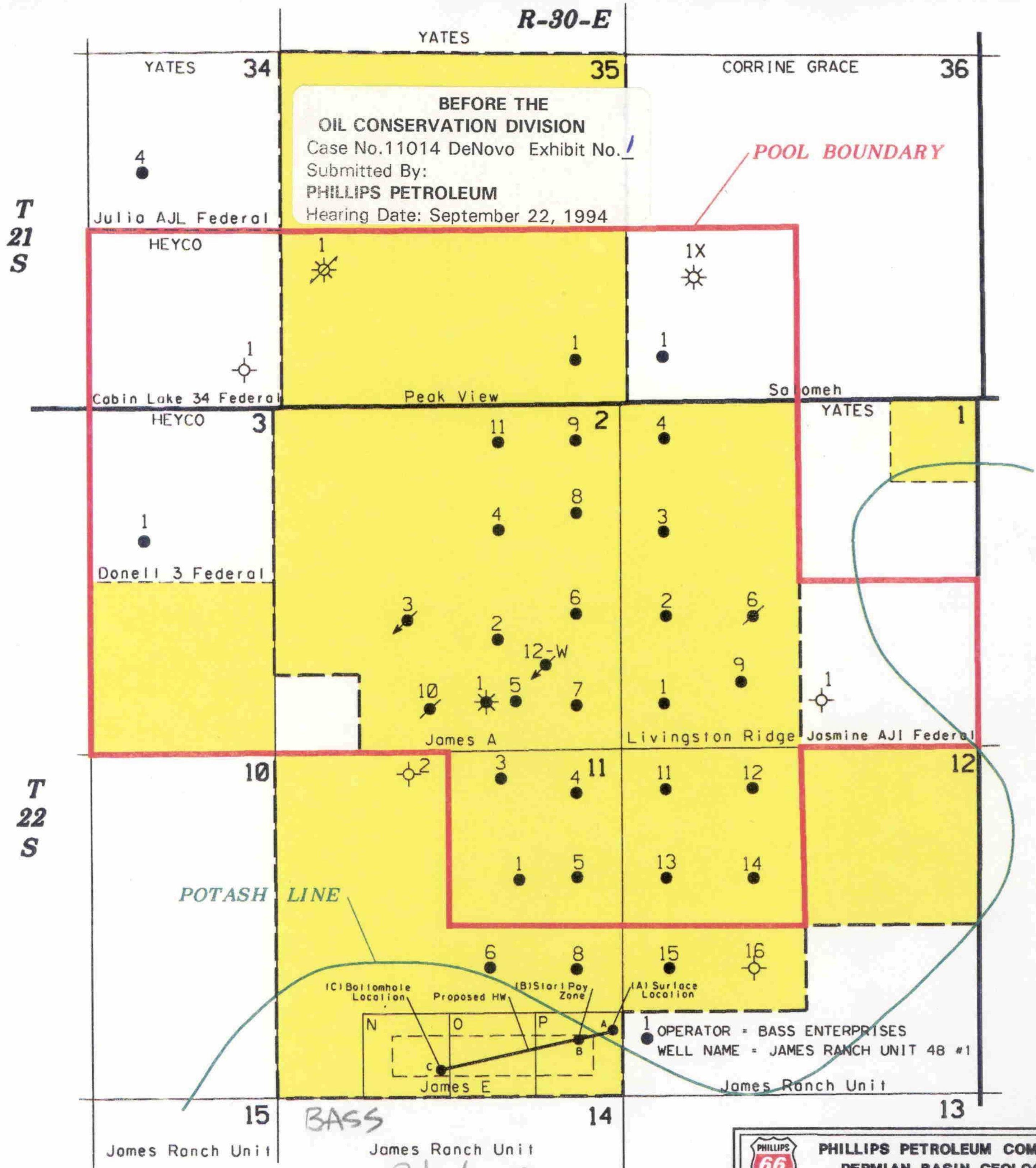
BEFORE THE
OIL CONSERVATION DIVISION
Case No.11014 DeNovo Exhibit No. 1
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994




Potash Area

- ○ Approved Well
- ● Producing Oil Well
- Water Injection (Pressure Maintence)
- Inactive Oil Well
- Dry Holes

The Yates Kaleidoscope AKO Federal #1, located in Section 33, T21S, R30E is in the Cabin Lake Delaware pool, but not shown above.

PHILLIPS 66

PHILLIPS PETROLEUM COMPANY
PERMIAN BASIN GEOLOGY

**CABIN LAKE FIELD**
T-21,22-S , R-30-E
EDDY CO., NEW MEXICO

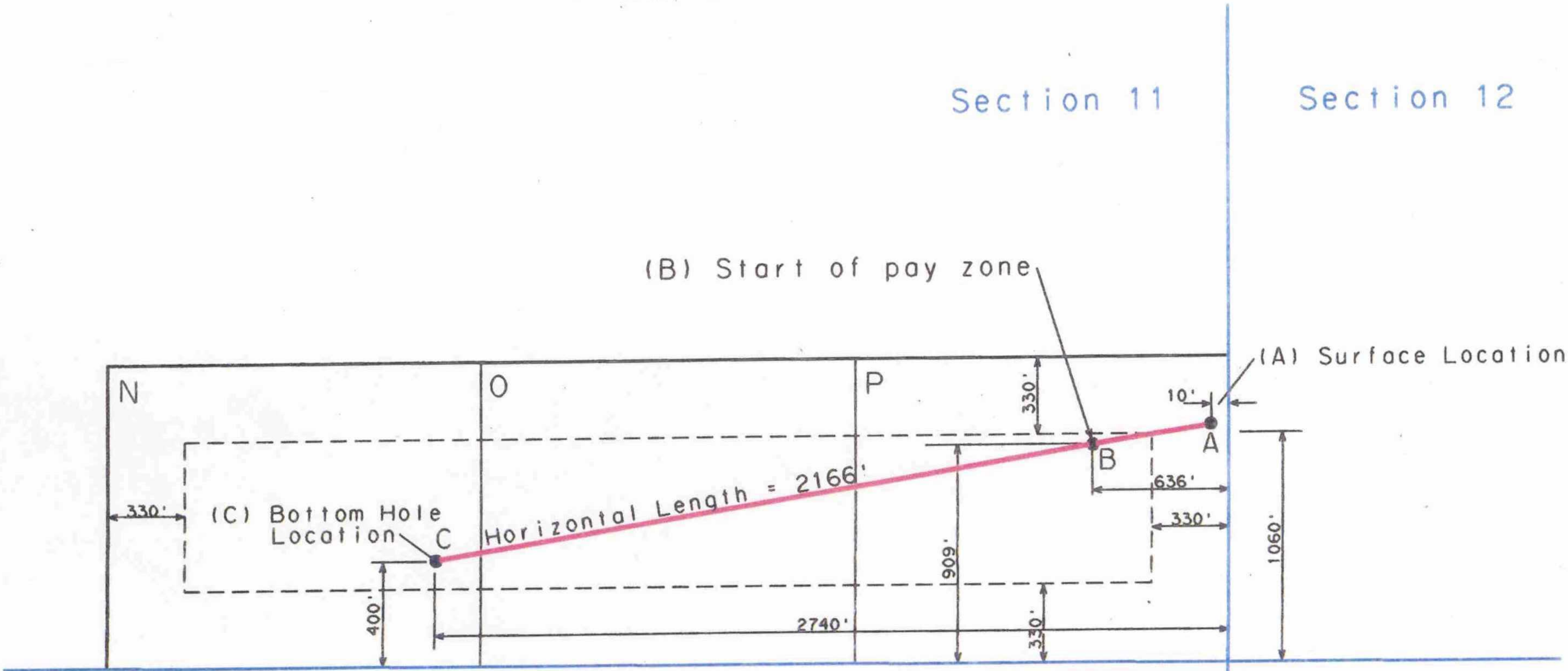
0 2,000
SCALE (FEET)

| SCALE | C.I. | GEOLOGY BY | DATE 3-94 |
|---|---|---|---|
| CONTOURED ON | | | MAP NO CABIN |
| TYPE INFO | | | DRAFTING R.COSSIN |

