

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 99-58**

**RESERVOIR CHARACTERIZATION OF NESS CITY NORTH FIELD,  
NESS COUNTY, KANSAS, FOR HORIZONTAL WELL APPLICATIONS**

by

Saibal Bhattacharya  
Paul Gerlach  
Alan Byrnes  
Evan Franseen

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Kansas Geological Survey  
1930 Constant Avenue  
University of Kansas  
Lawrence, KS 66047-3726

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Open file Report: 99-58  
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## **Objective**

Ness City North field is located in Ness County, Kansas. The study area is spread over sections 23, 24 and 25 of 18s-24w. The producing horizon is Mississippian carbonate. The area has been under production since early 1963. The objective of this study was to characterize the reservoir in the study area and generate the data necessary to simulate the field by CMG-IMEX (black-oil) reservoir simulator. Results from the simulation study would be used to generate a map of remaining oil-in-place as of year 2000. Based on the remaining-reserves map and in consultation with the field operator, horizontal wells with different trajectories and completion scenarios would be simulated to delineate the optimum well design. A horizontal well is planned to be drilled in the study area under a DOE contract, of which this study is a part of, and production results from this well would provide the opportunity to cross check the reservoir model and the assumptions made in the simulation study.

## **Study Area**

Wells included in the study area are: Ummel #1 (Mull Drilling), Ummel #2 (Mull Drilling), Ummel #3 (Mull Drilling), Ummel #4 (Mull Drilling), Ummel #1-24 (Mull Drilling), Pfannenstiel #2 (Sun Oil Co.), Pfannenstiel #1 (Associate Oil & Gas), Pfannenstiel #1 (Sun Oil Co.), A Pember #5 (Mineral Exploration), Ummel #1 (Hembree) and Pfannenstiel #1 (Sun Oil Co.).

## **Geologic Model**

A geologic model was developed from the log, core, DST and production data that was available in and around the study area. Tops of major formations above and below the Mississippian units were identified on well logs and these data were entered into a Geographix database. Figure 1 shows the structure map on top of the Mississippian surface along with the section-township lines and the well locations. The study area is also demarcated on this map. Correlation of the different sub-units of the Mississippian formation showed that the reservoir contained 5 layers. They have been named (shallow to deep) as LP1, LP2, LP3, HP1 and HP2. Isopach maps of these horizons are shown in Figures 2 to 6.

## **Petrophysical Model**

Porosity was determined from petrophysical logs and core studies at the well level. Correlation between the wells resulted in obtaining average porosity values for each of the Mississippian sub-units and they are tabulated in Table 1. Forty-one core plugs were available from three wells (Sun Ummel #1, Sun Pfannenstiel #1 and #2) within the study area and from one well (Walters Drilling Maier #1) located in the adjacent area. Standard laboratory measurements carried out on these core plugs included routine helium porosity and air permeability measurements, in situ and effective Klinkenberg permeability determination, irreducible water saturation measurements, and identification of the dominant lithofacies under the microscope. The laboratory results on the core plug study

are shown in Table 2. The permeability-porosity correlation for different lithofacies is shown in Figure 7. DST and IP results indicate that the average permeabilities of LP1 and LP3 horizons are lower than that of LP2 and those of HP1 and HP2 are distinctly higher than that of LP2. Permeability calculations from log porosity, using the permeability-porosity correlations, further corroborates this observation. A histogram (Figure 8) of the laboratory measured permeability values indicates that in the low permeability range the frequency peak occurs at 8 md, in the high permeability range the peaks occur at 40 and 60 md and in the medium permeability range the peaks occur at 25 md. Detailed information about the porosity or permeability in the Mississippian horizon is unavailable for most wells in the study-area. The initial reservoir model has been built by assuming uniform permeability values for the layers LP1, LP2, and LP3, namely 8 md, 25 md, and 8 md. These permeability values correspond to the frequency peaks observed at the low permeability and medium permeability ranges of the permeability histogram. In this initial reservoir model, layers HP1 and HP2 were assigned with uniform permeabilities of 60 md and 40 md and these values correspond to the frequency peaks in the high permeability range. Preliminary core studies indicate that moldic pack-wackestone is the dominant facies in LP1, LP2 and LP3, while moldic packstone dominates HP1 and HP2. The correlation equation (from the permeability-porosity equations in Figure 7) for moldic pack-wackestone was used to calculate the corresponding porosity for LP1, LP2, and LP3, while that of moldic packstone was used to calculate the porosity of HP1 and HP2. Like permeability, the initial reservoir model assigned a uniform porosity value to each layer. The porosity attributed to each layer was the lower value between that calculated from the permeability-porosity correlation and the highest measured porosity (from standard core analysis on plugs) for the corresponding dominant lithofacies. Table 1 shows the porosity and permeability values for each of the layers.

Capillary pressure measurements were carried out on core plug samples that represent each of the five Mississippian sub-units. The data is summarized in Figure 10. Relative permeability curves were generated for each layer by using the correlations of Honarpour<sup>1</sup>. For calculation of relative permeability of water, the equation corresponding to intermediately wet limestone/dolomite was used. The equation referring to limestone or dolomite of any wettability was used to generate the relative permeability curve for oil. The results are summarized in Figure 11. Irreducible water saturation ( $S_{wi}$ ) for each core plug under was measured at 150 feet above the free water level and was used in the calculation of the relative permeability. Figure 12 shows the results of  $S_{wi}$  measurements. Figure 13 displays the irreducible oil saturations ( $S_{orw}$ ) that were measured on some of the core plugs. The data show two loose clusters, with one representing  $S_{orw}$  values for porosities less than 20% and the other representing porosities above 20%. Average  $S_{orw}$  value from each cluster, selected according to the porosity of the core plug being above or below 20%, was used in the relative permeability calculations.

Sufficient log data were available for only two wells (Mull Pfannenstiel #1-24, and Mull Ummel #4) in the study area to complete Super-Pickett plot analysis. Appendix B shows the results of the Super-Pickett analysis. A salinity of around 34000 ppm (NaCl) was considered for the calculation of  $R_w$  (= 0.13 ohm-m) at a reservoir temperature of 115°F. The Super-Pickett plot of Pfannenstiel #1-24 indicates a  $BVW_i$  value of 0.066. The

average porosities calculated from Super-Pickett analysis for layers LP1, LP2, LP3, and HP1 are 0.144, 0.184, 0.163, and 0.178 respectively. These porosity values compare closely with the assumed porosity values for layers LP1 and LP3. The Rhomaa-Umaa plot for the same well indicates that the Mississippian sub-units are composed dominantly of dolomite with some quartz and calcite. Mull Ummel #4 proved to be a dry and abandoned well and all the tested intervals proved non-commercial. Thus, no  $BVW_i$  values could be obtained from the Super-Pickett analysis of this well. The average porosity values for layers LP1, LP2, and LP3 are 0.169, 0.176, and 0.174.

Very limited well logs, from which initial water saturation ( $S_w$ ) values could be derived, were available for wells included in the study area. Analysis of sample reports, DST data and production tests enabled mapping of an oil-water-contact (OWC) across the study area. The OWC was found to be flat and it was located at a subsea depth of -2035 feet, and this depth is confirmed from the available log data in Pfannenstiel #1-24 (Mull Petroleum) well. Saturation values for each layer was calculated from its representative capillary curve and the average height of the layer above the OWC. Table 4 compares the average water saturation values obtained from logs with that calculated from the capillary pressure curves. The saturation values, obtained from two different methods, for each of the layers appear to be reasonably close.

### **Pressure Analysis**

The DST analysis is included in Appendix A and the summary of the DST analysis is shown in Table 3. DST data were available for 4 wells in the study area and in only two of the wells the shut-in pressures appear to have stabilized. Also, in one of the stabilized wells the test interval straddles two productive zones (HP1 and LP2) and this further complicates the applicability of the permeability values calculated from the DST analysis. Figure 9 is a plot of the static reservoir pressure ( $P_i$ ) calculated from the DST analysis. The limited data show that the reservoir pressure declined by 450 psi over a period of 17 years and this supports the existence of an active bottom water drive in the reservoir.

### **Production Data Analysis**

For the wells, Mull Ummel #1, Mull Ummel #2, and Mull Ummel #1, production data included the monthly sales record for the Ummel lease and results from 24-hour barrel-tests at each well. The barrel test results included the oil and water production over a 24-hour period and they were carried out over the life of each well. The oil production from the barrel tests was used to allocate the monthly lease production of oil (actually volumes of oil sales) to the three contributing Ummel wells. The monthly oil production thus calculated for each well was used in conjunction with the corresponding water-oil ratio (WOR), obtained from the barrel test, to derive the monthly water production at each of the above three wells. The monthly oil and water production for these three wells were averaged over a three-month period and these are plotted in Figure 14. The same data are plotted as WOR versus cumulative oil production in Figure 15 along with the equations of the best fitting lines. This plot clearly indicates that Mull Ummel #1 is the most

productive well having produced the highest cumulative oil at the lowest WOR. Mull Ummel #2 is a medium performer and Mull Ummel #1 is the poorest performer.

Production data available for the other wells in the study area included the monthly volumes of oil sales from corresponding leases. The wells are located outside the Ummel lease and they included Pfannenstiel #1 (Associates Oil & Gas), Pfannenstiel #1-24 (Mull Petroleum), Pember #A5 (Mineral Management), Pfannenstiel #2 (Sun Oil Co.), and Ummel #1 (Hembree). These wells are the only wells in their respective leases and thus the lease sales relate to the well contained in the lease. The monthly oil production for each of these wells was obtained by averaging the lease sales volumes over a three-month period. A cumulative production profile was generated for each well and it is plotted in Figure 16. It is apparent from this plot that Mull Ummel #1 is in a class of its own having produced more than 100,000 bbls over its life. Irrespective of the producing life of each well, Figure 16 shows that the wells Ummel #2 (Mull Petroleum), Ummel #3 (Mull Petroleum), Pfannenstiel #1 (Associates Oil & Gas), and Pfannenstiel #1-24 (Mull Petroleum) show similar cumulative production patterns. The cumulative performance of Pfannenstiel #2 (Sun Oil, Co.) though better than this group is far behind that of Ummel #1 (Mull Petroleum) well.

In absence of any specific data, the WOR profile (with cumulative production) for Ummel #2 (the medium performer in the Ummel lease) was chosen to generate water production values from the cumulative oil production for wells located outside the Ummel lease. The production data for the wells outside the Ummel lease is plotted in Figure 17.

### **Tasks accomplished**

- a) Developed the preliminary geologic model for the Ness City North field and identified 5 major Mississippian sub-units called LP1, LP2, LP3, HP1 and HP2. Structure map of the Mississippian surface and the isopach maps of the Mississippian sub-units were constructed.
- b) Petrophysical analysis on the available core plugs was carried out to generate permeability-porosity correlations, capillary pressure curves, and to determine relative permeability end-points and to generate relative permeability curves using Honarpour's correlations. This exercise enabled assigning average porosity and permeability values to the Mississippian sub-units. Super-Pickett analysis was carried on available data.
- c) A flat OWC was identified from the analysis of sample data, production and DST test data.
- d) DST data were analyzed to obtain an understanding of the original reservoir pressure and its decline with production.
- e) Production data were analyzed to generate production histories of the wells in the study area.

## **Future Studies**

- a) Conduct reservoir simulation of the study area. Match the simulator output to the production history of the wells.
- b) Map remaining oil in place
- c) Study the applicability of a horizontal well to optimize recovery of the remaining reserves.

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Figure 2: Isopach map of layer LP1.

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Figure 12: Plot of  $S_{wi}$  versus porosity.

Figure 13: Plot of  $S_{orw}$  versus porosity.

Figure 14: 3-month average production of oil and water for the Ummel wells.

Figure 15: WOR versus cumulative oil production for the Ummel wells.

Figure 16: Cumulative production versus time for each well in the study area.

Figure 17: Production performance of wells outside the Ummel lease.

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Table 2: Laboratory measurements on core plugs.

Table 3: Summary of DST analysis.

Table 4: Comparison of average water saturation obtained from well logs with that calculated from the capillary pressure curves for Mull Ummel #4 and Mull Pfannenstiel #1-24.

**References:**

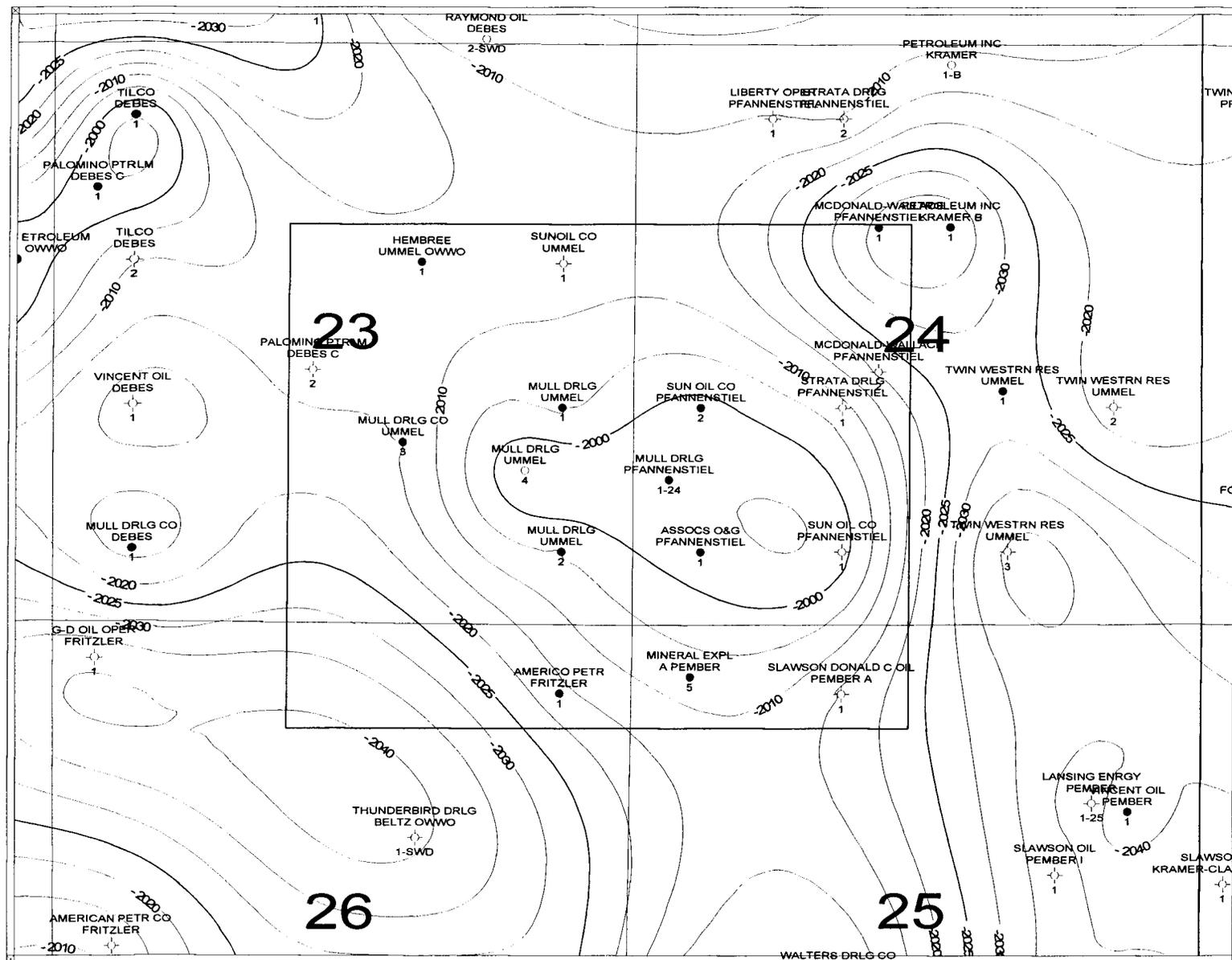
1. Honarpour, M., Koederitz, L., and Harvey, A.H.: Relative Permeability of Petroleum Reservoirs, CRC Press, Inc., Boca Raton, Florida, page 40.

