Chemical EOR Potential for Heavy Oil in the United States*

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Abstract

Large volumes of heavy oil are present in the lower 48 United States, mostly in California and along the Gulf Coast and in lesser amounts in other basins throughout the country. Over the past decade, several estimates suggested that the U.S. heavy oil resources exceed 100 billion bbls (excluding Alaska), of which only about 10% to 15% has been produced. Due to the high viscosity of heavy oil, primary production yields poor recovery and EOR techniques are generally considered as an option to increase recovery. Thermal recovery techniques by steam injection are by far the most commonly used methods in heavy oil fields. However, thermal methods are not suited when the reservoir is thin or at a depth greater than 4500 ft, due to heat loss to adjacent beds or in the well bore.

Chemical EOR methods such as polymer flooding and ASP (Alkaline-Surfactant-Polymer) were not considered until recently as viable options for heavy oil, because of the high viscosity of the oil. However, recent field applications of polymer flood using horizontal wells have proven successful for oil as viscous as several thousands of centipoises. Based on these considerations, we investigated the potential for chemical EOR in the U.S. (excluding Alaska) by screening heavy oil fields not suited for thermal recovery and fitting a set of criteria desired for polymer flooding and ASP. These criteria include oil viscosity, permeability, thickness, depth, temperature, and recovery factor. Our estimate, based on a heavy oil database published by the U.S. Department of Energy (2004) suggests that more than 200 fields representing over 6 billion bbls of heavy oil in place are

potential candidates for chemical EOR in the U.S. This article presents our screening method, the heavy oil basins in the U.S. that could be suitable for chemical EOR and summarizes relevant EOR field applications in heavy oil reservoirs.

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The EOR Alliance

Chemical EOR Potential for Heavy Oil in the United States

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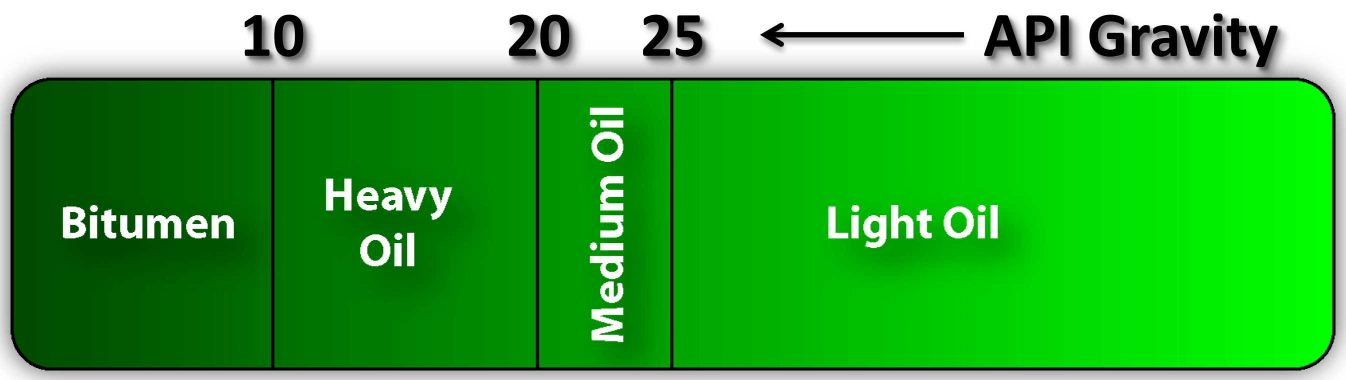
Definitions

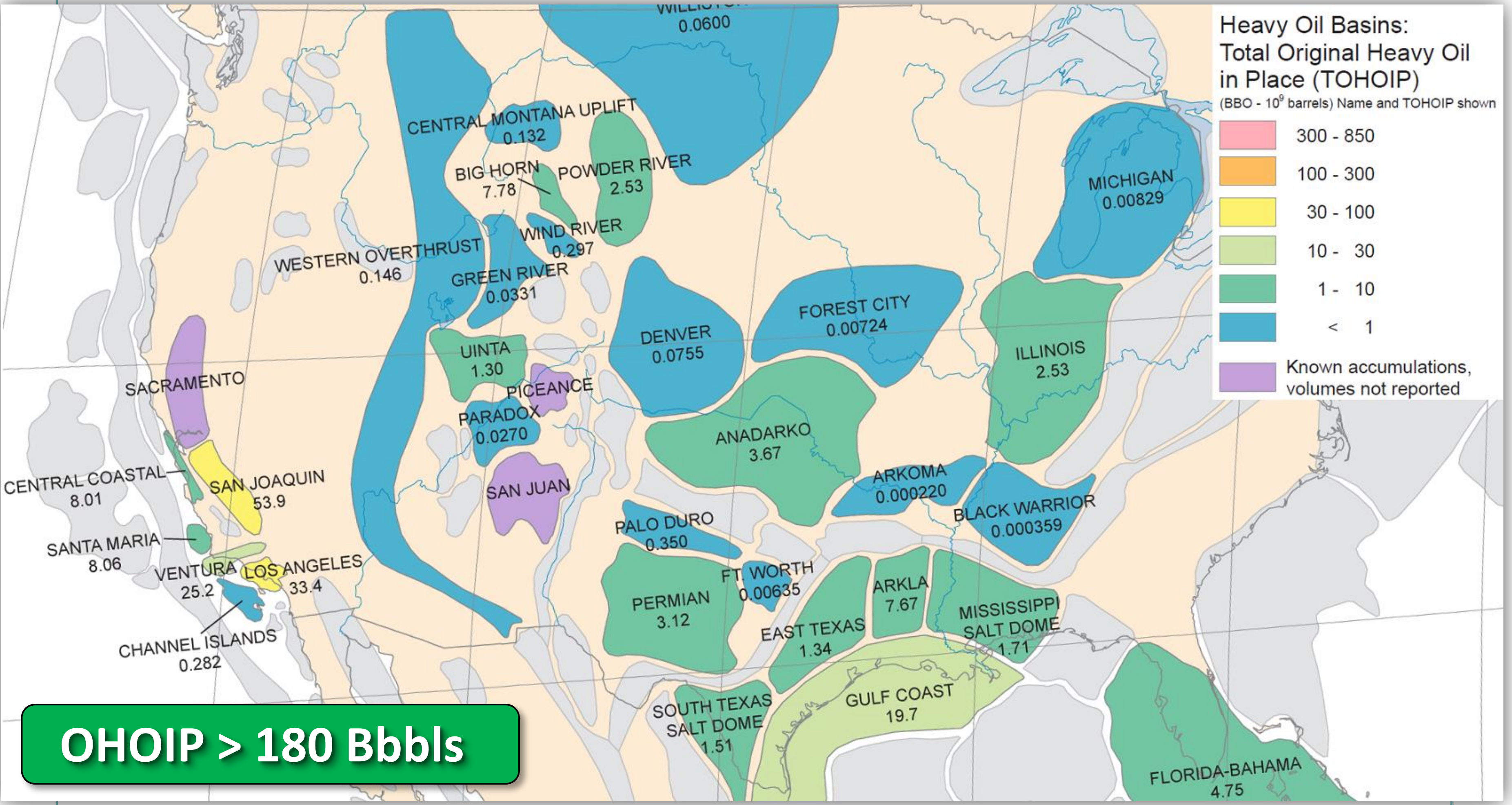
- **Heavy Oil**: Oil with API gravity between 10 and 20.



