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16. Abstract

Previous reports have described the effects of oil field development on surface-treated pavements. Oil field traffic, however, is rarely confined to just one road. Localized drilling and production can affect the performance of flexible pavements across a widespread area.

A case study example demonstrates the procedure for analyzing flexible pavement networks in oil field areas throughout the state. The analysis procedure involves collecting regional network data and site-specific pavement, environmental, baseline (existing/intended-use) traffic, and oil field traffic data.

The regional and site-specific input data are entered into the Oil Field Pavement Damage Program, a computer program which models flexible pavement performance under baseline and oil field traffic. Program results estimate various types of pavement distress and provide a basis for selecting appropriate maintenance or rehabilitation strategies for each pavement.

This report also includes documentation which outlines the structure of the Oil Field Pavement Damage Program and indicates how the program incorporates variable drilling and production characteristics to predict flexible pavement performance in oil and gas field areas throughout the state.

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The Effects of Oil Field Development on Flexible Pavement Networks

by

J. M. Mason, B. E. Stampley, H. C. Petersen,

T. Scullion, and D. A. Maxwell

Research Report 299-6F

Research Project 2-8-81-299

Final Report

Conducted for

The State Department of Highways and Public Transportation

by the

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Mr. Gerald B. Peck was the Contact Representative for the State Department of Highways and Public Transportation. The Technical Advisory Committee acted as an integral part of this study; their continuous guidance and support are greatly appreciated. C. J. Keese, R. L. Lytton, N. J. Rowan, and D. L. Woods provided technical advice throughout the conduct of this research. Their time and efforts were greatly appreciated. The help provided by the various staff members of the Texas State Department of Highways and Public Transportation and the Railroad Commission of Texas is fully acknowledged as being instrumental to the completion of this effort.

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ABSTRACT

Previous reports have described the effects of oil field development on surface-treated pavements. Oil field traffic, however, is rarely confined to just one road. Localized drilling and production can affect the performance of flexible pavements across a widespread area.

A case study example demonstrates the procedure for analyzing flexible pavement networks in oil field areas throughout the state. The analysis procedure involves collecting regional network data and site-specific pavement, environmental, baseline (existing/intended-use) traffic, and oil field traffic data.

The regional and site-specific input data are entered into the Oil Field Pavement Damage Program, a computer program which models flexible pavement performance under baseline and oil field traffic. Program results estimate various types of pavement distress and provide a basis for selecting appropriate maintenance or rehabilitation strategies for each pavement.

This report also includes documentation which outlines the structure of the Oil Field Pavement Damage Program and indicates how the program incorporates variable drilling and production characteristics to predict flexible pavement performance in oil and gas field areas throughout the state.

SUMMARY

This report contains a procedure for analyzing the performance of flexible pavement networks in oil and gas field areas throughout the state. A case study "example" demonstrates how to use the Oil Field Pavement Damage Program to predict current and future pavement performance under various traffic conditions.

Regional and site-specific data were collected for a network of six surface-treated pavements and one asphalt-concrete overlay pavement (US 59) in Nacogdoches County. Regional data included the location of major oil field traffic generators such as service companies, gathering terminals, and saltwater disposal wells. These major activity centers were oriented along a major north-south corridor and a major east-west corridor. The regional data enabled easy visualization of major oil field traffic flow patterns across the network.

Site-specific data were collected which described the individual case study roads. Pavement characteristics were obtained from District lab personnel. Environmental characteristics were taken from the Department's statewide data file. Department traffic counts provided the necessary baseline ADT and percent trucks values. Baseline traffic represents the intended-use traffic for which the roadway was initially designed. This traffic may be represented by existing conditions if new "special-use" traffic has not yet occurred. If identifiable special-users exist in the traffic-mix, these vehicles can be segregated and their individual effects analyzed separately.

Oil field traffic was assigned to each road using a grid/density map of the case study network, which was generated using the Railroad Commission of Texas' (RRC) drilling permit records. The grid/density map and the drilling

permit records combined to provide the necessary drilling and production information for use in the analysis procedure.

The Oil Field Pavement Damage Program was the primary analysis tool. The program was modified to permit analysis of any flexible pavement impacted by oil or gas field traffic anywhere in the state. Distress equations were added for black base, hot-mix, and overlay pavements, in addition to the original surface-treated pavement distress equations. Variable drill time and production truck traffic volumes were also added to the program.

The Oil Field Pavement Damage Program modeled the performance of each case study pavement under baseline and oil field traffic. For example purposes, each road was assumed to have been reconstructed in July, 1977 (which coincides with the first available drilling permit records). Reduction in service life ranged from 5 to 20 percent for four of the six surface-treated pavements, despite relatively low levels (3 to 13 wells over a seven-year period) of oil field activity. The overlay pavement, US 59, demonstrated no loss in service life due to the additional traffic associated with 25 wells.

Load-and-traffic-associated distress levels were predicted for seven years after reconstruction to determine which distress types were most prevalent. As expected, program results indicated that the surface-treated pavements, with their limited structural capacity, all showed signs of the accelerated development of load-associated distresses, especially rutting and patching. US 59, however, demonstrated no significant increase in load-associated distress types. Instead, the stronger overlay pavement results indicated severe longitudinal and transverse cracking -- which could be traffic-associated distresses brought about by the combined effects of high traffic volumes and environment.

The network analysis procedure described in this study may be used to predict the effects of oil or gas field development anywhere in Texas. Flexible pavement performance may be examined under new development, existing development, increasing development, or decreasing development. The pavement distress ratings identify predominant distress types and allow for judicious selection of appropriate maintenance or rehabilitation strategies. Because pavement performance is modelled under a specific truck traffic distribution, the utility of the analysis procedure is not limited just to oil and gas field areas. Research efforts are currently underway to apply the Oil Field Pavement Damage Program to other load-intensive, special-use truck traffic activity.

IMPLEMENTATION STATEMENT

The network analysis procedure outlined in this report is suitable for statewide use in evaluating the effects of oil and gas field truck traffic on rural flexible pavements. The analysis, however, depends upon several items which must be periodically updated to insure reliable results.

The county variability parameters and the grid/density maps were designed to be easily updated. Periodic updating of these analysis tools, and the RRC drilling permit records upon which they are based, is imperative to any implementation of the network analysis procedure.

The case study example demonstrates a general procedure for modeling flexible pavement performance under truck traffic. This procedure is suitable for integration into the Department's pavement management system "as is," or with the addition of traffic distributions obtained from on-site monitoring of major special-use activity centers.

DISCLAIMER

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CHAPTER 1 -- GENERATING INPUT DATA AND CASE STUDY NETWORK

INTRODUCTION

Texas has long been a major producer of oil and gas. While the state economy has benefited greatly from the prosperity of this industry, the burden it places upon the highway system has been recently investigated.

Drilling of an oil or gas well generates a substantial amount of load-intensive truck traffic. Since most oil and gas activity occurs in rural areas, the heavy truck traffic is distributed across networks of flexible pavements. Most of these are light-duty, surface-treated pavements designed for low volumes of passenger cars and light trucks. Rural areas are also served by high-type asphalt concrete or other similar pavements. These are designed for high volumes of passenger cars and accommodate a greater percentage of trucks.

Oil and gas field development generates a unique traffic distribution. Photographic monitoring of three oil well sites in Brazos County indicated that a typical oil well attracts 100 to 300 vehicles per day. This traffic is in addition to the baseline traffic already on the road generated by "normal" activity. (5) Truck traffic on a neighboring road typically increases from a baseline value of 5 percent up to 15 percent. Fifty percent of the trucks observed were 3-S2 semi-tractor trucks.

Truck traffic associated with just one oil well can double the total axle load and traffic volume experienced on nearby roads. Success of one well, however, encourages drilling of several other wells in the same area. Development often occurs at an exponential rate, resulting in accelerated pavement deterioration throughout the oil field region. The widespread consequences of oil and gas field development pose serious economic and scheduling problems for highway officials seeking to preserve the physical integrity of the rural highway system.

Analysis of the effects of oil field development on flexible pavements involves locating the major traffic generators using computer-generated grid/density maps. (8) A computer program, the Oil Field Pavement Damage Program, then converts the generated traffic into 18-kip equivalent single axle load (18-k ESAL) repetitions and computes pavement service life as a function of the area and severity of seven different types of pavement distress. (6) The program is based upon regression equations developed from ongoing field evaluations of over 400 flexible pavement sections across the state. With these equations, the Oil Field Pavement Damage Program can assess current flexible pavement condition under past or present development and predict future performance under projected baseline or increased oil field development conditions. (7)

Statewide variations in oil and gas formations are such that operations at a well site in one county will not be identical to those in another county. Each county has its own particular drilling and production characteristics. Since both of these operations directly affect traffic activity at the well site, variability parameters were developed for each county based upon computer tape records maintained by the Railroad Commission of Texas. (8) These parameters describe the county-specific characteristics of oil or gas field activity for use by the Oil Field Pavement Damage Program in computing flexible pavement performance.

The Oil Field Pavement Damage Program, coupled with the county variability parameters, computer-generated grid/density maps, and the network analysis techniques described in this report, may be incorporated into the Department's Pavement Management System. Although specifically developed for oil field activity, the rationale behind these techniques is generally applicable in PMS to any form of localized truck traffic activity.

NETWORK-LEVEL ANALYSIS

Analysis of flexible pavement performance in oil and gas field areas acknowledges the "network behavior" of highways in accommodating regional traffic. Since most wells are located in remote rural areas, traffic must travel along a series of roads to reach its destination. For example, a crude oil tanker truck may travel along a major state highway, then onto a farm-to-market road, and onto another farm-to-market road before reaching the well site. This three-road network may serve only one well or several wells. In either case, each of these roads has its own "baseline" traffic -- traffic which normally exists on the road. Each road must accommodate traffic resulting from the new development as well as its own initial baseline traffic. The onset of intense oil or gas field activity can severely tax the structural integrity and condition of each of the three pavements in the network.

The Oil Field Pavement Damage Program is applicable to such a network-level analysis. Input data must be collected both for the region itself and for the site-specific, individual elements of the network. Figure 1-1 outlines the process followed in generating regional input data.

REGIONAL INPUT DATA

Select Case Study Network

Northeast Nacogdoches County was the case study network selected for this report. The case study network consists of six surface-treated farm-to-market roads and one asphalt overlay pavement, as shown in Figure 1-2.

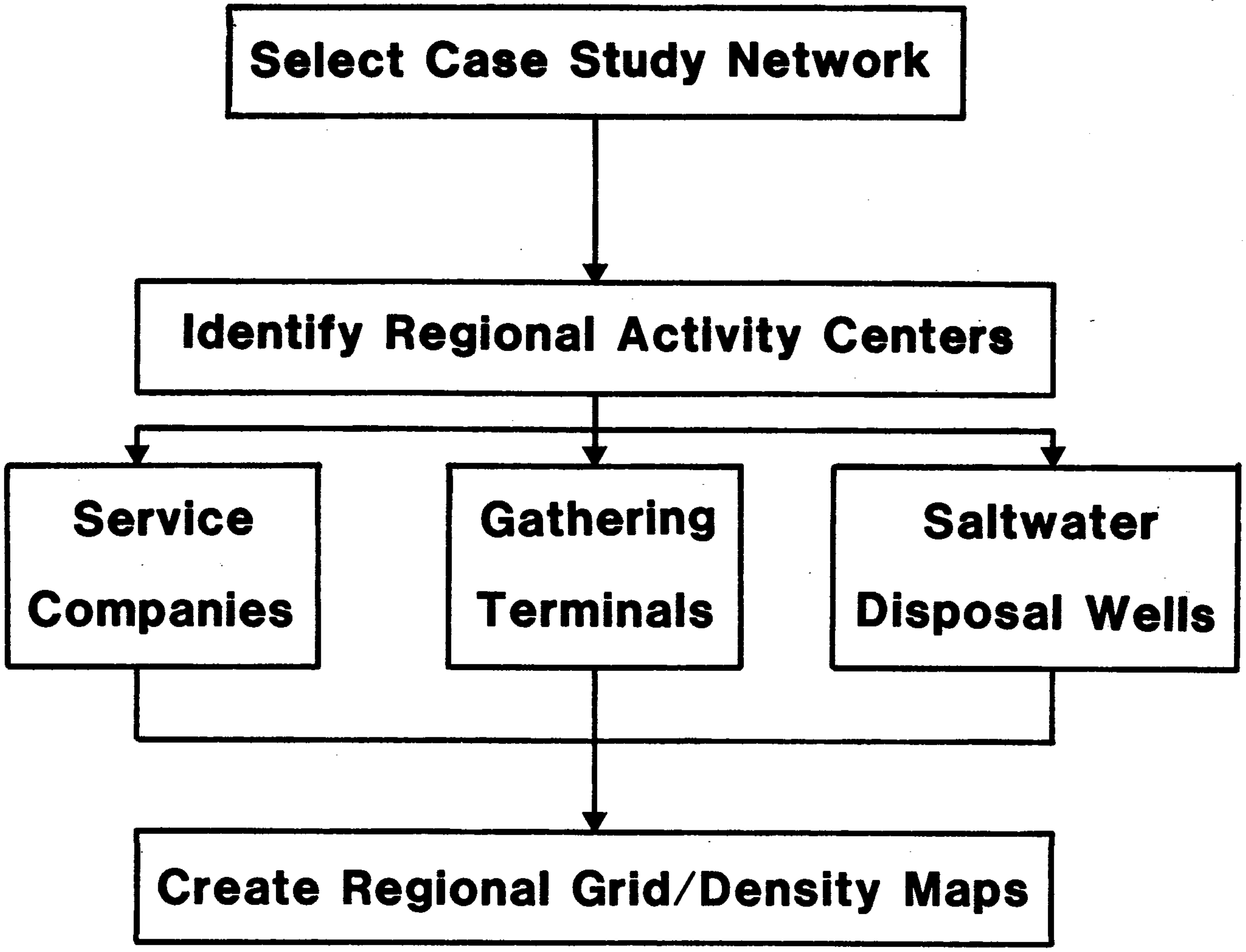

Figure 1-1. Generating Regional Input Data.

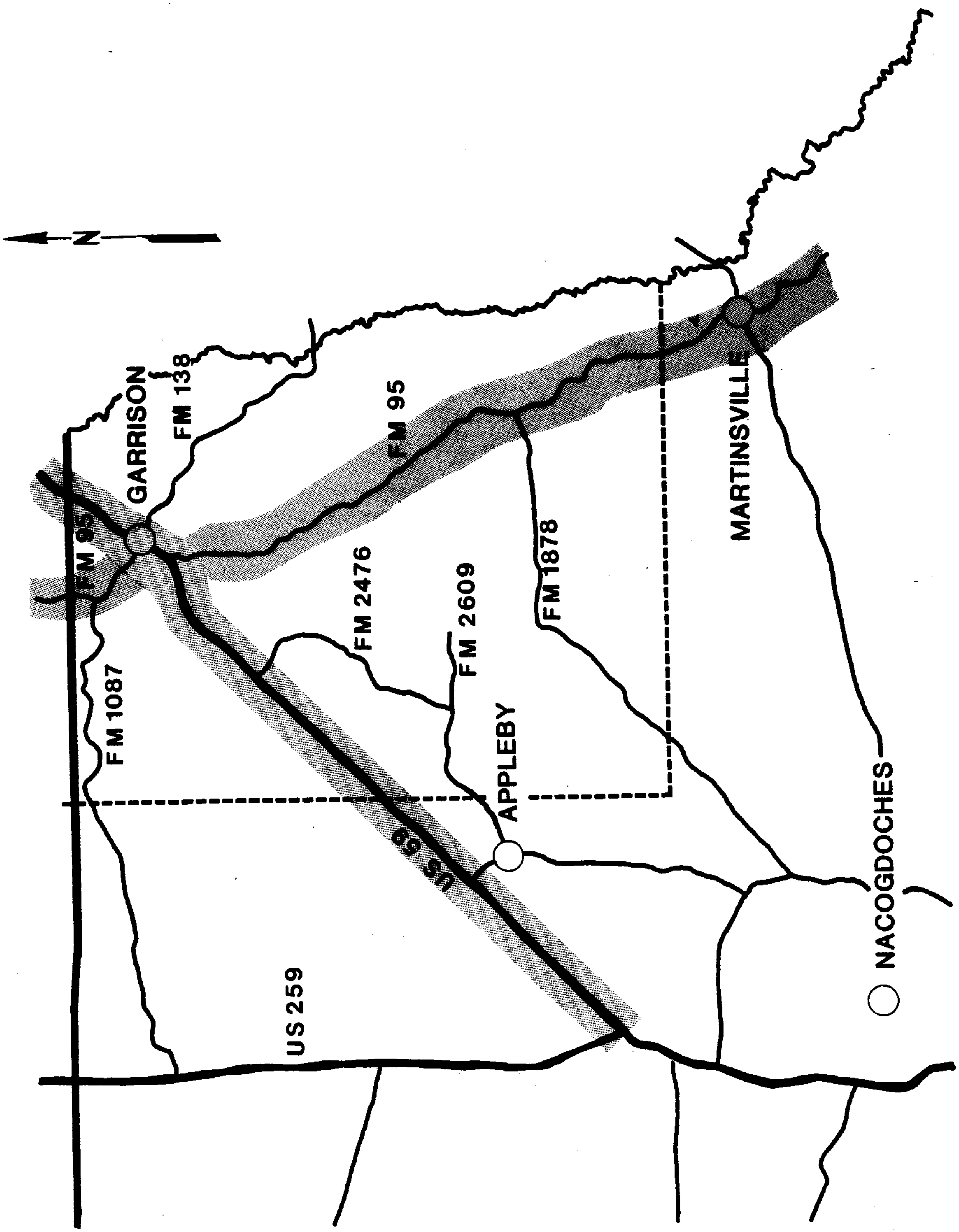

Figure 1-2. Map of Case Study Network.

The region was of interest because of a recent increase in oil and gas field activity. Although located only 50 miles south of the giant East Texas Oil Field, northeast Nacogdoches County did not experience the major oil boom which occurred in other areas, such as Brazos and Burleson counties, from 1977 to 1981. In 1982, however, oil and gas development began to increase. SDHPT officials in the area have expressed a concern that roads in this area, which already serve a load-intensive (high truck volume/heavy gross weight) timber hauling industry, will deteriorate even more rapidly under this additional special-use truck activity.

Identify Regional Activity Centers

The large volumes of heavy trucks associated with oil and gas field development threaten the condition of neighboring pavements. Determining major traffic flow patterns, then, was the fundamental task preceding any detailed analysis of the problem. Drilling and production operations were located by running a series of computer programs to generate a grid/density map of the study region. (9) Three other major traffic generators/attractors remained to be identified:

1. Service Companies
2. Gathering Terminals
3. Saltwater Disposal Wells

Service Companies. Service companies provide the major equipment needed during both the drilling and the production stages of well development. Frac tanks, vacuum tanks, cementing rigs, and drilling rigs are just some of the many different types of equipment which may be found in service company yards. Although they primarily service wells in their immediate vicinity, service company officials have indicated that they will travel to well sites within two or three hours of travel time. This large "radius of influence" placed the case study network within theoretical servicing range of Dallas, Bryan, Houston, Beaumont, and Texarkana. Realistically, however, service company traffic was expected to originate from Garrison or Nacogdoches with additional traffic originating from Henderson, north of the case study region.

Gathering Terminals. Gathering terminals store crude oil prior to distribution by pipeline. Many operators connect their high-producing wells directly to a major pipeline or pipeline network, but some must rely on trucks to enter their crude into the pipeline using the gathering terminal. Crude oil is the primary product involved since environmental and safety considerations limit the amount of truck transport of gas. Gathering terminals attract high volumes of production truck traffic, thus they may adversely affect pavement performance in an oil or gas field region.

The Railroad Commission of Texas (RRC) has issued permits to 19 pipeline operators in Nacogdoches County. Operator-supplied pipeline maps indicated the presence of five active pipelines within the case study network. Although no gathering terminals could be identified in the region, one was operating in Trawick (to the west) and another terminal was operating in Angelina County (directly south of Nacogdoches County).

Saltwater Disposal Wells. Both oil and gas wells produce various amounts of water, along with the expected oil or gas. Freshwater produced at the well site is returned to the groundwater at freshwater injection sites. Most of the water, however, is saltwater. Saltwater must be legally disposed of, either in a saltwater disposal pond or in a saltwater disposal wells. These saltwater disposal wells receive truckloads of saltwater from nearby wells and inject it back into regions of the earth where contamination of groundwater is considered least likely. Saltwater water disposal trucks add to the regional traffic and can also adversely affect pavement performance.

The RRC Underground Injection Control division has issued three permits for saltwater disposal wells in Nacogdoches County and 32 for neighboring Rusk County. Of the three Nacogdoches County sites, one was operating near Douglass (west of the network), one was recently plugged, and the other had not yet been drilled. The nearest saltwater disposal well for the case study network was located on FM 95, one mile north of Garrison, in Rusk County.

General Traffic Flow Patterns. Phase IV research did not specifically describe the traffic characteristics and flow patterns associated with the major oil field activity centers. A qualitative outlook, however, was sufficient to emphasize the potential impact of the new development on roads within the case study network. The evidence supported the following conclusions:

1. US 59 served as the primary corridor for service company traffic.
2. Gathering terminal activity was reduced because of the predominance of oil and gas pipelines within the area.
3. US 259, which is outside the network, diverted most saltwater disposal traffic from FM 95, which was the most direct route from within the network.

Create Regional Grid/Density Map

A regional grid/density map locating areas of well drilling and production activity was created using a series of FORTRAN computer programs. These programs were developed in Phase III and reported in Research Report 299-5. (9) The computer programs were used to: access the Railroad Commission's drilling permit master file (RRC.ROGFDM), extract the required information, and correct the drilling activity data to a more convent form. Figure 1-3 was developed from a computer-generated grid/density map of the case study network and defines the locations where permits have been issued along with the locations of drilled wells.

SITE-SPECIFIC INPUT DATA

The regional input data described the characteristics of the study region and located the major traffic generators and attractors. More detailed, site-specific input data was required by the Oil Field Damage Program to define the characteristics of each pavement in the case study network. Generating the necessary site-specific input data involved use of the regional input data, as depicted in Figure 1-4.

Obtain Existing System Data

The grid/density map located positions of existing and potential drilling/production activity within the case study region. A network of impacted roadways had already been suggested by SDHPT officials. Data concerning roadway characteristics such as traffic, pavement structure, and environment were also obtained. Table 1-1 contains baseline traffic volumes for the case study network taken from 1982 traffic counts conducted by the SDHPT.

Six of the seven roadways were surface-treated; US 59 consisted of an asphalt concrete overlay on a granular base. The inclusion of different flexible pavement structures was a key feature of the modified Oil Field Pavement Damage Program developed in Phase IV to perform network analysis.

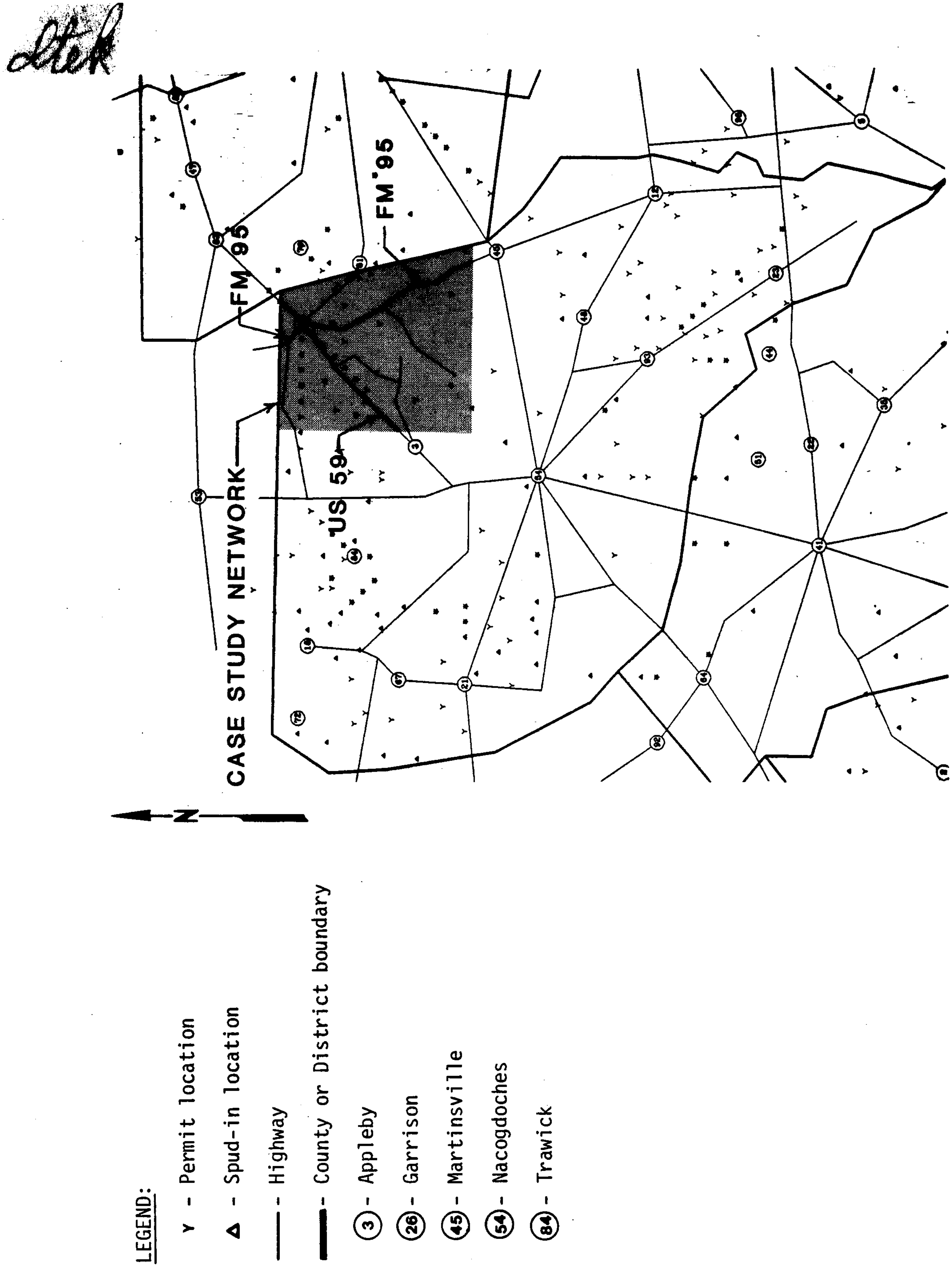

Figure 1-3. Grid/Density Map of the Case Study Network.

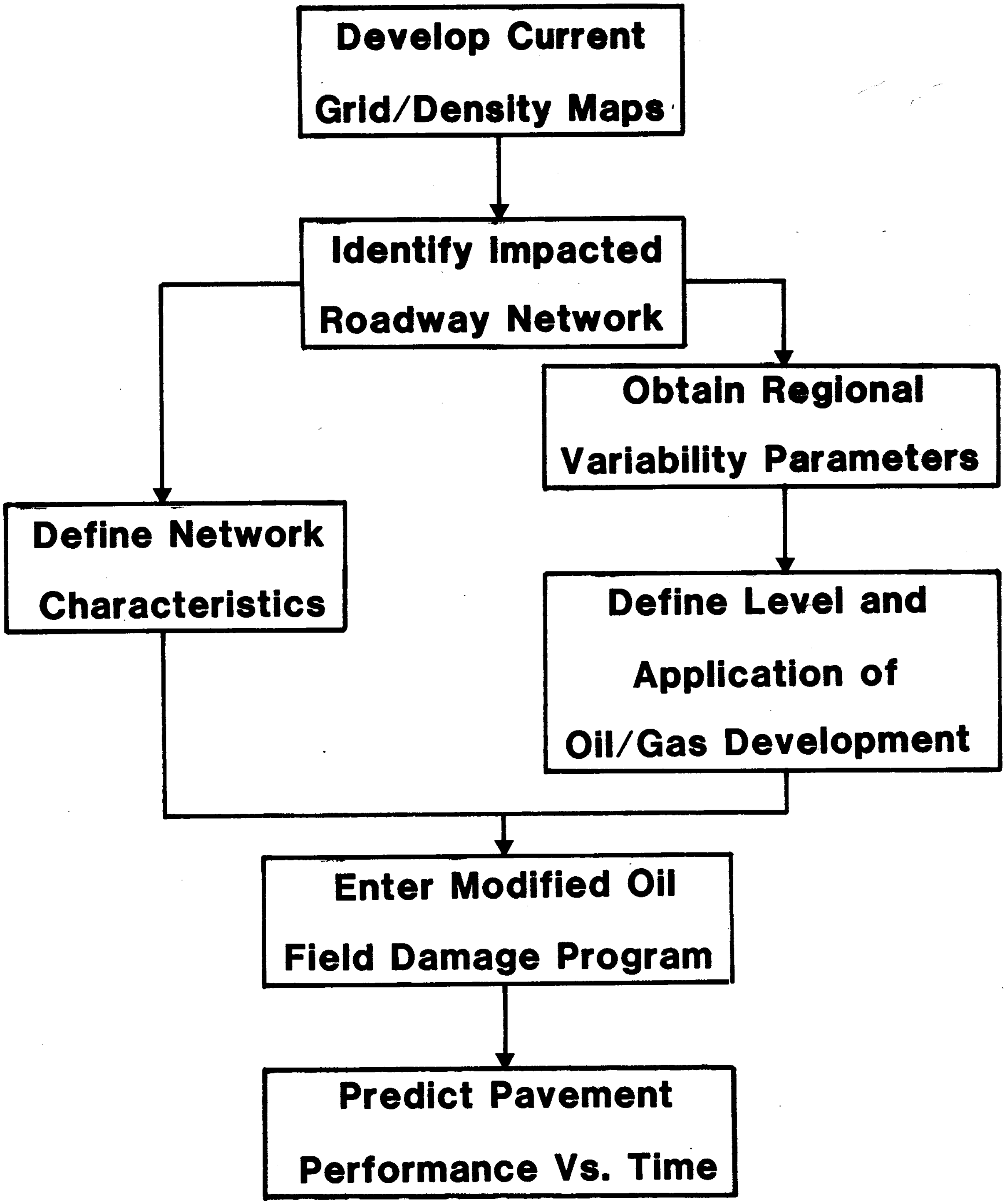

Figure 1-4. Generating Site-Specific Impact Data.

Environmental factors for Nacogdoches County were already contained within the Oil Field Pavement Damage Program. Pavement structure, however, had to be entered into the program. Table 1-2 describes the "typical" structural characteristics of each of the seven flexible pavements in the case study network.

Regional variability parameters for the case study network were taken from Nacogdoches County values contained in Research Report 299-4. (8) These parameters described various characteristics of oil and gas activity in the county and allowed consideration of drilling and production characteristics unique to the case study region. Table 1-3 contains the variability parameters used for Nacogdoches County.

Recent History of Oil and Gas Activity

The existing system data described the state of the case study network during baseline traffic conditions. Analysis of the effects of local oil and gas field development, however, required use of the grid/density map and the RRC.ROGFDM file.

The grid/density map, as mentioned before, can be used to identify locations of past, present and future drilling activity. The RRC.ROGFDM file contains the detailed record of every permit issued by the RRC since 1977. Records from this file may be extracted according to a number of criteria (i.e., by county, date, or well completion code). An extraction of the permit records for Nacogdoches County lead to the development of drilling and production "histories." These "histories" were essential to the analysis procedure because they defined the rate at which oil or gas field activity occurred in the case study region.

Table 1-1. 1982 Baseline Traffic Volumes for Case Study Network.

Road	Average Daily Traffic (ADT)	Percent Trucks
US 59	6700	10.0
FM 95	250	10.0
FM 138	470	10.5
FM 1087	230	10.0
FM 1878	200	10.5
FM 2476	420	5.0
FM 2609	480	7.0
Limits: Lat. $31^{\circ}40'$ N to Rusk County Line. Long. $94^{\circ}35'$ W to Shelby County Line.		

SOURCE: District 11

Table 1-2. Structural Characteristics of Network Pavements.

Road	Base Course	Surface Course
US 59	10-inch flexible base	2.5-inch ACP overlay
FM 95	6-inch base material*	0.5-inch seal coat
FM 138	6-inch base material*	0.5-inch seal coat
FM 1087	6-inch base material*	0.5-inch seal coat
FM 1878	6-inch base material*	0.5-inch seal coat
FM 2476	6-inch base material*	0.5-inch seal coat
FM 2609	6-inch base material*	0.5-inch seal coat

SOURCE: District 11

* Base Materials for these roadways is iron ore topsoil.

Table 1-3. Variability Parameters for Nacogdoches County.

Parameter	Description	Value
Lag Time	Expected response time for maintenance work before drilling begins	63 days
Percent Drilled	Probability of drilling activity at a given permit site	50.4%
Drill Time	Expected duration of drilling activity at a given well site	50 days
Success Rate	Probability of production activity at a given permit site	33.5%

SOURCE: Obtained from drilling activity tapes.

(RRC drilling permit records)

Drilling Activity. Table 1-4 contains drilling histories for six of the seven roadways in the network. These histories served as input data for the Oil Field Pavement Damage Program and were based upon data in the drilling permit master file.

Determining "when" drilling activity occurred involved making some assumptions, since some of the permit records in the RRC.ROGFDM file did not contain specific spud-in dates. The process involved either reading a specific drill date from the record, or determining the completion date and subtracting the typical county drill time of approximately two months to obtain the "spud-in date".

Determining "where" drilling activity occurred was less complicated. The grid/density map identified the approximate location of each well with respect to the existing highway system. Having located a well on the grid/density map, it was easy to identify the particular road which served it (i.e., FM 2476 does not serve any immediate well traffic). In addition, since the individual roads link up to form a network, it was easy to trace the expected flow of traffic from the minor roads onto the major roads. The net result was that major roads, such as US 59, were readily observed to carry the traffic associated with nearby wells and also with more remote well sites.

Production Activity. Production "histories" for the individual roadways in the network required reading the records of the RRC.ROGFDM file. Table 1-5 contains the production histories for the case study network.

The production histories gave the total number of producing wells which impacted each case study road. The ratio of producing wells (from Table 1-5) to drilled wells (from Table 1-4) was used to compute PRDPCT -- the

Table 1-4. Drilling Histories for Case Study Network.

US 59	
Month	No. of Wells
6	1
12	2
17	1
19	1
20	1
34	1
39	3
48	1
52	2
53	2
55	2
56	1
57	2
65	1
66	3
68	1
Total	25

FM 138	
Month	No. of Wells
33	2
37	1
49	1
53	1
57	1
58	1
60	1
Total	8

FM 1878	
Month	No. of Wells
8	1
43	1
51	1
Total	3

FM 95	
Month	No. of Wells
8	1
12	1
29	1
43	1
51	1
57	2
63	1
64	1
67	1
68	1
69	1
72	1
Total	13

FM 1087	
Month	No. of Wells
27	1
33	1
43	1
45	1
47	1
51	1
56	1
57	2
59	1
67	1
Total	11

FM 2609	
Month	No. of Wells
68	1
Total	1

<u>Note:</u> Month 1 = July, 1977

Table 1-5. Production Histories for Case Study Network.

US 59	
Month	No. of Wells
18	1
19	1
35	1
36	1
41	1
51	1
53	1
54	1
55	1
56	3
58	2
59	1
66	1
67	2
Total	18

FM 138	
Month	No. of Wells
36	1
50	1
54	1
56	1
61	1
Total	5

FM 1878	
Month	No. of Wells
57	1
62	1
66	1
Total	3

FM 95	
Month	No. of Wells
30	1
58	1
59	1
62	1
66	1
67	1
69	1
Total	7

FM 1087	
Month	No. of Wells
28	1
35	1
44	1
46	1
48	1
52	1
58	1
59	1
60	1
Total	9

Note: Month 1 = July, 1977

probability of production truck traffic ever being generated at a given drill site. Table 1-6 contains PRDPCT values used by the Oil Field Pavement Damage Program for each case study road. This wide range of values is typical of oil- and gas-bearing formations, even in relatively small geographical areas.

The case study analysis assumed that truck traffic would be generated at each production site. PRDPCT should be scaled down, however, if local conditions indicate that some producing wells are not serviced by truck traffic.

Table 1-6. Production Percent (PRDPCT) Values for Case Study Roads.

Road	Number of Drilled Wells	Number of Producing Wells	PRDPCT
FM 95	13	7	54
FM 138	8	5	63
FM 1087	11	9	82
FM 1878	3	3	100
FM 2476	0	0	0
FM 2609	1	0	0
US 59	25	18	72

SUMMARY

Network analysis recognizes that highways collect traffic as well as distribute traffic. Major highways, such as those on the Interstate or US system, may carry high traffic volumes originating from remote traffic generators. In the case of oil and gas field activity, major highways may deteriorate under heavy truck traffic, even if there are no wells nearby. While local roads often suffer an immediate, short-term loss of service life, major highways in oil and gas field areas bear the long-term burden of increased traffic volumes over a widespread area.

Analyzing the effects of oil and gas field development on flexible pavement networks depends upon a systematic methodology for generating the necessary regional and site-specific input data. This methodology involved identifying regional activity centers and the creation of regional grid/density maps. Site-specific data required oil and gas field development information from the Railroad Commission of Texas. Records from their computer files were extracted to establish drilling and production rate information.

The historical drilling/production data was used to segregate oil field generated traffic from the assumed "baseline" traffic demand. The following chapters demonstrate the conversion of traffic to 18-k ESAL repetitions, the use of the modified Oil Field Pavement Damage program, and the resulting estimates of reduced pavement performance under the oil field traffic demand.

CHAPTER 2 -- OIL FIELD PAVEMENT DAMAGE PROGRAM MODIFICATIONS

The initial research efforts in Brazos and Burleson counties defined pavement service life as a function of accumulated 18-k ESAL repetitions. Once traffic had exceeded the predicted accumulated 18-k ESAL capacity of the road, some form of pavement rehabilitation was necessary. For example, in Research Report 299-1, the AASHO Road Test procedures predicted that rehabilitation of a typical F.M. road under intended-use traffic was necessary at 3600 18-k ESAL repetitions. Intended-use traffic ("baseline" traffic) required 7.5 years to reach that total. Unfortunately, one oil well was found to generate 3600 18-k ESAL repetitions in only 3.3 years. (5)

The initial findings documented in Phase I of this project dramatized the pavement management problems posed by increased oil field development. Subsequent research, sought a more detailed analytical approach.

ORIGINAL OIL FIELD PAVEMENT DAMAGE PROGRAM

The Oil Field Pavement Damage Program developed in Phase II was based on work documented in Research Report 284-5 (2, 4, 6). This information enabled more reliable modeling of surface-treated pavements in the oil field areas of Brazos and Burleson counties. The program incorporated three major improvements over the Phase I analysis method:

1. Additional Monitoring of Oil Well Traffic.
2. Texas Distress Equations.
3. Pavement Score.

Additional Monitoring of Oil Well Traffic

Photographic monitoring of two additional Brazos County well sites verified the Phase I traffic distribution. A composite traffic distribution derived from these three observation sites formed the basis of the Oil Field Damage Program. Conversations with several petroleum consultants indicated that this composite distribution adequately described traffic activity at most other Texas oil well sites.

Texas Distress Equations

The AASHO Road Test Equation was used in Phase I to describe pavement performance under intended-use traffic. The predicted life of 3600 18-k ESAL repetitions, however, was considerably less than that observed for similar F.M. pavements in Texas. Since the AASHO Equation was derived for flexible pavements with a minimum surface course of 2 inches, it was expected that the predicted service life might not agree with observations of other "in-service" thin pavements in the state.

Data collection began in 1972 on a series of 400 flexible pavement sections, including 132 surface-treated sections, across the state. Periodic site inspections of these test sections provided information on the development of pavement distress. Stepwise regression of the test section data resulted in the development of separate "area" and "severity" equations for ride quality and pavement distress. Ride quality is described by a present serviceability index; pavement distress descriptors included: rutting, raveling, flushing, alligator cracking, longitudinal cracking, transverse cracking, and patching.

A detailed discussion of the development of the Texas Distress Equations and the Texas Flexible pavement Data Base are contained in Appendix F.

Pavement Score

The Texas Flexible Pavement Data Base contained test sections for surface-treated, black base, hot-mix, and overlay pavements. Each pavement type had its own set of distress equations. A new index, pavement score, incorporated all of the other distress equations into a single evaluator of condition for each pavement type.

