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A Pilot Study Of Maintenance Costs Of Idaho Highways

William J. Parman

Sponsors:
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(Research Project No. 32)

Bureau of Public Roads
U.S. Department of Commerce

A PILOT STUDY OF MAINTENANCE COSTS OF IDAHO HIGHWAYS

by

William J. Parman
Research Fellow

Engineering Experiment Station
College of Engineering
University of Idaho
Moscow, Idaho

In Cooperation With

IDAHO DEPARTMENT OF HIGHWAYS

and the

BUREAU OF PUBLIC ROADS
U. S. DEPARTMENT OF COMMERCE

March, 1965

FOREWORD

The content of this report is essentially the thesis submitted by William J. Parman to fulfill the research and thesis requirements for the degree of Master of Science in Civil Engineering at the University of Idaho. The research project was administered through the Engineering Experiment Station of the University and financed by the Idaho Department of Highways with H.P.R. funds as Highway Research Project No. 32,

SUMMARY

The purpose of this study was to investigate the various factors which influence maintenance expenditures and to develop mathematical formulas to predict future maintenance costs. The objective of this study was to develop the mathematical relationships by a least squares regression analysis. As this study was a pilot study, a further objective was to recommend areas of future research.

The factors which were investigated to determine their influence on maintenance expenditures included climatic data, environmental data, and highway characteristic data. The Idaho Department of Highways maintains 4,892 miles of primary and secondary highways which are divided into 248 highway maintenance sections. Many of these sections were deleted from the study due to insufficient weather data, poor mileage correlation between several data sources, inconsistency of the cost data for several years, and the planning of a practical route for field investigation.

The 80-series IBM multiple linear regression program was used on the IBM 1620 Computer to analyze and print the results. Maintenance expenditures analyzed for this study were snow-removal expenditures, travelway-routine repair expenditures, and the total of all routine regularly occurring expenditures.

The regression analyses of snow-removal expenditures and total routine maintenance expenditures were statistically significant, and they are therefore offered as valid explanations of these expenditures. The analysis of travelway-routine repair expenditures was statistically non-significant, and therefore the results are not conclusive in explaining the expenditures. Climatic data were the most important factors in explaining maintenance expenditures.

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CHAPTER I

INTRODUCTION

Research has found great favor in highway construction, highway design, and traffic engineering, but according to Edwards (1) it has been neglected in the general maintenance field. Today's roads are wider, there are many more miles of highways, the traffic volumes have increased, and the highway user demands more services (2).

From data published in Highway Statistics (3), (4) and the Idaho Department of Highways Maintenance Report (5), Figure 1 was prepared to show that both the national and State of Idaho maintenance cost index has risen substantially during the past 20 years, emphasizing the growing necessity for maintenance engineers to appriase in every way possible the economy of their operations. A very important part of this effort is the establishment of a good maintenance budget. A good maintenance budget will provide the highway administrator with a tool which will enable him to correctly allocate funds in accordance with need and better evaluate the economy of his organization.

I. OBJECTIVE

The object of this investigation was to study various factors that affect highway maintenance expenditures and to determine the extent that each of these factors contributed to the total expenditure. The study also investigated the feasibility of a practical formula for predicting future maintenance expenditures based on past correlations between expenditures and influencing factors. Based on information gained from this study, additional objectives were to recommend areas of future research and identify deficiencies in the current practice of reporting maintenance expenditures.

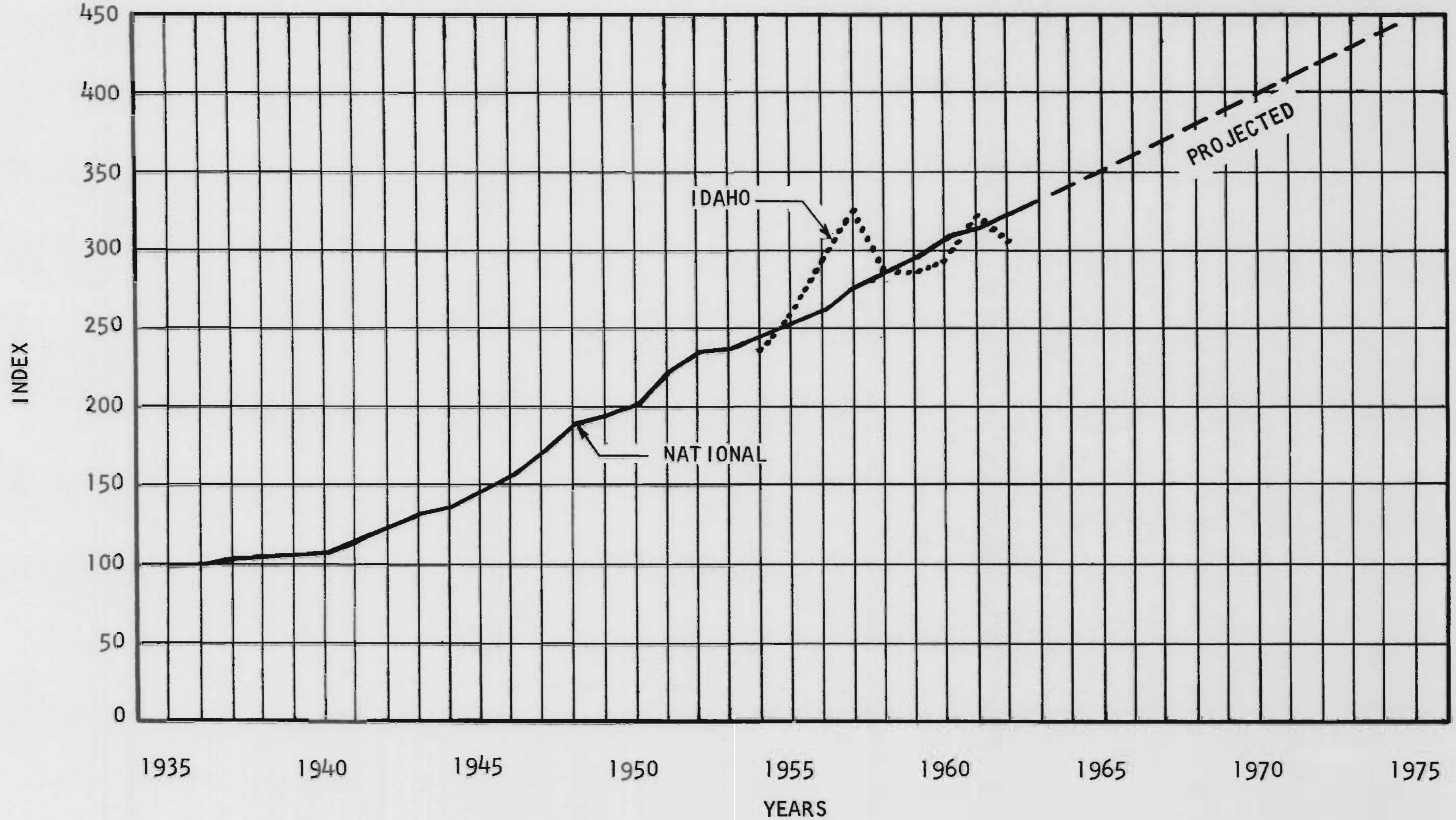

Figure 1. Highway maintenance cost trends

II. PURPOSE

Highway maintenance expenditures are known to vary widely throughout the state of Idaho. There appears to be no conclusive explanation for the variation of maintenance costs. An analytical means by which annual maintenance costs may be forecasted for a variety of conditions is not available; the present forecasting technique relies upon judgement and experience of administrative personnel. In order that maintenance expenses may be evaluated, it is desirable that the relationship between maintenance costs and their contributing factors be investigated and established to the fullest extent possible. With this knowledge, more reliable forecasts can be developed and inefficient operations can be more readily detected.

CHAPTER II

DATA COMPILATION

The data used in this study were collected from many sources. Wherever possible, official records of the Idaho Department of Highways, United States Weather Bureau, United States Forest Service, Soil Conservation Service and Northern Pacific Railroad were consulted to obtain highway characteristics and/or environmental characteristics for each maintenance section of highway. However, one problem which became apparent was the lack of agreement between two or more data sources for the same information.

I. COST DATA

Maintenance expenditures are cost accounted by the Idaho Department of Highways into twenty-four different maintenance codes. A list of these maintenance codes with their description appears in Table III of Appendix C on page 81. A record of maintenance expenditures is kept by the Idaho Department of Highways Accounting Section. The expenditure records for 1961, 1962, and 1963 were furnished by the Idaho Department of Highways for the study.

In order to analyze the maintenance sections, it was necessary to obtain a unit maintenance cost for each section. A unit area was needed which would be meaningful and yet would result in a number small enough to be carried on the IBM Computer and still be accurate. In routine IBM FORTRAN calculations, the IBM 1620 Computer will carry eight digits. More digits may be carried by coding the data to machine language. However, coding the data to machine language uses an excessive number of memory locations and reduces the number of independent variables which may be correlated with the dependent variable. As these memory locations were needed, the data were not coded. The computer does not round numbers off, but rather it truncates them. In a multiple regression analysis by the IBM 1620 Computer, the independent variables may be used 90 or more times in the calculations, thereby losing many digits in the process. Square feet and square yard unit areas resulted in numbers too large for accurate calculations by the computer. A foot-mile unit area representing a strip of roadway one foot wide and one mile in length was chosen as being more workable. The foot-mile area was the easiest to calculate using The Log of the Federal Aid Primary System and the State Federal Aid Secondary System in Idaho (Federal Aid Log) (6), since this publication lists the section length in miles and the section width in feet.

Maintenance expenditures for each highway maintenance section were divided by the foot-mile area of that maintenance section to obtain the maintenance cost per foot-mile. This unit cost is used as the dependent variable in the regression analyses.

Special Problems

The accuracy of a formula produced by a regression analysis is largely determined by the precision with which the dependent variable data (unit maintenance costs) are measured. Analysis of the data and the manner in which it is collected indicates that there are many opportunities for error to be introduced. The accuracy of the dependent variable depends directly upon the reporting of time and equipment by field maintenance forces. Non-productive time such as coffee breaks, travel time between the maintenance shed and the job site, travel time between job sites, and taining sessions must be reported to a productive time code. This reporting tends to bias the particular expenditure code. Accurate accounting of the field time by the Accounting Section of the Idaho Department of Highways is also of the utmost importance.

Many highway maintenance sections showed very large yearly differences in maintenance expenditures. The majority of these differences were due to periodic contract work which occurs every five or more years. Since the study only covered expenditures of three years, infrequent expenditures also tend to bias the expenditure codes.

In discussions with field maintenance crews, it was learned that the field forces do not always end their work at the end of the maintenance section to which they have been assigned. These maintenance section boundaries are defined in the Idaho Department of Highways Accounting Manual (7). In some instances highway maintenance section boundaries were on sharp curves on mountain grades. Two such sections are 095-238 (U. S. 95 on Whitebird Hill) and 093-164 (U. S. 93 on Granite Pass). On both sections the field maintenance forces actually ended their work operations approximately one and one-half miles into the next section, while they reported their time and equipment to the section to which they were assigned.

Selectivity

In the Idaho Department of Highways Accounting Manual, the length of each maintenance section is defined to the nearest one thousandth of a mile. The Federal Aid Log also gives section lengths to the nearest one thousandth of a mile; however, in many maintenance sections it was extremely difficult to correlate the two lengths. If the length given by the Federal Aid Log differed by more than 10 per cent from the length given by the Idaho Department of Highways Accounting Manual, the entire maintenance section was deleted from the study.

Another cause for deleting a maintenance section was the lack of similarity between costs for the years 1961; 1962 and 1963. If one year's expenditures differed from the average of the other two by over 100%, that particular year's expenditures were deleted from the study and the average expenditure of other other two years was used. In a few cases, the expenditure for each year of the study differed from the other two expenditures by over 100%, in which case the entire maintenance section was dropped from the study. The maintenance sections deleted from the study have been designated as such in Table II of Appendix A on page 63.

A few sections were also deleted from the study due to economic reasons. The State of Idaho contains 4,892 miles of primary and secondary roads which are divided into 248 highway maintenance sections. It was not economically practical to travel and inspect every one of these 248 sections. Therefore, a route of field inspection was planned to cover enough sections to assure reliable results while keeping the project travel expenses to a minimum consistent with quality and quantity of data. The highway maintenance sections used in the study are illustrated in Map 1 of Appendix B on page 71.

The 27 maintenance sections of the Interstate System were deleted from the study. It was felt that due to the differences in construction procedures and design standards, different maintenance practices would be required necessitating expenditures which would not be comparable with maintenance expenditures on primary and secondary routes.

II. HIGHWAY FEATURES DATA

Data concerning the physical features of each maintenance section used in the study were obtained from official records of the Idaho Department of Highways and from personal observations by the writer. The data accumulation from official records was done in the office at the University of Idaho. The data accumulation from personal observations was obtained by driving over each highway maintenance section in the study at a uniform speed. Topographic features were observed. Length of highway in cut, length of highway with guardrail, and total length were observed and recorded using stop watches.

Office Procedure

The office procedure consisted of extracting bits of data for each maintenance section in the study from the official records of the Idaho Department of Highways such as The Federal Aid Log, The Traffic Comparison Report for 1957, 1961 and 1962 (8), and the Idaho Department of Highways Accounting Manual.

The foot-mile area for each maintenance section was computed from the Federal Aid Log. Two separate foot-mile areas were required for each maintenance section in the study. For the snow-removal expenditure analysis, the entire roadway width was used (i.e., including shoulders), since the snow is usually removed from the shoulders with the use of wings on the snow plow vehicles. However, in the analysis of surface repair, only the actual travelway width of the highway was used. In the analysis of total maintenance expenditures, the roadway width was again used since the various maintenance operations making up the total expenditures include many operations on the roadway shoulders.

The Traffic Comparison Report for 1957, 1961 and 1962 was used to determine the average daily traffic (ADT), the rural commercial volume, and the rural commercial volume percentage of the average daily traffic. It was felt that since the study covers 1961, 1962 and 1963, that 1962 would be an average year if the traffic steadily increased from 1961 to 1963. However, a local trend may have reduced the 1962 traffic count on certain sections in which case the 1961 count was used if it were the higher value.

The Idaho Department of Highways prepared and furnished a map classifying traffic as light, average, or heavy. This map classifies traffic using actual ADT traffic counts based on a percentage of 2 and 5 axle trucks. Equivalent wheel load factors are given for each classification. The following numerical equivalents were used for the traffic classification factor, based on the equivalent wheel loads:

1.86 Light
3.05 Average
4.15 Heavy

The traffic classification factor map is found in Map 6 of Appendix B on page 76. If a particular maintenance section contained two or more traffic classifications, a weighted average was used. The average was weighted according to the length associated with each classification.

A particular maintenance section may be and usually is comprised of many short segments of highway differing in width, base thickness, surface thickness, surface type, and/or surfacing age. A typical highway maintenance section may consist of as many as thirty such variations requiring separate accumulative calculations of widths, thicknesses, and surfacing characteristics. In order to obtain an average value for the width, the accumulative foot-mile area of the section was divided by the total mileage. An average is also needed for base thickness, surface thickness, surfacing type and surfacing age. The Federal Aid Log gives values of base thickness in inches, surface thickness in inches, surfacing type, and surface age by year of construction. The year of construction was substracted from the average study year of 1962 to determine the age of the section.

The Federal Aid Log gives a symbolic identification and defines the various types of highway surfacing. However, a digital computer regression analysis requires numerical values for all variables. Numerical equivalents were assigned in an order felt consistent with the structural adequacy of the surfacing material. The numerical equivalents so assigned and the Federal Aid Log definitions and symbols are as follows:

F Numerical Equivalent 1: BITUMINOUS SURFACE-TREATED ROAD: An earth road, a soil-surface road, or a gravel or stone road to which has been added by any process a bituminous surface course, with or without seal coat, the total compacted thickness of which is less than one inch. Seal coats include those known as chip seals, drag seals, plant-mix seals and rock asphalt seals.

H-1 Numerical Equivalent 2: BITUMINOUS PENETRATION ROAD: A bituminous penetration road, the base course of which is of other than types J, K, or L, and the combined compacted thickness of surface and base is less than 7 inches, or the design is such as to produce a road having a characteristically low or non-uniform load-bearing capacity.

H-2 Numerical Equivalent 3: BITUMINOUS PENETRATION ROAD: A bituminous penetration road on any base of types J, K, or L; also on any other type of base where the combined compacted thickness of surface and base is 7 inches or more, or where, by reason of the presence of natural foundation materials which meet base requirements, the road has a characteristically high uniform load-bearing capacity.

G-1 Numerical Equivalent 5: MIXED BITUMINOUS ROAD: A mixed bituminous road, the base course of which is of other than types J, K, or L, and the combined compacted thickness of surface and base is less than 7 inches or more, or the design is such as to produce a road having a characteristically low or non-uniform load-bearing capacity.

G-2 Numerical Equivalent 6: MIXED BITUMINOUS ROAD: A mixed bituminous road on any base of types J, K, or L; also on any other type of base where the combined compacted thickness of surface and base is 7 inches or more, or where, by reason of the presence of natural foundation materials which meet base requirements, the road has a characteristically high uniform load-bearing capacity.

I Numerical Equivalent 8: BITUMINOUS CONCRETE, SHEET ASPHALT OR ROCK ASPHALT ROAD: A road on which has been constructed thickness consisting of bituminous concrete or sheet asphalt, prepared in accordance with precise specifications controlling gradation, proportions and consistency of composition, or of rock asphalt. The surface course may consist of combinations of two or more layers such as a bottom and a top course, or a binder and a wearing course.

J Numerical Equivalent 10: PORTLAND CEMENT CONCRETE ROAD: A road consisting of Portland cement concrete, with or without a bituminous wearing surface less than one inch in compacted thickness.

It was not felt that weighting the base thickness, surface thickness, surfacing type, and surface age data on a mileage basis would be as meaningful as weighting them in a foot-mile basis. These data are used mainly in the analysis of the surface repair expenditures. Since the surface repair expenditures cover the entire surfaced area, it was deemed advisable to take the difference in roadway width into account by weighting the averages on a foot-mile basis rather than using a mileage basis. This method requires the cumulative total of three multiplied numbers; the computer was used to obtain the weighted averages rather than an electric calculator. The computer program and a short description of the variables used are shown in Table VII in Appendix C on page 89.

The Federal Aid Log also lists all bridges on the Federal Aid Primary System and State Federal Aid Secondary System. The width and length of each bridge were used to determine the cumulative bridge area in square yards for each maintenance section. The bridge areas, as shown in Table II of Appendix A on page 63, were used in the analyses of both the total maintenance expenditures and snow-removal expenditures. In the study of snow-removal expenditures, bridge areas were considered equivalent to cut sections due to the interference they created for snow removal.

Field Measurements

Data concerning cuts, guardrail, and topographic characteristics were obtained by driving each maintenance section. It was felt that deep cut sections could increase maintenance costs because of extra ditch cleaning required due to sloughing or erosion, the increased potential of groundwater in or near the base material, the sun shading effects on the roadway, the tendency for drifting snow to accumulate, and/or the lack of space to plow snow off the roadway.

Guardrail areas along the roadway also increase the maintenance cost since they increase the difficulty of using wings on snow-plow vehicles to remove the snow on the shoulder areas and cause problems in mowing operations and weed control.

The field procedure consisted of determining the percentage of the total length of the maintenance section that was in deep cut or contained guardrail. This was accomplished with three stopwatches: one for total driving time from the beginning to the end of the maintenance section, one to record time of deep cut areas, and one to record time of guardrail sections. Thus, the percentage of the maintenance section in deep cut would simply be the ratio of deep cut time multiplied by 100 and divided by the total driving time. The driving speed was held as constant as possible at 40 miles per hour.

The criterion for a deep cut area was a V-bottom ditch with the back-slope cut on approximately a $1\frac{1}{4}:1$ or steeper, at least four feet above ditch grade. An area with a relatively flat bottom ditch was not considered criterion for a deep cut area. A peculiar problem arose on maintenance section 010-076 (U. S. 10 from Wallace, Idaho to the Montana State Line at Mullan Pass). Here the Northern Pacific Railroad parallels the highway with the inside rail four feet from the pavement edge. Since the snow cannot be plowed from the highway onto the Northern Pacific Railroad tracks, it must all be plowed to the other side of the roadway. Members of the field maintenance forces in the area agree that the proximity of the railroad causes the same problems as a deep cut section, especially in the snow-removal operations.

The criterion for a guardrail area was an area with posts and guardrail or just posts alone with no rail since either arrangement presents a problem to field maintenance forces, especially the snow removal forces.

The third factor determined in driving over the maintenance section was a topographic factor associated with the vertical alignment of the road.

Here again the mathematical analysis requires numerical values for the variables. Numerical equivalents were assigned in an order felt consistent with degree of severity to maintenance operations. The following numerical equivalents were assigned to the various topographic determinations:

1.0 Flat

2.0 Rolling

4.0 Mountainous

If portions of a maintenance section were partially flat and partially rolling a weighted average was assigned to the section. The average was weighted on a distance basis. The values assigned to each highway maintenance section are found in Table II of Appendix A starting on page 63.

III. ENVIRONMENTAL DATA

Environmental data mainly pertain to weather and climatic characteristics. Climatic information was supplied by the Idaho Department of Highways (9), or extracted from official records of the United States Soil Conservation Service (12), and the Northern Pacific Railroad (13). In all cases of disagreement between two or more data sources, the official records of the United States Weather Bureau were used as the standard.

Snowfall

The Climatologic Summary of the United States - Idaho (14) gives the 30 year mean of annual snowfall in inches for 128 weather stations throughout the State. These data were plotted on a map of Idaho and contour lines were drawn as illustrated on Map 2 on page 72. The contour lines represent the area contiguous with the highways and no regard was given to the snowfall in areas remote from the highway test sections. The average snowfall value for each maintenance section was taken from this map and is recorded in Table II of Appendix A on page 63.

