CHEMICAL EOR:

Powder River Basin Field Screening

Undergraduate Research Day Symposium

University of Wyoming
Department of
Petroleum Engineering

SACAN Corporation

Bringing you STELLAR
EOR Consultation

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Dr. Xuebing Fu

Date: April 30th, 2016

EPSCoR Wyoming

Outline

- PROJECT OVERVIEW AND PLANNING
- PRELIMINARY SCREENING
- PROJECT ALTERATION
- INDEXING
- FIELD HISTORIES
- DISCUSSIONS AND SUMMARY

PROJECT OVERVIEW AND PLANNING

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Original Project Scope (CO_2)

- EORI's data packet
- Screen for CO_2 EOR candidates in PRB
- Rank fields to find top candidates
- Contact companies to attain data
- Field analysis for EOR implementation
- Incremental production increases
- Report Creation and final preparations

*Economic in PRB at $70/bbl

Switch to Chemical Flooding

- EORI data packet
- Screen for Chemical EOR candidates PRB
- Index fields to find top 5
- Field analysis, re-indexing and verification of chemical flooding compatibility
- Report Creation and final preparations

Project Workflow

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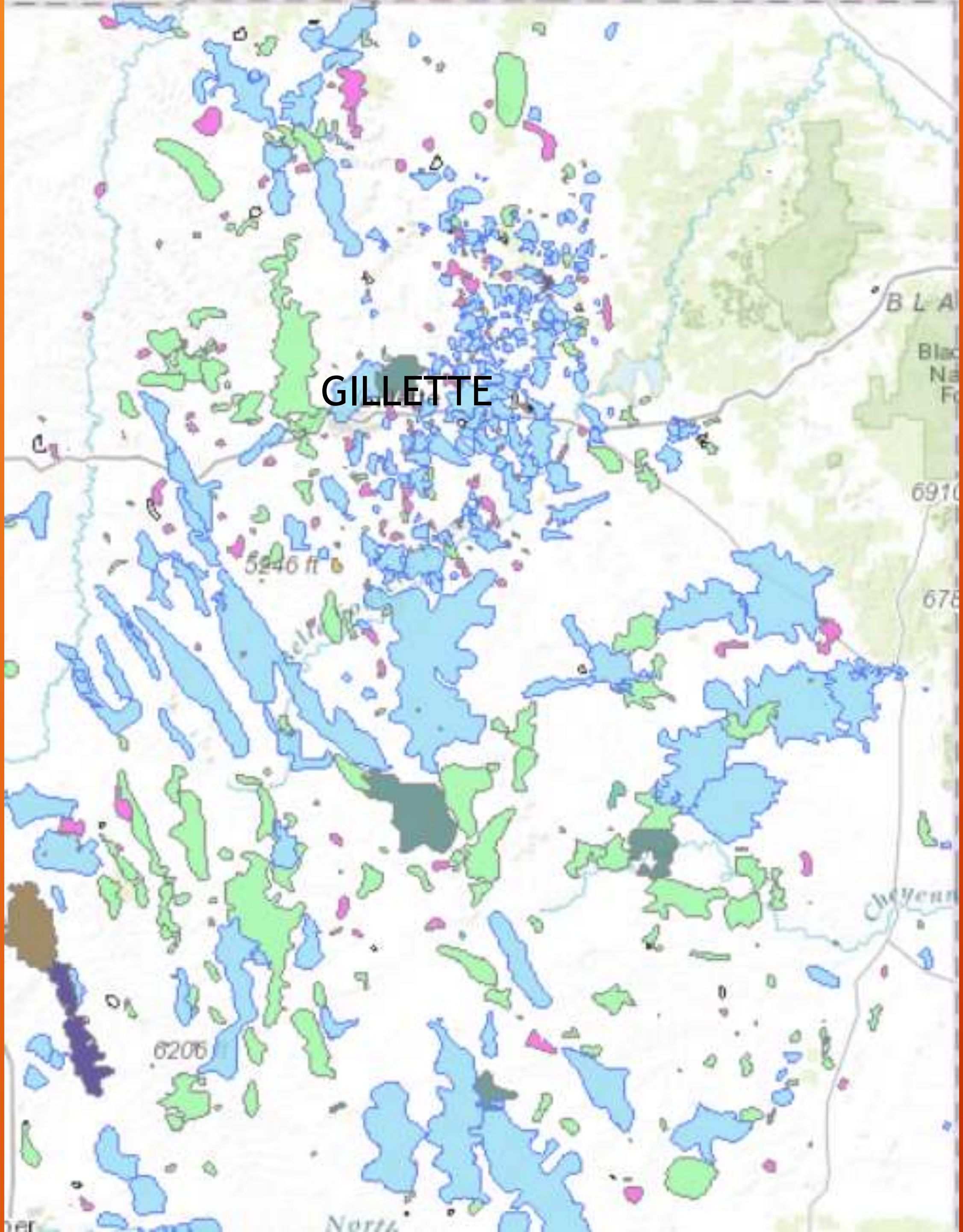
Phase I:
Planning
- Project Workflow
- Gantt Chart
- Creation of SACAN Corporation
- Fall Semester Symposium

