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SKID RESISTANCE OF DIFFERENT GRAVEL SURFACES IN DISTRICT 25

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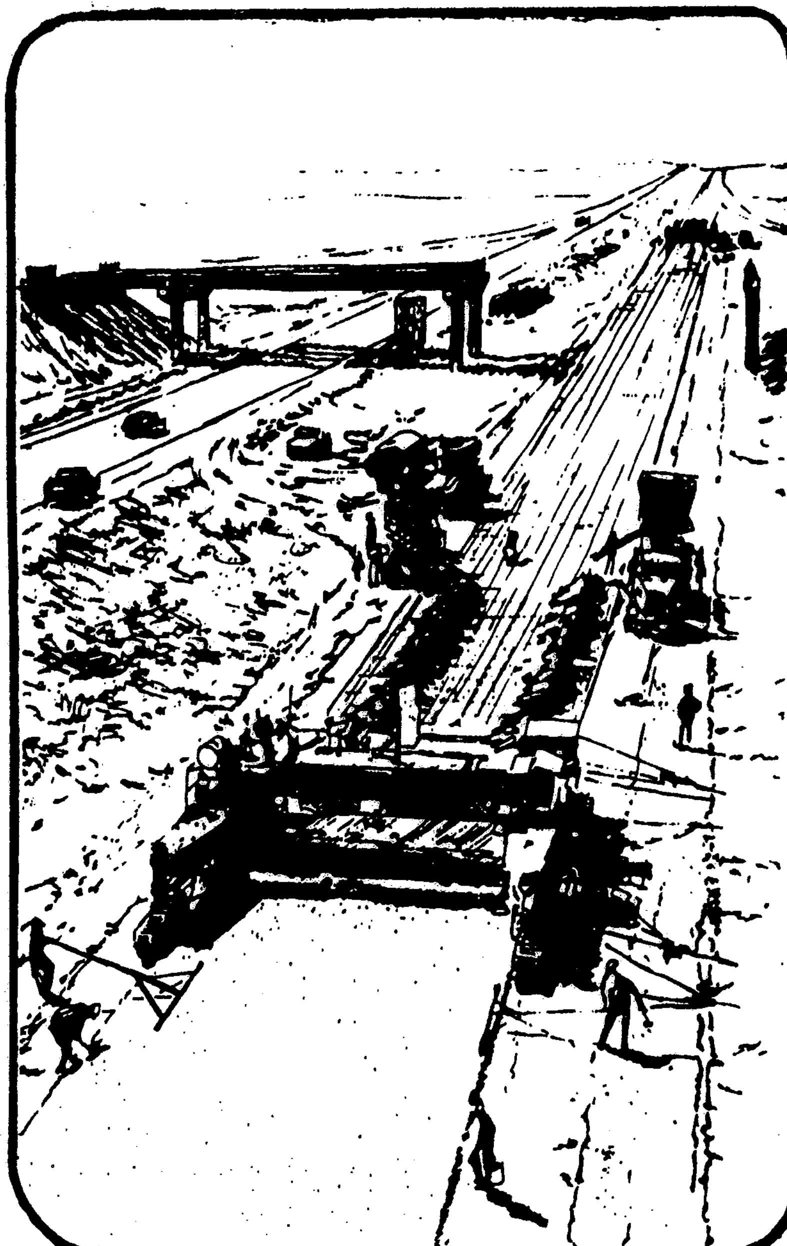

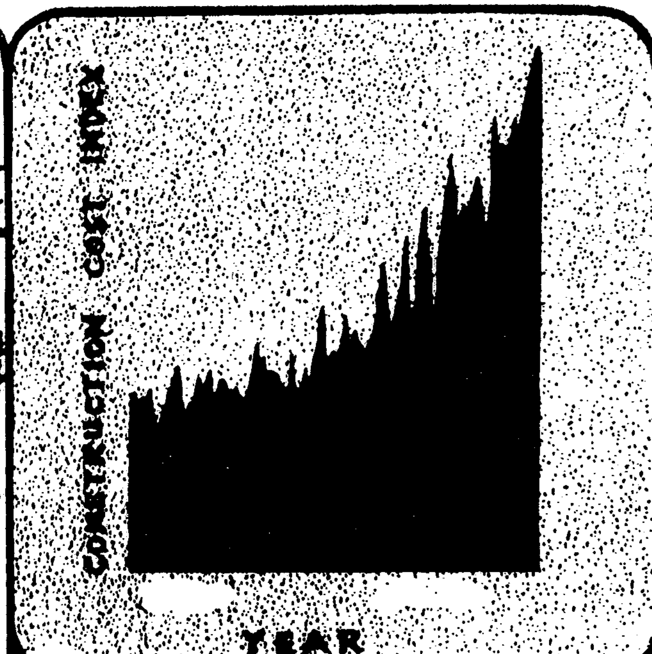

COOPERATIVE RESEARCH PROJECT 2-9-74-214

"ENGINEERING, ECONOMY AND ENERGY CONSIDERATIONS IN DESIGN, CONSTRUCTION AND MATERIALS"

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

AND

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

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VOLUME I

by

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Research Report 214-24

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EXECUTIVE SUMMARY

Selected gravel in District 25 of the Texas State Department of Highways and Public Transportation have been identified and qualified for use on highways in that district from a skid-resistance standpoint. Techniques developed in this study are suitable for use in qualifying aggregates utilized by other districts under different traffic volumes and climatic conditions.

The study method utilized in the study included both field data collection as well as an extensive evaluation phase. The field phase of this project was established to provide skid numbers at specific locations on the pavement sections selected for study. This technique allowed the engineers to evaluate the pavement section at the location of skid testing and to make other measurements that could be used for correlation studies with skid numbers.

The types of field data collected included a general history of the section under study, a visual condition survey, photographs, surface texture measurements, traffic information and skid measurements. The field study team consisted of personnel from Texas State Department of Highways and Public Transportation Districts and central office Divisions and the Texas Transportation Institute. Data collected were coded for computer analysis. Photographs for each section studied can be found in Volume II of this report. A summary of data pertaining to each section can be found in Appendix A.

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INTRODUCTION

Texas State Department of Highways and Public Transportation (SDHPT). The techniques developed in this study are suitable for use in qualifying aggregates utilized by other districts under different traffic and environmental conditions.

The Texas SDHPT uses the polish value test as a guideline to qualify coarse aggregates with respect to skid resistance for use in highway construction and maintenance. The polish test consists of running a wheel under controlled conditions over specifically prepared samples of the aggregate and then testing for a "polish value" with the British Portable Tester. A study by the highway department concluded that there is a relationship between ultimate polish value from the test and field skid resistance after 1,000,000 traffic applications. However, the rate of laboratory polish could not be related to the rate of decrease in resistance observed from field studies (1).

The skid resistance of a particular pavement is not easily predicted through use of readily available parameters such as pavement age, aggregate properties, and accumulated traffic volume. Skid resistance is a function of surface texture on both the macro and micro level. Microtexture refers to the surface texture of the individual aggregate particles and is difficult to measure. Macrotexture depends on the gradation and size of the coarse aggregate. Several methods have been used to measure this property (2). It is generally felt that both micro and macrotexture are required to provide good skid resistance at speeds common to a rural highway (3). Further, climate can greatly affect skid resistance. A recent research report shows that temperature and the number of days since the last rainfall can affect skid resistance. Skid numbers also tend to be higher in winter through spring than in summer through fall (4).

The emphasis of this study is to determine the skid resistance of pavements constructed with specific aggregate sources. The pavements studied were in service in District 25 of the Texas SDHPT. Mix design and climatic exposure may be assumed to be typical of pavements in the district; these properties will certainly influence the performance of the gravels tested. It is for the above reasons that the findings of this report are only intended to be representative of state highways in District 25.

District 25, headquartered at Childress, covers thirteen countries in north central Texas. The geographical region may be characterized as low rolling plains. Soil types are generally loam or sandy loam with clay subsoils (5). The mean annual precipitation ranges from 20 to 24 inches with an average temperature of 62°F. The mean annual minimum temperatures ranges between 5° and 10° Fahrenheit. Annual frost penetration is in the 5 to 10 inch range (6).

A total of 47 different roadway sections were selected for study in this district. Sections were selected to include both hot mix asphalt concrete (HMAC) and seal coat surfaces. Seven different aggregate or gravels were represented by the 47 sections.

STUDY APPROACH

The study method developed for use in this project and utilized on selected pavements in District 25 of the SDHPT is suitable for use in any district and therefore should be considered as a model for future studies of this type. The study approach utilized field data collection at each of 47 sites and the development of regression equations. The field phase of this project was established to provide skid numbers at specific locations on the pavement sections. This technique allowed the engineers to evaluate the pavement section at the location of skid testing and to make other measurements that could be used for correlation with skid numbers. The types of field data collected are described below. Techniques used for analysis of the data will be discussed in a later section of this report.

Field Data

Data collected included a general history of the section under study, visual condition survey, photographs, surface texture measurements, traffic information and skid measurement. The data were collected in June 1977 by SDHPT and Texas Transportation Institute engineers. A description of the specific information collected appears below.

General History of Section. A general history of the selection was obtained from the district files and from a "first hand" knowledge of the section provided by the research team members. Information obtained included:

1. Location of the test section,
2. Year surface placed,
3. Type of surfacing material,
4. Supporting pavement structure material,
5. History of the performance of the section,
6. Construction problems,
7. Maintenance requirements,
8. Future maintenace requirements and
9. Traffic data.

This information was collected on a form as shown in Figure A-1 of Appendix A and later transferred to computer input forms as shown in Appendix A.

Visual Condition Survey. The condition of the pavement was determined by use of a survey technique described in Reference 8. This technique involves the recording of the extent and degree of the following types of flexible pavement distress: rutting, raveling, flushing, corrugations, alligator cracking, longitudinal cracking, transverse cracking, patching and failures. This information may be utilized to determine a Pavement Rating Score. A Pavement Rating Score of 100 indicates the pavement section has no visual pavement distress. Deduct points associated with the type, extent and degree of distress are subtracted from 100 to obtain a Pavement Rating Score of a distressed pavement.

Use of the condition survey technique dates to 1972 in several districts (9); therefore, data are available for comparison purposes.

Data were recorded on a form shown in Figure A-2 of Appendix A.

Photographs. Photographs were obtained for each section of pavement studied. These photographs provide an overall view of the section as well as close-up views. Photographs can be found in Volume II of this report, copies of which are available on a loan basis from the Texas Transportation Institute.

Surface Texture. Surface texture measurements were made in the inner and outer wheel paths as well as between the wheel paths using the "silly putty" method (2). Single measurements were made at each of these designated areas for each pavement section studied.

Traffic. Average daily traffic (ADT) volumes were obtained from a map prepared by the Texas SDHPT (10). Accumulated traffic was calculated from average ADT and age of the roadway. A limited traffic count was performed to establish the lane distribution of the traffic on multilane highways. All traffic volumes on the 47 test sections have been converted to average daily traffic per lane (ADT/Lane) and accumulated traffic per lane.

Skid measurements. Tests which approximate the skid resistance of a fully braked tire on a passenger car were made on a number of pavement segments located in District 25. The measurements were made in the inner wheel path of each lane tested at 40 mph using a SDHPT locked wheel skid trailer. This trailer conforms to that described in ASTM Method of Test E274-70, "Skid Resistance of Paved Surfaces Using a Full Scale Tire" (11). The test provides for water to be applied to the pavement at a specified rate ahead of the locked wheel. The values which are produced from this test are coefficients of friction multiplied by 100 and are referred to as "skid numbers". Ten skid tests were obtained for most of the sections. Data were transferred to computer input forms as shown in Appendix A, Figure A-3.

Aggregates. Aggregate shape and surface texture were observed at each site. Sites containing predominately non-rounded aggregate in the asphalt concrete were identified for data analysis separate from sites containing rounded weathered aggregate.

SKID RESISTANCE ANALYSIS

Introduction

Considerable effort was expended to collect and analyze skid information collected on pavements of various ages and subjected to different traffic levels. As discussed above a locked wheel skid trailer was used to collect the data in the inside wheel path.

The skid tests were obtained on a forty-seven pavement segments each one mile long located throughout District 25. For all but three of the pavement segments, ten skid tests were conducted within the one mile distance. This provided for reasonable estimates of skid number for each pavement segment.

A goal of this data collection effort was to obtain information for several different gravel sources and then see how these materials perform with respect to skid resistance. Each gravel aggregate source will be treated separately and compared to the others. The aggregate sources which will be discussed are as follows:

1. Western McLean (hereafter referred to as Western)
2. Herring
3. Jarrett
4. McAlreath
5. Schmoker
6. Gregory
7. Crabtree
8. All Sources Combined

Some rain occurred during one day of the field studies. At all but two of the sites the pavement was damp or dry at the time of field observation and testing for skid numbers. The damp pavement was not felt to negatively affect skid numbers observed. Average skid numbers on the six damp sections ranged from a low of 42 to a high of 55. Two pavement sections, the only two containing aggregate from the Schmoker source, were wet at the time skid tests were conducted. Because the wheel paths were holding water, skid measurements were made adjacent to the normal wheel path. Skid resistance may have been higher than in the wheel paths due to decreased pavement wear and polish, but the excess water could contribute to reduction of measured skid numbers. The average skid number at these two Schmoker sites was 37.3.