Unfortunately the United States Weather Bureau has no data for the areas of critically high snowfall such as Lookout Pass on U. S. 10, Targhee Pass on U. S. 191, Lost Trail Pass on U. S. 93, and Lolo Pass on

U. S. 12. The Forest Service was contacted and they provided some information. The Soil Conservation Service only keeps snow depth measurements. Since the snow depth measurements depend heavily on wind velocity, temperature, and/or moisture density, these data could not be accurately correlated to the actual snowfall. The Northern Pacific Railroad records provided some data on the snowfall on Lookout Pass; however, their record exceeded by 176 per cent, the Weather Bureau reports from a station 3 miles away and at a higher elevation. It was felt that the Northern Pacific Railroad's average snowfall was too high and a Weather Bureau snowfall value was adjusted for elevation and used in the study.

The maintenance expenditures for snow removal were thought to depend quite heavily on the actual snowfall. It was assumed that the yearly expenditure differences for the same maintenance section could be explained by analyzing each year's expenditure against that particular year's snowfall. Thus, there would be three separate data observations for each maintenance section, one for 1961, 1962 and 1963. However, due to the lack of available Weather Bureau data, this plan proved unfeasible. It was therefore necessary to analyze the three year average snow removal expenditure per foot-mile against the 30 year man snowfall plus all the other variables which are fairly constant.

Mean Maximum and Minimum Temperatures

The Climatological Summary of the United States - Idaho (15) gives the 30 year mean of both mean maximum temperature and mean minimum temperature for 127 weather stations throughout the State of Idaho. These data points were plotted on separate maps of the State of Idaho and contour lines were drawn. The contour lines represent the areas in the immediate vicinity of the highway and no regard is given to remote areas. The average mean maximum and mean minimum temperatures for each maintenance section used in the study were taken from these contour maps, which are contained in Maps 4 and 5 of Appendix B on pages 74 and 75.

Elevation

The average elevation above mean sea level of each maintenance section in the study was taken from the United States Coast and Geodetic Survey-Sectional Aeronautical Charts (16) and from the listing of weather stations contained in the Climatological Summary of the United States - Idaho (17). These values were either used separately or averaged to determine the average elevations of each maintenance section used in the study. In mountainous areas the Sectional Aeronautical Charts were used exclusively because topographic differences between the beginning and end of each section were more apparent. The contour lines represent the immediate areas of highways only, with no regard given to remote areas. The elevation contour map appears in Map 3 of Appendix B on page 73.

Precipitation

A contour map of average annual precipitation was prepared and furnished by the Idaho Department of Highways (18). This map is based on United States Weather Bureau data. The precipitation contour map is contained in Map 7 of Appendix B on page 77. An average precipitation for each highway maintenance section in the study was determined from this map.

Degree Days

A contour map of average annual degree days (below 32°F) was prepared and furnished by Mr. L. F. Erickson, Research Engineer, Idaho Department of Highways (19). This map represents the cumulative total of each day during the year with an average daily temperature less than 32°F multiplied by the degree less than 32°F. Thus, a day with an average daily temperature of 29°F would be the equivalent of 3 degree days. An average degree day value for each highway maintenance section in the study was determined from this map. The degree-days contour map is contained in Map 8 of Appendix B on page 78.

Climatic Factor

A climatic factor is an arbitrary number used by the Idaho Department of Highways (20) to increase pavement structure thickness above the minimum design thickness due to climatic conditions. This factor depends on such things as precipitation, snowfall, mean temperature, and adverse spring breakup experience, all of which affect the structural adequacy of the roadbed material. The climatic factor contour map is contained in Map 9 of Appendix B on page 79. The climatic factor for each highway maintenance section was determined from this map.

CHAPTER III

DATA PROCESSING

The data were analyzed using an 80-series IBM multiple linear regression analysis program (21) on an IBM 1620 Computer. A description of the 80-series analysis is given in the first section of this chapter. By the multiple linear regression form of analysis it was hoped to determine to what extent each factor contributed to the maintenance expenditure. It was also hoped that the resultant formula of the regression analysis could be used to predict future maintenance costs. Three multiple linear regression maintenance expenditures analyses were run, one on snow-removal expenditures, one on travelway-routine repair expenditures, and one on total maintenance expenditures. Other analyses were attempted but data limitations precluded their completion.

I. 80-SERIES MULTIPLE REGRESSION PROGRAM

The 80-series multiple regression analysis utilizes a matrix algebra step-by-step process of picking the most potent variable. The most potent variable is that independent variable or group of independent variables which most closely correlate with the dependent variable.

In the first step, the regression analysis picks the single independent variable which most closely correlates with the dependent variable. In the second step, it picks the two independent variables which, when taken together, correlate most closely with the dependent variable. Each successive n^{th} step picks the n^{th} independent variable which when taken together with the n-1 previously chosen independent variables correlate most closely with the dependent variable.

The following abbreviations and definitions are used in the print-out of the IBM 1620 Computer.

STD. ERR. Y.X. - Standard Error Y on X- Y represents the dependent variable and X represents the independent variables. This abbreviation refers to the standard deviation remaining in the dependent variable after the dependent variable has been adjusted for the effect of the independent variables. The standard deviation is defined as the square root of the sum of the squares of the deviations from the mean divided by one less than the total number of observations. The smallest value is preferable.

R SQUARED- The Coefficient of Determination is the percentage of the variation of the dependent variable which is attributable to the variation of the combined effect of the independent variables. It might also be defined as a measure of the strength of association between the dependent and combined independent variables (22).

Y SUM SQRS. - Y Sum of Squares- The sum of the squares of the deviations of the dependent variable about its mean.

SUM SQR. RES.- The Sum of Squares Residual refers to the sum of the squares of the deviations of the dependent variable about its mean remaining after the dependent variable has been adjusted for the combined effect of the independent variables.

IND. VAR. USED - Independent Variables Used- The number of independent variables used in this step. This is also the step number. Each n^{th} step combines the effect of n independent variables.

F TEST- The F test is a test of the significance of the results. The calculated F value is compared to determine whether it exceeds the five or one per cent area of the theoretical F distribution as presented in Steel and Torrie (23). The following nomenclature is used to indicate the significance of the F test:

n.s. - non-significant- No conclusive explanation may be drawn from the results.

sign. - significant- The reduction of the total sum of the squares of the dependent variable by the combined effect of the independent variables is not a result of chance at the 5 per cent error level.

h. sign. - highly significant- The reduction of the total sum of the squares of the dependent variable by the combined effect of the independent variables is not a result of chance at the 1 per cent error level.

CONSTANT TERM- This represents the value of the dependent variable if all the independent variables would have a value of zero. The constant term is similar to the y-intercept of a simple straight line.

IND. VAR. - Independent Variable- Refer to Tables IV, V, and VI of Appendix C on pages 84, 85, and 87 for the lists of variables used in the regression analyses.

COEF. - The partial regression coefficient is the slope of the linear equation defining the value of the dependent variable for a specified value of the independent variable in the form Y = C + bX where Y is the dependent variable, C is the constant term, X is the independent variable, and b is the regression coefficient or slope.

STD. ERR.- The Standard Error is the standard deviation associated with each partial regression coefficient (COEF.).

T RATIO- The T test is a test of the significance of the direct effect of the independent variable as an estimator of the dependent variable. It is the ratio of the partial regression coefficient (COEF.) divided by its respective standard error (STD. ERR.).

II. SNOW-REMOVAL EXPENDITURES

Snow-removal expenditures are cost accounted by the Idaho Department of Highways to purpose code 1060. For a description of the work operations making up code 1060, refer to Table III in Appendix C on page 81.

The following factors hereafter referred to as independent variables, as discussed in Chapter II were examined as to their influence on snow-removal expenditures:

NOTE - * represents multiplied by

Snowfall
Topographic factor
Percentage of roadway in cut
Percentage of roadway with guardrail
Elevation
Total precipitation
Degree days (below 32°F)
Lane width
Shoulder width
Climatic factor
Mean minimum temperature
Lane width + Shoulder width
Degree days * Mean minimum temperature
Snowfall * Total precipitation
Snowfall * Percentage of roadway in cut
Snowfall * Elevation
Elevation * Total precipitation
Topographic factor squared
Snowfall + Total precipitation
(Snowfall * Elevation) 1.5 power
(Snowfall * Elevation) 0.5 power

A few field maintenance operators throughout the state were interviewed on the subject of snow-removal operations. They agreed that the following variables in order affected snow-removal expenditures:

Snowfall
Percentage of roadway in cut
Percentage of roadway with guardrail

After the data were analyzed by the IBM 80-series regression program, snowfall was found to be the most potent variable in every regression analysis but one: percentage of roadway in cut and percentage of roadway with guardrail also showed as important variables. This finding shows very good agreement between field experience and the regression analyses results.

Statewide Analysis

The first regression analysis covered 112 maintenance sections throughout the State of Idaho. A list of these maintenance sections and the data associated with each section are found in Table II of Appendix A on page 63.

The results of the first regression analysis of snow-removal expenditures for the entire state as printed by the IBM 1620 Computer are as follows:

STD ERR Y.X	.97319	
R SQUARED	.94689	
Y SUM SQRS	1,767.64120	
SUM SQR RES	94.70988	
IND VAR USED	11	
F TEST	71.4550	h. sign.
CONSTANT TERM	-.17978	

IND VAR	COEF	STD ERR	T RATIO
2	-.00777	.02182	-.35604
4	-.02261	.00984	-2.29739
5	.01720	.00904	1.90074
9	.03353	.01811	1.85169
14	$-.44777 \times 10^{-4}$	$.17406 \times 10^{-4}$	-2.57251
15	.00024	.00052	.46824
16	.00085	.00016	5.13887
17	$.16754 \times 10^{-4}$	$.74092 \times 10^{-5}$	2.26121
18	$.21780 \times 10^{-4}$	$.12055 \times 10^{-4}$	-1.80670
19	.05543	.03085	1.79658
21	$-.10999 \times 10^{-8}$	$.45685 \times 10^{-8}$	-.24075

The definitions used in the above and all following print-outs are found on pages 16, 17, and 18.

The results of the preceding regression analysis lead to the following snow-removal expenditure equation:

$$Y = -.17978 - (.00777)(X_2) - (.02261)(X_4) + (.01720)(X_5) + (.03353)(X_9) - (.44777 \times 10^{-4})(X_{14}) + (.00024)(X_{15}) + (.00085)(X_{16}) + (.16754 \times 10^{-4})(X_{17}) + (.21780 \times 10^{-4})(X_{18}) + (.05543)(X_{19}) - (.10999 \times 10^{-8})(X_{21})$$

where Y is the computed snow-removal expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

In this regression the coefficient of determination was .94689 which means that approximately 95 per cent of the variation of the snow-removal expenditures throughout the State of Idaho are attributable to the variation of the independent variables. This coefficient of determination is highly significant as noted by the F RATIO.

As part of this study, a special IBM FORTRAN program was written to plot-back the results of each regression. The plot-back program computes the estimated dependent variable utilizing the partial regression coefficients determined by a regression analysis. The program then compares the estimated dependent variable to the actual dependent variable and computes the percentage of error between the two. The plot-back program appears in Table VIII of Appendix C on page 90.

Although the previously mentioned coefficient of determination is high, the plot-back results showed that only 31 per cent of the estimated expenditures compared within ± 15 per cent of the actual expenditures. Fifteen per cent was used for a comparison figure, since this value was used in the only other known study of this type by the State of Louisiana (24).

Basis for Expenditure Split

Since snowfall is the most potent variable in each regression, it was decided to plot a graph of snowfall versus snow-removal expenditures

(Figure 2) for the 112 maintenance sections in the study. The dashed line in Figure 2 shows the slope of snowfall versus snow-removal expenditure. A decided change in grouping of the points is noted at an expenditure of about \$2.50 per foot-mile. In order to develop a more meaningful analysis, the data were split at a snow-removal expenditure of \$2.50 per foot-mile. There were 66 data observations below \$2.50 per foot-mile and 46 data observations above \$2.50 per foot-mile. Two regressions were then run, one with data containing snow-removal expenditures above \$2.50 per foot-mile and the other with snow-removal expenditures below \$2.50 per foot-mile.

Expenditures above \$2.50 per foot-mile. The results of the regression using 46 snow-removal expenditures above \$2.50 per foot-mile are as follows:

STD ERR Y.X	1.13705	
R SQUARED	.95786	
Y SUM SQRS	1,050.60290	
SUM SQR RES	45.25163	
IND VAR USED	10	
F TEST	23.226	h. sign.
CONSTANT TERM	3.98337	

IND VAR	COEF	STD ERR	T RATIO
2	.25651	.07709	3.32744
4	-.03443	.02256	-1.52641
5	.02253	.01330	1.69347
13	.04684	.02552	1.83510
14	$-.00010\times10^{-4}$	$.28581\times10^{-4}$	-3.68159
15	.00084	.00075	1.11184
16	.00063	.00028	2.26520
17	$.77658\times10^{-5}$	$.22693\times10^{-5}$	3.34299
20	.23436	.07584	-3.09003

The preceding regression analysis results lead to the following snow-removal expenditure equation:

$$Y = 3.98337 + (.25651)(X_2) - (.03443)(X_4) + (.02253)(X_5)$$

$$+ (.04684)(X_{13}) - (.00010\times10^{-4})(X_{14}) + (.00084)(X_{15})$$

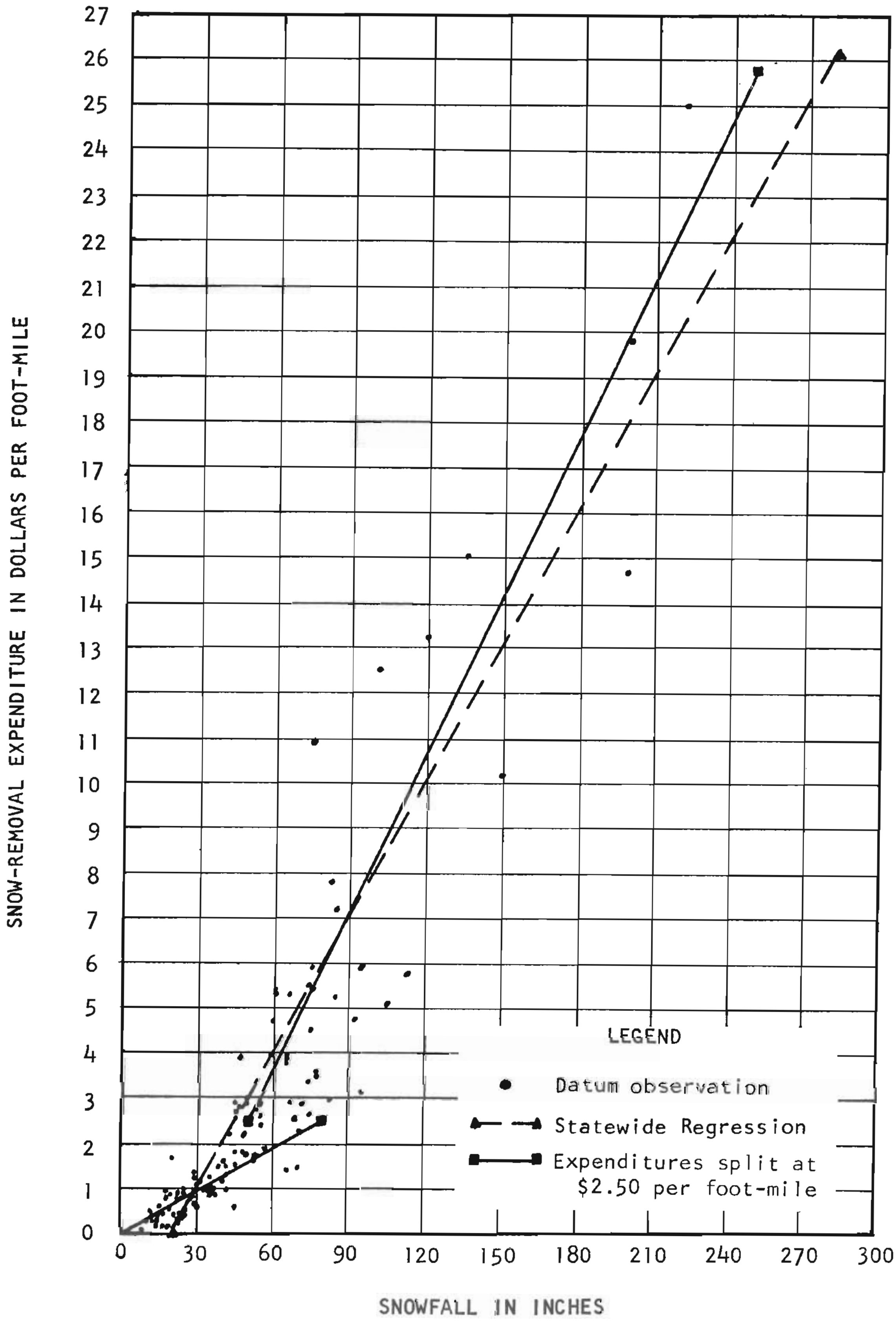

Figure 2. Snow-removal expenditures versus Snowfall

$$+ (.00063)(X_{16}) + (.77658\times10^{-5})(X_{17}) + (.18778)(X_{19}) - (.23436)(X_{20})$$

where Y is the computed snow-removal expenditure and an explanation of the X variables is contained in Table IV of Appendix C on page 84.

The above formula was used in the plot-back computer program to compare the computed expenditure per foot-mile to the actual expenditure per foot-mile. The results of the plot-back showed that 39 per cent of the computed expenditures compared within ± 15 per cent of the respective actual snow-removal expenditure. This showed some improvement over the plot-back results for the 112 observations covering the entire state where the plot-back showed that only 31 per cent of the computed expenditures compared within ± 15 per cent of the actual expenditures.

Expenditures below $2.50 per foot-mile. The results of the regression using 66 snow-removal expenditures below $2.50 per foot-mile are as follows:

STD ERR Y.X	.31378	
R SQUARED	.75627	
Y SUM SQRS	23.87190	
SUM SQR RES	5.90761	
IND VAR USED	5	
F TEST	5.943	h. sign.
CONSTANT TERM	-5.66059	

IND VAR	COEF	STD ERR	T RATIO
2	.00846	.00655	1.29067
6	$-.88377\times10^{-4}$	$.55573\times10^{-4}$	-1.59027
9	.01736	.00879	1.97441
11	5.73663	1.71687	3.34131
21	$.64433\times10^{-8}$	$.2497\times10^{-8}$	2.58024

The results of the preceding regression analysis lead to the following snow-removal expenditure equation:

$$Y = -5.66059 + (.00846)(X_2) - (.88377\times10^{-4})(X_6) + (.01736)(X_9) + (5.73663)(X_{11}) + (.64433\times10^{-8})(X_{21})$$

where Y is the computed snow-removal expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

The plot-back of the regression of snow-removal expenditures below $2.50 per foot-mile showed that 41 per cent of the computed expenditures compared within ± 15 per cent of the actual expenditure.

By splitting the data at an expenditure of $2.50 per foot-mile both the coefficient of determination and the percentage of computed expenditures comparing within ± 15 per cent of the actual expenditure showed improvement over those obtained by analyzing the entire state.

Basis for Snowfall Split

Reference to Figure 2 on page 22 shows a decided change in the grouping of data observations at an annual snowfall of approximately 40 inches which corresponds to a snow-removal expenditure of approximately $2.50 per foot-mile. It is difficult to determine in advance whether or not a particular highway maintenance section will have a snow-removal expenditure above or below $2.50 per foot-mile. Therefore, a split based on average annual snowfall of more and less than 40 inches was used because of the greater ease in analyzing data. There were 63 maintenance sections having snowfall greater than 40 inches and 49 maintenance sections having less than 40 inches average annual snowfall.

Snowfall above 40 inches. The results of the regression using 63 maintenance sections with an average annual snowfall equal to or greater than 40 inches are as follows:

STD ERR Y.X	1.35554	
R SQUARED	.91998	
Y SUM SQRS	104.73688	
SUM SQR RES	2,780.00770	
IND VAR USED	05	
F TEST	46.448	h. sign.
CONSTANT TERM	-3.64602	

IND VAR	COEF	STD ERR	T RATIO
2	.02465	.01602	1.53864
9	.06953	.02517	2.76160
16	.00061	.00015	3.99843
17	$.92337 \times 10^{-5}$	$.17246 \times 10^{-5}$	5.35385
19	.07195	.05247	1.37116

The results of the preceding regression lead to the following snow-removal expenditure equation:

$$Y = -3.64602 + (.02465)(X_2) + (.06953)(X_9) + (.00061)(X_{16})$$
$$+ (.92337 \times 10^{-7})(X_{17}) + (.07195)(X_{19})$$

where Y is the computed expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

The plot-back of the regression of the expenditures of maintenance sections with an average annual snowfall equal to or greater than 40 inches showed that 40 per cent of the computed expenditures compared within $\pm$ 15 per cent of the actual expenditure for the respective maintenance section. This was only slightly better than the 39 per cent comparison of the snow-removal expenditures above $2.50 per foot-mile. However, the standard error Y.X is somewhat higher with 1.35554 compared to 1.13705.