- **Enhanced Oil Recovery (EOR):** Injection of gases or liquid chemicals and/or the use of thermal energy to improve oil recovery beyond production from natural drive mechanisms or water flooding (Green and Wilhite, 1998).

U.S. Heavy Oil Resources

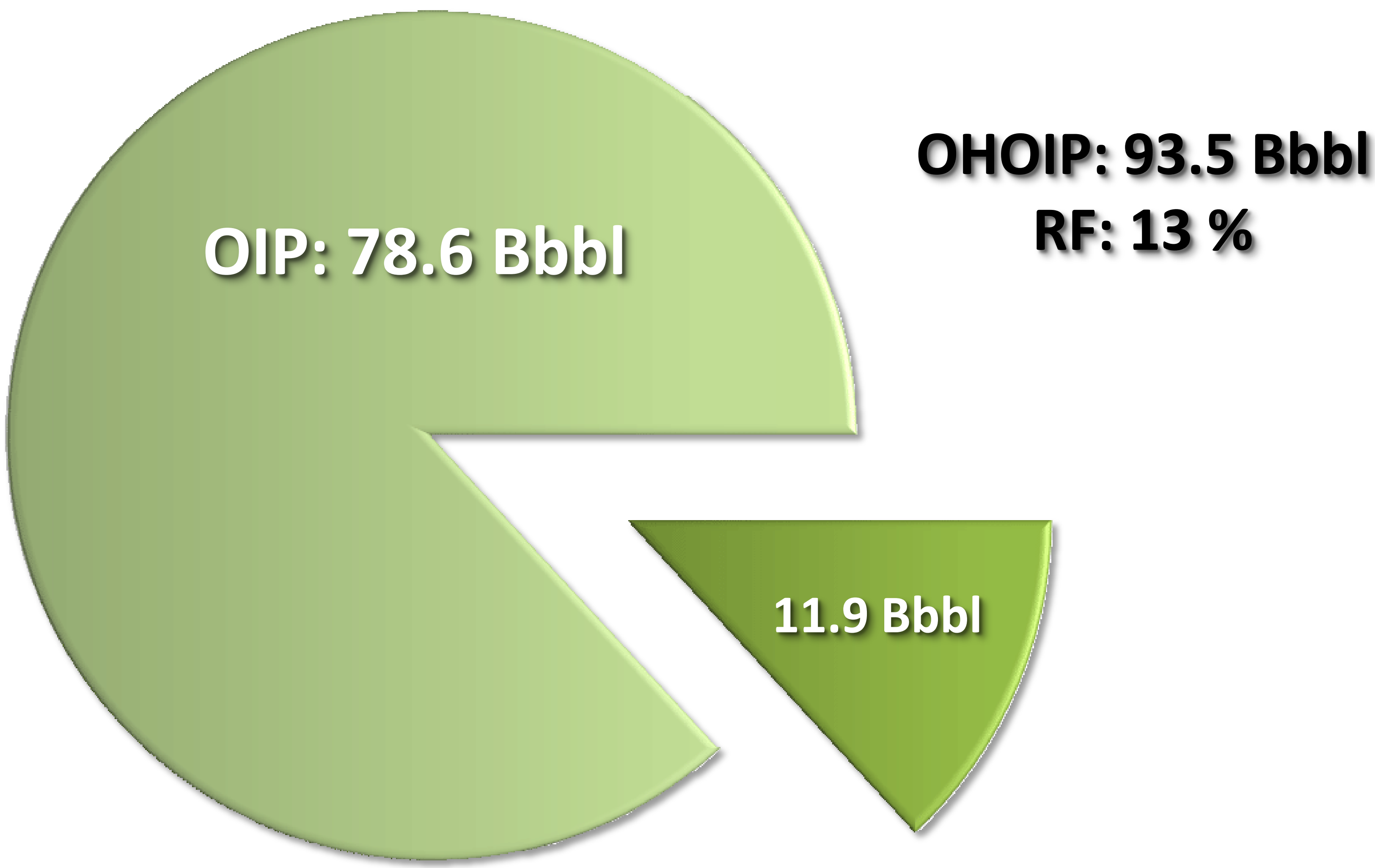
Heavy Oil Resources in U.S.



OHOIP > 180 Bbbls

Map of Sedimentary Provinces Reporting Heavy Oil (Meyer et al 2007, USGS)

Heavy Oil Resources in U.S.

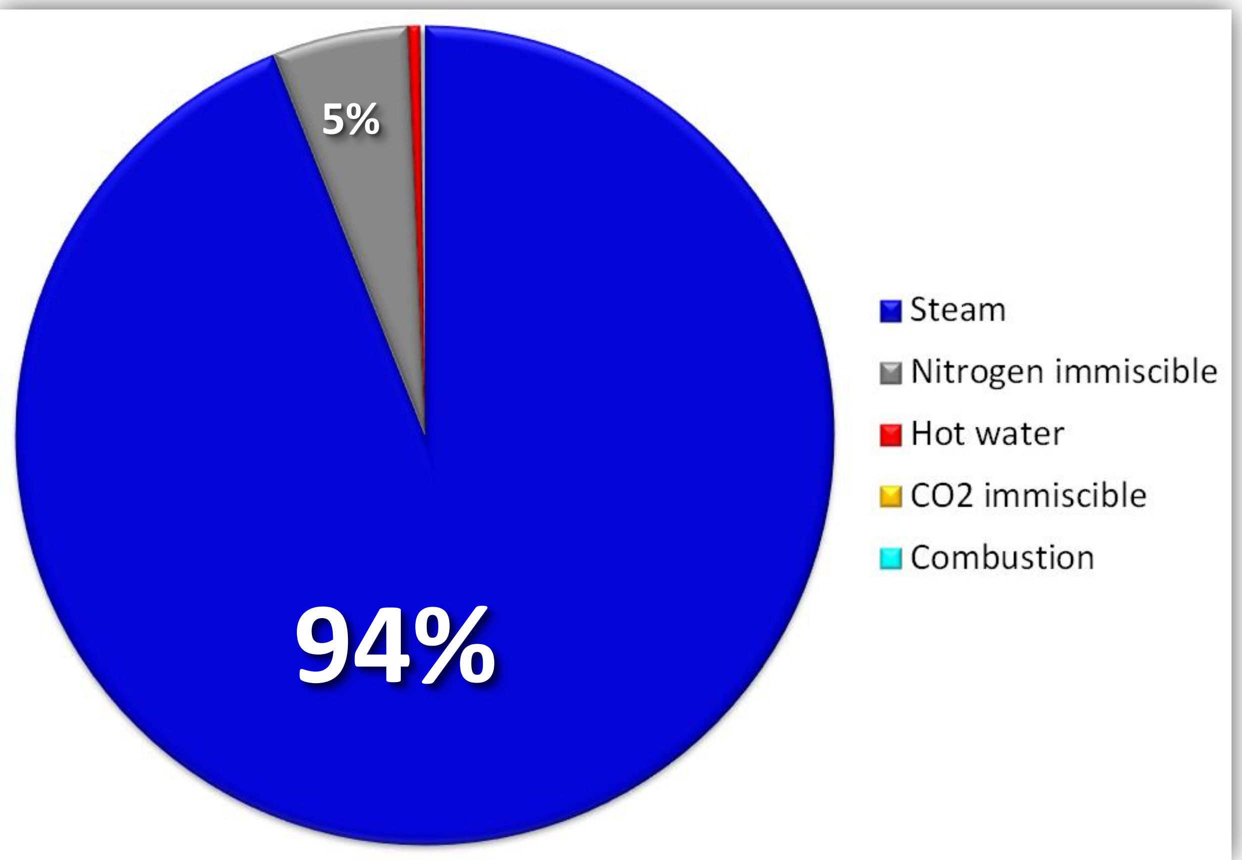


U.S. Lower 48 Heavy Oil Resources and Cumulative Production (DOE 1996, Updated 2003)

