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16. Abstract

This report presents the major results of an in-depth study of Snow and Ice Control Operations conducted in four States during the winter of 1975-76. The states involved were California, Colorado, Pennsylvania, and Utah. To the extent possible, within the time frame of the study, all aspects of snow and ice control activities (material, equipment and labor) were analyzed.

Initial estimates indicate potential savings on the order of $5 million among the four states upon implementation of the changes recommended as a result of this project. The recommendation with the greatest potential for immediate cost reduction are the control of application rates and the adoption of ground control spreaders.

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SNOW AND ICE CONTROL - OPERATIONS

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ACKNOWLEDGEMENT

Special appreciation is extended to the dozens of State maintenace personnel contacted by the team members, both collectively and individually, during the course of this study.

Snow fighting is a hazardous, tiring and lonely job which is not generally appreciated by the public. In this regard, a certain cynicism might be expected at our attempts to "scientifically" analyze this emergency maintenance activity with all its many variables. Just the opposite was true. Our efforts were met with interest, enthusiasm and cooperation throughout which certainly reflects the high quality and dedication of the maintenance personnel in the four States.

SUMMARY

This report presents the major results of an in-depth study of Snow and Ice Control Operations conducted in four States during the Winter of 1975 - 1976. The States involved were California, Colorado, Pennsylvania, and Utah. To the extent possible, within the time frame of the study, all aspects of snow and ice control activities (material, equipment and labor) were analyzed. The study, however, did not cover the unique problems of snow removal on city streets.

Initial estimates indicate potential savings on the order of $5,000,000 among the four States upon implementation of changes recommended as a result of this project. This more than justifies the project cost of $100,000. The $5,000,000 estimated savings was derived from the accumulation of potential savings from implementing all of the recommendations listed in this report. The recommendations with the greatest potential for immediate cost reduction are the control of application rates and the adoption of Ground Control Spreaders. It is conservatively estimated, based on observations, that at least a 20 percent savings in material alone (sand, salt, or mixture) can be realized in jurisdictions which do not currently use these procedures and equipment. Additional savings to the public should be realized if other snow belt States and Counties adopt the recommendations that apply to their particular operations.

The findings and recommendations detailed in this report are the consensus of the opinions of the four State teams involved in the study. As such, the results should not be considered entirely comprehensive nor the only possible means for improvements.

This report is written for use by practitioners familiar with the subject matter. A basic understanding of the problems and procedures in managing a snow and ice control program has been assumed in order to properly focus the results of the study.

FINDINGS AND RECOMMENDATIONS

The major findings and recommendations are briefly stated below. Details can be found in the like-numbered sections of the "Discussion" part of this report.

GENERAL:

1. The geographic and climatic differences between the States involved in the study had little effect on snow and ice control operations.

2. Snow and ice control activities should be budgeted separately from routine maintenance operations.

3. Spring cleanup of abrasive windrows and drainage structures is seldom considered a snow and ice control expense.

4. Snow poles should be left in place year-round.

5. Without continuing management review, actual levels of service tend to progress from low to high.

MATERIALS:

1. The application rate of salt should seldom exceed 500 pounds per two-lane mile. (141 kg per two lane km) The application rate of abrasives should seldomly exceed 1500 pounds per two-lane mile. (423 kg per two lane km)

2. Processed salt costs less and is as effective as kiln-dried salt.

3. YPS (Yellow Prussiate of Soda) as an additive to prevent caking, when used in the proper amounts, is not detrimental to the environment.

4. Use of bagged salt can seldom be justified economically.

5. When applied properly under suitable conditions, straight salt can be as effective and less expensive than abrasives or abrasive/salt mixtures.

6. New materials (fiberglass, plastic, etc.) being used for snowpoles can be cost-beneficial.

EQUIPMENT:

1. The use of Ground Control Spreaders can save time, material and fuel, with satisfactory results, at a relatively low cost for initial investment.

2. The use of snowplow blades with carbide inserts will substantially reduce the costs of operations which currently use carbon steel blades.

3. The use of single-purpose equipment (rotaries, hopper bodies, etc) should be thoroughly analyzed and questioned.

4. Under certain conditions, the use of rental equipment with operators (Contractors) can reduce operating costs significantly.

