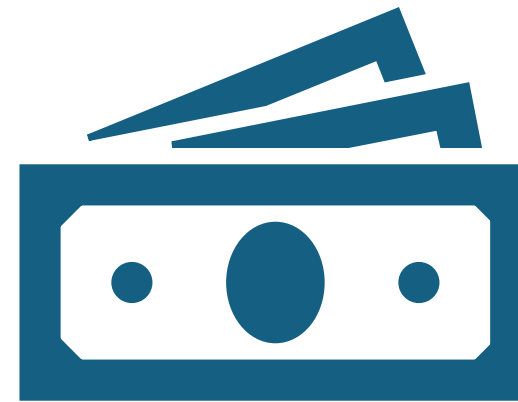
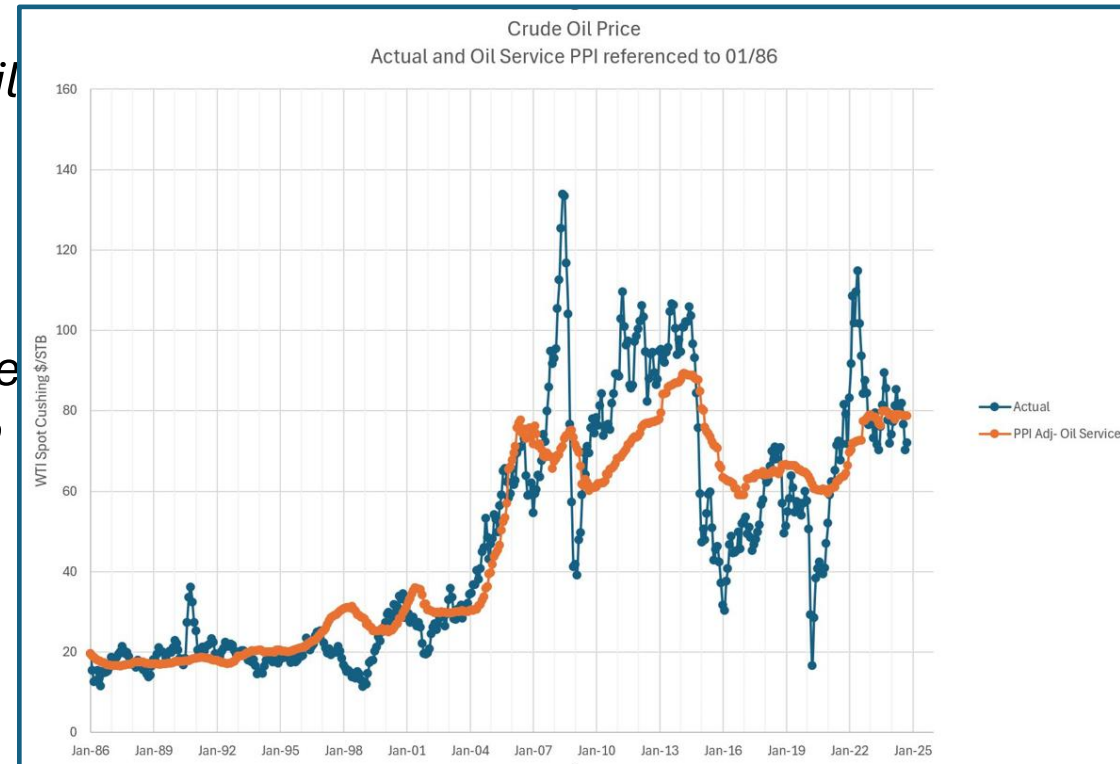


The \$50 Plus  
Breakeven Oil Reality:  
Making Steamfloods  
Work in the Illinois  
Basin



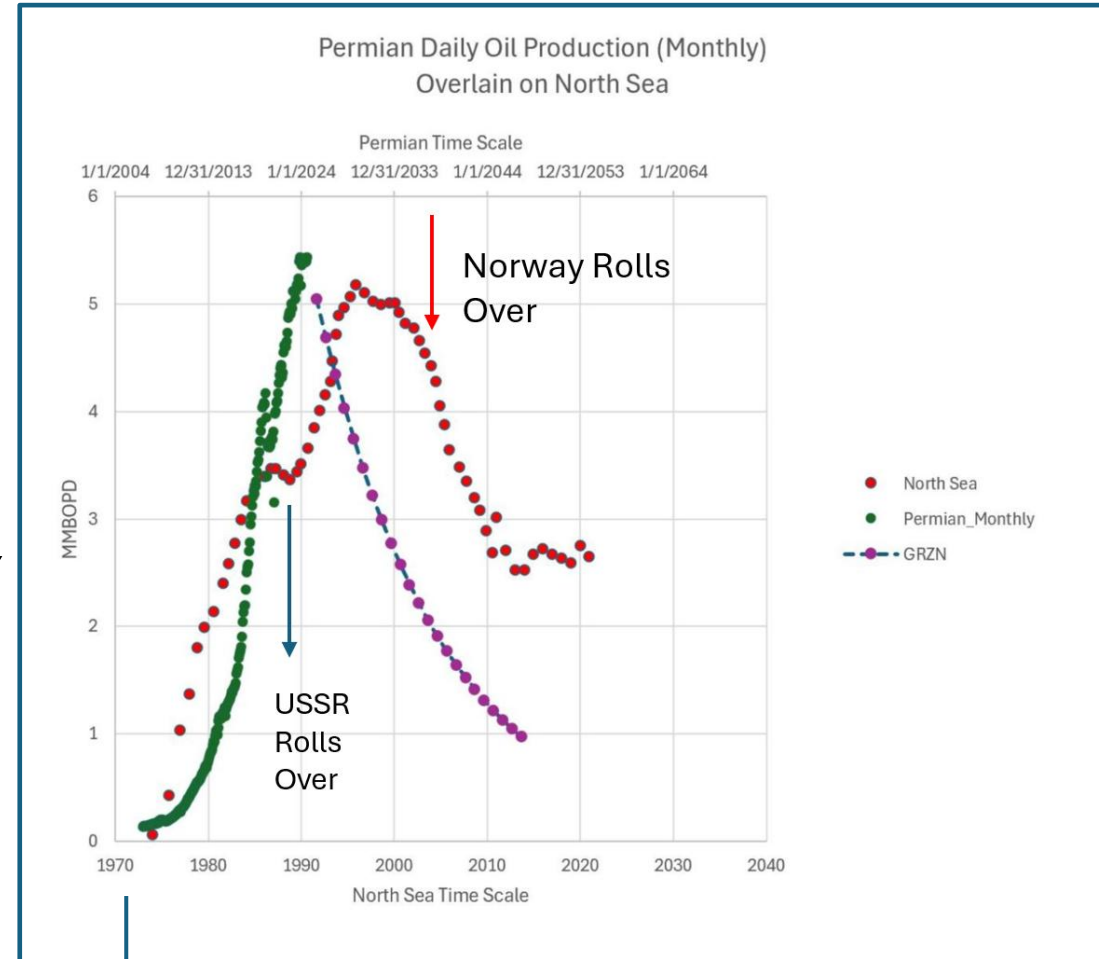
# Forty Years of Oil Prices Adjusted For Oil Service PPI- a \$40 move in 18 months

- *To Draw a “Best Fit” Line of PPI Adjusted Oil Price Through the Actual Oil Price, a Jan 86 Oil Price of \$19.52 per barrel is required. This makes the average escalation factor 3.5% over the last 40 years. But 90% of the move happened in an 18-month period around 20 years ago.*



# Three 5+ MMBOPD Rollovers in History- US Conventional(70), USSR(88), North Sea(04)

- Grozen forecasts Permian Ultimate Recovery of 35 BBO, about half the size of the North Sea. The projection shown uses this Ultimate Recovery Number and an economic limit of 10 BOPD with 100,000 wells.



