

Investigation of Oil-Trapping Mechanisms in Deepwater Gulf of Mexico

SPE 130927

Xin Li, Joe Lach, Kenneth McMillen

Presented by Joe Lach

Knowledge Reservoir, LLC

Outline

- Introduction to RPSEA 1701
- Reservoir Characteristics Overview
- Trapped Oil Mechanisms
- Case Studies
- Conclusions

RPSEA

Research Partnership to Secure Energy for America

Who is RPSEA:

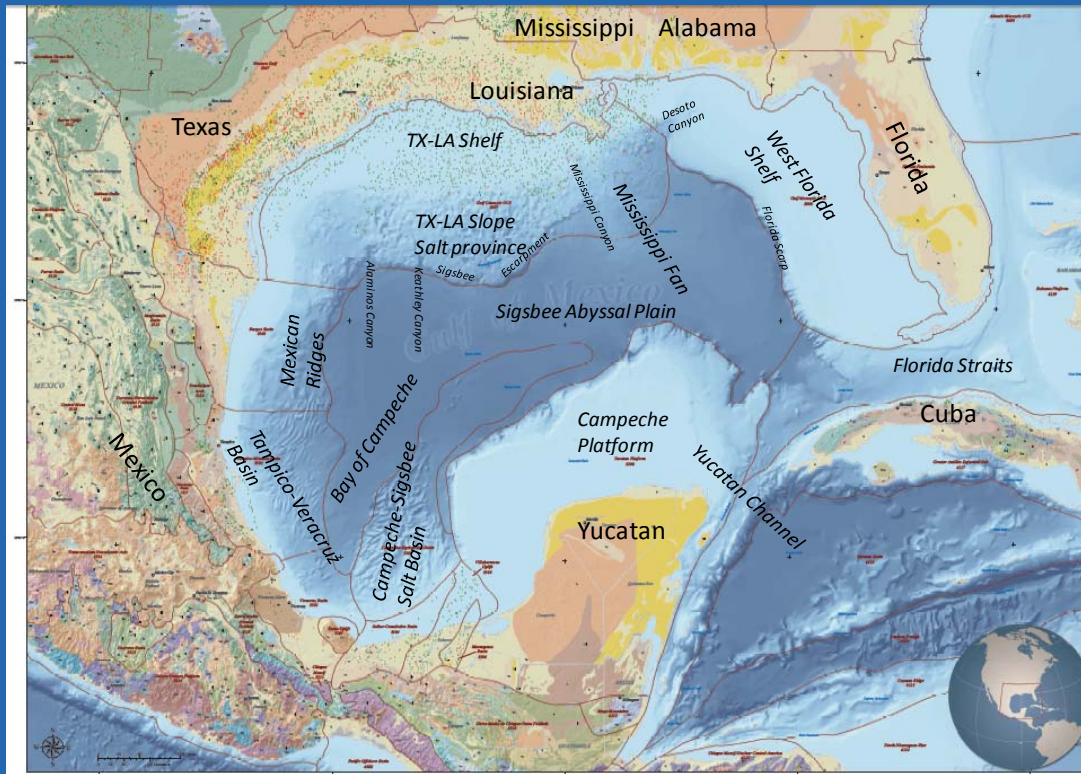
- Non-profit Corporation used to oversee funding under Energy Policy Act of 2005

RPSEA Mission:

- Facilitate cooperative effort to identify and develop new technology for exploring, producing and transporting energy
- Particular focus on –
 - Ultra-deepwater
 - Unconventional natural gas
 - Enabling small producers



RPSEA 1701 – Deepwater IOR Mission and Objectives



- Identify the trapped oil mechanisms and remaining oil-in-place
- Identify IOR Processes for deepwater GoM which could add substantial reserves
- Identify the “technical gaps” preventing application
- Recommend future R&D programs to bridge those technical gaps
- Collaborative effort with Anadarko and LSU

Deepwater Gulf of Mexico Geologic Description

ERA	PERIOD	EPOCH	Ma	
Cenozoic	Quaternary	Holocene	0.01	
		Pleistocene	Late	0.8
	Early		1.8	
	Tertiary	Pliocene	Late	3.6
			Early	5.3
		Miocene	Late	11.2
			Middle	16.4
			Early	23.7
		Tertiary	Oligocene	Late
	Early			33.7
	Eocene		Late	41.3
			Middle	49.0
			Early	54.8
	Tertiary	Paleocene	Late	61.0
Early			65.0	
Mesozoic	Cretaceous	Late	99.0	
		Early	144	
	Jurassic	Late	159	
		Middle	180	
	Triassic	Early	206	
		Late	227	
		Middle	242	
		Early	248	

- Pleistocene / Neogene
 - Age of most deepwater production experience
 - Average RF = 32%
 - Over-pressured, good permeability, modest natural drive energy, highly compacting rocks, limited waterflooding by operators
- Paleogene :
 - No producing experience (Shell, Perdido project recently started)
 - Estimated RF = 10%
 - High pressure and temperature, deep reservoirs, low permeability, poor natural drive energy, complex geology, highly challenging for oil recovery

Size of the Prize

	Neogene	Paleogene	Discovered Total
OOIP (billion STB)	31	25	56
Oil EUR (billion STB)	9.8	2.5	12.3
RF	31.6%	10%	
Remaining OIP (billion STB)	21	23	44
Number of Fields	90	15	105
Number of Reservoirs	450	30	480

Data based on performance of over 90 developed fields and published information from the BOEMRE