Polish Values

Polish values of gravels selected from the sources studied are presented in Table 1. The polish values were obtained from Reference 13 and similar previous tabulations prepared by the Texas SDHPT. Several years separate the time samples were selected for polish value tests and the time gravels were removed from pits and used for construction of the highway surfaces skidded. While the Texas SDHPT has a required minimum polish value for aggregates used in asphalt concrete surfaces, sources may also be approved on the basis of satisfactory skid performance (13).

Los Angeles wear values are also presented in Table 1 where available. The wear number represents the percent of sample, by weight, lost through a number 12 sieve after processing in a steel drum with a number of steel spheres. The higher the wear number, the more susceptible the samples are to abrasion (14).

Skid Resistance

To examine the skid resistance of these various District 25 gravel sources, two principal analysis techniques were used. One was to compute general statistics which included means, standard deviations, low and high values and coefficient of variations of separate subgroupings of the skid data collected as part of this study. Secondly, extensive regression modeling on these data was accomplished to determine which variables could best be used to estimate skid number. Additionally, a skid number summary of skid information stored on magnetic tape for all pavement surfaces in District 25 which have been skidded were made available by the SDHPT Transportation Planning Division. These summaries contain the average skid number of various construction sections along with other data such as average daily traffic (ADT), pavement type, aggregate type, data of skid data, etc. A computer program was prepared which accessed these data and prepared summaries of selected information.

Available data for each pavement segment surveyed in this study were stored on computer readable cards. This greatly facilitated processing the data with various statistically oriented computer programs. Most of the general statistics and regression modeling were obtained by using the Statistical Analysis System (SAS) computer program package (7).

Subgroupings of the original data were used to examine the skid data. Table 2 shows the different aggregate sources and the number of pavement segments examined for each. The number of segments obtained for asphalt concrete, seal coat and variations of seal coat surfaces are also shown.

Unfortunately a consensus does not exist among engineers as to what constitutes and adequate definition of "safe skid number; although, skid numbers greater than 35 are generally considered to be representative of pavement surfaces which do not have a significant potential for wet weather vehicle skidding accidents. Skid numbers are only on measure of skid hazards and should not be considered as absolutes. Other factors such as rural or urban driving environments and highway geometrics can also heavily influence wet weather skidding accidents (12).

General Statistics

Table 3 is a summary of the means obtained for each grouping of data. A more detailed table containing this information and more can be found in Appendix A Table A-1. The means shown in this table are for the following variables: skid number, age, average daily traffic per lane (ADT/Lane), accumulated traffic and surface texture (inner wheel path). How these individual variables were obtained was previously discussed with the exception of the age variable. Age of a pavement surface was taken as the difference between dates of construction and field data collection.

Figure 1 illustrates the cumulative frequency distributions for the mean (average) skid numbers of the pavement segments paved with various aggregate resources for asphalt concrete surfaces. Figure 2 is a similar treatment except for seal coat surfaces. For asphalt concrete pavements the Jarrett aggregate source appears to perform best with no surveyed pavement segments having a mean skid number of less than 40. The asphalt concrete aggregate with the poorest apparent performance is the Herring Source; although, this source has no surveyed segments with an average skid number of less than 30. For seal coat pavements the Herring source appears to be slightly better than the Western Source. Both of these seal coat aggregate sources have approximately 50 percent of their surveyed pavement segments with mean skid numbers ranging from 40 to 45. It is also of interest that the Herring aggregate source appears to perform better as a seal coat aggregate as opposed to use in asphalt concrete.

A comparison of mean skid numbers for the seven major aggregate sources can be made by examination of Table 3. For asphalt concrete surfaces the Jarrett aggregate has the highest mean skid number at 48.4. The source with the lowest mean skid number is Schmoker with a value of 37.3; but, only two pavement segments were surveyed for this source. The Herring aggregate is next lowest at 37.9 with this average being based on five pavement segments. The remaining sources for asphalt concrete surfaces fall in between the high and low values. The ADT/Lane values range from a low of 588 (Herring) to a high of 1,376 (Schmoker). Interestingly, these two sources with the largest difference in ADT/Lane both have the lowest skid numbers for this type of surface. In any case none of the pavement segments surveyed can be considered as being subjected to high traffic levels. A comparison of the mean surface textures does not show that this variable alone can account for the observed skid differences. The "age" variable has to be similarily considered since some of the aggregate sources with the lowest skid numbers were the most recently constructed.

Of the two aggregate sources surveyed for seal coat skid performance, the Herring source is highest overall with a mean skid number of 44.4. The remaining seal coat aggregate source is Western with a mean skid number of 40.8. There is not a large difference in skid resistance between these two sources based on the fifteen pavements segments surveyed. The mean skid numbers for both seal coat aggregate sources are approximately the same when only seal coats with no flushing are examined. The mean skid number increases four units for the Herring source and approximately six units for the Western source when non-flushed are compared to flushed surfaces.

Pavement Distress

Overall, the mean skid number for all sources combined is slightly higher for asphalt concrete surfaces (44.9) Than all seal coats (42.8). When seal coated surfaces with no flushing (48.0) are compared to asphalt concrete, the seal coats have a higher skid resistance. Regardless of the comparison made, overall the seal coats surveyed are older and have higher surface textures when compared to asphalt concrete. The ADT/Lane is approximately four times as large for asphalt concrete when compared to all seal coats; although, ADT/Lane values of less than 1,000 should be considered low for any surface type.

All but two of the forty-seven pavement segments surveyed exhibited slight to severe raveling distress with the majority having thirty percent or greater of the lane surface so affected. Of the two segments exhibiting no raveling, one was a seal coat surface with a mean skid number of twenty-six or about seventeen skid numbers below the average for all seal coats surveyed. The other segment was an asphalt concrete surface with a mean skid number of thirty-six or about nine skid numbers less than the overall average of all such surfaces. Thus, it appears that raveling on these District 25 surfaces is increasing skid resistance. In fact, without the raveling process many of the pavement segments surveyed might drop into undesirable skid number ranges. Of course, raveling can be destructive to the pavement surface from a structural standpoint.

District-Wide Skid Data

A comparison of the skid resistance of the gravel surfaces specifically surveyed for this study to those of all surfaces in District 25 which have previously been skidded were made. This additional data was obtained from a SDHPT magnetic tape which contained skid summaries for all pavements for which skid measurements have been made as described earlier in this report. To use this data it is assumed that the statistics obtained are true representations of the various population categories described. Table 4 contains this information for three surface types: combined (all surface types), asphalt concrete (HMAC) and surface treatments/seal coats (ST/SC). Additionally the means and standard deviations are shown for skid number, age and ADT. Age was taken as the time between the date a given surface was placed and January 1977. The ADT shown is for two-way traffic not ADT/Lane as previously used.

The combined surface type mean skid number in Table 4 is less than two skid numbers higher than the combination surface type for all gravel aggregate sources shown in Table 3. Both values, 45.6 and 44.0 respectively, are considered to be adequate; although, the age and traffic volumes are higher for Table 4 information. A comparison of the asphalt concrete mean skid number in Table 4 to that for the asphalt concrete surface type in Table 3 reveal these values to be virtually identical, 45.0 and 44.9 respectively. The ages are also similar but the sections summarized in Table 4 have been subjected to traffic levels approximately fifty percent higher. Traffic comparisons are made by dividing the ADT by two. Lastly, a comparison of the surface treatment/seal coat surfaces in Table 4 to the seal coat surfaces for all gravel aggregate sources in Table 3 reveals a difference of about four skid numbers, 46.5 and 42.8 respectively. The ages for these two surface types are about the same but once again the average traffic levels experienced for the pavements summarized in Table 4 are almost three times as large as shown for the gravel seal coats in Table 3. It should be noted that the traffic levels in either Table 3 or 4 are not considered to be high.

To summarize the discussion of the information contained in Tables 3 and 4, the differences in mean skid number of segments with gravel aggregate surfaces and for all segments which have been skidded by the SDHPT are not appreciable. Although, the segments summarized in Table 4 are generally older and have been subjected to higher amounts of traffic.

Regression Analysis

Extensive regression modeling was accomplished to examine any significant correlations between skid number and other variables for the data groupings shown in Table 2. Skid number was used as the dependent variable and the independent variables were age, surface texture (inner wheel path), accumulated traffic and ADT/Lane. The generalized regression model which was used had the following form:

$$Y_i = \beta_o + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_k X_{ik} + \varepsilon_i$$

where:

Y_i = independent variable

$\beta_o , \beta_1 , \ldots , \beta_k$ = Regression parameters

$X_{i1} , X_{i2} , \ldots , X_{ik}$ = independent variables

ε_i = error term

and k ranged from 1 to a maximum of 4.

Two of the major purposes these types of regression equations can serve are to allow estimation of skid numbers for District 25 gravel aggregate surfaces given simply obtained independent variable and to show how different levels of two independent variables can affect the estimated skid numbers. A goal of this process was to obtain regression models which use independent variables which are easy to obtain. In many cases, this goal was achieved.

For each pavement segment surveyed approximately ten skid numbers were obtained. Thus, the regression analysis could be performed in two ways: one, using all ten skid numbers as the dependent variable for each segment or two, using the mean skid number (averaged over the ten data points) to represent the segment. Extensive modeling was performed using both techniques with the result being, in general, only small differences between the two types of regression equations. Additionally, all variables used in each model were used with and without transformations. A transformation is composed of changing a variable in some manner such as taking the logarithm of the variable prior to development of the regression equation. Thus four basic models were prepared for each grouping of data: using all skid numbers or a mean skid number to represent the dependent variable for each segment and using nontransformed or logarithmic transformed dependent and independent variables. Transformations were made using common logarithms (base 10).

Table 5 contains a summary of all consistent regression models for the various groupings of data. The term "consistent model" indicates that no models were reported that had an inconsistent sign on the regression coeffiecient, i.e., the signs for the coefficients obtained for the independent variables of age, accumulated traffic and ADT/Lane are known to be negative (decrease skid resistance) and for surface texture positive (increase skid resistance). For certain pavement types, skid number can actually increase or remain unchanged with time and increased traffic passes. Phenomena such as differential rates of wear, renewal of granulation, and dispersion of particles can cause continued high skid numbers (15). Other "inconsistent" relationships relating to skid resistance can be documented and explained. However, due to the limited quantity of data used in this analysis it is reasonable not to try and document any of these "inconsistent" trends.

The summary contained in Table 5 identifies the aggregate source, type of pavement surface, dependent variable, transformation type, regression coefficients, coefficient of determination (R^2, single or multiple), total degrees of freedom in the model and the number of independent variables used.

The independent variable regression coefficients for nontransformed models are used as multipliers for the actual independent variable data values. The intercept regression coefficients for this type of model is added to the sum of the products of the independent variables and regression coeffiecient. An example is Model Number 1 as shown in Table 5.

Model No. 1: $SN_{40} = 40.20 + 68.07\ (SURTEX)$

where:

SN_{40} = skid number @ 40 mph

SURTEX = surface texture (inner wheel path)

The regression coefficients for the logarithm transformed models have a different form. Model Number 2 is shown as an example.

Model No. 2: $\log_{10} (SN_{40}) = 1.74 - 0.0410 \log_{10} (ADT/Lane)$

To obtain skid number directly this model changes to the following form:

Model No. 2: $SN_{40} = 10^{1.74} (ADT/Lane)^{-0.0410} = 54.95 (ADT/Lane)^{-0.0410}$

where:

ADTLANE = average daily traffic per lane

The coefficient of determination (R^2) shown for each model represents the amount of reduction in the observed variation of skid number associated by the use of the independent variables. This value ranges between 1.0 and 0. An R^2 of 1.0 indicates that the independent variables estimate without error any variation in skid number. An R^2 of 0 indicates no statistical relationship exists between skid number and the independent variables.

The total degrees of freedom also shown in Table 5 represent the number of skid numbers used to develop a given regression equation minus one. For analysis with mean skid number as the dependent variable, these total degrees of freedom do not always agree with the number of sites reported in Table 2. At one HMAC site that used the Herring gravels no surface texture measurement in the inside wheel path was available and thus that site was omitted from the regression runs.

Table 6 shows the "best" regression models selected from Table 5 for each of the data groupings. Selection of the models in this table was based on three criteria: maximize R^2, minimize the number of independent variables and select models without the independent variable of surfaces texture whenever possible. Referring to the first criterion, an R^2 of 0.25 for a one variable model and 0.50 for a two variable model were the minimums used to select the models for presentation in Table 6. For the third criterion, it is recognized that obtaining surface texture measurements on a given pavement can involve almost as much effort as obtaining actual skid numbers. Thus it was felt the use of surface texture as a estimator of skid number should be minimized. As can be seen in Table 6, surface texture often did provide the best two variable regression model for a given data grouping. Additionally, only the models developed using dependent variables composed of all skid data in each section are presented as opposed to using mean skid numbers for the dependent variable. It is felt these models more realistically consider the variability in skid number data. The R^2 values in each case are slightly lower as would be expected.

