DOE/BC/14960--T1

1 st Quarter, Fiscal Year 1995

POST WATERFLOOD CO2 MISCIBLE FLOOD IN LIGHT OIL FLUVIAL - DOMINATED DELTAIC RESERVOIRS.

DE - FC22 - 93BC14960

TEXACO EXPLORATION AND PRODUCTION INC.

January 15, 1994

Award Date: June 1, 1993.
Completion Date: December 31, 1997

Government Award for Current Fiscal Year

$ 1,045,000.00

Project Manager	(Texaco)	Sami Bou-Mikael
COR	(DOE)	Chandra Nautiyal
Contract Specialist	(DOE)	John Augustine

Reporting Period : ~~July~~ October 1, 1994 Through ~~September~~ December 30, 1994

TABLE OF CONTENTS

DISCLAIMER

POST WATERFLOOD CO_2 MISCIBLE FLOOD IN LIGHT OIL FLUVIAL DOMINATED DELTAIC RESERVOIRS"

"DE-FC22-93BC14960"
TECHNICAL PROGRESS REPORT

1st QUARTER, 1995.

EXECUTIVE SUMMARY.

Production is averaging about 450 BOPD for the quarter. The fluctuation was primarily due to a temporary shutdown of CO_2 delivery and maturing of the first WAG cycle. CO_2 and water injection were reversed again in order to optimize changing yields and water cuts in the producing wells. Measured BHP was close to the anticipated value. A limited CO_2 volume of 120 MMCF was injected to stimulate well Kuhn #6 to test the Huff-Puff process, since the well did not respond to CO_2 injection from the main reservoir. The well will be placed on February 1, 1995. Total CO_2 injection averaged this quarter about 8.8 MMCFD, including 3.6 MMCFD purchased CO_2 from Cardox.

1st QUARTER (1995) OBJECTIVES.

* Reverse the WAG cycle, in order to increase the CO_2 sweep efficiency. Monitor the producing wells performance.

The application of the WAG process in high porosity, high permeability sandstone reservoirs is unique and proving to be effective in diverting the CO_2 in an effort to improve the sweep efficiency. The reservoir performance has responded favorably to the alternating water and CO_2. Figure 3 shows the change in the reservoir daily production and yield in June and December when the switch was made in the injection wells. The results of the second switch back to the original well status (i.e. Wells Marg Area 1-H, Stark #7 and Kuhn # 36 injecting CO_2, Wells Stark 10 and Kuhn #17 injecting water) can not be fully evaluated at this time, however early indications are positive.

The need for additional cycles as well as the timing will be evaluated in the future as dictated by reservoir performance. Also we will evaluate switching wells Stark #7 and Kuhn #36 to producers when the reservoir simulator is completed.

* Huff-Puff well Kuhn #6 with a limited slug of CO_2 (100 MMCF), followed by a 3 weeks shut in period, then place the well on production.

After laying 1700' of welded injection line to the well, CO_2 injection began in early December and continued until a total of 127 MMCF was injected. Currently the well is shut in for 3 weeks soaking period, then the well will be open for production on February 1, 1995. The response from the well to the CO_2 Huff-Puff mechanism is proportional to the oil saturation around the wellbore, the reservoir pressure and the oil composition or crude gravity. The deeper the CO_2 penetration through the reservoir fluid the higher the oil recovery will be. As the CO_2 penetrates through the oil initially it bypasses the oil during the Huff phase, then it soaks into the oil and depending on the pressure it may become miscible in the oil. During the Puff phase the CO_2 at certain suitable conditions will recover between 3000 to 15000 Bbls of oil. Additional CO_2 injection cycles can be performed if the recovery from the first cycle was economical.

The BHP's measured in wells Kuhn #6 and Polk B#5 before and after the Huff-Puff cycle are shown below, indicate a separation between the two wells. Additional BHP's will be run in the two wells after the soak period and prior to opening the wells to production. This contradicts the initial analysis obtained from the 3-D seismic. This will require further evaluation which will delay the drilling of the last injection well in Area 2 of the project (Polk B#39). Currently we are evaluating initiating another Huff-Puff operation on well Polk B#5. The workover on well Polk B-5 was performed to prevent any potential oil spill in the case the well is connected to Well Kuhn #6 which is undergoing the first Huff-Puff cycle. This workover was planned for early 1995 along with the new drilling well polk B#39.

* Build a detailed strata model to use it in the development of the improved compositional model.

A Stratamodel showing the reservoir architecture and sand deposition has been built. Fine tuning the model will be complete by the end of January 1995. The reservoir basically is divided into two flow units separated by a shaled out section in the vicinity of Kuhn #9 well. The shaled out area is a fine filled abandoned channel that extends beyond the modeled area East of well Kuhn #9, where several other wells have similar characteristics. The segment to the north of the shaled out area, the sand interval is relatively thin, with the best reservoir quality is to the base of the sand. Toward the top of the sand the reservoir quality varies considerably laterally and

South of the shaled out area the sand is thicker, cleaner and more uniform sand distribution. The sand maintain good lateral and vertical reservoir quality. However, some small deterioration of sand quality occurs in stratigraphically higher portions of the sand as expected for channel sands deposit. Homogeneity of the Marginulina sand in the southern area should promote good performance. For additional information on the methodology, software used and analysis of results please refer to appendix A.

* Submit the Project Evaluation and Continuation Application, Environmental Constrain Report and the 1994 Annual Report.

The Project Evaluation and Continuation Application has been submitted to the DOE by the due date. The DOE has approved the Continuation Application for $2,984,599 through 1997. Also, the Environmental Constrain Report and the 1994 Annual Report have been submitted by the due date.

DISCUSSION OF RESULTS - FIELD OPERATIONS.

The measured reservoir pressure in well Kuhn #6 indicated that we have a slight decline in pressure in this side of the reservoir to 2602 psi. This contradicts somewhat the estimates from material balance of net reservoir voidage that predicts a increasing trend of reservoir pressure. This anomaly may be a direct result of temporary cessation of CO_2 delivery by Dupont for two weeks, and the simultaneous reduction of water injection due to pump breakdown. The WAG cycle was reversed between the water and CO_2 injection wells, after observing a declining trend in reservoir production and yield. the current daily production level is about 500 BOPD. The plan to increase production from Kuhn #6 and Polk B#5 has been delayed about 4 to 6 months due to delay in performing the work for budgetary constrains some technical data related to mapping reinterpretation. This will result in loss of 75 to 10 BOPD for a period of 6 months.