<u>Snowfall below 40 inches</u>. The results of the regression using 49 maintenance sections with an average annual snowfall less than 40 inches are as follows:

STD ERR Y.X	.26037	
R SQUARED	.66535	
Y SUM SQRS	34.05574	
SUM SQR RES	2.71177	
IND VAR USED	08	
F TEST	13.663	h. sign.
CONSTANT TERM	-2.43934	

IND VAR	COEF	STD ERR	T RATIO
2	.02516	.00712	3.53341
3	.32030	.21609	1.48220
5	.00585	.00531	1.10069
6	$.92128\times10^{-4}$	$.63906\times10^{-4}$	-1.44163
8	.00185	.00102	1.80472
11	2.42455	2.54980	.95087
14	$-.50928\times10^{-4}$	.32914	-1.29872
19	-.07998	.04609	-1.73515

The results of the preceding regression analysis lead to the following snow-removal expenditure equation:

$$Y = -2.43934 + (.02516)(X_2) + (.32030)(X_3) + (.00585)(X_5) - (.92128\times10^{-4})(X_6) + (.00185)(X_8) + (2.42455)(X_{11}) - (.50928\times10^{-4})(X_{14}) - (.07998)(X_{19})$$

where Y is the computed snow-removal expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

The plot-back of the regression of snow-removal expenditures of maintenance sections with an average annual snowfall less than 40 inches showed that 37 per cent of the computed expenditures compared within $\pm$ 15 per cent of the actual expenditure for the respective maintenance section. The standard error Y.X is somewhat lower than the standard error Y.X yielded by the regression of expenditures below $2.50 per foot-mile with .26037 compared with .31378. Only 37 per cent of the computed expenditures compared within $\pm$ 15 per cent of the respective actual expenditures, whereas 41 per cent compared within $\pm$ 15 per cent in the analyses of expenditures below $2.50 per foot-mile. Therefore, the results of splitting the maintenance sections at an average annual snowfall of 40 inches were not quite as significant as splitting the maintenance sections at a snow-removal expenditure of $2.50 per foot-mile.

Climatic Factor Analyses

Since the weather and climate of Idaho are so varied and have such wide extremes, the highway maintenance sections were split by some factor which included as many weather conditions as possible. The climatic factor furnished by the Idaho Department of Highways as discussed in Chapter II was chosen. Of the 112 highway maintenance sections used in the analysis of snow-removal expenditures, 31 sections have a climatic factor of 1.00, 20 sections have a climatic factor of 1.05, 41 sections have a climatic factor of 1.10, and 20 sections have a climatic factor of 1.15. It was anticipated to run a multiple regression of 22 variables on each of the four groups of maintenance sections. However, the 80-series multiple regression program solves the partial regression coefficients utilizing a 22 x 22 matrix. Thus, the data groups of climatic factors of 1.05 and 1.15 could not be run, since at least one data observation is needed for each variable. Further, the greater the number of data observations used in a multiple regression analysis, the more significance is attached to the results. The number of variables could not be reduced since it could not be determined which variable was used one or more times, and thus it could not be determined if the variable would again be chosen as a potent variable by the computer under different conditions.

Climatic factors of 1.00 and 1.05. By combining the maintenance sections with climatic factors of 1.00 or 1.05, the results of the regression analysis of the 51 observations are as follows:

STD ERR Y.X	.29455	
R SQUARED	.71472	
Y SUM SQRS	39.81330	
SUM SQR RES	3.90437	
IND VAR USED	05	
F TEST	13.325	h. sign.
CONSTANT TERM	3.12927	

IND VAR	COEF	STD ERR	T RATIO
5	.01409	.00520	2.70674
6	-.00023	$.81829 \times 10^{-4}$	-2.89263
12	-.06070	.02223	-2.73030
19	-.01475	.01364	-1.08105
21	$.14399 \times 10^{-7}$	$.24014 \times 10^{-8}$	5.99638

The results of this regression analysis lead to a snow-removal expenditure equation as follows:

$$Y = 3.12927 + (.01409)(X_5) - (.00023)(X_6) - (.06070)(X_{12}) - (.01475)(X_{19}) + (.14399 \times 10^{-7})(X_{21})$$

where Y is the computed snow-removal expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

The regression analysis of the maintenance sections with climatic factors of 1.00 and 1.05 was the only regression analysis that did not pick snowfall as a potent variable. This was expected to a certain extent since many of these maintenance sections are in deep river canyons such as the Salmon River Canyon near Riggins, Idaho and the Clearwater River Canyon from Lewiston, Idaho to the vicinity of Kooskia, Idaho.

The plot-back of the regression analysis of the snow-removal expenditures of maintenance sections with climatic factors of 1.00 and 1.05 showed that 33 per cent of the computed expenditures compared within $\pm$ 15 per cent of the actual expenditure of the respective maintenance section. This is somewhat lower than the percentage of comparisons for maintenance sections with a snow-removal expenditure under $2.50 per foot-mile and those sections with an average annual snowfall of less than 40 inches. Both the standard error Y.X and the coefficient of determination of this regression analysis are approximately the same as those determined by the regression analysis of snow-removal expenditures of less than $2.50 per foot-mile.

<u>Climatic factors 1.10 and 1.15</u>. The results of the regression analysis using 61 maintenance sections with a climatic factor of 1.10 and 1.15 are as follows:

STD ERR Y.X	1.20427	
R SQUARED	.94380	
Y SUM SQRS	2,769.56510	
SUM SQR RES	72.51335	
IND VAR USED	10	
F TEST	64.252	h. sign.
CONSTANT TERM	1.34971	

IND VAR	COEF	STD ERR	T RATIO
2	-.01209	.01900	-.63648
4	-.05274	.01799	-2.93138
5	.02493	.01372	1.81688
9	.03730	.02752	1.35525
11	.00486	11.95214	.00040
14	$-.78775\times10^{-4}$	$.29684\times10^{-4}$	-2.65372
16	.00105	.00021	4.78958
17	$.16660\times10^{-4}$	$.27981\times10^{-5}$	5.95416
18	$.24234\times10^{-4}$	$.12550\times10^{-4}$	-1.93093
19	.11807	.05159	2.28846

This regression analysis leads to a snow-removal expenditure equation of:

$$Y = 1.34971 - (.01209)(X_2) - (.05274)(X_4) + (.02493)(X_5) + (.03730)(X_9) + (.00486)(X_{11}) - (.78775\times10^{-4})(X_{14}) + (.00105)(X_{16}) + (.16660\times10^{-4})(X_{17}) - (.24234\times10^{-4})(X_{18}) + (.11807)(X_{19})$$

where Y is the computed snow-removal expenditure per foot-mile and the explanation of the X variables is found in Table IV of Appendix C on page 84.

The plot-back of the regression analysis of maintenance sections with a climatic factor of 1.10 or 1.15 showed that 49 per cent of the computed snow-removal expenditures compared within $\pm$ 15 per cent of the actual expenditure of the respective maintenance section. This is the largest percentage of any of the factors evaluated to compare within $\pm$ 15 per cent of the actual expenditure. The coefficient of determination is highly significant with a value of .94380. The standard error Y.X was slightly lower than the average of the regression analyses of those maintenance sections with an expenditure of over $2.50 per foot mile and those sections with an average annual snowfall of over 40 inches with a standard error of 1.20427 compared to 1.15787 and 1.35554.

III. TRAVELWAY-ROUTINE REPAIR EXPENDITURES

Travelway-routine repair expenditures are cost accounted by the Idaho Department of Highways to purpose code 1010. For a description of the work operations making up code 1010, refer to Table III of Appendix C on page 81.

The following variables as discussed in Chapter II were examined as to their influence on travelway-routine repair expenditures:

Mean maximum temperature
Mean minimum temperature
Total precipitation
Lane width
Type of surfacing
Surfacing age
Base thickness
Surfacing thickness
Percentage of roadway in cut
Percentage of roadway with guardrail
Average Daily Traffic (ADT)
Rural commercial volume as a percentage of ADT (% RCV)
Traffic classification factor
Degree days (below 32°F)
Snowfall
Elevation
Topography factor
Climatic factor
Minimum temperature * Precipitation
Minimum temperature * Surface type
Precipitation * Degree days
Precipitation * Snowfall
Precipitation * Elevation
Lane width * Surface type
Lane width * Surfacing age
Lane width * Base thickness
Lane width * Surfacing thickness
Lane width * ADT
Lane width * % RCV
Surface type * ADT
Surfacing age * ADT
Base thickness * ADT
Surfacing thickness * ADT
Percentage of roadway in cut * Snowfall
Percentage of roadway in cut * Elevation
ADT * % RCV
ADT * Traffic classification factor
% RCV * Traffic classification

The IBM 80-series multiple regression program was used to analyze the data.

Statewide Analysis

The first regression analysis of travelway-routine repair expenditures utilized 110 maintenance sections as shown in Table II of Appendix A on page 63. The results of the regression of travelway-routine repair expenditures for the entire state are as follows:

STD ERR Y.X	4.97214	
R SQUARED	.52129	
Y SUM SQRS	5,015.04780	
SUM SQR RES	2,422.77730	
IND VAR USED	11	
F TEST	1.920	h. sign.
CONSTANT TERM	17.77171	

IND VAR	COEF	STD ERR	T RATIO
5	-1.03812	.18005	-5.76548
10	.06803	.03101	2.19314
11	.06457	.04744	1.36107
17	.00152	.00055	2.76774
20	.00496	.00413	1.19910
21	.00085	.00091	.93335
29	.00025	$.57315 \times 10^{-4}$	4.46916
32	$.30860 \times 10^{-4}$	$.50699 \times 10^{-4}$	.60870
33	-.00017	.00010	-1.65587
37	-.00030	$.85439 \times 10^{-4}$	-3.58138
39	.12380	.04377	2.82815

The preceding regression analysis results lead to the following travelway-routine repair expenditure equation:

$$Y = 17.77171 - (1.03812)(X_5) + (.06803)(X_{10}) + (.06457)(X_{11}) + (.00152)(X_{17}) + (.00496)(X_{20}) + (.00085)(X_{21}) + (.00025)(X_{29}) + (.30860 \times 10^{-4})(X_{32}) - (.00017)(X_{33}) - (.00030)(X_{37}) + (.12380)(X_{39})$$

where Y is the computed expenditure per foot-mile and the explanation of the X variables is found in Table V of Appendix C on page 85.

In the above regression, the coefficient of determination was significant, but it was not highly significant. Only 52.1 per cent of the total variation in travelway-routine repair expenditures was accounted for by the independent variables. The plot-back of the regression analysis results showed that 31 per cent of the computed dependent variables compared within ± 15 per cent of the actual dependent variable.

Climatic Factor Analysis

In an attempt to increase the significance of the results, the highway maintenance sections were split according to climatic factors. The split by climatic factors was used since it yielded the best results in the snow-removal regression analyses.

Climatic factors of 1.00 and 1.05. The results of the regression analysis of travelway-routine repair expenditures on 51 highway maintenance sections with a climatic factor of 1.00 or 1.05 are as follows:

STD ERR Y.X	3.48382	
R SQUARED	.73640	
Y SUM SQRS	1,625.10610	
SUM SQR RES	436.93229	
IND VAR USED	014	
F TEST	7.670	h. sign.
CONSTANT TERM	-59.72928	

IND VAR	COEF	STD ERR	T RATIO
6	4.75927	2.23178	2.13249
12	.00198	.00437	.45434
13	-1.21639	.78565	-1.54825
16	.24572	.08227	2.98663
19	69.65636	38.83321	1.79373
24	-.00026	$.75555 \times 10^{-4}$	-3.57113
25	-.20800	.08885	-2.34090
27	-.01756	.01304	-1.34618
29	.00013	.00012	1.12417
30	.05129	.03301	1.55371
31	.00015	.00041	.36331
32	$-.27239 \times 10^{-5}$	$.50227 \times 10^{-4}$	-.05423
37	-.00040	.00012	-3.14107
39	.10630	.05590	1.90174

The preceding regression analysis results lead to the following travelway-routine repair expenditure equation:

$$Y = -59.72928 + (4.75927)(X_6) + (.00198)(X_{12}) - (1.21639)(X_{13})$$
$$+ (.24572)(X_{16}) + (69.65636)(X_{19}) - (.00026)(X_{24})$$
$$- (.20800)(X_{25}) - (.01756)(X_{27}) + (.00013)(X_{29})$$
$$+ (.05129)(X_{30}) + (.00015)(X_{31}) - (.27239\times10^{-5})(X_{32})$$
$$- (.00040)(X_{37}) + (.10630)(X_{39})$$

where Y is the computed travelway-routine repair expenditure per foot-mile and the explanation of the X variables is found in Table V of Appendix C on page 85.

The regression analysis of the highway maintenance sections with climatic factors of 1.00 or 1.05 yields a coefficient of determination of .73640 which is highly significant. The plot-back results of the regression analysis showed that 43 per cent of the computed dependent variables compared within ± 15 per cent of the respective actual dependent variables. This was an increase of 30 per cent over the plot-back results of the statewide analysis.

Climatic factors 1.10 and 1.15. The results of the regression analysis using 59 highway maintenance sections with a climatic factor of 1.10 or 1.15 are as follows:

STD ERR Y.X	4.79287	
R SQUARED	.68034	
Y SUM SQRS	2,825.87780	
SUM SQR RES	918.86617	
IND VAR USED	018	
F TEST	1.011	n.s.
CONSTANT TERM	94.63864	

IND VAR	COEF	STD ERR	T RATIO
2	-1.39116	.54639	-2.54607
5	-1.46790	.30944	-4.74367
10	.35795	.12697	2.81905
11	.12081	.06404	1.88630
13	1.72320	.78014	2.20883
14	9.53504	3.11380	3.06217
16	-.37156	.14151	-2.62558
17	.00319	.00165	1.92526
19	-22.25913	48.18836	-.46191
21	.00706	.00476	1.48069
23	.00481	.00344	1.39624
24	$.53630\times10^{-4}$	$.84523\times10^{-4}$	.63450

The results of the preceding regression analysis lead to the following travelway-routine repair expenditure equation:

$$Y = 94.63864 - (1.39116)(X_2) - (1.46790)(X_5) + (.35795)(X_{10}) + (.12081)(X_{11}) + (1.72320)(X_{13}) + (9.53504)(X_{14}) - (.37156)(X_{16}) + (.00319)(X_{17}) - (22.25913)(X_{19}) + (.00706)(X_{21}) + (.00481)(X_{23}) + (.53630\times 10^{-4})(X_{24})$$

where Y is the computed travelway-routine repair expenditure per foot-mile and an explanation of the X variables appears in Table V of Appendix C on page 85.

In the preceding regression the coefficient of determination was non-significant. This means that no statistical assurance was found that the variation of the dependent variable was influenced by the variation of the independent variables.

The plot-back results of the regression analysis show that 45 per cent of the computed dependent variables compared within ± 15 per cent of their respective dependent variables. This was an increase of 33 per cent over the plot-back results for the statewide analysis.

IV. TOTAL ROUTINE MAINTENANCE EXPENDITURES

The total maintenance expenditure for each highway maintenance section is comprised of a multitude of work operations. The majority of these work operations recur annually; however, a few recur irregularly. Inasmuch as the expenditures for only 3 years were used in this study, only those expenditures were included which occur annually. This avoided biasing the results by large irregular expenditures.

The following maintenance codes were included in the study:

1010 Travelway-routine repair
1025 Municipal maintenance contracts
1030 Shoulders and Side approaches
1032 Mowing
1033 Trash gathering
1034 Spraying and weed control
1040 Roadside and drainage routine
1050 Traffic services

1060 Snow and ice removal
1065 Sanding icy surface
1070 Bridge maintenance

The following maintenance codes were deleted from the analyses of total maintenance expenditures because of their non-uniform frequency of occurrence:

1000 Unusual or disaster maintenance
1020 Travelway surface repair
1021 Tear up and re-lay
1022 Half sole
1023 Seal coat
1045 Roadside and drainage - Extraordinary
1054 Signals and lighting
1055 Roadside parks and picnic areas
1071 Bridge painting
1080 Damage repair
1090 Maintenance general expense
1095 Maintenance and operation costs of yards and buildings
1099 Distribution of indirect charges

The following variables as discussed in Chapter II were investigated to determine their influence on the total routine maintenance expenditure for each highway maintenance section:

Mean maximum temperature
Mean minimum temperature
Total precipitation
Lane width
Type of surfacing
Surfacing age
Base thickness
Percentage of roadway in cut
Percentage of roadway with guardrail
Average Daily Traffic (ADT)
Rural commercial volume as a percentage of ADT (% RCV)
Traffic classification factor
Degree days (below $32^{o}F$)
Snowfall
Elevation
Topography factor
Climatic factor
Bridge area
Minimum temperature * Precipitation

Minimum temperature * Surface type
Precipitation * Degree days
Precipitation * Snowfall
Precipitation * Elevation
Lane width * Surface type
Lane width * Surfacing age
Lane width * Base thickness
Lane width * Surfacing thickness
Lane width * ADT
Lane width * % RCV
Surface type * ADT
Surfacing age * ADT
Base thickness * ADT
Surfacing thickness * ADT
Percentage of roadway in cut * Snowfall
Percentage of roadway in cut * Elevation
ADT * % RCV
ADT * Traffic classification factor
% RCV * Class
Precipitation * Bridge area
Snowfall * Bridge area

Statewide Analysis

The first regression analysis of the total routine maintenance expenditure per foot-mile utilized the 109 sections described in Table II of Appendix A on page 63. The results of the regression of total routine expenditures for the entire state are as follows:

STD ERR Y.X	6.26951	
R SQUARED	.86991	
Y SUM SQRS	$.27544 \times 10^{5}$	
SUM SQR RES	3,616.22660	
IND VAR USED	016	
F TEST	10.399	h. sign.
CONSTANT TERM	-.98001	

IND VAR	COEF	STD ERR	T RATIO
2	-.57026	.36550	-1.56023
3	1.51575	.54794	2.76626
11	.18427	.06393	2.88215
14	1.61779	.80308	2.01446
15	.03169	.00717	4.41905
18	1.71416	1.14306	1.49962
23	-.00153	.00033	-4.60955
24	.00550	.00254	2.16198
25	.00010	$.69298 \times 10^{-4}$	1.54174
30	-.77129	.14782	-5.21751
32	-.00045	.00037	-1.21169
33	$.68941 \times 10^{-4}$	$.68069 \times 10^{-4}$	1.02181

The preceding regression analysis results lead to the following total routine expenditure equation:

$$Y = -.98001 - (.57026)(X_2) + (1.51575)(X_3) + (.18427)(X_{11})$$
$$+ (1.61779)(X_{14}) + (.03169)(X_{15}) + (1.71416)(X_{18})$$
$$- (.00153)(X_{23}) + (.00550)(X_{24}) + (.00010)(X_{25})$$
$$- (.77129)(X_{30}) - (.00045)(X_{32}) + (.68941\times10^{-4})(X_{33})$$

where Y is the computed expenditure per foot-mile and the explanation of the X variables is found in Table VI of Appendix C on page 87.

In the preceding regression, the coefficient of determination is highly significant. The plot-back results of the regression analysis showed that 50 per cent of the computed expenditures compared within $\pm$ 15 per cent of the respective actual expenditure.

Climatic Factor Analysis

In an attempt to increase the significance of the results, the highway maintenance sections were split according to climatic factors. The split by climatic factors yielded the best results in the snow-removal regression analyses, and for that reason a similar split was again employed.

Climatic factors of 1.00 and 1.05. The results of the regression analysis of total routine maintenance expenditures on 51 highway maintenance sections with a climatic factor of 1.00 or 1.05 are as follows:

STD ERR Y.X	4.49020	
R SQUARED	.72108	
Y SUM SQRS	2,480.41400	
SUM SQR RES	705.66736	
IND VAR USED	15	
F TEST	4.79	h. sign.
CONSTANT TERM	-169.94617	

IND VAR	COEF	STD ERR	T RATIO
3	-1.58578	.59248	2.67650
4	-1.21916	.37982	-3.20983
9	-5.09637	1.97077	-2.58597
10	.39878	.11844	3.36682
12	.00563	.00358	1.56935
13	-2.40218	1.23680	-1.94224
14	6.06867	3.55934	1.70499
15	.00834	.00731	1.14010
19	177.78799	59.88920	2.96861
30	-1.65931	.64107	-2.58831
31	.09148	.05517	1.65815
35	.00150	.00080	1.87666
37	$-.86760\times10^{-4}$	$.34432\times10^{-4}$	-2.51971
39	-.00237	.00092	-2.57280
40	-.08866	.26412	-.33569

The results of the preceding regression lead to the following total routine expenditure equation:

$$\begin{aligned} Y = & -169.94617 + (1.58578)(X_3) - (1.21916)(X_4) - (5.09637)(X_9) \\ & + (.39878)(X_{10}) + (.00563)(X_{12}) - (2.40218)(X_{13}) \\ & + (6.06867)(X_{14}) + (.00834)(X_{15}) + (177.78799)(X_{19}) \\ & - (1.65931)(X_{30}) + (.09148)(X_{31}) + (.00150)(X_{35}) \\ & - (.86760\times10^{-4})(X_{37}) - (.00237)(X_{39}) - (.08866)(X_{40}) \end{aligned}$$

where Y is the computed total routine maintenance expenditure per foot-mile and the explanation of the X variables is found in Table VI of Appendix C on page 87.

The regression analysis of the highway maintenance sections with climatic factors of 1.00 or 1.05 yielded a coefficient of determination of .72108 which is highly significant. The plot-back results of the preceding regression analysis showed that 63 per cent of the computed expenditures compared within ± 15 per cent of the respective actual expenditures. This was an increase of 26 per cent over the plot-back results of the statewide regression.

