First Ever Field Pilot on Alaska's North Slope to Validate the Use of Polymer Floods for Heavy Oil Enhanced Oil Recovery (EOR)

a.k.a Alaska North Slope Field Laboratory (ANSFL) DE-FE0031606

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U.S. Department of Energy - National Energy Technology Laboratory
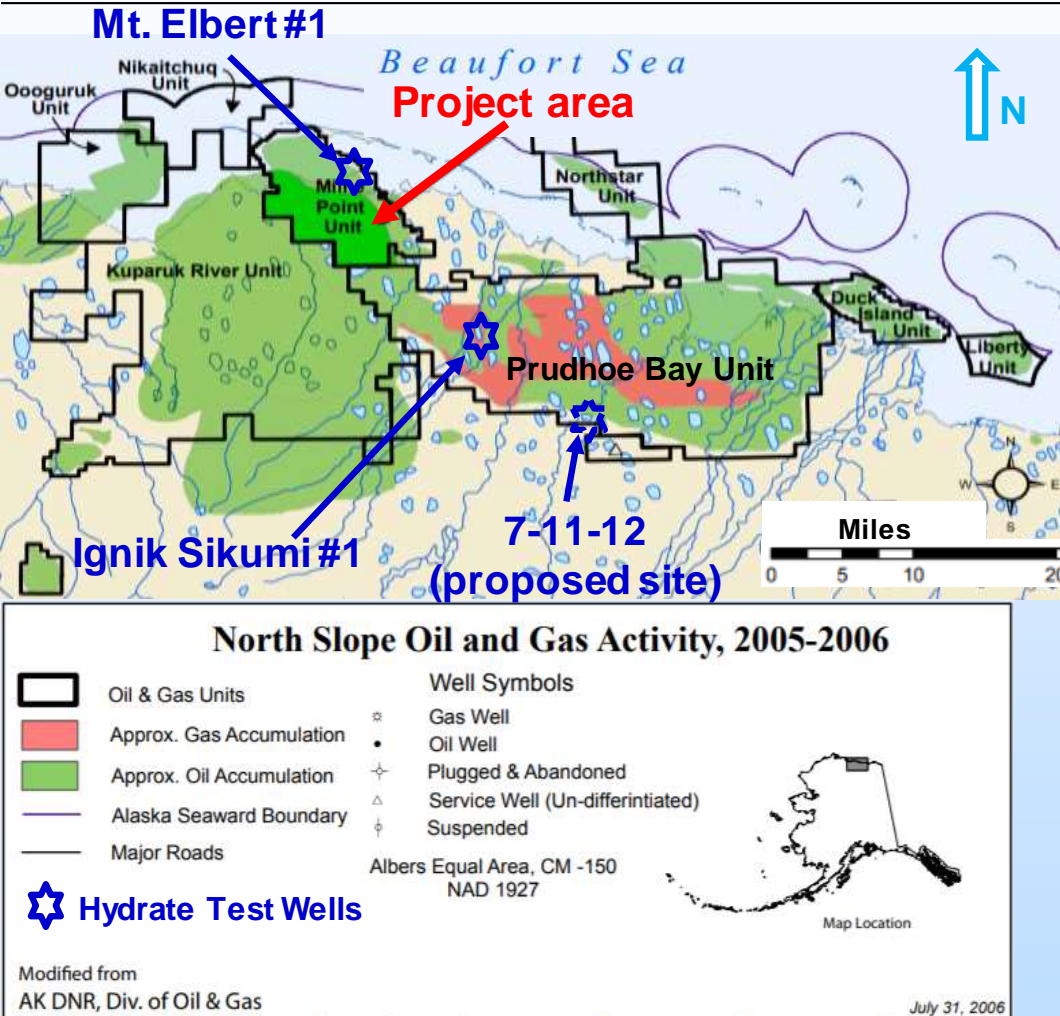
The objectives of the Program are to:

- Identify and accelerate development of economically-viable technologies to more effectively locate, characterize, and produce natural gas and oil resources, in an environmentally acceptable manner.
- Characterize emerging oil and natural gas accumulations at the resource and reservoir level and publish this information in a manner that supports effective development.
- Catalyze the development and demonstration of new technologies and methodologies for limiting the environmental impacts of unconventional oil and natural gas development activities.

August 13-16, 2018

Presentation Outline

- ANSFL Overview

- Review of Test Site Location and Details

- Project Progress – Field Level

- Technical Approach and Status

- Accomplishments to Date

- Synergy Opportunities

- Project Summary

- Appendix

Alaska North Slope Field Laboratory: Project Overview

Mt. Elbert #1

Project area

Beaufort Sea

Ignik Sikumi #1

7-11-12 (proposed site)

North Slope Oil and Gas Activity, 2005-2006

Hydrate Test Wells

Modified from
AK DNR, Div. of Oil & Gas

July 31, 2006

Source: AK DNR, Division of Oil & Gas

- Significant heavy oil resource (20-25 billion bbls); too large to ignore.

- Poor waterflood sweep due to mobility contrast.

- Limitation of deploying thermal methods due to "permafrost".

- Light crude diluent still available for high viscosity oil transport through Trans Alaska Pipeline System.

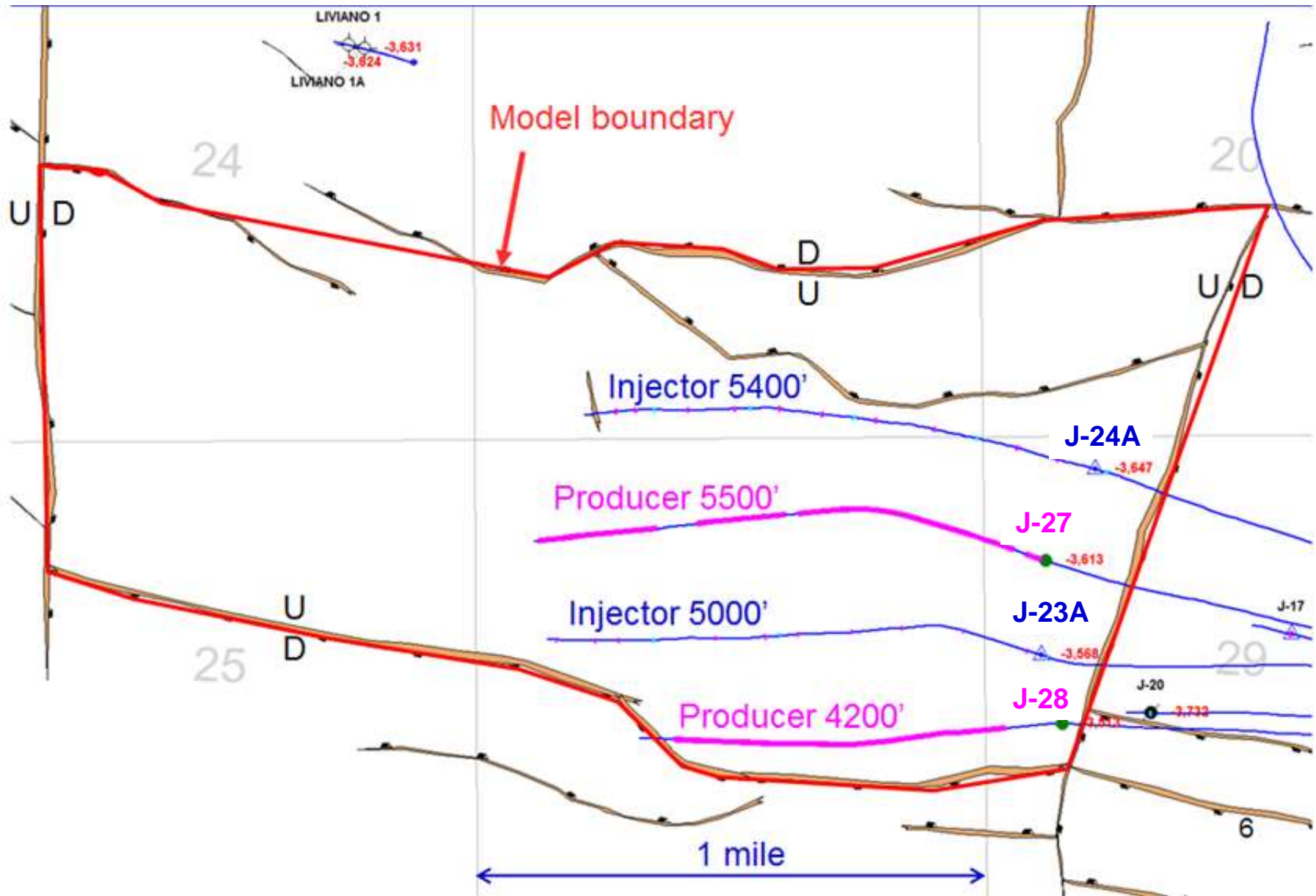# Comprehensive $9.6 million Research Program over Four Years

- High probability of success
  - ✓ Polymer flood has been proven effective in Canada and China
  - ✓ Need to figure out implementation details and quantify benefits on ANS
  - ✓ Synergy effect of polymer, low salinity water, horizontal wells, and conformance treatments

- Joint efforts among government, academia, and industry
  - ✓ Integrate lab work, reservoir simulation, field pilot performance, injection conformance and flow assurance studies in an iterative optimization process
  - ✓ Disseminate learnings from the pilot project across the industry (AAPG, SPE, URTeC etc.)

