TTI-2-8-81-299-4

TEXAS
TRANSPORTATION
INSTITUTE

STATE DEPARTMENT
OF HIGHWAYS AND
PUBLIC TRANSPORTATION

COOPERATIVE
RESEARCH

STATEWIDE VARIABILITY OF OIL AND GAS DRILLING AND PRODUCTION ACTIVITY

RESEARCH REPORT 299-4

STUDY 2-8-81-299

EFFECT OF OIL FIELD DEVELOPMENT

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TX-84/294-4		

4. Title and Subtitle	5. Report Date
STATEWIDE VARIABILITY OF OIL AND GAS DRILLING AND PRODUCTION ACTIVITY	July, 1984
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
J. M. Mason and B. E. Stampley	Research Report 299-4
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. 2-8-81-299
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Research Report Phase III April 1983 to December 1983
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

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Six variability parameters were defined for each county which aid in the derivation of input data for the computer analysis procedure. A procedure was also developed to convert crude oil production into truck traffic.

A detailed example illustrates the use of the variability parameters to establish site-specific input data for use in the Oil Field Damage Program. The computer program models pavement performance by calculating levels of pavement distress over time. This technique provides a basis for anticipating future maintenance and rehabilitation requirements for surface-treated pavements in oil or gas field areas.

17. Key Words	18. Distribution Statement
Truck Traffic, Pavement Distress, Oil Field Traffic, Pavement Serviceability, Pavement Design, Statewide Variability, Drilling Variability, Production Variability	No Restrictions. This document is available to the public through the National Technical Information Service 5285 Port Royal Road, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	71	

Form DOT F 1700.7 (8-69)

Statewide Variability of Oil and Gas Drilling and Production Activity

by

J. M. Mason and B. E. Stampley

Research Report 299-4

Research Project 2-8-81-299

Phase III

Conducted for

The State Department of Highways and Public Transportation

by the

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

July, 1984

ACKNOWLEDGEMENT

This phase of the project was sponsored by the Texas State Department of Highways and Public Transportation. John M. Mason served as the Principal Investigator and Bryan E. Stampley served as Graduate Research Assistant. 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.

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ABSTRACT

This report describes the variability of oil and gas activities in Texas. The characteristics of drilling and production operations vary widely across the state. Conversations with persons involved in the oil and gas industry enabled the development of variability parameters which describe local variations in activity on a countywide basis.

Six variability parameters were defined for each county which aid in the derivation of input data for the computer analysis procedure. A procedure was also developed to convert crude oil production into truck traffic.

A detailed example illustrates the use of the variability parameters to establish site-specific input data for use in the Oil Field Damage Program. The computer program models pavement performance by calculating levels of pavement distress over time. This technique provides a basis for anticipating future maintenance and rehabilitation requirements for surface-treated pavements in oil or gas field areas.

SUMMARY

The principal objective of this phase of study was to describe the statewide variability of oil and gas drilling and production activity. This information expands the applicability of the Phase II methodology from one unique region of oil field activity to any region within the state.

Photographic monitoring of several drilling sites in Brazos County formed the basis of the traffic distributions used in the Oil Field Damage Program. Conversations with petroleum engineers indicated that the traffic distribution obtained in Brazos County was typical of statewide use. Regional variations in drilling and production characteristics change the shape of the distribution, but the general traffic volumes predicted during each phase of the well development remain suitable for statewide analysis.

Variations in drilling characteristics are primarily due to differences in the length of the drilling phase. Production traffic characteristics are primarily caused by differences in oil- or gas-bearing formations. Transportation of final product is also a primary consideration. Several petroleum engineers noted that gas is typically transported from the well site by pipeline. Crude oil is also transported in pipelines, but usually only from centralized gathering terminals located near a major trunk line. As a result, trucks often haul crude oil from the well site to the gathering terminal where it is then piped to the refinery. The number of trucks required at the producing well eventually declines over time, with the actual rate of decline depending upon the characteristics of the producing formation.

Six parameters were developed to describe these regional variations in drilling and production activity. Four of the parameters--lag time, percent drilled, drill time, and drill time versus drill depth--describe variations

in drilling characteristics. Completion success rate and production per well describe regional variations in production activity. Each of the six variability parameters was defined on a county-by-county basis from the Railroad Commission of Texas Drilling Permit Records file.

The variability parameters were used to generate input data for the Oil Field Damage computer program. This program computes expected reduction in pavement service life due to oil field traffic. Minor modifications to the program will eventually be necessary to accommodate variable drill time and production truck volumes for use in statewide analysis.

This technique is an extension of Phase II (Report 299-2 and Report 299-3) methodology. The variability parameters permit consideration of unique county oil and gas characteristics while preserving the utility of the methodology as an assessment and planning tool. Since the Oil Field Damage Program converts truck traffic into 18-kip equivalent single axle loads, it has the potential for predicting the effects of other load-intensive "special-use" truck traffic on pavement performance.

IMPLEMENTATION STATEMENT

Previous investigations produced results for a small oil-producing region of the state. The current results lay the groundwork for future analysis aimed at monitoring and predicting surface-treated pavement performance under oil or gas field traffic throughout Texas.

Periodic updating of regional or District density maps is imperative to insure reliable results from the analysis procedure. Annual revision of the Railroad Commission of Texas Drilling Permit Records is suggested in order to support the computer-generated density map process (discussed in Report 299-5). Highway officials must also consider current local oil or gas field activity when implementing the analysis procedure. The study results are additional tools in the overall pavement management/design process; they are meant to supplement, not replace, local information.

DISCLAIMER

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INTRODUCTION

The Problem

Texas has long been known as a major producer of oil and gas. While the state economy has benefitted from the prosperity of this activity, the burden it places upon the highway system has just begun to be measured.

Drilling an oil or gas well generates a substantial amount of load-intensive truck traffic. The vehicle mix and axle configurations are unique and are not specifically considered in traditional pavement design techniques. In addition, this activity typically occurs in rural areas, where the heavy truck traffic must travel over light-duty rural roadways originally designed for low volumes of passenger cars and light trucks.

The Arab Oil Embargo of 1973 dramatized the nation's dependence upon a precarious energy supply and spurred a surge in the amount and intensity of oil field development nationwide. In Texas, the State Department of Highways and Public Transportation found it necessary to determine the effects of the renewed oil field development on rural highways. Phase One of this study estimated the effects of oil field development on rural pavements (1). Phase Two of the study involved the development of the "Oil Field Damage Program," a computer program which models present and future pavement performance under various levels of oil field development (2). Also included in this phase was a rational procedure for locating oil field activity centers and identifying impacted roadways through the development of density maps (3).

Phase III Objectives

The results obtained in Phases I and II were site-specific and applicable only to one small region of the state. In addition, the density maps were created manually and were not easily updated from year to year. To improve the comprehensiveness of the overall methodology for statewide use, the Technical Advisory Committee recommended the following objectives for Phase III of this study:

1. Describe statewide variability of oil and gas drilling and production activity.
2. Provide documentation of a procedure for developing computer-generated density maps from the Railroad Commission of Texas Drilling Permit Records.

This report covers the first objective of Phase III. A subsequent report, Report 299-5, will address the second Phase III objective.

STUDY PROCEDURE

Phase I and Phase II characterized oil field drilling and production for a small region of the state. In Phase III, the primary objective was to examine drilling and production activity for both oil and gas on a statewide level. This expansion of study scope formed the basis for the study procedure depicted in Figure 1. The procedure involved gathering information from the following sources:

1. Local Petroleum Consultants
2. Major Oil Companies
3. Railroad Commission of Texas

Local Petroleum Consultants

Five local petroleum consultants interviewed during the Phase III study indicated that the conditions observed in our previous studies were not typical of all oil and gas operations in Texas. They agreed with the study philosophy of supplementing our local knowledge with information obtained from other unique regions of the state.

The petroleum consultants also confirmed the basic components and shape of the oil field traffic histogram developed in previous study phases (Figure 2). Traffic volume and duration from three of the five stages outlined in the histogram--access road, rigging-up, and rigging-down--remain nearly constant throughout the state. Drilling and production, however, are sensitive to site-specific conditions and vary widely from region to region.

Drilling Phase. The duration of the drilling phase at any one well site is primarily dependent upon the final depth of the hole. Deep wells

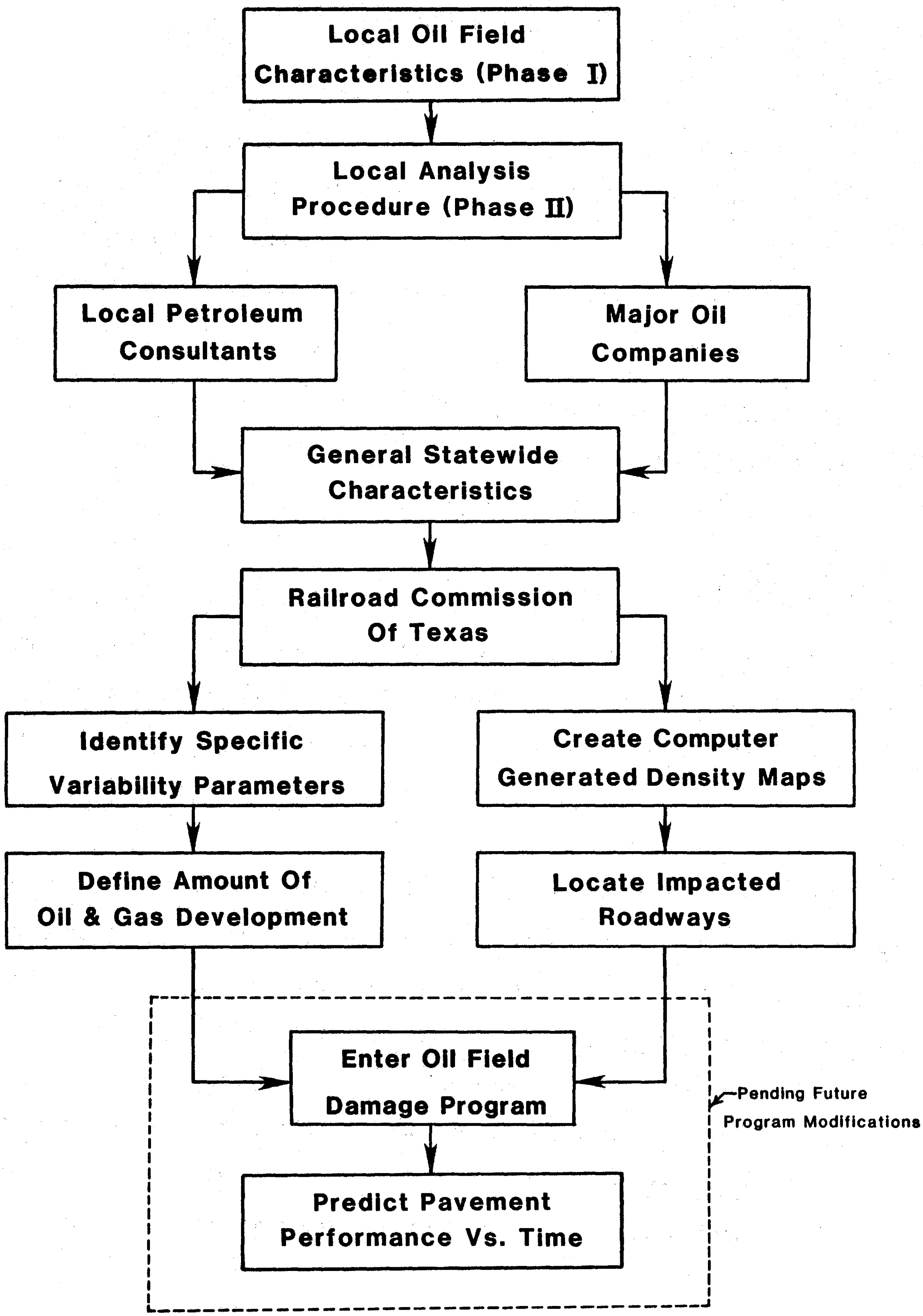

Figure 1. Phase III Study Procedure.

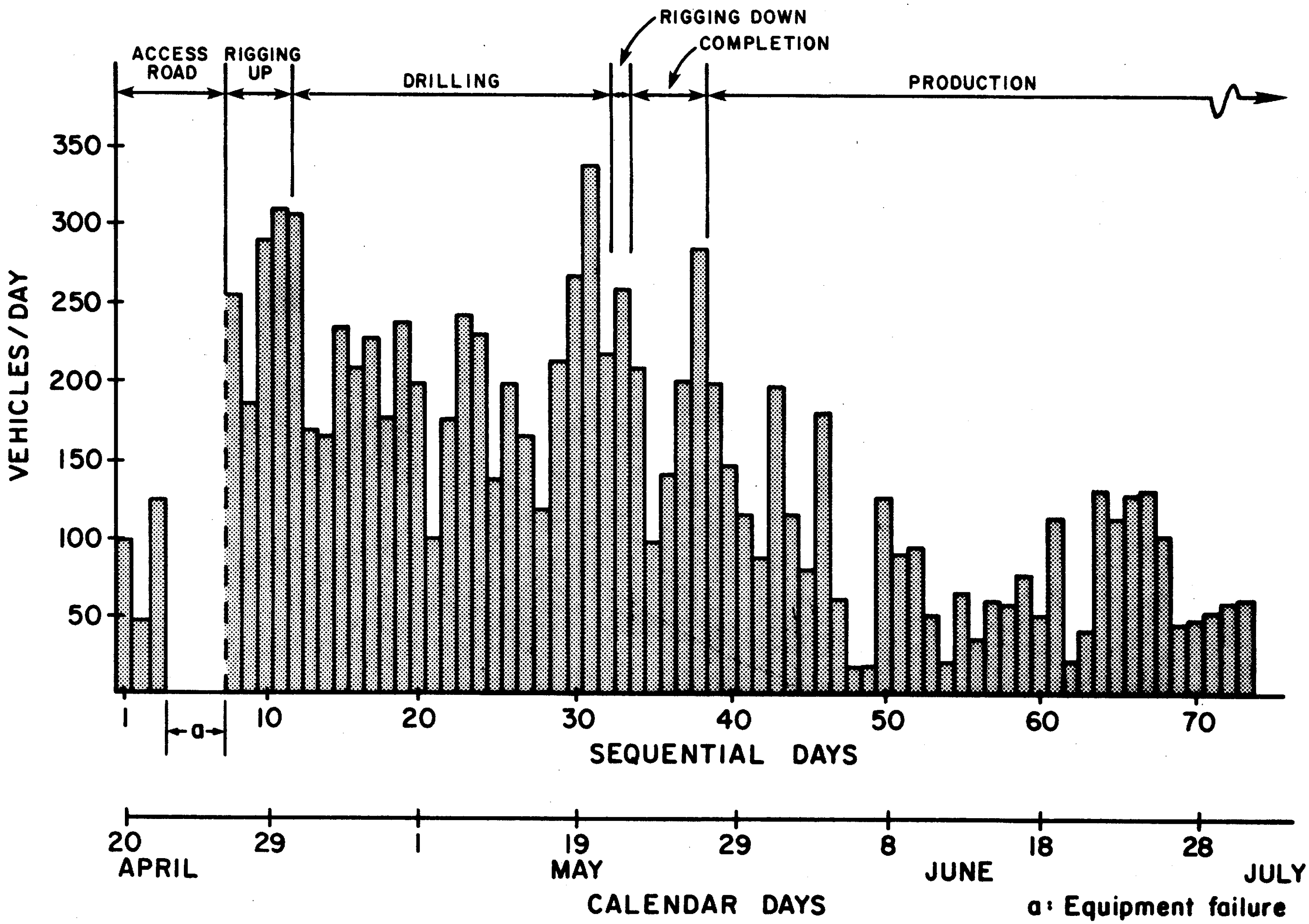

Figure 2. Daily Vehicle Histogram.

logically take longer to drill than do shallow wells. The variety of geological formations in Texas, however, precludes the definition of a single exact relationship between drilling depth and drilling time.