<u>Climatic factors 1.10 and 1.15</u>. The results of the regression analysis using 58 highway maintenance sections with a climatic factor of

1.10 and 1.15 are as follows:

STD ERR Y.X	5.37189	
R SQUARED	.95054	
Y SUM SQRS	$.20643 \times 10^{-5}$	
SUM SQR RES	1,038.86220	
IND VAR USED	21	
F TEST	6.74	h. sign.
CONSTANT TERM	520.64711	

IND VAR	COEF	STD ERR	T RATIO
2	-1.34616	.60448	-2.22698
5	-20.84163	13.00391	-1.60272
6	6.83516	4.73727	1.44284
7	-.40584	.26992	-1.50354
9	-16.91857	7.32537	-2.30958
11	.42281	.08567	4.93491
16	-.49162	.18609	-2.64175
17	.00303	.00109	2.77608
19	-366.21425	265.73893	-1.37809
22	.02143	.00539	3.97472
23	-.00047	.00023	-2.01780
25	$.82845 \times 10^{-4}$	$.56462 \times 10^{-4}$	1.46725
26	-.42592	.21111	-2.01750
29	.96075	.34600	2.77674
30	17.17601	11.55914	1.48592
32	.00010	.00191	.05418
33	.00034	.00026	1.31497
34	.00049	.00019	2.53110
35	-.00146	.00290	-.50552
36	.00386	.00067	5.73747
40	.11602	.07153	1.62191

The results of the preceding regression analysis yielded the following total routine maintenance expenditure formula:

$$Y = 520.64711 - (1.34616)(X_2) - (20.84162)(X_5) + (6.83516)(X_6)$$
$$- (.40584)(X_7) - (16.91857)(X_9) + (.42281)(X_{11})$$
$$- (.49162)(X_{16}) + (.00303)(X_{17}) - (366.21425)(X_{19})$$
$$+ (.02143)(X_{22}) - (.00047)(X_{23}) + (.82845 \times 10^{-4})(X_{25})$$
$$- (.42592)(X_{26}) \pm (.96075)(X_{29}) + (17.17601)(X_{30})$$
$$+ (.00010)(X_{32}) + (.00034)(X_{33}) + (.00049)(X_{34})$$
$$- (.00146)(X_{35}) + (.00386)(X_{36}) + (.11602)(X_{40})$$

where Y is the computed total routine maintenance expenditure per foot-mile and the explanation of the X variables is found in Table VI of Appendix C on page 87.

The regression analysis of the highway maintenance sections with climatic factors of 1.10 or 1.15 yielded a coefficient of determination of .95054 which is highly significant. The plot-back results of the preceding regression analysis showed that 76 per cent of the computed expenditures compared within ± 15 per cent of the respective actual expenditures. This was an increase of 52 per cent over the plot-back results of the statewide regression.

CHAPTER IV

ANALYSIS OF RESULTS

The equations developed in Chapter III produce relationships which vary in their reliability. Several reasons exist for the variability of the validity of the equations, and any attempt to apply the equations should give recognition to their limitations.

I. SNOW-REMOVAL EXPENDITURES

Seven regression analyses were run in an attempt to better correlate the factors with the snow-removal expenditure. Each regression analysis calculated a different standard error of Y on X, coefficient of determination, and percentage of computed expenditures comparing within ± 15 per cent of the respective actual expenditure.

The question as to which regression actually was the best fit was one on which no reference could be found. The highest coefficient of determination was desirable, the lowest standard error of Y on X was desirable, and the highest plot-back percentage was desirable. The selection of the best fitting equation was determined from the three preceding comparisons. One of the objectives of this study was to develop formulas to predict future maintenance expenditures; therefore, it was deemed advisable to use the plot-back percentage as the determining condition, if the various comparisons did not agree.

Table I was prepared by multiplying each coefficient of determination, standard error of Y on X, and plot-back percentage by the number of observations used to determine these statistics. Thus all comparisons were based on 112 observations.

The regression analysis of the snow-removal expenditure, split at $2.50 per foot-mile, yielded the lowest standard error Y.X. The statewide regression analysis yielded the highest coefficient of determination, and the regression analysis of the climatic factor split yielded the highest percentage comparison within ± 15 per cent (controlling condition).

TABLE I. SNOW-REMOVAL REGRESSION COMPARISON

Regression	No. of Obser.	Coefficient of Determination	Standard Error Y.X	Plot-back Percentage Comparison ± 15%
Desired value		highest	lowest	highest
Statewide	112	94.69	97.32	31.3
Expenditure Split				
above $2.50	46	44.06	52.30	17.99
below 2.50	66	49.61	20.71	27.06
	112	93.67	73.01	45.05
Snowfall Split				
above 40 in.	63	57.96	85.40	25.01
below 40 in.	49	32.60	12.76	18.00
	112	90.56	98.16	43.01
Climatic Factor Split				
1.00 and 1.05	51	36.45	15.02	17.00
	61	57.57	73.46	30.00
	112	94.02	88.48	47.00

══ Denotes the best fitting regression analysis

Equations

The regression analysis of highway maintenance sections grouped by climatic factors was judged the best fit and the equations derived from it were used to explain snow-removal expenditures:

Climatic factors of 1.00 and 1.05. The highway maintenance sections with a climatic factor of 1.00 and 1.05 yielded the following equation:

$$Y = 3.12927 + (.01409)(X_5) - (.00023)(X_6) - (.06070)(X_{12}) - (.01475)(X_{19}) + (.14399\times10^{-7})(X_{21})$$

where Y is the snow-removal expenditure per foot-mile and the X variables are listed in their order of importance or potency as follows:

X_{21}	$(\text{Snowfall} * \text{Elevation})^{1.5}$
X_5	Percentage of roadway in cut
X_6	Elevation in feet above MSL
X_{12}	Mean minimum temperature
X_{19}	$(\text{Topographic factor})^2$

Of the 7 regression analyses of snow-removal expenditures, this was the only regression which did not pick average annual snowfall as the most potent variable. As mentioned in Chapter III, this is somewhat expected since the sections with a climatic factor of 1.00 lie principally in the deep river canyons where relatively mild winters are experienced.

Climatic factors of 1.10 and 1.15. The highway maintenance sections with a climatic factor of 1.10 and 1.15 yielded the following equation:

$$Y = 1.34971 - (.01209)(X_2) - (.05274)(X_4) + (.02493)(X_5) + (.03730)(X_9) + (.00486)(X_{11}) - (.78775\times10^{-4})(X_{14}) + (.00105)(X_{16}) + (.16660\times10^{-4})(X_{17}) - (.24234\times10^{-4})(X_{18}) + (.11807)(X_{19})$$

where Y is the snow-removal expenditure per foot-mile and the X variables are listed in their order of importance or potency as follows:

X_2 Snowfall in inches

X_{19} (Topographic factor)^2

X_{17} Snowfall * Elevation

X_{16} Snowfall * Per cent of roadway in cut

X_9 Lane width in feet

X_{11} Climatic factor

X_4 Per cent of roadway in cut

X_{14} Degree days * Mean minimum temperature

X_{18} Elevation * Total precipitation

X_5 Per cent of roadway with guardrail

Both snow-removal expenditure analyses using the section split by climatic factors yielded a highly significant coefficient of determination. This means that if any sample of the same size were drawn from the same population (all highway maintenance sections), the opportunity of obtaining the same results by mere chance would only be one in one-hundred. In other words, there is highly significant evidence that this relationship is not a result of chance. It must be remembered that the above model has been developed purely from a mathematical analysis of historical data. It was found that the data points that did not correlate well were scattered evenly over a wide range and this confirms a good random sample and satisfactory regression fit.

The significance of a multiple regression analysis depends heavily on the sample size. Larger samples generally yield better results. Therefore, if the resultant formulas were used to calculate the snow-removal expenditure for only one maintenance section, the resultant computed cost could be very much in error. However, with sample sizes equivalent to those used, confidence may be placed in the resultant formulas.

II. TRAVELWAY-ROUTINE REPAIR EXPENDITURES

Three regression analyses were run on travelway-routine repair expenditures. One regression analysis covered the entire state. The other two analyses utilized the same climatic factor split that was used in the analyses of snow-removal expenditures.

The regression analyses of travelway-routine repair expenditures utilized 39 independent variables as compared to the 22 independent variables used in the snow-removal expenditure analyses. As the computer solves a multiple regression problem utilizing matrix techniques, the complexity of the problem increases in the ratio of 39 squared to 22 squared. The cost involved with such an analysis also increases in this ratio.

The results of the regression analysis of the travelway-routine repair expenditures for the entire state were far below expectations. The F TEST showed the coefficient of determination to be barely significant. The standard error of Y on X (STD ERR Y.X) was high and the plot-back results showed that only 31 per cent of the computed expenditures compared within ± 15 per cent of the actual respective expenditures.

Since the split of maintenance sections by climatic factors yielded the best results in the snow-removal analyses, this split was again used in the travelway-routine repair expenditures. The results utilizing this split were far more significant than the results of the analysis of the entire state. The standard error of Y on X was reduced, the coefficient of determination was increased, and the percentage of plot-back comparing within ± 15 per cent was increased.

Equations

Because of the increased significance of the climatic factor split over the analysis of the entire state, the regression analyses of maintenance sections grouped by climatic factors was judged the best fit. The equations developed by these regression analyses were used to explain the travelway-routine repair expenditures.

<u>Climatic factors of 1.00 and 1.05.</u> The highway maintenance sections with a climatic factor of 1.00 or 1.05 yielded the following equation:

$$Y = -59.72928 + (4.75927)(X_6) + (.00198)(X_{12}) + (1.21639)(X_{13}) + (.24572)(X_{16}) + (69.65636)(X_{19}) - (.00026)(X_{24}) - (.20800)(X_{25}) - (.01756)(X_{27}) + (.00013)(X_{29}) + (.05129)(X_{30}) + (.00015)(X_{31}) - (.27239\times 10^{-5})(X_{32}) - (.00040)(X_{37}) + (.10630)(X_{39})$$

where Y is the travelway-routine repair expenditure per foot-mile and the X variables are listed below in their order of importance or potency:

X_{32}	Surfacing age * ADT
X_{16}	Snowfall
X_{30}	Lane width * Rural commercial volume as a percentage of ADT
X_{24}	Precipitation * Elevation
X_{39}	Rural commercial volume as a percentage of ADT * Traffic classification factor
X_{19}	Climatic factor
X_{25}	Lane width * Surfacing type
X_{31}	Surfacing type * ADT
X_{37}	ADT * Rural commercial volume as a percentage of ADT = Commercial Volume
X_{12}	Average Daily Traffic (ADT)
X_6	Surfacing type
X_{13}	Commercial Volume as a percentage of ADT
X_{27}	Lane width * Base thickness
X_{29}	Lane width * ADT

In the preceding regression analysis no single variable contributed the majority of the significance. This strongly contrasts with the snow-removal expenditure analyses, where snowfall was very dominant in all but one of the regression analyses.

Two of the variables which have direct relationship to truck volumes (X_{37} and X_{13}) show a notable difference from the usual relationship of heavy truck volumes inducing increased pavement maintenance. The minus partial regression coefficients (COEF) show that as the rural commercial volume increases the travelway-routine repair expenditures decrease. However, one variable which is also related to truck volumes (X_{39}) shows the opposite; that is, as the rural commercial volumes and traffic classification factor increase the maintenance expenditure also increases.

Climatic factors of 1.10 and 1.15. The highway maintenance sections with a climatic factor of 1.10 or 1.15 yielded the following equation:

$$
\begin{aligned}
Y = {} & 94.63864 - (1.39116)(X_2) - (1.46790)(X_5) + (.35795)(X_{10}) \\
& + (.12081)(X_{11}) + (1.72320)(X_{13}) + (9.53504)(X_{14}) \\
& - (.37156)(X_{16}) + (.00319)(X_{17}) - (22.25913)(X_{19}) \\
& + (.00706)(X_{21}) + (.00481)(X_{23}) + (.53630\times10^{-4})(X_{24}) \\
& + (.00042)(X_{29}) + (.00012)(X_{32}) - (.00242)(X_{35}) \\
& - (.14265\times10^{-4})(X_{36}) - (.00268)(X_{38}) - (.37438)(X_{39})
\end{aligned}
$$

where Y is the travelway-routine repair expenditure per foot-mile and the X variables are listed in their order of importance or potency as follows:

X_{32}	Surfacing age * ADT
X_{36}	Percentage of roadway in cut * Elevation
X_5	Lane width
X_{29}	Lane width * ADT
X_{11}	Percentage of roadway with guardrail

X_{39} Rural commercial volume as a percentage of ADT * Traffic classification factor

X_{38} ADT * Traffic classification factor

X_{24} Precipitation * Elevation

X_{19} Climatic factor

X_{14} Traffic classification factor

X_{16} Snowfall in inches

X_{13} Rural commercial volume as a percentage of ADT

X_{2} Mean maximum temperature

X_{10} Percentage of roadway in cut

X_{21} Mean minimum temperature * Surfacing type

X_{17} Elevation

X_{35} Percentage of roadway in cut * Snowfall

X_{23} Precipitation * Snowfall

The preceding regression picked independent variable X_{32} as the most potent variable, as did the previous regression of sections with a climatic factor of 1.00 or 1.05. However, the correlation between X_{32} and the expenditures was non-significant. Since there is no statistical assurance as to the validity of the data, no deductions may be drawn from the results to show factors which influence travelway-routine repair expenditures.

Generally travelway-routine repair expenditures (purpose code 1010) represent a catch-all code. This code includes patrol of the highway and many incidentals which will be discussed in Chapter V. For this reason it is not suggested that any confidence be placed in the equations developed.

III. TOTAL ROUTINE MAINTENANCE EXPENDITURES

As discussed in Chapter III, only those codes which occur regularly were included in these analyses. Codes which occur irregularly were deleted due to their biasing influences on the results. Forty-two independent variables were used in the three analyses of total routine maintenance expenditures.

The first regression analysis was of 109 highway maintenance sections throughout the state. Statistically the regression analysis was highly significant. The coefficient of determination of .87 was fairly high and the standard error of Y on X was within reason with a value of 6.27. However, the plot-back percentage comparing within ± 15 per cent was below expectation with a value of 50 per cent.

In an attempt to increase the significance of the results, the highway maintenance sections selected for study were split according to climatic factors. The climatic factors were used since they yielded the best fitting results of the snow-removal expenditures.

Equations

The results of the two regression analyses utilizing a climatic factor split yielded a higher coefficient of determination, a lower standard error of Y on X, and a much higher plot-back percentage comparing within ± 15 per cent than those determined by the statewide regression. Therefore, the regression analyses of the split by climatic factors were judged to be the best fitting regressions, and were used to explain the total routine maintenance expenditures.

Climatic factors of 1.00 and 1.05. The total routine maintenance expenditure equation developed utilizing 51 highway maintenance sections with a climatic factor of 1.00 or 1.05 was as follows:

$$Y = -169.94617 + (1.58578)(X_3) - (1.21916)(X_4) - (5.09637)(X_9) + (.39878)(X_{10}) + (.00563)(X_{12})$$

$$- (2.40218)(X_{13}) + (6.06867)(X_{14}) + (.00834)(X_{15})$$
$$+ (177.78799)(X_{19}) - (1.65931)(X_{30}) + (.09148)(X_{31})$$
$$+ (.00150)(X_{35}) - (.86760\times10^{-4})(X_{37}) - (.00237)(X_{39})$$
$$- (.08866)(X_{40})$$

where Y is the computed total routine maintenance expenditure per foot-mile and the X (independent) variables are listed in their order of importance or potency as follows:

X_{31}	Lane width * Rural commercial volume as a percentage of ADT
X_{10}	Percentage of roadway in cut
X_{12}	Average Daily Traffic
X_{40}	Rural commercial volume as a percentage of ADT * Traffic classification factor
X_{39}	ADT * Traffic classification factor
X_4	Total precipitation
X_{37}	Percentage of roadway in cut * Elevation
X_{19}	Climatic factor
X_3	Mean minimum temperature
X_9	Surfacing in thickness
X_{14}	Traffic classification factor
X_{30}	Lane width * ADT
X_{13}	Rural commercial volume as a percentage of ADT
X_{35}	Surfacing thickness * ADT
X_{15}	Degree days

The plot-back percentage comparing within $\pm$ 15 per cent was 63 per cent, which was 26 per cent greater than that determined by the statewide regression. The constant term is somewhat unreasonable with a value of -\$169.95 per foot-mile. This suggests that if all independent variables had a value of zero, it would pay the state \$169.95 per foot-mile to maintain a section of highway. Of course it is impossible for all the independent variables to be zero.

The percentage of the roadway in cut is a potent variable having a plus coefficient (COEF) in both equations. Thus as the percentage of the roadway in cut increases, the maintenance expenditure increases.

The other potent variables have either a plus or minus (COEF) and thus sometimes increase the cost and other times decrease the cost. The preceding regression analysis picked quite a few transformation variables (an arithmetic combination of independent variables). This suggests that the explanation of the total maintenance expenditures may be far more complex than originally anticipated.

<u>Climatic factors of 1.10 and 1.15</u>. The total routine maintenance expenditure equation developed utilizing 58 highway maintenance sections with a climatic factor of 1.10 or 1.15 was as follows:

$$\begin{aligned} Y = {} & 520.64711 - (1.34616)(X_2) - (20.84163)(X_5) + (6.83516)(X_6) \\ & - (.40584)(X_7) - (16.91857)(X_9) + (.42281)(X_{11}) \\ & - (.49162)(X_{16}) + (.00303)(X_{17}) - (366.21425)(X_{19}) \\ & + (.02143)(X_{22}) - (.00047)(X_{23}) + (.82845\times10^{-4})(X_{25}) \\ & - (.42592)(X_{26}) + (.96075)(X_{29}) + (17.17601)(X_{30}) \\ & + (.00010)(X_{32}) + (.00034)(X_{33}) + (.00049)(X_{34}) \\ & - (.00146)(X_{35}) + (.00386)(X_{36}) + (.11602)(X_{40}) \end{aligned}$$

where Y is the computed total routine maintenance expenditure per foot-mile and the X (independent) variables are listed in their order of importance or potency as follows:

X_{36} Percentage of roadway in cut * Snowfall

X_{33} Surfacing age * ADT

X_{30} Lane width * ADT

X_{11} Percentage of roadway with guardrail

X_7 Surfacing age

X_{22} Mean minimum temperature * Surface type

X_{23} Precipitation * Degree days

X_{17} Elevation

X_{35} Surface thickness * ADT

X_6 Surface type

X_{29} Lane width * Surface thickness

X_{34} Base thickness * ADT

X_{32} Surface type * ADT

X_9 Surface thickness

X_{26} Lane width * Surface type

X_{16} Snowfall

X_2 Mean maximum temperature

X_{40} Rural commercial volume as a percentage of ADT * Traffic classification factor

X_{25} Precipitation * Elevation

X_5 Lane width

X_{19} Climatic factor

In this regression the plot-back percentage comparing within $\pm$ 15 per cent was 76 per cent which was a 52 per cent increase over that obtained by regressing the entire state. The constant term is somewhat high with a value of \$520.65.

In the previous regression, an increase in Average Daily Traffic in all cases but one showed an increase in the total maintenance expenditure. An increase in elevation yielded an increase in total maintenance expenditures. Increases in percentage of roadway in cut and with guardrail yielded an increase in the total expenditure. The three most potent variables were tansformation variables. This again suggests a more complex problem than originally anticipated.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study has presented much data from many sources in pursuit of the objectives. Some of the data point to obvious and definite conclusions, while other data point to areas of future research.

Conclusions

From the analyses discussed in Chapters III and IV, the following conclusions are offered:

1. The data used in this study were random and evenly distributed about the regression equation thus assuring a good sample and a satisfactory regression fit.
2. The results reached in the analyses of snow-removal expenditures split by climatic factors are valid and the equations are found in Chapter IV on pages 43 and 44.
3. The results of the regression analyses of travelway-routine repair expenditures are not valid due to the statistical non-significance of the coefficient of determination.
4. The analyses of total routine maintenance expenditures are held to be valid based on the highly significant coefficient of determination and the high percentage of plot-back comparisons. The equations explaining total routine maintenance expenditures are found in Chapter IV on page 50.
5. Climatic conditions such as precipitation, snowfall temperature, etc. are the most potent variables in explaining maintenance expenditures.
6. The plot-back results of the regression analyses of this study were not as high as those obtained by the State of Louisiana (25). This is mainly due to the fact that climate was a very potent variable in every analysis and the State of Louisiana does not experience the climatic extremes which Idaho experiences.
7. As transformation variables (a mathematical combination of independent variables) proved to be such potent variables, it

appears the correlation between the expenditures and the influencing factors may be more complex than originally thought.

Recommendations

Based on the preceding conclusions and information from other sources, the following recommendations are offered:

Construction Practices. The construction of a new highway section is always followed by maintenance. The Idaho Department of Highways (26) defines highway maintenance as the preservation, upkeep, and restoration of each roadway, roadside, structure, and facility as nearly as possible in its original condition as constructed.

It is recognized that higher construction standards generally result in lower maintenance expenditures. It is recommended that a study be made to attempt to correlate various levels of design and construction standards with the maintenance expenditures so as to determine the optimum total highway cost. Such a study should include anticipated expenditure increases as shown in Figure 1 on page 2.

Surfacing type, surfacing age, and surfacing thickness were used as independent variables. However, the type or thickness of the surfacing material is not an indication of the adequacy of the pavement design. It is recommended that a variable indicating the adequacy of the pavement design be introduced in any future studies of this type.

Accounting Practices. The Accounting Section of the Idaho Department of Highways follows the AASHO recommendations as closely as possible. The yearly summary of maintenance expenditures is compiled on the Department of Highways' UNIVAC SS-90 Computer. These maintenance expenditures are totaled and printed by maintenance section, purpose code and district, and they show the participation by the Bureau of Public Roads. As the Bureau of Public Roads does not participate in maintenance, this is an unneeded portion of the program. The program used to compile maintenance expenditures is the same program used to compile construction expenditures in which the Bureau of Public Roads does participate.

It is suggested that the maintenance program be revised to delete the Bureau of Public Roads participation section and in its place compute a unit maintenance expenditure for each maintenance section, purpose code, and district. These unit expenditures would be in addition to the total computations. The total expenditures are needed for budget purposes, and the unit expenditures would be useful for performance indices and cost comparisons. A unit maintenance expenditure might have units of cost per mile, cost per lane-mile, or cost per foot-mile. The first two unit expenditures have the advantage of relatively simple calculations. The foot-mile unit expenditure has the advantage of realism and conformity since it takes roadway width into account. However, the foot-mile unit is not recognized by AASHO.