<b>Table 1</b>						
<b>Mississippian sub-unit</b>		<b>Porosity</b>		<b>Permeability</b>		
		%		md		
LP1		15		8		
LP2		21.5		25		
LP3		15		8		
HP1		23.6		60		
HP2		22.2		40		

Table 2											
Ness City Core Data											
	Depth		Routine Helium	Routine Air	Insitu Klinkenberg	keo,Siw Effective klink	keo,Sw50' Effective klink	"Irreducible" Water	Water Saturation	Grain Density	Dominant Lithfacies
Well Name	(ft)	Plug ID	Porosity (%)	Permeability (md)	Permeability (md)	Permeability (md)	Permeability (md)	Saturation (h=150',%)	(h=50',%)	(g/cc)	
Walters Drlg. 1 Maier	4256.0		18.2	67.3	53.9	49.6	57.1	15.6	15.6	2.85	4
Walters Drlg. 1 Maier	4261.0		19.1	30.2	23.9	15.1	18.6	31.4	38.5	2.85	4
Walters Drlg. 1 Maier	4263.1		20.5	11.7	9.0	1.59	23.6	9.6	9.6	2.86	4
Walters Drlg. 1 Maier	4263.9		19.6	24.5	18.8	3.78	8.08	16.1	16.1	2.85	4
Sum 1 Ummel	4290	1	5.5	0.053	0.018	0.02	0.0138	51.9	51.9	2.84	1
Sum 1 Ummel	4291	2	16.4	3.8	2.9	2.91	7.75	13.0	13.0	2.85	4
Sum 1 Ummel	4292	3	14.3	13.5	10.6	9.43	9.43	11.0	11.0	2.85	4
Sum 1 Ummel	4293	4	15.1	28.8	21.8	20.6	20.4	11.3	13.6	2.83	4
Sum 1 Ummel	4294	5	21.7	42.6	33.4	33.41	33.9	10.8	11.8	2.85	4
Sum 1 Ummel	4295	6	12.9	0.348	0.187	0.032	0.0008	72.3	87.1	2.81	2
Sum 1 Ummel	4296	7	16.1	1.86	1.19	0.62	0.770	52.1	55.1	2.83	2
Sum 1 Ummel	4297	8									4
Sun 1 Pfannenstiel	4265	1	23.3	35.3	28.3	28.27	28.2	17.2	19.7	2.83	4
Sun 1 Pfannenstiel	4266	2	12.2	6.5	5.0	4.49	4.37	28.8	32.8	2.70	4
Sun 1 Pfannenstiel	4267	3	12.0	2.4	1.7	1.48	1.43	44.7	46.3	2.82	4
Sun 1 Pfannenstiel	4272	4	24.6	10.8	8.3	6.77	5.46	78.3	78.3	2.40	2
Sun 1 Pfannenstiel	4276	5	17.2	1.35	0.98	0.53	0.158	48.5	68.1	2.81	2
Sun 1 Pfannenstiel	4277	6	17.0	4.96	3.69	3.04	1.01	44.5	49.9	2.82	2
Sun 1 Pfannenstiel	4279	7	14.1	1.67	1.20	1.07	0.851	32.9	41.4	2.85	4
Sun 1 Pfannenstiel	4280	8	21.7	17.8	13.7	13.3	11.4	23.3	35.5	2.81	2
Sun 1 Pfannenstiel	4281	9	12.5	0.140	0.045	0.002	0.00001	91.2	93.6	2.79	1
Sun 1 Pfannenstiel	4282	10	18.1	1.99	1.02	0.31	0.1653	51.1	55.1	2.81	1
Sun 1 Pfannenstiel	4283	11	12.5	0.604	0.362	0.041	0.0052	58.4	84.3	2.81	1
Sun 2 Pfannenstiel	4266	1	8.3	0.140	0.042	0.010	0.0010	61.1	62.1	2.83	4
Sun 2 Pfannenstiel	4267	2	15.0	7.58	5.69	5.44	5.98	12.6	12.6	2.85	4
Sun 2 Pfannenstiel	4268	3	13.4	8.79	6.32	6.32	7.15	35.5	35.5	2.85	4
Sun 2 Pfannenstiel	4269	4									2
Sun 2 Pfannenstiel	4270	5	8.7	9.65	6.07	6.07	6.09	31.0	31.0	2.86	4
Sun 2 Pfannenstiel	4271	6	7.3	1.66	1.16	0.98	2.70	29.1	29.1	2.85	4
Sun 2 Pfannenstiel	4272	7	16.6	10.3	7.64	6.44	7.92	23.9	23.9	2.87	4
Sun 2 Pfannenstiel	4277	8	9.8	0.625	0.223	0.020	0.0029	41.7	59.5	2.83	2
Sun 2 Pfannenstiel	4278	9	8.8	0.568	0.387	0.231	0.131	28.3	45.4	2.85	2
Sun 2 Pfannenstiel	4279	10	23.6	67.7	55.2	55.2	59.1	9.2	12.8	2.84	4
Sun 2 Pfannenstiel	4280	11	21.5	10.8	8.25	7.15	6.39	30.4	41.4	2.82	4
Sun 2 Pfannenstiel	4281	12	19.8	77.3	63.2	63.2	67.2	17.6	21.3	2.81	4
Sun 2 Pfannenstiel	4282	13	19.4	8.73	6.65	5.70	4.41	9.6	21.3	2.86	4
Sun 2 Pfannenstiel	4283	14	20.1	45.3	36.4	36.4	36.7	9.9	13.1	2.83	4
Sun 2 Pfannenstiel	4284	15	18.4	13.1	10.2	9.9	8.62	20.3	24.2	2.83	4
Sun 2 Pfannenstiel	4285	16	10.5	2.70	2.02	1.88	1.78	26.1	37.7	2.83	4
Sun 2 Pfannenstiel	4286	17	15.9	3.55	2.52	2.26	2.23	28.3	28.3	2.83	4
Sun 2 Pfannenstiel	4287	18	23.3	70.4	57.5	27.6	57.0	5.4	7.5	2.83	4
		18b									4
Sun 2 Pfannenstiel	4288	19	13.2	2.36	1.77	1.38	1.16	51.6	61.7	2.83	4
Sun 2 Pfannenstiel	4289	20	15.1	5.09	3.81	3.56	2.73	22.1	34.2	2.81	4

Table 3												
Name	Completion date	FFP, psi	FSIP, psi	Pi, psi	IP - oil, B/D	IP - wtr, B/D	K, md	Layer	RE, %	DST rec.	Eff flow, B/d	Comments
<b>Ummel 1</b>	<b>Mar-76</b>	1125	1272	1300	115	nw	167.9	LP2 & HP1	24.4	2570' CO, 400' MO, 180' GIP	208.7	
<b>Ummel 2</b>	<b>Jun-76</b>	62	1129	1280	15	45	0.8	LP1	3.6	30' M with oil spots	8.7	Starting to Stab.
<b>Ummel 3</b>	<b>Aug-78</b>	103	1113	1250	30	120	0.4	LP2	9.9	3' CO, 117' SOCM	2.3	
<b>Ummel 4</b>	<b>Aug-95</b>	186	671	900	D&A	D&A	7.3	LP2		335 CGO, 82' OCM, 248' GIP	21.5	Not Stab.
<b>Debes 1</b>	<b>Mar-78</b>	197	1338	1362	26	80	9.9			380' GFMO	11.4	

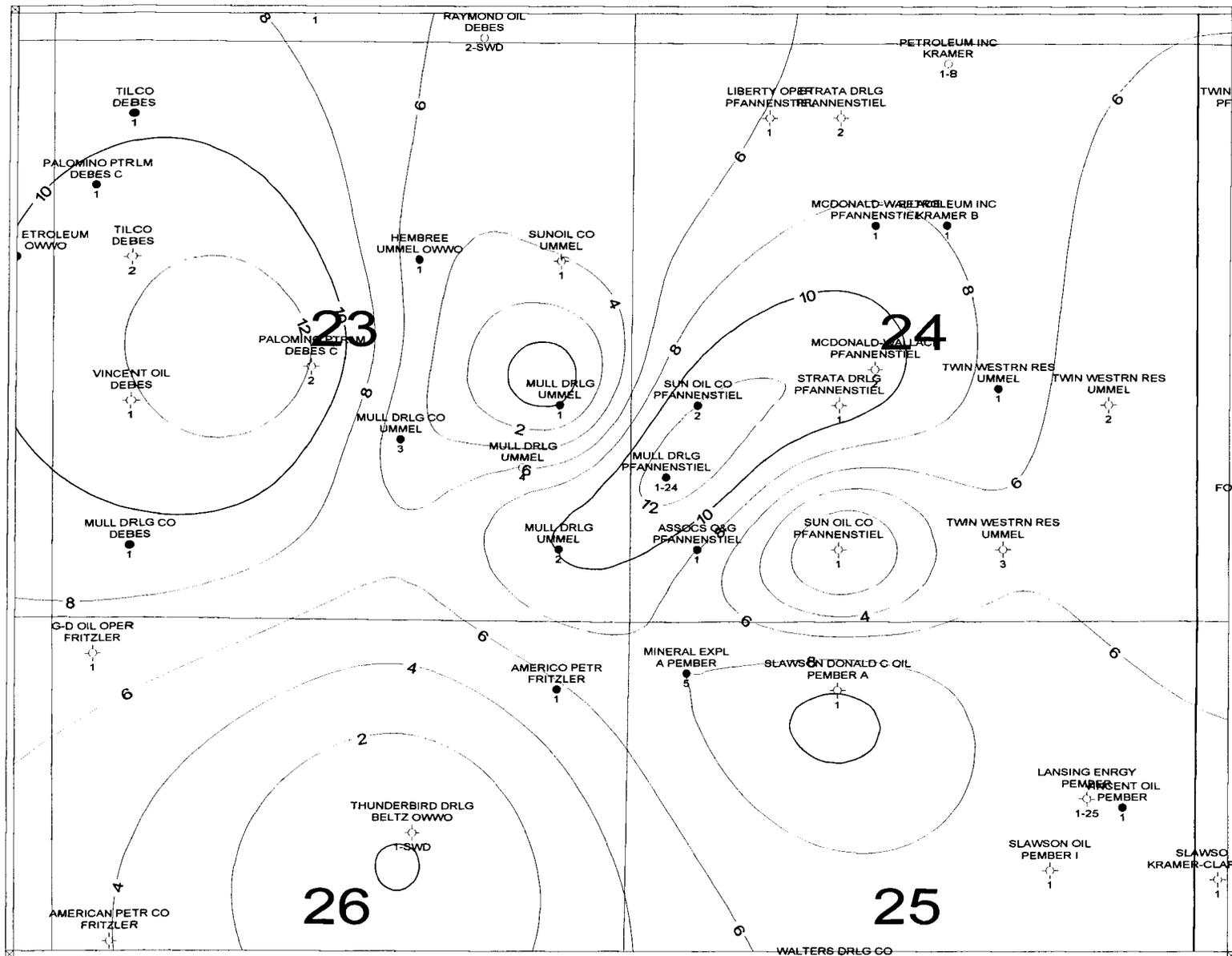




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Figure 1  
Ness City North Field  
Structure on Mississippian

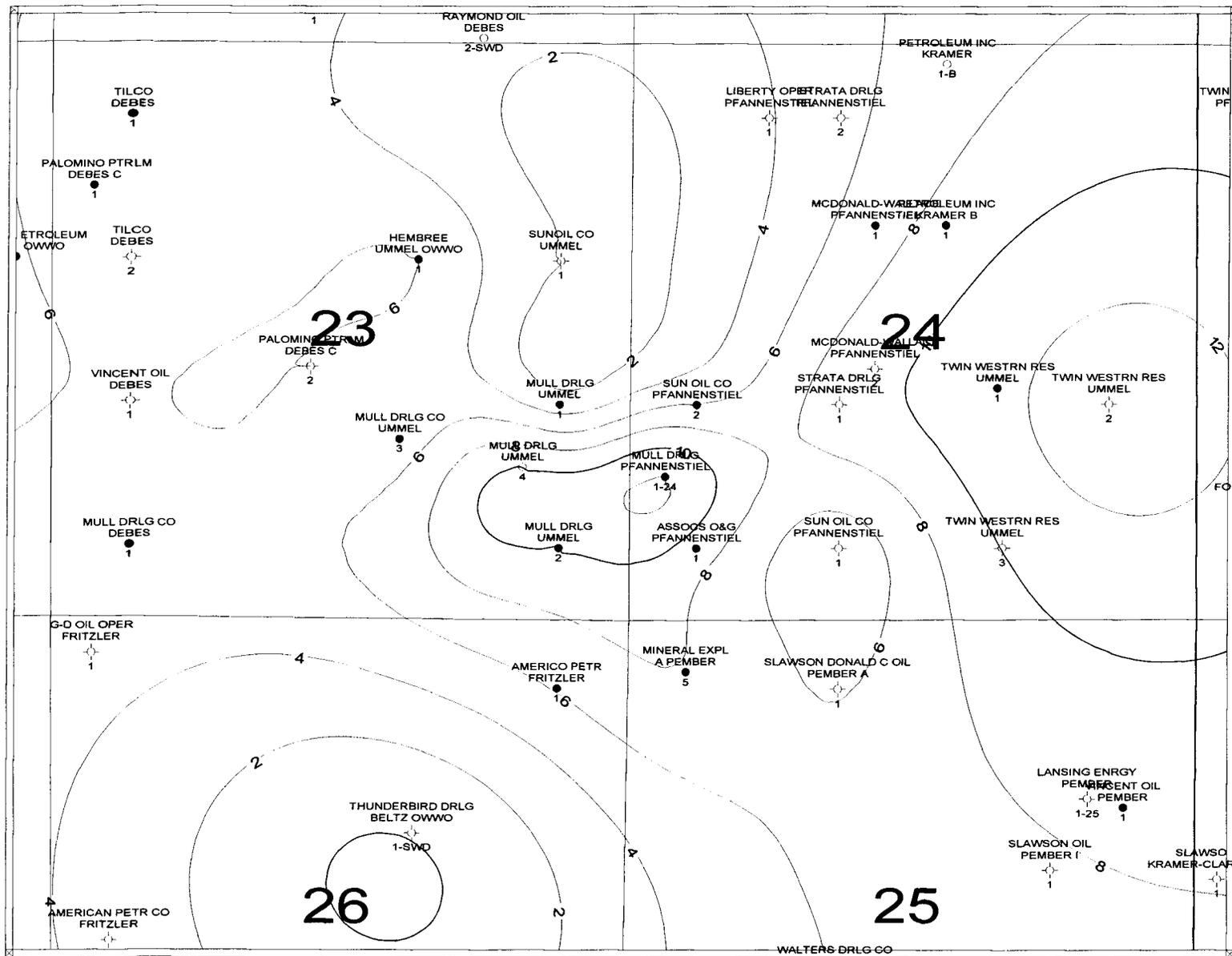
paul gerlach		02/07/19100
Scale 1:17000.18		



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Figure 2  
Ness City North Field  
Isopach of L<sub>P1</sub> (layer 1)

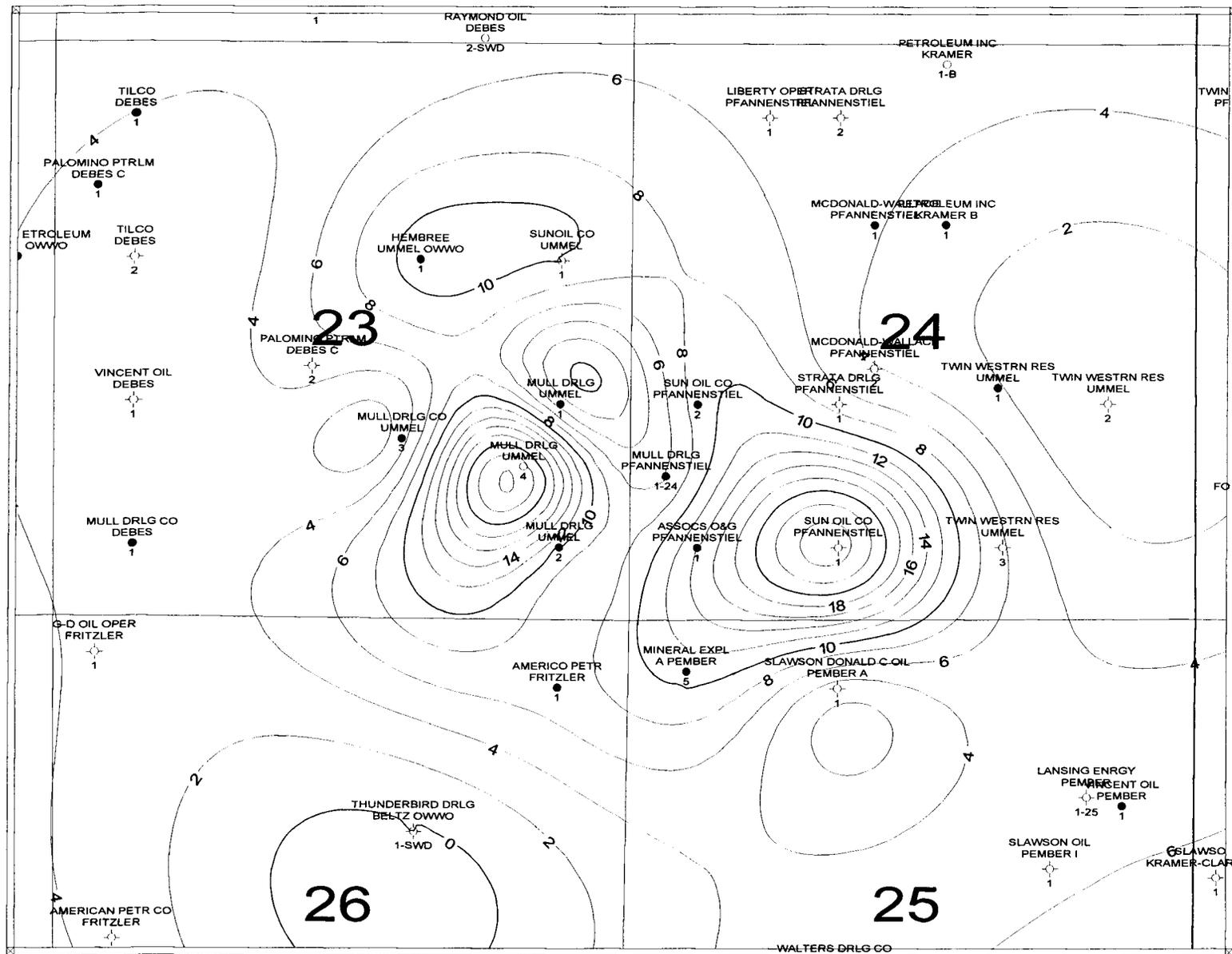
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Figure 3  
Ness City North Field  
Isopach of LP2 (layer 2)