5. Calibration of spreaders is essential regardless of the type of spreader or material used.

6. In many areas the use of underbody plows rather than front-mounted plows will result in more efficient and economical operations.

PROJECT PROCEDURES

This project was initiated in the late summer of 1975 by Task Order Agreements with the States of California, Colorado, Pennsylvania and Utah. Three-man teams were provided by each State except Pennsylvania, which had a two-man team. The make-up of the teams was multidisciplined with at least one member of each team from maintenance and in a position to implement changes.

The Value Engineering concepts of functional analysis and a "challenge everything" approach were the basic project guide-lines. Projects of this nature have been identified as the top priority in the Report "Highway Maintenance Research Needs", Report No. FHWA-RD-75-511, March, 1975.

The initial meeting of the State teams and FHWA coordinators was held in Utah in October, 1975. Subsequent meetings were held in Colorado, December 1975; California, February 1976; and finally in Pennsylvania, April 1976. These meetings were held to provide project coordination, exchange information, brainstorm the subject, and provide the host State with a critique of their operations by experts from different parts of the country.

The California and Pennsylvania teams were concurrently involved in their own in-house snow and ice control studies and hence were able to contribute more to this report than would normally be expected within the time and funding limits provided. Each State team prepared their own report which detailed the findings and recommendations which they deemed most important to their State. These reports were then forwarded to the FHWA Project Coordinator to be condensed and summarized in this final project report.

DISCUSSION

The findings and recommendations previously listed will be repeated here followed by a brief discussion of the details which led to the conclusions.

GENERAL:

1. The geographic and climatic differences between the States involved in the study had little effect on snow and ice control operations.

   Although this "finding" is of little economic significance, it is important for the overall credibility of this report and to reduce the inclination of others to reject any new improvements because "their conditions are different from ours." One of the reasons for selecting the States involved in this study was to determine if geographic differences actually did have a major impact on snow and ice control operations. In fact, the general feeling of the State teams in the first meeting was that these differences would be a major problem in reaching a consensus. As the study progressed, however, these concerns were minimized as the States became more aware of each other's operations. Great differences in snowfall, temperatures, durations etc., were found within the individual States. Each State had "wet" and "dry" snows, "heavy" and "light" areas, drifting and avalanche problems to various degrees and approximately the same philosophies regarding levels of service. It was also noted that in every State the temperature during snowfall seldom varied from between 20 and 35 degrees F (-7 and 2 degrees C). Although not all the recommendations in this report will be implemented in all States involved, the reasons are not because of geographic differences.

2. Snow and ice control activities should be budgeted separately from routine maintenance budgets.

In most maintenance management systems snow and ice control activities are budgeted as line items along with patching, mowing, etc. This presents two problems; (1) there is seldom an "average" winter upon which budgets must be based, and (2) a severe winter will require the expenditure of funds which would normally be required for preservation of the facilities. An associated problem is the tendency for maintenance managers to conserve on routine maintenance activities to assure that adequate funds will be available in the event of a severe winter.

The establishment of a separate "emergency" budget for snow and ice control will eliminate these problems. This procedure has been implemented in Utah.

3. <u>Spring cleanup of abrasive windrows and drainage structure is seldom considered a snow and ice control expense.</u>

This activity is an especially important consideration in urbanized areas where the economics of the use of salt <u>vs.</u> abrasives is being analyzed. Cleanup of salt/ sand mixtures on structures is also essential during the winter season since accelerated damage to bridge decks can be expected if they are left in place. Any cleanup of abrasives requires a high percentage of labor and equipment and is therefore expensive (Fig. 1).

Figure 1. Accumulated abrasives at an intersection. In addition to the problem of cleanup costs, abrasives may mask pavement markings and reduce traction on dry pavements.

4. <u>Snow poles should be left in place year-round.</u>

In some States it was observed that snow poles were periodically installed in the Fall and removed in the Spring. The only reason cited for this was "esthetics" but the consensus of the State teams was that this was a minor consideration compared to the highly labor-intensive, and thus costly, activity of snow pole removal/installation. This operation is also likely to be hazardous to both maintenance personnel and motorists (Fig. 2).

