MANAGERIAL ASPECTS OF A CHEMICAL REDUCTION PROGRAM

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Increasing public pressures on the use of chemicals on roadways has caused a reassessment of the techniques in controlling usage. Previous controls were designed primarily to achieve a road condition. New techniques should be designed to produce levels of service with a minimum of chemicals. The development of a reporting system to obtain this objective is discussed, and conclusions are made on the success of the various managerial devices used. Recommendations for research and development in some of the most promising areas are given wherever possible. Full analysis of cost factors was beyond the scope of this investigation.

•ANY ASSESSMENT of a managerial system must begin with an understanding of the historical developments that brought the manager to the point of devising the system. With this in mind, a brief background on winter chemical usage in Minnesota should preface this report.

Within the present century heavy-duty trucks have replaced the use of horses with sleds on roadways. With the advent of the automobile, the various governmental units began first to remove snow from the roadway and, then, to apply an abrasive to provide a nonskid surface for the new transportation mode.

The clearing of the roadways with the plow and the application of sand and cinders became a quite common practice by the end of the 1920s, and by the beginning of World War II it had spread through almost every system of roadways.

World War II brought with it demands to maintain factories and war production 24 hours a day. The first direct demand by the war industry was for 24-hour snow removal coverage on certain key routes. Along with this expanded coverage came the increasing use of sand and salt mixtures to provide the war workers with an accident-free roadway network.

The post-war years showed an expanded round-the-clock service and the gradual increase in the ratio of salt to sand. By the 1960s, the American society's dependence on the rubber tire was generating demands for a bare pavement policy, which was largely accomplished by the use of heavy applications of salt. Most management controls used by the various maintenance departments were result-oriented. Environmental factors were of lower priority. Levels of service required to attain the bare pavement were not defined beyond the simple "bare pavement" statement.

In the late 1960s, some highway districts in Minnesota began to search for a definable statement measuring levels of service. These statements were included in annual district snow and ice control plans, primarily in the two metropolitan districts in Minnesota, climaxed in a statewide level of service policy in 1971 (Table 1).

As success in obtaining a bare pavement policy was reached, the highway department began to receive criticism on the side effects of some of the chemicals. At first, most of the criticism was general in nature and the complainants did not appear too knowledgeable about the particular products they were discussing. The first large broadside on chemical use concerned the effect on vehicles. When answers to this criticism were forthcoming, an attack on the environmental effects of chemical usage began.

The district began to receive numerous complaints in the form of letters, calls, and newspaper articles. We found that response to the individual complaints had to be general in nature because we were unable to provide factual information about a specific usage at a specific time and place.

By the 1970-71 season, it was apparent that we needed more accurate information to respond to these critics. We then developed a simple chemical usage ticket that was filled out by the truck operators and that provided us with the area, route, time used, and the salt-sand ratio. It also gave us some general information on the application rates and the effectiveness of various types of equipment. This reporting device was an eye-opener. The actual users of the chemical recognized the need to inform the supervisors of what they were actually doing, and what we were doing in the application of the chemical varied considerably from theory.

The shift foremen or crew chiefs merely summed up the day's work without actually trying to relate the chemical usage for that period. Consequently, they did not make good use of the information. The district summed up the tickets at the end of the season and was quite surprised by the reduction in use. A reduction of 26 percent from a similar year had been realized.

The summary at the end of the first season was made too late for effective managerial action. The massive amount of data and limited research capabilities of the district also limited use of the information. The district did, however, decide that the chemical usage ticket should be continued in a reduction program during 1971-72.

During the winter of 1970-71, our legislature was in session and a number of "anti-salt" bills were introduced. The debate over salt use continued to rage in the newspapers and the political arena, and the legislature finally passed a bill that basically requires the department to use reasonable prudence in its application of salt:

> 160.215 Snow removal; use of salt or chemicals restricted in order to:
>
> (1) Minimize the harmful or corrosive effects of salt or other chemicals upon vehicles, roadways, and vegetation;
>
> (2) Reduce the pollution of waters; and
>
> (3) Reduce the driving hazards resulting from chemicals on windshields: road authorities, including road authorities of cities, villages, and boroughs, responsible for the maintenance of highways or streets during periods when snow and ice are prevalent, shall utilize such salt or other chemicals only at such places as upon hills, at intersections, or upon high speed or arterial roadways where vehicle traction is particularly critical and only if, in the opinion of the road authorities, removal of snow and ice or reduction of hazardous conditions by blading, plowing, sanding, including chemicals needed for free flow of sand, or natural elements cannot be accomplished within a reasonable time.
>
> Approved June 1, 1971.

