71-003-7781

CHEMICAL CONTROL OF SNOW AND ICE

(Second Interim Report)

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in collaboration with
Division of Maintenance and Equipment
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ABSTRACT

The objective of this snow and ice control study is to investigate various mixtures of sodium and calcium chloride and various rates of application, in an effort to achieve a bare pavement condition in a minimum of time and with a minimum amount of material. The past year's efforts, which are the subject of this report, were concentrated on evaluating 4:1 and 3:1 mixtures spread at rates varying from 250#/lane mile to 650#/lane mile.

After reviewing the information gained during this second winter, it was judged that there still is not sufficient basis for establishing a new chemical-use policy for the entire state route system. However, it was believed justifiable to recommend a 4:1 mixture spread at a rate of 250#/lane mile, for use in the central portion of the state during relatively "warm" storms (average temperature above 25^{0}F).

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I. INTRODUCTION

During the winter of 1968-1969 a study was initiated to test chemical applications and mixtures used for snow removal on highways. The objective of this study was to investigate various chemical mixtures and rates of application in an effort to achieve a bare pavement condition in a minimum amount of time and with a minimum of cost.

After the first year of testing the original short term work plan was discarded for a long term work plan spanning several years. The new work plan included testing different mixtures and rates of application each year until the optimum mixture and rate of application was found. Testing of mixtures and application rates will continue until the final year of testing when abrasives will be tested.

Qualified conclusions reached after the first year of testing (Report 70-006-7781 Chemical Control of Snow and Ice, October 31, 1969), indicate the optimum rate of application with the 3:1 mixture as 250 lbs. per lane mile. The 3:1 mixture was the only mixture tested during the first year of testing due to difficulties with manpower and equipment.

Included in the first interim report was a literature review of research conducted by other agencies. Tables A1 and A2, in the appendix, supplement research sited in the first interim report.

A. Objective: The objective of this second interim report is to analyze data gathered during the winter of 1969-70. In this second year of the study, an attempt was made to evaluate two chemical mixtures (4 parts salt and 1 part calcium chloride by volume, and 3 parts salt and 1 part calcium chloride by volume) with four rates of application (250#/lane mile, 350#/lane mile, 450#/lane mile and 650#/lane mile).

B. Test Areas: Two general areas were selected for division into three test sections. (Fig. 1, 2, 3) These two areas are two of the three areas used in the previous year's investigation. One area is located in the central portion of the state, straddling the Mercer County-Hunterdon County line. The other is located in the northeastern part of the state in Bergen County.

As stated in the first interim report, the northern portion of the State generally receives heavier accumulation of snow and generally has lower temperatures during snowfall, than the southern portion of the State.

Each of the three test sections were divided into four subsections on which the four different rates of application were randomly tested with each mixture. Test section #1, (Fig. 1) Route 31 from the Pennington Circle, north to County Route 518, is a two lane semi-rural highway originally constructed of portland cement concrete. It has many large bituminous patches and a small overlaid area. Test section #2 (Fig. 2) Route 31 from County Route 518 north to Larsons Corner (just north of Ringoes), is of the same pavement type as the central and southerly portions in test section #1. However, the northerly most subsection of test section #2, is a bituminous concrete pavement. Test section #3, (Fig 3) Route I-80, Lodi from Fletcher Avenue, west to Riverview Avenue, is a multi-lane divided bituminous concrete highway.

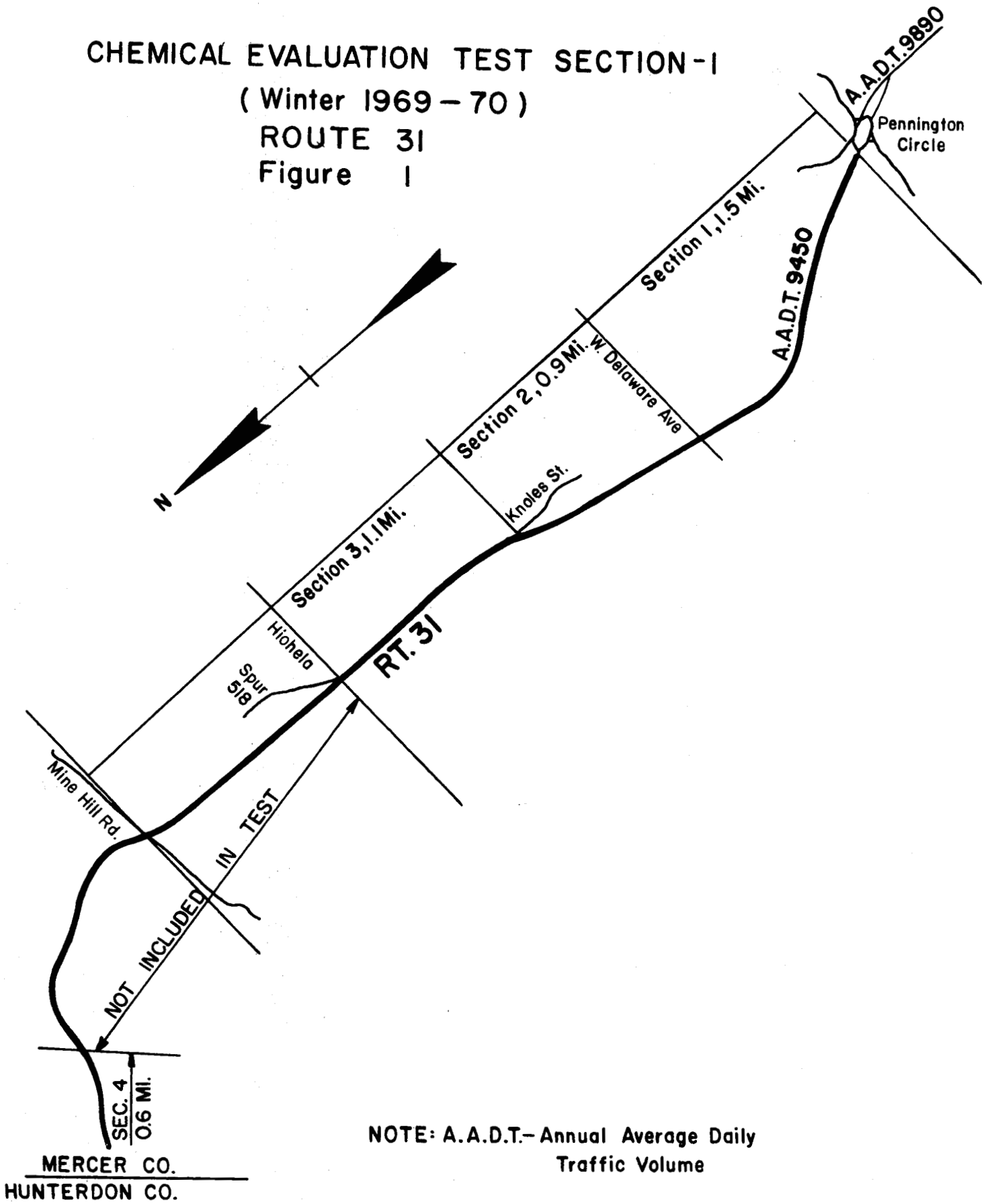
The 3:1 mixture was applied on test section #1, and the 4:1 mixture was applied on test section #2, to hopefully result in a comparative evaluation between combinations of mixture and rates of application under virtually similar conditions of time, temperature, and snowfall. Subsection 4 of test section #1 and subsection 1 of test section

CHEMICAL EVALUATION TEST SECTION-1

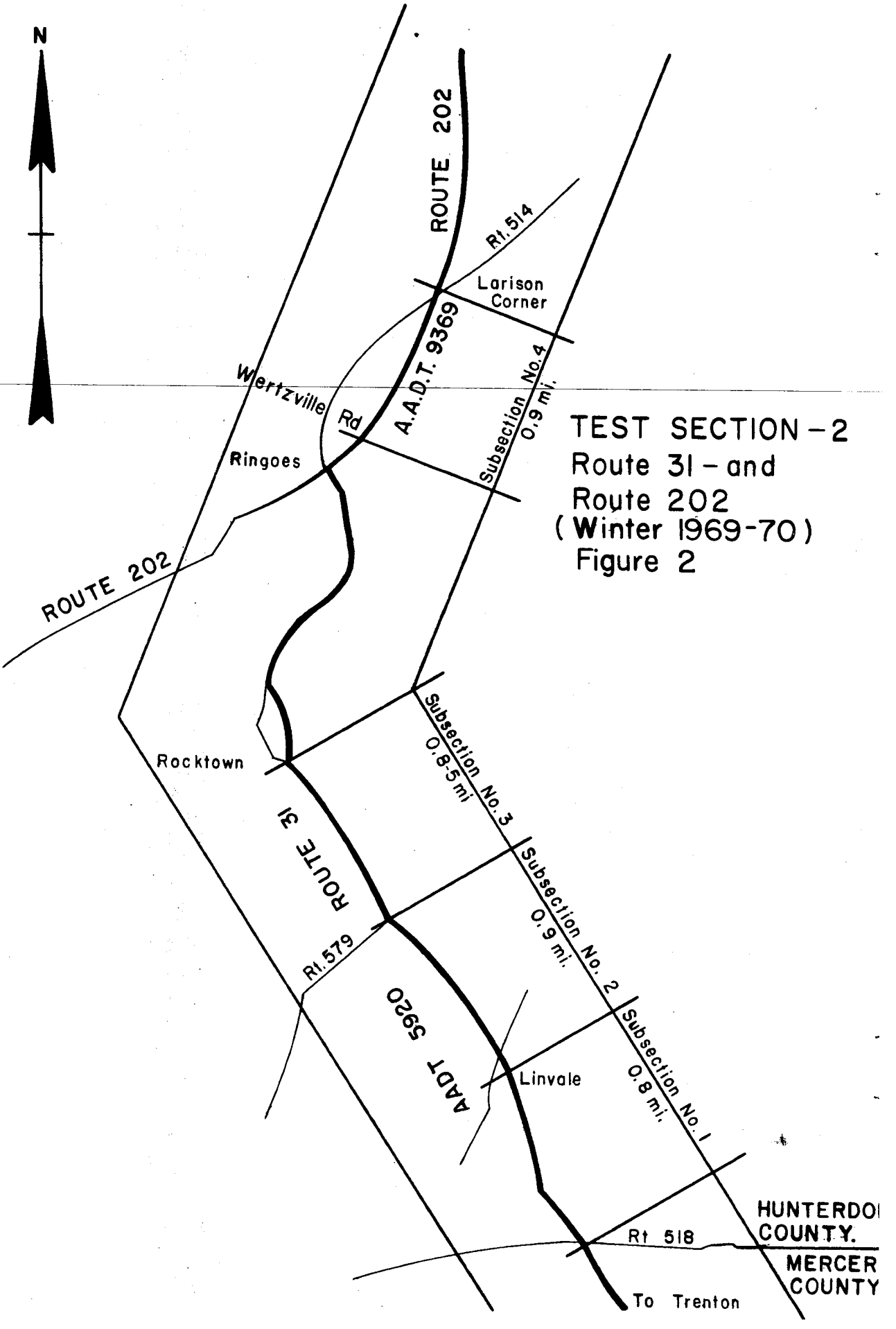
(Winter 1969 – 70)