Production Phase. Site-specific geologic conditions directly affect both the duration and the amount of oil or gas produced during the production phase. In some regions (such as the Kurten field studied previously), production may decline almost immediately. Wells in other regions (such as the Bryan Woodbine, in the city of Bryan) may not experience a significant decline in production for several years.

The inclusion of gas wells into the analysis was an important feature of Phase III. Specifically, there was a need to determine the fundamental operational differences between gas wells and oil wells. The local petroleum consultants indicated that the most important difference was that gas is normally transported in pipelines, whereas oil is moved either in trucks or in pipelines. All other phases of operation could be assumed to be similar to those at an oil well.

Major Oil Companies

Interviews with representatives of two major oil companies verified the information obtained from the local petroleum consultants. The oil company representatives, however, were more cognizant of the wide variety of oil- and gas-bearing formations in Texas. With 11,361 active oil fields and 16,382 active gas fields in 1982, the major oil company representatives suggested an analysis based upon characteristics of "major" fields (4).

Railroad Commission of Texas

The Railroad Commission of Texas (R.R.C.) regulates the statewide operations of the oil and gas industry. The R.R.C. continually updates a Master Drilling Permits Record file--a series of computer tapes of well permits issued, wells drilled, and wells completed. These tapes may be purchased from the R.R.C. and updated quarterly. TTI submitted its previous set of computer tapes for updating in June, 1983. These computer tapes provided most of the information used in the Phase III analysis.

ANALYSIS PROCEDURE

The results of the data collection process describe general statewide oil and gas characteristics. Figure 3 illustrates the basic Phase III analysis procedure to demonstrate statewide application.

Of the five phases in the development of an oil or gas well, only the drilling and production phases vary significantly from region to region. Variability parameters were obtained for each county through manipulation of the updated version of the R.R.C. Drilling Permit Records. These parameters included:

1. Lag Time
2. Percent Drilled
3. Drilling Time
4. Drilling Time Versus Drilling Depth
5. Completion Success Rate
6. Production Per Well

Lag Time

Lag time measures the length of time elapsed between the issuing of a permit and the actual drilling of the well itself. More specifically,

Lag Time = "Spud-in" (drill) Date - Permit Date

This parameter provides a measure of available response time for maintenance activities on roadways in areas of oil and gas development. In certain counties, lag time is quite long, and maintenance crews have enough time to rehabilitate roadways before drilling begins. In other counties there is not enough time available for any such work. Lag time is thus useful in scheduling maintenance and rehabilitation activities.

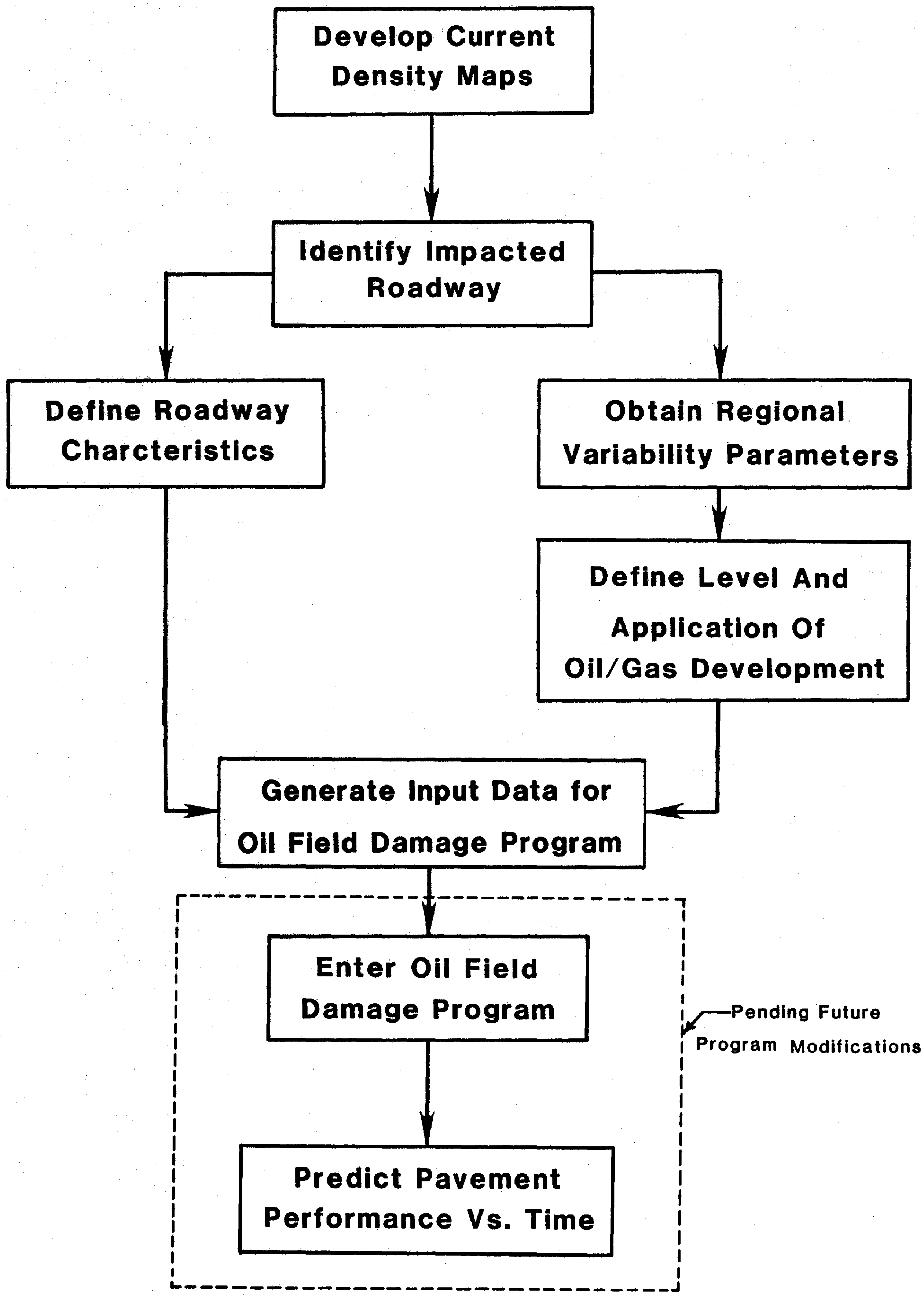

Figure 3. Phase III Analysis Procedure.

However, one problem with lag time is that it is a function of both spud-in date and permit date. Every well in the R.R.C. Drilling Permit Records is given a permit date. Well operators, however, are not required to report actual spud-in date. These wells, along with those that have not yet been drilled, have spud-in dates of " 0/ 0/ 0" in the Drilling Permit Records. As a result, only 20-30 percent of the total number of records in a region (e.g., a SDHPT District) are actually used in the lag time computations. Lag time, as with the other variability parameters described in this report, provides an initial estimate of regional conditions and should be supplemented by local knowledge whenever possible.

Figure 4 depicts statewide variability in lag time. Data for the map was retrieved from the R.R.C. permit records using a FORTRAN computer program. The program computed lag time from the R.R.C. records (when lag time could actually be computed) on a county basis for each well spud-in between 1977 and 1982. Average lag time, the arithmetic mean of the values for each county, was entered into a Statistical Analysis System (SAS) program for use by SAS/GRAPH in plotting the statewide variability map (5, 6).

Percent Drilled

Percent drilled measures the probability that drilling activity will occur at any one permit site. Specifically,

$$\text{Percent Drilled} = \frac{\text{Total Number of Spud-Ins}}{\text{Total Number of Permits}} \times 100\%$$

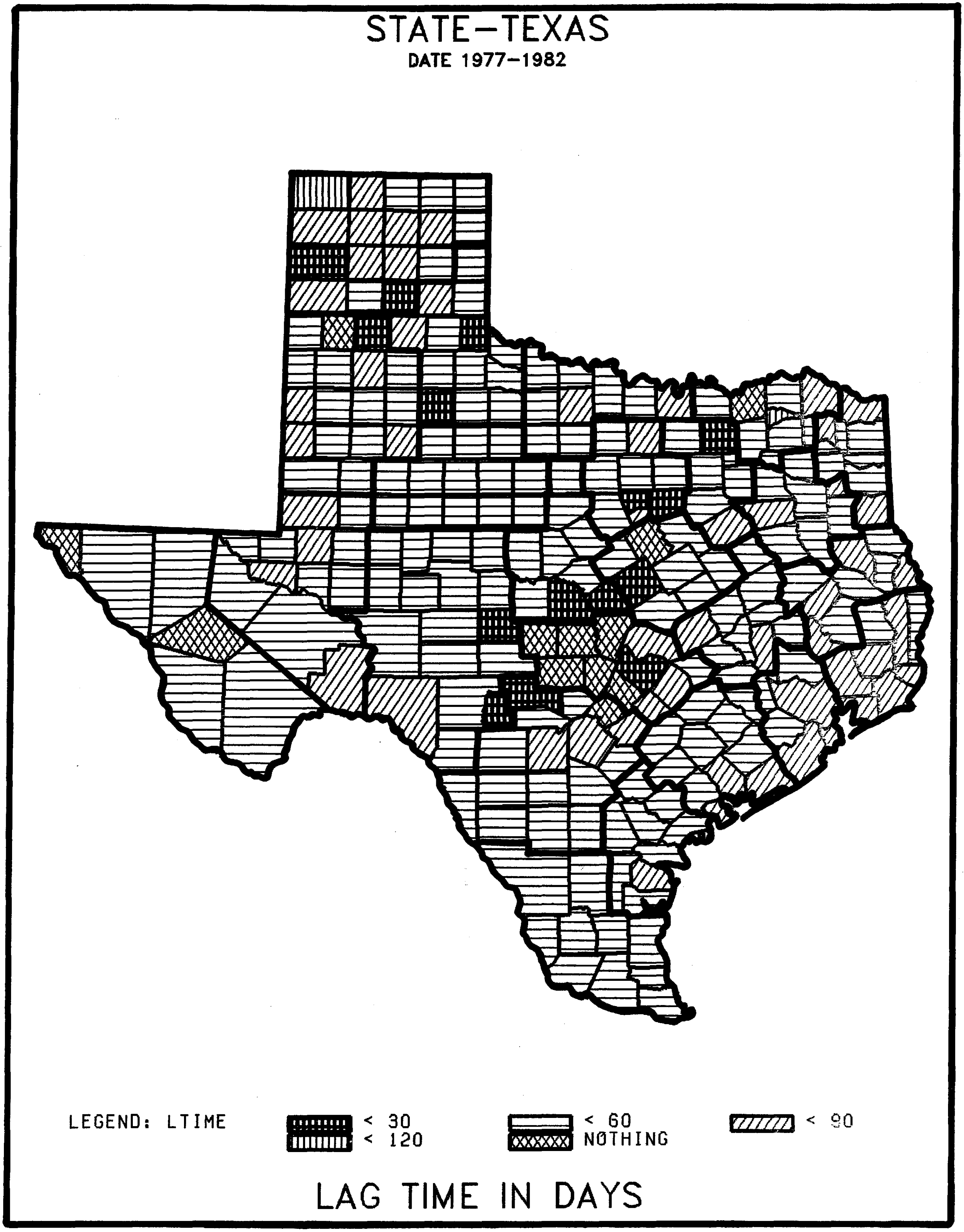

Figure 4. Variability of Average Lag Time Parameter.

Figure 5 portrays statewide variability in percent drilled on a county basis. This map was produced in a manner similar to the statewide lag time map (Figure 4).

Percent drilled is an important parameter because it basically predicts the occurrence (or non-occurrence) of oil or gas field traffic. Issuing a permit only indicates an interest in future development and has a minor influence on traffic volumes. The actual drilling of a well produces a dramatic increase in traffic. This increase occurs not only during the drilling of the well but also for several weeks before development.

The percent drilled parameter complements the lag time parameter. For any given county, the percent drilled value indicates the average likelihood of drilling at a permit site. Lag time approximates when the activity will actually begin.

Drill Time

The third variability parameter, drill time, is computed as follows:

Drill Time = Completion "W" Date - Spud-in Date

Drill time provides a measure of the duration of drilling activity at a well site. Figure 6 demonstrates the statewide variability in average drill time for each county in Texas.

Drill time is a function of spud-in date and completion "W" date. The completion "W" date on a permit record indicates the date that drilling ended on a "successful" well. Operators are required to submit periodic "status" reports on their drilled wells to the R.R.C. in the form of CW-1 update codes. Table 1 lists the recognized update codes. Code "W" acknowledges that the well has been completed and production is anticipated.

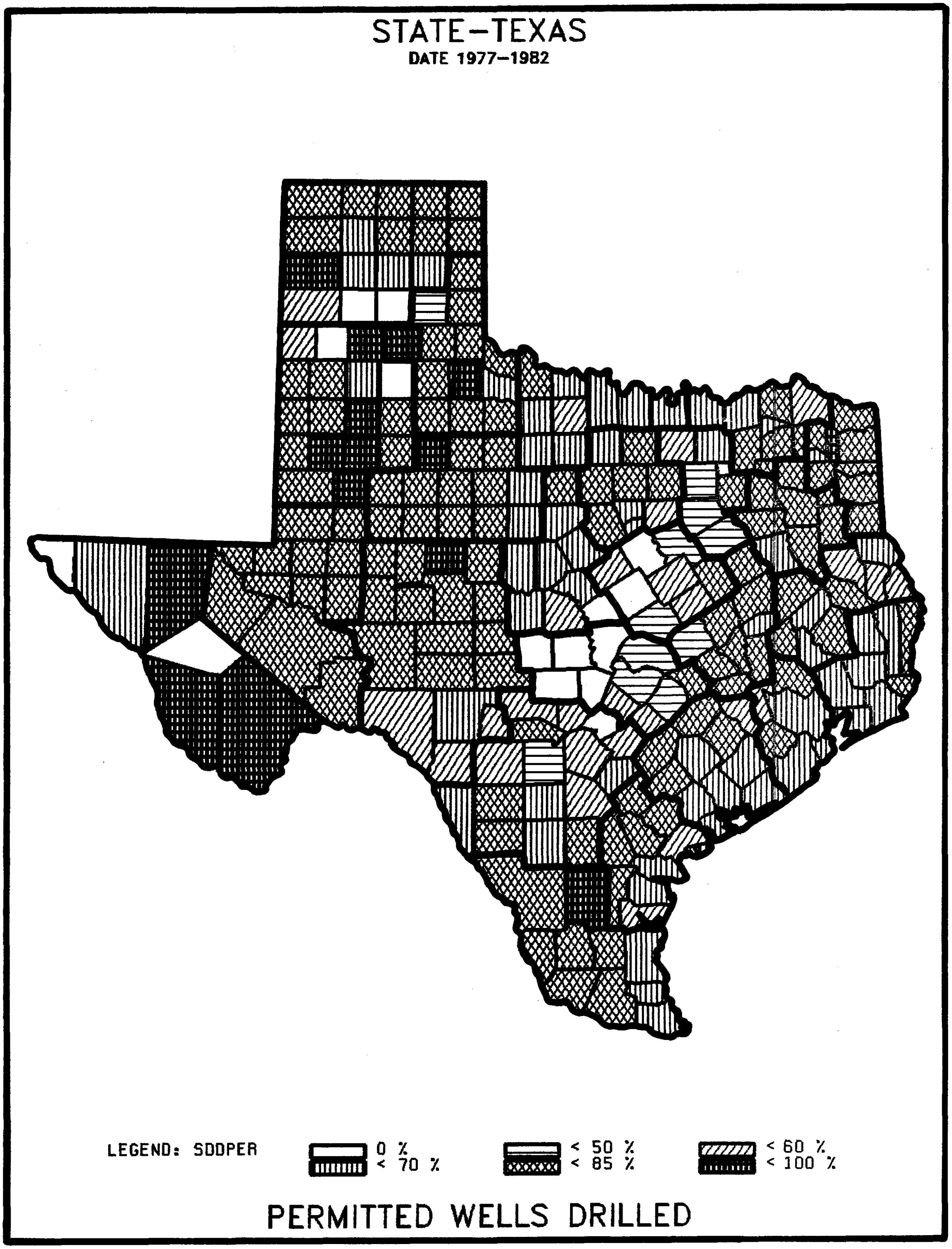

Figure 5. Variability of Percent Drilled Parameter.