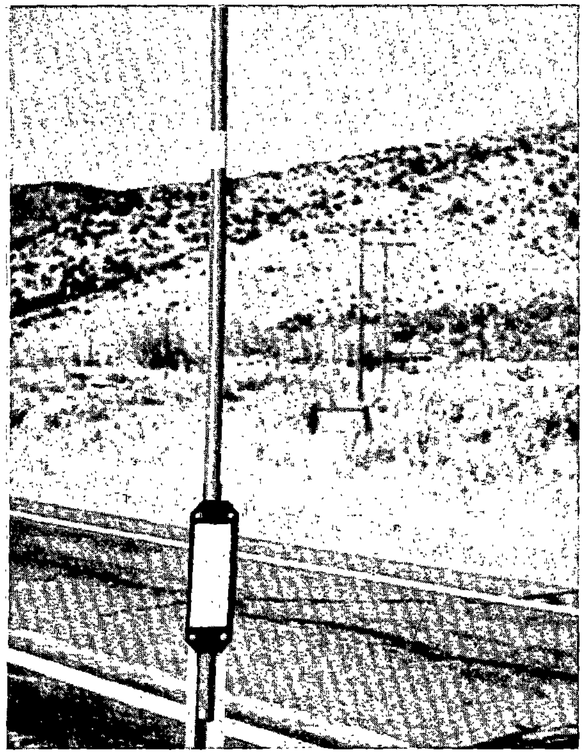

Figure 2. Five foot (1.5 metre) PVC slip-in snow pole left in place year-around.

5. <u>Without continuing management review, actual levels of service tend to progress from low to high</u>

Maintenance personnel, as a rule, are dedicated individuals who attempt to do the best job possible. This normally admirable trait can be counterproductive to the effective management of an economical snow and ice control program. It was noted that, for instance, roads designated to receive level of service 3 will, over a period of time, gradually begin to receive level of service 2 and even 1. This problem can be eliminated by periodic management review of <u>actual</u> levels of service being provided and by following this up with corrective measures as necessary (Figs. 3 & 4).

Figure 3. High level of service on a primary road. Deicing chemicals are spread uniformly across the roadway.

Figure 4. Reduced level of service on a secondary road. Deicing chemicals are "windrowed" along a 4' (1.2 m) wide swath along the centerline.

MATERIALS:

1. The application rate of salt should seldom exceed 500 pounds per two-lane mile (141 kg per two lane km). The application rate of abrasives should seldom exceed 1500 pounds per two-lane mile (423 kg per two lane km).

   This recommendation is based on research work conducted in Utah and Pennsylvania. It also reinforces the recommended application rates contained in the report "Manual for De-icing Chemicals: Application Practices" Report No. EPA-670-2-74-045, Environmental Protection Agency, Cincinnati, Ohio 45268, December 1974.

If salt and sand are mixed, the application rate of salt should be the controlling factor. For example, a 1:1 mixture of salt and sand would cover only one-half the distance that could be covered with straight salt.

This recommendation has one of the highest probabilities for immediate cost reduction if adopted by agencies which presently have no control of application rates. It was noted throughout the study that in areas where there was no control the actual rates were always considerably higher than necessary (Fig. 5). One State has mechanically restricted its spinners and augers so that maximum rates cannot be exceeded.