# JAMES E #9: HORIZONTAL WELL APPLICATION

## Cabin Lake - Delaware Pool Eddy County, NM

## T-22-S R-30-E




Surface Location: 10' FEL/ 1060' FSL
S-11 T-22-S R-30-E

Bottomhole Location: 2740' FEL/ 400' FSL
S-11 T-22-S R-30-E

Start of Pay Zone: 636' FEL/ 909' FSL
S-11 T-22-S R-30-E

Section 14 Section 13

**BEFORE THE**
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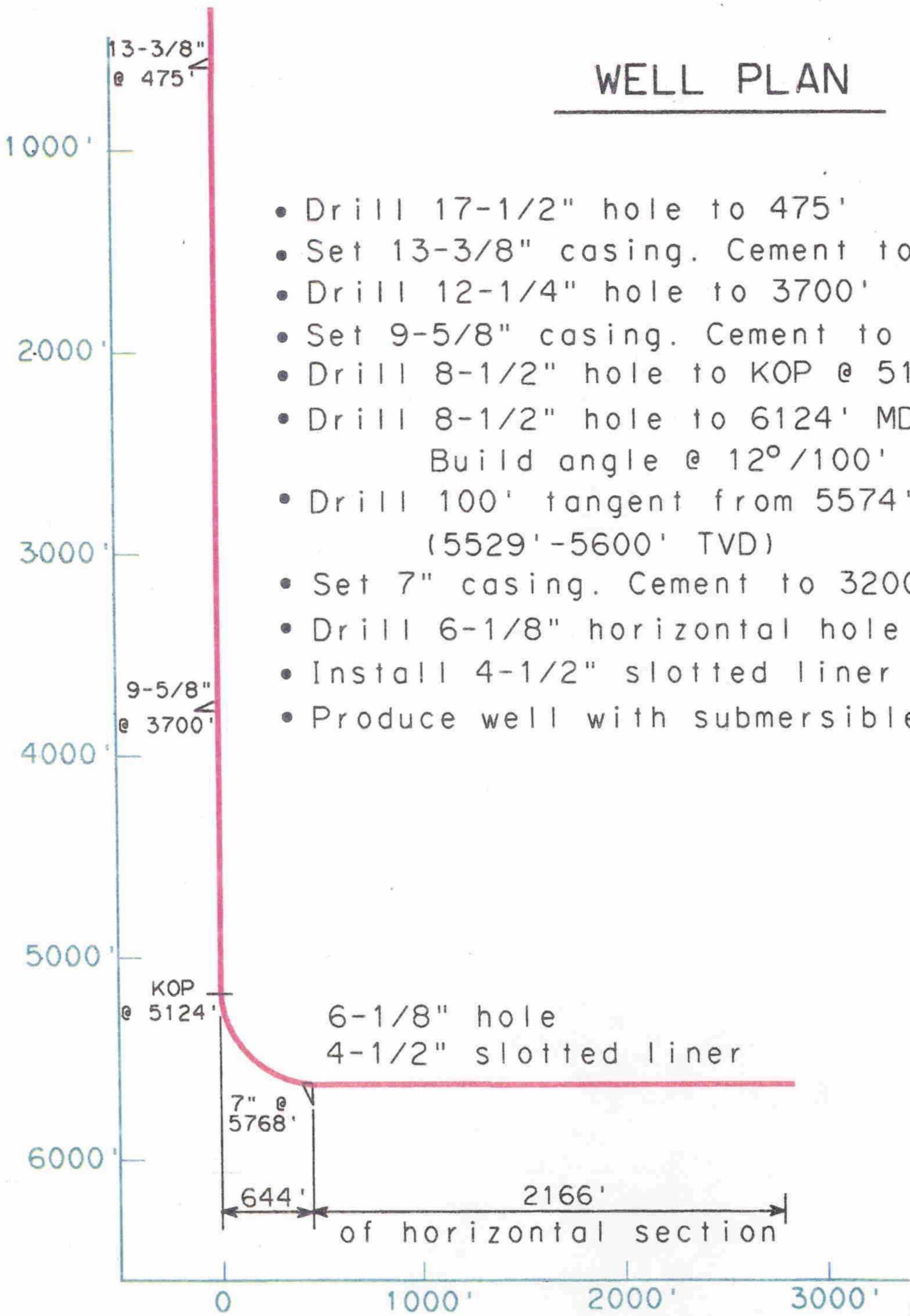
Submitted By:
**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

# JAMES E #9 HORIZONTAL WELL
# CABIN LAKE-DELAWARE POOL
# EDDY COUNTY, NEW MEXICO

## WELL PLAN

- Drill 17-1/2" hole to 475'
- Set 13-3/8" casing. Cement to surface
- Drill 12-1/4" hole to 3700'
- Set 9-5/8" casing. Cement to surface
- Drill 8-1/2" hole to KOP @ 5124'
- Drill 8-1/2" hole to 6124' MD/ 5768' TVD
  Build angle @ 12°/100' to 87°
- Drill 100' tangent from 5574'-5674' MD
  (5529'-5600' TVD)
- Set 7" casing. Cement to 3200'
- Drill 6-1/8" horizontal hole 2166' long
- Install 4-1/2" slotted liner
- Produce well with submersible pump

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Submitted By:
**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

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Case No.11014 DeNovo Exhibit No. 4
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994

HALLIBURTON LOGGING SERVICES, INC.

# SPECTRAL DENS
# DUAL SPACE
# NEUTRON LO

WELL JAMES -E- NO. 8
FIELD CABIN LAKE (DELAWARE)
COUNTY EDDY STATE NM

COMPANY PHILLIPS PETROLEUM COMPANY

WELL JAMES -E- NO. 8

FIELD CABIN LAKE (DELAWARE)