US Rollover

# When is the Permian Going to Rollover?

Open Access Article

## Forecast of Economic Tight Oil and Gas Production in Permian Basin

by Wardana Saputra \* , Wissem Kirati  and Tadeusz Patzek \* 

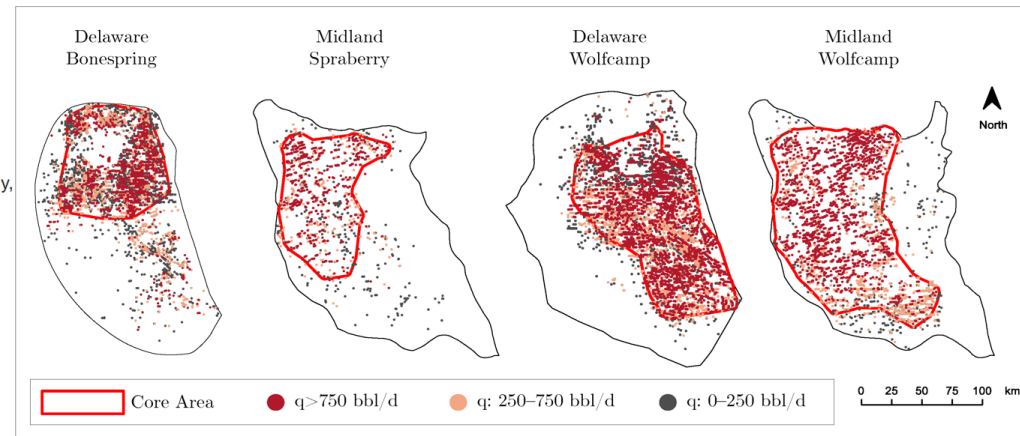
The Ali I. Al-Naimi Petroleum Engineering Research Center, King Abdullah University of Science and Technology, Thuwal 23955-6900, Saudi Arabia

\* Authors to whom correspondence should be addressed.

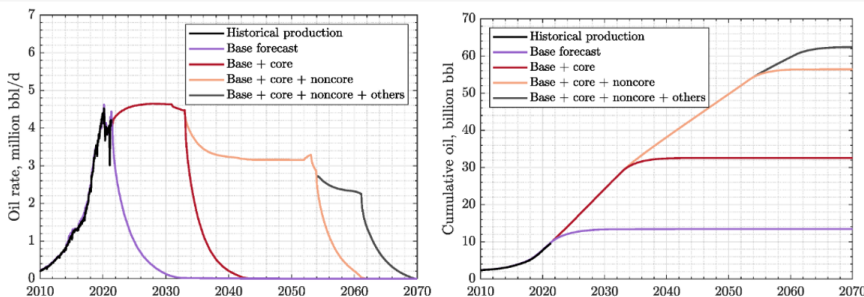
Energies 2022, 15(1), 43; <https://doi.org/10.3390/en15010043>

Submission received: 22 November 2021 / Revised: 4 December 2021 / Accepted: 14 December 2021 / Published: 22 December 2021

(This article belongs to the Special Issue Unconventional Oil and Gas: Latest Challenges and Advances of Energies)



**Figure 15.** Infill forecast scenario for oil production in the Permian tight reservoirs. The total field EUR is 62.4 billion bbl or 54.4 billion bbl by neglecting the less profitable “Others” region.



### THE PERMIAN BASIN NONCONVENTIONAL PLAY- A TRIBUTE TO THE EFFICIENCY OF THE CAPITALIST ECONOMIC SYSTEM

Supatra et al  
Table of Per Well Recoveries  
Revenue Breakdown at \$70 per barrel

	Wells	Np, MSTBO		Price	Revenues, MM\$		
		Total	Per Well		Gross	Net	After SevAdVal
Base + Core	111,000	32,200,000	290	\$ 70.00	\$ 20.31	\$ 15.23	\$ 14.12
NonCore	100,314	22,200,000	221	\$ 70.00	\$ 15.49	\$ 11.62	\$ 10.77
Totals	211,314	54,400,000	257	\$ 70.00	\$ 18.02	\$ 13.52	\$ 12.53

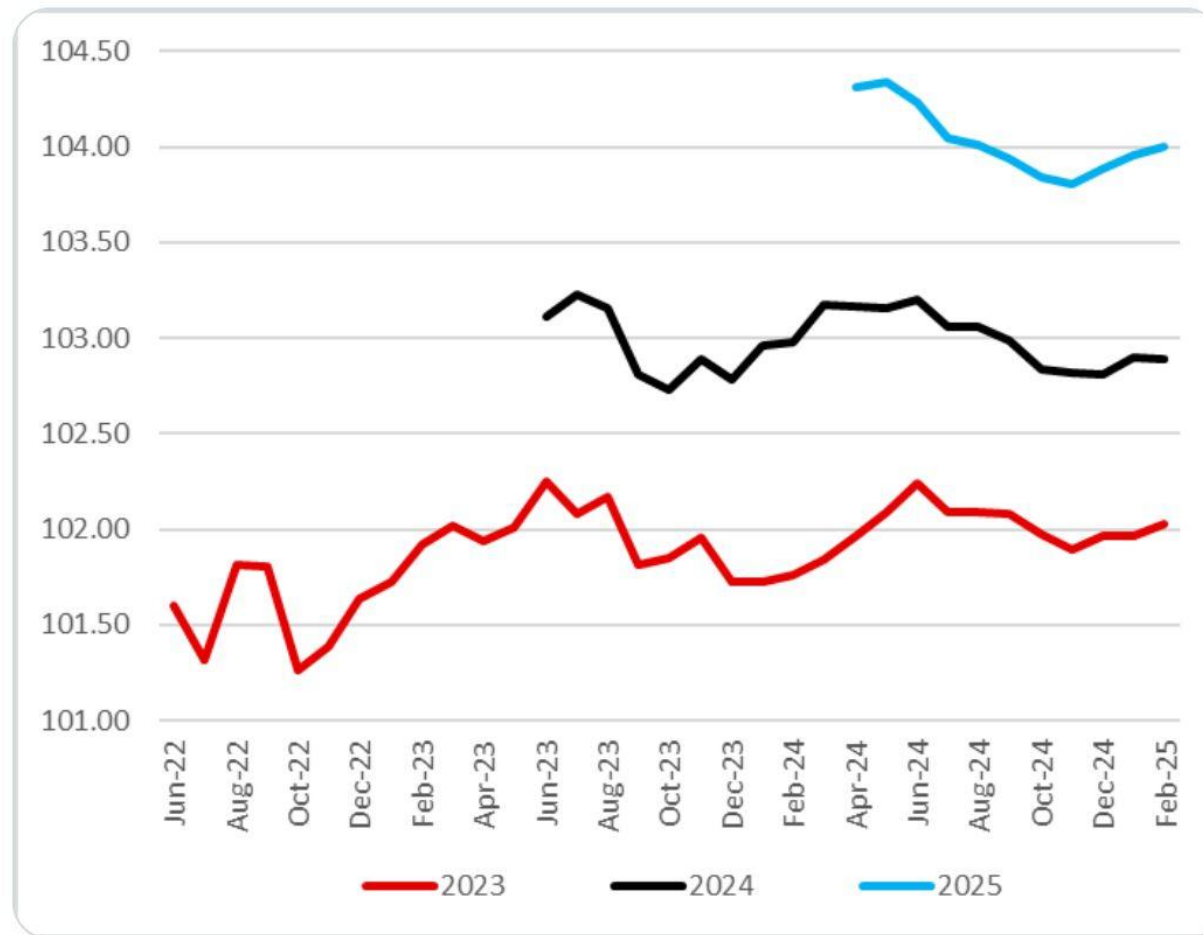
# The Elusive Rollover of World Oil Demand Wash, Rinse, Repeat