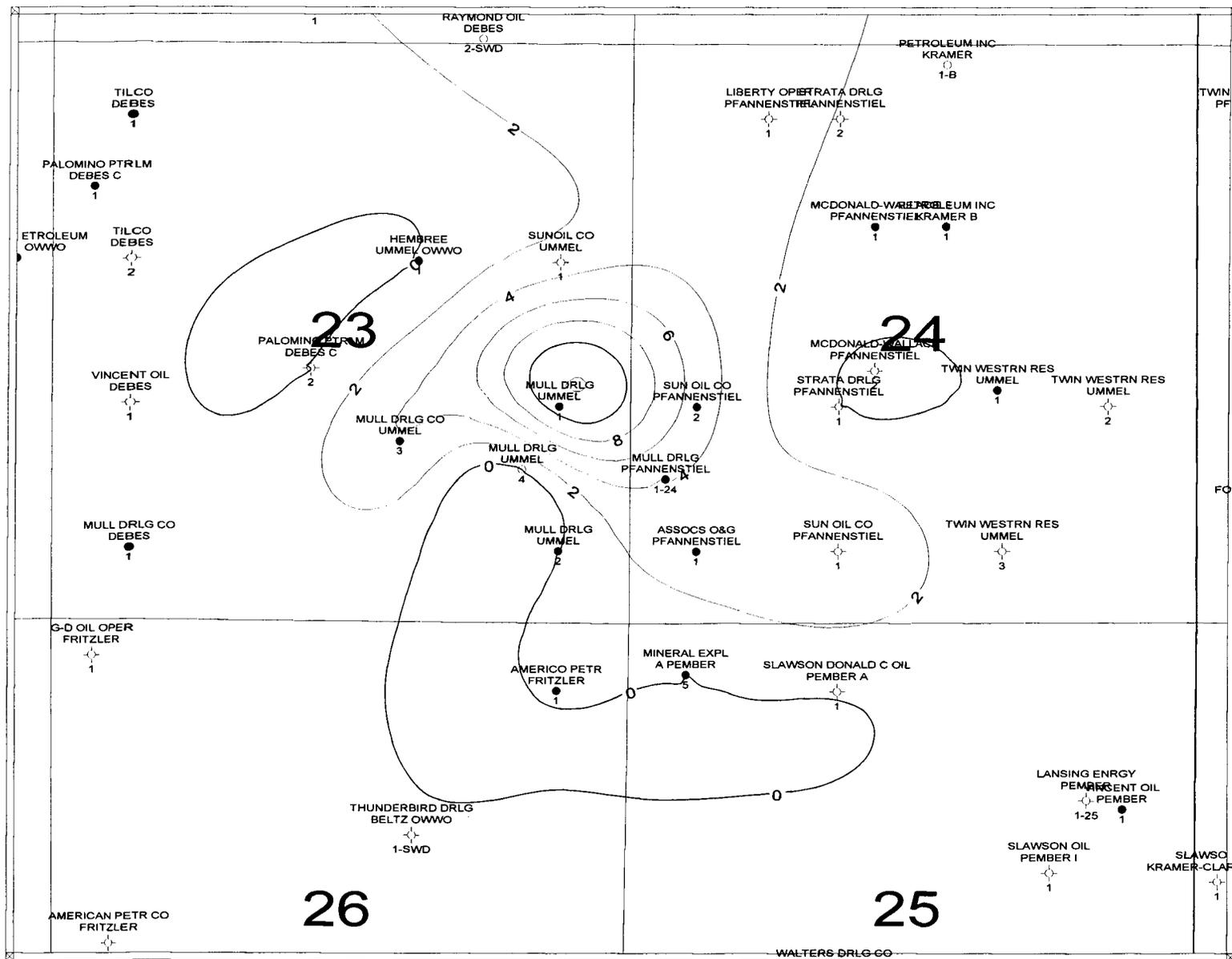
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Figure 4  
Ness City North Field  
Isopach of LP3 (layer 3)

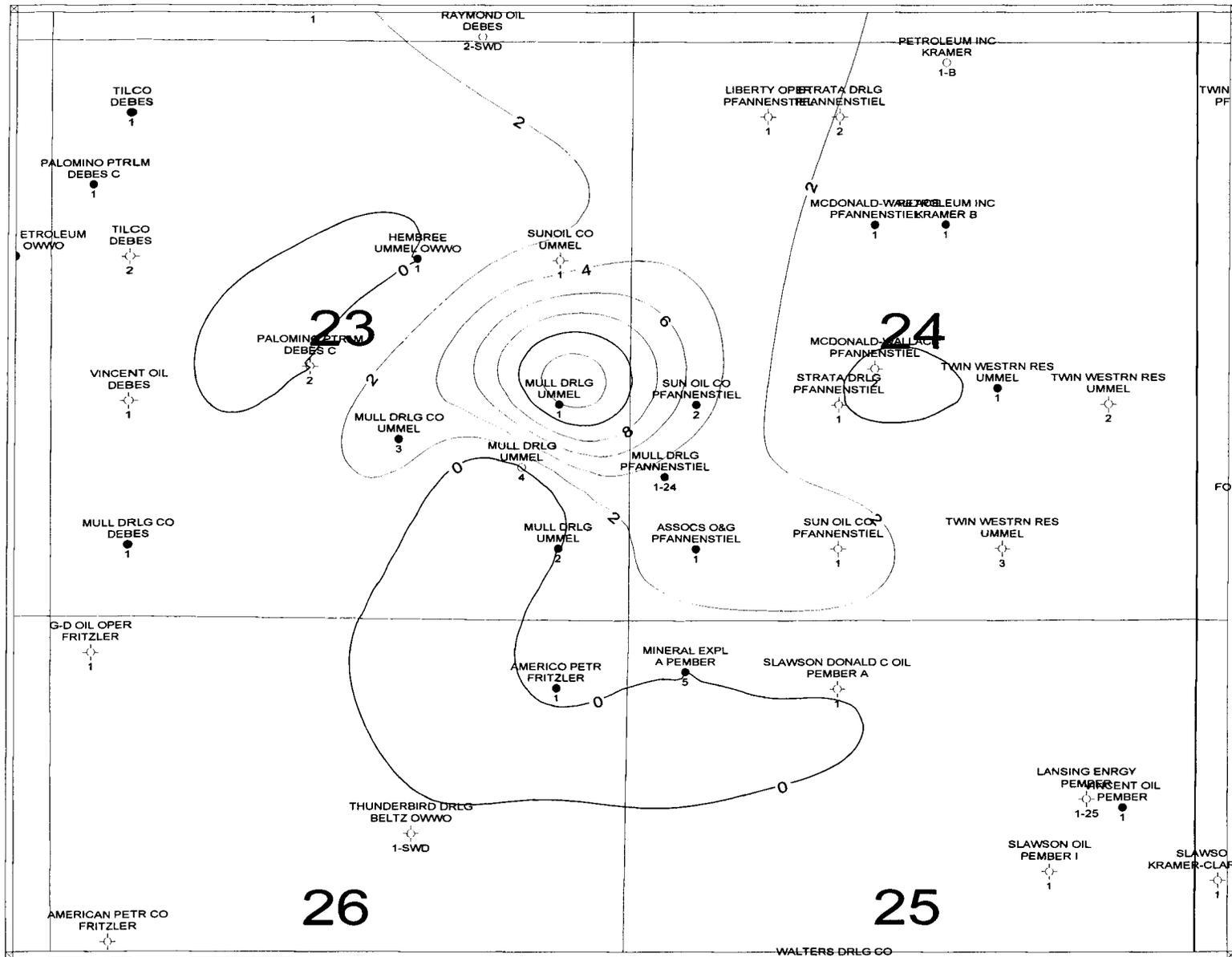
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Scale 1:17000.18	



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Figure 5  
Ness City North Field  
Isopach of HP1 (layer 4)

Paul Goffich	02/07/19100
Scale 1:17000.18	



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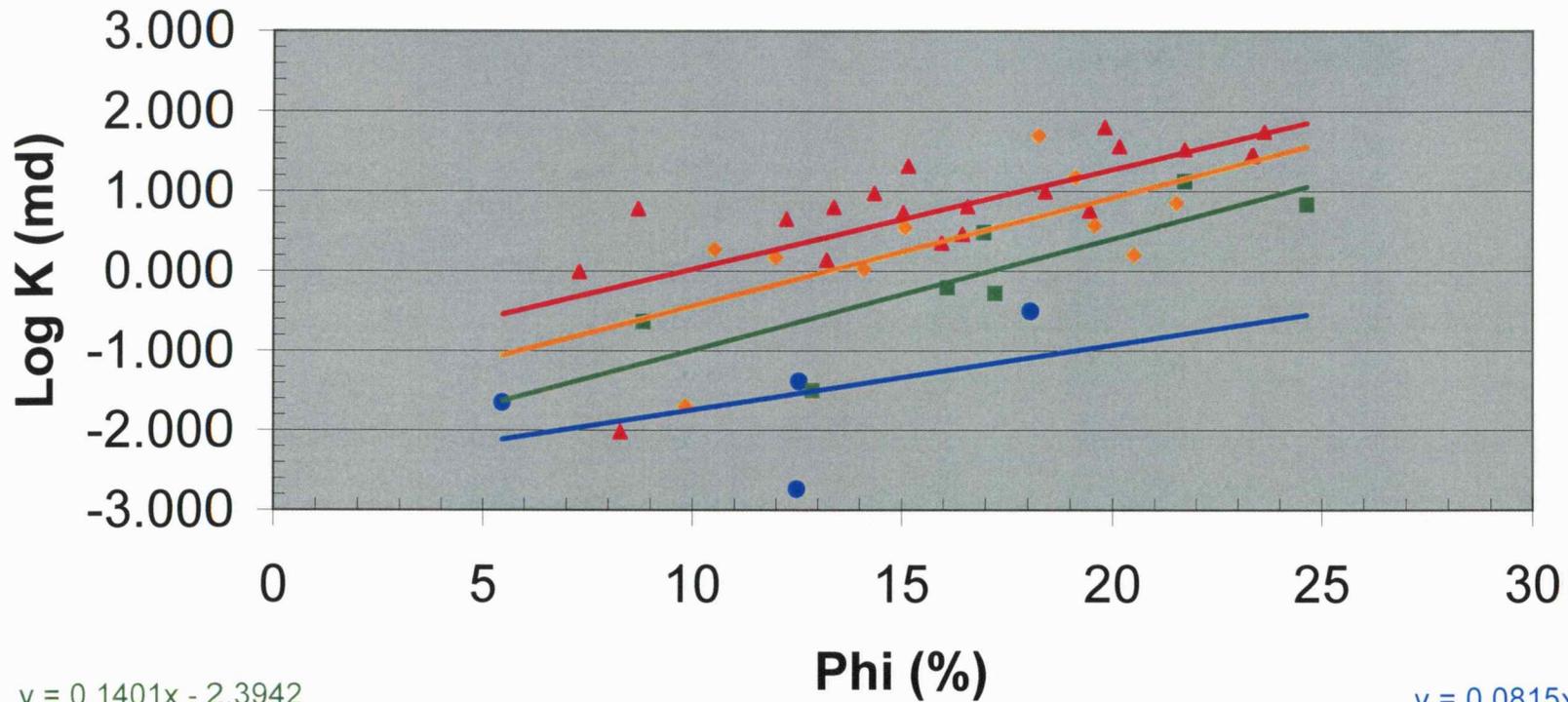
Figure 6  
Ness City North Field  
Isopach of HP2 (layer 5)

paul perlach		02/01/1990
Scale 1:12000 ft		

$$y = 0.1251x - 1.2269$$
$$R^2 = 0.5407$$

$$y = 0.1361x - 1.7989$$
$$R^2 = 0.43$$

## Log K (eff. Klink) vs. Phi



$$y = 0.1401x - 2.3942$$
$$R^2 = 0.6537$$

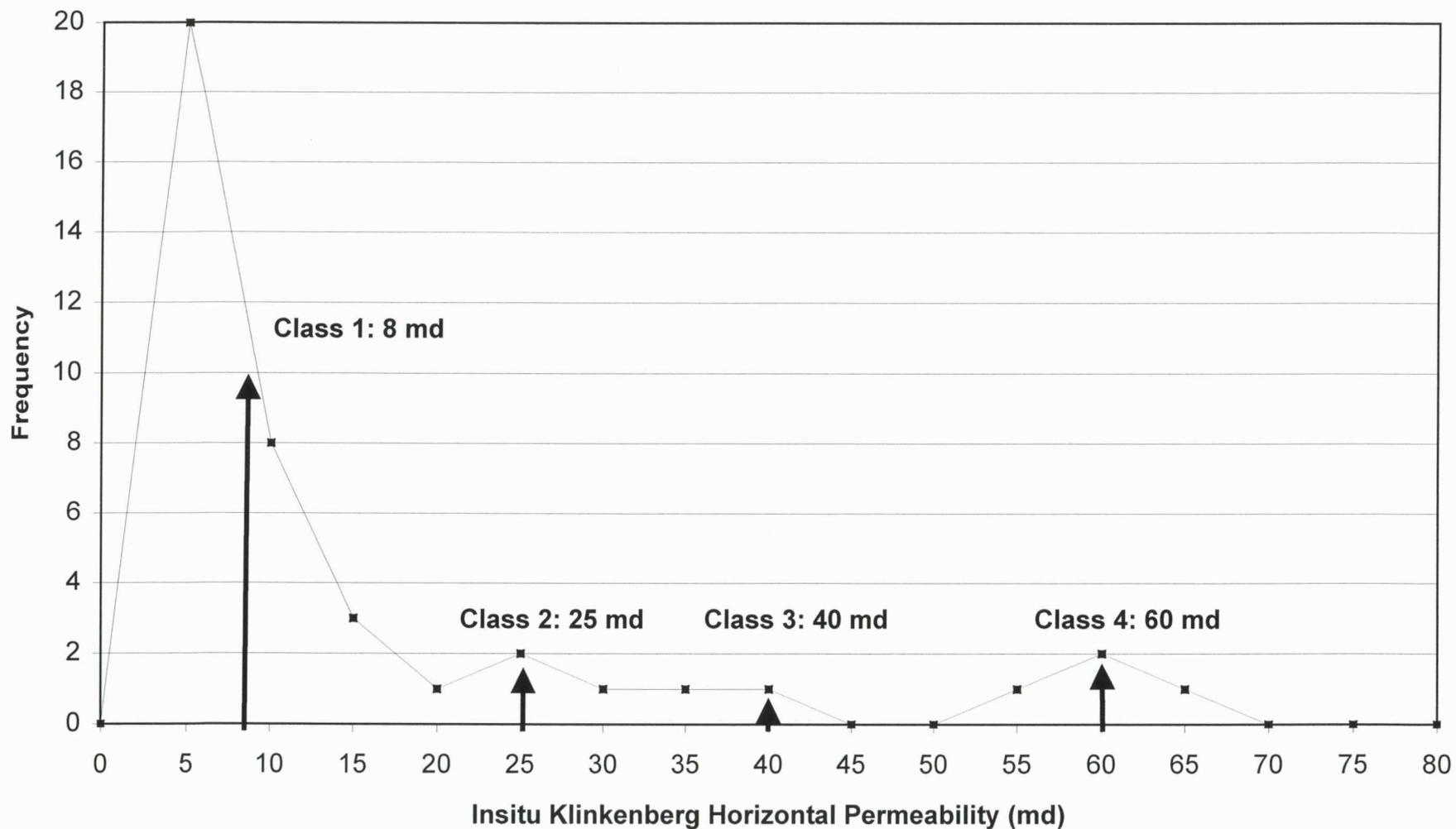
$$y = 0.0815x - 2.5567$$
$$R^2 = 0.209$$