COUNTY EDDY STATE NM

API NO 30-015-27441 OTHER SE

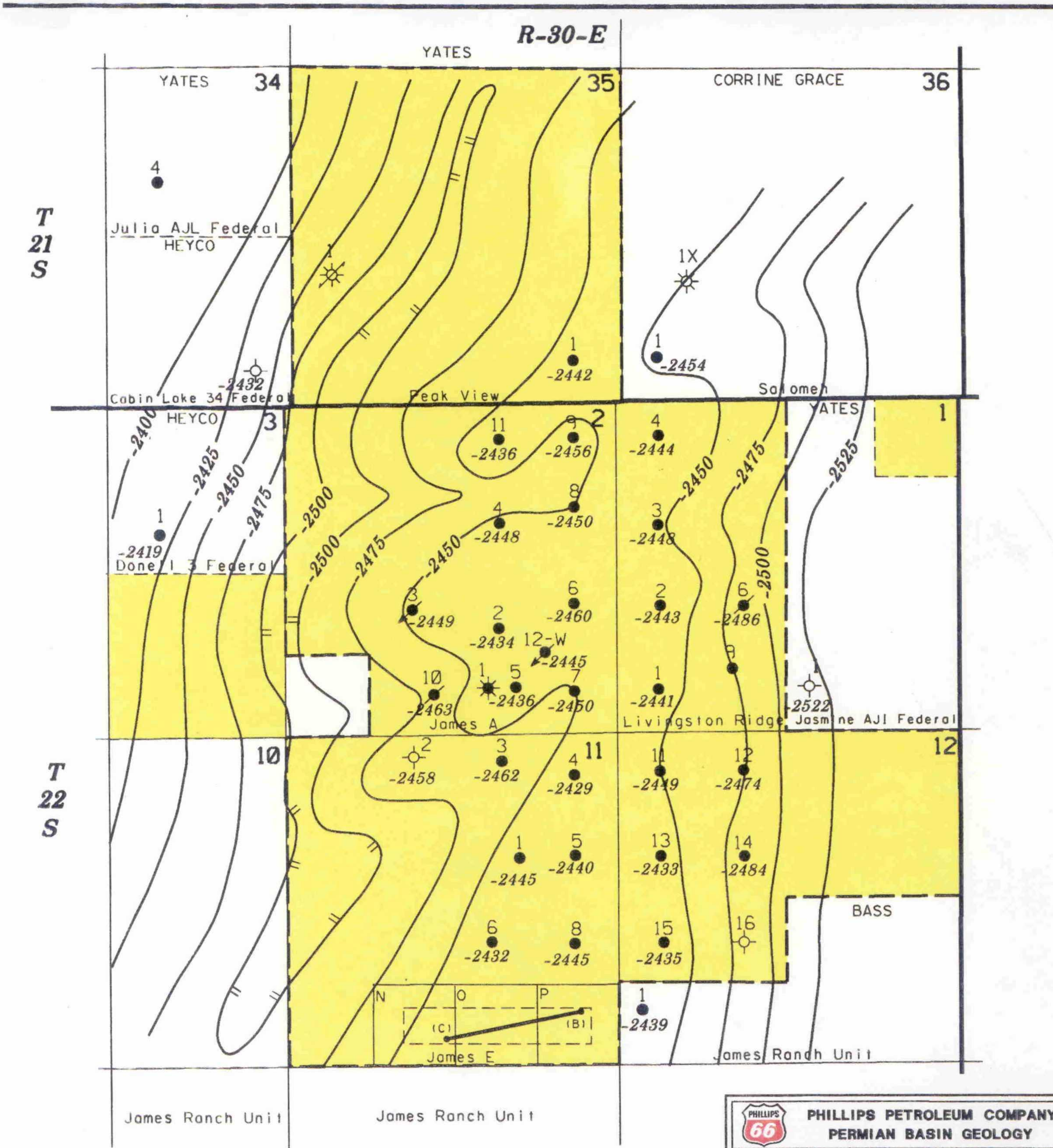
LOCATION DLL-MSF

2240 FSL AND 1550 FEL
SECTION 11; T-22-S, R-30-E

SECT 11 TWP 22-S RGE 30-E

PERMANENT DATUM G. L. ELEV. 3228
LOG MEASURED FROM K.B. 10.00 FT. ABOVE PERM DATUM
DRILLING MEASURED FROM KELLY BUSHING

| | | | |
|---|---|---|---|
| DATE | 09/06/93 | | |
| RUN | ONE | | |
| DEPTH-DRILLER | 7600 | | |
| DEPTH-LOGGER | 7604 | | |
| BTM LOG INTER | 7600 | | |
| TOP LOG INTER | 50 | | |
| CASING-DRILLER | 8.625 @ 3500 | @ | @ |
| CASING-LOGGER | 3507 | | |
| BIT SIZE | 7.875 | | |
| TYPE FLUID IN HOLE | SALT GEL | | |
| DENS. & VISC. | 9.1 ; 35 | ; | ; |
| PH: FLUID LOSS | 9.5 ; 8.0 | ; | ; |
| SOURCE OF SAMPLE | MUD PIT | | |
| RM @ MEAS. TEMP. | .215 @ 85 | @ | @ |
| RMF @ MEAS. TEMP. | .204 @ 85 | @ | @ |
| RMC @ MEAS. TEMP. | .237 @ 85 | @ | @ |
| SOURCE RMF RMC | MEAS. MEAS. | ; | ; |
| RM @ BHT | .147 @ 127 | @ | @ |
| TIME SINCE CIRC. | 14.5 HOURS | | |
| TIME ON BOTTOM | 5:31 A.M. | | |
| MAX REC TEMP. | 127 @ T.D. | @ | @ |
| EQUIP. LOCATION | 51941 100.TX | ; | ; |
| RECORDED BY | MART RILEY | | |
| WITNESSED BY | K. SCHRAED | J. BROWN | |

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**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