EnergyCynic reposted



**Giovanni Staunovo** @staunovo · 2h

Oil demand estimates (IEA) in mbpd over time #OOTT



9

23

63

7.7K

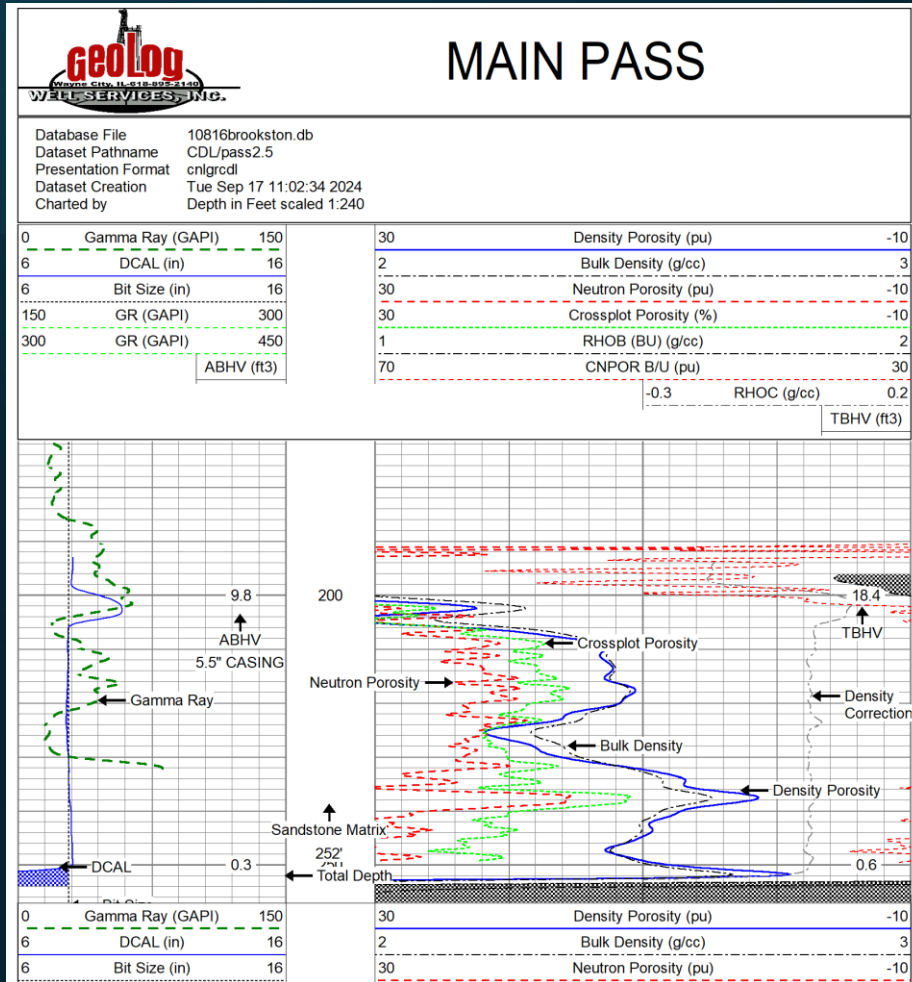
Share icon

# A Story- California Steamflood Engineer

## Fluid Saturations

The Abbey Unit is a 3.3 million barrel pore volume which has recovered 208 MSTBO in 50 years. Even though an estimated 2 million barrels of water has been injected, only 208,000 barrels of that water have served to displace the original oil in place. Therefore, oil saturation has been reduced by 6.3% and water saturation has increased by 6.3%.

# Porosity Type Log & Core Analysis Abbey Unit

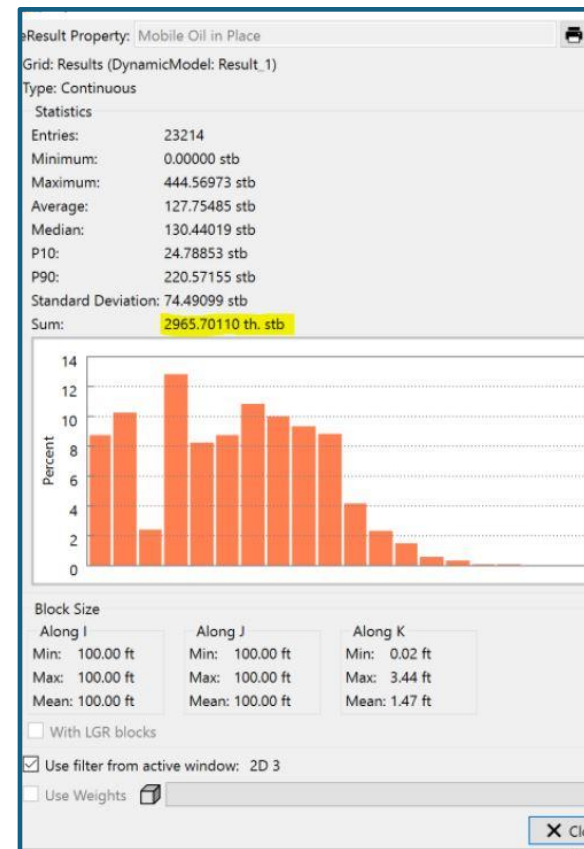
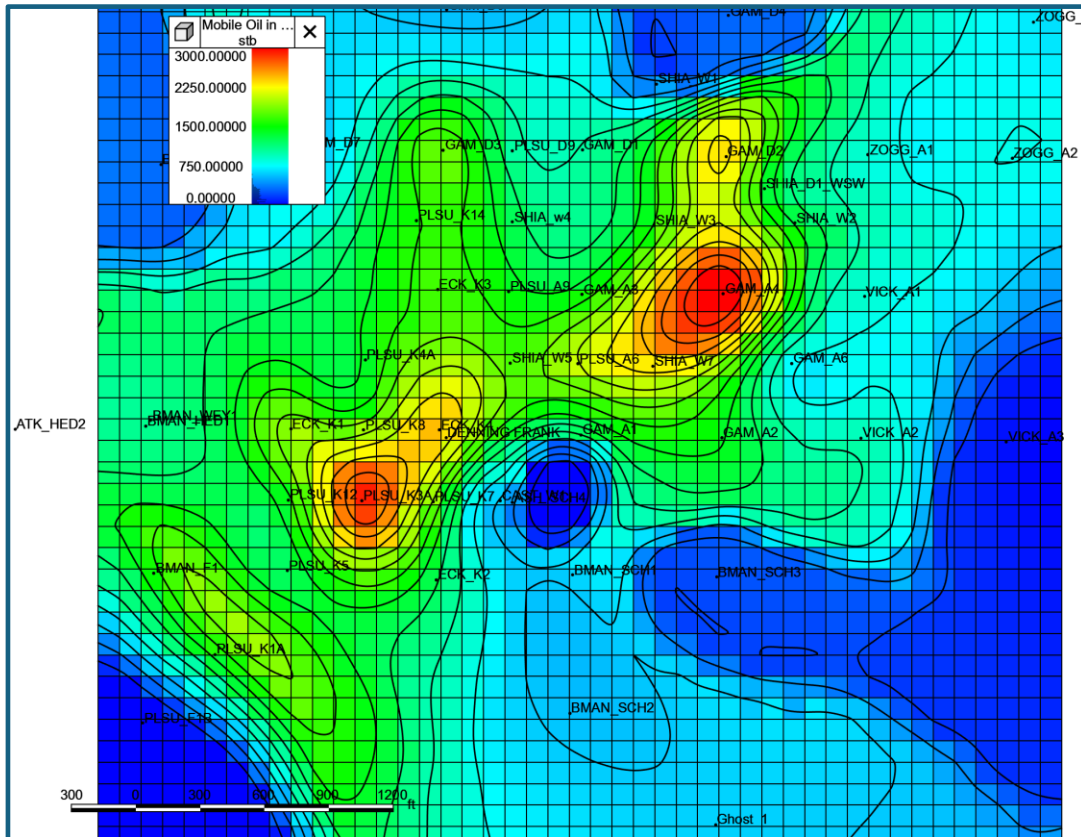


Basinwide, LLC							
Core Analysis Results							
Company: Brookston Resources INC				Formation: Tar Springs SS			
Well: Abbey Unit 3A				County, State: Spencer, Indiana			
Permit: 55832				GL/KB: 413, 413			
Location: 11-4S-4W 20FSL 320FWL SwNeSe				Date Cored: 9-16-2024			
Sample #	Depth	Horizontal Perm md	Vertical Perm md	Porosity percent	Bulk Wet Density gm/cc	Saturation percent OIL	Saturation percent WATER
1	203	87.77	71.42	18.2	2.31	50.7	22.2
2	204	7.25	2.99	18.2	2.29	41.9	19.5
3	205	33.29	8.90	19.3	2.29	34.8	38.6
4	206	2.48	1.99	14.6	2.37	23.7	33.2
5	207	4.14	0.60	13.0	2.45	22.6	46.2
6	208	3.83	2.28	14.1	2.44	39.3	49.4
7	209	NS	NS	11.7	2.48	2.8	82.0
8	210	1.38	>.01	12.9	2.48	12.8	74.2
9	211	NS	NS	11.7	2.46	8.40	45.1
10	212	NP	>.01	14.6	2.45	33.6	59.6
11	213	3.93	1.60	14.2	2.43	41.0	45.3
12	214	NS	NS	13.0	2.48	30.6	62.1
13	215	>.01	>.01	12.8	2.48	23.3	64.1
14	216	2.69	>.01	13.1	2.48	30.3	66.3
15	217	1.76	>.01	12.6	2.48	15.8	68.1
16	218	>.01	NP	13.0	2.47	22.8	63.7
17	219	108.09	7.70	17.0	2.33	38.4	32.2
18	220	48.57	27.17	17.5	2.32	42.4	27.1
19	221	88.65	125.67	18.8	2.30	58.7	16.5
20	222	327.99	219.13	19.8	2.26	33.4	25.6
21	223	315.73	190.64	20.1	2.26	46.5	17.4
22	224	71.17	8.39	16.7	2.35	58.0	19.0
23	225	41.68	44.35	15.7	2.34	41.7	18.6
24	226	28.58	5.68	13.5	2.44	38.6	42.5
25	227	73.33	18.40	16.8	2.34	37.0	35.4
26	228	70.07	37.40	16.2	2.35	52.3	21.1
27	229	5.31	NP	14.8	2.39	51.7	26.6
		<b>Avg. Horiz. Perm-md</b>	<b>Avg. Vert Perm-md</b>	<b>Avg. Por. Percent</b>		<b>Avg. Oil Percent</b>	<b>Avg. Wtr. Percent</b>
<b>Depth</b>							
203-229		63.2	45.5	15.3		34.6	41.5