With the knowledge we had acquired from our research of 1970-71 and because of the continuing interest of the legislature and the public in 1970-71, our district formalized plans for a salt reduction program. The objectives of this program were as follows:

1. Reduce the amount of chemicals necessary and still maintain the recommended levels of service (Table 1);
2. Study the efficiency of various types of sanders with particular emphasis on ground-oriented sand spreaders versus the conventional for future possible reductions in chemical usage;
3. Develop graphs and charts that relate chemical usage with time periods, storms, and uniformity of one route to another; and
4. Establish uniform and practical reporting procedures for the control of salt use.

Because any managerial system is tailored around its particular organization and its decision-making structure, a brief explanation of our district organization may be of value. The district organization is structured as shown in Figure 1 and is described as follows:

1. A route on our metropolitan freeways (some of which carry traffic volumes of 100,000 vehicles per day) should be manned so as to provide a 2-hour cycle time that relates geographically to 30 lane-miles or a predetermined number of interchanges.

2. A subarea is a combination of a number of routes whose geographic boundaries are determined by some practical considerations such as turn-around points, traffic characteristics, storage facilities, and number of men to be supervised.

3. An area consists of two to three subareas with common traffic characteristics. This enables the district to provide more local supervision to the subareas.

4. The district itself is composed of five areas that report directly to the maintenance operations engineer. This person maintains a radio-controlled operation center during the winter season.

To provide assistance to the maintenance engineer in the second season of the control program, the district engineer assigned a graduate engineer to direct, monitor, and analyze the system as it operated during the winter. Prior to the first storm, the graduate engineer met with the operators in each subarea in a question-and-answer session. This very informal approach proved to be extremely effective. The men readily accepted the need for a reporting device and almost immediately obtained high levels of accuracy in completing it.

The basic device used in the winter of 1971-72 was much the same as originally designed (Fig. 2). It was slightly modified to provide all strata of supervision in the maintenance district with first-hand knowledge of actual chemical use. Again, the ticket was designed to provide information on the route, supervisor, time, and quantities and to maintain simplicity of reporting by the operator.

Among the measures taken in this reduction program, the maintenance engineer established district parameters on salt-sand mixture ratios. The most effective of these was a dictum that no more than 50 percent salt to sand could be applied without specific permission from the operations center (Fig. 3). The extensive use of two-way radios within the district simplified the communications of any variations in policies. The resulting year's summary indicated acceptance by the operators of these parameters, and it also highlighted the need for requirement setting by the managers. As long as variable conditions can be recognized and flexibility can be built into the control device, requirement setting will be quite easily accepted.

For comparative purposes, a pass mile was used as a common denominator. A pass mile was defined as a mile of traveled roadway consisting of (totally or in combination) turn lanes, acceleration and deceleration lanes, interchange ramps and loops, tapers, truck climbing lanes, and through lanes. The term pass mile refers to the fact that a truck must travel a certain number of vehicle-miles in making a continuous chemical application. There are 2,018 pass miles in our district.

To maintain consistency, we published summarized reports listing all chemical and sand use at 2- and 4-week intervals. The 2-week report was designed to provide the first- and second-line supervisors with a comparison of data for their individual routes and the usage by the shift foreman. The biweekly report (Fig. 4) was sent in by each subarea and summarized for the maintenance engineer. This report provided a quick overall look at the district average and the relationship of each subarea's use to this average. After this summary, the entire report was sent to each subarea with no comments made. Variations from one area to another at times were great and quite apparent to the supervisors involved.

The 4-week report (Fig. 5) was quite similar in nature and was designed to be used by the central office for analyzing statewide salt usage.

Because of the geographic size of the district and the turn-around points of the routes, 25 chemical stockpiles have been maintained for the past several years. Because any one stockpile should be available to two or more routes, subareas, or even areas, it is necessary to provide periodic inventories. These inventories provided us with a means of monitoring the accuracy of the reporting system and a method by which we can easily focus our energy on the exception.

An inventory analysis of each of the 25 stockpile locations was taken twice during the winter. The midwinter inventory had a 4.44 percent discrepancy as compared to the usage reports, and the year-end discrepancy was only 1.32 percent (Fig. 6).