Trapped Oil Mechanisms

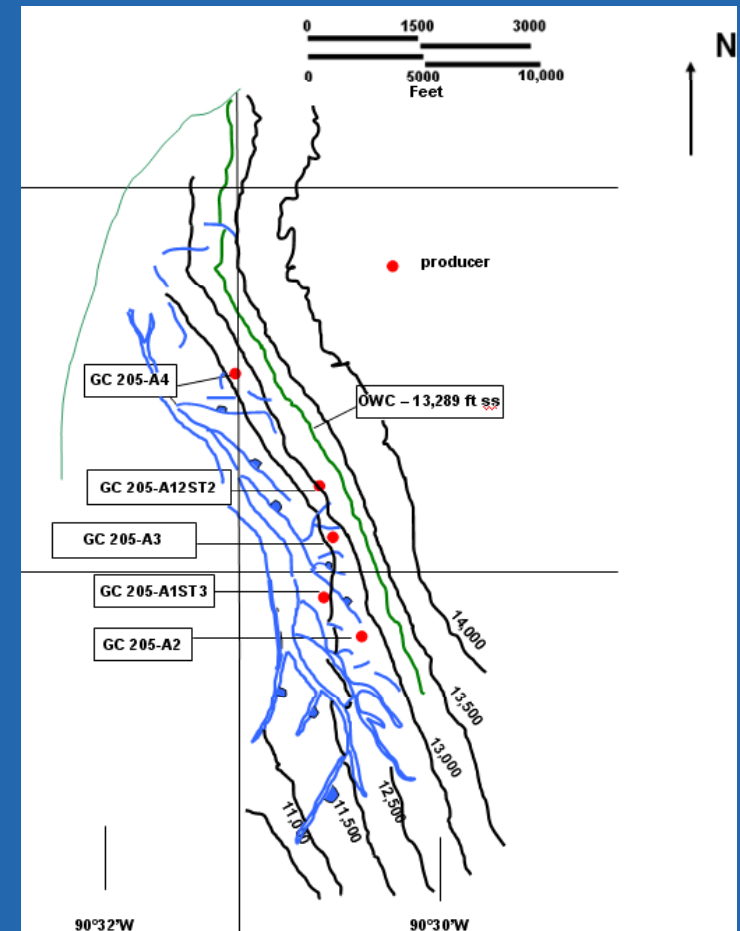
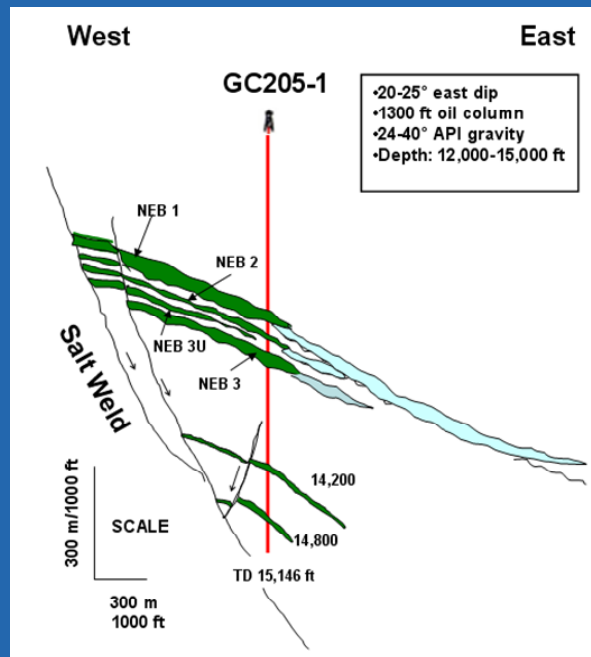
- Non-Connected to Wells
- Capillary Bound
- Poor Sweep Efficiency
- Limited Displacement Drive Energy
- High Abandonment Pressure / Low Water Cut

Workflow

- Volumetric OOIP
- Connected OOIP calculated by sum of well drainage area divided by total hydrocarbon area
 - Volumetrics for each well based on net pay thickness and estimated oil RF
- Capillary bound from published S_{wi} and estimated S_{or}
- Abandonment pressure / low water cut based on average C_t and assumed ΔP reduction of 1000 psi
- ROIP fraction due to “limited drive energy” and/or “poor sweep efficiency”
 - How to split between the two?
- Plotted cumulative % of ROIP versus cumulative water/oil ratio (WOR) for 49 deepwater fields
 - WOR levels defined for minimum aquifer influx (i.e. limited drive energy), moderate and high influx

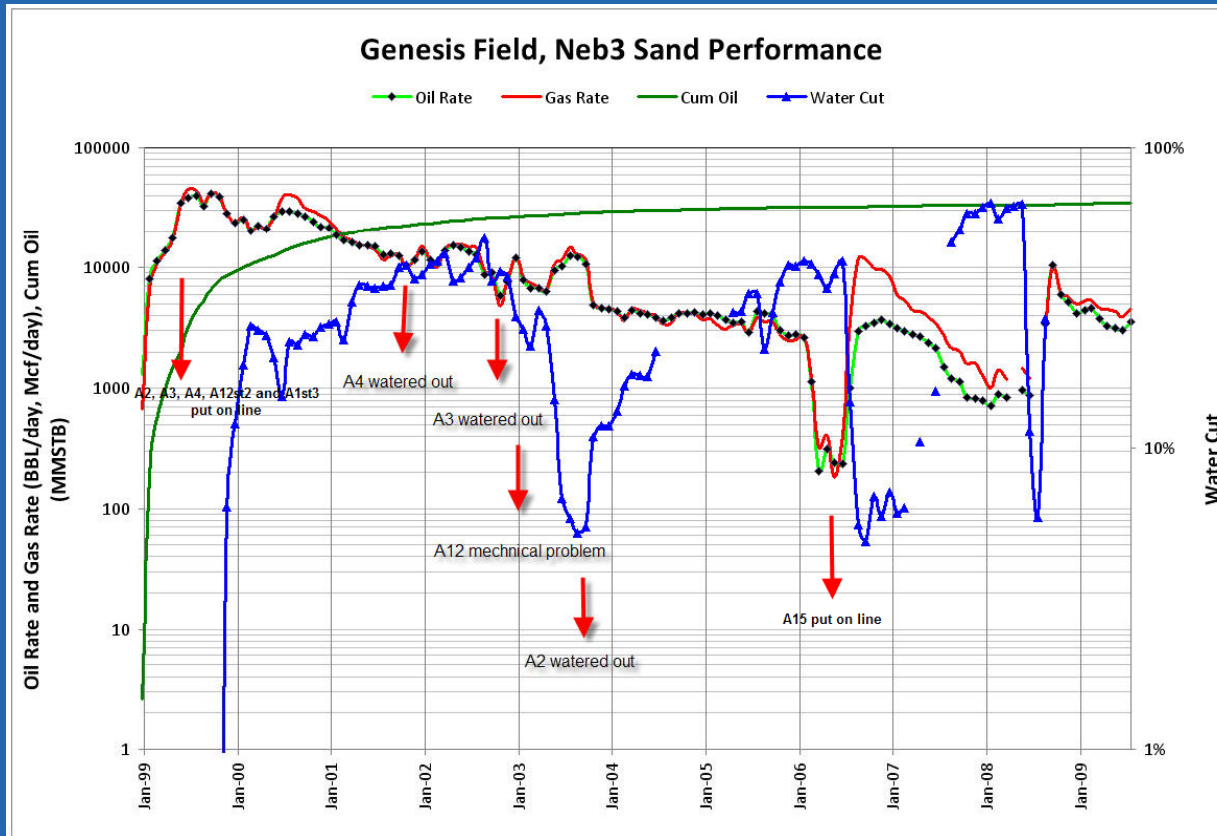
Example: Genesis Field, Green Canyon 160

