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COOPERATIVE
RESEARCH

THE EFFECTS OF OIL FIELD DEVELOPMENT ON RURAL HIGHWAYS

RESEARCH REPORT 299-1
STUDY 2-10-81-299
EFFECT OF OIL FIELD DEVELOPMENT

THE EFFECTS OF OIL FIELD DEVELOPMENT ON RURAL HIGHWAYS

by

John M. Mason
Assistant Research Engineer

Mark J. Metyko
Graduate Research Assistant

N. J. Rowan
Research Engineer

Interim Report 299-1

Phase I--Identification of Traffic Characteristics, Pavement Serviceability and Annual Cost Comparison

Research Project 2-8-81-299

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Technical Advisory Committee

J. L. Beaird	District Engineer	District 11 - Lufkin
Robert R. Guinn	Engineer of Maintenance	SDHPT D-18
Kenneth Jones	Asst. Engr. Planning Service	SDHPT D-10
Gerald B. Peck	Engineer of Pavement Design	SDHPT D-8
Carl V. Ramert	District Engineer	District 13 - Yoakum
Carol D. Zeigler	District Engineer	District 17 - Bryan

Texas Transportation Institute

Jack Keese	MacDonald Professor
John M. Mason	Design & Implementation
Mark J. Metyko	Design & Implementation
Donald A. Maxwell	Design & Implementation
N. J. Rowan	Design & Implementation
Donald L. Woods	Design & Implementation

ABSTRACT

This study identifies oil field traffic and provides an estimate of annual cost associated with a reduced pavement serviceability. Identification of oil field traffic through site specific observation provides the basis for the investigation. The study includes a description of traffic during the development of an oil well, an estimate of reduced pavement service under these operating conditions, and an estimate of increased annual pavement cost due to oil well traffic.

The evolution of an oil well was photographically documented. This film documentation provided both a count of the number of axles and an identification of the physical characteristics of the vehicle. Axle weights were estimated using standard "W-Tables" for Texas rural highways. These estimates were converted to equivalent 18 kip single axle (18KSA) load repetitions.

Three main components of the analysis procedure include a pavement analysis, traffic analysis, and an estimate of traffic generated by an oil well. A resurfacing interval for a low volume bituminous surface treated pavement was determined by comparing the estimated cumulative traffic demand with the terminal pavement serviceability of the pavement section.

Comparison of the resurfacing intervals resulted in a reduced pavement life; a further comparison was made of the respective annual cost per mile of roadway. The difference between the estimated annual costs constituted a unit capital loss due to increased oil field traffic.

SUMMARY

The principal objectives of this study were to identify the primary phases of development of an oil well, describe the vehicle-mix during the development, and estimate an annual cost associated with a reduced pavement life. Five general activities comprise the sequential development. The activities include site preparation, rigging up, drilling, completion, and production. These primary stages are typical operations associated with the development of any oil well.

Traffic generated by the drilling of an oil well was recorded using photographic equipment. A total of 22,923 single axle repetitions were recorded by a 8mm movie camera. Peak volumes of up to 350 vehicle per day occurred during the rigging stages. Approximately 200 vehicles per day were present during the drilling phase. An average daily traffic of 150 vehicles per day was observed over the 73 day filming period. The average daily traffic is estimated at 50 vehicles per day once the production phase stabilizes.

Truck combinations made up 14 percent of the traffic mix during the filming period. Seven (7) percent of the total traffic mix consisted of the 3-S2 (tractor-semitrailer) type. Since actual axle weight measurements were not possible in this study, the observed truck counts were distributed across the axle load ranges complied by the State and listed in the axle load distribution tables ("W-Tables"). When converted to 18 kip single axle repetitions, 945 equivalent load repetitions were estimated in the design lane at the oil well site for the first year.

When the oil well traffic repetitions (945) are added to the intended use 18KSA load repetitions (445), 1390-18KSA load repetitions result after one year of service. The concept of pavement serviceability developed at the AASHO Road Test was then used to determine a reduction in pavement service life due to this increased traffic demand.

An increased annual cost of $12,500 per mile was estimated for a low volume (250 ADT), light duty (1/2 inch bituminous surface treatment on a 6 inch foundation base course) pavement section. This cost considered only a capital investment for a surface treated pavement and the cost to resurface the pavement for the intended use condition. The initial pavement placement cost was estimated at $61,000/mile and $8,600/ mile for a future seal coat surface treatment. It was further assumed that oil production would last at least 3 years. Final pavement design may actually necessitate the reconstruction of a higher type pavement to cost-effectively serve the increased traffic demand generated by ultimate oil field development.

Oil field traffic occurring simultaneously with a growing intended use traffic demand dramatically reduces the expected service life of low volume F.M. roadways. While the range of impact will vary among roadway locations, the increase in annual costs is a "separable cost" that can be attributed to oil field related traffic.

IMPLEMENTATION STATEMENT

Previous investigations of roadway pavement deterioration have addressed state-wide needs. None of the past research has considered the impact of localized oil field traffic. The basic problem is that existing methods used to examine roadway rehabilitation needs are deficient in assessing regional impacts created by specialized development. This study provides site specific information to help fill that void.

The results of this analysis serve as a prediction of roadway damage under similar conditions. Collected data are helpful to the engineer responsible for the maintenance and rehabilitation of the roadway. This study also provides the basis for estimating the effects of oil field truck traffic on a low volume farm-to-market (F.M.) roadways in other oil producing counties in Texas. This estimation demonstrates the need to anticipate the costs of rehabilitation, restoration, and resurfacing on rural highways carrying vehicles associated with the continual operation of oil fields.

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INTRODUCTION

The Problem

The oil embargo of the early 1970s dramatized the dependence of the United States on foreign oil production. Curtailment of crude shipments demonstrated that oil producing nations are a primary source of economic control. The unfavorable consequences of import reliance encouraged our country to strive for energy self-sufficiency. In an attempt to realize this independence, oil exploration is being accelerated, dormant wells rejuvenated, and trapped deposits reclaimed. These successful ventures have increased domestic production throughout the oil pool area of the Gulf States. The efforts have resulted in the enjoyment of the benefits of economic growth. An adverse effect of this intense activity, however, has been the physical destruction of the pavement surface on the highways serving the productive oil fields.

The highways and farm roads in the oil producing counties of Texas were not initially constructed to endure the impact of intense oil field truck traffic. A condition of persistent rehabilitation was not anticipated under normal operating situations, and a restoration cost was not normally accounted for in the planning of maintenance. Since typical traffic characteristics and usual vehicle distributions are not applicable to roadways carrying oil field traffic, there is a need to determine the definitive elements of the oil field traffic demand.

Traffic volume and vehicle weight are important contributing variables in the design of a roadway pavement. Once the types and number of trucks are established, various traditional methods may be used to determine an adequate and economic pavement thickness. Because the traffic on rural roads serving the oil fields is atypical, it is necessary to identify the characteristics of oil field equipment operating on the rural highway system. Identification of the vehicle mix and the associated pavement damage can be documented and ultimately used to assess the degradation of service.

Objectives

The goal of this research was to examine the effects of oil field traffic on Texas highways. In working toward this goal, several separate investigations are envisioned. Objectives of this particular study phase include:

1. Identification of the primary stages in the evolution of an oil well.
2. Description of the vehicle-mix during the development of an oil well.
3. Estimation of increased annual cost associated with reduced pavement serviceability on a low volume roadway.

State-of-the-Art

An extensive literature search, consisting primarily of a TRIS-ON-LINE (Transportation Research Information Service) computer search and a physical search of the literature published by the Transportation Research Board, federal, and state highway research agencies, did not reveal research that examined the specific effects of petroleum production on low volume roadways. There are, however, numerous studies that address other influencing and associated factors. Those related to this investigation fall into the following major categories:

- Vehicle Size and Weight Limitations
- Pavement Rehabilitation Analysis
- Pavement Management

Existing literature has addressed pavement damage costs on a generalized basis, usually relating statewide needs to a representative sample of traffic demands. The consensus of each report has been the need to collect and analyze data on a site specific level. If the recommended strategies and innovative computer models are to become more effective in predicting future conditions, future research must consider the influence of unique traffic demands. The findings of this research begin to satisfy these needs by examining the effects of oil field traffic on low volume roadways.

STUDY PROCEDURE

Identification of oil field traffic through site specific observation provided the basis for the overall analysis. The study procedure included a description of traffic during the development of an oil well, an estimation of reduction in pavement life under these operating conditions, an estimate of an increase in annual cost due to a reduced pavement serviceability. The investigation addressed the following basic considerations:

- Evolution of an Oil Well
- Description of Traffic Characteristics
- Pavement Serviceability/Annual Cost Analysis

Evolution of an Oil Well

The transportation related activity occurring during the evolution of an oil well is established through a process of continuous monitoring. Monitoring included daily site visits to talk with servicing companies and the field representative. The evolution of the well was documented with traffic counts of vehicles entering and leaving the site. Specific information was provided using a super 8-mm camera to photograph vehicles as they entered or left the site. The camera, actuated by a pneumatic tube, signaled individual frame exposures. This procedure provided a count of the number of axles and an identification of vehicle characteristics. A historical evolution of the oil well site is reported based on conversations held at the site with field representatives and on the supplemental photographs taken during the duration of the project.

Texas Railroad Commission. Ultimate development of an oil field is regulated by the Texas Railroad Commission and basically consists of a series of individual production wells. Optimum production of the resources, consistent with the geological structure of the reservoir, is also controlled by the Commission (1). The control is primarily enforced through spacing requirements for wells. The rule, identified as "Rule 37. Statewide Spacing Rule," is partially cited as follows (2):

> (A) (1) No well for oil, gas or geothermal resource shall hereafter be drilled nearer than twelve hundred (1200) feet to any well completed in or drilling to the same horizon on the same tract or farm, and no well shall be drilled nearer than four hundred sixty-seven (467) feet to any property lease line, or subdivision line; provided that the Commission, in order to prevent waste or to prevent the confiscation of property, may grant exceptions to permit drilling within shorter distances than above prescribed when the Commission shall determine that such exceptions are necessary either to prevent waste or to prevent the confiscation of property.

Exceptions to the rule can be filed with proper justification. The aforementioned distances are considered minimum distances to provide standard development on a pattern of one (1) well to each forty (40) acres in areas where proration units have not been established (2). Pooling of two or more small tracts to form a drill site in connection with a program of uniform well-spacing can also be authorized by the Commission. This method is used to prevent waste, protect correlative rights, and to avoid unnecessary wells (3).

The Commission also determines the allowable production of oil for each month. Each field in the state is given a "Maximum Efficient Rate" (MER) of production (3). The primary effort of the Commission is to conserve and allocate the amount of oil produced. Avoiding rapid depletion or oversupply of crude assures the state of maximum benefits that can be derived through reasonable regulation.

Operational Stages. Five general activities comprise the sequential development of a production well. These include:

1. Site Preparation
2. Rigging-Up
3. Drilling
4. Rigging-Down/Completion
5. Production

Stage 1 through 4 will exist whether the well is abandoned or continues into production. As such, the impact of any drilling operation will place additional traffic on the surrounding roadways.

Study Site. Each fundamental stage of oil well activity develops unique traffic characteristics. Specifically, the vehicle mix comprises a disproportionate frequency of large vehicles, as compared to typical operating conditions on many farm-to-market roads. In order to identify the types of vehicles serving an oil field area, a potential oil well site was sought.

Following several conversations, permission was granted by a private investor to monitor the activity at an oil well site. The oil well site is located on the Kurten Field Annex, Bryan, Texas. Fortunately, the entrance to the secured site occurs at the terminus of an existing roadway, where there is no through traffic, and the site cannot be accessed from any other point in the surrounding area. As such, the study site was virtually access controlled. A location map is shown in Figure 1 and schematic plan of the study site is depicted in Figure 2.

Two servicing companies occupy the properties adjacent to the immediate terminus of the existing roadway. Occasional vehicles traverse the terminus of the roadway to access their respective properties. These trips are minimal and were "adjusted out" in the analysis procedure.

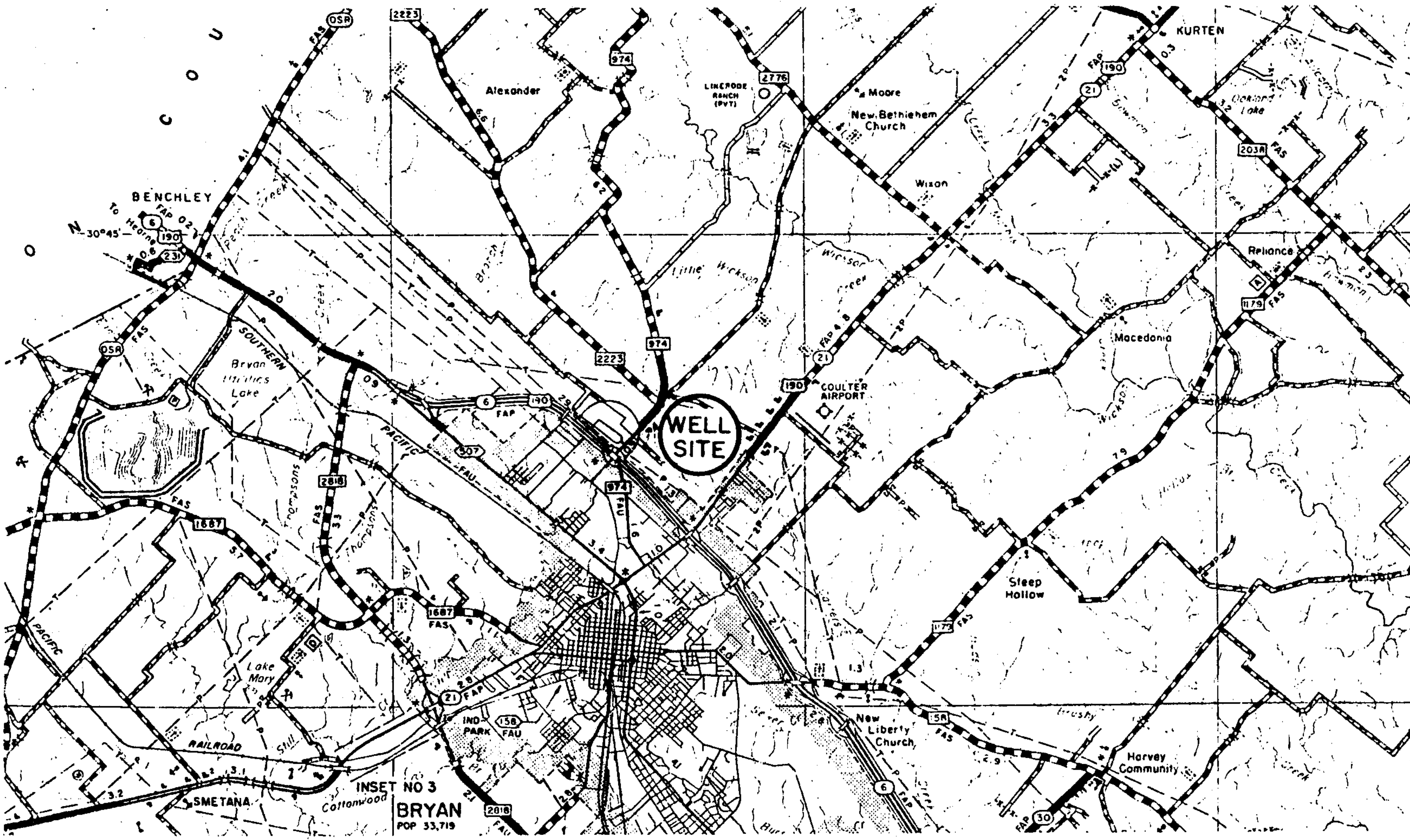


Figure 1. Location Map for Oil Well Site.