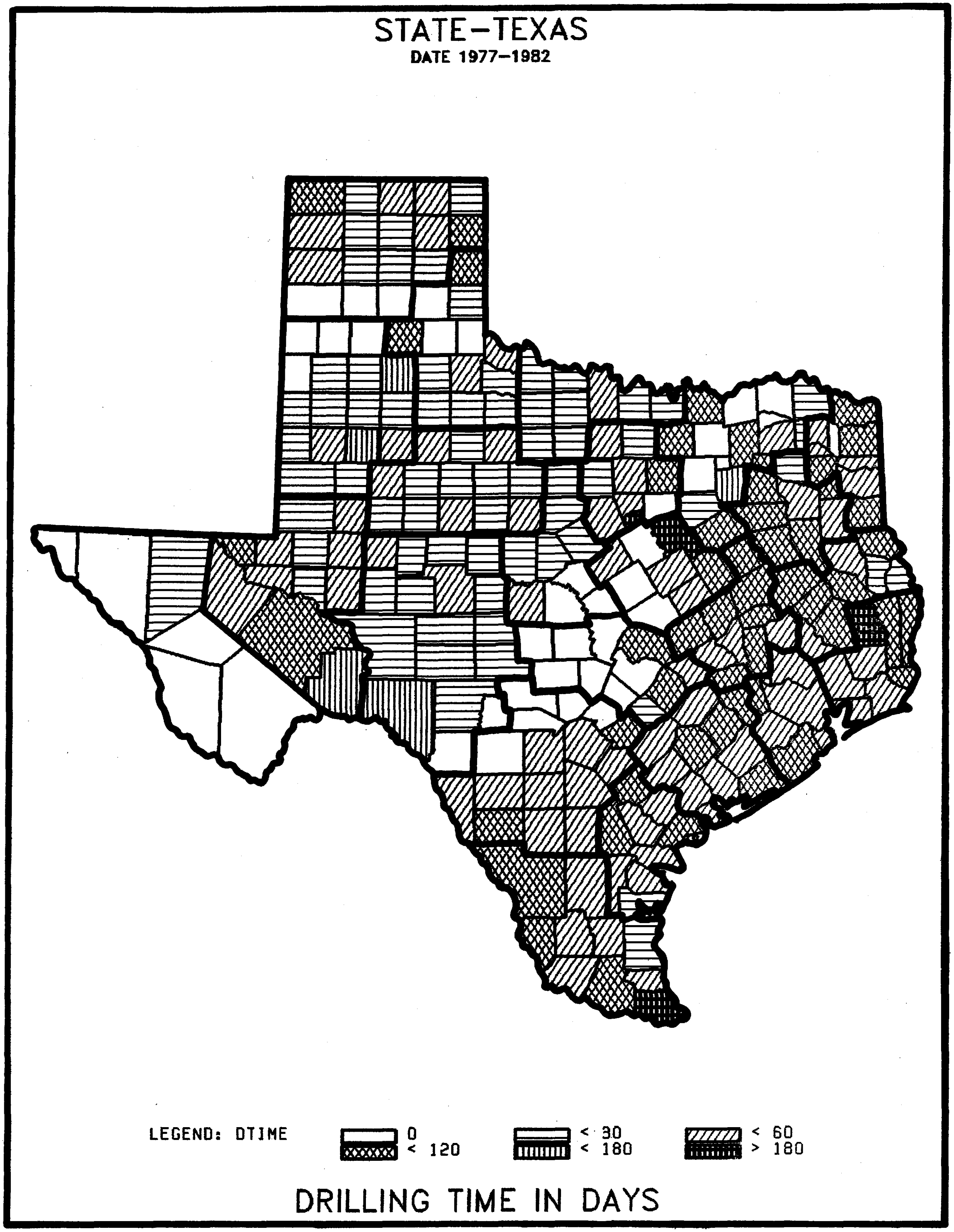

Figure 6. Variability of Average Drill Time Parameter.

Table 1. CW-1 Update Codes. (7)

Reserve Code	Activity Status
A	Long String
B	Conductor Casing
C	Test Bottom Hole Pressure
D	Plug Dry Hole - P & A (W-3)
E	(Not defined by R.R.C.)
F	Circulate Production String Casing
G	Drive Pipe
H	Plug Dry Hole - P & A (ltr.)
I	Temperature Survey
J	Liner
K	P & A Sulphur Core Test
L	Plug Back
M	Core Test (P & A)
N	Intermediate String
O	Plug Dry Hole (oil)
P	Plug Dry Hole (gas)
Q	Plug Fresh Water
R	Plug Stat Test
S	Plug Dry Hole (Explorate)
U	Unsuccessful Workover
V	Plug Uranium Test
W	Final Completion
X	Lignite Expl. (P & A)
Z	Removed Reserve Code

Since drilling time and production length are the two major descriptors of oil and gas well variability, the drill time parameter is an important piece of information in the statewide analysis procedure.

Drilling Time Versus Drilling Depth

The drill time parameter provides an estimate of the duration of drilling traffic at a well site. Each person interviewed agreed that the depth of the hole being drilled is the primary factor influencing drilling time.

Permit records used in the computation of average drill time served as the source of the drill depth information. The large number of records in the drill time file necessitated limiting the comparisons of drill time vs. drill depth to wells in SDHPT District 11, 13, and 17. A SAS computer program assembled the time/depth data by county and printed the results for the 25th, 50th, and 75th percentile drill times and drill depths. Tables 2, 3, and 4 display the results obtained for SDHPT Districts 11, 13, and 17, respectively. In District 11, for example, 75 percent of the wells drilled in Nacogdoches County are less than 10,992 feet deep.

The resulting comparisons of drill time and drill depth provide generalized information about drilling operations in a county. Highway officials may use the information to assign values for drilling time in a county for use in regional planning and analysis. Local officials may also use this information to predict the effects of isolated oil or gas development. For example, an engineer may wish to determine the potential impact if three gas wells are drilled near a remote county road. By determining the proposed depths of the wells (either from the well operators or the R.R.C.) and converting those depths into drill times, the engineer can use the Oil Field Damage Program to estimate future pavement service life and performance.

Table 2. Drilling Time Versus Drilling Depth for SDHPT District 11.

County	Percentile					
	25th		50th		75th	
	Depth*	Time**	Depth	Time	Depth	Time
Angelina	9150.00	22.50	9696.00	38.50	12375.00	91.00
Houston	8791.00	27.00	10216.00	49.00	11494.00	87.00
Nacogdoches	7837.50	23.00	9525.00	38.00	10991.80	65.25
Polk	7800.00	18.00	9500.00	25.00	10463.50	52.00
Sabine	5352.25	14.00	6371.50	17.50	8000.00	41.00
San Augustine	7767.00	31.00	8515.00	43.00	9524.00	139.50
San Jacinto	8459.00	18.25	11150.00	37.50	12125.00	100.75
Shelby	4709.50	21.00	8000.00	39.00	9000.00	73.50
Trinity	9437.50	24.50	9872.50	39.50	11573.80	79.50

* Depth = Well depth, in feet
** Time = Drill time, in days

Table 3. Drilling Time Versus Drilling Depth for SDHPT District 13.

County	Percentile					
	25th		50th		75th	
	Depth*	Time**	Depth	Time	Depth	Time
Austin	7131.25	17.50	10900.00	39.50	15687.50	131.75
Calhoun	6500.00	9.00	8600.00	20.00	9500.00	62.00
Colorado	4940.00	9.00	9806.00	23.00	10811.30	44.75
DeWitt	5500.00	7.00	8491.50	18.50	10500.00	35.00
Fayette	8500.00	18.00	9539.00	27.50	11000.00	53.25
Gonzales	7121.50	12.00	7800.00	17.00	8392.50	40.50
Jackson	5000.00	6.00	6300.00	9.00	7461.00	21.00
Lavaca	5155.00	13.00	9180.00	32.00	12000.00	89.50
Matagorda	7000.00	12.00	9400.00	27.00	10740.00	54.00
Victoria	4050.00	5.00	4213.00	7.00	6500.00	13.00
Wharton	5500.00	6.00	6202.50	9.00	7409.80	18.00

* Depth = Well depth, in feet
** Time = Drill time, in days

Table 4. Drilling Time Versus Drilling Depth for SDHPT District 17.

County	Percentile					
	25th		50th		75th	
	Depth*	Time**	Depth	Time	Depth	Time
Brazos	8800.00	17.00	9200.00	28.00	10000.00	60.00
Burleson	8358.00	14.00	9000.00	20.00	9900.00	36.00
Freestone	11372.00	38.00	12500.00	54.00	13200.00	83.50
Grimes	10206.50	28.50	11089.00	49.00	11921.50	109.50
Leon	6796.50	14.00	8000.00	29.00	12000.00	117.50
Madison	8963.50	22.00	9925.00	36.00	10275.00	99.50
Milam	1050.00	5.00	2400.00	10.00	3800.00	26.00
Robertson	7485.30	16.25	13250.00	65.00	14427.00	132.25
Walker	910.00	1.00	6500.00	26.00	12598.80	44.25
Washington	10950.00	25.00	11500.00	33.00	12000.00	51.00

* Depth = Well depth, in feet
** Time = Drill time, in days

The lag time, percent drilled, drill time, and drill time/depth factors affect the drilling phase of an oil or gas well. Completion success rate and production per well describe the production phase.

Completion Success Rate

Completion success rate defines the probability that a given permit site will actually be completed (i.e., produce oil or gas). Specifically,

$$\text{Completion Success Rate} = \frac{\text{Total Number of Completion W's}}{\text{Total Number of Permits}} \times 100\%$$

This parameter identifies the potential onset of long-term production truck traffic. Completion success rate is particularly important in areas where trucking of crude oil is common. It is less important in gas field areas because, as the petroleum consultants mentioned, gas is predominantly transported by pipelines. Statewide variability of completion success rate is shown in Figure 7.

Production Per Well

The final variability parameter, production per well, describes the expected decline in production over time at a well site in any Texas county.

$$\text{Production Per Well} = \frac{\text{Annual Oil Production (Bbls)}}{\text{Number of Producing Oil Wells}}$$

$$= \frac{\text{Annual Gas Production (Mcf)}}{\text{Number of Producing Gas Wells}}$$

where 1 Bbl = 42 U.S. Gallons

1 Mcf = 1000 cu. ft. gas

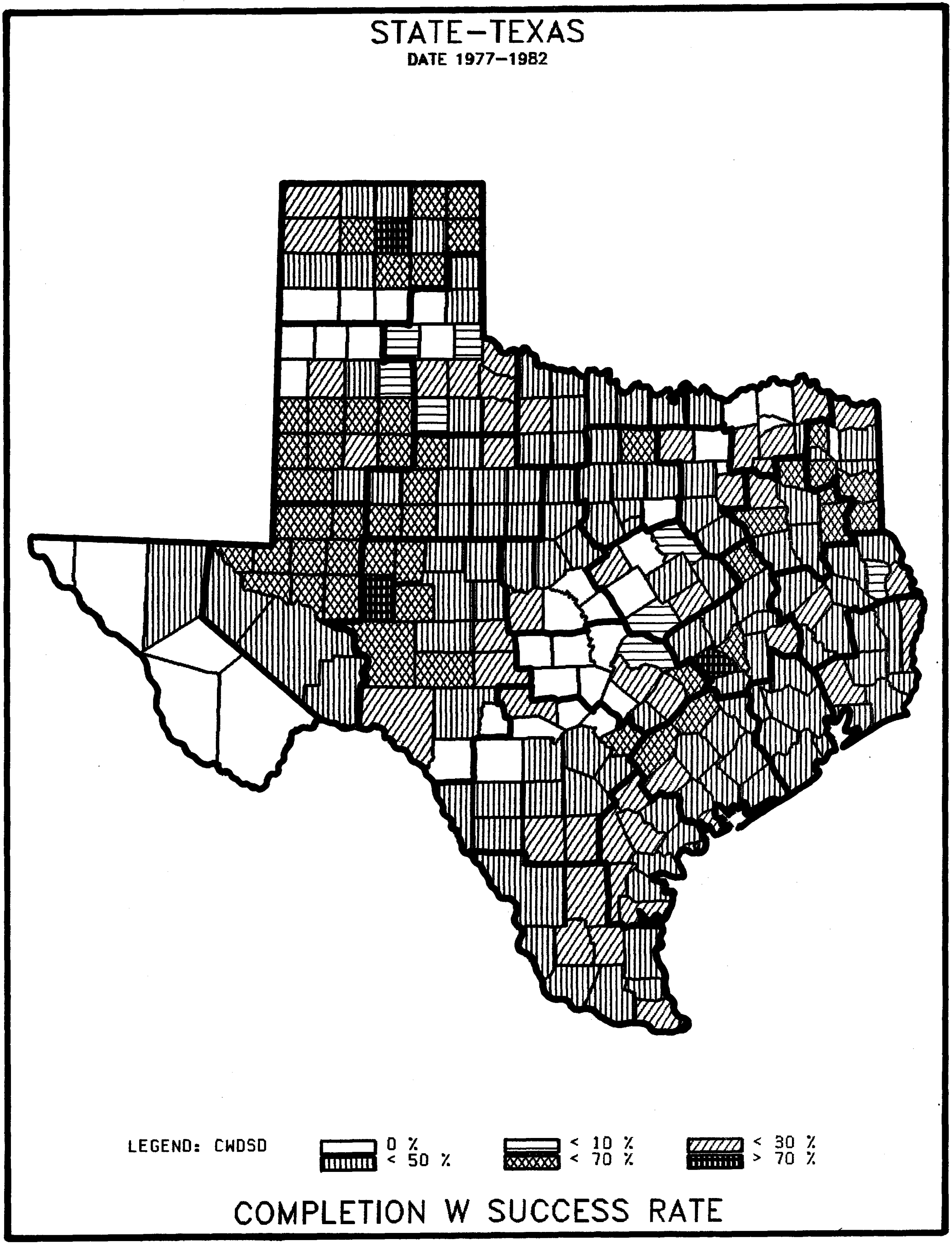

Figure 7. Variability of Completion Success Rate Parameter.

Annual oil and gas production figures were obtained from Annual Reports of the R.R.C. Oil and Gas Division (1977-1982). Personnel in the Automated Data Processing division of the R.R.C. conducted a special series of computer runs to provide the necessary information on producing wells in each county in Texas for 1979, 1980, 1981, and 1982. These figures, coupled with the annual oil and gas production figures for each county, enabled the computation of the production per well parameter (oil and gas) for each year. Gas production per well was not computed since gas wells were assumed not to generate any additional production truck traffic.