# TNav Simulator Initialization

## Waterflood Mobile Oil in Place 2.965 MMSTB

# Abbey Unit Volumetric Iterations



# Every Explanation for This Problem is Contained in Darcy's Law

- An \$80,000 Reservoir Model isn't really required
  - What if your sand well?
    - Had 100 psi static bottomhole pressure
    - You couldn't stimulate it
    - The oil was 5-8 times more viscous than normal

$$q = \frac{2\pi kh (P_{res} - P_{wf})}{\mu B \left[ \ln \left( \frac{r_e}{r_w} \right) - \frac{3}{4} + S \right]}$$

# Why Only 220 MSTBO Recovery? Less Than 10% of the OOIP

Horizontal  
Fracture  
Propagation

Injection  
Pressure  
Function of Burial  
Depth

*Video- It went  
around it not  
through it.....*



The Oil Producers Goal is to minimize  $S_o$

Only way is to increase  $S_w$  and/or  $S_g$

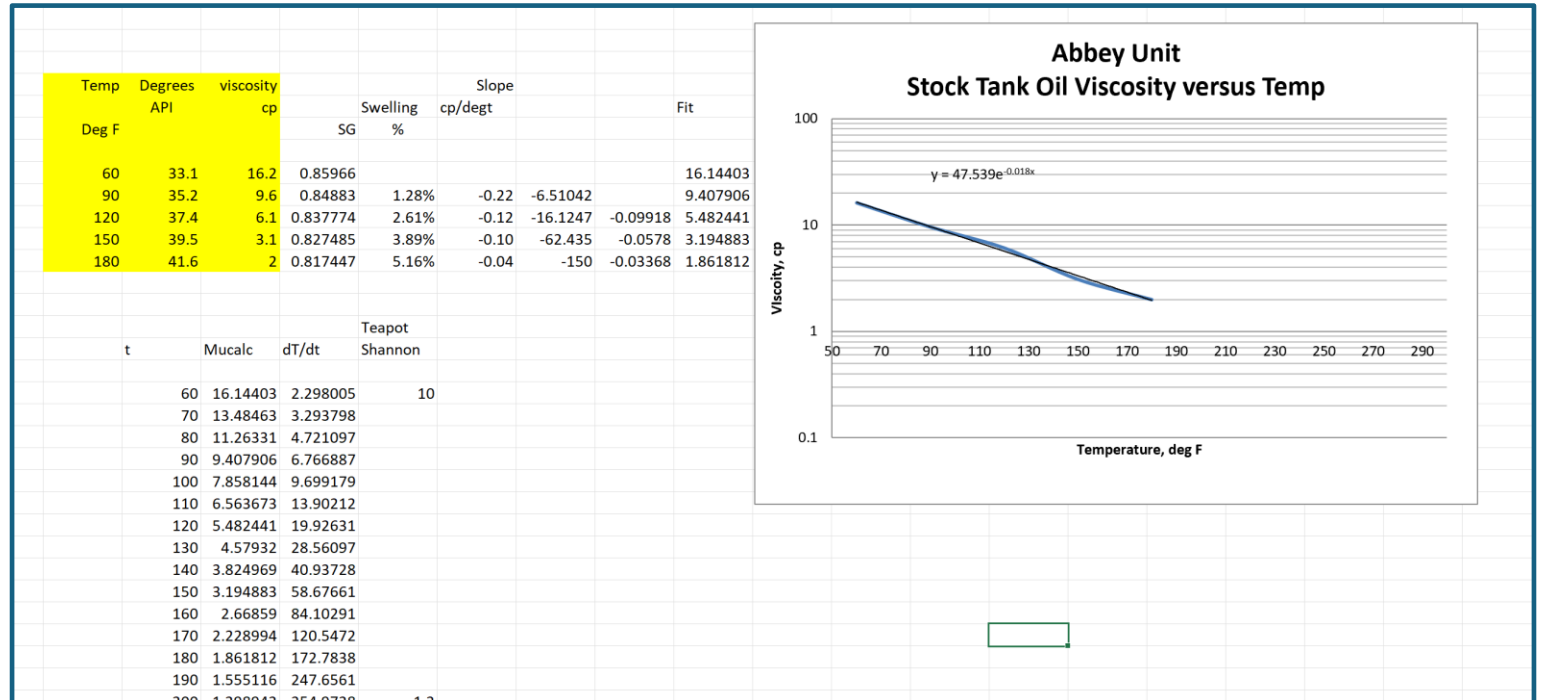
What Matters is  $\Delta S_o$

*What if this reservoir was sitting atop the ground and you were looking at it?*

*Steam is one of the only known substances that has the theoretical capability to reduce  $S_o$  to 0 in light oil applications*

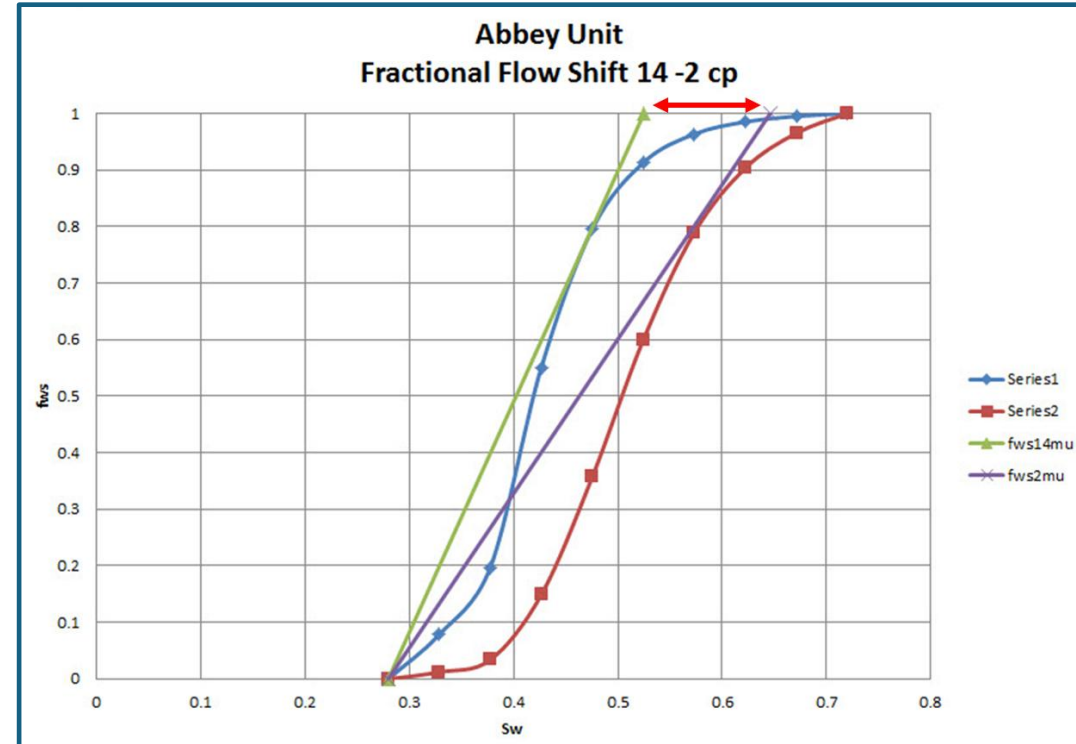
$$1 = S_o + S_w + S_g$$

Laboratory Rolling Ball  
Viscosimeter  
Oil Viscosity versus  
Temperature  
Abbey Unit  
One Suspects There is a  
Tremendous Quantity of  
Illinois Basin Oil  
Which Would Behave  
Similarly



# First Principle Aside- The Effect of Oil Viscosity Reduction on the Displacement Process

- *The Shape of the Higher viscosity fractional flow curve illustrates that a lot of oil remains in the ground above a 90% water cut, nearly 20% of a pore volume, or a million barrels in the case of the Abbey Unit or Union Chapel.*



