Effective Water Treatment for Optimizing Enhanced Oil Recovery (EOR) Production

MYCELX

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Why EOR?

- Enhanced Oil Recovery can unlock 300 billion additional barrels of oil[1]

- Represents almost $15 Trillion Dollars of what was previously deemed “Non Recoverable” [2]

[1] According to the International Energy Agency
[2] Based upon $50 per barrel

EOR Methods and Challenges

- Energy is typically input into the reservoir in the form of heat (SAGD, CSS) or chemical (polymer, SP, or ASP) introduced into reservoir

- EOR production methods present unique water treatment challenges

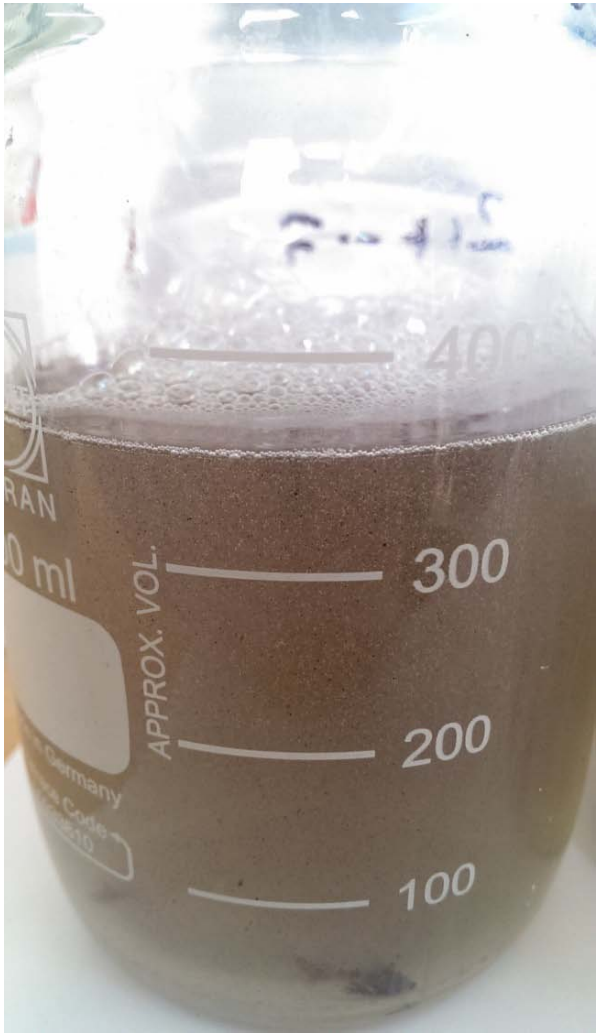
- Water used for EOR has to be properly conditioned so that it is a cost effective process. This requires reliable water treatment.

Chemical Flood Challenges (CEOR)

Polymer Flood, SP, ASP Flood Produced Water

- Requires clean (SOFT) water to effectively hydrolyze the polymer into water phase for re-injection into the reservoir
- Varying viscosities and complex chemical emulsions make water treatment difficult
- Parameters that affect treatment
  - Viscosity
  - Polymer Concentration
  - Oil (type and concentration)
  - T.S.S.
  - pH
  - Surfactant Concentration