EOR projects in Heavy Oil: Current U.S. production

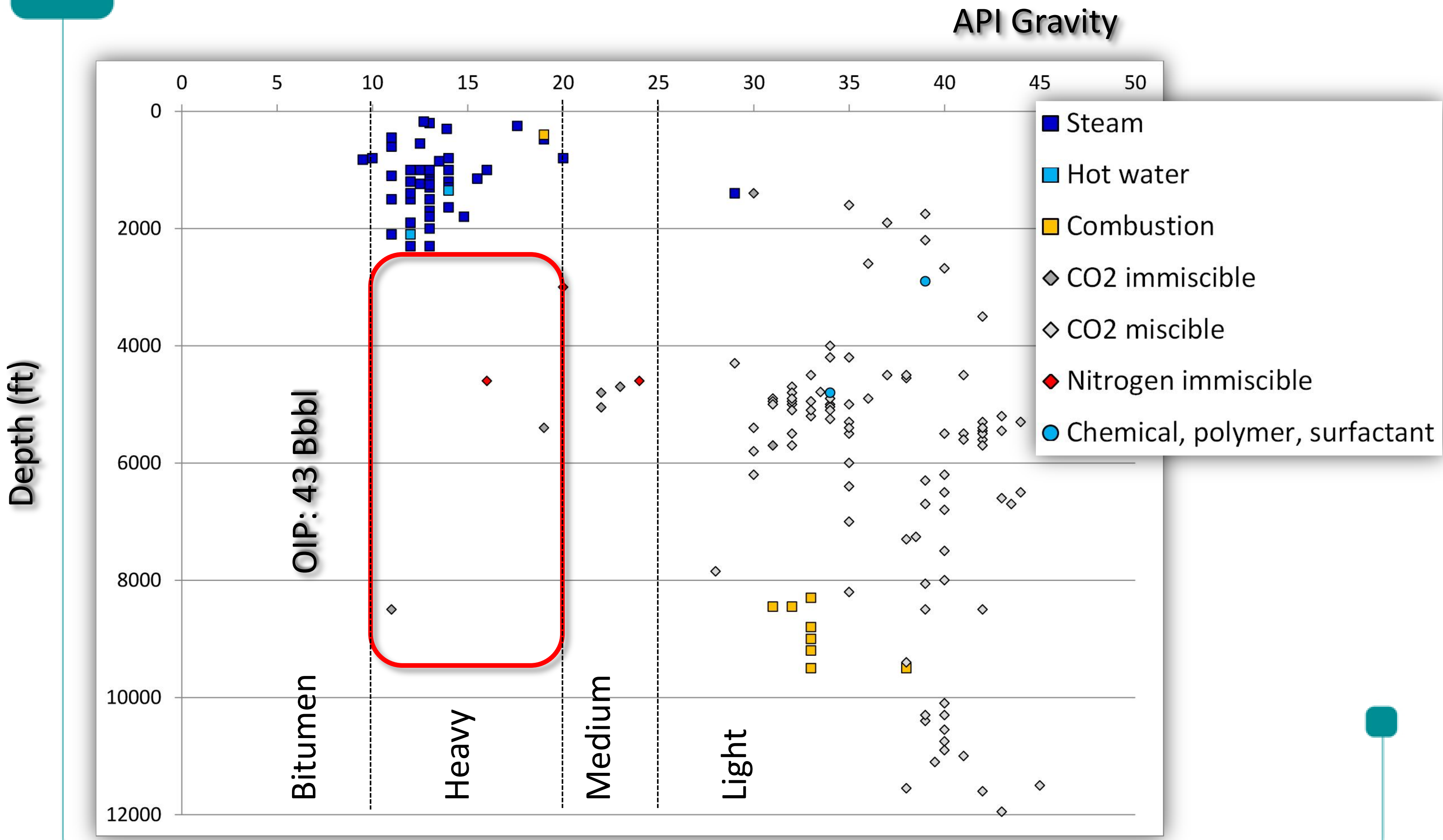
EOR Production Methods in U.S. Heavy Oil

Current U.S. heavy oil production rate from EOR: 300,000 bbl/d



U.S. EOR production (2012 worldwide EOR survey, Oil and Gas Journal)

EOR Production Methods in U.S



2012 worldwide EOR survey (Oil and Gas Journal)

Why chemical EOR?

- Thermal is usually the method of choice for heavy oil EOR

- Chemical EOR can be applied when thermal does not work
  - Too deep
  - Too thin

- Capital cost is lower

What is Chemical EOR?