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Test Site and Reservoir

Beaufort Sea

TEST SITE
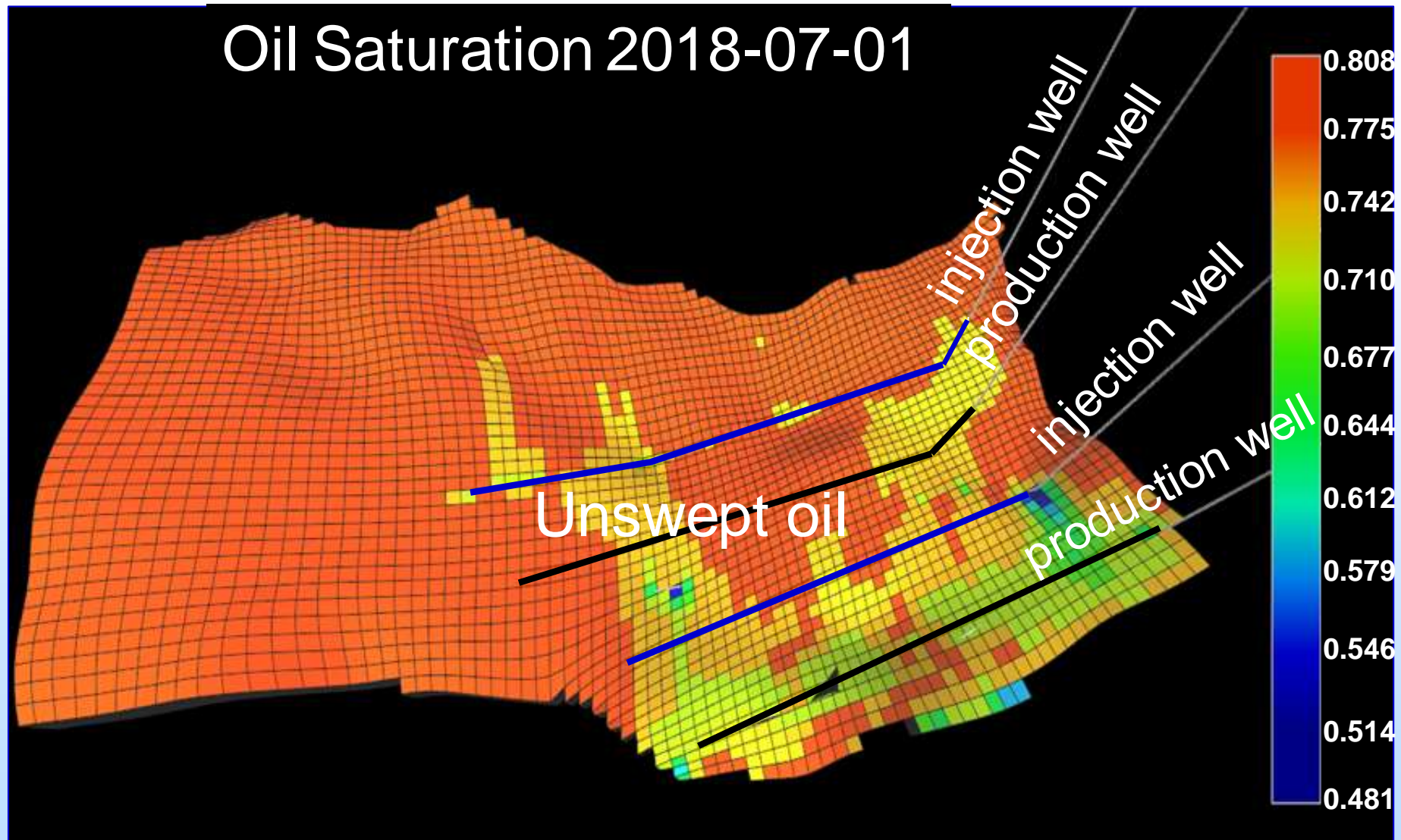
Milne Point Field

5 miles

N
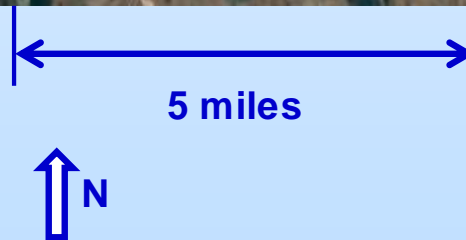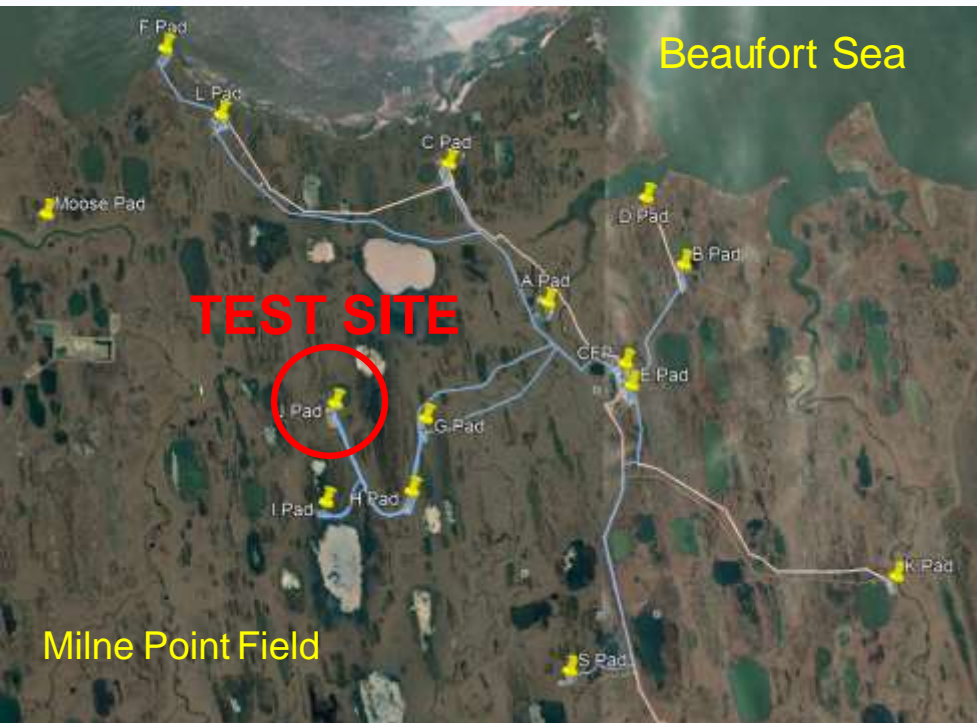
- Milne Point (MPU), 30 miles NW of Prudhoe Bay.
- Schrader Bluff formation, Porosity: 31–35%, Permeability: 100–3,000 mD.
- Low reservoir temperature: ~70°F.
- Oil API: ~15 with in-situ oil viscosity of 330 cP.
- Low salinity source water: 5,000 ppm.

Horizontal Well Patterns
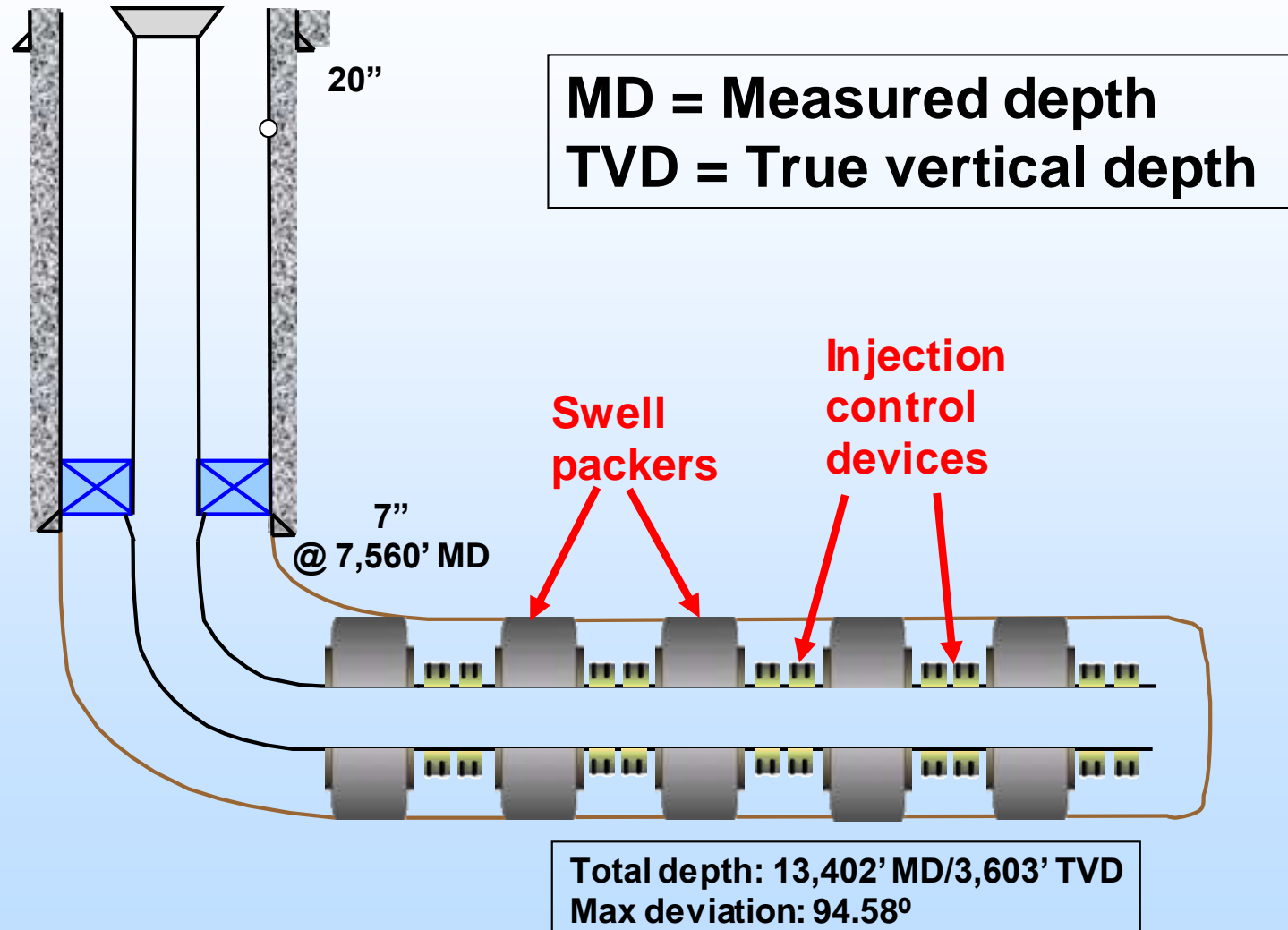
Poor Waterflood Sweep