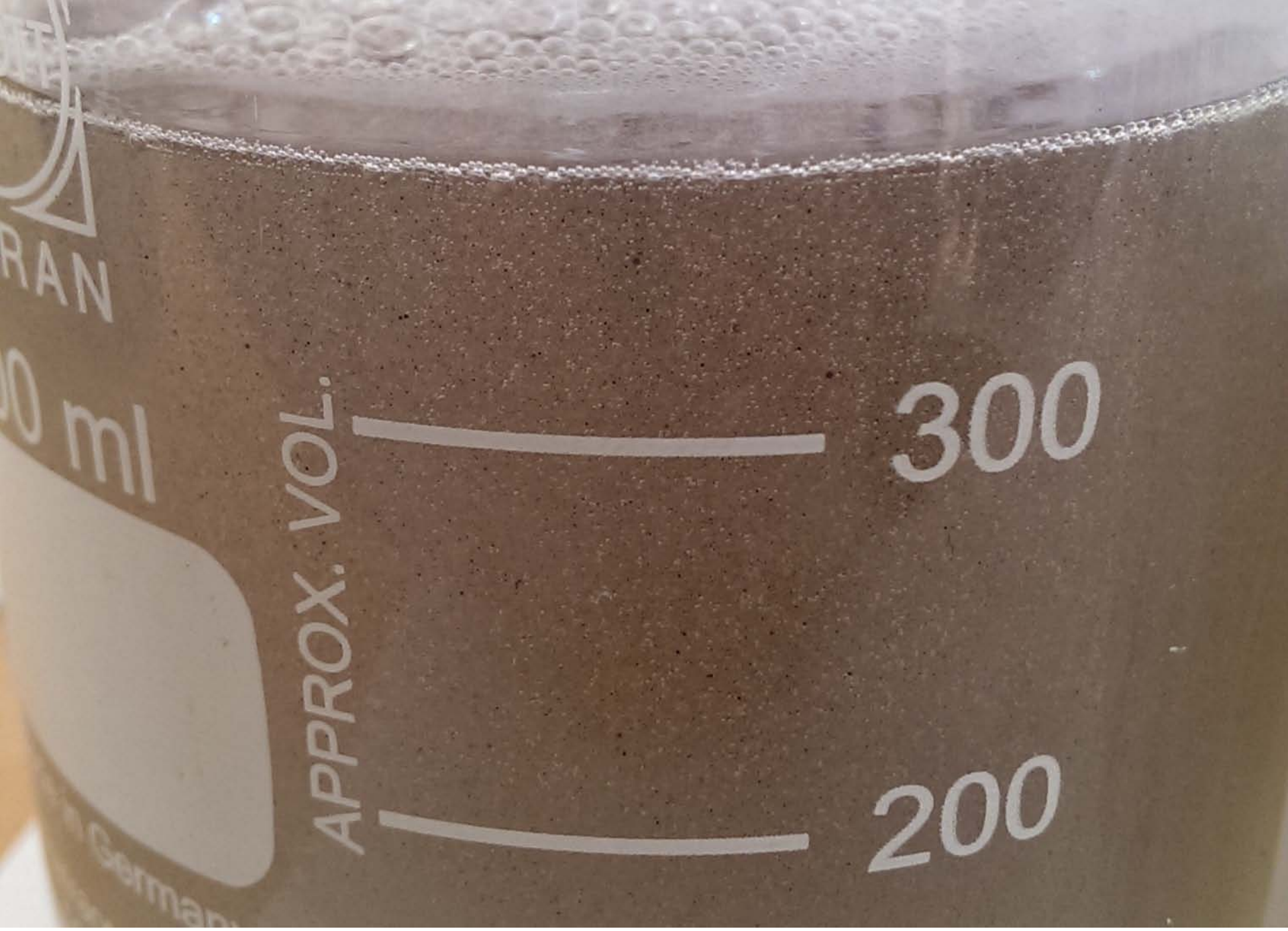
Viscosity Modification Affects Separation of Oil Droplets