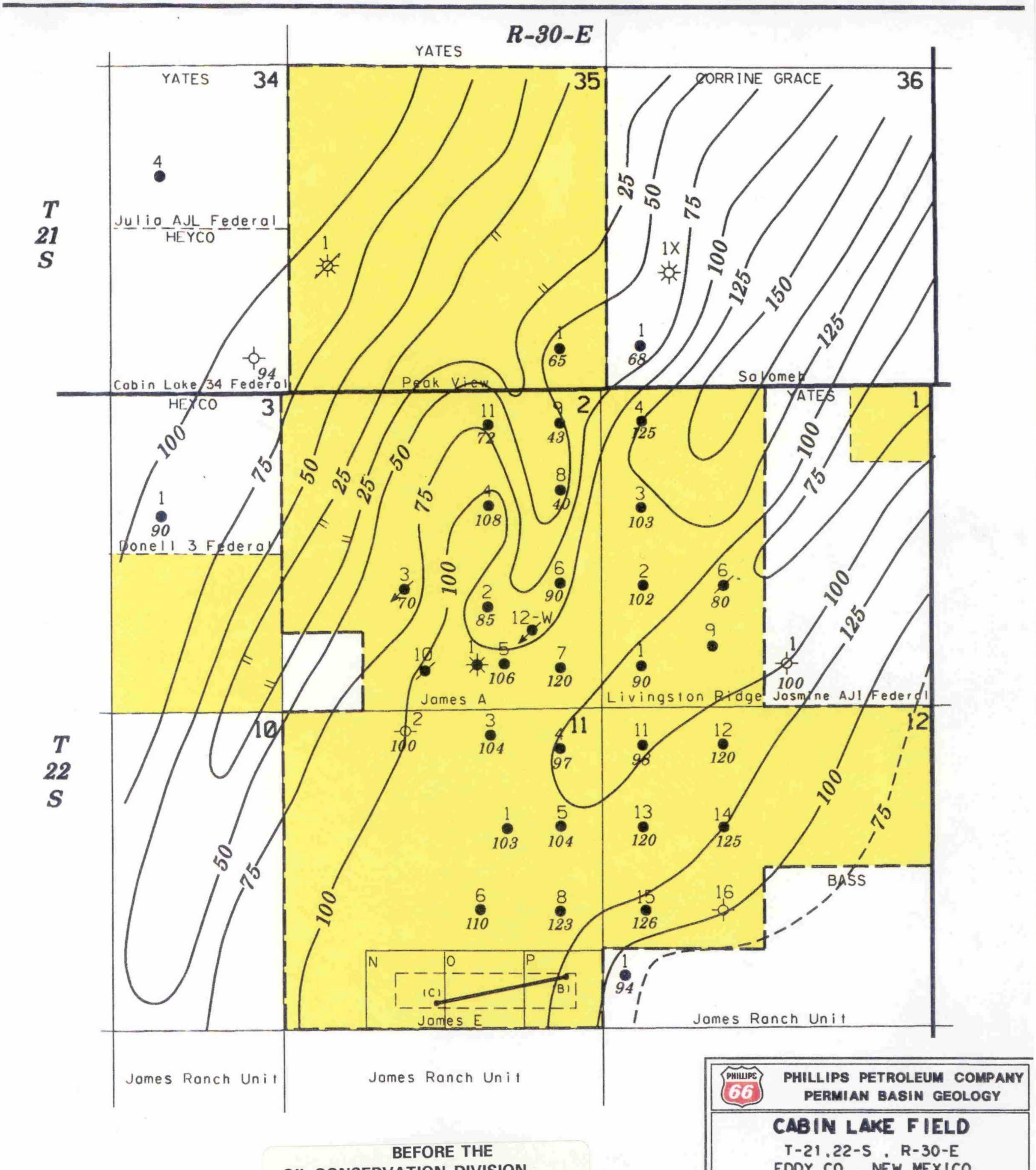
**PHILLIPS PETROLEUM COMPANY**
**PERMIAN BASIN GEOLOGY**

## CABIN LAKE FIELD

T-21,22-S . R-30-E
EDDY CO., NEW MEXICO

0 2,000
SCALE (FEET)

| | | | |
|---|---|---|---|
| SCALE | C.I. 25' | GEOLOGY BY J.L. BROWN | DATE 3-94 |
| CONTOURED ON | MAIN CHERRY CANYON | | MAP NO. CBNLAKE3 |
| TYPE INFO | PAY SAND | | DRAFTING R.COSSIN |

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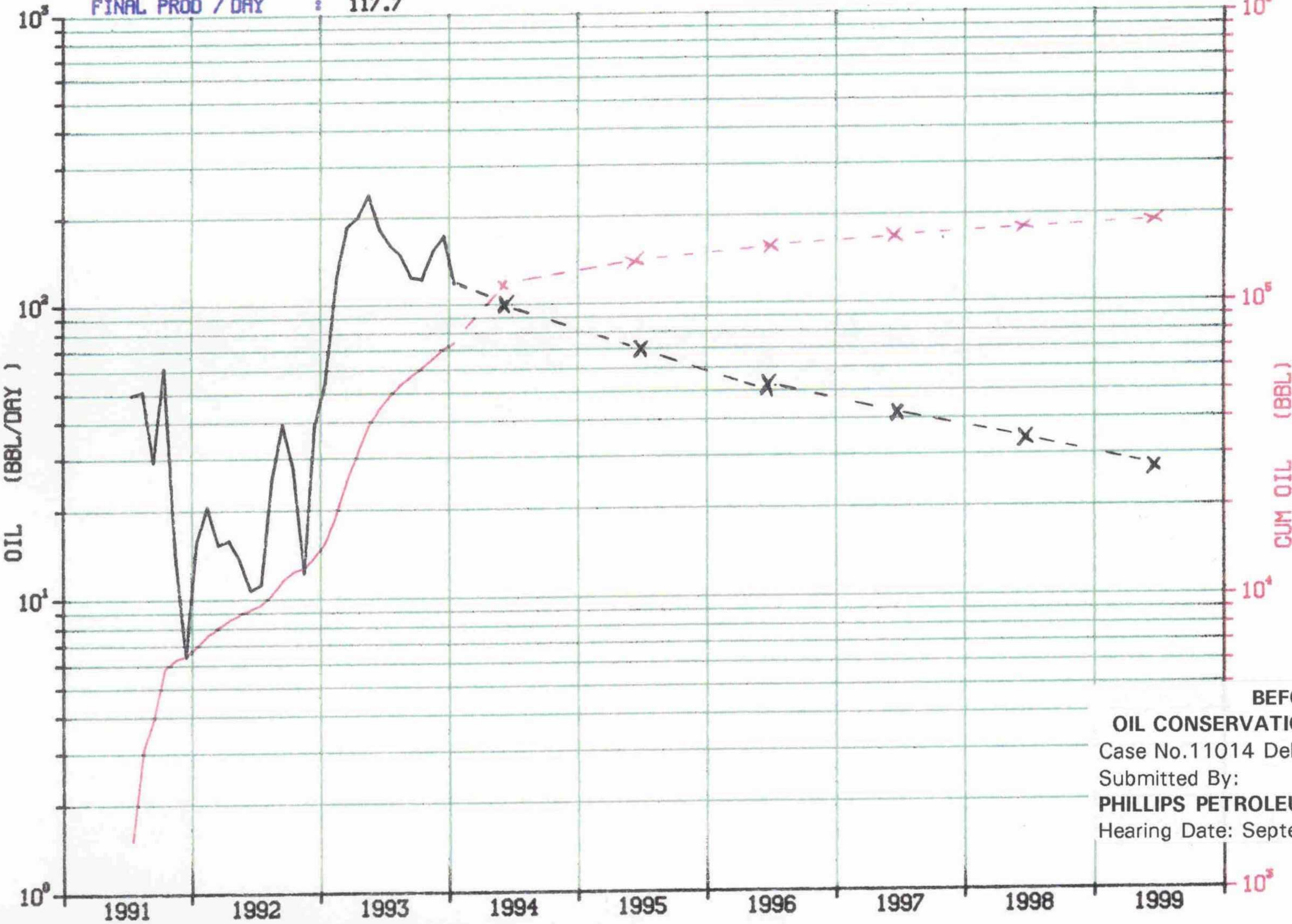
**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

| 7/91-1/94 | |
|---|---|
| INITIAL PROD / DAY | : 49.7 |
| REMAINING LIFE | : 2.58 |
| | 0.00 |
| CUM PRODUCTION | : 74335. |
| FINAL PROD / DAY | : 117.7 |

CUMS - 1/94
74335. BBL OIL
15841. MCF GAS
159495. BBL WTR

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OIL CONSERVATION DIVISION
Case No.11014 DeNovo Exhibit No. 7
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994

LEASE- 600136 : JAMES-E
RESVR- 324 : CABIN LAKE DELAWARE
WELL - 000011 PHS WELL PRODUCTION

WELL-600136324000011
API-30015266550000



#4I1 03/02/94 13:08

## JAMES E #9 HORIZONTAL WELL
## CABIN LAKE- DELAWARE POOL
## EDDY COUNTY, NEW MEXICO

### DEA-44 "RESMOD-3" Model Input

| INPUT PARAMETER | VALUE |
|---|---|
| Drainage Radius | 660 feet |
| Horizontal length | 2,166 feet |
| Thickness | 40 feet |
| Reservoir Pressure | |
| Initial shut-in | 2,700 psia |
| Flowing bottomhole | 600 psia |
| Wellbore radius | 4.25 inches |
| Permeability | |
| vertical | .2 md |
| horizontal | 2.0 md |
| Porosity | 18 % |
| Oil Viscosity | 1.5 cp |
| Formation Vol. Factor | 1.2 |
| Initial Oil Saturation | 50 % |

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# 6. Basis of the Models

This section describes the equations, correlations, and assumptions used in constructing the RESMOD3 reservoir production models. The mathematical symbols, in Section 9, are consistent with those presented in the literature and may differ from those used in the computer program.