Maintenance Practices. Purpose code 1010 (travelway-routine repair) is a catch-all code; it includes patching the roadway surface, patrol of the section, trash collection, picking up beer bottles, removing dead animals from the roadway, etc. The factors (independent variables) used to explain travelway-routine repair expenditures in this study could not account for such a variety of work operations. As mentioned in Chapter III, the accuracy of a regression type analysis is largely dependent upon the accuracy of the dependent variable (in this case the unit maintenance expenditures.) The results of the analyses of travelway-routine repair expenditures were statistically non-significant, and the reason proposed for this is the varied activities covered by code 1010.

A regular patrol schedule is followed whereby a maintenance man travels the length of the highway maintenance section each workday. The amount of physical improvement or maintenance during this patrol is comparatively small. However, the patrol probably constitutes a significant amount of man-hours compared to the total man-hours devoted to routine maintenance. For this reason, it is recommended that a separate purpose code be set up for patrol. This new code would then account for time and equipment used in the patrol of highway maintenance sections and only for patrol. This patrol would include the daily drive over the highway maintenance section to detect items requiring attention. If the patrol was interrupted to perform an actual work operation, then the maintenance man would report his time and equipment to the code encompassing the work operation. This procedure would allow purpose code 1010 to more nearly cover items which would be much easier analyzed.

At present all maintenance charges incurred within a highway maintenance section are simply charged to the section and the appropriate code. Thus, if two miles of a section are in such condition as to warrant the majority of the maintenance effort, there is no way to identify this particular segment. The section may show a moderate unit maintenance expenditure when actually only a small portion of it needs the attention.

It would be a difficult and enormous task to break the state into smaller maintenance sections. Therefore, it is suggested that the District Maintenance Superintendents and/or their staff keep a continuous file of such segments of roadway requiring abnormal maintenance effort. If such a file were maintained, a regression analysis could be developed for these segments to permit a better correlation and understanding of the factors related to high maintenance costs.

Level of Service. This study presupposes that the level of maintenance service is uniform throughout the state. The study covered both primary and secondary roads. The question arises as to whether the level of service is actually the same for both classes of roads; and, for that matter, should the level of service be the same for both classes of roads. A further evaluation of maintenance costs might be made by splitting the primary and secondary systems for separate regression analyses.

Level of service is recognized in construction projects in the economic analysis. An attempt is made to select the construction project which insures benefits comparable to the costs of the project and future maintenance costs. A similar analysis might be made of the level of service provided by maintenance that is compatible with the benefits derived. A future study might be made in an attempt to correlate the benefits derived from the costs required to provide various levels of maintenance service.

Climate. There were thirteen regression analyses conducted in this study. Each regression picked factors related to climate as potent variables. Since weather and climate are not exact sciences, either in measurement or prediction, climate could be an area of extensive research. Such research could perhaps be carried out jointly with the United States Weather Bureau.

As discussed in Chapter II, the climatic factors are arbitrary numerical equivalents based on precipitation, degree days, temperature, and personal evaluations by District Engineers. These numerical equivalents are arbitrary and no work has been done in an attempt to refine them. This is an area for future research because, despite their arbitrary nature, they figured extensively in the regression analyses results of this study.

There are 128 weather stations in the State of Idaho (27) to give climatic data for the 4,892 miles of highway on the state system. It is very difficult to obtain an accurate measurement of the average climate for each and every highway maintenance section where the source data are so limited. Straight line averages between weather stations were used unless a disconforming land form was evident between stations. In this case the value was adjusted by an amount felt consistent with the degree of change produced by the land form. It is not known if this amount is correct. This could be an area of research which could also be coordinated with the United States Weather Bureau.

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REFERENCES CITED

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APPENDIX A

TABLE 11 COST, HIGHWAY CHARACTERISTIC, AND ENVIRONMENTAL DATA

DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
1	020-270	14.5545	8.7911	1.2741	254.388	254.388	1.0	0.00	14.33	0.57	33.84	8.85	2.04	8.04	1.01	1,430	110	7.69	4.15	11.0	1,000	28	5,200	26	54	1.05	0
1	020-305	13.7983	8.6148	0.8841	1,025.990	1,110.230	1.0	2.39	13.20	0.28	29.07	8.26	5.85	10.01	2.33	1,185	155	13.09	4.15	9.0	875	35	4,900	27	55	1.05	147
1	022-286	Deleted due to economic route planning																									
1	026-321	Deleted due to economic route planning																									
1	630-005	Deleted due to poor mileage correlation																									
1	730-274	Deleted due to economic route planning																									
1	730-300	Deleted due to economic route planning																									
1	730-351	34.2514	17.5655	5.2934	717.690	813.506	2.0	3.29	32.80	7.91	24.67	7.52	4.48	10.04	1.81	1,305	210	16.10	4.15	16.1	875	60	5,200	31	57	1.10	1,449
1	730-367	Deleted due to poor cost and weather data																									
1	730-397	Deleted due to poor cost and weather data																									
1	730-419	45.7966	33.1166	5.3128	450.504	525.726	2.0	3.57	33.40	12.14	21.26	4.96	5.50	20.46	2.46	893	100	11.20	4.15	15.1	1,000	66	6,100	26	54	1.10	153
1	034-006	23.6575	12.8097	1.7053	169.736	169.736	1.0	0.00	7.54	8.46	22.96	4.00	6.00	6.00	3.00	760	120	15.80	1.86	20.0	750	52	4,700	30	60	1.10	0
1	034-030c 034-053c	25.5742	17.0454	2.3565	1,172.451	1,287.313	2.0	2.63	40.62	10.41	25.24	9.92	4.37	11.36	1.74	567	104	18.34	1.86	16.3	960	55	5,500	30	57	1.10	3,101
1	034-096	Deleted due to economic route planning																									
1	034-116	Deleted due to poor cost data																									
1	036-034	Deleted due to poor mileage correlation																									
1	037-022	23.6119	18.1454	2.1706	487.103	531.289	2.0	1.94	24.70	0.00	20.97	4.75	2.50	16.45	1.15	325	60	18.47	1.86	14.6	600	50	4,800	30	59	1.10	0
1	037-039	Deleted due to gravel surfacing																									
1	037-063	19.0221	13.5447	1.2081	586.696	677.642	2.0	3.12	27.30	0.24	20.15	4.55	3.47	14.95	1.49	245	41	16.73	1.86	12.9	560	35	4,670	32	59	1.10	325
1	039-0[illegible]c 039-056c	17.8530	12.6748	0.9936	1,354.312	1,591.508	1.0	4.30	24.03	1.75	24.56	7.46	5.56	14.20	2.19	900	148	16.44	1.86	9.7	660	35	4,410	31	60	1.05	1,161
1	089-026	18.8761	8.8790	3.9123	703.892	796.052	2.0	3.55	15.93	0.37	25.58	10.77	6.00	14.22	2.45	1,260	113	8.96	1.86	16.5	1,000	65	6,000	28	56	1.10	983
1	089-044	39.3577	14.9516	7.2020	377.738	384.916	2.0	0.39	47.10	0.28	20.39	3.00	5.21	22.21	2.37	750	84	11.20	2.16	16.8	1,000	85	6,200	26	54	1.10	221
1	091-030	Deleted due to poor mileage correlation																									
1	091-054	Deleted due to poor weather data																									
1	191-014	Deleted due to poor mileage correlation																									
1	191-023	Deleted due to poor weather data																									
1	191-076	34.0783	22.1420	1.4956	526.580	587.530	2.0	7.16	37.72	3.05	23.04	6.75	7.67	19.07	4.04	3,910	521	13.33	4.15	15.0	725	40	4,700	31	60	1.10	0
1	191-101	Deleted due to poor mileage correlation																									
1	191-121	Deleted due to poor mileage correlation																									
2	021-124	Deleted due to poor mileage correlation																									
2	023-211	18.6402	6.5066	2.2070	496.165	533.225	2.0	1.69	8.70	0.16	22.65	4.91	4.46	15.68	1.98	372	58	15.60	1.86	13.3	850	70	4,900	29	56	1.10	328
2	024-008	22.4170	16.4300	0.5585	147.348	196.992	2.0	6.10	5.18	0.00	18.10	2.03	5.00	24.51	1.51	322	55	17.09	1.86	10.2	510	45	4,000	33	62	1.05	192
2	024-037	Deleted due to poor cost data																									
2	024-051	Deleted due to poor cost data																									
2	024-017	Deleted due to poor mileage correlation																									
2	025-177	10.0996	3.2172	0.3167	722.446	929.282	1.0	8.46	7.58	0.43	29.56	6.85	2.96	10.88	1.36	2,514	538	21.40	4.15	10.5	205	24	3,527	35	64	1.00	788

c - Two sections combined for study

TABLE 11 (continued)

DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
2	025-202	26.1173	12.8632	0.8198	674.905	717.917	2.0	1.74	3.24	0.08	26.28	8.15	2.59	11.72	1.22	2,260	383	16.96	4.15	9.5	230	28	3,925	35	64	1,00	112
2	025-226	13.4549	4.9163	0.6768	655.412	670.310	1.0	0.62	4.33	0.86	26.83	9.45	2.36	3.97	1.09	2,490	688	27.62	3.93	9.3	300	29	4,132	34	62	1.00	994
2	026-163	17.0201	7.7891	0.6588	317.968	344.908	2.0	2.41	6.70	2.28	28.38	5.15	2.42	11.36	1.25	1,000	85	8.50	3.05	11.2	300	28	3,422	34	63	1.00	473
2	026-180	23.4243	20.2501	0.8094	427.182	448.122	2.0	1.22	7.71	0.15	22.24	6.63	5.92	13.62	2.56	1,110	94	8.47	3.60	11.0	500	38	3,770	33	62	1.05	420
2	026-196	31.1294	14.6666	1.2732	302.392	389.742	2.0	5.42	3.36	0.10	18.77	4.76	2.20	23.78	1.18	926	100	10.80	4.15	10.5	575	41	4,140	31	60	1.05	293
2	026-218	28.6649	15.7619	2.1864	446.784	467.528	1.0	0.92	4.98	0.00	19.89	2.70	4.95	14.03	1.91	783	84	10.73	4.15	11.1	730	50	4,450	30	58	1.05	167
2	026-237	Deleted due to economic route planning																									
2	026-263	Deleted due to poor cost data																									
2	027-027	15.4624	9.2289	0.5069	600.531	586.197	1.0	5.86	7.30	0.00	18.26	6.12	5.29	19.41	2.20	1,272	152	11.94	1.86	10.2	350	26	4,300	34	62	1.00	2,736
2	030-151	Deleted due to poor mileage correlation																									
2	030-181	22.2609	9.1663	0.3018	816.970	892.159	2.0	2.64	27.23	15.50	28.69	7.13	2.71	11.28	1.28	1,156	120	10.39	3.05	10.2	200	22	3,535	36	64	1.00	8,617
2	030-198	Deleted due to poor cost data																									
2	030-222	18.3698	9.9195	0.8678	802.108	688.680	1.0	5.25	3.32	4.12	25.78	8.30	6.00	14.98	2.44	3,346	469	14.02	3.60	9.9	210	22	4,000	35	63	1.00	1,532
2	030-239	12.1941	7.9615	0.9855	603.768	494.146	1.0	1.02	4.22	0.66	32.04	9.89	3.64	8.15	1.77	3,480	500	14.37	4.15	9.7	290	25	4,100	35	63	1.00	0
2	730-003	Deleted due to poor cost data																									
2	730-253	Deleted due to poor mileage correlation																									
2	830-297	Deleted due to poor mileage correlation																									
2	046-032	Deleted due to poor mileage correlation																									
2	046-043	Deleted due to poor cost data																									
2	050-013	Deleted due to poor mileage correlation																									
2	068-163	Deleted due to poor mileage correlation																									
2	068-189	Deleted due to poor mileage correlation																									
2	074-046	21.1718	7.3466	0.5794	189.402	167.018	2.0	1.90	0.58	0.35	22.60	11.35	6.08	12.00	2.02	1,816	220	12.11	4.15	9.9	200	19	3,800	35	63	1.00	1,308
2	075-012	Deleted due to poor cost data																									
2	075-042	Deleted due to poor cost data																									
2	077-028	Deleted due to poor cost data																									
2	077-041	Deleted due to poor cost data																									
2	077-046	Deleted due to poor mileage correlation																									
2	079-011	24.5425	10.4332	0.7508	251.560	312.796	2.0	5.90	8.56	0.00	24.23	5.75	5.83	14.34	2.00	2,200	170	7.73	1.86	9.5	215	24	3,780	36	63	1.00	132
2	093-042	Deleted due to poor weather data																									
2	093-051	Deleted due to poor cost data																									
2	093-074	18.2791	4.4813	0.8293	490.803	706.353	2.0	9.20	15.97	0.00	20.94	7.14	5.72	21.56	2.29	1,705	185	10.85	3.05	10.1	350	35	3,880	34	63	1.00	2,690
2	093-105	10.2314	2.7328	1.6868	864.656	1,006.636	2.0	4.55	13.66	0.00	27.73	4.48	3.12	13.85	1.60	770	120	15.60	3.05	12.3	675	50	4,000	31	59	1.10	1,496
2	093-130	34.0923	20.9003	5.9419	477.642	609.510	2.0	5.61	2.78	0.38	20.33	5.40	5.57	29.47	2.50	1,190	142	11.93	2.26	20.0	1,000	94	5,400	27	57	1.15	993
2	093-164	33.1810	3.8839	15.0564	931.042	1,004.970	4.0	2.14	41.58	13.76	26.98	6.28	4.20	10.21	1.87	250	20	8.00	1.86	28.8	1,250	135	7,800	17	50	1.15	1,320
2	093-190	19.5413	7.8623	5.9718	691.566	691.566	2.0	0.00	14.99	4.58	25.99	5.50	1.00	5.51	0.75	260	20	7.69	1.86	18.1	1,500	75	6,800	19	52	1.15	1,229

TABLE 11 (continued)

DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
2	093-228	41.6834	17.4051	4.6879	828.071	828.071	4.0	0.00	63.85	7.91	21.99	4.00	1.00	7.21	0.75	280	20	7.14	1.86	16.7	1,450	60	5,800	23	54	1.15	3,344
2	093-245	10.9953	1.4989	0.1521	443.248	443.248	4.0	0.00	45.51	2.93	26.00	4.00	1.00	8.00	0.75	340	40	11.76	1.86	11.5	1,075	19	5,300	27	57	1.05	1,071
2	093-275	Deleted due to poor mileage correlation																									
2	993-028	19.9336	13.6249	0.9593	521.696	682.662	1.0	5.71	0.63	0.09	18.49	3.48	5.17	28.38	2.46	880	69	7.84	1.86	11.0	1,000	34	5,610	27	57	1.05	486
2	993-056	Deleted due to poor mileage correlation																									
2	993-079	Deleted due to poor weather data																									
3	015-020	Deleted due to economic route planning																									
3	015-034	Deleted due to poor weather data																									
3	015-053	Deleted due to poor weather data																									
3	015-087	24.1730	8.7635	5.1326	1,037.882	1,128.154	1.3	2.65	30.20	5.00	30.48	5.96	5.93	11.54	2.31	960	150	15.63	3.60	25.4	1,000	105	4,860	26	55	1.15	3,760
3	015-112	28.1948	9.7769	5.7572	501.960	653.983	2.0	6.16	20.57	1.94	20.32	9.04	5.92	24.73	2.50	1,090	113	10.60	3.49	25.1	1,000	113	4,860	25	54	1.15	1,040
3	016-045	17.1310	5.5294	0.4640	413.044	434.726	2.0	1.53	30.60	21.33	29.11	8.51	5.94	6.85	2.45	1,535	171	11.13	3.05	12.6	200	25	2,650	37	65	1.00	701
3	018-005	Deleted due to poor cost data																									
3	019-005	Deleted due to poor cost data																									
3	019-021	22.1886	7.9164	0.3405	254.084	319.344	1.0	5.69	0.34	0.24	22.16	3.85	5.56	22.97	2.28	2,400	370	15.41	1.86	9.7	200	16	2,370	36	64	1.00	186
3	020-002	Deleted due to poor cost data																									
3	020-022	15.7678	5.0681	0.5455	512.180	553.692	1.0	2.83	1.71	1.44	21.31	6.70	6.00	4.64	3.57	2,680	429	16.01	3.16	10.0	200	15	2,300	36	65	1.00	133
3	020-057	12.4391	6.1056	0.2390	754.330	990.960	1.0	10.02	4.13	1.85	31.95	12.33	6.00	11.60	2.38	4,665	698	14.97	4.15	12.2	200	13	2,500	36	64	1.00	2,824
3	021-022	19.5932	3.8152	1.1571	705.350	621.352	2.0	1.71	44.40	47.80	28.89	6.87	6.00	9.73	2.40	1,475	190	12.89	4.15	20.0	280	31	3,000	35	62	1.05	2,638
3	021-039	32.7570	13.4233	3.1012	335.940	410.778	2.0	4.46	50.68	2.82	20.00	5.84	5.61	22.93	2.50	560	70	12.50	4.15	25.0	850	95	4,900	30	62	1.15	1,850
3	021-079	Deleted due to poor cost data																									
3	021-112	Deleted due to new construction																									
3	030-009	Deleted due to poor mileage correlation																									
3	030-034	Deleted due to poor mileage correlation																									
3	030-053c 030-062c	26.3185	12.9957	0.3690	861.771	918.709	1.0	8.69	0.25	0.00	29.01	11.70	6.02	13.90	2.80	6,400	644	10.06	3.05	11.5	200	13	2,490	37	65	1.00	4,733
3	030-081	Deleted due to new construction																									
3	030-102	Deleted due to new construction																									
3	030-136	Deleted due to poor mileage correlation																									
3	730-001	Deleted due to poor mileage correlation																									
3	044-057	Deleted due to poor mileage correlation																									
3	045-028	19.7264	7.3127	0.2712	602.977	605.608	1.3	3.88	12.11	2.70	19.90	4.27	5.31	18.93	2.31	980	151	15.40	1.86	10.0	200	9	2,400	39	66	1.00	1,872
3	051-033	Deleted due to poor mileage correlation																									
3	051-073	Deleted due to poor mileage correlation																									
3	051-093	Deleted due to poor mileage correlation																									
3	052-001	Deleted due to poor mileage correlation and cost data																									
3	052-011	Deleted due to economic route planning																									

c - Two sections combined for study

TABLE 11 (continued)

DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
3	052-030	Deleted due to economic route planning																									
3	052-034	25.1391	12.3859	0.3398	90.938	101.252	1.0	3.16	8.33	0.00	27.90	6.17	5.74	21.34	2.77	2,600	380	14.61	3.05	13.4	200	14	2,450	38	66	1.00	1,086
3	052-054	20.6737	8.5198	0.5936	408.256	478.624	1.7	3.41	53.10	17.27	19.77	5.18	5.68	22.77	2.10	585	99	16.92	3.05	16.1	275	30	2,700	36	65	1.05	373
3	952-007	Deleted due to poor cost data																									
3	067-009	18.7583	21.9077	0.3405	218.784	361.370	1.0	15.64	0.00	0.00	24.00	4.00	5.00	20.00	2.50	5,600	460	8.22	3.05	10.0	200	21	3,160	35	65	1.00	0
3	068-134	Deleted due to economic route planning																									
3	069-010	14.8403	6.4451	0.1315	225.728	248.280	1.0	2.21	2.52	0.36	22.13	7.64	5.95	16.17	2.43	1,100	85	7.73	1.86	11.0	200	16	2,650	37	64	1.00	648
3	069-016	11.2095	1.9775	0.1351	72.000	72.000	1.0	0.00	0.00	0.00	24.00	4.00	5.00	33.00	2.50	1,250	150	12.00	1.86	12.5	200	14	2,600	37	64	1.00	0
3	069-018	23.9933	3.8715	0.3152	40.014	53.352	1.0	6.00	28.08	0.00	18.00	4.00	5.00	29.00	2.50	1,250	150	12.00	1.86	12.6	200	14	2,600	37	64	1.00	1,918
3	070-005	Deleted due to poor cost data																									
3	071-029	Deleted	Deleted	1.7529	755.290	755.290	4.0	0.00	66.50	10.58	26.19	6.00	1.00	4.00	0.75	243	40	16.46	3.05	18.0	515	45.	2,500	34	64	1.15	1,226
3	072-043	18.2618	7.3994	0.0611	379.704	454.576	1.0	4.67	8.55	3.33	23.68	6.57	6.00	13.11	2.48	1,970	161	8.18	4.15	10.0	200	8	2,480	38	63	1.00	2,987
3	073-013	Deleted due to poor cost data																									
3	095-026	Deleted due to poor cost data																									
3	095-035	Deleted due to poor weather data																									
3	095-047	Deleted due to new construction																									
3	095-049	Deleted due to economic route planning																									
3	095-063	39.9022	19.3766	0.7353	297.416	348.600	2.0	3.78	17.06	5.53	21.96	6.04	6.00	15.39	2.29	1,575	127	8.06	3.05	10.1	200	18	2,190	37	65	1.00	1,965
3	095-071	Deleted due to poor cost data																									
3	095-085	19.6943	9.7839	0.8021	294.868	375.912	1.0	5.88	1.47	0.00	21.41	6.20	6.00	24.43	2.42	1,940	204	10.51	3.05	11.8	200	24	2,140	37	65	1.00	1,147
3	095-113	Deleted due to new construction																									
3	095-140	28.3269	9.6168	2.5591	607.486	713.040	2.3	3.92	30.60	7.22	22.53	13.67	6.00	18.58	2.36	802	90	11.22	3.49	23.8	880	69	2,970	34	62	1.15	1,296
3	095-165	31.2458	13.3241	5.2443	583.644	676.283	2.0	3.67	55.90	0.09	23.11	9.78	6.00	15.91	2.19	605	95	15.70	3.71	26.9	970	85	3,500	30	59	1.15	1,219
3	095-187	27.2370	10.4334	3.8577	499.108	547.108	2.0	2.20	40.67	9.76	22.93	10.43	5.19	19.15	2.06	710	100	14.09	3.05	29.0	650	65	3,300	29	59	1.15	1,785
4	006-005	31.8084	25.4210	1.7708	84.180	101.188	2.0	3.74	78.90	0.00	18.52	4.00	5.09	31.18	2.91	500	55	11.00	1.86	24.6	200	48	2,600	33	60	1.10	0
4	007-270	Deleted due to gravel surfacing																									
4	007-278	Deleted due to gravel surfacing																									
4	007-291	Deleted due to gravel surfacing																									
4	007-324	Deleted due to poor weather data																									
4	007-344	Deleted due to poor weather and elevation data																									
4	007-364	Deleted due to gravel surfacing																									
4	008-002	23.1358	17.7566	2.4802	74.292	61.440	1.0	0.00	13.92	0.00	40.00	13.64	6.00	9.00	3.00	4,785	270	5.64	4.15	22.4	200	52	2,560	37	58	1.10	0
4	008-014	30.0924	19.9292	1.8336	274.890	308.102	2.0	2.87	37.58	4.96	23.75	10.83	6.00	14.36	2.13	1,200	130	10.83	1.86	22.7	200	57	2,600	36	58	1.10	767
4	008-037	Deleted due to poor weather data																									
4	011-070	Deleted due to economic route planning																									
4	011-095	Deleted due to economic route planning																									