# Laboratory Data from the Literature- Two Additive Effects of Light Oil Steam

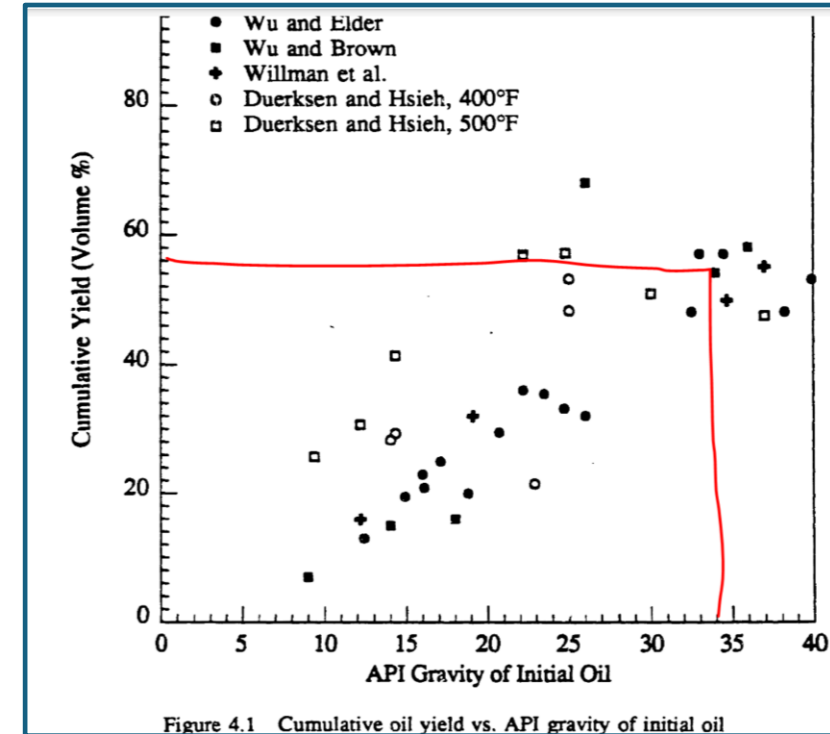
5222

TABLE 4<sup>1</sup>  
Laboratory Hot Water Coreflood Results at 70° F and 400° F

Initial condition	Terminal condition			Oil recovery	
	Effective permeability to oil, mD	Oil saturation, % PV	Effective permeability, to water mD	% Pore volume	Oil in place, %
70° F	26	30.8	3.8	20.0	39.4
400° F	30	20.9	1.3	29.9	58.9

Reference 3. Note: Core sample was obtained from a depth of 281 ft from well 58-66-SX-3-L11. Air as 46 mD with a porosity of 20.6%. The flood was conducted with 300 psi backpressure to ensure liquid with no steam vapor phase present. These tests are representative of the performance of a hot water bank lead of a steam zone.

TABLE 5



# What About Successful Water Floods?- Jackson Sand Union Chapel

Temp	Degrees	viscosity
Deg F	API	cp
60	33.1	16.2
90	35.2	9.6
120	37.4	6.1
150	39.5	3.1
180	41.6	2

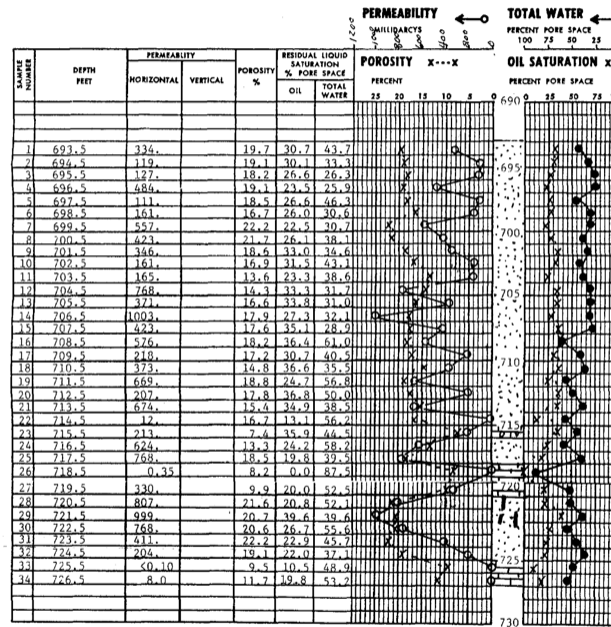
Technically, there is a trivial difference between this 700 ft zone and the 200 ft deep Abbey Oil. Namely, about 1 centipoise starting viscosity.

FIELD \_\_\_\_\_ COUNTY SPENCER STATE IND. TYPE OF CORE DIAMOND PERMIT NO. \_\_\_\_\_ LOCATION \_\_\_\_\_ REMARKS \_\_\_\_\_ SAMPLED BY CLIENT \_\_\_\_\_

## CORE ANALYSIS REPORT

SANDSTONE  LIMESTONE  VUGS  VERTICAL FRACTURES

The expressed opinions and interpretations represent the best judgment of Oilfield Research, Inc. of the data provided by the client or obtained from our laboratory testing. Oilfield Research, Inc. its offices and employees, assume no responsibility and make no warranty as to the accuracy of the reported interpretations and opinions.



## CORE SUMMARY

FORMATION	DEPTH, FEET	FEET CORE ANALYZED	AVERAGE PERMEABILITY		AVERAGE POROSITY %	AVERAGE LIQUID SATURATION, %	
			HORIZONTAL	VERTICAL		OIL	WATER
JACKSON	693.0 - 727.0	28.0'	45.8	18.2	28.4	40.2	

(Excluding Sample Nos. 22, 23, 26, 27, 33 & 34)

The residual core saturations cut from this water core in a well that IP'd at 90% water almost meet the steam screening criteria of oil saturation \* thickness equals 0.06

Transmissibility-  
the  
Proportionality  
Constant in  
Darcy's Law

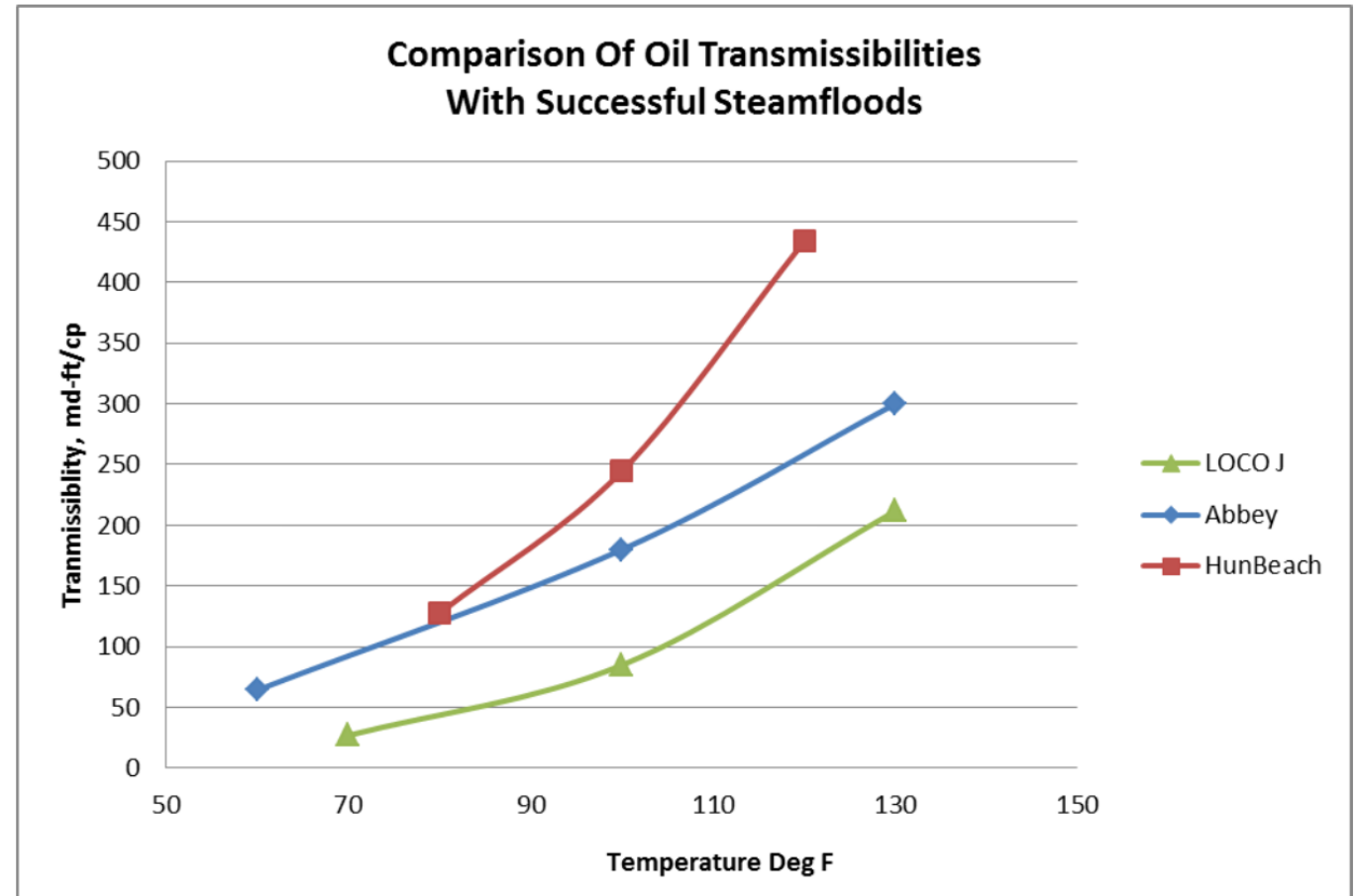


Figure 7- Comparison of Oil Transmissibilities versus temperature for the Abbey and successful steam drive projects