The following is a list of the most recent well tests taken on January 3, 1995 for all the producing and injection wells:

Kuhn	#15R	97 BOPD,	550 BWPD,	380 MMCFD,	17 CHOKE.
Kuhn	#38	245 BOPD,	276 BWPD,	3310 MMCFD,	22 CHOKE.
KUHN	#33	56 BOPD,	874 BWPD,	381 MMCFD,	18 CHOKE.
STARK	#8	101 BOPD,	464 BWPD,	2011 MMCFD,	28 CHOKE.
KUHN	#6	0 BOPD,	0 BWPD,	0 MMCFD,	OL CHOKE.
KUHN	#14	-- BOPD,	-- BWPD,	-- MMCFD,	-- CHOKE.
POLK	#B5	-- BOPD,	-- BWPD,	-- MMCFD,	-- CHOKE.

MARG AREA #1H	5483 MMCFD,	1300 PSI.
KUHN #36	3188 MMCFD,	1380 PSI.
STARK #7	1155 MMCFD,	1500 PSI.
KUHN #17	1958 BWPD,	1600 PSI.
STARK #10	1821 BWPD,	1790 PSI.

The average injection and production volumes for this quarter are as follow:

Oil Production:	435	BOPD.
Water Production:	2581	BWPD.
Gas Production:	5528	MMCFD.
Water Injection:	2680	BWPD.
Gas Injection:	8919	MMCFD.
Reservoir Voidage:	1780	BPD.

DISCUSSION OF RESULTS - TECHNOLOGY TRANSFER.

The Environmental Constrain Topical Report has been finalized and submitted to the DOE on time. LSU finished screening and preparing the database for FDD reservoirs in South Louisiana, identifying CO_2 sources in South Louisiana and East Texas and update and expand existing maps if fields locations to determine proximity to CO_2 sources. A report will be issued during the spring semester to cover the completed work. Additionally LSU will be selecting one reservoir to apply the screening techniques and perform a reservoir analysis. LSU work will be extended through 1996.

2nd Quarter (1995) Objectives.

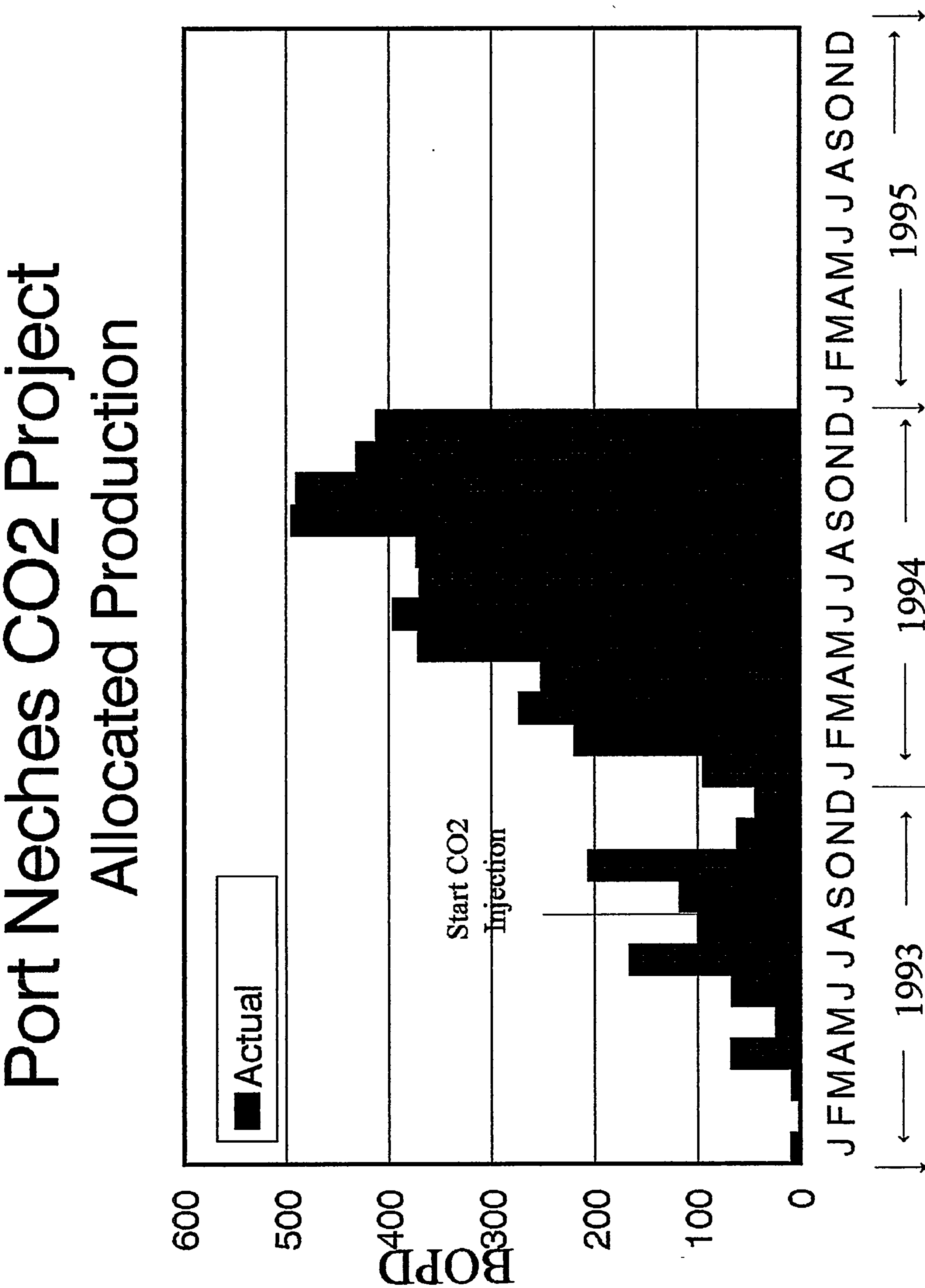
* Monitor and optimize reservoir production.

* Evaluate performing Huff-Puff cycle on well Polk B#5.

* Evaluate the need to drill well Polk B#39 in project Area 2, using BHP data and 3-D mapping.

* Resume working on the reservoir compositional model. Set a target date to complete the model by June 30, 1995.

* Evaluate a workover on either Kuhn # 16 or Kuhn #42, to improve reservoir sweep efficiency, and to increase the production rate.