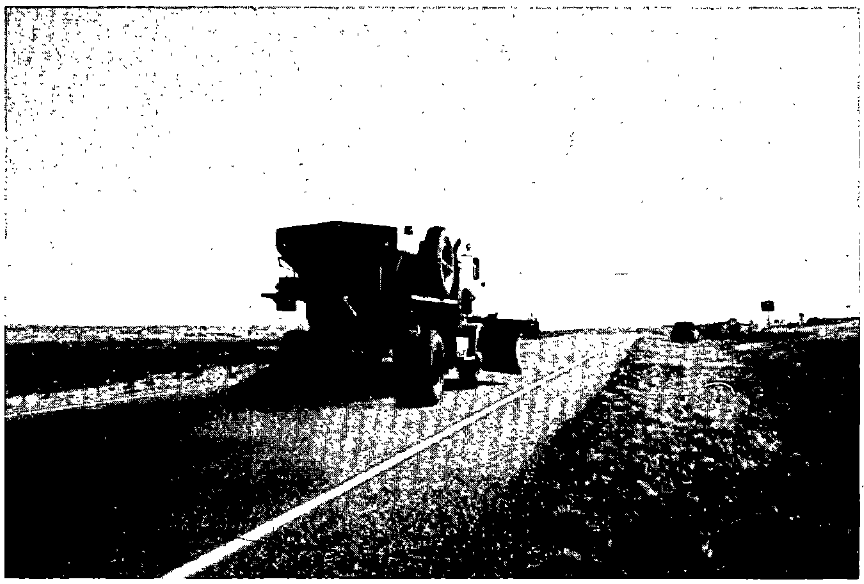

Figure 5. This uncalibrated spinner-type spreader was field checked and found to be spreading material at a rate of 20,000 pounds per two-lane mile (5640 kg per two lane km): more than 13 times the recommended maximum rate.

2. <u>Process salt costs less and is as effective as kiln-dried salt.</u>

Process salt is salt that has been mined and graded but not completely purified and dried. The only noted advantage of kiln-dried salt was that it would not cake up when stored properly. Process alt, however, will not cake up either when anti-caking additives are used. Also, storage conditions are not as critical. Only one State was using kiln-dried salt and savings of $3.00 to $6.00 per ton ($3.31 to $6.61 per metric ton) were estimated if process salt was specified as an alternative (Fig. 6).

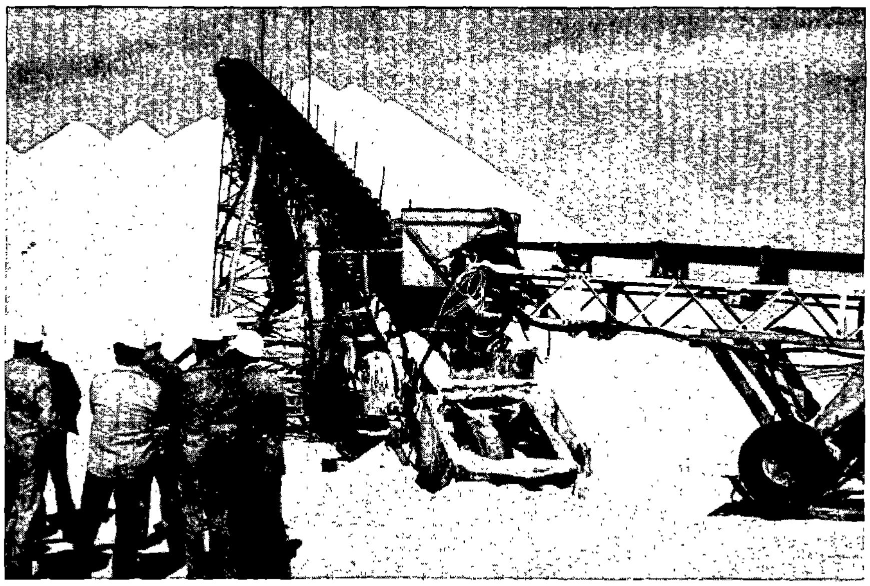

Figure 6. Process salt stockpile at the Great Salt Lake Minerals and Chemicals plant in Utah. Additives have been mixed with the salt in the conveyor chain and the salt is ready for bulk shipment.

3. <u>YPS (Yellow Prussiate of Soda) as an additive to prevent caking when used in proper amounts, is not detrimental to the environment.</u>

Another name for YPS is Sodium Ferrocyanide and there was some concern that this might be detrimental to fish if it leached into streams. YPS is added to road salts in amounts ranging from 80 to 200 ppm. The Food and Drug Administration (Code of Federal Regulations 121.1032) has approved YPS as an anti-caking additive in table salt based on exhaustive tests wherein no evidence of toxicity was demonstrated at 500 ppm (1). Treated stockpiles exposed to the elements were still observed to develop their own "caps" but this never appeared to exceed 1-2 inches (25-51 mm) in thickness (Fig. 7).

(1) Transportation Research Record #506, p. 45, 1974.

Figure 7. Test pile of treated process salt showing "cap" development and no evidence of leaching.