- Operator – Chevron
- First Production 1999
- Truss Spar
- Stacked Pliocene-Pleistocene age reservoirs
- Channel-fill and channel-levee
- 3 Major oil reservoirs: Neb 1, 2 and 3 Sands



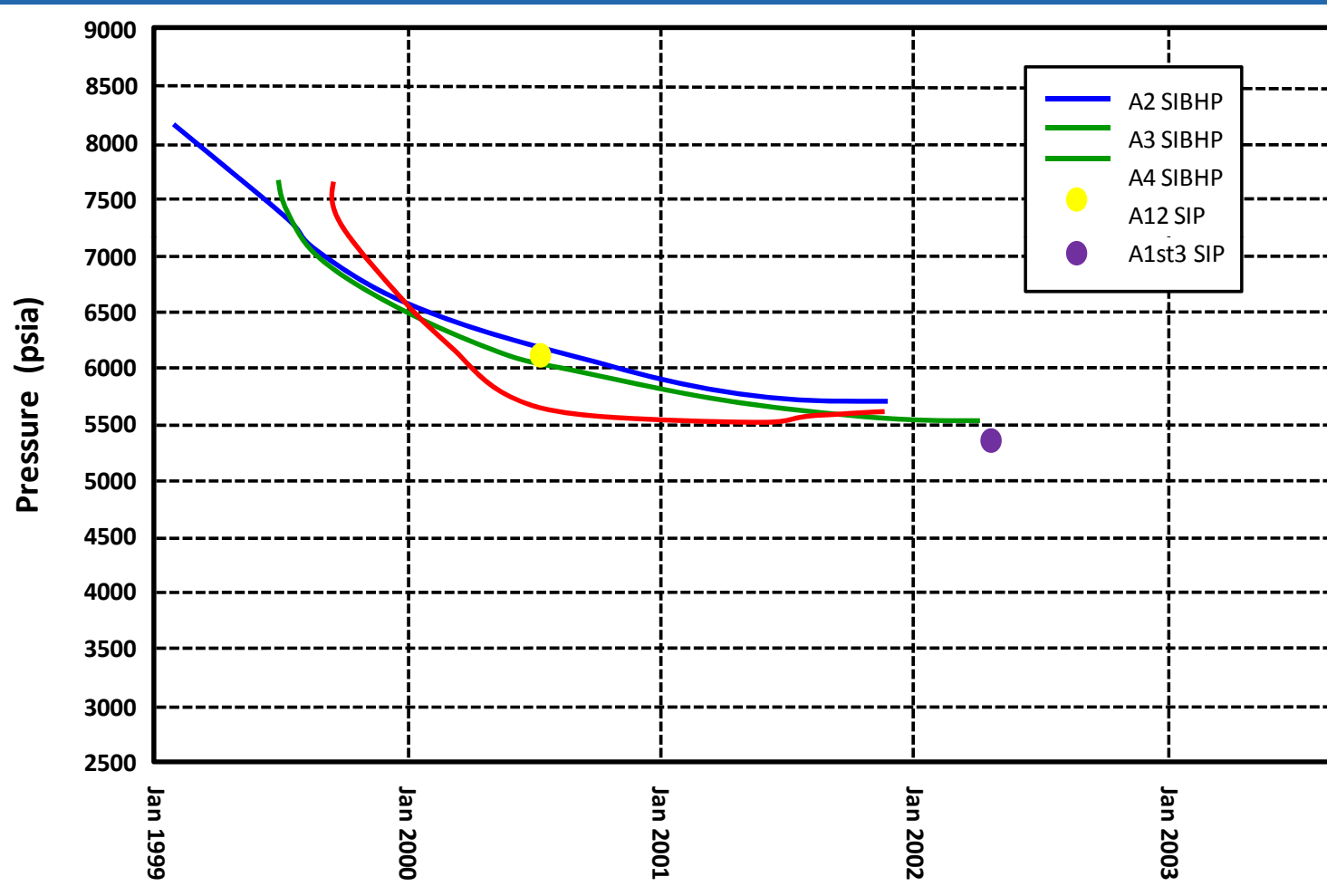
Adapted from Sweet, AAPG 2007

Genesis Neb 3 Sand Production Performance



- OOIP = 94 MMSTB
- 6 Producers
- Peak rate: 41,000 STB/D, 43 MMSCF/D
- Current production rate 3,600 STB/D
- Cumulative at Oct 2009 35 MMSTB and 39 BSCF
- Forecast RF = 40%
 - Moderate aquifer influx
 - Highly compacting rock
 - Good lateral connectivity (Sweet, 2007) (Pourciau, 2003)