Pavement score considers ride quality as well as the area and severity of each type of pavement distress. A new pavement begins with a pavement score of 100. As the pavement ages, ride quality and distress worsen, and pavement score drops. Failure is said to have occurred when pavement score drops below a pre-determined level, usually 35, as defined in the Department's Pavement Evaluation System.

The Oil Field Pavement Damage Program described in Research Report 299-2 was designed to assess and predict surface-treated pavement performance under oil field traffic in Brazos and Burleson counties. (7) While environmental data was included for each Texas county, the oil traffic distribution used the composite traffic distribution developed in the Phase II efforts of the study. (6) The original program did not address the statewide management of pavements in oil field areas.

MODIFIED OIL FIELD PAVEMENT DAMAGE PROGRAM

The modified version of the Oil Field Pavement Damage Program allows network analysis of flexible pavements in oil and gas field areas in any

Texas county. The modifications involved three major program functions:

1. Input Different Drill Times.
2. Input Different Production Truck Traffic Characteristics.
3. Analyze Flexible Pavements Other Than Surface-Treated Pavements.

Input Different Drill Times

The original program included a 2-month drilling period for each well. This value was taken from photographic monitoring of the three Brazos county well sites and was also confirmed by several persons familiar with local drilling activities. Analysis of drilling permit records maintained by the Railroad Commission of Texas (RRC), however, indicated a wide variety of average county drill times. (8)

The Oil Field Pavement Damage Program has been modified to allow consideration of drill times of up to 6 months. Drilling traffic remains at 150 vehicles for each day of drilling activity. This enables analysis of heavy traffic demands associated with the drilling of very deep oil or gas wells.

Input Different Production Truck Traffic Characteristics

Drilling traffic often results in immediate pavement damage due to high traffic volumes of heavy vehicles occurring over short periods of time. Production traffic, while usually of lesser volume, may be spread out over many years. The predominance of heavy trucks associated with production poses continuing problems for pavement networks in producing oil field areas.

Oil well production is extremely sensitive to site-specific geologic conditions. Highly permeable formations may yield initial production rates for many years, while neighboring formations, though holding more oil, may exhibit an almost immediate decline in production.

The production per well variability parameter described in Research Report 299-4 may be used in lieu of a comprehensive geologic survey to predict monthly production truck traffic volumes. (8) Monthly volumes for each year of production should demonstrate a decline in activity over time. This decline may then be converted to an annual production traffic decay rate for use in the Oil Field Pavement Damage Program.

The production success rate parameter from Report 299-4 may also be entered directly into the program. This allows analysis of the effects of multiple "what-if" production scenarios on a given network.

Analyze Flexible Pavements Other Than Surface-Treated Pavements

The Texas Flexible Pavement Data Base contained test sections of four types of flexible pavement, each with its own set of statistically-derived distress equations. The original Oil Field Pavement Damage Program only contained the surface-treated pavement distress equations, since those pavements were being most severely impacted by oil field truck traffic. The other three sets of distress equations were added in Phase IV to allow analysis of flexible pavement networks in oil and gas field areas.

SUMMARY

The Oil Field Pavement Damage Program was originally intended for use in analyzing surface-treated pavements in the oil field areas of Brazos and Burleson counties. Several assumptions were incorporated into the program when it was introduced in Report 299-2 and demonstrated in Report 299-3. (6, 7)

Statewide network analysis represents an expansion in the scope of the research efforts. As the primary analysis technique, the Oil Field Pavement

Damage Program has been modified to meet the newly-expanded scope. Local drilling and production characteristics have been replaced by county-specific values. Black base, hot-mix, and overlay pavements may now be analyzed, along with surface-treated pavements, either individually or in networks. The modified program tabulates pavement performance over time under various levels of oil or gas field activity and documents the development of pavement distress. These results can assist in the scheduling of maintenance and rehabilitation work for each pavement in the area. The program permits application of pavement management systems' techniques to flexible pavements in oil and gas field areas and can be integrated into the Department's existing PMS framework.

CHAPTER 3 -- CASE STUDY ANALYSIS AND FINDINGS

The Oil Field Pavement Damage Program used the regional and site-specific input data derived in Chapter 1 to compute the performance of each pavement in the case study network under oil and gas field traffic. A time-specific analysis scenario was developed before making the final program runs. This scenario allows comparison of different pavements with different traffic loads at the same point in time.

ANALYSIS SCENARIO

Analysis of each pavement in the study network assumed a starting date of July, 1977. This corresponded with the first month of drilling permit records as contained in the RRC.ROGFDM files. Drilling and production histories (Table 1-4 and Table 1-5, respectively) were developed for each of the seven case study roads using the RRC.ROGFDM file. Both the county variability parameters and the regional grid/density map were developed using drilling records from July, 1977, to June, 1983.

Baseline ADT values were taken from the Department's traffic maps for District 11. Nacogdoches county maps from 1977 to 1982 gave ADT values at two or three locations on each case study road. The available values were then converted into overall values, one per road, for each year (1977-1982). Least-squares regression of the overall values for each road gave approximate annual ADT growth factors for use in the Oil Field Pavement Damage Program. Truck percentages for each road were held constant at the 1982 values since the program does not consider the effects of increasing truck percentages.

District 11 lab personnel assisted in collecting structural information on each of the seven case study pavements. Lab records provided typical surface and base course thicknesses; dynaflect and ride quality measurements were made using Department equipment. Values for subgrade plasticity index and liquid limit were taken from Nacogdoches county test sections in the Texas Flexible Pavement Data Base being maintained by TTI under a separate contract. Each pavement was assumed to have been reconstructed immediately before July, 1977, to minimize complexity in the analysis.

The program output, included in Chapter 4, listed all of the input data (traffic, pavement, and environmental data; as well as baseline and oil field values) used in computing the performance of each of the case study roads.

CASE STUDY FINDINGS

The Oil Field Pavement Damage Program computed performance over time for each of the seven case study roadways under baseline and oil field traffic. Pavement performance was described in terms of pavement score, ride quality (PSI), load-associated pavement distresses, and traffic-associated distresses.

Pavement Score

Pavement score describes overall pavement condition by considering the combined effects of pavement distress and ride quality. Pavement score ranges from a high of 100 to a low of 0, with 35 generally defined as when the pavement has "failed." Table 3-1 lists predicted time to failure since the last rehabilitation, in months, for each case study roadway under baseline and oil field traffic. Figures 3-1 through 3-7 are plots of pavement score versus time for each of the case study roads.

Ride Quality

Figures 3-8 through 3-14 depict ride quality (P.S.I.) performance over time for each road in the case study network.

Table 3-1. Predicted Time to Failure in Months for Case Study Roadways.

Road	Baseline Traffic	Oil Field Traffic	Percent Reduction
US 59	71.5	71.5	0
FM 95	84.0	70.1	16.5
FM 138	61.6	55.5	9.9
FM 1087	113.5	92.7	18.3
FM 1878	85.0	78.5	7.6
FM 2476*	117.7	117.7	0
FM 2609	116.1	115.8	0.3

* No oil field traffic impacting roadway.

Notes: Failure = Pavement score ≤ 35.
Values indicate time to failure, in months.
Previous reconstruction in July, 1977 (month 1).

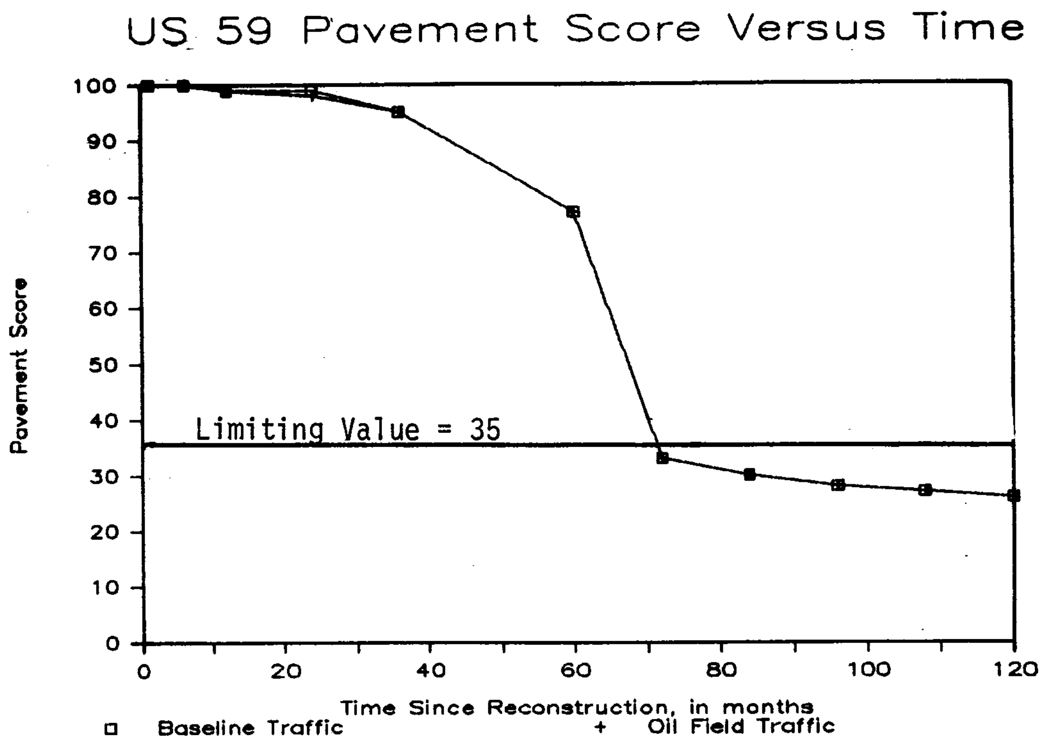

Figure 3-1. Pavement Score Versus Time for US 59.

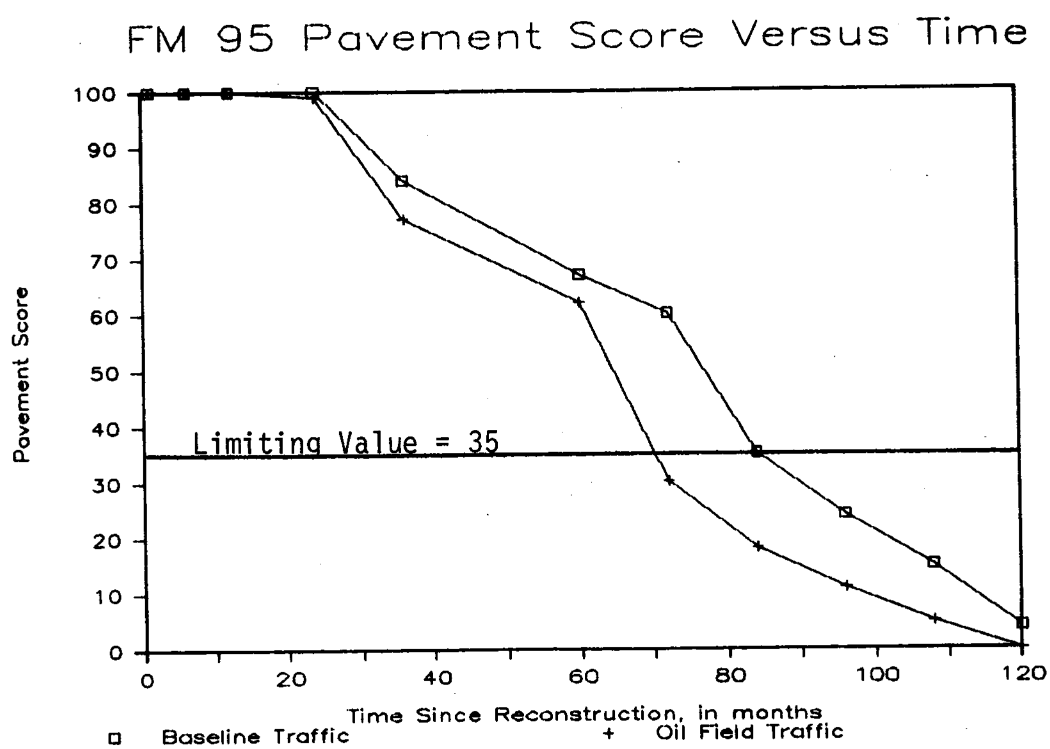

Figure 3-2. Pavement Score Versus Time for FM 95.

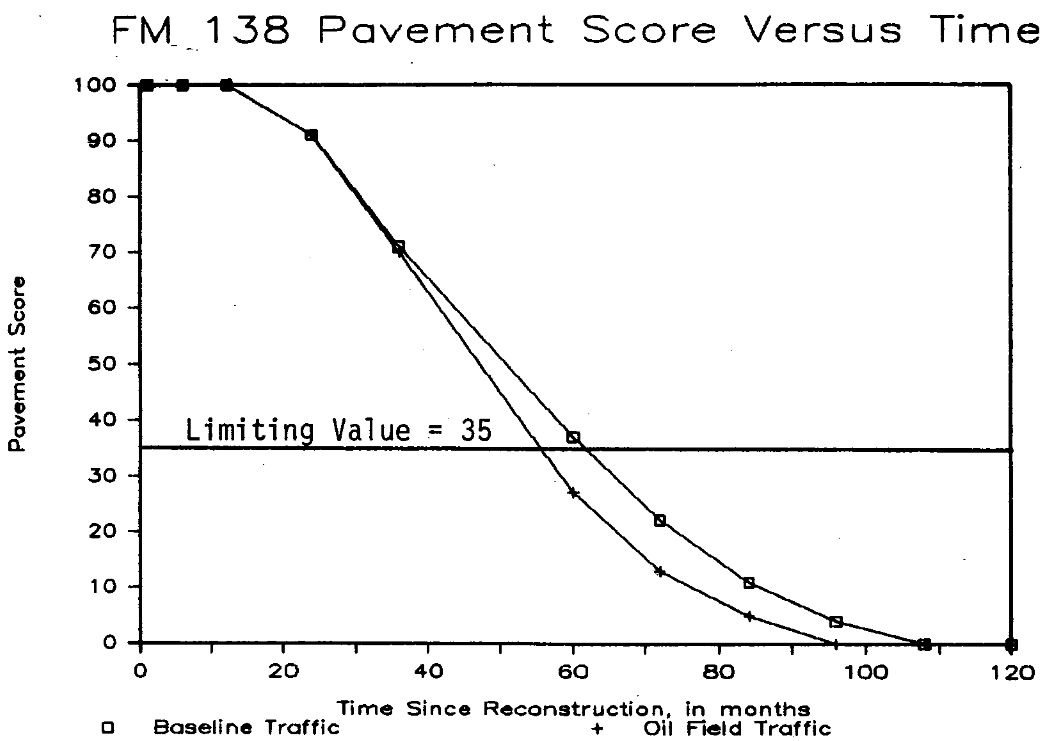

Figure 3-3. Pavement Score Versus Time for FM 138.

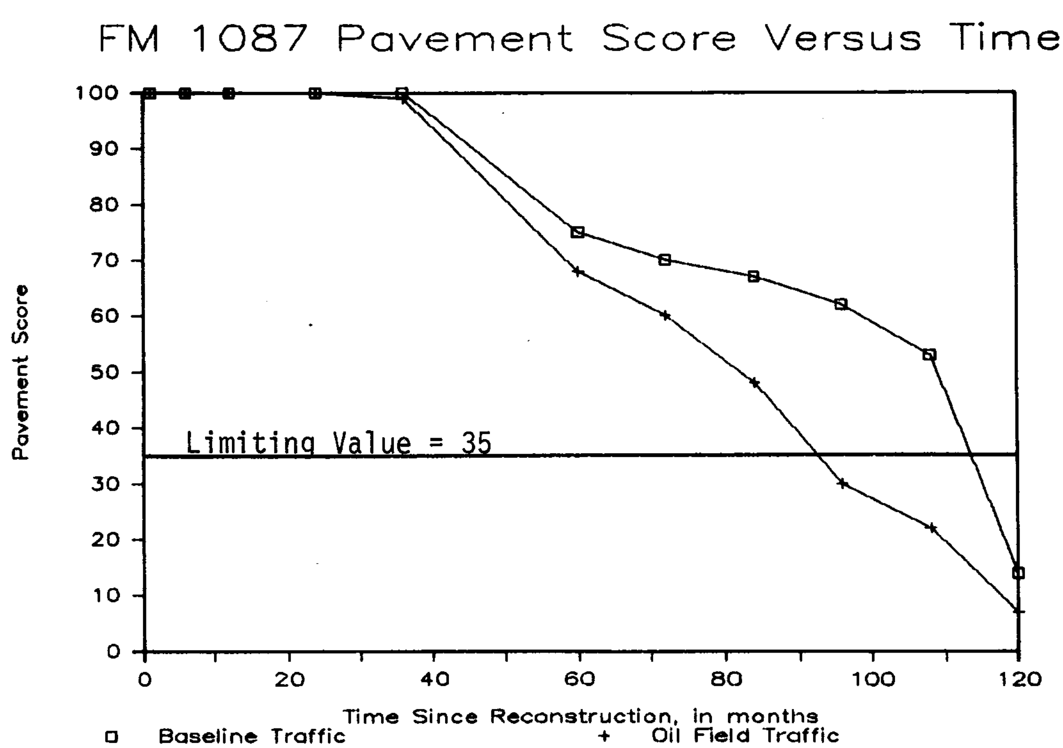

Figure 3-4. Pavement Score Versus Time for FM 1087.

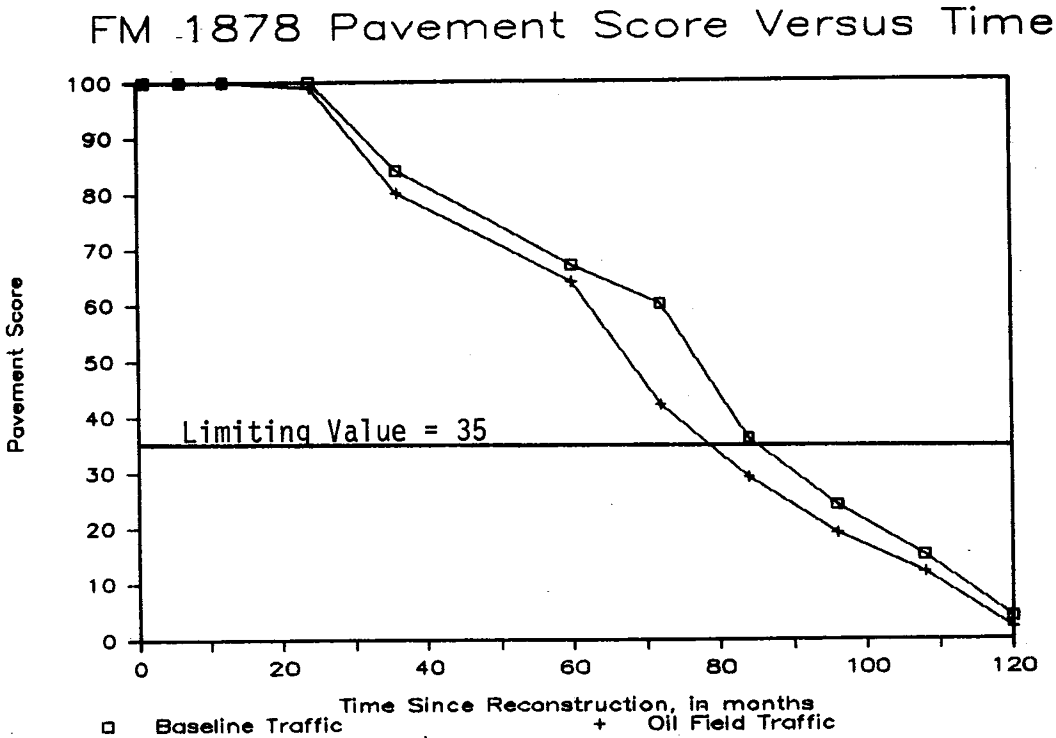

Figure 3-5. Pavement Score Versus Time for FM 1878.

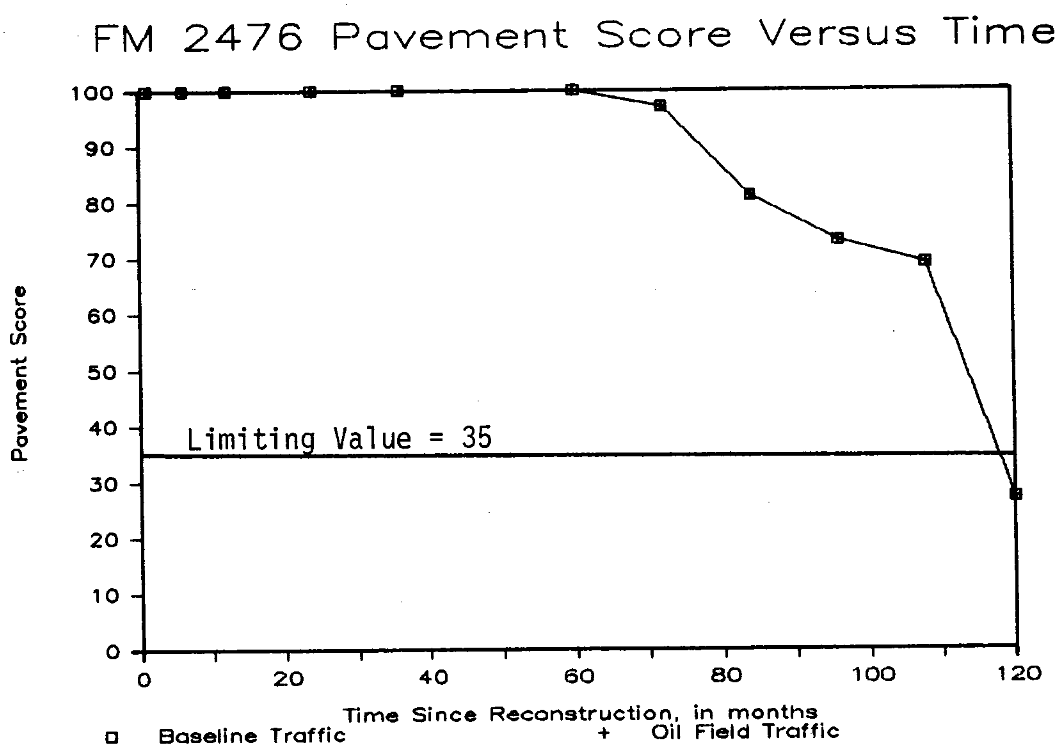

Figure 3-6. Pavement Score Versus Time for FM 2476.

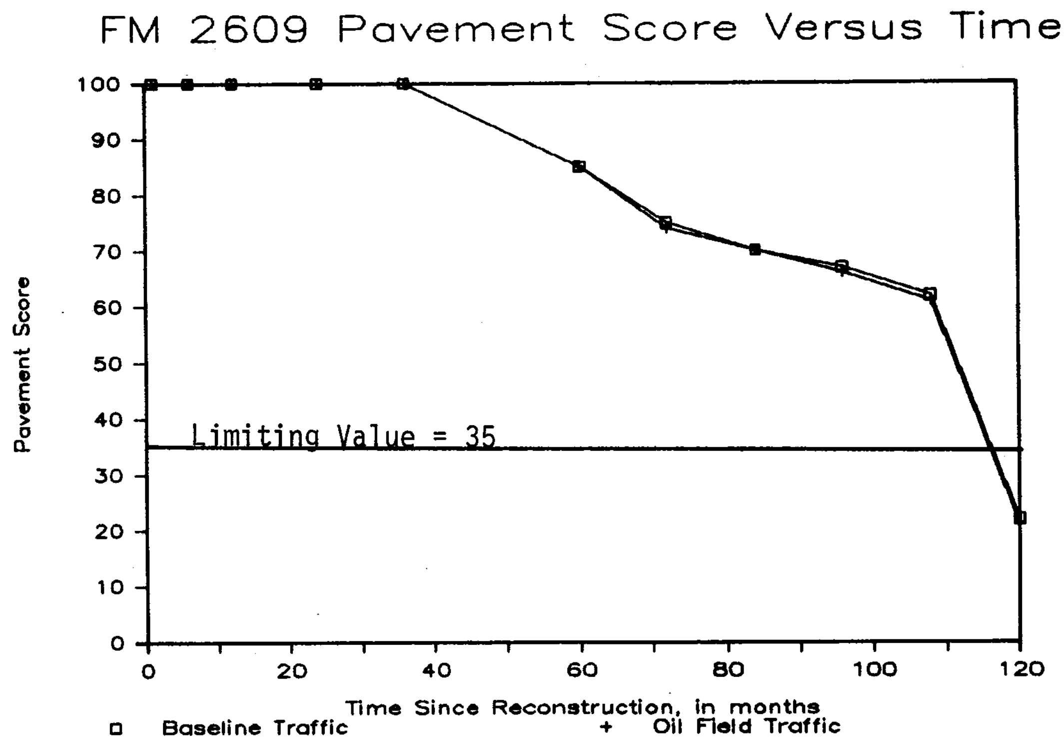

Figure 3-7. Pavement Score Versus Time for FM 2609.

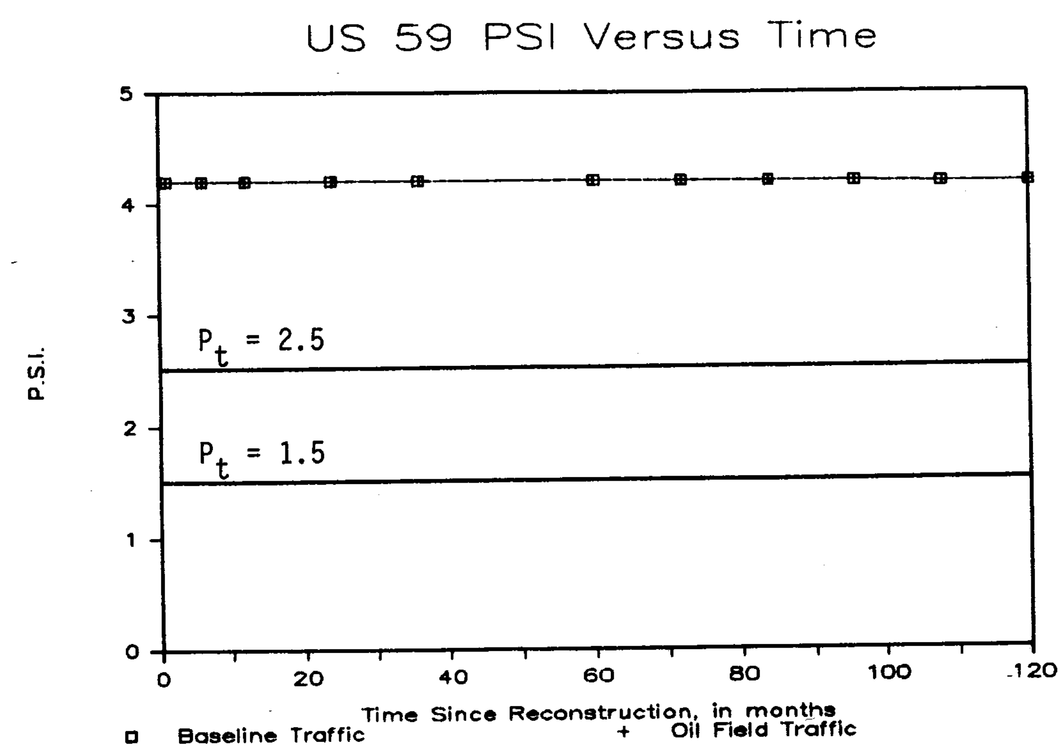

Figure 3-8. P.S.I. Versus Time for US 59.

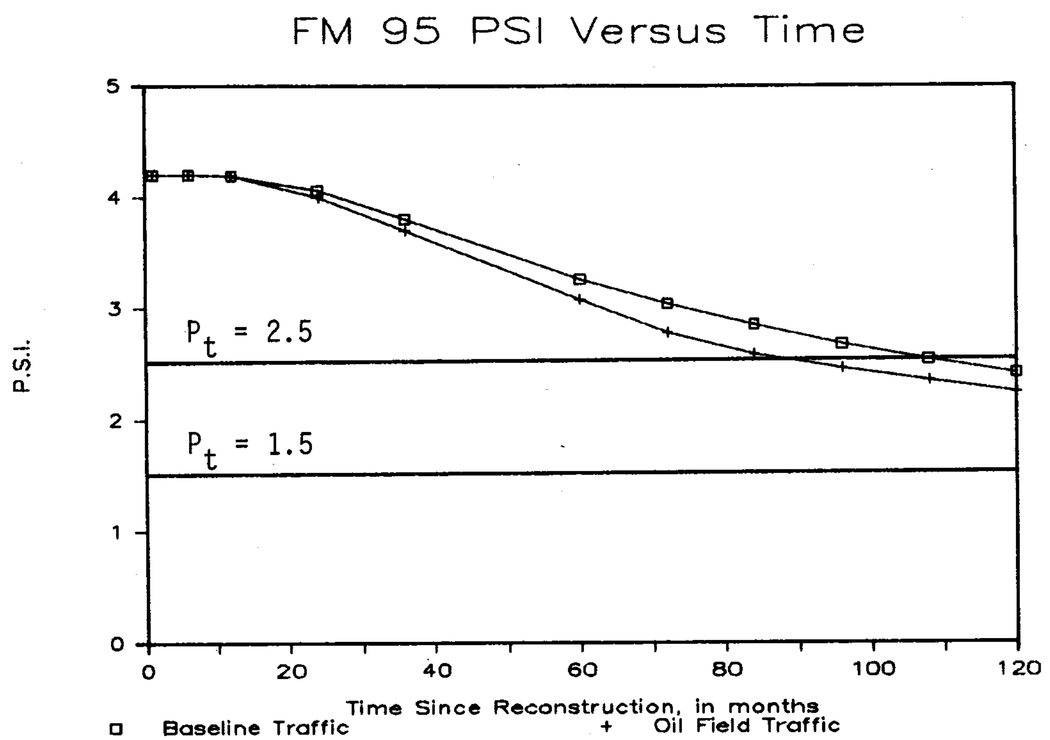

Figure 3-9. P.S.I. Versus Time for FM 95.

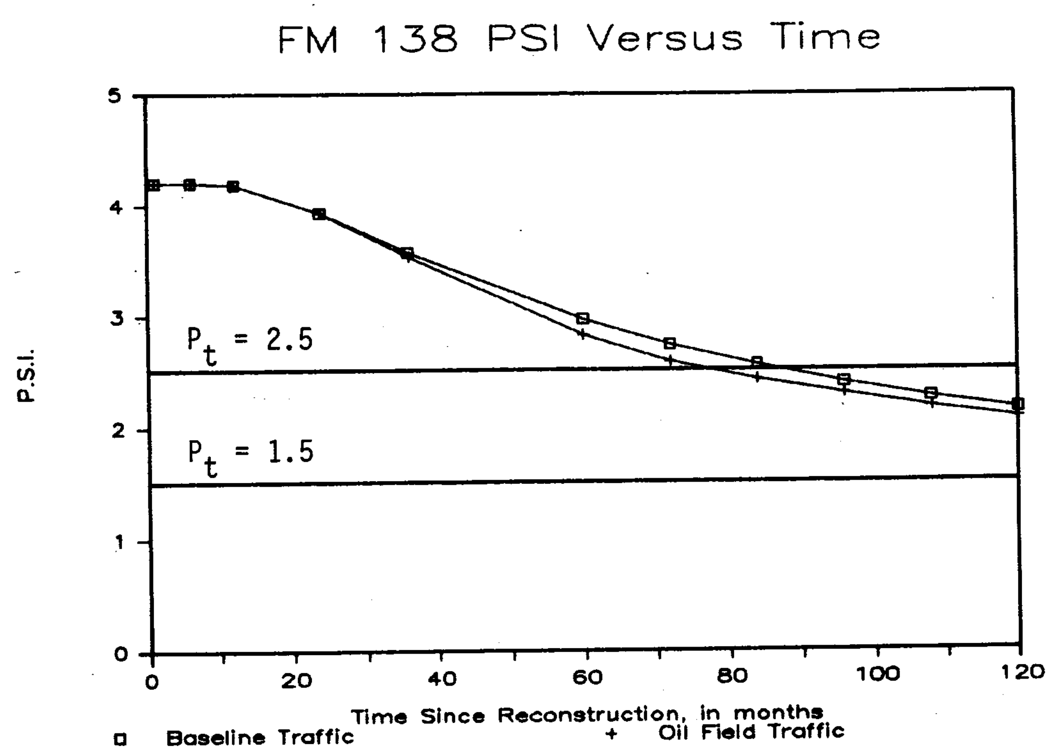

Figure 3-10. P.S.I. Versus Time for FM 138.

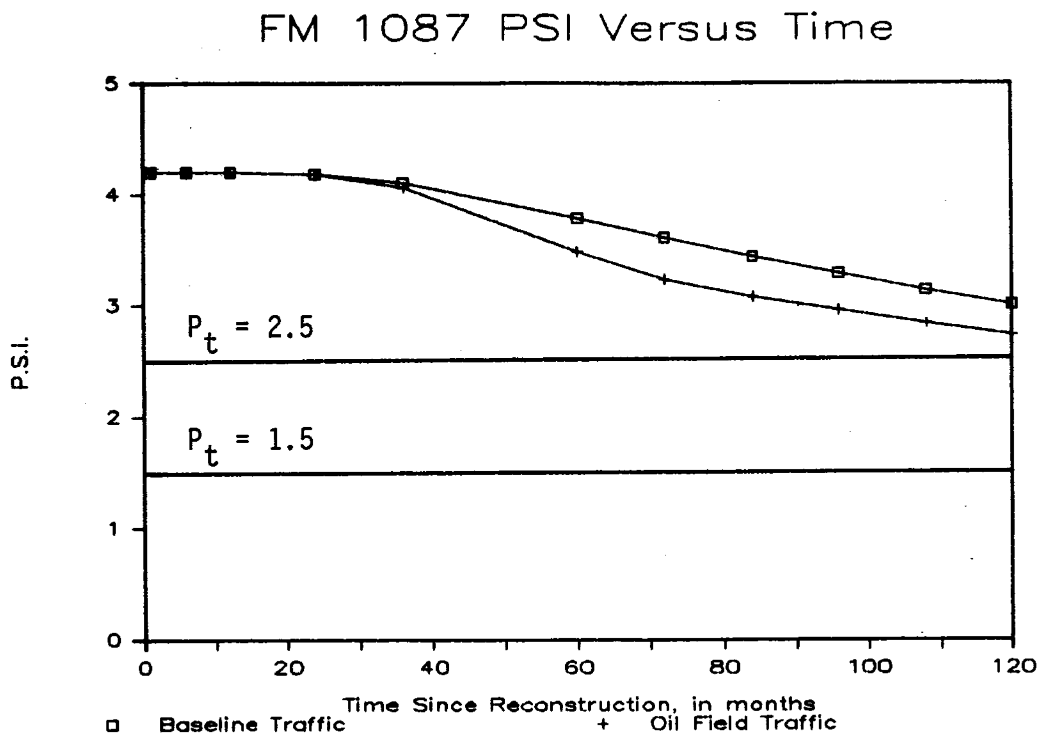

Figure 3-11. P.S.I. Versus Time for FM 1087.

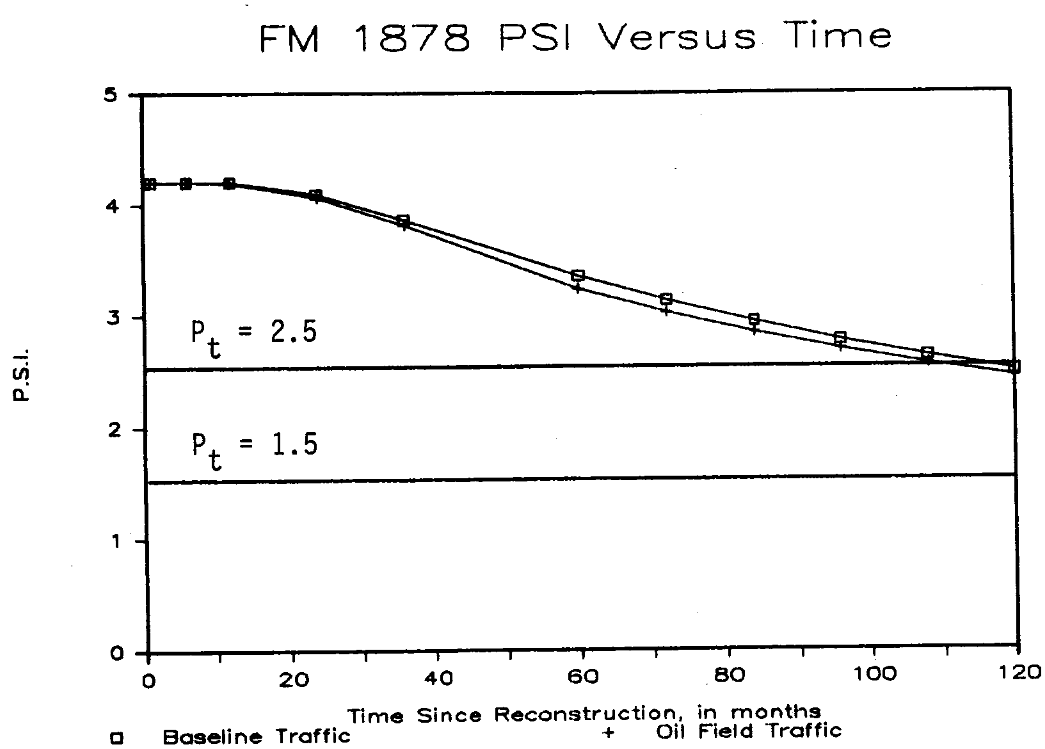

Figure 3-12. P.S.I. Versus Time for FM 1878.

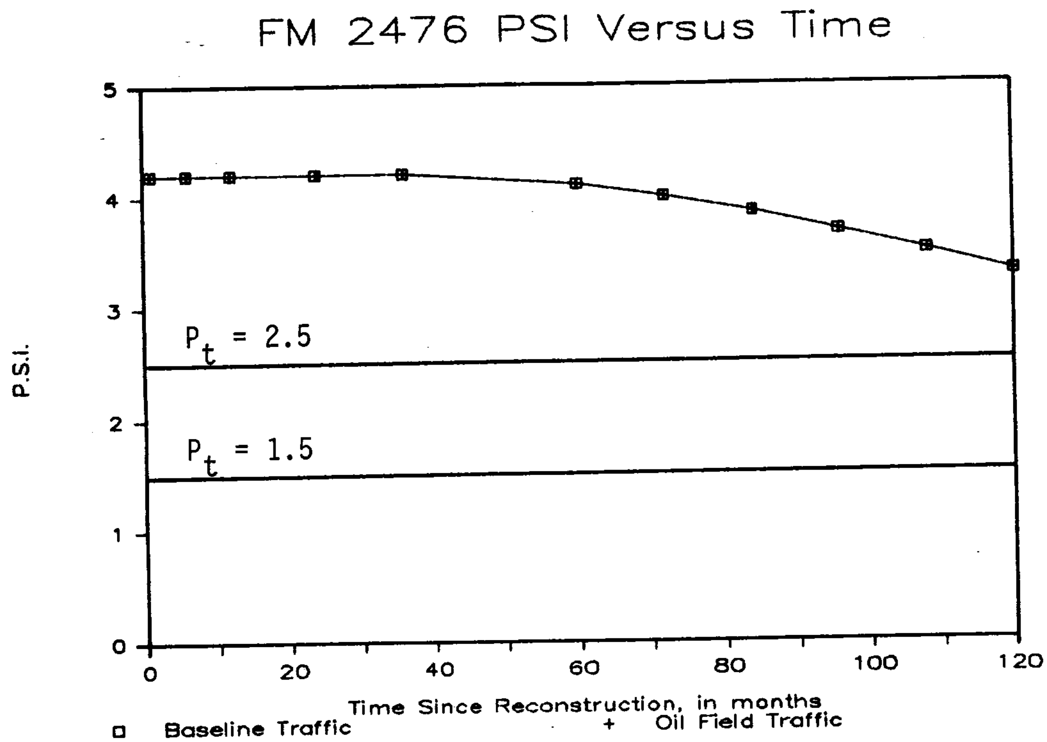

Figure 3-13. P.S.I. Versus Time for FM 2476.