Chemical EOR basics: components

Polymer

- Makes water more viscous,
- Improves mobility ratio and sweep efficiency

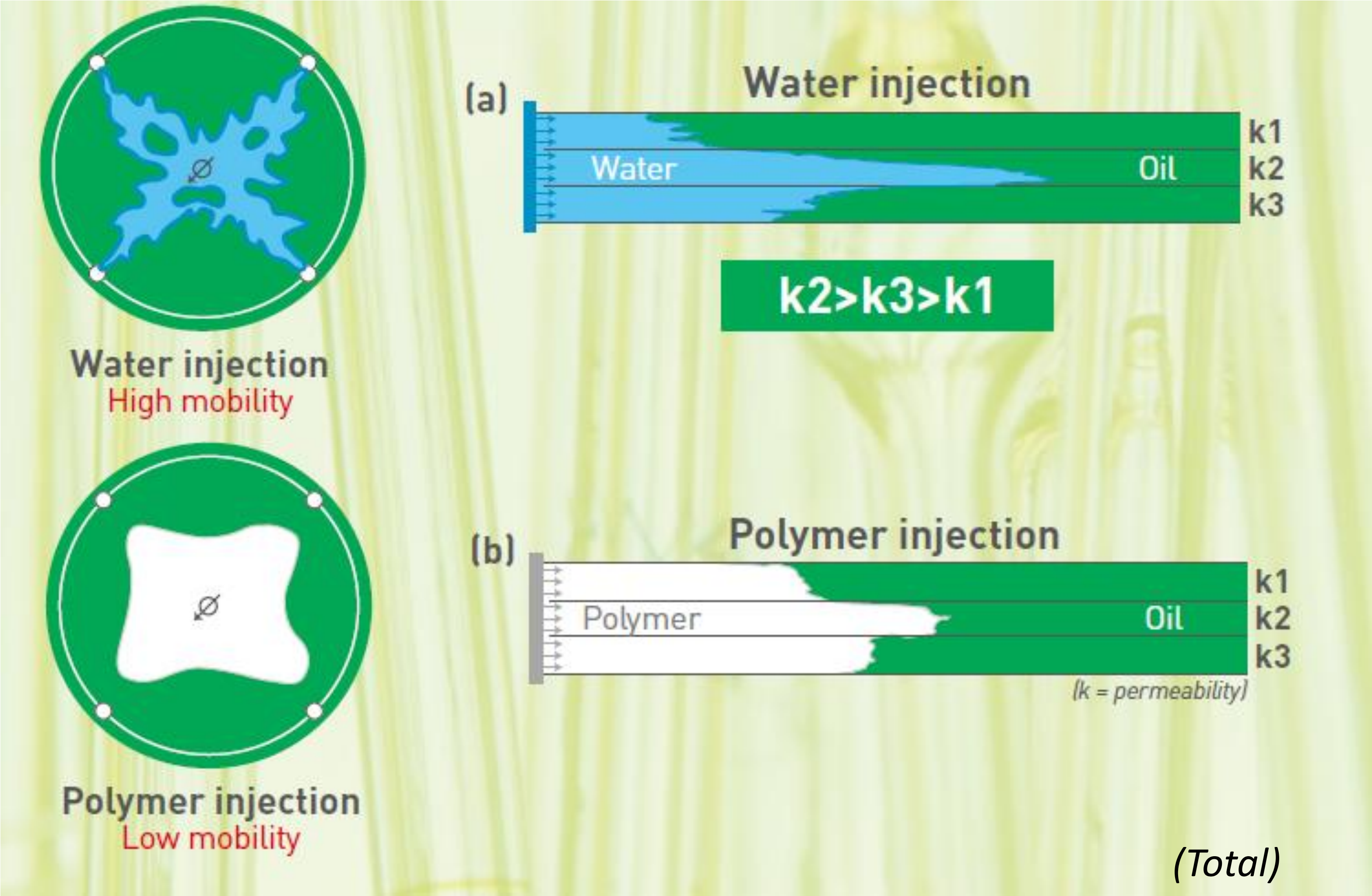
Surfactant

- Reduces capillary forces trapping oil in the reservoir

Alkali

- Generates surfactant in the reservoir

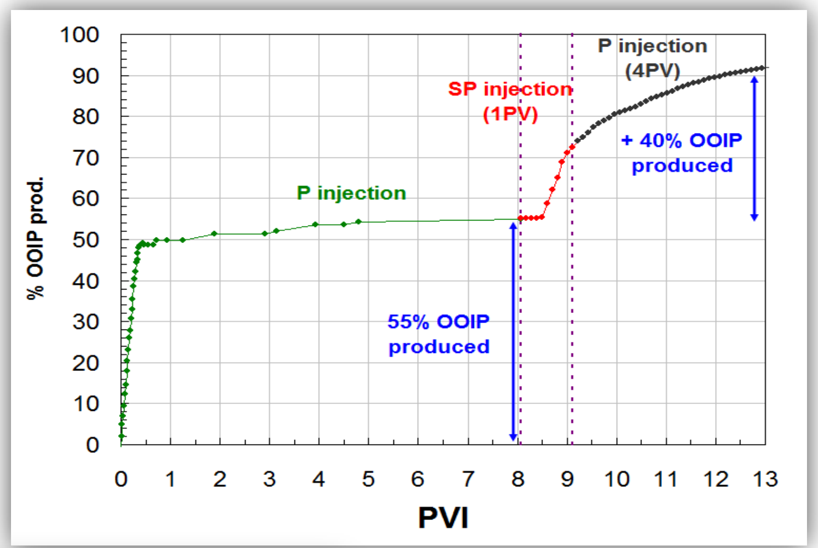
Effects of polymer

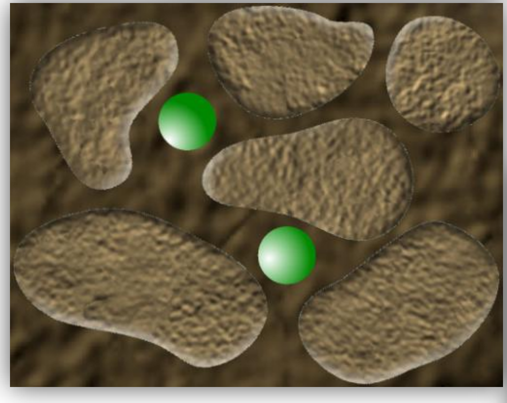


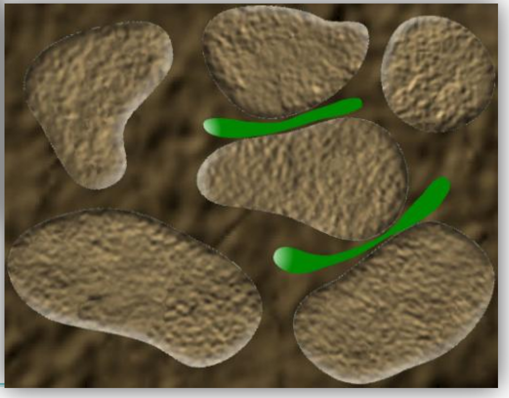
(Total)

Surfactant targets residual oil

- It is the oil left behind after a water(gas) flood
- At the pore scale it is a microscopic phenomenon which is due to capillary trapping
- The most efficient way to decrease the residual oil saturation is to reduce the interfacial tension