Port Neches CO2 Project
Allocated Production
Actual
Start CO2 Injection
BOPD
600
500
400
300
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1993
1994
1995

FIG. 1

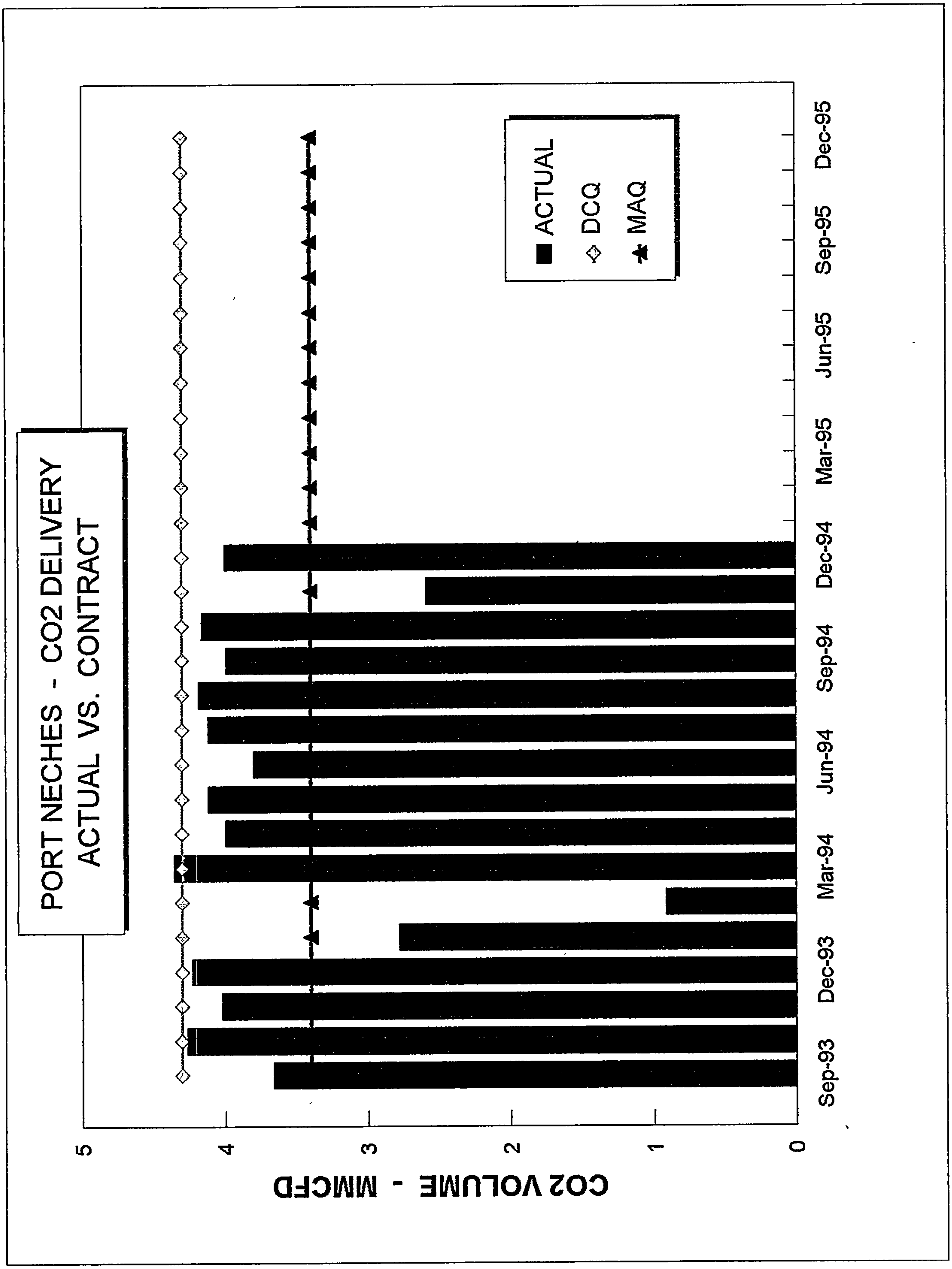

PORT NECHES - CO2 DELIVERY
ACTUAL VS. CONTRACT
ACTUAL
DCQ
MAQ
CO2 VOLUME - MMCFD
0
1
2
3
4
5
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95

FIG. 2

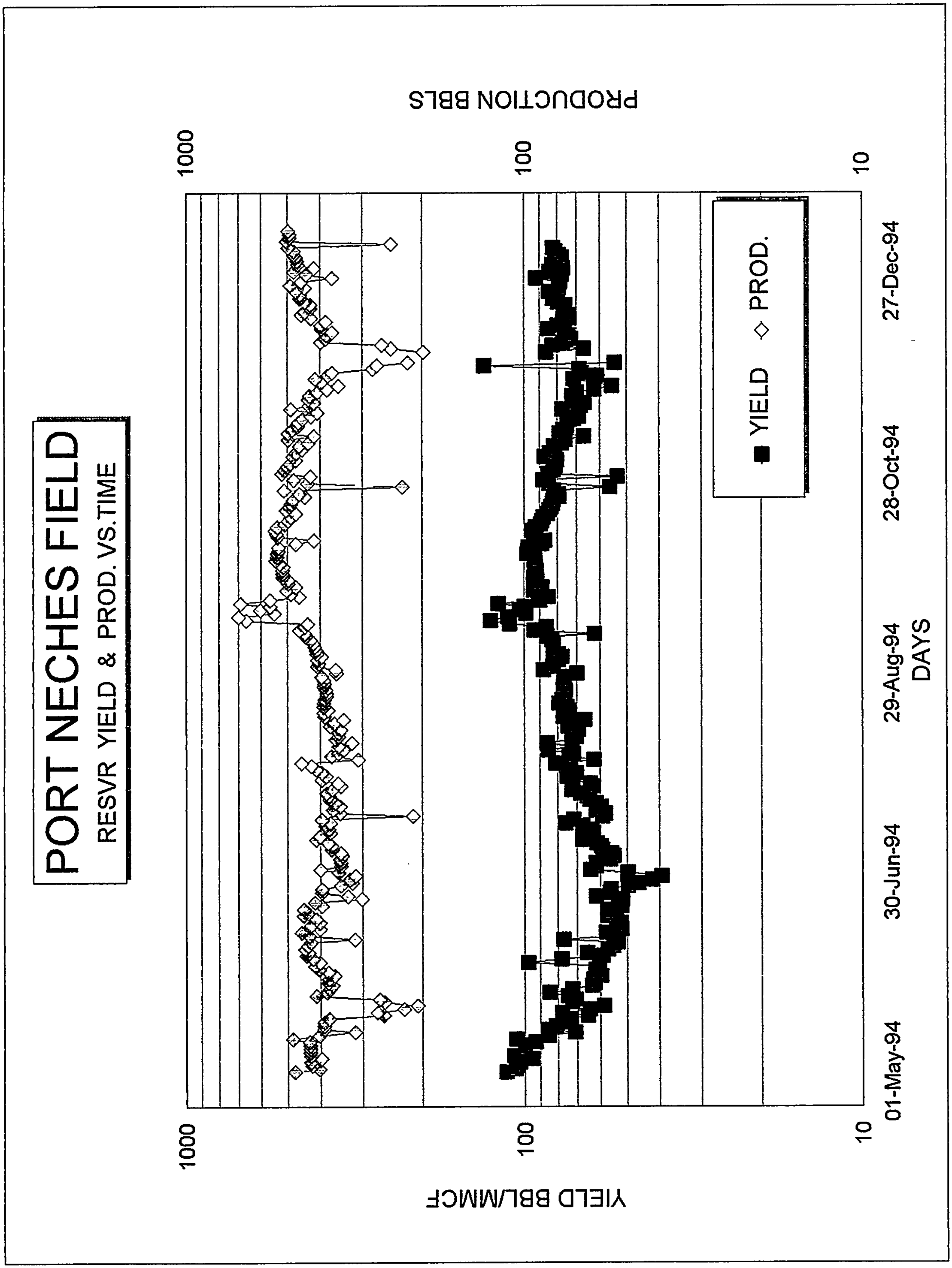

PORT NECHES FIELD
RESVR YIELD & PROD. VS.TIME
PRODUCTION BBLS
1000
100
10
YIELD BBL/MMCF
1000
100
10
■ YIELD ◇ PROD.
01-May-94
30-Jun-94
29-Aug-94
28-Oct-94
27-Dec-94
DAYS