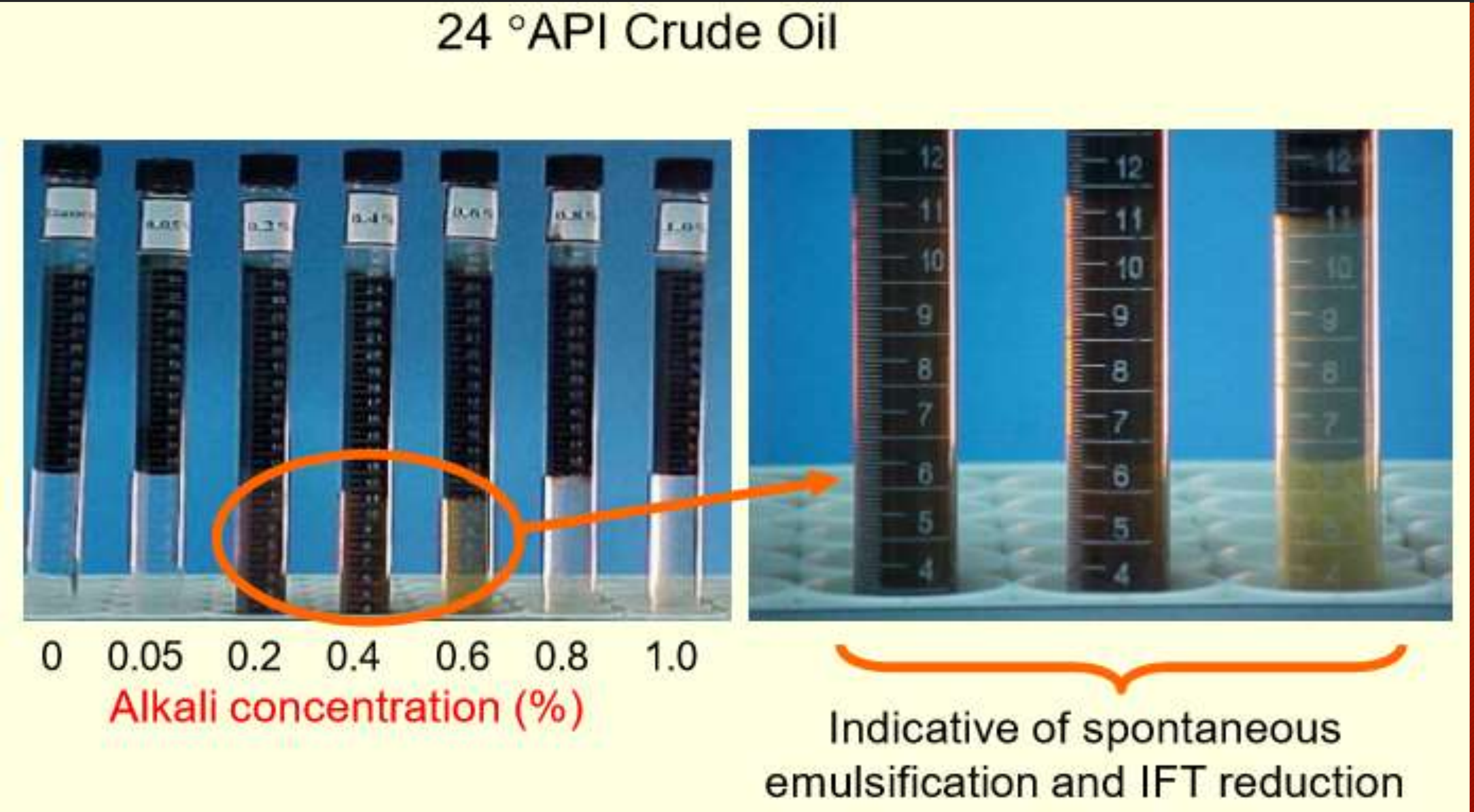
Phase II:
Screening, Filling in Data, Indexing
- Preliminary Screening
- Filling in Data
- Indexing method creation
- Identify top fields

Phase III:
Field Histories
- Access esri
- Collect data
- Public databases
- Re-index fields
- Recommendation