## 6.1 DARCY UNITS

Unless stated otherwise, reservoir engineering equations in this report are in Darcy units which are defined by the equation

$$Q = \frac{KA}{\mu}\frac{\Delta P}{\Delta x} \tag{6-1}$$

where

| | | |
|---|---|---|
| Q | = | Flow Rate in Cubic Centimeters per Second |
| A | = | Cross Sectional Area in Square Centimeters |
| $\Delta P$ | = | Pressure Difference in Atmospheres |
| $\Delta x$ | = | Distance in Centimeters |
| $\mu$ | = | Viscosity in Centipoise |

The constant of proportionality, K, is in darcies. This is a definition.

## 6.2 OIL-FIELD UNITS

Changing from Darcy units to field units requires a conversion constant. The conversion constant for Eq. 6-1 is:

0.0011272

In radial flow equations such as

$$Q = \frac{2\pi Kh(Pe - Pw)}{\mu \ln\left(\frac{r_e}{r_u}\right)} \tag{6-2}$$

the "2 $\pi$" is replaced by

$$2\pi(0.0011272) = 0.0070822$$

which is sometimes written as

$$\left(\frac{1}{141.2}\right)$$



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Field units for Eqs. 6-1 and 6-2 are as follows:

| | | |
|---|---|---|
| Q | = | Barrels/Day |
| K | = | Millidarcies |
| h | = | Feet |
| Pe and Pw | = | Pounds/Square Inch |
| $r_e$ and $r_w$ | = | Feet |
| A | = | Square Feet |
| $\Delta p/\Delta x$ | = | Pounds/Square Inch/Foot |

## 6.3 MODEL ASSUMPTIONS

It is important that the user appreciate the limitations and assumptions used in the model so that reasonable alterations to input parameters can be made. The models are explained in detail in the DEA-44 report *Horizontal Reservoir Models*. The most critical parameters are listed below.

### 6.3.1 Homogeneous

In reality, very few reservoir settings are purely homogeneous. Most heterogeneous settings have varying characteristics and can be described reasonably well by a set of "average" parameters. The "average" reservoir parameter inputs are applied over the total drainage area assigned to a vertical well. Thus, where the model is optimistic the parameters such as porosity, permeability and thickness can be varied to better match actual vertical well behavior.

### 6.3.2 Closed Tank

The model assumes a vertical well is draining an assigned radius bounded by no-flow boundaries. This limits the drive energy available and assumes an equal drainage from the total area.

### 6.3.3 Single-Phase Flow

The model deals with single-phase flow only, thus the relative permeability reductions caused by water and/or gas (in the oil case) are disregarded. Methods to account for this might include raising the skin or reducing permeability.

### 6.3.4 Pseudo-Steady State

The model does not consider flush or transient flow production. This can result in an under-estimate of initial production rates when compared to the historic initial vertical well production. Where high flush production exists, it is often better to disregard the early production profile and match the stabilized decline of the vertical wells.

Given an understanding of the assumptions inherent in the DEA-44 screening models, the user can quickly run cases to best match the historic vertical well production.

There will be a number of input parameter combinations which result in a close fit to actual field behavior. Site specific understanding of the reservoir and production behavior will dictate which particular combination is most appropriate for a given field. Having defined a set (or sets) of input parameters which closely match the vertical well behavior, the user can now use the model to predict the productivity of a horizontal well placed in the candidate reservoir.

#### 6.3.5 Drainage Area

The model assumes that the horizontal well will drain an ellipse with a minor axis equal to the drainage radius assigned to the vertical well, and a inter-focii distance equal to horizontal well length. The productivity prediction is sensitive to the assigned vertical well drainage radius. The smaller the vertical well drainage radius and the longer the horizontal well length, the higher the productivity improvement predicted for a horizontal well versus a vertical well.

#### 6.3.6 Vertical And Horizontal Permeability

With a vertical well, all flow is horizontal so only the horizontal permeability affects flow rate. With a horizontal well, some of the fluid flows vertically through the formation to the horizontal well, so both the vertical and horizontal permeability affect flow rates. The higher the ratio of horizontal to vertical permeability, the lower the predicted flow rate. Most horizontal wells undulate sinusoidally along their length. Thus they tend to cross horizontal permeability barriers (i.e., tight streaks). The model does not consider the localized effects of horizontal permeability barriers, but it does consider different values for horizontal and vertical permeability.

#### 6.3.7 Reservoir Pressure

RESMOD3 assumes an equal pressure at the external boundary of the assigned drainage ellipse. The drive energy is limited to volume expansion. Therefore the productivity prediction will not take benefit from access to undrained (i.e., non-depleted) reservoir. Nor will it benefit from exterior pressure support (i.e., natural water drive) or a gravity drainage aspect. In many cases all three of these factors may be in existence.

#### 6.3.8 Wellbore Pressure

The model predicts drive energy from the drawdown pressure existing between the reservoir boundary and the wellbore. The current RESMOD3 model does not take into account pressure losses in the wellbore, a factor which may be important in high flow-rate wells (5,000 to 10,000 BPD) or in long heavy-oil wells. The DEA-44 project has developed a program "HOPE" which predicts multiphase-flow pressure drops along segments of the wellbore. In cases where pressure drop may be a concern — "HOPE" can be run to calculate the magnitude of pressure loss along the well length. The wellbore pressure at the midpoint can then be assigned as wellbore pressure to approximate the effect of this factor on horizontal well productivity.

### 6.3.9 Horizontal Well Length

Although the model assumes uniform inflow along the wellbore length, production logs show that inflow in actual horizontal wells is often not uniform. The more varied the reservoir the more erratic the inflow along the well length. The more laterally variable the reservoir, the more likelihood of a horizontal well accessing "sweet spots" along its length. Drilling technology is constantly improving and statistics indicate that incremental well length is often not a major cost factor in simple completion designs. The user should assign a wellbore length consistent with field boundary and drilling system limitations. Wellbore length sensitivity runs should be made to examine the effect of drilling out of the pay or encountering varying amounts of the productive reservoir.

### 6.3.10 Residual Oil Saturation (Vertical & Horizontal)

The model allows the user to assign different residual oil saturations for the vertical and horizontal wells. Changing the residual oil factor changes the shape of the decline curve, but has no affect on the initial production rate. Vertical well residual saturations should be applied to the horizontal well as a worst case; then increasingly lower horizontal well residual saturations can be applied to identify the sensitivity to this parameter.

### 6.3.11 Skin Factor

Skin damage is the most variable and unknown parameter used by the model. "Skin" in this case applies to both induced and dynamic skin effects. It is treated as a unit of pressure loss and impedes productivity at the same magnitude as would occur in a vertical well. That is, if a skin factor of 1 impedes the vertical well productivity by 20% (versus zero skin), then a skin factor of 1 will impede the horizontal productivity by 20%. The 20% productivity loss is spread equally over the well length. The model allows the user to assign a separate skin value to the horizontal and vertical wells since:

a) It may be possible to reduce the dynamic skin effect of convergence in a horizontal well in the plane of the well;

b) Many operators are treating horizontal drilling as a "completion" activity, and are concentrating on reducing the drilling/completions damage or induced skin effect caused by these activities.

The user should first apply the skin value identified in the vertical well production history match. Then run sensitivity cases with higher and lower skin values to identify the magnitude of skin effect on the horizontal well productivity.

### 6.3.12 Drive Mechanisms

1. Oil Depletion—drawdown is assumed to be proportional to remaining producible oil in place resulting in an exponential decline curve:

$$Q(t) = Q(0) \cdot \exp(-ct) \tag{6-3}$$

This model is based on the work of Giger (1983) and Joshi (1986) as shown in Figure 6-3.