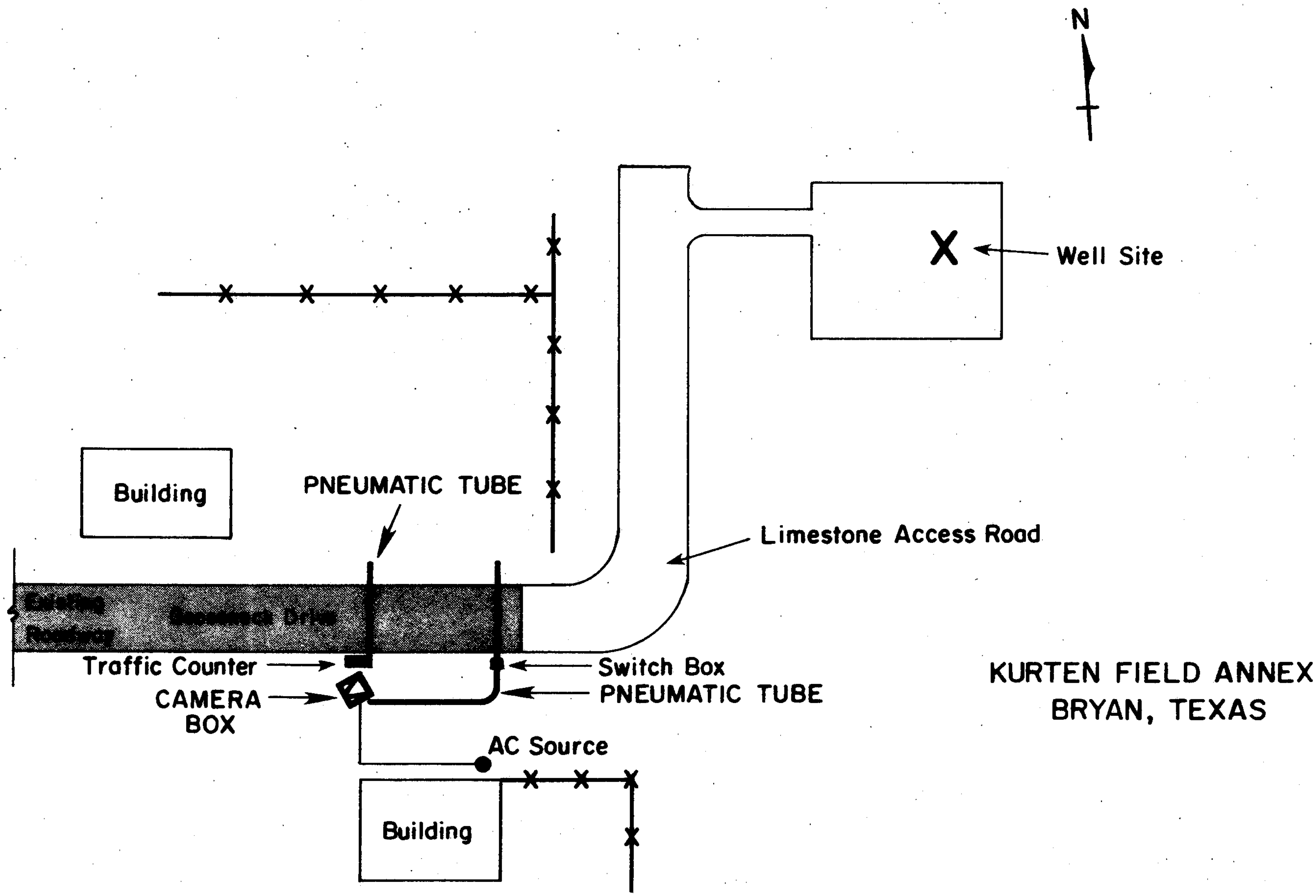


Figure 2. Schematic Plan of Study Site.

The well site is situated in a rural area on open pasture land. After removing overburden and topsoil, a 6-inch limestone base was placed and compacted to serve as the access road. This crushed stone access road abuts the terminus of an existing bituminous surface roadway.

Site observations began on April 13, 1981 with the clearing and grubbing operation. A "Super 8 mm" camera was installed on April 20, 1981 with the arrival of the first limestone gravel haul truck. Natural production began on May 28, 1981 with a final depth of hole at approximately 8500 feet. Filming continued for a total period of 73 days. The entire photographic record was supplemented by continuous site visits by the researchers.

Description of Traffic Characteristics

Description of vehicle traffic during the development of an oil well was provided through site specific observations. The basic intent of this task was to answer the following questions:

1. What types of vehicles are used at an oil well site?
2. What is the frequency of travel?
3. When are these vehicles used?
4. What are the axle configurations of the trucks serving the well site?

Monitoring Equipment. The data collection equipment is portable, easily assembled, weatherproof, reuseable and required a relatively low initial investment. Approximately $500.00 was expended to purchase all items. The individual components include:

1. Camera
2. Power Source
3. Housing Unit
4. Pneumatic Tube/Air Switch
5. Pneumatic Tube/Traffic Counter

Daily Site Visits. The study site was visited on a daily basis to confirm security and the operation of the equipment. A site observation form was used to maintain consistency in reporting developmental changes. This form is included in the Appendix. Photographic color slides were taken of the various stages of development. Vehicles, equipment and accessories, and site conditions were also photographed. If the situation permitted, conversations were held with the drilling supervisor and field service representatives. In many instances, the working environment was not conducive to casual conversation.

Interviews. Several attendant servicing companies were subsequently interviewed. These meetings provided supplemental information regarding type of service, frequency of travel, vehicle characteristics and material transported. A prepared questionnaire was used to record responses and general comments. The questionnaire is included in the Appendix. In most cases, the answers to the various questions resulted in mere approximations and estimates. The interviews primarily aided in distinguishing the stages of operations and the purpose of the service company.

Data Reduction. The data collected at the oil well site were compiled using a Timelapse 3410 Super 8 projector equipped with a remote control single frame adaptor. On each visit to the site, the observer signaled the camera and recorded the date and time of day.

Since the camera operated 24 hours a day, each new day (approximately 6:00 a.m.) was obvious to the film observer. Although the site entrance was not illuminated, the configuration of vehicles entering at night was distinguishable. Headlight, sidelight, and taillight position provided enough evidence to establish a general vehicle classification. Since a frame is exposed upon each axle application, a valid count of axles was possible and daily record of vehicle travel was established.

The various vehicle classifications were tabulated on a standard form. This form is included in the Appendix. A "self-check" was created by noting whether the vehicle was entering (I) or leaving the site (O). Each day's tabulation was summarized and checked for logical completion, i.e., any vehicle entering the site must eventually leave, either the same day or later. Finally, the various stages of development were determined based on the daily log.

Vehicle Classification. The vehicles observed entering and leaving the site were classified according to axle combination. Table 1 lists the vehicles defined according to axle combination and corresponding vehicle type code. The vehicle type code is used on the film reduction tabulation and eventually for assigning vehicle load weights to the various axle configurations. Coding of the vehicle type generally follows the AASHTO classification for axle combinations; however, for additional segregation and specialized cases, the PU-1 and PU-2 coding was developed.

Reliability of Filmed Observations. A "total count" traffic counter was installed at the site as a means to check the operation of the camera. The traffic count values were used to "rough" check the reduced film counts. Nine rolls of film were used to monitor the traffic. A detailed check was made of the seventh roll of collected data. This film recorded oil well traffic from May 30, 1981 to June 12, 1981. The reduced film data indicated 3,431 axle repetitions and the traffic counter recorded 3,544 axle repetitions. The counter record exceeded the camera count by 3.29 percent. While minor camera failure may have occurred during this time period, the difference between the counts was negligible and therefore recording capability of the camera was considered acceptable.

Frequency of Travel During Observation Period. Because minor descrepancies may exist with the collected data, only the axle repetitions actually verified by the developed film were used in the analysis. Any vehicles not associated with the oil well were excluded from the record. The study site was virtually access controlled and therefore non-oil well related traffic was minimal.

A total of 22,923 total single axle repetitions were recorded by the camera. Axle repetitions were highest during both the rigging up and rigging down phase of the oil well development. Cumulative percent of axle repetitions increased rather uniformly during the first 50 days of development; the rate of accumulation decreased during the production stage.

A total of 10,353 vehicles were recorded by the camera. The average daily traffic over the 73 days of camera data was approximately 150 vehicles per day. Specific information on the daily traffic pattern is shown in Figure 3. Peaking characteristics of 300-350 vehicles per day occurred in the rigging up and rigging down stages. During the actual

Table 1. Vehicles Defined According to Axle Combination and Corresponding Vehicle Type Code.

Axle Combinations	Vehicle Type Code For Axle Combination
Single-Unit Vehicles	
Passenger car	PC
2 Axle-4 Tires (Pickup Truck)	PU-1
2-Axle-6 Tires (Pickup Truck)	PU-2
2-Axle, 6 Tires	SU-1
3-Axle	SU-2
Multi-Unit Vehicles	
2-Axle Tractor, 1-Axle Semitrailer	2-S1
2-Axle Tractor, 2-Axle Semitrailer	2-S2
3-Axle Tractor, 1-Axle Semitrailer	3-S1
3-Axle Tractor, 2-Axle Semitrailer	3-S2
2-Axle Tractor, 3-Axle Semitrailer	2-S3
3-Axle Tractor, 3-Axle Semitrailer	3-S3
2-Axle Truck, 1-Axle Balance Trailer	2-1
2-Axle Truck, 2-Axle Full Trailer	2-2
2-Axle Truck, 3-Axle Full Trailer	2-3
3-Axle Truck, 2-Axle Full Trailer	3-2
3-Axle Truck, 3-Axle Full Trailer	3-3
3-Axle Truck, 1-Axle Balance Trailer	3-1
2-Axle Tractor, 1-Axle Semitrailer, 2-Axle Full Trailer	2-S1-2
3-Axle Full Trailer, 1-Axle Semitrailer 2-Axle Full Trailer	3-S1-2

drilling process volumes of up to 200 vehicles per day were recorded. It should be noted that this magnitude of volume is generally considered as the typical average daily traffic on a low volume F.M. roadway serving **only its intended use traffic!**

A review of the calendar days indicated that Saturdays generally followed the same trend as weekday traffic. On Sundays, the traffic decreased to approximately 100 vehicles per day. During the production stages, weekend traffic appears minimal.

Figure 4 provides a frequency distribution of vehicles per day with a central tendency between 100 and 200 vehicles per day. The cumulative percent of vehicles (Figure 5) depicts a rather uniform rate of traffic activity between the rigging up stage and completion phase. A slower uniform rate is experienced in the production stage.

Distribution of vehicles by code type classification is shown in Figure 6. Passenger cars and pick-up trucks comprised approximately 86 percent of the total vehicles mix; truck combinations approximately 14 percent, with almost 7 percent including the 3-S2 (semi-trailer) type. This total truck percentage is almost three times the anticipated truck percentage on low volume farm-to-market roadways.

Percent of trucks classified by vehicle type code is illustrated in Figure 7. Multi-unit vehicles made up 68 percent of the truck combination with the semi-trailer combination (3-S2 or >) comprising almost half of the truck population. These axle combinations contributed to the majority of the axle load repetitions. The number of trucks is further catgorized by commodity in Figure 8, and the percent

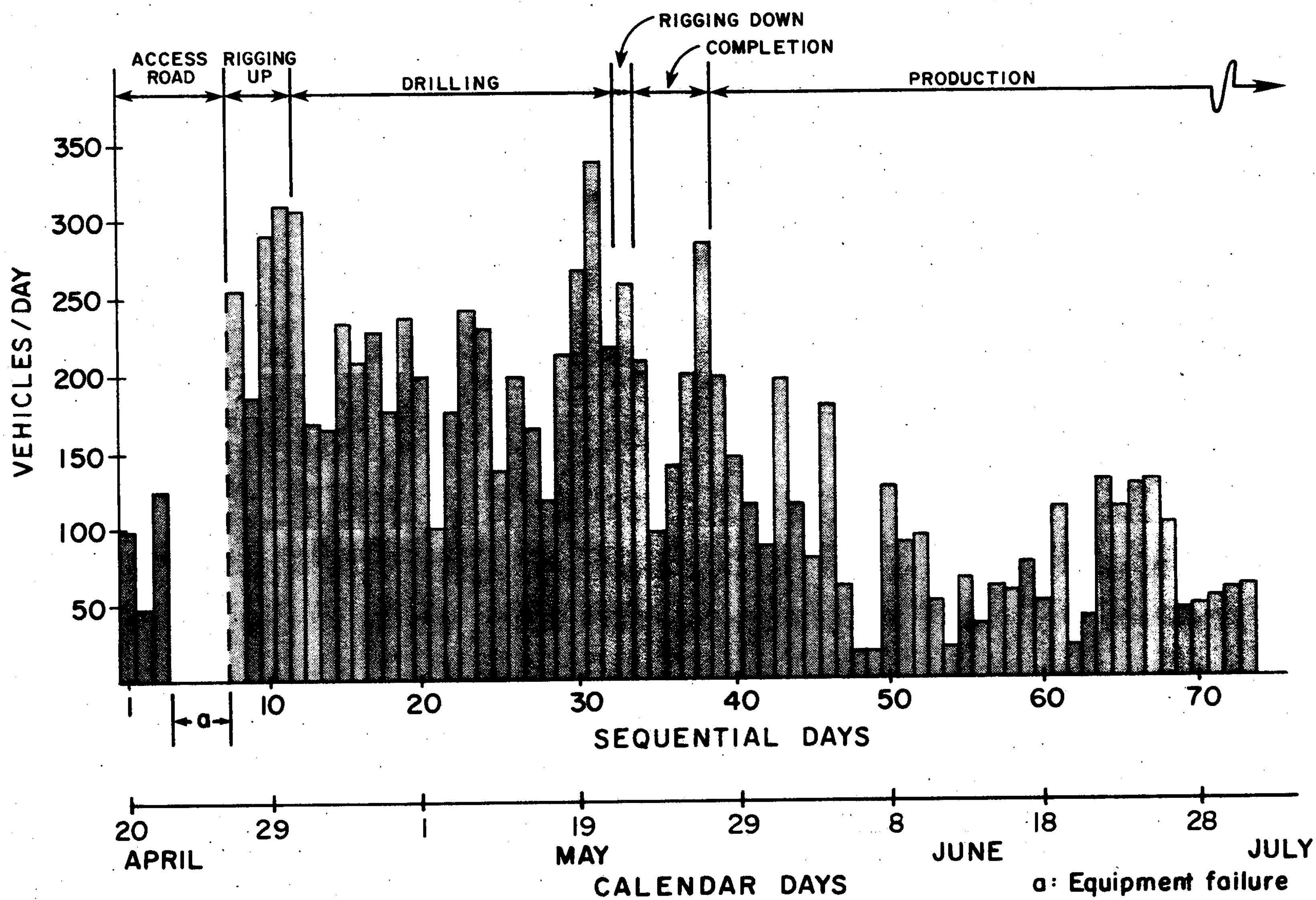


Figure 3. Daily Vehicle Histogram.

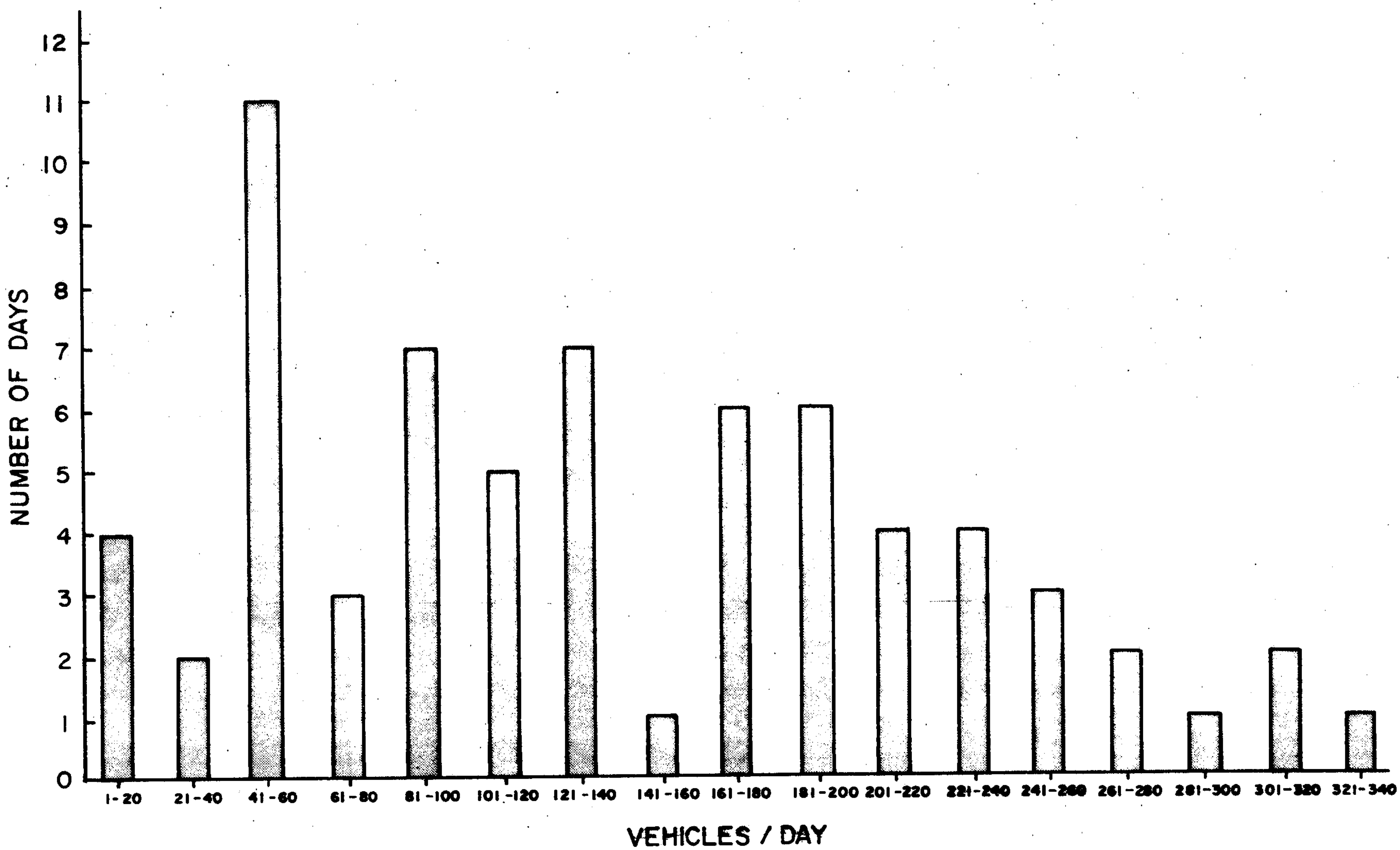


Figure 4. Frequency of Vehicles/Day.