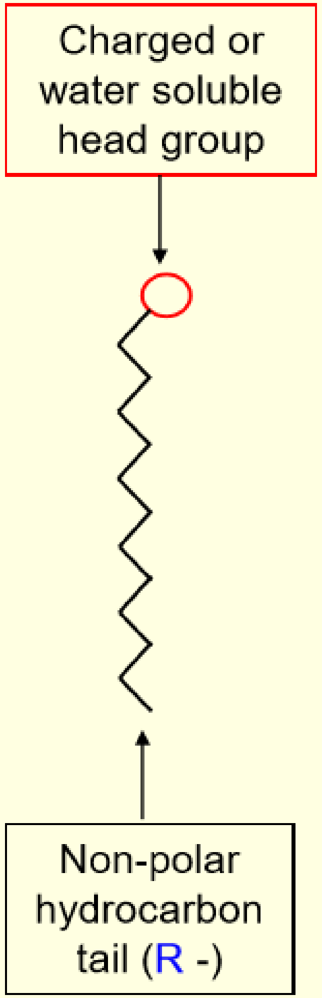

GILLETTE

GILLETTE

Alkali Flooding



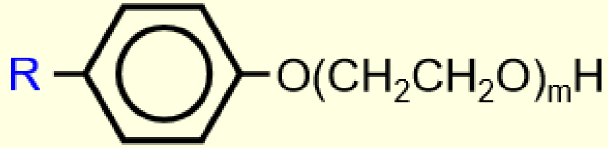
Surfactants



Anionic

R - $OSO_3^- Na^+$ (i.e., Sodium sulfonates)

Nonionic (Does not ionize)



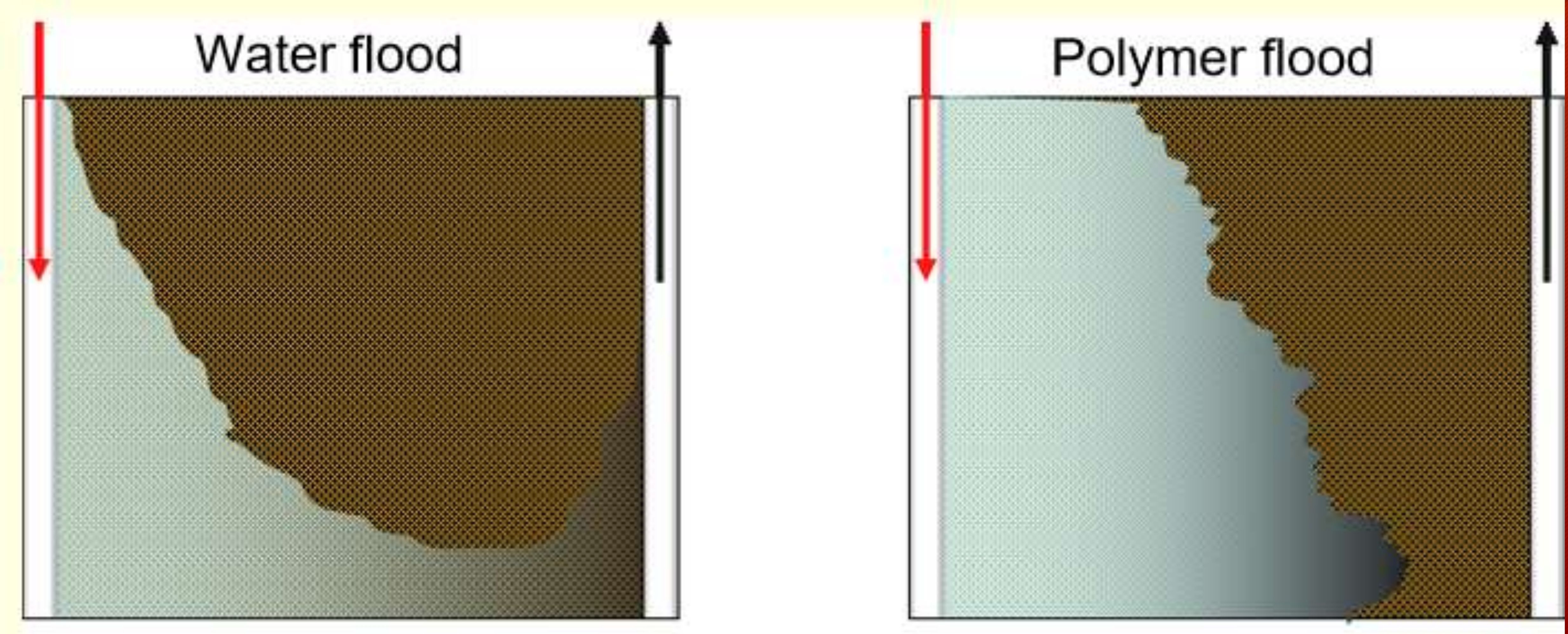
(i.e.: Ethoxylated Octylphenol, m = 2 - 100)