Computing the parameter on a county basis, as opposed to a per well basis, yielded some interesting results. **Approximately half of the counties demonstrated an increase in the production per well parameter over time!** Since this parameter was intended to model individual well production, the increase meant production at the average oil well actually increases over time. The increase is usually due to a surge in activity where a few new oil wells produce at a high initial rate and cause a dramatic rise in annual production for a county. Another logical explanation is the presence of "work-over" operations in the county. These work-over operations seek to increase the production from "old" or low-producing wells. Success of these work-over operations results in an increase in annual production without increasing the number of wells actually contributing to the production. In either case, the production per well parameter for the county increases and individual wells may appear to be producing more oil as they age.

The problems posed by short-term surges in production are magnified by the small sample size currently available. In the future, more data points will be available and a more reliable model of individual well production can be defined for any county in Texas. Linear regression of the available production per well data is currently the most practical method of defining county models of individual well production. Officials may, however, choose to base their models upon production per well data obtained during relatively "quiet" periods of oil and gas stability. As with all of the other variability parameters described in this report, local information should be used to supplement these parameters whenever it is available.

The production per well parameter is eventually used to convert barrels of oil (or mcf of gas) per well into trucks per well. Conversations with several oil field servicing businesses indicated that the average capacity of a crude oil tank truck is 180 barrels. As a result, the oil production per well parameter can be converted into monthly crude oil truck traffic by dividing by 2160, as shown below:

$$\text{Production Traffic}\left(\frac{\text{trucks/well}}{\text{month}}\right) = \left(\frac{\text{Bbls/well}}{\text{year}}\right) X \left(\frac{\text{1 year}}{\text{12 months}}\right) X \left(\frac{\text{1 truck}}{\text{180 Bbls}}\right)$$

$$= \frac{\text{Production Per Well}}{2160}$$

The six variability parameters provide qualitative and quantitative descriptions of oil and gas activity in a county. These parameters are vital inputs into the analysis procedure because they are interrelated--each one describing a different facet of local oil and gas activity. Table 5 illustrates the interrelationships between the six variability parameters.

Table 5. Interrelationships Between Oil and Gas Variability Parameters.

Question	Phase of Oil/Gas Well Development	
	Drilling	Production
Will it occur?	Percent Drilled	Completion Success Rate
When?	Lag Time	Lag Time + Drill Time
For how long?	Drill Time either average or from drill depth	Production Per Well decline in Bbls/well

These variability parameters, in conjunction with current versions of the density maps, provide the fundamental information for analyzing the impact of oil or gas development on surface-treated pavements in Texas.

SAMPLE PROCEDURE

Many factors influence the level of regional oil and gas development and its impact on flexible pavements. Some of these factors, such as pavement thickness, subgrade plasticity index and liquid limit, and average daily traffic, are contained in local roadway inventory records. Other factors, such as the oil and gas variability parameters, may be obtained from R.R.C. records. The following discussion illustrates how the variability parameters are used to generate site-specific input data for the Oil Field Damage Program.

SDHPT District 11 (1977-1982)

SDHPT District 11 (Figure 8) was selected as the example district. It comprises a nine-county area located in a heavily-forested region of East Texas. In 1982, District 11 accounted for over 1.7 million barrels of crude oil and over 76 billion cubic feet of gas.

The six variability parameters are based primarily upon the following:

1. Number of permits issued.
2. Number of spud-in wells.
3. Number of completion "W" wells.
4. Annual oil and gas production.

Figures 9 through 18 depict the values obtained for each county in District 11 during the study period, 1977-1982. These diagrams were created using SAS computer programs and SAS/GRAPH plotting capabilities. The variability parameters have been extracted from Appendix A (County Variability Parameters), illustrated in Figure 19, and tabulated in Table 6. Recommended production truck traffic volumes for oil wells are given in Table 7. The

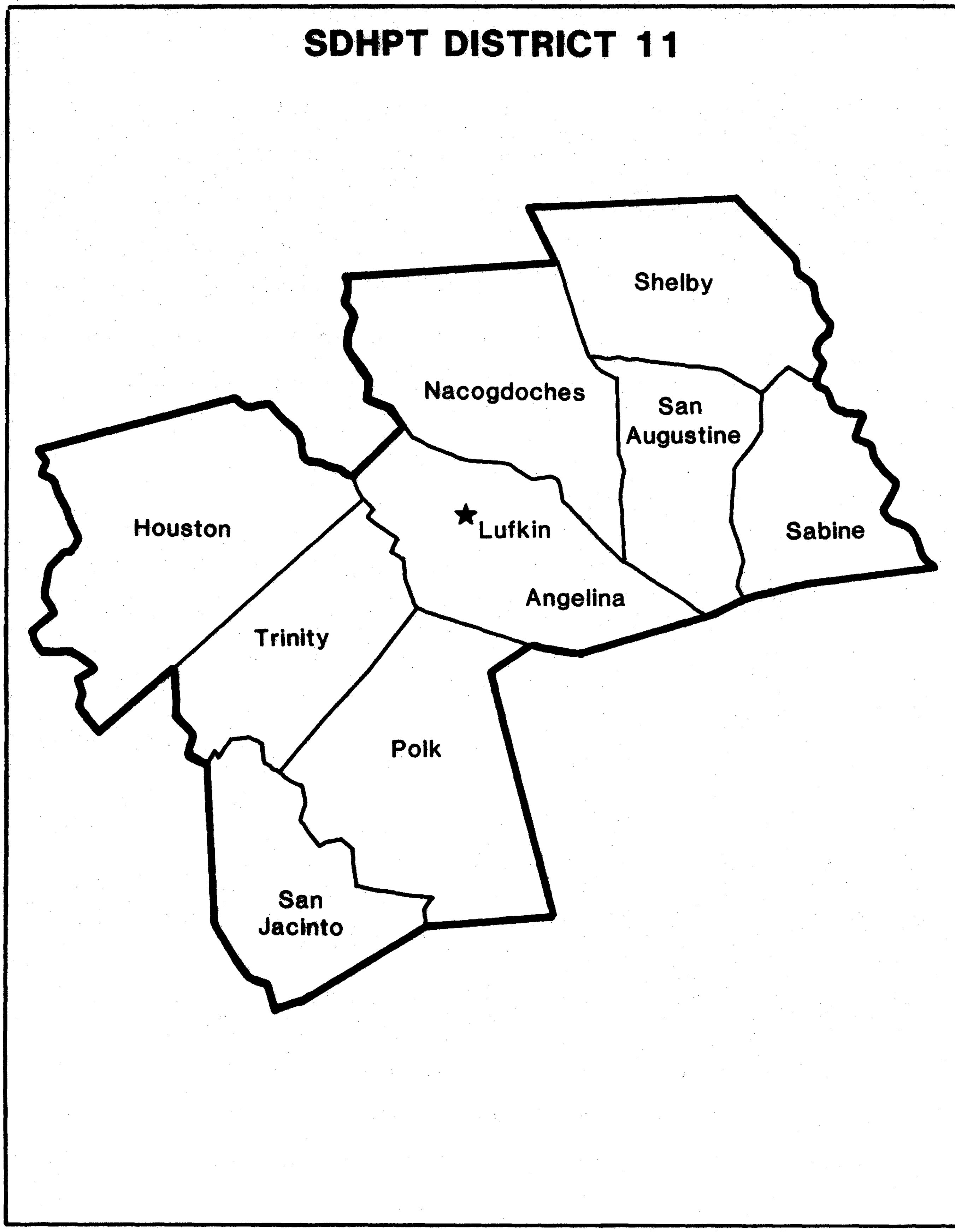

Figure 8. SDHPT District 11 County Map.

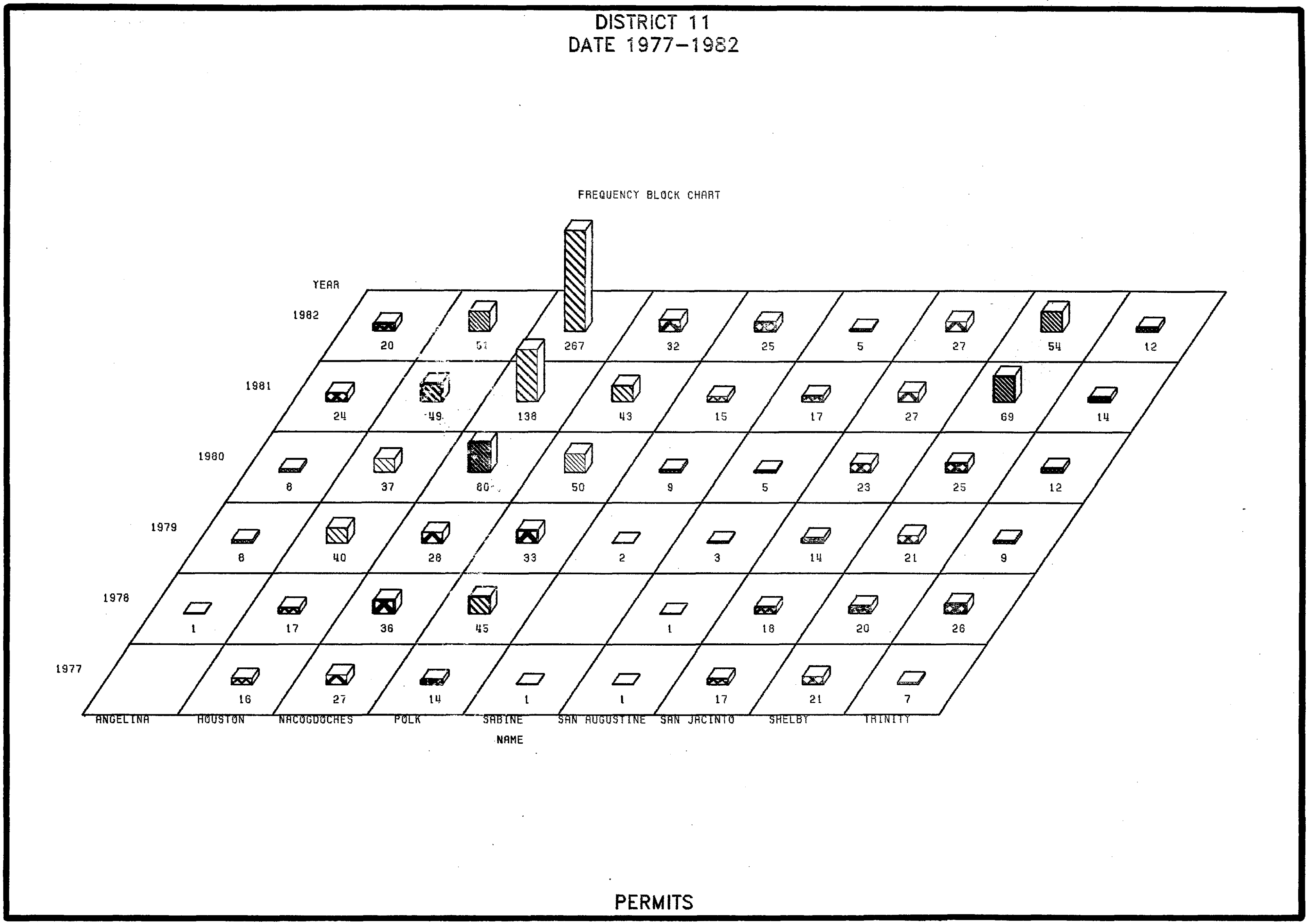

Figure 9. Total Permits Issued - District 11.

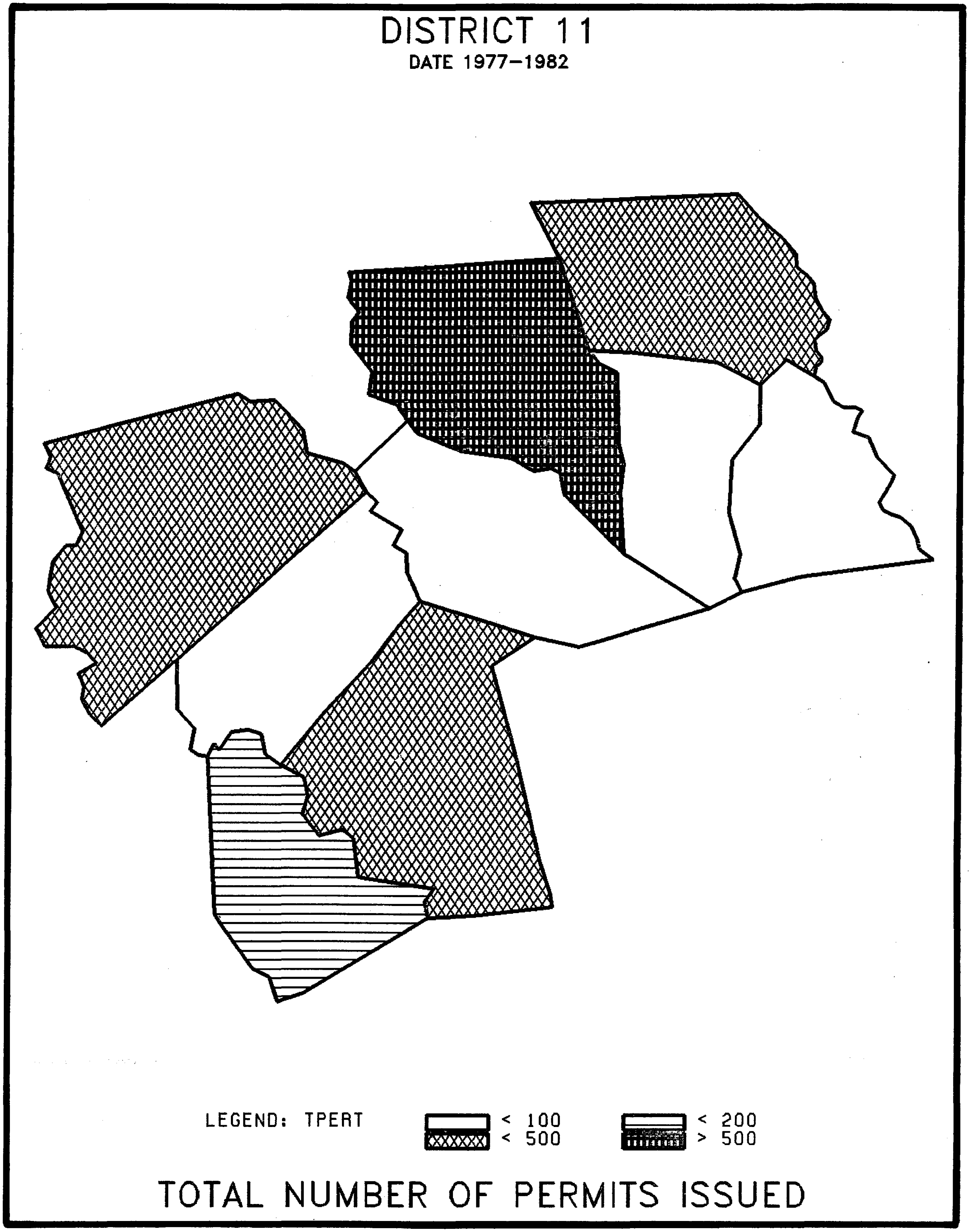

Figure 10. Total Permits - District 11 Map.