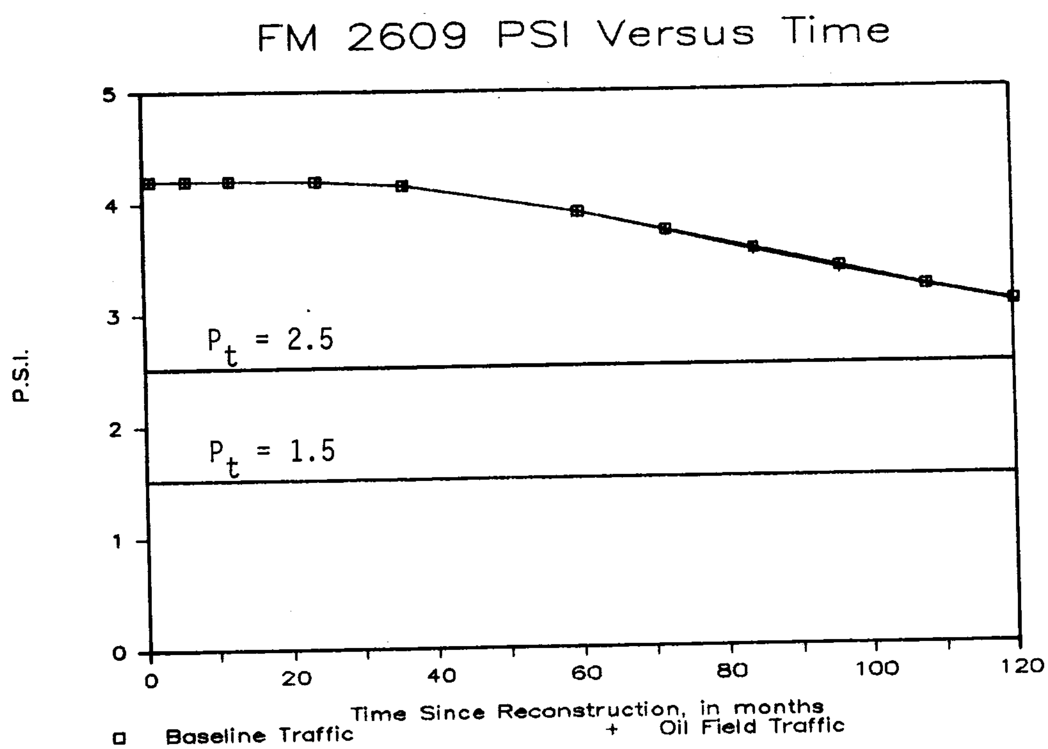

Figure 3-14. P.S.I. Versus Time for FM 2609.

Load-Associated Distresses

The Oil Field Pavement Damage Program contains area and severity equations for up to seven different types of pavement distress: rutting, raveling, flushing, alligator cracking, longitudinal cracking, transverse cracking, and patching. Three of these distress types -- rutting, alligator cracking, and patching -- are directly related to increased load. Final selection depends upon which of the four possible flexible pavement types is under analysis.

Rural flexible pavements intended for low-volume use are built primarily to provide an all-weather surface which is easily and inexpensively-maintained. Oil field traffic, however, involves large volumes of heavy trucks. The increased load accelerates the development of load-associated pavement distresses, reduces ride quality, and reduces anticipated pavement performance.

Table 3-2 contains area (A) and severity (S) ratings for rutting, alligator cracking, and patching for each of the case study roads seven years after reconstruction. As expected, the surface-treated pavements in active oil field areas (FM 95, FM 1087, and FM 1878) demonstrated the highest levels of load-associated pavement distress.

Traffic-Associated Distresses

The Oil Field Pavement Damage Program also contains distress equations which are not principally related to increased axle load repetitions. Flushing, raveling, longitudinal cracking, and transverse cracking are typically traffic-associated distresses which can result from environmental factors and expected increases in traffic volumes. As a result, high-volume regional highways such as US 59, while being structurally stronger than neighboring roads, often exhibit these types of distress.

Table 3-2. Load-Associated Distress on Case Study Roads Seven Years After Reconstruction.

Road	Rutting		Alligator Cracking		Patching	
	A	S	A	S	A	S
US 59	23.8	6.4	0.0	22.6	*	*
FM 95	**87.7**	**79.1**	35.5	32.0	**58.5**	**66.7**
FM 138	**92.8**	**85.2**	42.7	**50.0**	**69.1**	**73.6**
FM 1087	**77.7**	**69.3**	25.6	9.8	43.6	**57.1**
FM 1878	**82.7**	**74.0**	30.5	19.9	**50.3**	**61.5**
FM 2476**	14.7	23.4	5.9	0.0	4.0	21.4
FM 2609	45.3	**45.1**	12.7	0.1	16.8	37.1

Notes:
* Not calculated by Oil Field Pavement Damage Program.
** No oil field traffic impacting roadway.
[hatched box] These exceed maximum acceptable distress rating. (See Appendix A for further details).

Table 3-3 contains the traffic-associated distress area (A) and severity (S) ratings for each case study road seven years after reconstruction. As expected, US 59 demonstrated the highest levels of traffic-associated distress.

Table 3-3. Traffic-Associated Distress on Case Study Roads Seven Years After Reconstruction.

Road	Raveling		Flushing		Longitudinal Cracking		Transverse Cracking	
	A	S	A	S	A	S	A	S
US 59	*	*	*	*	2.1	31.0	23.0	56.5
FM 95	4.2	6.1	6.4	7.8	10.7	5.2	19.8	0.5
FM 138	6.3	9.2	10.1	12.8	10.7	5.2	19.8	0.5
FM 1087	0.6	1.0	1.8	1.8	10.7	5.2	19.8	0.5
FM 1878	1.3	2.1	2.8	3.1	10.7	5.2	19.8	0.5
FM 2476**	0.5	0.8	1.3	1.3	10.7	5.2	19.8	0.5
FM 2609	0.4	0.7	1.2	1.2	10.7	5.2	19.8	0.5

Notes: * Not calculated by Oil Field Pavement Damage Program.
** No oil field traffic impacting roadway.
[hatched box] These exceed maximum acceptable distress rating.
(See Appendix A for further details).

SUMMARY

The results demonstrated a significant reduction in service life of the surface-treated pavements even under low levels of oil field activity. Of the six surface-treated pavements, FM 95 (which served 13 wells) and FM 1087 (which served 11 wells) experienced the greatest percent reduction in performance due to their larger oil field traffic demands. Service life for FM 138 (which served 8 wells) and FM 1878 (which served 3 wells) was reduced by about six months. FM 2476 (serving 0 wells) and FM 2609 (serving 1 well) were not significantly affected by the regional oil field activity. The surface-treated pavements, with their limited structural capacity, all showed signs of the accelerated development of load-associated distress after seven years of baseline and oil field traffic.

Service life for US 59 was not reduced by the added truck traffic. Although carrying regional traffic associated with 25 wells, the increased pavement structure exhibited only minor increases in load-associated distresses upon failure. The program results indicated no increase in any of the traffic-associated distresses over the seven-year analysis scenario, even with the addition of over 510,000 vehicles.

The results of the case study network analysis demonstrate the utility of the modified Oil Field Pavement Damage Program. The program estimates pavement performance for immediate use in identifying current and future rehabilitation needs. The program also provides area and severity ratings for load- and traffic-associated pavement distresses for systematic use in selecting rehabilitation strategies for flexible pavements in oil and gas field areas.

CHAPTER 4 -- DESCRIPTION OF THE OIL FIELD PAVEMENT DAMAGE PROGRAM

This chapter describes the Oil Field Pavement Damage Program which has been developed under Project 299. A flowchart of the Fortran 77 program is given in Figure 4-1, and a complete listing of the program is presented in Appendix B.

The program was developed in two steps. The first step is described in TTI Report 299-2 and was developed by Tom Scullion. (6) It predicted pavement life for a single surface-treated pavement per computer run. The second step, described here, was a modification of the original program by H. C. Petersen to enable choice of flexible pavements, along with the capability to simulate a number of pavements and traffic scenarios per computer run. This program calculates:

A) Life to failure under baseline traffic,

B) Life to failure under baseline + oil field traffic,

for four different pavements, as selected by the user.

The program operates in three stages. The first stage reads in all of the input data and then computes baseline and baseline + oil field traffic characteristics. These traffic characteristics are loaded into an array for use by six traffic subroutines.

The second and third stages loop until PSI, pavement score, and pavement distress ratings have been calculated. This loop from Stage 2 to Stage 3 is run for each month that the user requested, once for baseline traffic and once for baseline plus oil field traffic, as described in the General Program Structure Section and Appendix A.

Please note the following assumptions:

1. The program considers all pavements to be two-lane roads, with one lane for each direction. In order to examine multilane facilities, lane distribution information must be developed to adequately describe the traffic mix. Although some initial work has been conducted by the Department, existing data are insufficient to summarize truck type distribution by lane assignments. Site specific data should be collected to properly classify the vehicle mix in a particular corridor.
2. Pavement distress equations were developed using stepwise regression of data gathered at the test sections included the Texas Flexible Pavement Data Base. (4) [See APPENDIX F for details].
3. Pavement score has been defined to be a function of PSI, visual score, and maintenance cost, a multiplicative utility approach. Pavement score considers the combined effects of pavement distress and ride quality in describing pavement condition. Equations have been developed to predict both area and severity ratings for several common distress types. These ratings range from 0 (no distress) to 100 (total distress).
4. The Dynaflect Maximum Deflection (DMD) [sensor #1 reading], is used to represent the structural strength of the pavement. This DMD value is used in the performance equations to calculate pavement deterioration rates.

INPUT FILES

The program reads input data from two files:

FILE01 - Contains county environmental data.

FILE02 - Contains user-supplied traffic and pavement data.

FILE01 (FT01F001, fixed file NOT user-supplied)

This file contains the required environmental data for each of the counties in Texas, one county per record. Table 4-1 below shows the first five and last five records from this file, which are the required environmental data for counties 1 through 5 and 250 through 254. The FILE01 format is as follows:

Table 4-1. Extracts From FILE01.

Co. No.	Th. Index	RFALL.	FTC.	W.FTC.	M.Max.T.	AV.T.
1	12.5	3.57	4.82	0.900	76.7	65.4
2	-39.3	1.14	8.48	0.637	77.8	63.3
3	11.7	3.60	3.81	0.430	78.1	66.7
4	-10.3	3.10	0.610	0.167	78.0	70.6
5	-16.2	2.35	5.83	0.854	76.3	63.9
---	----	----	----	-----	----	----
---	----	----	----	-----	----	----
250	9.81	2.59	9.73	1.16	73.4	60.0
251	-25.5	1.41	10.5	0.715	74.1	58.7
252	-14.9	2.48	8.77	0.800	76.9	63.7
253	-40.1	1.63	0.886	0.182	84.6	72.9
254	-30.2	1.87	1.61	0.117	82.7	71.0

OILFIELD DAMAGE PROGRAM

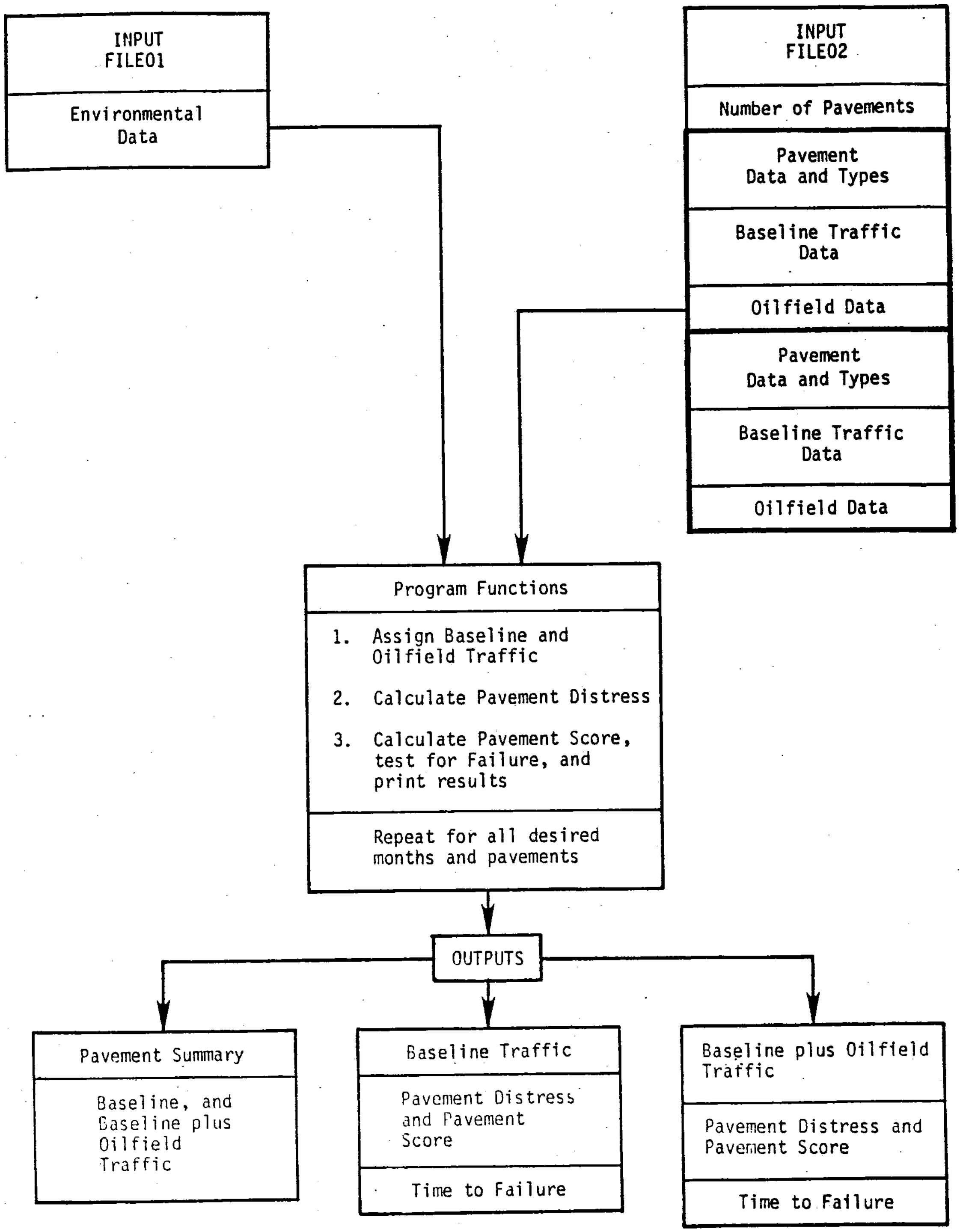

Figure 4-1. Program Operation

FILE02 (FT02F001, user-supplied)

This file contains all pavement and traffic data pertaining to the section under analysis. A complete FILE02 list for the Nacogdoches County case study network is provided at the end of the chapter.

FILE02 begins with a single card (Card 0) which tells the program how many pavements are to be analyzed. Each pavement then requires at least seven additional cards containing all of the necessary pavement and traffic (baseline and oil field) data. The Oil Field Pavement Damage Program loops through each pavement card deck until all of the Card 0 pavements have been analyzed. See Appendix A.

Table 4-2. Pavement Structure Input.

Input Data
County Number
Thickness of Flexible Base Layer (inches)
Dynaflect Mean Maximum Deflection (mils)
Subgrade Plasticity Index
Subgrade Liquid Limit
Pavement Strength
Surface Course Thickness
Percent Asphalt in Surface Course

Table 4-3. Traffic Input Data.

Input Data
Average Daily Traffic
Percentage Trucks
Annual ADT Growth Rate
Percentage of ADT in Design Lane (of 2-lane road)
Drill Time in Months
Production % Annual Decay
Percent of Drilled Wells Which Produce

FILE02 begins with Card 0, which indicates the number of pavements to be analyzed during the program run. Each pavement then has its own separate set of input cards, numbered 1 through NDATES + 6, containing the necessary pavement and traffic information. These cards must be repeated for each pavement, as shown below:

FILE02: Card 0

Card 1
Card 2
Card 3
Card 4
Card 5
Card 6
Card 7
. . .
Card (NDATES + 6)

} PAVEMENT # 1

Card 1
Card 2
Card 3
Card 4
Card 5
Card 6
Card 7
. . .
Card (NDATES + 6)

} PAVEMENT # 2

. . .
. . .
For all pavements.

GENERAL PROGRAM STRUCTURE

The program consists of one main program and fifteen subroutines, which gives the user the ability to simulate pavement damage under both baseline and baseline plus oil field traffic over a choice of a number of flexible pavements, along with the ability to simulate a number of pavements and traffic scenarios per computer run.

This is accomplished by use of three nested DO loops. The innermost loop repeats the pavement distress and utility calculations for each month selected by the user in FILE02. The next outer loop cycles the program twice for each pavement to calculate damage with baseline traffic (J = 1), and then repeats the calculations with baseline plus oil field traffic (J = 2). The outermost loop cycles the complete program (except the initialization section) for each pavement.

For each pavement run, the program calculates:

A) Life to failure under baseline traffic.

B) Life to failure under baseline + oil field traffic.

For any one of the following types of flexible pavement:

1. Surface-treated.
2. Black base.
3. Hot-mix.
4. Overlay.

The complete series of pavement calculations involves three stages. The first stage reads in environmental data for all counties, followed by the data for a given pavement, and then calculates baseline traffic and baseline plus oil field traffic on the road. Traffic for the months selected for study are then loaded into an array for use by the appropriate pavement damage program. The environmental data is read into the weather parameter arrays by the main program. Then the main program reads the first card of FILE02, (number of pavements).

The second stage selects the appropriate pavement damage subroutine and calculates pavement distress for a single month. The third stage calculates pavement score, tests for pavement failure (and month of failure, if failed), and prints a line of output. The program loops through the second and third stages for each month to be analyzed to calculate damage and pavement scores for each traffic (baseline or baseline plus oil field) and pavement. See Figure 4-1.

OUTPUTS

For each pavement type selected on the first page, FILE02, three pages are output. Pavement data are summarized, followed by traffic data including a table of cumulative traffic at each selected month. Both normal baseline (N) and oil field (O) traffic is output.

The second page tabulates pavement damage values and pavement scores for normal (baseline) traffic with no oil field traffic, for each month investigated. If failure occurs, the month of failure is calculated.

The third page tabulates pavement damage values and pavement scores for baseline plus oil field traffic, for the same months. If failure occurs, the month of failure with oil field traffic is calculated. Finally, the oil well development schedule is printed. These three pages of output are repeated for all pavements.

SUMMARY

The Oil Field Pavement Damage Program reads weather data (FILE01) and pavement and traffic data (FILE02), and uses this to calculate pavement damage values and pavement scores as well as if and when pavement Failure occurs. This Fortran 77 program operates in three stages. First, traffic ADT and 18-k ESAL repetitions are computed. Second, the appropriate subroutine calculates pavement distress. Third, pavement scores are calculated and tested for pavement failure. The results are then printed out. The program loops for all months, traffics, and pavements.

Detailed program information can be found in Appendix A. Appendix B lists the Fortran program, Appendices C and D contain the listings of the input files used in this study, and Appendix E contains the program output for the District 11 case study network.

CHAPTER 5 -- CONCLUSIONS AND RECOMMENDATIONS

Oil and gas field truck traffic causes a significant reduction in available service life for light-duty flexible pavements. The reduced performance results in accelerated maintenance and rehabilitation requirements. Even under light development, surface-treated pavements may require full reconstruction one to two years earlier than expected. Black base, hot-mix, and overlay pavements accommodate the increased load but fail under the increased traffic volumes generated by nearby well site activity.

Computer-generated grid/density maps locate centers of drilling and production activity and aid in identifying flexible pavements impacted by oil field development. Variability parameters describe the magnitude and duration of county well activity. The Oil Field Pavement Damage Program considers these regional and site-specific factors in modeling flexible pavement performance under oil and gas field truck traffic.

RECOMMENDATIONS FOR IMPLEMENTATION

The analysis procedure described in this report can be used as a supplemental "tool" within the Department's current pavement management system (PMS). The Oil Field Pavement Damage Program analyzes flexible pavements under a particular truck traffic distribution. <u>Although the current version contains oil field truck characteristics, other special-use activities may be considered by entering the appropriate truck traffic characteristics</u> and <u>modifying several of the "oil field" calculation routines.</u> When incorporated into the PMS, program results may eventually be used to compute the additional cost incurred by the Department as a result of the additional truck traffic.

The grid/density maps and the county variability parameters can be upgraded to reflect current conditions. Both are derived from the Railroad Commission of Texas drilling permit records. It is recommended that the Department acquire a copy of these computer records and update them annually. Each District may then use the updated records to develop their own grid/density maps and county variability parameters for use in monitoring present and future oil field development. It should be noted that much "hand-coding" of city, county, and road coordinates is necessary. Efforts to digitize towns, cities, county boundaries, and highways would greatly expedite the production of the grid/density maps.

At the District level, the Oil Field Pavement Damage Program can be used to identify roads which are in need (or will soon be in need) of maintenance or reconstruction. Pavement designers can use the program as an additional source of information to evaluate the effectiveness of alternative designs under assumed traffic loads. Others can also use the program results to select the most appropriate maintenance or reconstruction strategy for a given road.

At the state level, the total analysis procedure can assist in identifying areas in particular need of increased maintenance or reconstruction. The Department could then provide justification for needed funds and also more effectively estimate future funding requirements. The versatility of the original Oil Field Pavement Damage Program has been retained. The modified program can assist highway engineers in anticipating <u>where</u> work will be needed, identifying <u>what</u> work will be needed, and estimating <u>when</u> work will be needed.

INTERPRETATION

Interpretation of the case study results must consider the assumptions described in this report. All pavement distress calculations were performed assuming newly-reconstructed pavements. However, the current program is capable of using actual pavement score and PSI values associated with routine pavement maintenance. Well locations, start of drilling and production, and levels of well production truck traffic were also assumed from the best possible information available. The results of the case study were intended to demonstrate the methodology and applicability of analyzing flexible pavement networks in oil and gas field areas.

RECOMMENDATIONS FOR FUTURE RESEARCH

This report describes techniques which are suitable for statewide analysis of flexible pavements in oil and gas field areas. Complete integration into the Department's pavement management system points toward further research efforts in the following areas:

1. Special-Use Truck Traffic Characteristics.
2. Axle Load and Vehicle Weight Data.
3. Digitize Towns, County Boundaries, and State-Funded Highways.

Special-Use Truck Traffic Characteristics

Truck traffic characteristics for oil field development were defined from photographic monitoring at actual oil well drilling sites. Analysis of pavement performance under other load-intensive, special-use truck traffic must incorporate traffic characteristics obtained from on-site monitoring of major activity centers. Research efforts are currently underway in an effort to characterize traffic associated with timber, grain, cattle, poultry, produce, and surface mining activity.

Axle Configuration and Load Data

The Oil Field Pavement Damage Program uses truck traffic characteristics taken from the Department's W-4 tables to describe the axle and axle weight distribution of a selected traffic stream. Axle load equivalency factors used to convert mixed axle configurations into 18-k ESAL repetitions were also taken from generalized data. (1) Because the W-4 tables and equivalency factors were derived for average highway traffic, they do not represent the actual axle leads associated with oil field activity. Information provided on the W-4 Tables represents data that are collected at six (6) weigh-in-motion stations in the state. The stations are located on either interstate routes or major U. S. routes that serve inter-city truck traffic. These stations are not representative of the site-specific truck traffic demands associated with unique industries. Analysis of the effects of oil field and any other special-use truck activity can be improved by sampling axle loads of each hauler. Site-specific axle weight information is very important in making decisions concerning pavement design and pavement rehabilitation strategies.

Digitize Towns, County Boundaries, and State-Funded Highways

The computer-generated grid/density maps locate oil field activity centers and aid in identifying impacted roadways. However, these maps were prepared only for Districts 11, 13, and 17. Developing maps for other Districts would involve approximately one man-month each spent in hand-coding coordinates for towns, county boundaries, and state-funded highways taken from the Department's small-scale general highway map for each District. Once completed, however, the grid/density map could be generated at any time from the current RRC drilling permit records.

A comprehensive statewide data base of town, county boundary, and highway coordinates taken from a single, arbitrarily assigned coordinate system would enable the Department to examine oil and gas field development at any conceivable level. District personnel could generate grid/density maps for the entire District, individual counties, or even isolated pavement networks. At the state level, the Department could generate District maps, county maps, or even state maps. Placing the grid/density map program and data files on the Department's interactive graphics system would allow rapid turnaround for engineers at both the local and state levels.

CHAPTER 6 -- PROJECT SUMMARY

This chapter summarizes the results of each phase of Research Project 2-8-81-299.

Phase I dealt with quantifying the effect of oil field traffic on rural highways by determining the traffic levels and axle configurations associated with the drilling and production of one oil well. (5) The traffic generated by the drilling of an oil well was recorded using photographic equipment. A total of approximately 23,000 single axle repetitions were generated by an average daily traffic of 150 vehicles per day. Peak volumes of up to 350 vehicles per day were typical. These volumes were found to be generated by oil field traffic in addition to normal "intended-use" traffic on the rural farm-to-market roadway. Fifty percent of the truck traffic (approximately 15% of the ADT) were of the 3-S2 type (tractor-semi-trailer) configuration.

The reduction in pavement service life was determined based on the concept of pavement serviceability developed at the AASH(T)O Road Test. This loss in pavement performance resulted in an increased annual cost of $12,320 per mile for a low volume (250 ADT), light duty (1/2 inch bituminous surface treatment on a 6-inch foundation base course) pavement section.

Phase II verified the oil well characteristics at two additional oil well sites. An analysis procedure was developed to assess the impact of additional ("special-use") traffic on an existing surface treated pavement section. The Texas Pavement Distress Equations were used to predict pavement performance under various levels of oil field development. (6)

A Fortran 77 computer program, the "Oil Field Pavement Damage Program," was developed to predict the changes in pavement serviceability and individual types of pavement distress due to oil field traffic. To demonstrate the analytic capabilities of the program, a case study example was conducted in the oil field areas of Brazos County. Several "density" maps were prepared depicting drilling locations, producing well locations, and generalized activity centers of oil field servicing companies. The "influence" area of the oil fields was delineated, an estimate of trips produced, and axle equivalencies calculated to estimate the reduction in pavement service life under the oil field truck traffic demand.

Phase III described the statewide variability of oil and gas drilling and production activity. (7) The Railroad Commission of Texas regulates the statewide operations of the oil and gas industry and continually updates a Master Drilling Permits Record file of well permits issued, wells drilled, and wells completed. These data were compiled and six "variability" parameters were defined on a county-by-county basis. The resulting parameters were used to generate input data for the "Oil Field Pavement Damage Program" such that pavement performance under traffic generated by servicing oil field developments in any Texas County could be predicted, considering statewide variabilities.

Phase III also culminated in a report (8) that outlined a series of computer programs and data files that create "grid/density" maps from computer plots. These maps can locate the major activity centers and identify impacted roadways within an area of oil field development.

Phase IV documented the procedure for analyzing the performance of flexible pavement networks in oil and gas field areas throughout the state. The Oil Field (Pavement) Damage Program was modified to permit the analysis of various flexible pavement structures. A case study example was prepared in detail in the final report to demonstrate the entire analysis procedures.

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APPENDIX A -- DOCUMENTATION FOR THE OIL FIELD PAVEMENT DAMAGE PROGRAM

This appendix describes the Oil Field Pavement Damage Program, writt in Fortran 77, which has been developed under Project 299. A flow chart the program is given in Figure A-1, and a complete listing of the progra is presented in Appendix B. The flow chart has been limited to describing the functions of the main program, and the subroutines and arrays used in the program. Description of the program variables is presented with the description of the appropriate program elements.

The program was developed in two steps. The first step is described in TTI Report 299-2 and was developed by Tom Scullion. (6) It predicted pavement life for a single surface-treated pavement per computer run. The second step, described here, was a modification of the original program by H. C. Petersen to enable choice of flexible pavements, along with the capability to simulate a number of pavements and traffic scenarios per computer run.

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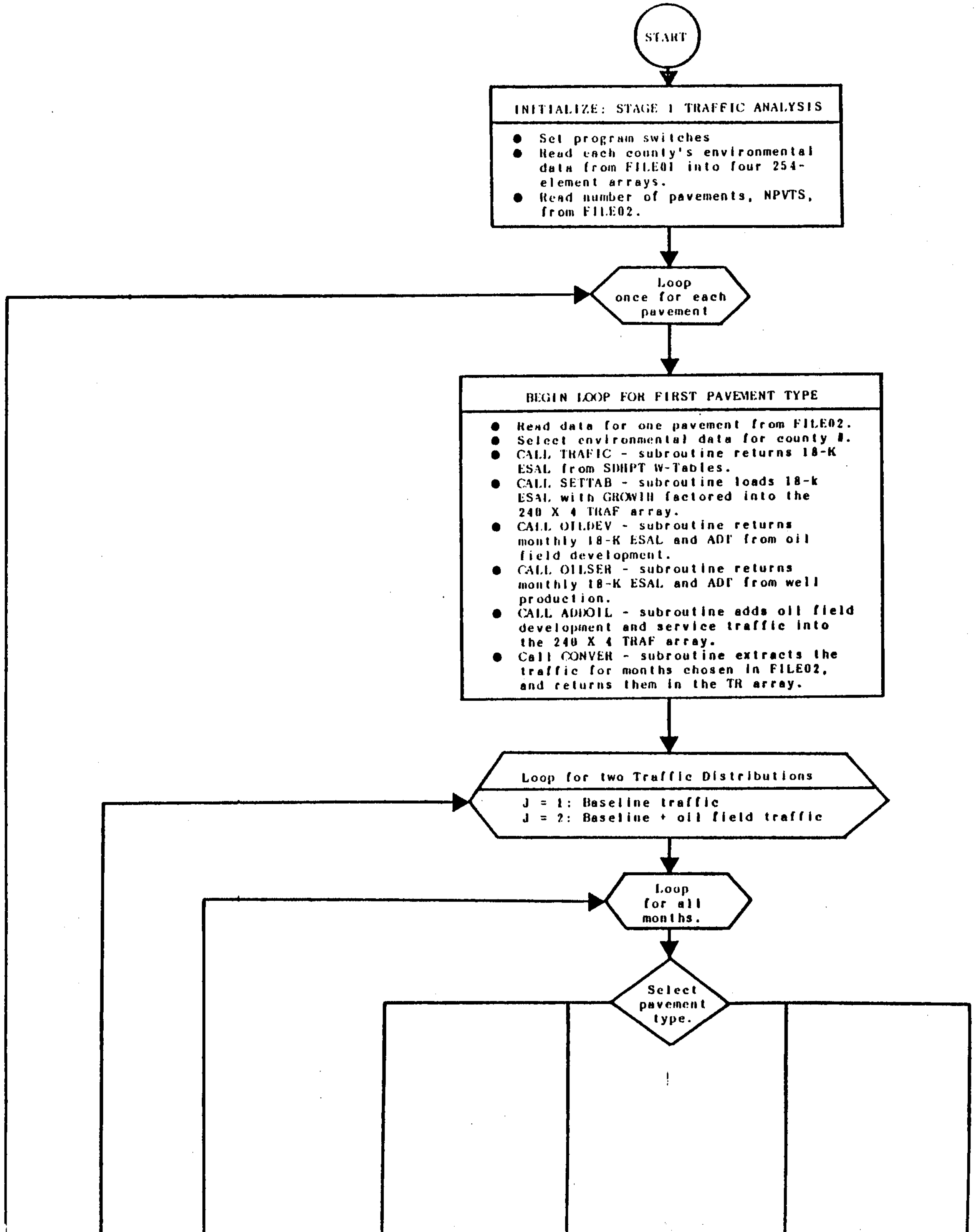
Modified by: H. C. Petersen
Texas Transportation Institute
Texas A&M University
College Station, Texas 77843
(409) 845-1726

This program calculates:

A) Life to failure under baseline traffic.

B) Life to failure under baseline + oil field traffic.


START
INITIALIZE: STAGE 1 TRAFFIC ANALYSIS
● Set program switches
● Read each county's environmental data from FILE01 into four 254-element arrays.
● Read number of pavements, NPVTS, from FILE02.
Loop once for each pavement
BEGIN LOOP FOR FIRST PAVEMENT TYPE
● Read data for one pavement from FILE02.
● Select environmental data for county #.
● CALL TRAFIC - subroutine returns 18-K ESAL from SDHPT W-Tables.
● CALL SETTAB - subroutine loads 18-k ESAL with GROWTH factored into the 240 X 4 TRAF array.
● CALL OILDEV - subroutine returns monthly 18-K ESAL and ADT from oil field development.
● CALL OILSER - subroutine returns monthly 18-K ESAL and ADT from well production.
● CALL ADDOIL - subroutine adds oil field development and service traffic into the 240 X 4 TRAF array.
● Call CONVER - subroutine extracts the traffic for months chosen in FILE02, and returns them in the TR array.
Loop for two Traffic Distributions
J = 1: Baseline traffic
J = 2: Baseline + oil field traffic
Loop for all months.
Select pavement type.

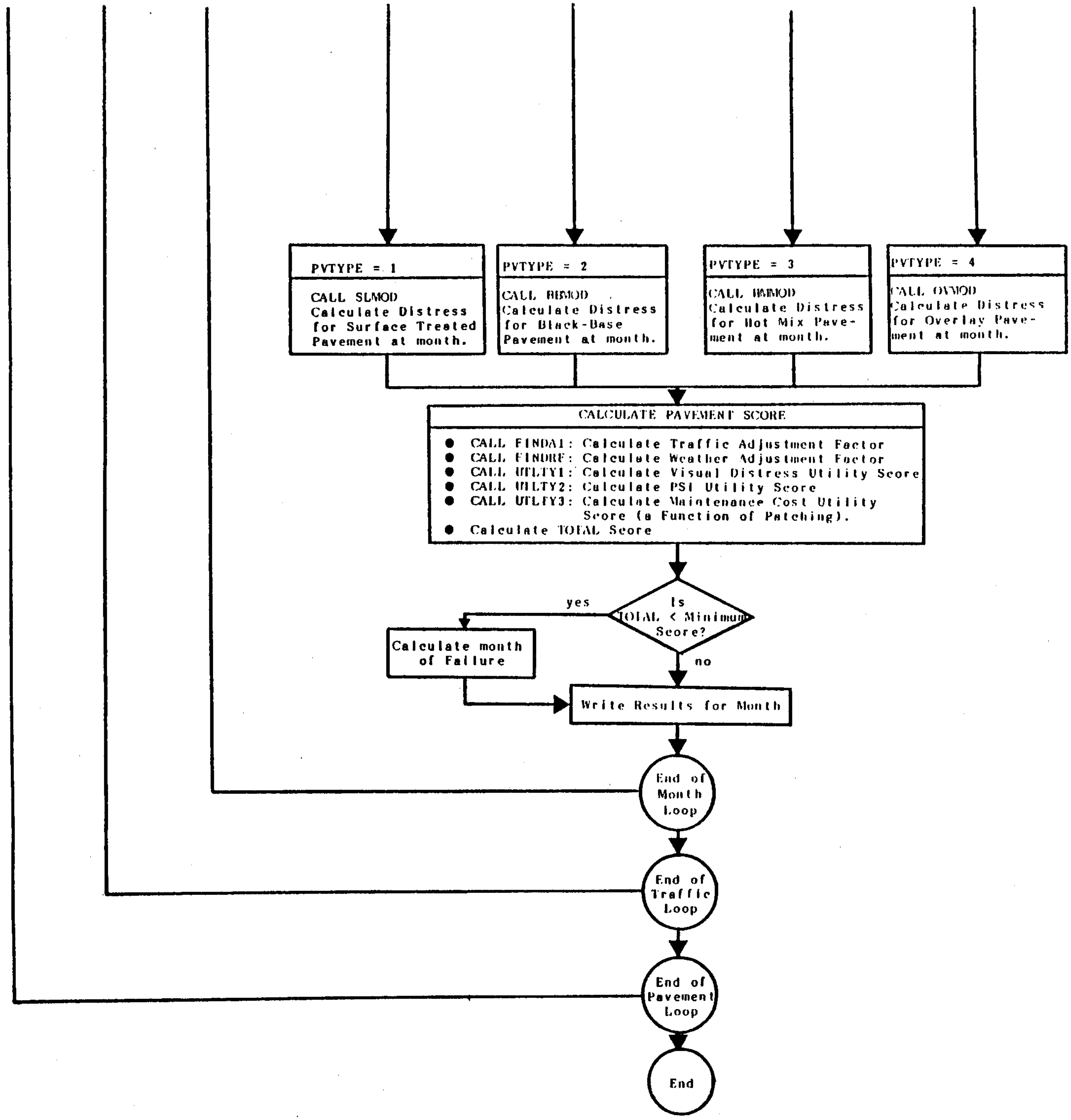


Figure A-1. Flowchart of the Oil Field Damage Program.

For any one of the following types of flexible pavement:

1. Surface-treated.
2. Black base.
3. Hot-mix.
4. Overlay.

The program operates in three stages. The first stage reads in all of the input data and then computes baseline and baseline + oil field traffic characteristics. These traffic characteristics are loaded into an array for use by six traffic subroutines.

The second and third stages loop until PSI, pavement score, and pavement distress ratings have been calculated. In stage two, the main program calls the appropriate pavement damage subroutine (depending upon which pavement type was selected) and calculates the PSI and pavement distress ratings. Stage three then computes and prints pavement score values. This loop from Stage 2 to Stage 3 is run for each month that the user requested: once for baseline traffic and once for baseline plus oil field traffic.

Please note the following assumptions:

1. The program considers all pavements to be two-lane roads, with one lane for each direction.
2. Pavement distress equations were developed using stepwise regression of data from site inspections of the test sections in the Texas Flexible Pavement Data Base. (4)
3. Pavement score has been defined to be a function of PSI, visual score, and maintenance cost-a multiplicative utility approach. Pavement score considers the combined effects of pavement distress and ride quality in describing pavement condition. Equations have

been developed to predict both area and severity ratings for several common distress types. These ratings range from 0 (no distress) to 100 (total distress).

INPUT FILES

The program reads input data from two files:

FILE01 - Contains county environmental data.

FILE02 - Contains user-supplied traffic and pavement data.

FILE01

FILE01 contains the following environmental data for each of the 254 Texas counties, one county per record:

1. TIN(I) - Thornthwaite index. (13)
2. RAIN(I) - Average Rainfall.
3. FRTH(I) - Air freeze-thaw cycles.
4. AVTP(I) - Average maximum temperature.

FILE02

The user supplies the following pavement and traffic data:

NPVTS - Number of pavements to be analyzed.

These may be entire roads or just short sections. Each pavement must have the remaining FILE02 data entered for analysis.

MINSCR - Pavement score at failure (usually 35).

PVTYPE - Type of flexible pavement. Choose from:

1) Surface-treated.

2) Black base.

3) Hot mix.

4) Overlay.

COUTY - County where pavement is located. TTI Research Report 229-5, Table A-2, contains acceptable values for each Texas county. (9)

FLEXL - Base course thickness.

DMD - Mean dynaflect deflection (sensor W1).

PI - Subgrade plasticity index.

LL - Subgrade liquid limit.

PVSTRN - Pavement strength. Choose from:

1) Strong.

2) Medium.

3) Weak.

This variable is not used for surface-treated pavements. PVSTRN established values for HPR2 and HPR3, as described elsewhere in Chapter 4. (2)

ASPH - Surface course thickness.

BINDER - Percent asphalt used in surface course.

MON(I) - Commands program to print PSI, Pavement Score, and distress ratings at specific times. For example,

1, 6, 12, 24, 36, 60, and 72 months

after reconstruction. Normally, 12 times are requested.

HEAD(I)- User-supplied heading. This may be used to identify the pavement section and location, or other descriptive information. (Maximum length of HEAD is 60 characters.)

ADT - Average Daily baseline Traffic. Use two-way values.

PCTTRK - Percent trucks in baseline traffic.

GROWTH - Annual percent growth in baseline traffic.

PCTLNE - Baseline traffic distribution. Normally, use 50 percent. Design lane distributions for multilane highways are not considered by the program.

DTIME - Average number of months required to drill an oil or gas well.

DECAY - Percent decline in annual truck traffic during production phase. TTI Research Report 299-4 contains information pertinent to both the DECAY and the DTIME variables. (8)

PRDPCT - Percentage of drilled wells which generate truck traffic during production.