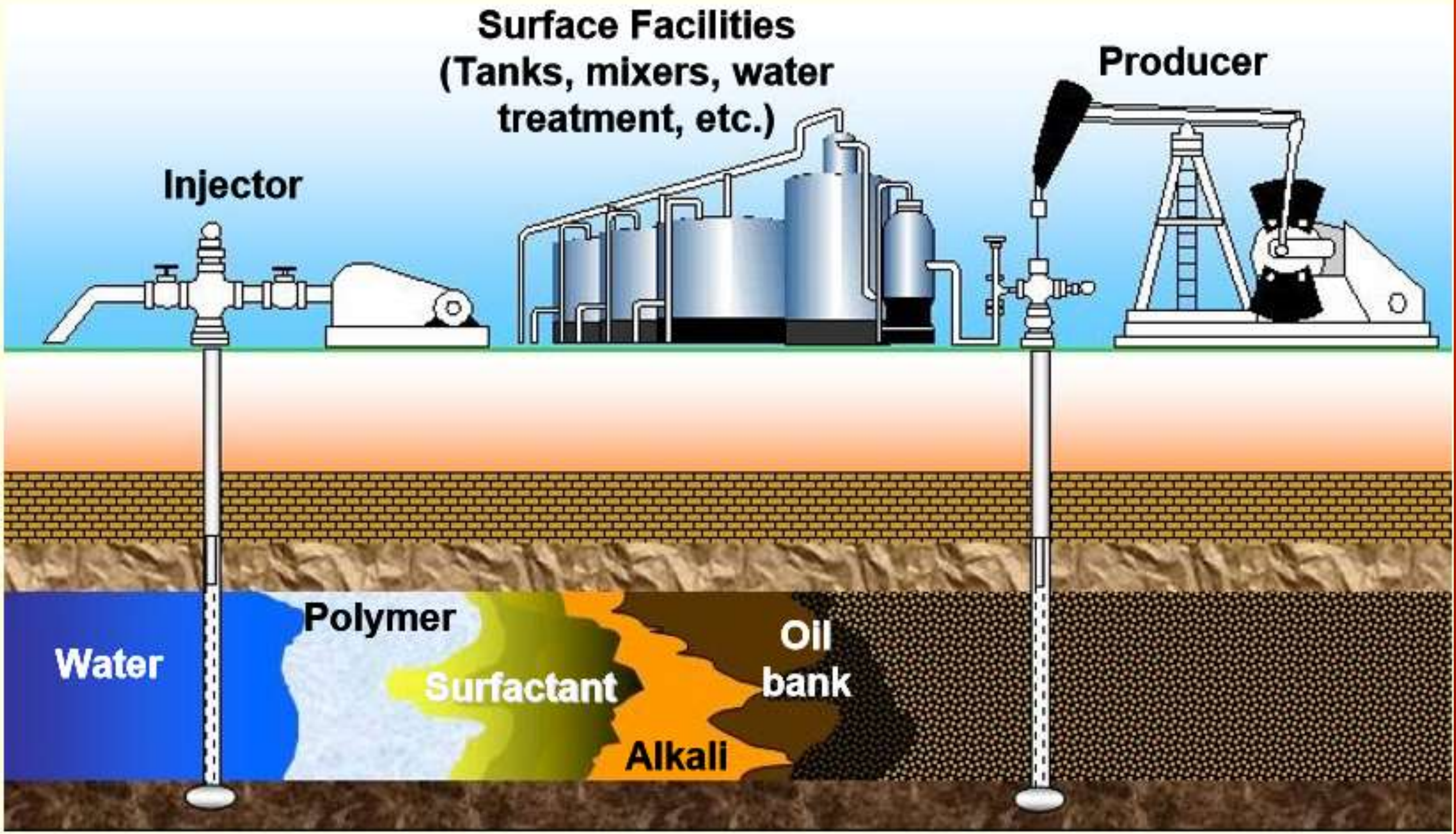
Cationic

$$R - \overset{\displaystyle CH_3 \atop |}{\underset{| \atop \displaystyle CH_3}{N^+}} - CH_3\ X^-$$

(i.e., Alkyl trimethyl ammonium halide - alkyl “quat”)

Polymer Flooding





Modified from ENHANCED OIL RECOVERY-NATIONAL PETROLEUM COUNCIL, 1986

PRELIMINARY SCREENING

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Data Review: ~5,000 fields

- Location
- Discovery year
- WOGCC Remarks
- 2008 production (oil, gas, water)
- Lithology
- Porosity
- K
- Depth
- Pay thickness
- Production area
- Temperature
- API
- Specific gravity
- Viscosity
- Mole weight
- Minimum miscibility pressure
- Fracture pressure
- CO_2
- Pour point
- Sulfur content
- Water pH
- Salt content