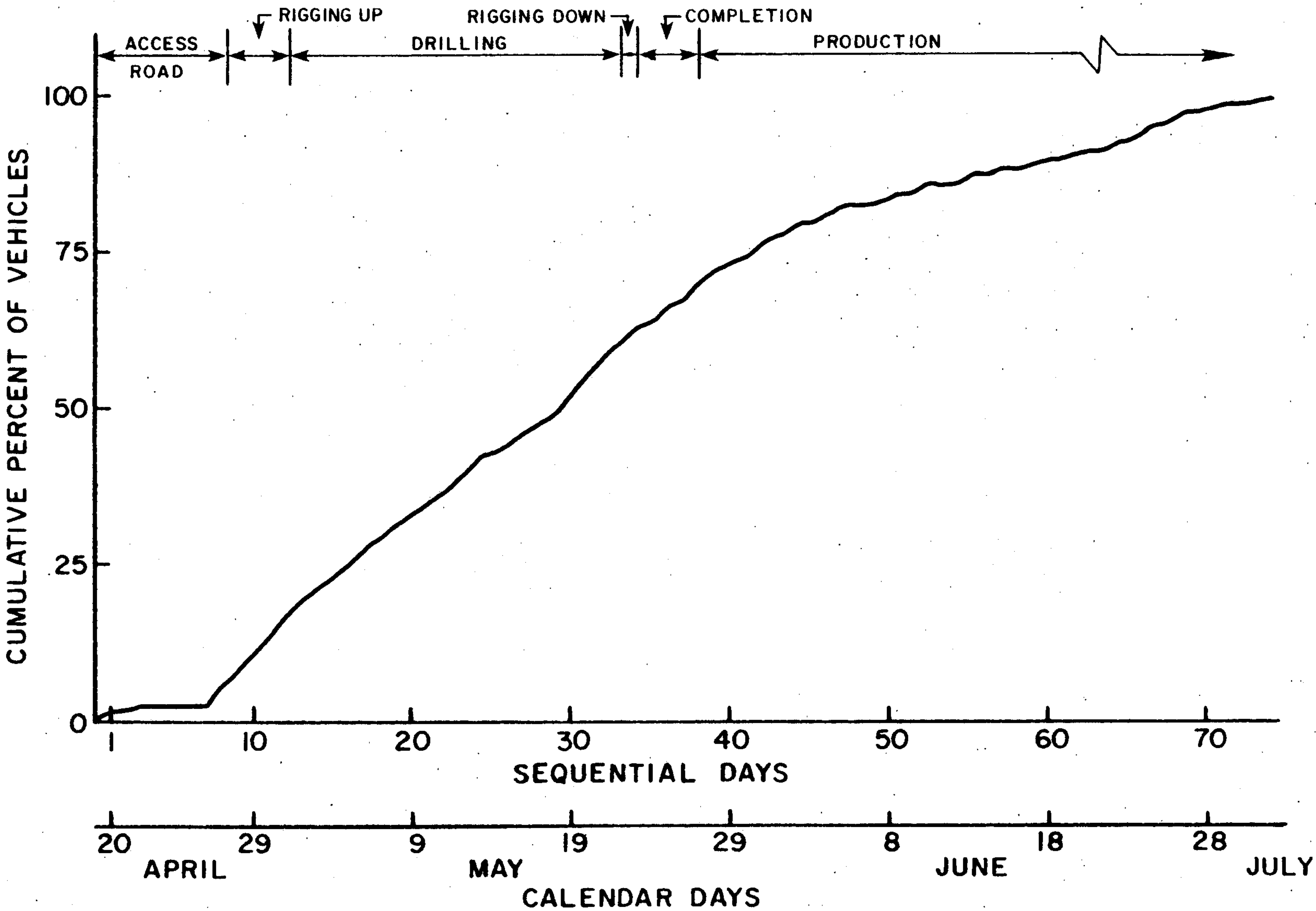


Figure 5. Cumulative Percent of Vehicles.

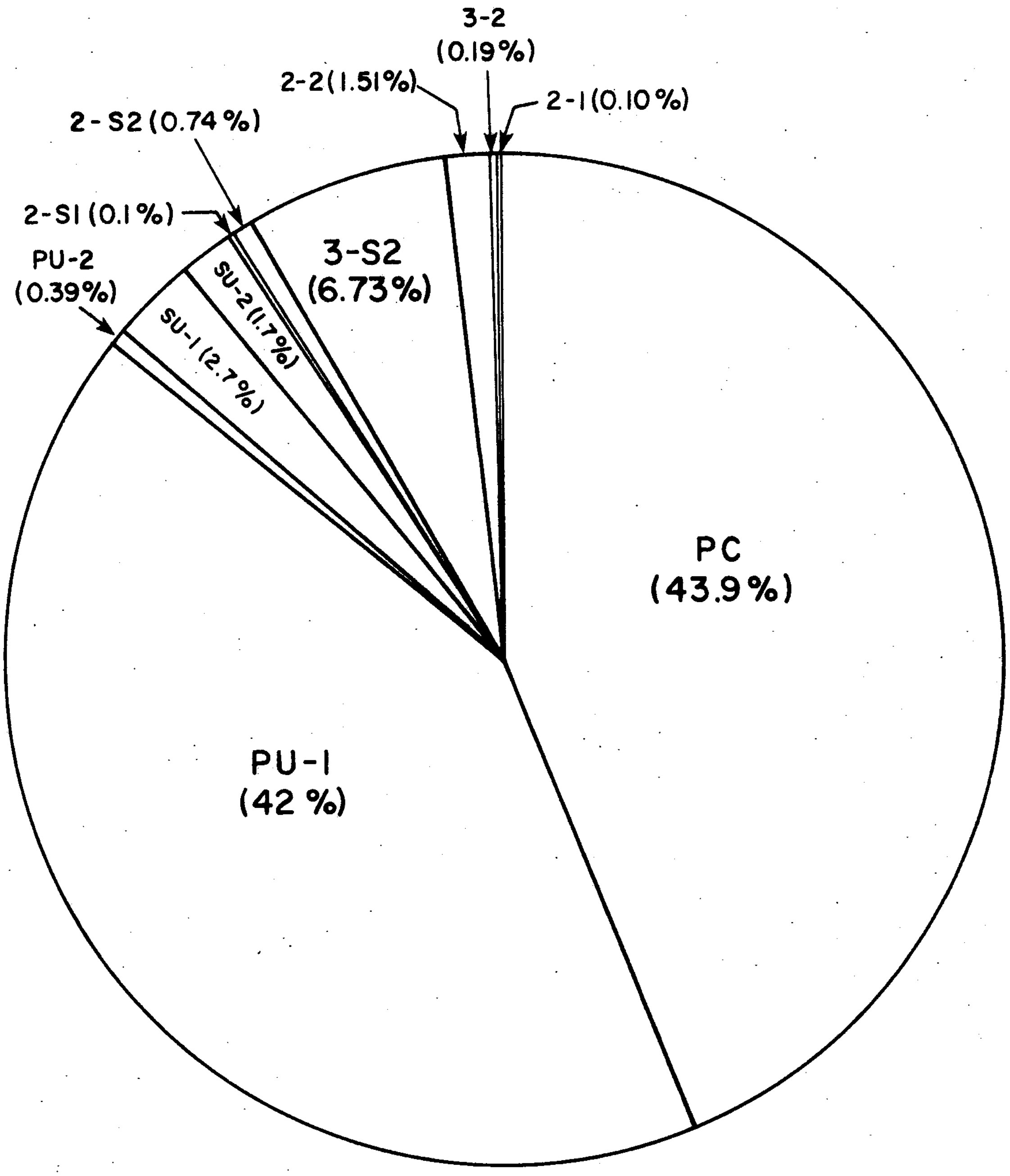


Figure 6. Percent of Vehicles by Code Type Classification.

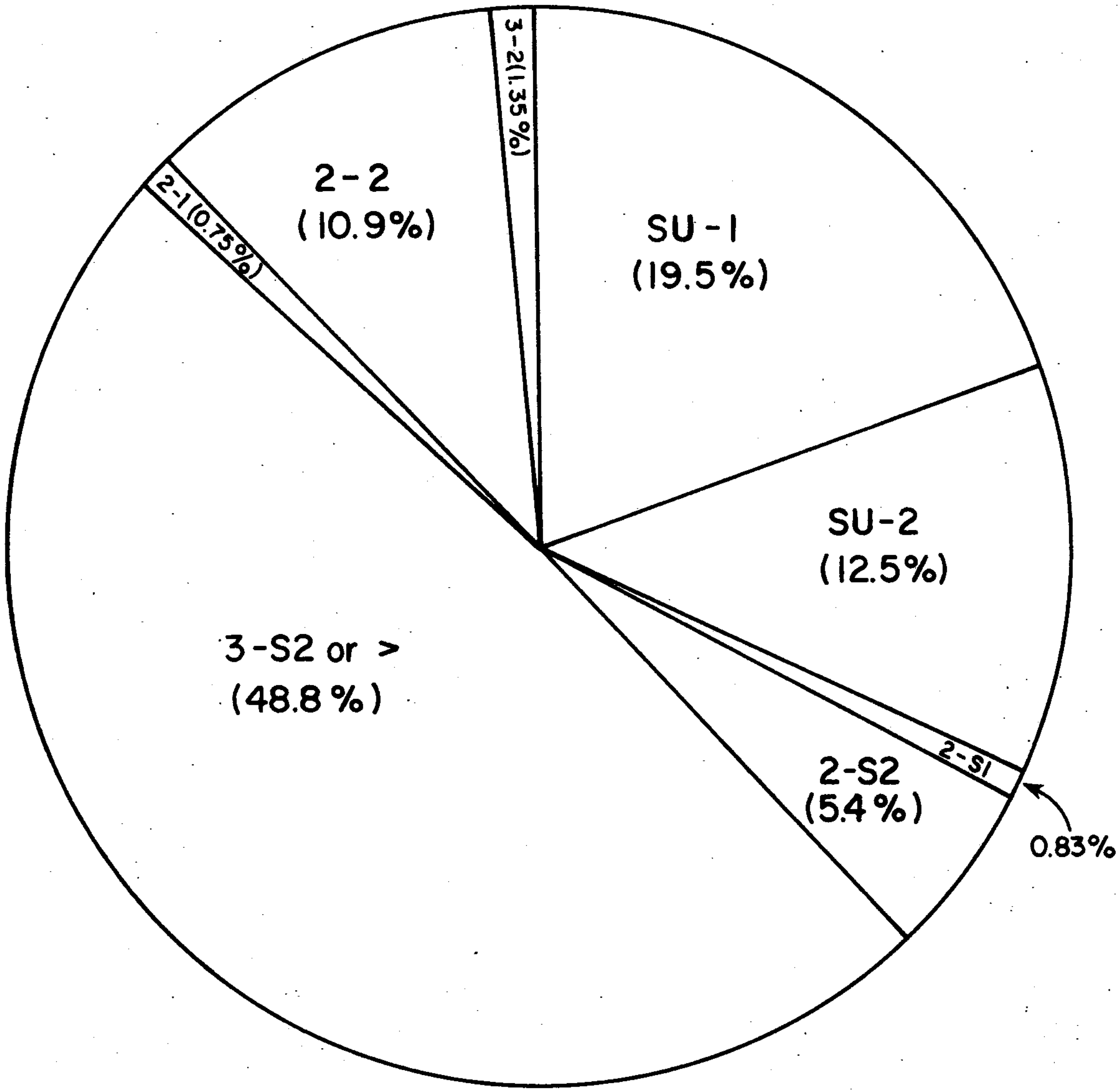


Figure 7. Percent of Trucks by Code Type Classification.

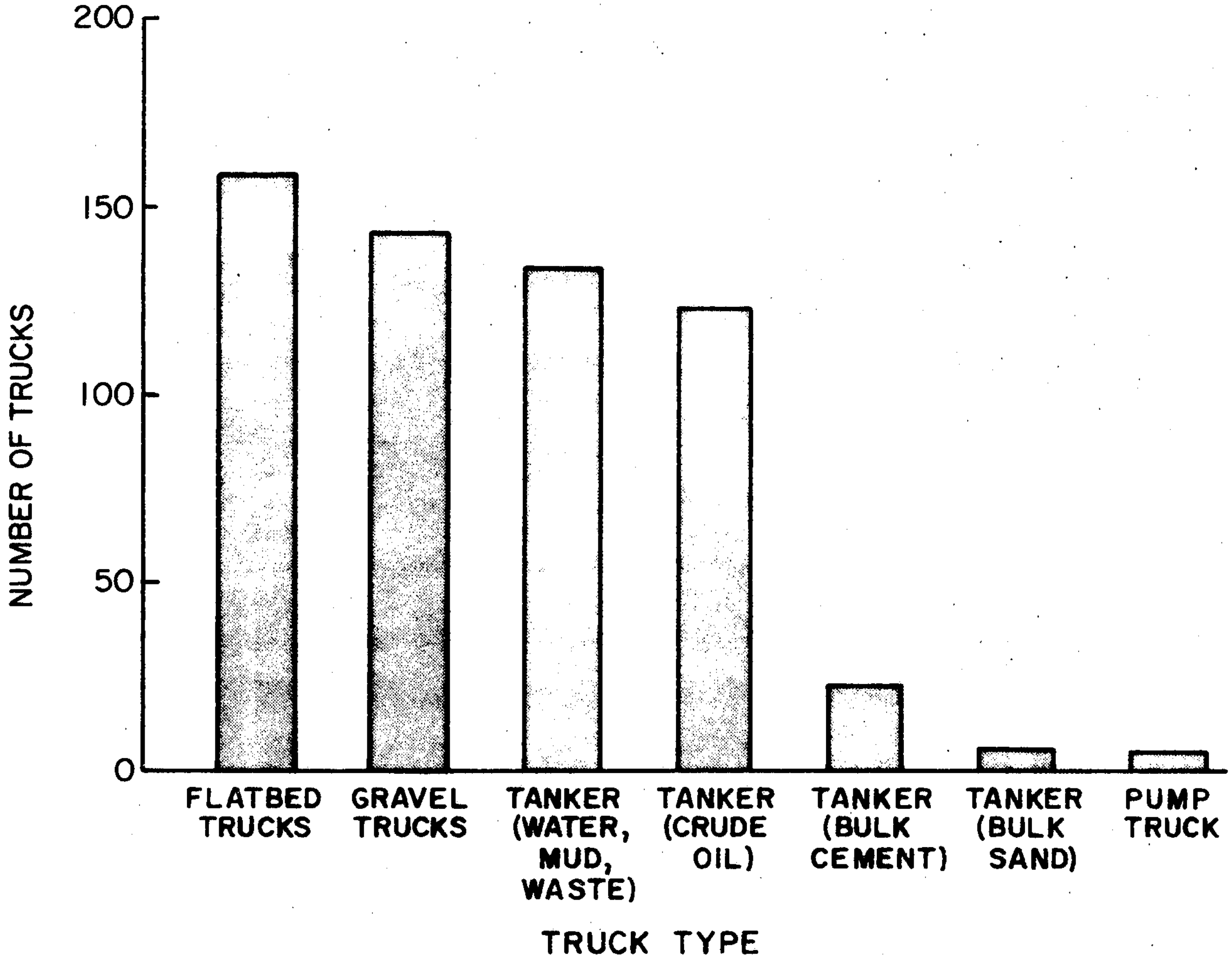


Figure 8. Number of Trucks by Descriptive Classification.

distribution of each descriptive type is shown in Figure 9. These trucks are basically of the 3-S2 type and were approximately evenly distributed. The specialized truck combinations comprised 6 percent of the multi-unit vehicles.