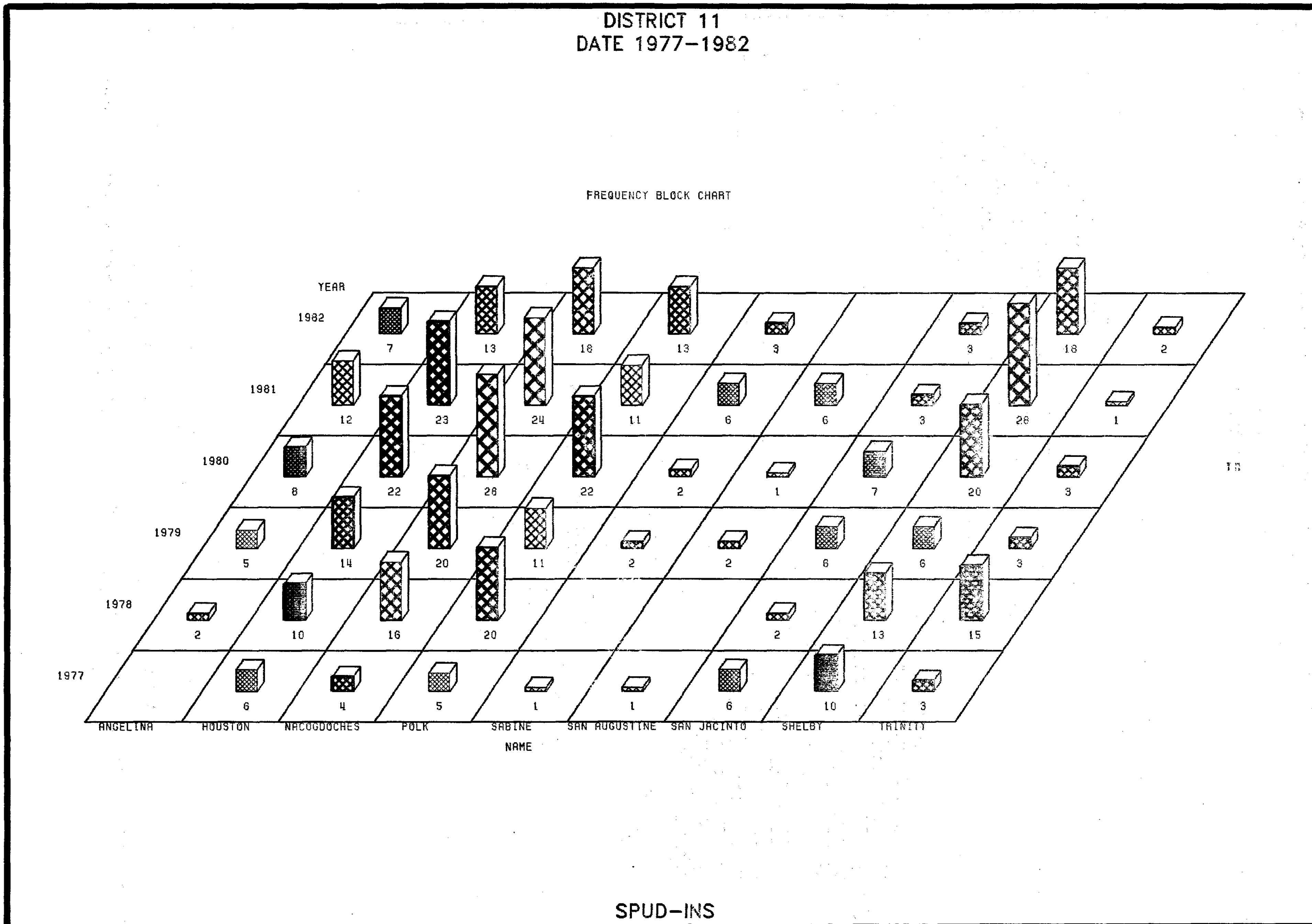

Figure 11. Total Spud-ins - District 11.

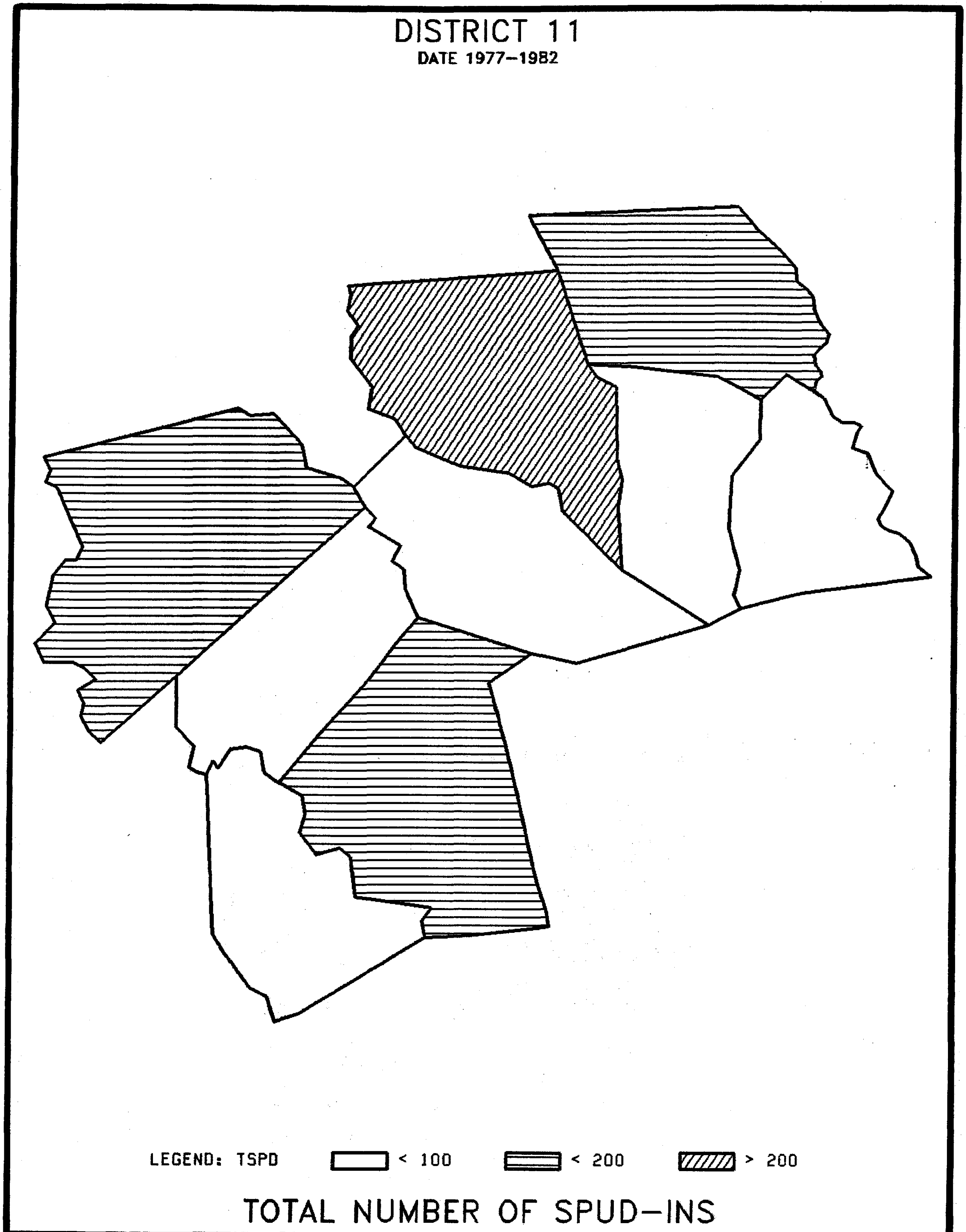

Figure 12. Total Spud-ins - District 11 Map.

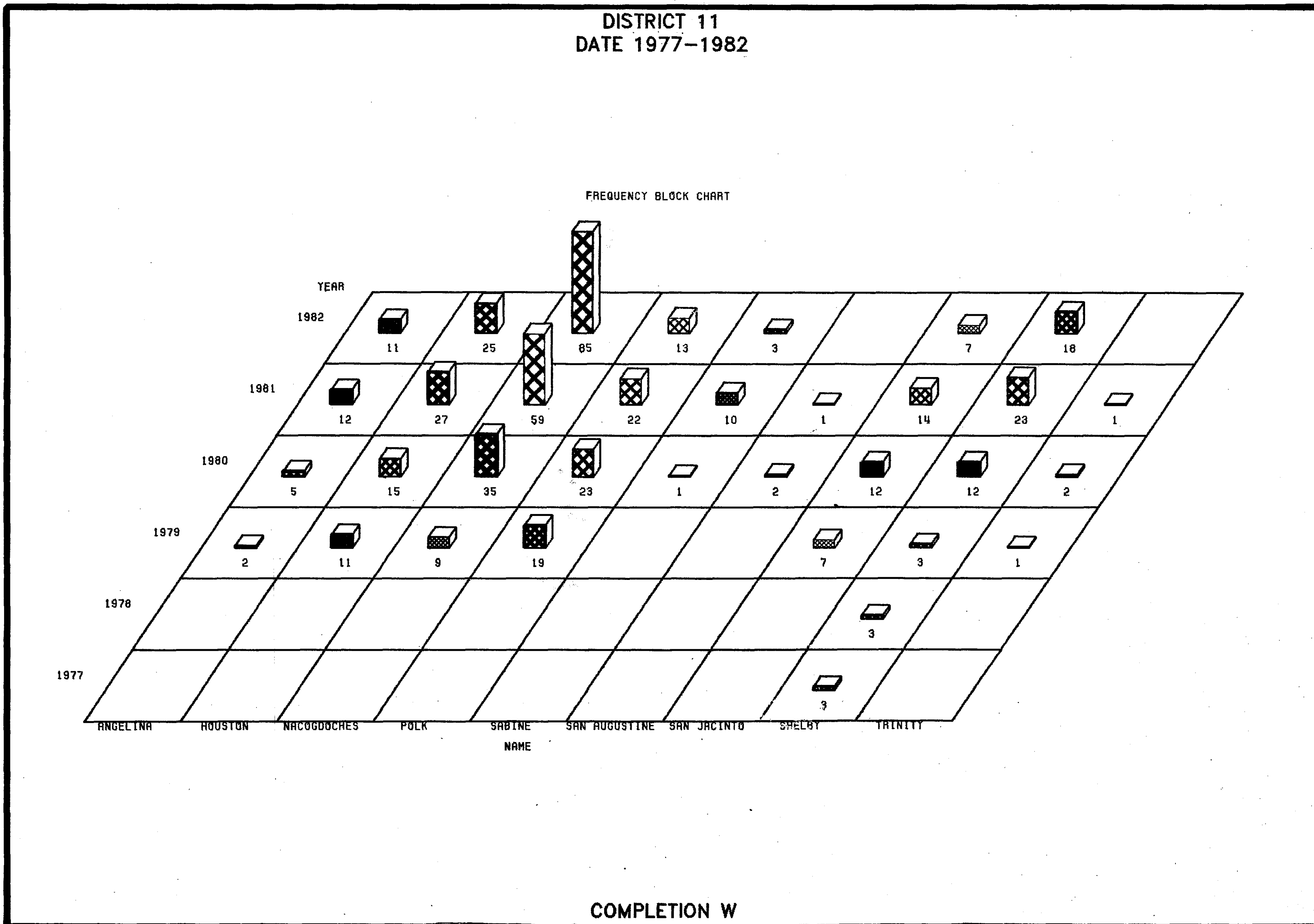

Figure 13. Total Completion W's - District 11.

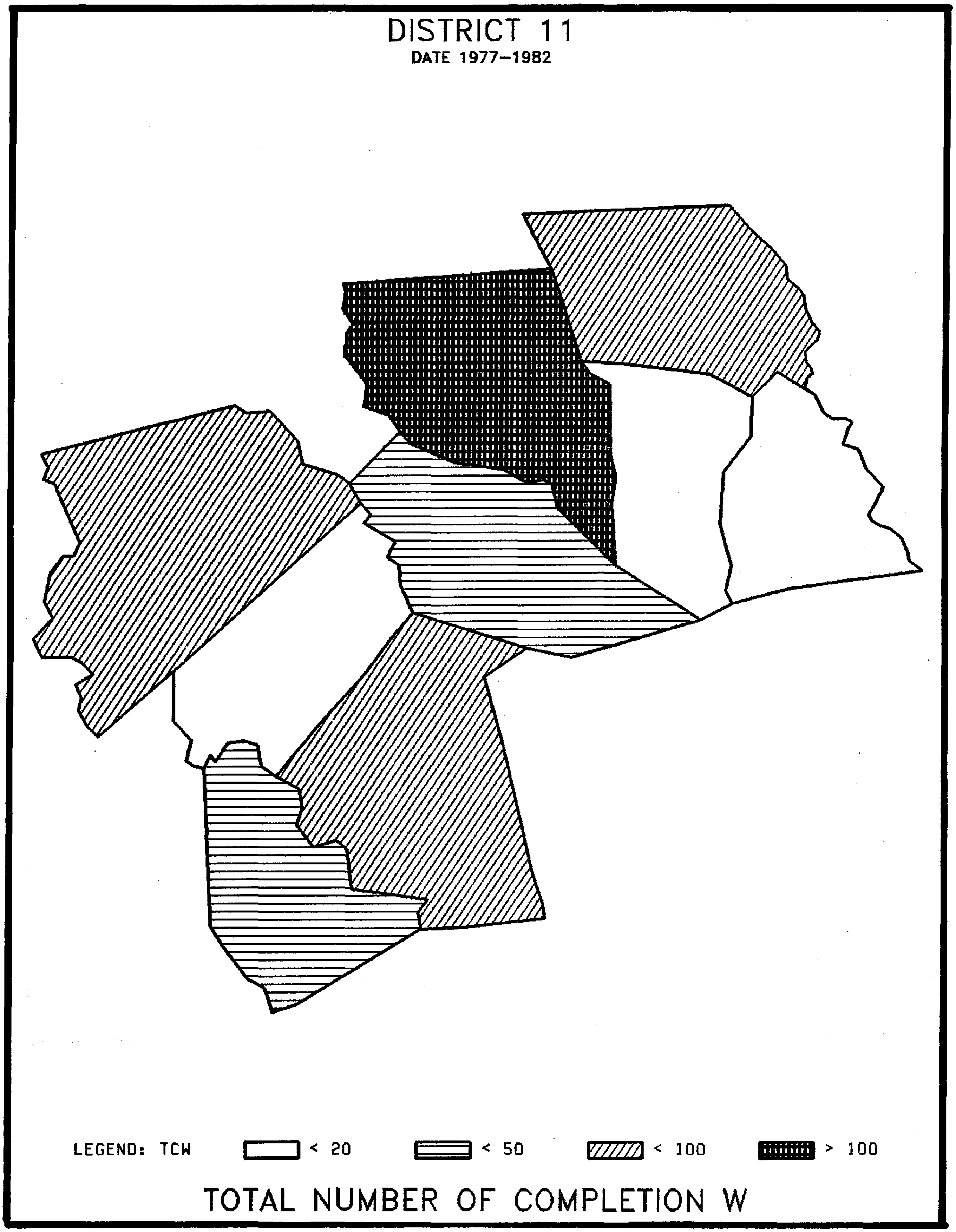

Figure 14. Total Completion W's - District 11 Map.