MAJOR CHALLENGE: LACK OF DATA

Methods

CO_2 Flooding Screening Criteria					
API Gravity	Viscosity [cp]	Oil Saturation	Lithology	Depth [ft]	Temperature
>22↗36↗	<10↘1.5↘	>20↗55↗	SS or Carbonate	>2500	Not Critical

Data Filter:

- Location: Powder River Basin
- Production: 2008 Oil Production > 10,000
- API Gravity: > 22
- Viscosity: < 10 cp
- Depth: >2500
- Temperature: No screening

Results: 193 fields, some with blanks for the above major criteria

Methods: Missing Data

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Wyoming Oil and Gas conservation Commission

Wyoming Oil and Gas Conservation Commission

- Permeability, Porosity, Viscosity, API Gravity, Composition
- Well logs
- Core analysis (if available)

US Energy Information Administration

Independent Statistics & Analysis U.S. Energy Information Administration

- General production values
- Lithology
- Infrastructure (from maps)

EORI Interactive Data Platform (EORI IDP)

- Software for pulling up well depths and other necessary information

Overcoming Challenges

Huge number of fields to go through

Solution: Preliminary screening

Outcome: Reduced 4,896 fields to 193

Few results

Solution: Work harder

Outcome: Gantt chart adjusted, Scope reduced

RESEARCH SHOWED THAT CHEMICAL FLOODING MORE APPROPRIATE

PROJECT ALTERATION

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CO_2 to Chemical Flooding

CO_2 Flooding

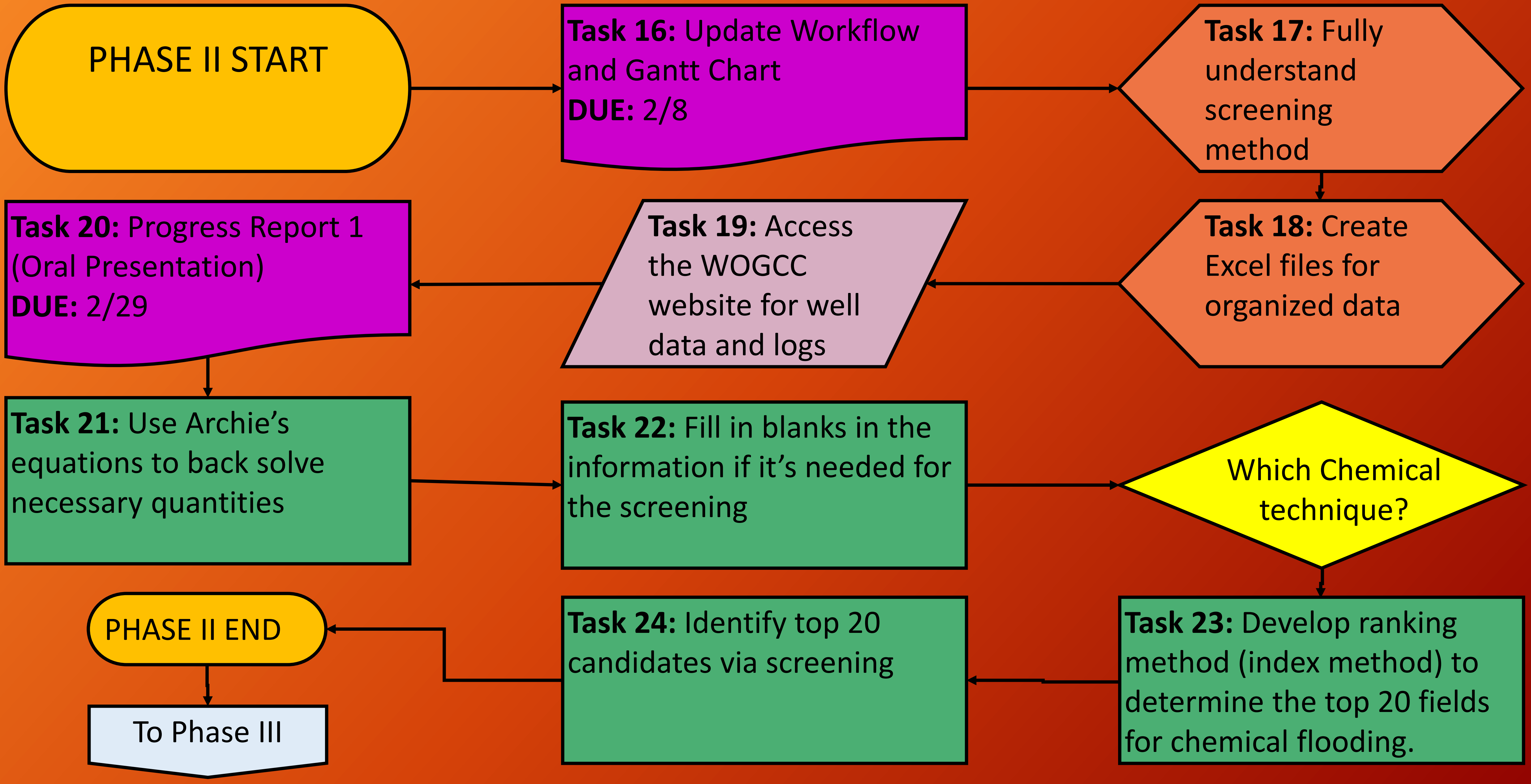
- API Gravity > 22
- Viscosity < 10 cp
- K not critical
- Depth > 2500 ft
- Temperature not critical