Oil Saturation 2018-07-01

injection well
production well
injection well
production well

Unswept oil

0.808
0.775
0.742
0.710
0.677
0.644
0.612
0.579
0.546
0.514
0.481

Injection Wellbore Schematic

20"

MD = Measured depth
TVD = True vertical depth

Swell packers

Injection control devices

7" @ 7,560' MD

Total depth: 13,402' MD/3,603' TVD
Max deviation: 94.58º

Project Progress Since June 1 – Field Level

- Initial polymer selection: SNF Flopaam™ 3630, 100 super sacs already on site. Each sac contains 1650 lbm of polymer (~ 1 day of injection).

- Polymer equipment installation and testing completed.

- Pre-polymer tracer test, pressure fall off test completed, injection profile log soon.

- Polymer injection targeted to start mid August.

Polymer Injection Unit

Technical Approach and Status

*No large scale polymer projects in the US, and many unresolved issues that need to be addressed via:*

- Laboratory corefloods
  - optimization of injected polymer viscosity/concentration, quantification and retention.
  - optimization of injection water salinity and identification of conformance control strategies.

- Reservoir simulation
  - history matching (HM) of laboratory corefloods, waterfloods.
  - optimization of the polymer injection strategy for the project reservoir.
  - scale up to full field oil recovery from polymer injection.

# Technical Approach and Status

- Implementation of polymer flood field pilot
  - prior lab studies used in initial polymer selection.
  - interactively integrate lab tests, reservoir simulations, and field tests.
  - long time (years) required for polymer injection to quantify the benefit.
- Flow assurance
  - develop literature based initial strategy to deal with produced fluids.
  - revise flow assurance strategy concurrently.
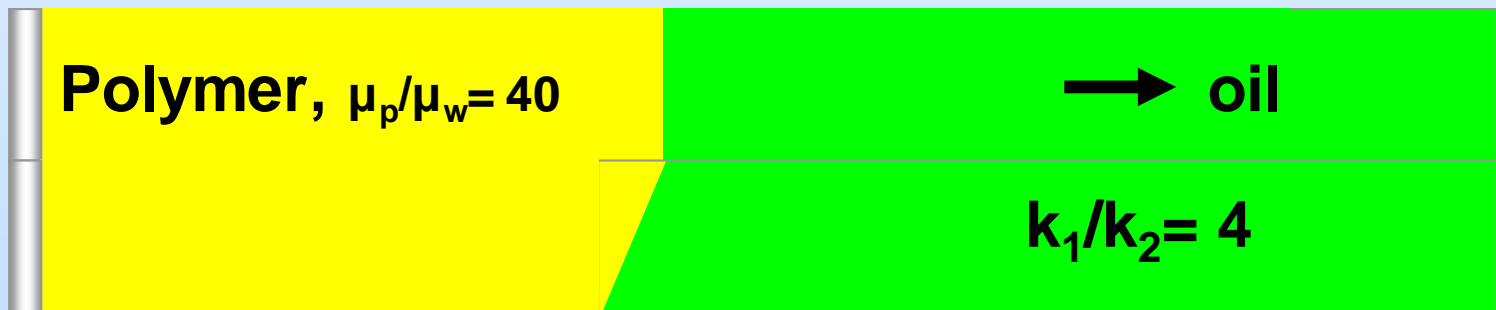
Selection of Polymer Viscosity

Water flood: M = 10

Water

oil

$k_1/k_2 = 4$
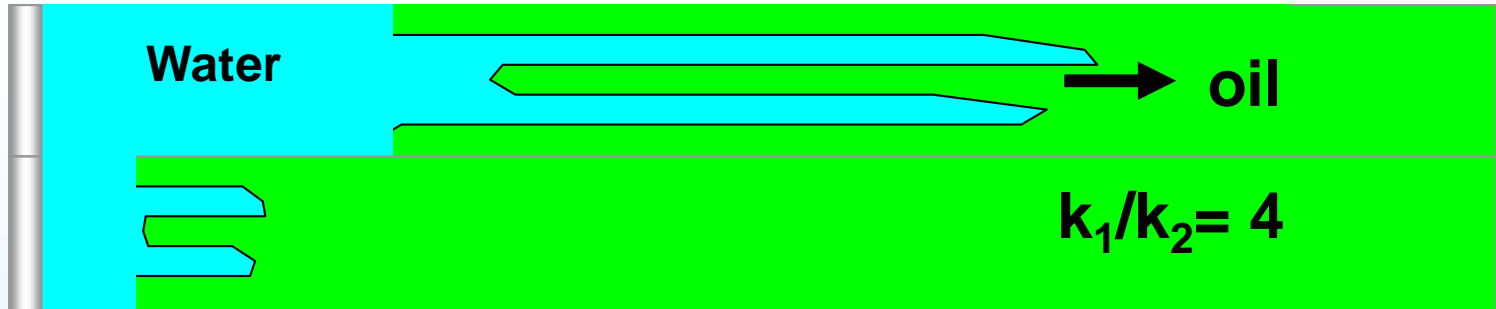
Polymer flood: M ~ 1

Polymer, $\mu_p/\mu_w = 10$;

oil

$k_1/k_2 = 4$
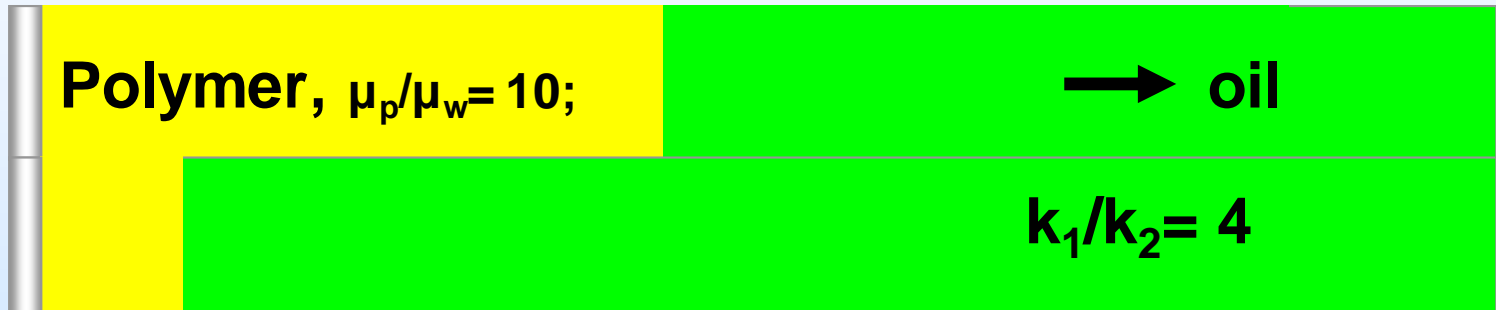
Polymer flood: M ~ 0.25

Polymer, $\mu_p/\mu_w = 40$

oil

$k_1/k_2 = 4$

- Want to make the water flood mobility ratio (M) favorable.
- Want to overcome the permeability contrast.

Selection of Polymer Viscosity

In some Canadian reservoirs, beneficial relative permeabilities allowed 25 centipoise (cP) polymer to effectively displace 1600 cP oil.