Figure: 7

# Horizontal Permeability Histogram and Average Permeability Ranges

Figure 8



# Ness City North

$$y = -0.0587x + 2953.3$$
$$R^2 = 0.9316$$

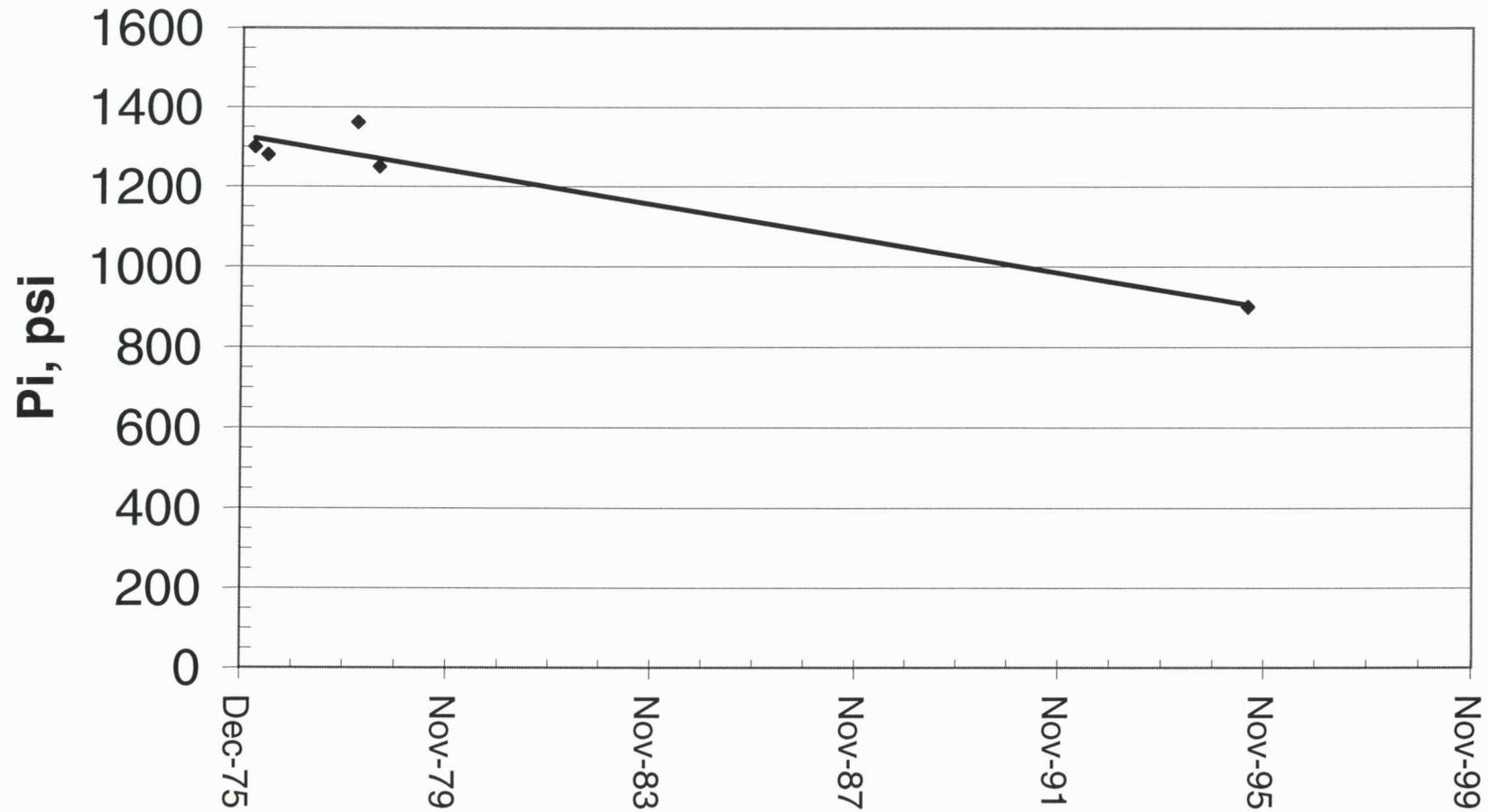


Figure: 9

### Cap Pr - Ness City

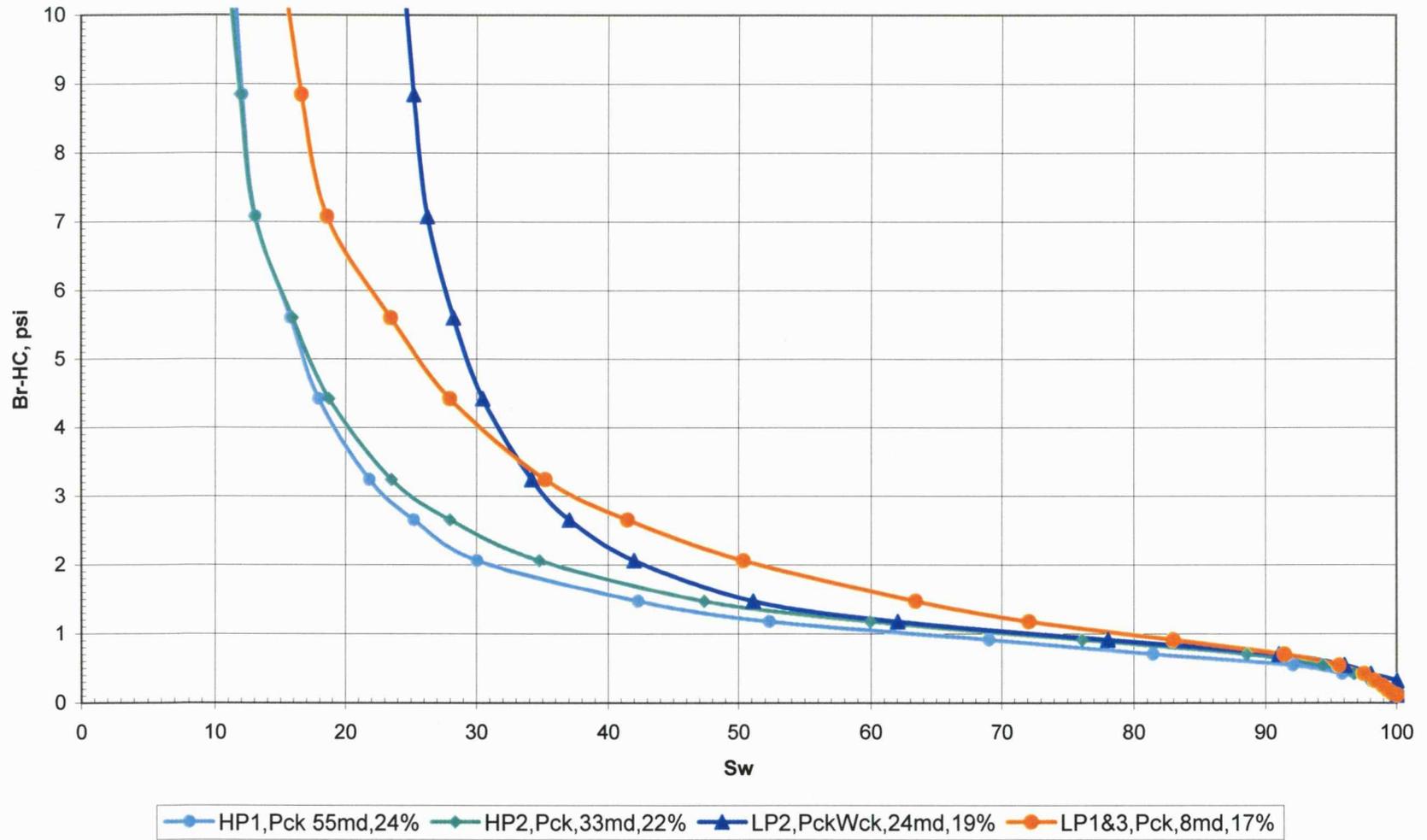


Figure 10a

### Cap Pr. - Ness City

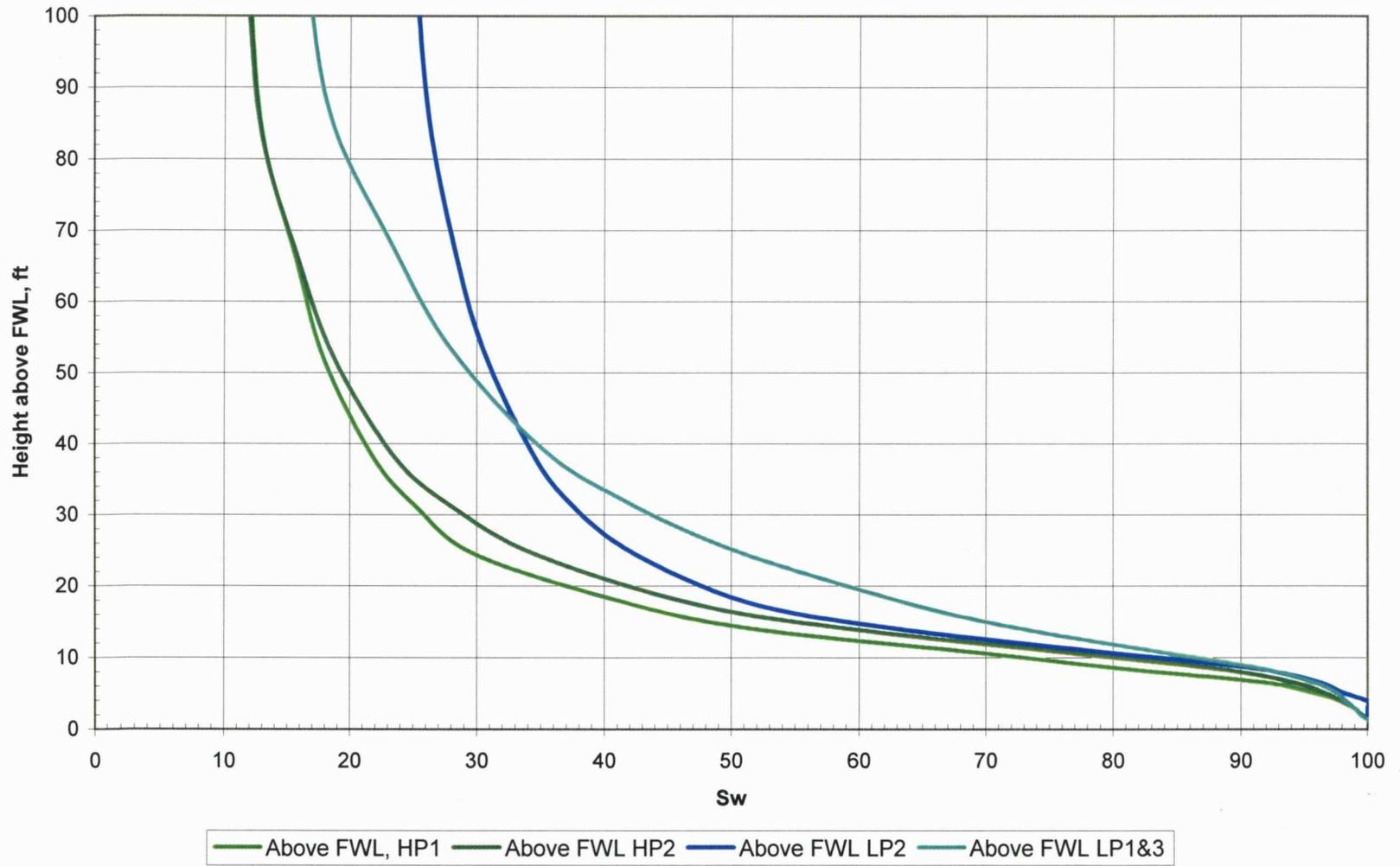


Figure 10b

# Ness City North

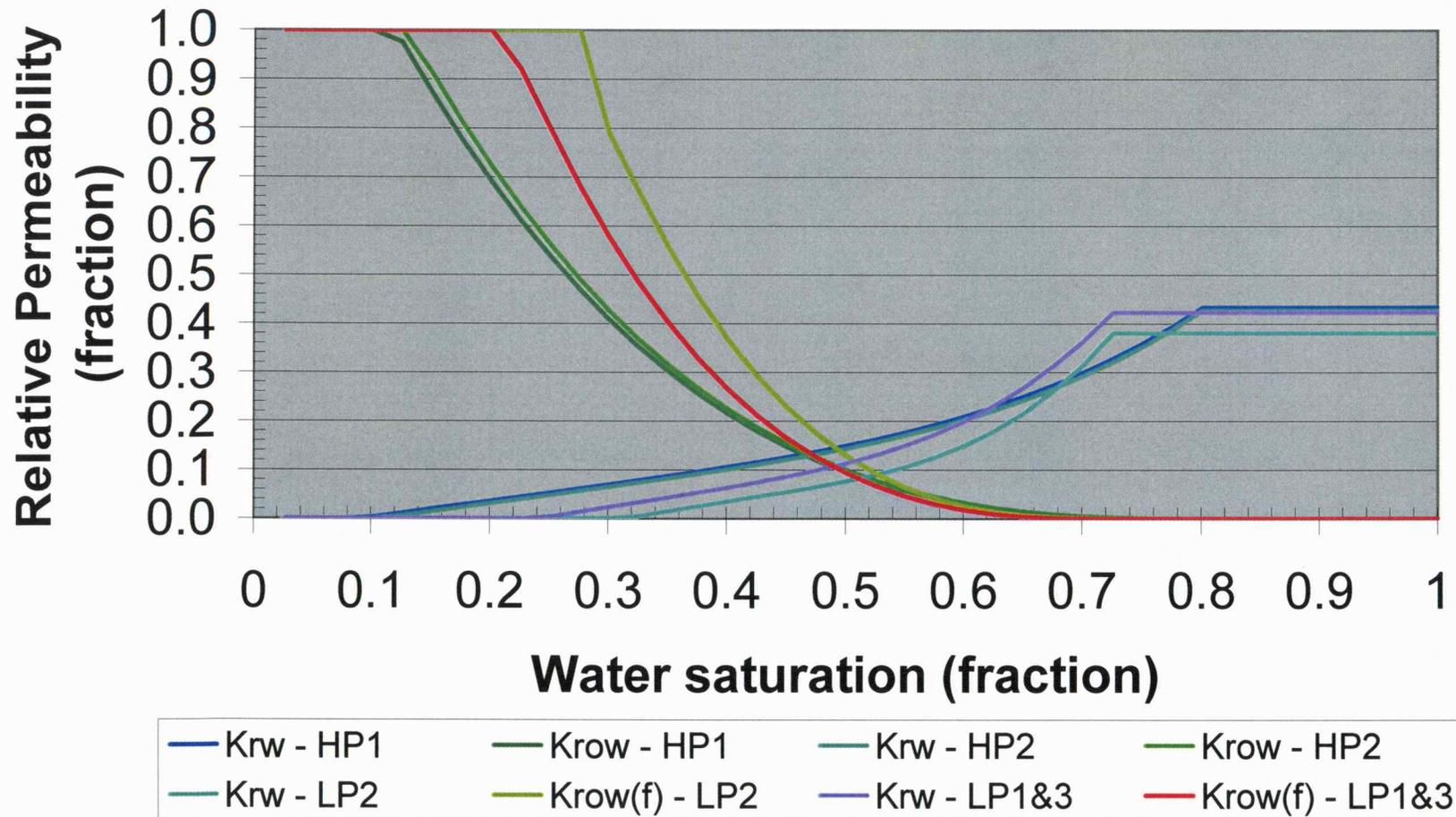


Figure: 11

# Ness City North

$$y = -2.0764x + 55.709$$