Chemical Flooding

- API Gravity > 15
- Viscosity < 35,150 cp
- K > 10 mD
- Depth < 9000 ft
- Temperature < 200

CHANGES REQUIRED RE-SCREENING, SETTING US BACK SEVERAL DAYS

Updated Workflow



Gantt Chart - Updated

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Gantt Chart: Phase II						
Task #	Task Name	Team Member	Duration	Start	Finish	Predecessors
16	Update Workflow and Gantt Chart	T	6 days	32	38	-
17	Screening method	All	4 days	39	43	16
18	Excel files	T	2 days	44	46	17
19	Public Data	All	4 days	47	51	18
20	Progress Report I	All	4 days	52	56	19
21	Archie's Equation	All	7 days	57	64	20
22	Blanks in data	T,S	5 days	65	70	21
23	Indexing Method	All	2 days	71	73	22
24	Top 20 fields	All	4 days	74	78	23

Research and Screening

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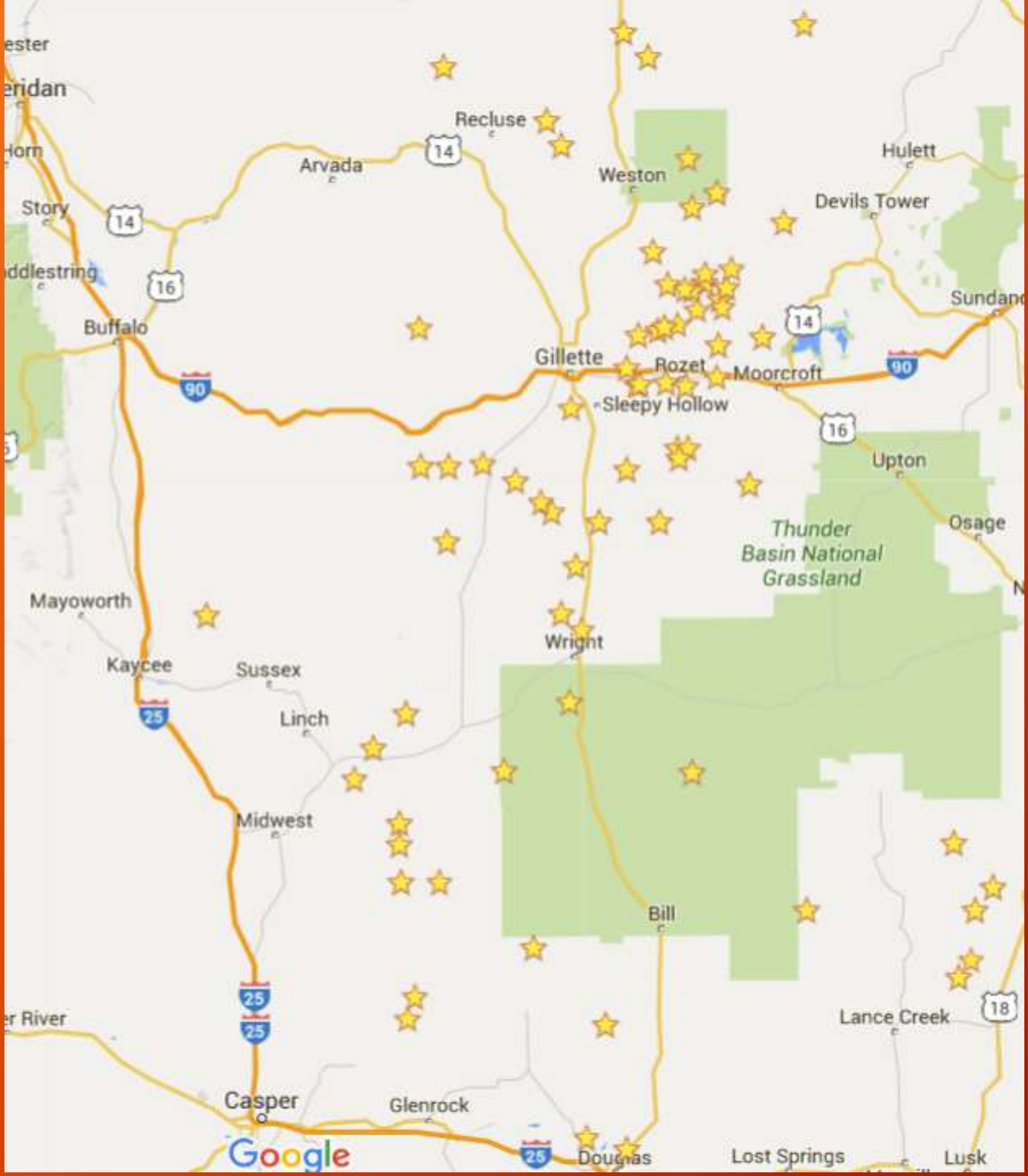
- Literature Review
- Several types of chemical flooding techniques:
  - Polymer Injection
  - Alkali Injection
  - Surfactant Injection
  - AS (Alkali-Surfactant, not commonly used or tested)
  - SP (Micellar-Polymer)
  - ASP (All three, most common chemical injection method)
- Several lookup tables were found → EORI's table most applicable
- Narrowed list to 114; still multiple blanks