The aforementioned observations must be cautiously viewed as being a conservative estimate of well drilling traffic. The well site monitored in this study was developed with no special drilling problems. No intense "fracturing", "acidizing", or "reworking" was necessary as is required of some wells. This hole was considered a "clean find" and resulted in a textbook drilling sequence. The findings of this study should be viewed with these considerations in mind.

Traffic Characteristics Beyond Observation Period. In order to collect other data, the camera and road tubes were moved to a new location. Traffic beyond the 73 day observation period consisted mainly of tankers (3-S2 type). Conversations with the fuel hauler and lease owners indicated that 1 or 2 trips per day are anticipated during the production phase.

A review of the film during the early stages of production, site visits, and interviews indicates the approximately 52 tankers visited the site over 34 days. Therefore, an estimate of 1.5 (3-S2) trucks per day is used to project the remaining 292 days of a full year. This results in an estimated 876 trucks entering and leaving the well site beyond the observation period.

Pavement Serviceability/Annual Cost Analysis

The axle repetitions of the heavy vehicles occurring during the development of an oil well were used to estimate a reduction in pavement service. Since traffic volume and vehicle weight are important contrib-

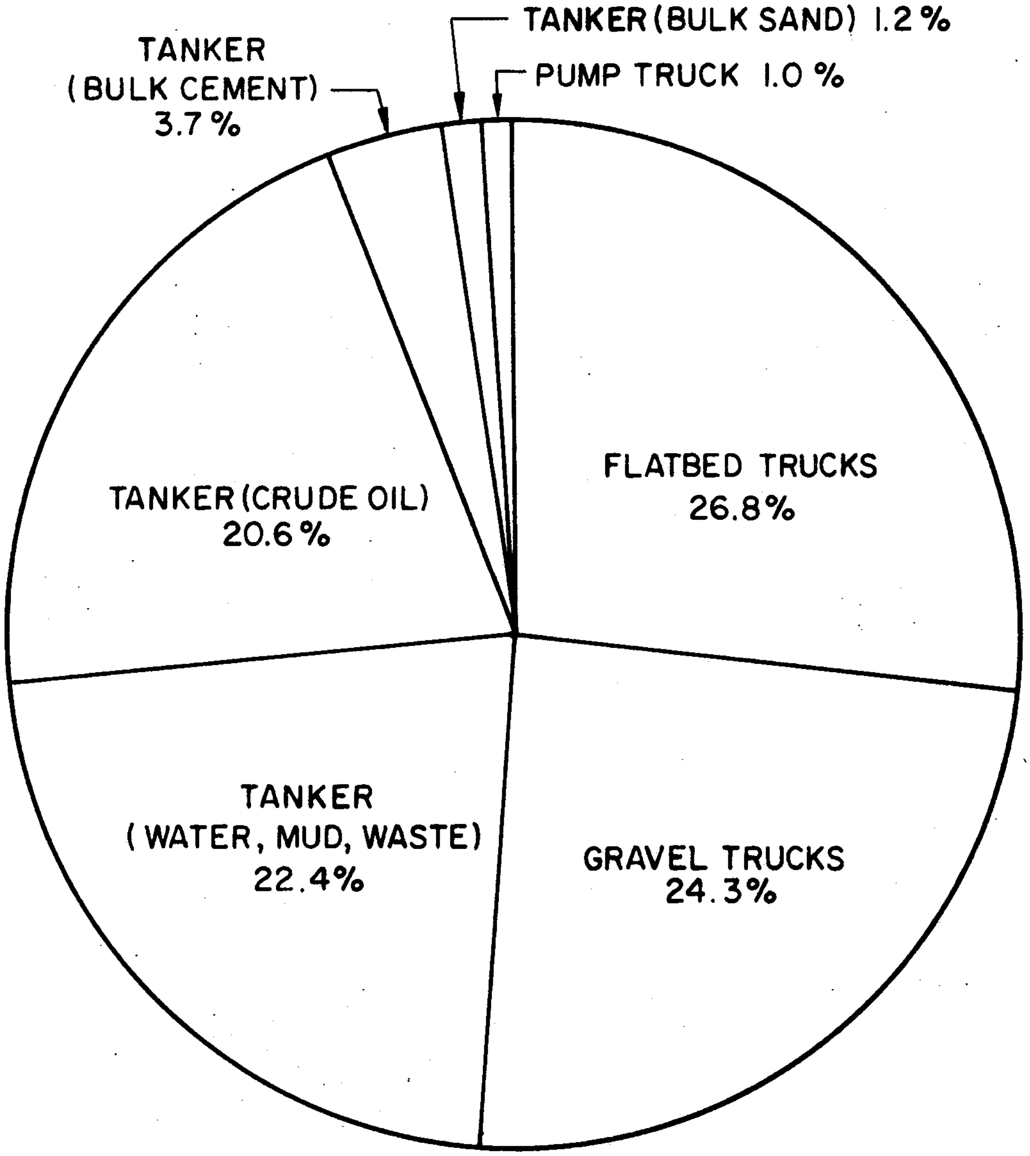


Figure 9. Percent of Trucks by Descriptive Classification.

uting variables in the life of a roadway pavement, the analysis of pavement serviceability was used to assess the degradation of service due pavement failure.

A concept of "separable costs" was then used to estimate an annual expenditure due to oil field traffic. The attempt was to segregate costs directly attributable to the use of the roadway by a special group of vehicles. It is assumed that these costs would not be incurred if those vehicles did not use the roadway.

Since the time intervals between resurfacing varies considerably among pavement structures, a comparison of cost is difficult unless the costs can be compared to an identical time base. A common and traditional base of comparison in the highway field is the calculation of an equivalent uniform annual cost. The annual cost so found, if charged at the end of each year for the assumed life span, will repay the initial investment with interest.

The result of the annual cost comparison is an estimate of a separable cost above an intended expediture. Basically, the Department accepts, and would anticipate, an annual cost associated with the roadway serving its intended purpose. The difference between an anticipated annual cost, and the cost due to increased traffic demand, is the one attributable to oil field traffic.

An extension of the findings of this investigation is the ability to demonstrate the potential impact of additional wells drilled in an oil field area. The documentation and identification of the unique vehicle demands serve as a prediction of roadway degradation under similar conditions. Anticipation of the impacts may justify alternative design and maintenance procedures used in an oil field area.

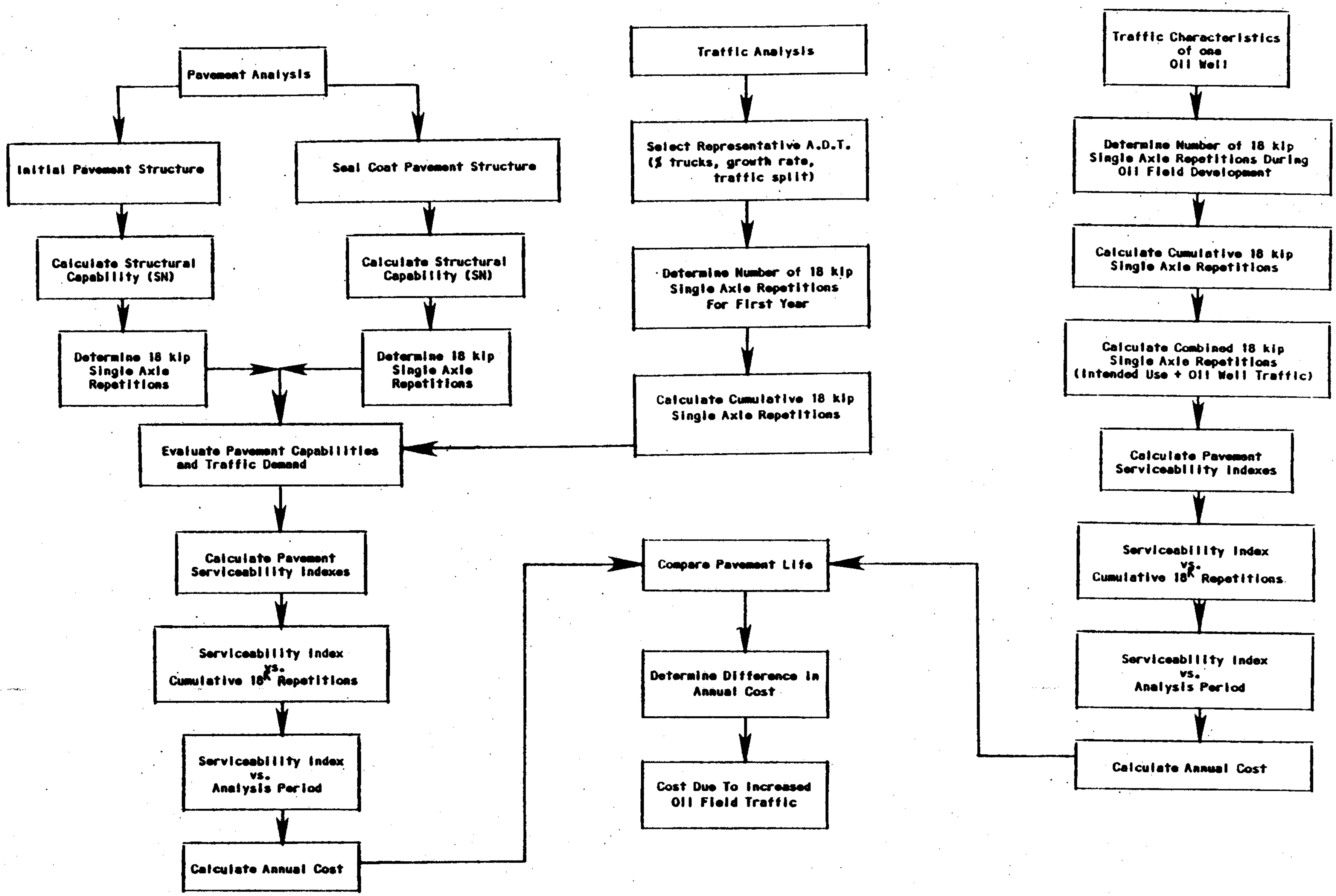
ANALYSIS

The effect of oil field traffic on a low volume roadway was evaluated based on pavement serviceability. Having determined the traffic characteristics associated with an oil well, a comparison of annual costs to provide a "suitable" pavement surface was made. The comparison was between the intended design traffic volume, and the atypical oil field demand volume.

Three main components of the procedure included a pavement analysis, traffic analysis, and an estimate of traffic generated by an oil well. The conceptual framework is shown in Figure 10. The structural capabilities of a bituminous surface treated pavement were determined for an intended use situation. Similarly, the projected traffic demand was estimated for a typical low volume F.M. roadway. Respective 18 kip single axle (18KSA) repetitions were calculated for each analysis. The rehabilitation interval for a bituminous surface treated pavement was then determined. This was done by comparing the estimated cumulative traffic demand with the terminal pavement serviceability of the intended use pavement section.

The traffic characteristics of a single oil well served as the basis for defining the anticipated traffic attracted to a new well. These characteristics were used to estimate the associated axle load repetitions. The number of 18 kip single axle repetitions were calculated for an oil well. A cumulative 18KSA value was established for the well served by the F.M. road over the analysis period. Since a

Figure 10. Flow Chart of Analysis Procedure.



F.M. road would continue to serve both the intended use traffic and the attracted oil field traffic, the 18KSA intended use repetitions were combined with the 18KSA oil field traffic to represent the total 18KSA applications over a study section. The general serviceability of the existing pavement, under this combined impact, was examined over the same analysis period as the intended use condition.

Comparison of the resurfacing intervals over the design period for the two 18KSA repetitions (intended use and intended use plus oil field traffic) indicated a reduction in pavement life; therefore, a further comparison was made of the respective total annual costs. The difference between the estimated total annual costs constituted a unit capital loss due to increased traffic, namely, oil field truck traffic. This loss of value represents a consumption, or expenditure of capital, that must be borne by the Department and the general public. These costs consider only the cost of an initial pavement structure and seal coat resurfacing, and do not include costs associated with a complete pavement reconstruction, vehicle damage, or accidents.

The basic considerations of the analytic procedure included the following:

- Pavement Analysis - Intended Use
- Traffic Analysis - Intended Use
- Oil Well Traffic Analysis
- Pavement Serviceability
- Reduction in Service Life
- Annual Cost Comparison

Data collected at the study site and conversations with Department personnel were used in the development of this procedure. Occasional assumptions and estimates were necessary in lieu of specific information.

Pavement Analysis - Intended Use

Farm-to-market roads in Texas are built for an intended use characterized by low traffic volumes and light weight vehicles. These F.M. roads are typically constructed as a bituminous surface treated pavement. As such, this analysis assumed a 1/2-inch crushed stone bituminous surface course (seal coat), over a 6-inch foundation base course (local run), representative of an initial pavement structure. A second 1/2-inch seal coat then served as the intended rehabilitation.

Pavement Serviceability. The objective of the pavement analysis was to determine the 18KSA repetitions sustained over the intended use period. One traditional procedure for defining a pavement's ability to serve traffic is the calculation of a Serviceability Index (4). The serviceability-performance concept is the basic philosophy of the AASHTO Guide for the design of pavement structures, and is used as the basis for this analysis. Pavements are designed for the level of serviceability desired at the end of the selected traffic analysis period, or after exposure to a specific total traffic volume.

Selection of the terminal serviceability index (p_t) is based on the lowest index that will be tolerated before resurfacing or reconstruction becomes necessary (5). The specific values for p_t vary with the type (class) of roadway. A terminal serviceability index of 2.5 is suggested as a guide for design of major highways, and 2.0 for highways with lesser traffic volumes (5). A lower terminal serviceability value of 1.5 was chosen at the AASHO Road Test for the bituminous surface treatments. In this analysis, a standard value of 4.2 is assumed as the initial serviceability, and 1.5 as the terminal serviceability index for a F.M. roadway surface.

Structural Capability. The flexible pavement design equation developed at the AASHO Road Test was used in this analysis. The pavement design expression follows:

$$\log W_{t_{18}} = 9.36 \log (SN+1) - 0.20 + \frac{\log[(p-p_t)/(p-1.5)]}{0.40 + [1094/(SN+1)^{5.19}]} + \log \frac{1}{R} + 0.372(S_i-3.0) \quad (1)$$

The assumed input values for the various structural parameters represent generalized site conditions. It was beyond the intended scope of this study to take physical measurements on the basic factors. However, the assumed values were based on sound engineering judgement. Selection of the specific values was made in such a manner so as to not bias the capabilities of a particular pavement structure. In each case, the magnitude of the value conforms to the intended use of a typical F.M. roadway.

Determination of 18KSA Repetitions. The flexible pavement design equation (1) was used to express the number of 18KSA load repetitions required to reach a predefined terminal serviceability level (p_t). Assumed input values for both the initial pavement structure and the overlay seal coat are shown in Table 2. In this analysis, the pavement cross section was considered the given; therefore, the pavement structure was analyzed to estimate sustained 18KSA repetitions. Following this determination, a comparison was made between the sustained 18KSA repetitions and the anticipated traffic volumes.

Using the AASHTO equation (1), 1420 - 18KSA load repetitions were determined for the initial pavement structure. An additional 2180 - 18KSA load repetitions were calculated considering a seal coat rehabilitation. An estimated total 3600 - 18KSA load repetitions was considered the anticipated capacity of a typical F.M. road under intended use conditions.

Traffic Analysis - Intended Use

The pavement analysis was based on a constructed typical pavement section; the traffic analysis assumed a low traffic volume condition. In each procedure, the level of analysis corresponded to an anticipated intent of an F.M. roadway.

Table 2. Assumed Input Values for Initial and Seal Coat Pavements.

Variable	Initial Structure	Seal Coat
a_1[a]	0.20	0.20
a_2[b]	0.14	0.14
a_3	----	----
D_1	0.5	1.0
D_2	6.0	6.0
D_3	----	----
SN	0.94	1.04
p	4.2	4.2
p_t	1.5	1.5
R	1.25	1.25
S_i	5.0	5.0

[a] Low stability - surface course.
[b] Crushed stone.

Traffic Conditions. An ADT of 250 was selected and considered representative of a low volume farm-to-market traffic condition.

Additional assumptions of traffic conditions follow:

- o Percent Heavy Trucks: 1%,
- o Annual Traffic Growth: 3% per year, and
- o Traffic Split: 50/50 on design lanes.

Determination of 18KSA Repetitions. The following calculations demonstrate the procedure used in estimating the annual 18KSA repetitions on the assumed F.M. roadway.