NDATES - Number of months in which drilling was actually underway in the pavement study region.

IDATE - Elapsed time (in months) from pavement reconstruction to the start of drilling on each well.

NWELLS - Number of wells actually drilled in month "IDATE".

PREPARATION OF INPUT DATA

Input data for the Oil Field Pavement Damage Program must be entered exactly as specified by the program's formatted READ statements. Both FILE01 and FILE02 input data must be entered according to the following guidelines in order for the program to execute properly.

FILE01 (FT01F001, fixed file NOT user-supplied)

This file contains the required environmental data for each of the counties in Texas, one county per record. Table A-1 below shows the first five and last five records from this file, which are the required environ mental data for counties 1 through 5 and 250 through 254. The FILE01 format is as follows:

1. County Number — Columns 2 - 4
2. Thornthwaite Index — Columns 8 - 12
3. Rainfall Per Month — Columns 18 - 22
4. Freeze-Thaw Cycles per Month — Columns 28 - 32
5. Wet Freeze-Thaw Cycles per Month — Columns 38 - 42
6. Mean Maximum Temperature — Columns 48 - 52
7. Mean Average Temperature — Columns 58 - 62

Note that the Oil Field Pavement Damage Program uses only Thornthwaite Index, rainfall per month, freeze-thaw cycles per month, and mean average temperature (in columns 2, 3, 4, and 7, respectively) during execution. The other columns are stored in FILE01 but never read.

Table A-1. Extracts From FILE01.

County No.	Th. Index	Rain Fall	F.T.C.	Wet F.T.C.	M. Max. Temp.	M.Avg. Temp.
1	12.5	3.57	4.82	0.900	76.7	65.4
2	-39.3	1.14	8.48	0.637	77.8	63.3
3	11.7	3.60	3.81	0.430	78.1	66.7
4	-10.3	3.10	0.610	0.167	78.0	70.6
5	-16.2	2.35	5.83	0.854	76.3	63.9
250	9.81	2.59	9.73	1.16	73.4	60.0
251	-25.5	1.41	10.5	0.715	74.1	58.7
252	-14.9	2.48	8.77	0.800	76.9	63.7
253	-40.1	1.63	0.886	0.182	84.6	72.9
254	-30.2	1.87	1.61	0.117	82.7	71.0

FILE02 (FT02F001, user-supplied)

This file contains all pavement and traffic data pertaining to the section under analysis. A complete FILE02 list for the Nacogdoches County case study network is provided at the end of the chapter.

FILE02 begins with a single card (Card 0) which tells the program how many pavements are to be analyzed. Each pavement then requires at least seven additional cards containing all of the necessary pavement and traffic (baseline and oil field) data. The Oil Field Pavement Damage Program loops through each pavement card deck until all of the Card 0 pavements have been analyzed.

Card 0: NPVTS (I3). This is the total number of pavements to be simulated. It is entered only once and is the first card in FILE02.

Card 1: MINSCR (I2), PVTYPE (I2). MINSCR is the minimum score permissible for the section under analysis. This is normally fixed at 35 as defined in the Department's Pavement Evaluation System for this type of pavement. (3) PVTYPE is the type of flexible pavement to be studied; either surface-treated, black base, hot-mix, or overlay (PVTYPE = 1, 2, 3, or 4, respectively).

Card 2. This card contains structural information which is eventually printed in the "Structural Variables" section of the program output. Each of the four flexible pavement types has its own set of structural variables which must be entered in this card. Table A-2 provides the format of the Card 2 pavement structure data.

Dynaflect deflection values should be taken from existing laboratory records whenever possible. However, some suggested values are listed below.

Table A-2. Card 2 Pavement Structure Data.

Name	Code	Columns	Format
County Number	COUTY	1-9	F9.2
Thickness of Flexible Base Layer (inches)	FLEXL	10-18	F9.2
Dynaflect Mean Deflection (mils)	DMD	19-27	F9.2
Subgrade Plasticity Index	PI	28-36	F9.2
Subgrade Liquid Limit	LL	37-45	F9.2
Pavement Strength	PVSTRN	46-54	F9.2
Surface Course Thickness	ASPH	55-63	F9.2
Percent Asphalt in Surface Course	BINDER	64-72	F9.2

Weak Pavement	$(N + \sigma)$	= 2.04 mils
Medium Pavement	(N)	= 1.55 mils
Strong Pavement	$(N - \sigma)$	= 1.06 mils

Note: Mean dynaflect = 1.55 mils.
Standard deviation = 0.49 mils.

The subgrade soils' information can readily be obtained from county soil survey maps.

Pavement strength, PVSTRN, is simply an index: 1 - strong

2 - medium

3 - weak

These index numbers are used in subroutines BBMOD (Black Base MODel), HMMOD (Hot Mix MODel), and OVMOD (OVerlay MODel) to assign estimated averaged values of HPR2 and HPR3 (2) as shown in Table A-3.

Table A-3. Suggested HPR2 and HPR3 Values.

Subroutine	Pavement Strength Index, PVSTRN	HPR2	HPR3
BBMOD	1 2 3	10.0 20.0 30.0	2.50 1.50 0.25
HMMOD	1 2 3	10.0 20.0 30.0	3.50 1.75 0.50
OVMOD	1 2 3	5.0 20.0 40.0	10.0 5.0 0.25

ASPH and BINDER should be readily available, either from pavement design or laboratory records.

Note that Card 2 has two different types of inputs: the first for surface-treated pavements, and the second for the other three pavement types. For surface-treated (PVTYPE = 1) pavements, input COUTY, FLEXL, DMD, PI, and LL. For the other pavement types, input COUTY, PI, PVSTRN, ASPH, BINDER. The other inputs are not used, and so may be actual values or simply entered as zeros.

Card 3: MON(I) (16I5). These are the months at which PSI, pavement score, and pavement distress ratings are to be calculated. Although sixteen values may be entered into Card 3 for analysis, the user must enter at least eleven different months to insure proper program execution. The program reads each MON value from I = 1 to I = NYR and loops through the analysis procedures, computing PSI, pavement score, and the pavement distress ratings. NYR, which is currently set equal to 11, can only be changed from within the program. As a result, unless internal program modifications are made, the user will only receive solutions for 11 of the months in the analysis period.

Card 4: HEAD(1), (15A4). This heading will appear at the top of each page of program output. The user may type in anything up to 60 characters.

Card 5. This card contains baseline traffic data and local oil field drilling and production characteristics. Table A-4 contains input data formats for Card 5.

Table A-4. Card 5 Input Data Formats.

Name	Variable Name	Columns	Input Format
Average Daily Traffic	ADT	1-8	F8.0
Percentage Trucks	PCTTRK	9-13	F5.1
Annual ADT Growth Rate	GROWTH	14-18	F5.1
Percentage of ADT in Design Lane (of 2-lane road)	PCTLNE	19-23	F5.1
Drill Time in Months	DTIME	24-28	F5.1
Production % Annual Decay	DECAY	29-33	F5.1
Percent of Drilled Wells Which Produce	PRDPCT	34-38	F5.1

Card 6: NDATES, (I3). NDATES is the number of dates in which oil field activity started. Note that there are NDATES cards which follow this card, each giving month number and number of wells started that month.

Cards 7 Through (NDATES + 6): IDATE, NWELLS (I3, 1X, I3). Card 7 tells how many months (NDATES) in the analysis period were marked by new oil well drilling activity. The remaining NDATES cards indicate how many wells (NWELLS) began drilling in each month (IDATE). For example, if one new well were drilled each month for a five-year period, the cards would look like this:

```
Card  7:  060
Card  8:  001 001      because NDATES = 60 months
Card  9:  002 001               IDATE = month 1, 2,
Card 10:  003 001                         3, ..... 60
Card 11:  004 001          and NWELLS = 1 new well
   .         .                          per month
   .         .
   .         .
Card 64:  058 001
Card 65:  059 001
Card 66:  060 001
```

IDATE = month number in which oil well drilling begins;

NWELLS = the number of new oil wells drilled each month, IDATE.

Summary of FILE02 Input Requirements.

FILE02 begins with Card 0, which indicates the number of pavements to be analyzed during the program run. Each pavement then has its own separate set of input cards, numbered 1 through NDATES + 6, containing the necessary pavement and traffic information. These cards must be repeated for each pavement, as shown below:

```
FILE02:   Card 0

          Card 1             }
          Card 2             }
          Card 3             }
          Card 4             }  PAVEMENT # 1
          Card 5             }
          Card 6             }
          Card 7             }
           . . .             }
          Card (NDATES + 6)  }

          Card 1             }
          Card 2             }
          Card 3             }
          Card 4             }  PAVEMENT # 2
          Card 5             }
          Card 6             }
          Card 7             }
           . . .             }
          Card (NDATES + 6)  }
           . . .
           . . .
          For all pavements.
```

A complete FILE02 list for the Nacogdoches County case study network is included at the end of this chapter. This file listing demonstrates the use of separate card decks for each pavement section and should clarify the use of Card 0 to coordinate the program run.

Running the Program

The following job control language was used to run the program on the Amdahl at Texas A&M University.

```
//F77D11 JOB (W250,505A,S5,2,BS), 'OILFIELD°
//EXEC FORTVCLG,FVREGN=1204K
//FORT.SYSIN DD *
C
C
C
            (program listing goes here)
C
C
C
     END
//GO.FT01F001 DD DSN=USR.W250.BS.FILE01,DISP-SHR
//GO.FT02F001 DD DSN=USR.W250.BS.FILE02,DISP=SHR
/*END
```

GENERAL PROGRAM STRUCTURE

The program consists of one main program and fifteen subroutines, which gives the user the ability to simulate pavement damage under both baseline and baseline plus oil field traffic over a choice of a number of flexible pavements, along with the ability to simulate a number of pavements and traffic scenarios per computer run.

This is accomplished by use of three nested DO loops. The innermost loop repeats the pavement distress and utility calculations for each month selected by the user in FILE02. The next outer loop cycles the program twice for each pavement to calculate damage with baseline traffic (J = 1), and then repeats the calculations with baseline plus oil field traffic

(J = 2). The outermost loop cycles the complete program (except the initialization section) for each pavement.

For each pavement run, the program calculates:

A) Life to failure under baseline traffic.

B) Life to failure under baseline + oil field traffic.

For any one of the following types of flexible pavement:

1. Surface-treated.
2. Black base.
3. Hot-mix.
4. Overlay.

The complete series of pavement calculations involves three stages. The first stage reads in environmental data for all counties, followed by the data for a given pavement, and then calculates traffic on the road. This traffic, consisting of baseline traffic and baseline plus oil field traffic, is first loaded into the TRAF array, and then traffic for the months selected for study are loaded into the TR array for use by the appropriate pavement damage program. The environmental data is read into the TIN, RAIN, FRTH, and AVTP weather parameter arrays (numbered according to county number, 1 through 254, in each array) by the main program. Then the main program reads the first card of FILE02, NPVTS (number of pavements), and prints this out. The main program will now loop to calculate damage for each pavement.

Stage 1: Process Traffic Subroutines

The first stage now reads the data from FILE02 for the first pavement, and calculates the traffic analysis using the following subroutines:

TRAFIC - Converts baseline traffic into 18-k equivalent single axle load (ESAL) repetitions per month, using values from the SDHPT W-Tables. This process is described in TTI Research Report 299-1. (5)

SETTAB - Loads the results of Subroutines "TRAFIC" into the 240 X 4 TRAF array, multiplying each successive entry by the GROWTH factor. The array contains the total number of vehicles (ADT) and 18-k ESAL repetitions which have passed over the pavement since reconstruction. This subroutine does not load the oil field related traffic into the TRAF array at this time.

OILDEV - Computes the 18-k ESAL repetitions and ADT per month due to oil and gas well drilling. These are returned as N18OIL and ADTOIL, respectively.

OILSER - Computes 18-k ESAL repetitions and ADT per month due to oil well production, returning these as N18OIL and ADTSER.

ADDOIL - Adds the drilling and production traffic values (from Subroutines "OILDEV" and "OILSER") to the TRAF array. This subroutine factors in the drilling time per well in months (DTIME), the rate of decau of oil production in percent per year (DECAY), and the percent of wells drilled which result in added truck traffic during OIL production.

CONVER - Accesses the TRAF array and extracts only those traffic values for those months which the user had requested in the MON (I) list in FILE02.

Stage 2: Compute PSI and Pavement Damage Ratings

The second and third stages loop until damage for all desired months has been calculated. In the second stage, during each loop, the main program calls the appropriate Pavement Damage subroutine, depending upon which pavement type was selected (1 = SLMOD, 2 = BBMOD, 3 = HMMOD, and 4 = OVMOD). This subroutine calculates the amount of damage which has occurred up to the month being simulated, and returns the various damage parameters in the DIS array. See PROGRAM ELEMENTS for the contents of this array.

Stage 3: Compute Pavement Score

During the third stage, in each loop, the program calls five subroutines to determine the adjustment factors for use in computing pavement score at each MON(I). These subroutines are:

FINDA1 - Calculates and returns traffic adjustment parameters.

FINDRF - Calculates and returns weather adjustment parameters.

UTLTY1 - Calculates the utility value of VISUAL.

UTLTY2 - Calculates the utility value of PSI.

UTLTY3 - Calculates the utility value of MCOST (Maintenance COST).

The main program then adjusts, computes, and prints the pavement score for each month specified in FILE02. Once pavement score has been calculated for each MON(I) under baseline traffic, the program repeats the same process for baseline + oil field traffic. Variables used to compute pavement score are:

VISUAL- Utility value of Pavement Distress types from subroutine "UTLTY1".

PSI - Utility value of PSI from subroutine "UTLTY2".

MCOST - Utility value of Maintenance Cost from subroutine "UTLTY3".

TOTAL - Total overall Pavement Score.

The main program completes the Stage 1, 2, and 3 calculations for each of the NPVTS pavements contained in Card 0 of FILE02. In Stage 1, the program reads in the next pavement's input from FILE02 and generates the TRAF and TR arrays. In Stage 2, the program computes PSI and pavement distress ratings for each MON(I) for baseline traffic (J = 1) and baseline + oil field traffic (J = 2). The program finally computes pavement score in Stage 3. The Oil Field Pavement Damage Program stops running when all NPVTS pavements have been analyzed.

Please note the following items:

1. The program considers all pavements to be two-lane roads, with one lane for each direction. Lane distributions for oil field traffic on multilane highways were not obtained in this project.

2. The calculation of 18-k ESAL repetitions is described in TTI Research Report 299-1. (5)

3. Pavement distress equations were developed using stepwise regression of data from site inspections of the test sections in the Texas Flexible Pavement Data Base. (4) For example,

   Distress = exp (RHO/N18) ** BETA

   Where Distress Range = 0 - 100

   RHO = Regression coefficient

   BETA = Regression coefficient

   RHO = F(Rainfall, PI, LL, Layer thickness, ...)

4. Pavement score has been defined in SDHPT Project 2239 to be a function of PSI, visual score, and maintenance cost. (11) This is a multiplicative utility approach

where: PSI = Utility value of PSI

Visual = Utility value of distress types

Maint. Cost = Utility value of maintenance cost (considered to be a function of the area of patching)

Pavement score considers the combined effects of pavement distress and ridequality in describing pavement condition. Equations have been developed to predict both area and severity ratings for several common distress types. These ratings range from 0 (no distress) to 100 (total distress).

Table A-5 lists the maximum acceptable area and severity ratings.

Table A-5. Maximum Acceptable Distress Area and Severity Ratings.

Distress Type	Area	Severity
Rutting	50	30
Raveling	80	30
Flushing	80	30
Alligator Cracking and Patching	50	50
Longitudinal Cracking	70	30
Transverse Cracking	70	30

Minimum PSI = 1.5 (Range = 4.2 to 0)

These values are part of the Oil Field Pavement Damage Program. They cannot be changed from outside of the program.

5. Refer to TTI Research Report 299-2 for additional details. (6)

Input Files and Variables

The program reads input data from two files:

FILE01 - Contains county environmental data.

FILE02 - Contains user-supplied traffic and pavement data.

The first input file, FILE01, uses the following environmental variable arrays which contain data for each of the 254 Texas counties (one county per record):

1. TIN(I) - Thornthwaite Index.
2. RAIN(I) - Average Rainfall.
3. FRTH(I) - Air Freeze-Thaw Cycles.
4. AVTP(I) - Average Maximum Temperature.

Note that these files reside in memory for all counties throughout the computer run. Thus, it is not necessary to return to the original FILE02 when simulating roads in different counties; a number of different counties can be input in a single computer run.

In the second input file, FILE02, the user supplies the following:

NPVTS - Number of pavements to be analyzed.

These may be entire roads or just short sections. Each pavement must have the remaining FILE02 data entering for analysis.

MINSCR - Pavement score at failure (usually 35).

PVTYPE - Type of flexible pavement. Choose from:

1) Surface-treated.
2) Black base.
3) Hot mix.
4) Overlay.

COUTY - County where pavement is located. TTI Research Report 229-5, Table A-2, contains acceptable values for each Texas county.

FLEXL - Base course thickness.

DMD - Mean dynaflect deflection (sensor W1).

PI - Subgrade plasticity index.

LL - Subgrade liquid limit.

PVSTRN - Pavement strength. Choose from:

1) Strong.
2) Medium.
3) Weak.

This variable is not used for surface-treated pavements. PVSTRN establishes values for pavement strength parameters HPR2 and HPR3, as described in Table 4-3 and later in this chapter.

ASPH - Surface course thickness.

BINDER - Percent asphalt used in surface course.

MON(I) - Commands program to print PSI, pavement score, and distress ratings at specific times. For example,

1, 6, 12, 24, 36, 60, and 72 months

after reconstruction. Normally, 12 times are requested.

HEAD(I)- User-supplied heading. This may be used to identify the pavement section and location, or other descriptive information. (Maximum length of HEAD is 60 characters.)

ADT - Average Daily baseline Traffic. Use two-way values.

PCTTRK - Percent trucks in baseline traffic.

GROWTH - Annual percent growth in baseline traffic.

PCTLNE - Baseline traffic distribution. Normally use 50 percent. Design lane distributions for multilane highways are not considered by the program.

DTIME - Average number of months required to drill an oil or gas well.

DECAY - Percent decline in annual truck traffic during production phase. TTI Research Report 299-4 contains information pertinent to both the DECAY and the DTIME variables. (8)

PRDPCT - Percentage of drilled wells which generate truck traffic during production.

NDATES - Number of months in which drilling was actually underway in the pavement study region.

IDATE - Elapsed time (in months) from pavement reconstruction to the start of drilling on each well.

NWELLS - Number of wells actually drilled in month "IDATE".

PROGRAM ELEMENTS

This section describes some of the major variables used along with a more detailed structure of this program (See flow chart, Figure A-1). The information contained in this section is not necessary to run the program. It is intended to simplify the programmer's task in the event that modifications are desired to change the program or any of its default values. This section assumes that the reader has a knowledge of FORTRAN syntax and protocol.

The program consists of the main program, which calls 15 subroutines as needed. These subroutines may be grouped into one of the following three stages:

Stage 1. Traffic Subroutines.

Stage 2. Pavement Damage Subroutines.

Stage 3. Pavement Score Subroutines.

The main program reads the environmental data from FILE01 into four 254-element weather arrays;

TIN(I) = Thornthwaite INdex

RAIN(I) = RAINfall per month

FRTH(I) = FReeze-THaw cycles per month

AVTP(I) = Mean AVerage TemPerature

where (I) = CounTY (CTY) number (Refer to Table A-2 in TTI Research Report 299-5).

These are then accessed and converted into annual values for the single county under study in the main program during each pavement loop. Next, the main program reads the number of pavements to be simulated on the first card of FILE02, NPVTS (number of pavements), and prints this number out. The main program will now use the outermost DO loop to calculate damage for each pavement, with the DO loop counter IPVTS incrementing from one to NPVTS, the number of pavements input in FILE02.

In the first stage, the main program then reads the road and traffic data from FILE02 for the first pavement to be simulated, changing from integer to real number format where appropriate, and calculates the traffic analysis using the following subroutines: TRAFIC, SETTAB, OILDEV, OILSER, ADDOIL, and CONVER.

The second and third stages cycle twice, once for baseline traffic and once for baseline plus oil field traffic, using the middle DO loop with counter J incrementing from one to two (J = 1 for baseline traffic, and J =

2 for baseline plus oil field traffic). The innermost DO loop cycles through the second and third stages for each month, with the DO loop counter NYR incrementing from one to the number of months to be investigated. At the present time, the value of NYR is programmed in as eleven and cannot be changed from outside the program. The program would require additional program lines to allow input of a variable number of months, probably from FILE02.

In the second stage, IF tests select the proper subroutine call to calculate pavement damage for a single month. The value of PVTYPE from FILE02 determines the pavement damage subroutine selected. (1 = Subroutine SLMOD, 2 = Subroutine BBMOD, 3 = Subroutine HMMOD, and 4 = Subroutine OVMOD.) The appropriate pavement damage subroutine returns the pavement damage parameters in the DIS array shown in Table A-6.

Note that only the subroutine SLMOD returns all 15 DIS values. The other three subroutines return zeros for Raveling, Flushing, and Patching DIS array values.

The third stage loops along with the second stage. This stage calculates the pavement utility values for a single month by calling subroutines FINDA1 and FINDRF to compute adjustment values, followed by calls to subroutines UTLTY1, UTLTY2, and UTLTY3 to calculate VISUAL, PSI, and MCOST values. The main program then calculates TOTAL utility value (i.e., Pavement Score), and uses an IF test to set the variable IFAIL. IFAIL = 0 if the pavement has not failed, and IFAIL = 1 when the pavement has failed, that is, when TOTAL is not greater than the minimum allowable score, MINSCR. If pavement has failed, the main program calculates the time to failure in months. Finally, the program prints out the values. This is the end of a single month's calculations; the inner DO loop increments to the next month, and the program continues.

Table A-6. Oil Field Pavement Damage Program DIStress Array.

DIS(1)	= PSI
DIS(2)	= Rutting Area
DIS(3)	= Rutting Severity
DIS(4)	= Raveling Area
DIS(5)	= Raveling Severity
DIS(6)	= Flushing Area
DIS(7)	= Flushing Severity
DIS(8)	= Alligator Crack Area
DIS(9)	= Alligator Crack Severity
DIS(10)	= Longitudinal Crack Area
DIS(11)	= Longitudinal Crack Severity
DIS(12)	= Transverse Crack Area
DIS(13)	= Transverse Crack Severity
DIS(14)	= Patching Area
DIS(15)	= Patching Severity

In summary, these are the subroutines which are called:

TRAFIC SETTAB OILDEV OILSER ADDOIL CONVER	Stage 1
SLMOD BBMOD HMMOD OVMOD	Stage 2
FINDA1 FINDRF UTLTY1 UTLTY2 UTLTY3	Stage 3

These subroutines, and the variables transferred, are described below.

Non-default variables used in the main program are INTEGER: CTY(CounTY number), ENDSCR (Pavement END of life SCoRe), ENDMTH (END of pavement life MonTH number), PVTYPE (PaVement TYPE), and PVSTR (PaVement STRength).

Variables are passed to the subroutines in two ways. The first method of passing variables is through the CALL statement. To simplify program tracing, the same variable names were used in both the main program and the subroutines wherever possible. The second method of passing variables is to make them accessible by use of a COMMON statement. The COMMON statement is used to pass the following variables to the appropriate pavement damage subroutine in Stage 2: FLEXL, DMD, PI, LL, PVSTRN, ASPH, and BINDER.

Traffic Subroutines

Six subroutines compute the traffic on the road and put the values into the TRAF and the TR arrays:

Subroutine TRAFIC converts baseline traffic into 18-k equivalent single axle load (ESAL) repetitions per month, using values from the SDHPT W-4 Tables. This process is described in TTI Research Report 299-1. (5) It brings in the values of ADT (Average Daily Traffic), PCTTRK (PerCenT TRucKs), and PCTLNE (PerCenT of total ADT in the LaNe under study), and uses REAL-format data which is read from programmed-in DATA statements taken from the SDHPT W-4 tables:

- PERCNT - Contains the percentage of each truck type in the baseline traffic stream.
- SINGLE - Contains the number of single axles by truck type.
- TANDEM - Contains the number of tandem axles by truck type.
- DISTSN - Contains the single axle load distributions as measured at weighing stations for each truck type.
- DISTAN - Contains tandem axle load distributions for each truck type.
- ESING - Contains equivalency factors for single wheel loads.
- ETAND - Contains equivalency factors for tandem wheel loads.

The subroutine converts two-way baseline ADT to one-way, and returns this one-way ADT (note that the value changes in this subroutine) and monthly N18 18-k ESAL (N18 is declared to be REAL). Passenger cars are not used to compute 18-k ESAL repetitions. All variable values are passed through the CALL statement.

Subroutine SETTAB loads the results from Subroutine "TRAFIC" into the 240 X 4 TRAF array, multiplying each successive entry by the GROWTH factor. The array structure is:

Column 1 - ADT (baseline).

Column 2 - ADT (baseline + oil field).

Column 3 - 18-k ESAL (baseline).

Column 4 - 18-k ESAL (baseline + oil field).

The array contains the total number of vehicles (ADT) and 18-k ESAL repetitions which have passed over the pavement since reconstruction. This subroutine does not load the oil field related traffic into the TRAF array at this time. The oil field values are added later by the subroutine ADDOIL.

N18 is declared to be REAL. All variable values, including the TRAF array, are passed through the CALL statement.

Subroutine OILDEV computes the 18-k ESAL repetitions and ADT per month due to oil and gas well drilling. These are returned as N18OIL and ADTOIL, respectively. The subroutine uses statements from the SDHPT W-4 Tables to compute 18-k ESAL repetitions associated with the TTYPE distribution, which are programmed in as DATA statements. TTYPE contains the number of each truck type used during oil and gas well drilling, observed during photographic monitoring of three oil well sites in Brazos County over a 60-day oil well development period. Table A-7 contains the final values used in TTYPE to describe truck traffic at an oil well drilling site.

Drilling daily traffic volume (ADTOIL = 150) is an average value, taken from film records in Brazos County and confirmed by several petroleum consultants as a typical value for drilling traffic at most Texas oil and gas well sites.

At the present time, this and the following data are programmed in as DATA statements. If it is desired to represent a different distribution, the DATA statements must be changed, or additional READ statements could be used to access other distribution files.

PCT - Converts two-way ADT and N18 into one-way ADT and N18, under the assumption that whatever enters the well site must later exit the well site over the same roads. Thus PCT = 0.50; if

Table A-7. Oil Well Truck Traffic Distribution.

AASHTO Truck Type	Number Observed
SU-1	300
SU-2	150
2-S1	45
2-S2	0
3-SU and greater	655
2-S1-2	0
3-S1-2	0
2-1	90
2-2	0
3-2 and greater	125

Number of trucks observed = 1365 (2-month period).

this assumption is invalid for the roads under study, the program must be changed.

SINGLE - Contains the number of single axles by truck type.

TANDEM - Contains the number of tandem axles by truck type.

DISTSN - Contains the single axle load distributions as measured at weighing stations for each truck type.

DISTAN - Contains tandem axle load distributions for each truck type.

ESING - Contains equivalency factors for single wheel loads. (1)

ETAND - Contains equivalency factors for tandem wheel loads.

Other than the programmed-in DATA statements, all values are passed through by the CALL statement.

Subroutine OILSER computes 18-k ESAL repetitions and ADT per month due to oil well production, returning these as N18SER and ADTSER. Programmed in data statements are used for the following variables:

SDISTR - Distribution of single-axle trucks.

TDISTR - Distribution of tandem-axle trucks.

ESING - From SDHPT W-4 Tables.

ETAND - From SDHPT W-4 Tables.

The variables N18SER (declared to be REAL) and ADTSER are passed by the CALL statement.

Production traffic is assumed to be 50 passenger cars (ADTSER = 50) and 150 3-S2 trucks (SRVICE = 150). The subroutine converts two-way monthly passenger car ADT into one-way on the assumption that what enters the production site must later exit (PCT = 0.5). Two way monthly truck traffic is used to compute production 18-k ESAL repetitions, and then is converted to the one-way 18-k ESAL value.

Subroutine ADDOIL adds the drilling and production traffic values (from Subroutines "OILDEV" and "OILSER") to the TRAF array. This subroutine factors in the drilling time per well in months (DTIME), the rate of decay of oil production in percent per year (DECAY), and the percent of wells drilled which result in added truck traffic during OIL production.

The program assumes that production at the well site will decline over time. Production traffic follows an annual stepwise decline in the subroutine, assuming that 12 months of constant traffic is followed by a drop of magnitude "DECAY", then another constant 12 months, followed by another "DECAY" percent drop. There is also the assumption that not all wells produce oil or gas. The user-input variable "PRDPCT" converts the number of drill sites into the number of producing sites. The variability parameter "Completion Success Rate" from TTI Research Report 299-4 may be used here, but only if all producing wells generate truck traffic. Gas wells, as mentioned in Report 299-4, usually do not generate production truck traffic. (8)

The subroutine is capable of inputting drill times of one to six months as integers. Partial months are rounded to the nearest integer. Thus, 1.49 months becomes one month, but 1.5 months becomes 2 months. This is accomplished through a series of IF tests with GOTO statements to terminate the adding of additional months' oil development traffic.

All values computed in OILSER are passed through the CALL statement.

Subroutine CONVER accesses the TRAF array and extracts only those traffic values for those months which the user had requested in the MON(I) list in FILE02. It loads the 15 X 4 TR array, supplying most of the traffic values for the pavement distress tables which are output at the end of the program. All variable values are passed through the CALL statement.

Pavement Damage Subroutines

Four subroutines compute pavement distress area and severity ratings. Only one of these is selected, according to the value of PVTYPE (1 = SLMOD, 2 = BBMOD, 3 = HMMOD, 4 = OVMOD). The appropriate subroutine returns the severity damage parameters in the 15-element DIS array, described above.

Subroutine SLMOD contains pavement distress equations for surface-treated pavements. These equations were developed from regression analysis of inspection data collected on over 100 thin pavement sections in Texas. (4) TTI Research Report 299-2 describes the use and derivation of these distress equations. (6)

This is the original distress subroutine contained in the program which was described in TTI Report 299-2. It brings in the variables N18, ADT, and MTH through the CALL statement, returning the full DIS array in this manner. Table 4-6 describes the structure of the DIS array. This subroutine uses only the variables FLEXL, DMD, PI, LL, AVT50, TI50, and FTC from the COMMON statement; the remaining variables are not used here and thus may be zeros.

Subroutine BBMOD contains pavement distress equations for black base pavements. These equations were developed from regression analysis (12) of inspection data from the Texas Flexible Pavement Data Base. TTI Research Report 299-2 describes the use and derivation of these distress equations.

This subroutine was derived from an original complete TTI pavement distress program. It brings in the variables N18, ADT, and MTH through the CALL statement and returns the DIS array as shown in Table A-6. Note that the DIS array contains zeros for raveling, flushing, and patching, as these are not now calculated in this subroutine. An intermediate DS array was used in the subroutine to maintain compatibility with the original distress array in the main program. This was done to simplify the programmer's task when updating this subroutine, but it required equating the subroutine's DS array elements to the main program's DIS array through a series of equations contained in Table A-8.

The subroutine uses only the variables PI, AVT50, TI50, FTC, PVSTR, ASPH, and BINDER from the common statement; the remaining variables are not used and thus may be zeros. The variable PVSTR is used to assign the value of the pavement strength parameters HPR2 and HPR3, as indicated in Table A-3.

Note that maximum and minimum values are placed on each rho and beta value. These are in the programmed DATA statements.

Subroutine HMMOD contains pavement distress equations for hot-mix pavements. These equations were also developed from regression analysis of inspection data from the Texas Flexible Pavement Data Base. TTI Research Report 299-2 describes the use and derivation of these distress equations.

Just as Subroutine BBMOD, Subroutine HHMOD was derived from an original complete TTI pavement distress program. It brings in the variables N18, ADT, and MTH through the CALL statement, and returns the DIS array (Table A-6 gives the structure of this array). Again, note that the DIS array contains zeros for raveling, flushing, and patching, as these are not now calculated in this subroutine. In order to maintain compatability between the original program and this subroutine, an intermediate DS array was used as a substitute for the original distress array in the complete program. This was done to simplify the programmer's task when updating this subroutine, but it required equating the subroutine's DS array elements to the main program's DIS array through the series of equations in Table A-8.

Table A-8. Equations for Conversion Between DS and DIS Arrays in Pavement Damage Subroutines.

DIS(1) = DS(9)
DIS(2) = DS(1)
DIS(3) = DS(2)
DIS(4) = 0.0
DIS(5) = 0.0
DIS(6) = 0.0
DIS(7) = 0.0
DIS(8) = DS(3)
DIS(9) = DS(4)
DIS(10)= DS(7)
DIS(11)= DS(8)
DIS(12)= DS(5)
DIS(13)= DS(6)
DIS(14)= 0.0
DIS(15)= 0.0

Subroutine HMMOD uses only the variables PI, AVT50, TI50, FTC, PVSTR, ASPH, and BINDER from the common statement; the remaining variables are not used and thus may be zeros. The variable PVSTR is used to assign the value of the pavement strength parameters HPR2 and HPR3, as indicated in Table A-3.

Note that again maximum and minimum values are placed on each rho and beta value. These are in the programmed DATA statements.

Subroutine OVMOD contains pavement distress equations for overlay pavements. These equations were also developed from regression analysis of inspection data from the Texas Flexible Pavement Data Base. TTI Research Report 299-2 describes the use and derivation of these distress equations.

This subroutine was derived from an original complete TTI pavement distress program. It, too, brings in the variables N18, ADT, and MTH through the CALL statement and returns the DIS array (Table A-6 gives the structure of this array). Again, note that the DIS array contains zeros for raveling, flushing, and patching, as these are not now calculated in this subroutine. In order to maintain compatability between the original program and this subroutine, an intermediate DS array was used to substitute for the original program's distress array. This was done to simplify the programmer's task when updating this subroutine, but it required equating the subroutine's DS array elements to the main program's DIS array through the series of equations in Table A-8.

Subroutine OVMOD uses only the variables PI, AVT50, TI50, FTC, PVSTR, ASPH, and BINDER from the common statement. The remaining COMMON variables are not used and thus may be zeros. The variable PVSTR is used to assign the value of the pavement strength parameters HPR2 and HPR3, as indicated in Table A-3.

Note that maximum and minimum values are placed on each rho and beta value. These are in the programmed DATA statements.

Pavement Score Subroutines

Five subroutines provide values used in computing the pavement score of each road:

Subroutine FINDA1 applies traffic adjustment factors for use in computing pavement score. The variables ADT and AKIP are passed through the CALL statement, and the adjustment factor A1 is returned in the same manner. Remaining variables are read from DATA statements.

Subroutine FINDRF applies weather adjustment factors for use in computing pavement score. The variables RFAL and FTC for the appropriate county are passed through the CALL statement, and the adjustment factor array V is returned in the same manner. Remaining variables are read from DATA statements.

Subroutine UTLTY1 computes utility value of PSI and AVUC for input into pavement score formula. The RX array and the V array are passed through the CALL statement, and the Visual parameter AVUC is returned for computing VISUAL in the main program. DATA statements are used in this subroutine.

Subroutine UTLTY2 computes utility value of distress types, SIUC, for input into pavement score formula. ADTS and SRCE pass through the CALL statement, and SUIC is returned for computation of PSI in the main program. DATA statements are used in this subroutine.

Subroutine UTLTY3 computes utility value of maintenance cost, RMUC, for input into pavement score formula. This is considered to be associated with the area of patching. PATCH equals the total area of road covered by patching, and is passed from the main program through the CALL statement. This subroutine calculates the cost associated with PATCH, and also calculates a utility score for that cost (3) (refer to the Texas Pavement Evaluation System). For example:

If PATCH = 10%, cost = $1400 (where U decreases).

If PATCH = 75%, cost = $3100 (where U = 0).

Use linear interpolation to compute cost between PATCH = 10% and PATCH = 75%.

The value of RMUC is returned through the CALL statement for calculation of MCOST, the index of the cost of maintenance.

No COMMON or DATA statements are used in this subroutine, but some values are directly programmed into the formulas.

Possible Program Modifications

The Oil Field Pavement Damage Program presently contains a number of assumptions and programmed-in data variables, as indicated throughout this report. The program has been intentionally written and documented to allow improvements and additional input variables to be programmed. New defaults and programmed data can be "hard-wired" into the program, or added READ statements can access user-supplied defaults. Another possibility is to incorporate a series of READ statements for different default files (DEFAULT1, DEFAULT2, DEFAULT 3, etc.) which could be read in as a single-value default index in FILE02, in a manner similar to the method used to select pavement type and pavement strength. The ultimate capability would be reached by re-programming to access SDHPT files which are currently updated.

Another possible use of the program would be as part of an overall pavement management computer system. The Stage 1 traffic subroutines, in particular, could be integrated as an "oil field development" module into the main pavement analysis system. Oil field development is just one of many types of special-use truck traffic currently impacting rural highways in Texas. Research is now underway to determine the characteristics of other special-use truck activity such as timber, grain, cattle, poultry, produce, and surface mining. In fact, the original Oil Field Pavement Damage Program developed in Phase II has already been modified to analyze the effects of timber truck traffic on surface-treated pavements. (9) Many unique truck traffic distributions could be organized in a similar manner into modules for use in the master pavement management program. The master program could also include a "user-friendly" data input/control routine to guide the user step-by-step through the data input process.

Programmers should refer to the "PROGRAM ELEMENTS" section of this chapter when modifying the program for specialized use. The authors hope that this chapter will be of assistance to persons using the Oil Field Pavement Damage Program.

SUMMARY

This chapter contains general and specific information on the Oil Field Pavement Damage Program. The general information involves data and input and other steps necessary for running the program. Specific information concerns the program's structure, which may be used by programmers attempting to adapt the program for special requirements. This program documentation may also be used as a reference manual detailing program structure, assumptions, subroutines, and data input formats.