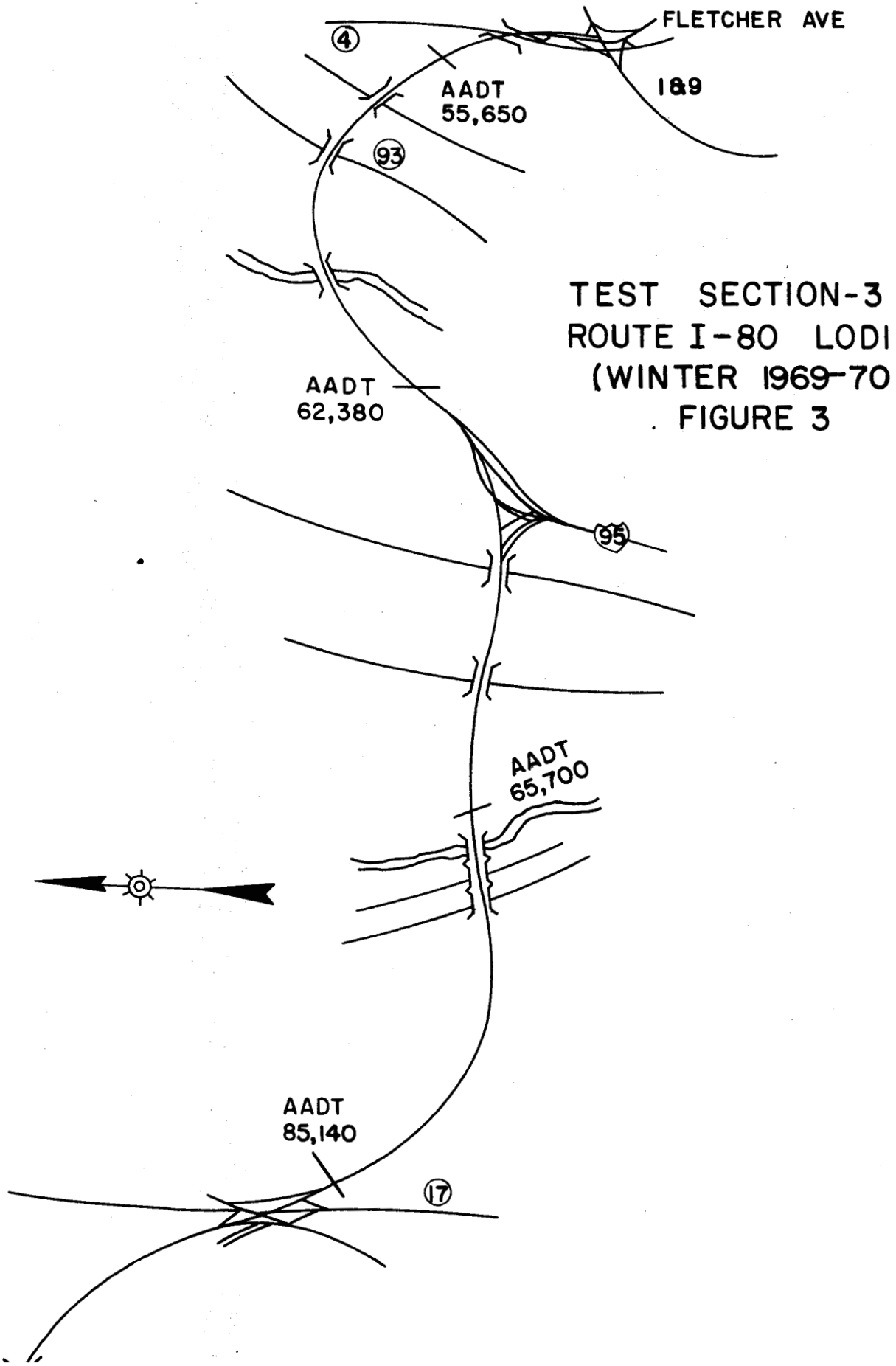
ROUTE 31

Figure 1



NOTE: A.A.D.T.– Annual Average Daily Traffic Volume


N
ROUTE 202
Rt. 514
Larison Corner
A.A.D.T. 9369
Subsection No. 4
0.9 mi.
Wertzville Rd
Ringoes
ROUTE 202
TEST SECTION – 2
Route 31 – and
Route 202
(Winter 1969-70)
Figure 2
Rocktown
Subsection No. 3
0.8-5 mi
ROUTE 31
Subsection No. 2
0.9 mi.
Rt. 579
AADT 5920
Linvale
Subsection No. 1
0.8 mi.
HUNTERDON COUNTY.
MERCER COUNTY
Rt 518
To Trenton



TEST SECTION-3
ROUTE I-80 LODI
(WINTER 1969-70)
FIGURE 3

#2 were always spread at the same rate of application so that a common reference datum of mixtures was established as a further aid in evaluation. On test section #3, the 4:1 and 3:1 mixtures were alternated between storms; each storm receiving a different mixture from the previous storm.

A randomization of rates of application was established to minimize and overcome differences between subsections. The Division of Research, with the use of a table of random numbers, developed a table of randomized applications for each test section.

C. Test Data: Data gathered from test sections were recorded on data sheets of which a sample is contained in the Appendix (Figures A1 and A2). There are two types of data sheets; (1) the storm data sheet contains all the weather information gathered during a storm, and (2) the spreading and observation data sheet contains spreading and observation information. Observation teams recorded all pertinent information on these two data sheets for each storm.

The data gathered during the second year of testing consisted of: rate of application, time of spread, type of precipitation, intensity of storm, accumulation of snow, temperature, and comments. In addition to the above, at each test section a rating or ordering of the subsections on terms relative clearness or traversability was given at two hour intervals. The rating system was based on a scale ranging from 1 to 4, a rating of 1 being the best. Each subsection of the individual sections was objectively rated by the team assigned to monitor the test section.

Collected data are presented on summary data sheets contained in the Appendix, Fig. A3 and A6. Only the more important factors were transcribed on the summary data sheets.

D. Cost Data: For the purpose of evaluation, costs were calculated not only for the 4:1 and 3:1 mixtures but for other mixtures as well. The four rates of application for each individual mixture were included in the calculated costs. This data, based on 1969 unit prices is presented in Table #1.

TABLE 1

COST DATA

(1969 Prices)

RATE OF APPLICATION

Mixture	650# per lane mile	450# per lane mile	350# per lane mile	250# per lane mile
5:1	$5.72	$3.96	$3.08	$2.20
4:1	5.94	4.11	3.20	2.28
3:1	6.25	4.33	3.37	2.40
2:1	6.83	4.73	3.68	2.62
1:1	8.09	5.59	4.36	3.10

II. METHOD OF ANALYSIS

A. Rating System Data

One method of evaluating the adequacy of the rates of application studied is a rating or ordering of these rates of application in terms of relative effectiveness. A subsection was ordered, 1, 2, 3, or 4, depending on its relationship to the other subsections. If two or more subsections appeared to have the same condition, the subsections were given the same rating and the next higher numerical rating was given to the next best subsection.

In order to evaluate rating data, it became necessary to tabulate the number of times a spread was rated 1, 2, 3, or 4. This was done with the use of histograms for each mixture and rate of application within respective sections, and with consideration to the following temperature conditions.