Number of Trucks = 250 vehicles/day x .50 (vehicles in the design lane) x 365 days/year x .01 (percent trucks)

= 456 trucks in the design lane per year.

In order to calculate the annual 18KSA repetitions on a low volume F.M. roadway, some estimate of the distribution of axle loads must be assumed. One technique followed in the structural design of a roadway pavement is to rely on Department loadometer data. These data are complied on an annual basis at various loadometer locations throughout the state. The results are tabulated as "W-Tables" (See Appendix).

The percent distribution of various truck types is shown in Table 3. These values are derived from the 1980 W-5 tables for all rural roads in Texas. Table 4 lists the estimated number of trucks in each truck type classification for the intended use traffic analysis. These

Table 3. Percentages of Trucks for 1980 on Rural Texas Highways.

Truck Types	Total Trucks Weighed[a]	Percent (Rounded)
Single-Unit		
2 Axle, 6 Tires	535	14
3 Axle or More	139	4
Tractor-Semi-Trailer		
3 Axle	43	1
4 Axle	191	5
5 Axle or More	2646	68
Semi-Trailer-Trailer		
5 Axle	88	2
6 Axle or More	8	-
Truck and Trailer[b]		
3 Axle	79	2
4 Axle	79	2
5 Axle or More	79	2
Total Vehicles Weighed	3887	100

[a]From W-5 Tables for 1980

[b]Probable number combinations

Table 4. Determination of Number of Trucks in Each Class for Intended Use Traffic Analysis.

Truck Types	1980 Percentages	Number of Trucks
Single-Unit		
2 Axle, 6 Tires	14	64
3 Axle or More	4	18
Tractor-Semi-Trailer		
3 Axle	1	5
4 Axle	5	23
5 Axle or More	68	310
Semi-Trailer-Trailer		
5 Axle	2	9
6 Axle or More	-	-
Truck and Trailer		
3 Axle	2	9
4 Axle	2	9
5 Axle or More	2	9
Total	100	456[a]

[a] Total number of trucks in the design lane per year.

trucks were distributed across appropriate axle load ranges by their respective percentage distribution. The percent distributions are found in the W-4 Tables (See Appendix). The number of trucks in Table 4 were mutliplied by the respective precentage in each weight class for each truck combination. A summary of the distribution of single and tandem axle loads for the intended use analysis can be found in the Appendix. The result of this calculation was the number of axle repetitions for each weight category. The factors to convert the various weight classes into 18KSA equivalents are also listed in the Appendix. The calculation of 18KSA loads for the intended use is demonstrated in Table 5. This total represents the estimated 18KSA repetitions during the first year of intended use service.

An estimate of the projected 18KSA repetitions is determined assuming an annual traffic growth rate of 3 percent. The projected repetitions are presented in Table 6.

Evaluation of Pavement Analysis and Traffic Analysis - Intended Use. The pavement serviceability was calculated independent of the intended traffic demand. Results of the pavement analysis indicated that 1420-18KSA load repetitions should be sustained by the initial pavement structure; an additional 2180-18KSA load repetitions are possible after the first seal coat rehabilitation. An estimated total 3600-18KSA load repetitions was considered the anticipated capacity of a typical F.M. road under the intended use condition.

The traffic analysis computations indicated that an estimated 445 - 18KSA load repetitions can be assumed during the first year of service. Cumulative 18KSA repetitions for an 8 year period are shown in

Table 5. Determination of 18KSA Loads--Intended Use Analysis.

Axle Loads in Pounds	Representative Axle Load (5)	Equivalency Factor[a]	No. of Axles[b]	Equivalent 18KSA
Single Axle				
Under 3,000	2,000	-	8	-
3,000 - 6,999	5,000	0.005	114	0.6
7,000 - 7,999	7,500	0.025	55	1.4
8,000 - 11,999	10,000	0.070	356	24.9
12,000 - 15,999	14,000	0.320	49	15.7
16,000 - 18,000	17,000	0.795	16	12.7
18,001 - 18,500	18,000	1.000	3	3.0
18,501 - 20,000	19,000	1.285	8	10.3
20,001 - 21,999	21,000	1.980	4	7.9
22,000 - 23,999	23,000	2.670	3	8.0
24,000 - 25,999	25,000	3.710	0	0
26,000 - 29,999	27,000	6.085	0	0
30,000 or Over	-	-	0	0
		SUBTOTAL	616	84.5
Tandem Axle				
Under 6,000	4,000	-	0	0
6,000 - 11,999	9,000	0.008	81	0.6
12,000 - 17,999	15,000	0.030	120	3.6
18,000 - 23,999	21,000	0.110	91	10.0
24,000 - 29,999	27,000	0.360	141	50.8
30,000 - 32,000	31,000	0.670	63	42.2
32,001 - 32,500	32,000	0.760	20	15.2
32,501 - 33,999	33,000	0.870	44	38.3
34,000 - 35,999	35,000	1.140	58	66.1
36,000 - 37,999	37,000	1.470	32	47.0
38,000 - 39,999	39,000	1.875	20	37.5
40,000 - 41,999	41,000	2.435	12	29.2
42,000 - 43,999	43,000	3.120	6	18.7
44,000 - 45,999	45,000	3.860	0	0
46,000 - 49,999	48,000	5.130	0	0
50,000 or Over	-	-	0	0
		SUBTOTAL	688	359.2
		TOTAL	1304	443.7
			SAY	445

[a] P_t = 1.5, Flexible Pavement (6)
[b] From distribution table for intended use analysis

Table 6. Cumulative 18KSA Repetitions -- Intended Use Analysis.

End of Year,n	Growth Factor[a] $(1+i)^{n-1}$	Annual 18KSA Repetitions, Design Lane	Cumulative 18KSA Repetitions
1	1	445	445
2	1.03	458	903
3	1.06	472	1375
4	1.09	485	1860
5	1.13	503	2363
6	1.16	516	2879
7	1.19	530	3409
8	1.23	547	3956

[a] i=.03

Table 6. These cumulative values are plotted in Figure 11. Given the assumptions of the traffic analysis, a load of 1420-18KSA is accumulated after approximately 3.2 years, and a load of 3600-18KSA is accumulated after approximately 7.5 years. These values represent the respective initial life and first seal coat life of a typical F.M. roadway for its intended use condition.

Conversations with the Department indicate a practical verification of the pavement life estimated by this analysis. A 2 to 4 year period is generally considered the anticipated life for the initial pavement section of a low volume F.M. roadway. The first seal coat can extend the pavement life to approximately 8 years before additional rehabilitation is necessary. Since the prediction of pavement life is not finite, the results of the analysis appear to be in suitable agreement for the intended use condition.

Oil Well Traffic Analysis

Traffic characteristics of a single oil well served as the basis for defining the anticipated traffic generated by a new well. The number of 18 kip single axle repetitions was calculated using the reduced film data plus an estimate of activity during the production phase. A cumulative 18KSA value was established for one year (365 days). Since a typical F.M. road must serve both an intended use traffic and the added oil field traffic, the combined effect of both conditions was

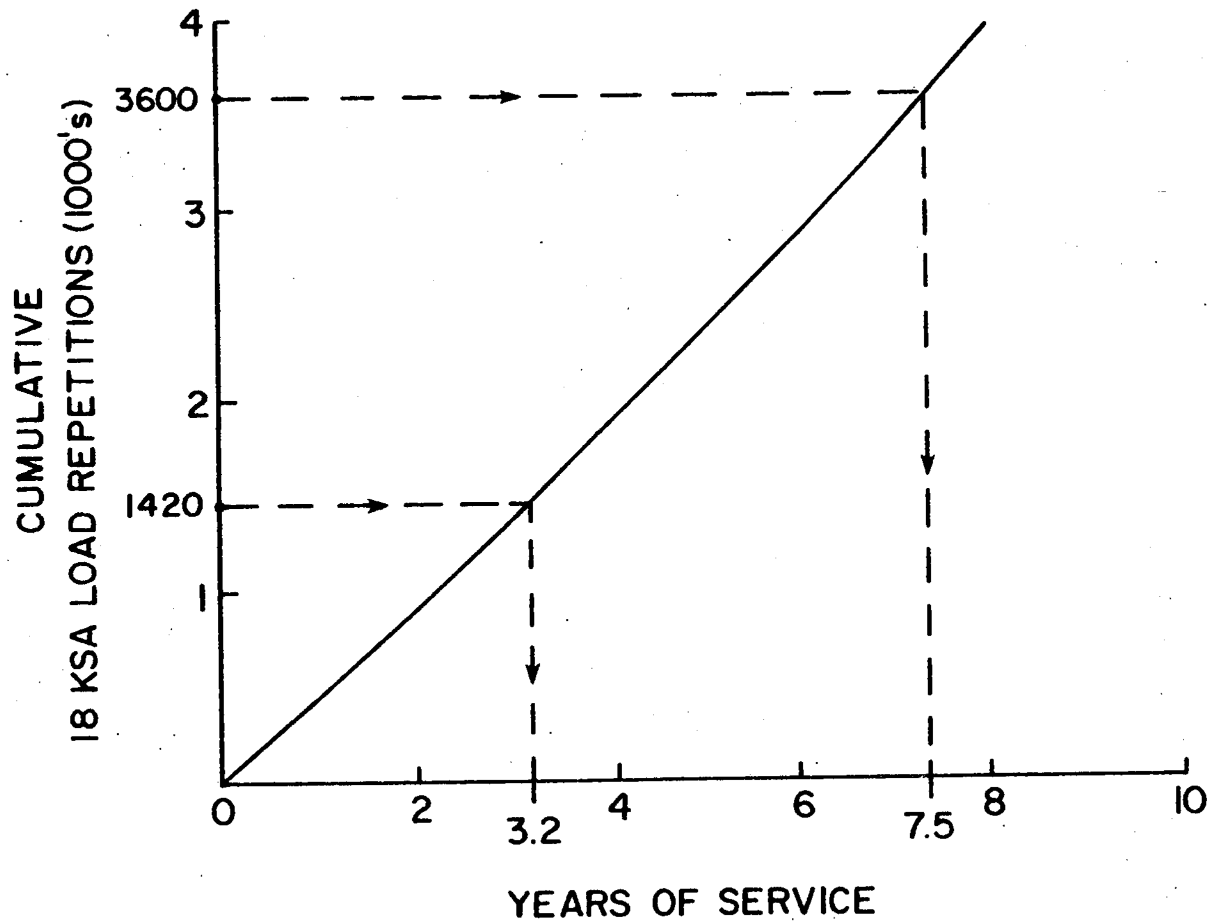


Figure 11. Cumulative 18KSA Load Repetitions versus Years of Service.

used to determine the annual 18KSA load repetitions applied to the F.M. road pavement section. An estimate of the resulting pavement serviceability was then calculated. The following demonstrates the computational procedure.

Determination of 18KSA Repetitions. A summary of the number of trucks in each vehicle class is provided in Table 7. One immediate observation is that the one well attracted 1102 trucks in the design lane. This is approximately 2.4 times the estimated 456 trucks in the design lane per year assumed in the intended use condition.

The observed truck counts were distributed across the axle load ranges by their respective percentage distribution. To maintain consistency in the analysis, the percent distribution again corresponded to the values found in the W-4 Tables (see Appendix). This approach prevented biasing the oil truck traffic, since actual axle weights were not taken. The method was considered "conservative" because it assumed the axle weight distribution of oil trucks was typical of all other truck combinations operating on the Texas highway system. Comparison and interpretation of the findings are on the same basis, and therefore protected. Further, the axle weight method is conservative because many oil field vehicles must secure overweight permits to legally operate on the highway. It is suspected that many of the axle loads actually exceed the allowable legal load limits.

A summary of the distributions of single and tandem axle loads for the 73 day observation period and 292 day projection of the oil well traffic are found in the Appendix. The 292 day truck projection is based on the 1.5 trip/day average previously described. The total single and tandem axle load distributions are listed in Table 8. These axle loads were converted into 18KSA equivalents. The determination of

Table 7. Summary of Truck Counts for Each Vehicle Classification.

Vehicle Type	Vehicle Code	Number of Axles	Number of Trucks (365 Days): 73 Days Observation	Number of Trucks (365 Days): 292 Days Estimate
Single Unit				
	SU-1	2	259	0
	SU-2	>3	166	0
Tractor + Semitrailer				
	2-S1	3	11	0
	2-S2	4	71	0
	>3-S2	>5	647	876
Semitrailer + Trailer				
	2-S1-2	5	0	0
	3-S1-2	>6	0	0
Truck + Trailer				
	2-1	3	10	0
	2-2	4	145	0
	>3-2	>5	18	0
			1327	876[a]

TOTAL NUMBER OF TRUCKS OBSERVED AND ESTIMATED = 2203/1102 In Design Lane

[a] 1.5(trips/day) x 2(Enter + Exit Site) x 292 days = 876

Table 8. Total Number of Axles in Each Road Class for 365 Days.

Axles Loads (Pound)	Number of Axles		
Single Axle	73 Day Distribution	292 Day Distribution	365 Days
Under 3,000	31	0	31
3,000 - 6,999	469	438	907
7,000 - 7,999	191	0	191
8,000 - 11,999	917	438	1355
12,000 - 15,999	163	0	163
16,000 - 18,000	33	0	33
18,001 - 18,500	8	0	8
18,501 - 20,000	15	0	15
20,001 - 21,999	10	0	10
22,000 - 23,999	7	0	7
24,000 - 25,999	0	0	0
26,000 - 29,999	0	0	0
30,000 or Over	0	0	0
Tandem Axle			
Under 6,000	0	0	0
6,000 - 11,999	196	876	1072
12,000 - 17,999	327	0	327
18,000 - 23,999	214	0	214
24,000 - 29,999	396	0	396
30,000 - 32,000	138	0	138
32,001 - 32,500	45	0	45
32,501 - 33,999	95	876	971
34,000 - 35,999	133	0	133
36,000 - 37,999	73	0	73
38,000 - 39,999	44	0	44
40,000 - 41,999	30	0	30
42,000 - 43,999	16	0	16
44,000 - 45,999	3	0	3
46,000 - 49,999	2	0	2
50,000 or Over	0	0	0

18KSA loads for the oil well traffic is shown in Table 9. This total represents the estimated 18KSA repetitions during 365 days of activity at the oil well site.

Evaluation of Oil Well Traffic Analysis. The 945 design lane equivalent 18KSA applications demonstrates the impact one oil well can have on a low volume rural roadway. Based on the assumptions used so far in this analysis, one oil well attracts 2.12 times more 18KSA repetitions than anticipated in the intended use condition.

Figure 12 shows the historical distribution of total 18KSA repetitions at the oil site during the observation period. Three distinct peaks occurred, first during the construction of the access road, then during rigging up, and also at rigging down stage. These three stages comprised 34.6% of the period's total 18KSA repetitions. Table 10 shows the percent 18KSA repetitions during each stage of development; daily application rates are also calculated. The daily rates for the access road construction, rigging up, and rigging down indicated markedly high application rates. Total cumulative 18KSA repetitions over the duration of the observation is depicted in Figure 13.

The data presented in Figure 13 is helpful in analyzing cumulative 18KSA repetitions for oil wells at various stages of their development. If a roadway section adjacent to a similar type well is to be evaluated for effects oil well traffic, and its stage of development can be identified, the cumulative 18KSA repetitions up to that point in time can be estimated. Subtracting this cumulative value from an estimated total cumulative value (prior to the production stage) would provide an estimate of future anticipated repetitions.

Table 9. Determination of 18KSA Loads--Oil Well Traffic.