Monthly weather summaries were obtained from the U. S. Weather Bureau and were found to be essential. Amounts of precipitation (both snow and rain), flooding, ice

Table 1. Recommended levels of service in Minnesota.

Road Classification	ADT	Level of Service
Urban commuter	>10,000	Bare pavement within 6 hours
Rural commuter	2,000 to 10,000	Bare pavement within 24 hours
Primary	800 to 2,000	Intermittent bare pavement; clear wheel tracks
Secondary	400 to 800	Two bare wheel tracks and sanded hills and curves
Secondary	250 to 400	Bare left wheel track and sanded hills and curves
Secondary, including gravel roads	<250	Compacted snow acceptable

Figure 1. Organizational structure of highway district.

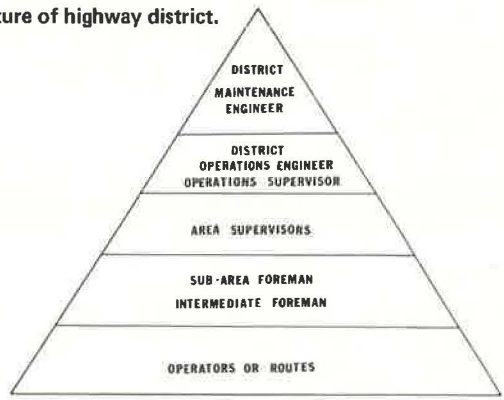
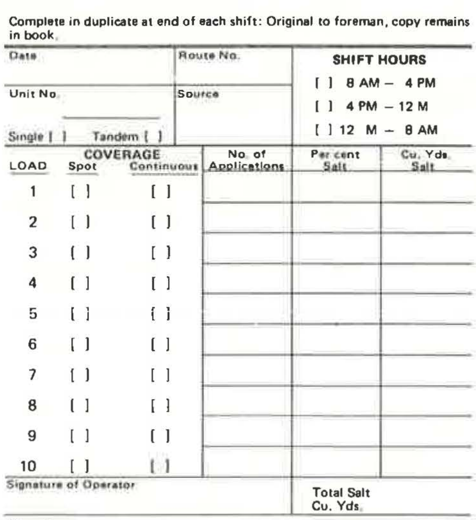


Figure 2. Log of salt use for Minnesota Highway Department.


Complete in duplicate at end of each shift: Original to foreman, copy remains in book.

Date | Route No.
Unit No. | Source
Single [ ] Tandem [ ]

SHIFT HOURS
[ ] 8 AM – 4 PM
[ ] 4 PM – 12 M
[ ] 12 M – 8 AM

LOAD	COVERAGE Spot	COVERAGE Continuous	No. of Applications	Per cent Salt	Cu. Yds. Salt
1	[ ]	[ ]			
2	[ ]	[ ]			
3	[ ]	[ ]			
4	[ ]	[ ]			
5	[ ]	[ ]			
6	[ ]	[ ]			
7	[ ]	[ ]			
8	[ ]	[ ]			
9	[ ]	[ ]			
10	[ ]	[ ]			

Signature of Operator

Total Salt Cu. Yds.

Remarks:

Figure 3. Sand-salt mixture ratios.

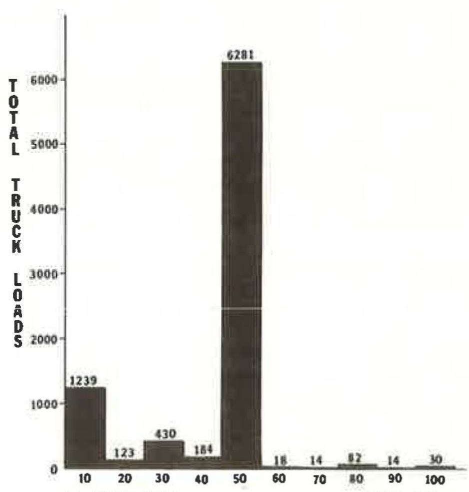


Figure 4. Biweekly sand-salt usage summary.