At the Daqing polymer flood in China 150-300 cP polymer was used to displace 10 cP oil because they believed oil saturation (S_{or}) was reduced.
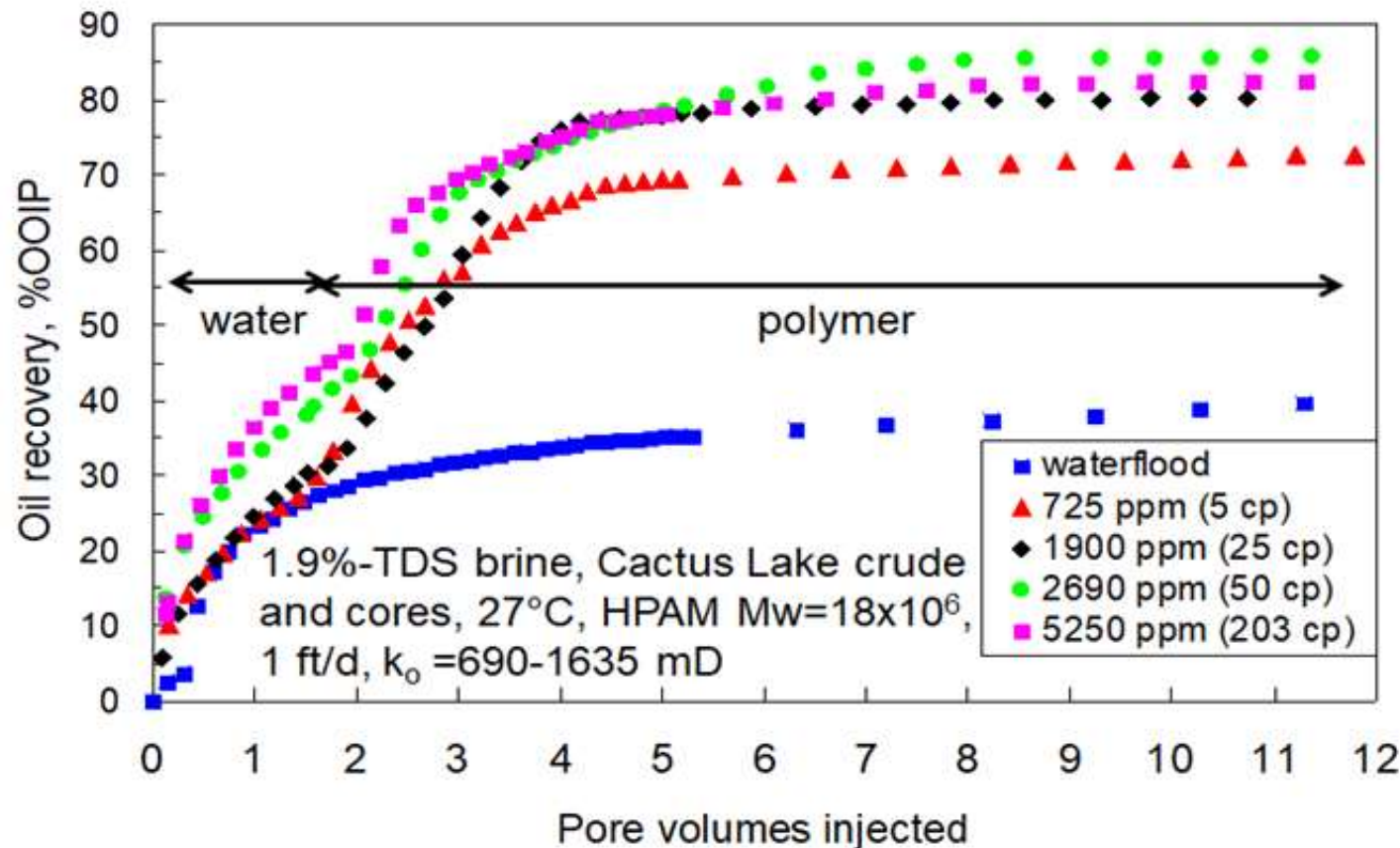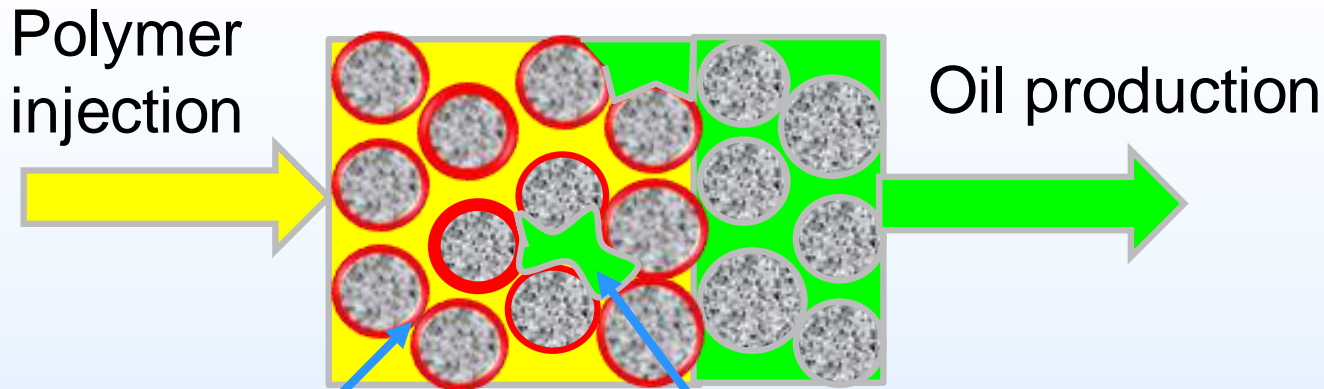

k = Permeability;

TDS = Total Dissolved Solids;
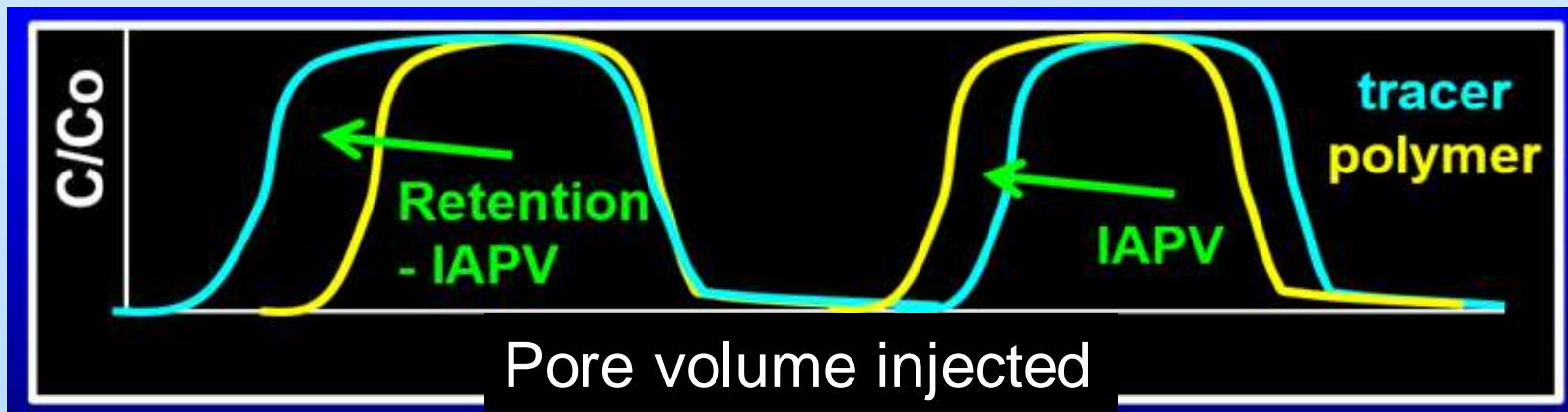
ppm = Parts Per Million;

OOIP = Original Oil in Place

Polymer Retention and Inaccessible Pore Volume

Polymer injection

Oil production

Polymer retention increases polymer needed and reduces permeability

Inaccessible Pore Volume (IAPV) reduces polymer needed and traps oil

C/Co

Retention - IAPV

IAPV

tracer
polymer

Pore volume injected

Optimization of Injection Water Salinity

- Conduct lab experiments and simulation work to elucidate the effect of salinity on oil recovery.