Curlew Sand  
Omaha- Kh/u  
a tenth of the  
Abbey Unit

## Omaha Curlew Sand Heavy Oil Reservoir Properties

- Reservoir depth, ft 535
- Net Pay, ft 38.5
- Oil viscosity, cp 400-1,000
- Porosity, % 15
- $k_{\text{horz}}$ , md 51
- $k_{\text{vert}}$ , md 1.5
- $S_o$  (est), % 65
- $S_w$  (est), % 35
- Transmissivity, md-ft/cp 2-5

# First Principles How Much to Heat and How Much to Recover?

- The Reservoir Volumetric Specific Heat  $(\rho C)_{res}$  would be calculated as follows:
- $(\rho C)_{res} = (1-\phi)\rho_r c_r + \phi(S_w \rho_w c_w + S_o \rho_o c_o)$
- $(\rho C)_{res} = (1-.17)(165)(.22) + .17*(.35*62.4*1 + .65*53.3*.46)$
- $C_{res} = 36.6$  BTU/ft<sup>3</sup> deg F
- Assuming an acre with 15-foot thickness, the bulk volume would be 653,000 cubic feet and the heat required to raise the temperature one degree F would be 24 million BTU. To obtain the objective temperature of 160 degrees F across that acre with 100% efficiency would require an input of 2.4 billion BTUs, or the equivalent of 2,400 MCF, or 400 barrels of oil.
- That same acre would have a pore volume of 19,800 barrels. The initial oil saturation of 72% gives an original oil in place of 14,300 barrels. A residual oil saturation to water of 28% results in an estimated displaceable saturation of about 40%, or nearly 8,000 barrels of oil per acre. This represents 56% of the original oil in place, which is not unreasonable compared to the results obtained from a heavy oil steamflood at a similar depth.
- The Energy Efficiency of the ideal process so outlined would be 95%. Only 5% of the energy produced would be consumed as fuel. Currently natural gas delivered retail at this location is trading at a 50% energy discount to posted crude oil, the revenue efficiency would be 97.5%, or potentially 40 times your money on fuel purchased.
- ***There is a lot of room for inefficiency in this idealized process.***

# Thermal Efficiency, $E_h$

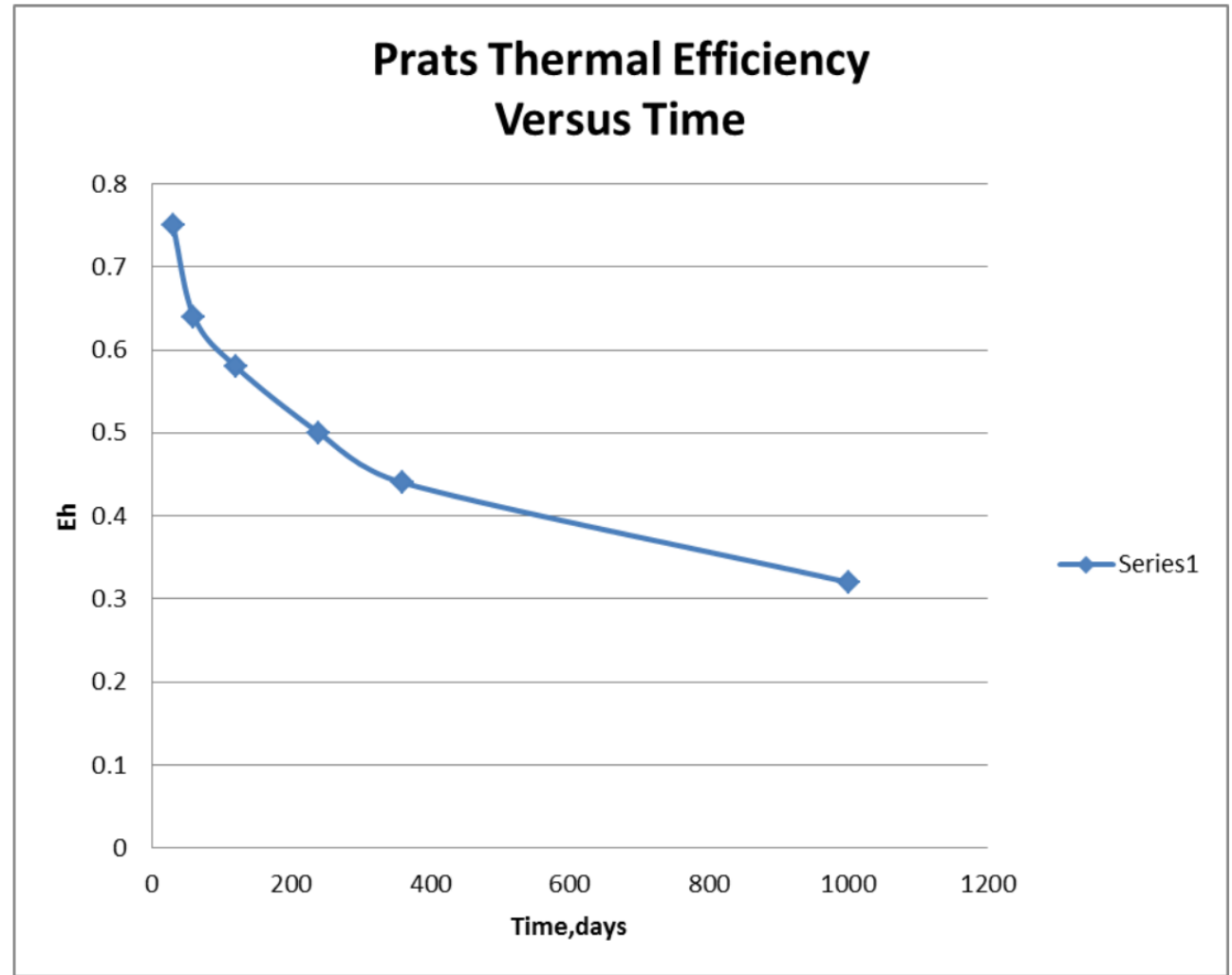


Figure 8- Prats Thermal Efficiency versus Time

# Steam Oil Ratio (SOR)

- Amount of oil recovered by barrel of steam injected
- A barrel of water weighs 350 lbs
- A pound of steam at the necessary temperature and pressure for this project contains around 1,200 btus.
- So a barrel of steam is around 420 MBTUs, or 0.42 MMBTU (MCF)
- So at a SOR of 2.4, one MCF recovers one barrel of oil.
- The idealized process assumed above works out to a steam oil ratio of 0.7 (5,700 barrels of steam to recover 8,000 barrels of oil), so everything is about *efficiency*.

# Fuel Costs Per Barrel of Oil Versus MMBTU Price and SOR

Water 350.4 lbs/bbl  
 Enthalpy 1202 btu/lb  
 Steam 421181 BTU/bbl

Superheated steam enthalpy at different pressures and temperatures:

Superheated Steam - Enthalpy vs. Pressure

Pressure (bar) (psi)	Saturation Temperature (°C)	Enthalpy of Superheated Steam (kJ/kg) (Btu/lb)						
		Saturation	Temperature (°C) (deg F)					
			200	250	300	350	400	450
15 217	198.3 389	2792 1201	2796 1202	2925 1258	3039 1307	3148 1354	3256 1400	3364 1447
20 290	212.4 414	2799 1204		2904 1249	3025 1301	3138 1349	3248 1397	3357 1444
30 435	233.8 453	2809 1208		2858 1229	2995 1288	3117 1340	3231 1389	3343 1437
40 580	250.3 483	2801 1204			2963 1274	3094 1330	3214 1382	3330 1432