4. Use of bagged salt can seldom be justified economically.

   This should be obvious but several areas were noted where bagged salt was being purchased for no apparent reason other than personal preference or the fact that it had "always" been purchased bagged.

5. When applied properly under suitable conditions, straight salt can be as effective and less expensive than abrasives or abrasive/salt mixture.

   In considering the economics of salt vs. abrasives, the principal variable is the price of the salt. This, in turn, is largely controlled by transportation costs and type of salt specified. Each agency should, therefore, conduct its own analysis. An example is shown below based on a portion of the work conducted by Pennsylvania during the course of this project. Straight salt should be most effective at a rate of snowfall of 2 inches (51 mm) per hour or less.

PERFORMANCE AND COST COMPARISON

(From Pennsylvania Report)

"The Indiana County report and our review of the 35mm slides confirm reports from preceding studies that minimal straight salt applications, when properly applied, provide the melting action required to keep ice and snow from bonding to the roadway surface. During the 1975-1976 winter, Indiana County paid the following prices for winter materials;

Sodium Chloride	$14.29 per ton*
Cinders	$ 5.69 per ton
Sand	$ 5.48 per ton

* Cost/metric ton = 1.102 x cost/ton

Materials costs to treat a two-lane mile.

MATERIAL	APPLICATION RATE (1)	COST (2)
100% salt	200 lbs.	$1.43
100% salt	300 lbs.	$2.13
100% salt	500 lbs.	$3.57
100% cinders	1000 lbs.	$2.85
100% sand	1000 lbs.	$2.74
3:1 mix cinders/salt	1000 lbs.	$3.93
1:1 mix cinders/salt	1000 lbs.	$4.99
3:1 mix sand/salt	1000 lbs.	$3.85
1:1 mix sand/salt	1000 lbs.	$4.94

(1) 1 lb = .4536 kg

(2) Cost x .6214 = cost per two lane km

The above table was prepared using the application rates and materials/material combinations reported by Indiana County. In addition to the obvious dollar savings that this County could realize by using 100 percent salt on more roads, an economic analysis must consider truck spreading distances and the elimination of deadheading."

To document the effectiveness of the various methods, Penn DOT conducted several controlled tests on different roads in the same areas which had similar traffic and service levels. An example is shown below in Figures 8 and 9. The photos were taken during a 5-inch (127 mm) snowstorm which occurred January 27 and 28, 1976. Temperatures were in the low thirties throughout January 27 and dropped to 18° F. (-8°C) by 4:45 a.m. January 28.

Figure 8. Road "A." Material: Cinder/Salt mix @ 1000 lbs./2-lane mile (282 kg per two lane km). Road plowed and spread: 10:30 a.m. 1/27/76. Time of photo: 11:00 a.m. 1/27/76.

Figure 9. Road "B". Material: 100% salt @ 200 lbs./2-lane mile (56 kg per two lane km). Road plowed and spread: 9:30 a.m. 1/27/76. Time of photo: 10:00 a.m. 1/27/76.

6. <u>New materials (Fibergass, plastic, etc.) being used for snow poles can be cost-beneficial.</u>

The potential of these new materials for snow poles surfaced during the course of the study. The unit costs appear to be less than metal or wood poles currently being used and they are typically attached to existing delineators rather than driven separately. It is not known yet, based on this study, how these materials will perform when subjected to the pressures of heavy wet snow cast to the side by fast moving plows. The States involved in this project plan to experiment with these materials during the 1976-1977 season (Fig. 10).

Figure 10. Plastic slip-in type snow pole.

EQUIPMENT:

1. The use of ground control spreaders can save time, material, and fuel, with satisfactory results, at a relatively low cost for initial investment.

   Many existing hydraulic spreaders can be adapted to ground control systems for less than $1,500.

Controlled tests in Pennsylvania have shown that these units can save up to 40 percent of the material which would normally be spread by non-ground oriented spreaders. These units are particularly valuable in urbanized areas where constant speeds are difficult to maintain. In addition to the economic benefits of ground control spreaders, the operation is made safer and easier because the operator does not have to attempt to spread material at a preselected speed which may or may not be proper for the conditions and traffic encountered during a storm (Fig. 11).