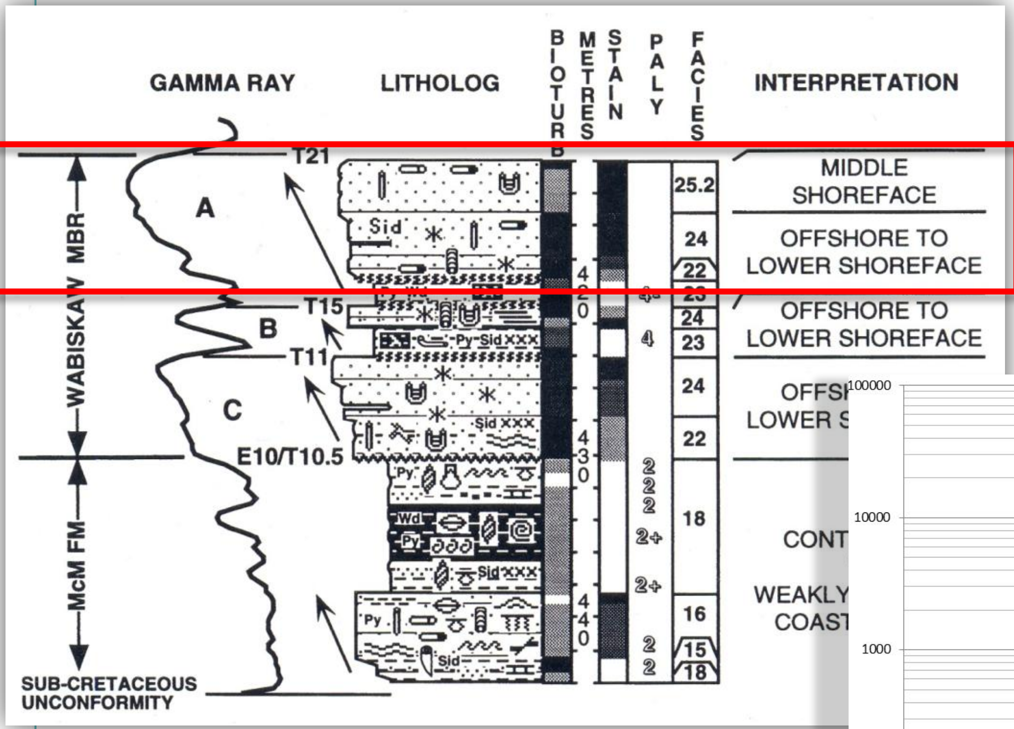


Chemical EOR in Heavy Oil: Canadian Experience

Main projects characteristics

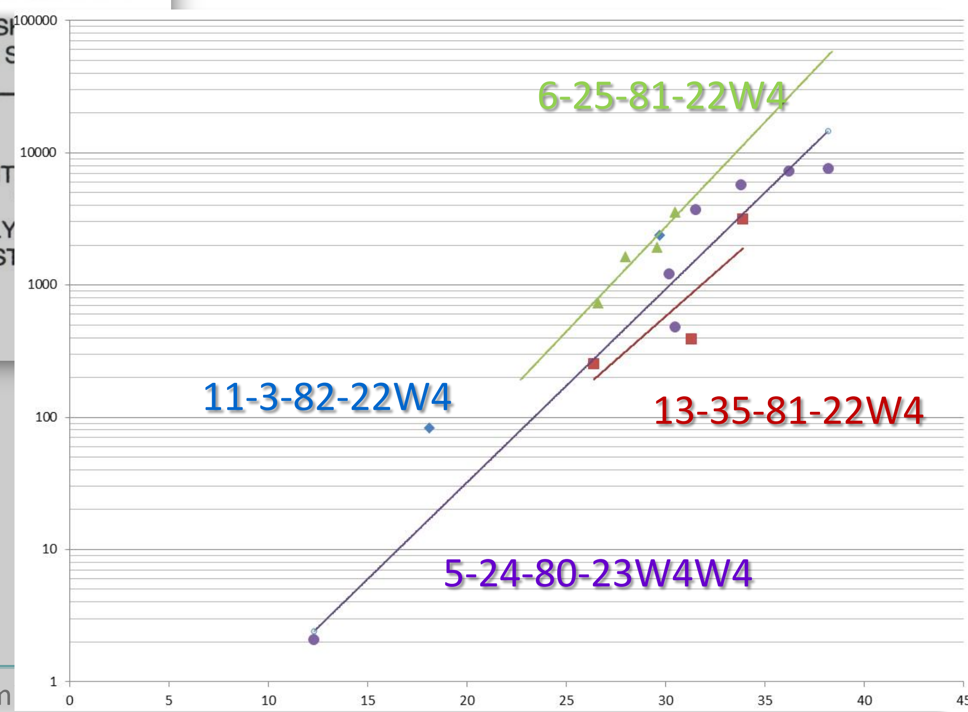
Projects	Pelican Lake	Mooney	Seal	Taber	Suffield
Company	**CNRL and Cenovus**	BlackPearl	Murphy	**Husky**	Cenovus
Type	**PF**	PF & ASP	PF	**ASP**	ASP
Formation	**Wabiskaw**	Bluesky	Bluesky	**Mannville**	U. Mannville
Average depth (m)	**300-450**	900-950	610	**985**	930
Average net pay (m)	**1-9**	2.5	8.5	**7.1**	2.9
Porosity	**28%-32%**	30%	27%-33%	**18% - 28%**	30%
Permeability (md)	**300-5,000**	100-10,000+	300-5,800	**1,500-3,500**	1,000-3,000?
Water saturation	**30-40%**	30%	20%-35%	**18%**	20%-30%
Reservoir temperature (°C)	**12-17**	29	20	**35**	32
Initial reservoir pressure (bar)	**18-26**	58.0	51.5	**99.5**	104.9
API gravity	**12-14**	12-19	10-12	**19**	15
Solution Gas-Oil ratio (m3/m3)	**4-6**	17.5	9.9	**16.7**	28
Dead oil viscosity @ Res. T^0 (cp)	**800-80,000**	300-500	5,000-12,000	**120**	600
Live oil viscosity @ Res. T^0 (cp)	**800-80,000?**	120-300?	3,000-7,000	**40**	130
Recovery at start of EOR (%OOIP)	**5-10**			**38.7**	14.1

Pelican Lake Reservoir

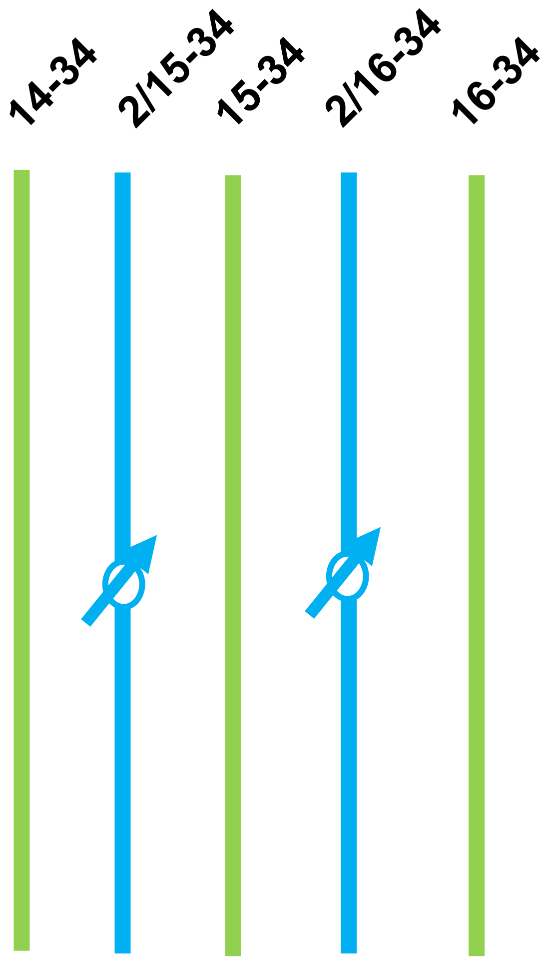


Pilot
Producing interval

Type Section (Wightman et al 1997)