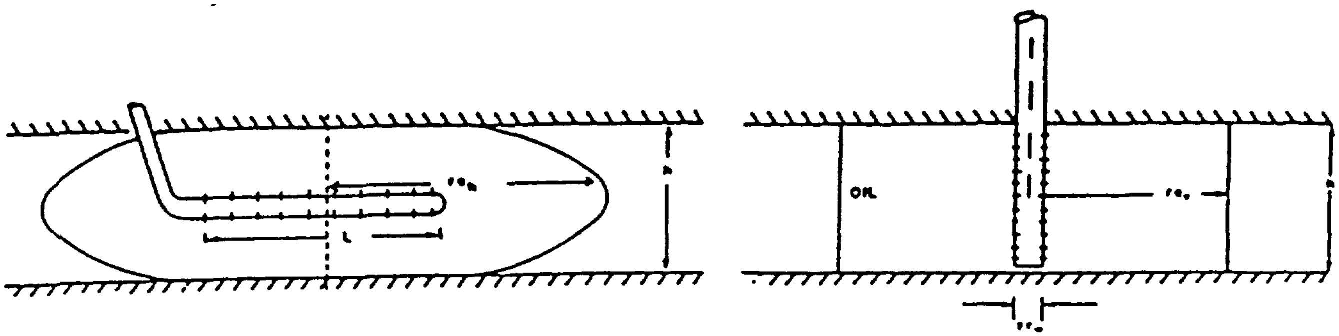

Figure 6-3. Horizontal Well Drainage Schematics (HWELL)

Joshi divided the three-dimensional problem into a pair of two-dimensional problems as shown in Figure 6-4.

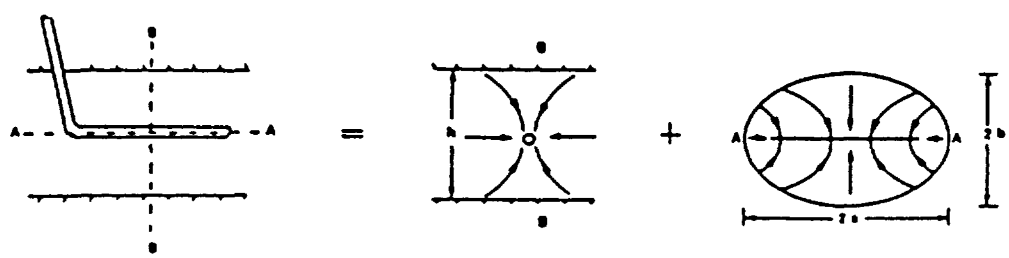

Figure 6-4. Three-Dimensional Horizontal Flow Problem (Joshi, 1986)

The flow rate $q_H$ into this horizontal well equals (Joshi, 1986)

$$q_H = \frac{2\pi K_H H B\,(P_e - P_w)}{\mu\left[\ln\left(\left[1+\left(\frac{2R_e}{L}\right)^2\right]^{\frac{1}{2}}+\frac{2R_e}{L}\right)+\frac{\beta H}{L}\ln\left[\frac{\beta H}{2\pi R_w}\right]\right]\left[1+\frac{S_H}{\ln\left(\frac{R_e}{R_w}\right)}\right]} \tag{6-9}$$

where

$$\beta = \sqrt{K_H/K_v}$$

$K_v$ = Vertical Permeability (md)
$K_H$ = Horizontal Permeability (md)
L = Horizontal Well Length (ft)

and the other variables were defined in the previous VWELL section.

Additional details on this model are presented in DEA-44 report *Horizontal Reservoir Models*.

# JAMES E #9 HORIZONTAL WELL
# CABIN LAKE- DELAWARE POOL
# EDDY COUNTY, NEW MEXICO

## Production Forecasts
## From 3 Reservoir Models

| Year | DEA - 44 Maurer Eng. (BOPD) | Phillips Pet. Horizontal Model (BOPD) | Phillips Pet. Vertical Model (BOPD) |
|---|---|---|---|
| 1 | 971 | 904 | 950 |
| 2 | 470 | 392 | 445 |
| 3 | 150 | 222 | 178 |
| 4 | 60 | 144 | 86 |
| 5 | 31 | 71 | 43 |
| 6 | 16 | 36 | 23 |
| 7 | 11 | 18 | 13 |
| 8 | 8 | 9 | 7 |
| 9 | 5 | 5 | 4 |

| | DEA - 44 Maurer Eng. ~~(BOPD)~~ | Phillips Pet. Horizontal Model (BOPD) | Phillips Pet. Vertical Model ~~(BOPD)~~ |
|---|---|---|---|
| Ult. Recovery (MBO) | 628 | 661 | 638 |

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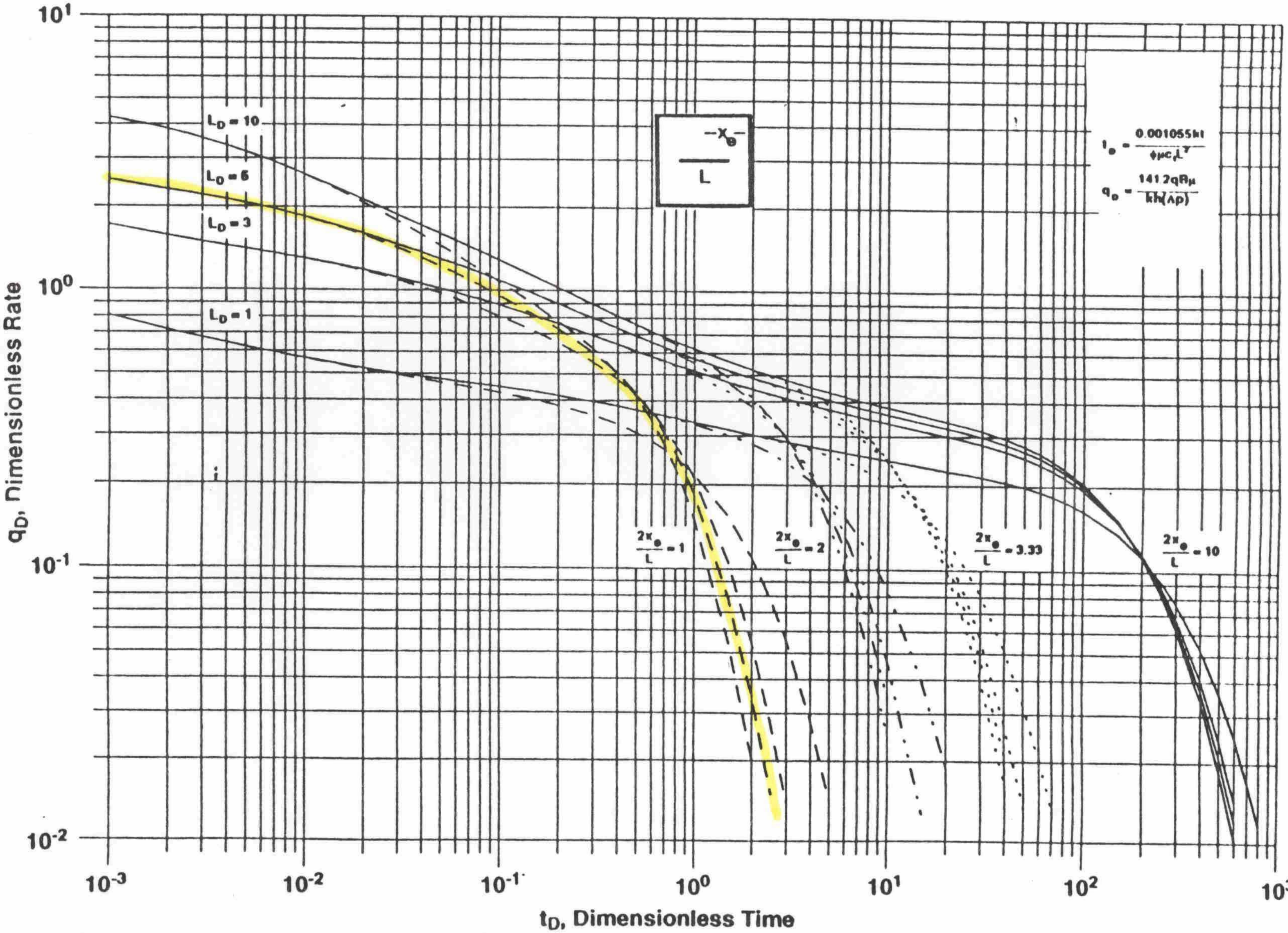
Submitted By:
**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