Neb3 Pressure History



OOIP Non-connected to Wells

1. Estimated well drainage areas and compared with total reservoir area

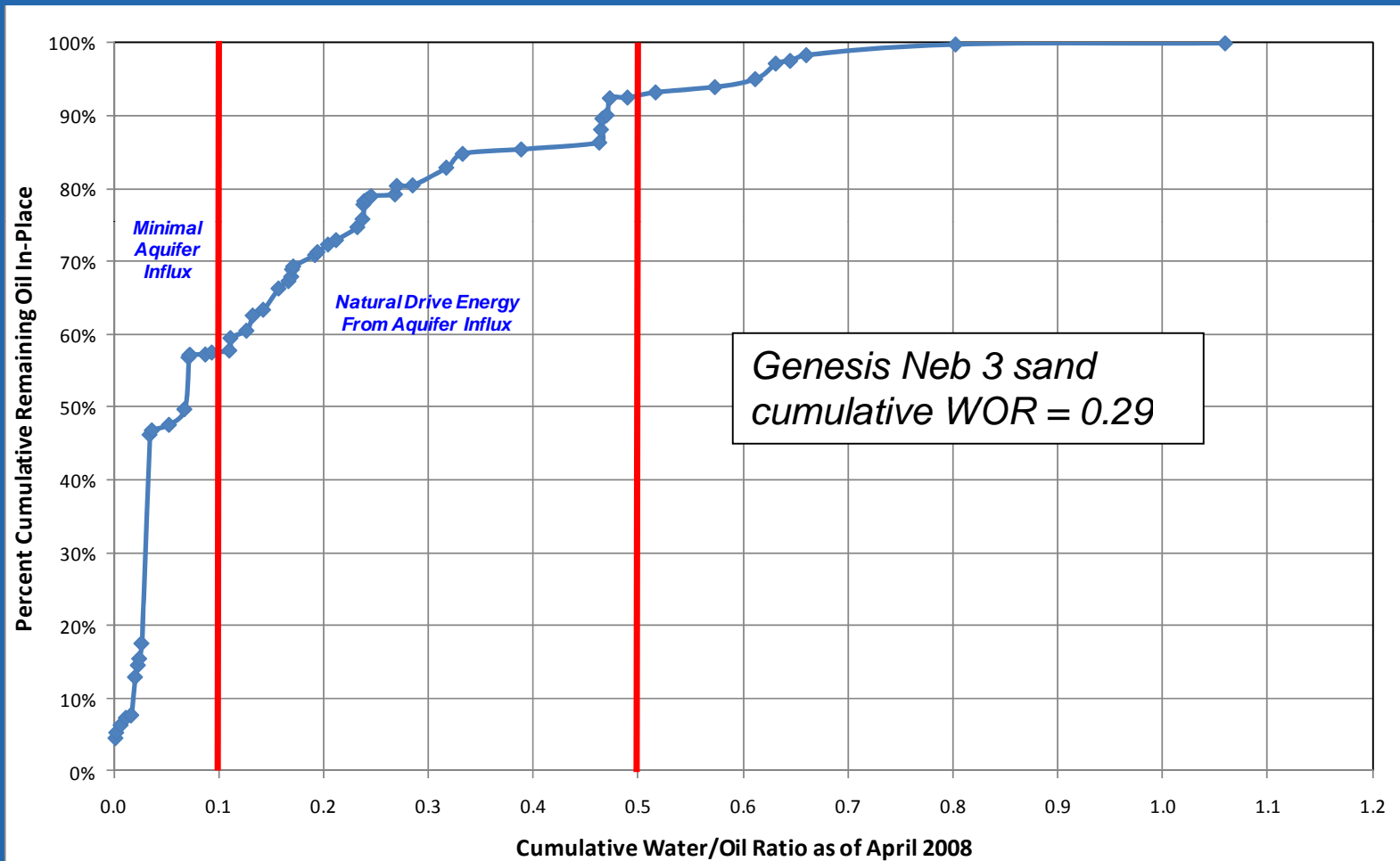
Well	First Production	Current Status	Cumulative Oil Oct-09 (MMSTB)	EUR Oil (MMSTB)	Net Pay Thickness (ft)	Well Area
A1	Apr-02	Prod	6.2	7.4	92	134
A2	Jan-99	Off 2003	16.7	16.7	49	565
A3	Jun-99	Off 2002	6.3	6.3	133	78
A4	Sep-99	Off 2001	2.3	2.3	17	223
A12	Jun-00	Off 2003	3.3	3.3	92	60
A15	Aug-06	Prod	1.4	2.4	15	263
Reservoir			36.2	38.4		1322

2. Connected area is 1322 acre of total 1420 acre
Unconnected Area = 7% of OOIP

Capillary Bound Trapped Oil

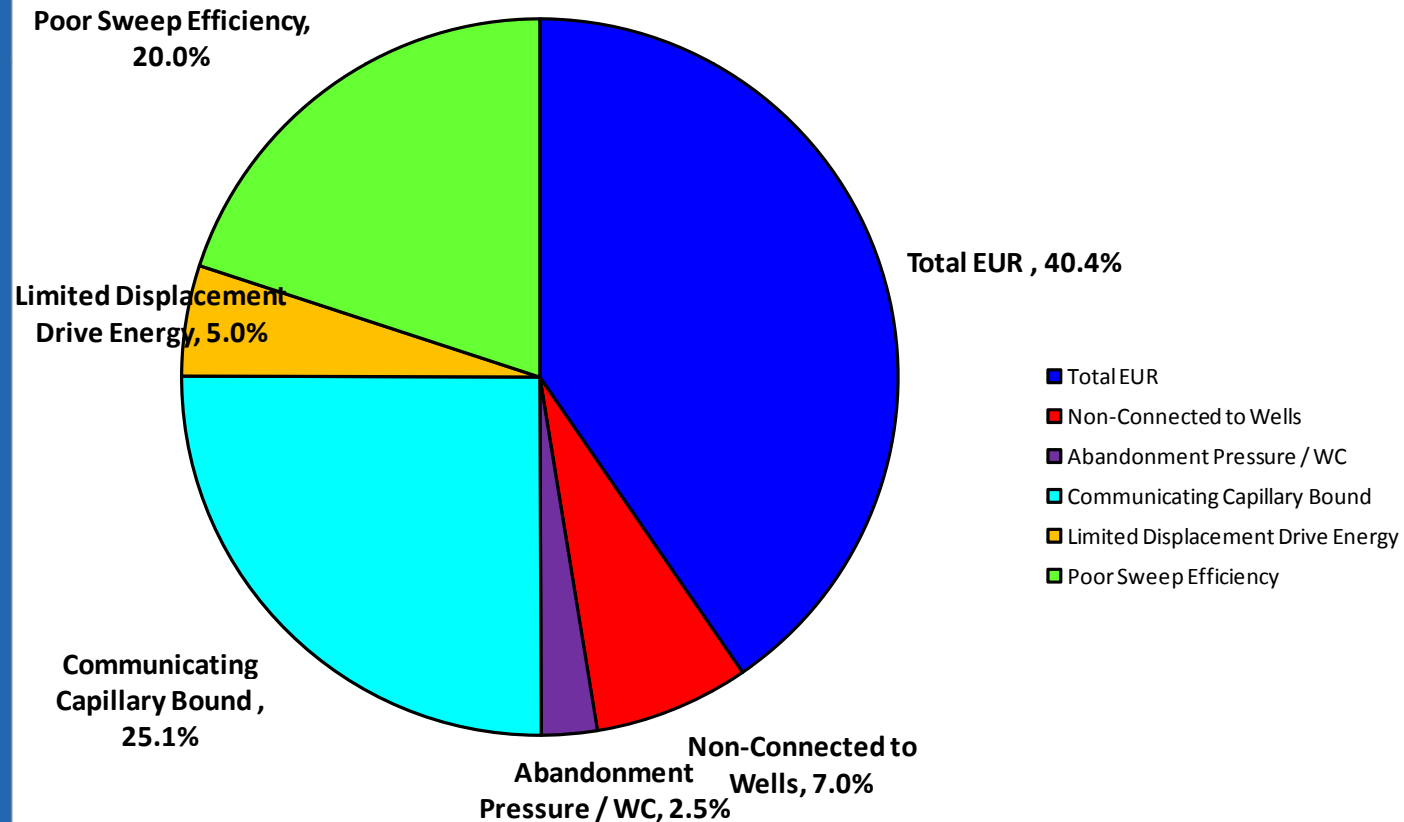
Fluid and Reference Volume	Percent
Residual Oil Saturation as a percent of Reservoir Pore Volume	20%
Average Initial Water Saturation	26%
Initial Oil Saturation	74%
Capillary Bound Fluids (% of OOIP)	27%
Capillary Bound Fluids (% of Connected OOIP)	25%