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APPENDIX B

OIL FIELD DAMAGE PROGRAM LISTING

```
//F77D11 JOB (W250,008D,S40,5,BS),'OILFIELD'
//*TAMU PRTY=1
// EXEC FORTVCLG,FVREGN=1024K,GOREGN=256K
//FORT.SYSIN DD *
C
C *****************************************************************
C *                                                               *
C *                  TTI  OIL FIELD DAMAGE PROGRAM                *
C *                                                               *
C *                  FORTRAN 77 VERSION OF 8/24/84                *
C *                                                               *
C *                    PROJECT 2 - 8 - 81 - 299                   *
C *                                                               *
C *****************************************************************
C
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C                       COLLEGE STATION, TEXAS  77843
C         PHONE:        (409) 845-1726
C
C -----------------------------------------------------------------
C
C     THIS PROGRAM CALCULATES:
C          A) LIFE TO FAILURE UNDER BASELINE TRAFFIC.
C          B) LIFE TO FAILURE UNDER BASELINE + OIL FIELD TRAFFIC.
C
C    FOR ANY ONE OF THE FOLLOWING TYPES OF FLEXIBLE PAVEMENT:
C
C          1.  SURFACE-TREATED.
C          2.  BLACK BASE.
C          3.  HOT-MIX.
C          4.  OVERLAY.
C
C     PLEASE NOTE THE FOLLOWING ITEMS:
C
C          1.  THE PROGRAM CONSIDERS ALL PAVEMENTS TO BE TWO-LANE ROADS,
C              WITH ONE LANE IN EACH DIRECTION. LANE DISTRIBUTIONS FOR
C              OIL FIELD TRAFFIC ON MULTILANE HIGHWAYS WERE NOT OBTAINED
C              IN THIS PROJECT.
C
C          2.  THE CALCULATION OF 18-K ESAL REPETITIONS IS DESCRIBED IN
C              TTI RESEARCH REPORT 299-1.
C
C          3.  PAVEMENT DISTRESS EQUATIONS WERE DEVELOPED USING STEPWISE
C              REGRESSION OF DATA FROM SITE INSPECTIONS OF THE TEST
C              SECTIONS IN THE TEXAS FLEXIBLE PAVEMENT DATA BASE.
C              FOR EXAMPLE,
C
C                   DISTRESS = EXP(RHO/N18) ** BETA
C
C              WHERE     DISTRESS RANGE = 0 TO 100
C                                   RHO = REGRESSION COEFFICIENT
C                                  BETA = REGRESSION COEFFICIENT
```

```
C
C                RHO = F(RAINFALL, PI, LL, LAYER THICKNESS, ...)
C
C         4.  PAVEMENT SCORE HAS BEEN DEFINED IN SDHPT PROJECT 2239 TO
C             BE A FUNCTION OF PSI, VISUAL SCORE, AND MAINTENANCE COST.
C             THIS IS A MULTIPLICATIVE UTILITY APPROACH WHERE:
C                          PSI = UTILITY VALUE OF PSI
C                       VISUAL = UTILITY VALUE OF DISTRESS TYPES
C                  MAINT. COST = UTILITY VALUE OF MAINTENANCE COST
C                                (CONSIDERED TO BE A FUNCTION OF
C                                THE AREA OF PATCHING.)
C
C             PAVEMENT SCORE RANGES FROM 100 (FOR NEWLY-CONSTRUCTED
C             ROADS) TO 0. THE OIL FIELD DAMAGE PROGRAM DEFINES
C             PAVEMENT FAILURE AS A PAVEMENT SCORE OF 35 OR LESS.
C
C         5.  PAVEMENT SCORE CONSIDERS THE COMBINED EFFECTS OF PAVEMENT
C             DISTRESS AND RIDE QUALITY IN DESCRIBING PAVEMENT
C             CONDITION. EQUATIONS HAVE BEEN DEVELOPED TO PREDICT BOTH
C             AREA AND SEVERITY RATINGS FOR SEVERAL COMMON DISTRESS
C             TYPES. THESE RATINGS RANGE FROM 0 (NO DISTRESS) TO 100.
C
C             MAXIMUM ACCEPTABLE AREA AND SEVERITY RATINGS ARE:
C
C             -------------------------------------------------------
C
C                    DISTRESS TYPE              AREA       SEVERITY
C
C             -------------------------------------------------------
C
C                  RUTTING                      50            30
C                  RAVELING                     80            30
C                  FLUSHING                     80            30
C                  ALLIGATOR CRACKING +
C                       PATCHING                50            50
C                  LONGITUDINAL CRACKING        70            30
C                  TRANSVERSE CRACKING          70            30
C
C             -------------------------------------------------------
C
C             MINIMUM PSI = 1.5  (RANGE = 4.2 TO 0)
C
C             THESE VALUES ARE PART OF THE OIL FIELD DAMAGE PROGRAM.
C             THEY CANNOT BE CHANGED FROM OUTSIDE THE PROGRAM.
C
C         6.  ONLY ONE PAVEMENT TYPE CAN BE INPUT AT A TIME, BUT THE
C             PROGRAM CAN RUN MULTIPLE PAVEMENT TYPES CONSECUTIVELY.
C
C         7.  REFER TO TTI RESEARCH REPORTS OF THE 299 SERIES FOR
C             ADDITIONAL DETAILS.
C
C ------------------------------------------------------------------
C
C
C         INPUT FILES:
C
C              THE PROGRAM READS INPUT DATA FROM 2 FILES:
C                   FILEO1 - COUNTY ENVIRONMENTAL DATA.
C                   FILEO2 - USER-SUPPLIED TRAFFIC AND PAVEMENT DATA.
C
C              **** FILEO1:  HAS STORED FOR EACH OF THE 254 TEXAS COUNTIES:
```

```
C
C         1.   TIN(I) - THORNTHWAITE INDEX.
C         2.  RAIN(I) - AVERAGE RAINFALL.
C         3.  FRTH(I) - AIR FREEZE-THAW CYCLES.
C         4.  AVTP(I) - AVERAGE MAXIMUM TEMPERATURE.
C
C    **** FILE02:  USER SUPPLIES THE FOLLOWING:
C
C              NPVTS - NUMBER OF PAVEMENTS TO BE ANALYZED.
C                      THESE MAY BE ENTIRE ROADS OR JUST
C                      SHORT SECTIONS.  EACH PAVEMENT MUST
C                      HAVE THE REMAINING FILE02 DATA ENTERED
C                      FOR ANALYSIS.
C
C             MINSCR - PAVEMENT SCORE AT FAILURE (USUALLY 35).
C             PVTYPE - TYPE OF FLEXIBLE PAVEMENT.  CHOOSE FROM:
C                         1.  SURFACE-TREATED.
C                         2.  BLACK BASE.
C                         3.  HOT-MIX.
C                         4.  OVERLAY.
C
C              COUTY - COUNTY WHERE PAVEMENT IS LOCATED.
C                      TTI RESEARCH REPORT 299-5, TABLE A-2,
C                      CONTAINS ACCEPTABLE VALUES FOR EACH
C                      TEXAS COUNTY.
C              FLEXL - BASE COURSE THICKNESS.
C                DMD - MEAN DYNAFLECT DEFLECTION (SENSOR W1).
C                 PI - SUBGRADE PLASTICITY INDEX.
C                 LL - SUBGRADE LIQUID LIMIT.
C             PVSTRN - PAVEMENT STRENGTH.  CHOOSE FROM:
C                        1 - STRONG
C                        2 - MEDIUM
C                        3 - WEAK
C                      THIS VARIABLE IS NOT USED FOR SURFACE-
C                      TREATED PAVEMENTS.  PVSTRN ESTABLISHES
C                      VALUES FOR HPR2 AND HPR3, AS DESCRIBED
C                      IN CHAPTER 4 OF REPORT 299-6.
C               ASPH - SURFACE COURSE THICKNESS.
C             BINDER - PERCENT ASPHALT USED IN SURFACE COURSE.
C
C             MON(I) - COMMANDS PROGRAM TO PRINT PSI, PAVEMENT
C                      SCORE, AND DISTRESS RATINGS AT SPECIFIC
C                      TIMES.  FOR EXAMPLE,
C                          1, 6, 12, 24, 36, 60, AND 72 MONTHS
C                          AFTER RECONSTRUCTION.
C                      PRESENTLY, 11 TIMES ARE REQUESTED.
C
C            HEAD(I) - USER-SUPPLIED HEADING.  MAY BE USED TO
C                      IDENTIFY THE PAVEMENT SECTION AND LOCATION,
C                      OR FOR OTHER DESCRIPTIVE INFORMATION.
C                      (MAXIMUM LENGTH = 60 CHARACTERS).
C
C                ADT - AVERAGE DAILY BASELINE TRAFFIC.
C                      USE TWO-WAY VALUES!
C             PCTTRK - PERCENT TRUCKS IN BASELINE TRAFFIC.
C             GROWTH - ANNUAL PERCENT GROWTH IN BASELINE TRAFFIC.
C             PCTLNE - BASELINE TRAFFIC DISTRIBUTION.  NORMALLY,
C                      USE 50 PERCENT.  DESIGN LANE DISTRIBUTIONS
C                      FOR MULTILANE HIGHWAYS ARE NOT CONSIDERED
C                      BY THE PROGRAM.
C
```

```
C                              DTIME - AVERAGE NUMBER OF MONTHS REQUIRED TO
C                                      DRILL AN OIL OR GAS WELL.
C                              DECAY - PERCENT DECLINE IN ANNUAL TRUCK TRAFFIC
C                                      DURING PRODUCTION PHASE.  TTI RESEARCH
C                                      REPORT 299-4 CONTAINS INFORMATION PERTINENT
C                                      TO BOTH THE DECAY AND THE DTIME VARIABLE.
C                             PRDPCT - PERCENTAGE OF DRILLED WELLS WHICH
C                                      GENERATE TRUCK TRAFFIC DURING PRODUCTION.
C
C                            NDATES - NUMBER OF MONTHS IN WHICH NEW WELLS
C                                      WERE ACTUALLY BEING DRILLED
C                                     WITHIN THE PAVEMENT STUDY REGION.
C
C                              IDATE - ELAPSED TIME (IN MONTHS) FROM PAVEMENT
C                                      RECONSTRUCTION TO THE START OF DRILLING
C                                      ON EACH WELL.
C                             NWELLS - NUMBER OF WELLS ACTUALLY DRILLED IN
C                                      MONTH "IDATE".
C
C -------------------------------------------------------------------
C
      REAL N18, LL, MTH , N18OIL, N18SER
      REAL*8 FAIL, HEAD
      INTEGER CTY, VISUAL, PSI, TOTAL, ENDSCR, ENDMTH, PVTYPE, PVSTR
      COMMON   FLEXL, DMD, PI, LL, AVT50, TI50, FTC,PVSTR,ASPH,BINDER
      DIMENSION HEAD(15), DIS(15), DISLIM(15),MON(15),FAIL(15), TR(15,4)
      DIMENSION RAIN(254), FRTH(254), TIN(254), AVTP(254), RX(8), V(8)
      DIMENSION TRAF(240,4), IW(60,2)
C
C     SET PROGRAM SWITCHES
C
      JSW = 0
      NST = 4
      NEN = 3
      NYR = 11
      NDS = 15
      NDSPR = 13
C
C     READ ENVIRONMENTAL DATA FROM FILE01
C
      DO 95  I = 1, 254
   95 READ(01,97) TIN(I), RAIN(I), FRTH(I), AVTP(I)
   97 FORMAT( 7X, G9.3, 2G10.3, 20X, G10.3)
C
C     READ PAVEMENT AND TRAFFIC DATA FROM FILE02
C
      READ(02,78)NPVTS
   78 FORMAT(I3)
      WRITE(6,67)NPVTS
   67 FORMAT('1 NUMBER OF PAVEMENTS = ',I3)
      WRITE(6,68)
   68 FORMAT(/,' OIL FIELD DAMAGE PROGRAM:  8/24/84 FORTRAN 77 VERSION')
C
C     BEGIN PAVEMENT LOOP.
C
      DO 990 IPVTS = 1, NPVTS
C
      READ(02,, 98) MINSCR, PVTYPE
   98 FORMAT (2(I2))
C
      READ(02,102) COUTY, FLEXL, DMD, PI, LL,PVSTRN,ASPH,BINDER
```

```
      CTY = INT(COUTY)
      PVSTR = INT(PVSTRN)
  102 FORMAT( 8F9.2)
      RFAL  =  RAIN(CTY) * 12.0
      AVT   =  AVTP(CTY)
      TI    =  TIN(CTY)
      FTC   =  FRTH(CTY) * 12.0
      JSW   =  0
C
      READ(02,108) (MON(I), I = 1, NYR )
  108 FORMAT( 16I5  )
C
      READ(02,104) (HEAD(I), I = 1, 15 )
  104 FORMAT( 15A4  )
C
   10 READ(02,106,END=50) ADT, PCTTRK, GROWTH, PCTLNE,DTIME,DECAY,PRDPCT
  106 FORMAT( F8.0, 6(F5.1))
C
C ------------------------------------------------------------------
C
C     TRAFFIC ANALYSIS IS PERFORMED BY THE FOLLOWING SUBROUTINES:
C
C        TRAFIC - CONVERTS BASELINE TRAFFIC INTO 18-K ESAL REPETITIONS
C                 PER MONTH USING THE SDHPT W-TABLES.  THIS PROCESS IS
C                 DESCRIBED IN TTI RESEARCH REPORT 299-1. THE SUBROUTINE
C                 RETURNS 18-K ESAL PER MONTH  BASED ON W-TABLES
C                 DESCRIBED IN RESEARCH REPORT 299-1 OF PROJECT
C                 2-8-81-299.
C
C        SETTAB - LOADS RESULTS OF SUBROUTINE "TRAFIC" INTO A 240 X 4
C                 ARRAY.  THE ARRAY CONTAINS THE TOTAL NUMBER OF VEHICLES
C                 AND 18-K ESAL REPETITIONS WHICH HAVE PASSED OVER THE
C                 PAVEMENT SINCE RECONSTRUCTION.  "TRAFIC" PROVIDES THE
C                 BASELINE ADT AND 18-K VALUES.
C                 THIS ROUTINE LOADS THE ACCUMULATIVE ADT AND N18
C                 VALUES FOR 240 MONTHS INTO THE ARRAY. NOTE OIL FIELD
C                 TRAFFIC WILL BE ADDED TO COLS 2 AND 4 IN SUBROUTINE
C                 ADDOIL.  AFTER "SETTAB", THE OIL FIELD VALUES ARE
C                 ADDED BY THE FOLLOWING THREE SUBROUTINES:
C
C        OILDEV - COMPUTES 18-K ESAL REPETITIONS AND ADT PER MONTH DUE
C                 TO OIL AND GAS WELL DRILLING.  THIS SUBROUTINE
C                 RETURNS 18K ESAL AND ADT PER MONTH ASSOCIATED
C                 WITH OIL FIELD DEVELOPMENT FOR FURTHER PROCESSING.
C
C        OILSER - COMPUTES 18-K ESAL REPETITIONS AND ADT PER MONTH DUE
C                 TO OIL WELL PRODUCTION.   SUBROUTINE "OILSER"
C                 RETURNS 18K ESAL AND ADT PER MONTH ASSOCIATED
C                 WITH OIL FIELD SERVICING TRAFFIC.
C
C        ADDOIL - ADDS DRILLING AND PRODUCTION VALUES (FROM "OILDEV"
C                 AND "OILSER") TO THE SUBROUTINE "TRAFIC" ARRAY.
C
C        CONVER - ACCESSES THE SUBROUTINE "TRAFIC" ARRAY AND EXTRACTS
C                 VALUES ONLY FOR THOSE MONTHS THAT THE USER REQUESTED
C                 IN THE MON(I) LIST FROM FILE02. THIS SUBROUTINE
C                 RETURNS THE 15 X 4 ARRAY TR WHICH CONTAINS THE
C                 ADT AND 18K ESAL UNDER OIL FIELD AND NORMAL
C                 TRAFFIC FOR EACH MONTH CHOSEN IN THE PLANNING
C                 HORIZON SPECIFIED IN MON(I) ARRAY.
C
```

```
C ----------------------------------------------------------------------
C
      CALL TRAFIC ( ADT, PCTTRK, PCTLNE, N18)
      CALL SETTAB ( N18, ADT, GROWTH, TRAF )
      CALL OILDEV ( N18OIL, ADTOIL, DTIME )
      CALL OILSER ( N18SER, ADTSER )
      READ (02, 107) NDATES
  107 FORMAT ( I3)
      DO 110 I = 1, NDATES
      READ (02, 109 , END=710 ) IDATE , NWELLS
  109 FORMAT ( I3, 1X, I3)
      IW(I,1) = IDATE
      IW(I,2) = NWELLS
      CALL ADDOIL ( IDATE, NWELLS, N18OIL, ADTOIL, N18SER, ADTSER,
     1                  TRAF, DECAY, DTIME, PRDPCT)
  110 CONTINUE
      CALL CONVER ( MON , NYR, TRAF, TR )
C
C     WRITE OUT INPUT DATA AND HEADINGS
C
      WRITE(6,200) (HEAD(I), I = 1, 15  )
  200 FORMAT( '1', T26, 15A4, / )
C
      IF(PVTYPE.EQ.1)WRITE(6,190)
  190 FORMAT(T26,'SURFACE-TREATED PAVEMENT',/)
C
      IF(PVTYPE.EQ.2)WRITE(6,191)
  191 FORMAT(T26,'BLACK BASE PAVEMENT',/)
C
      IF(PVTYPE.EQ.3)WRITE(6,192)
  192 FORMAT(T26,'HOT-MIX PAVEMENT',/)
C
      IF(PVTYPE.EQ.4)WRITE(6,193)
  193 FORMAT(T26,'OVERLAY PAVEMENT',/)
C
      IF(PVTYPE.EQ.1)WRITE(6,202) FLEXL, DMD, PI, LL
  202 FORMAT( T26, 'STRUCTURAL VARIABLES' // T26,
     1 'FLEXIBLE LAYER THICKNESS', T60, F7.2 / T26,
     2 'W1, MEAN DEFLECTION', T60, F7.2 / T26,
     3 'SUBGRADE PLASTICITY INDEX', T60, F7.2 / T26,
     4 'SUBGRADE LIQUID LIMIT', T60, F7.2  //  )
C
      IF(PVTYPE.GT.1)WRITE(6,203) PVSTR, ASPH, PI, BINDER
  203 FORMAT( T26, 'STRUCTURAL VARIABLES' // T26,
     1 'PAVEMENT STRENGTH INDEX', T61, I3, / T26,
     2 'ASPHALT COURSE THICKNESS', T60, F7.2 / T26,
     3 'SUBGRADE PLASTICITY INDEX', T60, F7.2 / T26,
     4 'PERCENT ASPHALT', T60, F7.2  //  )
C
      WRITE(6,204) CTY, AVT, TI, FTC
  204 FORMAT( T26, 'ENVIRONMENTAL VARIABLES FOR COUNTY ', I3, // T26,
     1 'MEAN TEMPERATURE', T60, F7.2 / T26,
     2 'THORNTWAITE INDEX', T60, F7.2 / T26,
     3 'FREEZE /THAW CYCLES', T60, F7.2 // )
C
      WRITE ( 6, 205) MINSCR
  205 FORMAT (1X,//,T26,'MINIMUM PAVEMENT SCORE ALLOWED = ',I2, //)
C
      WRITE(6,207)
      WRITE(6,208) N18, ADT, DTIME, DECAY
      WRITE(6,209) PCTTRK, GROWTH, PRDPCT
```

```
      WRITE(6,210) PCTLNE
  207 FORMAT ( T26, 'TRAFFIC ANALYSIS DATA',T75,'OIL FIELD DATA', /,
     1           T26, '*********************',T75,'**************',/)
  208 FORMAT(1X,T26, 'N18/MTH = ', F5.0, '     ADT/LANE = ', F5.0 , T75,
     1 'AV. MONTHS DRILL TIME =',F4.0,/,T75,'AV. % PROD DECAY/YEAR =',
     1 F4.0)
  209 FORMAT(1X,T26, '% TRUCKS = ', F5.2 , '    % GROWTH = ', F5.2, T75,
     1 'AV. % PRODUCING WELLS =',F4.0,/)
  210 FORMAT ( T26, 'BASELINE DIRECTIONAL DISTRIBUTION = ',F5.1,'%')
C
      WRITE ( 6, 60)
      DO 70  I = 1, NYR
      WRITE ( 6, 80) MON(I), TR(I,1), TR(I,2), TR(I,3), TR(I,4)
   70 CONTINUE
   60 FORMAT ( /, 30X, 'MONTH   ADT(N)   ADT(O)   N18(N)   N18(O)')
   80 FORMAT ( 30X, I3, 3X, F9.0 , F9.0, 2(1X, F8.0))
C
C     THE FIRST TIME THRU INITIALIZE THE FOLLOWING
C
      IF( JSW .GT. 0 ) GO TO 12
      JSW = JSW + 1
      AVT50 = AVT - 50.
      TI50 = TI + 50.
      AKIP = 1.0
      CALL FINDRF ( RFAL, FTC, V)
      CALL FINDA1 ( ADT, AKIP, A1)
   12 CONTINUE
C
C
C -----------------------------------------------------------------
C         THIS IS THE MAIN CALCULATION LOOP OF THE PROGRAM
C
C         J = 1  BASELINE TRAFFIC
C         J = 2  BASELINE TRAFFIC + OIL FIELD TRAFFIC
C
C -----------------------------------------------------------------
C
C
      DO 26 J = 1, 2
      IF (·J .EQ. 1 ) WRITE ( 6, 299) (HEAD(I), I = 1, 15)
      IF ( J .EQ. 2 ) WRITE ( 6, 300) (HEAD(I), I = 1, 15)
      IFAIL = 0
      TOTAL  = 100
C
      IF(PVTYPE.EQ.1)WRITE(6,215)
  215 FORMAT( T17, 'RUTTING     RAVELING   FLUSHING    ALLIGATOR ',
     1'  LONGITUDNL  TRANSVERSE  PATCHING      PAVEMENT  SCORE (PES)'
     2  / T3, 'MONTH  RIDE  AREA  SEV.  AREA  SEV.  AREA  SEV.  ',
     3 'AREA  SEV.  AREA  SEV.  AREA  SEV.  AREA  SEV.' ,
     4 '    VISUAL  PSI   MCOST  TOTAL')
C
      IF(PVTYPE.GT.1)WRITE(6,217)
  217 FORMAT( T17, 'RUTTING     NOT CALC.  NOT CALC.   ALLIGATOR ',
     1'  LONGITUDNL  TRANSVERSE  NOT CALC.     PAVEMENT  SCORE (PES)'
     2  / T3, 'MONTH  RIDE  AREA  SEV.  ----  ----  ----  ----  ',
     3 'AREA  SEV.  AREA  SEV.  AREA  SEV.  ----  ----' ,
     4 '    VISUAL  PSI   MCOST  TOTAL')
C
C -----------------------------------------------------------------
C
C     PRESENTLY NYR = 11 AND THE PROGRAM PRINTS PSI, PAVEMENT SCORE, AND
```

```
C     PAVEMENT DISTRESS VALUES FOR EACH ONE OF THE 11 MONTHS LISTED IN THE
C     MON(NYR) LIST.
C
C     THE PROGRAM USES THE SUBROUTINE "TRAFIC" ARRAY TO FIND THE ACCUMULATED
C     18-K AND ADT VALUES FOR EACH MON(I) REQUESTED.  THESE VALUES ARE THEN
C     ENTERED INTO DISTRESS EQUATIONS CORRESPONDING TO THE PAVEMENT TYPE UNDER
C     ANALYSIS.  THE PROGRAM COMPUTES PSI AND PAVEMENT DISTRESS VALUES FROM
C     THE 18-K AND ADT TOTALS.  FINALLY, THE PROGRAM COMPUTES PAVEMENT SCORE.
C
C ---------------------------------------------------------------------
C
      DO 25 I = 1, NYR
      INPES = TOTAL
      ADT = TR( I, J) / 1000000.
      N18 = TR( I, J+2) / 1000000.
      MTH = MON(I)
C
C ---------------------------------------------------------------------
C
C     PROGRAM CALLS APPROPRIATE SUBROUTINE FOR THE PAVEMENT TYPE
C     BEING ANALYZED (1, 2, 3, OR 4).
C
C ---------------------------------------------------------------------
C
      IF(PVTYPE.EQ.1)CALL SLMOD( N18, ADT, MTH, DIS )
      IF(PVTYPE.EQ.2)CALL BBMOD( N18, ADT, MTH, DIS )
      IF(PVTYPE.EQ.3)CALL HMMOD( N18, ADT, MTH, DIS )
      IF(PVTYPE.EQ.4)CALL OVMOD( N18, ADT, MTH, DIS )
C
C ---------------------------------------------------------------------
C
C     THE PROGRAM COMPUTES PAVEMENT SCORE HERE.
C
C     THE "DIS" ARRAY CONTAINS THE AREA AND SEVERITY VALUES.
C     THESE VALUES ARE NOW PRE-PROCESSED BEFORE ENTRY INTO THE
C     ESTIMATED PAVEMENT SCORE CALCULATION ROUTINES.
C
C     NOTE THAT THE AREA OF DISTRESS IS ONLY USED WHEN THE SEVERITY
C     VALUE EXCEEDS 10.0 PERCENT.
C
C     THE FOLLOWING UTILITY VALUES ARE TAKEN FROM TTI PROJECT 2239.
C
C          PESC = PAVEMENT SCORE. THIS APPEARS AS A PERCENT IN THE
C                 PRINTOUT COLUMN LABELED "TOTAL".
C          AVUC = UTILITY VALUE OF PAVEMENT DISTRESS TYPES FROM SUB-
C                 ROUTINE "UTILITY1", PRINTED OUT AS PERCENT IN THE
C                 COLUMN LABELED "VISUAL".
C          SIUC = UTILITY VALUE OF PSI FROM SUBROUTINE "UTILITY2",
C                 PRINTED OUT AS PERCENT IN COLUMN LABELED "PSI".
C          RMUC = UTILITY VALUE OF MAINTENANCE COST FROM SUBROUTINE
C                 "UTILITY3", PRINTED OUT AS PERCENT IN COLUMN
C                 LABELED "MCOST".
C        A1, A2, AND A3 ARE UTILITY WEIGHING VALUES.
C
C     TTI RESEARCH REPORT 299-2 DESCRIBES THE PAVEMENT SCORE EQUATION.
C
C ---------------------------------------------------------------------
C
      ADTS = ADT * 55.0
      SRCE = DIS(1)
      DO 135  N = 1, 8
```

```
      RX(N) = 0.0
  135 CONTINUE
      IF ( DIS(3) .LT. 0.15 ) GOTO 140
      RX(1)  = 0.0
      RX(2)  = DIS(2)
      GOTO 150
  140 RX(1) = DIS(2)
      RX(2) = 0.0
  150 CONTINUE
      IF ( DIS(5) .GT.  10.0) RX(3) = DIS(4)
      IF ( DIS(7) .GT.  10.0) RX(4) = DIS(6)
      IF ( DIS(9) .GT.  10.0) RX(6) = DIS(8)
      IF ( DIS(11) .GT.  10.0) RX(7) = DIS(10)
      IF ( DIS(13) .GT.  10.0) RX(8) = DIS(12)
      PATCH = DIS(14)
      CALL UTLTY1 ( RX, V, AVUC)
      CALL UTLTY2 ( ADTS, SRCE, SIUC)
      CALL UTLTY3 ( PATCH, RMUC )
      A2  = 1.0
      A4  = 1.0
      PESC  = AVUC ** A1 * SIUC **A2 * RMUC **A4
      TOTAL  = INT(PESC * 100.)
      VISUAL  = INT(AVUC * 100.)
      PSI  = INT(SIUC * 100.)
      MCOST  = INT(RMUC * 100.)
C
   22 WRITE(6,220) MON(I), (DIS(L), L=1,NDS), VISUAL, PSI, MCOST,TOTAL
  220 FORMAT( /, T2, I4, F8.2, 14F6.1, 4(4X, I3) )
C
      IF (TOTAL .GT. MINSCR ) GOTO 25
      IF (IFAIL.GT. 0 )  GOTO 25
      IFAIL = 1
      INSCR = INPES
      ENDSCR = TOTAL
      INMTH = MON(I-1)
      ENDMTH = MON(I)
   25 CONTINUE
      IF ( IFAIL .EQ. 0 ) GOTO 99
      IDIF = INSCR - ENDSCR
      IREQ = INSCR - MINSCR
      IMTH = ENDMTH - INMTH
      RABC = FLOAT(IREQ) / FLOAT(IDIF)
      REQ  = INMTH + RABC * IMTH
      IF ( J .EQ. 1) WRITE (6, 301) REQ
      IF ( J .EQ. 2) WRITE(6,302) REQ, ((IW(I,M),M=1,2),I=1,NDATES)
      GOTO 26
   99 IF ( J .EQ. 1) WRITE (6, 303)
      IF ( J .EQ. 2) WRITE ( 6, 304)
   26 CONTINUE
C
      GOTO 900
   50 WRITE(6,250)
  250 FORMAT( '1' )
  299 FORMAT(1H1,///,T20,15A4,//,T20, 'OIL FIELD DAMAGE PROJECT ---- ',
     1         'NORMAL TRAFFIC', /// )
  300 FORMAT(1H1,///,T20,15A4,//,T20, 'OIL FIELD DAMAGE PROJECT ---- ',
     1              'NORMAL PLUS OIL FIELD TRAFFIC',/// )
  301 FORMAT ( ////, 10X, 'TIME TO FAILURE UNDER NORMAL TRAFFIC',
     1          20X, '=  ', F5.1, ' MTHS' )
  302 FORMAT ( ///, 10X, 'TIME TO FAILURE UNDER NORMAL + OIL FIELD',
     1        ' TRAFFIC     = ', F5.1, ' MTHS', //,
```

```
     2          10X, 'OIL WELL DEVELOPMENT          MONTH      NO. WELLS',
     3          /, 15(40X, I3, 10X, I3 , /))
 303 FORMAT ( ///, 10X, 'SECTION DID NOT FAIL UNDER NORMAL TRAFFIC',
     1                  ' IN ANALYSIS PERIOD')
 304 FORMAT ( ///, 10X, 'SECTION DID NOT FAIL UNDER NORMAL PLUS ',
     1                 'OIL FIELD TRAFFIC IN ANALYSIS PERIOD')
 710 WRITE ( 6, 720)
 720 FORMAT ( 1H1, ' ERROR IN INPUT DATA', /
     1           10X, ' NUMBER OF INPUT DATES DOES NOT MATCH ACTUAL NO.')
 900 CONTINUE
 990 CONTINUE
C
C END OF PAVEMENT LOOPS
C
1000 CONTINUE
C
      STOP
      END
C
      SUBROUTINE SLMOD( N18, ADT, MTH, DIS )
C
C  ********************************************************************
C
C     SUBROUTINE SLMOD:  CONTAINS PAVEMENT DISTRESS EQUATIONS FOR
C                        SURFACE-TREATED PAVEMENTS.  THESE EQUATIONS
C                        WERE DEVELOPED FROM REGRESSION ANALYSIS OF
C                        INSPECTION DATA COLLECTED ON OVER 100 THIN
C                        PAVEMENT SECTIONS IN TEXAS DURING SDHPT PROJECT
C                        2284.  TTI RESEARCH REPORT 299-2 DESCRIBES
C                        THE USE AND DERIVATION OF THESE DISTRESS EQUATIONS.
C
C                 NOTE:  MAXIMUM AND MINIMUM VALUES HAVE BEEN PLACED ON
C                        EACH RHO AND BETA VALUE.
C
C  ********************************************************************
C
      DIMENSION DIS(15)
C
C   THIS IS THE SAME DIS ARRAY USED IN THE MAIN PROGRAM.
C
      REAL N18, LL, MTH
      COMMON   FLEXL, DMD, PI, LL, AVT50, TI50, FTC,PVSTR,ASPH,BINDER
C
      P1 = 4.2
      PF = 0.83
C
C    PSI
C
      RHO = -0.173 + 0.00687*AVT50 - 0.000632*TI50 + 0.0133*FLEXL
     1 + .00075*LL + .00153*FTC - 0.0214*DMD
C
      IF( RHO .GT. 0.511 )  RHO = 0.511
      IF( RHO .LT. 0.0009 ) RHO = 0.0009
C
      DIS(1) = 4.2
      X       = ( RHO/N18)
      IF ( X .GT. 10.0 ) GOTO 1
      DIS(1) = P1 - (P1 - PF) * EXP( - (X))
    1 CONTINUE
C
C     RUTTING AREA
```

```
C
      RHO = -0.1035 + 0.00549*AVT50 + 0.0067*FLEXL - 0.0015*LL
     & + 0.00162*PI + 0.00077*FTC
      BETA = 1.540 + 0.0169*TI50 - 0.072*FLEXL
C
      IF( RHO .GT. 0.117 ) RHO = 0.117
      IF( RHO .LT. 0.0036 ) RHO = 0.0036
C
      IF( BETA .GT. 6.27 ) BETA = 6.27
      IF( BETA .LT. 0.615 ) BETA = 0.615
C
      DIS(2) = 0.0
      X      = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 2
      DIS(2) = EXP ( -(X))
    2 CONTINUE
C
C     RUTTING SEVERITY
C
      RHO = -0.0678 + 0.0032*AVT50 + 0.00566*FLEXL - 0.00031*LL
     & + 0.00048*FTC
      BETA = 1.780
C
      IF( RHO .GT. 0.121 ) RHO = 0.121
      IF( RHO .LT. 0.0027 ) RHO = 0.0027
C
      IF( BETA .GT. 5.94 ) BETA = 5.94
      IF( BETA .LT. 0.527 ) BETA = 0.527
C
      DIS(3) = 0.0
      X      = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 3
      DIS(3) = EXP ( -(X))
    3 CONTINUE
C
C     RAVELING AREA
C
      RHO = 1.030 + 0.0146*TI50 + 0.0064*FTC - 0.6089*DMD
      BETA = 1.28
C
      IF( RHO .GT. 2.76 ) RHO = 2.76
      IF( RHO .LT. 0.095 ) RHO = 0.095
C
      IF( BETA .GT. 6.1 ) BETA = 6.1
      IF( BETA .LT. 0.52 ) BETA = 0.52
C
      DIS(4) = 0.0
      X      = ( RHO/ADT) ** BETA
      IF ( X .GT. 10.0 ) GOTO 4
      DIS(4) = EXP ( -(X))
    4 CONTINUE
C
C     RAVELING SEVERITY
C
      RHO = 0.621 + 0.0129*TI50 + 0.0066*FTC - 0.449*DMD
      BETA = 1.40
C
      IF( RHO .GT. 2.8 ) RHO = 2.8
      IF( RHO .LT. 0.077 ) RHO = 0.077
C
      DIS(5) = 0.0
```

```
      X       = ( RHO/ADT) ** BETA
      IF ( X .GT. 10.0 ) GOTO 5
      DIS(5) = EXP ( -(X))
    5 CONTINUE
C
C     FLUSHING AREA
C
      RHO = 0.488 + 0.0127*TI50 + 0.00345*FTC - 0.213*DMD
      BETA = 1.27
C
      IF( RHO .GT. 2.84 ) RHO = 2.84
      IF( RHO .LT. 0.062 ) RHO = 0.062
C
      DIS(6) = 0.0
      X       = ( RHO/ADT) ** BETA
      IF ( X .GT. 10.0 ) GOTO 6
      DIS(6) = EXP ( -(X))
    6 CONTINUE
C
C     FLUSHING SEVERITY
C
      RHO = -0.14 + 0.031*AVT50 + 0.0103*TI50 + 0.00541*FTC - 0.201*DMD
      BETA = 1.50
C
      IF( RHO .GT. 2.18 ) RHO = 2.81
      IF( RHO .LT. 0.063 ) RHO = 0.063
C
      IF( BETA .GT. 5.45 ) BETA = 5.45
      IF( BETA .LT. 0.51 ) BETA = 0.51
C
      DIS(7) = 0.0
      X       = ( RHO/ADT) ** BETA
      IF ( X .GT. 10.0 ) GOTO 7
      DIS(7) = EXP ( -(X))
    7 CONTINUE
C
C     ALLIGATOR CRACKING AREA
C
      RHO = -0.179 + 0.0121*AVT50 + 0.0040*FLEXL - 0.0011*LL
     !  + 0.00153*FTC
      BETA = 1.867 - 0.00908*TI50 + 0.144*FLEXL - 0.572*DMD
C
      IF( RHO .GT. 0.19 ) RHO = 0.19
      IF( RHO .LT. 0.003 ) RHO = 0.003
C
      IF( BETA .GT. 7.29 ) BETA = 7.29
      IF( BETA .LT. 0.51 ) BETA = 0.51
C
      DIS(8) = 0.0
      X       = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 8
      DIS(8) = EXP ( -(X))
    8 CONTINUE
C
C     ALLIGATOR CRACKING SEVERITY
C
      RHO = -0.2219 + 0.0119*AVT50 + 0.000327*TI50 + 0.00274*FLEXL
     1      - 0.000579*LL + 0.00166*FTC
      BETA = 2.909 + 0.0998*AVT50 + 0.013*LL -1.567*DMD
C
      IF( RHO .GT. 0.07 ) RHO = 0.07
```

```
      IF( RHO .LT. 0.003 ) RHO = 0.003
C
      IF( BETA .GT. 9.8 ) BETA = 9.8
      IF( BETA .LT. 0.51 ) BETA = 0.51
C
      DIS(9) = 0.0
      X      = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 9
      DIS(9) = EXP ( -(X))
    9 CONTINUE
C
C     LONGITUDINAL CRACKING AREA
C
      RHO = -63.1 + 4.52*AVT50 + 0.541*TI50 + 7.41*FLEXL + 1.1145*FTC
      BETA = 1.15
C
      IF( RHO .GT. 172.0 ) RHO = 172.0
      IF( RHO .LT. 30.0 ) RHO = 30.0
C
      IF( BETA .GT. 2.65 ) BETA = 2.65
      IF( BETA .LT. 0.68 ) BETA = 0.68
C
      DIS(10) = 0.0
      X      = ( RHO/MTH) ** BETA
      IF ( X .GT. 10.0 ) GOTO 10
      DIS(10) = EXP ( -(X))
   10 CONTINUE
C
C     LONGITUDINAL CRACKING SEVERITY
C
      RHO = -120.1 + 6.77*AVT50 + 1.146*TI50 + 4.78*FLEXL + 1.32*FTC
      BETA = 1.58
C
      IF( RHO .GT. 167.0 ) RHO = 167.0
      IF( RHO .LT. 21.0 ) RHO = 21.0
C
      DIS(11) = 0.0
      X      = ( RHO/MTH) ** BETA
      IF ( X .GT. 10.0 ) GOTO 11
      DIS(11) = EXP ( -(X))
   11 CONTINUE
C
C     TRANSVERSE CRACKING AREA
C
      RHO = -66.4 + 2.156*TI50 + 10.12*FLEXL + 0.718*FTC
      BETA = 2.059 + 0.0734*FLEXL - 0.06*LL + 0.0607*PI - 0.00375*FTC
      IF( RHO .GT. 176.0 ) RHO = 176.0
      IF( RHO .LT. 41.0 ) RHO = 41.0
C
      IF( BETA .GT. 2.65 ) BETA = 2.65
      IF( BETA .LT. 0.61 ) BETA = 0.61
C
      DIS(12) = 0.0
      X      = ( RHO/MTH) ** BETA
      IF ( X .GT. 10.0 ) GOTO 12
      DIS(12) = EXP ( -(X))
   12 CONTINUE
C
C     TRANSVERSE CRACKING SEVERITY
C
      RHO = 96.3 - 1.04*AVT50 + 1.068*TI50 - 0.318*FTC
```

```
      BETA = 1.10 + 0.1606*LL - 0.237*PI -0.0154*FTC
C
      IF( RHO .GT. 173.0 ) RHO = 173.0
      IF( RHO .LT. 33.0 ) RHO = 33.0
C
      IF( BETA .GT. 6.65 ) BETA = 6.65
      IF( BETA .LT. 0.56 ) BETA = 0.56
C
      DIS(13) = 0.0
      X       = ( RHO/MTH) ** BETA
      IF ( X .GT. 10.0 ) GOTO 13
      DIS(13) = EXP ( -(X))
   13 CONTINUE
C
C     PATCHING AREA
C
      RHO = 0.00799 + 0.00252*AVT50 + 0.000218*TI50 + 0.00166*FLEXL
     1      - 0.00125*PI
      BETA = 1.75
C
      IF( RHO .GT. 0.104 ) RHO = 0.104
      IF( RHO .LT. 0.0036 ) RHO = 0.0036
C
      IF( BETA .GT. 5.36 ) BETA = 5.36
      IF( BETA .LT. 0.63 ) BETA = 0.63
C
      DIS(14) = 0.0
      X       = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 14
      DIS(14) = EXP ( -(X))
   14 CONTINUE
C
C     PATCHING SEVERITY
C
      RHO = -0.0404 + 0.0035*AVT50 + 0.0029*FLEXL - 0.000424*LL
     & + 0.000389*FTC
      BETA = -0.158 + 0.0504*AVT50 + 0.0897*FLEXL - 0.0687*LL
     1      + 0.0820*PI + 0.0270*FTC
      IF( RHO .GT. 0.090 ) RHO = 0.090
      IF( RHO .LT. 0.0027 ) RHO = 0.0027
C
      IF( BETA .GT. 3.27 ) BETA = 3.27
      IF( BETA .LT. 0.527 ) BETA = 0.527
C
      DIS(15) = 0.0
      X       = ( RHO/N18) ** BETA
      IF ( X .GT. 10.0 ) GOTO 15
      DIS(15) = EXP ( -(X))
   15 CONTINUE
       DO 16 L = 2,15
   16  DIS(L) = DIS(L)*100
C
C
      RETURN
      END
C
      SUBROUTINE BBMOD(N18,ADT,MTH,DIS)
C
C ********************************************************************
C
C     SUBROUTINE BBMOD: CONTAINS PAVEMENT DISTRESS EQUATIONS FOR
```

```
C                        BLACK-BASE PAVEMENTS. THESE EQUATIONS WERE
C                        DEVELOPED FROM REGRESSION ANALYSIS OF INSPEC-
C                        TION DATA COLLECTED IN SDHPT PROJECT 2284.
C                        TTI RESEARCH REPORT 239-2 DESCRIBES THE USE
C                        AND DERIVATION OF THESE DISTRESS EQUATIONS.
C
C                  NOTE: MAXIMUM AND MINIMUM VALUES HAVE BEEN PLACED
C                        ON EACH RHO AND BETA VALUE.
C
C *******************************************************************
C
      REAL MTH, N18,N18MTH
      DIMENSION DIS(15), RMIN(19), RMAX(19), X(19),DS(10)
      INTEGER PVSTR
      COMMON FLEXL, DMD, PI, LL, AVT50, TI50, FTC,PVSTR,ASPH,BINDER
      DATA RMIN/0.04, 0.5, 0.05, 0.5, 0.3, 0.6, 0.1, 0.8, 63.0, 0.5,
     & 50.0, 0.5, 63.0, 0.5, 65.0, 0.5, 0.04, 0.4, 0.5 /
      DATA RMAX/ 9.6, 6.7, 6.1, 5.2, 9.8, 4.7, 4.5, 6.7, 400.0, 4.2,
     & 250.0, 7.2, 400.0, 5.33, 225.0, 6.9, 10.0, 6.0, 4.0 /
C
      KNT = 0
      PO = 4.6
C
       AVT = AVT50 + 50.0
C
C  ASSIGN VALUES FOR HPR2 AND HPR3 BASED ON PVSTR *********
C
       IF (PVSTR.EQ.1)HPR2=10.
       IF (PVSTR.EQ.1) HPR3 = 2.5
       IF (PVSTR.EQ.2) HPR2 = 20.
       IF (PVSTR.EQ.2) HPR3 = 1.5
       IF (PVSTR.EQ.3) HPR2 = 30.
       IF (PVSTR.EQ.3) HPR3 = 0.25
C
C     RUTTING AREA
C
      X(1) = 0.00175*FTC - 0.0141*AVT + 0.257*ASPH
      X(2) = -0.00493*FTC + 0.0262*AVT + 0.0387*PI  - 0.0433*ASPH
C
C     RUTTING SEVERITY
C
      X(3) = 0.00263*FTC - 0.0137*AVT + 0.253*ASPH
      X(4) = 0.00337*TI50-0.00928*FTC+0.0341*AVT+0.0242*PI-0.071*ASPH
C
C     ALLIGATOR CRACKING AREA
C
      X(5) = 0.134*HPR2 - 0.067*HPR3
      X(6) = 0.856*HPR3
C
C     ALLIGATOR CRACKING SEVERITY
C
      X(7) = -0.00986*PI + 0.0422*ASPH + 0.0554*HPR2
      X(8) = 1.37*HPR3
C
C     LONGITUDINAL CRACKING AREA
C
      X(9) = 5.33*ASPH + 29.44*BINDER - 6.88*HPR3
      X(10) = 0.0181*AVT + 0.421*HPR3
C
C     LONGITUDINAL CRACKING SEVERITY
C
```

```
      X(11) = -0.425*FTC-0.0943*PI+2.915*ASPH+22.16*BINDER-11.59*HPR3
      X(12) = 0.118*TI50 + 0.0389*FTC - 0.701*BINDER + 0.553*HPR3
C
C     TRANSVERSE CRACKING AREA
C
      X(13) = -1.739*PI + 0.428*ASPH + 48.88*BINDER - 46.7*HPR3
      X(14) = 0.0153*FTC + 0.625*HPR3
C
C     TRANSVERSE CRACKING SEVERITY
C
      X(15) = -0.502*PI + 26.75*BINDER - 29.96*HPR3
      X(16) = 0.105*TI50 + 0.0362*FTC - 1.047*BINDER + 1.1488*HPR3
C
C     RHO, BETA, PF FOR PSI
C
      X(17) = -0.02182*FTC - 0.00831*PI + 0.04499*BINDER + 0.15019*HPR2
      X(18) = 0.01201*TI50 + 0.03166*FTC + 0.13775*AVT50 + 0.00114*PI
     & - 0.31331*BINDER - 0.03234*HPR2
      X(19) = -0.00637*FTC - 0.0155*AVT50 - 0.00658*PI + 0.27714*BINDER
     & + 0.05097*HPR2
C
      DO 12 I = 1, 19
      IF( X(I) .GT. RMAX(I) ) X(I) = RMAX(I)
      IF( X(I) .LT. RMIN(I) ) X(I) = RMIN(I)
   12 CONTINUE
C
      RHORA = X(1)
      BETRA = X(2)
      RHORS = X(3)
      BETRS = X(4)
      RHOAA = X(5)
      BETAA = X(6)
      RHOAS = X(7)
      BETAS = X(8)
      RHOLA = X(9)
      BETLA = X(10)
      RHOLS = X(11)
      BETLS = X(12)
      RHOTA = X(13)
      BETTA = X(14)
      RHOTS = X(15)
      BETTS = X(16)
      RHOP  = X(17)
      BETAP = X(18)
      PF    = X(19)
C
      DO 15 I = 1, 10
C
   15 DS(I) = 0.0
C
C ----------------------------------------------------------------
C
C     BUILD THE DS ARRAY.
C
C ----------------------------------------------------------------
C
      DS(9) = PO
C
      PWR = (RHORA/N18)**BETRA
      IF( ABS(PWR) .GE. 174.6) GO TO 21
      DS(1) = EXP( -PWR) * 100.0
```

```
   21 PWR = (RHORS/N18)**BETRS
      IF( ABS(PWR) .GE. 174.6) GO TO 22
      DS(2) = EXP(-PWR) * 100.0
C
   22 PWR = (RHOAA/N18)**BETAA
      IF( ABS(PWR) .GE. 174.6) GO TO 23
      DS(3) = EXP( -PWR) * 100.0
   23 PWR = (RHOAS/N18)**BETAS
      IF( ABS(PWR) .GE. 174.6) GO TO 24
      DS(4) = EXP( -PWR) * 100.0
C
   24 PWR = (RHOTA/MTH)**BETTA
      IF( ABS(PWR) .GE. 174.6) GO TO 25
      DS(5) = EXP( -PWR) * 100.0
   25 PWR = (RHOTS/MTH)**BETTS
      IF( ABS(PWR) .GE. 174.6) GO TO 26
      DS(6) = EXP( -PWR) * 100.0
C
   26 PWR = (RHOLA/MTH)**BETLA
      IF( ABS(PWR) .GE. 174.6) GO TO 27
      DS(7) = EXP( -PWR) * 100.0
   27 PWR = (RHOLS/MTH)**BETLS
      IF( ABS(PWR) .GE. 174.6) GO TO 28
      DS(8) = EXP( -PWR) * 100.0
C
   28 IF( RHOP .LE. 0.0 ) GO TO 30
      PWR = (RHOP/N18)**BETAP
      IF( ABS(PWR) .GE. 174.6) GO TO 30
      DS(9) = PO - (PO - PF) * EXP( -PWR)
   30 CONTINUE
C
C -------------------------------------------------------------------
C
C   THIS SUBROUTINE WAS DERIVED FROM A COMPLETE PAVEMENT DISTRESS
C   PROGRAM DEVELOPED BY TTI. TO MAINTAIN VARIABLE COMPATIBILITY WITH
C   FUTURE REVISIONS OF THESE PAVEMENT DISTRESS PROGRAMS, THE DS ARRAY
C   CORRESPONDS WITH THE DISTRESS ARRAY IN THE ORIGINAL STAND-ALONE
C   PROGRAM "BBMOD". THE FOLLOWING STATEMENTS CONVERT THIS DS ARRAY