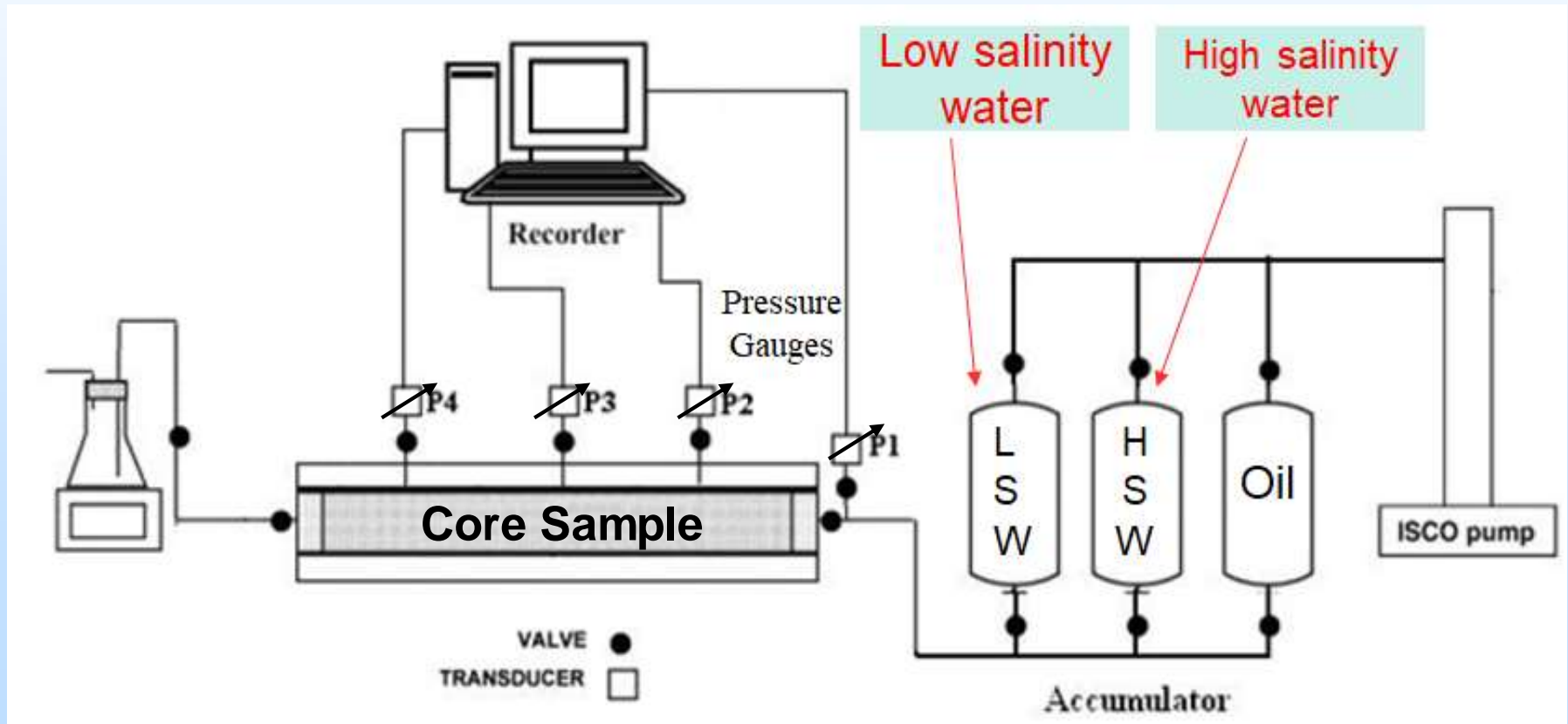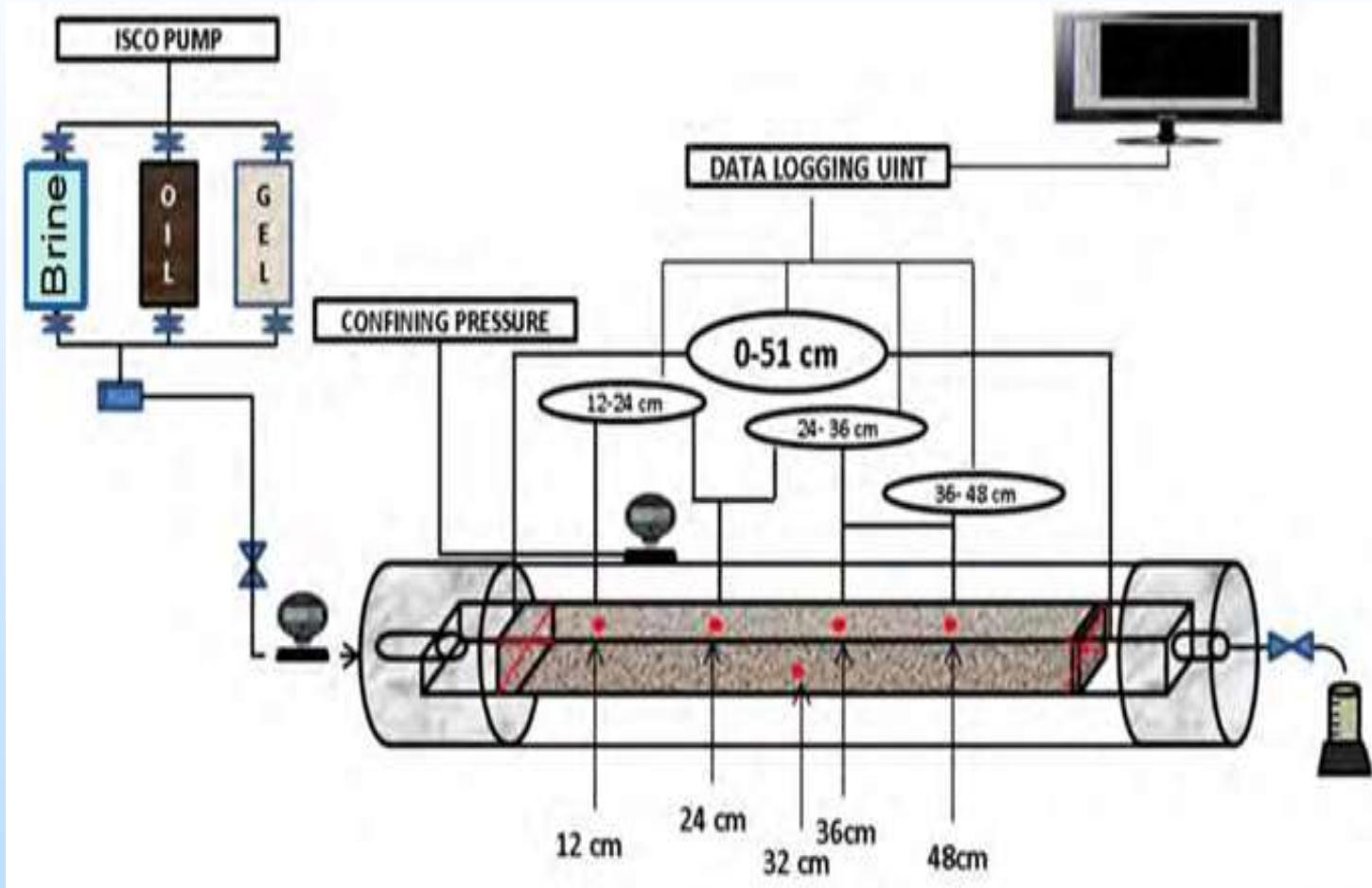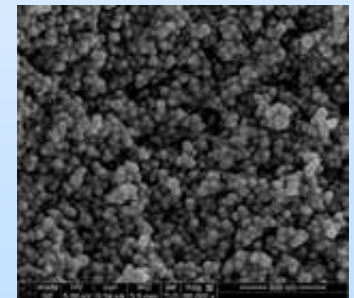- Obtain favorable injection water salinity.

Figure source: Bai, 2013; Alhuraishawy, Bai, and Wei (2018)

Conformance Control

- Conduct laboratory tests and simulation work to identify proper conformance control strategy.

mm-size Preformed Particle Gel (PPG)

Micro or Nano-sized PPG

Figure source: Bai et. al. (2013) and Alhuraishawy, Bai, and Wei (2018)
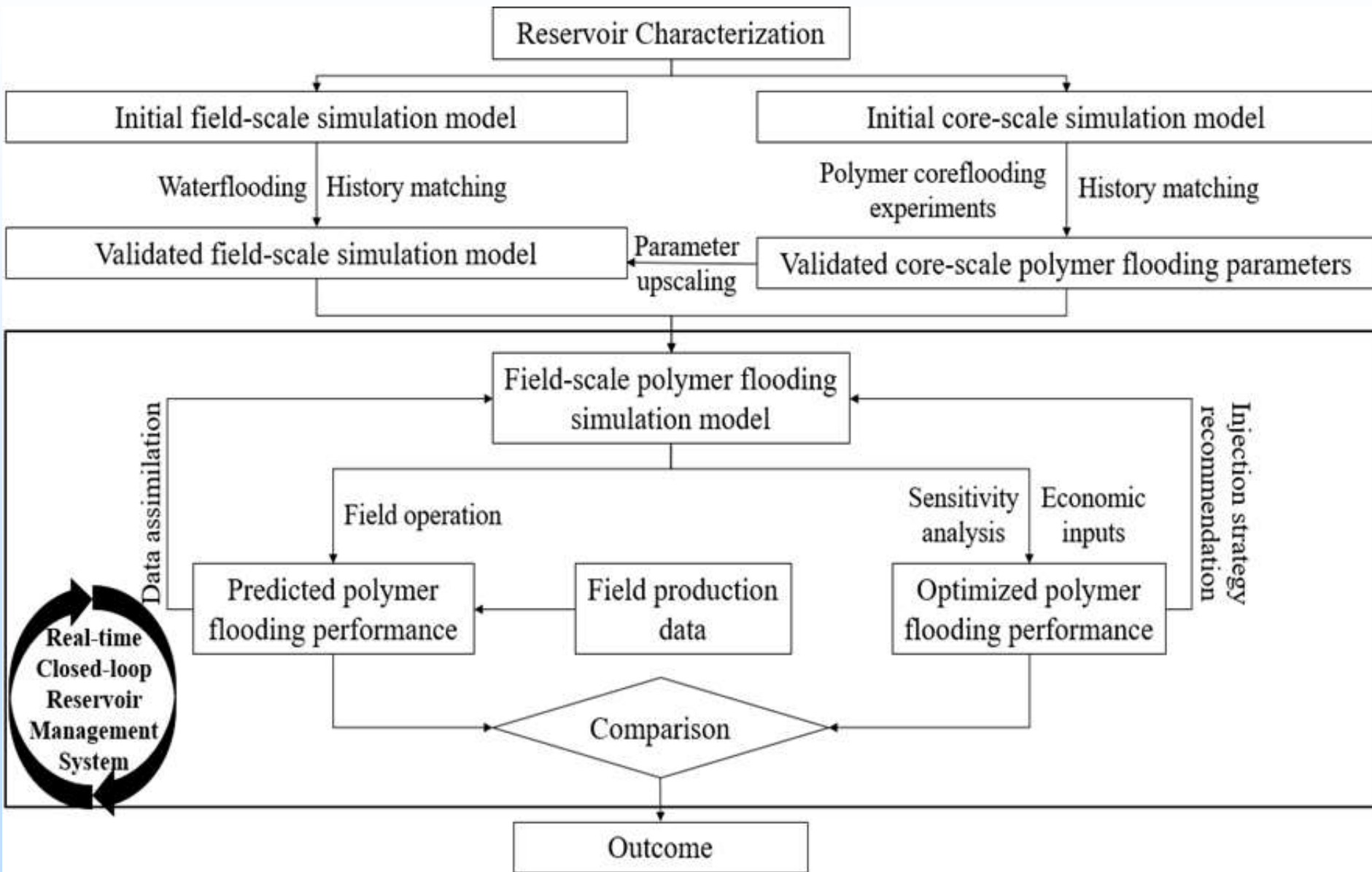
Reservoir Simulation Objectives