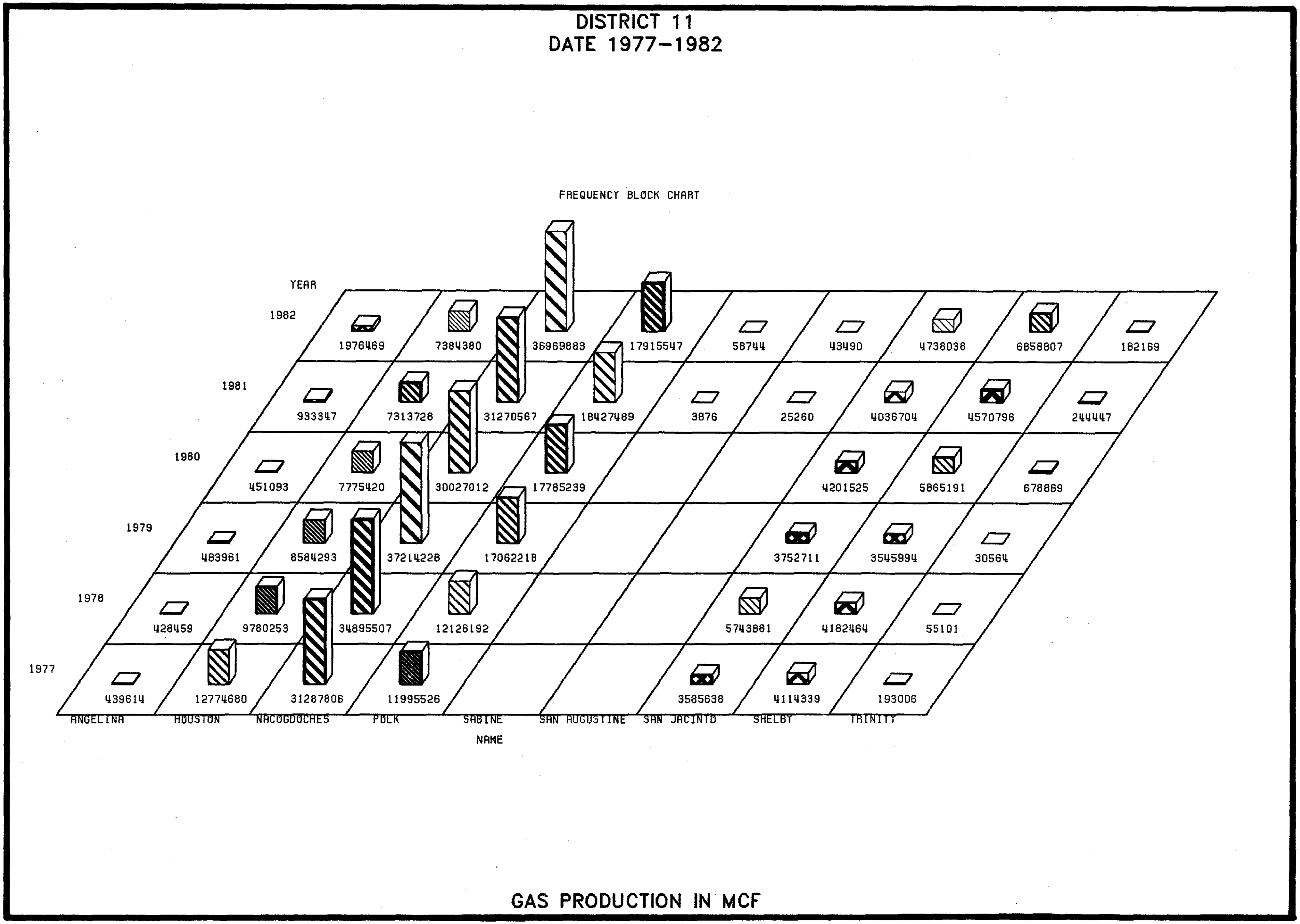

Figure 15. District 11 Annual Gas Production (1977-1982).

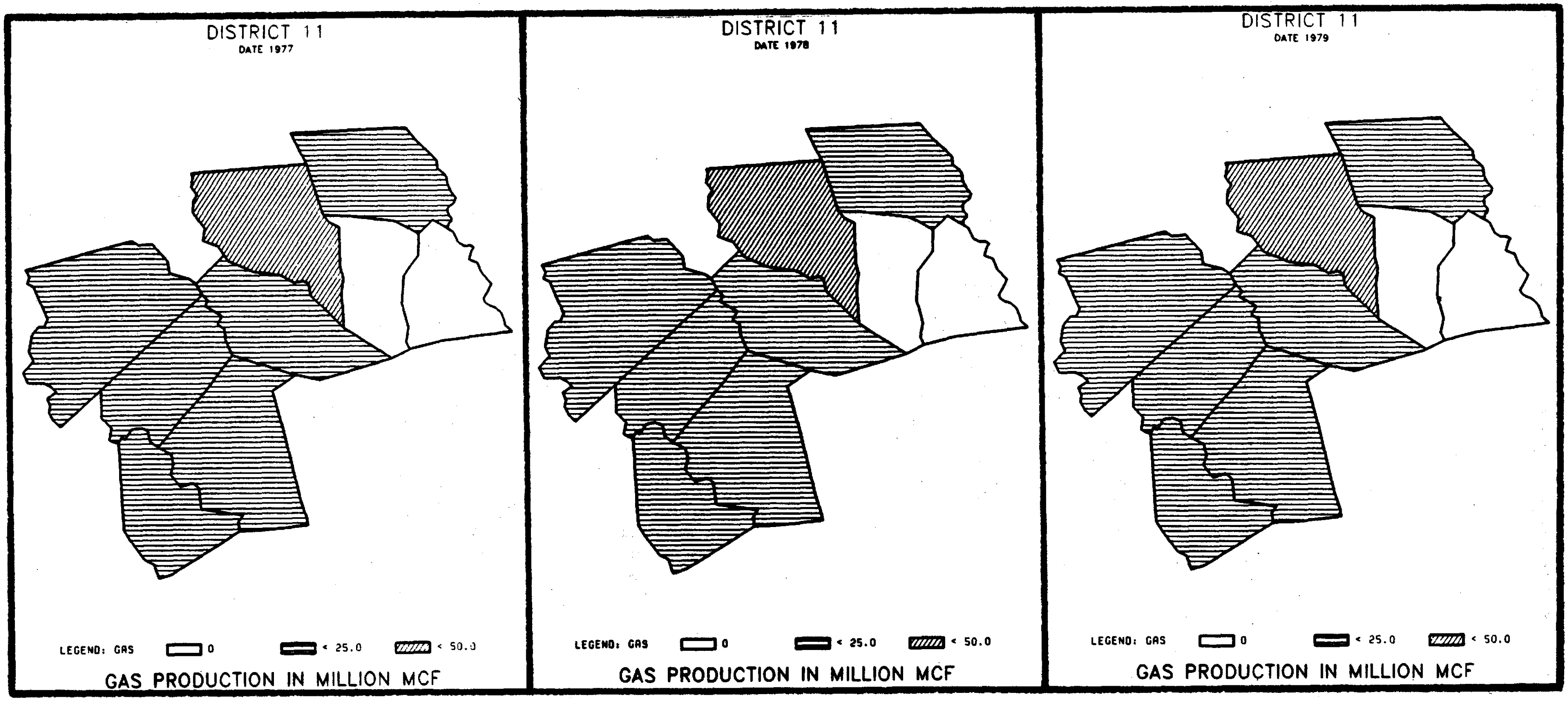

Figure 16. District 11 Gas Production Map (1977-1982).

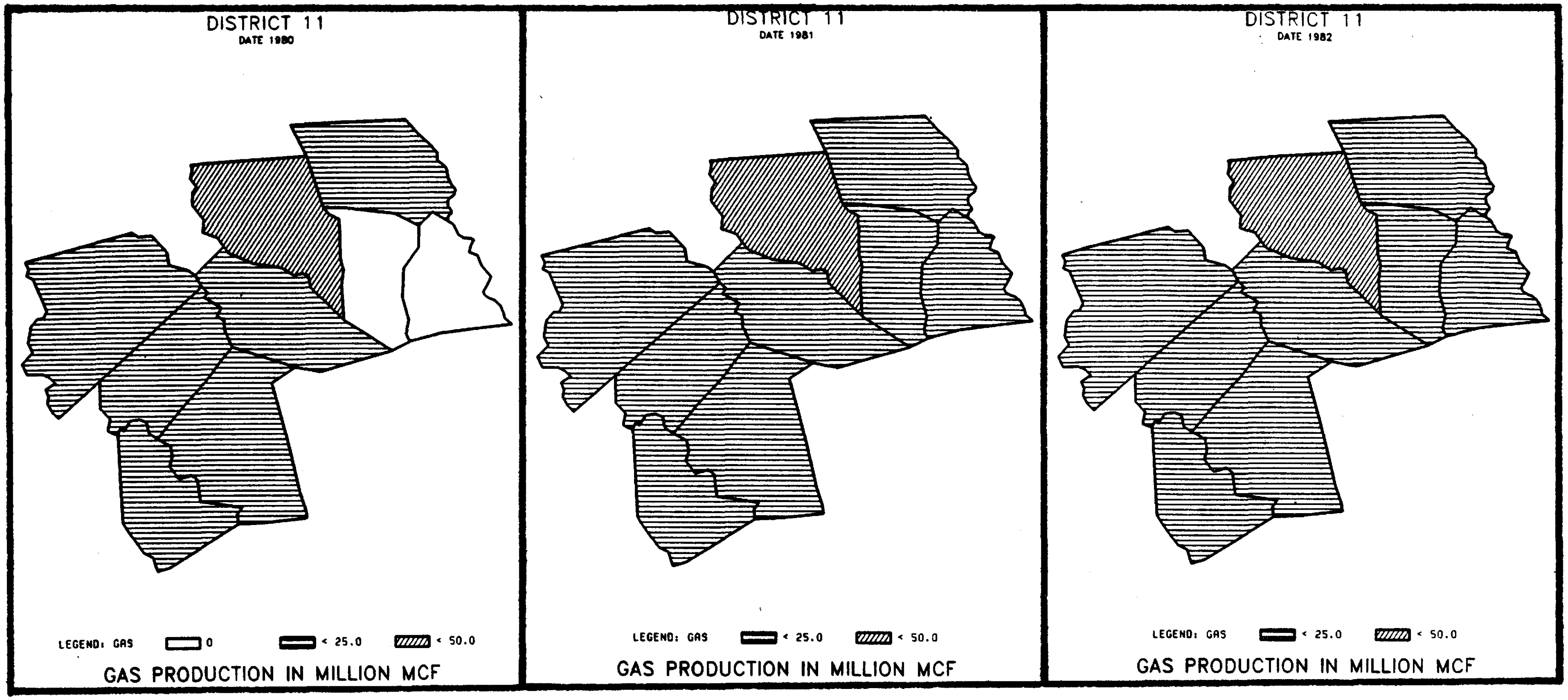

Figure 16. District 11 Gas Production Map (1977-1982) Continued.

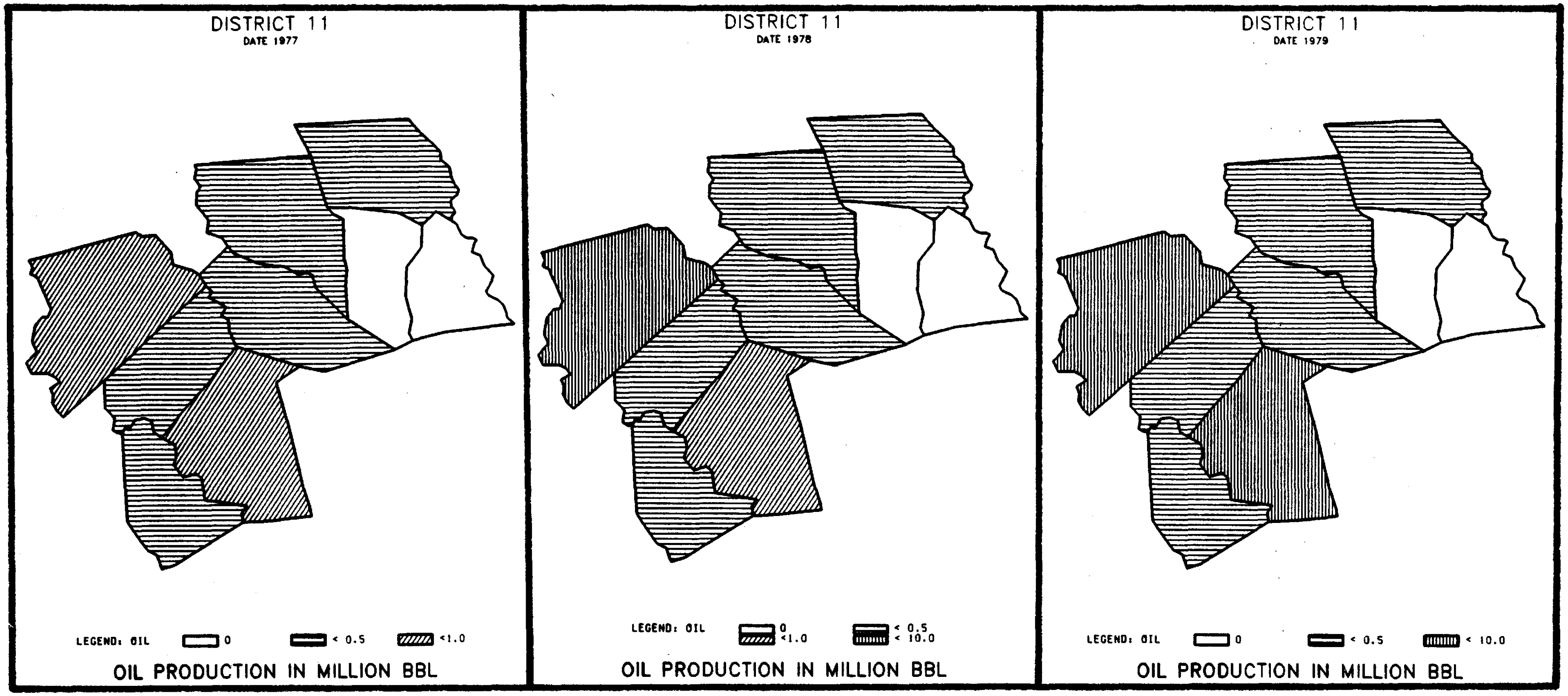

Figure 17. District 11 Oil Production
Map (1977-1982).

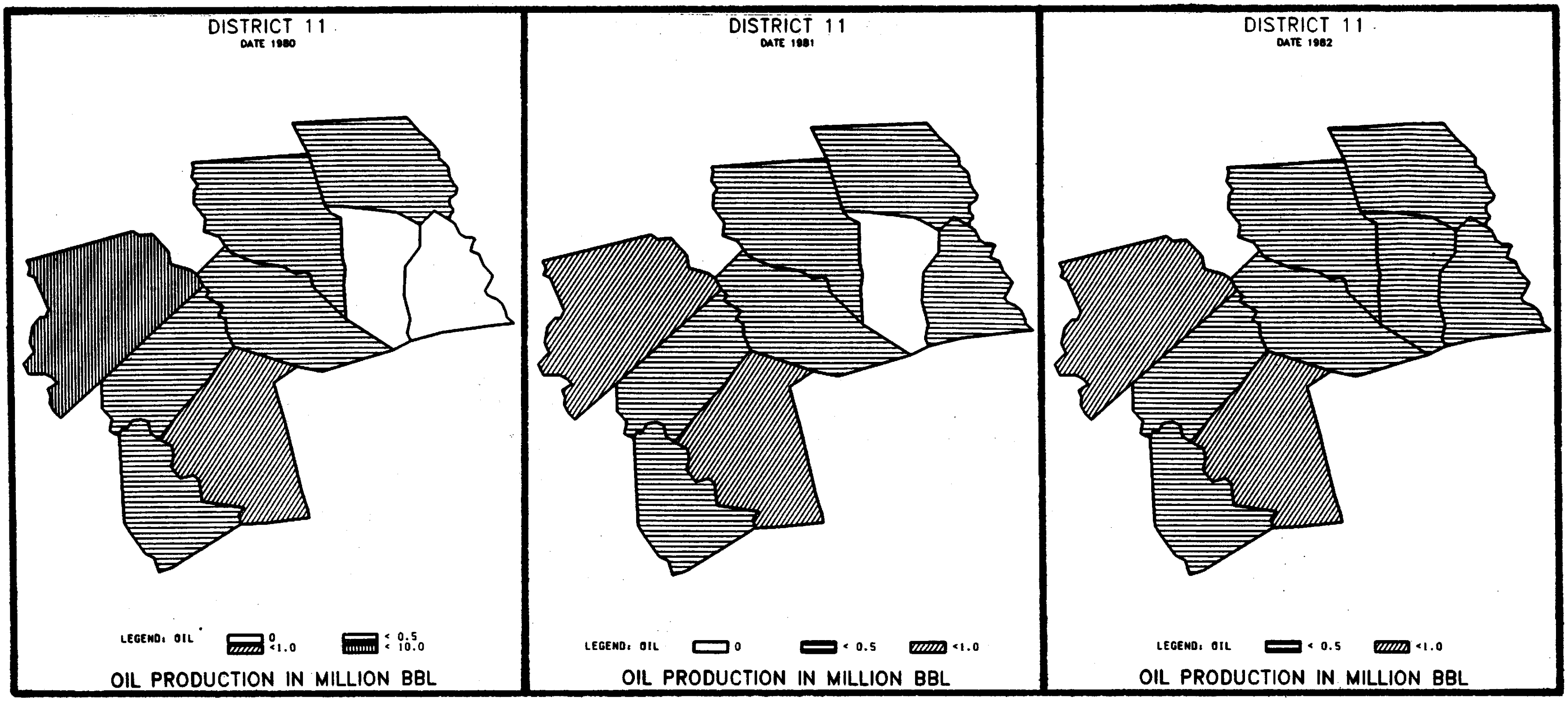

Figure 17. District 11 Oil Production Map (1977-1982) Continued.