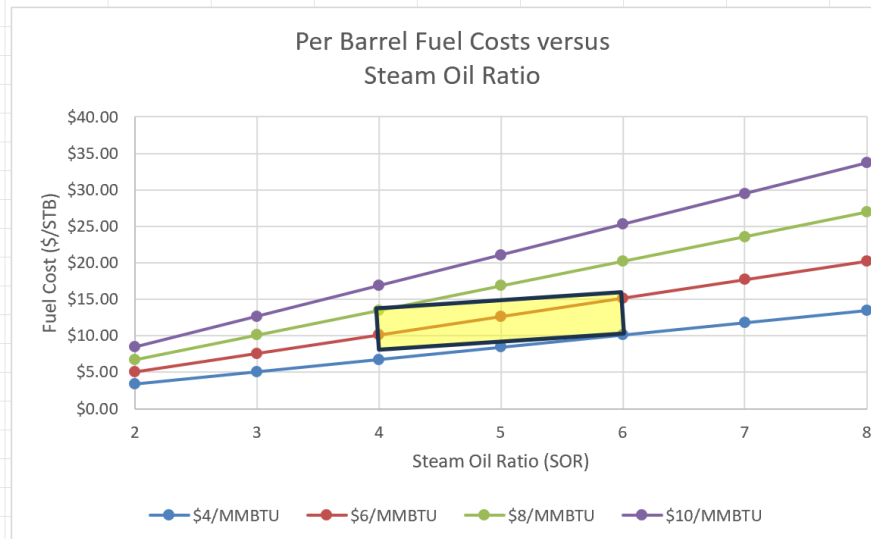
what are typical steam oil ratios in the Athabasca Tar Sands

The steam-to-oil ratio (SOR) in the Athabasca oil sands varies depending on the recovery method, reservoir characteristics, and operational efficiencies. Typical SORs for common in-situ recovery techniques are as follows:

### 1. Steam-Assisted Gravity Drainage (SAGD)

- Typical SOR: 2.5 to 5.0 (meaning 2.5 to 5 barrels of steam are required to produce 1 barrel of oil).
- Details: SAGD is widely used in the Athabasca region for its efficiency in high-quality, continuous bitumen deposits. Lower SORs are achieved with well-optimized operations and favorable reservoir conditions, such as high permeability and low clay content.

Fuel Cost per Barrel Oil- Versus SOR and Gas Price		Gas Price, \$/MMBTU			
SOR	MMBTU	\$ 4.00	\$ 6.00	\$ 8.00	\$ 10.00
2	0.842362	\$3.37	\$5.05	\$6.74	\$8.42
3	1.263542	\$5.05	\$7.58	\$10.11	\$12.64
4	1.684723	\$6.74	\$10.11	\$13.48	\$16.85
5	2.105904	\$8.42	\$12.64	\$16.85	\$21.06
6	2.527085	\$10.11	\$15.16	\$20.22	\$25.27
7	2.948266	\$11.79	\$17.69	\$23.59	\$29.48
8	3.369446	\$13.48	\$20.22	\$26.96	\$33.69



# Analog Project in Oklahoma *This Just Doesn't Happen*

**SPE 7548**  
CASE HISTORY OF A SUCCESSFUL STEAMFLOOD  
PROJECT-LOCO FIELD  
By Robert Miller, Member SPE-AMC  
Copyright © 1977, American Institute of Professional Engineers, Inc.

**FIG. 1 - LOCO STEAMFLOOD, STEAMING QUANTITY, OKLAHOMA**

**FIG. 2 - PATTERN # ONE - J-SHALLOW: HEAT INJECTION AND OIL PRODUCTION**

**FIG. 3 - PATTERN # ONE - J-SHALLOW: STEAM INJECTION/PRODUCER OIL RATIO**

**TABLE NO. 1**  
**LOCO STEAMFLOOD RESERVOIR DATA**

Zone	J-shallow	44 m	J-shallow Formation - 200 - 220 Ft.	Gravity,	19.8° API	12.48 kg/m <sup>3</sup>
Depth	210 Ft.	44 m		Gravity, Specific, 60/60° F.	0.9352	
Oil Saturation	74%			Viscosity, Kinematic,		
Permeability Range	10 md - 5 d	0.01 - 3 μm <sup>2</sup>		at 70° F. 21.1° C	798 cSt	798 mm <sup>2</sup> /s
Original Oil in Place	1350 M/AC. Ft.	0.3 m <sup>3</sup> /m <sup>2</sup>		at 100° F. 37.8° C	254 cSt	254 mm <sup>2</sup> /s
				at 130° F. 54.4° C	102 cSt	102 mm <sup>2</sup> /s
Zone	B-shallow	150 m				
Depth	500 Ft.	150 m				
Oil Saturation	68%					
Permeability Range	40 md - 1.3 d	0.04 - 1.3 μm <sup>2</sup>				
Original Oil in Place	1470 M/AC. Ft.	0.19 m <sup>3</sup> /m <sup>2</sup>				

**Jim Brooker** • You  
President at Brookston Resources Inc  
1mo •

One of the most remarkable individual Enhanced Oil Recovery Projects I have read is encapsulated by the montage below, which pertains to Conoco's 1970's steam injection project in the Loco J Shallow Sand in Oklahoma. One 2.5 acre pattern 200 feet deep with 15 ft of pay and largely immobile oil was making 4 BOPD from 4 producers- just 7 days after steam injection started this pattern went to over 200 BOPD. The steam oil ratio for most of the project was around 5. For a heat content of 1,200 BTU per pound, without losses around 2.1 MMBTU would be needed to recover a barrel of oil using this SOR. Given the current capital costs of oil development projects around the world, it makes one wonder how competitive shallow light oil steam floods, both for residual distillation recove ...more

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Most relevant

**Kevin Watts** • 1st  
Global Oil and Gas Director, Moleaar, Inc. 2mo

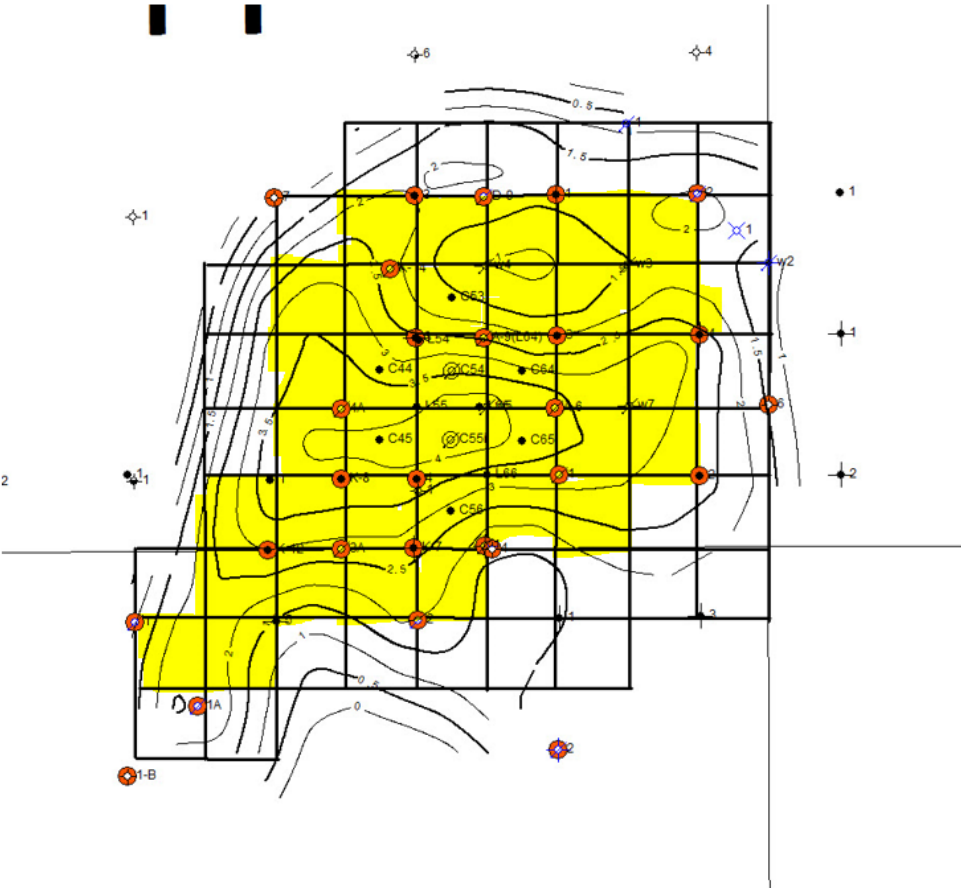
Lots of very cool projects were done before the advent of shale resources. There is a boat load of oil to recover in conventional fields with a little thinking outside the box.