Axle Loads in Pounds	Representative Axle Load (5)	Equivalency Factor[a]	No. of Axles[b]	Equivalent 18KSA
Single Axle				
Under 3,000	2,000	-	31	0.0
3,000 - 6,999	5,000	0.005	907	4.5
7,000 - 7,999	7,500	0.025	191	4.8
8,000 - 11,999	10,000	0.070	1355	94.9
12,000 - 15,999	14,000	0.320	163	52.2
16,000 - 18,000	17,000	0.795	33	26.2
18,001 - 18,500	18,000	1.000	8	8.0
18,501 - 20,000	19,000	1.285	15	19.3
20,001 - 21,999	21,000	1.980	10	19.8
22,000 - 23,999	23,000	2.670	7	18.7
24,000 - 25,999	25,000	3.710	0	0.0
26,000 - 29,999	27,000	6.085	0	0.0
30,000 or Over	-	-	0	0.0
		SUBTOTAL		248.4
Tandem Axle				
Under 6,000	4,000	-	0	0.0
6,000 - 11,999	9,000	0.008	1072	8.6
12,000 - 17,999	15,000	0.030	327	9.8
18,000 - 23,999	21,000	0.110	214	23.5
24,000 - 29,999	27,000	0.360	396	142.6
30,000 - 32,000	31,000	0.670	138	92.5
32,001 - 32,500	32,000	0.760	45	34.2
32,501 - 33,999	33,000	0.870	971	844.8
34,000 - 35,999	35,000	1.140	133	151.6
36,000 - 37,999	37,000	1.470	73	107.3
38,000 - 39,999	39,000	1.875	44	82.5
40,000 - 41,999	41,000	2.435	30	73.1
42,000 - 43,999	43,000	3.120	16	49.9
44,000 - 45,999	45,000	3.860	3	11.6
46,000 - 49,999	48,000	5.130	2	10.3
50,000 or Over	-	-	0	0.0
		SUBTOTAL		1642.3
		TOTAL		1890.7
		DESIGN LANE	= 945.4	= 945

[a] P_t = 1.5, Flexible Pavement (6)
[b] From distribution table for intended use analysis

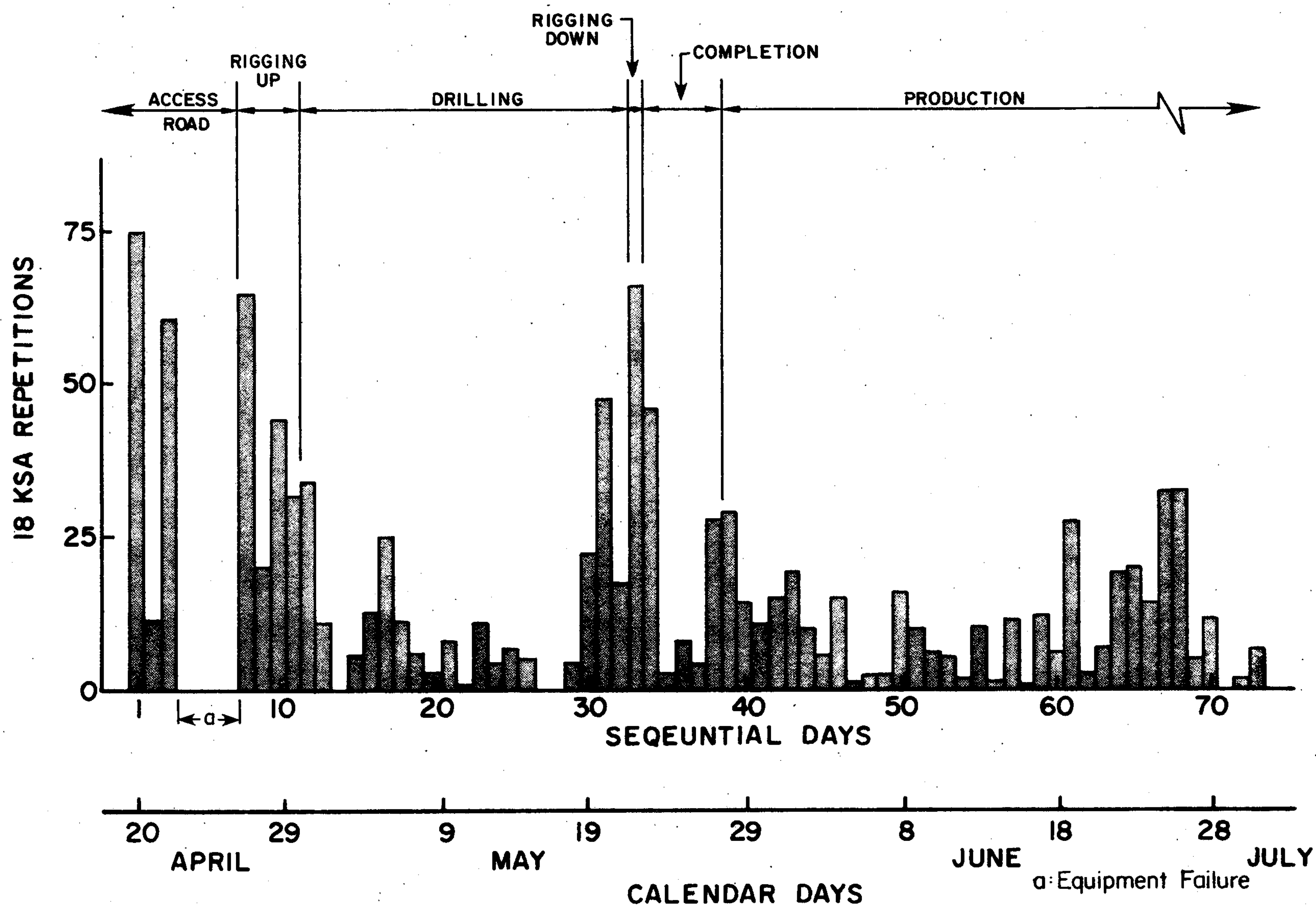


Figure 12. 18KSA Repetitions Histogram.

Table 10. 18KSA Repetitions at Oil Well Site.

Stage of Development	18KSA Repetitions	Percent	Average Daily 18KSA
Access Road	149	13.7	49.67
Rigging Up	161	14.8	40.25
Drilling	236	21.7	11.80
Rigging Down	66	6.1	66.00
Completion	88	8.1	17.60
Production	388	35.6	11.41
TOTAL	1088	100.0	

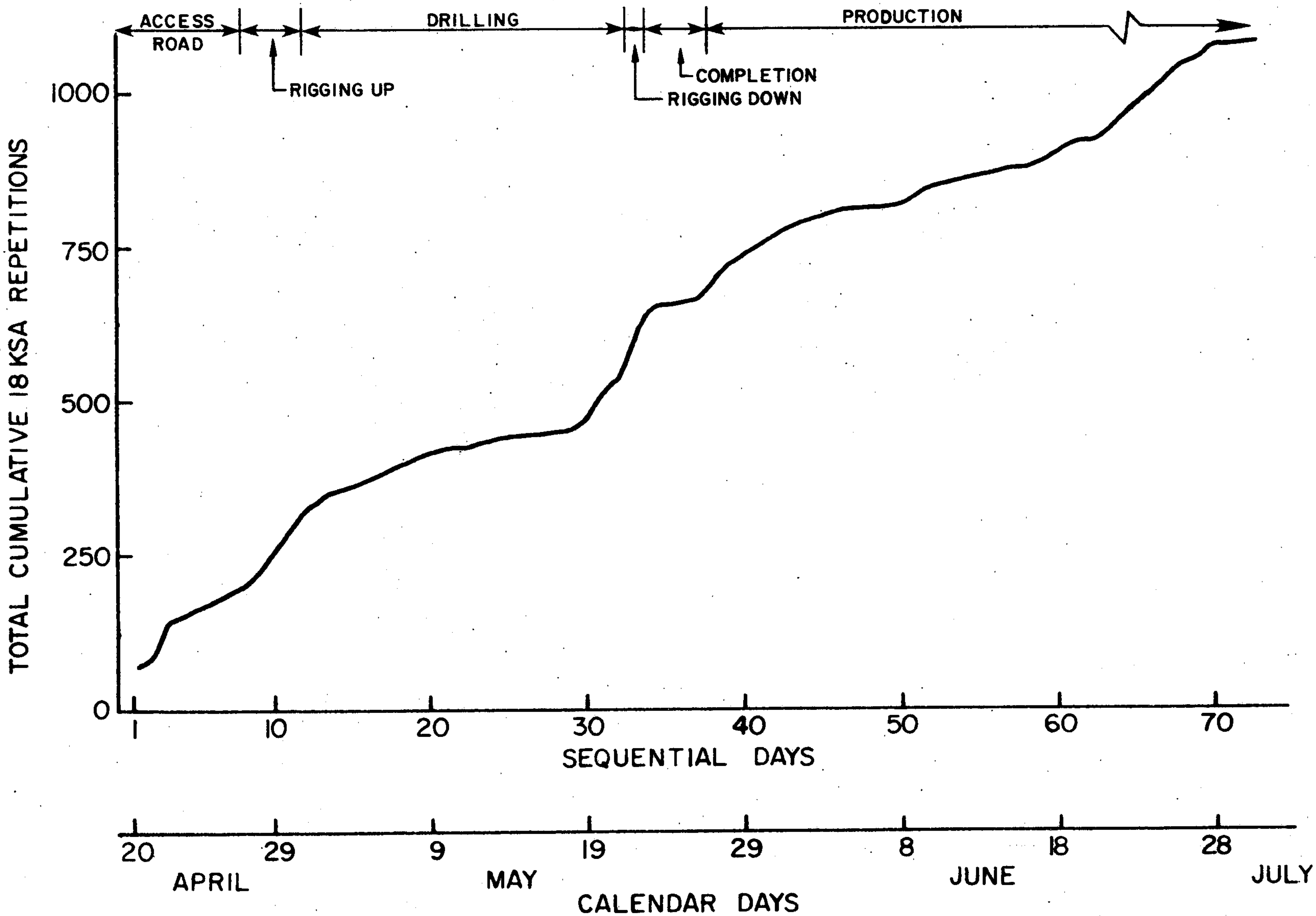


Figure 13. Total Cumulative 18KSA Repetitions.

Pavement Serviceability

18KSA Repetitions for First Year. Since a typical F.M. road must serve both an intended use traffic and the attracted oil well traffic, the 18KSA intended use repetitions were added to the 18KSA oil well repetitions to represent the total 18KSA applications over a study section. If the position taken is to examine the least effects of oil well traffic, it can be assumed that the development of the well occurs during the first year of pavement life. This assumes full structural benefit from the roadway pavement. Further, only one well is assumed to be developed during the 7.5 years of service. The combined 18KSA repetitions during the first year equals 445 + 945 = 1390 - 18KSA applications.

18KSA Repetitions for Production Beyond the First Year. Calculation--365 Days/year x (1.5 visits/day x 2 (for round trip) = 1096 trucks/year.

It was assumed that half (548 trucks) will not be loaded upon entry to the site, therefore there will be 548 single axles in the 3,000 to 6,999 pound range and 1096 (2 x 548) tandem axles in the 6,000 to 11,999 pound range. These axle weights were based on a Department's estimate of unloaded vehicle weight. Likewise, it was assumed that the remaining tracks will be partially to fully loaded when leaving the site. This will place 548 single axles in the 8,000 to 11,999 pound range and 1096 tandem axles in the 32,501 - 33,999 pound range. These axle weights were based on maximum legal axle weights of 12,000 and 34,000 pounds respectively.

If the productive phase extended beyond the first year, the expected 18KSA repetitions in the design lane would be increased by 502-18KSA per year for one well. The value of 502-18KSA repetitions per year assumes that the tankers (3-S2) will continue to visit the well site at an average of 1.5 trips per day.

Reduction in Service Life

If the intended use 18KSA load repetitions (445) are added to the oil well traffic repetitions (945), 1390 - 18KSA load repetitions result in the first year. The cumulative effect of intended use traffic plus cumulative oil well traffic is depicted in Table 11. If no additional wells are drilled during the expected service life (7.5 years), the net effect of the drilling and producing of one well is a reduced service life of 4.2 years. In another manner, the first rehabilitation is required in year 1.0, rather than year 3.2; the second rehabilitation is needed in year 3.3 versus year 7.5. Figure 14 graphically depicts the lost in pavement utilization.

Table 11. Cumulative 18KSA Repetitions.

Year	Cumulative Intended 18KSA	Cumulative Oil Well 18KSA	Cumulative Oil Well + Intended Use 18KSA
1	445	945	1390
(1.03)			(1420)[a]
2	903	1447	2350
3	1375	1949	3334
(3.3)			(3600)[a]
4	1860	2451	4311
5	2363	--	--

[a] Initial pavement capability 1420 - 18KSA
Seal coat capability 2180 - 18KSA
3600 - 18KSA

Annual Cost Comparison

The effect of a reduction in service life was examined by estimating the annual cost of providing a suitable pavement surface. This cost considers only the investment cost of the roadway pavement structure, and does not include costs associated with vehicle wear, accidents, or other related adverse consequences of a vehicle operating on an unsuitable pavement surface.

The annual cost comparison was performed by converting the costs of capital improvements (initial pavement cost) and resurfacing, into equivalent uniform annual costs using a capital recovery factor (CRF). The single payment cost for resurfacing, at some specific year in the future, was also considered in the calculation. This is done by means of the single payment present worth factor (PWF).

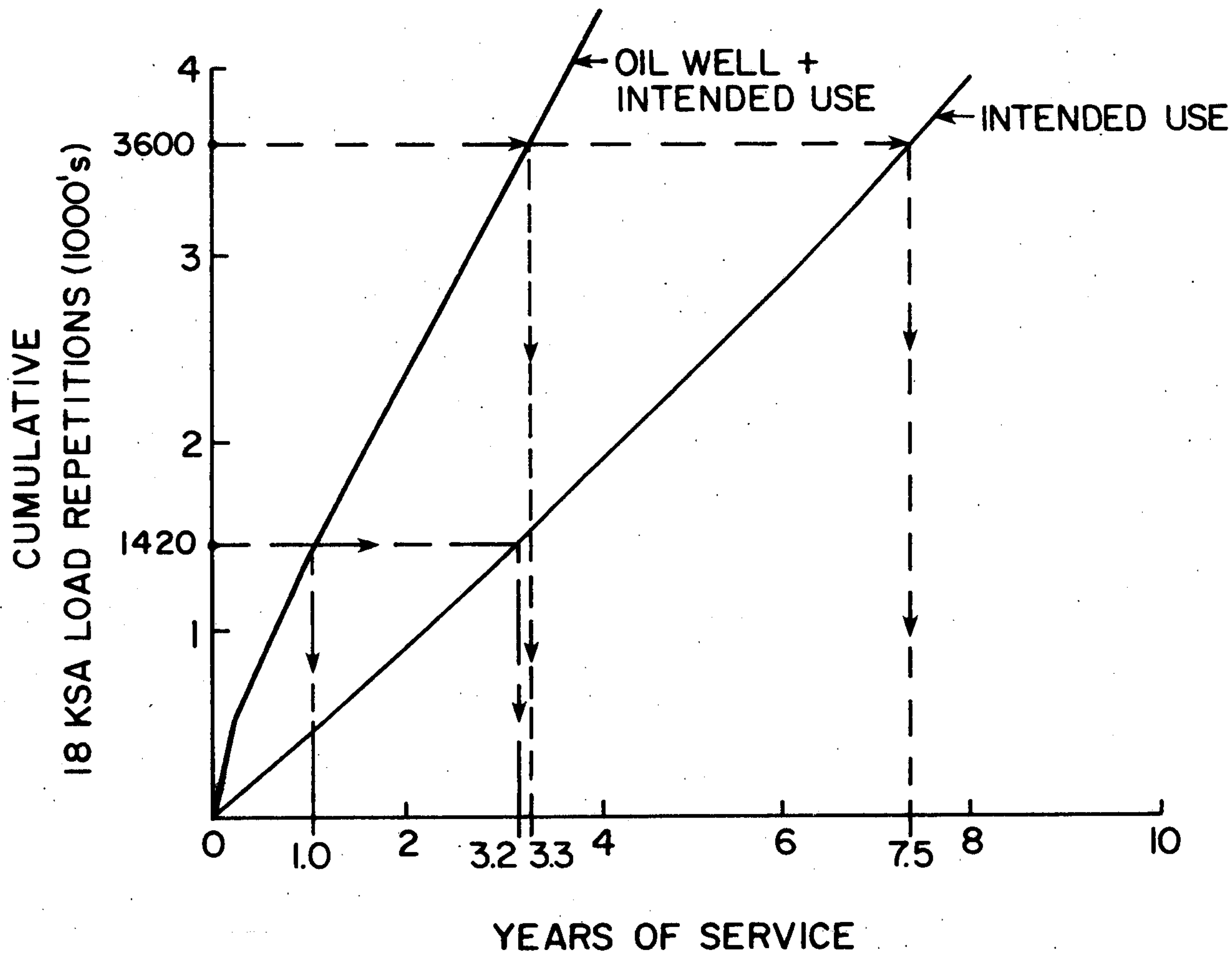


Figure 14. Reduction in Service Life.

The annual cost formula for analyzing pavement service life (7) is given as:

$$C = CRF_n[I + (R_1 \times PWF_{n_1})] \qquad (2)$$

where C = annual cost for pavement per mile,

n = analysis period (time between initial construction and second resurfacing) in years,

$$CRF = \text{uniform capital recovery factor} = \frac{i(1 + i)n}{(1 + i)^n - 1} \qquad (3)$$

I = initial cost of pavement per mile,

R_1 = first resurfacing cost per mile,

n_1 = number of years between initial construction and first resurfacing,

$$PWF_{n_1} = \text{single payment present worth factor} = \frac{1}{(1 + i)^{n_1}} \qquad (4)$$

i = interest rate = 12%.