$$R^2 = 0.4884$$

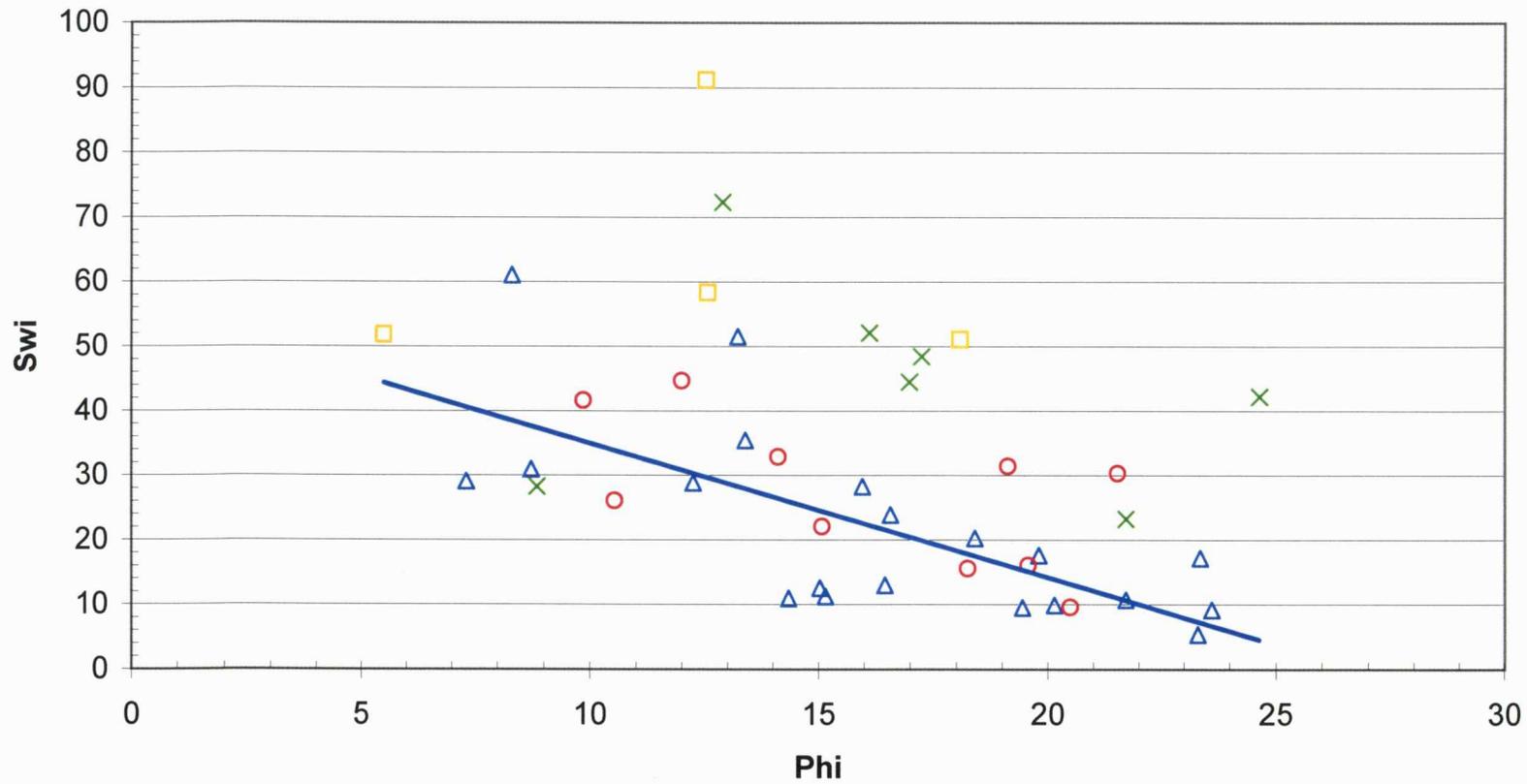


Figure: 12

# Ness City North

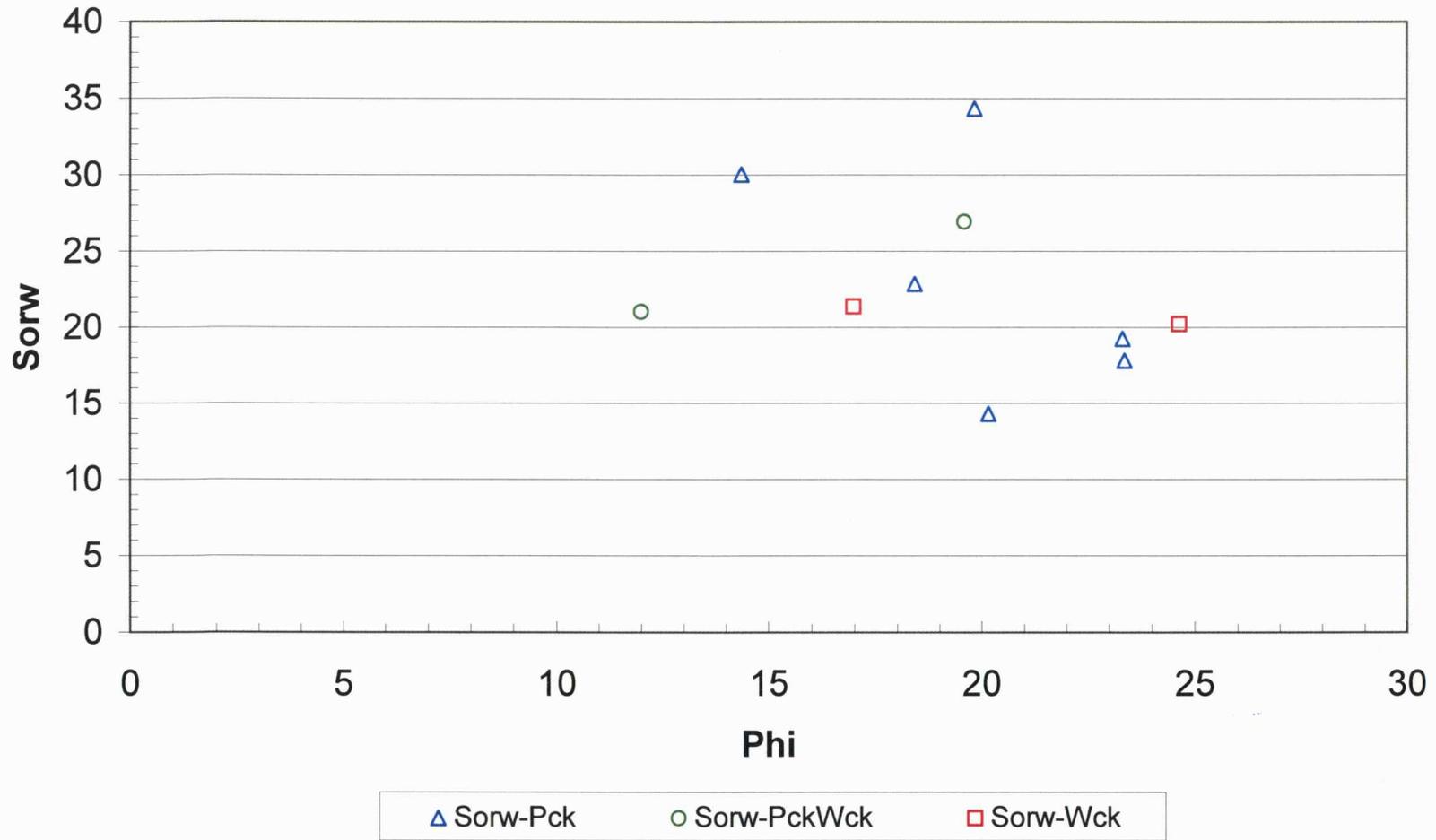


Figure: 13

# Ummel wells - 3 month avg

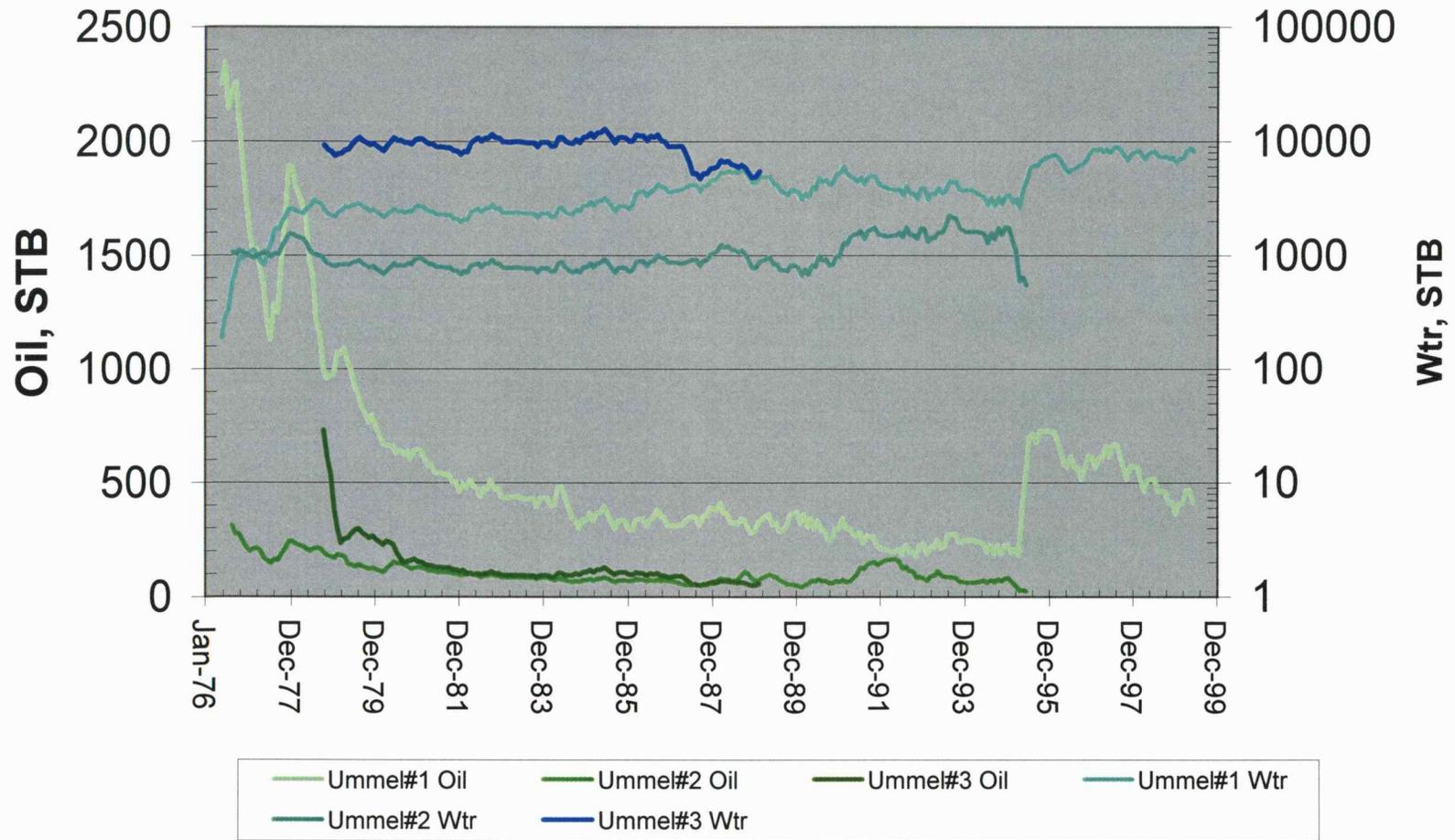
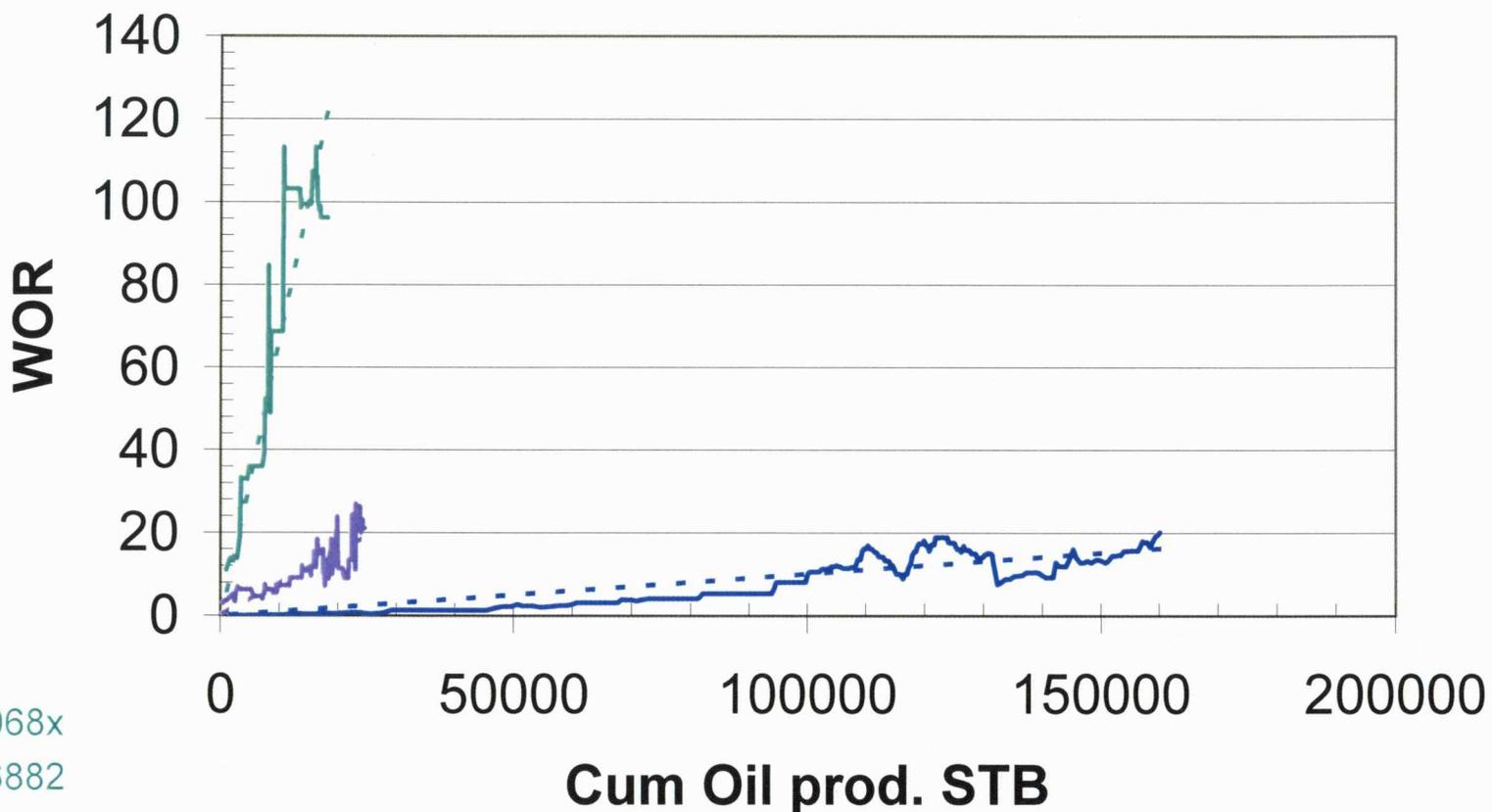


Figure: 14

# Ness City North

$y = 0.0008x$   
 $R^2 = 0.684$

$y = 0.0001x$   
 $R^2 = 0.6933$



$y = 0.0068x$   
 $R^2 = 0.6882$

- Ummel#1
- Ummel#2
- Ummel#3
- - - Linear (Ummel#1)
- - - Linear (Ummel#2)
- - - Linear (Ummel#3)