1. The average observed air temperature during a particular snow storm was equal to a greater than 25^{o}F.

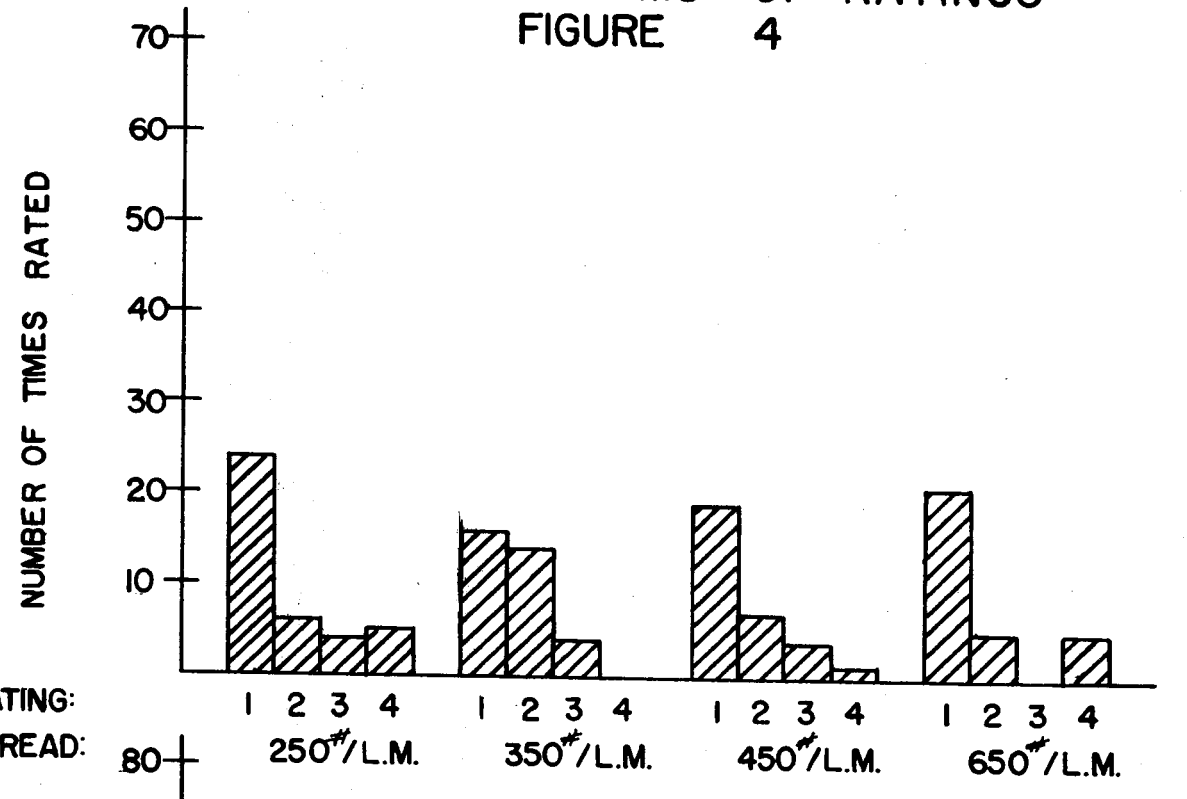
2. The average observed air temperature during a particular snow storm was less than 25^{o}F.

3. Without regard to any temperature limitations.

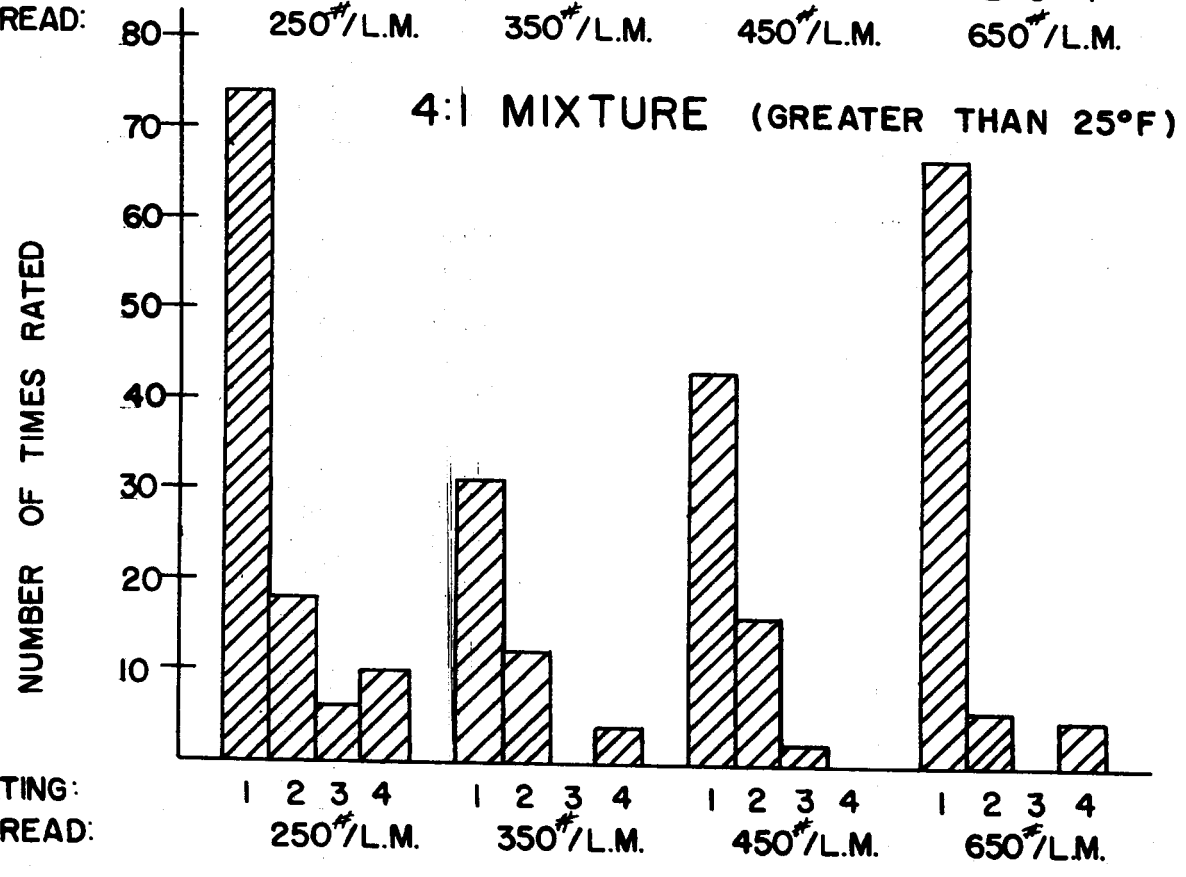
The foregoing is summarized and illustrated graphically in figures 4 (greater than 25^{o}F), and 5 (less than 25^{o}F) and 6 (no temperature limitation).

Previous research studies by Pennsylvania, New York, Maryland [3] on the use of chemicals in the control of ice and snow have indicated that the 25^{o}F point is the approximate dividing line between "warm" and "cold" storms. The "cold" and "warm" storms have been found by others to require different treatments when chemicals are being utilized.

HISTOGRAMS OF RATINGS
FIGURE 4

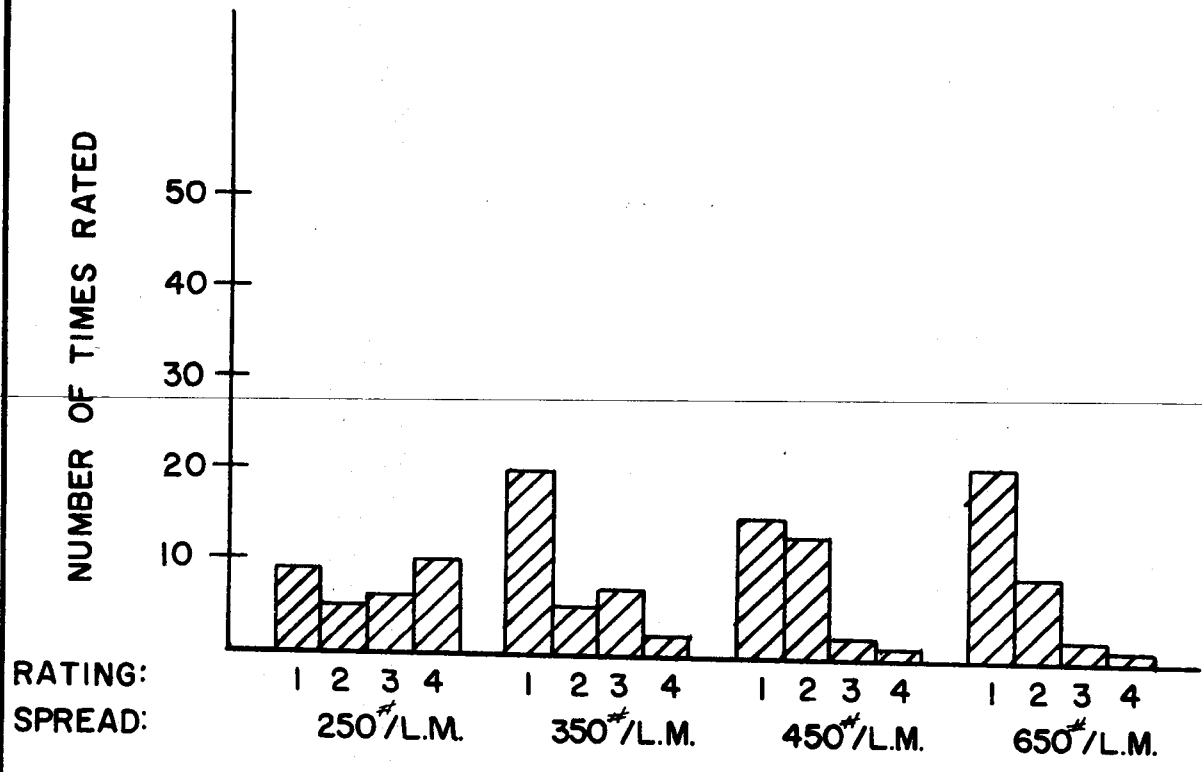


4:1 MIXTURE (GREATER THAN 25°F)