From the models with the highest R^2 values for each of the seven aggregate sources, accumulated traffic is the single best estimator of skid number appearing as the single independent variable five times, ADT/Lane appears four times and surface texture twice. For models with two independent variables, the combination of surface texture and ADT/Lane appears three times, and surface texture and accumulated traffic twice. The fact that different variables appear in each equation is not unexpected. The phenomena of skid resistance is not easily predicted even if additional independent variables and data points were available.

Further, the independent variables used herein are not truly independent. Accumulated traffic is actually the product of age and average daily traffic per lane. Surface texture is certainly affected by the other variables. The R^2 of all models in this table range from a high of 0.92 to a low of 0.25 with the logarithm transformed models providing the best overall fit of the data nine out of seventeen times.

In using these models, the range of the independent variables should not in any case exceed the high and low values for any of the variables shown in Table A-1. The models should also not be used for pavements outside of District 25 of the Texas SDHPT. This is important in that regression equations are only valid for the range of the variables and conditions used to develop the equations. Figures 3 through 6 are used to represent some of the regression equation relationships between skid number and the independent variables.

It should be noted before discussion of Figures 3 through 6 that many of the regression equations used to generate these plots are not the "best" regression equations contained in Table 6. This occurred because equations of similar form (nontransformed as opposed to transformed) had to be used in making comparisons among the various regression relationships. Since the difference in R^2 between nontransformed and transformed equations for a given data grouping are usually rather small, this procedure is reasonable.

Figure 3 is a plot of two regression equations for asphalt concrete surfaces. One is for the Gregory aggregate source and the other the Herring source. These asphalt concrete aggregate sources are the only two with similar regression equations which allows a comparison to be made. The Gregory source is relatively insensitive to ADT/Lane levels. The skid number drops about six units for ADT/Lane levels ranging from about 100 to 2,500. The Herring aggregate source appears to drop more quickly. Approximately a ten skid number reduction occurs over and ADT/Lane range of 1,000. It is important to note that the regression equations for the Gregory and Herring sources are based on data from six and five pavement segments, respectively. These numbers of pavement segments are considered to be rather small for developing regression equations. Additionally, a precaution should be stated concerning regression relationships containing ADT/Lane as the only independent variable. This occurs because age is not directly considered since ~~it was~~ not a significant variable in the majority of the models attempted for pavements in District 25.

Figure 4 is a plot of skid number versus accumulated traffic for three seal coat data groupings. The dashed line shows the regression line developed for seal coat skid numbers for all sources. A total of fifteen pavement segments were used to develop this relationship. The initial skid number (no traffic condition) appears to be about 50 thereafter decreasing approximately 11.5 skid numbers per 1,000,000 vehicle applications. The regression lines for the Western aggregate source decreases at slightly higher rates ranging from 13.8 to 14.8 skid numbers per 1,000,000 vehicles. All three regression lines indicate that an accumulated traffic level of 1,000,000 vehicles will produce skid numbers of about 35. For an ADT/Lane level of about 1,000, a skid number of 35 would be reached about 2.7 years after construction. But, for the traffic levels typically encountered in District 25, 1,000,000 vehicle applications can take much longer. This fact is apparent by noting that the mean age for these two aggregate source groupings range from 6.3 to 7.9 years. These ages are slightly higher than for seal coats surveyed throughout the state (based on unpublished data developed by authors). Thus, for the traffic levels typically encountered in District 25, the skid number trends for these gravel seal coats appear to be adequate. Climate probably affects such relationships which unfortunately cannot be evaluated at this time.

Figure 5 is a plot of skid number versus accumulated traffic for various levels of surface texture for District 25 seal coats. The regression relationships shown in this figure are curvilinear. This occurs because the regression models used were logarithm transformed. Two surface texture levels were used (0.050 and 0.100 cu. in. per sq. in.) for all aggregate sources combined. The influence of surface texture is notable because the expected skid number after 1,500,000 vehicle applications decreases five skid numbers for the range of surface textures shown. Of the two independent variables for this case, accumulated traffic is still the dominant indicator of skid number decrease. A surface texture of 0.075 cu. in. per. sq. in. was used for the Western aggregate source and the resulting relationships plots approximately between the range of surface textures used for the all sources combined grouping. A relatively narrow range of surface textures were measured for the surveyed pavement segments surfaced with Western aggregate seal coats. Thus, the 0.075 value is approximately the mean surface texture for these pavement segments.

Figure 6 is a plot of skid number versus accumulated traffic for two ADT/Lane levels for the all sources combined seal coat grouping. The range of ADT/Lane was small thus only ADT/Lane values of 100 and 500 are shown. Approximately a five skid number drop is observed to occur between these ADT/Lanes levels. It is not possible with the available data and developed relationships to speculate what magnitude of skid number drop can be expected for higher ADT/Lane levels. What is important is that the gravel seal coats perform rather well with respect to skid resistance for the traffic levels encountered in District 25.

The effect of raveling in District 25 seal coats should again be noted. To make a proper evaluation of raveling, construction and environmental effects must be fully understood for each of the pavement segments surveyed. Unfortunately, this is not possible. It suffices that the gravel seal coats in the district perform well overall given the sum of the conditions encountered by these pavements.

All of the regression equations developed for this study can only in a general way represent actual data trends. The more data points (pavement segments) used in such an analysis generally enhances the validity of the equations though not necessarily the accuracy. In this study all of the regression equations are based on data obtained from relatively few pavement segments, but it is not recommended that additional data be collected and analyzed at this time.

Qualification of Sources Based Upon Skid Numbers

The Texas SDHPT has adopted a method to qualify an aggregate source based upon measured skid numbers (16). The method may be applied where a source does not qualify based upon the results of polish value tests. Sufficient data were available to study the extent of qualification of aggregate from the Western, Herring, Jarrett, and Gregory sources. The findings of the analysis are summarized in Table 7. Figures 7-10 present the data used in the analysis, equations of lines of best fit, and correlation coefficients. These data should be interpreted considering the following comments pertaining to each source.

Western. Three test sites were eliminated due to excessive surface asphalt, bleeding or flushing. Only nine test sections remained upon which to qualify the source based on skid testing. Six test sections on the same type of pavement, seal coat or HMAC, did not remain in the data. Thus an exact qualification could not be determined. The data did indicate that the skid number increased with increased traffic passes. No limit is applicable.

Herring. Three of the Herring sites were eliminated from the test data. One site was eliminated because it was not representative of the Herring source. The others were dropped because of a rain shower during testing and flushing in the wheelpath. Of the ten sites used in the qualification analysis, six were seal coats and four were

HMAC.

Jarrett. All ten sites used were HMAC pavements. The rate of skid number decline is so low that the Jarrett source would qualify for virtually any traffic service level expected. However, the correlation between the data and the equation used to qualify the Jarrett source is low.

Gregory. The six sites used in the analysis were all HMAC pavements. Six are the minimum required to qualify a source based upon measured skid number.

The equations presented in Figures 7-10 may be compared to the following equation developed from data collected at all sites studied. Selected sites were removed before development of the equation as described above for the Western and Herring sources.

$$y = 1.78 - 0.216\,x$$

where

y = Log of average SN_{40} measured at each test section

x = Log of accumulated traffic having passed over the lane in which the test was conducted.

The correlation coefficient for the combined source equation was 0.28.

CONCLUSIONS

Data collected in this study defined certain skid resistance properties of aggregates in District 25. Although the collection of additional data would enhance the accuracy of the regression equations developed in this study, data collected plus a knowledge of the phenomena of skid resistance (3,4,13) allow the following conclusions.

1. All of the gravels studied appear to be acceptable for use on state highways in District 25. Few observations of skid number below 35 were obtained. However, none of the pavement sections surveyed can be considered to be subjected to high traffic levels. The maximum observed ADT per lane was 2,690. Only five of 47 sites studied has average skid number below 35. Each aggregate source studied had a mean skid number above 35 for all sites represented by that source.

2. Flushing was found to be associated with a decrease in skid number for the seal coat surfaces studied. All but one site with mean skid number below 35 exhibited some flushing. Without the raveling process, many of the surfaces surveyed might drop into undesirable skid number ranges. Asphalt concrete surfaces containing non-rounded aggregates exhibited slightly higher mean skid numbers than all asphalt concrete surfaces. Seal coat surfaces with non-rounded aggregate showed no difference in mean skid number. However, only one aggregate source included both rounded and non-rounded aggregates in seal coat surfaces studied. Crushed aggregates are important

in providing a surface with good skid resistance.

3. Development of sound regression equations to predict skid number with the independent variables of accumulated traffic volume, average daily traffic per lane, surface texture of the pavement, and pavement age is not always possible. No acceptable relationships were obtained for many subsets of the data and for the case where data from all sites studied were combined.

No one independent variable can regularly and consistently be expected to be useful in predicting skid number. Acceptable regression equations containing only one independent variable used accumulated traffic volume five times, average daily traffic per lane four times, and surface texture twice. Surface texture appeared most often in regression models containing two independent variables.

RECOMMENDATIONS

1. The aggregates studied herein should continue to be used in asphalt concrete and seal coat mixes for highway surfaces in District 25. They provide adequate skid resistance up to the limit of traffic volume and age observed for each source. When service beyond these limits is expected, the polish value specification requirements of the Texas SDHPT should be followed.

2. Further study of the relationship between flushing, skid number, and wet weather accident frequency is warranted. The study should be directed towards the establishment of a highway department policy as to the appropriate action, if any, to be taken once a surface is identified as flushed. Flushing may be a mechanism for identification of a hazardous location prior to the occurrence of accidents.

3. The regression equations developed and reported herein should be applied only within the range of variables upon which they were based and then only to the conditions of District 25 of the Texas SDHPT.

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Table 1. Material Description and Available Polish Values.

Source	Material Description	Polish Value(s)	Report Date
Western	Siliceous Gravels, L.A. Wear 16-27	35	5/74
	Gravel partially crushed	31,30,27	8/79
Herring	Limestone-Siliceous, L.A. Wear 28, Gravel Partly crushed	31	4/74
Jarrett	Limestone-Siliceous, Partly crushed gravel	34	4/74
	Limestone-Siliceous gravel	34	7/74
McAlreath	Siliceous and Limestone Gravel, Crushed	40	7/74
Schmoker	Siliceous and Limestone, Partly crushed gravel	28	7/74
Gregory	Siliceous Gravel	32	5/74
	Crushed	31	8/74
	Crushed Gravel	34	8/79
Crabtree	Siliceous and Limestone, Partly Crushed Gravel	31	7/74

Table 2. Number of Pavement Segments Surveyed by Pavement Type and Aggregate Source.

	Surface Type				
Aggregate Source	Seal Coats				
	With No Flushing	With Sub Rounded Aggregate*	Total All Seal Coats	Hot Mix Asphalt Concrete	Total All Surface Types
Western	3	5	7	5	12
Herring	6	0	8	5	13
Jarrett	0	0	0	10	10
McAlreath	0	0	0	2	2
Schmoker	0	0	0	2	2
Gregory	0	0	0	6	6
Crabtree	0	0	0	2	2
Total all Sources	9	5	15	32**	47

*Partially crushed.

**Twenty-three of the hot mix asphalt concrete sites contained non-rounded aggregate.

Table 3. Summarized Means for Various Data Groupings - District 25 Gravel Aggregates.

Data Grouping		Means				
Source	Surface Type	SN_{40}	Age	ADT/Lane	Accumulated Traffic	Surface Texture
Western						
	Combination	42.4	6.1	570	1,077,800	0.068
	AC	44.5	5.8	802	1,735,400	0.058
	SC	40.8	6.3	404	680,200	0.074
	SC-No Flushing	47.2	8.0	175	214,400	0.084
	SC-Non Rounded Aggregate	40.8	6.6	471	722,600	0.074
Herring						
	Combination	42.1	7.9	295	760,700	0.072
	AC	37.9	5.5	588	1,212,200	0.038
	SC	44.4	9.4	111	478,500	0.089
	SC-No Flushing	48.4	7.8	42	128,400	0.101
Jarrett						
	AC	48.4	7.1	894	2,550,000	0.039
McAlreath						
	AC	45.5	3.0	1305	1,429,500	0.028
Schmoker						
	AC	37.3	2.0	1376	1,001,500	0.032
Gregory						
	AC	45.0	4.2	1255	1,919,500	0.045
Crabtree						
	AC	46.4	7.0	1272	3,250,000	0.046
All Sources						
	Combination	44.0	6.3	746	1,514,900	0.055
	AC	44.9	5.6	978	2,002,200	0.043
	SC	42.8	7.9	248	539,000	0.082
	SC-No. Flushing	48.0	7.9	87	157,000	0.096
	AC-Non Rounded Aggregate	46.3	5.7	1004	2,111,000	0.044

AC = Asphalt Concrete

SC = Seal Coat

Table 4. Summary of Skid Number and Related Data From SDHPT Skid Summaries for District 25.