- Scaling laboratory experiments to the pilot scale

- Calibration to pilot performance

- Optimization of polymer injection strategy for pilot test

- Polymer flood benefit scaled up for economic analysis

Schrader Bluff N-sand thickness
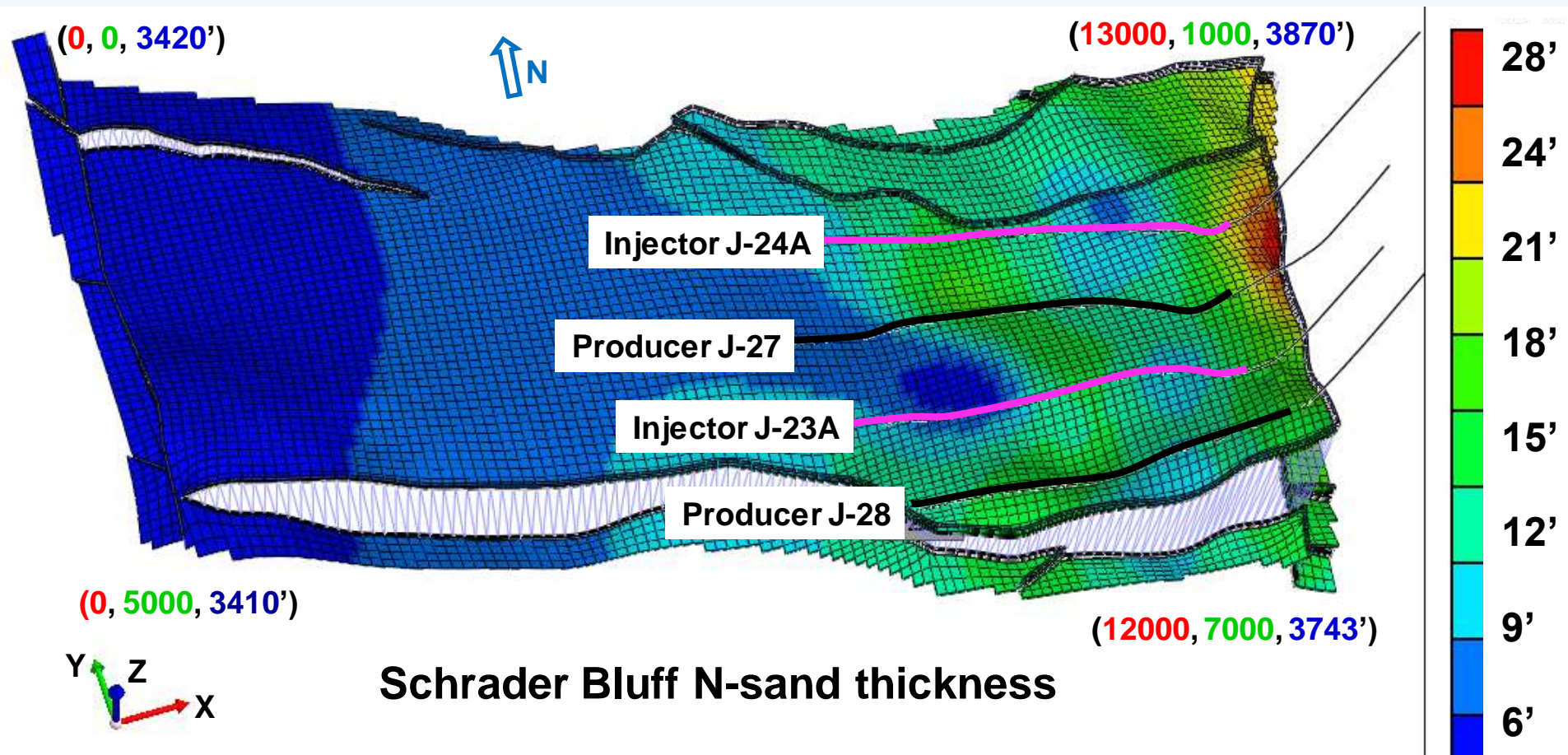
Reservoir Simulation

Simulation Example (Polymer Flood Tambaredjo Heavy Oil Field)

Water cut match (symbols are field data and line is simulation)

Cum. oil produced match (symbols are field data and line is simulation)

Cumulative oil produced, bbl

Water cut, %

Time scale 2009 - 2014

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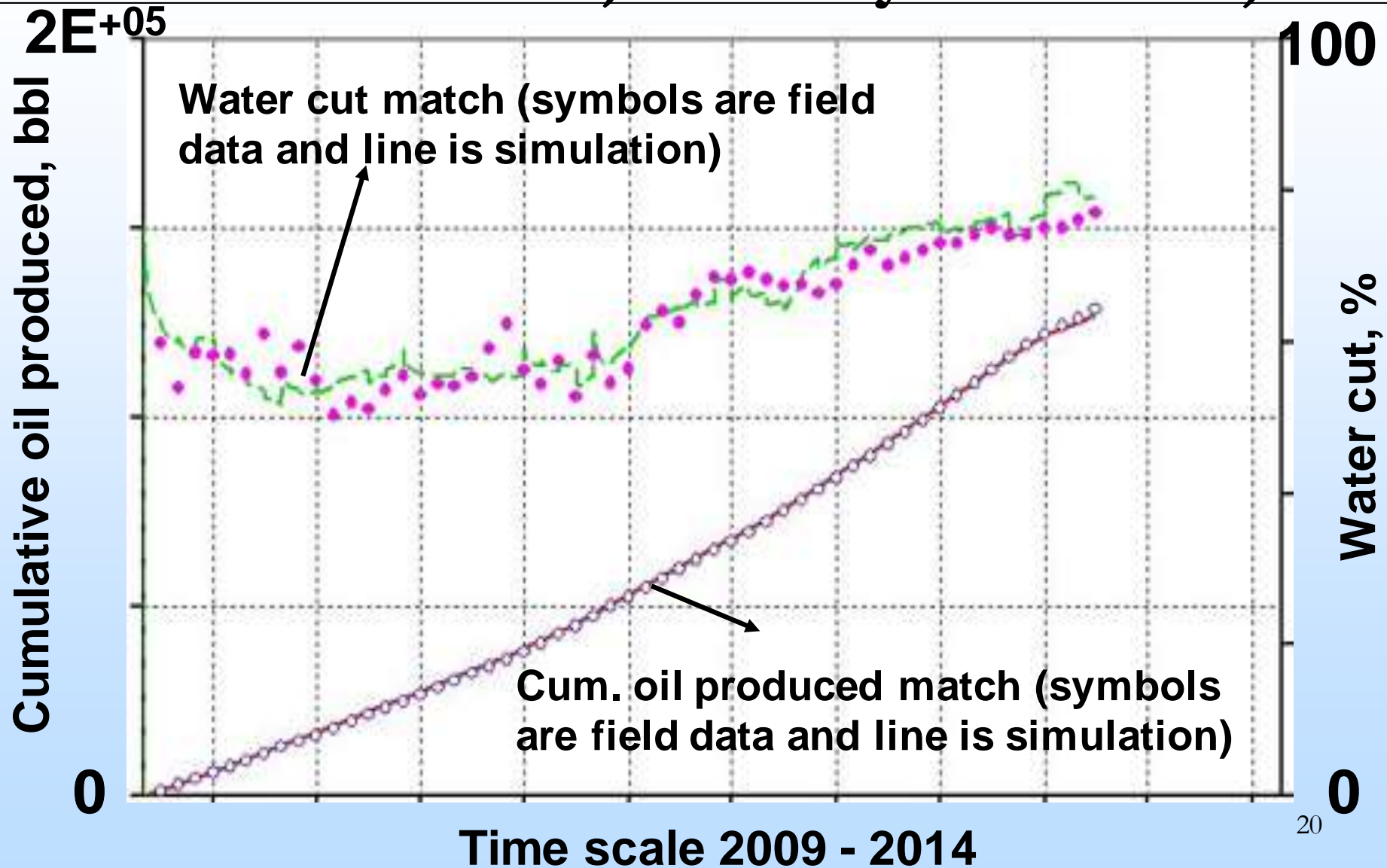
Flow Assurance

➢ **Oil/water separation techniques**

✓ Mechanical method
- API gravity separator
- Hydrocyclones/centrifugation

✓ Chemical method
- Emulsion breaker
- Chemical flocculation

✓ Filtration method
- Media filter (such as Walnut Shell Filter) and membrane filter

✓ Hybrid method
- Hybrid centrifugal and cyclonic flotation

Flow Assurance Experiments

- Design of experiments (DOE) based on literature review (main controlling variables) and initial field data

  - fixed parameters – oil type and temperature

  - variables – water salinity; demulsifier type; polymer type; controlled polymer shearing; electrostatic separation (ΔV)