# TYPE CURVE FOR A HORIZONTAL WELL IN THE CENTER OF A SQUARE DRAINAGE AREA FOR $r^*_{wD} = 0.005$




**Note: This type curve is for an Exponential Decline, b = 0, and a constant flowing bottomhole pres**

**Also note that for a Rectangular area,** $\frac{2x_e}{L} = \frac{\sqrt{Area}}{L} = \frac{\sqrt{(2x_e)(2y_e)}}{L}$

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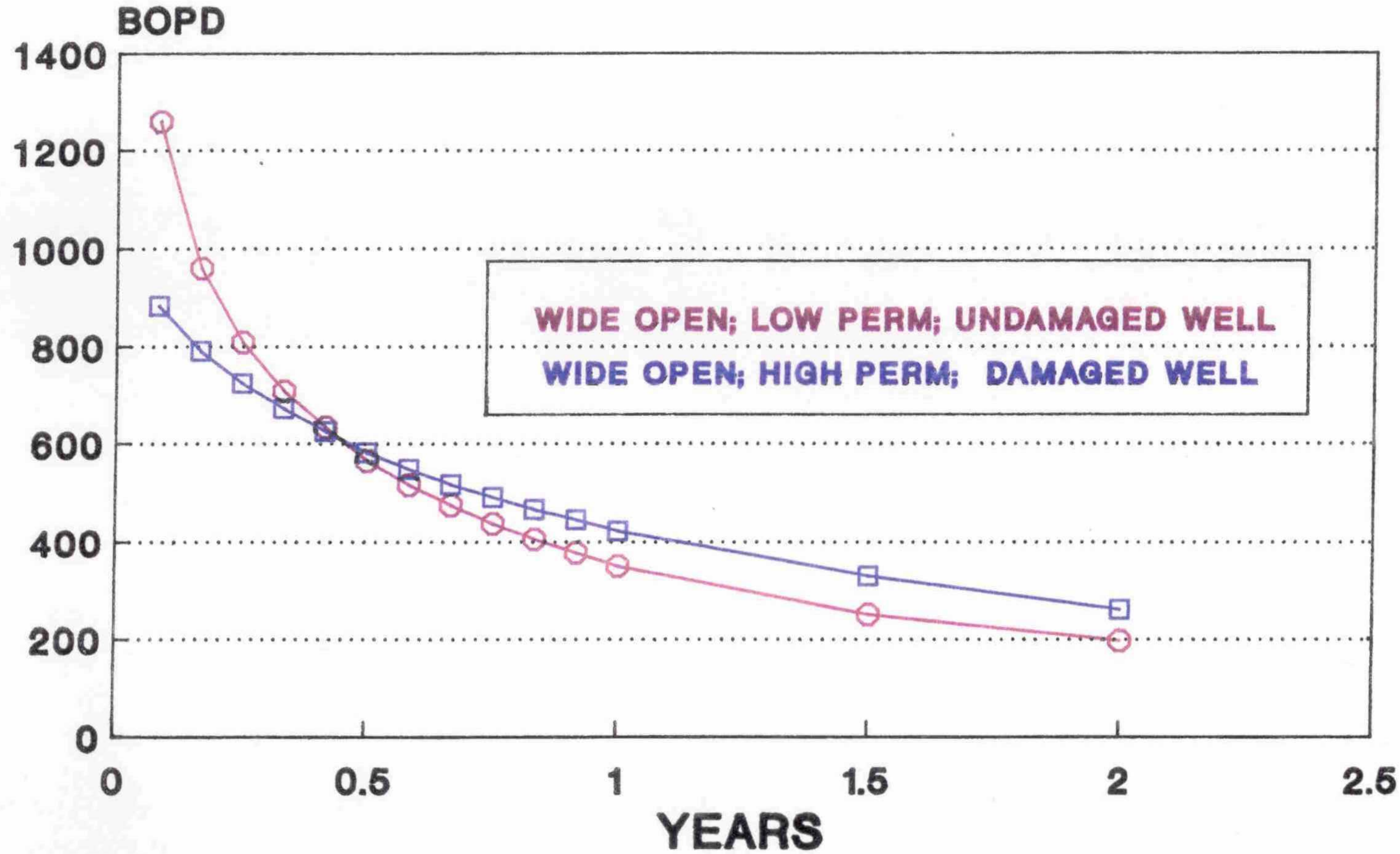
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994

# JAMES E #9 HORIZ. WELL
## RATE - TIME ANALYSIS

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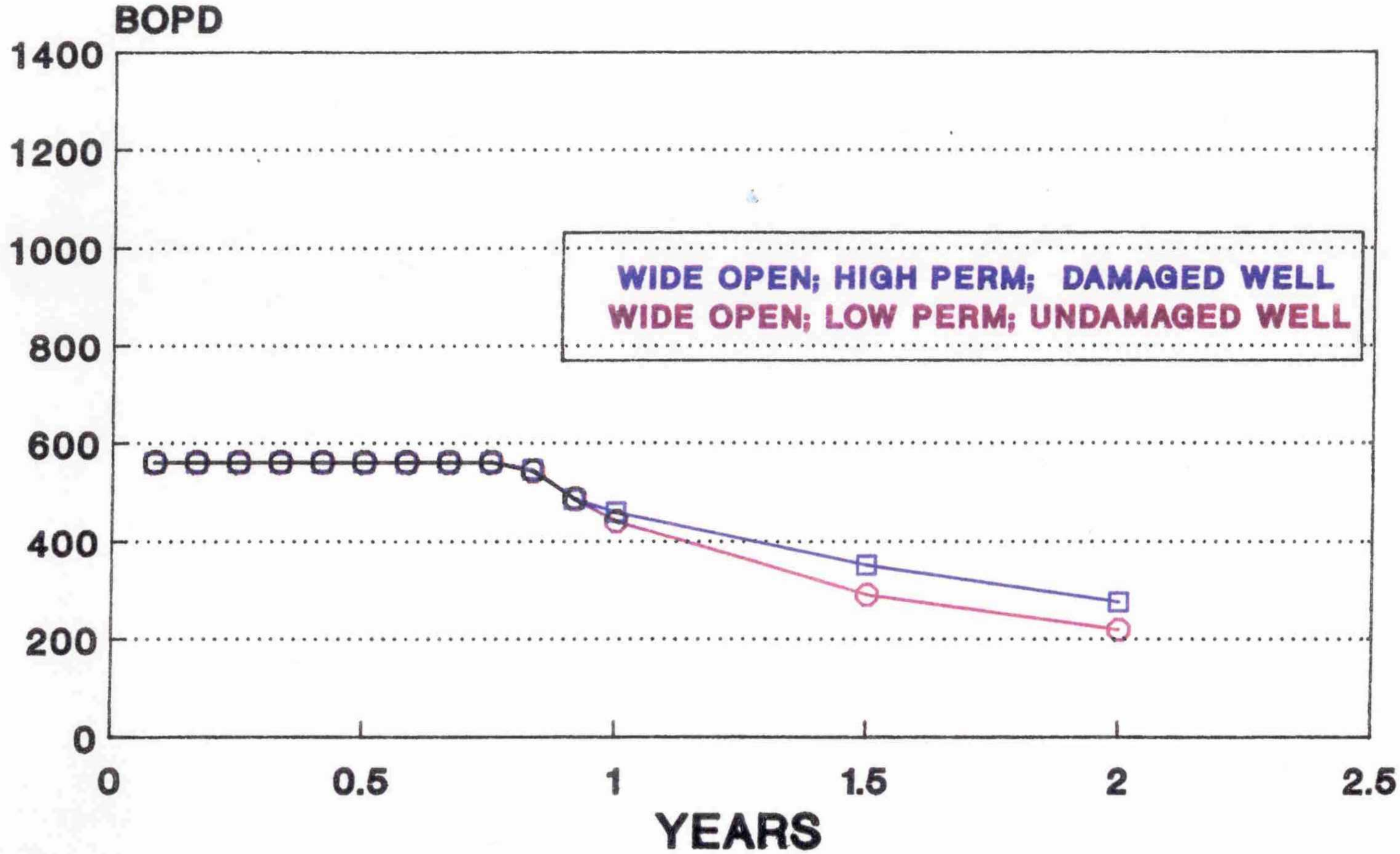
# JAMES E #9 HORIZ. WELL