Type Surface	SN_{40}		Age		ADT (two way)		No. of Sections
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	
Combined	45.6	7.7	8.5	7.9	2,382	2,359	149
HMAC	45.0	5.4	6.5	4.1	2,935	2,439	75
ST/SC	46.5	9.9	8.6	5.4	1,414	1,756	64

HMAC = Hot Mix Asphalt Concrete

ST/SC = Surface Treatment/Seal Coats

Table 5. Summary of All Consistent Regression Models for District 25 Gravel Aggregate Sources.

Model Number	Aggregate Source	Type of Pavement Surface	Dependent Variable	Model Transformation	Regression Coefficients: Intercept	Age	Surface Texture	Accumulated Traffic	ADT/Lane	R^2	Total Degrees of Freedom	Number of Independent Variables in Model
1	All Sources	Combination	All SN	---	40.20		68.07			0.08	448	1
2	"	"	"	$\log_{10}$	1.74				-4.10 E-02	0.13	448	1
3	"	"	SN Avg	---	40.30		65.05			0.07	45	1
4	"	"	"	$\log_{10}$	1.74				-4.19 E-02	0.14	45	1
5	"	Seal Coat	All SN	---	48.60			-1.15 E-05		0.70	144	1
6	"	"	"	"	49.25			-8.20 E-06	-1.04 E-02	0.75	144	2
7	"	"	"	$\log_{10}$	2.45			-1.53 E-01		0.72	144	1
8	"	"	"	"	2.51		2.28 E-01	-1.19 E-01		0.79	144	2
9	"	"	"	"	2.42		2.48 E-01	-8.78 E-02	-2.71 E-02	0.80	144	3
10	"	"	SN Avg	---	48.59			-1.15 E-05		0.76	14	1
11	"	"	"	"	49.12			-8.23 E-06	-9.22 E-03	0.81	14	2
12	"	"	"	$\log_{10}$	2.45			-1.53 E-01		0.78	14	1
13	"	"	"	"	2.52		2.22 E-01	-1.20 E-01		0.86	14	2
14	"	Seal Coat-No Flushing	All SN	---	49.73			-1.08 E-05		0.08	89	1
15	"	"	"	"	42.38		89.99	-1.88 E-05		0.27	89	2
16	"	"	"	$\log_{10}$	1.90			-4.23 E-02		0.14	89	1
17	"	"	"	"	2.22		1.83 E-01	-6.88 E-02		0.37	89	2
18	"	"	"	"	2.33	-4.41 E-02	1.88 E-01	-8.15 E-02		0.44	89	3
19	"	"	SN Avg	---	42.93		53.01			0.11	8	1
20	"	"	"	"	42.21		91.07	-1.86 E-05		0.38	8	2
21	"	"	"	$\log_{10}$	1.90			-4.37 E-02		0.22	8	1
22	"	"	"	"	2.23		1.85 E-01	-7.05 E-02		0.57	8	2

Table 5. Continued.

Model Number	Aggregate Source	Type of Pavement Surface	Dependent Variable	Model Trans-formation	Regression Coefficients: Intercept	Age	Surface Texture	Accumulated Traffic	ADT/ Lane	R^2	Total Degrees of Freedom	Number of Independent Variables in Model
23	Western	Combination	All SN	---	30.80		170.13			0.25	114	1
24	"	"	"	$\log_{10}$	1.89		2.24 E-01			0.18	114	1
25	"	"	"	"	1.94		2.00 E-01		-3.27 E-02	0.23	114	2
26	"	"	SN Avg	---	29.34		184.59			0.29	11	1
27	"	"	"	$\log_{10}$	1.90		2.41 E-01			0.20	11	1
28	"	"	"	"	1.97		2.10 E-01		-4.01 E-02	0.27	11	2
29	Western	Seal Coat	All SN	---	48.26			-1.38 E-05		0.80	64	1
30	"	"	"	"	40.13		96.62	-1.22 E-05		0.84	64	2
31	"	"	"	$\log_{10}$	2.54			-1.70 E-01		0.62	64	1
32	"	"	"	"	3.03		5.06E-01	-1.55 E-01		0.88	64	2
33	"	"	"	"	3.13	-5.57 E-02	4.58E-01	-1.75 E-01		0.89	64	3
34	"	"	SN Avg	---	48.34			-1.35 E-05		0.89	6	1
35	"	"	"	"	40.12		97.72	-1.19 E-05		0.92	6	2
36	"	"	"	$\log_{10}$	2.55			-1.72 E-01		0.71	6	1
37	"	"	"	"	3.00		4.97E-01	-1.51 E-01		0.96	6	2
38	"	Seal Coat-No Flushing	All SN	$\log_{10}$	1.68	-1.16 E-02				0.03	29	1
39	"	"	"	"	1.71	-1.44 E-02		-3.93 E-03		0.04	29	2
40	"	Seal Coat-Non Rounded Aggregate	All SN	---	50.20			-1.48 E-05		0.89	44	1
41	"	"	"	"	54.06	-4.25 E-01		-1.62 E-05		0.92	44	2
42	"	"	"	$\log_{10}$	2.53			-1.68 E-01		0.62	44	1
43	"	"	"	"	3.04		5.01E-01	-1.55 E-01		0.90	44	2
44	"	"	"	"	3.15	-7.39 E-02	4.44E-01	-1.79 E-01		0.92	44	3
45	"	"	SN Avg	---	50.30			-1.45 E-05		0.95	4	1
46	"	"	"	"	54.32	-4.42 E-01		-1.60 E-05		0.98	4	2
47	"	"	"	$\log_{10}$	2.54			-1.70 E-01		0.69	4	1

Table 5. Continued.

Model Number	Aggregate Source	Type of Pavement Surface	Dependent Variable	Model Transformation	Regression Coefficients: Intercept	Age	Surface Texture	Accumulated Traffic	ADT/ Lane	R^2	Total Degrees of Freedom	Number of Independent Variables in Model
48	Western	Seal Coat-Non Rounded Aggregate	SN Avg	$\log_{10}$	3.01		5.01E-01	-1.51 E-01		0.96	4	2
49	Herring	Combination	All SN	---	29.64		171.98			0.58	119	1
50	"	"	"	"	36.25		118.16	-3.38 E-06		0.68	119	2
51	"	"	"	"	42.78	-6.23 E-01	102.89		-9.89 E-03	0.71	119	3
52	"	"	"	$\log_{10}$	2.27			-1.16 E-01		0.75	119	1
53	"	"	"	"	2.24		5.81E-02	-1.00 E-01		0.76	119	2
54	"	"	SN Avg	---	29.83		169.35			0.62	11	1
55	"	"	"	"	36.22		117.36	-3.26 E-01		0.72	11	2
56	"	"	"	"	42.50	-5.92 E-01	102.14		-9.61 E-03	0.76	11	3
57	"	"	"	$\log_{10}$	2.25			-1.14 E-01		0.82	11	1
58	"	"	"	"	2.24		5.31E-02	-9.94 E-02		0.83	11	2
59	Herring	Asphalt Concrete	All SN	---	44.40				-1.01 E-02	0.56	39	1
60	"	"	"	"	44.47	-1.18 E-02			-1.01 E-02	0.56	39	2
61	"	"	"	"	41.03	-1.18	321.03		-1.23 E-02	0.57	39	3
62	"	"	"	$\log_{10}$	2.08				-1.81 E-01	0.49	39	1
63	"	"	"	"	4.61		6.75E-01	-3.39 E-01		0.51	39	2
64	"	"	"	"	7.66	-2.95 E-01	1.67	-5.71 E-01		0.53	39	3
65	"	Seal Coat	All SN	---	50.92				-5.84 E-02	0.71	79	1
66	"	"	"	"	42.46		79.46		-4.59 E-02	0.83	79	2
67	"	"	"	$\log_{10}$	1.96				-1.79 E-01	0.87	79	1
68	"	"	"	"	2.06		1.54E-01		-1.41 E-01	0.91	79	2

Table 5. Continued.

Model Number	Aggregate Source	Type of Pavement Surface	Dependent Variable	Model Trans-formation	Regression Coefficients: Intercept	Age	Surface Texture	Accumulated Traffic	ADT/ Lane	R^2	Total Degrees of Freedom	Number of Independent Variables in Model
69	Herring	Seal Coat	SN Avg	---	50.80				-5.78 E-02	0.85	7	1
70	"	"	"	"	42.39		79.02		-4.54 E-02	0.89	7	2
71	"	"	"	$\log_{10}$	1.96				-1.78 E-01	0.94	7	1
72	"	"	"	"	2.05		1.41E-01		-1.43 E-01	0.98	7	2
73	"	Seal Coat-No Flushing	All SN	---	54.76				-1.48 E-01	0.36	59	1
74	"	"	"	"	43.43		129.48		-1.91 E-01	0.63	59	2
75	"	"	"	$\log_{10}$	1.88				-1.25 E-01	0.44	59	1
76	"	"	"	"	2.13		2.22E-01		-1.40 E-01	0.64	59	2
77	"	"	SN Avg	---	55.09				-1.59 E-01	0.51	5	1
78	"	"	"	"	42.82		140.27		-2.05 E-01	0.91	5	2
79	"	"	"	$\log_{10}$	1.90				-1.35 E-01	0.65	5	1
80	"	"	"	"	2.16		2.40E-01		-1.50 E-01	0.95	5	2
81	Jarrett	Asphalt Concrete	All SN	---	33.11		400.28			0.47	93	1
82	"	"	"	"	36.25		366.38		-1.77 E-03	0.65	93	2
83	"	"	"	$\log_{10}$	2.13		3.17E-01			0.46	93	1
84	"	"	"	"	2.21		3.05E-01		-3.26 E-02	0.64	93	2
85	"	"	Sn Avg	---	34.95		349.24			0.46	9	1
86	"	"	"	$\log_{10}$	2.07		2.74E-01			0.46	9	1
87	"	"	"	"	2.14		2.62E-01		-3.01 E-02	0.65	9	2

Table 5. Continued.

Model Number	Aggregate Source	Type of Pavement Surface	Dependent Variable	Model Transformation	Regression Coefficients					R^2	Total Degrees of Freedom	Number of Independent Variables in Model
					Intercept	Age	Surface Texture	Accumulated Traffic	ADT/ Lane			
88	McAlreath	Asphalt Concrete	All SN	---	47.88			-1.67 E-06		0.82	19	1
89	"	"	"	"	47.88				-1.83 E-03	0.82	19	1
90	"	"	"	$\log_{10}$	1.76				-3.60 E-02	0.83	19	1
91	Schmoker	Asphalt Concrete	All SN	$\log_{10}$	1.22			5.81E-02		0.09	19	1
92	Gregory	Asphalt Concrete	All SN	---	47.52				-2.05 E-03	0.45	59	1
93	"	"	"	$\log_{10}$	1.76				-3.98 E-02	0.50	59	1
94	"	"	SN Avg	---	47.72				-2.03 E-03	0.55	5	1
95	"	"	"	$\log_{10}$	1.76				-3.91 E-02	0.60	5	1

Table 6. "Best" Regression Models for District 25 Gravel Aggregate Sources.

Aggregate Source	Type of Pavement Surface	"Best" Regression Model and R^2
All Sources	Combination	No Appropriate Model
	Asphalt Concrete	No Appropriate Model
	Seal Coat	$SN_{40} = 281.84\ (ACCTRAF)^{-0.153}$ $R^2 = 0.72$ $SN_{40} = 323.59\ (SURTEX)^{0.228}\ (ACCTRAF)^{-0.119}$ $R^2 = 0.79$
	Seal Coat No Flushing	No Appropriate Model
Western	Combination	$SN_{40} = 30.80 + 170.13\ (SURTEX)$ $R^2 = 0.25$
	Seal Coat	$SN_{40} = 48.26 - 0.0000138\ (ACCTRAF)$ $R^2 = 0.80$ $SN_{40} = 1071.52\ (SURTEX)^{0.506}\ (ACCTRAF)^{-0.155}$ $R^2 = 0.88$
	Seal Coat No Flushing	No Appropriate Model
	Seal Coat - Non Rounded Aggregate	$SN_{40} = 50.20 - 0.0000148\ (ACCTRAF)$ $R^2 = 0.89$ $SN_{40} = 54.06 - 0.425\ (AGE) - 0.0000162(ACCTRAF)$ $R^2 = 0.92$

Table 6. Continued.