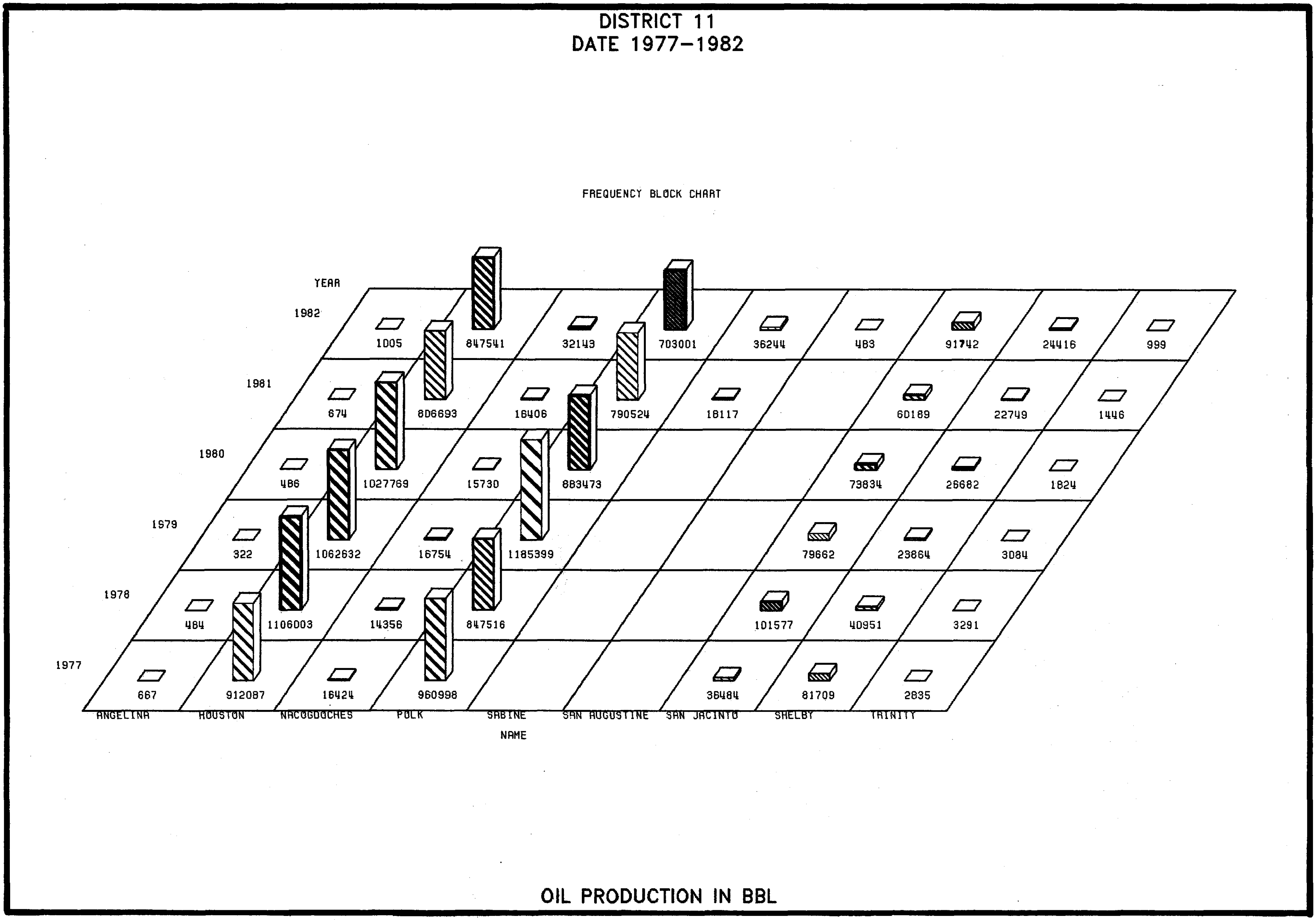

Figure 18. District 11 Annual Oil Production (1977-1982).

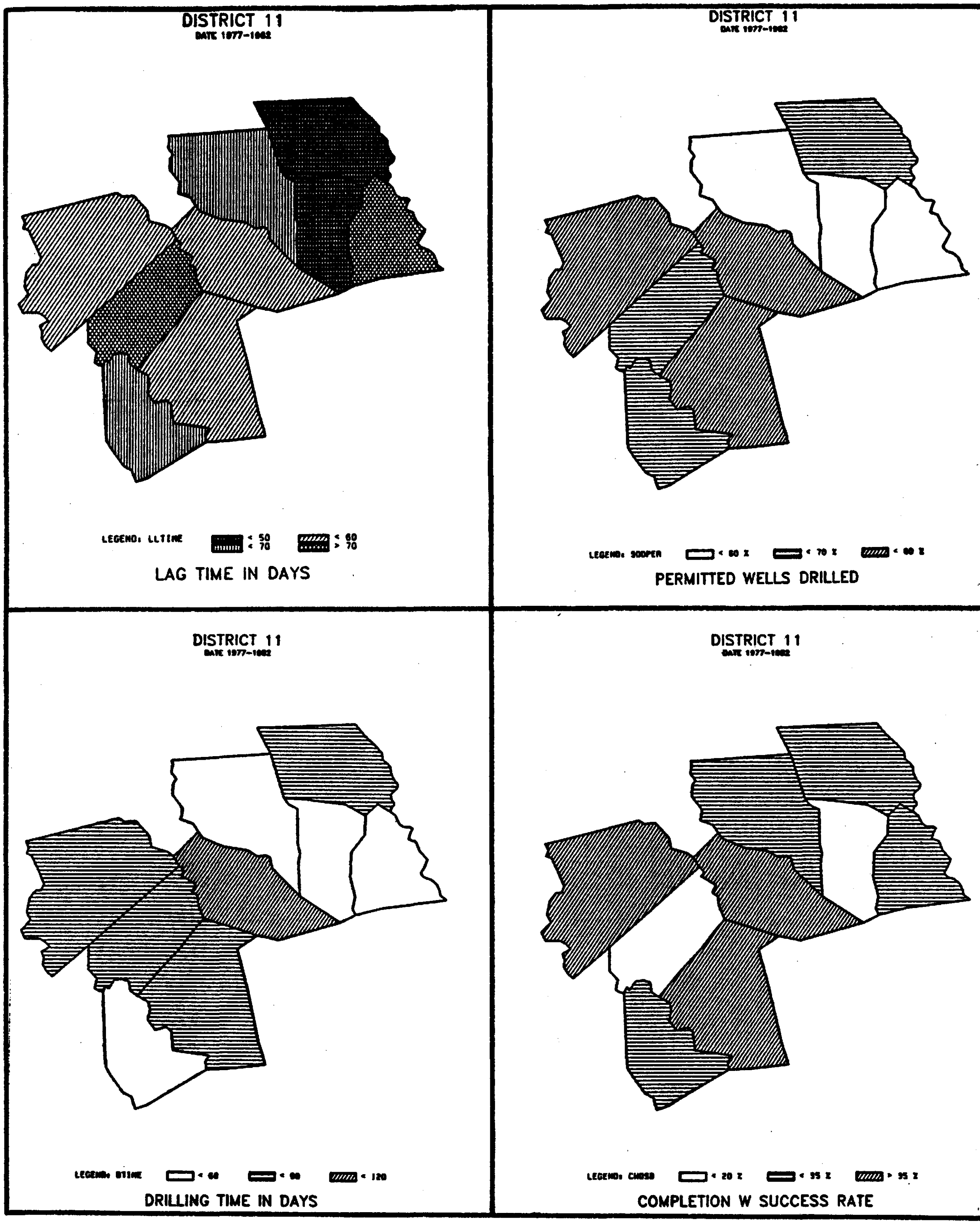

Figure 19. Variability Parameter Maps for District 11 Case Study Example.

Table 6. SDHPT District 11 Oil and Gas Variability Parameters.

County	Variability Parameter			
	Lag Time	Percent Drilled	Drill Time	Success Rate
Angelina	55	77.9	94	44.1
Houston	56	76.3	88	39.5
Nacogdoches	63	50.4	50	33.5
Polk	53	74.1	60	36.4
Sabine	77	57.1	25	26.8
San Augustine	35	56.5	12	6.5
San Jacinto	62	69.7	40	31.8
Shelby	45	68.6	76	30.1
Trinity	79	67.5	69	15.0

Table 7. Recommended Monthly Oil Production Truck Traffic Volumes for SDHPT District 11.

County	Years of Production*											
	1	2	3	4	5	6	7	8	9	10	11	12
Angelina	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0
Houston	6.0	5.0	4.0	3.5	3.0	2.0	1.0	0.5	0	0	0	0
Nacogdoches	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Polk	3.0	3.0	2.0	2.0	1.5	1.0	0.5	0	0	0	0	0
Sabine	0	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
San Augustine	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
San Jacinto	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0
Shelby	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5
Trinity	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0
DISTRICT 11	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0

* Year 1 = First 12 months of production.

necessary drill depth/drill time quartile information can be found in Table 2.

The established information is useful in defining the level and general characteristics of oil and gas field development within the influence area of a light-duty flexible pavement. The following example illustrates the actual data development process.

Example

Consider a 6-inch flexible surface-treated pavement in an area of new oil and gas field development. The road is located in Nacogdoches County. Current density maps indicate that 50 permits have been issued within the influence area of this surface-treated roadway. Thirty of the permits are for gas wells and twenty are for oil wells. What input data values are necessary to predict present and future pavement performance using the Oil Field Damage Program? The Oil Field Damage Program predicts present and future performance of surface-treated pavements using the following input data:

1. Intended-use ADT, directional distribution, percent trucks, and annual growth rate.
2. Flexible base thickness.
3. Subgrade Atterberg limits (PI, LL).
4. Section maximum dynaflect deflection.
5. Texas county number.
6. Number of wells drilled in each month of development.

The first five input items may be obtained from District records or field studies. Definition of the sixth item, number of wells drilled by month, requires use of the county variability parameters.

The percent drilled parameter aids in computing how many oil and gas wells will actually be drilled. Thus, for this influence area located in Nacogdoches County;

Gas wells drilled = (30 wells)X(50.4%)
= 15 gas wells

Oil wells drilled = (20 wells)X(50.4%)
= 10 oil wells

Total wells drilled = 25

The 25 wells are expected to be drilled in the influence area, based upon previous oil and gas well drilling in the county. These wells may be applied to the roadway at the beginning of the study period, 63 days into the study period (using average lag time for the county from Table 6), or at any rate and time which seems appropriate to the designer. The major concern is that this application of development must be consistent with the local activity.

The drill time parameter defines the average length of the drilling phase from spud-in date to final completion. For the 25 new wells in this example, the expected drilling time may be given as 50 days (average drill time for the county from Table 6) or any other reasonable value. If the final drilling depth can be approximated for any of the wells being drilled, the drill time/drill depth quartile tables (Tables 2-4) may be used instead. These tables also provide a method of predicting the effect of individual wells (given the R.R.C. permitted final well depth) on a given surface-treated pavement.

The completion success rate parameter defines the number of wells expected to generate production activity. Thus, for the original 50 permits issued in the case-study influence area:

Producing gas wells = (30 wells)X(33.5%)
= 10 gas producers

Producing oil wells = (20 wells)X(33.5%)
= 6 oil producers

Thus, 16 wells are expected to generate production activity. Of primary concern are the six oil producers, since they will likely generate production truck traffic on a periodic basis. The actual magnitude and duration of this oil production truck traffic may be taken from the recommended values for Nacogdoches County in Table 7, or from other local estimates. Production truck traffic from the 10 gas wells may be ignored, unless it is specifically known that certain operators in the area are transporting gas from various well sites by truck. As with all of the other variability parameters, site-specific information should be used in lieu of the regional values whenever possible.

Oil Field Damage Program Input Data

Typical characteristics of oil and gas field development in the sample region are summarized in Table 8. Actual rate of the drilling activity assumed in this example is given in Table 9. These two tables summarize the input data necessary to use the Oil Field Damage Program to predict the performance of the surface-treated pavement.

Table 8. Input Data for District 11 Example.

Item	Value	Source
Intended-Use ADT	500	District Records
Traffic Distribution	50/50	District Records
Annual Growth Rate	5 percent	District Records
Intended-Use %Trucks	5 percent	District Records
Flexible Base Thickness	6 inches	District Records
Subgrade PI	12.00%	District Lab
Subgrade LL	41.63%	District Lab
Maximum Dynaflect	1.55 mils	District Records
County Number	174	State Records
Wells Drilled	15 gas 10 oil	Permits X Percent Drilled
Average Lag Time	63 days	County Value
Average Drill Time	50 days	County Value
Wells Producing	5 gas 3 oil	Permits X Success Rate
Gas Production Traffic	0 trucks/mo.	Assumed
Oil Production Traffic	0.5 trucks/mo.	Table 7 (for first year only)

Table 9. Application of Development for District 11 Example.

Month	Wells Drilled	Well Type
1	1	Oil
2	1	Gas
3	1	Gas
4	1	Oil
5	1	Gas
6	1	Gas
7	1	Oil
8	1	Gas
9	1	Gas
10	1	Oil
11	1	Gas
12	1	Gas
13	1	Oil
14	1	Gas
15	1	Gas
16	1	Oil
17	1	Gas
18	1	Gas
19	1	Oil
20	1	Gas
21	1	Gas
22	1	Oil
23	1	Gas
24	1	Oil
25	1	Oil

CONCLUSIONS AND RECOMMENDATIONS

The formation of oil and gas deposits is the result of a complex series of geological, chemical, and physical activities taking place over millions of years. The characteristics of deposits in one area rarely hold true for other nearby areas. As a result, site-specific relationships are truly useful only for very small regions.

Previous studies have demonstrated the dramatic impact of localized oil field development on one rural surface-treated pavement. These studies have dealt only with one region of the state. The procedures described in this report, however, represent an expansion from local to statewide applicability. The variability parameters illustrated in the case study example should enable the Department to deal with the problems posed by oil and gas field development.