**Figure: 15**

# Ness City North

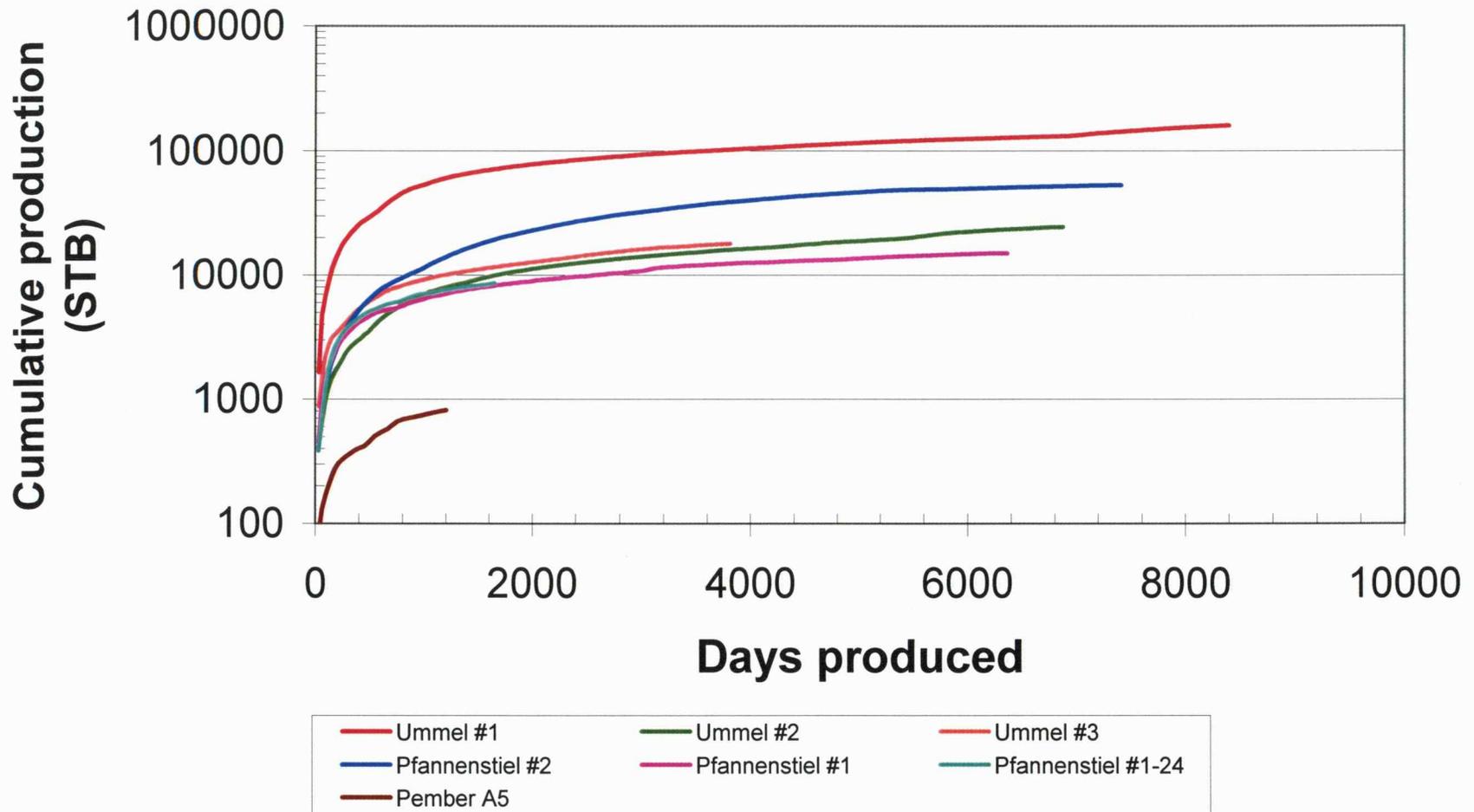


Figure: 16

## Well production outside Ummel Lease

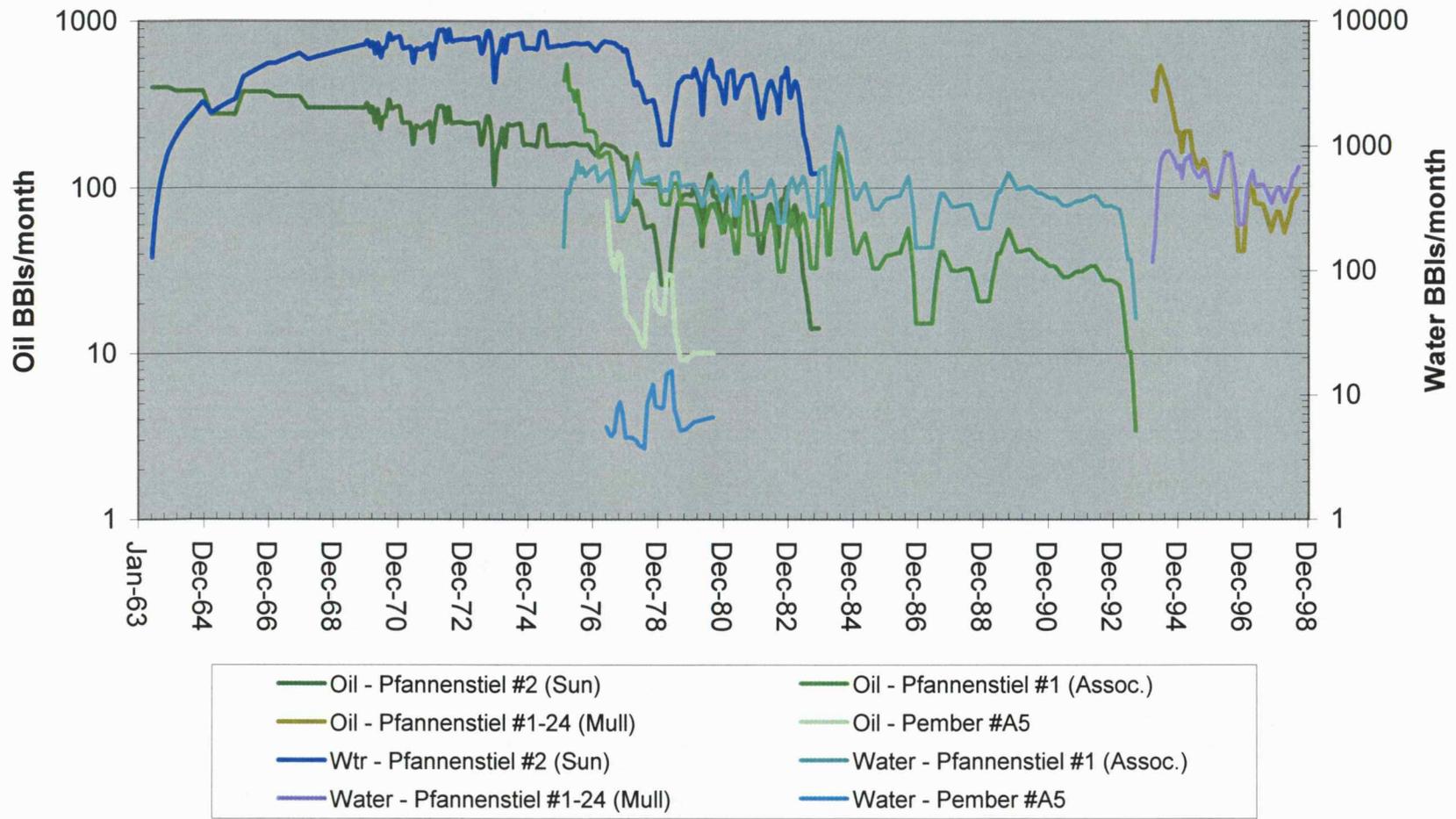
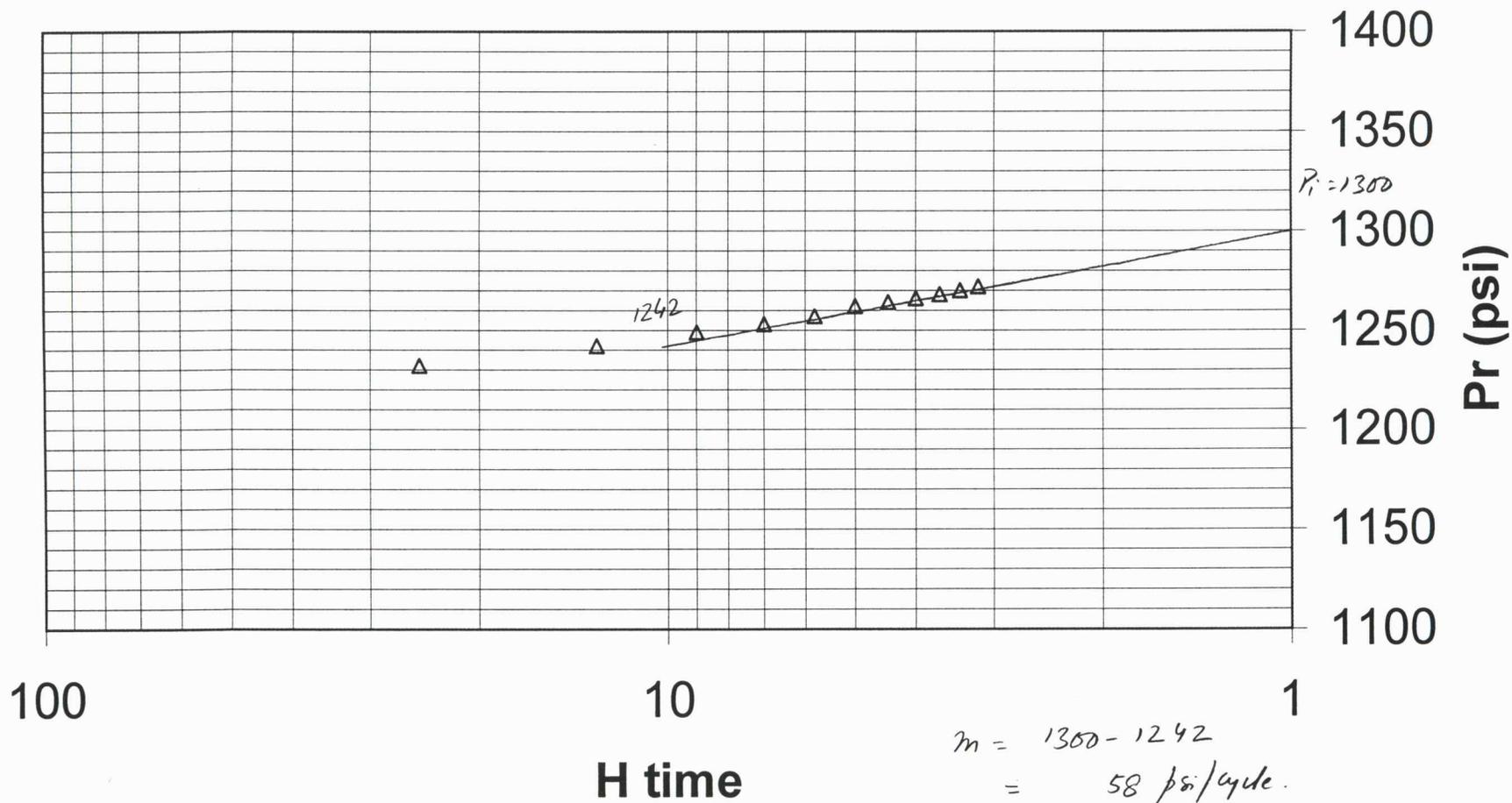


Figure: 17

**Appendix A: DST analysis**

# Ummel 1 4236-4295 ft



**Well:** Ummel #1

	from, ft	to, ft	thickness, ft
DST range:	4236	4295	59

Miss pay 7  
 DST covers LP2 and LP3 and extends into 2 ft of HP1.  
 4 ft of LP2 and 2 ft of HP 1 have very good permeability. Effective Miss pay = 7 ft

**Reservoir gas properties:**

Sp gr., Rog =	<span style="background-color: #ccffcc;">0.73</span>	gas specific gravity (avg from 3 samples)
Tpc =	<span style="background-color: #ccffff;">386</span> R	pseudocritical temp
Ppc =	<span style="background-color: #ccffff;">660</span> psia	pseudocritical pressure

**DST analysis - Oil:**

Pi =	<span style="background-color: #ffffcc;">1300</span> psi	
m =	<span style="background-color: #ffffcc;">58</span> psi/cycle	
Qo =	<span style="background-color: #ccffcc;">208.7</span> bbl/d	
Qg =	<span style="background-color: #ccffcc;">Mcf/d</span>	
Pwf =	<span style="background-color: #ccffcc;">1125</span> psi	(related to Qo - end of second flow)
P l hr =		

**Transmissibility:**

Kh/Muo =	162.6*Qo*Bo/m	
Bo =	1.03 bbl/STB	oil fm vol factor @ BP - Schaben
Muo =	1.95 cp	at BP - Schaben

GOR, Rs =	<span style="background-color: #ccffcc;">scf/bbl</span>
API stock tank =	<span style="background-color: #ffcccc;">F</span>
Sp gr oil, Roo =	<span style="background-color: #ffcccc;">F</span>
Res temp =	<span style="background-color: #ccffcc;">F</span>

$Bo = 0.972 + 0.000147 * (Rs * (Rog/Roo)^{0.5} + 1.25 * T)^{1.175}$   
 Bo @ bubble pt = bbl/STB

$Kh/Muo =$  602.71714 md-ft/cp

**Permeability:**

h =	7 ft	pay
Muo, 1 atm & res temp =	<span style="background-color: #ccffff;">cp</span>	
Muo, gas sat. =	<span style="background-color: #ccffff;">cp</span>	

$K =$  167.9 md

<span style="background-color: #ccffcc;">entered data</span>
<span style="background-color: #ccffff;">read from correlations</span>
<span style="background-color: #ffffcc;">read from Horner plot</span>
<span style="background-color: #ffcccc;">calculation</span>

**Production rate calculation:**

**Liquid recovery:**

Clean oil =	2570 ft	
Muddy oil =	400 ft	Assume: 50% oil and 50% mud
Total =	<span style="background-color: #ffcccc;">2770</span> ft	

Drill collar length =	<span style="background-color: #ccffcc;">369</span> feet
Drill collar ID =	<span style="background-color: #ccffcc;">2.25</span> inch
Drill pipe ID =	<span style="background-color: #ccffcc;">3.5</span> inch
Fluid in drill pipe =	<span style="background-color: #ffcccc;">2401</span> feet

Effective ID =	<span style="background-color: #ffcccc;">3.4</span> inch
Effective capacity =	<span style="background-color: #ffcccc;">0.01097</span> bbl/ft

**Pre-flow recovery:**

FFP - end of pre-flow =	<span style="background-color: #ccffcc;">642</span> psi
FFP - end of main flow =	<span style="background-color: #ccffcc;">1125</span> psi

Recovery from pre-flow =	<span style="background-color: #ffcccc;">1581</span> ft
Pre-flow volume =	<span style="background-color: #ffcccc;">17.3</span> bbl
Pre-flow time =	<span style="background-color: #ccffcc;">30</span> min

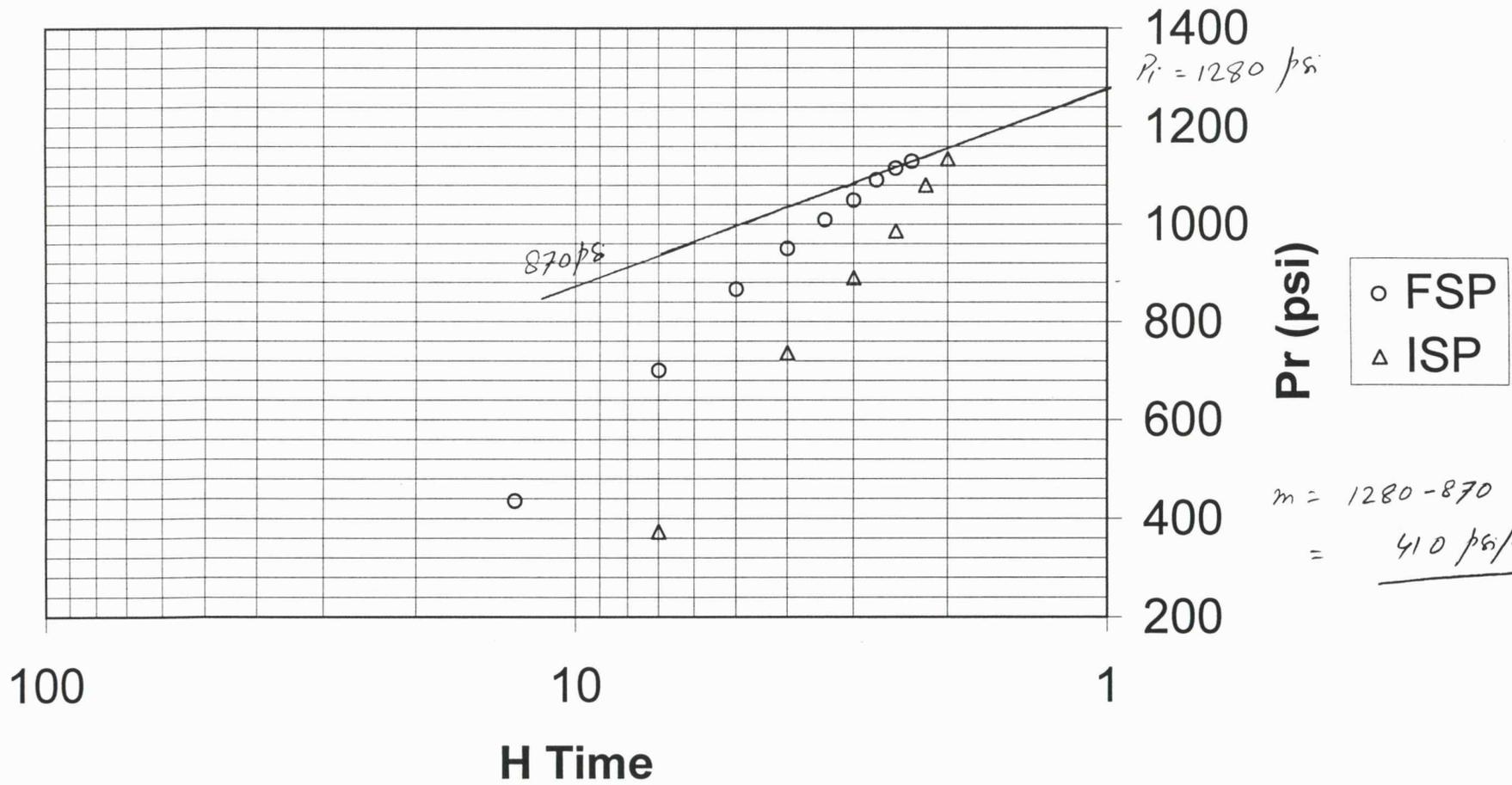
Pre-flow rate = 832.3 bbl/d

**Main-flow recovery:**

Recovery from main-flow =	<span style="background-color: #ffcccc;">1189</span> ft
Main-flow volume =	<span style="background-color: #ffcccc;">13.0</span> bbl
Main flow time =	<span style="background-color: #ccffcc;">90</span> mins

Main-flow rate = 208.7 bbl/d

# Ummel 2 4225-4280 ft



Well: **Ummel #2**  
 from, ft to, ft thickness, ft  
 DST range: 4225 4280 55

entered data  
 read from correlations  
 read from Horner plot  
 calculation

Miss pay 2.5  
 DST extends over LP1 only. LP1 is 10ft in this well. Of this 10 ft, about 2 to 3 ft have permeability values more than 1 md. Assume Miss pay = 2.5 ft.