C   INTO THE DIS ARRAY OF THE OIL FIELD DAMAGE MAIN LOOP.  NOTE
C   THAT THE VALUES NOT CALCULATED IN THIS SUBROUTINE ARE RETURNED
C   AS ZEROS. (THE DIS ARRAY IS DESCRIBED IN CHAPTER 4 OF TTI
C   RESEARCH REPORT 299-6.)
C
C -------------------------------------------------------------------
C
       DIS(1) = DS(9)
       DIS(2) = DS(1)
       DIS(3) = DS(2)
       DIS(4) = 0.0
       DIS(5) = 0.0
       DIS(6) = 0.0
       DIS(7) = 0.0
       DIS(8) = DS(3)
       DIS(9) = DS(4)
       DIS(10) = DS(7)
       DIS(11) = DS(8)
       DIS(12) = DS(5)
       DIS(13) = DS(6)
       DIS(14) = 0.0
       DIS(15) = 0.0
      RETURN
```

```
      END
C
      SUBROUTINE HMMOD(N18,ADT,MTH,DIS)
C
C  *********************************************************************
C
C     SUBROUTINE HMMOD:  CONTAINS PAVEMENT DISTRESS EQUATIONS FOR
C                        HOT-MIX PAVEMENTS.  THESE EQUATIONS WERE DEVELOPED
C                        FROM REGRESSION ANALYSIS OF INSPECTION DATA
C                        COLLECTED IN SDHPT PROJECT 2284.  TTI RESEARCH
C                        REPORT 299-2 DESCRIBES THE USE AND DERIVATION OF
C                        THESE DISTRESS EQUATIONS.
C
C                 NOTE:  MAXIMUM AND MINIMUM VALUES HAVE BEEN PLACED ON
C                        EACH RHO AND BETA VALUE.
C
C  *********************************************************************
C
      REAL MTH, N18,N18MTH
      DIMENSION DIS(15), RMIN(19), RMAX(19), X(19),DS(10)
      INTEGER PVSTR
      COMMON FLEXL, DMD, PI, LL, AVT50, TI50, FTC,PVSTR,ASPH,BINDER
      DATA RMIN/0.05, 0.5, 0.06, 0.5, 0.1, 0.5, 0.05, 0.5, 58.0,
     & 0.5, 45.0, 0.5, 40.0, 0.5, 30.0, 0.5, 0.04, 0.4, 0.5 /
      DATA RMAX/ 5.1, 8.0, 2.7, 6.6, 3.6, 5.8, 2.5, 8.5, 400.0, 9.0,
     & 230.0, 6.3, 380.0, 10.0, 250.0, 7.4, 10.0, 6.0, 4.0 /
C
      KNT = 0
      PO = 4.2
       AVT = AVT50 + 50.0
       HMAC = ASPH
C
C  ASSIGN VALUES FOR HPR2 AND HPR3 BASED ON PVSTR *********
C
       IF (PVSTR.EQ.1)HPR2=10.
       IF (PVSTR.EQ.1) HPR3 = 3.5
       IF (PVSTR.EQ.2) HPR2 = 20.
       IF (PVSTR.EQ.2) HPR3 = 1.75
       IF (PVSTR.EQ.3) HPR2 = 30.
       IF (PVSTR.EQ.3) HPR3 = 0.50
C
C     RUTTING AREA
C
      X(1) = 0.2776*HMAC + 0.0151*HPR2
      X(2) = 0.0128*TI50 + 0.0326*AVT - 0.0331*AVT - 0.00382*HPR2
C
C     RUTTING SEVERITY
C
      X(3) = -0.0077*PI + 0.386*HMAC
      X(4) = -0.000072*FTC + 0.0273*AVT - 0.00267*HMAC - 0.000418*HPR2
C
C     ALLIGATOR CRACKING AREA
C
      X(5) = 0.372*HMAC
      X(6) = 2.198*HPR3
C
C     ALLIGATOR CRACKING SEVERITY
C
      X(7) = -0.0000749*PI + 0.291*HMAC
      X(8) = 3.145*HPR3
C
```

```
C     LONGITUDINAL CRACKING AREA
C
      X(9) = -0.988*FTC + 4.38*AVT - 2.99*PI + 7.21*HMAC
      X(10) = 0.0422*FTC + 0.359*HPR3
C
C     LONGITUDINAL CRACKING SEVERITY
C
      X(11) = -0.144*TI50 + 3.018*AVT - 3.155*PI + 8.331*HMAC
      X(12) = 0.0343*TI50 + 0.0502*FTC
C
C     TRANSVERSE CRACKING AREA
C
      X(13) = -1.97*TI50 - 0.826*FTC + 5.193*AVT - 1.768*PI - 26.3*HPR3
      X(14) = 0.017*TI50+0.0433*FTC-0.115*HMAC-0.0159*HPR2+0.259*HPR3
C
C     TRANSVERSE CRACKING SEVERITY
C
      X(15) = -0.196*TI50 + 2.9*AVT - 2.69*PI + 5.475*HMAC
      X(16) = 0.0519*FTC + 0.537*HPR3
C
C     RHO, BETA, PF FOR PSI
C
      X(17) = -0.02*1I50 - 0.02481*FTC - 0.03078*PI + 0.6078*BINDER +
     & 0.06424*HPR2
      X(18) = 0.04045*FTC + 0.22931*AVT50 - 0.5301*BINDER
      X(19) = -0.0065*FTC - 0.07017*AVT50 - 0.02472*PI + 0.57235*BINDER
     & + 0.00722*HPR2
C
      DO 12 I = 1, 19
      IF( X(I) .GT. RMAX(I) ) X(I) = RMAX(I)
      IF( X(I) .LT. RMIN(I) ) X(I) = RMIN(I)
   12 CONTINUE
C
      RHORA = X(1)
      BETRA = X(2)
      RHORS = X(3)
      BETRS = X(4)
      RHOAA = X(5)
      BETAA = X(6)
      RHOAS = X(7)
      BETAS = X(8)
      RHOLA = X(9)
      BETLA = X(10)
      RHOLS = X(11)
      BETLS = X(12)
      RHOTA = X(13)
      BETTA = X(14)
      RHOTS = X(15)
      BETTS = X(16)
      RHOP  = X(17)
      BETAP = X(18)
      PF    = X(19)
C
      DO 15 I = 1, 10
   15 DS(I) = 0.0
C
C ---------------------------------------------------------------
C
C     BUILD THE DS ARRAY.
C
C ---------------------------------------------------------------
```

```
C
      DS(9) = PO
C
      PWR = (RHORA/N18)**BETRA
      IF( ABS(PWR) .GE. 174.6) GO TO 21
      DS(1) = EXP( -PWR) * 100.0
   21 PWR = (RHORS/N18)**BETRS
      IF( ABS(PWR) .GE. 174.6) GO TO 22
      DS(2) = EXP(-PWR) * 100.0
C
   22 PWR = (RHOAA/N18)**BETAA
      IF( ABS(PWR) .GE. 174.6) GO TO 23
      DS(3) = EXP( -PWR) * 100.0
   23 PWR = (RHOAS/N18)**BETAS
      IF( ABS(PWR) .GE. 174.6) GO TO 24
      DS(4) = EXP( -PWR) * 100.0
C
   24 PWR = (RHOTA/MTH)**BETTA
      IF( ABS(PWR) .GE. 174.6) GO TO 25
      DS(5) = EXP( -PWR) * 100.0
   25 PWR = (RHOTS/MTH)**BETTS
      IF( ABS(PWR) .GE. 174.6) GO TO 26
      DS(6) = EXP( -PWR) * 100.0
C
   26 PWR = (RHOLA/MTH)**BETLA
      IF( ABS(PWR) .GE. 174.6) GO TO 27
      DS(7) = EXP( -PWR) * 100.0
   27 PWR = (RHOLS/MTH)**BETLS
      IF( ABS(PWR) .GE. 174.6) GO TO 28
      DS(8) = EXP( -PWR) * 100.0
C
   28 IF( RHOP .LE. 0.0 ) GO TO 30
      PWR = (RHOP/N18)**BETAP
      IF( ABS(PWR) .GE. 174.6) GO TO 30
      DS(9) = PO - (PO - PF) * EXP( -PWR)
   30 CONTINUE
C
C -----------------------------------------------------------------
C
C    THIS SUBROUTINE WAS DERIVED FROM A COMPLETE PAVEMENT DISTRESS
C    PROGRAM DEVELOPED BY TTI. TO MAINTAIN VARIABLE COMPATIBILITY WITH
C    FUTURE REVISIONS OF THESE PAVEMENT DISTRESS PROGRAMS, THE DS ARRAY
C    CORRESPONDS WITH THE DISTRESS ARRAY IN THE ORIGINAL STAND-ALONE
C    PROGRAM "HMMOD". THE FOLLOWING STATEMENTS CONVERT THIS DS ARRAY
C    INTO THE DIS ARRAY OF THE OIL FIELD DAMAGE MAIN LOOP.  NOTE
C    THAT THE VALUES NOT CALCULATED IN THIS SUBROUTINE ARE RETURNED
C    AS ZEROS. (THE DIS ARRAY IS DESCRIBED IN CHAPTER 4 OF TTI
C    RESEARCH REPORT 299-6.)
C
C -----------------------------------------------------------------
C
       DIS(1) = DS(9)
       DIS(2) = DS(1)
       DIS(3) = DS(2)
       DIS(4) = 0.0
       DIS(5) = 0.0
       DIS(6) = 0.0
       DIS(7) = 0.0
       DIS(8) = DS(3)
       DIS(9) = DS(4)
       DIS(10) = DS(7)
```

```
        DIS(11) = DS(8)
        DIS(12) = DS(5)
        DIS(13) = DS(6)
        DIS(14) = 0.0
        DIS(15) = 0.0
       RETURN
       END
C
       SUBROUTINE OVMOD(N18,ADT,MTH,DIS)
C
C  *********************************************************************
C
C      SUBROUTINE OVMOD:   CONTAINS PAVEMENT DISTRESS EQUATIONS FOR
C                          OVERLAY PAVEMENTS.  THESE EQUATIONS WERE DEVELOPED
C                          FROM REGRESSION ANALYSIS OF INSPECTION DATA
C                          COLLECTED IN SDHPT PROJECT 2284.  TTI RESEARCH
C                          REPORT 299-2 DESCRIBES THE USE AND DERIVATION OF
C                          THESE DISTRESS EQUATIONS.
C
C                   NOTE:  MAXIMUM AND MINIMUM VALUES HAVE BEEN PLACED ON
C                          EACH RHO AND BETA VALUE.
C
C  *********************************************************************
C
       REAL MTH, N18,N18MTH
       DIMENSION DIS(15), RMIN(19), RMAX(19), X(19),DS(10)
       INTEGER PVSTR
       COMMON FLEXL, DMD, PI, LL, AVT50, TI50, FTC,PVSTR,ASPH,BINDER
       DATA RMIN/0.02, 0.5, 0.02, 0.5, 0.02, 0.58, 0.02, 0.44, 18.7,
      & 0.5, 24.0, 0.5, 18.7, 0.5, 24.0, 0.5, 0.04, 0.4, 0.5 /
       DATA RMAX/ 5.6, 3.48, 8.66, 6.1, 13.9, 4.49, 5.37, 6.28, 400.0,
      & 7.0, 350.0, 5.3, 400.0, 9.0, 194.8, 5.25, 10.0, 6.0, 4.0 /
C
       KNT = 0
       PO = 4.2
C
        AVT = AVT50 + 50.0
        OVTH = ASPH
C
C  ASSIGN VALUES FOR HPR2 AND HPR3 BASED ON PVSTR *********
C
        IF (PVSTR.EQ.1)HPR2=5.
        IF (PVSTR.EQ.1) HPR3 = 10.0
        IF (PVSTR.EQ.2) HPR2 = 20.
        IF (PVSTR.EQ.2) HPR3 = 5.0
        IF (PVSTR.EQ.3) HPR2 = 40.
        IF (PVSTR.EQ.3) HPR3 = 0.25
C
C      RUTTING AREA
C
       X(1) = 1.71
       X(2) = 14.6 - 0.146*OVTH + 0.0842*HPR3 - 0.033*FTC - 0.184*AVT
C
C      RUTTING SEVERITY
C
       X(3) = 1.69
       X(4) = 1.42
C
C      ALLIGATOR CRACKING AREA
C
       X(5) = -2.5 + 0.192*HPR2 + 0.0322*TI50
```

```
      X(6) = 1.629 + 0.132*HPR3 - 0.00797*FTC - 0.0111*PI
C
C     ALLIGATOR CRACKING SEVERITY
C
      X(7) = 1.09
      X(8) = 1.78 + 0.201*HPR3 - 0.0164*PI
C
C     LONGITUDINAL CRACKING AREA
C
      X(9) = 73.0 + 19.5*OVTH + 22.8*HPR3 + 1.12*TI50 - 1.08*FTC
      X(10) = 0.231 + 0.241*HPR3 + 0.0204*TI50
C
C     LONGITUDINAL CRACKING SEVERITY
C
      X(11) = 72.8 + 8.34*HPR3 + 0.505*TI50 - 0.407*FTC
      X(12) = 1.38
C
C     TRANSVERSE CRACKING AREA
C
      X(13) = 9.06 + 39.7*OVTH + 2.98*PI
      X(14) = 0.405 + 0.439*HPR3
C
C     TRANSVERSE CRACKING SEVERITY
C
      X(15) = 70.8 + 7.7*OVTH + 5.73*HPR3 - 0.28*FTC
      X(16) = 4.25
C
C     RHO, BETA, PF FOR PSI
C
      X(17) = 0.26503*OVTH + 0.0718*HPR2
      X(18) = 1.0
      X(19) = 0.33037*OVTH + 0.07627*HPR2
C
      DO 12 I = 1, 19
      IF( X(I) .GT. RMAX(I) ) X(I) = RMAX(I)
      IF( X(I) .LT. RMIN(I) ) X(I) = RMIN(I)
   12 CONTINUE
C
      RHORA = X(1)
      BETRA = X(2)
      RHORS = X(3)
      BETRS = X(4)
      RHOAA = X(5)
      BETAA = X(6)
      RHOAS = X(7)
      BETAS = X(8)
      RHOLA = X(9)
      BETLA = X(10)
      RHOLS = X(11)
      BETLS = X(12)
      RHOTA = X(13)
      BETTA = X(14)
      RHOTS = X(15)
      BETTS = X(16)
      RHOP  = X(17)
      BETAP = X(18)
      PF    = X(19)
C
      DO 15 I = 1, 10
   15 DS(I) = 0.0
C
```

```
C --------------------------------------------------------------------
C
C     BUILD THE DS ARRAY.
C
C --------------------------------------------------------------------
C
      DS(9) = PO
C
      PWR = (RHORA/N18)**BETRA
      IF( ABS(PWR) .GE. 174.6) GO TO 21
      DS(1) = EXP( -PWR) * 100.0
   21 PWR = (RHORS/N18)**BETRS
      IF(-ABS(PWR) .GE. 174.6) GO TO 22
      DS(2) = EXP(-PWR) * 100.0
C
   22 PWR = (RHOAA/N18)**BETAA
      IF( ABS(PWR) .GE. 174.6) GO TO 23
      DS(3) = EXP( -PWR) * 100.0
   23 PWR = (RHOAS/N18)**BETAS
      IF( ABS(PWR) .GE. 174.6) GO TO 24
      DS(4) = EXP( -PWR) * 100.0
C
   24 PWR = (RHOTA/MTH)**BETTA
      IF( ABS(PWR) .GE. 174.6) GO TO 25
      DS(5) = EXP( -PWR) * 100.0
   25 PWR = (RHOTS/MTH)**BETTS
      IF( ABS(PWR) .GE. 174.6) GO TO 26
      DS(6) = EXP( -PWR) * 100.0
C
   26 PWR = (RHOLA/MTH)**BETLA
      IF( ABS(PWR) .GE. 174.6) GO TO 27
      DS(7) = EXP( -PWR) * 100.0
   27 PWR = (RHOLS/MTH)**BETLS
      IF( ABS(PWR) .GE. 174.6) GO TO 28
      DS(8) = EXP( -PWR) * 100.0
C
   28 IF( RHOP .LE. 0.0 ) GO TO 30
      BETAP = 0.00413*TI50 + 0.01036*FTC + 0.04769*AVT50 + 0.01707*
     &  N18 - 0.09144*OVTH - 0.01066*HPR2
      PWR = (RHOP/N18)**BETAP
      IF( ABS(PWR) .GE. 174.6) GO TO 30
      DS(9) = PO - (PO - PF) * EXP( -PWR)
   30 CONTINUE
C
C --------------------------------------------------------------------
C
C   THIS SUBROUTINE WAS DERIVED FROM A COMPLETE PAVEMENT DISTRESS
C   PROGRAM DEVELOPED BY TTI. TO MAINTAIN VARIABLE COMPATIBILITY WITH
C   FUTURE REVISIONS OF THESE PAVEMENT DISTRESS PROGRAMS, THE DS ARRAY
C   CORRESPONDS WITH THE DISTRESS ARRAY IN THE ORIGINAL STAND-ALONE
C   PROGRAM "OVMOD". THE FOLLOWING STATEMENTS CONVERT THIS DS ARRAY
C   INTO THE DIS ARRAY OF THF OIL FIELD DAMAGE MAIN LOOP.  NOTE
C   THAT THE VALUES NOT CALCULATED IN THIS SUBROUTINE ARE RETURNED
C   AS ZEROS. (THE DIS ARRAY IS DESCRIBED IN CHAPTER 4 OF TTI
C   RESEARCH REPORT 299-6.)
C
C --------------------------------------------------------------------
C
       DIS(1) = DS(9)
       DIS(2) = DS(1)
       DIS(3) = DS(2)
```

```
       DIS(4) = 0.0
       DIS(5) = 0.0
       DIS(6) = 0.0
       DIS(7) = 0.0
       DIS(8) = DS(3)
       DIS(9) = DS(4)
       DIS(10) = DS(7)
       DIS(11) = DS(8)
       DIS(12) = DS(5)
       DIS(13) = DS(6)
       DIS(14) = 0.0
       DIS(15) = 0.0
      RETURN
      END
C
      SUBROUTINE SETTAB ( N18, ADT, GROWTH, TRAF)
C
C   ********************************************************************
C
C     SUBROUTINE SETTAB:  LOADS RESULTS OF SUBROUTINE "TRAFIC" INTO A
C                         240 X 4 ARRAY.  THIS ARRAY CONTAINS THE TOTAL
C                         NUMBER OF VEHICLES AND 18-K ESAL REPETITIONS
C                         WHICH HAVE PASSED OVER THE PAVEMENT SINCE
C                         RECONSTRUCTION.  THE ARRAY STRUCTURE IS . . .
C
C              COLUMN 1 - ADT (BASELINE).
C              COLUMN 2 - ADT (BASELINE + OIL FIELD).
C              COLUMN 3 - 18-K ESAL (BASELINE).
C              COLUMN 4 - 18-K ESAL (BASELINE + OIL FIELD).
C
C                         . . . FOR EACH ONE OF 240 MONTHS.
C
C                  NOTE:  BASELINE VALUES ARE COMPUTED BY "TRAFIC".
C                         OIL FIELD VALUES ARE ADDED LATER BY "ADDOIL".
C
C   ********************************************************************
C
      DIMENSION TRAF(240,4)
      REAL N18
      X1  = ADT * 30.
      X3  = N18
      TRAF(1,1) = X1
      TRAF(1,2) = X1
      TRAF(1,3) = X3
      TRAF(1,4) = X3
      DO 50 I = 2, 240
      K = I - 1
      X1 = X1 * ( 1.0 + GROWTH/(12.0 * 100.0) )
      X3 = X3 * ( 1.0 + GROWTH/(12.0 * 100.0) )
      TRAF(I,1)  = TRAF(K,1) + X1
      TRAF(I,2)  = TRAF(I,1)
      TRAF(I,3)  = TRAF(K,3) + X3
      TRAF(I,4)  = TRAF(I,3)
   50 CONTINUE
      RETURN
      END
C
      SUBROUTINE ADDOIL ( IDATE, NWELLS, N18OIL, ADTOIL, N18SER,
     1                    ADTSER, TRAF, DECAY, DTIME, PRDPCT )
C
C   ********************************************************************
```

```
C
C     SUBROUTINE ADDOIL:  ADDS DRILLING AND PRODUCTION VALUES (ADT AND
C                         18-K) TO THE TRAF ARRAY BUILT BY SUBROUTINE
C                         "SETTAB".  ADT VALUES GO INTO COLUMN 2 AND
C                         18-K VALUES GO INTO COLUMN 4.
C
C  ********************************************************************
C
      DIMENSION TRAF(240,4), ASER(240), BSER(240)
      REAL N18OIL, N18SER
      X1  = ADTOIL * 30.0
      X2  = ADTSER * 30.0
      X3  = N18OIL
      X4  = N18SER
C
C ---------------------------------------------------------------------
C
C     DRILL TIME VALUES ARE ROUNDED TO THE NEAREST INTEGER VALUE.
C          THE MAXIMUM DTIME IS 6 MONTHS.  FOR EXAMPLE,
C
C               DTIME = 1.49  BECOMES DTIME = 1
C               DTIME = 1.5   BECOMES DTIME = 2
C               DTIME = 6.4   BECOMES DTIME = 6
C           AND DTIME = 6.5   BECOMES DTIME = 6
C ---------------------------------------------------------------------
C
      DO 10  I = IDATE, 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   10 CONTINUE
C
C     ADD ON SECOND MONTHS'S OIL DEVELOPMENT TRAFFIC
C
      IF (DTIME.LT.1.5) GOTO 23
C
      L = IDATE + 1
      DO 12 I = L , 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   12 CONTINUE
C
C     ADD ON THIRD MONTHS'S OIL DEVELOPMENT TRAFFIC
C
      IF (DTIME.LT.2.5) GOTO 23
C
      L = IDATE + 2
      DO 16 I = L , 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   16 CONTINUE
C
C     ADD ON FOURTH MONTHS'S OIL DEVELOPMENT TRAFFIC
C
      IF (DTIME.LT.3.5) GOTO 23
C
      L = IDATE + 3
      DO 20 I = L , 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   20 CONTINUE
C
```

```
C     ADD ON FIFTH MONTHS'S OIL DEVELOPMENT TRAFFIC
C
      IF (DTIME.LT.4.5) GOTO 23
C
      L = IDATE + 4
      DO 21 I = L , 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   21 CONTINUE
C
C     ADD ON SIXTH MONTHS'S OIL DEVELOPMENT TRAFFIC
C
      IF (DTIME.LT.5.5) GOTO 23
C
      L = IDATE + 5
      DO 22 I = L , 240
      TRAF(I,2) = TRAF(I,2) + NWELLS*X1
      TRAF(I,4) = TRAF(I,4) + NWELLS*X3
   22 CONTINUE
C
   23 CONTINUE
C
C ------------------------------------------------------------------
C
C     THE PROGRAM ASSUMES THAT PRODUCTION AT THE WELL SITE WILL DECLINE
C     OVER TIME.  PRODUCTION TRAFFIC HERE FOLLOWS A STEPWISE DECLINE, WITH
C     12 MONTHS OF CONSTANT TRUCK TRAFFIC, A DROP OF MAGNITUDE "DECAY"
C     PERCENT, THEN 12 MONTHS OF CONSTANT TRUCK TRAFFIC, FOLLOWED BY ANOTHER
C     "DECAY" PERCENT DROP.
C
C     ANOTHER ASSUMPTION IS THAT SOME WELLS DO NOT PRODUCE OIL OR GAS.  THE
C     USER-INPUT VARIABLE "PRDPCT" CONVERTS THE NUMBER OF DRILL SITES INTO
C     THE NUMBER OF PRODUCING SITES.  THE VARIABILITY PARAMETER "COMPLETION
C     SUCCESS RATE" FROM TTI RESEARCH REPORT 299-4 MAY BE USED HERE -- BUT
C     ONLY IF ALL PRODUCING WELLS GENERATE TRUCK TRAFFIC.  GAS WELLS, AS
C     MENTIONED IN REPORT 299-4, USUALLY DO NOT GENERATE PRODUCTION TRUCK
C     TRAFFIC.
C
C ------------------------------------------------------------------
C
C     OIL FIELD TRAFFIC DECAYS PRDPCT PERCENT PER YEAR:
C
      L = IDATE + INT(DTIME + 0.5)
      LEFT = 240 - L + 1
      DO 30  I = 1, LEFT
      ASER(I) = X2 * NWELLS * (PRDPCT/100)
      BSER(I) = X4 * NWELLS * (PRDPCT/100)
      IF ( MOD(I,12) .NE. 0 ) GOTO 25
      X2 = X2 * (DECAY/100)
      X4 = X4 * (DECAY/100)
   25 CONTINUE
   30 CONTINUE
C
      DO 35 J = 2, LEFT
      ASER(J) = ASER(J-1) + ASER(J)
   35 BSER(J) = BSER(J-1) + BSER(J)
C
      DO 40 I = L, 240
      K = I - L + 1
      TRAF(I,2) = TRAF(I,2) + ASER(K)
      TRAF(I,4) = TRAF(I,4) + BSER(K)
```

```
   40 CONTINUE
C
      RETURN
      END
C
      SUBROUTINE CONVER ( MON, NYR, TRAF, TR)
C
C    **********************************************************************
C
C     SUBROUTINE CONVER:  ACCESSES TRAF ARRAY FROM SUBROUTINES "TRAFIC" AND
C                         "ADDOIL", THEN EXTRACTS VALUES ONLY FOR THOSE
C                         MONTHS WHICH THE USER REQUESTED IN THE MON(I)
C                         LIST IN FILE02.  "CONVER" SUPPLIES MOST OF
C                         THE VALUES FOR THE PAVEMENT DISTRESS TABLES
C                         AT THE END OF EACH PROGRAM RUN. IT LOADS THE
C                         TR ARRAY.
C
C    **********************************************************************
C
      DIMENSION  MON(15), TRAF(240, 4), TR(15, 4)
      DO 10 I = 1, NYR
      TR(I,1) = TRAF(MON(I),1)
      TR(I,2) = TRAF(MON(I),2)
      TR(I,3) = TRAF(MON(I),3)
      TR(I,4) = TRAF(MON(I),4)
   10 CONTINUE
      RETURN
      END
C
      SUBROUTINE TRAFIC ( ADT, PCTTRK, PCTLNE, N18 )
C
C *******************************************************************
C
C     SUBROUTINE TRAFIC: CONVERTS BASELINE TRAFFIC INTO 18-K ESAL
C                        REPETITIONS PER MONTH USING THE SDHPT W-4
C                        TABLES. THIS PROCESS IS DESCRIBED IN TTI
C                        RESEARCH REPORT 299-1.
C
C     THE NUMBERS IN THE FOLLOWING ARRAYS ARE TAKEN FROM THE
C     SDHPT W-4 TABLES.
C
C     PERCNT - CONTAINS THE PERCENTAGE OF EACH TRUCK TYPE IN
C              THE BASELINE TRAFFIC STREAM.
C     SINGLE - CONTAINS THE NUMBER OF SINGLE AXLES BY TRUCK TYPE.
C     TANDEM - CONTAINS THE NUMBER OF TANDEM AXLES BY TRUCK TYPE.
C     DISTSN - CONTAINS THE SINGLE AXLE LOAD DISTRIBUTIONS AS
C              MEASURED AT WEIGHING STATIONS FOR EACH TRUCK TYPE.
C     DISTAN - CONTAINS THE TANDEM AXLE LOAD DISTRIBUTION FOR
C              EACH TRUCK TYPE.
C     ESING  - CONTAINS EQUIVALENCY FACTORS FOR SINGLE WHEEL LOADS.
C     ETAND  - CONTAINS EQUIVALENCY FACTORS FOR TANDEM WHEEL LOADS.
C
C *******************************************************************
C
      REAL N18, NSING, NTAND, NSINGL, NTANDM,N18SIN, N18TAN, NTRUKS
C
      DIMENSION DISTSN(10,13), DISTAN(10,16), ESING(13), ETAND(16),
     + NSING(13), NTAND(16), NSINGL(10), NTANDM(10), PERCNT(10),
     * SINGLE(10), TANDEM(10), TTYPE(10)
C
      DATA DISTSN / 6.0,9*0.0,64.0,20.0,13.0,9.0,2.0,8.0,0.0,3*22.0,
```

```
     + 9.0,6.0,10.0,8.0,7.0,5.0,0.0,3*22.0,11.0,61.0,36.0,46.0,88.0,
     * 31.0,44.0,3*34.0,4.0,12.0,23.0,14.0,3.0,25.0,34.0,3*22.0,3.0,
     & 1.0,12.0,8.0,0.0,12.0,16.0,3*0.0,1.0,2*0.0,2.0,0.0,3.0,4*0.0,
     ) 1.0,0.0,2.0,6.0,0.0,8.0,6.0,3*0.0,1.0,0.0,2.0,3.0,0.0,5.0,4*0.0,
     ( 2*0.0,2.0,4.0,0.0,2.0,4*0.0,5*0.0,1.0,4*0.0,10*0.0,10*0.0 /
C
      DATA DISTAN / 10*0.0,0.0,18.0,0.0,16.0,12.0,0.0,25.0,3*0.0,0.0,
     + 21.0,0.0,35.0,16.0,0.0,50.0,0.0,33.0,33.0,0.0,15.0,0.0,30.0,
     = 13.,0.,25.,3*0.,0.,12.,0.,13.,19.,0.,0.,0.,67.,67.,0.,5.,0.,
     * 1.,10.,5*0.,0.,3.,0.,1.,3.,5*0.,0.,1.,0.,3.,7.,5*0.,0.,10.,
     & 0.,0.,9.,5*0.,0.,5.,0.,0.,5.,5*0.,0.,3.,0.,0.,3.,5*0.,0.,2.,
     ) 0.,1.,2.,5*0.,0.,2.,0.,0.,1.,5*0.,0.,2.,8*0.,0.,1.,8*0.,10*0./
C
      DATA ESING / 0.0,0.005,0.025,0.07,0.32,0.795,1.0,1.285,1.98,
     + 2.67,3.71,6.085,0.0 /
C
      DATA ETAND / 0.0,0.003,0.03,0.11,0.36,0.67,0.76,0.87,1.14,1.47,
     + 1.875,2.435,3.12,3.86,5.13,0.0 /
C
      DATA SINGLE / 2.0,1.0,3.0,2.0,1.0,5.0,2.0,3.0,2.0,1.0 /
      DATA TANDEM /0.0,1.0,0.0,1.0,2.0,0.0,2.0,0.0,1.0,2.0 /
C
      DATA PERCNT / 14.0,4.0,1.0,5.0,68.0,2.0,0.0,3*2.0 /
C
      NTYP = 10
C
C -----------------------------------------------------------------
C
C     CONVERT TWO-WAY BASELINE ADT TO ONE-WAY.
C     COMPUTE ANNUAL NUMBER OF TRUCKS IN BASELINE TRAFFIC.
C
C -----------------------------------------------------------------
C
      ADT = ADT * (PCTLNE/100.0)
      NTRUKS = ADT * 365.0 * (PCTTRK/100.0)
C
      DO 10 I = 1, NTYP
      TTYPE(I) = PERCNT(I) * NTRUKS * 0.01
      NSINGL(I) = TTYPE(I) * SINGLE(I)
      NTANDM(I) = TTYPE(I) * TANDEM(I)
   10 CONTINUE
C
      DO 14 J = 1, 13
   14 NSING(J) = 0.0
C
      DO 15 J = 1, 16
   15 NTAND(J) = 0.0
C
      DO 30 K = 1, 10
      DO 20 J = 1, 13
   20 NSING(J) = NSING(J) + NSINGL(K)*DISTSN(K,J)/100.0
   30 CONTINUE
C
      DO 50 K = 1, 10
      DO 40 J = 1, 16
   40 NTAND(J) = NTAND(J) + NTANDM(K)*DISTAN(K,J)/100.0
   50 CONTINUE
C
      N18SIN = 0.0
C
      DO 60 J = 1, 13
```

```
   60 N18SIN = N18SIN + NSING(J) * ESING(J)
C
      N18TAN = 0.0
      DO 70 J = 1, 16
   70 N18TAN = N18TAN + NTAND(J) * ETAND(J)
C
      N18 = N18SIN + N18TAN
C
C -------------------------------------------------------------------
C
C     PASSENGER CARS ARE NOT USED TO COMPUTE 18-K ESAL REPETITIONS.
C     ANNUAL NUMBER OF ONE-WAY TRUCKS IS DIVIDED BY 12 MONTHS.
C
C -------------------------------------------------------------------
C
      N18 = N18 / 12.0
      RETURN
      END
C
      SUBROUTINE OILDEV ( N18OIL, ADTOIL,DTIME )
C
C *******************************************************************
C
C     SUBROUTINE OILDEV:  COMPUTES 18-K ESAL REPETITIONS (N18OIL) AND
C                         ADT (ADTOIL) PER MONTH DUE TO OIL AND GAS
C                         WELL DRILLING.
C
C                 TTYPE - CONTAINS THE NUMBER OF EACH TRUCK TYPE USED
C                         DURING OIL AND GAS WELL DRILLING,  OBSERVED
C                         DURING PHOTOGRAPHIC MONITORING OF THREE OIL
C                         WELL SITES IN BRAZOS COUNTY OVER A 60-DAY OIL
C                         WELL DEVELOPMENT PERIOD.
C
C                    AASHTO TRUCK TYPE         NUMBER OBSERVED
C                    ----------------------------------------
C                         SU-1                        300
C                         SU-2                        150
C                         2-S1                         45
C                         2-S2                          0
C                         3-S2 AND GREATER            655
C                         2-S1-2                        0
C                         3-S1-2                        0
C                         2-1                          90
C                         2-2                           0
C                         3-2 AND GREATER             125
C                    ----------------------------------------
C                     NUMBER OF TRUCKS OBSERVED = 1365  (2 MONTH PERIOD).
C
C     THE SUBROUTINE USES STATEMENTS FROM THE SDHPT W-4 TABLES TO COMPUTE
C     18-K ESAL REPETITIONS ASSOCIATED WITH THE TTYPE DISTRIBUTION. DATA
C     STATEMENTS ARE AS DESCRIBED IN SUBROUTINE "TRAFIC".
C
C *******************************************************************
C
      REAL N18, NSING, NTAND, NSINGL, NTANDM,N18SIN, N18TAN
      REAL N18OIL
C
      DIMENSION DISTSN(10,13), DISTAN(10,16), ESING(13), ETAND(16),
     + NSING(13), NTAND(16), NSINGL(10), NTANDM(10),
     * SINGLE(10), TANDEM(10), TTYPE(10)
C
```

```
      DATA DISTSN / 6.0,9*0.0,64.0,20.0,13.0,9.0,2.0,8.0,0.0,3*22.0,
     + 9.0,6.0,10.0,8.0,7.0,5.0,0.0,3*22.0,11.0,61.0,36.0,46.0,88.0,
     * 31.0,44.0,3*34.0,4.0,12.0,23.0,14.0,3.0,25.0,34.0,3*22.0,3.0,
     & 1.0,12.0,8.0,0.0,12.0,16.0,3*0.0,1.0,2*0.0,2.0,0.0,3.0,4*0.0,
     ) 1.0,0.0,2.0,6.0,0.0,8.0,6.0,3*0.0,1.0,0.0,2.0,3.0,0.0,5.0,4*0.0,
     ( 2*0.0,2.0,4.0,0.0,2.0,4*0.0,5*0.0,1.0,4*0.0,10*0.0,10*0.0 /
C
      DATA DISTAN / 10*0.0,0.0,18.0,0.0,16.0,12.0,0.0,25.0,3*0.0,0.0,
     + 21.0,0.0,35.0,16.0,0.0,50.0,0.0,33.0,33.0,0.0,15.0,0.0,30.0,
     = 13.,0.,25.,3*0.,0.,12.,0.,13.,19.,0.,0.,0.,67.,67.,0.,5.,0.,
     * 1.,10.,5*0.,0.,3.,0.,1.,3.,5*0.,0.,1.,0.,3.,7.,5*0.,0.,10.,
     & 0.,0.,9.,5*0.,0.,5.,0.,0.,5.,5*0.,0.,3.,0.,0.,3.,5*0.,0.,2.,
     ) 0.,1.,2.,5*0.,0.,2.,0.,0.,1.,5*0.,0.,2.,8*0.,0.,1.,8*0.,10*0./
C
      DATA ESING / 0.0,0.005,0.025,0.07,0.32,0.795,1.0,1.285,1.98,
     + 2.67,3.71,6.085,0.0 /
C
      DATA ETAND / 0.0,0.003,0.03,0.11,0.36,0.67,0.76,0.87,1.14,1.47,
     + 1.875,2.435,3.12,3.86,5.13,0.0 /
C
      DATA SINGLE / 2.0,1.0,3.0,2.0,1.0,5.0,2.0,3.0,2.0,1.0 /
      DATA TANDEM /0.0,1.0,0.0,1.0,2.0,0.0,2.0,0.0,1.0,2.0 /
C
      DATA TTYPE / 300.0,150.0,45.0,0.0,655.0,0.0,0.0,90.0,0.0,
     + 125.0 /
C
C ------------------------------------------------------------------
C
C     ADTOIL FROM OIL DRILLING = 50% OF 2-WAY TRAFFIC.
C
C     VARIABLE "PCT" CONVERTS TWO-WAY ADT INTO ONE-WAY ADT, ASSUMING
C     THAT WHATEVER ENTERS THE WELL SITE MUST LATER EXIT THE
C     WELL SITE (PCT = 0.50).  DRILLING ADT = 150 IS AN AVERAGE
C     VALUE, TAKEN FROM FILM RECORDS.  "PCT" LATER CONVERTS
C     TWO-WAY 18-K ESAL INTO ONE-WAY.
C
C ------------------------------------------------------------------
C
      PCT = 50.0/100.0
C
      NTYP = 10
      ADTOIL = 150.0 * PCT
C
      DO 10 I = 1, NTYP
      NSINGL(I) = TTYPE(I) * SINGLE(I)
      NTANDM(I) = TTYPE(I) * TANDEM(I)
   10 CONTINUE
C
      DO 14 J = 1, 13
   14 NSING(J) = 0.0
C
      DO 15 J = 1, 16
   15 NTAND(J) = 0.0
C
      DO 30 K = 1, 10
      DO 20 J = 1, 13
   20 NSING(J) = NSING(J) + NSINGL(K)*DISTSN(K,J)/100.0
   30 CONTINUE
C
      DO 50 K = 1, 10
      DO 40 J = 1, 16
```

```
   40 NTAND(J) = NTAND(J) + NTANDM(K)*DISTAN(K,J)/100.0
   50 CONTINUE
C
      N18SIN = 0.0
C
      DO 60 J = 1, 13
   60 N18SIN = N18SIN + NSING(J) * ESING(J)
C
      N18TAN = 0.0
      DO 70 J = 1, 16
   70 N18TAN = N18TAN + NTAND(J) * ETAND(J)
C
      N18 = N18SIN + N18TAN
C
      N18OIL = N18 * PCT
C
C ------------------------------------------------------------------
C
C     THE ORIGINAL STUDY COVERED 2 MONTHS; THUS DIVIDE N18OIL BY 2.
C
C     TOTAL 18-K ESAL FROM THE TTYPE DRILLING TRAFFIC IS CONVERTED
C     FROM TWO-MONTH INTO ONE-MONTH FOR USE BY SUBROUTINE "ADDOIL"
C     WITH DTIMES OF ANY LENGTH.
C
C ------------------------------------------------------------------
C
      N18OIL = N18OIL / 2
C
      RETURN
      END
C
      SUBROUTINE OILSER ( N18SER, ADTSER )
C
C ******************************************************************
C
C     SUBROUTINE OILSER:  COMPUTES 18-K ESAL REPETITIONS AND ADT PER
C                         MONTH DUE TO OIL WELL PRODUCTION.
C
C               SDISTR - DISTRIBUTION OF SINGLE-AXLE TRUCKS.
C               TDISTR - DISTRIBUTION OF TANDEM-AXLE TRUCKS.
C                ESING - FROM SUBROUTINE "TRAFIC" (SDHPT W-4 TABLES).
C                ETAND - FROM SUBROUTINE "TRAFIC" (SDHPT W-4 TABLES).
C
C ******************************************************************
C
      REAL N18, NSING, NTAND, N18SIN, N18TAN
      REAL N18SER
C
      DIMENSION SDISTR(13), TDISTR(16), ESING(13), ETAND(16),
     + NSING(13), NTAND(16)
C
      DATA SDISTR / 0.0, 0.5, 0.0, 0.5, 9*0.0 /
C
      DATA TDISTR / 0.0, 1.0, 5*0.0, 1.0, 8*0.0 /
C
      DATA ESING / 0.0,0.005,0.025,0.07,0.32,0.795,1.0,1.285,1.98,
     + 2.67,3.71,6.085,0.0 /
C
      DATA ETAND / 0.0,0.003,0.03,0.11,0.36,0.67,0.76,0.87,1.14,1.47,
     + 1.875,2.435,3.12,3.86,5.13,0.0 /
C
```

```
C ------------------------------------------------------------------
C
C     ADTSER & N18SER FROM OIL PRODUCTION = 50% OF 2-WAY TRAFFIC.
C
C     PRODUCTION TRAFFIC = 50 PASSENGER CARS (ADTSER = 50) AND
C                          150 3-S2 TRUCKS (SRVICE = 150).
C
C                          TWO-WAY MONTHLY PASSENGER CAR ADT IS CONVERTED
C                          INTO ONE-WAY ADT ON THE ASSUMPTION THAT WHAT ENTERS
C                          THE PRODUCTION SITE MUST LATER EXIT.  (PCT = 0.5).
C
C                          TWO-WAY MONTHLY TRUCK TRAFFIC (SRVICE = 150) IS
C                          USED TO COMPUTE PRODUCTION 18-K ESAL REPETITIONS,
C                          THEN CONVERTED TO ONE-WAY 18-K VALUE.
C
C ------------------------------------------------------------------
C
      PCT = 50.0/100.0
C
      ADTSER = 50.0 * PCT
      SRVICE = 150.0
C
      DO 14 J = 1, 13
   14 NSING(J) = 0.0
C
      DO 15 J = 1, 16
   15 NTAND(J) = 0.0
C
      DO 20 J = 1, 13
   20 NSING(J) = SRVICE * SDISTR(J)
C
      DO 40 J = 1, 16
   40 NTAND(J) = SRVICE * TDISTR(J)
C
      N18SIN = 0.0
C
      DO 60 J = 1, 13
   60 N18SIN = N18SIN + NSING(J) * ESING(J)
C
      N18TAN = 0.0
      DO 70 J = 1, 16
   70 N18TAN = N18TAN + NTAND(J) * ETAND(J)
C
      N18 = N18SIN + N18TAN
C
      N18SER = N18 * PCT
C
      RETURN
      END
C
      SUBROUTINE  FINDA1 ( ADT, AKIP, A1 )
C
C ******************************************************************
C
C     SUBROUTINE FINDA1: APPLIES TRAFFIC ADJUSTMENT FACTORS
C                        FOR USE IN COMPUTING PAVEMENT SCORE.
C
C ******************************************************************
C
      DIMENSION   AUPL(6), EUPL(3)
      DIMENSION   ADTF(6), EALF(3)
```

```
      DATA AUPL   /0.0, 300.0, 750.0, 2000.0, 75000.0, 250000.0/
      DATA ADTF   /1.00, 0.96, 0.92, 0.88, 0.84, 0.80/
      DATA EUPL   /0.0, 6.0, 12.0/
      DATA EALF   /1.00, 0.95, 0.90/
      DO 2100 K = 1, 5
      IF ( ADT .LT. AUPL(K+1) ) GO TO 2200
 2100 CONTINUE
      K          = 6
 2200 Z1         = ADTF(K)
      DO 2300 K = 1, 2
      IF ( AKIP .LT. EUPL(K+1) ) GO TO 2400
 2300 CONTINUE
      K          = 3
 2400 Z2         = EALF(K)
      A1         = 1.00 / ( Z1 * Z2 )
      RETURN
      END
C
      SUBROUTINE FINDRF ( RFAL, FTC, V )
C
C ******************************************************************
C
C     SUBROUTINE FINDRF: APPLIES WEATHER ADJUSTMENT FACTORS
C                        FOR USE IN COMPUTING PAVEMENT SCORE.
C
C ******************************************************************
C
      DIMENSION   V(8), RUPL(2), FUPL(3), RFFR(2), FTFR(3)
      DATA RUPL   /20.0, 40.0/
      DATA RFFR   /0.97, 0.94/
      DATA FUPL   /10.0, 30.0, 50.0/
      DATA FTFR   /0.973, 0.967, 0.960/
      RF         = 1.0
      IF ( RFAL .LE. RUPL(1) ) GO TO 1200
      RF         = RFFR(2)
      IF ( RFAL .GT. RUPL(2) ) GO TO 1200
      RF         = RFFR(1)
 1200 CONTINUE
      FF         = 1.00
      IF ( FTC .LE. FUPL(1) ) GO TO 1500
      FF         = FTFR(3)
      IF ( FTC .GT. FUPL(3) ) GO TO 1500
      FF         = FTFR(2)
      IF ( FTC .GT. FUPL(2) ) GO TO 1500
      FF         = FTFR(1)
 1500 CONTINUE
      V(1)       = 1.00 / RF
      V(2)       = V(1)
      V(3)       = 1.0
      V(4)       = V(1)
      V(5)       = V(1) / FF
      V(6)       = V(5)
      V(7)       = V(5)
      V(8)       = V(5)
      RETURN
      END
C
      SUBROUTINE UTLTY1 ( RX,V,AVUC)
C
C ******************************************************************
C
```

```
C     SUBROUTINE UTLTY1: COMPUTES UTILITY VALUE OF PSI & AVUC
C                        FOR INPUT INTO PAVEMENT SCORE FORMULA.
C
C ******************************************************************
C
      DIMENSION   A(8), B(8), U(8), V(8), RX(8)
      DATA    A   /-0.2540, -0.3396, -0.6703, -0.8106,
     1             -1.4918, -0.8607, -1.0000, -0.7408/
      DATA    B   /- 18.940, -  9.770, - 42.580, - 59.700,
     1             - 6.2044, - 43.750, -191.200, -  8.892/
      U(1)        = 1.00
      DO 1100 I = 1, 8
      U(I) = 1.0
      IF ( RX(I) .GT. 0.5) GOTO 1000
      GOTO 1100
 1000 IF((B(I)/RX(I)).LT.-20.)GOTO 1100
      U(I) = 1.0 + A(I) *  EXP( B(I) / RX(I))
 1100 CONTINUE
 1200 CONTINUE
      AVUC        = 1.0
      DO 1500 K = 1, 8
      AVUC        = AVUC * U(K) ** V(K)
 1500 CONTINUE
      RETURN
      END
C
      SUBROUTINE  UTLTY2 ( ADTS, SRCE, SIUC )
C
C ******************************************************************
C
C    SUBROUTINE UTLTY2: COMPUTES UTILITY VALUE OF DISTRESS TYPES,
C                       SIUC, FOR INPUT INTO PAVEMENT SCORE FORMULA.
C
C ******************************************************************
C
      DIMENSION   A(3,3), B(3)
      DATA    A   /0.8, 1.3, 1.8, 2.0, 2.5, 3.0, 2.5, 3.0, 3.5/
      DATA    B   /-0.26666, -0.55833, -0.85000/
      SIUC        = 0.0
      IF ( SRCE .LT. 0.0 ) GO TO 2000
      NC          = 3
      IF ( ADTS .GT. 165000 ) GO TO 1300
      NC          = 2
      IF ( ADTS .GT.  27500 ) GO TO 1200
      NC          = 1
 1200 CONTINUE
 1300 SIUC        = 1.00
      IF ( SRCE .GE. A(NC,3) ) GO TO 2000
      IF ( SRCE .LT. A(NC,2) ) GO TO 1500
      SIUC        = 1.00 - 0.4 * ( A(NC,3) - SRCE ) ** 2
      GO TO 2000
 1500 IF ( SRCE .LT. A(NC,1) ) GO TO 1600
      SIUC        = B(NC) + 0.58333 * SRCE
      GO TO 2000
 1600 SIUC        = 0.20 * ( SRCE / A(NC,1) ) ** 2
 2000 CONTINUE
      RETURN
      END
C
      SUBROUTINE UTLTY3 ( PATCH, RMUC)
C
```

```
C ******************************************************************
C
C    SUBROUTINE UTLTY3: COMPUTES UTILITY VALUE OF MAINTENANCE COST,
C                       RMUC, FOR INPUT INTO PAVEMENT SCORE FORMULA.
C                       THIS IS CONSIDERED TO BE ASSOCIATED WITH THE
C                       AREA OF PATCHING.
C
C               PATCH = AREA OF ROAD COVERED BY PATCHING.
C
C                       THIS SUBROUTINE
C                            A) CALCULATES COST ASSOCIATED WITH PATCH.
C                            B) CALCULATES A UTILITY SCORE FOR THAT
C                               COST (REFER TO TEXAS PES).
C
C                       IF PATCH = 10%, COST = $1400 (WHERE U DECREASES).
C                       IF PATCH = 75%, COST = $3100 (WHERE U = 0).
C                       USE LINEAR INTERPOLATION TO COMPUTE COST
C                       BETWEEN PATCH = 10% AND PATCH =75%.
C
C ******************************************************************
C
      IF  ( PATCH .GT. 10) GOTO 1000
      RMUC = 1.0
      GOTO 2000
 1000 CONTINUE
      COST = 1400.0 + 26.15 * ( PATCH -10.0 )
      RMUC = 1.0 - 0.13*(((COST - 1400.0)/700.0) ** 2)
      IF ( COST .GT. 2100.0 ) RMUC = 2.69 - 0.00087 * COST
      IF ( RMUC .LT. 0.0 ) RMUC = 0.0
 2000 CONTINUE
      RETURN
      END
//GO.FT01F001 DD DSN=USR.W250.BS.FILE01,DISP=SHR
//GO.FT02F001 DD DSN=USR.W250.BS.FILE02,DISP=SHR
```