Intended Use Condition. The annual cost for a 250 ADT F.M. roadway is calculated assuming the following:

n = analysis period = 7.5 years

$$CRF = \frac{i\ (1 + i)^n}{(1 + i)^n - 1} = \frac{.12(1.12)^{7.5}}{(1.12)^{7.5} - 1} = 0.2096$$

I = \$61,100/miles

R_1 = \$8,600/mile

n_1 = 3.2 years

$$PWF = \frac{1}{(1 + i)^{n_1}} = \frac{1}{(1.12)^{3.2}} = 0.6958$$

$$C = CRF_n\ [I + (R_1 \times PWF_{n_1})]$$

$$= 0.2096\ [\$61,100 + (\$8,600 \times 0.6958)]$$

$$= \$14,000/\text{mile}$$

Oil Well Traffic Condition. The annual cost for a 250 ADT F.M. roadway also serving one (1) oil well is calculated assuming the following:

$n = 3.3$ years

$$CRF = \frac{i\ (1 + i)^n}{(1 + i)^n - 1} = \frac{.12(1.12)^{3.3}}{(1.12)^{3.3} - 1} = 0.3846$$

$I = \$61,100/\text{mile}$

$R_1 = \$8,600/\text{mile}$

$n_1 = 1.0$ years

$PWF = 0.8929$

$$C = CRF_n[\ I + (R_1 \times PWF_{n_1})]$$

$$= 0.3846[\$61,100 + (\$8,600 \times 0.8929)]$$

$$= \$26,500/\text{mile}$$

Difference in Annual Cost.

\$14,000/mile	Intended Use Condition
\$26,500/mile	Oil Well Traffic Condition
\$12,500/mile	Increased Annual Cost

This increase in annual pavement cost reflects the impact of one oil well on a low volume, light duty F.M. pavement section.

Although this increase in annual cost demonstrates the effect of one oil well, the practical impact must also be addressed. It is unrealistic to consider restoring a pavement to its intended use condition. Once a "find" is made, a field is vigorously developed and the demand traffic volumes simultaneously increase as ultimate development is pursued. If the axle repetitions are simply considered multiplicative, the end result is a losing battle using minimal maintenance techniques.

In reality, there exists a need to determine what pavement structure is necessary for a design condition that will provide an acceptable level of service for future demand. The future demand must consider both the growth in intended use traffic as well as ultimate development of a particular field. These considerations are the primary objectives of the future research effort.

CONCLUSIONS AND RECOMMENDATIONS

As the country's need for petroleum continues, efforts to produce and reclaim additional crude oil will also continue. This desire for energy self-sufficiency encourages the development of new oil fields. These ventures have resulted in the enjoyment of the benefits of economic growth. The people, and the technology they have developed are commended for their achievements. However, there is an associated cost that needs to be recognized. The rehabilitation of the roadways providing service to the oil wells is a cost that has not been accounted in the cost of petroleum production.

Roadway networks throughout the state of Texas carry numerous types of commercial vehicle traffic. Each commodity shares in the cost of providing an acceptable roadway pavement. The design, or intended use, of a particular facility will serve its original intent for some period of time. The system can fail due to numerous enviromental changes, but it is in serious jeopardy when subjected to a traffic condition well beyond its intended purpose.

Unfortunately, the burden of the associated costs has fallen on a state agency already obligated with a host of maintenance responsibilities. Any attempts at predicting and anticipating needed financial resources and expenditures can aid in the planning and distribution of allocated funds. The estimates developed in this study provide site specific information to assess the impact of oil field traffic on low volume roadways.

Recommendations for Implementation

The findings of this study can be used in existing computer models that calculate the effects of trucks on Texas highways. Researchers responsible for the modification of these prediction models need site specific data to improve the capabilities of existing computer programs. The supplemental information collected in this research identifies and describes the unique traffic characteristics of oil field related traffic. These traffic volumes and axle configurations are required input variables in the NULOAD and REHAB computer models. Although the synthesized version of the two programs is currently in progress, it is anticipated that it will have the potential to analyze site specific problems. As such, the particulars of oil well traffic should prove beneficial in efforts aimed at improving the simulation capabilities of the model.

The analysis procedure developed in this research can be used to assist in anticipating roadway damage under similar conditions. Practical application of the results of this research is possible at the district level of the Department. Generally, the impact of reduction in service to the motoring public is felt initially at the local level. Administrative, maintenance, and design engineers at a district office can use the findings reported in this research to anticipate a measure of increased traffic demand along low volume roadways serving an oil field area.

While a reduction in pavement life is inevitable, the effects of increased cost should not be ignored. In a time of financial austerity, justification for additional allocations is mandatory. If rational analysis is coupled with convincing evidence, the Department will be able to adequately respond to the needs of a District.

Phase II Considerations

This Interim Report summarizes the findings of the initial Phase of the research. The goal of Phase I was to begin to identify and describe oil field traffic through site specific observation. Additionally, a preliminary estimate of the reduction in pavement service life was developed. The primary purpose of these reported findings is to document the impact that one oil well can have on a low volume, surface treated pavement.

Because the collected data are limited, efforts to improve the comprehensiveness of the data are the main objectives of the current Phase II considerations. The following briefly summarizes the objectives recommended by the Technical Advisory Committee:

1. Monitor additional well sites to provide an improved data base.

2. Examine the results of the initial findings using the Texas Distress Equations.

3. Further cost analysis should consider the following alternatives:

I. Do "nothing" but provide minimum maintenance.

II. Restore pavement to "intended use" condition.

III. Provide a pavement structure to accommodate the newly developed traffic -- consider a 10 year projected life of oil development.

IV. Provide a pavement structure in anticipation of a 20 year potential demand.

4. In cooperation with the Texas Railroad Commission, pursue the collection of pertinent information that can benefit the Department. This is to be accomplished by identifying activity centers, reviewing permitting procedures, and development of "reasonable" traffic projections.

Interpretation

The interpretation of the results of the initial phase must consider the inherent assumptions of the analytic procedures. Although the study is limited in scope, the conceptual argument is considered sound. The added utility of the research findings may be demonstrated using the Texas Distress Equations. Additional pavement sections, at various "ages", with different intended use situations, can then be evaluated.

Recommendations for Future Research

Future research needs relative to the investigation undertaken in this study may be categorized into three types as follows:

1. Actual axle weight measurements.
2. Pavement service life.
3. Other unique traffic demands.

Actual Axle Weight Measurements. The use of loadometer data is typical in the design of roadway pavement structures. However, if the concept of "separable costs" is pursued, qualified axle weights and repetitions must be representative of the various vehicles used in each special category.

Pavement Service Life. While research is presently addressing the distribution of pavement service life on existing roadways, roadways carrying oil field traffic need to be identified. Data on these roads can be used to calibrate the models to better represent the effects of oil field traffic.

Other Unique Traffic Demands. Oil field traffic is not the only commodity that impacts on the highway system. Special activities with unique traffic characteristics must be assessed to determine the effects their operations have on existing or intended use roadways. The timber industry, lignite mining, gravel haulers, etc., each develop unique traffic demands. These activities must be identified, their developmental operation defined, resulting traffic characteristics described, and the consequences analyzed on a equivalent basis with all other roadway users.

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APPENDIX

Page

Site Observation Form - Kurten Field Annex

By: ______________________________

Date: ____________________

Time: ____________________

Weather: ____________________

STAGE OF OPERATION:

CONTRACTOR NAME:

ADDRESS:

FIELD REPRESENTATIVE:

(List others as applicable):

DESCRIPTION OF EQUIPMENT/MATERIALS USED OR DELIVERED (TRADE NAME):

VEHICLES USED TO TRANSPORT EQUIPMENT/MATERIALS (TRADE NAME):

Number of Axles:
Height:
Width:
Length:

NUMBER OF TRIPS (FREQUENCY OF VEHICLES):

APPROXIMATE WEIGHT (LOADED & UNLOADED):

SPECIAL NOTES:

CHECK SITE EQUIPMENT:

_______ Counter Reading _____________________

_______ Film in Camera _____________________

_______ Security of System _________________

_______ Condition of System _________________

INTERVIEW QUESTIONNAIRE BY: ______________

DATE: ______________

Company Name: ________________ Representative: ________________

Address: ________________ How Long at this Locaton: ________

________________ Type of Service: ________________

Phone: ________________ ________________

1. At what phase(s) in the development of a well is your service provided?

2. How many trips do you usually make to an oil well during its development?

3. What is the length of time of your service per trip? (Average)

4. What type of equipment do you use?

5. How do you transport it to the site?

6. How many and what type (make and manufacturer) of trucks are needed to transport your equipment and personnel? (Average)

7. What are the trucks dimensions? (Average)

Truck #	I	II	III	IV	V (if different)
Ht:					
Wt (Loaded):					
Wt (Unloaded):					
Length (Loaded):					
Length (Unloaded):					
Width (Loaded):					
Width (Unloaded):					

8. What is the general range of your servicing costs?

9. What is your travel range for your service?

10. Are your materials, supplies, and equipment kept locally or regularly shipped in? Which ones and from where?

11. Do you have any literature or brochure on your servicing operations?

12. Do you have any vehicle specifications that may be of use to us? May we take some pictures of your servicing units?

13. What are any problems you have encountered in the transportation system and what would you recommend as a solution to these problems?

SHEET NO. ____

REEL # ____________________ FILMING DATES ____________ to ____________ DATE REDUCED ____________________

By: ____________________

STAGE OF OPERATION: ____

SPECIAL NOTES/COMMENTS: ____

____

____

____

____

VEHCILE CLASSIFICATION

I = Entering Site 0 = Leaving Site

NO.	PC	PU-1	PU-2	SU-1	SU-2	2-S2	3-S2	3-S3	2-2	3-2	COMMENTS/MISC.

W-3 Table for 1980.

Texas, All Functional Classes, All Stations

Vehicle Type	TOTAL VEHICLES Number Counted	TOTAL VEHICLES Average Gross Wt. (lbs.)
SINGLE UNIT TRUCKS		
Panel and Pickup	8,265	--
2-Axle, 4 Tire	64	--
2-Axle, 6 Tire	1,399	12,817
3-Axle, or More	214	32,961
COMBINATIONS		
Tractor + Semitrailer		
2 Axle Tractor	498	40,750
3 Axle Tractor	6,806	59,987
Truck + Full Trailer		
2 Axle Tractor	28	--
3 Axle Tractor	231	50,000
Tractor + Semitrailer + Full Trailer		
2 Axle Tractor	204	65,855
3 Axle Tractor	27	73,875

W-4 Table for 1980.

State of Texas, All Rural, Includes 5 Stations

Axle Loads in Pounds	Single-Unit Trucks			
	2 Axle, 6 Tire		3 Axle or More	
	Single Axle	Percent	Single Axle	Percent
Under 3,000	62	6	0	-
3,000 - 6,999	690	64	27	20
7,000 - 7,999	92	9	9	6
8,000 - 11,999	121	11	85	61
12,000 - 15,999	45	4	16	12
16,000 - 18,000	29	3	2	1
18,001 - 18,500	7	1	0	-
18,501 - 20,000	13	1	0	-
20,001 - 21,999	6	1	0	-
22,000 - 23,999	3	-	0	-
24,000 - 25,999	2	-	0	-
26,000 - 29,999	0	-	0	-
30,000 or Over	0	-	0	-
Total Single Axles Weighed	1070	100	139	100
	Tandem Axle Groups			
Under 6,000	0	-	0	-
6,000 - 11,999	0	-	25	18
12,000 - 17,999	0	-	29	21
18,000 - 23,999	0	-	21	15
24,000 - 29,999	0	-	17	12
30,000 - 32,000	0	-	7	5
32,001 - 32,500	0	-	4	3
32,501 - 33,999	0	-	1	1
34,000 - 35,999	0	-	13	10
36,000 - 37,999	0	-	7	5
38,000 - 39,999	0	-	4	3
40,000 - 41,999	0	-	3	2
42,000 - 43,999	0	-	3	2
44,000 - 45,999	0	-	3	2
46,000 - 49,999	0	-	2	1
50,000 or Over	0	-	0	-
Total Tandem Axles Weighed	0	-	139	100

W-4 Table for 1980 cont.

Axle Loads In Pounds	Tractor Semi-Trailer					
	Single Axle Groups					
	3 Axle	Percent	4 Axle	Percent	5 Axle or More	Percent
Under 3,000	0	-	0	-	1	-
3,000 - 6,999	17	13	35	9	45	2
7,000 - 7,999	13	10	30	8	193	7
8,000 - 11,999	46	36	176	46	2353	88
12,000 - 15,999	30	23	52	14	69	3
16,000 - 18,000	15	12	30	8	5	-
18,001 - 18,500	0	-	7	2	0	-
18,501 - 20,000	3	2	22	6	1	-
20,001 - 21,999	2	2	13	3	0	-
22,000 - 23,999	3	2	14	4	0	-
24,000 - 25,999	0	-	1	-	0	-
26,000 - 29,999	0	-	2	-	0	-
30,000 or Over	0	-	0	-	0	-
Total Single Axles Weighed	129	100	382	100	2667	100
	Tandem Axle Groups					
Under 6,000	0	-	0	-	3	-
6,000 - 11,999	0	-	31	16	616	12
12,000 - 17,999	0	-	67	35	841	16
18,000 - 23,999	0	-	58	30	695	13
24,000 - 29,999	0	-	26	13	1041	19
30,000 - 32,000	0	-	2	1	511	10
32,001 - 32,500	0	-	1	1	139	3
32,501 - 33,999	0	-	5	3	373	7
34,000 - 35,999	0	-	0	-	453	9
36,000 - 37,999	0	-	0	-	286	5
38,000 - 39,999	0	-	0	-	185	3
40,000 - 41,999	0	-	1	1	90	2
42,000 - 43,999	0	-	0	-	34	1
44,000 - 45,999	0	-	0	-	11	-
46,000 - 49,999	0	-	0	-	8	-
50,000 or Over	0	-	0	-	2	-
Total Tandem Axles Weighed	0	-	191	100	5288	100

W-4 Table for 1980 cont.

Axle Loads in Pounds	Semi-Trailer - Trailer			
	Single Axle Groups			
	5 Axle	Percent	6 Axle or More	Percent
Under 3,000	0	-	0	-
3,000 - 6,999	38	8	0	-
7,000 - 7,999	20	5	0	-
8,000 - 11,999	138	31	14	44
12,000 - 15,999	111	25	11	34
16,000 - 18,000	54	12	5	16
18,001 - 18,500	12	3	0	-
18,501 - 20,000	34	8	2	6
20,001 - 21,999	20	5	0	-
22,000 - 23,999	7	2	0	-
24,000 - 25,999	5	1	0	-
26,000 - 29,999	1	-	0	-
30,000 or Over	0	-	0	-
Total Single Axles Weighed	440	100	32	100
	Tandem Axle Groups			
Under 6,000	0	-	0	-
6,000 - 11,999	0	-	0	-
12,000 - 17,999	0	-	2	25
18,000 - 23,999	0	-	4	50
24,000 - 29,999	0	-	2	25
30,000 - 32,000	0	-	0	-
32,001 - 32,500	0	-	0	-
32,501 - 33,999	0	-	0	-
34,000 - 35,999	0	-	0	-
36,000 - 37,999	0	-	0	-
38,000 - 39,999	0	-	0	-
40,000 - 41,999	0	-	0	-
42,000 - 43,999	0	-	0	-
44,000 - 45,999	0	-	0	-
46,000 - 49,999	0	-	0	-
50,000 or Over	0	-	0	-
Total Tandem Axles Weighed	0	-	8	100

W-4 Table for 1980 cont.

Axle Loads In Pounds	Truck and Trailer[a]					
	Single Axle Groups					
	3 Axle	Percent	4 Axle	Percent	5 Axle or More	Percent
Under 3,000	0	-	0	-	0	-
3,000 - 6,999	52	22	52	22	52	22
7,000 - 7,999	53	22	53	22	53	22
8,000 - 11,999	79	34	79	34	79	34
12,000 - 15,999	53	22	53	22	53	22
16,000 - 18,000	0	-	0	-	0	-
18,001 - 18,500	0	-	0	-	0	-
18,501 - 20,000	0	-	0	-	0	-
20,001 - 21,999	0	-	0	-	0	-
22,000 - 23,999	0	-	0	-	0	-
24,000 - 25,999	0	-	0	-	0	-
26,000 - 29,999	0	-	0	-	0	-
30,000 or Over	0	-	0	-	0	-
Total Single Axles Weighed	237	100	237	100	237	100
	Tandem Axle Groups					
Under 6,000	0	-	0	-	0	-
6,000 - 11,999	0	-	0	-	0	-
12,000 - 17,999	0	-	26	33	52	33
18,000 - 23,999	0	-	0	-	0	-
24,000 - 29,999	0	-	53	67	106	67
30,000 - 32,000	0	-	0	-	0	-
32,001 - 32,500	0	-	0	-	0	-
32,501 - 33,999	0	-	0	-	0	-
34,000 - 35,999	0	-	0	-	0	-
36,000 - 37,999	0	-	0	-	0	-
38,000 - 39,999	0	-	0	-	0	-
40,000 - 41,999	0	-	0	-	0	-
42,000 - 43,999	0	-	0	-	0	-
44,000 - 45,999	0	-	0	-	0	-
46,000 - 49,999	0	-	0	-	0	-
50,000 or Over	0	-	0	-	0	-
Total Tandem Axles Weighed	0	0	79	100	158	100

[a]Probable number combinations used due to lack of 1980 data.