Oil Field Damage Program Modifications

The previous example illustrates the development of input data for the Oil Field Damage Program. However the current version of the program is not suitable for statewide use. Actual analysis cannot take place until the following modifications are made to incorporate the oil and gas variability information described in this report:

1. Input Different Drill Times.
2. Input Different Production Truck Traffic Characteristics.

Input Different Drill Times. The Oil Field Damage Program is presently set to model wells with a drill time of 60 days. Most wells in Texas are not drilled in 60 days, as indicated by the wide range of county average drill time values. Adding this variable drill time capability would enable the program to examine the effect of drilling time (and possibly drilling depth) on pavement performance.

Input Different Production Truck Traffic Characteristics. Variations in production activity at different well sites require a modification of the Oil Field Damage Program's modelling of production truck traffic. Some wells, such as dry holes and gas wells, are assumed to generate no production truck traffic. Producing oil wells, however, may generate truck activity during production. The computer program should be modified to reflect potential variations in the magnitude and the duration of production truck traffic activity within an oil field region.

Phase IV Considerations

Phase III was intended to expand the utility of the earlier site-specific results to statewide analysis of individual surface-treated pavements in oil and gas field areas. This report, in conjunction with Report 299-5, satisfies the Phase III objectives.

Oil and gas well traffic is rarely confined to just one road. Traffic to and from the well site usually travels over a network of two or more roadways. Most of these flexible rural pavements are surface-treated; others are not. The current Oil Field Damage Program is not capable of analyzing overlay, black base, and hot-mix flexible pavements. In addition, the current program does not accommodate different drilling and production characteristics. These limitations severely restrict the implementation of the current study results. To improve the applicability of these results for statewide Department use, the Technical Advisory Committee recommended that the following objectives be considered in Phase IV of this study:

1. Demonstrate the use of the current methodology in assessing and predicting the effects of oil or gas field activity on a network of flexible pavements.
2. Develop pavement distress equations for flexible pavements other than surface-treated pavements.
3. Modify the Oil Field Damage Program for use with both the new pavement distress equations and the Phase III variability parameters to analyze flexible pavement networks.

Interpretation

Interpretation of the information contained in this report must consider the generality of the input data. The descriptors of county activity are based upon previous oil or gas activity and may not specifically represent current characteristics at any one site. The case study example presented in this report was intended to illustrate the potential use of the overall analysis procedure.

Recommendations for Future Research

The results of Phase IV will finalize the procedure for analyzing the effects of oil or gas field development on light-duty, flexible rural highways in Texas. Future research efforts should be directed towards simplifying implementation and broadening the general applicability of the study procedures:

1. Initiate a Unified State Plane Coordinate System.
2. Coordinate With R.R.C. Graphics Computerization Efforts.
3. Identify and Analyze Other "Special-Use" Activities.

State Plane Coordinate System. Texas is now divided into five state plane coordinate regions. These regions, however, are independent of one another and cannot easily be consolidated into one system. Such a unified state plane coordinate system would aid immeasurably in the accurate location of towns, county lines, roadway mileposts, and other similar geographic landmarks used to create the regional density maps. The increased reliability of the density maps would be just one of many benefits accrued by the Department from a unified state plane coordinate system.

R.R.C. Graphics Computerization. The R.R.C. recently began a long-term program aimed at computerizing all of their graphics materials. Such a program would include their well location maps and lease maps. Assistance in this effort by members of the Department could yield mutual benefits.

"Special-Use" Activities. The vehicle mix and axle loads of trucks used by the timber, grain, and gravel industries are atypical. Research is currently underway to identify the activity centers and unique traffic characteristics generated by these localized "special-use" activities. Future project efforts will maintain the generality of the Oil Field Damage Program to preserve its potential utility in analyzing the effects of these other load-intensive "special-use" activities.

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3. Mason, J. M., Underbrink, D., Stampley, B., Scullion, T., and Rowan, N.J., "Methodology for Assessing and Predicting the Effects of Oil Field Development," Research Report 299-3, Texas Transportation Institute, Texas A&M University, College Station, Texas, July, 1983.

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5. "SAS User's Guide 1979 Edition," SAS Institute Inc., Box 8000, Cary, North Carolina, 27511.

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7. Slavin, Bill, "Drilling Permit System Manual," Railroad Commission of Texas, Austin, Texas, October, 1980.

APPENDIX A

County Variability Parameters - by SDHPT District Number

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
1	Delta	111	63.6	**	0.0
	Fannin	**	60.0	**	0.0
	Franklin	50	74.8	20	47.5
	Grayson	51	65.7	74	32.2
	Hopkins	39	77.1	43	16.9
	Hunt	48	71.4	63	10.7
	Lamar	46	84.6	**	0.0
	Rains	52	77.8	80	27.8
	Red River	65	58.1	27	18.0
2	Erath	53	73.0	51	45.8
	Hood	28	64.1	30	37.4
	Jack	51	65.3	34	38.3
	Johnson	15	50.0	**	0.0
	Palo Pinto	45	74.6	25	45.0
	Parker	37	73.1	35	40.5
	Somervell	85	66.7	299	41.7
	Tarrant	53	81.3	91	37.5
	Wise	60	72.4	29	53.4
3	Archer	61	59.7	28	32.5
	Baylor	55	65.5	10	22.2
	Clay	52	67.1	35	38.1
	Cooke	62	64.6	24	33.8
	Montague	49	69.5	29	38.5
	Throckmorton	51	67.2	24	30.8
	Wichita	55	63.7	18	41.2
	Wilbarger	46	72.1	15	47.5
	Young	51	63.5	25	37.3

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
4	Armstrong	20	100.0	**	0.0
	Carson	66	69.0	16	56.7
	Dallam	117	83.3	119	16.7
	Deaf Smith	65	53.8	**	0.0
	Gray	50	68.3	21	53.1
	Hansford	56	80.1	36	32.2
	Hartley	73	72.5	54	17.5
	Hemphill	48	83.7	69	52.9
	Hutchinson	77	82.4	17	71.9
	Lipscomb	59	84.0	29	54.0
	Moore	70	67.6	17	51.6
	Ochiltree	46	80.6	41	52.5
	Oldham	22	88.0	32	37.6
	Potter	62	65.9	7	44.1
	Randall	44	100.0	**	0.0
	Roberts	60	76.9	43	43.2
	Sherman	62	77.2	23	31.7
5	Bailey	43	80.0	**	0.0
	Castro	**	100.0	**	0.0
	Cochran	63	82.9	14	55.2
	Crosby	59	81.7	23	65.6
	Dawson	44	86.4	28	47.6
	Floyd	39	100.0	129	4.8
	Gaines	58	82.8	24	52.2
	Garza	60	84.4	32	57.2
	Hale	80	68.8	24	35.9
	Hockley	59	84.5	17	58.8
	Lamb	47	82.7	20	22.7
	Lubbock	51	89.9	18	57.0
	Lynn	41	87.4	128	28.3
	Parmer	50	57.1	**	0.0
	Swisher	13	92.0	**	0.0
	Terry	38	89.9	31	51.7
	Yoakum	76	83.9	23	58.3

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
6	Andrews	65	80.3	22	65.3
	Crane	55	79.6	24	61.1
	Ector	60	75.1	19	52.6
	Loving	51	77.4	109	54.4
	Martin	48	83.1	33	67.3
	Midland	44	76.2	33	62.5
	Pecos	56	70.8	65	48.8
	Reeves	36	77.6	56	41.4
	Terrell	61	73.9	138	37.7
	Upton	48	75.4	38	55.6
	Ward	63	76.0	45	57.0
	Winkler	54	74.2	38	56.4
7	Coke	50	89.0	23	44.3
	Concho	37	79.2	17	32.9
	Crockett	52	74.5	22	51.7
	Edwards	54	66.0	8	34.5
	Glasscock	44	78.1	33	51.5
	Irion	43	82.7	19	55.9
	Kimble	43	77.0	17	14.8
	Kinney	39	56.0	**	0.0
	Menard	25	76.2	23	23.8
	Reagan	52	83.2	15	73.0
	Real	17	55.6	**	0.0
	Runnels	49	76.8	22	35.5
	Schleicher	42	79.3	26	39.1
	Sterling	57	77.1	23	53.1
	Sutton	55	81.8	12	55.4
	Tom Green	38	76.9	35	35.8
	Val Verde	88	54.9	128	20.3
8	Borden	50	80.9	43	33.5
	Callahan	40	69.4	36	31.5
	Fisher	43	77.6	26	38.2
	Haskell	46	76.5	32	27.9
	Howard	52	80.5	22	55.3
	Jones	40	79.4	24	33.5
	Kent	45	87.8	56	50.3
	Mitchell	55	78.3	17	56.2
	Nolan	46	77.9	31	41.2
	Scurry	59	80.4	27	60.9
	Shackelford	41	67.4	20	35.9
	Stonewall	54	80.1	25	36.3
	Taylor	49	77.0	25	35.7

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
9	Bell	40	34.5	**	3.4
	Bosque	**	100.0	**	0.0
	Coryell	8	100.0	**	0.0
	Falls	54	54.2	47	21.7
	Hamilton	35	58.9	56	19.6
	Hill	34	44.3	198	5.7
	Limestone	52	74.9	71	35.8
	McLennan	52	50.2	53	34.2
10	Anderson	49	62.6	88	36.3
	Cherokee	44	78.8	74	45.4
	Gregg	62	70.7	87	52.3
	Henderson	61	81.3	87	51.6
	Rusk	47	79.0	58	55.8
	Smith	38	80.4	47	41.0
	Van Zandt	42	79.5	84	26.3
	Wood	53	77.8	24	51.4
11	Angelina	55	77.9	94	44.1
	Houston	56	76.3	88	39.5
	Nacogdoches	63	50.4	50	33.5
	Polk	53	74.1	60	36.4
	Sabine	77	57.1	25	26.8
	San Augustine	35	56.5	12	6.5
	San Jacinto	62	69.7	40	31.8
	Shelby	45	68.6	76	30.1
	Trinity	79	67.5	69	15.0
12	Brazoria	63	63.8	73	32.9
	Fort Bend	53	70.7	56	39.2
	Galveston	84	66.0	45	34.4
	Harris	82	64.1	46	31.9
	Montgomery	51	71.6	32	36.7
	Waller	55	53.4	83	33.7

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
13	Austin	56	59.8	93	33.9
	Calhoun	60	66.5	45	28.1
	Colorado	46	70.9	64	30.8
	DeWitt	49	73.6	55	29.2
	Fayette	49	76.3	50	63.9
	Gonzales	43	72.1	48	56.0
	Jackson	62	69.1	31	40.1
	Lavaca	42	67.8	110	35.6
	Matagorda	73	68.4	74	31.7
	Victoria	47	68.8	58	38.5
	Wharton	54	66.8	53	33.6
14	Bastrop	89	48.2	74	24.4
	Blanco	**	**	**	**
	Burnet	**	0.0	**	0.0
	Caldwell	40	69.4	36	31.5
	Gillespie	**	**	**	**
	Hays	**	50.0	**	**
	Lee	38	73.6	36	56.8
	Llano	**	**	**	**
	Mason	**	**	**	**
	Travis	20	40.6	**	15.6
	Williamson	61	29.5	76	5.3
15	Atascosa	49	57.8	48	41.1
	Bandera	48	70.0	**	0.0
	Bexar	74	54.7	48	48.0
	Comal	**	0.0	**	0.0
	Dimmit	42	71.3	63	41.3
	Frio	47	64.9	42	46.1
	Guadalupe	69	58.2	73	50.1
	Kendall	43	57.1	**	0.0
	Kerr	4	55.6	**	11.1
	LaSalle	58	65.9	57	25.2
	Maverick	47	68.6	40	37.5
	McMullen	56	70.5	59	17.7
	Medina	84	46.5	59	35.6
	Uvalde	34	50.0	**	0.0
	Wilson	47	66.0	52	46.5
	Zavala	46	72.3	47	33.3

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
16	Aransas	83	66.3	54	31.7
	Bee	48	75.0	34	25.6
	Goliad	44	70.1	40	34.1
	Jim Wells	41	71.3	55	29.5
	Karnes	49	74.6	62	16.9
	Kleberg	44	53.1	29	25.8
	Live Oak	53	78.8	70	19.5
	Nueces	62	68.5	49	36.3
	Refugio	57	56.6	62	37.5
	San Patricio	52	68.6	48	35.7
17	Brazos	30	77.5	53	59.3
	Burleson	44	84.2	36	76.4
	Freestone	42	76.0	72	50.5
	Grimes	65	80.0	77	39.4
	Leon	47	73.6	107	44.5
	Madison	55	68.9	63	46.2
	Milam	73	44.5	70	31.4
	Robertson	38	75.8	87	42.4
	Walker	56	80.9	41	14.7
	Washington	48	75.6	70	48.0
18	Collin	9	66.7	**	0.0
	Dallas	31	33.3	**	33.3
	Denton	50	50.0	60	17.9
	Ellis	45	43.8	19	36.3
	Kaufman	58	76.4	133	15.3
	Navarro	66	48.8	62	33.4
	Rockwall	31	100.0	**	0.0
19	Bowie	67	82.4	63	17.6
	Camp	47	69.8	43	45.3
	Cass	43	83.2	67	42.6
	Harrison	50	78.9	51	55.7
	Marion	47	79.9	41	36.5
	Morris	51	87.5	**	0.0
	Panola	60	81.0	61	59.9
	Titus	75	73.4	35	52.6
	Upshur	44	81.3	61	51.6

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
20	Chambers	72	62.2	48	33.1
	Hardin	70	66.2	42	41.8
	Jasper	70	66.7	81	35.8
	Jefferson	63	63.5	57	30.7
	Liberty	64	60.1	51	29.1
	Newton	45	73.6	95	22.5
	Orange	62	74.7	62	37.1
	Tyler	53	68.8	225	31.3
21	Brooks	40	70.9	35	27.8
	Cameron	40	65.6	224	19.4
	Duval	46	86.6	59	12.1
	Hidalgo	47	72.0	74	39.4
	Jim Hogg	36	84.6	32	16.0
	Kenedy	46	65.5	28	32.6
	Starr	48	70.9	57	39.3
	Webb	43	78.7	62	45.5
	Willacy	45	66.8	42	39.3
	Zapata	37	72.1	68	38.7
23	Brown	52	60.1	21	36.5
	Coleman	40	63.5	25	34.3
	Comanche	38	67.5	25	38.6
	Eastland	41	65.4	27	38.8
	Lampasas	6	100.0	**	0.0
	McCulloch	43	66.1	35	18.2
	Mills	34	60.0	**	0.0
	San Saba	22	54.2	**	0.0
	Stephens	49	73.7	28	46.6
24	Brewster	50	91.0	**	0.0
	Culberson	33	85.2	16	36.2
	El Paso	**	0.0	**	0.0
	Hudspeth	58	61.1	**	0.0
	Jeff Davis	**	100.0	**	0.0
	Presidio	38	95.4	**	0.0

** No records available to compute this parameter.

District	County	Lag Time	Percent Drilled	Drill Time	Success Rate
25	Briscoe	87	94.4	82	0.8
	Childress	17	80.0	**	3.3
	Collingsworth	54	73.0	28	46.7
	Cottle	37	85.7	59	22.9
	Dickens	25	83.3	18	3.0
	Donley	75	33.3	**	0.0
	Foard	38	65.5	20	24.1
	Hall	46	70.0	**	0.0
	Hardeman	42	75.1	39	27.8
	King	37	78.6	18	33.5
	Knox	34	74.6	17	23.9
	Motley	50	84.0	17	12.0
	Wheeler	48	73.3	85	45.9

** No records available to compute this parameter.