Water Influx – 49 Fields

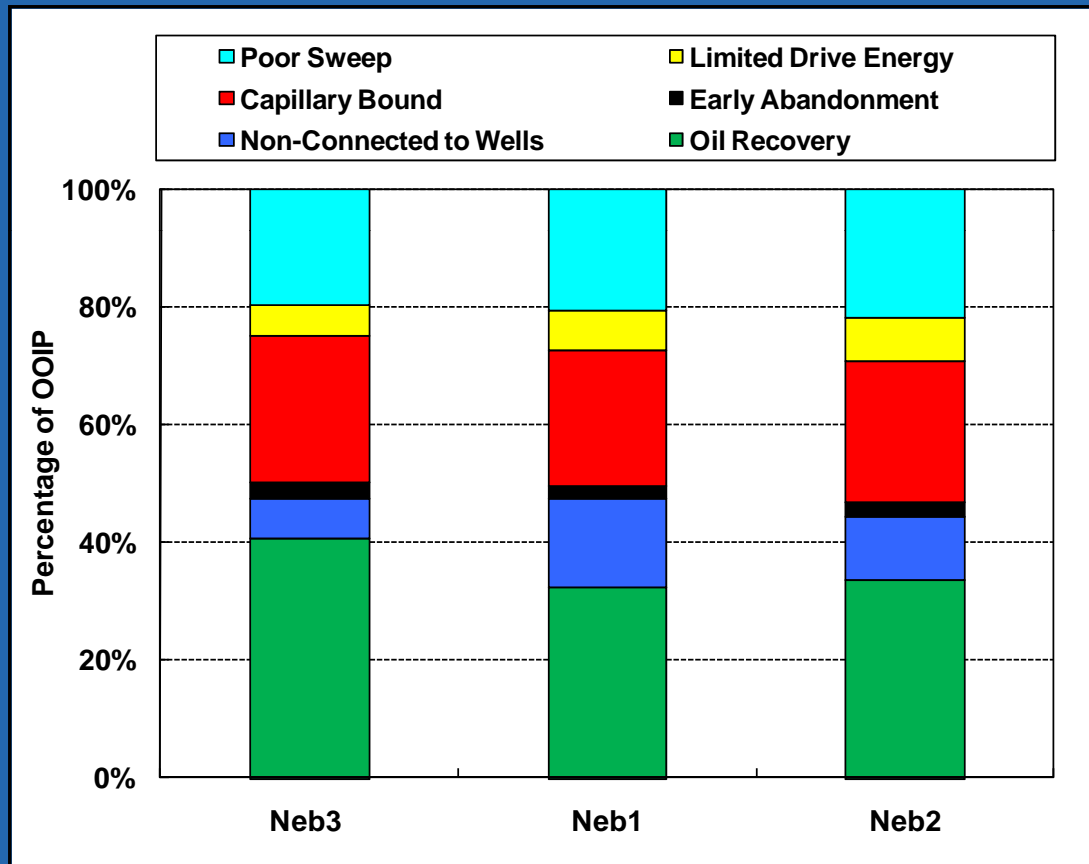


Summary – Neb3 Trapped Oil

Produced and Trapped Oil Mechanisms as Percentage of OOIP
Genesis Neb3 Reservoir



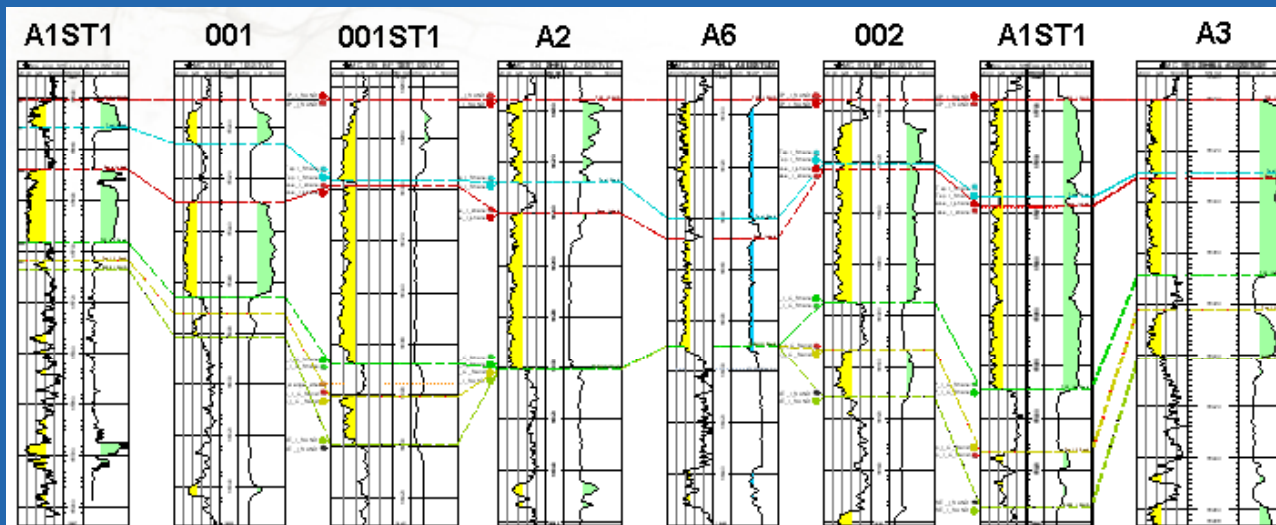
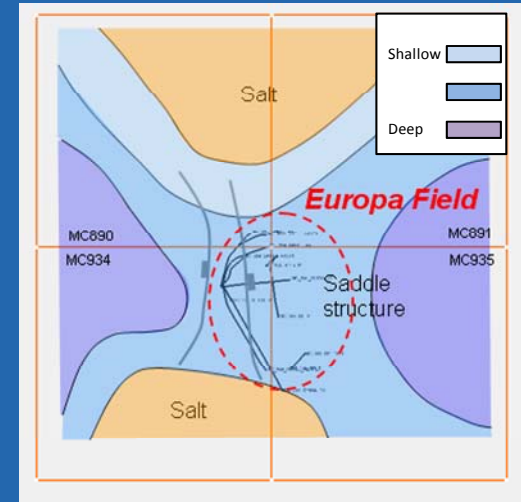
Summary of Genesis Neb Reservoirs



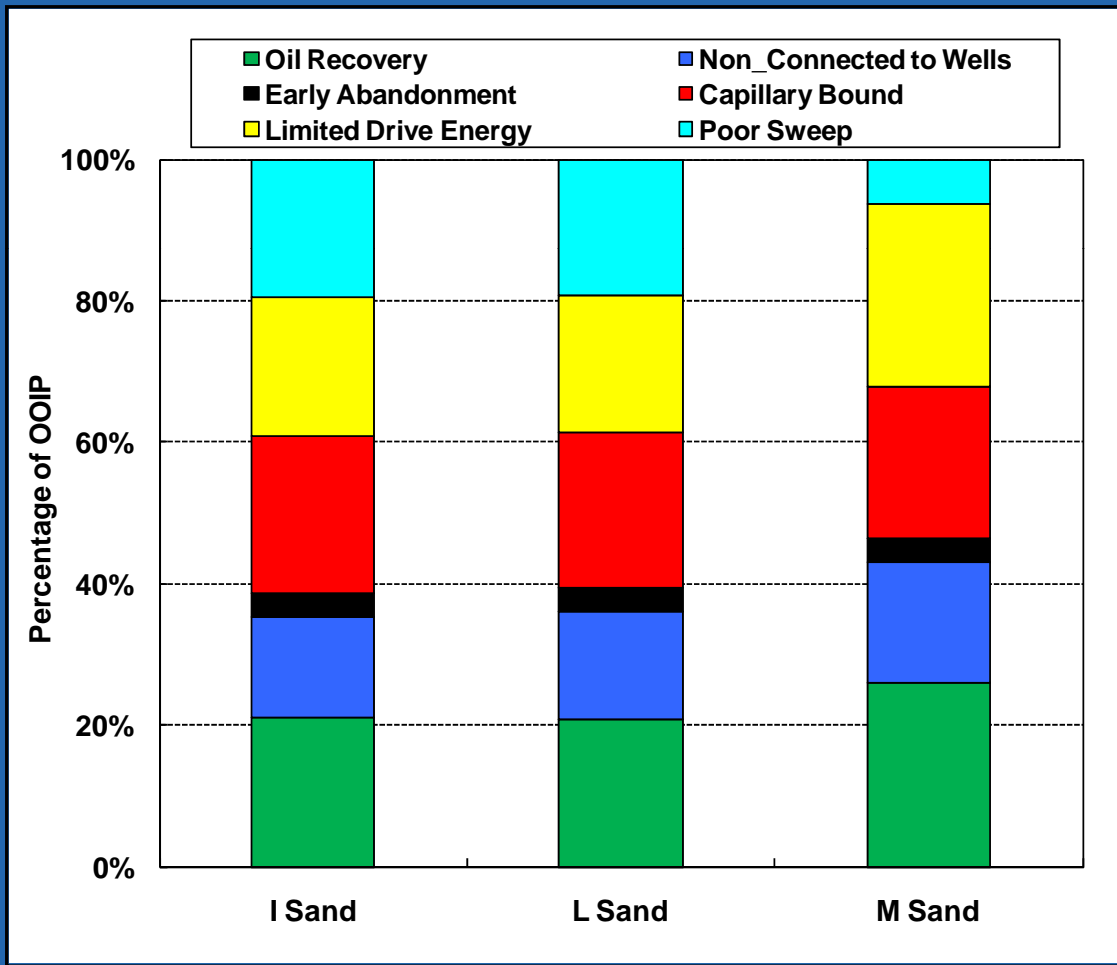
- High primary oil recovery ranging from 33% - 40%
- Moderate aquifer influx and highly compacting rocks
- Combined ROIP target due to poor sweep and limited drive energy is not sufficient for water injection IOR project in deepwater
- IOR projects may need to target capillary bound fluids along with ROIP from poor sweep and limited drive energy

Europa Field, Mississippi Canyon 935

- Operator – Shell, and partners ENI and BP
- First Production Jan 2000
- Subsea tie-back 18 miles to Mars TLP
- Stacked Pliocene to Upper Miocene age reservoirs
- Turbidite sheet sand
- 3 Major oil reservoirs: I, L, M sands