Aggregate Source	Type of Pavement Surface	"Best" Regression Model and R^2
Herring	Combination	$SN_{40} = 186.21\ (ACCTRAF)^{-0.116}$ $R^2 = 0.75$
	Asphalt Concrete	$SN_{40} = 44.40 - 0.0101\ (ADTLANE)$ $R^2 = 0.56$
	Seal Coat	$SN_{40} = 91.20\ (ADTLANE)^{-0.179}$ $R^2 = 0.87$ $SN_{40} = 114.82\ (SURTEX)^{0.154}\ (ADTLANE)^{-0.141}$ $R^2 = 0.91$
	Seal Coat No Flushing	$SN_{40} = 75.86\ (ADTLANE)^{-0.125}$ $R^2 = 0.44$ $SN_{40} = 134.90\ (SURTEX)^{0.222}\ (ADTLANE)^{-0.140}$ $R^2 = 0.64$
Jarrett	Asphalt Concrete	$SN_{40} = 33.11 + 400.28\ (SURTEX)$ $R^2 = 0.47$ $SN_{40} = 36.25 + 366.38(SURTEX)-0.00177\ (ADTLANE)$ $R^2 = 0.65$
McAlreath	Asphalt Concrete	$SN_{40} = 47.88-0.00000167(ACCTRAF)$ $R^2 = 0.82$
Schmoker	Asphalt Concrete	No Appropriate Model
Gregory	Asphalt Concrete	$SN_{40} = 57.54\ (ADTLAND)^{-0.0398}$ $R^2 = 0.50$

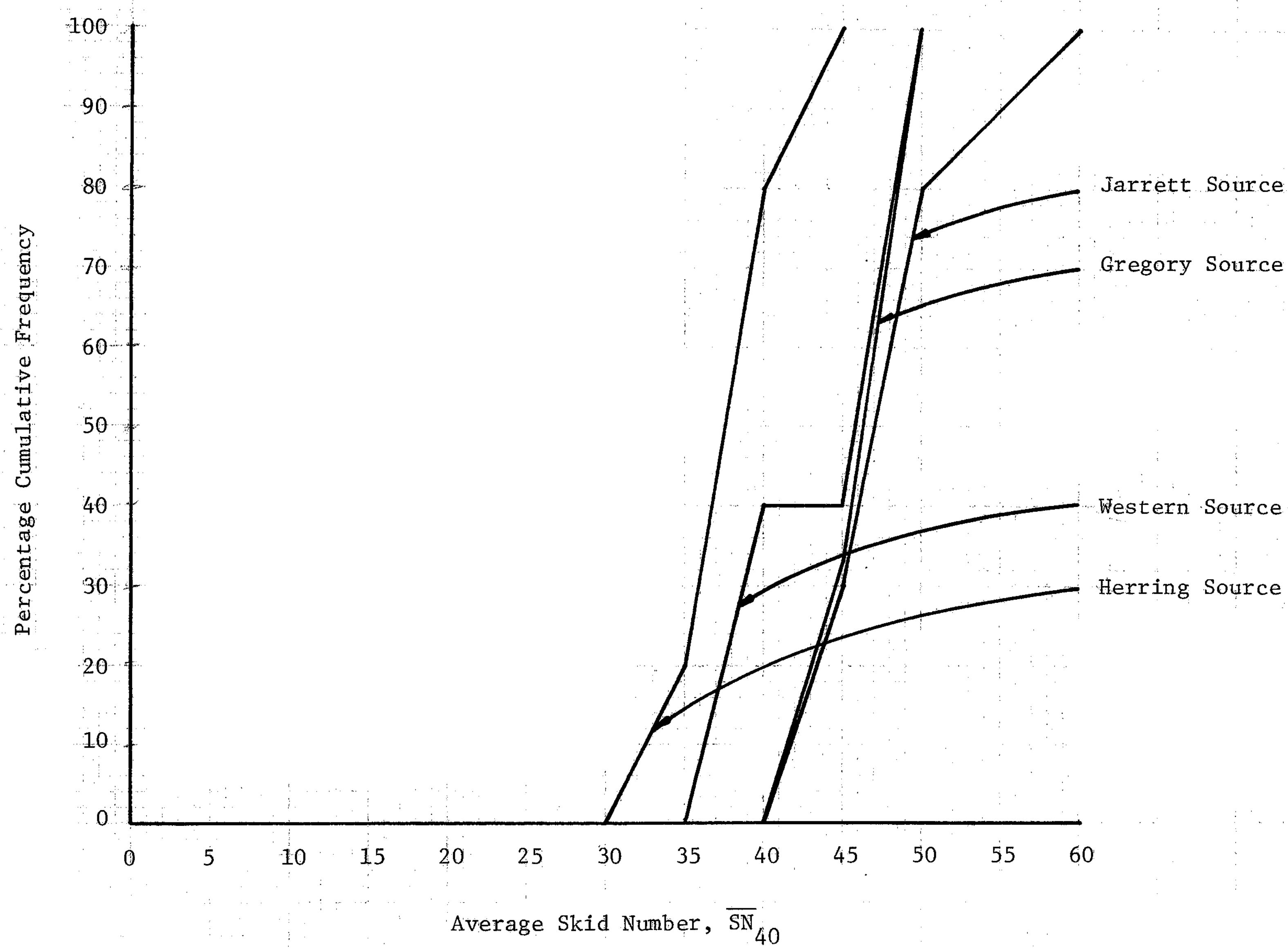

Figure 1. Mean Skid Number Cumulative Frequency Plot for District 25 Gravel Asphalt Concrete.

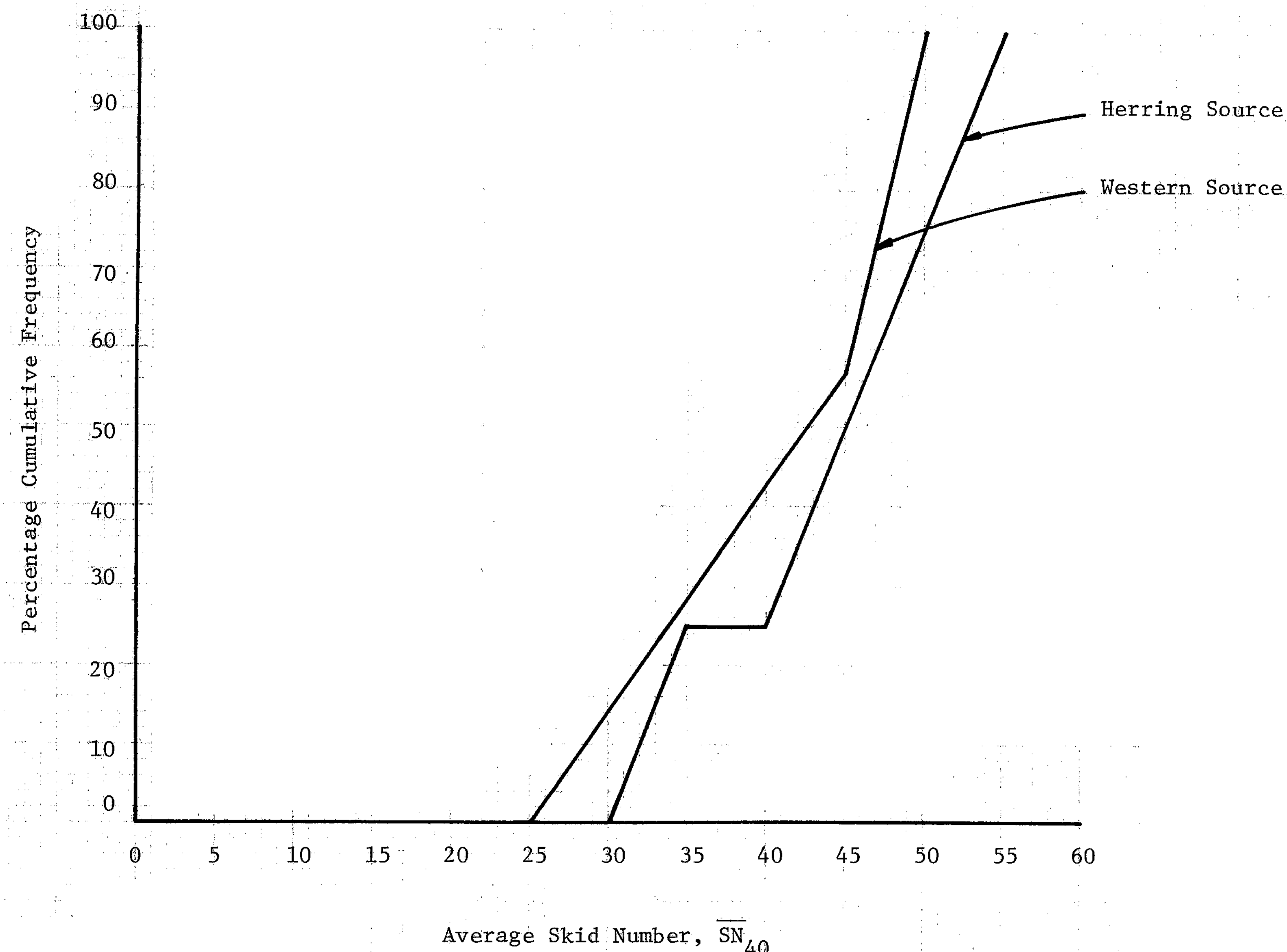

Figure 2. Mean Skid Number Cumulative Frequency Plot for District 25 Gravel Seal Coats.

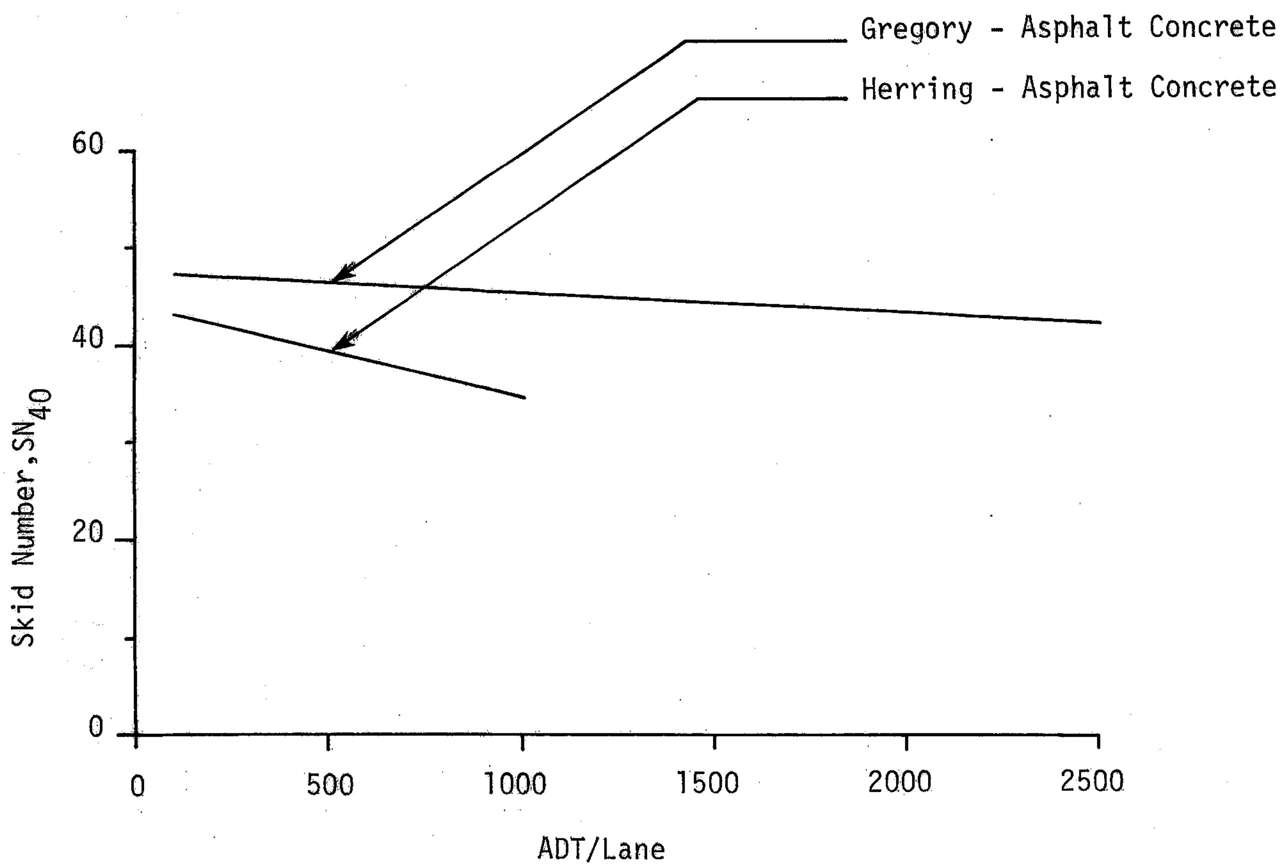

Figure 3. Skid Number Versus ADT/Lane for District 25 Gravel Asphalt Concrete Surfaces.