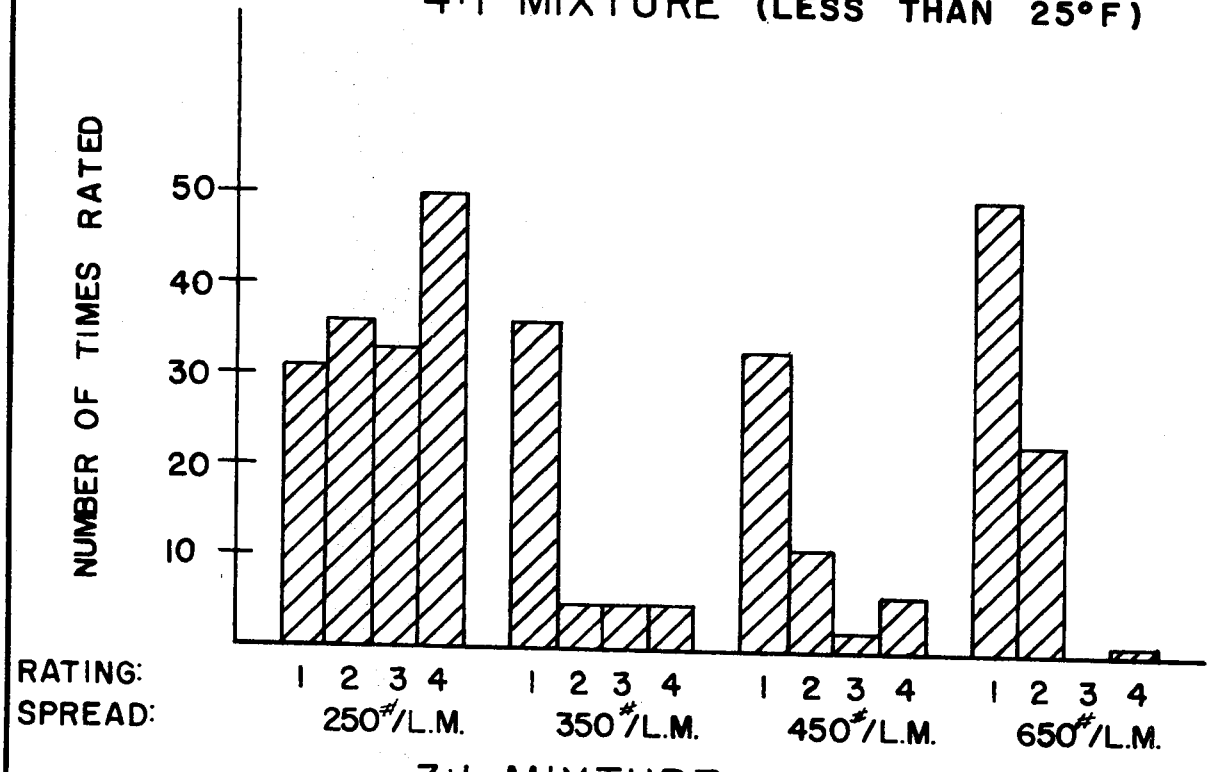


3:1 MIXTURE (GREATER THAN 25°F)

HISTOGRAMS OF RATINGS
FIGURE 5

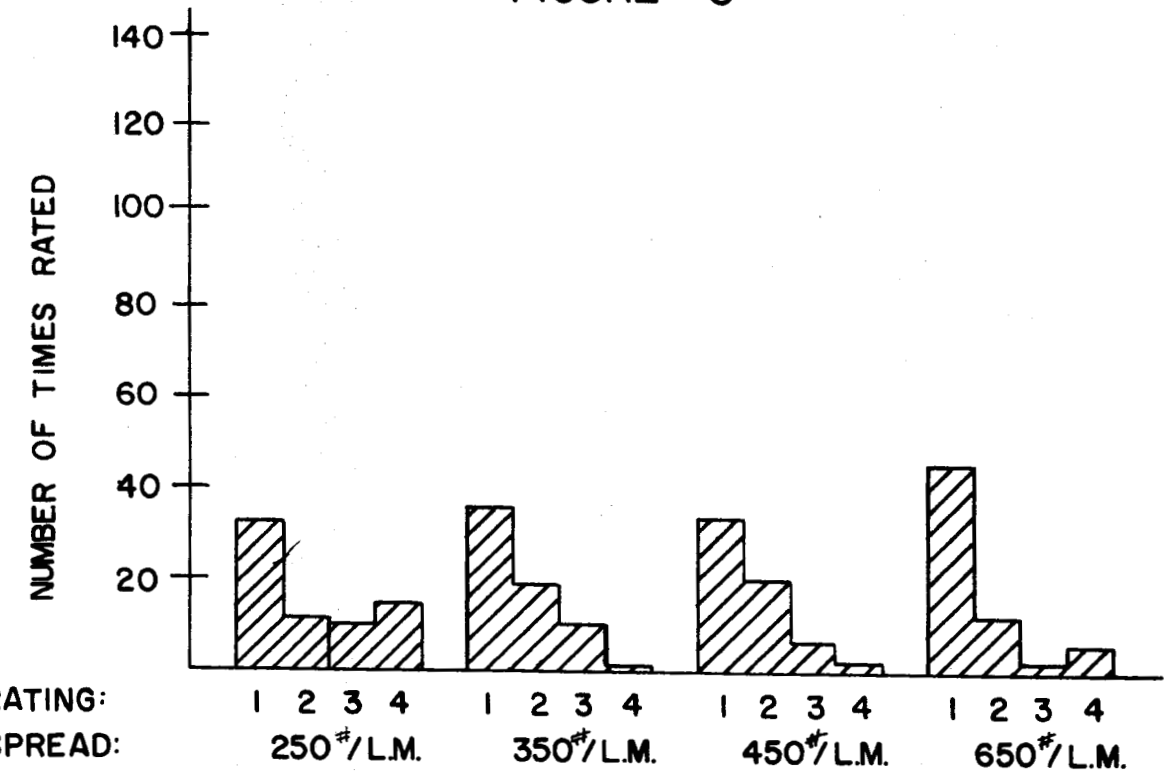


4:1 MIXTURE (LESS THAN 25° F)

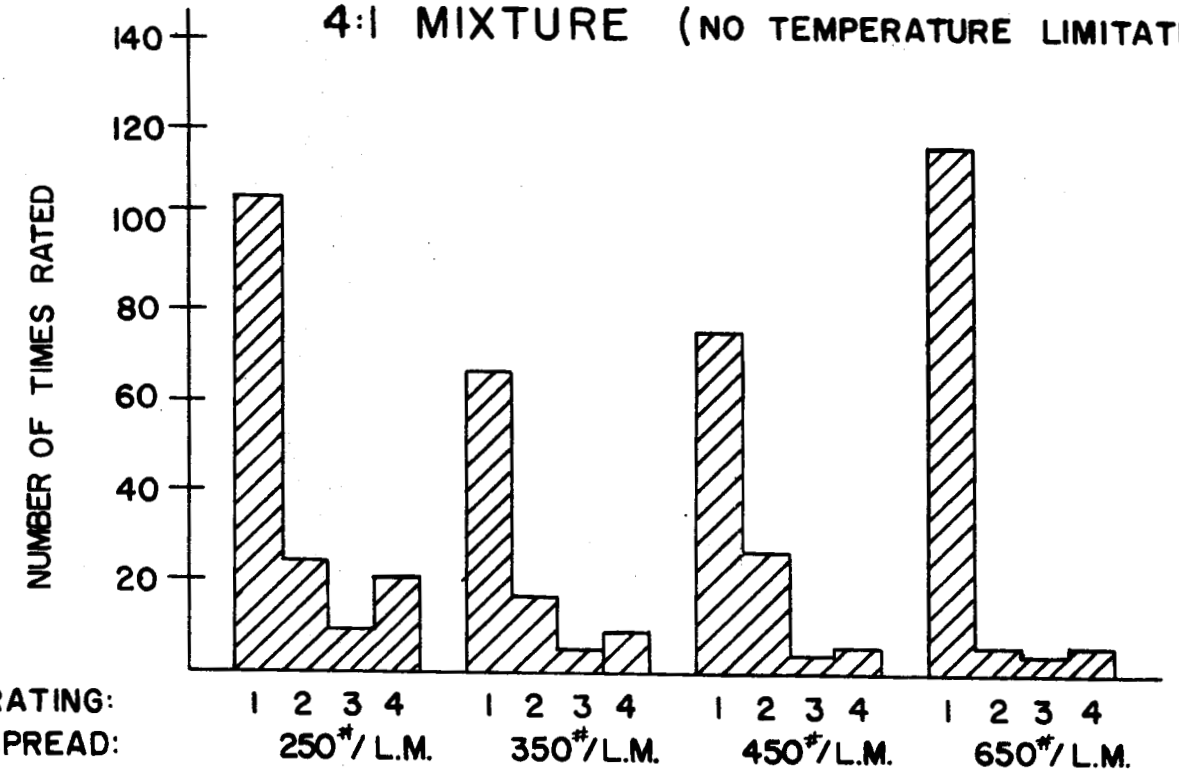


3:1 MIXTURE (LESS THAN 25° F)

HISTOGRAMS OF RATINGS
FIGURE 6



4:1 MIXTURE (NO TEMPERATURE LIMITATIONS)



3:1 MIXTURE (NO TEMPERATURE LIMITATIONS)

B. Average Time Between Spread Data:

Another method of evaluating the effectiveness of the rates of application is to determine the average time between spreads, for each application rate, during each storm at each test section. This method was previously used in analyzing the first year's testing. A comparison of the average times, for a specific storm within a given test section, gives an indication of the relative effectiveness of the different rates. In such a comparison, the rate of application which kept the pavement clear for the longest time would be considered the most effective.