FIG. 3

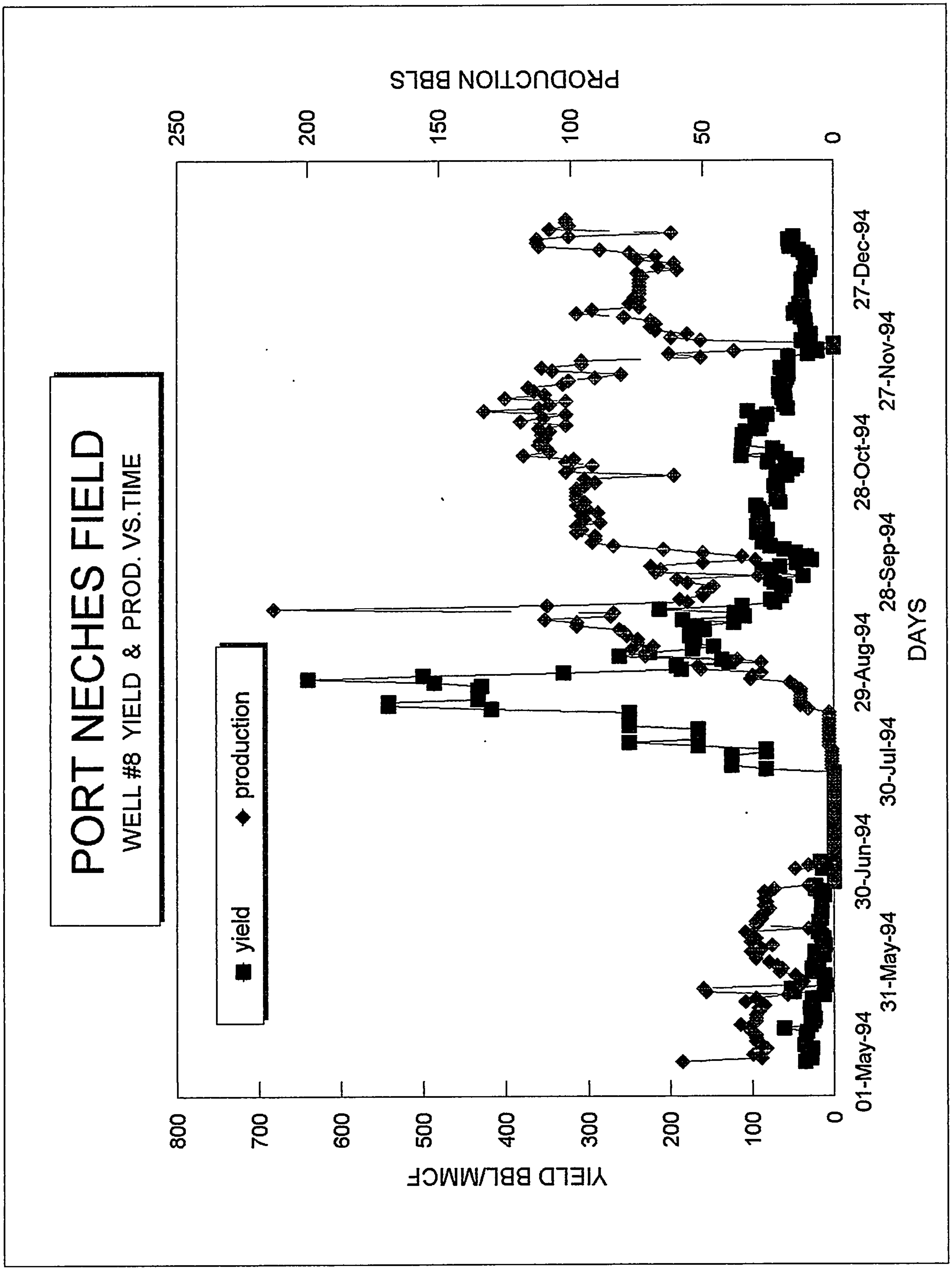

PORT NECHES FIELD
WELL #8 YIELD & PROD. VS.TIME
yield
production
YIELD BBL/MMCF
PRODUCTION BBLS
DAYS
0
100
200
300
400
500
600
700
800
0
50
100
150
200
250
01-May-94
31-May-94
30-Jun-94
30-Jul-94
29-Aug-94
28-Sep-94
28-Oct-94
27-Nov-94
27-Dec-94