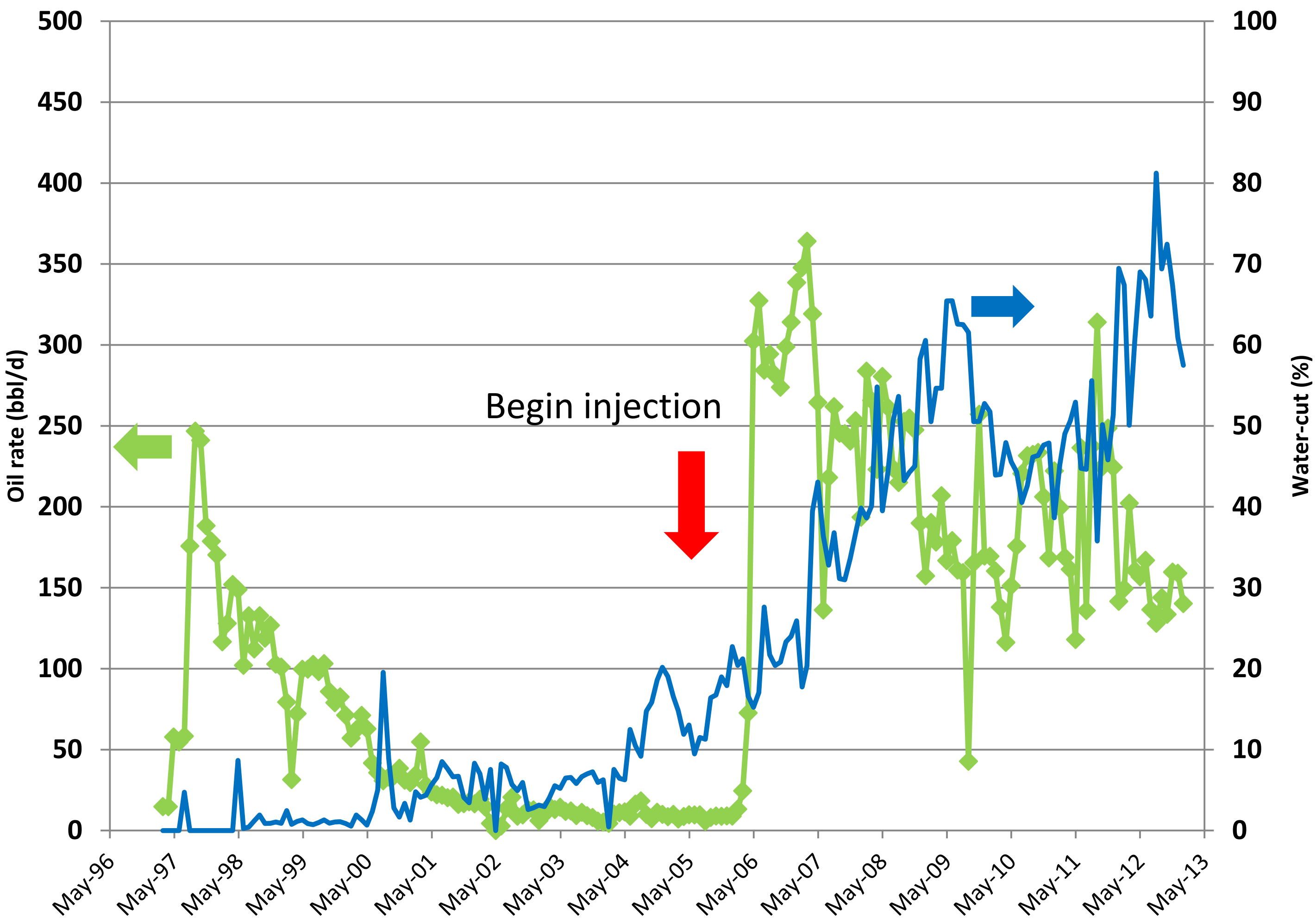
Pelican Lake polymer flood pilot



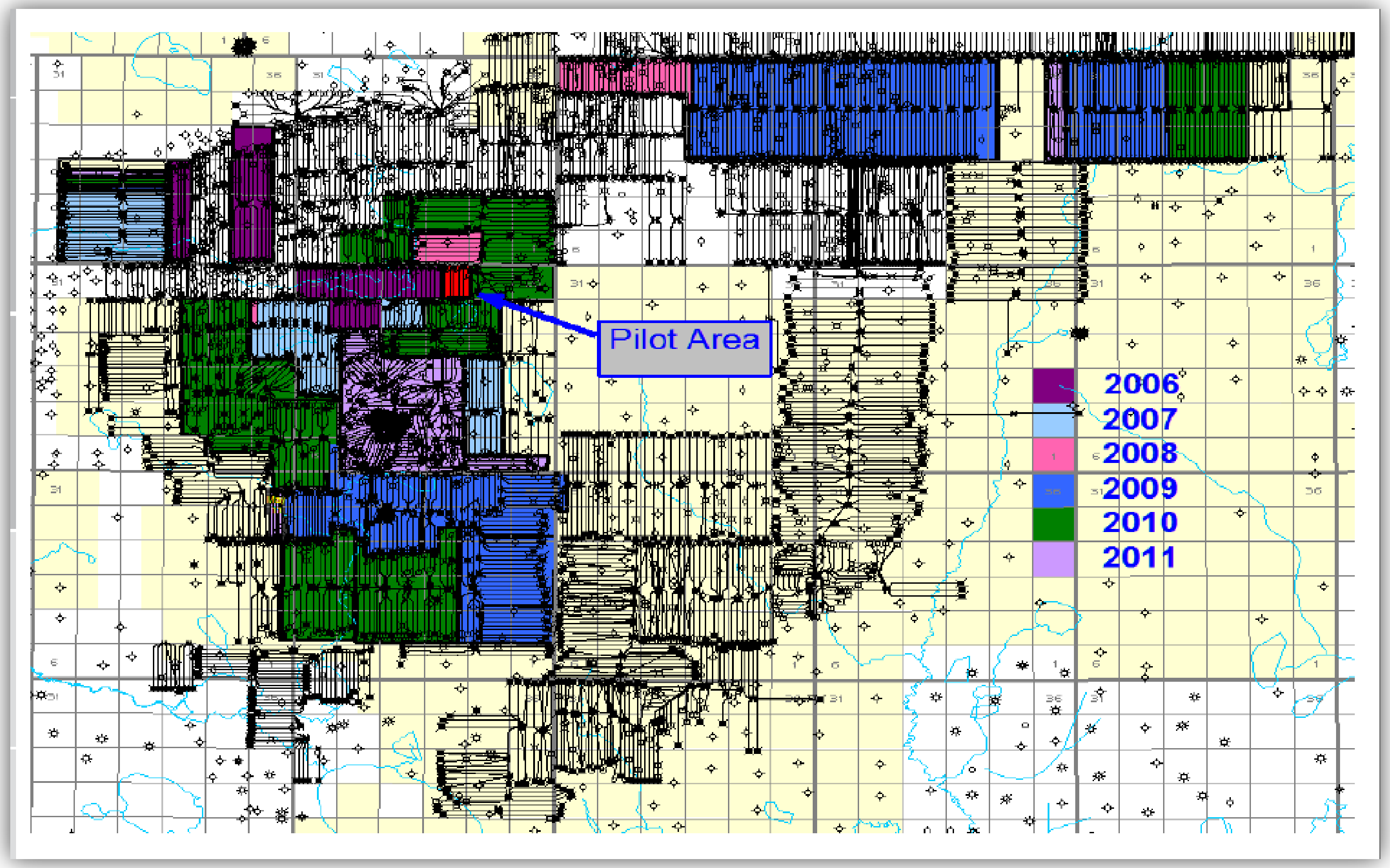
- Initiated in 2005
- 1,500 m (4,900 ft) long horizontals
- 175 m (575 ft) spacing
- Live oil viscosity: 1,500 -2,000 cp
- Polymer
  - HPAM
  - 20MM (later reduced to 12 MM)
  - Viscosity 20 cp to 13 cp
  - Injection 930 bbl/d/well initially

(SPE 165234)