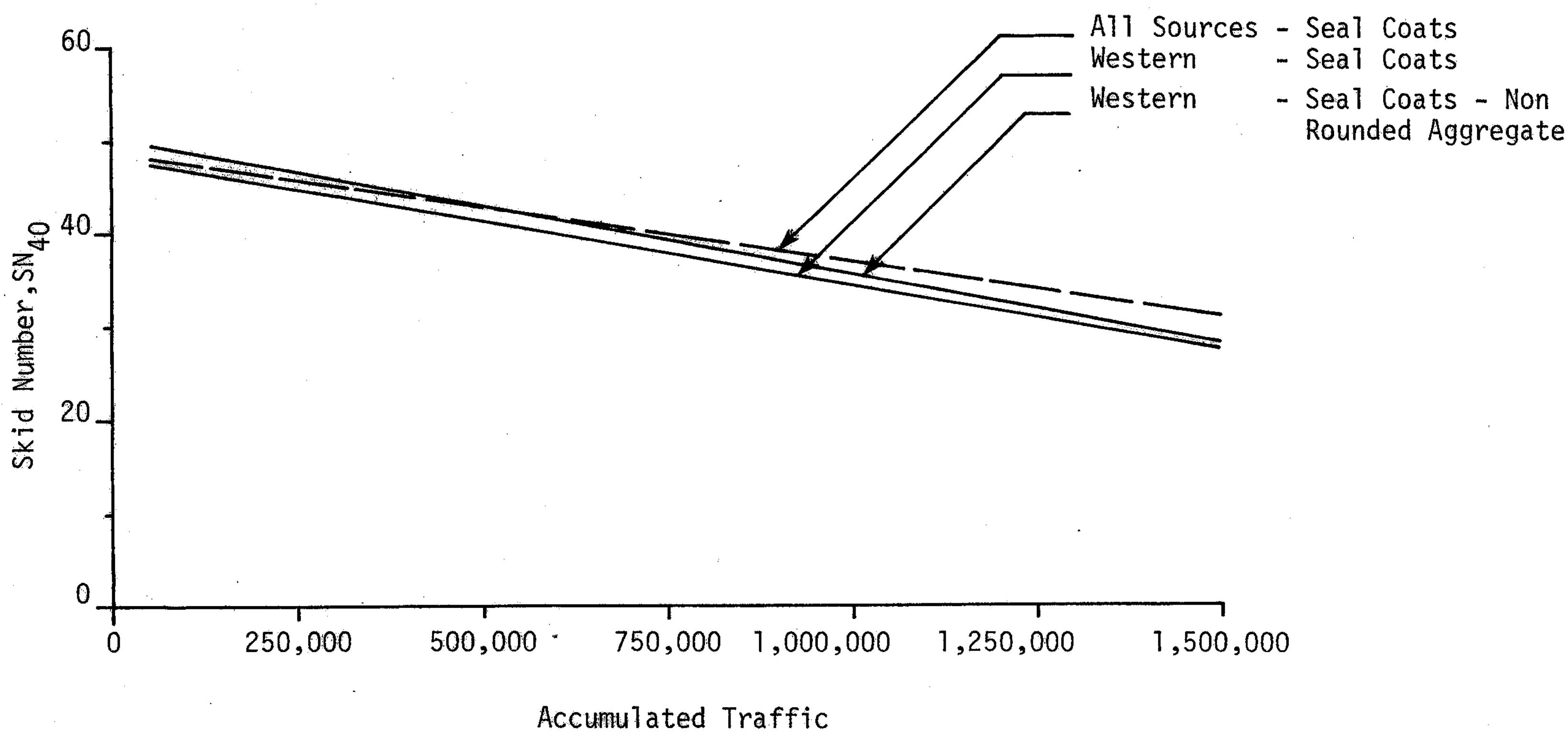

Figure 4. Skid Number Versus Accumulated Traffic for District 25 Gravel Seal Coats.

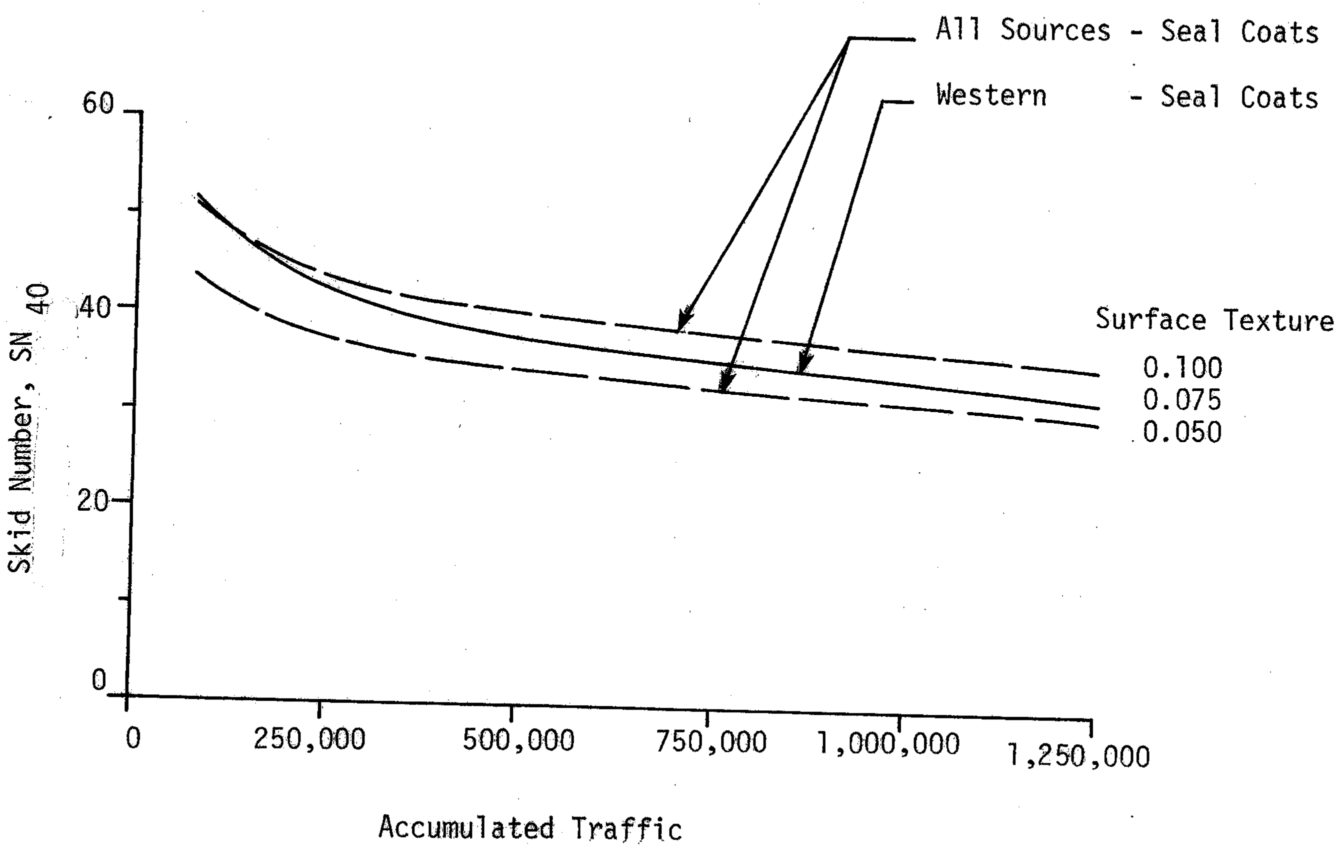

Figure 5. Skid Number Versus Accumulated Traffic for Various Levels of Surface Texture - District 25 Gravel Seal Coats.

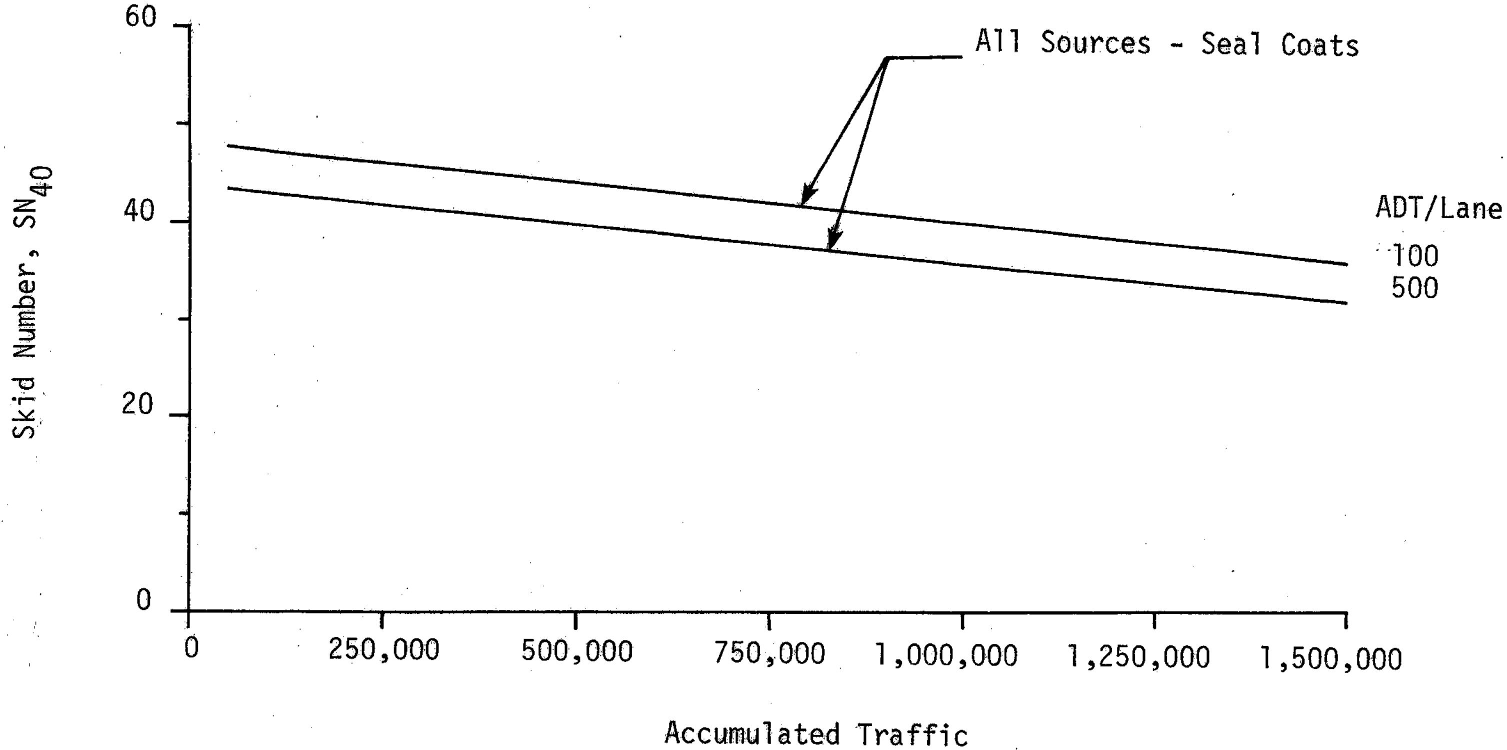

Figure 6. Skid Number Versus Accumulated Traffic for Two Levels of ADT/Lane - District 25 Gravel Seal Coats.

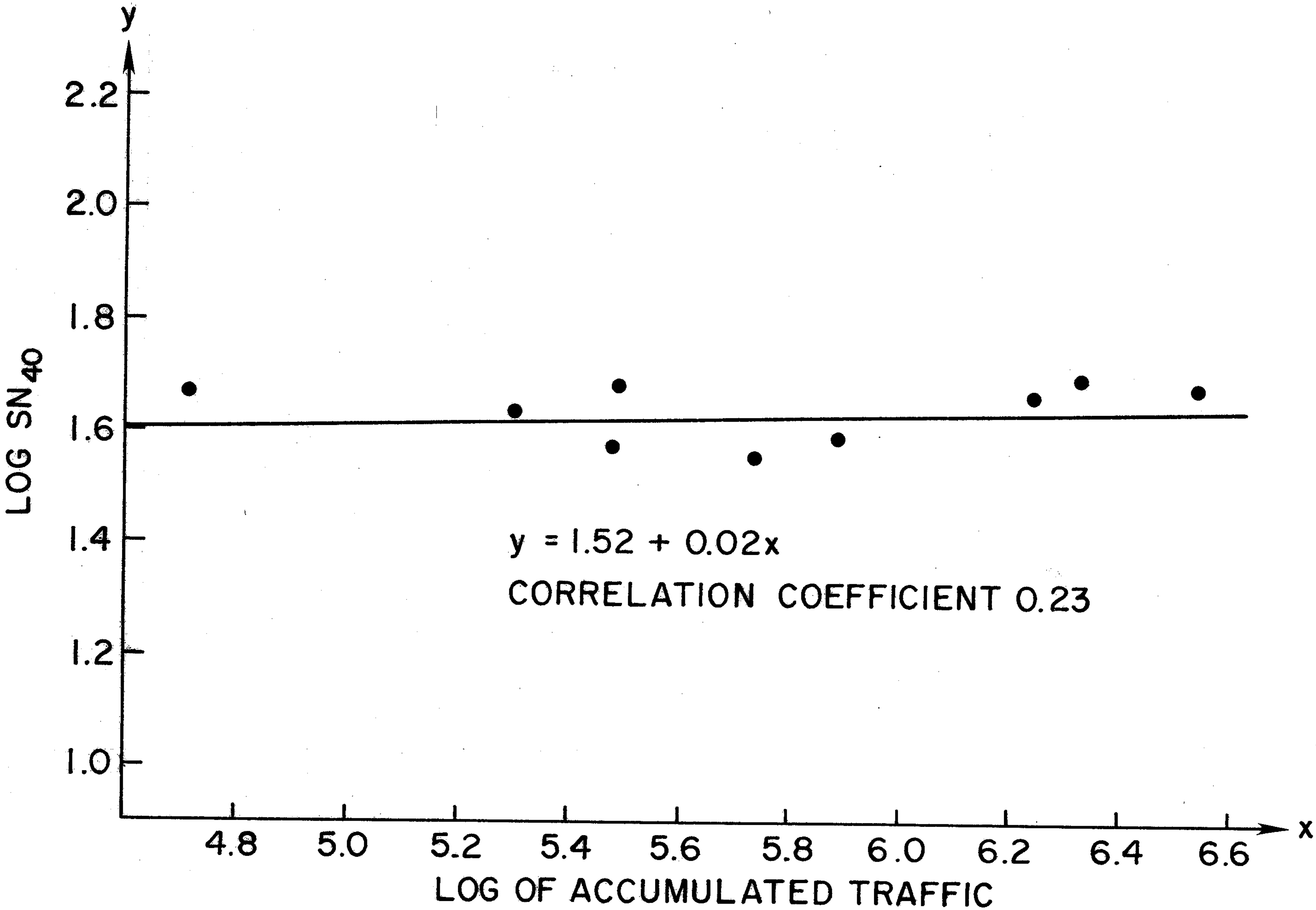

Figure 7. Qualification of Western Source Based Upon Skid Number.