APPENDIX C

INPUT DATA FOR CASE STUDY NETWORK

1	12.5	3.57	4.82	0.900	76.7	65.4
2	-39.3	1.14	8.48	0.637	77.8	63.3
3	11.7	3.60	3.81	0.430	78.1	66.7
4	-10.3	3.10	0.610	0.167	78.0	70.6
5	-16.2	2.35	5.83	0.854	76.3	63.9
6	-17.5	1.69	12.7	0.802	72.2	57.5
7	-22.3	2.36	2.30	0.325	81.9	70.0
8	4.46	3.40	2.71	0.540	79.5	68.0
9	-21.9	1.40	12.8	0.993	72.3	56.9
10	-11.4	2.59	5.52	0.504	79.6	65.7
11	-10.7	2.91	2.92	0.341	79.1	67.6
12	-19.0	2.21	8.57	0.659	76.3	62.5
13	-15.9	2.64	1.64	0.276	80.9	69.7
14	-12.5	2.77	3.97	0.361	79.2	66.8
15	-15.7	2.50	2.49	0.385	79.5	68.6
16	-6.67	2.85	4.62	0.652	78.4	65.5
17	-30.4	1.64	6.74	0.608	77.0	63.3
18	-10.2	2.76	4.99	0.762	77.1	65.2
19	49.1	4.01	8.03	1.04	75.1	63.0
20	38.5	4.64	1.70	0.207	78.5	68.5
21	4.59	3.55	2.07	0.400	77.9	67.7
22	-31.6	1.08	3.36	0.486	79.8	66.4
23	-17.9	1.81	10.2	0.809	72.8	58.6
24	-28.0	2.17	1.53	0.202	84.0	71.8
25	-19.1	2.36	5.79	0.580	77.4	65.0
26	2.10	3.30	2.96	0.430	78.2	67.4
27	-13.9	2.64	4.14	0.458	78.2	65.9
28	-6.16	2.92	3.03	0.573	79.4	67.6
29	1.15	3.61	0.862	0.237	79.4	70.6
30	-19.7	2.24	5.74	0.920	77.7	64.5
31	-27.7	2.28	0.387	0.040	83.8	73.3
32	47.4	3.85	5.36	0.960	75.2	63.5
33	-18.7	1.71	10.4	1.34	72.6	58.2
34	49.2	3.97	6.95	1.16	75.1	63.0
35	-22.1	1.52	12.1	0.938	72.5	57.0
36	39.1	4.29	2.21	0.461	78.8	68.3
37	35.3	3.89	4.34	0.646	76.0	65.0
38	-26.1	1.73	7.92	0.767	74.4	61.5
39	-14.1	2.65	7.08	0.888	75.8	63.2
40	-20.4	1.50	11.4	0.853	73.1	57.9
41	-28.6	1.80	6.08	0.633	77.9	64.4
42	-16.6	2.27	5.47	0.642	75.4	63.2
43	16.1	3.19	5.39	0.849	74.8	64.0
44	-22.8	1.75	9.62	0.737	75.0	61.0
45	5.62	3.55	3.05	0.650	79.9	68.4
46	-9.79	2.84	2.73	0.620	80.1	68.0
47	-15.4	2.44	5.70	0.770	76.6	64.5
48	-25.0	2.07	5.17	0.635	80.0	65.8
49	18.6	2.84	7.33	1.25	74.6	62.5
50	-14.1	2.78	5.23	0.587	78.6	66.0
51	-25.1	1.89	7.40	0.853	76.3	62.8
52	-39.8	1.16	5.82	0.604	77.9	64.1
53	-32.8	1.55	5.85	0.445	78.5	64.6
54	-20.7	1.77	10.9	1.10	73.5	59.2
55	-44.1	0.852	7.08	0.597	77.6	62.8
56	-20.4	1.47	12.9	0.915	70.0	55.1
57	-1.36	3.05	4.08	0.530	76.1	66.1
58	-32.5	1.41	9.20	0.575	76.1	61.3
59	-21.4	1.64	11.7	0.926	73.3	58.5
60	56.1	3.82	6.86	1.05	74.2	62.9

61	8.85	3.02	4.69	0.810	76.7	65.0
62	-10.1	2.98	2.57	0.342	81.3	69.3
63	-26.8	1.70	7.65	0.615	75.5	61.9
64	-26.8	1.78	1.44	0.075	84.6	71.9
65	-20.0	1.74	11.7	0.994	73.6	59.0
66	-28.4	2.24	0.985	0.105	84.4	72.4
67	-28.7	2.14	1.68	0.130	83.3	71.1
68	-15.3	2.39	6.72	0.657	76.1	63.4
69	-38.7	1.17	5.96	0.547	77.3	63.6
70	-26.4	1.90	3.92	0.253	78.2	65.4
71	-2.03	3.17	4.97	0.680	77.6	65.6
72	-46.6	0.678	9.52	0.508	78.2	61.8
73	-6.52	2.69	6.01	0.874	74.8	63.2
74	-7.31	3.12	4.44	0.429	78.9	67.0
75	57.9	3.66	5.13	0.743	75.2	63.7
76	1.94	3.27	2.30	0.502	79.5	68.8
77	-26.9	1.87	7.01	0.820	77.6	63.8
78	-21.8	1.68	9.76	1.06	73.4	58.9
79	-22.6	1.95	9.88	0.721	74.9	61.5
80	13.1	3.86	1.70	0.367	78.8	68.5
81	46.2	3.82	5.60	1.14	74.6	62.9
82	9.49	3.39	3.74	0.524	77.4	66.2
83	-22.9	2.11	1.66	0.260	83.4	70.7
84	-33.1	1.33	9.79	1.03	76.6	61.2
85	18.4	3.38	0.417	0.125	74.4	69.7
86	-23.5	1.75	8.82	0.922	74.7	60.8
87	-18.5	2.41	3.44	0.530	78.0	65.9
88	-35.6	1.31	7.32	0.628	76.5	62.7
89	-13.7	3.06	1.42	0.325	82.1	71.0
90	-14.5	2.78	2.89	0.466	80.9	68.9
91	-16.3	1.72	10.7	1.20	71.2	57.4
92	46.3	3.21	5.02	0.608	74.5	63.4
93	36.2	4.04	4.77	0.880	76.2	64.8
94	5.74	3.49	3.52	0.450	79.5	67.8
95	-16.3	2.62	2.74	0.387	79.8	68.6
96	-20.4	1.60	11.9	0.862	72.3	58.0
97	-24.5	1.75	9.48	0.565	75.1	61.1
98	-12.4	2.60	4.88	0.667	76.6	64.6
99	-20.7	1.64	11.7	0.929	73.0	57.8
100	-22.3	1.95	9.88	0.721	74.9	61.5
101	34.8	4.35	3.34	0.389	78.8	66.6
102	11.2	4.01	1.28	0.250	78.8	69.0
103	39.7	3.83	5.95	0.907	76.0	64.4
104	-22.0	1.39	13.6	1.13	70.1	55.4
105	-22.8	2.13	6.44	0.808	76.3	63.5
106	-8.34	2.87	4.09	0.669	79.0	67.1
107	-22.8	1.67	11.7	0.825	73.6	59.5
108	7.04	3.43	3.27	0.581	77.9	66.4
109	-37.0	1.82	0.462	0.050	84.1	73.7
110	-7.70	2.94	4.16	0.590	76.9	65.4
111	-20.1	1.62	11.2	1.20	74.4	59.2
112	-7.10	2.68	5.64	1.12	75.3	63.3
113	67.2	3.81	6.69	1.02	74.8	63.0
114	14.0	3.54	5.67	0.842	77.6	65.6
115	-33.7	1.50	6.43	0.666	77.3	64.1
116	-41.7	0.910	7.14	0.477	77.2	61.7
117	41.6	3.55	5.74	1.22	74.4	63.1
118	-23.4	1.63	10.3	1.01	73.0	59.1
119	-30.6	1.65	6.73	0.794	77.5	64.4
120	-18.2	2.45	4.66	0.530	77.9	65.5
121	7.78	3.67	2.50	0.617	79.8	68.5

122	26.9	4.31	3.00	0.512	78.7	66.4
123	-11.7	1.60	6.35	0.953	69.2	57.3
124	31.5	4.49	1.62	0.400	78.0	68.4
125	-33.2	1.94	1.01	0.193	84.1	72.2
126	-21.8	2.52	0.810	0.133	83.1	71.8
127	-10.5	2.83	4.93	0.632	78.2	65.9
128	-25.9	2.06	5.17	0.495	78.1	65.4
129	-15.7	2.84	2.14	0.458	82.6	70.4
130	8.35	3.35	5.54	1.00	76.3	64.6
131	-6.99	2.77	4.04	0.540	77.7	65.5
132	-28.8	1.66	8.34	0.580	76.6	62.2
133	-8.38	2.57	6.55	0.800	77.3	63.9
134	-27.6	1.88	6.08	0.598	79.8	65.5
135	-23.0	1.89	8.00	0.577	75.9	61.9
136	-31.9	1.86	2.55	0.200	81.0	68.4
137	-25.5	2.33	0.809	0.158	83.3	72.3
138	-24.5	2.01	7.21	0.730	76.8	63.5
139	48.0	3.94	6.36	1.12	74.1	63.2
140	-16.9	1.55	12.6	0.921	72.6	57.8
141	-14.7	2.69	4.01	0.510	78.7	66.5
142	-31.7	1.90	1.54	0.300	83.1	71.2
143	-2.41	3.31	2.44	0.276	81.5	69.6
144	-8.83	2.88	3.17	0.491	78.7	67.6
145	7.31	3.32	3.91	0.770	77.9	65.9
146	30.6	4.18	2.80	0.437	79.3	68.1
147	4.30	3.27	3.50	0.582	76.3	65.6
148	-17.2	1.66	11.7	0.777	70.6	56.8
149	-19.1	2.61	1.58	0.224	81.0	69.9
150	-21.9	2.29	5.07	0.570	78.8	65.9
151	-46.1	0.845	7.71	0.483	80.7	64.8
152	-25.8	1.55	10.2	1.04	73.3	59.7
153	-24.9	1.60	9.69	0.967	74.4	60.1
154	2.00	3.49	3.52	0.450	79.5	67.8
155	38.7	3.77	6.06	0.886	75.8	64.3
156	-38.5	1.14	7.05	0.593	76.7	62.7
157	-21.3	2.19	5.18	0.523	78.6	65.2
158	4.39	3.69	0.880	0.125	78.8	70.6
159	-30.4	1.89	2.21	0.153	82.8	70.3
160	-19.1	2.22	5.76	0.841	77.4	64.0
161	-15.5	2.71	2.71	0.413	77.6	67.0
162	-29.2	1.95	2.04	0.262	82.9	70.9
163	-19.2	2.41	2.72	0.312	82.4	69.2
164	-22.4	2.08	6.58	0.625	79.5	64.9
165	-38.6	1.18	6.78	0.780	76.5	63.3
166	-10.5	2.90	2.71	0.437	79.8	68.1
167	-18.9	2.35	4.64	0.530	77.7	65.6
168	-25.4	1.94	6.20	0.730	79.4	65.3
169	0.214	2.67	4.71	0.850	76.7	64.8
170	13.1	3.91	3.33	0.392	79.0	67.5
171	-20.8	1.48	12.8	0.734	72.2	57.4
172	32.2	3.85	4.33	0.704	77.3	65.8
173	-25.2	1.74	8.10	0.720	75.0	61.6
174	39.6	4.18	5.32	0.880	77.2	65.0
175	3.70	3.20	4.76	0.812	76.6	65.3
176	33.1	4.74	3.27	0.500	79.5	67.2
177	-21.6	2.08	6.11	0.880	76.7	63.7
178	-19.1	2.56	0.520	0.200	80.7	71.6
179	-15.6	1.76	11.9	1.38	71.3	57.1
180	-18.2	1.51	12.5	1.21	69.9	55.4
181	40.1	4.60	3.15	0.385	78.2	67.0
182	-13.5	2.62	5.23	0.720	76.8	64.9

183	25.8	3.88	4.24	0.564	77.5	65.7
184	-7.32	2.70	5.71	1.10	75.4	63.3
185	-25.9	1.37	13.6	1.09	71.6	56.7
186	-42.4	0.997	7.11	0.646	79.2	64.1
187	23.5	4.08	3.97	0.650	78.1	66.2
188	-17.6	1.65	11.6	1.16	70.5	57.1
189	-3.45	1.02	7.79	0.417	79.9	62.8
190	34.5	3.73	6.55	0.904	75.1	63.2
191	-21.0	1.62	11.7	0.897	73.4	58.5
192	-31.1	1.51	7.27	0.780	76.8	63.2
193	-21.8	2.15	5.81	0.404	78.0	64.7
194	47.5	3.86	6.87	1.02	74.4	62.8
195	-46.6	0.821	8.31	0.383	81.6	64.9
196	-9.92	3.28	1.36	0.151	81.9	71.0
197	-15.8	1.76	11.9	1.38	71.4	57.1
198	1.27	3.26	3.82	0.610	78.3	66.6
199	-1.72	2.85	4.88	0.914	76.5	64.6
200	-26.7	1.88	6.74	0.610	78.4	64.6
201	30.0	3.91	4.65	0.692	75.9	64.7
202	36.6	4.29	4.43	0.665	77.2	64.8
203	36.0	4.11	4.93	0.753	77.3	65.2
204	25.5	4.03	5.05	0.610	77.9	66.3
205	-18.4	2.84	0.961	0.243	82.0	71.3
206	-22.3	2.16	5.51	0.731	77.6	64.5
207	-27.3	1.77	7.10	0.505	77.8	64.2
208	-25.8	1.75	8.55	0.744	76.3	62.3
209	-15.3	2.33	7.01	0.932	77.7	63.7
210	39.0	4.21	5.52	0.914	77.2	64.8
211	-20.1	1.47	12.9	0.915	70.0	55.1
212	-19.5	1.52	11.6	0.961	71.1	56.5
213	-9.30	2.74	5.69	0.820	77.6	64.8
214	-41.2	1.62	0.680	0.100	85.6	73.5
215	-17.1	2.33	6.27	0.990	77.1	64.3
216	-30.2	1.67	6.73	0.720	77.8	63.8
217	-26.6	1.86	7.62	0.966	77.4	63.3
218	-27.6	1.85	5.64	0.528	79.3	65.4
219	-22.7	1.52	11.1	0.992	72.0	57.2
220	-3.79	2.83	4.77	1.05	76.0	64.8
221	-22.4	2.14	5.14	0.800	76.0	64.3
222	-40.4	1.11	5.98	0.379	78.3	64.0
223	-25.3	1.55	11.0	0.901	74.3	59.4
224	-19.5	2.21	6.79	0.840	75.9	63.3
225	47.0	3.92	7.28	1.10	75.5	62.9
226	-31.3	1.65	6.56	0.730	77.1	64.2
227	-14.3	2.72	2.27	0.617	78.5	68.1
228	17.9	3.87	4.11	0.644	78.1	66.3
229	30.8	4.33	3.63	0.311	78.8	66.5
230	42.1	3.84	5.26	0.930	75.1	63.5
231	-38.3	1.29	5.56	0.364	78.9	65.4
232	-28.7	2.03	3.77	0.341	81.6	68.6
233	-38.6	1.39	3.51	0.299	80.4	67.7
234	17.5	3.65	4.54	0.842	76.2	64.4
235	-8.68	3.01	1.52	0.375	80.6	69.9
236	10.8	3.71	3.17	0.560	77.9	67.0
237	16.3	3.70	3.06	0.325	78.9	67.5
238	-44.4	0.934	6.38	0.497	79.7	64.8
239	3.27	3.40	2.71	0.540	79.5	68.0
240	-33.6	1.90	1.22	0.218	84.0	72.0
241	3.30	3.57	2.27	0.488	79.7	68.6
242	-21.8	1.75	10.7	0.787	74.1	59.8
243	-15.3	2.28	6.35	0.890	75.8	63.4

244	-21.5	2.19	5.92	0.727	77.4	64.1
245	-28.1	2.25	0.737	0.117	84.1	72.9
246	-12.3	2.96	3.23	0.599	79.6	67.6
247	-19.0	2.49	1.99	0.382	80.7	69.1
248	-44.2	0.921	7.38	0.570	78.8	64.2
249	-12.0	2.51	6.43	0.820	77.2	64.0
250	9.81	2.59	9.73	1.16	73.4	60.0
251	-25.5	1.41	10.5	0.715	74.1	58.7
252	-14.9	2.48	8.77	0.800	76.9	63.7
253	-40.1	1.63	0.886	0.182	84.6	72.9
254	-30.2	1.87	1.61	0.117	82.7	71.0

APPENDIX D

FILE02 INPUT DATA FOR CASE STUDY NETWORK

```
007
3504
   174.00    10.00     0.77    23.30    50.40     3.00     2.50     5.50
     1    6    12    24    36    60    72    84    96   108   120
PROJECT 2299 - PHASE IV - US 59 - NACOGDOCHES COUNTY          *
   5300. 10.0  5.0 50.0  2.0 01.0 72.0
016
006 001
012 002
017 001
019 001
020 001
034 001
039 003
048 001
052 002
053 002
055 002
056 001
057 002
065 001
066 003
068 001
3501
   174.00     6.00     1.88    23.30    50.40     1.00     0.00     0.00
     1    6    12    24    36    60    72    84    96   108   120
PROJECT 2299 - PHASE IV - FM 95 - NACOGDOCHES COUNTY          *
    420. 10.0  0.0 50.0  2.0 01.0 53.8
012
008 001
012 001
029 001
043 001
051 001
057 002
063 001
064 001
067 001
068 001
069 001
072 001
3501
   174.00     6.00     1.69    23.30    50.40     1.00     0.00     0.00
     1    6    12    24    36    60    72    84    96   108   120
PROJECT 2299 - PHASE IV - FM 138 - NACOGDOCHES COUNTY         *
    550. 10.5  0.0 50.0  2.0 01.0 62.5
007
033 002
037 001
049 001
053 001
057 001
058 001
060 001
3501
   174.00     6.00     1.50    23.30    50.40     1.00     0.00     0.00
     1    6    12    24    36    60    72    84    96   108   120
PROJECT 2299 - PHASE IV - FM 1087 - NACOGDOCHES COUNTY        *
    300. 10.0  0.0 50.0  2.0 01.0 81.8
010
```

```
027 001
033 001
043 001
045 001
047 001
051 001
056 001
057 002
059 001
067 001
3501
   174.00     6.00     1.71    23.30    50.40     1.00     0.00     0.00
     1    6   12   24   36   60   72   84   96  108  120
PROJECT 2299 - PHASE IV - FM 1878 - NACOGDOCHES COUNTY        *
    400. 10.5  0.0 50.0  2.0 01.0100.0
003
008 001
043 001
051 001
3501
   174.00     6.00     1.65    23.30    50.40     1.00     0.00     0.00
     1    6   12   24   36   60   72   84   96  108  120
PROJECT 2299 - PHASE IV - FM 2476 - NACOGDOCHES COUNTY        *
    260. 05.0 10.0 50.0  2.0 01.0 00.0
001
001 000
3501
   174.00     6.00     1.61    23.30    50.40     1.00     0.00     0.00
     1    6   12   24   36   60   72   84   96  108  120
PROJECT 2299 - PHASE IV - FM 2609 - NACOGDOCHES COUNTY        *
    320. 07.0  4.0 50.0  2.0 01.0 00.0
001
068 001
```

APPENDIX E

COMPUTER OUTPUT FOR CASE STUDY NETWORK

```
NUMBER OF PAVEMENTS =    7

OIL FIELD DAMAGE PROGRAM:  8/24/84 FORTRAN 77 VERSION
```

PROJECT 2299 - PHASE IV - US 59 - NACOGDOCHES COUNTY *

OVERLAY PAVEMENT

STRUCTURAL VARIABLES

PAVEMENT STRENGTH INDEX	3
ASPHALT COURSE THICKNESS	2.50
SUBGRADE PLASTICITY INDEX	23.30
PERCENT ASPHALT	5.50

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 7980.   ADT/LANE = 2650.

% TRUCKS = 10.00   % GROWTH = 5.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	79500.	79500.	7980.	7980.
6	481996.	484246.	48384.	48653.
12	976166.	987866.	97990.	99312.
24	2002264.	2054666.	200993.	206534.
36	3080852.	3152023.	309265.	316643.
60	5406386.	5589843.	542711.	561981.
72	6659120.	6915105.	668465.	694980.
84	7975941.	8251867.	800652.	828983.
96	9360130.	9636255.	939602.	967951.
108	10815131.	11091258.	1085659.	1113993.
120	12344569.	12620696.	1239183.	1267517.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 72.

PROJECT 2299 - PHASE IV - US 59 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		NOT CALC.		NOT CALC.		ALLIGATOR		LONGITUDNL		TRANSVERSE		NOT CALC.		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	----	----	----	----	AREA	SEV.	AREA	SEV.	AREA	SEV.	----	----	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
12	4.20	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	99	100	100	99
24	4.20	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.1	0.0	0.0	0.0	99	100	100	99
36	4.20	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	2.3	10.3	0.0	0.0	0.0	96	100	100	95
60	4.20	16.9	0.7	0.0	0.0	0.0	0.0	0.0	6.4	0.0	15.5	17.4	9.2	0.0	0.0	79	100	100	77
72	4.20	20.2	2.4	0.0	0.0	0.0	0.0	0.0	13.1	0.5	23.5	20.3	33.3	0.0	0.0	37	100	100	33
84	4.20	23.2	5.6	0.0	0.0	0.0	0.0	0.0	20.9	2.1	31.0	23.0	56.5	0.0	0.0	35	100	100	30
96	4.20	25.9	10.0	0.0	0.0	0.0	0.0	0.1	28.9	5.5	37.8	25.3	72.4	0.0	0.0	33	100	100	28
108	4.19	28.5	15.3	0.0	0.0	0.0	0.0	0.2	36.6	10.4	43.7	27.5	82.2	0.0	0.0	31	100	100	27
120	4.19	30.9	21.1	0.0	0.0	0.0	0.0	0.5	43.6	16.3	48.9	29.4	88.2	0.0	0.0	30	100	100	26

TIME TO FAILURE UNDER NORMAL TRAFFIC = 71.5 MTHS

PROJECT 2299 - PHASE IV - US 59 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

MONTH	RIDE	RUTTING AREA	RUTTING SEV.	NOT CALC. ----	NOT CALC. ----	NOT CALC. ----	NOT CALC. ----	ALLIGATOR AREA	ALLIGATOR SEV.	LONGITUDNL AREA	LONGITUDNL SEV.	TRANSVERSE AREA	TRANSVERSE SEV.	NOT CALC. ----	NOT CALC. ----	PAVEMENT SCORE (PES) VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
12	4.20	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	99	100	100	99
24	4.20	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.1	0.0	0.0	0.0	99	100	100	98
36	4.20	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.3	10.3	0.0	0.0	0.0	96	100	100	95
60	4.20	17.5	0.8	0.0	0.0	0.0	0.0	0.0	7.4	0.0	15.5	17.4	9.2	0.0	0.0	79	100	100	77
72	4.20	20.8	2.9	0.0	0.0	0.0	0.0	0.0	14.7	0.5	23.5	20.3	33.3	0.0	0.0	37	100	100	33
84	4.20	23.8	6.4	0.0	0.0	0.0	0.0	0.0	22.6	2.1	31.0	23.0	56.5	0.0	0.0	35	100	100	30
96	4.20	26.5	11.0	0.0	0.0	0.0	0.0	0.1	30.5	5.5	37.8	25.3	72.4	0.0	0.0	33	100	100	28
108	4.19	29.0	16.4	0.0	0.0	0.0	0.0	0.3	37.9	10.4	43.7	27.5	82.2	0.0	0.0	31	100	100	27
120	4.19	31.3	22.2	0.0	0.0	0.0	0.0	0.5	44.8	16.3	48.9	29.4	88.2	0.0	0.0	30	100	100	26

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 71.5 MTHS

OIL WELL DEVELOPMENT

MONTH	NO. WELLS
6	1
12	2
17	1
19	1
20	1
34	1
39	3
48	1
52	2
53	2
55	2
56	1
57	2
65	1
66	3
68	1

PROJECT 2299 - PHASE IV - FM 95 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.88
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 632. ADT/LANE = 210.