MHD DISTRICT MAINTENANCE AREA 5A

Date__________ Period Ending__________

Sub-Area	Total Sand (cu. yds.)	Total Salt (lbs.)	Lbs. Salt / pass. mile	Tons Salt / pass mile	Salt Usage % (+) or (-)
Anoka					
Laddie					
G. Valley					
Osseo					
Plymouth					
Wayzata					
Hopkins					
France					
Snelling					
Montrose					
Chaska					
Jordan					
TOTALS:					

District 5A Average = ________ tons/pass mile

Submitted by__________

Verified by__________

Figure 5. Four-week chemical use summary.

Maintenance Area __________ **4 Week Period** from ______ to ______ **Submitted by** __________

Route Class	Lane Miles*	Sand Usage (Tons)	Chemical Usage (Tons)	Tons/L.M.		Average No. of Coverages	Remarks
				Sand	Chemicals		
Urban Commuter							
Rural Commuter							
Primary							
Secondary							

*Indicate: Mainline only ☐ Mainline plus turn lanes, acceleration lanes and ramps ☐

pellets, hard glaze, and blowing snow are all recorded. We found that, although weather conditions are extremely variable not only from one location within the district to another but also from one storm to another, annual averages could be derived that are applicable to chemical use analysis (Fig. 7). A quick view of this figure seems to indicate the normal erratic pattern of weather. However, a closer look would indicate that there has been some unexplained change occurring since 1960. A 10-year average taken from 1961 to 1971 shows an increase of approximately 22 percent. In addition to this unexplained increase, a monthly average (Fig. 8) indicates that the peak month for snowfall moved from March in a 40-year cycle to December. This factor alone has introduced new problems to the maintenance unit. More storage has to be found for snow, and snow dump areas have to be increased. Types and numbers of equipment also are subject to change.

Through the use of these annual averages, the district developed a graph (Fig. 9) relating salt usage to snowfall frequency. The time period was deliberately kept short (5 years) because salt use has been changing and will continue to change. Although this graph may not fit technical research standards, it is accurate enough for managerial decisions, such as budgeting of materials, equipment, and manpower. It does enable the manager to budget for an average usage and to avoid the extremes that might have been the case in the past.

We were able to measure accomplishment in the salt reduction program by relating the 1971-72 use to this graph. We found that the reduction from a 5-year average and from similar years dropped by 42 percent.

Public reaction to the subsequent use of an increased sand-salt ratio was excellent. The decrease in adverse criticism from the public and the news media indicated that they were favorably accepting our attempts to reduce chemicals by the use of more abrasives. A review of the accident rates substantiated our visual observation that the levels of service had not changed from those recommended.

Two experimental ground-oriented spreaders were assigned to the district in the middle of the winter. Initially, mechanical malfunctions and operator inexperience with the spreaders were the major problems. Despite some negative criticisms, the data led to the conclusion that a ground-oriented sander is effective in reducing salt use. The data input was limited, and the validity of the results thus obtained may be questionable. The savings indicated from the limited input by the use of these ground-oriented spreaders in comparison to a similar type of conventional unit was approximately one-third.

We also attempted in sampling various bodies of water to monitor the amounts of salt reaching lakes and streams. The results obtained were erratic enough to indicate a major problem in sampling techniques, especially during March and April, high runoff months.

Because any reduction program must also include some measurement of levels of service, an operations review team of maintenance supervisors was formed. Three teams of two men, including one maintenance operations center man, were formed. At the outset of a storm, one or more of these teams were informed and alerted to duty. Their instructions were to travel the entire district, make visual observations of the roadways during one work shift, and observe variations in the levels of service as determined by state policy and operational procedures as set by the district. No subarea boundary lines were to be held sacred.

Every 2 weeks, these six men met in critique sessions that were completely unsupervised by the next level of authority. Solutions or problems were brought from these meetings to the maintenance operations center. We found that this "military critique" procedure worked extremely well; first, it freed the supervisors from any adverse criticism by eliminating the defense mechanism that usually springs up from an operational review team action. Second, it allowed them to be very free in their criticism of non-uniform practices throughout the area, and the lack of a prescribed reporting form seemed to encourage not only better communications among themselves but also much more creative activity in problem solutions.

In addition to this district operational review team, a review team from our central office visited the area several times during snowstorms. Their comments can generally be summed up as stated in their last review, "The district easily met the standards."

Figure 6. Midwinter and year-end salt inventory sheets.