Figure 11. Penn DOT 14 CY (10.7cm) 10-wheel plow equipped with a Swenson single auger, ground oriented, tailgate spreader with cleanout gate.

2. The use of carbide insert snowplow blades will substantially reduce the costs of operations which currently use carbon steel blades.

   Although initial costs of carbide insert blades are approximately four times higher than carbon steel blades, the carbide insert blades will last at least 23 times longer. This results in a considerable reduction in materials costs with the additional benefits of reduced down-time on the plows and the reduction in labor costs which would normally be required for constantly changing carbon steel blades. All of the States involved in the study have either changed or are in the process of changing to carbide insert blades.

3. The use of single-purpose equipment (rotaries, hopper bodies, etc.) should be thoroughly analyzed and questioned.

   In some areas it became evident that too much equipment was available or that the specialized functions performed by single-purpose equipment could be done adequately by other equipment. For instance, it was observed that in some places a wing plow, or a rotary attachment to a front end loader, would probably do the same work as presently being accomplished by a rotary at substantially reduced cost.

4. Under certain conditions, the use of rental equipment with operators (Contractors) can reduce operating costs significantly.

Pennsylvania has successfully employed contractors for snow and ice control operations for several years. The other States involved in this study recognized the potential for savings in areas where equipment, for instance, was allocated based on winter maintenance but remained idle the rest of the year.

It should be emphasized that the use of contractors can only be successful if they are assigned specific routes and are called out at the same time as the State Forces. It would not be practical or economical to expect contractors to "standby" solely to supplement State crews during severe storms. Each agency contemplating the use of contractors must assess its own local economic factors regarding seasonality of employment, availability of trucks and drivers, competition (parking lots, shopping centers, etc.), insurance rates and legal responsibilities.

5. Calibration of spreaders is essential regardless of the type of spreader or material used.

The adoption of maximum application rates by "inventory control" or some other means will generally be inefficient and can even be counter-productive. All spreaders, even ground controlled, must be calibrated at least annually if an efficient snow and ice control program is to be managed effectively. The experience of the States involved in the study who calibrate their spreaders annually has shown that apparently minor changes in the equipment due to wear and tear will significantly affect the application rates. Pennsylvania has developed a procedure with forms and a slide-tape training package which has been proven to be effective in the rapid calibration of large numbers of spreaders.

6. In many areas the use of underbody plows rather than front-mounted plows will result in more efficient and economical operations.

   In many cases underbody plows can accomplish the job faster, safer, and with less fuel consumption than front-mounted plows. They are also more versatile since down-pressure can be more accurately controlled. Details of this and other equipment must wait for another report of this nature.

OTHER CONSIDERATIONS

STANDARDS AND PLANNING:

The only "standards" observed during the study were actually guidelines regarding plowing and spreading frequencies and levels of service based on "average" storms. There were no true productivity type standards available.

A large amount of data was collected from several maintenance stations during the course of this study with the intention of developing a workable productivity standard. An extensive analysis of the data has shown that this is probably impossible. However, the data indicated that an "efficiency factor" could probably be developed which would help management to analyze the operations of individual maintenance stations on a seasonal basis. Much more work needs to be done in this area in order to develop meaningful values, however, our initial analysis is briefly outlined below in order to indicate the direction which future studies should take.

If all storms measured 1 inch (25 mm) or more of snow there would be no problem in developing a standard such as "man-hours/inch/mile." It is the "nuisance" storms which may involve a trace of snow, freezing rain, blowing and drifting, etc., which make the analysis of productivity difficult. To ignore these nuisance storms would not be realistic.

Based on this, the concept of an efficiency factor based on seasonal averages was proposed for the comparative analysis of the operations of different maintenance stations in similar climatic zones. To be practical, the information required to develop these factors should be readily obtainable. The factor that evolved from the data that appeared to be the most significant and easily derived was "average man-hours/storm/season" (MH/S). To absorb the effects of nuisance storms, a "storm" in this analysis is defined as occurring any day on which snow and ice control activities are reported. Also, a two-day storm would be shown as two storms. The MH/S factor can then be obtained by totalling the number of days in which snow and ice control activities are reported during a season and dividing this into the total man-hours reported for those same activities.