W-5 Table for 1980.

State of Texas, All Rural, Includes 5 Stations

Number of Loaded and Empty Trucks and Truck Combinations of Each Type of Various Total Weights During 1980

Gross Operating Weigh in Pounds	Single-Unit Trucks			
	Panel And Pickup (Under 1 Ton)	2 Axle 4 Tire	2 Axle 6 Tire	3 Axle Or More
Under 3,999	0	0	0	0
4,000 - 9,999	0	0	205	0
10,000 - 13,499	0	0	150	3
13,500 - 19,999	0	0	101	24
20,000 - 21,999	0	0	13	8
22,000 - 23,999	0	0	23	12
24,000 - 25,999	0	0	19	7
26,000 - 27,999	0	0	9	4
28,000 - 29,999	0	0	9	5
30,000 - 31,999	0	0	5	7
32,000 - 33,999	0	0	0	5
34,000 - 35,999	0	0	1	5
36,000 - 37,999	0	0	0	2
38,000 - 39,999	0	0	0	6
40,000 - 44,999	0	0	0	17
45,000 - 49,999	0	0	0	23
50,000 - 54,999	0	0	0	8
55,000 - 59,999	0	0	0	3
60,000 - 64,999	0	0	0	0
65,000 - 69,999	0	0	0	0
70,000 - 72,000	0	0	0	0
72,001 - 74,999	0	0	0	0
75,000 - 79,999	0	0	0	0
80,000 - 84,999	0	0	0	0
85,000 - 89,999	0	0	0	0
90,000 - 94,999	0	0	0	0
95,000 - 99,999	0	0	0	0
100,000 - 104,999	0	0	0	0
105,000 - 109,999	0	0	0	0
110,000 or Over	0	0	0	0
Total Vehicles Weighed	0	0	535	139

W-5 Table for 1980 cont.

Gross Operating Weight in Pounds	Tractor Semi-Trailer		
	3 Axle	4 Axle	5 Axle Or More
Under 3,999	0	0	0
4,000 - 9,999	0	0	0
10,000 - 13,499	0	0	0
13,500 - 19,999	1	1	0
20,000 - 21,999	1	4	0
22,000 - 23,999	6	2	5
24,000 - 25,999	1	6	12
26,000 - 27,999	1	9	45
28,000 - 29,999	4	8	74
30,000 - 31,999	1	7	84
32,000 - 33,999	5	15	107
34,000 - 35,999	2	12	96
36,000 - 37,999	7	12	76
38,000 - 39,999	4	9	58
40,000 - 44,999	5	31	147
45,000 - 49,999	4	29	159
50,000 - 54,999	1	14	159
55,000 - 59,999	0	22	138
60,000 - 64,999	0	7	210
65,000 - 69,999	0	2	247
70,000 - 72,000	0	1	137
72,001 - 74,999	0	0	193
75,000 - 79,999	0	0	337
80,000 - 84,999	0	0	226
85,000 - 89,999	0	0	99
90,000 - 94,999	0	0	27
95,000 - 99,999	0	0	5
100,000 - 104,999	0	0	1
105,000 - 109,999	0	0	1
110,000 or Over	0	0	3
Total Vehicles Weighed	43	191	2646

W-5 Table for 1980 cont.

State of Texas, All Rural, Includes 5 Stations

Gross Operating Weight in Pounds	Semi-Trailer-Trailer 5 Axle	Semi-Trailer-Trailer 6 Axle or More
Under 3,999	0	0
4,000 - 9,999	0	0
10,000 - 13,499	0	0
13,500 - 19,999	0	0
20,000 - 21,999	0	0
22,000 - 23,999	1	0
24,000 - 25,999	1	0
26,000 - 27,999	2	0
28,000 - 29,999	3	0
30,000 - 31,999	2	0
32,000 - 33,999	0	0
34,000 - 35,999	0	0
36,000 - 37,999	1	0
38,000 - 39,999	0	0
40,000 - 44,999	2	0
45,000 - 49,999	2	0
50,000 - 54,999	5	0
55,000 - 59,999	6	0
60,000 - 64,999	8	0
65,000 - 69,999	11	4
70,000 - 72,000	3	0
72,001 - 74,999	9	1
75,000 - 79,999	16	2
80,000 - 84,999	9	0
85,000 - 89,999	4	1
90,000 - 94,999	2	0
95,000 - 99,999	1	0
100,000 - 104,999	0	0
105,000 - 109,999	0	0
110,000 or Over	0	0
Total Vehicles Weighed	88	8

W-5 Table for 1980 cont.

Gross Operating Weight in Pounds	Truck and Trailer[a]		
	3 Axle	4 Axle	5 Axle Or More
Under 3,999	0	0	0
4,000 - 9,999	0	0	0
10,000 - 13,499	0	0	0
13,500 - 19,999	0	0	0
20,000 - 21,999	0	0	0
22,000 - 23,999	0	0	0
24,000 - 25,999	0	0	0
26,000 - 27,999	0	0	0
28,000 - 29,999	0	0	0
30,000 - 31,999	0	0	0
32,000 - 33,999	0	0	0
34,000 - 35,999	0	0	0
36,000 - 37,999	0	0	0
38,000 - 39,999	27	27	27
40,000 - 44,999	26	26	26
45,000 - 49,999	0	0	0
50,000 - 54,999	0	0	0
55,000 - 59,999	26	26	26
60,000 - 64,999	0	0	0
65,000 - 69,999	0	0	0
70,000 - 72,000	0	0	0
72,001 - 74,999	0	0	0
75,000 - 79,999	0	0	0
80,000 - 84,999	0	0	0
85,000 - 89,999	0	0	0
90,000 - 94,999	0	0	0
95,000 - 99,999	0	0	0
100,000 - 104,999	0	0	0
105,000 - 109,999	0	0	0
110,000 or Over	0	0	0
Total Vehicles Weighed	79	79	79

[a]Probable number combinations used due to lack of 1980 data.

Distribution of Axle Loads for Intended Use.

Vehicle Type	Single-Unit		Tractor-Semi-Trailer			Semi-Trailer Trailer		Truck-Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks[a]	64	18	5	23	310	9	0	9	9	9	Class Total
Axle Loads in Pounds					Single Axle Groups [b]						
Under 3,000	8	0	0	0	0	0	0	0	0	0	8
3,000 - 6,999	82	4	2	4	6	4	0	6	4	2	114
7,000 - 7,999	12	1	2	4	22	2	0	6	4	2	55
8,000 - 11,999	14	11	5	21	273	14	0	9	6	3	356
12,000 - 15,999	5	2	4	6	9	11	0	6	4	2	49
16,000 - 18,000	4	0	2	4	0	6	0	0	0	0	16
18,001 - 18,500	1	0	0	1	0	1	0	0	0	0	3
18,501 - 20,000	1	0	0	3	0	4	0	0	0	0	8
20,001 - 21,999	1	0	0	1	0	2	0	0	0	0	4
22,000 - 23,999	0	0	0	2	0	1	0	0	0	0	3
24,000 - 25,999	0	0	0	0	0	0	0	0	0	0	0
26,000 - 29,999	0	0	0	0	0	0	0	0	0	0	0
30,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Single Axles	128	18	15	46	310	45	0	27	18	9	616

[a] Number of trucks in each class for intended use traffic analysis.

[b] Rounded to whole numbers to approximate 1980 W-4 Table distributions.

Distribution of Axle Loads for Intended Use cont.

Vehicle Type	Single-Unit		Tractor Semi-Trailer			Semi-Trailer Trailer		Truck Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks[a]	64	18	5	23	310	9	0	9	9	9	Class Total
Axle Loads in Pounds											
Tandem Axle Groups[b]											
Under 6,000	0	0	0	0	0	0	0	0	0	0	0
6,000 - 11,999	0	3	0	4	74	0	0	0	0	0	81
12,000 - 17,999	0	4	0	8	99	0	0	0	3	6	120
18,000 - 23,999	0	3	0	7	81	0	0	0	0	0	91
24,000 - 29,999	0	2	0	3	118	0	0	0	6	12	141
30,000 - 32,000	0	1	0	0	62	0	0	0	0	0	63
32,001 - 32,500	0	1	0	0	19	0	0	0	0	0	20
32,501 - 33,999	0	0	0	1	43	0	0	0	0	0	44
34,000 - 35,999	0	2	0	0	56	0	0	0	0	0	58
36,000 - 37,999	0	1	0	0	31	0	0	0	0	0	32
38,000 - 39,999	0	1	0	0	19	0	0	0	0	0	20
40,000 - 41,999	0	0	0	0	12	0	0	0	0	0	12
42,000 - 43,999	0	0	0	0	6	0	0	0	0	0	6
44,000 - 45,999	0	0	0	0	0	0	0	0	0	0	0
46,000 - 49,999	0	0	0	0	0	0	0	0	0	0	0
50,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Tandem Axles	0	18	0	23	620	0	0	0	9	18	688

[a] Number or trucks in each class for intended use traffic analysis.
[b] Rounded to whole numbers to approximate 1980 W-4 Table distributions.

Summary of Developed Equivalency Factors for Flexible Pavements for a Terminal Serviceability Index of 1.5.[a]

Total Axle Load, Kips	Single Axle	Tandem Axle
2	--	--
4	.002	--
6	.008	--
8	.03	--
10	.07	.006
12	.16	.01
14	.32	.02
16	.59	.04
18	1.00	.05
20	1.57	.09
22	2.39	.13
24	2.95	.21
26	4.47	.30
28	7.70	.42
30	10.38	.58
32	14.26	.76
34	19.56	.98
36	25.98	1.30
38	33.54	1.64
40	42.79	2.11
42	--	2.76
44	--	3.48
46	--	4.24
48	--	5.13
50	--	--

[a] Compiled from reference (6) page 120.

Distribution of Axle Loads for Oil Well Traffic for the First 73 Days.

Vehicle Type	Single-Unit		Tractor-Semi-Trailer			Semi-Trailer Trailer		Truck-Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	>3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks	259	166	11	71	647	0	0	10	145	18	Class Total
Axle Loads in Pounds											
				Single Axle Groups							
Under 3,000	31	0	0	0	0	0	0	0	0	0	31
3,000 - 6,999	331	33	4	13	13	0	0	7	64	4	469
7,000 - 7,999	47	10	3	11	45	0	0	7	64	4	191
8,000 - 11,999	57	101	12	65	569	0	0	9	98	6	917
12,000 - 15,999	21	20	7	20	20	0	0	7	64	4	163
16,000 - 18,000	16	2	4	11	0	0	0	0	0	0	33
18.001 - 18,500	5	0	0	3	0	0	0	0	0	0	8
18,501 - 20,000	5	0	1	9	0	0	0	0	0	0	15
20,001 - 21,999	5	0	1	4	0	0	0	0	0	0	10
22,000 - 23,999	0	0	1	6	0	0	0	0	0	0	7
24,000 - 25,999	0	0	0	0	0	0	0	0	0	0	0
26,000 - 29,999	0	0	0	0	0	0	0	0	0	0	0
30,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Single Axles	518	166	33	142	647	0	0	30	290	18	1844

Distribution of Axle Loads for Oil Well Traffic for the First 73 Days cont.

Vehicle Type	Single-Unit		Tractor Semi-Trailer			Semi-Trailer Trailer		Truck Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	>3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks	259	166	11	71	647	0	0	10	145	18	Class Total
Axle Loads in Pounds					Tandem Axle Groups						
Under 6,000	0	0	0	0	0	0	0	0	0	0	0
6,000 - 11,999	0	30	0	11	155	0	0	0	0	0	196
12,000 - 17,999	0	35	0	25	207	0	0	0	48	12	327
18,000 - 23,999	0	25	0	21	168	0	0	0	0	0	214
24,000 - 29,999	0	20	0	9	246	0	0	0	97	24	396
30,000 - 32,000	0	8	0	1	129	0	0	0	0	0	138
32,001 - 32,500	0	5	0	1	39	0	0	0	0	0	45
32,501 - 33,999	0	2	0	2	91	0	0	0	0	0	95
34,000 - 35,999	0	17	0	0	116	0	0	0	0	0	133
36,000 - 37,999	0	8	0	0	65	0	0	0	0	0	73
38,000 - 39,999	0	5	0	0	39	0	0	0	0	0	44
40,000 - 41,999	0	3	0	1	26	0	0	0	0	0	30
42,000 - 43,999	0	3	0	0	13	0	0	0	0	0	16
44,000 - 45,999	0	3	0	0	0	0	0	0	0	0	3
46,000 - 49,999	0	2	0	0	0	0	0	0	0	0	2
50,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Tandem Axles	0	166	0	71	1294	0	0	0	145	36	1712

Distribution of Axle Loads for Oil Well Traffic for the 292 Day Extension.

Vehicle Type	Single-Unit		Tractor-Semi-Trailer			Semi-Trailer Trailer		Truck-Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	>3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks	0	0	0	0	876	0	0	0	0	0	Class Total
Axle Loads in Pounds											
				Single Axle Groups							
Under 3,000	0	0	0	0	0	0	0	0	0	0	0
3,000 - 6,999	0	0	0	0	438	0	0	0	0	0	438
7,000 - 7,999	0	0	0	0	0	0	0	0	0	0	0
8,000 - 11,999	0	0	0	0	438	0	0	0	0	0	438
12,000 - 15,999	0	0	0	0	0	0	0	0	0	0	0
16,000 - 18,000	0	0	0	0	0	0	0	0	0	0	0
18.001 - 18,500	0	0	0	0	0	0	0	0	0	0	0
18,501 - 20,000	0	0	0	0	0	0	0	0	0	0	0
20,001 - 21,999	0	0	0	0	0	0	0	0	0	0	0
22,000 - 23,999	0	0	0	0	0	0	0	0	0	0	0
24,000 - 25,999	0	0	0	0	0	0	0	0	0	0	0
26,000 - 29,999	0	0	0	0	0	0	0	0	0	0	0
30,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Single Axles	0	0	0	0	876	0	0	0	0	0	876

Distribution of Axle Loads for Oil Well Traffic for the 292 Day Extension cont.

Vehicle Type	Single-Unit		Tractor Semi-Trailer			Semi-Trailer Trailer		Truck Trailer			
Vehicle Code Type	SU-1	SU-2	2-S1	2-S2	3-S2	2-S1-2	3-S1-2	2-1	2-2	>3-2	
Number of Axles	2	>3	3	4	>5	5	>6	3	4	>5	
Number of Trucks	0	0	0	0	876	0	0	0	0	0	Class Total
Axle Loads in Pounds											
Tandem Axle Groups											
Under 6,000	0	0	0	0	0	0	0	0	0	0	0
6,000 - 11,999	0	0	0	0	876	0	0	0	0	0	876
12,000 - 17,999	0	0	0	0	0	0	0	0	0	0	0
18,000 - 23,999	0	0	0	0	0	0	0	0	0	0	0
24,000 - 29,999	0	0	0	0	0	0	0	0	0	0	0
30,000 - 32,000	0	0	0	0	0	0	0	0	0	0	0
32,001 - 32,500	0	0	0	0	0	0	0	0	0	0	0
32,501 - 33,999	0	0	0	0	876	0	0	0	0	0	876
34,000 - 35,999	0	0	0	0	0	0	0	0	0	0	0
36,000 - 37,999	0	0	0	0	0	0	0	0	0	0	0
38,000 - 39,999	0	0	0	0	0	0	0	0	0	0	0
40,000 - 41,999	0	0	0	0	0	0	0	0	0	0	0
42,000 - 43,999	0	0	0	0	0	0	0	0	0	0	0
44,000 - 45,999	0	0	0	0	0	0	0	0	0	0	0
46,000 - 49,999	0	0	0	0	0	0	0	0	0	0	0
50,000 or Over	0	0	0	0	0	0	0	0	0	0	0
Total Tandem Axles	0	0	0	0	1752	0	0	0	0	0	1752