- Time required for a 50 micron sized oil droplet to rise approximately 1 foot

Time (minutes)	Viscosity (cP)
37	1
110	3
220	6

- Assume a density of 0.9 g/cm2
  Droplet size of 50 micron



Surfactant and pH Modification

Polymer Injection Issues

Case Study

Site #1

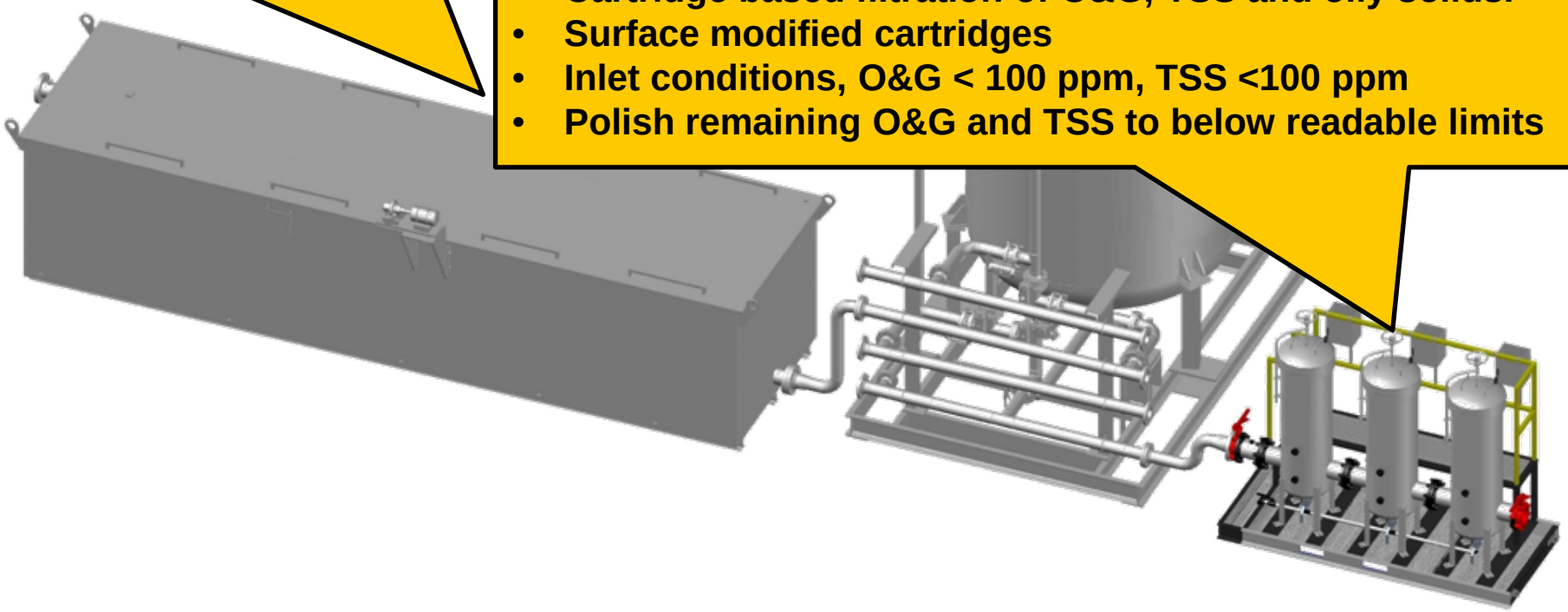
- End User Parameters
  - Inlet OIW: 500 mg/L to 2500 mg/L
  - Inlet T.S.S.: 100 – 400 mg/L
  - Inlet Viscosity: 2 cP – 7 cP
  - Flow Rate (Pilot) – 2800 bbl/day (~ 50 gpm)
  - Oil API = 25 - 27
- Discharge Requirement(s):
  - OIW: less than or equal to 10 mg/L
  - T.S.S.: less than or equal 10 mg/L