TABLE II (continued)

DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
4	012-044	36.2432	18.5015	0.9469	638.124	765.288	2.0	3.99	64.80	6.95	20.01	7.76	6.00	25.43	2.49	1,345	218	16.20	4.15	17.6	200	17	900	39	66	1.00	835
4	012-067	Deleted due to poor cost data																									
4	012-075	18.5099	7.2984	0.4412	216.100	218.380	2.0	0.33	56.20	4.43	27.33	8.82	6.00	11.49	2.00	1,250	140	11.20	3.05	24.0	200	22	1,225	37	65	1.00	2,585
4	012-115	Deleted	10.1588	2.6670	992.314	997.304	4.0	0.12	67.95	0.35	24.43	9.47	1.06	4.38	0.76	405	33	8.15	4.15	33.4	200	45	1,550	36	64	1.10	1,376
4	012-146	Deleted due to poor cost data																									
4	012-176	Deleted	Deleted	14.6767	820.440	820.440	4.0	0.00	65.55	0.01	27.71	*	*	*	*	130	16	12.30	4.15	44.4	835	200	4,700	25	56	1.15	1,426
4	013-090	19.5809	8.7113	0.7086	357.912	357.912	3.4	0.00	58.10	15.20	24.00	4.80	6.00	9.00	2.40	806	82	10.17	3.78	23.8	200	22	1,500	36	64	1.00	411
4	013-100	35.2429	21.4510	2.8440	251.716	252.588	2.0	0.08	58.18	23.07	22.48	6.92	5.86	15.98	2.13	1,005	80	7.96	4.15	22.2	200	49	3,100	35	59	1.10	0
4	014-140	Deleted due to gravel surfacing																									
4	042-009	Deleted due to economic route planning																									
4	043-010	Deleted due to poor weather data																									
4	043-057	Deleted due to poor weather data																									
4	062-082	Deleted due to economic route planning																									
4	064-014	Deleted due to poor cost data																									
4	064-031	Deleted due to poor cost data																									
4	066-001	Deleted due to poor mileage correlation																									
4	095-213	25.7494	7.6504	0.4482	730.910	763.410	2.0	1.27	60.27	10.39	28.67	7.68	2.09	8.99	1.05	660	105	15.91	3.05	18.4	200	11	1,840	40	66	1.00	1,784
4	095-238	28.5821	7.6216	0.4167	574.026	619.174	4.0	1.83	67.98	20.71	23.22	4.73	3.62	11.95	1.24	660	105	15.91	3.05	15.0	200	15	2,000	36	62	1.00	696
4	095-252	62.1511	27.4691	10.8608	308.534	308.534	4.0	0.00	63.38	18.10	22.22	3.55	5.03	5.97	1.53	670	110	16.41	4.15	18.0	200	75	3,800	34	57	1.10	0
4	095-286	26.7943	14.8487	2.6230	853.548	874.412	2.0	0.64	32.58	0.69	26.27	13.21	6.00	6.82	2.67	1,045	115	11.00	3.05	23.9	200	45	4,000	33	57	1.10	324
4	095-301	32.8177	13.8145	3.9264	466.948	500.122	2.0	1.97	32.32	20.94	27.75	10.12	6.00	8.58	2.43	947	88	9.29	3.05	21.8	200	58	4,000	32	57	1.10	0
4	095-331	19.8603	9.3498	0.8278	815.596	874.254	2.0	2.18	31.05	19.18	30.35	10.01	4.25	13.04	1.79	1,505	177	11.76	3.05	16.8	200	20	1,000	37	65	1.00	6,209
4	095-348	33.8220	15.5702	1.4819	402.802	447.902	4.0	2.79	61.05	45.10	24.90	9.82	5.31	14.80	2.65	1,935	153	7.91	4.15	16.6	200	39	2,000	38	63	1.05	0
4	095-363	21.5427	10.5889	1.6109	411.787	425.779	2.0	0.90	23.77	0.00	26.62	11.03	6.00	15.79	2.40	1,598	176	11.00	4.15	23.3	200	52	2,700	36	60	1.10	248
4	095-389	36.6514	13.9861	2.6491	644.292	696.684	2.0	2.02	44.50	19.75	24.86	10.41	6.02	18.93	2.24	2,127	149	7.00	4.15	26.0	200	55	2,600	35	59	1.10	890
4	995-400	Deleted due to poor weather data																									
4	099-013	Deleted due to gravel road																									
4	410-003	Deleted due to being entirely within the city limits of Lewiston, Idaho																									
5	001-555	14.4949	9.0126	1.3840	224.200	269.040	2.0	4.00	25.40	21.60	20.00	6.82	6.00	23.00	2.00	250	20	8.00	3.05	21.4	600	66	1,750	34	57	1.10	0
5	002-015	31.0267	14.2519	4.5155	415.810	456.412	2.0	2.79	37.80	32.89	28.61	6.10	6.00	11.93	2.57	1,740	156	8.96	3.60	27.5	360	75	2,000	34	57	1.10	3,536
5	002-029	41.1664	22.1937	3.3394	271.348	352.290	2.0	5.72	42.30	12.86	19.17	8.13	6.00	26.79	2.45	1,170	120	10.25	3.05	29.1	370	74	2,000	34	57	1.10	1,163
5	002-549	42.4894	7.9841	2.6153	379.648	455.958	2.0	4.44	45.40	13.11	22.10	4.20	5.31	10.87	2.97	992	110	11.10	3.05	24.6	590	75	2,100	34	57	1.10	570
5	003-462	23.4167	6.9794	1.5533	457.684	502.506	2.0	2.03	43.55	14.05	20.76	5.00	6.00	12.00	2.00	480	40	8.33	3.05	26.4	275	45	2,150	34	60	1.10	2,021
5	004-005	40.8107	17.2018	4.7266	129.428	142.308	4.0	1.99	42.50	0.59	20.02	3.81	6.02	19.19	2.81	1,006	75	7.46	1.86	39.8	500	93	3,500	33	57	1.15	360
5	005-019	41.2165	21.1760	2.8343	366.508	459.182	2.0	4.78	63.55	15.44	18.91	9.94	5.98	25.62	2.49	838	110	13.12	3.05	25.5	280	45	2,150	34	60	1.10	2,394
5	010-013	35.9484	19.1801	3.9009	573.228	753.378	1.0	14.81	27.70	8.74	47.11	6.70	9.45	16.77	6.53	4,051	341	8.41	4.15	24.8	200	46	2,150	36	59	1.10	1,716

* Items not listed in Federal Aid Log

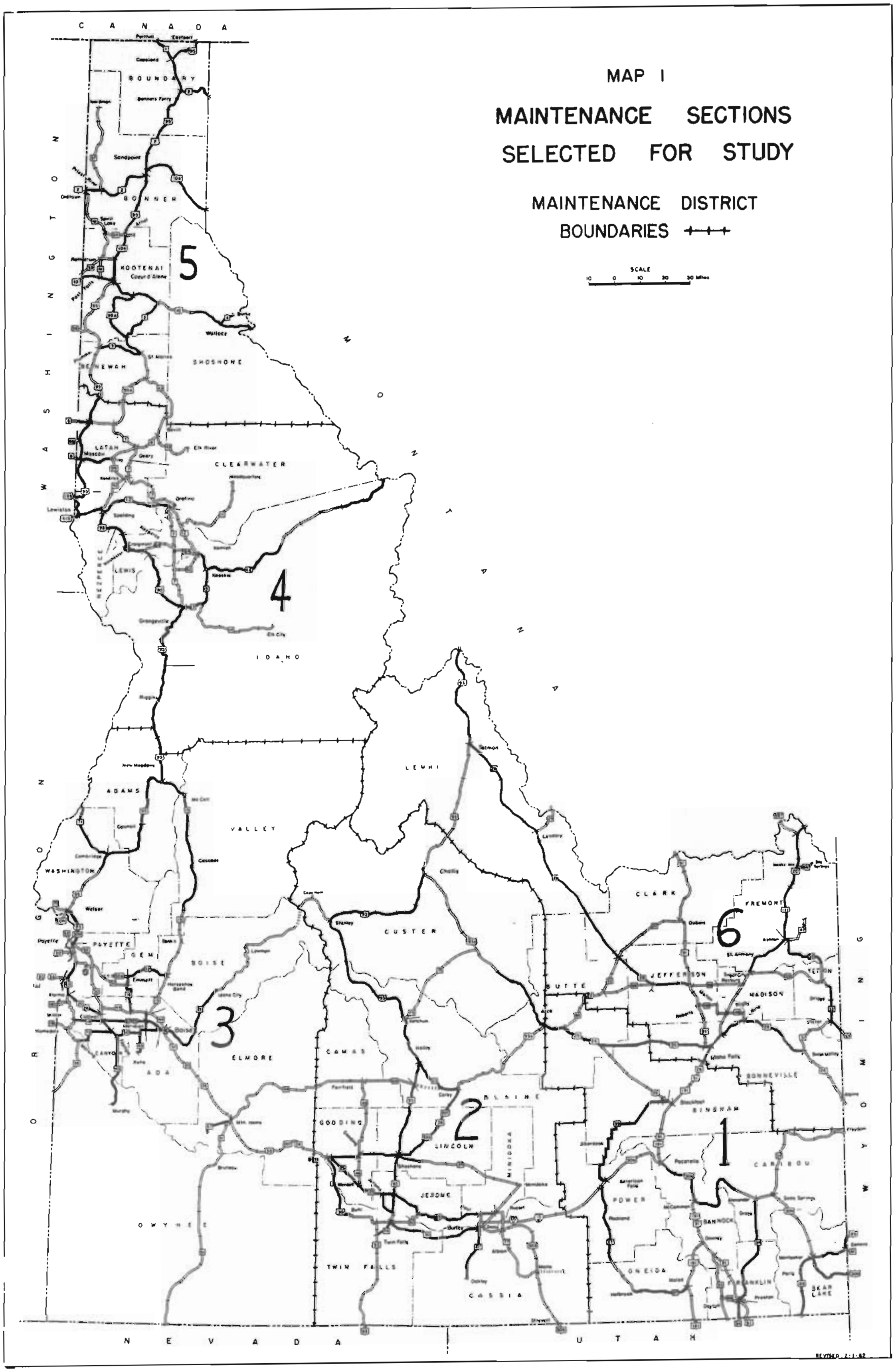
TABLE II (continued)

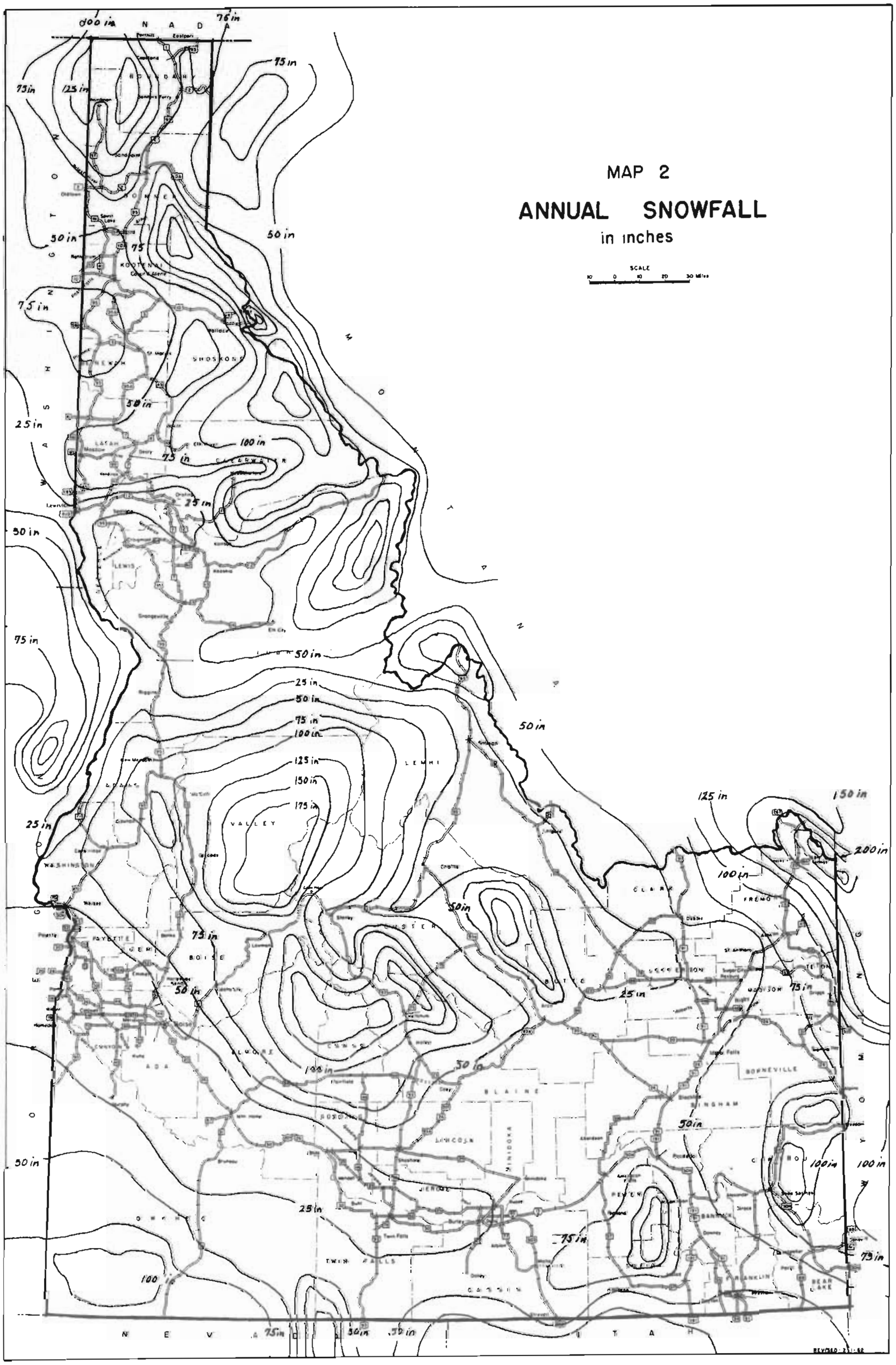
DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
5	010-035	33.4269	6.9723	5.4340	1,317.874	1,383.967	2.0	2.99	63.62	62.02	59.64	7.09	6.00	6.38	3.58	2,043	199	9.73	4.15	33.6	240	75	2,600	34	59	1.10	8,676
5	010-052	Deleted due to new construction																									
5	010-063	35.5356	20.4411	3.7420	419.902	513.086	2.0	8.33	15.92	84.51	37.52	7.82	5.99	14.80	2.33	2,743	224	8.16	4.15	36.7	465	65	2,520	35	59	1.10	1,227
5	010-076	156.1005	28.0247	24.9770	283.454	320.493	4.0	2.87	73.50	41.17	21.98	8.74	5.94	13.92	2.51	2,462	328	13.32	4.15	42.0	555	220	4,000	32	52	1.15	2,551
5	910-013	Deleted due to poor mileage correlation																									
5	910-063	39.2896	18.4286	2.8556	667.396	873.256	2.0	6.19	46.10	15.66	20.06	5.96	5.05	20.78	1.65	958	92	9.61	4.15	31.9	500	72	2,110	34	57	1.10	1,900
5	041-008	Deleted due to poor weather data																									
5	041-019	Deleted due to poor weather data																									
5	041-039	Deleted due to poor weather data																									
5	043-032	Deleted due to poor weather data																									
5	053-009	Deleted due to poor weather data																									
5	053-014	Deleted due to economic route planning																									
5	054-016	Deleted due to poor mileage correlation																									
5	057-037	Deleted due to economic route planning																									
5	058-003	Deleted due to poor cost data																									
5	060-006	Deleted due to economic route planning																									
5	095-414	Deleted due to poor weather data																									
5	095-428	Deleted due to poor mileage correlation and weather data																									
5	095-448	Deleted due to poor mileage correlation and weather data																									
5	095-470	19.8738	11.8584	2.7533	524.278	752.590	1.0	10.33	7.75	0.00	23.73	5.30	5.43	20.03	2.32	2,570	216	8.41	3.30	25.0	200	53	2,300	35	59	1.10	844
5	095-493	22.9657	10.6293	2.9100	738.130	799.581	1.0	2.60	34.78	24.54	31.29	7.04	5.87	9.19	2.27	2,048	285	13.90	3.05	26.7	390	67	2,300	34	58	1.10	20,481
5	095-511	46.0564	14.7778	3.5963	409.074	465.732	1.0	3.32	13.41	20.44	23.97	15.36	6.00	13.62	2.49	1,937	204	10.53	4.15	30.0	490	77	2,300	34	57	1.10	1,032
5	095-528	47.8759	19.3056	2.9046	367.950	448.062	2.0	4.68	30.80	25.81	21.48	7.50	6.00	22.04	2.45	1,820	187	10.27	4.15	26.0	550	82	2,000	34	58	1.10	1,691
5	095-544	39.8515	13.1207	1.4435	347.797	413.309	2.0	4.22	39.63	19.30	22.41	9.58	5.82	23.84	2.49	1,388	96	6.92	3.05	21.2	580	70	1,900	34	57	1.10	2,996
5	095-559	41.5470	7.2891	3.5496	312.940	375.528	2.0	4.00	36.48	8.75	20.00	4.50	6.00	26.00	2.50	730	60	8.22	3.05	19.9	600	77	2,100	34	57	1.10	1,264
5	995-415	Deleted due to poor weather data																									
5	995-429	Deleted due to poor weather data																									
5	995-440	27.8336	21.0445	0.9151	232.121	247.123	2.0	1.34	42.60	11.87	20.75	5.64	5.75	15.10	1.68	560	46	8.22	3.05	25.5	310	42	2,150	35	60	1.10	1,533
5	995-476	29.2174	7.7951	2.9047	775.811	778.988	3.7	0.08	70.80	14.25	21.56	5.64	2.23	12.74	1.08	252	21	8.34	1.86	25.2	260	49	2,350	35	60	1.10	2,126
6	020-328	21.9984	8.0139	1.5070	737.816	747.296	1.0	0.42	30.81	0.76	32.48	9.92	6.00	7.16	2.40	1,356	216	15.94	4.15	9.7	850	40	4,800	30	58	1.05	0
6	022-308	Deleted due to poor mileage correlation																									
6	022-338	Deleted due to economic route planning																									
6	026-347	11.5298	0.6535	0.8177	382.774	382.774	1.0	0.00	0.01	0.00	32.97	12.00	6.00	8.00	2.40	1,650	140	8.49	3.05	9.7	1,000	35	4,900	31	57	1.05	133
6	026-376	26.7161	5.3299	5.3477	810.546	881.354	2.0	2.51	42.45	10.53	28.73	7.29	2.99	8.55	1.38	1,000	110	11.00	3.05	13.9	1,000	60	5,130	29	57	1.10	1,554
6	026-401	Deleted due to economic route planning																									
6	028-185	14.5566	6.3787	1.3059	766.620	859.752	1.0	3.04	2.25	0.00	25.01	7.15	3.77	9.79	1.67	601	96	15.99	3.60	9.6	980	28	4,900	26	58	1.05	1,251