% TRUCKS = 10.00 % GROWTH = 0.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	6300.	6300.	632.	632.
6	37800.	37800.	3794.	3794.
12	75600.	83560.	7589.	8506.
24	151200.	169493.	15178.	17100.
36	226800.	252498.	22767.	25492.
60	378000.	433872.	37945.	43930.
72	453600.	553671.	45534.	56249.
84	529200.	650680.	53122.	65851.
96	604800.	726875.	60711.	73494.
108	680400.	802481.	68300.	81083.
120	756000.	878081.	75889.	88672.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 54.

PROJECT 2299 - PHASE IV - FM 95 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.19	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.1	100	100	100	100
24	4.06	0.2	4.1	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	2.6	0.0	0.1	6.3	100	100	100	100
36	3.80	11.9	21.1	0.0	0.0	0.0	0.0	7.9	0.0	0.3	0.0	6.0	0.0	3.2	19.7	84	100	100	84
60	3.26	57.3	53.4	0.2	0.3	0.4	0.3	19.2	2.6	3.7	0.6	13.4	0.0	24.4	43.5	69	100	96	67
72	3.04	70.8	63.6	0.7	1.0	1.3	1.2	24.3	8.3	7.0	2.3	16.7	0.0	35.9	51.9	68	100	87	60
84	2.85	79.4	70.9	1.6	2.4	2.8	3.1	28.9	16.7	10.7	5.2	19.8	0.5	45.8	58.5	54	100	65	35
96	2.68	85.0	76.2	3.1	4.5	4.9	5.8	32.9	25.9	14.8	9.1	22.7	2.5	53.8	63.8	51	100	47	24
108	2.54	88.8	80.2	5.0	7.3	7.4	9.2	36.6	34.9	18.8	13.7	25.3	6.8	60.4	68.0	48	100	32	15
120	2.42	91.4	83.3	7.3	10.4	10.2	13.0	39.9	43.0	22.8	18.5	27.7	13.2	65.8	71.5	19	99	20	4

TIME TO FAILURE UNDER NORMAL TRAFFIC = 84.0 MTHS

PROJECT 2299 - PHASE IV - FM 95 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.19	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.3	100	100	100	100
24	4.00	1.1	7.5	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	2.6	0.0	0.3	9.4	99	100	100	99
36	3.70	20.6	28.0	0.0	0.0	0.0	0.0	10.0	0.0	0.3	0.0	6.0	0.0	5.9	24.7	77	100	100	77
60	3.08	68.4	61.7	0.5	0.7	1.0	0.9	23.3	6.9	3.7	0.6	13.4	0.0	33.6	50.3	69	100	89	62
72	2.78	82.0	73.3	2.0	3.0	3.4	3.9	30.6	20.4	7.0	2.3	16.7	0.0	49.3	60.8	52	100	57	30
84	2.59	87.7	79.1	4.2	6.1	6.4	7.8	35.5	32.0	10.7	5.2	19.8	0.5	58.5	66.7	49	100	36	18
96	2.46	90.6	82.4	6.4	9.2	9.1	11.5	38.9	40.6	14.8	9.1	22.7	2.5	64.2	70.4	47	99	23	11
108	2.35	92.7	85.0	8.9	12.5	12.1	15.5	41.9	48.1	18.8	13.7	25.3	6.8	68.9	73.5	44	99	13	5
120	2.25	94.2	87.1	11.5	16.0	15.2	19.6	44.6	54.5	22.8	18.5	27.7	13.2	72.7	76.0	18	97	4	0

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 70.1 MTHS

OIL WELL DEVELOPMENT

MONTH	NO. WELLS
8	1
12	1
29	1
43	1
51	1
57	2
63	1
64	1
67	1
68	1
69	1
72	1

PROJECT 2299 - PHASE IV - FM 138 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.69
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 870. ADT/LANE = 275.

% TRUCKS = 10.50 % GROWTH = 0.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	8250.	8250.	870.	870.
6	49500.	49500.	5217.	5217.
12	99000.	99000.	10435.	10435.
24	198000.	198000.	20870.	20870.
36	297000.	307875.	31304.	32551.
60	495000.	554691.	52174.	58571.
72	594000.	674790.	62609.	70991.
84	693000.	774447.	73043.	81485.
96	792000.	873454.	83478.	91921.
108	891000.	972454.	93913.	102355.
120	990000.	1071452.	104348.	112790.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 63.

PROJECT 2299 - PHASE IV - FM 138 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.18	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	1.1	100	100	100	100
24	3.93	6.9	16.3	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	2.6	0.0	1.8	16.2	91	100	100	91
36	3.57	39.8	41.4	0.0	0.0	0.0	0.0	12.1	0.1	0.3	0.0	6.0	0.0	13.9	34.3	72	100	99	71
60	2.97	78.5	70.1	0.7	1.2	1.8	1.8	27.3	13.1	3.7	0.6	13.4	0.0	44.6	57.8	55	100	68	37
72	2.74	86.1	77.3	2.0	3.2	4.1	4.7	33.5	27.0	7.0	2.3	16.7	0.0	55.6	64.9	50	100	43	22
84	2.56	90.5	82.3	4.1	6.2	7.2	8.8	38.9	40.6	10.7	5.2	19.8	0.5	63.9	70.2	47	100	24	11
96	2.40	93.2	85.7	6.8	9.9	10.8	13.7	43.5	52.0	14.8	9.1	22.7	2.5	70.1	74.3	44	99	10	4
108	2.27	95.0	88.3	9.9	14.1	14.7	18.8	47.6	61.1	18.8	13.7	25.3	6.8	74.9	77.5	41	97	0	0
120	2.16	96.2	90.2	13.2	18.5	18.7	24.1	51.0	68.3	22.8	18.5	27.7	13.2	78.7	80.1	16	95	0	0

TIME TO FAILURE UNDER NORMAL TRAFFIC = 61.6 MTHS

PROJECT 2299 - PHASE IV - FM 138 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.18	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	1.1	100	100	100	100
24	3.93	6.9	16.3	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	2.6	0.0	1.8	16.2	91	100	100	91
36	3.53	43.5	43.9	0.0	0.0	0.1	0.0	13.1	0.2	0.3	0.0	6.0	0.0	15.8	36.2	71	100	99	70
60	2.83	83.7	74.9	1.4	2.2	3.0	3.3	31.2	21.5	3.7	0.6	13.4	0.0	51.7	62.4	52	100	52	27
72	2.59	89.8	81.4	3.7	5.6	6.5	7.9	37.9	38.0	7.0	2.3	16.7	0.0	62.5	69.3	47	100	27	13
84	2.43	92.8	85.2	6.3	9.2	10.1	12.8	42.7	50.0	10.7	5.2	19.8	0.5	69.1	73.6	44	99	12	5
96	2.30	94.7	87.8	9.3	13.4	14.0	17.9	46.8	59.6	14.8	9.1	22.7	2.5	74.1	77.0	42	98	1	0
108	2.18	96.0	89.8	12.6	17.7	18.0	23.1	50.4	67.0	18.8	13.7	25.3	6.8	78.0	79.7	38	95	0	0
120	2.08	96.9	91.4	16.0	22.1	22.0	28.2	53.6	72.9	22.8	18.5	27.7	13.2	81.1	81.9	15	93	0	0

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 55.5 MTHS

OIL WELL DEVELOPMENT

MONTH	NO. WELLS
33	2
37	1
49	1
53	1
57	1
58	1
60	1

PROJECT 2299 - PHASE IV - FM 1087 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.50
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 452.   ADT/LANE = 150.

% TRUCKS = 10.00   % GROWTH = 0.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	4500.	4500.	452.	452.
6	27000.	27000.	2710.	2710.
12	54000.	54000.	5421.	5421.
24	108000.	108000.	10841.	10841.
36	162000.	177135.	16262.	17897.
60	270000.	361197.	27103.	36690.
72	324000.	450036.	32524.	45411.
84	378000.	509247.	37945.	51306.
96	432000.	563299.	43365.	56732.
108	486000.	617299.	48786.	62152.
120	540000.	671299.	54207.	67573.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 82.

PROJECT 2299 - PHASE IV - FM 1087 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.18	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.6	0.0	0.0	1.4	100	100	100	100
36	4.10	0.6	5.9	0.0	0.0	0.0	0.0	1.0	0.0	0.3	0.0	6.0	0.0	0.2	8.0	100	100	100	100
60	3.78	26.0	32.0	0.0	0.0	0.0	0.0	6.9	0.0	3.7	0.6	13.4	0.0	7.9	27.5	75	100	100	75
72	3.61	43.4	43.9	0.0	0.0	0.1	0.0	11.0	0.0	7.0	2.3	16.7	0.0	15.8	36.1	71	100	99	70
84	3.44	57.3	53.4	0.1	0.1	0.3	0.2	15.3	0.5	10.7	5.2	19.8	0.5	24.4	43.5	69	100	96	67
96	3.29	67.5	61.0	0.2	0.3	0.7	0.6	19.6	2.6	14.8	9.1	22.7	2.5	32.8	49.7	69	100	90	62
108	3.14	75.0	67.0	0.4	0.7	1.4	1.3	23.7	7.0	18.8	13.7	25.3	6.8	40.3	54.9	68	100	78	53
120	3.01	80.4	71.7	0.8	1.4	2.4	2.5	27.6	13.5	22.8	18.5	27.7	13.2	47.0	59.3	23	100	63	14

TIME TO FAILURE UNDER NORMAL TRAFFIC = 113.5 MTHS

PROJECT 2299 - PHASE IV - FM 1087 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.18	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.6	0.0	0.0	1.4	100	100	100	100
36	4.06	1.8	9.2	0.0	0.0	0.0	0.0	1.6	0.0	0.3	0.0	6.0	0.0	0.5	10.8	99	100	100	99
60	3.48	54.4	51.4	0.0	0.1	0.2	0.1	14.3	0.3	3.7	0.6	13.4	0.0	22.4	41.9	70	100	97	68
72	3.23	70.6	63.4	0.2	0.4	0.9	0.8	21.2	3.9	7.0	2.3	16.7	0.0	35.7	51.8	68	100	87	60
84	3.08	77.7	69.3	0.6	1.0	1.8	1.8	25.6	9.8	10.7	5.2	19.8	0.5	43.6	57.1	68	100	70	48
96	2.96	82.4	73.6	1.1	1.8	2.9	3.1	29.4	17.1	14.8	9.1	22.7	2.5	49.8	61.2	53	100	56	30
108	2.84	85.8	77.1	1.8	2.9	4.3	4.8	32.9	25.1	18.8	13.7	25.3	6.8	55.2	64.6	51	100	44	22
120	2.74	88.5	79.9	2.7	4.3	5.8	6.9	36.1	33.3	22.8	18.5	27.7	13.2	59.9	67.6	20	100	33	7

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 92.7 MTHS

OIL WELL DEVELOPMENT

MONTH	NO. WELLS
27	1
33	1
43	1
45	1
47	1
51	1
56	1
57	2
59	1
67	1

PROJECT 2299 - PHASE IV - FM 1878 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.71
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 632. ADT/LANE = 200.

% TRUCKS = 10.50 % GROWTH = 0.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	6000.	6000.	632.	632.
6	36000.	36000.	3794.	3794.
12	72000.	78750.	7589.	8332.
24	144000.	157522.	15178.	16537.
36	216000.	229590.	22767.	24132.
60	360000.	397621.	37945.	41755.
72	432000.	472741.	45534.	49628.
84	504000.	544772.	53122.	57220.
96	576000.	616772.	60711.	64809.
108	648000.	688772.	68300.	72397.
120	720000.	760772.	75889.	79986.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS =100.

PROJECT 2299 - PHASE IV - FM 1878 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1	100	100	100	100
24	4.09	0.2	4.1	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	2.6	0.0	0.1	6.3	100	100	100	100
36	3.86	11.9	21.1	0.0	0.0	0.0	0.0	5.9	0.0	0.3	0.0	6.0	0.0	3.2	19.7	84	100	100	84
60	3.35	57.3	53.4	0.1	0.1	0.2	0.2	17.4	1.4	3.7	0.6	13.4	0.0	24.4	43.5	69	100	96	67
72	3.13	70.8	63.6	0.3	0.5	0.8	0.7	22.9	6.2	7.0	2.3	16.7	0.0	35.9	51.9	68	100	87	60
84	2.94	79.4	70.9	0.9	1.3	2.0	2.0	28.0	14.5	10.7	5.2	19.8	0.5	45.8	58.5	54	100	65	36
96	2.77	85.0	76.2	1.8	2.8	3.6	4.1	32.5	24.6	14.8	9.1	22.7	2.5	53.8	63.8	51	100	47	24
108	2.63	88.8	80.2	3.2	4.8	5.7	6.9	36.6	34.6	18.8	13.7	25.3	6.8	60.4	68.0	48	100	32	15
120	2.50	91.4	83.3	4.9	7.3	8.2	10.2	40.2	43.8	22.8	18.5	27.7	13.2	65.8	71.5	19	100	20	4

TIME TO FAILURE UNDER NORMAL TRAFFIC = 85.0 MTHS

PROJECT 2299 - PHASE IV - FM 1878 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.19	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.2	100	100	100	100
24	4.06	0.7	6.4	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	2.6	0.0	0.2	8.5	99	100	100	99
36	3.81	16.1	24.6	0.0	0.0	0.0	0.0	6.9	0.0	0.3	0.0	6.0	0.0	4.5	22.2	80	100	100	80
60	3.23	64.8	59.0	0.2	0.2	0.5	0.4	20.2	3.3	3.7	0.6	13.4	0.0	30.4	48.0	69	100	92	64
72	3.02	75.9	67.8	0.6	0.9	1.4	1.4	25.7	10.3	7.0	2.3	16.7	0.0	41.4	55.7	56	100	75	42
84	2.84	82.7	74.0	1.3	2.1	2.8	3.1	30.5	19.9	10.7	5.2	19.8	0.5	50.3	61.5	52	100	55	29
96	2.69	87.2	78.5	2.5	3.9	4.8	5.6	34.8	30.1	14.8	9.1	22.7	2.5	57.6	66.2	49	100	38	19
108	2.56	90.3	82.0	4.1	6.2	7.1	8.7	38.6	39.7	18.8	13.7	25.3	6.8	63.5	70.0	47	100	25	12
120	2.44	92.4	84.7	6.0	8.9	9.7	12.2	42.0	48.3	22.8	18.5	27.7	13.2	68.2	73.1	19	99	14	2

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 78.5 MTHS

OIL WELL DEVELOPMENT

MONTH	NO. WELLS
8	1
43	1
51	1

PROJECT 2299 - PHASE IV - FM 2476 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.65
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 196. ADT/LANE = 130.

% TRUCKS = 5.00 % GROWTH = 10.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	3900.	3900.	196.	196.
6	23893.	23893.	1199.	1199.
12	49006.	49006.	2460.	2460.
24	103142.	103142.	5177.	5177.
36	162947.	162947.	8179.	8179.
60	301999.	301999.	15158.	15158.
72	382625.	382625.	19205.	19205.
84	471694.	471694.	23675.	23675.
96	570090.	570090.	28614.	28614.
108	678788.	678788.	34070.	34070.
120	798868.	798868.	40097.	40097.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 0.

PROJECT 2299 - PHASE IV - FM 2476 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	100	100	100	100
36	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	6.0	0.0	0.0	0.2	100	100	100	100
60	4.10	0.2	4.0	0.0	0.0	0.0	0.0	1.3	0.0	3.7	0.6	13.4	0.0	0.1	6.3	100	100	100	100
72	3.99	3.6	12.2	0.1	0.1	0.4	0.3	3.1	0.0	7.0	2.3	16.7	0.0	1.0	13.2	97	100	100	97
84	3.85	14.7	23.4	0.5	0.8	1.3	1.3	5.9	0.0	10.7	5.2	19.8	0.5	4.0	21.4	81	100	100	81
96	3.68	31.1	35.5	1.5	2.4	3.3	3.7	9.6	0.0	14.8	9.1	22.7	2.5	9.9	30.0	73	100	100	73
108	3.50	47.8	46.8	3.5	5.4	6.6	7.9	13.8	0.3	18.8	13.7	25.3	6.8	18.2	38.4	70	100	98	69
120	3.31	61.8	56.7	6.6	9.8	10.9	13.7	18.5	1.9	22.8	18.5	27.7	13.2	27.8	46.1	29	100	94	27

TIME TO FAILURE UNDER NORMAL TRAFFIC = 117.7 MTHS

PROJECT 2299 - PHASE IV - FM 2476 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	100	100	100	100
36	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	6.0	0.0	0.0	0.2	100	100	100	100
60	4.10	0.2	4.0	0.0	0.0	0.0	0.0	1.3	0.0	3.7	0.6	13.4	0.0	0.1	6.3	100	100	100	100
72	3.99	3.6	12.2	0.1	0.1	0.4	0.3	3.1	0.0	7.0	2.3	16.7	0.0	1.0	13.2	97	100	100	97
84	3.85	14.7	23.4	0.5	0.8	1.3	1.3	5.9	0.0	10.7	5.2	19.8	0.5	4.0	21.4	81	100	100	81
96	3.68	31.1	35.5	1.5	2.4	3.3	3.7	9.6	0.0	14.8	9.1	22.7	2.5	9.9	30.0	73	100	100	73
108	3.50	47.8	46.8	3.5	5.4	6.6	7.9	13.8	0.3	18.8	13.7	25.3	6.8	18.2	38.4	70	100	98	69
120	3.31	61.8	56.7	6.6	9.8	10.9	13.7	18.5	1.9	22.8	18.5	27.7	13.2	27.8	46.1	29	100	94	27

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 117.7 MTHS

OIL WELL DEVELOPMENT	MONTH	NO. WELLS
	1	0

PROJECT 2299 - PHASE IV - FM 2609 - NACOGDOCHES COUNTY *

SURFACE-TREATED PAVEMENT

STRUCTURAL VARIABLES

FLEXIBLE LAYER THICKNESS	6.00
W1, MEAN DEFLECTION	1.61
SUBGRADE PLASTICITY INDEX	23.30
SUBGRADE LIQUID LIMIT	50.40

ENVIRONMENTAL VARIABLES FOR COUNTY 174

MEAN TEMPERATURE	65.00
THORNTWAITE INDEX	39.60
FREEZE /THAW CYCLES	63.84

MINIMUM PAVEMENT SCORE ALLOWED = 35

TRAFFIC ANALYSIS DATA
****

N18/MTH = 337. ADT/LANE = 160.

% TRUCKS = 7.00 % GROWTH = 4.00

BASELINE DIRECTIONAL DISTRIBUTION = 50.0%

MONTH	ADT(N)	ADT(O)	N18(N)	N18(O)
1	4800.	4800.	337.	337.
6	29041.	29041.	2041.	2041.
12	58668.	58668.	4122.	4122.
24	119725.	119725.	8413.	8413.
36	183269.	183269.	12878.	12878.
60	318228.	318228.	22361.	22361.
72	389858.	394358.	27395.	27933.
84	464406.	468906.	32633.	33171.
96	541990.	546490.	38085.	38623.
108	622735.	627235.	43758.	44297.
120	706769.	711269.	49663.	50201.

OIL FIELD DATA
****

AV. MONTHS DRILL TIME = 2.
AV. % PROD DECAY/YEAR = 1.
AV. % PRODUCING WELLS = 0.

PROJECT 2299 - PHASE IV - FM 2609 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.3	100	100	100	100
36	4.15	0.0	1.4	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.0	6.0	0.0	0.0	3.3	100	100	100	100
60	3.90	10.8	20.1	0.0	0.0	0.1	0.0	4.7	0.0	3.7	0.6	13.4	0.0	2.9	19.0	85	100	100	85
72	3.73	27.0	32.7	0.1	0.2	0.4	0.3	8.2	0.0	7.0	2.3	16.7	0.0	8.3	28.0	75	100	100	75
84	3.56	43.7	44.1	0.4	0.6	1.2	1.1	12.2	0.1	10.7	5.2	19.8	0.5	16.0	36.3	71	100	99	70
96	3.39	57.6	53.7	1.1	1.7	2.6	2.8	16.5	0.9	14.8	9.1	22.7	2.5	24.7	43.7	69	100	96	67
108	3.22	68.2	61.5	2.2	3.5	4.7	5.4	20.8	3.7	18.8	13.7	25.3	6.8	33.4	50.1	69	100	90	62
120	3.07	76.0	67.8	4.0	6.1	7.4	9.0	25.1	9.2	22.8	18.5	27.7	13.2	41.5	55.7	29	100	75	22

TIME TO FAILURE UNDER NORMAL TRAFFIC = 116.1 MTHS

PROJECT 2299 - PHASE IV - FM 2609 - NACOGDOCHES COUNTY *

OIL FIELD DAMAGE PROJECT ---- NORMAL PLUS OIL FIELD TRAFFIC

		RUTTING		RAVELING		FLUSHING		ALLIGATOR		LONGITUDNL		TRANSVERSE		PATCHING		PAVEMENT SCORE (PES)			
MONTH	RIDE	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	AREA	SEV.	VISUAL	PSI	MCOST	TOTAL
1	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
6	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	100	100
12	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100	100	100	100
24	4.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.3	100	100	100	100
36	4.15	0.0	1.4	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.0	6.0	0.0	0.0	3.3	100	100	100	100
60	3.90	10.8	20.1	0.0	0.0	0.1	0.0	4.7	0.0	3.7	0.6	13.4	0.0	2.9	19.0	85	100	100	85
72	3.72	28.8	33.9	0.1	0.2	0.4	0.3	8.6	0.0	7.0	2.3	16.7	0.0	9.0	28.9	74	100	100	74
84	3.54	45.3	45.1	0.4	0.7	1.2	1.2	12.7	0.1	10.7	5.2	19.8	0.5	16.8	37.1	71	100	99	70
96	3.37	58.8	54.5	1.1	1.8	2.7	2.9	16.9	1.1	14.8	9.1	22.7	2.5	25.5	44.4	69	100	95	66
108	3.21	69.0	62.1	2.3	3.6	4.8	5.6	21.2	4.1	18.8	13.7	25.3	6.8	34.1	50.7	68	100	89	61
120	3.06	76.5	68.3	4.1	6.2	7.5	9.2	25.5	9.8	22.8	18.5	27.7	13.2	42.2	56.2	29	100	73	21

TIME TO FAILURE UNDER NORMAL + OIL FIELD TRAFFIC = 115.8 MTHS

OIL WELL DEVELOPMENT	MONTH	NO. WELLS
	68	1

APPENDIX F

DEVELOPMENT OF THE OIL FIELD DAMAGE PROGRAM

DEVELOPMENT OF THE OIL FIELD DAMAGE PROGRAM

AASHO Road Test Equations

The AASHO Road Test conducted in Ottawa, Illinois, in 1960 has been a major source of pavement performance data. Numerous inferences (1) have been drawn from this test, including the interim guide equations (2) for the design of flexible and rigid pavements. This design equation relates the number of 18-kip equivalent single axle load repetitions required to reach a predetermined terminal serviceability level for any given pavement structure, climatic condition, and subgrade soil.

Damage was defined at the AASHO Road Test to be a normalized score between 0 and 1; when the pavement reaches a terminal condition, the damage is 1. A "damage function" is an equation which describes how the damage proceeds from its initial value to its terminal value and beyond. In the AASHO Road Test (3), the damage function was assumed to be of the form

$$g = \left(\frac{N}{\rho}\right)^{\beta} \qquad (1)$$

where g = the damage;

N = the number of 18-kip equivalent single axle loads;

ρ = a constant which equals the number of 18-kip equivalent single axle loads when g = 1; and

β = a power which dictates the curvature of the damage function.

In the AASHO Road Test, damage was defined as

$$g = \frac{P_i - P}{P_i - P_t} \qquad (2)$$

where P_i = initial serviceability index;

P_t = terminal serviceability index; and

P = present serviceability index.

Values of ρ and β were found for each pavement section by regressing the logarithm of damage against the logarithm of 18-kip equivalent single axle loads. Further regression analysis determined how and depended upon the thickness and stiffness of each pavement layer.

This analysis led to the development of the AASHTO flexible pavement design system, first published as an Interim Design Guide in 1961 and issued as a revised edition in 1972 (2). A design equation similar to the AASHO equation was required for this study in order to predict reductions in pavement life caused by the oil field traffic. However, the AASHTO design equation is recommended for flexible pavements with a minimum asphalt surfacing thickness of 2 inches (3). As such, the researchers expected that the AASHO equation might not yield satisfactory estimates of pavement life for the thin surface-treated pavements under investigation in this study. With a structural number of approximately 1 to 1.5, the AASHO equation predicts a life for Texas pavements of less than 5000 18-kip equivalent single axle loads. However, this is considerably less than has been observed on "in-service" thin pavements in the state. For these reasons, it was decided to develop new performance equations for thin flexible pavements in Texas.

Texas Flexible Pavement Data Base

As the AASHO Road Test drew to a close, one of the strongest recommendations made by the Test Staff was that "satellite" studies should be made in other parts of the country in order to determine, with some objectivity, the real effects of subgrade and climate.

Texas participated in these studies with the establishment of a Flexible Pavement Data Base (4) containing detailed data on over 400 sections of pavement. The sections were chosen by a stratified random selection process which gave a reasonably uniform distribution of pavement type, age, materials, layer thickness, soil types, and climate. Of these 400 sections, 132 were on thin surface-treated pavements on farm-to-market type routes. These thin pavement sections were chosen for analysis in this study. They typically carry between 100 and 750 vehicles per day and were constructed with granular base courses ranging in thickness from 4 to 10 inches. All of these sections originially had a single or double seal surfacing, and many have received additional seal coat treatments.

Data collection of these sections started in 1972 when each section's full construction, maintenance, and traffic history was compiled. Riding quality (PSI), distress, and skid surveys have been made periodically on all sections since 1973. In most cases, five or six separate observations have been made on each section since the survey began.

During the distress survey, the following eight types of distress were observed: alligator cracking, transverse cracking, longitudinal cracking, rutting, raveling, flushing (or bleeding), failures (potholes), and patching. Each of these were rated for its area and severity of distress according to the distress identification manual prepared for the State of Texas (5).

Texas Pavement Distress Equations

In this study, a different form of damage function was assumed which produces a sigmoidal (S-shaped) curve, a shape that appears to reproduce long term pavement distress and performance better than does the assumed form of the AASHO Road Test damage function (6, 7, 8). The assumed form of the damage function for Texas flexible pavements is

$$g = \exp - \left(\frac{\rho}{N}\right)^{\beta}$$

where g = the normalized damage;

N = the number of 18-kip equivalent single axles; and

ρ, β are constants for each pavement section.

Space does not permit a full description of the analysis undertaken to produce the pavement performance equations used in this study. However, the procedure and typical equations have been published elsewhere (9). An overview of the procedure is as follows:

1. For each pavement section, the observed distress and serviceability index histories were analyzed to determine the values of and .
2. Regression analysis, using SAS (10) stepwise regression, was then performed to explain the variations between sections of the same pavement type. The final regression equations are as shown:

   ρ = f(climate, base thickness, subgrade properties, etc.)

   An example equation is given below for rutting area:

   $$\rho = [-0.1035 + 0.00549\ (AVT)\ 0.00670\ (D) - 0.0015\ (LL) + 0.00162\ (PI) + 0.00077\ (FTC)] \times 10^6 \text{ with } R^2 = 0.38$$

where AVT = average district temperature °F = 50°F;

D = thickness of flexible base course;

LL = liquid limit of subgrade soil;

PI = plasticity index of subgrade soil; and

FTC = average number of annual air freeze-thaw cycles.

Equations such as the above have been generated for each of the seven distress types and for present serviceability index. The correlation coefficients, R^2, of these equations, in general, range from 0.30 to 0.60. For a few distress types, particularly raveling and flushing, no acceptable models were found. In these instances, the mean values of ρ and/or β were used for predictive purposes.

Several runs were made to test the validity of predicting pavement performance with these regression equations. Such a prediction using the PSI equation is shown in Figure F-1 for Texas F.M. 556 in District 19, which is a section in the earlier described TTI flexible pavement data base. This section was reconstructed in 1969, and PSI measurements were made in 1974 thru 1977.

As can be seen from Figure F-1, the Texas regression equations fit the observed data very well. However, the AASHO Road Test Equation does not do a good job of predicting actual performance. The pavement depicted in Figure 4 has a Structural Number of approximately 1.0. The AASHO equation predicted a life until PSI = 1.5 of 5000 18-k ESALs. Under actual traffic levels, these axle repetitions would be achieved in the first six months of service.

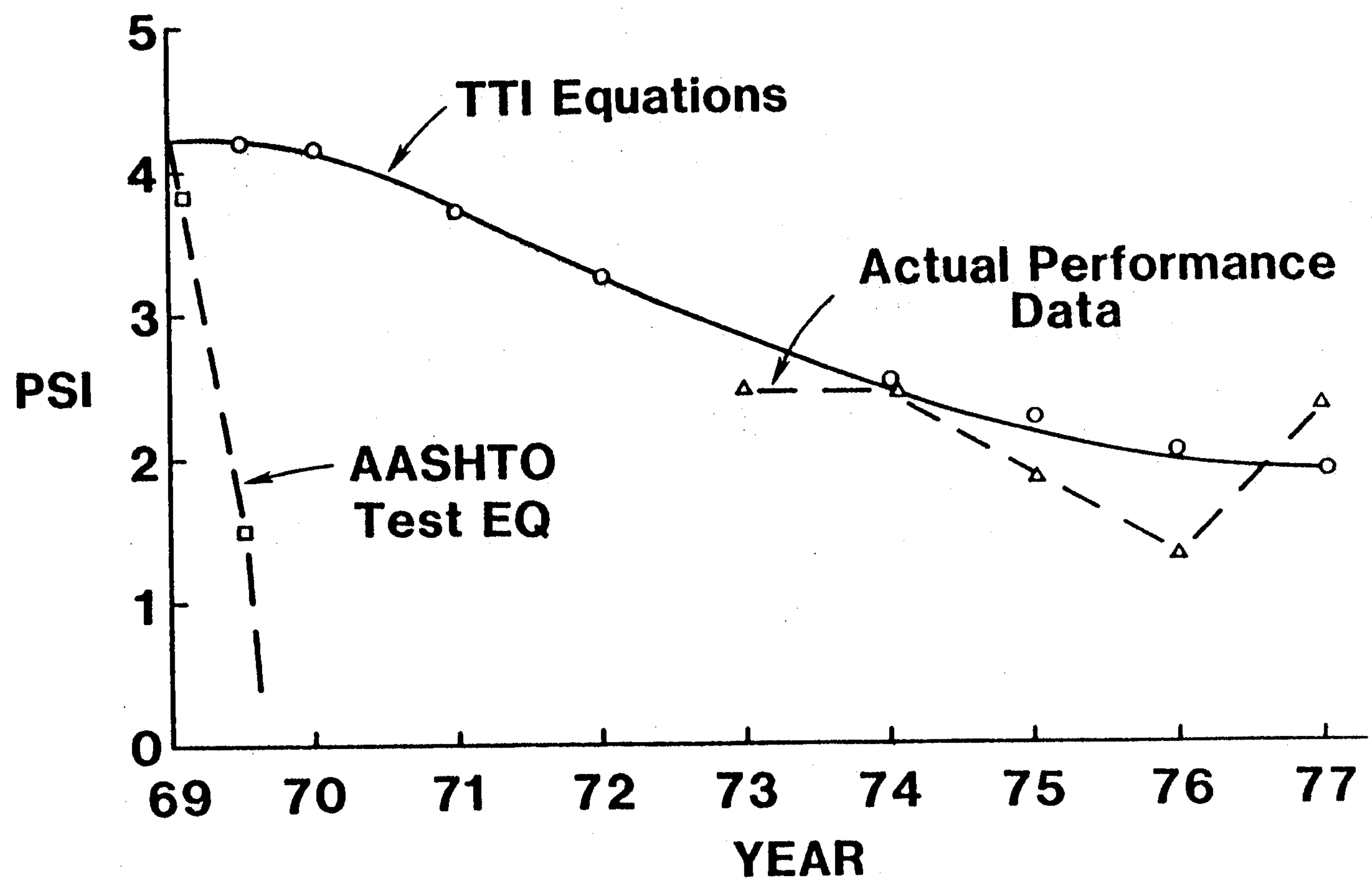

Figure F-1. Regression Equation Versus Actual Performance.

Pavement Score. In the AASHO Road Test, damage was defined in terms of reduction in present serviceability index (PSI). In this study, damage was made more general by applying it to distress as well as to a loss of serviceability index. Pavement condition (damage) was expressed in terms of a composite index which combines distress with loss in serviceability to produce a Pavement Score. Several states and agencies, including Arizona, Florida, Utah, and the U.S. Air Force, are using such a composite index (11). In general, these indices are used to determine which pavement sections are most in need of rehabilitation, the section with the lowest score being the one most in need of repair.

Texas also uses this pavement score approach (12). A pavement utility score (range 0-1) is calculated using the following equation. The final pavement score is equal to this utility score x 100:

$$\text{Pavement Utility Score} = U_{RIDE}{}^{a_1} \times U_{DIST}{}^{a_2}$$

Where U_{RIDE} = the riding quality utility score of range 0-1;

U_{DIST} = the visual distress utility score of range 0-1; and

a_1, a_2 are weighting factors on each utility score.

The visual distress utility score is further defined as

$$U_{DIST} = (U_{rut})^{b_1} (U_{ravel})^{b_2} (U_{flush})^{b_3} (U_{failures})^{b_4} (U_{allig.})^{b_5} (U_{long.})^{b_6} (U_{trans.})^{b_7}$$

Where each U_i value is determined from the visual inspection data and has a range of 0 to 1, the b_i are weighting factors.

Using the Texas definition of pavement score, if any single utility value becomes low, the Pavement Utility score will be low. For instance, if the highway's ride value falls to a critical level, then the pavement score will drop to a failure level. Alternatively, a pavement score may reach failure by a combination of distress types while still maintaining a high PSI. In Texas, new pavements have a pavement score of 100, and for surface-treated pavements, failure level is defined to be a pavement score of 35.

With the Texas Pavement Evaluation System (13), this pavement score is used to determine which strategy should be used to rehabilitate those pavements below minimum score. This is done by examining what are the principal causes of a low pavement score. For surface type distresses, (e.g., transverse cracking, raveling, or flushing), a seal coat would be recommended. For other load associated distress types, (e.g., severe rutting, alligator cracking, failures or loss in PSI), a sectional or full reconstruction would be recommended.

Oil Field Damage Program. A computer program was written to incorporate the Texas Pavement Distress Equations and pavement score concepts discussed above. The input required to make predictions of pavement performance are as follows:

- Average daily traffic.
- Percentage of trucks.
- Flexible base thickness.
- Subgrade Atterberg limits (PI, LL), obtained from construction records or county soil reports.

- Section maximum dynaflect deflection, obtained from a field observation or elastic layered analysis.
- Texas county number. For each of the 254 Texas counties, the program has stored the relevant climatic data, such as rainfall and average temperatures.

The program uses the input traffic data to calculate the expected 18-kip loading for the analysis period (10 years). It then uses the distress equations to predict pavement condition and hence pavement score for each year in the analysis period. When the pavement score reaches the failure level (35), the number of months to failure is calculated. Once failure has occurred, it is then possible to determine which distress types have caused the reduction in pavement life (Figure F-2) and, consequently, which rehabilitation strategy would be most appropriate.

The three curves illustrate the predicted change in pavement score for pavements with three different granular base thicknesses. The important points from this figure are (1) as expected, the thinner pavements require rehabilitation much earlier, and (2) the most significant distresses on the thin 4-inch pavements are rutting and loss of PSI, which would indicate that costly pavement strengthening is required. However, the 8-inch pavement only requires a seal coat.

The above described work has concentrated on the development of a predictive procedure to calculate distress values for any level of 18-kip equivalent single axle loads. The developed computer program has been

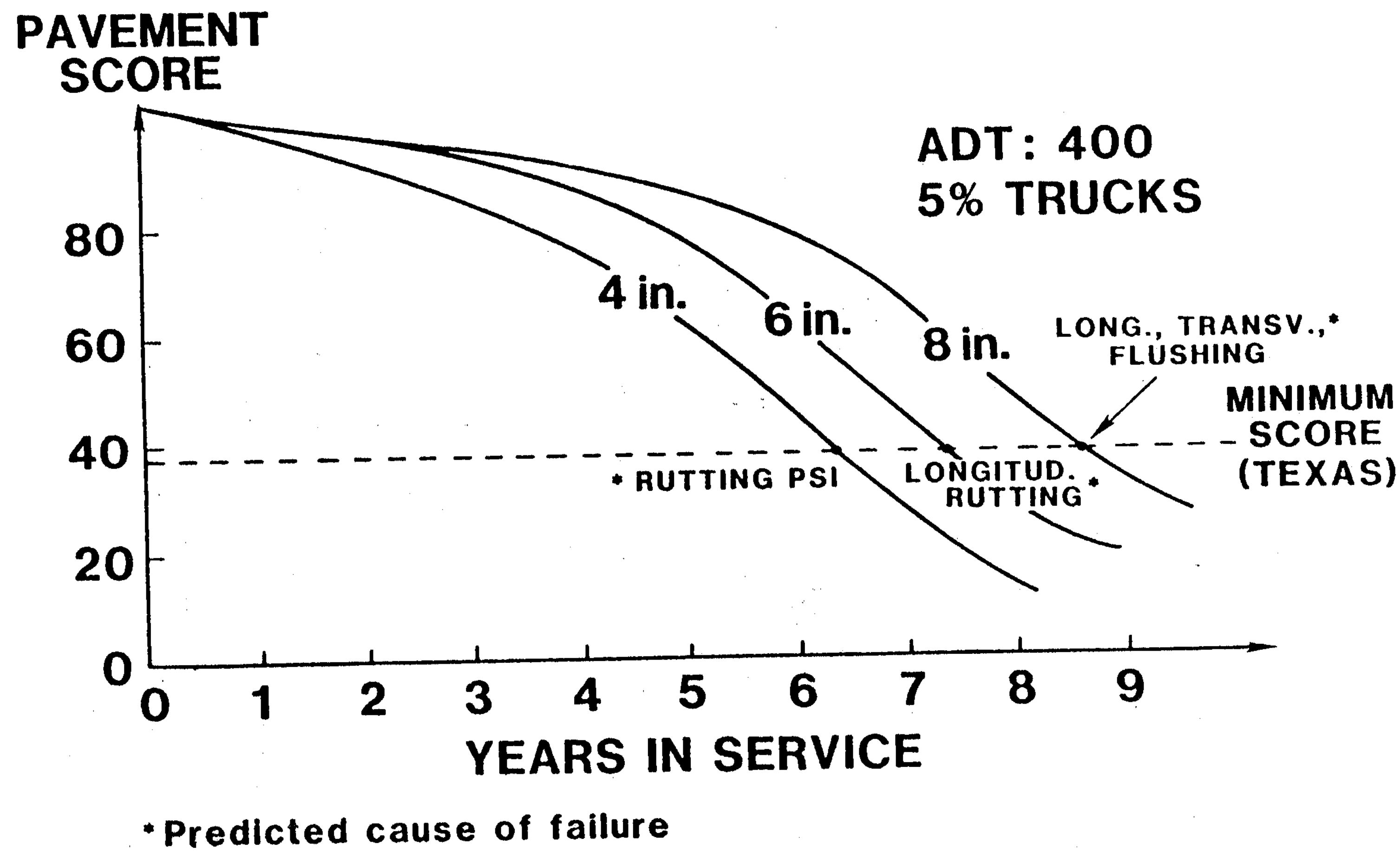

Figure F-2. Pavement Score Versus Time.

extended to permit analysis of what impact oil field development and servicing work will have on pavement performance. A case study describing this work is presented in the main body of this report.

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