**Reservoir gas properties:**

Sp gr., Rog = 0.73 gas specific gravity (avg from 3 samples)  
 Tpc = 386 R pseudocritical temp  
 Ppc = 660 psia pseudocritical pressure

DST analysis - Oil: 410

Pi = 1280 psi  
 m = 410 psi/cycle DST - hasn't stabilised  
 Q = 8.7 bbl/d Flowed mud only  
 Qg = Mcf/d  
 Pwf = 62 psi (related to Qo - end of second flow)  
 P I hr =

**Transmissibility:**

Kh/Muo = 162.6\*Q\*B/m  
 B = 1 rb/STB wtr fm vol factor @ BP

Chlorides = 11000 ppm (Ummel #4)  
 1.1 %  
 Reservoir temp = 122 F  
 Mu = 0.54 cp at res temp and 1 atm  
 Pr multiplier = 1.05 to convert to res pr  
 Mu at res pr = 0.567 cp

GOR, Rs = scf/bbl  
 API stock tank =  
 Sp gr oil, Roo =  
 Res temp = F

Bo = 0.972+0.000147\*(Rs\*(Rog/Roo)^0.5+1.25\*T)^1.175  
 Bo @ bubble pt = bbl/STB

Kh/Mu = 3.4490402 md-ft/cp

**Permeability:**

h = 2.5 ft pay  
 Muo, 1 atm & res temp = cp  
 Muo, gas sat. = cp approx.  
 K = 0.8 md

**Production rate calculation:**

**Liquid recovery:**

Mud = 30 ft  
 Mud weight = 9.7 lbs/gal  
 Conversion factor = 0.052 (to convert lbs/gal to psi/ft)  
 Hydrostatic gradient of mud = 0.5044 psi/ft

FFP at end of main flow = 62 psi

Calculated fluid recovered = 123 ft

Flexweight length = 861 feet All fluid in flexweight  
 Drill collar ID = 2.8 inch  
 Drill pipe ID = 3.5 inch  
 Drill collar capacity = 0.007616 bbl/ft

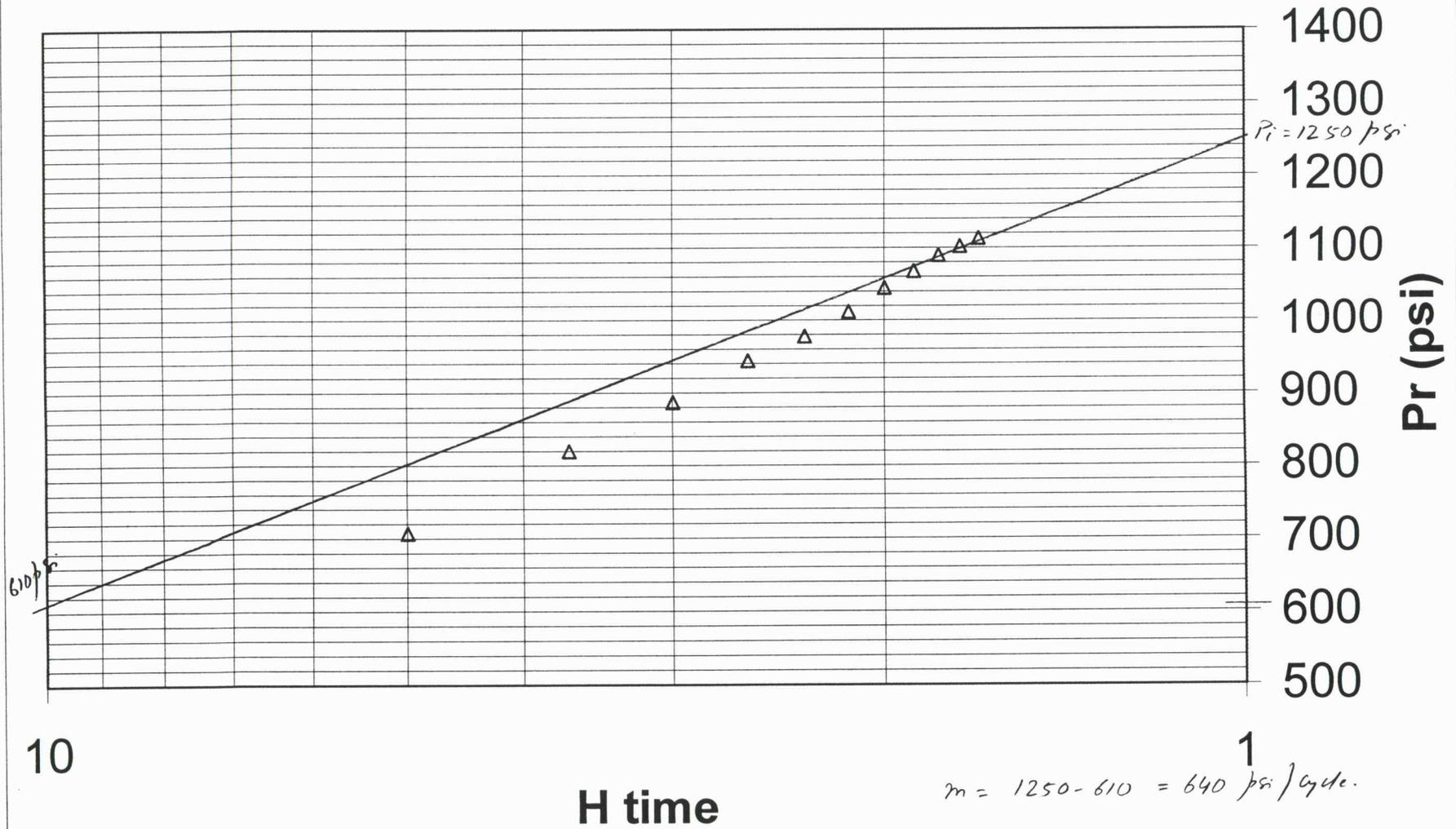
**Pre-flow recovery:**

FFP - end of pre-flow = 50 psi  
 FFP - end of main flow = 62 psi  
 Recovery from pre-flow = 99 ft

**Main-flow recovery:**

Recovery from main-flow = 24 ft  
 Main-flow volume = 0.2 bbl  
 Main flow time = 30 mins  
 Main-flow rate = 8.7 bbl/d

# Ummel 3 4251-4294 ft



**Well:** **Ummel # 3**

	from, ft	to, ft	thickness, ft
DST range:	4251	4294	43

Miss pay 3  
 DST extends over LP1 and 3 ft of LP2.  
 Effective Miss pay = 3 ft

**Reservoir gas properties:**

Sp gr., Rog =	0.73	gas specific gravity (avg from 3 samples)
Tpc =	386 R	pseudocritical temp
Ppc =	660 psia	pseudocritical pressure

**DST analysis - Oil:**

Pi =	1250 psi	
m =	640 psi/cycle	
Qo =	2.3 bbl/d	
Qg =	Mcf/d	
Pwf =	103 psi	(related to Qo - end of second flow)
P l hr =		

**Transmissibility:**

Kh/Muo =	162.6*Qo*Bo/m	
Bo =	1.03 bbl/STB	oil fm vol factor @ BP - Schaben
Muo =	1.95 cp	at BP - Schaben

GOR, Rs =	scf/bbl
API stock tank =	
Sp gr oil, Roo =	
Res temp =	F

Bo = 0.972+0.000147\*(Rs\*(Rog/Roo)^0.5+1.25\*T)^1.175  
 Bo @ bubble pt = bbl/STB

Kh/Muo = 0.608291 md-ft/cp

**Permeability:**

h = 3 ft pay

Muo, 1 atm & res temp =	cp
Muo, gas sat. =	cp

K = 0.4 md

	entered data
	read from correlations
	read from Horner plot
	calculation

**Production rate calculation:**

**Liquid recovery:**

CO =	3 ft		
SOCM =	117 ft	Oil % =	10
Total =	14.7 ft		

Drill collar length =	150 feet
Drill collar ID =	2.25 inch
Drill pipe ID =	3.25 inch
Fluid in drill collar =	14.7 feet
Fluid in drill pipe =	0 feet

Effective ID =	2.25 inch
Effective capacity =	0.00492 bbl/ft

**Pre-flow recovery:**

FFP - end of pre-flow =	80 psi
FFP - end of main flow =	103 psi

Recovery from pre-flow =	11.4 ft
Pre-flow volume =	0.1 bbl
Pre-flow time =	30 min

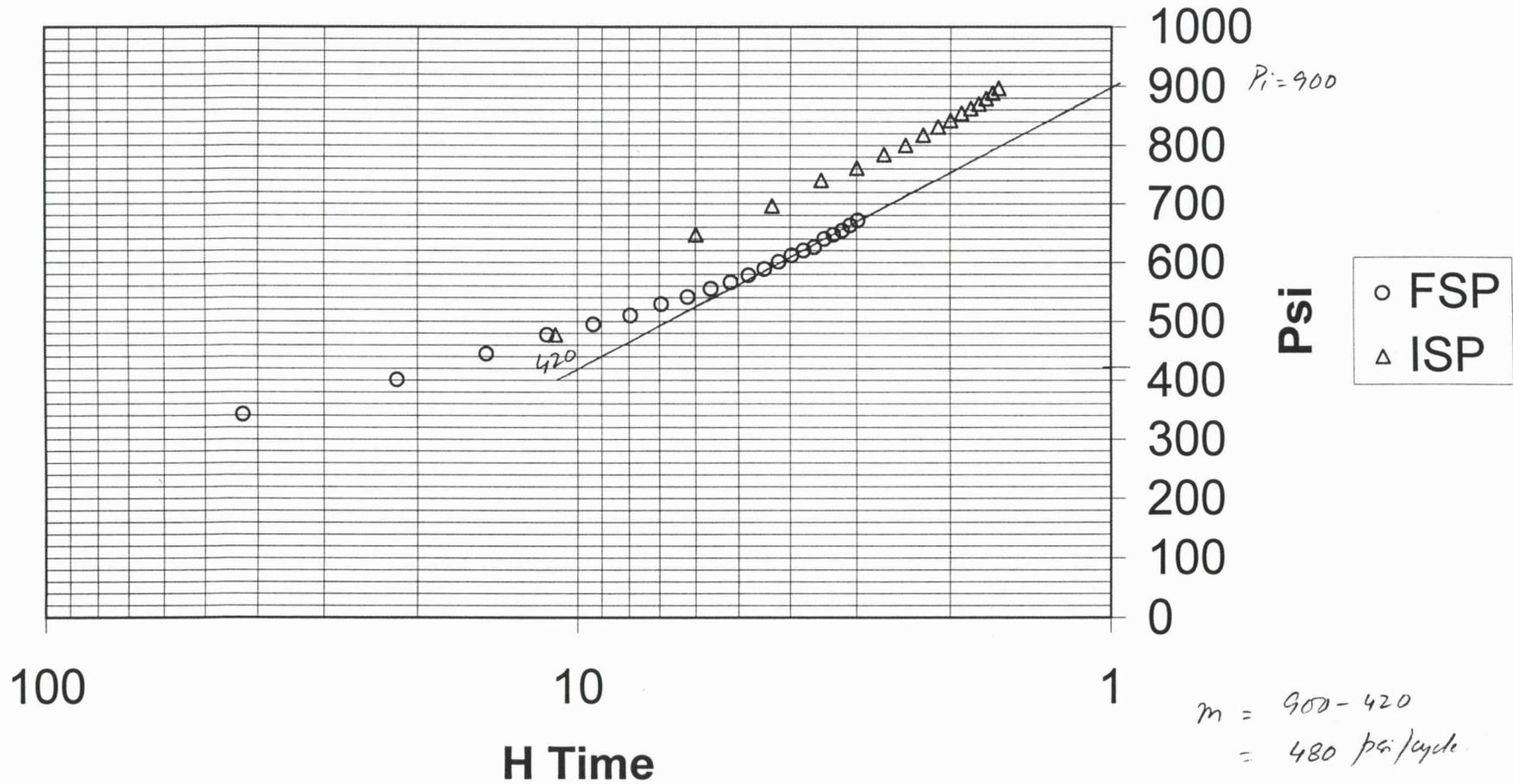
Pre-flow rate = 2.7 bbl/d

**Main-flow recovery:**

Recovery from main-flow =	3.3 ft
Main-flow volume =	0.02 bbl
Main flow time =	10 mins

Main-flow rate = 2.3 bbl/d

# Ummel 4 4252-4289 ft



**Well:** **Ummel #4**  
 DST range: from, ft 4252 to, ft 4289 thickness, ft 37

Miss pay 2  
 DST extends over LP1 and LP2.  
 Perm is more than 2 md for 2 ft in LP2. Effective Miss pay = 2 ft

**Reservoir gas properties:**

Sp gr., Rog = 0.73 gas specific gravity (avg from 3 samples)  
 Tpc = 386 R pseudocritical temp  
 Ppc = 660 psia pseudocritical pressure

**DST analysis - Oil:**

Pi = 900 psi  
 m = 480 psi/cycle  
 Qo = 21.5 bbl/d  
 Qg = Mcf/d  
 Pwf = 186 psi (related to Qo - end of second flow)  
 P l hr =

**Transmissibility:**

Kh/Muo = 162.6\*Qo\*Bo/m  
 Bo = 1.03 bbl/STB oil fm vol factor @ BP - Schaben  
 Muo = 1.95 cp at BP - Schaben

GOR, Rs = scf/bbl  
 API stock tank =  
 Sp gr oil, Roo =  
 Res temp = F

Bo = 0.972+0.000147\*(Rs\*(Rog/Roo)^0.5+1.25\*T)^1.175  
 Bo @ bubble pt = bbl/STB

Kh/Muo = 7.5095832 md-ft/cp

**Permeability:**

h = 2 ft pay

Muo, 1 atm & res temp = cp  
 Muo, gas sat. = cp

K = 7.3 md

entered data  
 read from correlations  
 read from Horner plot  
 calculation

**Production rate calculation:**

**Liquid recovery:**

Clean gassy oil = 335 ft  
 OCM = 82 ft Oil % =  
 Total = 343.2 ft

Drill collar length = feet  
 Drill collar ID = inch  
 Drill pipe ID = 3.25 inch  
 Fluid in drill pipe = 343.2 feet

Effective ID = 3.25 inch  
 Effective capacity = 0.01026 bbl/ft

**Pre-flow recovery:**

FFP - end of pre-flow = 111 psi  
 FFP - end of main flow = 186 psi

Recovery from pre-flow = 205 ft  
 Pre-flow volume = 2.1 bbl  
 Pre-flow time = 30 min