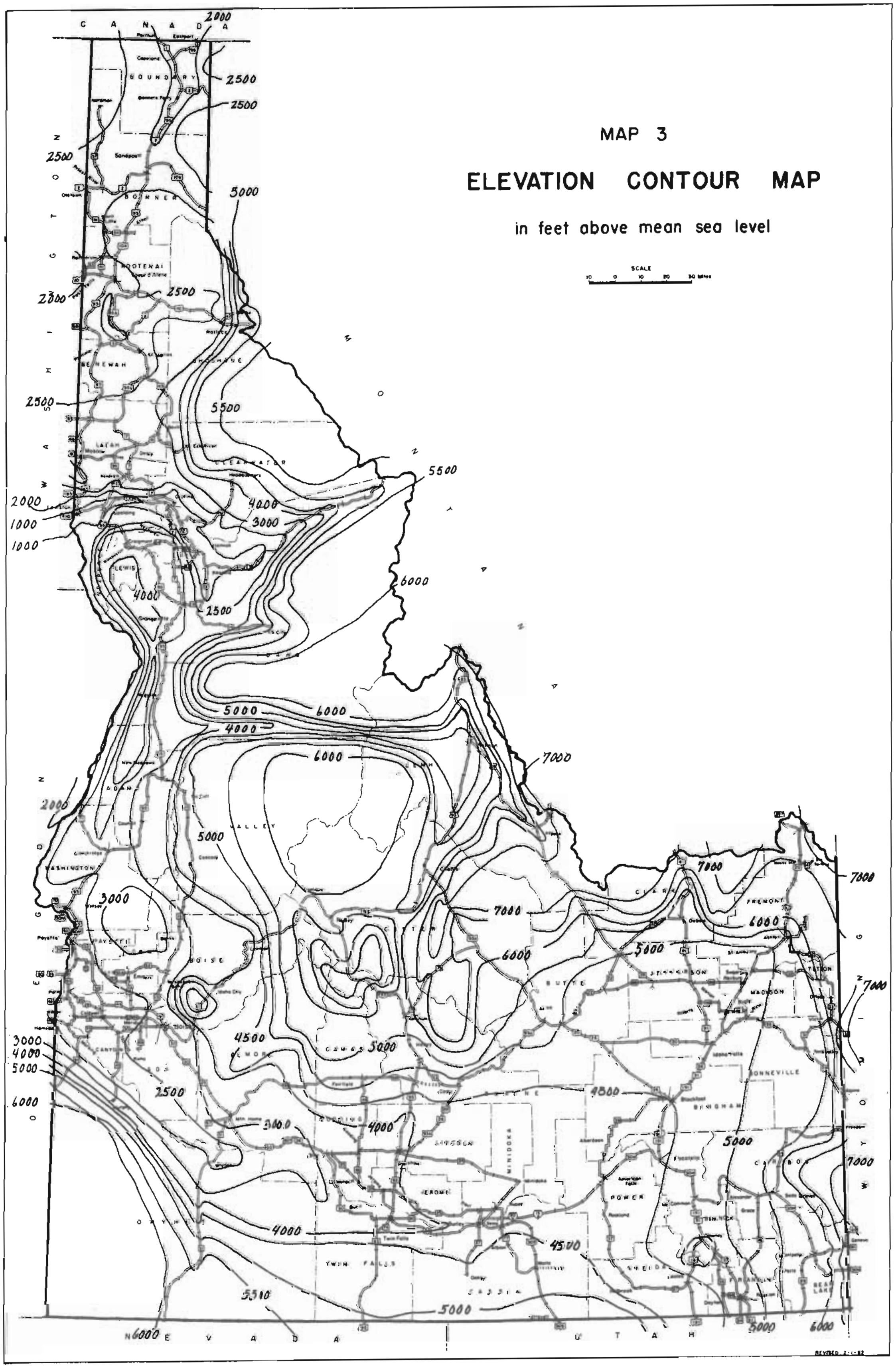
TABLE II (continued)

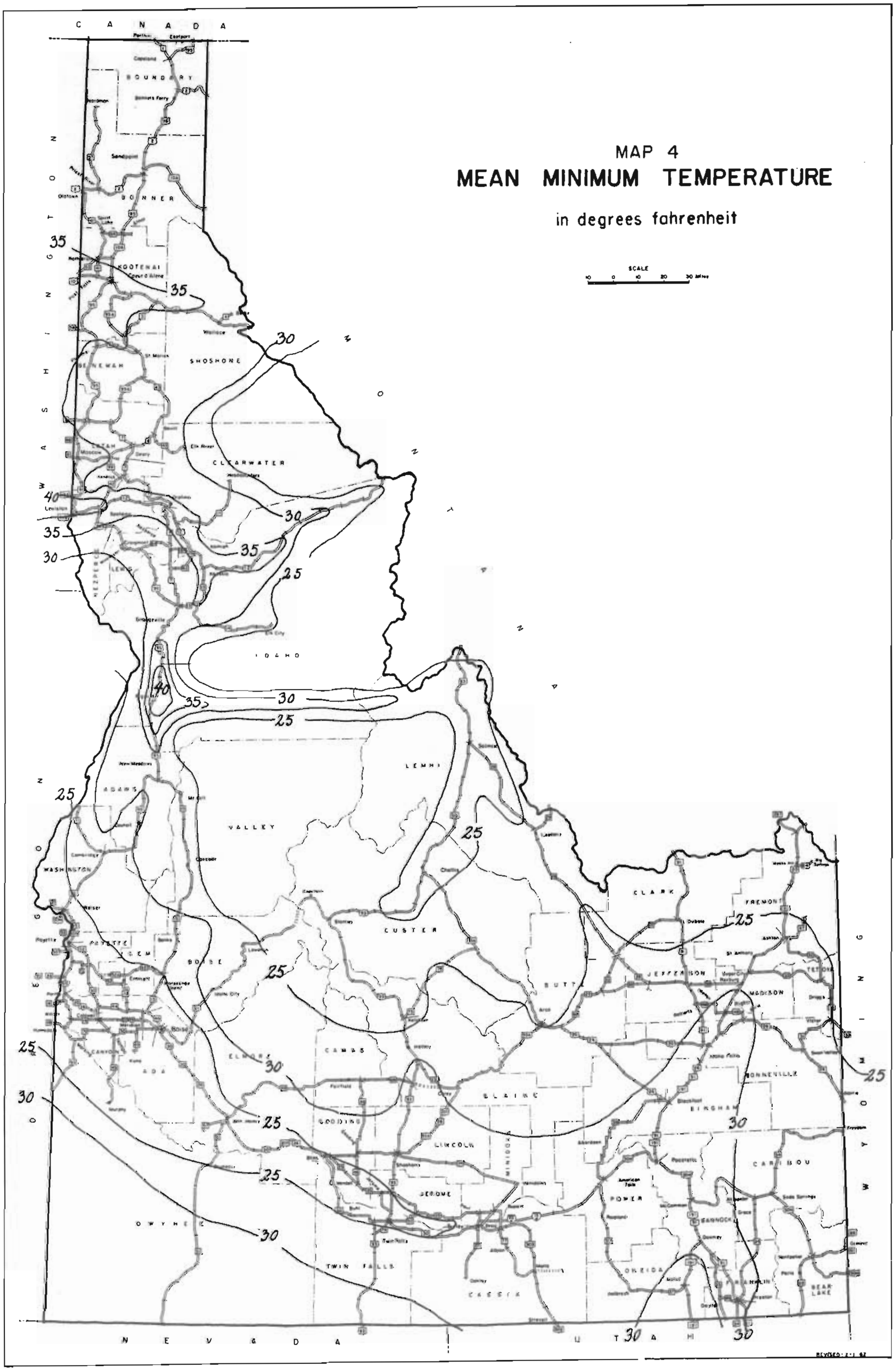
DISTRICT	SECTION	TOTAL COST PER FOOT MILE	1010 COST PER FOOT MILE	1060 COST PER FOOT MILE	SURFACE FOOT MILES	ROADWAY FOOT MILES	TOPOGRAPHY	SHOULDER WIDTH (FT.)	% ROADWAY IN CUT	% ROADWAY WITH GUARDRAIL	AVERAGE LANE WIDTH (FT.)	AVERAGE BASE THICKNESS (IN.)	AVERAGE SURFACE TYPE	AVERAGE SURFACE AGE (YRS.)	AVERAGE SURFACE THICKNESS (IN.)	AVERAGE DAILY TRAVEL	RURAL COMMERCIAL VOLUME	% RURAL COMMERCIAL VOL.	TRAFFIC CLASSIFICATION FACTOR	AVERAGE ANNUAL PRECIPITATION (IN.)	DEGREE DAYS	AVERAGE ANNUAL SNOWFALL (IN.)	MEAN ELEVATION (FT.)	AVE. ANNUAL MEAN MINIMUM TEMP.	AVE. ANNUAL MEAN MAXIMUM TEMP.	CLIMATIC FACTOR	SQUARE YARDS OF BRIDGE AREA
6	028-245	14.0995	10.3365	2.7250	1,351.452	1,683.598	1.0	5.58	10.31	0.20	22.70	2.96	1.68	16.37	0.96	227	35	15.41	4.15	11.8	1,000	45	6,600	24	54	1.05	88
6	028-291	17.0218	8.5680	1.1563	1,248.186	1,392.210	1.0	3.17	2.56	1.35	27.49	5.98	2.10	9.16	1.10	490	76	15.51	4.15	12.2	1,000	30	5,000	26	57	1.05	2,132
6	029-258	Deleted due to economic route planning																									
6	031-021	Deleted due to poor weather data																									
6	032-008	Deleted due to poor weather data																									
6	032-030	20.0853	7.8751	7.7378	488.126	565.440	2.0	3.59	20.18	2.09	22.64	7.16	5.50	8.80	2.04	321	45	14.02	1.86	16.5	1,150	82	5,500	26	55	1.15	1,015
6	033-178	Deleted due to economic route planning																									
6	033-192	Deleted due to economic route planning																									
6	033-215	23.0853	5.3615	5.3705	551.489	630.449	2.0	3.48	5.55	1.74	24.33	7.60	5.84	12.30	2.30	723	48	6.64	1.86	22.2	1,100	74	6,100	25	54	1.15	590
6	047-012	Deleted due to economic route planning																									
6	048-024	Deleted due to economic route planning																									
6	084-005	Deleted due to seasonal operation																									
6	287-240	Deleted due to gravel surfacing																									
6	088-314	Deleted due to poor mileage correlation																									
6	088-340	Deleted due to poor cost data																									
6	088-349	Deleted due to poor mileage correlation																									
6	091-154	Deleted due to new construction																									
6	091-180	Deleted due to new construction																									
6	091-210	Deleted due to new construction																									
6	093-306	Deleted due to economic route planning																									
6	093-327	25.0384	9.7660	1.6586	491.116	590.766	2.0	4.62	27.82	4.97	22.78	3.50	5.24	14.38	2.26	730	50	6.85	4.15	11.9	1,000	20	3,900	28	59	1.05	1,516
6	093-352	53.4610	14.7806	13.2760	588.874	588.874	4.0	0.00	59.33	2.81	23.81	4.98	5.49	8.99	2.00	464	39	8.40	4.15	21.7	1,010	120	6,000	26	56	1.15	516
6	191-127	30.9070	24.8528	1.1668	159.300	220.222	1.0	10.00	3.80	0.24	24.00	6.33	6.21	22.93	1.55	6,586	620	9.41	3.05	9.9	940	40	4,700	32	58	1.05	0
6	191-132	37.6383	26.4798	0.9799	197.982	117.296	1.0	13.06	0.65	0.00	26.14	8.43	6.00	10.36	2.86	4,743	255	5.38	3.05	9.9	990	33	4,750	31	57	1.05	168
6	191-160	Deleted due to poor cost data																									
6	191-182	27.6092	14.1572	3.8573	502.819	568.107	1.0	3.14	4.48	3.06	24.17	6.38	5.94	13.40	2.25	2,438	192	7.88	4.15	13.6	1,050	65	5,030	28	56	1.10	3,016
6	191-210	31.4261	14.7865	12.5194	550.285	811.300	3.0	13.00	35.90	15.19	27.42	10.84	6.00	5.89	3.13	1,164	100	8.59	4.15	22.6	1,200	110	5,600	24	54	1.15	1,879
6	191-222	34.7108	34.4476	10.1596	291.552	461.624	2.0	14.00	29.93	0.39	24.00	6.00	5.00	13.00	2.00	1,100	100	9.09	4.15	33.1	1,300	150	6,100	22	52	1.15	960
6	191-236	27.5662	5.0406	19.8513	504.146	504.146	2.0	0.00	18.32	1.99	37.37	8.07	1.00	4.70	0.75	890	75	8.43	4.15	34.0	1,300	200	6,800	20	50	1.15	242

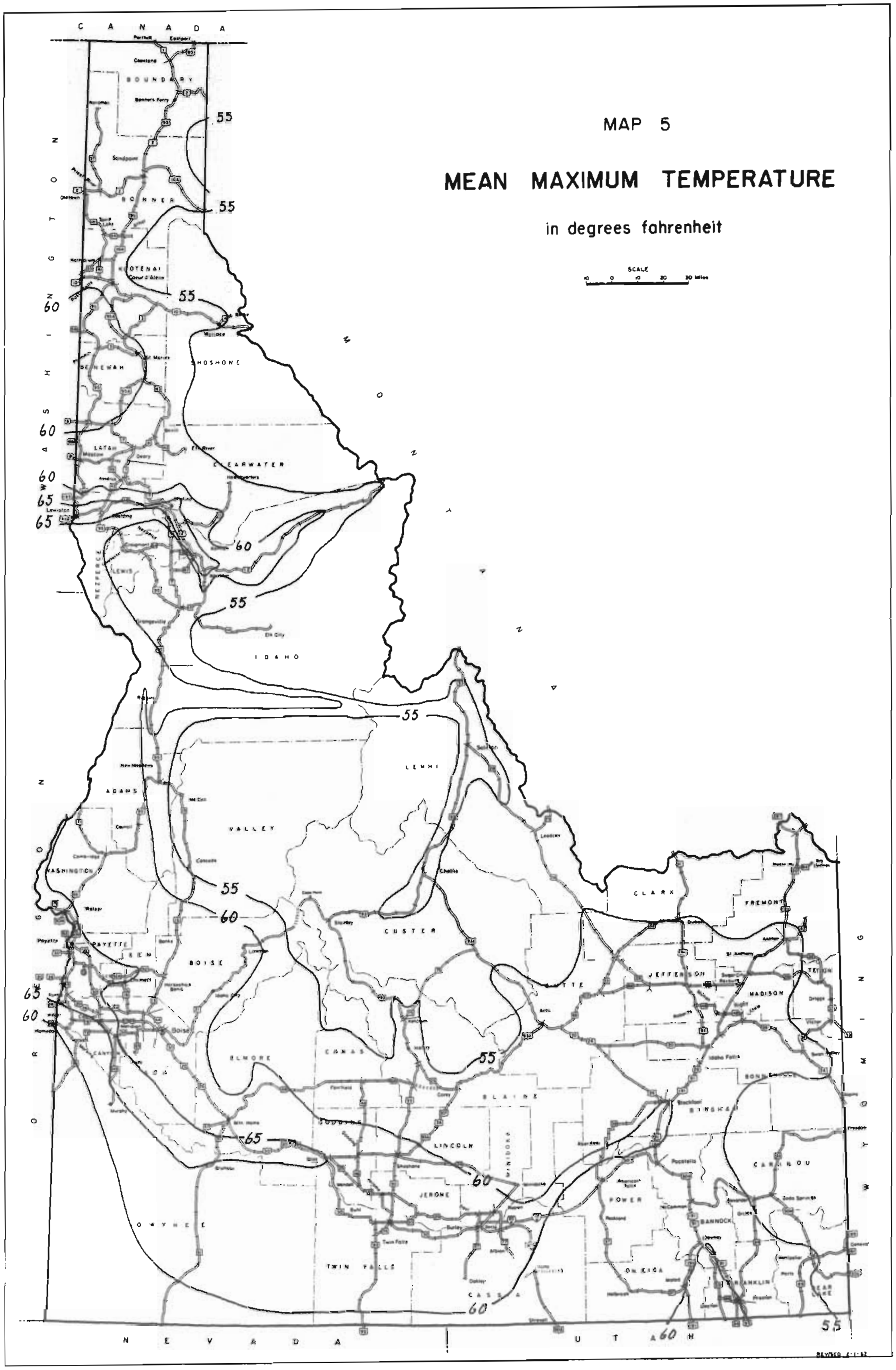
APPENDIX B

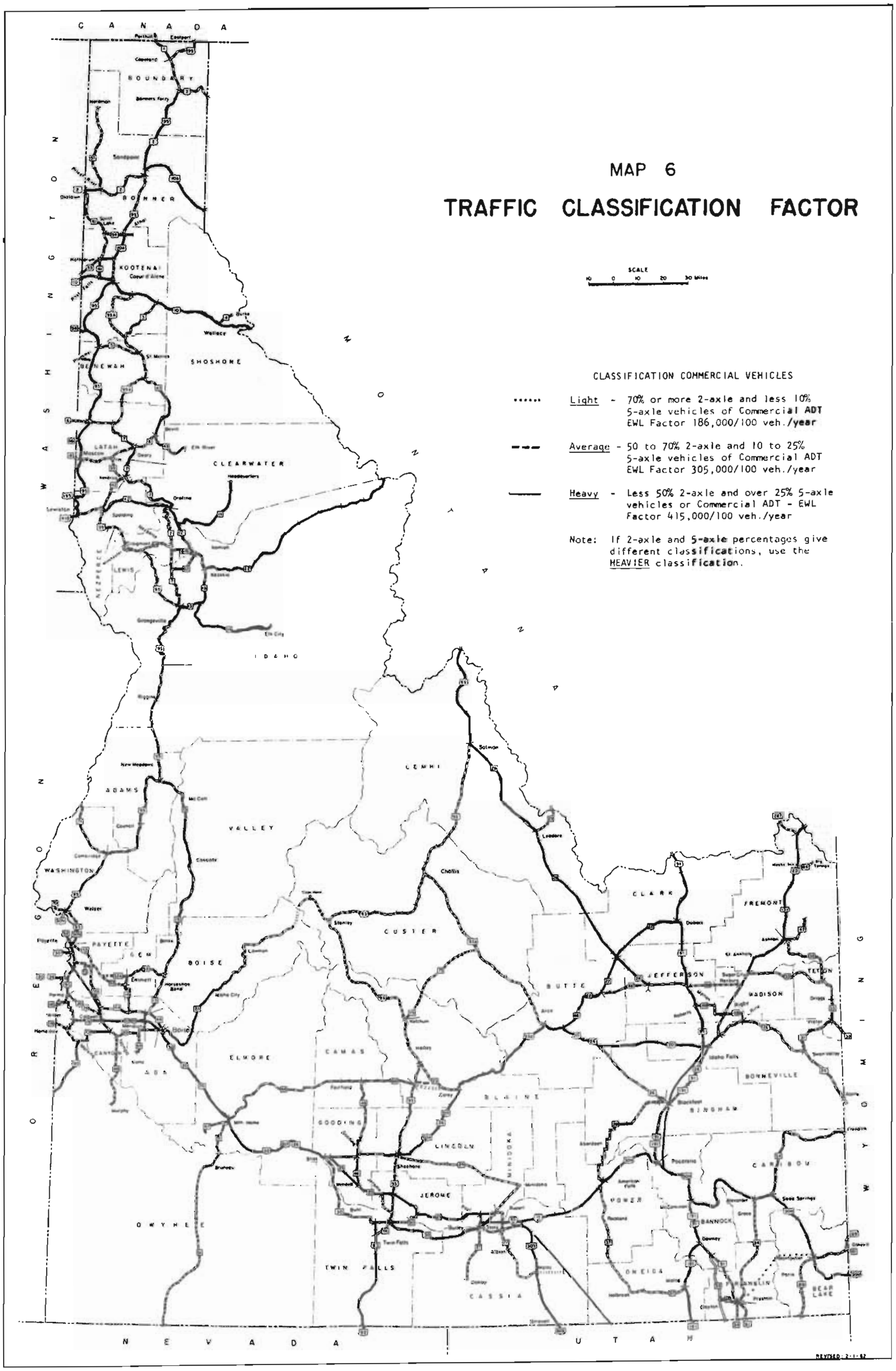

MAP I
MAINTENANCE SECTIONS
SELECTED FOR STUDY
MAINTENANCE DISTRICT
BOUNDARIES
SCALE
CANADA
WASHINGTON
OREGON
MONTANA
WYOMING
NEVADA
UTAH
IDAHO
BOUNDARY
BONNER
KOOTENAI
SHOSHONE
BENEWAH
LATAH
CLEARWATER
LEWIS
NEZPERCE
ADAMS
VALLEY
WASHINGTON
PAYETTE
GEM
BOISE
CANYON
ADA
ELMORE
OWYHEE
CAMAS
GOODING
LINCOLN
JEROME
TWIN FALLS
CASSIA
MINIDOKA
BLAINE
CUSTER
LEMHI
BUTTE
CLARK
FREMONT
JEFFERSON
MADISON
TETON
BONNEVILLE
BINGHAM
POWER
BANNOCK
CARIBOU
ONEIDA
FRANKLIN
BEAR LAKE
1
2
3
4
5
6


MAP 2
ANNUAL SNOWFALL
in inches
SCALE
LEMHI
VALLEY
CLARK
BONNEVILLE
BLAINE
LINCOLN
JEROME
TWIN FALLS
CASSIA
OWYHEE
ELMORE
BOISE
ADA
WASHINGTON
LEWIS
KOOTENAI
SHOSHONE


MAP 3
ELEVATION CONTOUR MAP
in feet above mean sea level
SCALE
CANADA
MONTANA
WASHINGTON
OREGON
NEVADA
UTAH
WYOMING
BOUNDARY
BONNER
KOOTENAI
SHOSHONE
BENEWAH
LATAH
CLEARWATER
LEWIS
ADAMS
WASHINGTON
PAYETTE
BOISE
VALLEY
CUSTER
BUTTE
CLARK
FREMONT
JEFFERSON
MADISON
TETON
BONNEVILLE
BINGHAM
CARIBOU
POWER
JEROME
MINIDOKA
TWIN FALLS
CASSIA
BEAR LAKE
2000
2500
5000
5500
6000
7000
4000
3000
1000
4500
4800
5310
6000