  - resulting data – separation efficiency, Oil/Water or Water/Oil emulsions, viscosity and stability as a function of test variables
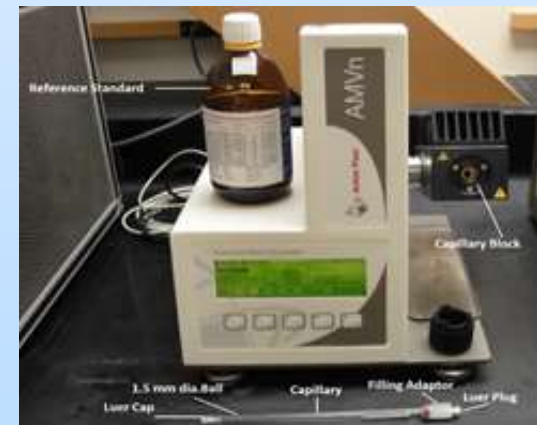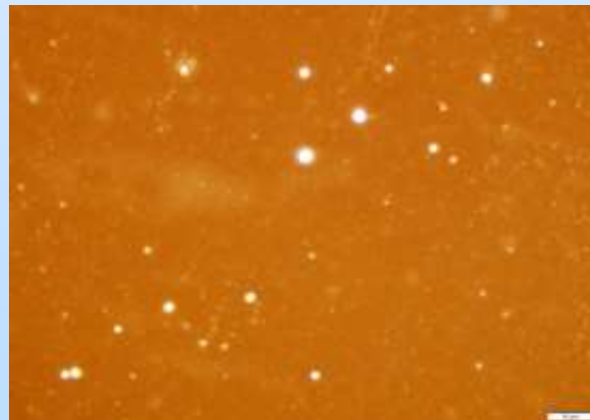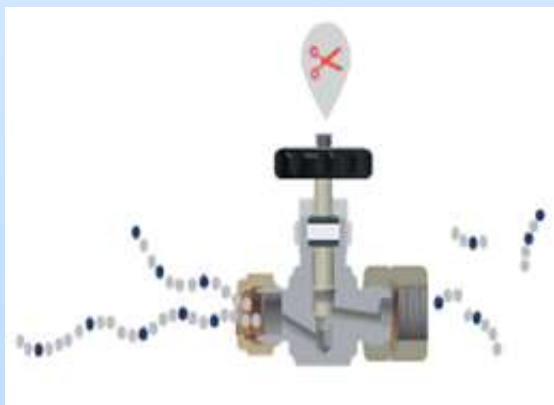

Figure source: www.snf.us; Cheng (2018) and Shukla (2011)

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Demulsifier Evaluation

➢ **Bottle test method**

✓ Add certain amount of demulsifier into the prepared crude oil emulsion, mix thoroughly, and dehydrate at desired temperature

➢ **Expected outcomes**

✓ Recommended demulsifier

✓ Recommended application concentration

General Bottle Test Procedure

chemical (ppm)

heat agitation time

A top sample (thief) is removed to determine oil dehydration at end of test

Interface quality

Water quality

emulsified crude

"demulsified" crude

Water drop is measured over time in milliliters

Figure source: Hirasaki et. al. (2011)

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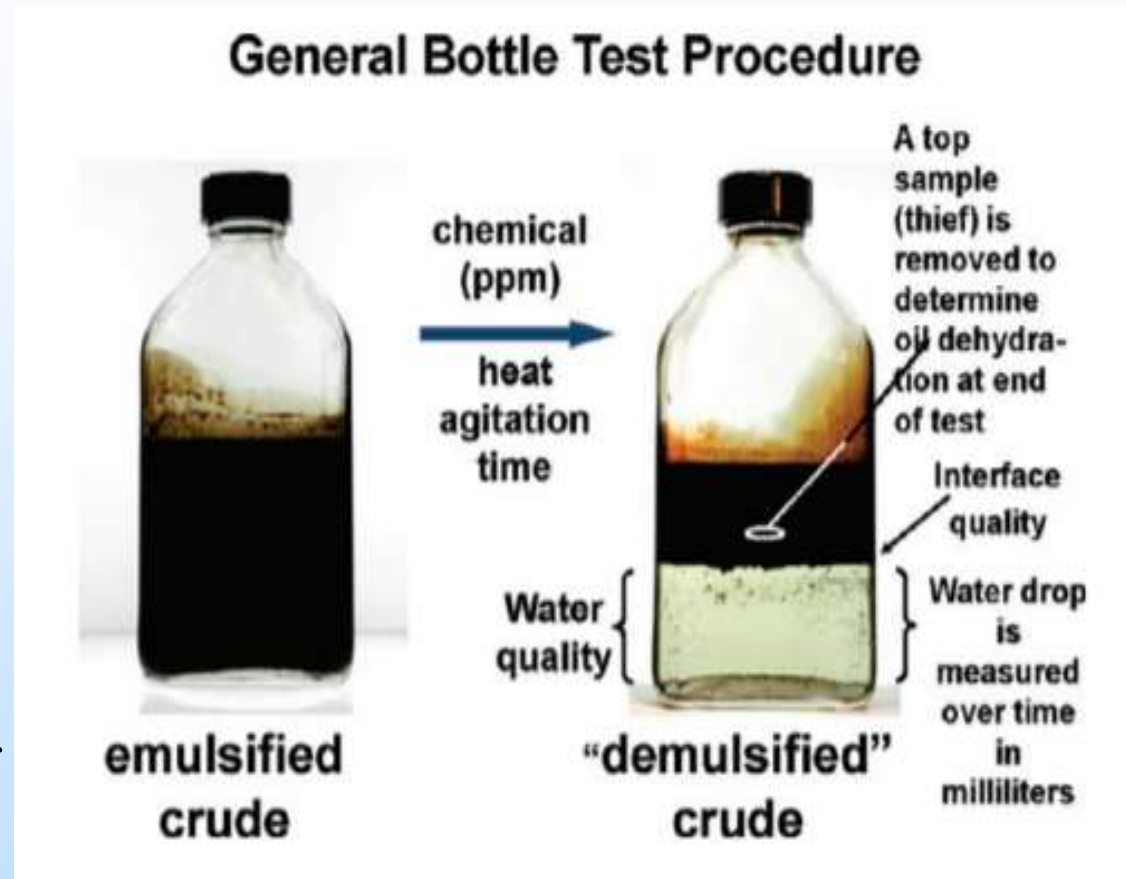
Accomplishments to Date

- Award effective June 1, 2018.

- Sub-awards to Hilcorp, New Mexico Tech, Missouri S&T, and University of North Dakota issued.

- Project Management Plan (PMP) completed.

- First version of Data Management Plan (DMP) completed.

- Rock and fluid samples, and reservoir characterization data sent to university participants.

- Preliminary coreflooding tests have been initiated.

- Literature review on produced fluid treatment completed.

- Pre-polymer tracer and PFO tests completed.

- Field polymer injection starting soon.

Lessons Learned

- Multi-disciplinary industry – academia teamwork is a pre-requisite for successful execution of a research program of this scale.
- The use of existing wells in the project area reduces risks associated with well availability and timing of operations.
- As the project moves forward careful pre-planning and being proactive will ensure deliverables within budget and on time.

Synergy Opportunities

Government

Industry

Academia
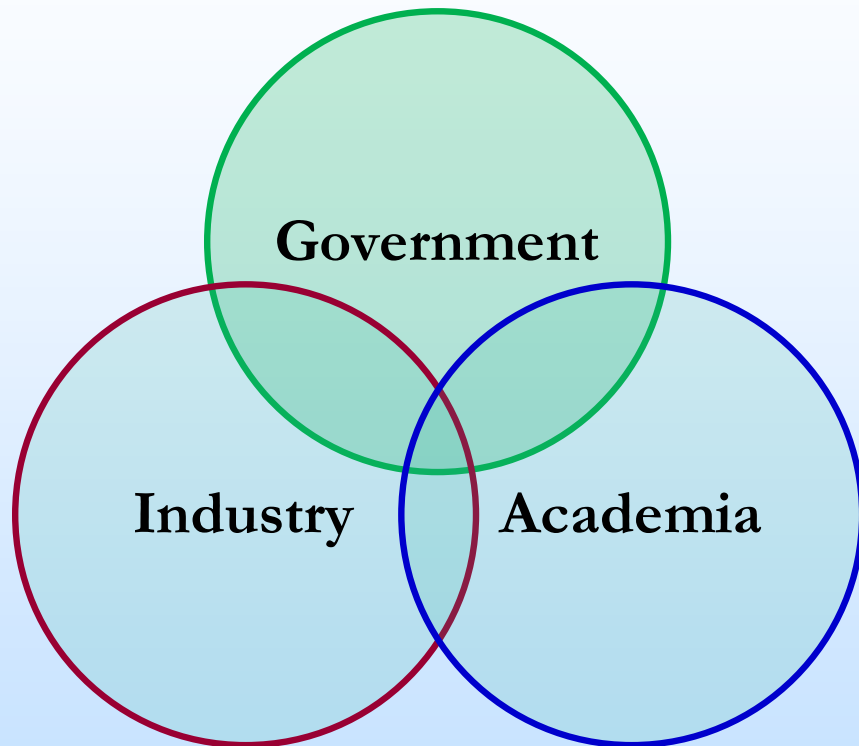
- Potential synergy between (FE0024558) that aims to develop swelling-rate-controllable particle gels to enhance CO_2 EOR.

- BP Alaska, as a working interest owner, is fully supportive of the project.

- ConocoPhillips Alaska is closely watching the developments, and may be interested in participating in the future.

- Potential interest amongst other ANS independents such as Burgundy Exploration?

- Access to field samples and data in the near future, conducive to continued public – private partnership.

Project Summary

- Research program in early stages, all the preparatory work for the initial field pilot done, industry – academia team ready to embark on the project.

