have found liquid chemicals to be a valuable addition to their snow removal and ice control operations. Is this approach applicable at the local level in West Virginia? What are the advantages and disadvantages of using liquid chemicals in our part of the country?

The public works departments in Fairmont, Morgantown, and Philippi used West Virginia natural brines to pre-wet rock salt/abrasive mixtures during the 1998-1999 winter. The necessary equipment and the characteristics of the brine were identified in advance. During the winter, the results were monitored visually, by public works personnel, to evaluate the effectiveness of the material.

Brine Supply

Research performed at West Virginia University during the 1980's demonstrated that many West Virginia brines have high concentrations of sodium, calcium, magnesium and potassium chlorides, and have good potential in winter maintenance operations. Their effects on highway materials are essentially the same as those associated with rock salt. Previous studies identified geologic formations in the state, which produce brines suitable for roadway use.



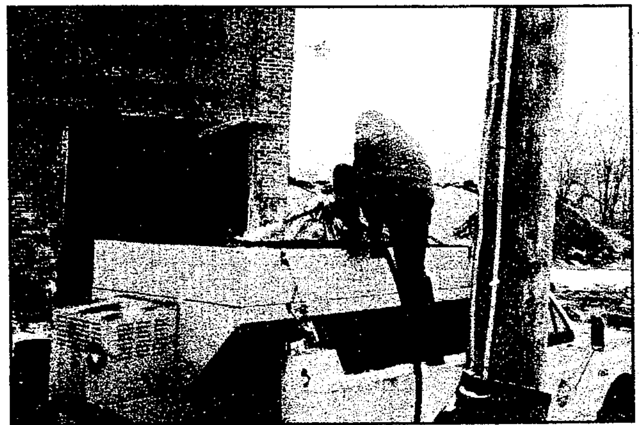
For the demonstration project, Columbia Natural Resources, through its Hawg Hauling and Disposal, Inc. subsidiary, provided brine to the three communities. The brine used was a combination of several wells from the Oriskany Formation.

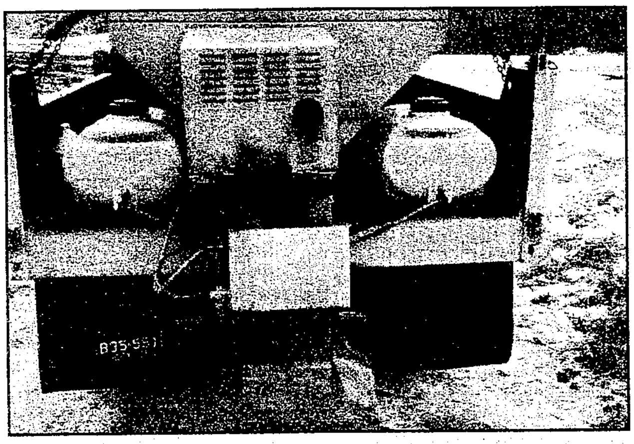
In addition, Hawg Hauling provided one or more 4200-gallon capacity storage tanks at the maintenance yards in Fairmont, Morgantown, and Philippi. They also assisted in constructing the diking required for the tanks.

WV Transportation Technology Transfer Center
College of Engineering and Mineral Resources,
PO Box 6103
Morgantown, WV 26506-6103

Equipment Required

One truck in each community was outfitted with an on-board pre-wetting system, consisting of one or two 25-gallon polyethylene tanks, a 12-volt DC electric pump rated at up to 3 gallons per minute, spray nozzle and associated hardware. The spray nozzles are positioned so that they spray either down into the spinner or in the chute. A small pump and hose are needed to transfer brine from the large storage tank to the on-board tanks.





Results

During winter 1998-1999, natural brine was sprayed, as a pre-wetting agent, on the rock salt and salt/abrasive mixtures at the rate of about 12 gallons per ton of material. Public works personnel in each community completed data forms, which provided information on weather conditions, amount of materials placed, and an assessment of road surface condition.

Results of the field tests showed that, in all three communities, brine was a valuable supplement to winter maintenance operations. In all three communities, better levels of service were provided to the traveling public; roads cleared more quickly than those treated by conventional techniques. The brine-enhanced mixtures worked well in temperatures as low as 3 degrees F and under a variety of winter storm conditions. Less material was used overall since the reduced bounce-off associated with pre-wetted materials kept more of the salt/abrasives in the travel lanes where it was needed. Less salt went on lawns and driveways. Where ice or snow had bonded to the pavement surface, the brine treated salt was able to break the bond in about one-half the time of conventional materials.

Brine enhanced mixtures showed considerable flexibility in the type and nature of application. Due to positive comments received from citizens, the City of Fairmont expanded its use of brine beyond the single truck and sprayed the top of each truckload of material with brine before it left the yard. City crews also had success in hand application of brines to public sidewalks where they were beneficial in breaking up ice/snowpack. The City of Morgantown's experience demonstrated that the brine-treated mixes could be applied to the roadway either prior to or early into the storm, so that the snow or ice was not able to bond to the roadway surface.

Roadway use of brines could also have more widespread economic benefits since wells currently capped due to excess brine production could be re-opened. Additional production would mean increased tax revenue and job opportunities.

For more information on this project contact the Center at: 304-293-3031 ext. 2612