With this approach, it was found that, for nearly every storm at a test section, the longest time between spreads was associated with not just one, but several rates of application, in other words, several rates used generated the same average time between spreads. In such an instance, the lowest of the rates, resulting in the same maximum time between spreads, would be both the most effective and the most efficient rate usable in that storm.

The average time between spreads, when applicable, is presented in Table #2.

TABLE 2

AVERAGE TIME BETWEEN SPREADS **

TEST SECTION #1 (3:1 mixture)

Rate of Application	250#/lane mile	350#/lane mile	450#/lane mile	650#/lane mile
Storm #1	A	A	A	A
Storm #2	(1)	--	(1)	(1)
Storm #3	(1)	(1)	*	(1)
Storm #4	(1)	(1)	(1)	(1)
Storm #5	(1)	(1)	(1)	(1)
Storm #6	(1)	17 hrs.	(1)	(1)
Storm #7	(1)	(1)	(1)	(1)
Storm #8	7 hrs.	6 hrs. 35 min.	7 hrs.	7 hrs.
Storm #9	2 hrs.	(1)	2 hrs.	(1)
Storm #10	5 hrs. 30 min.	5 hrs. 30 min.	5 hrs. 30 min.	5 hrs. 30 min.
Storm #11	(1)	++	++	++
Storm #12	*	*	*	*

** For storm of two or more spreads
* Spreading errors occurred during storm

(1) Only one spread
+ Only first two spreads used due to equipment breakdown

++ Spot spread or none at all
A No test

TABLE 2

AVERAGE TIME BETWEEN SPREADS **

TEST SECTION #2 (4:1 mixture)

Rate of Application	250#/lane mile	350#/lane mile	450#/lane mile	650#/lane mi
Storm #1	(1)	(1)	(1)	(A)
Storm #2	1 hr. 45 min.	1 hr. 35 min.	1 hr. 45 min.	1 hr. 45 min
Storm #3	(1)	(1)	(1)	(1)
Storm #4	(A)	(A)	(A)	(A)
Storm #5	(1)	2 hrs. 45 min.	2 hrs. 45 min.	(1)
Storm #6	3 hrs.	3 hrs.	3 hrs.	3 hrs.
Storm #7	(1)	(1)	(A)	(1)
Storm #8	6 hrs.	6 hrs.	6 hrs.	6 hrs.
Storm #9	2 hrs. 45 min.	6 hrs. 30 min.	6 hrs. 30 min.	13 hrs. 15 mi
Storm #10	2 hrs. 15 min.	2 hrs. 15 min.	2 hrs. 30 min.	2 hrs. 30 mi
Storm #11	(1)	(1)	(1)	(1)
Storm #12	16 hrs.	16 hrs.	16 hrs.	16 hrs.
Storm #13	(A)	(A)	(1)	(A)

** For storm of two or more spreads
* Spreading errors occurred during storm

(1) Only one spread
+ Only first two spreads used due to equipment breakdown

++ Spot spread or none at all
A No test

TABLE 2

AVERAGE TIME BETWEEN SPREADS **

TEST SECTION #3 (3:1 mixture)

Rate of Application	250#/lane mile	350#/lane mile	450#/lane mile	650#/lane mile
Storm #2	(1)	(1)	(1)	(1)
Storm #6	4 hrs. 40 min.	4 hrs. 40 min.	4 hrs. 40 min.	4 hrs. 40 min.
Storm #8	(1)	(1)	(1)	(1)
Storm #10	11 hrs. 15 min.	11 hrs. 15 min.	(1)	11 hrs. 15 min.
Storm #12	(1)	(1)	(1)	(1)
Storm #14	25 hrs. 15 min.	25 hrs. 15 min.	25 hrs. 15 min.	25 hrs. 15 min.

TABLE #2

AVERAGE TIME BETWEEN SPREADS **

TEST SECTION #3 (4:1 mixture)

Rate of Application	250#/lane mile	350#/lane mile	450#/lane mile	650#/lane mile
Storm #1	(1)	(1)	(1)	(1)
Storm #3	(1)	(1)	(1)	(1)
Storm #5	(1)	(1)	(1)	(1)
Storm #9	5 hrs.	5 hrs. 15 min.	5 hrs.	5 hrs. 15 min.
Storm #11	(1)	(1)	(1)	(1)
Storm #13	(1)	(1)	(1)	(1)

** For storm of two or more spreads
* Spreading errors occurred during storm

(1) Only one spread
+ Only first two spreads used due to equipment breakdown

++ Spot spread or none at all
A No test

III. DISCUSSION

A. Subsection Ratings

In order to proceed with an analysis of the ratings recorded in Figures 4, 5 and 6, it was determined that a spread with the greatest number of ratings of 4 would not be as good as a spread with the greatest number of ratings of 1. However, when comparing the number of ratings of one spread with another spread, the number of times a spread is rated should be taken into account.

The following discussion centers about the three temperature conditions previously defined.

1. The average temperature is greater than 25°F (Figure 4)

It would appear from Figure 4, 3:1 mixture, that all of the spreads tested are acceptable having a rating of one the greatest number of times. However, the 250 and 650/lane mile spreads would appear to be the most effective in that they had by far the greatest percentage of their ratings in the "one" category.

It is also worthy to note that the least spread, 250#/lane mile, was rated first a greater number of times than the other spreads.

All of the rates of application tested with the 4:1 mixture, Figure 4 also appear to be acceptable. The histograms for the four spreads were almost identical with the greatest number of ratings falling within the one category for each spread. Considering the economics involved, the least spread, 250#/lane mile, was apparently the most efficient spread for the storms encountered.

2. The average temperature is less than 25°F (Figure 5). It is evident from Figure 5, 3:1 mixture, that the 250#/lane mile spread was rated 4 a greater number of times than it was rated 1, 2, or 3. All of the re-

maining spreads (350, 450 and 650) seemed to function quite similarly having the greatest number of their ratings in the one category and the smallest number of ratings in the four category. It would appear from the ratings then, that the most efficient spread of the 3:1 mixture for the conditions encountered would have been the 350#/lane mile spread.

From Figure 5, 4:1 mixture, it would appear again that the 250#/lane mile spread was given a rating of four more times than it received any other rating. In contrast, the 350, 450 and 650 spreads all had the greatest percentage of their ratings fall in the one category.

It appears from Figure 5, that in the lower temperature storms, spreads of 250#/lane mile with both mixtures may not be adequate. Higher rates of application may be necessary.

3. No temperature limitation (Figure 6)

The histograms for the 3:1 mixture, Figure 6, tend to indicate that all spreads tested are acceptable, having a rating of one the greatest number of times. The 650#/lane mile spread was rated one the greatest number of times on both an absolute and percentage basis.

From Figure 6, 4:1 mixture, it would again appear that all spreads tested are acceptable, having a rating of one the greatest number of times.

B. Time Between Spreads

After reviewing available data, an evaluation of mixtures and rates of application regarding average time between spreads seemed warranted.

In considering the data present in this section of the report, it should be kept in mind that, generally, a spread was made when the overall condition of a subsection warranted the spread.

The calculated average time between spread data is presented in Table #2. This data is listed by test section, only for ease of compilation. A quick review of the contents of this table show a continuous pattern of similar average spreading time. This indicates that the spreading of subsections during storms usually occurred simultaneously. However, in test section 2 during storm #9, subsections were spread at different intervals. It appears that the 650#/lane mile spread has the longest time between spreads and the 250#/lane mile spread has the shortest time between spreads. However, it is difficult to draw firm conclusions from this data due to the fact a spreading error occurred during testing.

Comments by test section monitors during storm #9, test section 2, indicate that the 250#, 350#, and 450#/lane mile rates of application were reacting very slowly. The monitors appear to indicate that additional spreads, especially with the 250#/lane mile spread during this storm, were warranted. The initial temperature of storm #9, test section 2, was 18^{o}F.

It should be noted that a slight difference is indicated in the time between spreads for storm #10, test section 2. Data sheets reveal that additional spreads were made for the 250#/lane mile and 350#/lane mile rates of application.

The occurrence of spreading errors, such as in storm #12, test section 1, and storm #9, test section 2, caused difficulties in evaluating portions of the time between spread data.

Due to the limited number of multiple spread storms, a break-down of average time between spread data into temperature ranges is difficult. However, generally speaking, storms where average temperature was below

25°F, had a greater number of spreads than storms where temperatures were above 25°F.

Considering overall average time between spreads for the 3:1 mixture and the 4:1 mixture, it is difficult to determine which mixture has the greatest overall time between spreads. The number of multiple spread storms and the number spreads on such storms was too few to permit firm comparison between test sections and hence mixtures. The available data is, in essence, too small to be assured that differences in monitor judgment between test sections has been effectively overcome.