- Immediate next steps

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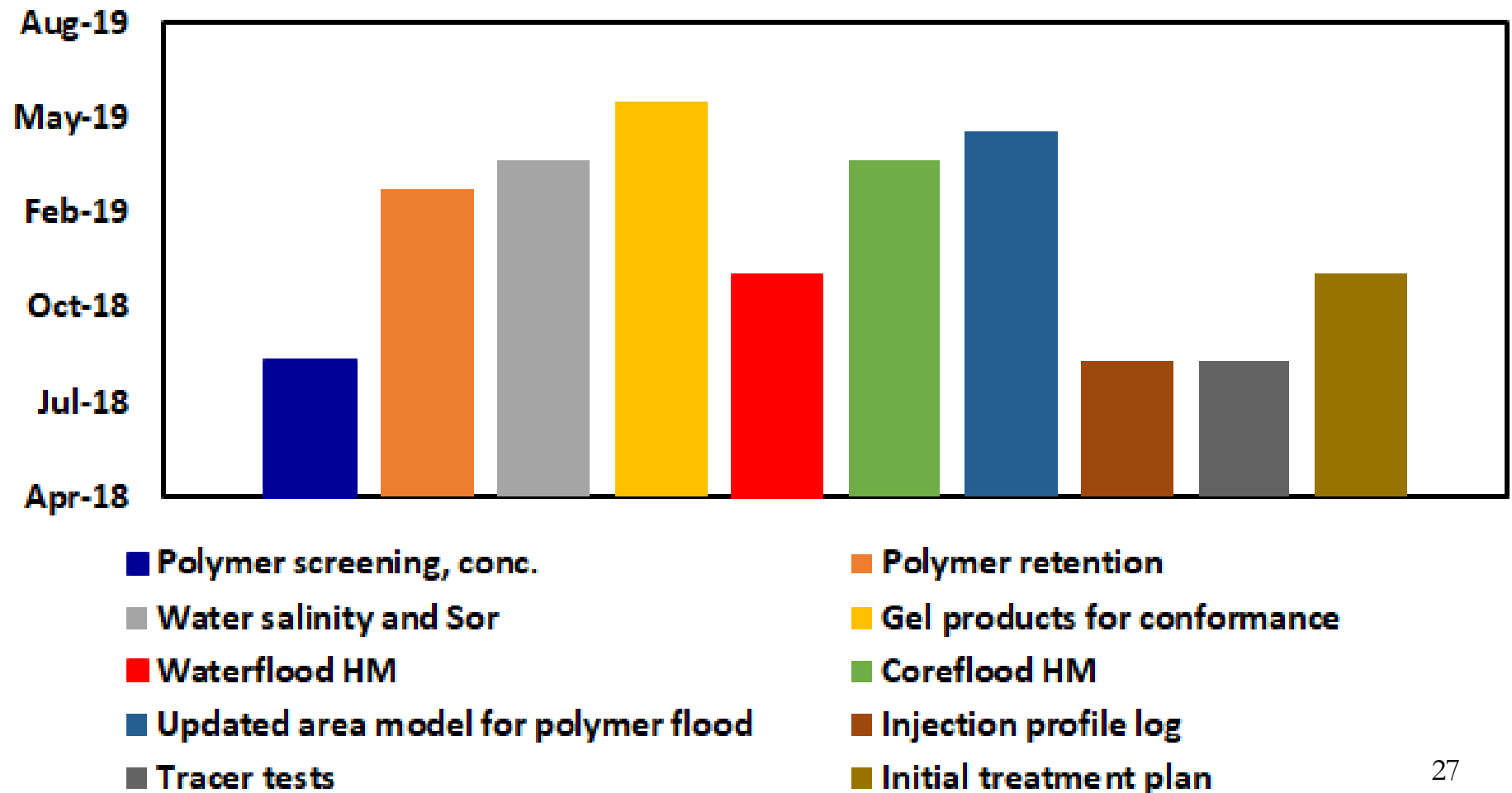
Appendix

– These slides will not be discussed during the presentation, but are mandatory.
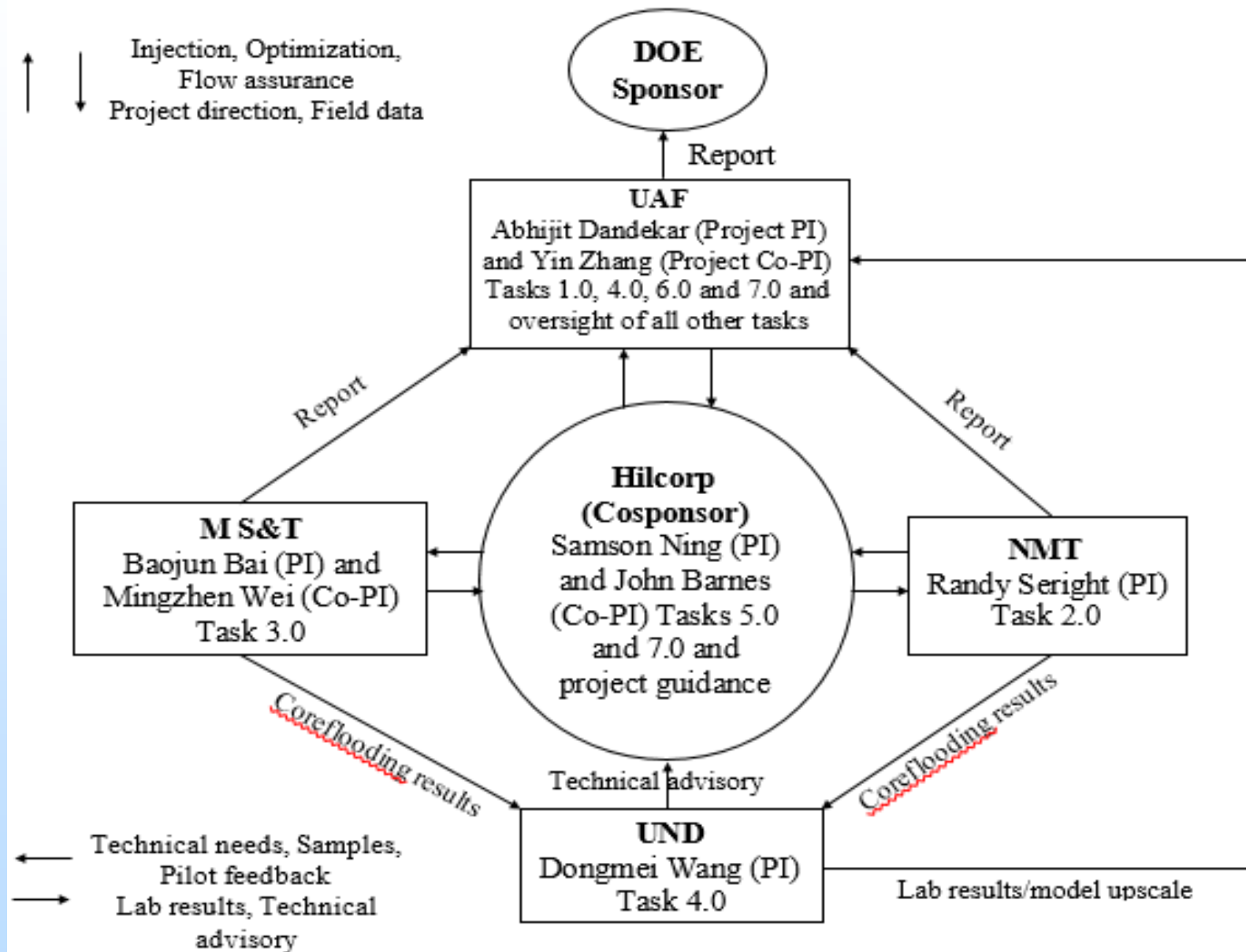
Benefit to the Program

- The primary goal of ANSFL project is to validate the use of polymer floods for heavy oil Enhanced Oil Recovery (EOR) on Alaska North Slope (ANS).

- Benefits to accrue from the proposed research:
  - 8-10% of OOIP recovery increment over waterflooding.
  - extend the life of the Trans Alaska Pipeline System.
  - environmentally friendly EOR method.

Project Overview
Goals and Objectives

- The specific objectives that would enable the achievement of project goals:
  - assess polymer injectivity into the Schrader Bluff formations
  - evaluate water salinity effect
  - estimate polymer retention
  - assess incremental oil recovery vs. polymer injected
  - assess effect of polymer flow back on surface facilities
- Major decision points and the success criteria based on:
  - polymer injectivity
  - conformance control
  - impact of produced polymer on facilities
  - switching from polymer to water injection
  - feasibility of polymer flood

Organization Chart

Injection, Optimization, Flow assurance, Project direction, Field data

DOE Sponsor

Report

UAF
Abhijit Dandekar (Project PI) and Yin Zhang (Project Co-PI) Tasks 1.0, 4.0, 6.0 and 7.0 and oversight of all other tasks

Report

Report

Hilcorp (Cosponsor)
Samson Ning (PI) and John Barnes (Co-PI) Tasks 5.0 and 7.0 and project guidance

M S&T
Baojun Bai (PI) and Mingzhen Wei (Co-PI) Task 3.0

NMT
Randy Seright (PI) Task 2.0

Coreflooding results

Coreflooding results

Technical advisory

UND
Dongmei Wang (PI) Task 4.0

Technical needs, Samples, Pilot feedback
Lab results, Technical advisory

Lab results/model upscale

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Gantt Chart

Bibliography

- None to report at this time. However, the research team endeavors to publish in high impact petroleum engineering focused refereed journals and/or suitable SPE conferences.

Acknowledgements

Thanks to US DOE, NETL, Hilcorp Alaska LLC and BP Exploration Alaska