FIG. 4

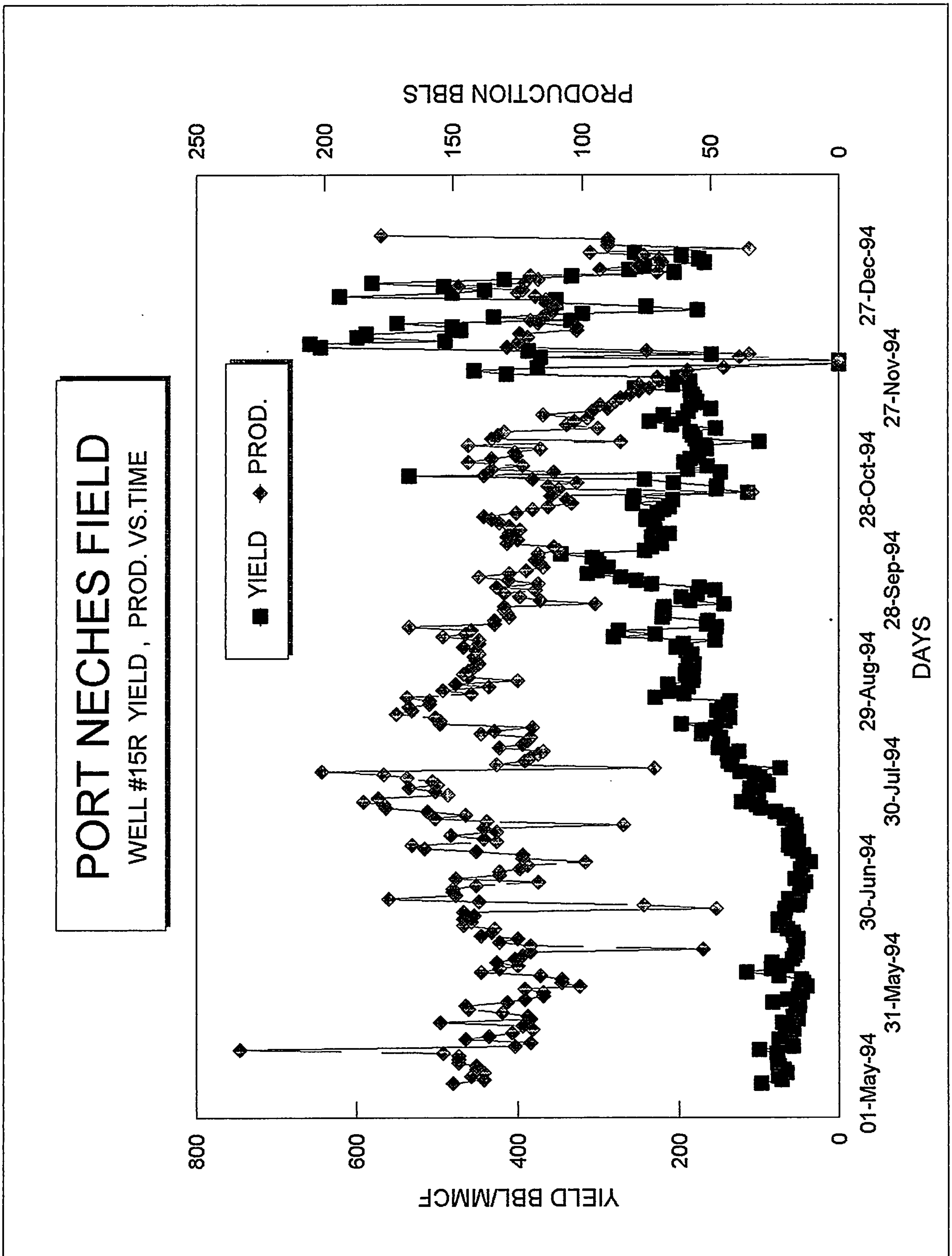

PORT NECHES FIELD
WELL #15R YIELD , PROD. VS.TIME
YIELD
PROD.
PRODUCTION BBLS
250
200
150
100
50
0
YIELD BBL/MMCF
800
600
400
200
0
01-May-94
31-May-94
30-Jun-94
30-Jul-94
29-Aug-94
28-Sep-94
28-Oct-94
27-Nov-94
27-Dec-94
DAYS

FIG. 5

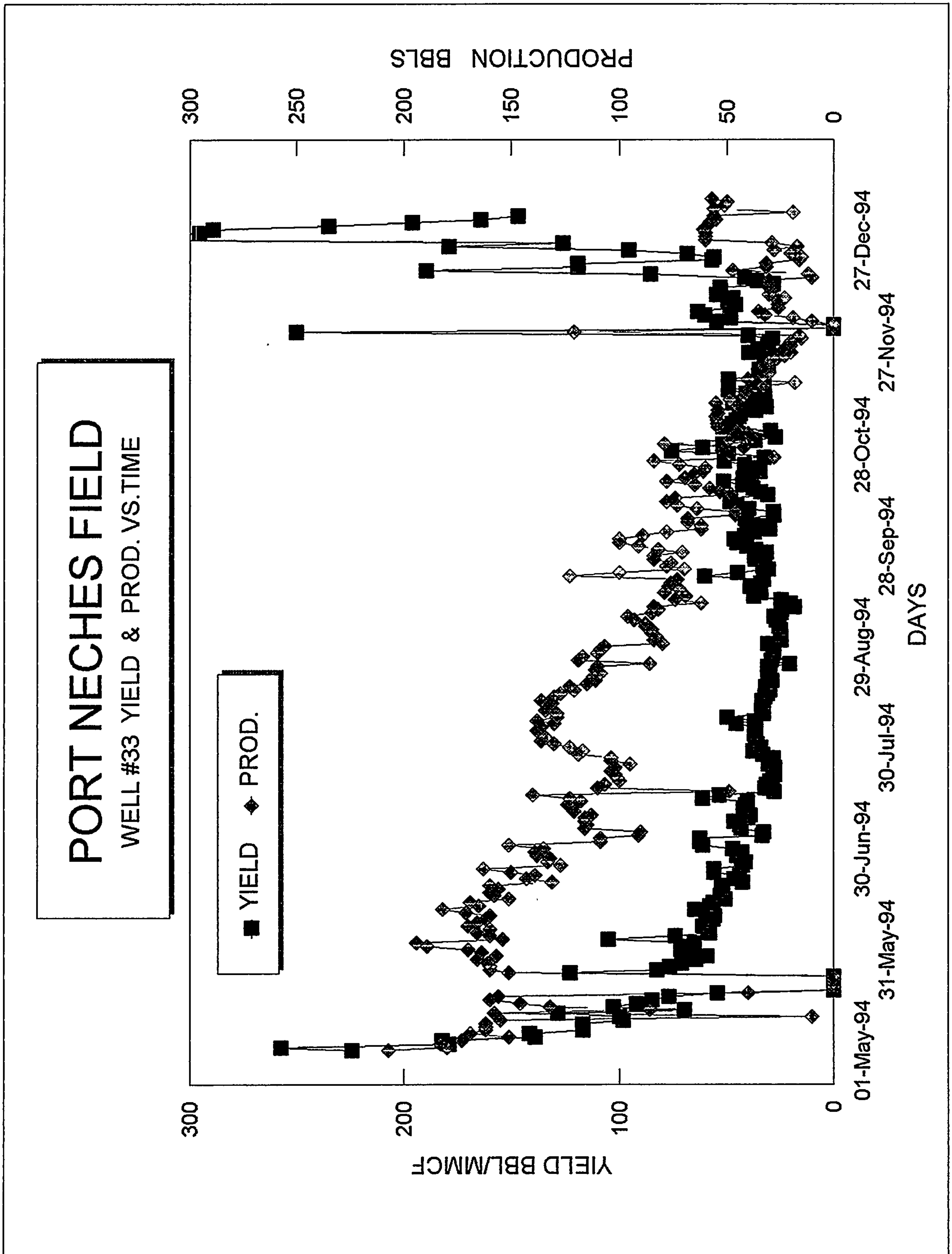

PORT NECHES FIELD
WELL #33 YIELD & PROD. VS.TIME
YIELD
PROD.
PRODUCTION BBLS
300
250
200
150
100
50
0
YIELD BBL/MMCF
300
200
100
0
01-May-94
31-May-94
30-Jun-94
30-Jul-94
29-Aug-94
28-Sep-94
28-Oct-94
27-Nov-94
27-Dec-94
DAYS