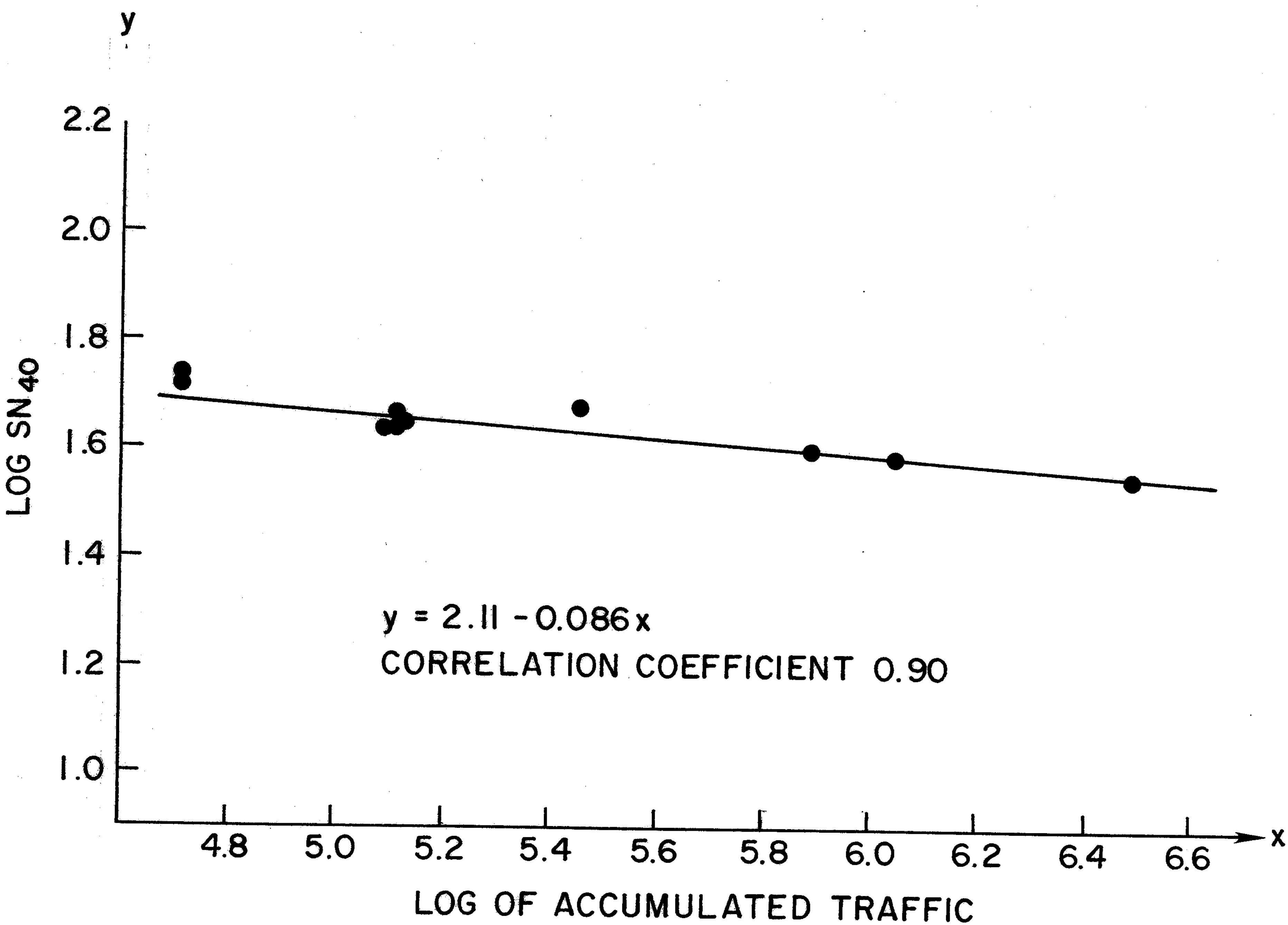

Figure 8. Qualification of Herring Source Based Upon Skid Number.

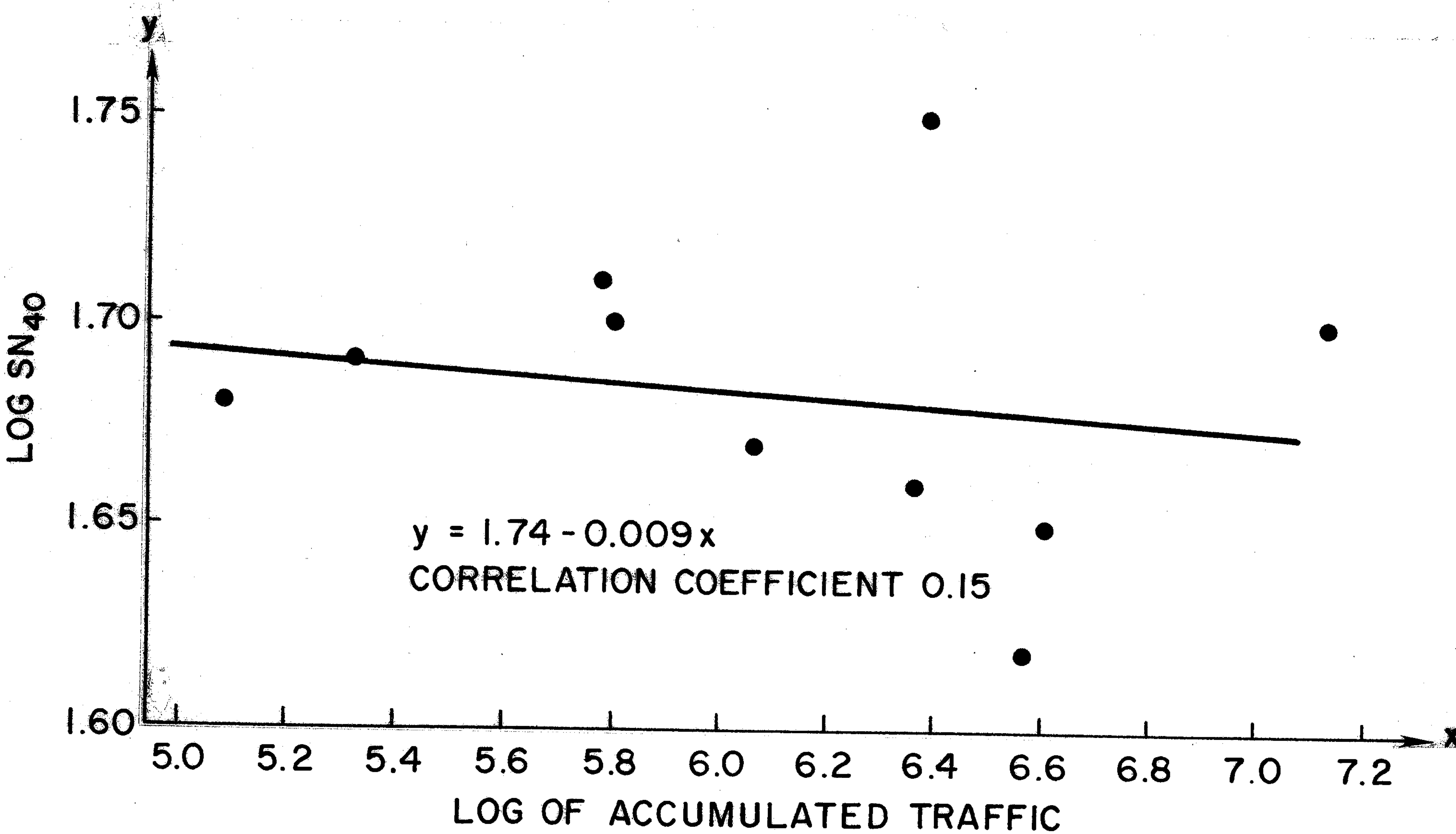

Figure 9. Qualification of Jarrett Source Based Upon Skid Number.

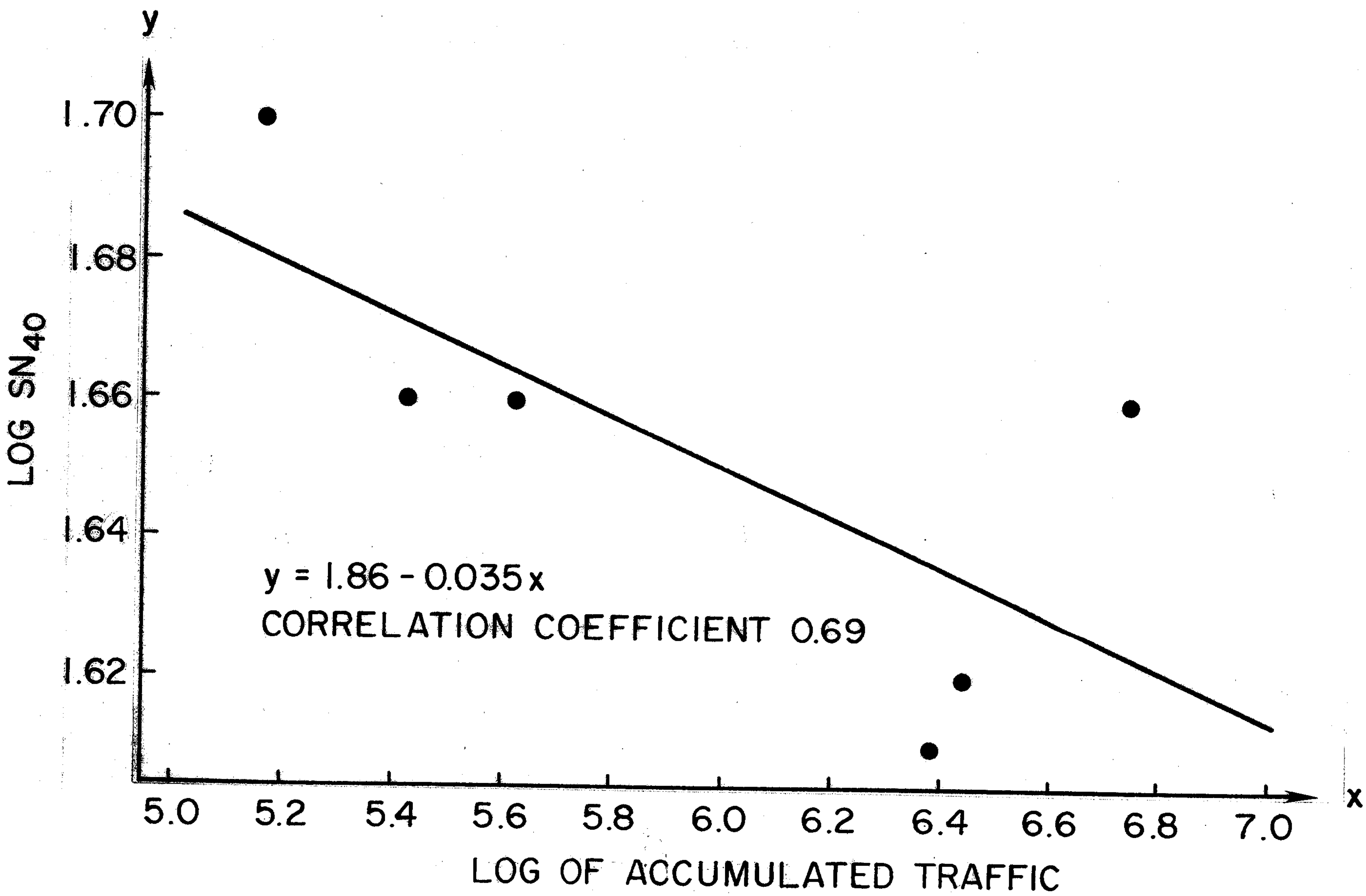

Figure 10. Qualification of Gregory Source Based Upon Skid Number.

APPENDIX A

Table A-1. General Statistical Summary for District 25 Gravel Sources and Pavement Types.