Pertinent to this comparison, it is of value to point out that, subsection 4 of test section 1 (3:1 mixture) and subsection 1 of test section 2 (4:1 mixture) were evaluated by both monitoring teams for four separate storms. Although the quantitative data obtained was insufficient to determine the precise effectiveness of each mixture, comments did indicate that the 3:1 mixture on test section 1 appeared to work slightly better than the 4:1 mixture on test section 2.

Traffic conditions on Route I-80 differ greatly from traffic conditions on New Jersey Route 31. It was hoped that the effect of traffic on snow removal could be quantified by comparing the time between spread data of the I-80 section to that of the other sections. Unfortunately, an insufficient number of common storms occurred to permit this comparison.

C. Cost Data:

Cost data was calculated from 1969 year prices. Cost data presented in Table 1, shows that the cost of material rises as the rate of application increases, and decreases as the percentage of sodium chloride in a mixture increases. For example, spreading the 3:1 mixture at a rate of

250#/lane mile cost $2.24 and spreading the 4:1 mixture at 250#/lane mile cost $2.14. However, spreading the 4:1 mixture at 350#/lane mile costs $2.98. In this particular case, it would be less costly to spread the 3:1 mixture at 250#/lane mile than it would be to spread the 4:1 mixture at 350#/lane mile. The large cost difference between rates of application and percentage of sodium chloride therefore are important factors for determining the appropriate mixture for de-icing chemicals. From a cost stand-point rate of application is more critical than type of mixture.

D. Personal Observations

Personal observations and general comments appear to indicate that the 3:1 mixture with a 250#/lane mile rate of application is acceptable under conditions encountered during the 1969-70 year tests (the 3:1 mixture had been tested during the winter of 1968-69 with the 250#/lane mile rate of application established as being adequate). It was also indicated that the 4:1 mixture with the 250#/lane mile rate of application appeared to work adequately. However, it was further contended by a research observer that of low temperatures in order for the results of the 4:1 mixture to be directly equal to the 3:1 mixture a 350#/lane mile application would be necessary.

Test section monitors indicated that subsections with low rates of application (250#/lane mile) appeared to dry quicker than subsection with higher rates of application. According to monitors this applies to both mixtures. The monitors also noted that they "experienced more stiffening with the 3:1 mixture than the 4:1 mixture".

E. Ecological Considerations:

In a report entitled "Effects of De-icing Salts on Water Quality and Biota, [1] water contamination by de-icing chemicals was stated as a dangerous side effect when using such chemicals. The survey showed that ponds, lakes and reservoirs can serve as collection points for de-icing salts contained in water runoffs from highways. Twelve states included in the survey reported water pollution from de-icing salts and thirteen states reported plant injury due to de-icing salts.

Grasses are not injured by de-icing salts as readily as trees. Salts cause stunted grass growth due to small leaves and stems and fewer cells than normal plants.

It was concluded in the aforementioned referenced report that "the problem can be minimized by applying salts as sparingly as possible to maintain safe traffic flows".

IV. CONCLUSIONS

Testing during the second year continued as planned except for the fact that insufficient quantitative data could be gathered to draw firm and definite conclusions. Therefore, conclusions and recommendations that follow are primarily inferences based on data from time between spreads, ratings, and comments recorded by the monitoring teams. Data and comments reflect the variability of the test section areas, and variability which is normally anticipated between raters. Any attempt to relate the following conclusions to areas not covered in testing would be impossible.

For the environmental conditions encountered at the studied test sections during the past year, it can be concluded that when temperatures are above 25^{0}F and either the 3:1 or 4:1 mixture is being used, a rate of application of 250#/lane mile appears to be acceptable for obtaining bare pavement. When temperatures fall below 25^{0}F and either the 3:1 or 4:1 mixture is being used, it appears that the 350#/lane mile and 450#/lane mile rates of application may be necessary for obtaining bare pavement. Referring to the 1968-69 report where only 3:1 mixture was used, the 250#/lane mile spread rate was considered adequate.

Using high rates of application has three bad results; (1) high cost, (2) water contamination and damage to vegetation, (3) and longer drying time after a snow storm. Referring to Table #1, spreads of 650#/lane mile and 450#/lane mile are in some cases almost twice the cost of the 250#/lane mile rate. The 350#/lane mile rate of application is approximately 1-1/2 times the cost of the 250#/lane mile rate. Considering the requirements for spreads greater than 250#/lane mile, it would ap-

pear more economical to use the 350#/lane mile rate.

A precise comparison of the relative effectiveness of the 3:1 mixture and 4:1 mixture is most difficult from the presented data. Substantial reliance has to be placed on the comments of the observers. Weighing these comments against what quantitative data that could be utilized, it would seem that the 3:1 mixture is slightly more effective than the 4:1 mixture. In contrast considering the cost involved, it is apparent that the 3:1 mixture is slightly more expensive than the 4:1 mixture at the same rate of application (the cost of the 3:1 mixture is approximately 5% more at the same application rate, than the 4:1 mixture).

Another factor that relates to the comparison of the two mixtures is operational problems. There was a definite tendency for the 3:1 mixture to "stiffen up" more than the 4:1 mixture while in the distribution truck. Material that "stiffens-up" does hamper significantly the entire spreading operation.

In view of information given in the above commentary, it is extremely difficult to conclude which mixture would actually best serve the purposes of the Department. However, after considering the relative importance of the different factors involved, it is the opinion of the study participants that, overall, the 4:1 mixture was the better of the two mixtures for the conditions encountered.

V. RECOMMENDATIONS

1. When the average temperature of a storm is 25°F or greater, it was concluded from the testing this year that a spread of 250#/lane mile with the 4:1 mixture would be adequate for conditions experienced on the three test sections. It can be assumed, after examining weather data from the previous year, that weather conditions experienced during testing this year may be typical of storms generally occurring in the central portion of New Jersey. Therefore, it is believed possible to recommend the use of the 4:1 mixture at 250#/lane mile under the condition previously expressed, for the central portion of New Jersey where generally mild storms exist.

2. When the average temperature of a storm is less than 25°F, it was concluded from testing this year, that a spread of 350#/lane mile with the 4:1 mixture would be adequate for conditions experienced on the three test sections. However, test section monitors feel further testing of this mixture at various rates of application may be warranted before a recommendation can be given to use the 4:1 mixture at 350#/lane mile at temperatures below 25°F.

3. It is recommended that the study be continued with future tests being concentrated at the extremes of New Jersey. Various chemical mixtures and rates of application should be tested in the southern and northern portions of the state. In the colder areas major emphasis should be placed on investigating the use of the 4:1 mixture at 350#/lane mile during below 25°F storms. In the warmer areas the studying of a 5:1 or 6:1 mix should be considered.

4. It is recommended that the present rating system be used for comparison of test sections if future testing is to be conducted. Since test section monitors prefer using an ordering system, a rating system of sequential numbers should be used, without omitting successive numbers.

5. In the future at the end of each storm, test section monitors should prepare a brief summary of the significant facts obtained in that storm.

VI. REFERENCES:

1. "Effects of De-Icing Salts on Water Quality and Biota" NCHRP Report #91 Highway Research Board.
2. "Snow and Ice Control" (1966) Maintenance Department Virginia Highway Commission.
3. "Chemical Control of Snow and Ice" (1969) Bureau of Structures and Materials, Department of Transportation of N. J.

APPENDIX

Appendix

The following is a review of recommendations by Virginia agencies for the use of de-icing salts. Table A1 and A2 are presented here to supplement previous references of the 1968-1969 Report.

TABLE A-1

SUGGESTED SALT APPLICATION RATES(2)

Chemical	Application Rate* (lb/Lane-Mile) for Temp. of		
	Below 10_F	$10\text{-}25_F$	$25\text{-}32_F$
$CaCl_2$, pellets	300-375	250-300	175-250
$CaCl_2$, flake	350-450	275-350	200-275
NaCl	400-550	250-400	200-250
1/4 $CaCl_2$ pellets, 3/4 NaCl	350-475	250-300	175-250
1/4 $CaCl_2$ flake, 3/4 NaCl	250-500	250-350	200-250

*Salt application rates suggested by the Virginia Highway Department are given in Table A-1, in which the recommended rates are underscored. These application rates closely correspond with the rates recommended for New Jersey de-icing methods.

For application of de-icing salts, storm conditions as well as temperature are considered when recommendations are made. The following Table A-2, is recommended by Diers and Reppel[2] for de-icing salts based on environmental conditions.

TABLE A-2

REMOVAL TREATMENTS FOR VARIOUS CLIMATIC AND ROAD CONDITIONS, AS RECOMMENDED BY DIERS AND REPPEL[2]

Condition No.	Temperature	Precipitation	Pavement	Treatment	
				Immediate	Subsequent
1.	Freezing or above, and rising	Snow,sleet freezing rain	Wet	(a) Snow or sleet: Application of salt at 400 lb/mi.	(a) If snow or sleet continues or accumulates, plow and repeat salting simultaneously
				(b) Freezing rain: Application of salt at 200 lb/mi.	(b) If rain continues to freeze, re-apply salt at 200 lb/mi.
2.	Below freez. or falling	Dry snow	Dry	Plow as soon as practical. Do not apply salt or chemcial mixture.	Continue to plow and patrol to check for wet, packed, or icy spots. Treat with plain abrasives.
3.	Below freez. or falling	Snow,sleet freezing rain	Wet or sticky	(a) Snow or sleet: Application of salt (2 parts) calcium chloride (1 part) mixture at 400 lb/mi.	(a) If snow or sleet continues and accumulates, plow and repeat chemical mixture application.
				(b) Freezing rain: Application of salt (2 parts) calcium chloride (1 part) mixture at 200 lb/mi.	(b) If freezing rain continues, re-apply chemical mixture at 200 lb/mi.
4.	10F and below	Snow,sleet freezing rain	Accum. of packed snow or thick ice	(a) Snow or sleet: Underbody blading and concurrent application of abrasives at 1 cu. yd/mi.	Application of salt (2 parts) calcium chloride (1 part) mixture at 400 lb/mi. When snow or ice becomes slushy, remove with blades as required. Repeat chemical application and blading until pavement is clear.
				(b) Ice: Application of abrasives at 1 cu. yd/mi.	