FIG. 6

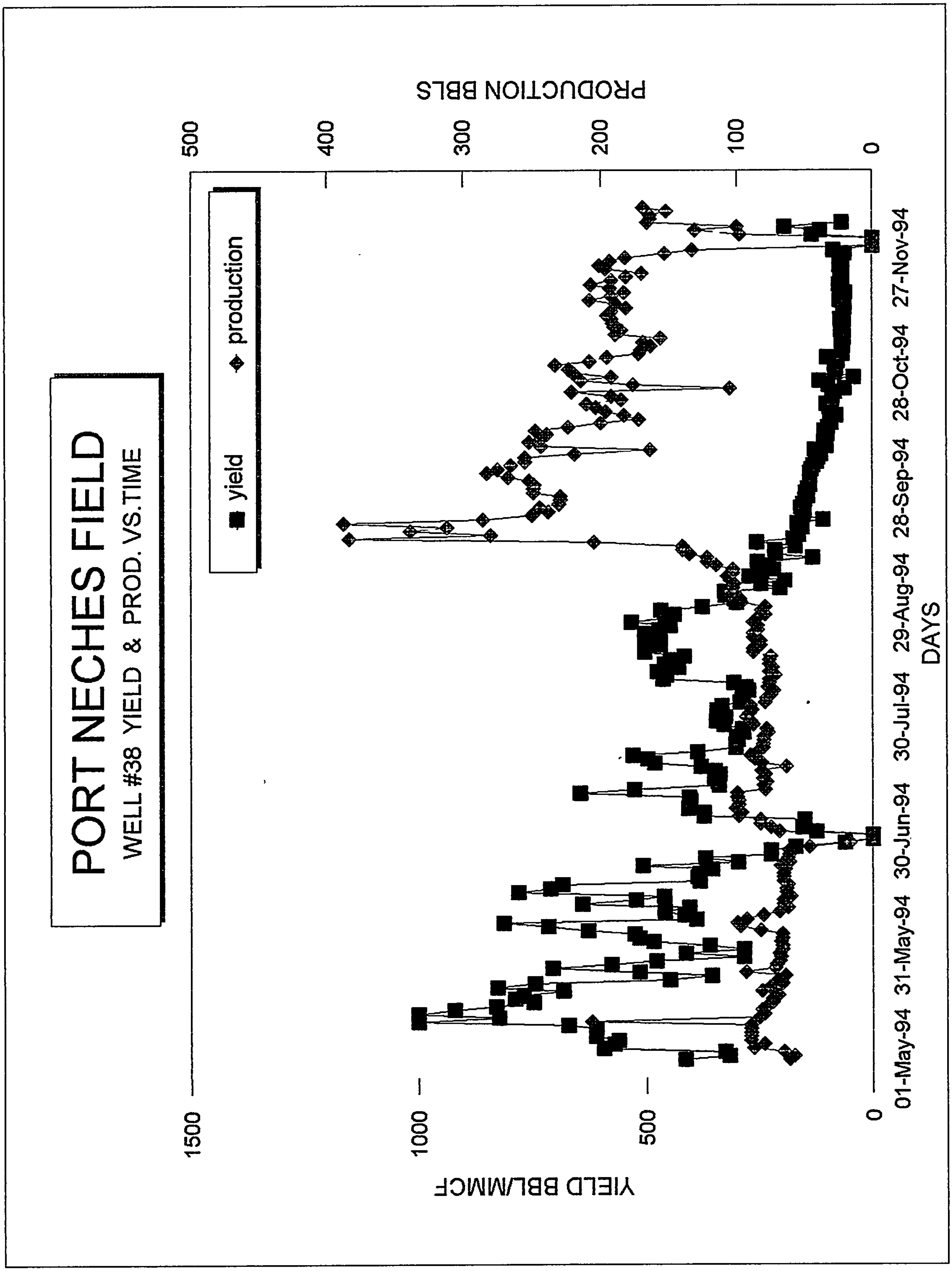

PORT NECHES FIELD
WELL #38 YIELD & PROD. VS.TIME
yield
production
YIELD BBL/MMCF
PRODUCTION BBLS
DAYS
0
500
1000
1500
0
100
200
300
400
500
01-May-94
31-May-94
30-Jun-94
30-Jul-94
29-Aug-94
28-Sep-94
28-Oct-94
27-Nov-94