STOCKPILE LOCATION	TONS ON HAND & DELIVERED	TONS ON HAND 2/1/72 F'MAN EST.	TONS USED TO DATE	TONS RECORDED ON SALT USAGE LOG	DIFFERENCE	% SURPLUS (+) OR SHORTAGE (-)
ANOKA	2526.33	1305	1221.33	1220.86	-0.47	-0%
SODERVILLE	625.77	290	335.77	378.11	+42.34	+13 %
LADDIE LAKE ETC.	2440.15	795	-1645.15	1468.15	-177.00	-11 %
TOTALS	28,933.60	10,919.00	18,014.60	17,214.44	-800.16	-4.44%

SALT INVENTORY FOR 1971-72

SUB-AREA	STOCKPILE	TONS ON HAND & DELIVERED	TONS ON HAND 4-12-72	1971-72 TONS USED	TONS RECORDED	DIFFERENCE	% SURPLUS (+) OR SHORTAGE (-)
ANOKA	ANOKA SODERVILLE	2847.10	732.24	2114.86	2557.09	442.23	+21%
LADDIE ETC.	LADDIE LAKE	2440.15	192.24	2247.91	2230.14	17.77	-1%
TOTALS		30,111.60	3739.09	26,372.51	26,721.59	349.08	+1.32%

TABULATED BY: D.S. LUOTO

REVIEWED BY: P.L. CHANDLER

Figure 7. Total yearly snowfall.

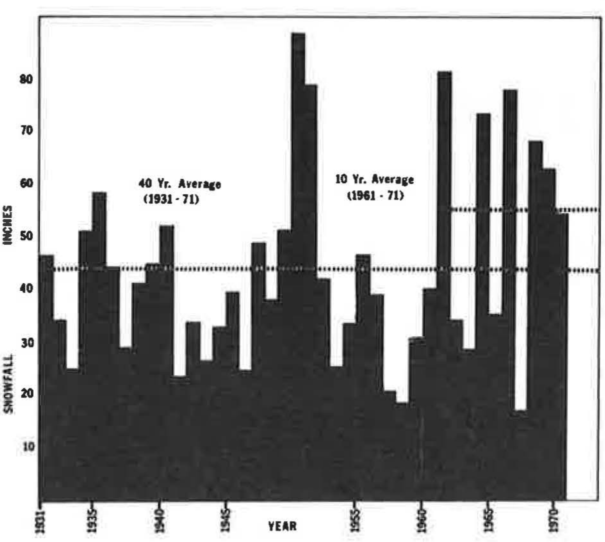


Figure 8. Monthly snowfall.

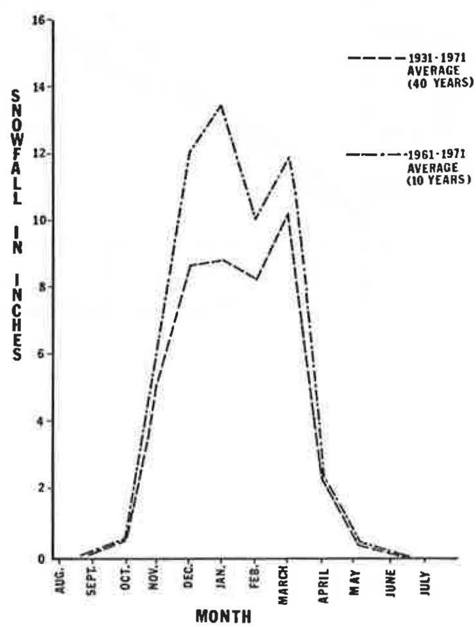


Figure 9. Relationship of snowfall frequency to salt use.