DATA SHEET Page 1 of 2

SPREADING & OBSERVATIONS Evaluators: Suess, Olzanowski

STORM NO. 2

Figure A-2

		LENGTH (MI.
ROUTE 31	LIMITS Pennington Circle to County Rt. 518 (County Line) (Piece Excluded)	4.1 miles
SUBSECTION NO. 1:	LIMITS Pennington Circle to W. Delaware Ave. (Hill House)	1.5 miles
SUBSECTION NO. 2:	LIMITS W. Delaware Ave. (Hill House) to Knoles St. (Kreme King)	0.9 miles
SUBSECTION NO. 3:	LIMITS Knoles St. (Kreme King) to County 518 Spur (Hiahela)	1.1 miles
SUBSECTION NO. 4:	LIMITS 600' south of Stony Brook Sta. 202 to Co. Rt. 518 (County Line)	0.6 miles

Note: Section from County 518 Spur to 600' south of Stony Brook excluded from test section.

MIX 3 to 1 DATE 12/7/69

700 810 1540 300 1100

SUB SECT. = 250 #

Time	Subsection No. 1 250 # Spread	Rating	Mat'l Spread to Date	Subsection No. 2 450 # Spread	Rating	Mat'l Spread to Date	Subsection No. 3 700 # Spread	Rating	Mat'l Spread to Date	Subsection No. 4 250 # Spread	Rating	Mat'l Spread to Date	Observation & Road Condition (ROAD OUTSIDE TEST SPREAD at 250 #. ONE SPREAD)
530	✓		250 #	✓		450 #	✓		700 #	✓		250 #	SNOW Cov'd & ICY
540		1			1			1			1		LT. SLUSH WET - BETWEEN WHE
550		3			2			1			4		LT. ACC. - ALL SECT.
630		3			2			1			4		SECT. SECT NEARLY EQUAL - BEG. TO
730		1			1			1			4		PAV'T WET - LT. ACC.
													OUTSIDE WHEEL TRACK - SEC. 4 PAV'D. P.
730		1			1			1			1		WET - SECT. 4 NOT AS BAD
130		1			1			1			4		WET - SECT. 4 BETWEEN
330		1			1			1			4		WET - LT. SLUSH BET. SECT. 4

STORM DATA SHEET

Evaluators: Susan Olsanowski

Storm No. 2

Figure A-1

		LENGTH (MI.)
ROUTE 31	LIMITS Pennington Circle to County Rt. 518 (County Line) (Piece Excluded)	4.1 miles
SUBSECTION NO. 1:	LIMITS Pennington Circle to W. Delaware Ave. (Hill House)	1.5 miles
SUBSECTION NO. 2:	LIMITS W. Delaware Ave. (Hill House) to Knoles St. (Kreme King)	0.9 miles
SUBSECTION NO. 3:	LIMITS Knoles St. (Kreme King) to County 518 Spur (Hiahela)	1.1 miles
SUBSECTION NO. 4:	LIMITS 600' south of Stony Brook Sta. 202 to Co. Rt. 518 (County Line)	0.6 miles

Note: Section from County 518 Spur to 600' south of Stony Brook excluded from test section.

INITIAL STORM DATA:

DATE 12-7-69 TIME INITIAL PRECIPITATION 1415 TYPE PRECIPITATION RAIN SLEET

INTENSITY LIGHT TEMPERATURE 32° - 35° WIND NONE

SUBSECTION	TIME	Type Precip.	Intensity	Accumulation (In.)	Temperature	Wind	REMARKS
-2-3-4	1530	SLEET RAIN	Lt	0	-	0	Lt. COVER - SLIPPERY - SLEET
1-2-3-4	1540	"	"	TRACE	32°	0	10 MIN. REACTION TIME - ROAD WET
-2-3-4	1550	"	"	"	32°	0	Lt. ACC. ON PAV't.
4	1730	"	Lt	1/4"	32°	0	Lt. ACC. o PAV't.
1-2-3	1730	"	"	TRACE	32°	0	RAIN MELTING SNOW ACC.
1-2-3	1930	RAIN	Lt	1/4"	34°	0	" " " " -Lt SLUSH
4	1930	SLEET	Lt	1/4"	32°	0	Lt. ACC. ON PAV't.
4	2030	RAIN	Lt	1/4"	33°	0	RAIN MELTING SNOW -
1-2-3	2030	"	"	TRACE	34°	0	" " "
1-2-3	2130	RAIN	MED		34°	0	" " "
4	2130	"	"		33°		" " "
1-2	2330	"	HVY		34°		" " " PAV't Wet
3	2330	"	HVY		33°		" " "
1	2330	"	HVY		33°		" " " Lt. SLUSH ON PAV't

ROUTE 31 TEST SECTION 1 (Pennington Circle to Route 518)

SUBSECTION 1 MIXTURE 3:1 FIGURE A3

Snow Storm No.	1	2 12-7-69	3 12-14-69	4 12 -18-69	5 12-22-69	6 12-25-69	7 1-3-70	8 1-6-70	9 1-11-70	10 1-20-70	11 1-27-70	12 2-14-70		
Temperature Range		32°-34°	30°-34°	28°-31°	30°-32°	22°-32°	28°-32°	20°-31°	18°-24°	10°-22°		21°-27°		
No. of Spreads		1	Sprd.err 2(1)	1	1	1	1	3	5	3		10		
Rate of Application	NO TEST	250	450	250	450	450	350	700	350	450	NO TEST	700		
Type of Final Precipitation		Rain	Rain	Snow	Rain	Rain	Snow	Snow	Snow	Snow		Fr. Rain		
Average Rating After 1st Spread		1.6	1.3	1.0	1.0	1.4	1.0	1.0	-	2.0		(1)		
Accumulation		Trace-Slt-Rain	1/2"-1"	Trace	Rain	2"	Trace	4"	1-1/2"	2-1/2"		2-1/2"		

SUBSECTION 2

(1) Foreman spread subsections with standard before test

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range		32°-34°	30°-34°	28°-34°	30°-32°	22°-32°	28°-32°	20°-31°	18°-24°	10°-22°		21°-27°		
No. of Spreads		1	1	1	1	1	1	3	6	3		10		
Rate of Application	NO TEST	450	250	250	250	250	250	450	250	700	NO TEST	350'		
Type of Final Precipitation		Rain	Rain	Snow	Rain	Rain	Snow	Snow	Snow	Snow		Fr. Rain		
Average Rating After 1st Spread		1.3	1.3	1.0	1.0	1.4	1.0	2.0	-	1.0		(1)		
Accumulation		Trace	1/2"-1"	Trace	Rain	2"	Trace	4"	1-1/2"	2-1/2"		2-1/2"		

ROUTE 31 TEST SECTION 1 (Pennington Circle to Route 518)

SUBSECTION 3 MIXTURE 3:1 FIGURE A3

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range		32°-34°	30°-34°	28°-31°	30°-32°	22°-32°	28°-32°	20°-31°	18°-24°	10°-22°		21°-27°		
No. of Spreads		1	1	1	1	1	1	3	6	3		10		
Rate of Application		700	700	450	350	700	450	250	450	250		450'		
Type of Final Precipitation	NO TEST	Rain	Rain	Snow	Rain	Rain	Snow	Snow	Snow	Snow	NO TEST	Fr. Rain		
Average Rating After 1st Spread		1.0	1.0	1.0	1.0	1.1	1.0	2.5	-	3.3		(1)		
Accumulation		Trace	1/2"-1"	Trace	Rain	2"	Trace	4"	1-1/2"	2-1/2"		2-1/2"		

SUBSECTION 4

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range		32°-34°	30°-34°	28°-31°	30°-32°	22°-32°	28°-32°	20°-31°	18°-24°	10°-22°		21°-27°		
No. of Spreads		1	1	1	1	2	1	3	5	3		10		
Rate of Application		250	250	700	700	350	700	350	700	350		250'		
Type of Final Precipitation	NO TEST	Rain	Rain	Snow	Rain	Rain	SSnow	Snow	Snow	Snow	NO TEST	Fr. Rain		
Average Rating After 1st Spread		3.6	3.5	1.0	3.2	2.2	1.0	3.0	-	3.0		(1)		
Accumulation		Trace	1/2"-1"	Trace	Fr. Rain	2"	Trace	4"	1-1/2"	2-1/2"		2-1/2"		

ROUTE 31 TEST SECTION 2 (518 North)