Pelican Lake central well production history

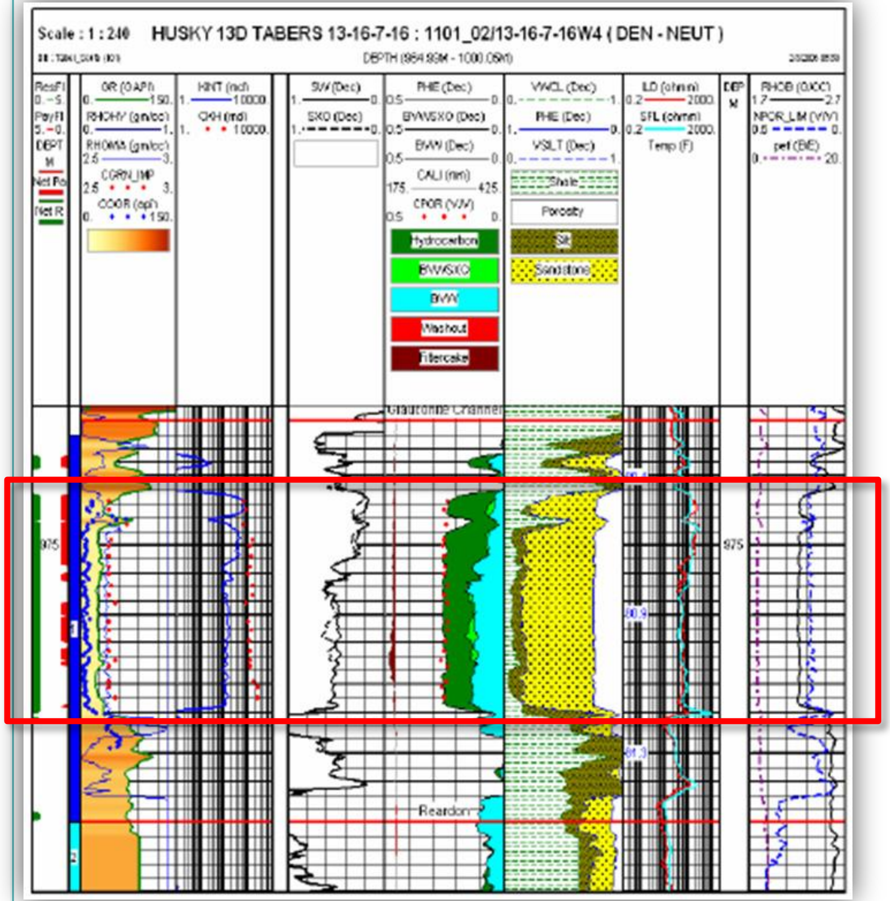


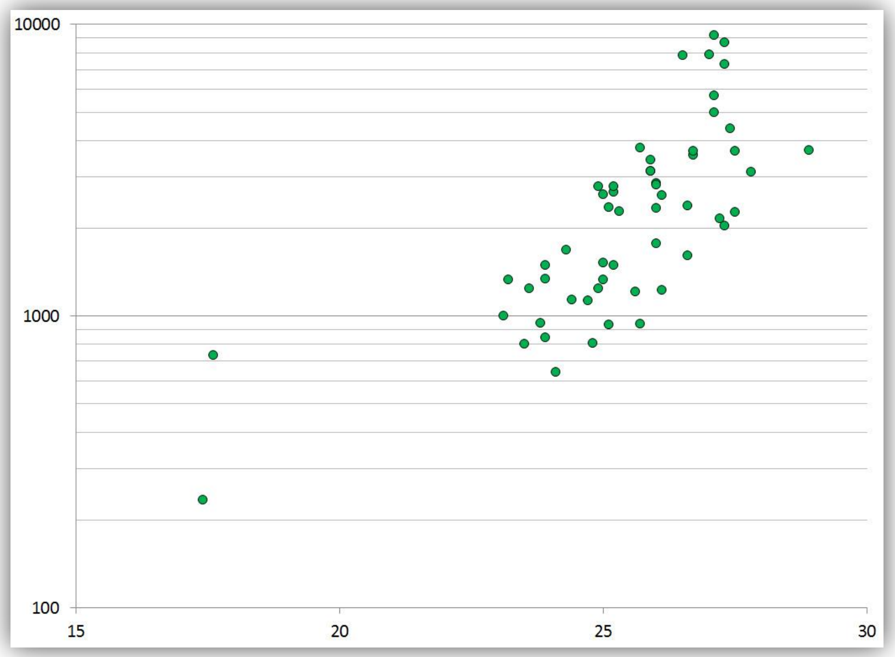
Pelican Lake Polymer Flood Development



CNRL map

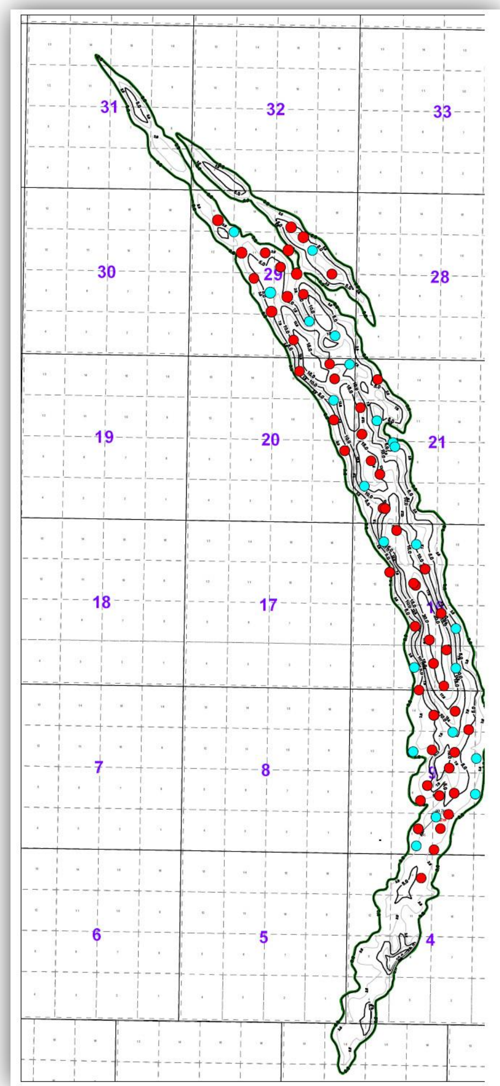
Taber Reservoir





Producing interval

Taber ASP flood

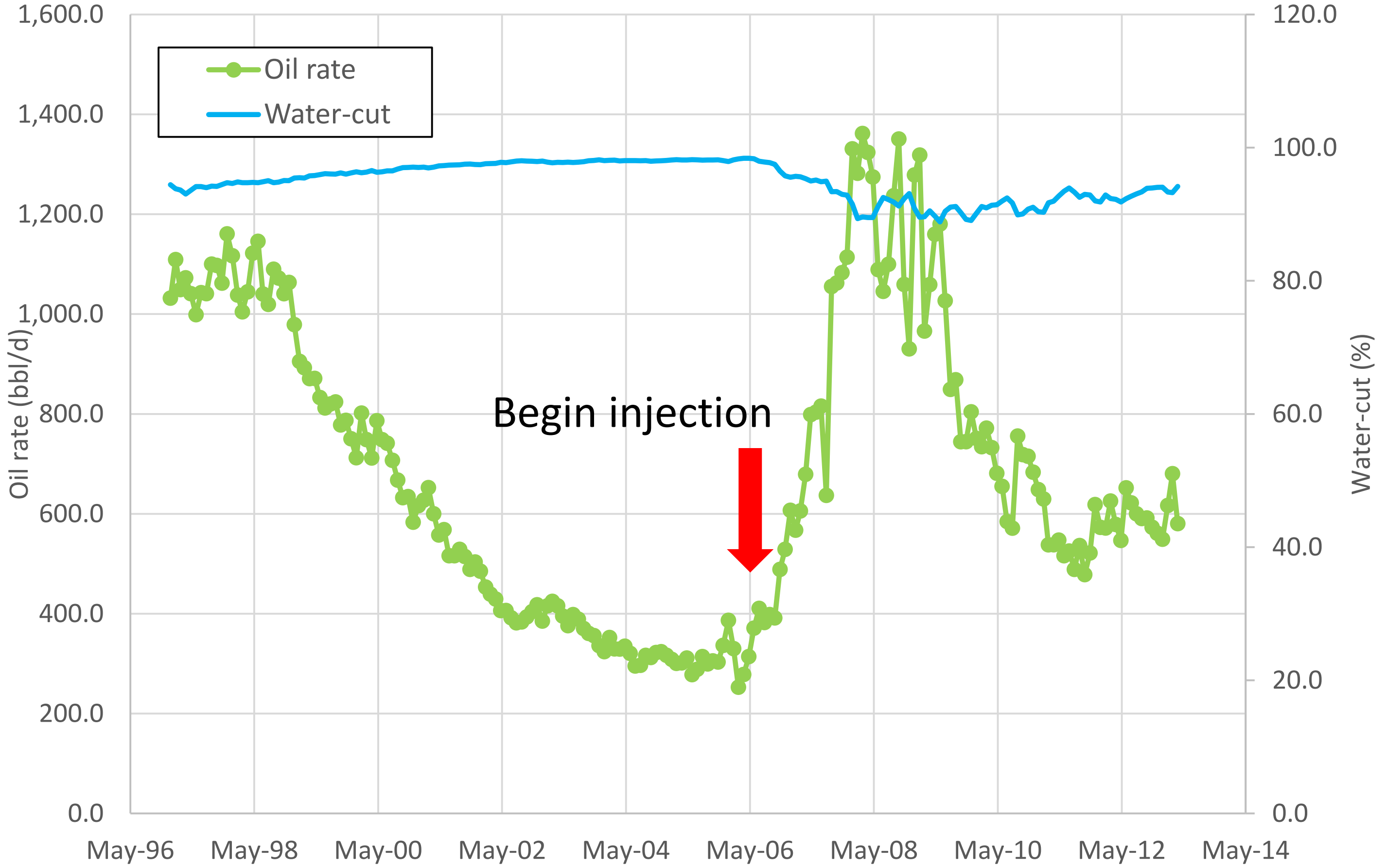


Net thickness map (McInnis et al 2013)

- Injection began May 2006
- Dead/Live oil viscosity 120/40 cp
- Injection fluid composition
  - Softened water
  - Main slug (0.34 PV)
    - Alkaline (NaOH) @ 0.75% wt
    - Surfactant @ 0.15% wt
    - Polymer @ 1,200 ppm
  - Tapered polymer (0.30 PV)
    - from 0.12%wt down to 0.06%wt

(SPE 165264)

Taber ASP response



Chemical EOR in Heavy Oil: What Potential in the U.S.?

Chemical EOR Screening Method

OHOIP

U.S. National Institute for Petroleum and Energy Research Heavy Oil Database (1995-2003): Oil gravity 10-20 API

93.5 Bbbl