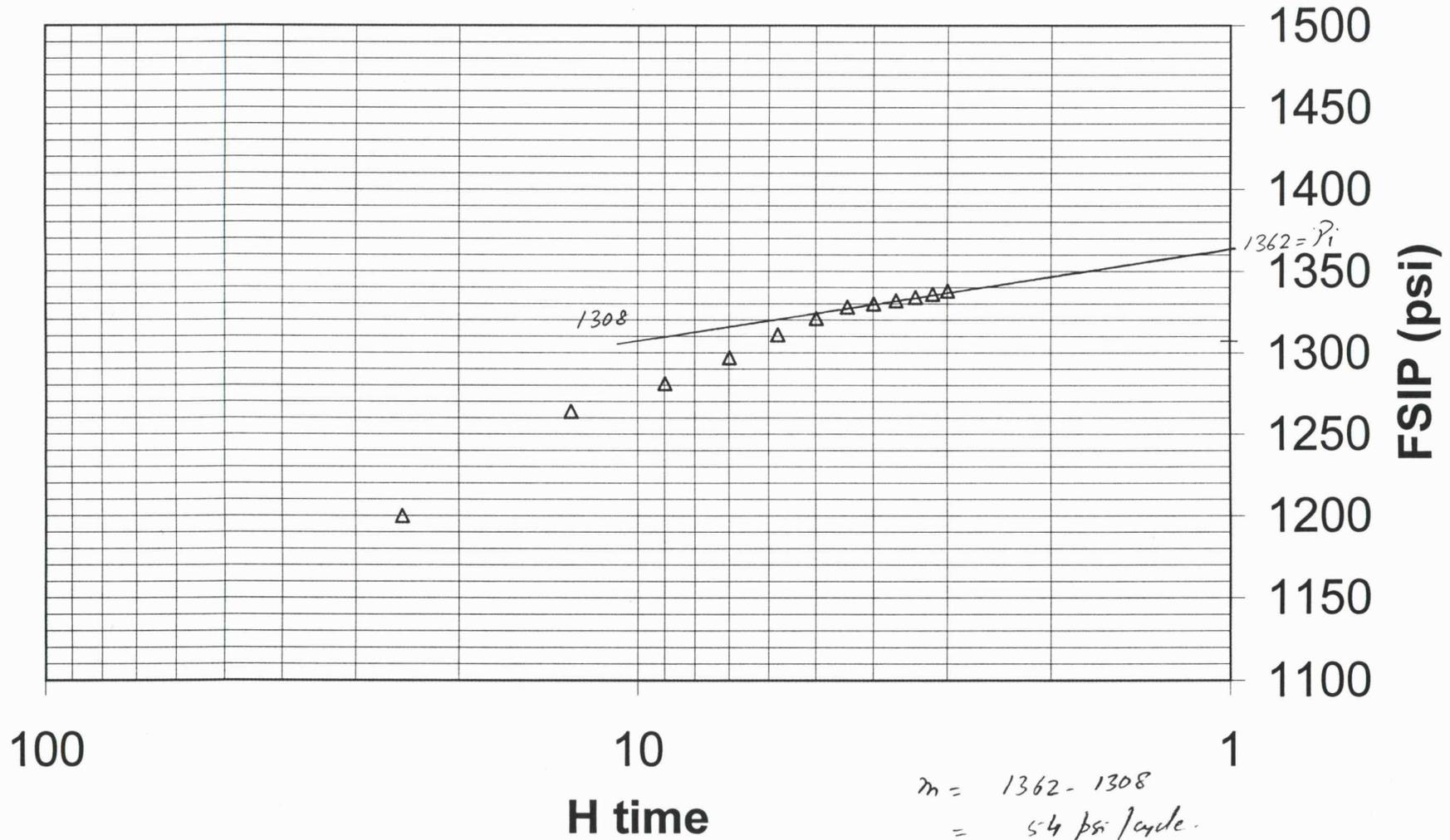
Pre-flow rate = 100.9 bbl/d

**Main-flow recovery:**

Recovery from main-flow = 138 ft  
 Main volume = 1.4 bbl  
 Main flow time = 95 mins

Main-flow rate = 21.5 bbl/d

# Debes 1 4250-4295 ft



Well:	Debes # 1		
	from, ft	to, ft	thickness, ft
DST range:	4250	4295	45

Miss pay 7

DST 3: 4250-88: Rec 10' mud only

DST 4: 4250-95: showed significant fluid recovery. Effective Miss pay 7 ft (4288 -95)

**Reservoir gas properties:**

Sp gr., Rog =	0.73	gas specific gravity (avg from 3 samples)
Tpc =	386 R	pseudocritical temp
Ppc =	660 psia	pseudocritical pressure

**DST analysis - Oil:**

Pi =	1362 psi	
m =	54 psi/cycle	
Qo =	11.4 bbl/d	
Qg =	Mcf/d	
Pwf =	197 psi	(related to Qo - end of second flow)
P I hr =		

**Transmissibility:**

Kh/Muo =	162.6*Qo*Bo/m	
Bo =	1.03 bbl/STB	oil fm vol factor @ BP - Schaben
Muo =	1.95 cp	at BP - Schaben

GOR, Rs =	scf/bbl
API stock tank =	
Sp gr oil, Roo =	
Res temp =	F

$$Bo = 0.972 + 0.000147 * (Rs * (Rog/Roo)^{0.5} + 1.25 * T)^{1.175}$$

Bo @ bubble pt = bbl/STB

Kh/Muo = 35.484043 md-ft\cp

**Permeability:**

h = 7 ft pay

Muo, 1 atm & res temp =	cp
Muo, gas sat. =	cp

K = 9.9 md

	entered data
	read from correlations
	read from Horner plot
	calculation

**Production rate calculation:**

**Liquid recovery:**

CO =	ft		
GFMO =	380 ft	Oil % =	75
Total =	285 ft		

Drill collar length =	281 feet
Drill collar ID =	2.25 inch
Drill pipe ID =	3.25 inch
Fluid in drill collar =	281 feet
Fluid in drill pipe =	4 feet

Effective ID =	2.27 inch
Effective capacity =	0.00499 bbl/ft

**Pre-flow recovery:**

FFP - end of pre-flow =	98 psi
FFP - end of main flow =	197 psi

Recovery from pre-flow =	141.8 ft
Pre-flow volume =	0.7 bbl
Pre-flow time =	30 min

Pre-flow rate = 34.0 bbl/d

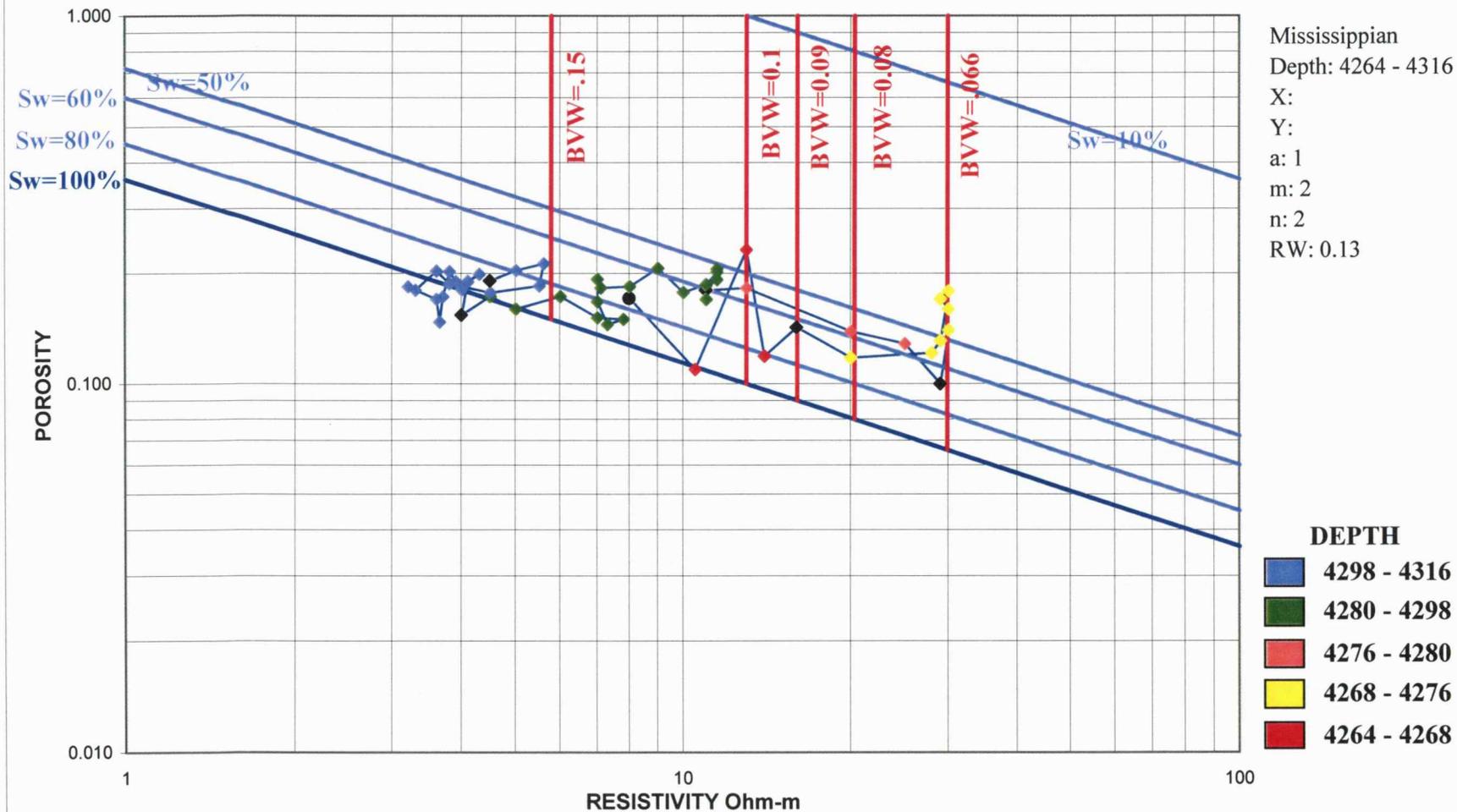
**Main-flow recovery:**

Recovery from main-flow =	143.2 ft
Main-flow volume =	0.72 bbl
Main flow time =	90 mins

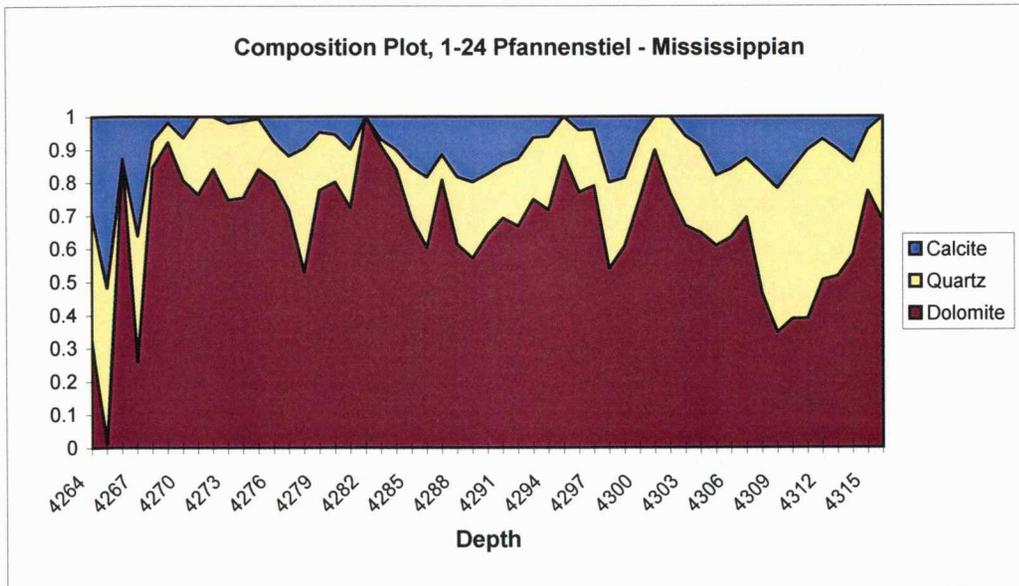
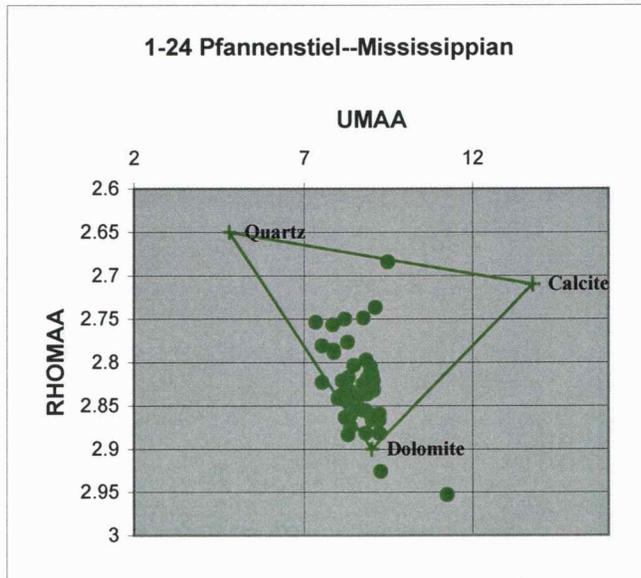
Main-flow rate = 11.4 bbl/d

## **Appendix B: Super-Pickett analysis**

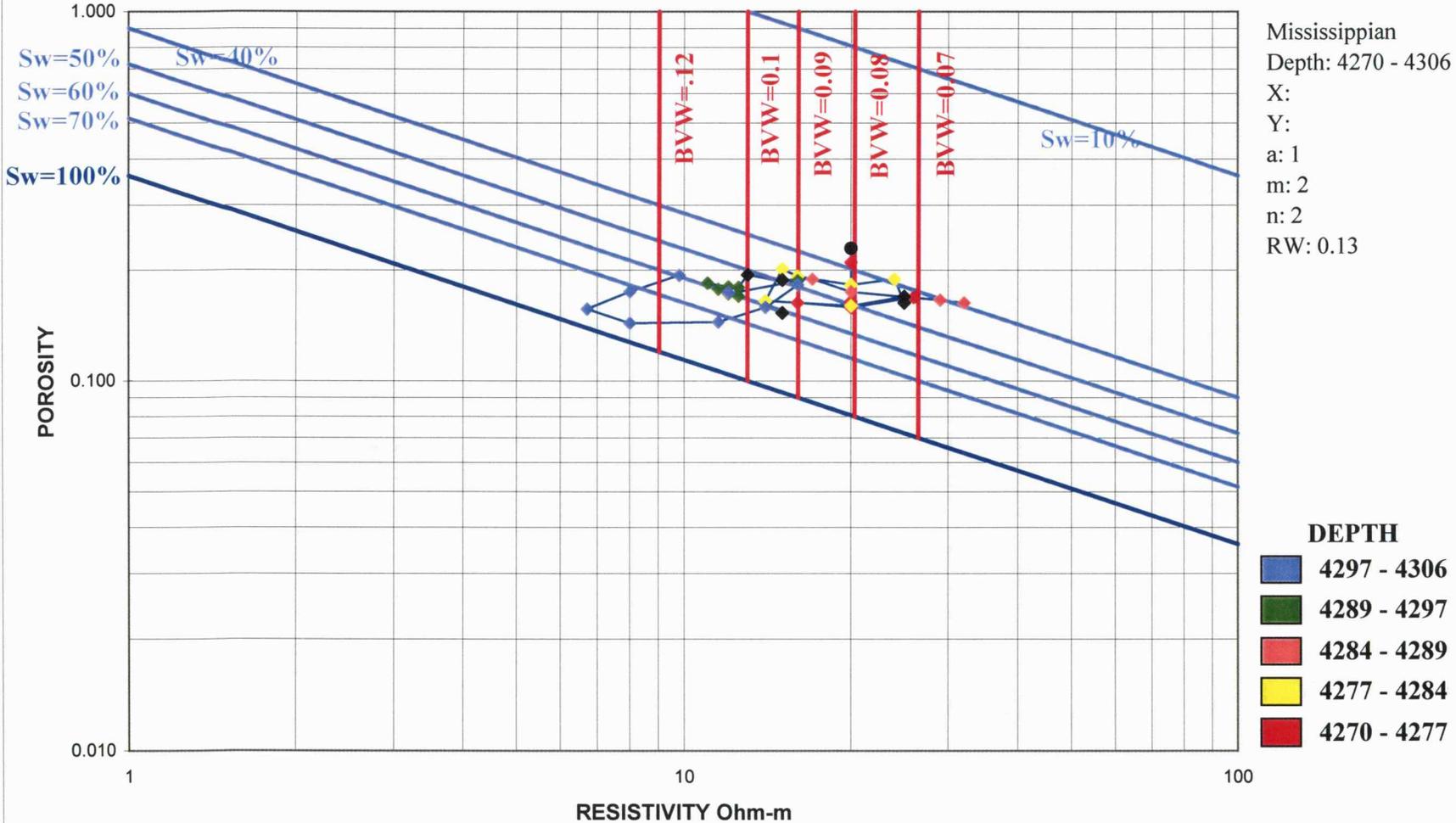
# 1-24 Pfannenstiel



DST: 4250-4280. Rec: 130' GIP, 170' GsyO, 120' HOcm, 60' GSOWCM, 180' MW  
Original perf: 4268-76. IP: 15 bopd, tr w. Later perf: 4264-68. IP: N/A



# Ummel # 4



DST: 4252-4289. Rec: 335 CGO, 82' OCM, & 248 GIP. D&A