Total snowfall during a season will affect the MH/S factor and stations should be assigned to "zones" based on this information which is available from the Weather Bureau. No more than three zones should be required within an individual State. A tabulation of MH/S factors for 13 stations in two States for the winter of 1975-1976 is shown below in Table 1.

TABLE 1.

DATA FROM 13 STATIONS IN TWO STATES, WINTER: 1975-1976

STATION	NO. "STORMS"	MAN-HOURS	MH/S
A	16	1320	82
B	18	436	24
C	38	878	23
D	11	277	25
E	25	1318	53
F	30	1237	41
G	32	1845	58
H	27	1877	70
I	24	1858	77
J	16	708	44
K	54	1172	22
L	57	1401	25
M	74	3235	44

In the above table, the stations with MH/S factors in the twenties had similar total snowfalls. The other stations had similar, but higher, snowfalls. Based on this and other observations, an analysis of the operations of stations A, H and I would be the most likely to produce improvements. Again, much additional work needs to be done in this area since other factors such as miles or service levels may locally significantly affect the efficiency factor.

NEW EQUIPMENT:

During the course of this study, the California Team developed a Salt Hopper attachment which was mounted on a conventional hopper body. This attachment allows the operator to mix any desirable proportion of salt with the abrasives or apply 100 percent salt as needed (Figs. 12 & 13). This attachment has great potential both for eliminating expensive premixing, where this is still done, and allowing operators flexibility during rapidly changing weather conditions.

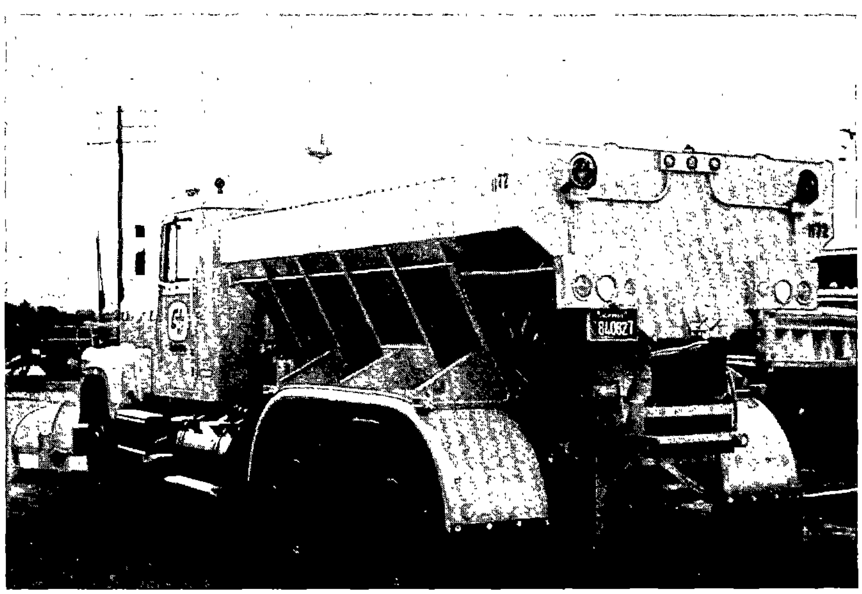

Figure 12. California Salt Hopper Attachment.

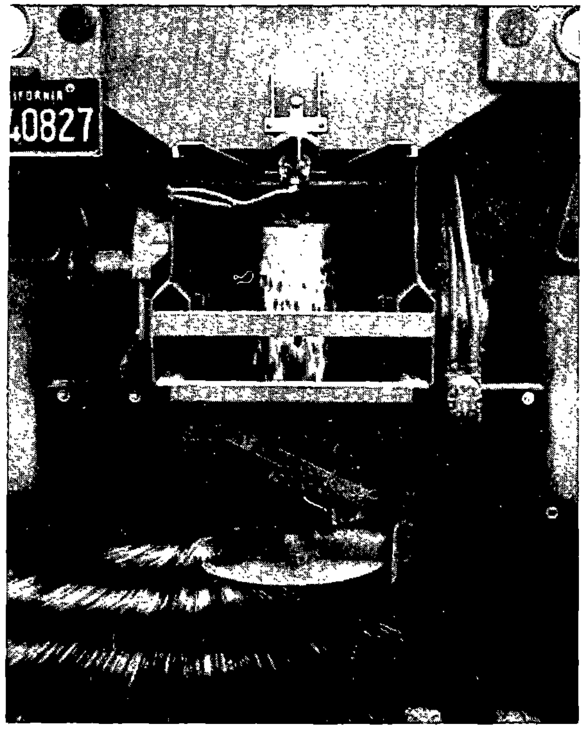

Figure 13. California Salt Hopper Attachment in operation. Note the salt flowing down and being mixed with the abrasives before spreading.