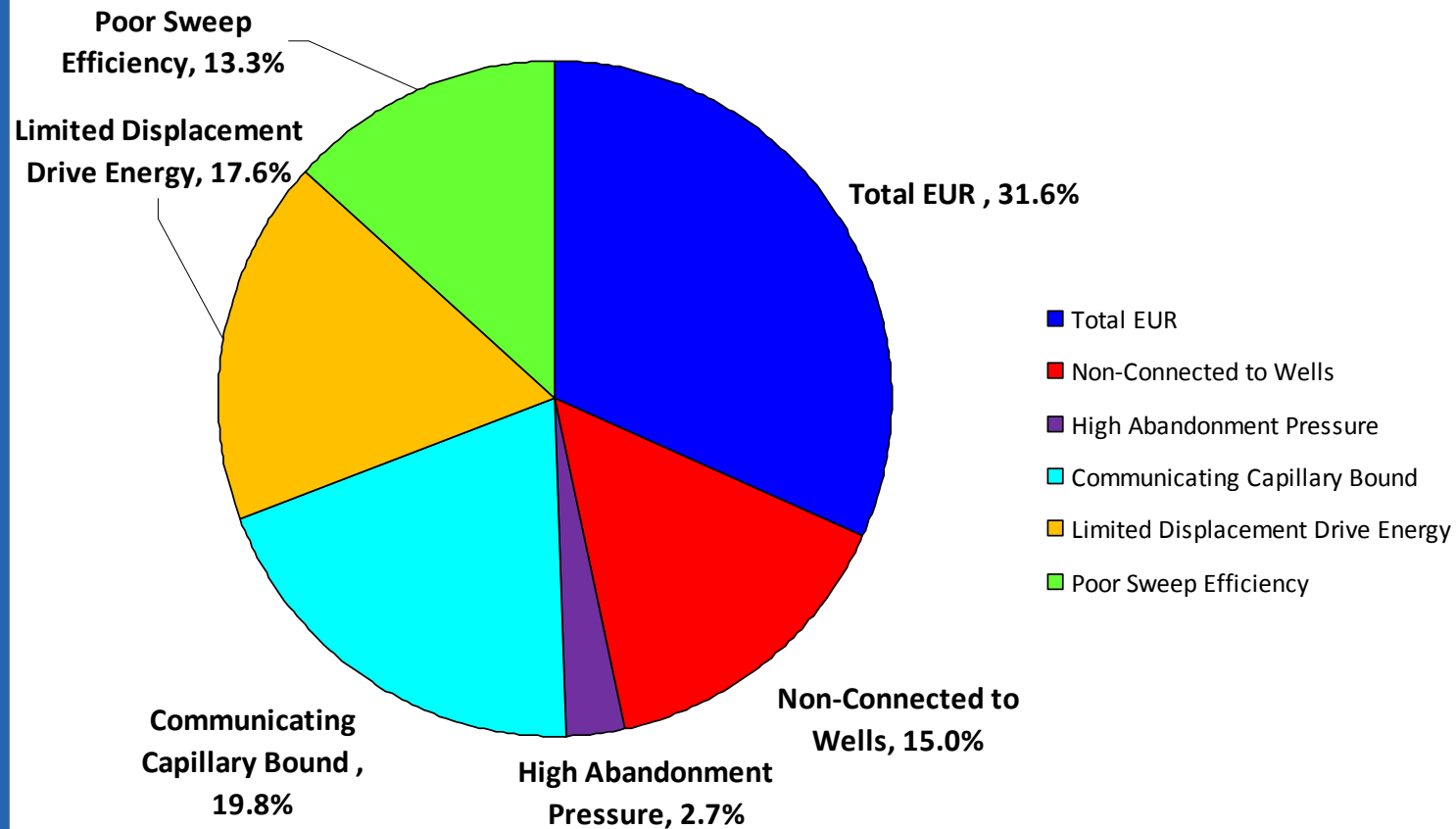
Europa Production and Trapped Oil



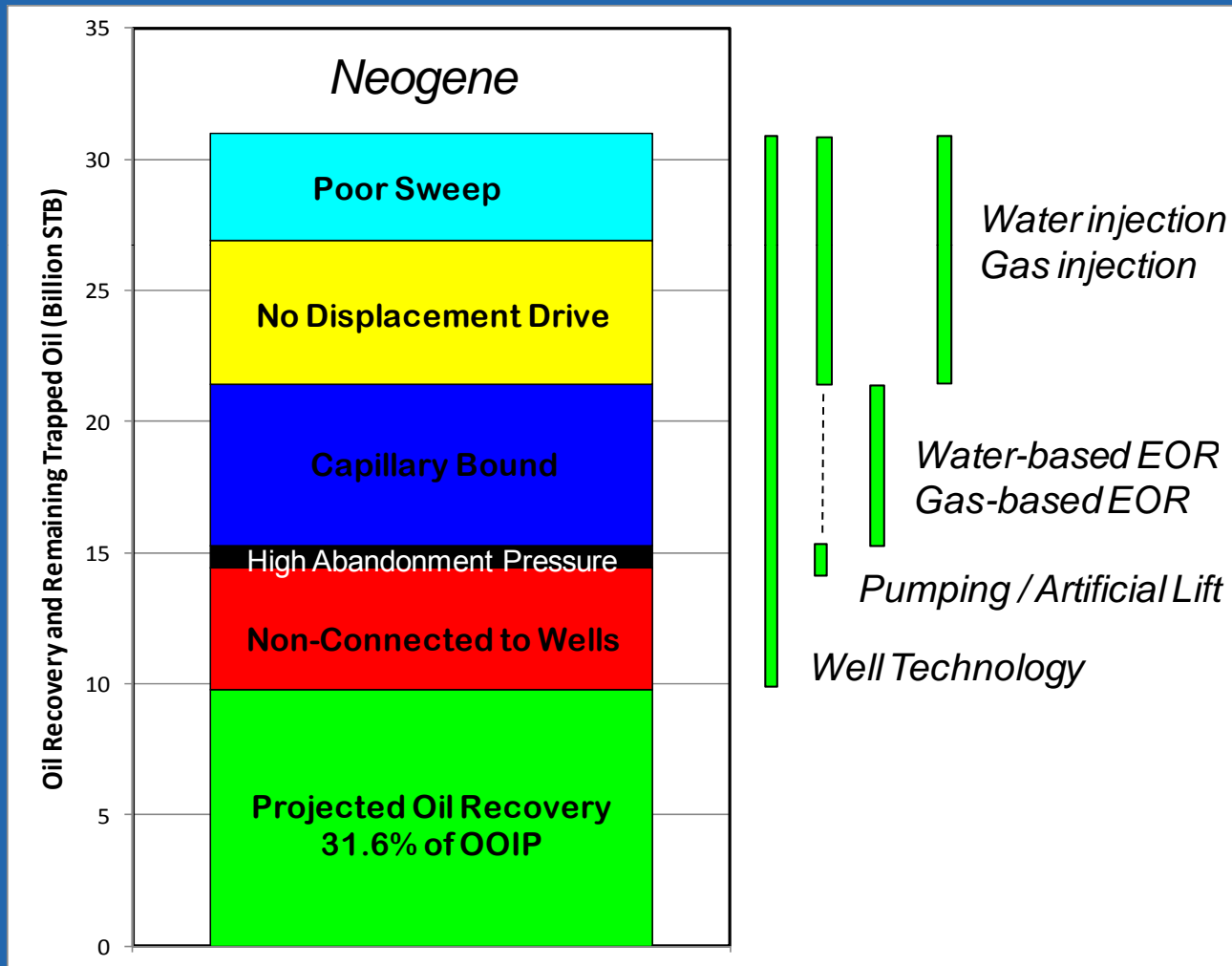
- Low primary oil recovery ranging from 21% - 26%
- Weak to moderate drive energy from aquifer influx
- Estimate large OOIP volume not connected to wells (16%) indicating compartmentalization
- IOR needs:
 - Displacement drive energy from water injection
 - Additional (low cost?) wells to target non-connected volume