SUBSECTION 1 MIXTURE 4:1 FIGURE A4

Snow Storm No.	1 12-1-69	2 12-7-69	3 12-14-69	4 12-18	5 12-22-69	6 12-25-69	7 1-3-70	8 1-6-70	9 1-12-70	10 1-20-70	11 1-23-70	12		
Temperature Range	33°	32°-34°	29°-34°		29°-32°	19°-33°	18°-33°	18°-30°	17°-24°	9°-19°	28°-29°	16°-27°		
No. of Spreads	1	2	1		1		1	3	2	3	1	3		
Rate of Application	450	250	250		650		650	350	650	450	250	250		
Type of Final Precipitation	Snow	Rain	Rain	NO TEST	Rain	NO TEST	Snow	Snow	Snow Flurries	Snow	Snow	Rain		
Average Rating After 1st Spread	1.33	-	3.75		1.0		1.0	1.0	1.0	3.0	-	3.3		
Accumulation	Trace	1/2"	2"		Sleet		3/4"	5"	2-1/2"	2-1/2"	1/2"	1-1/2"		

SUBSECTION 2

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range	33°	32°-34°	29°-34°		29°-32°									
No. of Spreads	1	2	1		2		1	3	3	2	1	3		
Rate of Application	250	450	450	NO TEST	350	NO TEST	350	250	350	650	450	450		
Type of Final Precipitation	Snow	Rain	Rain		Rain		Snow	Snow	Snow Flurries	Snow	Snow	Rain		
Average Rating After 1st Spread	1.0	-	2.0		1.5		1.0	1.0	3.0	2.0	-	2.0		
Accumulation	Trace	1/2"	2"		Sleet		3/4"	5"	2-1/2"	2-1/2"	1/2"	1-1/2"		

ROUTE 31 TEST SECTION 1

SUBSECTION 4 FIGURE A6

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12	13	
Temperature Range		32°-34°	30°-34°	28°-31°	30°-32°	22°-32°	28°-32°	20°-31°	18°-24°	10°-22°		21°-27°		
No. of Spreads		1	1	1	1	2	1	3	5	3		10		
Rate of Application		250	250	430	700	350	700	350	700	350		250		
Type of Final Precipitation	NO TEST	Rain	Rain	Snow	Rain	Rain	Snow	Snow	Snow	Snow	NO TEST	Fr. Rain	NO TEST	
Average Rating After 1st Spread		3.6	3.5	1.0	3.2	2.2	1.0	3.0		3.0		-		
Accumulation		Trace	1/2"-1"	Trace	Fr. Rain	2"	Trace	4"	1-1/2"	2-1/2"		2-1/2"		
Mixture		3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1		3:1		

Route 31 TEST SECTION II SUBSECTION 1

Snow Storm No.	1 12-1-69	2 12-7-69	3 12-14-69	4 12-18-69	5 12-22-69	6 12-25-70	7 1-3-70	8 1-6-70	9 1-12-70	10 1-20-70	11 1-23-70	12 2-14-70	13	
Temperature Range	33°	32°-34°	29°-34°		29°-32°		18°-33°	18°-30°	17°-24°	9°-19°	28°-29°	16°-27°		
No. of Spreads	1	2	1		1		1	3	2	3	1	3		
Rate of Application	450	250	250		650		650	350	650	350	250	250		
Type of Final Precipitation	Snow	Rain	Rain	NO TEST	Rain	NO TEST	Snow	Snow	Snow Flurries	Snow	Snow	Rain	NO TEST	
Average Rating After 1st Spread	1.33	3.0	3.75		1.0		1.0	1.0	1.0	3.0	-	3.3		
Accumulation	Trace	1/2"	2"		Sleet		3/4"	5"	2-1/2"	2-1/2"	1/2"	1-1/2"		
Mixture	4:1	4:1	4:1		4:1		4:1	4:1	4:1	4:1	4:1	4:1		

ROUTE 31 TEST SECTION 2

SUBSECTION 3 MIXTURE 4:1 FIGURE A4

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range	33°	32°-34°	29°-34°	-	29°-32°		18°-33°	18°-30°	17°-24°	9°-19°	28°-29°	16°-27°		
No. of Spreads	1	2	1		2		1	3	3	3	1	3		
Rate of Application	350	650	350		450		250	450	450	250	350	350		
Type of Final Precipitation	Snow	Rain	Rain	NO TEST	Rain	NO TEST	Snow	Snow	Snow	Snow	Snow	Rain		
Average Rating After 1st Spread	1.33	-	2.5		1.5		1.0	1.0	2.0	3.5	-	2.0		
Accumulation	Trace	1/2"	2"		Sleet		3/4"	5"	2-1/2"	2-1/2"	1/2"	1-1/2"		

SUBSECTION 4

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature Range		32°-34°	29°-34°		29°-32°			18°-30°	17°24°	9°-19°	28°-29°	16°-27°		
No. of Spreads		2	1		1			3	4	2	1	3		
Rate of Application		350	650		250			650	250	350	650	650		
Type of Final Precipitation	NO TEST	Rain	Rain	NO TEST	Rain	NO TEST	NO TEST	Snow	Snow	Snow	Snow	Rain		
Average Rating After 1st Spread	NO	-	1.0	NO	1.0	NO	NO	1.0	4.0	1.0	-	1.0		
Accumulation		1/2"	2"		Sleet			5"	2-1/2"	2-1/2"	1/2"	1-1/2"		

ROUTE 80 TEST SECTION 3

SUBSECTION 1 FIGURE A5

Snow Storm No.	1 12-7-69	2 12-14-69	3 12-18-69	4	5 12-25-69	6 12-30-69	7	8 1-6-70	9 1-12-70	10 1-20-70	11 1-23-70	12 1-25-70	13 2-5-70	14 2-14-70
Temperature Range	32°-34°	32°	30°-32°		24°-33°	29°-31°		22°-26°	21°-28°	14°-20°	21°-26°	22°-28°	31°-32°	19°-30°
No. of Spreads	1	1	1		1	2		1	3	1	1	1	1	2
Rate of Application	250	350	350		650	450		650	650	450	250	650	250	350
Type of Final Precipitation	Rain	Snow	Snow	NO TEST	Rain	Rain	NO TEST	Snow	Rain Sleet	Snow	Snow	Snow	Snow	Rain Sleet
Average Rating After 1st Spread	2.5	2.0	1.75		3.1	2.5		2.5	2.6	3.1	2.0	1.6	-	2.9
Accumulation	None	1/2"	1/4"		6-1/2"	Fr. Rain		3-3/4"	1-3/4"	4"	Trace	Trace	Trace	3.0"
Mixture	4:1	3:1	4:1		4:1	3:1		3:1	4:1	3:1	4:1	3:1	4:1	3:1

SUBSECTION 2

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature Range	32°-34°	32°	30°-32°		24°-33°	29°-31°		22°-26°	21°-28°	14°-20°	21°-26°	22°-28°	31°-32°	19°-30°
No. of Spreads	1	1	1		1	3		1	3	2	1	1	1	2
Rate of Application	450	650	450	NO TEST	350	250	NO TEST	450	350	650	450	350	250	250
Type of Final Precipitation	Rain	Snow	Snow		Rain	Rain		Snow	Rain Sleet	Snow	Snow	Snow	Snow	Rain Sleet
Average Rating After 1st Spread	2.5	2.0	1.75		2.5	3.0		2.6	3.6	3.1	2.0	1.6	-	2.8
Accumulation	None	1/2"	1/4"		6-1/2"	Fr. Rain		3-3/4"	1-3/4"	4"	Trace	Trace	Trace	3"
Mixture	4:1	3:1	4:1		4:1	3:1		3:1	4:1	3:1	4:1	3:1	4:1	3:1

ROUTE 80 TEST SECTION 3

SUBSECTION 3

FIGURE A5

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature Range	32°-34°	32°	30°-32°		24°-33°	29°-31°		22°-26°	21°-28°	14°-20°	21°-26°	22°-28°	31°-32°	19°-30°
No. of Spreads	1	1	1		1	2		1	2	2	1	1	1	1
Rate of Application	350	250	250		450	650		250	450	250	350	450	250	450
Type of Final Precipitation	Rain	Snow	Snow	NO TEST	Rain	Rain	NO TEST	Snow	Rain Sleet	Snow	Snow	Snow	Snow	Snow
Average Rating After 1st Spread	2.5	2.0	1.75		2.7	2.5		2.8	3.0	2.6	2.0	1.6	-	2.8
Accumulation	None	1/2"	1/4"		6-1/2"	Fr. Rain		3-3/4"	1-3/4"	4"	Trace	Trace	Trace	3"
Mixture	4:1	3:1	4:1		4:1	3:1		3:1	4:1	3:1	4:1	3:1	4:1	3:1

SUBSECTION 4

Snow Storm No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature Range	32°-34°	32°	30°-32°		24°-33°	29°-31°		22°-26°	21°-28°	14°-20°	21°-26°	22°-28°	31°-32°	15°-30°
No. of Spreads	1	1	1		1	2		1	2	2	1	1	1	2
Rate of Application	650	450	650	NO TEST	250	350	NO TEST	350	250	350	650	250	250	650
Type of Final Precipitation	Rain	Snow	Snow		Rain	Rain		Snow	Rain Sleet	Snow	Snow	Snow	Snow	Snow
Average Rating After 1st Spread	2.5	2.0	1.75		2.7	2.5		2.6	3.6	3.1	1.5	3.0	-	2.5
Accumulation	None	1/2"	1/4"		6-1/2"	Fr. Rain		3-3/4"	1-3/4"	4"	Trace	Trace	Trace	3"
Mixture	4:1	3:1	4:1		4:1	3:1		3:1	4:1	3:1	4:1	3:1	4:1	3:1