Airfoils fabricated from old salvaged 1/8-round guardrail have been noted to be effective in two applications for snow and ice control: (1) Mounted atop a two-way plow to improve driver visibility by deflecting blown snow down behind the plow and, (2) Mounted atop the rear of a hopper to deflect air down the back, keeping lights and equipment free of snow accumulation (Figs. 14-15).

Figure 14. Rear of hopper without the airfoil attachment.

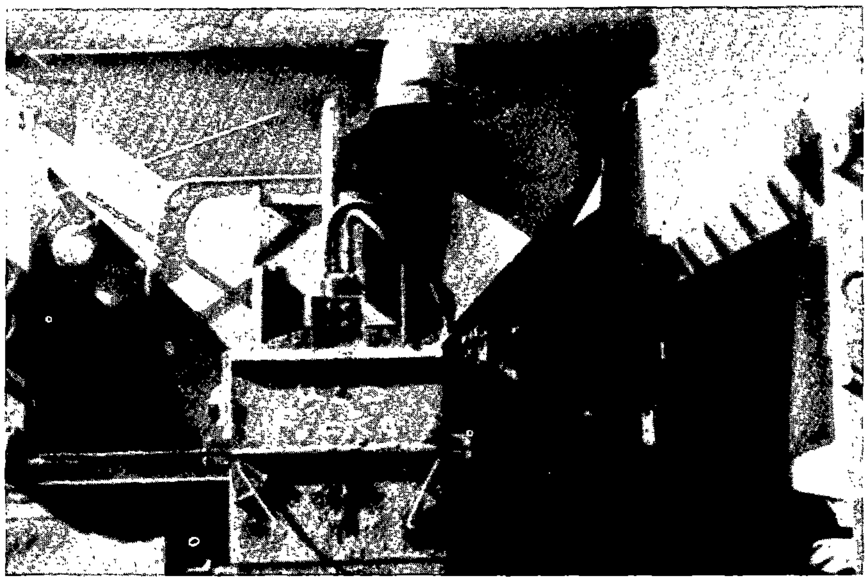

Figure 15. Rear of hopper with airfoil (Turner Airfoil - Arizona Department of Transportation).

LEGAL AND POLICY:

Chain laws have been proven effective when implemented. The expense of manning chain control inspection stations should be analyzed. It could be questioned that these are required.

Two taxing proposals have been proposed or contemplated: (1) A local tax on ski-lift tickets dedicated for the additional costs of snow and ice control services to these areas, and (2) A local tax on studded tires dedicated to the States's general maintenance fund.

A systemwide "Bare Pavement" policy as generally construed can no longer be economically justified. None of the States involved in the study use this term any longer. This has been replaced with the highest level of service, designated within a State, which has a certain amount of flexibility depending on the length and severity of a storm.

This study, as well as the adoption of specified levels of service, has pointed out the need for a continuing snow and ice control management improvement program in each agency with these responsibilities. It was the consensus that certain inefficiencies have probably crept in over the years in an operation which has essentially not changed, even after the adoption of a Maintenance Management System. A continuing study of snow and ice control operations should pay for itself many times over and allow an agency to better allocate scare funds for the benefit of all.

FUTURE STUDIES:

This study has shown a benefit/cost ratio of 50:1 just among the States involved. Very seldom will research show this kind of return to the public for public dollars spent. Future studies should continue to utilize the Value Engineering approach and teams of State and Local Operations personnel who are in the position to initiate changes.

Future studies of snow and ice control should be directed toward optimizing the efficiency factors discussed above with the goal of establishing national guide values, analysis of equipment types and usage, and development of a two-tiered Training/Educational program for management and operations personnel based on the results of these studies.