Produced and Remaining Oil In-Place All Neogene Reservoirs

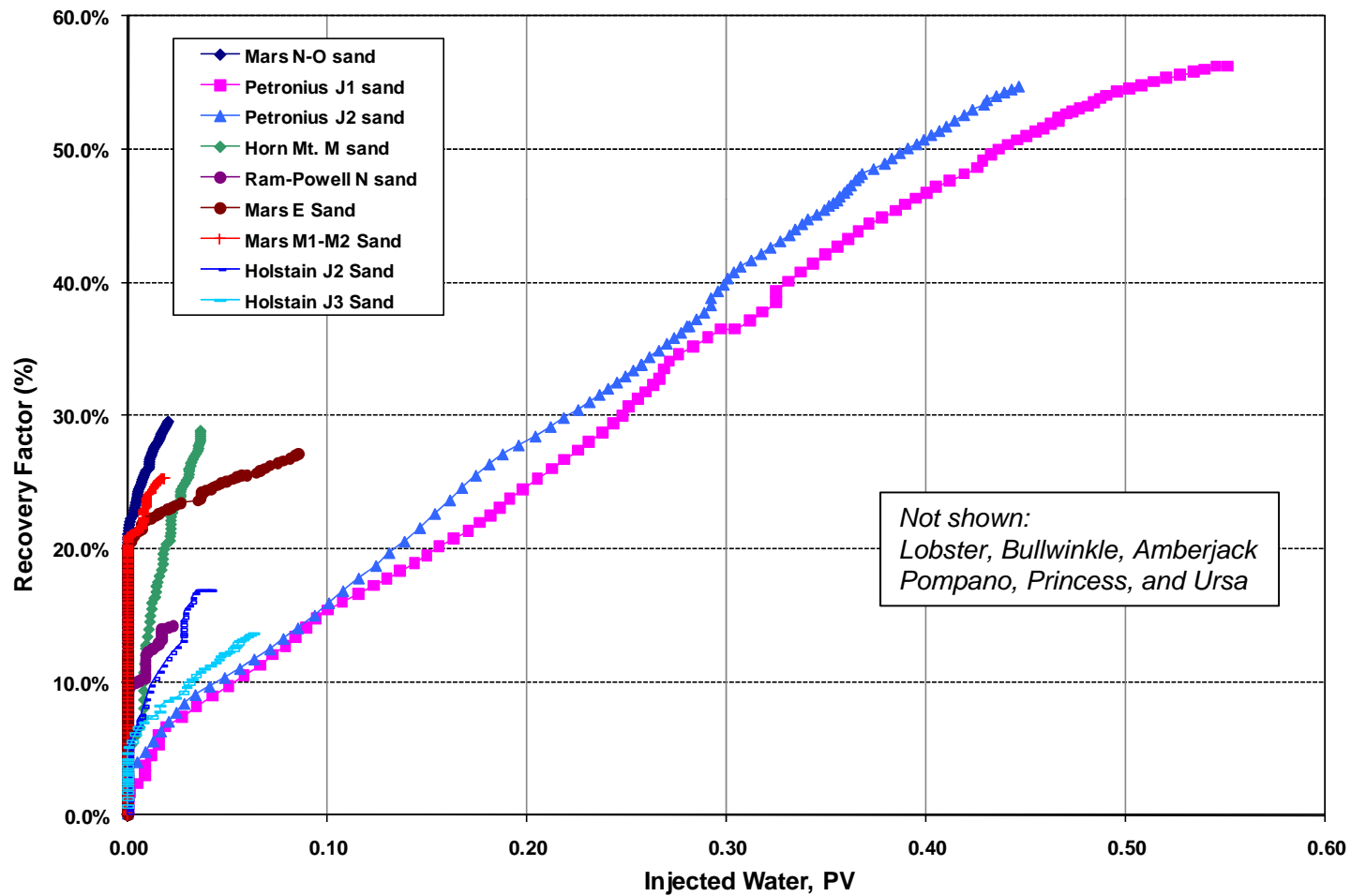
Produced and Trapped Oil Mechanisms as Percentage of OOIP
Deepwater Gulf of Mexico, Neogene Age Reservoirs



Matching IOR themes to Trapped Oil Mechanisms



Water Injection Experience



Conclusions

- Trapped oil mechanisms were reviewed as a precursor to scoping IOR for deepwater Gulf of Mexico
- Oil RF in Neogene reservoirs ranges from 16% - 48% with the P50 of 32%
- Key oil trapping targets for IOR:
 - 31% of OOIP remaining due to limited drive energy and poor sweep
 - 15% of OOIP is isolated and not connected to wells
 - 20% is capillary bound and 3% is left due to high abandonment pressure
- Key IOR themes:
 - Need to add reservoir energy through water injection
 - Need low cost water injection alternative (dump flooding or raw seawater)
 - Lower cost wells and improved reservoir characterization are “Enabling Technologies” and needed for all incremental projects
 - Need hybrid IOR technology to target capillary bound fluid while adding reservoir energy – most promising are LowSal and MEOR due to lower cost