System Design

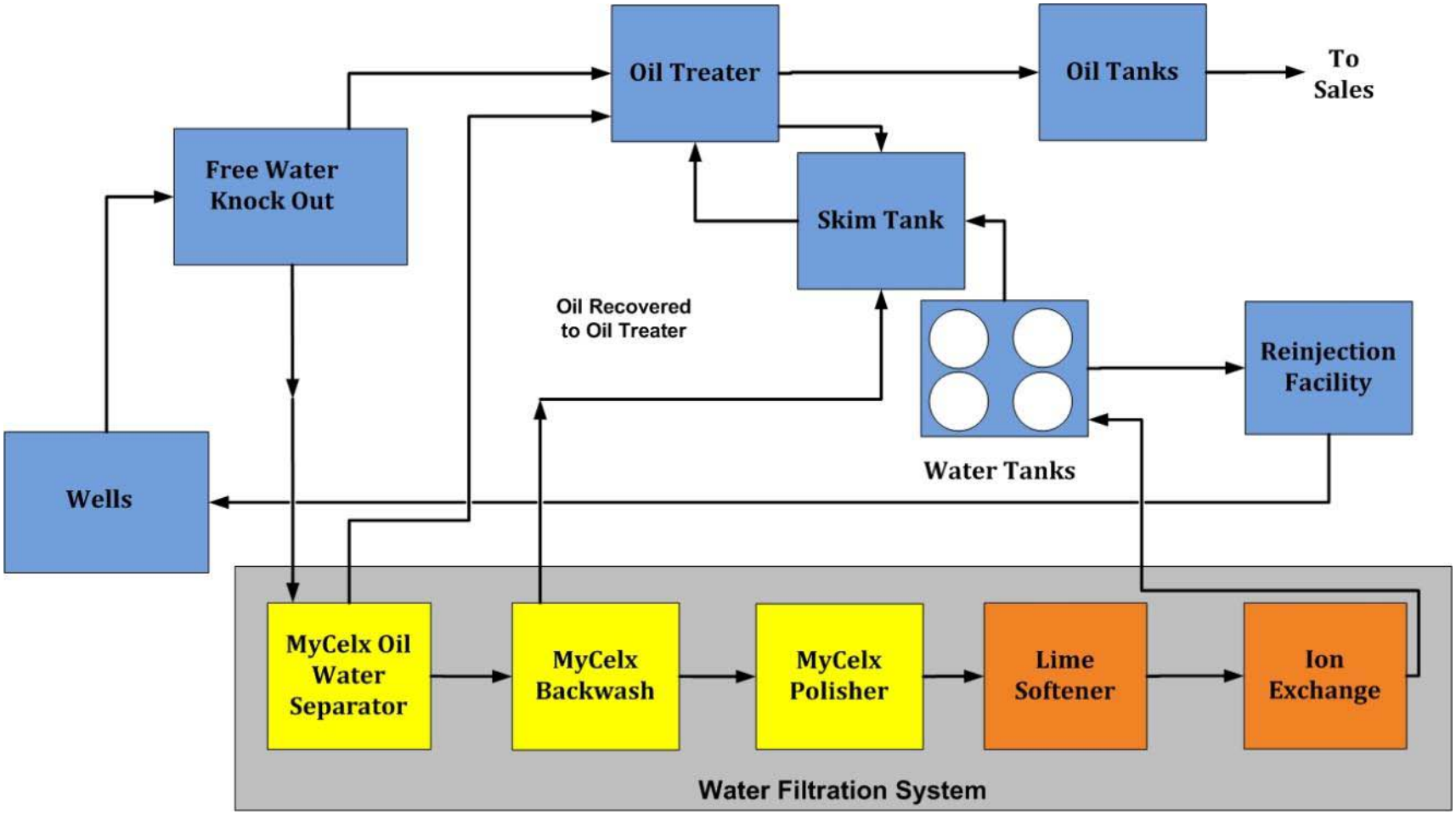
- Separation >50 micron
- Coalescing internals
- Sludge clarifier
- Inlet conditions, O&G <

- Deep bed filtration of O&G, TSS and oily solids.
- Surface modified granular media
- Inlet conditions, O&G < 1,000 ppm, TSS <1,000 ppm
- 95% removal O&G > 5 microns, TSS > 2 microns

- Cartridge based filtration of O&G, TSS and oily solids.
- Surface modified cartridges
- Inlet conditions, O&G < 100 ppm, TSS <100 ppm
- Polish remaining O&G and TSS to below readable limits