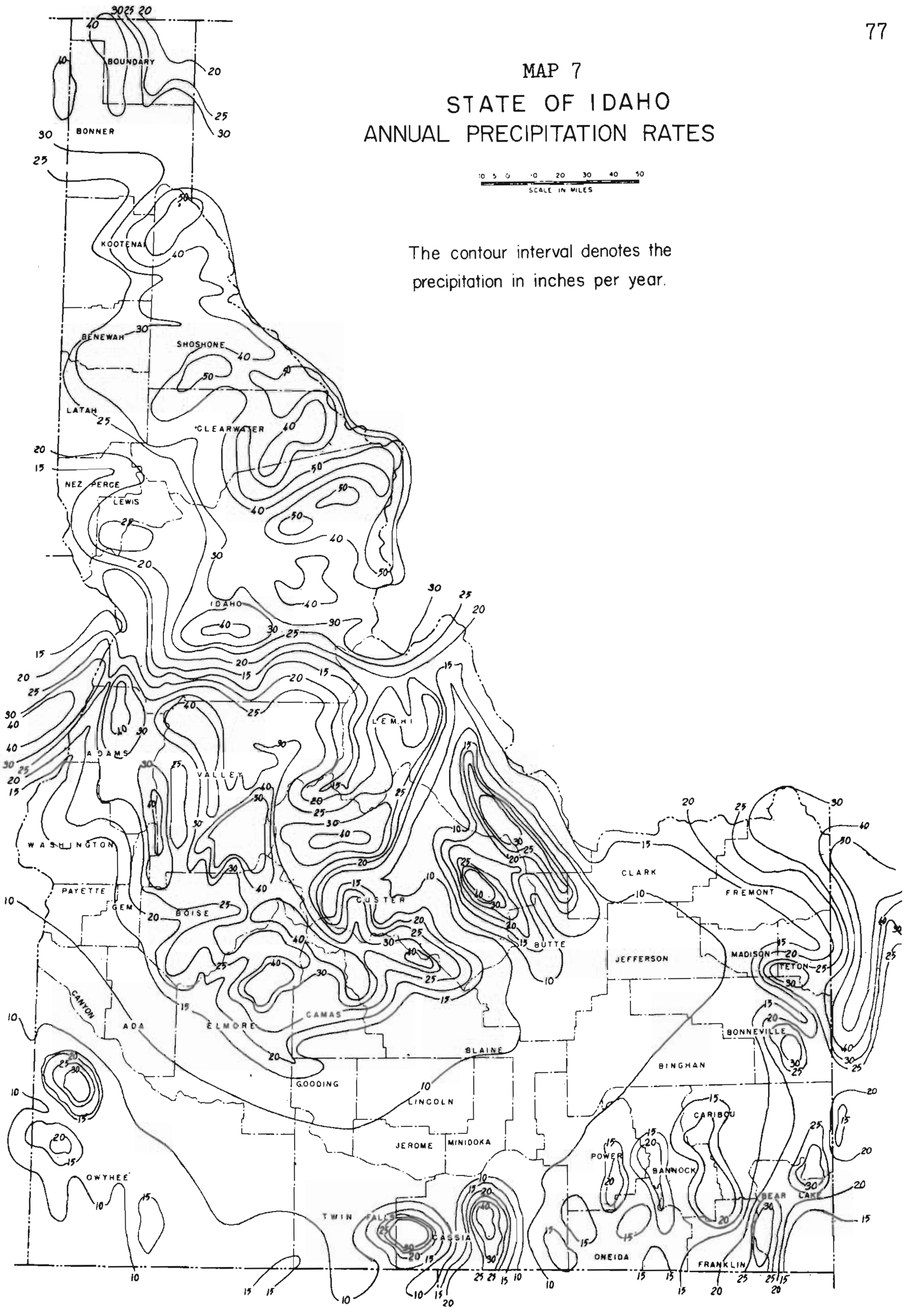

MAP 4
MEAN MINIMUM TEMPERATURE
in degrees fahrenheit
SCALE
CANADA
NEVADA
UTAH
BOUNDARY
BONNER
KOOTENAI
SHOSHONE
CLEARWATER
IDAHO
LEMHI
ADAMS
VALLEY
WASHINGTON
CUSTER
CLARK
FREMONT
JEFFERSON
MADISON
BUTTE
BOISE
CAMAS
ELMORE
ADA
CANYON
BLAINE
GOODING
LINCOLN
JEROME
OWYHEE
TWIN FALLS
CASSIA
POWER
BANNOCK
BINGHAM
BONNEVILLE
CARIBOU
ONEIDA
BEAR LAKE

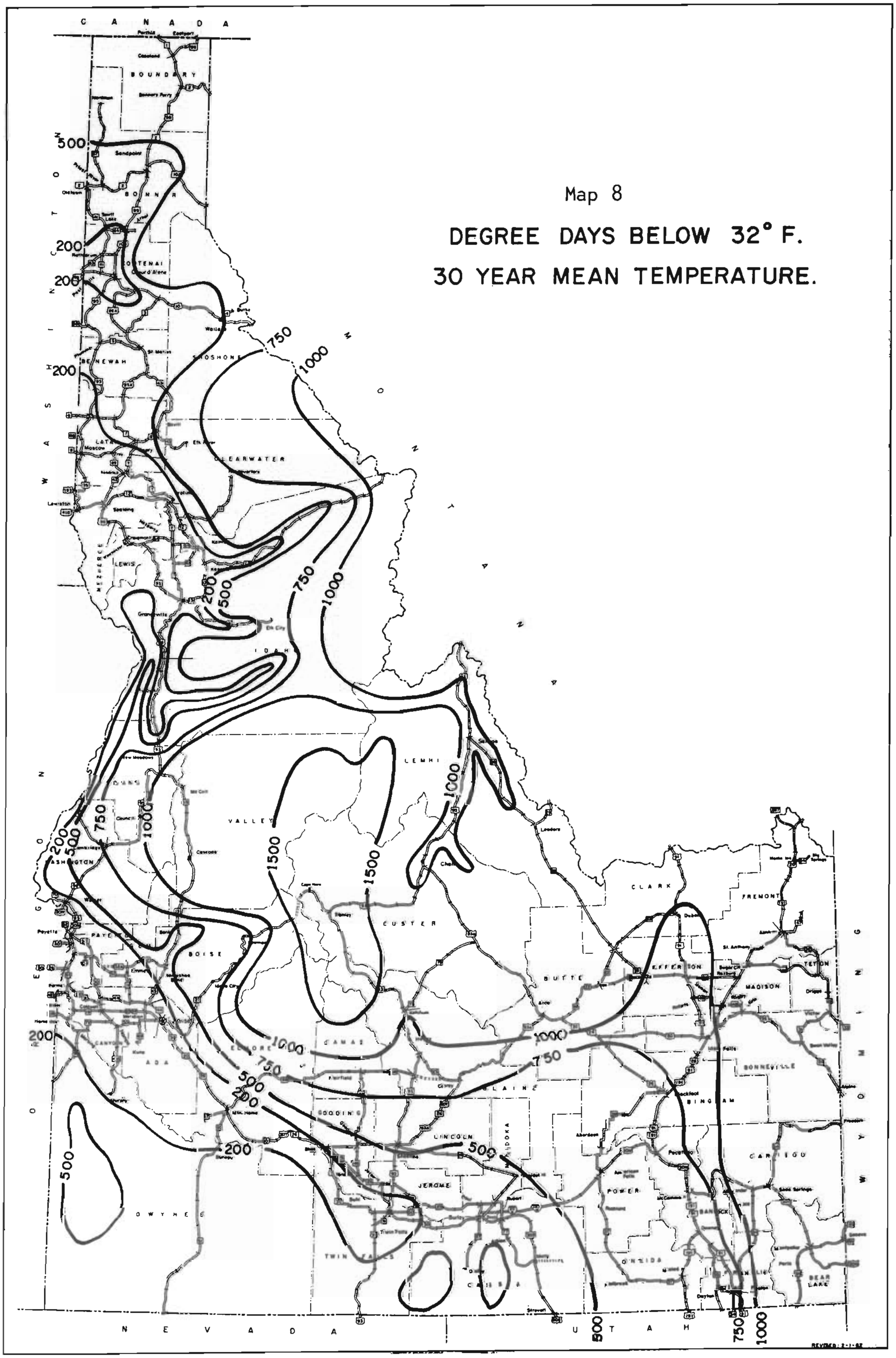

MAP 5
MEAN MAXIMUM TEMPERATURE
in degrees fahrenheit
SCALE
CANADA
NEVADA
UTAH
WASHINGTON
OREGON
MONTANA
WYOMING
BOUNDARY
BONNER
KOOTENAI
BENEWAH
SHOSHONE
LATAH
CLEARWATER
NEZ PERCE
LEWIS
IDAHO
LEMHI
ADAMS
VALLEY
WASHINGTON
PAYETTE
GEM
BOISE
CUSTER
CLARK
FREMONT
JEFFERSON
MADISON
TETON
BUTTE
ELMORE
CAMAS
BLAINE
BINGHAM
BONNEVILLE
LINCOLN
GOODING
JEROME
MINIDOKA
POWER
BANNOCK
CARIBOU
OWYHEE
TWIN FALLS
CASSIA
ONEIDA
FRANKLIN
BEAR LAKE
Lewiston
Boise
Pocatello
Idaho Falls
Challis
55
60
65
REVISED

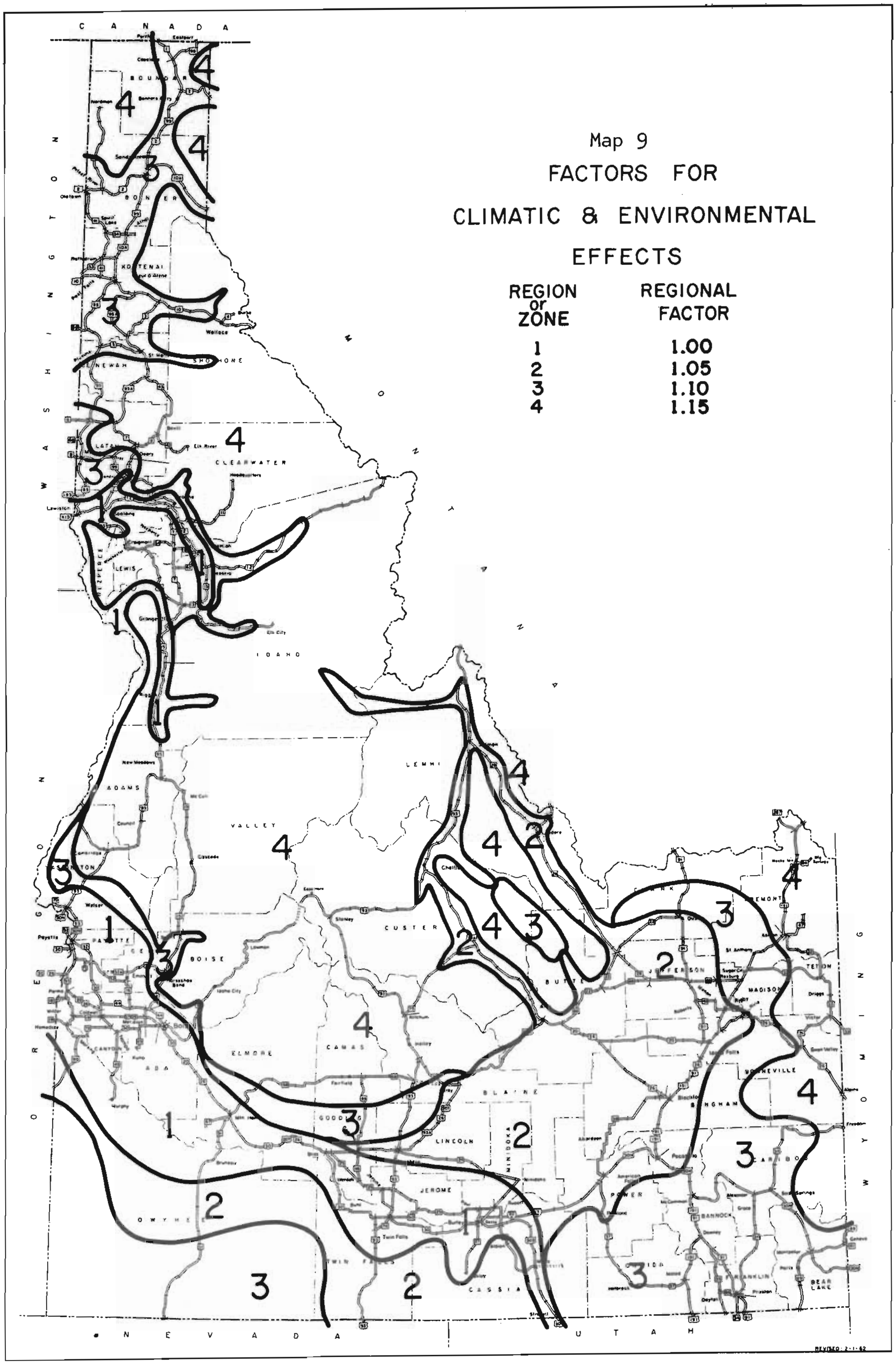

MAP 6
TRAFFIC CLASSIFICATION FACTOR
SCALE
CLASSIFICATION COMMERCIAL VEHICLES
Light - 70% or more 2-axle and less 10% 5-axle vehicles of Commercial ADT EWL Factor 186,000/100 veh./year
Average - 50 to 70% 2-axle and 10 to 25% 5-axle vehicles of Commercial ADT EWL Factor 305,000/100 veh./year
Heavy - Less 50% 2-axle and over 25% 5-axle vehicles or Commercial ADT - EWL Factor 415,000/100 veh./year
Note: If 2-axle and 5-axle percentages give different classifications, use the HEAVIER classification.
CANADA
WASHINGTON
OREGON
MONTANA
WYOMING
NEVADA
UTAH
IDAHO
BOUNDARY
BONNER
KOOTENAI
SHOSHONE
BENEWAH
LATAH
CLEARWATER
NEZPERCE
LEWIS
ADAMS
VALLEY
LEMHI
WASHINGTON
PAYETTE
GEM
BOISE
CUSTER
CLARK
FREMONT
JEFFERSON
MADISON
TETON
BUTTE
CANYON
ADA
ELMORE
CAMAS
BLAINE
BONNEVILLE
BINGHAM
GOODING
LINCOLN
MINIDOKA
JEROME
POWER
CARIBOU
BANNOCK
OWYHEE
TWIN FALLS
CASSIA
ONEIDA
FRANKLIN
BEAR LAKE

MAP 7
STATE OF IDAHO
ANNUAL PRECIPITATION RATES

The contour interval denotes the precipitation in inches per year.




Map 8
DEGREE DAYS BELOW 32° F.
30 YEAR MEAN TEMPERATURE.
CANADA
WASHINGTON
OREGON
NEVADA
UTAH
MONTANA
WYOMING
500
200
750
1000
1500



Map 9
FACTORS FOR
CLIMATIC & ENVIRONMENTAL
EFFECTS

REGION or ZONE	REGIONAL FACTOR
1	1.00
2	1.05
3	1.10
4	1.15

TABLE III

IDAHO DEPARTMENT OF HIGHWAYS
MAINTENANCE CODES (28)

Purpose Code	Explanation
1000	Unusual or Disaster Maintenance This code is used for items stated above including road closures, landslides, floods, etc.
1010	Travelway-Routine Repair The work that might be performed by one or two men on the surface of the roadway. This involves repairing potholes, small hand seals, crack filling, etc. This item also includes charges for the patrol of the highway. This patrol includes a man and truck daily surveying the roadway for needed repairs, pushing rocks off the roadway, etc.
1020	Travelway Surface Repair This surface repair involves more than two people with added equipment such as motor patrol, roller, etc. The magnitude of the work is greater than that for the Purpose Code 1010. Road mix material may be hauled in and spread, rolled, etc. Flagmen may be necessary for control of traffic. This repair involves digging out small sections of base or replacing it with sound materials, constructing French drains, etc. This work is less in magnitude than 1022.
1021	Tear Up and Relay This work involves scarifying a roadway, remixing with the addition of asphalt and rolling, etc.
1022	Half Sole Work involved herein is greater in magnitude than 1020. This work is really construction involving special crews with considerable equipment and involves at least one half mile of work, more than 3/4" in thickness in any maintenance section. The work also would exceed $1,000.

TABLE III (continued)

Purpose Code	Explanation
1023	Seal Coats This work consists of special highway forces or contract seal coat projects. The first seal coat on any project is charged to Construction and thereafter charged to Maintenance.
1030	Shoulders and Side Approaches Repairs by one or two men on the shoulders and side slopes of the roadway similar to that in Purpose Code 1010.
1032	Mowing Mowing on high type roadways, interstate, etc., is necessarily much more frequent than on much less frequently traveled highways such as secondary roads, etc.
1033	Trash Gathering (Including Turnouts and Parks) This work consists of roadside pick up, emptying litter barrels, etc.
1034	Spraying and Weed Control This work consists of spraying herbisides at guard-rails, sign, etc. This item does not only include weed control by contract with the Counties.
1040	Roadside Drainage Routine This item involves the heavy work of improving road-side drainage by special crews, cleaning of pipe, etc. Work beyond the capabilities of one or two men.
1045	Roadside and Drainage Extraordinary This work involves the odd work with power shovels as the Michigan loader in cleaning of ditches, etc.

TABLE III (continued)

Purpose Code	Explanation
1050	Traffic Services This work involves replacing vandalized signs, centerline, exchanging signs to new standards, etc. Sign work is distributed annually on a pro rata basis to each maintenance section including salaries, wages, materials, equipment rental, etc. Centerline painting is charged to each section by proration of the gallons of paint used within the section. This was begun in 1963.
1054	Signals and Lighting This code includes replacement of units, globes, power and the power bill for signals and lights. The item for power is the largest item.
1055	Roadside Parks and Picnic Areas Work herein involves mowing, upkeep of shrubs, emptying litter barrels, cleaning toilets, etc.
1060	Snow and Ice Removal Work involves removal of snow and ice from roadway pavement. Does not include patrol as described in Section 1010.
1065	Sanding This item is similar to snow and ice removal, but includes cost of material used in sanding the roadway.
1070	Bridge Maintenance Work performed by the special bridge crews normally. It could include some charges by a single maintenance man cleaning bridge seats.
1071	Bridge Painting Generally involves contract painting of bridge structures.
1080	Damage Repair This involves emergency type repair by special crews.

TABLE IV

VARIABLES USED IN SNOW-REMOVAL EXPENDITURE ANALYSES

Variable	Transformation	Explanation
01(Y)		Snow-removal expenditure per foot-mile
02		Snowfall in inches
03		Topographic factor
04		Percentage of roadway in cut
05		Percentage of roadway with guardrail
06		Elevation in feet above MSL
07		Total precipitation in inches
08		Degree days (below $32^{o}F$)
09		Lane width in feet
10		Shoulder width in feet
11		Climatic factor
12		Mean minimum temperature
13	09+10	Lane width + Shoulder width
14	08*12	Degree days * Mean minimum temperature
15	02*07	Snowfall * Total precipitation
16	02*04	Snowfall * Percentage of roadway in cut
17	02*06	Snowfall * Elevation
18	06*07	Elevation * Total precipitation
19	03*03	Topographic factor squared
20	02+07	Snowfall + Total precipitation
21	$(02*06)^{1.5}$	$(\text{Snowfall} * \text{Elevation})^{1.5}$
22	$(02*06)^{0.5}$	$(\text{Snowfall} * \text{Elevation})^{0.5}$

TABLE V

VARIABLES USED IN TRAVELWAY-ROUTINE REPAIR EXPENDITURE ANALYSES

Variable	Transformation	Explanation
01(Y)		Travelway-routine repair expenditure per foot-mile
02		Mean minimum temperature
03		Mean maximum temperature
04		Total precipitation in inches
05		Lane width in feet
06		Surfacing type
07		Surfacing age in years
08		Base thickness in inches
09		Surfacing thickness in inches
10		Percentage of roadway in cut
11		Percentage of roadway with guardrail
12		Average Daily Traffic (ADT)
13		Rural commercial volume as a percentage of ADT
14		Traffic classification factor
15		Degree days (below 32°F)
16		Snowfall in inches
17		Elevation in feet above MSL
18		Topographic factor
19		Climatic factor
20	03*04	Mean minimum temperature * Precipitation
21	03*06	Mean minimum temperature * Surfacing type
22	04*15	Precipitation * Degree days
23	04*16	Precipitation * Snowfall
24	04*17	Precipitation * Elevation

TABLE VIII

PLOT-BACK FORTRAN PROGRAM

```
C       PLOT-BACK OF SNOW-REMOVAL REGRESSION
        N=0
        M=0
        MN=61
        PRINT 102
  102   FORMAT(63HPLOT-BACK OF SNOW-REMOVAL COST REGRESSION, LIMITS AT 15
       1PERCENT//)
        PRINT 107, NN
  107   FORMAT(6X,I4,12HOBSERVATIONS/)
        PRINT 104
  104   FORMAT(1X,7HSECTION,1X,11HACTUAL COST,1X,13HCOMPUTED COST,1X,13HPE
       1RCENT ERROR,1X,8HRESIDUAL/)
        DO 5 I=1,NN
        READ 101, IEC, A, J, B, C, GR, L, P, K, D, E, F, MIN
  101   FORMAT(3X,I4,F8.4,I4,F4.1,2F6.2,I5,F5.1,I5,2F6.2,F5.2,I3)
        BJ=J
        BK=K
        BMIN=MIN
        BL=L

                                    } Insert appropriate statements to
                                    } compute estimated expenditure (SUMA)

        SUMA=AJ+AC+AGR+AD+AF+AKMIN+AJC+AJL+ALP+ABB+1.34971
        ERROR=SUMA-A
        PCER=ERROR*100./A
        IF(ABSF(PCER)-15.) 1,1,2
    1   M=M+1
        GO TO 5
    2   N=N+1
    5   PRINT 103, IEC, A, SUMA, PCER, ERROR
  103   Format(3X,I4,3X,F8.4,4X,F8.4,8X,F8.3,8X,F8.3)
        PRINT 105
  105   FORMAT(21HERROR OVER 15 PERCENT,4X,22HERROR UNDER 15 PERCENT)
        PRINT 106, N, M
  106   FORMAT(9X,I4,22X,I4/)
        PM=M
        PM=N
        PMM=PM*110,PMM
  110   FORMAT(22HPERCENT ERROR UNDER 15,6X,F6.2)
        END
```

APPENDIX C