Aggregate Source: All Sources		Type of Pavement Surface: Combination				
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	454	44.0	6.6	22.0	60.0	15.0
Age	47	6.3	3.9	2.0	20.0	61.5
Surface Texture (Inner Wheelpath)	46	0.055	0.027	0.025	0.130	48.5
Accumulated Traffic	47	1,514,943	2,212,646	51,000	13,150,000	146.1
ADT/Lane	47	746	806	10	2,690	108.1

Aggregate Source: All Sources		Type of Pavement Surface: Asphalt Concrete				
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	299	44.9	5.2	34.0	58.0	11.6
Age	31	5.6	3.4	2.0	15.0	60.2
Surface Texture (Inner Wheelpath)	30	0.043	0.016	0.025	0.085	36.4
Accumulated Traffic	31	2,002,161	2,566,517	120,000	13,150,000	128.2
ADT/Lane	31	978	877	69	2,690	89.7

Table A-1. Continued.

Aggregate Source: All Sources			Type of Pavement Surface: Seal Coat			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coeffiecient of Variation (percent)
Skid $Number_{40}$	145	42.8	8.3	22.0	60.0	19.5
Age	15	7.9	4.5	2.0	20.0	56.4
Surface Texture (Inner Wheelpath)	15	0.082	0.025	0.039	0.130	30.9
Accumulated Traffic	15	539,020	640,052	52,100	2,008,000	118.7
ADT/Lane	15	248	309	10	1000	124.5

Aggregate Source: All Sources			Type of Pavement Surface: Seal Coat - No Flushing			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	90	48.0	3.9	39.0	60.0	8.1
Age	9	7.9	3.3	2.0	14.0	41.3
Surface Texture (Inner Wheelpath)	9	0.096	0.022	0.057	0.130	23.2
Accumulated Traffic	9	157,033	106,097	51,100	300,000	67.6
ADT/Lane	9	87	126	10	415	145.6

Table A-1. Continued.

Aggregate Source: All Sources Type of Pavement Surface: Asphalt Concrete - Non Rounded Aggregate						
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	224	46.3	4.5	34.0	58.0	9.8
Age	23	5.7	3.7	2.0	15.0	63.9
Surface Texture (Inner Wheelpath)	23	0.044	0.017	0.025	0.085	38.9
Accumulated Traffic	23	2,111,000	2,793,010	120,000	13,150,000	132.3
ADT/Lane	23	1004	928	83	2690	92.5

Aggregate Source: Western Type of Pavement Surface: Combination						
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	115	42.4	7.4	22.0	52.0	17.5
Age	12	6.1	3.6	2.0	14.0	58.9
Surface Texture (Inner Wheelpath)	12	0.068	0.022	0.029	0.106	32.8
Accumulated Traffic	12	1,077,841	1,023,597	51,100	3,490,000	95.0
ADT/Lane	12	570	377	10	1,195	66.2

Table A-1 Continued.

Aggregate Source: Western			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	50	44.5	5.5	34.0	52.0	12.4
Age	5	5.8	3.1	2.0	8.0	53.3
Surface Texture (Inner Wheelpath)	5	0.058	0.025	0.029	0.085	43.2
Accumulated Traffic	5	1,735,400	1,181,450	537,000	3,490,000	68.1
ADT/Lane	5	802	229	595	1195	28.5

Aggregate Source: Western			Type of Pavement Surface: Seal Coat			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	65	40.8	8.3	22.0	52.0	20.3
Age	7	6.3	4.1	2.0	14.0	65.6
Surface Texture (Inner Wheelpath)	7	0.074	0.019	0.055	0.106	25.4
Accumulated Traffic	7	608,157	610,438	51,100	1,510,000	100.4
ADT/Lane	7	404	386	10	1,000	95.6

Table A-1. Continued.

Aggregate Source: Western Type of Pavement Surface: Seal Coat - No Flushing

Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	30	47.2	2.4	40.0	52.0	5.1
Age	3	8.0	6.0	2.0	14.0	75.2
Surface Texture (Inner Wheelpath)	3	0.084	0.025	0.057	0.106	29.6
Accumulated Traffic	3	214,367	141,450	51,100	300,000	66.0
ADT/Lane	3	175	213	10	415	121.5

Aggregate Source: Western Type of Pavement Surface: Seal Coat - Non-Rounded Aggregate

Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	45	40.8	9.6	22.0	52.0	23.6
Age	5	6.6	4.7	2.0	14.0	70.9
Surface Texture (Inner Wheelpath)	5	0.074	0.023	0.055	0.106	31.3
Accumulated Traffic	5	722,620	703,327	51,100	1,510,000	97.3
ADT/Lane	5	471	436	10	1000	92.7

Table A-1. Continued.

Aggregate Source: Herring			Type of Pavement Surface: Combination			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	125	42.1	7.5	26.0	60.0	17.8
Age	13	7.9	4.2	2.8	20.0	53.7
Surface Texture (Inner Wheelpath)	12	0.072	0.035	0.029	0.130	48.8
Accumulated Traffic	13	760,708	904,935	51,100	3,030,000	119.0
ADT/Lane	13	295	337	20	1015	114.4

Aggregate Source: Herring			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	45	37.9	3.7	26.0	46.0	9.8
Age	5	5.5	2.7	2.8	10.0	48.1
Surface Texture (Inner Wheelpath)	4	0.038	0.011	0.029	0.054	30.1
Accumulated Traffic	5	1,212,200	1,087,872	122,000	3,030,000	89.7
ADT/Lane	5	588	369	69.0	1015.0	62.8

Table A-1. Continued.

Aggregate Source: Herring			Type of Pavement Surface: Seal Coat			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	80	44.4	8.1	29.0	60.0	18.1
Age	8	9.4	4.5	7.0	20.0	48.0
Surface Texture (Inner Wheelpath)	8	0.089	0.029	0.039	0.130	33.1
Accumulated Traffic	8	478,525	700,692	51,100	2,008,000	146.4
ADT/Lane	8	111	130	20	360	117.2

Aggregate Source: Herring			Type of Pavement Surface: Seal Coat - No Flushing			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	60	48.4	4.4	39.0	60.0	9.2
Age	6	7.8	1.6	7.0	11.0	20.4
Surface Texture (Inner Wheelpath)	6	0.101	0.020	0.077	0.130	20.2
Accumulated Traffic	6	128,367	83,958	51,100	281,000	65.4
ADT/Lane	6	42	19	20	70	45.7

Table A-1. Continued.

Aggregate Source: Jarrett			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	94	48.4	4.2	35.0	58.0	8.6
Age	10	7.1	4.6	2.2	15.0	64.3
Surface Texture (Inner Wheelpath)	10	0.039	0.007	0.027	0.051	19.2
Accumulated Traffic	10	2,550,000	3,905,783	120,000	13,150,000	153.2
ADT/Lane	10	894	970	83	2690	108.6

Aggregate Source: McAlreath			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid Number$_{40}$	20	45.5	2.3	43.0	49.0	5.0
Age	2	3.0	0.0	3.0	3.0	0.0
Surface Texture (Inner Wheelpath)	2	0.028	0.0	0.028	0.028	0.0
Accumulated Traffic	2	1,429,500	1,697,763	229,000	2,630,000	86.2
ADT/Lane	2	1305	1549	209	2400	86.2

Table A-1. Continued.

Aggregate Source: Schmoker			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	20	37.3	2.0	34.0	41.0	5.3
Age	2	2.0	0.0	2.0	2.0	0.0
Surface Texture (Inner Wheelpath)	2	0.032	0.004	0.029	0.034	12.5
Accumulated Traffic	2	1,001,500	365,574	743,000	1,260,000	36.5
ADT/Lane	2	1376	506	1018	1733	36.8

Aggregate Source: Gregory			Type of Pavement Surface: Asphalt Concrete			
Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	60	45.0	3.3	40.0	53.0	7.4
Age	6	4.2	1.9	3.0	6.7	44.8
Surface Texture (Inner Wheelpath)	6	0.045	0.017	0.025	0.070	37.5
Accumulated Traffic	6	1,919,500	2,101,256	147,000	5,520,000	109.5
ADT/Lane	6	1255	1182	134	2546	94.2

Table A-1. Continued.

Aggregate Source: Crabtree — Type of Pavement Surface: Asphalt Concrete

Variable	N	Mean	Standard Deviation	Lowest Value	Highest Value	Coefficient of Variation (percent)
Skid $Number_{40}$	20	46.4	3.3	41.0	51.0	7.2
Age	2	7.0	0.0	7.0	7.0	0.0
Surface Texture (Inner Wheelpath)	2	0.046	0.007	0.041	0.051	15.4
Accumulated Traffic	2	3,250,000	3,676,955	650,000	5,850,000	113.1
ADT/Lane	2	1272	1439	255	2290	113.1

Figure A-1. General Information Form

District No. ______County No. ______Highway_____From MP_____To MP_____Section No. ______

HISTORY: Year surface placed __________________ Type of Surface ________________________

Supporting Structure:

Construction Problems:

Performance:

DISTRESS:

DISCUSSION:

FUTURE MAINTENANCE:

CORES:

TRAFFIC: ________________ADT No. of Lanes _____________Accumulative Traffic____________

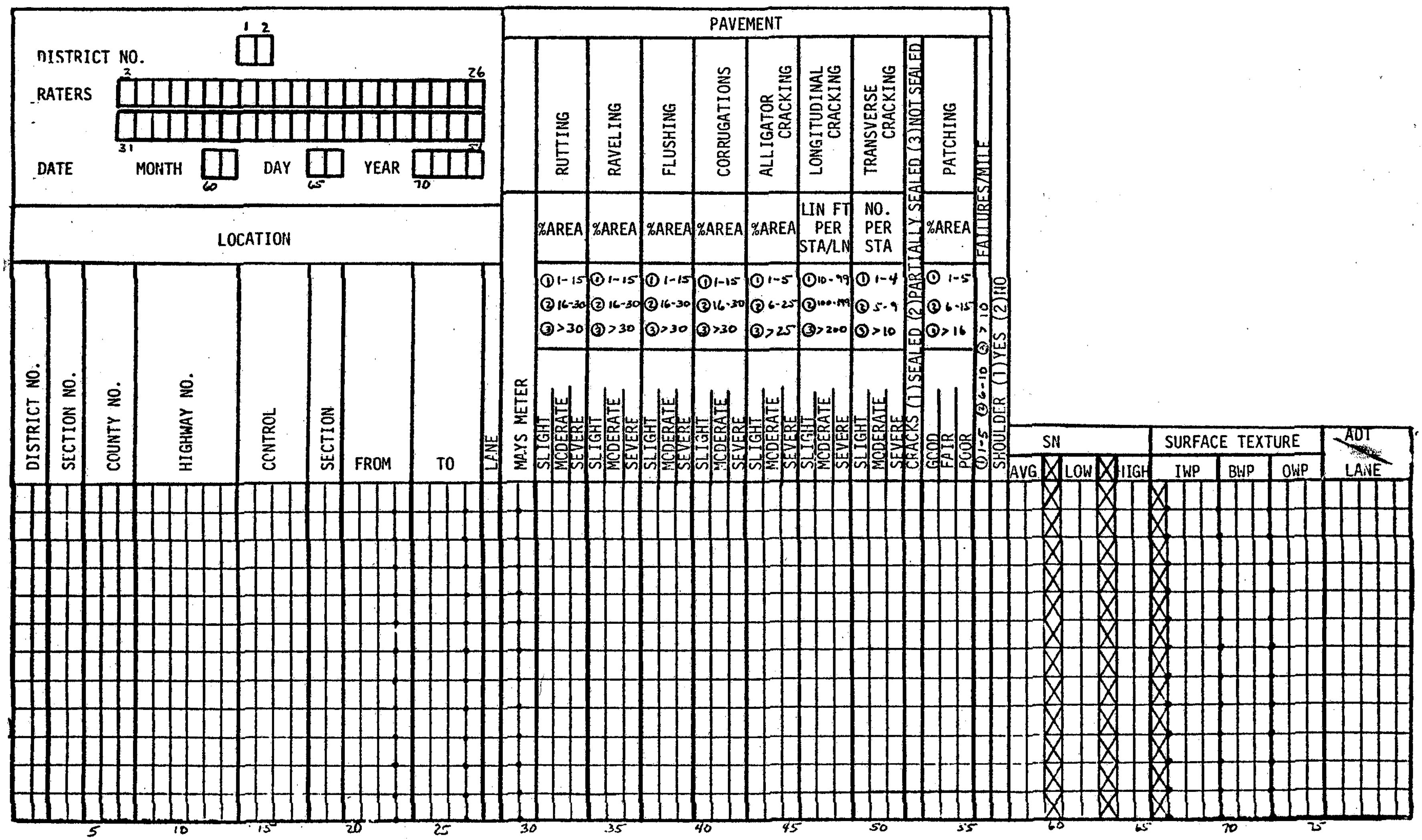

Figure A-2. Card No. 1

LOCATION											
DISTRICT NUMBER	SECTION NUMBER	COUNTY NO.	HIGHWAY NO.	CONTROL	SECTION	FROM	TO	LANE	SKID NUMBER 40 MPH	SURFACE TEXTURE	ACCUMULATIVE TRAFFIC

Figure A-3. Card No. 2