Viscosity 10 – 15,000 cp: **77.5 Bbbl**

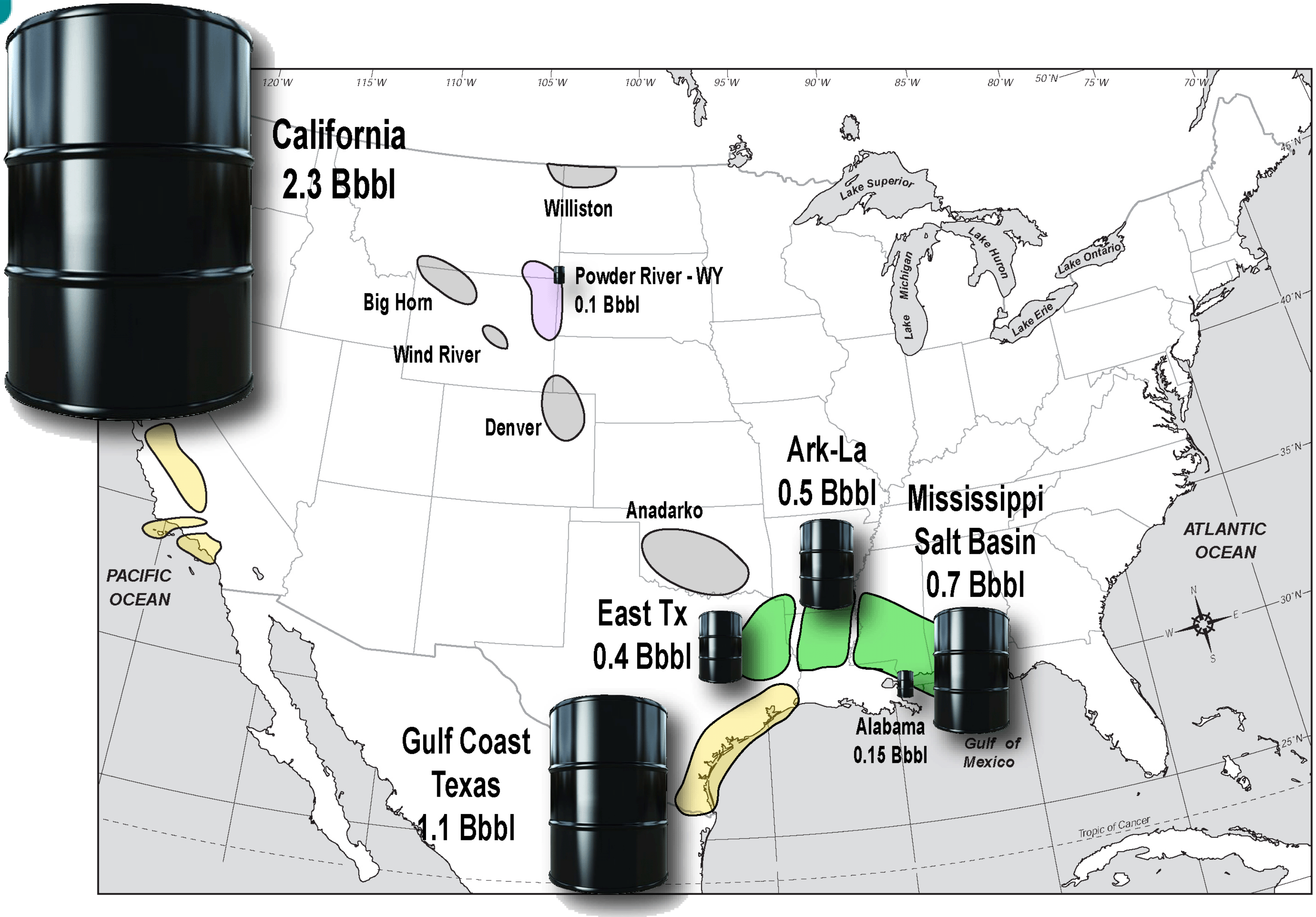
Permeability > 100 md (No Fract.): **66.5 Bbbl**

Net pay < 35 ft or Depth > 4500 ft: **6.7 Bbbl**

Recovery Factor < 40%: **5.5 Bbbl**

HOIP = 4.7 Bbbl

U.S. Chemical EOR potential



Summary

- According to different evaluators the U.S. lower 48 **heavy oil resource**s range between **90 and 180 Bbbl**.
- Due to the high oil viscosity, the **average recovery factor is below 15%** and EOR technologies will be required in order to significantly increase this number
- Currently, **thermal methods account for about 95%** of the EOR production from U.S. heavy oil fields (Lower 48)
- Recent success in Canada demonstrate that **chemical EOR has a great potential for heavy oil**.
- Our data screening suggests that at least about **5 Bbbl of heavy oil in place may be prospective for chemical EOR** applications in U.S.