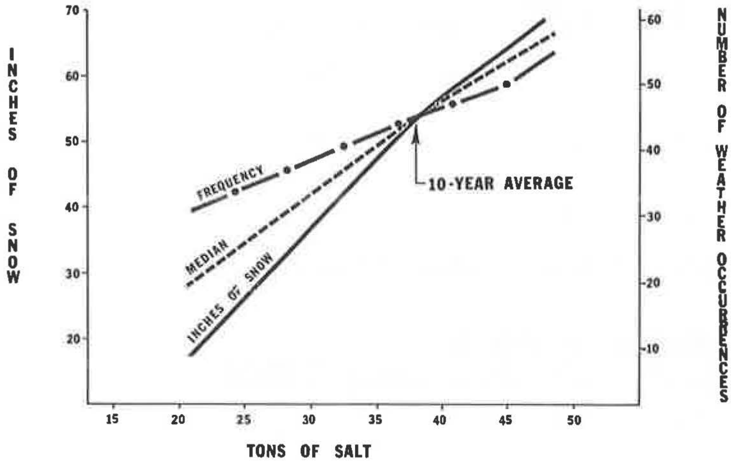
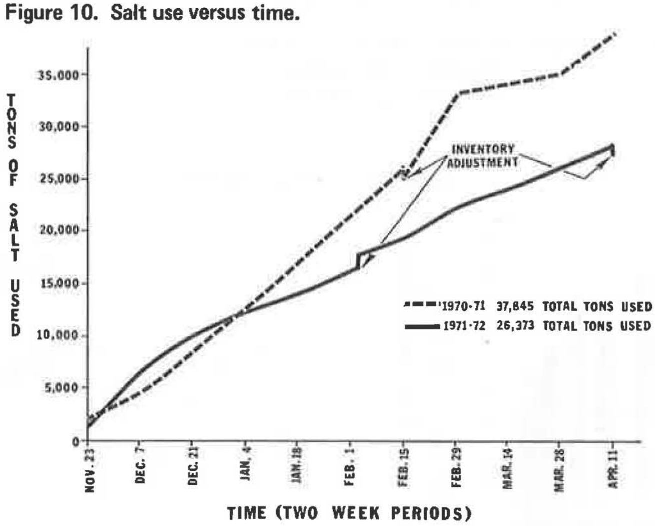


Figure 10. Salt use versus time.



CONCLUSIONS

Chemical use can be reduced without lowering existing levels of service. Levels of service and weather conditions can be quantified to the point where a relationship with chemical usage can be determined. This is quite clearly indicated by Figure 10, which shows salt use versus time. In this figure, the year 1970-71 was plotted in relationship to the study period of 1971-72. Our annual averages for the period 1970 indicated less snowfall and lower frequencies of snowfall than occurred in the study period, and yet the chart shows a very substantial reduction.

Any effective control mechanism must be based on the premise that responsibility for chemical use remains largely in the hands of the individual operator. As a corollary to this premise, it follows that responsibility or control methods must be completely defined for each level of authority. The degree and success of controls can be directly related to the clarity and understanding of the instructions.

First- and second-line supervisors must be provided with an effective management reporting tool to give immediate knowledge of the salt use in their area. This tool or device must be uniform and explicit and must cover the whole area to be controlled. It should provide the manager with a means of comparison between the various sectors of responsibility that he delegates to others, and it should provide him a means of comparison between his own area of responsibility and similar parallel areas. In effect, we were convinced that any control system should be a comparison type.

Chemical use can be easily related to several key factors or barometric factors (climatological conditions over a time period and in an individual storm period). Annual frequency and snowfall charts do provide a manageable way for budgeting annual quantities of chemicals. (Intensity may be a factor in other geographic and climatological areas.)

Although the input data were limited, we found there was considerable variation in the efficiency of the different mechanical devices used for spreading chemicals. This indicates that mechanical spreaders would be a fertile field for a future study.

RECOMMENDATIONS

Any managerial system for chemical usage control should be based on comparative values. Accountability for the individual actions should be provided by the use of a reporting device similar to the salt tickets. This device must be completed immediately following the expiration of the work shift. Training should be provided for shift leaders, foremen, and supervisors in the use and assessment of this reporting device. Training sessions should be held before, during, and after the winter season.

The use of the military critique method is highly recommended. An award system for the best maintained system with the lowest salt usage could be added as an incentive. Possibilities for such systems could be trophies, achievement awards, or promotional points. All reports to the operational management must be concise and brief in order to allow the manager to focus his time and attention on only the problem areas.

Meetings between the operation center managers and the area supervisors should be held monthly to review policies and procedures to allow full expression to suggestions and for improvement from the lower levels.

Practical periodic inventories of salt storage piles should be made during the winter. Care should be taken that the degree of accuracy be only that required for managerial purposes and not the decimal point accuracy needed for cost accounting purposes. Parameters of authority should be written in a clear, concise manner so that they may be well defined and understood by each individual governed by them. A greater use should be made of ground-oriented sanders, and continued research into their efficiency should be encouraged. We would also recommend more research on the national level in the development of a practical metering device for spreaders. And, finally, uniformity should be encouraged within the district by interchanging supervisors laterally from one area to another and providing a challenge to these supervisors by moving them into the maintenance operations center during storm periods.