# Steam Injection- Consider the Benefits

- Low Injection Pressure and Establishment of Matrix Displacement
  - $1 = S_o + S_w + S_g$  -> Doesn't matter if you're not in zone
  - $S_{ors} < S_{orw}$  in light oil environment due to steam distillation
- Limit/Control Horizontal Hydraulic Fracture Propagation
  - Contrast this With Polymer/Alkaline Flooding
  - Mobility Ratio improvement not by increasing water viscosity, but reducing oil viscosity
- Recovered Heat at Tank Battery utilized to Deliver Hot Water to Remainder of Field
- Arbitrage Opportunity to Convert Low Value BTUs (gas) into High Value BTUs (oil)

# Abbey Unit

## Conceptual 2.5 acre Steamflood Grid overlain on Total Phi-h map- Based on Analogy Loco J Sand Project







Enbridge Oil Spill

# Practical Considerations



- Regulatory
  - Groundwater Protection
    - Quantifying the Groundwater Resource
    - Designing an Effective Protection Program
    - Must Preserve Expensive Heat in Zone
    - If monitoring has to be conducted- extremely shallow and inexpensive
- Fuel Source
  - ANR Interstate Pipeline 1 mile from Unit Boundary
  - Ohio Valley Gas in Tell City can provide a 4" 60 psi line
- Source Water
  - Patoka Regional Water is 4,400 feet away-pricing a line

# Conclusion

$$q = \frac{2\pi kh(P_{res} - P_{wf})}{\mu B \left[ \left( \ln \left( \frac{r_e}{r_w} \right) \right) - \frac{3}{4} + S \right]}$$

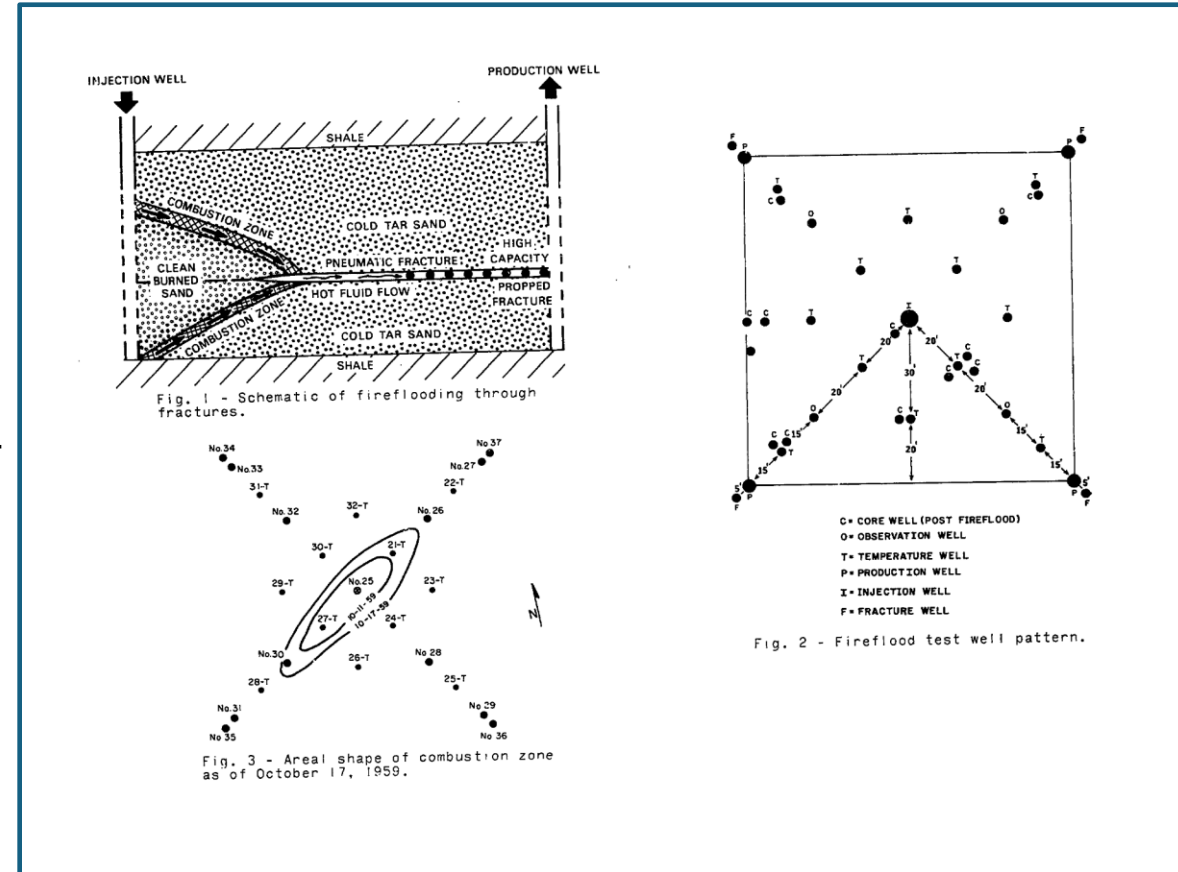
$$1 = S_o + S_w + S_g$$

- Geology/Reservoir Engineering Hold the Key:
  - Last 20 years- Make Pres, Perm & Negative Skin
  - Next 20 years- Good Perm, Reduce Vis and Sor

Supporting Slides Follow

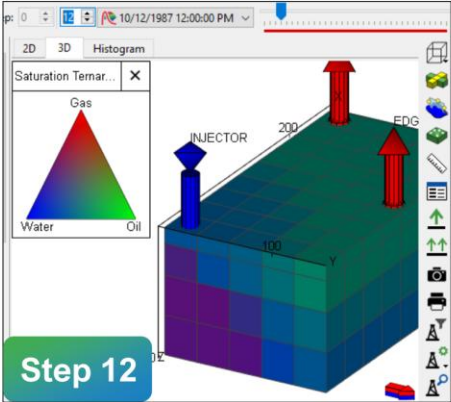
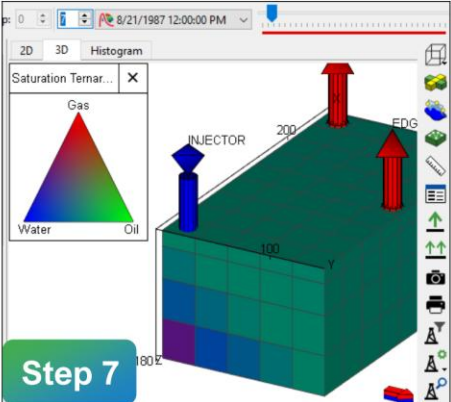
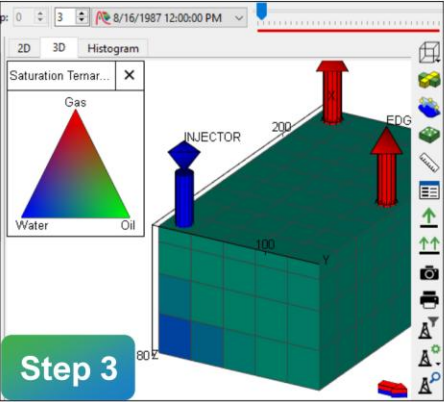
# Gulf Fireflood Western Kentucky Tar Sands

- Some Degree of “Channeling” is Viewed Positively in Low Mobility Thermal Applications
- To the Point of Artificially Creating It

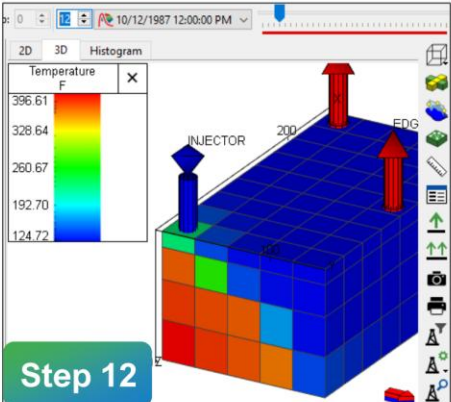
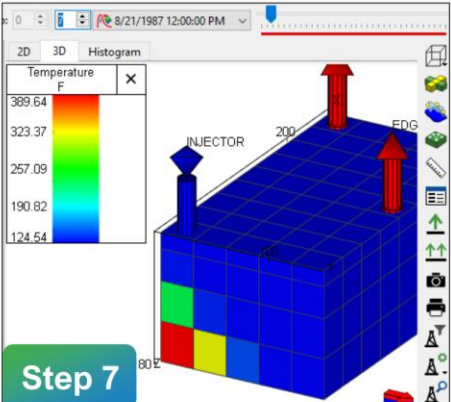
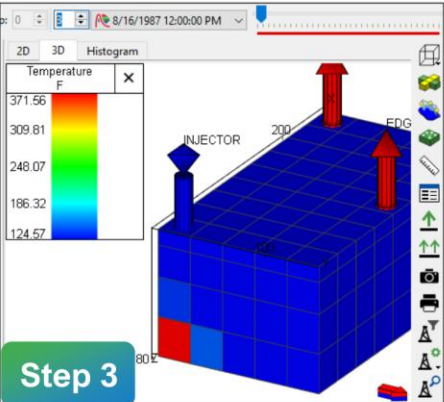


# Sample Tnavigator Thermal Model Geology Will Rule

Saturation Ternary Diagram



Temperature, °F



# Supatra etal Update and Forecast