Polymer Flood Process Layout

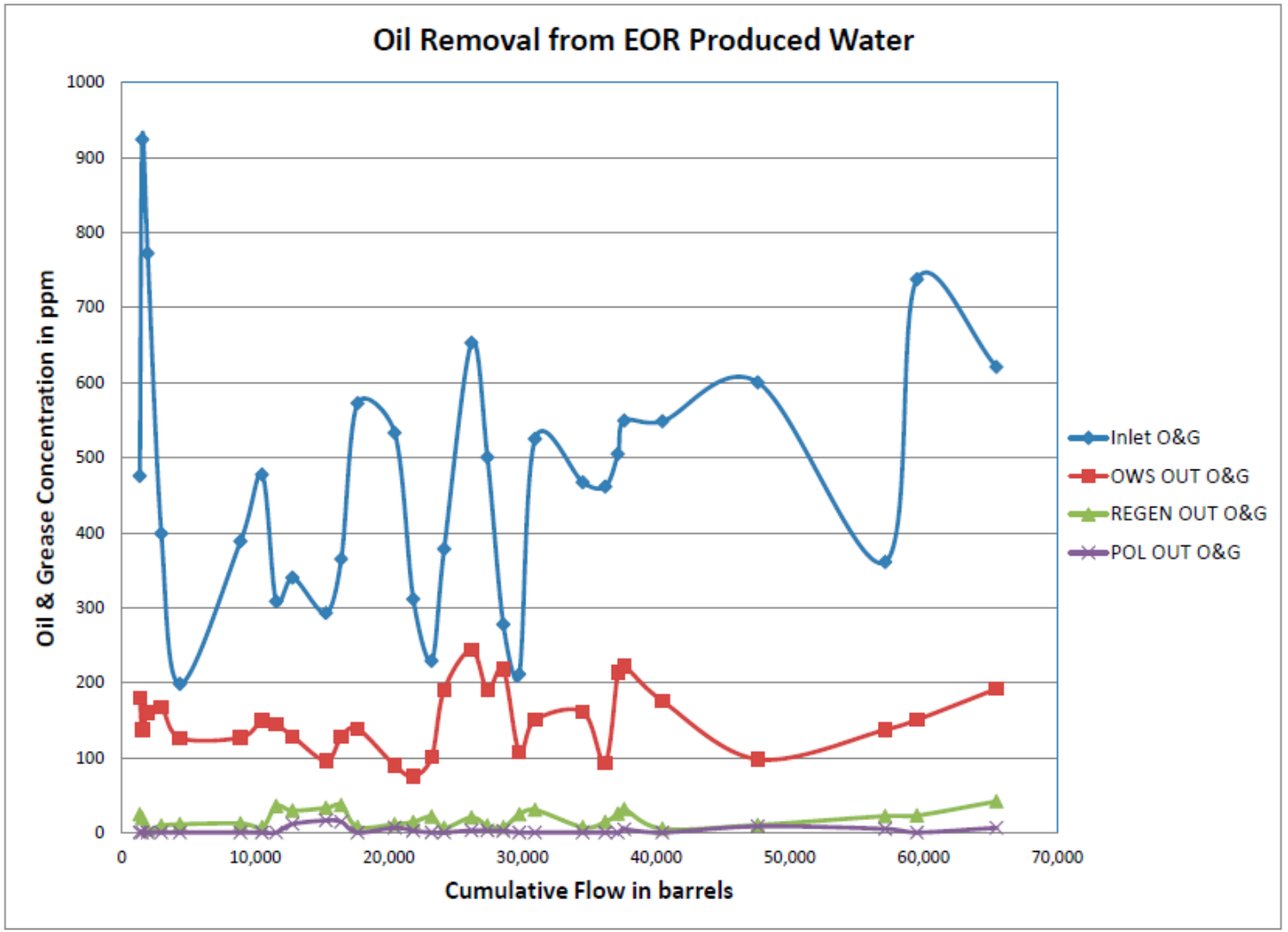


Analysis and Characterization

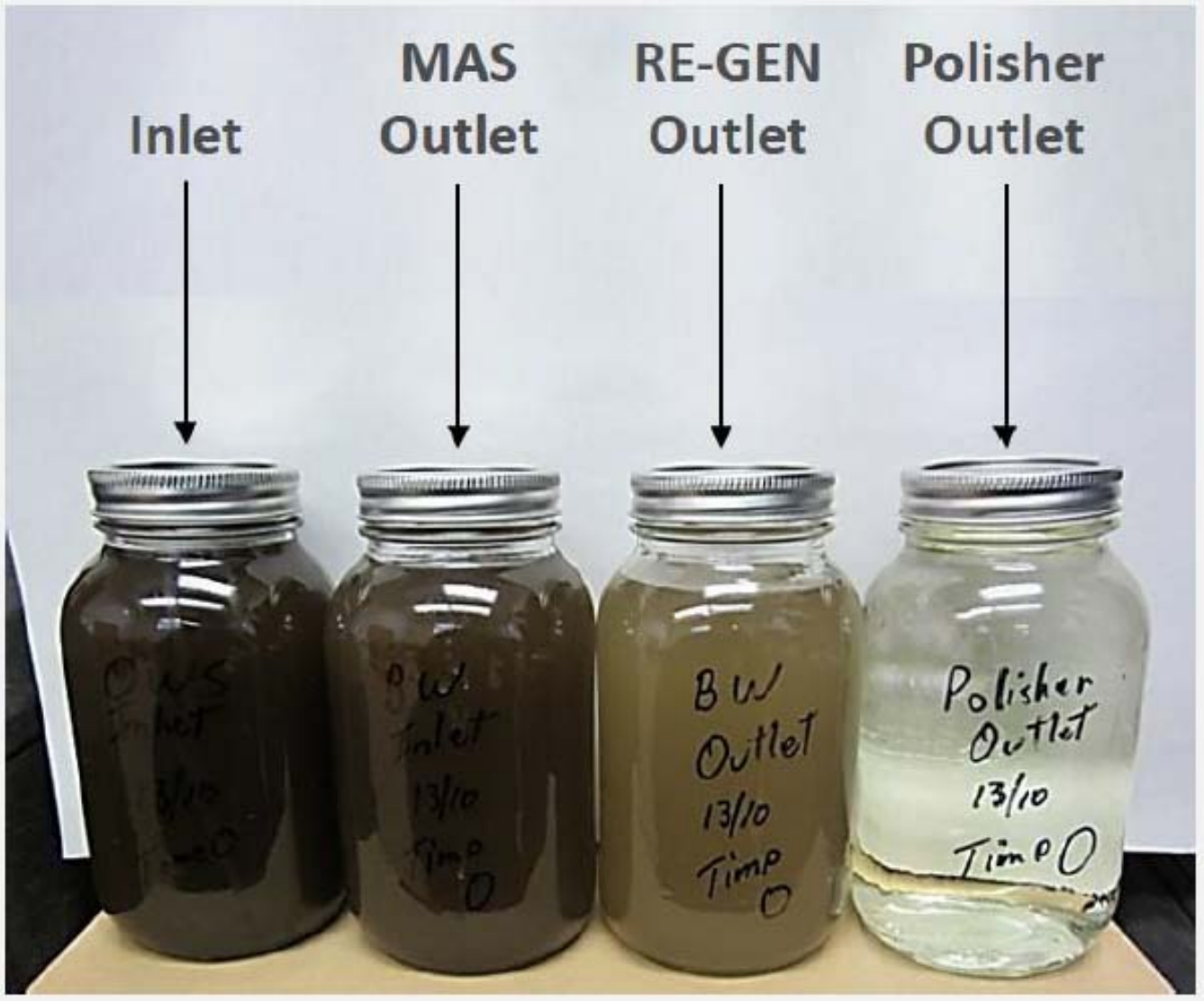
- Onsite Analysis:
  - Hach DR-2800 for OIW and T.S.S.
  - Viscometer: monitor viscosity of produced water

- Third Party Analysis:
  - Gravimetric Hexane Extractions to correlate to onsite O&G readings
  - APHA 2540 D: Total Suspended Solids
  - API RP63 – Residual Polymer Concentration