FIG. 7

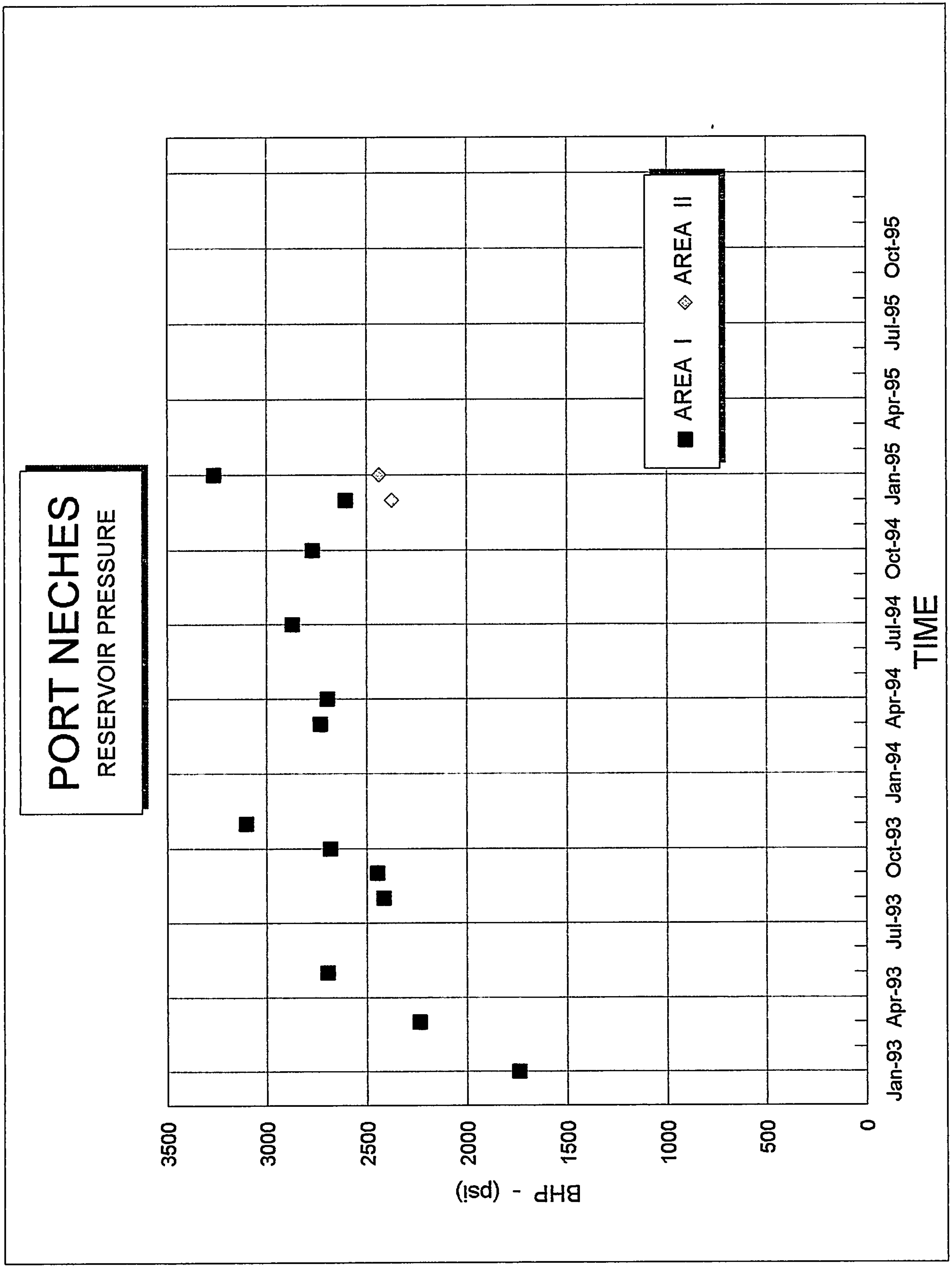

PORT NECHES
RESERVOIR PRESSURE
AREA I
AREA II
BHP - (psi)
3500
3000
2500
2000
1500
1000
500
0
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
Apr-94
Jul-94
Oct-94
Jan-95
Apr-95
Jul-95
Oct-95
TIME

FIG. 8

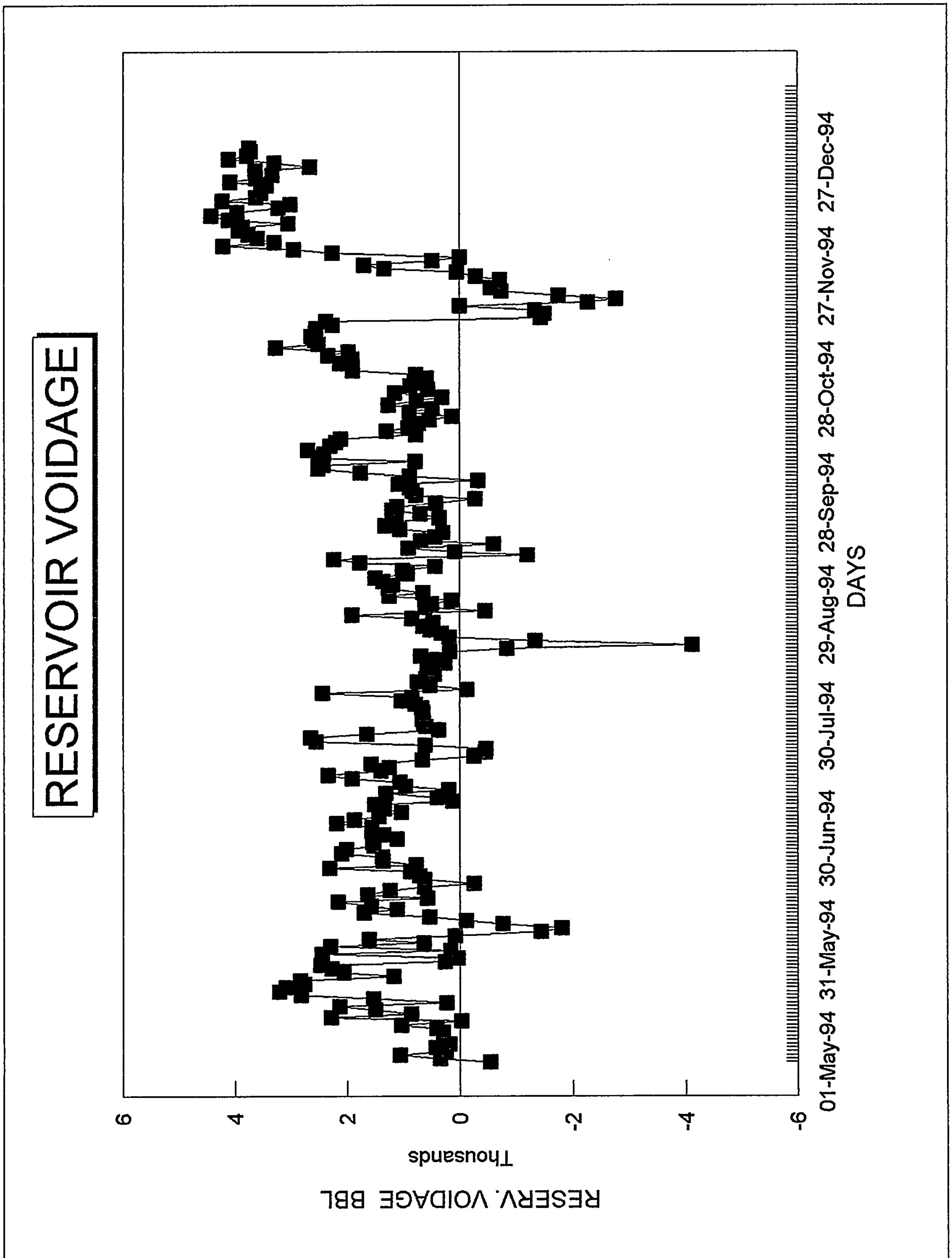


FIG. 9

financial information removed.

MARGINULINA SAND GEOCELLULAR MODELING FOR CO_2 INJECTION EOR PROJECT PORT NECHES FIELD, ORANGE COUNTY, TEXAS

M. D. Hogg
Texaco Exploration and Producing - East Region
Petro-Technical Services Department
12/27/94

INTRODUCTION

The present interpretation of the Marginulina interval is that of a fluvial-dominated deltaic system (D. Kuhfal, personal communication). Nearly all the SP logs of the Marginulina sand have a profile strongly suggestive of channelized deposits. An interpretation suggesting that a fines-filled abandoned channel exists across the field (as seen in the Kuhn #9) is consistent with this depositional setting.

In the context of CO_2 performance, whether or not fines-filled channels cross the field is an important issue to address. Firstly, such a channel would act at least as a flow baffle which would strongly affect CO_2 sweep patterns even if the zone possesses a finite permeability. In addition, sedimentary structures, bedding types, and facies relations related to energy of deposition within sub-environments of channalized reservoirs needs to be constrained as much as possible in order to construct reasonable fluid-flow models.

Reservoir quality in channel sands typically decreases upwards within the sand body due to decreasing grain size and the occurrence of interbedded shales associated with lower depositional energy further away from the river responsible for sedimentation. Thus, stratigraphically high portions of a channel-type reservoir may have vertical permeabilities several orders of magnitude lower than basal portions of the sand body. This case is demonstrated by the Marginulina sand at Port Neches.