## RATE - TIME ANALYSIS

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Submitted By:
**PHILLIPS PETROLEUM**
Hearing Date: September 22, 1994

## JAMES E #9 HORIZONTAL WELL
## CABIN LAKE-DELAWARE POOL
## EDDY COUNTY, NEW MEXICO

**Flow Velocity**

$$\textbf{Velocity} = \frac{\text{Flowrate}}{\text{Cross Sectional Area}} = \frac{Q}{A}$$

$$\textbf{Velocity Ratio} = \frac{\text{Velocity}_{VERT}}{\text{Velocity}_{HORIZ}} = \frac{(Q/A)_{VERT}}{(Q/A)_{HORIZ}} = \frac{(Q_{VERT})}{(Q_{HORIZ})}\frac{(A_{HORIZ})}{(A_{VERT})}$$

$$A_{HORIZ} = (\text{Circumference}) * (\text{Length})$$

$$A_{VERT} = (\text{Circumference}) * (\text{Pay Thickness})$$

$$\frac{A_{HORIZ}}{A_{VERT}} = \frac{\text{Length}}{\text{Pay}}$$

$Q_{VERTICAL}$ = 300 BOPD    $Q_{HORIZONTAL}$ = 1600 BOPD

PAY = 60′    Length = 2166′

$$\textbf{Velocity Ratio} = \frac{300}{1600} \times \frac{2166}{60}$$

$$\textbf{Velocity Ratio} = 6.8$$

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Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994

# JAMES E #9 HORIZONTAL WELL
## CABIN LAKE - DELAWARE POOL
## EDDY COUNTY, NEW MEXICO

REQUESTED TEST PERIOD PREVENTS WASTE

### GENERAL RISK ANALYSIS OF STIMULATIONS

| Wellbore Condition | Possible Outcomes | PROBABILITY Early In Life | Late In Life |
|---|---|---|---|
| DAMAGED | Complete Damage Removal | 25% | 20% |
| | Partial Damage Removal | 50% | 40% |
| | No Change | 10% | 20% |
| | Cause Damage | 10% | 15% |
| | Lose Well | <5% | <5% |
| | TOTAL | 100% | 100% |
| UNDAMAGED | No Change | 85% | 80% |
| | Cause Damage | 10% | 15% |
| | Lose Well | <5% | <5% |
| | TOTAL | 100% | 100% |

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Case No.11014 DeNovo Exhibit No. 15
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994

### SPECIFIC ANALYSIS OF HORIZONTAL WELLS

| CONDITIONS: | RESERVES |
|---|---|
| • A 2166' Horizontal Well Is Drilled | 628 MBO |
| • Effective Length Is 1700' | 526 |
| • Potential Benefit Of Stimulation | 100 MBO |

### IF TEST PERIOD IS GRANTED

| Wellbore Condition | Possible Outcomes | Potential Benefit | Prob | Risked Reserves |
|---|---|---|---|---|
| DAMAGED | Complete | 100 MBO | 25% | 25 MBO |
| | Partial | 50 | 50% | 25 |
| | No Change | 0 | 10% | 0 |
| | Cause Damage | -20 | 10% | -2 |
| | Lose Well | -526 | <5% | -26 |

RISK - ASSESSED BENEFIT: 22 MBO

CONCLUSION: STIMULATE THE WELL

OUTCOME: IMPROVE ULTIMATE RECOVERY

### IF TEST PERIOD IS NOT GRANTED

| Wellbore Condition | Possible Outcomes | Potential Benefit | Prob | Risked Reserves |
|---|---|---|---|---|
| DAMAGED | Complete | 100 MBO | 10% | 10 MBO |
| | Partial | 50 | 20% | 10 |
| | No Change | 0 | 10% | 0 |
| | Cause Damage | -20 | 7.5% | -2 |
| | Lose Well | -526 | <2.5% | -13 |
| UNDAMAGED | No Change | 0 | 40% | 0 |
| | Cause Damage | -20 | 7.5% | -2 |
| | Lose Well | -526 | <2.5% | -13 |

RISK - ASSESSED BENEFITS -20 MBO

CONCLUSION: DO NOT STIMULATE WELL

OUTCOME: REDUCE ULTIMATE RECOVERY

## JAMES E #9 HORIZONTAL WELL
## CABIN LAKE- DELAWARE POOL
## EDDY COUNTY, NEW MEXICO

### Production Forecasts
### Test Period and Over Production

| Month | Production If Test Period Is Granted (BOPD) | Project Allowable (BOPD) | Monthly Over Production ( MBO ) | Cumulative Overage (MBO) |
|---|---|---|---|---|
| 1 | 1600 | 561 | 31 | 31 |
| 2 | 1425 | 561 | 26 | 57 |
| 3 | 1275 | 561 | 21 | 78 |
| 4 | 1150 | 561 | 18 | 96 |
| 5 | 1050 | 561 | 15 | 111 |
| 6 | 950 | 561 | 12 | 123 |
| 7 | 850 | 561 | 8 | 131 |
| 8 | 775 | 561 | 6 | 137 |
| 9 | 700 | 561 | 4 | 141 |
| 10 | 650 | 561 | 3 | 144 |
| 11 | 625 | 561 | 2 | 146 |
| 12 | 600 | 561 | 1 | 147 |

Year One Summary

Total Production: 352 MBO
Annual Allowable: 205 MBO (561 BOPD * 365 days)
Over production: 147 MBO

BEFORE THE
OIL CONSERVATION DIVISION
Case No.11014 DeNovo Exhibit No. 16
Submitted By:
PHILLIPS PETROLEUM
Hearing Date: September 22, 1994