Field Data



Treatment Samples



Recovered Oil

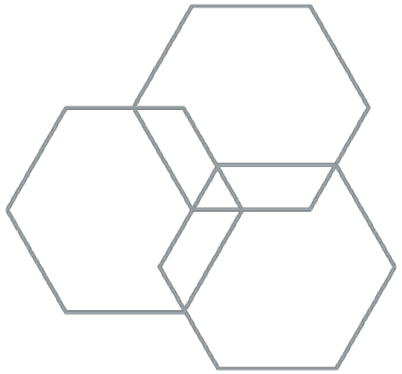
15

Case Study

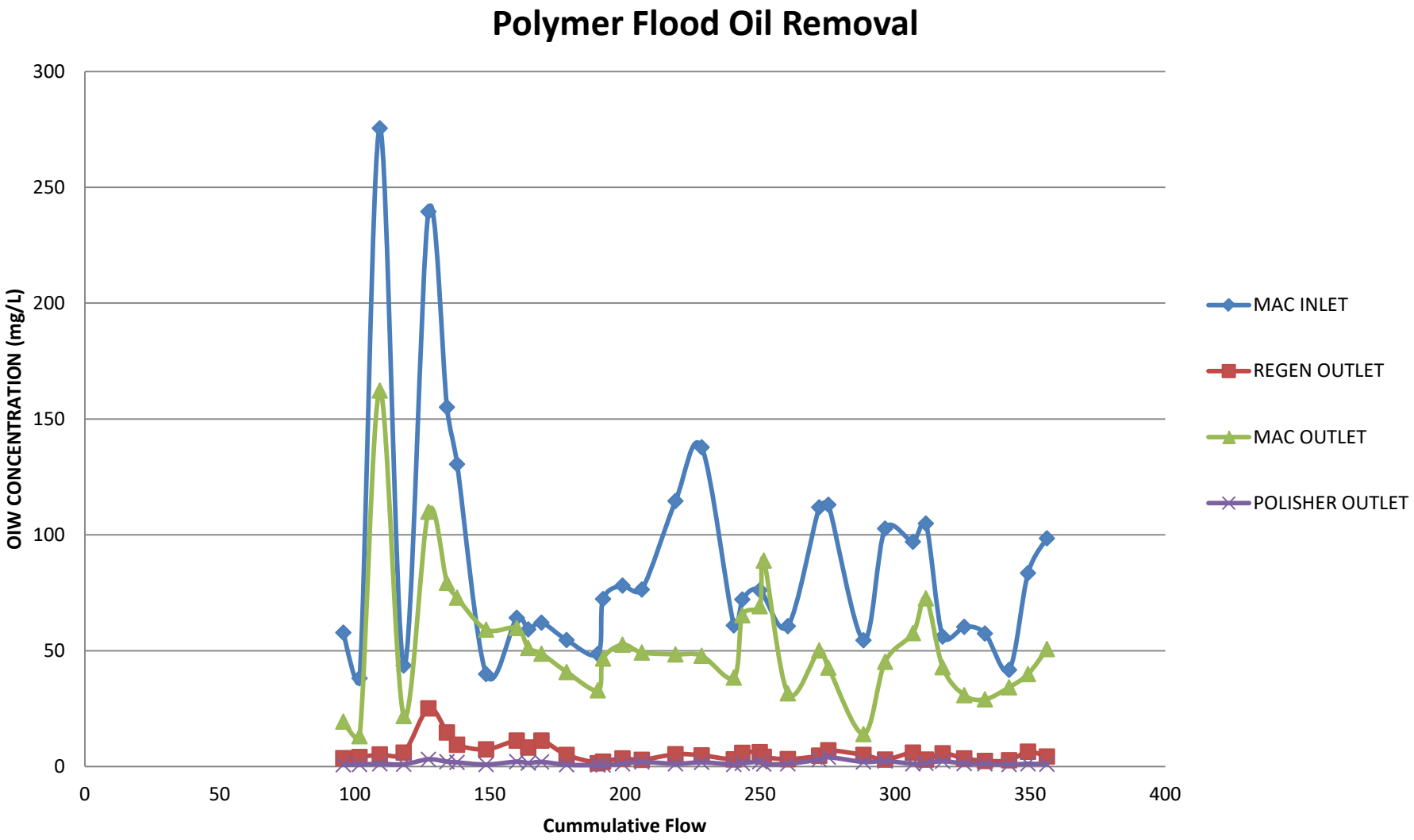
Site #2

- End User Parameters
  - Inlet OIW: 100 – 300 mg/L
  - Inlet T.S.S.: 20 mg/L
  - Inlet Viscosity: 2 cP – 12 cP
  - Flow Rate (Pilot) ~ 25 gpm
  - Oil API = 15 - 17

- Discharge Requirement(s):
  - OIW: less than or equal to 10 mg/L
  - T.S.S.: less than or equal 10 mg/L



Field Data



Field Data

	MIN (mg/L)	MAX (mg/L)	AVERAGE (mg/L)	OVERALL EFFICIENCY
MAC INLET	38.7	275.5	88.2	98.2%
MAC OUTLET	13.1	162.3	56.6	
REGEN OUTLET	1.4	25.1	5.9	
POLISHER OUTLET	0.7	4	1.6	