Furthermore, computer attribute interpolation for geocellular modeling may be strongly affected by the nature of bedding and lithology (rock type) changes within the modeled interval. If rock property changes are transitional, model attributes should be interpolated without biasing the data. However, if rock property changes are rapid, biasing well data is appropriate in order to achieve realistic reservoir rock property distributions.

MARGINULINA SAND GEOCELLULAR MODELING

Two principal versions of Marginulina sand geology have been identified in the modeling process to-date. Within the productive area, and relatively high on structure, the Marginulina sand is absent in the Kuhn #9 well. It is possible that the sand is faulted out, but 3-D seismic data does not indicate the presence of a significant fault at this location. Alternatively, the Marginulina sand can be interpreted as shaling-out towards the Kuhn #9, either by gradual facies transition, or by a sharp facies change due to the presence of a fines-filled abandoned channel. Numerous wells beyond the modeled area, to the east of the Kuhn #9, are also shaled out at the Marginulina sand level, suggesting continuation of a fines-filled abandoned channel into the modeled area. In order to evaluate both geological interpretations, two versions of normalized SP interpolations (i.e., sand distribution and quality) were generated

An unbiased version utilized SP data from the Kuhn #9 well for normalized SP interpolation within the area of interest (AOI). This scenario assumes that reservoir properties are *transitional* in the area. The second *biased* version of normalized SP computer interpolation excluded Kuhn #9 data by restricting the Kuhn #9 SP data to within a fines-filled channel defined by the geologist modeling the reservoir. Thus, the algorithm use to interpolate normalized SP ignored Kuhn #9 SP data within the fines-filled channel. This scenario assumes that changes in reservoir rock properties in the area are *abrupt*.

Examples of biased and unbiased interpolations are given in accompanying diagrams.

RESULTS

In addition to the shaled-out fines-filled channel area in the vicinity of the Kuhn #9, the Marginulina sand has two contrasting stratigraphic patterns. North of the shaled-out area the gross sand interval is relatively thin. The lower portion of the sand, as expected, possesses the best reservoir quality based on normalized SP character. Above this relatively high-quality homogeneous zone, reservoir quality varies considerably laterally and vertically. As a result, high-quality sand appears to have "shoestring" geometries and meander about as if they consist of individual channel-fill sands as opposed to the homogeneous high-quality stacked(?) channel sands near the base of the marginulina section.

South of the shaled-out area, in the vicinity of the Polk "B" 5, the gross sand interval is relatively thick, and the distribution of sand and shale zones is relatively uniform compared to the northern portion of the Marginulina area. This may have contributed significantly to the prolific production from the Polk "B" 5 well.

The sand maintains good lateral and vertical reservoir quality in the southern area, though some deterioration of sand quality, based on normalized SP character, occurs in stratigraphically higher portions of the sand as expected for a channel deposit.

Homogeneity of the Marginulina sand in the area should promote good CO_2 flood performance.

Further refinement of reservoir units will be performed prior to finalizing a simulation deck in order to best estimate the distribution of high transmissibility and intervening areas of lower transmissibility. Once appropriate transforms are established to estimate flow characteristics, 3-D volumes will be constructed using various cutoffs such that a wide range of reservoir quality an connectivity scenarios can be assessed. These procedures will ensure flow simulation that is consistent with available geological data. In addition, refinement of sand heterogeneity will also enhance selection of optimum future injection and recovery well locations, perforation location, etc.

METHODOLOGY

A study of the Marginulina sand reservoir at Port Neches Field is being performed to characterize lateral and vertical variations of reservoir quality in order to help constrain the distribution of geological features affecting fluid flow and to constrain fluid saturation estimates. The principal tools employed in the characterization are the software packages Stratigraphic Geocellular Modeling (SGM) and Geocellular Template Modeling (GTM) developed by Stratamodel, Inc., which is now a part of Landmark Graphics Corporation.

The end-product of an SGM/GTM model is a cellular-based 3D volume of an area of interest. Each cell in the model can contain up to 100 attributes, e.g., porosity, water saturation, shale content, spontaneous potential, etc. The are no restrictions as to the source of data, and data may be generated within the model by applying transforms based on known relationships. Below is a generalized list of steps involved in creating a geocellular model. This is the same series of steps that is being used to study intricacies of the Port Neches Marginulina sand.

1) **Generate grids** ("surfaces") of significant stratigraphic and structural horizons.

2) **Create a stratigraphic framework** for the model using the surfaces defined in step 1.

3) **Build a well model.** This step positions the well surface locations by latitude and longitude and includes directional survey data of deviated wells to track subsurface paths of wellbores and maintaining accurate correlations to other wells and attribute distribution by automatically calculating true vertical depths (TVD). Well log data, or other information to be used to model formation properties, are loaded in this module and each cell penetrated by the wellbore is populated with model attributes.

4) **Build an attribute model.** In this step, the information loaded in step 3 is interpolated from points of well control throughout all cells in the model. It is in this step that directional components of an attribute(s) distributions can be influenced by using anisotropic search radii, minimizing the effect of clustered data, etc.

STRATIGRAPHIC FRAMEWORK

The primary horizon grids used in the model are the top-of-Marginulina sand and base-of-Marginulina sand surfaces. The top-of-sand surface was created by gridding top-of-sand picks from well logs. The base-of-sand surface was created by subtracting the gross Marginulina sand isochore from the top-of-sand surface. This procedure ensured structural cohesion between top and base of sand horizons, and provided a consistent means of extrapolation of the base-of-sand depth at wells that did not fully penetrate the reservoir.

Bounding fault surfaces were created by gridding fault cuts picked in well logs. Contours of fault planes were edited in areas of little fault control to maintain correct spatial relations with Marginulina sand distribution, then regridded for use in model construction. One fault, occurring along the crest of the producing structure which dies-out at the northern end of the field, was accounted for during computer mapping. This fault appears as extreme dips on the top- and base-of-sand structure maps. This procedure was used because of limitations of the geocellular modeling software. This fault can be readily accounted for in fluid-flow simulation by placing a no-flow barrier coincident with the extreme dips marking the position of the fault.

WELL AND ATTRIBUTE MODEL

Twenty-three wells penetrating the Marginulina interval were incorporated into the geological model. Because of the age of most well data, spontaneous potential (SP) is the only information that is sufficiently abundant to provide viable and meaningful interpolation between points of well control. Furthermore, raw SP data was found to be of little use in modeling because baseline values between wells vary dramatically. In fact, there is SP baseline overlap between some "clean" shale and "clean" sand within the limits of the study area.

In order to compensate for the inconsistency of SP baselines, all SP logs used in the model were normalized to 100% shale and 100% sand end-members such that SP values within a given interval can be used as an estimate of shale volume (Vshale). Thus, SP is presented as a value ranging from 1 (100% shale) to 0 (100% sand). This will become particularly important when estimating values for effective porosity, permeability, and other parameters important for Marginulina sand layers used in fluid-flow simulation.