Field Data, *Cont.*

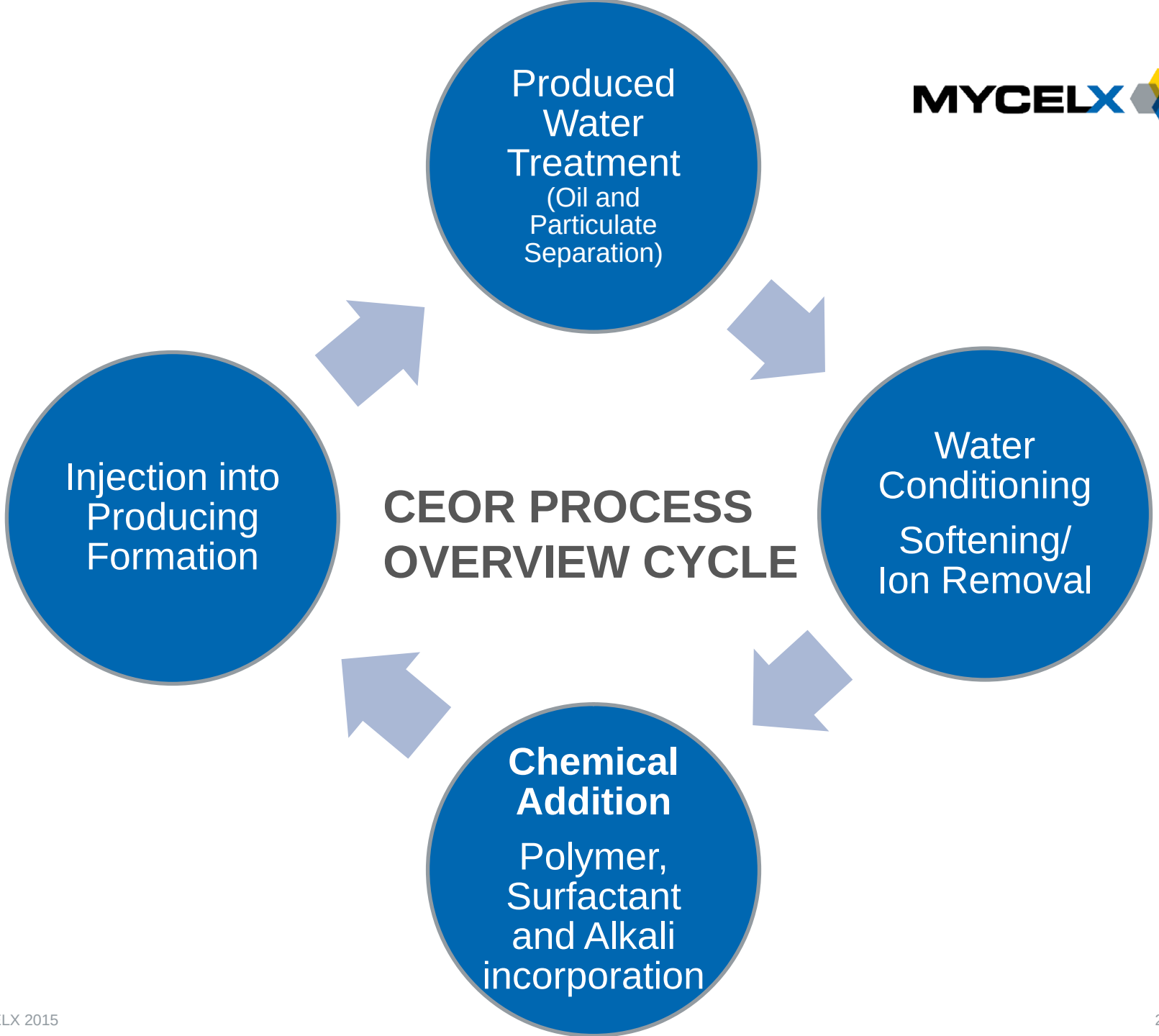
	Oil in Water Readings (OIW) mg/L				Oil Removal Efficiency			Viscosity	Polymer Concentration (mg/L)
	MAC INLET	MAC OUTLET	REGEN OUTLET	POLISHER OUTLET	MAC	REGEN	Polisher	cP	
	275.5	162.3	5.2	1.2	41.1%	96.8%	76.9%	4.7	N/A
	57.4	29	2.4	1.2	49.5%	91.7%	50.0%	8.2	818.6
	98.5	50.7	4.3	1	48.5%	91.5%	76.7%	13.4	1013.35
	84.5	41.2	13.4	5.3	51.2%	67.5%	60.4%	3.4	N/A

Treatment samples

Conclusions

- CEOR relies on the end users ability to appropriately condition the water being used for injection

- Without reliable water treatment most CEOR projects will not be economically viable


Produced Water Treatment (Oil and Particulate Separation)
Water Conditioning Softening/ Ion Removal
Chemical Addition Polymer, Surfactant and Alkali incorporation
Injection into Producing Formation
CEOR PROCESS OVERVIEW CYCLE