114 Field locations: Post-screening



Major Challenges and Solutions

Lack of tangible results
Solution: Quick indexing method
Outcome: Incorrect top fields?

Oil Saturation was difficult to obtain
Solution: Temporarily neglected
Outcome: Non-compatible fields

Changing of EOR method
Solution: Project alteration
Outcome: More realistic

Filling in blanks time consuming
Solution: Indexing of fields
Outcome: Possible incorrect top fields

INDEXING

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Data Review Analysis

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WOGCC Accessible:

- Depth (logs)
- Temperature (correlation)
- Permeability (logs)

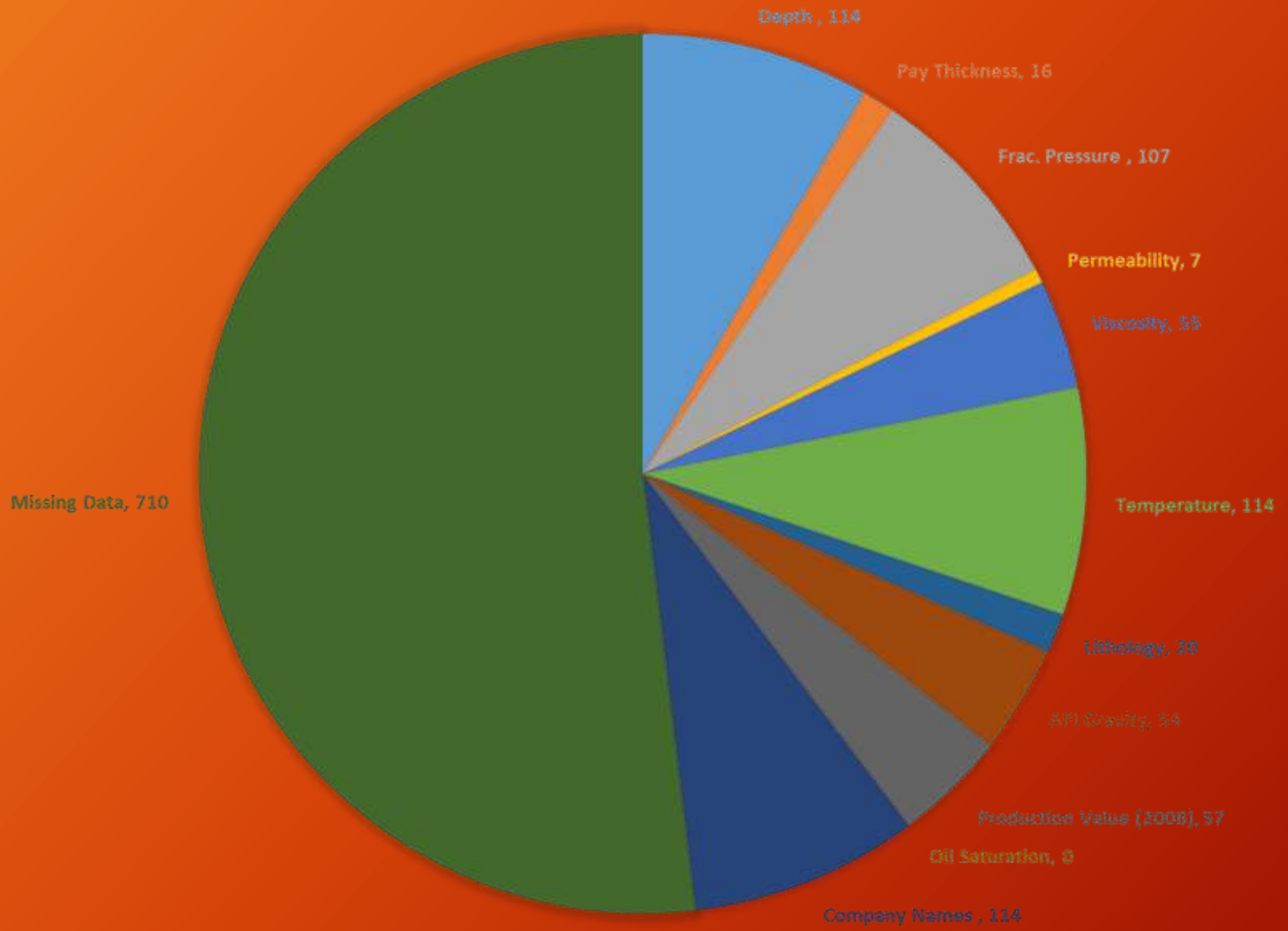
Additional Sources Needed:

- Viscosity -EORI(Esri)
- Oil API -EORI(esri)
- Oil Saturation-(Unknown)

Public Data Sources:

- AAPG (American Association of Petroleum Geologists)
- SPE (Society of Petroleum Engineers): membership
- NETL (National Energy Technology Laboratory)
- EORI (Enhance Oil Recovery Institute) website
- Wyoming Geological Association: Wyoming Oil and Gas Fields Symposium Powder River Basin (2000 A.D.+)

COMPLETED



Depth , 114
Pay Thickness, 16
Frac. Pressure , 107
Permeability, 7
Viscosity, 55
Temperature, 114
Lithology, 20
API Gravity, 54
Production Value (2008), 57
Oil Saturation, 0
Company Names , 114
Missing Data, 710

Screening Method – Follow the Arrows

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Pointing Up (Higher the Better)	Pointing Down (Lower the Better)
API Oil Saturation Permeability	Viscosity Depth Temperature

$$Parameter\ Index\ = \frac{Field\ Value\ - Lower\ Limit}{Median\ Value\ - \ Lower\ Limit}$$

$$Parameter\ Index\ = \frac{Upper\ Limit - Field\ Value}{Upper\ Limit - Median\ Value}$$

- *If Individual Index value is negative set to 0*
- *If no data, set as 0*
- $Total\ Index\ = Average(\frac{FV-20}{35-20}, \frac{150-FV}{150-13}, \frac{FV-35}{53-35}, \frac{FV-10}{450-10}, \frac{9000-FV}{9000-3250}, \frac{200-FV}{200-140})$

Methods

- Field Ranking Indexing

API Gravity	
Median	35
Low	20
Field Median	20
Index	0

Viscosity	
Median	12
High	150
Field Median	78
Index	0.5256

Oil Saturation	
Median	53
Low	35
Field Median	
Index	0

Average K	
Median	450
Low	10
Field Median	50
Index	0.09091

Depth	
Median	3250
High	9000
Field Median	1593
Index	1.288

Temperature	
Median	140
High	200
Field Median	81
Index	1.9833

Methods

Field Ranking Indexing:

Field Compatibility	
Current Field:	Thompson Creek
Chemical Flooding?	Compatible
Average Field Index:	0.63247

Field Compatibility	
Current Field:	West Fork
Chemical Flooding?	Not Compatible
Average Field Index:	0

Problems with Method

- Oil Saturation was taken into consideration as a 0 index for all fields screened
- Index values > 1 were possible
  - Allowed because of the nature of the screening criteria
- Weighted index proposed, denied due to several problems
- If a field does not have any parameters (or very few) the average field index suffers because of it

Results

Ranked #	Field	Index:
1	THOMSON CREEK	0.63247
2	THOMSON CREEK	0.61263
3	GREASEWOOD	0.60025
4	THOMSON CREEK	0.54913
5	TAYLOR	0.54913
6	CRAWFORD DRAW	0.49175
7	SCOTT	0.49037
8	TWENTY-ONE MILE BUTTE	0.47643
9	HIGH ROAD	0.47530
10	SCHOOL CREEK	0.47289

Ranked #	Field	Index:
11	OTTIE DRAW	0.45849
12	TUIT DRAW	0.44767
13	TRIANGLE U EAST	0.43768
14	BEAVER HOLE	0.43548
15	FISH	O.42343
16	COLLINS	0.40121
17	KICKEN DRAW	0.39524
18	MALMQUIST	0.38534
19	SIDNER DRAW	0.38534
20	GREASEWOOD	0.37000

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Results

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Ranked #	Fields:	Formations:	Index:
1	THOMPSON CREEK	MUDDY	0.63247
2	GREASEWOOD	MORRISON	0.60025
3	TAYLOR	MINNELUSA	0.54913
4	CRAWFORD DRAW	FRONTIER	0.49175
5	SCOTT	TEAPOT-PARKMAN	0.49037

FIELD HISTORY

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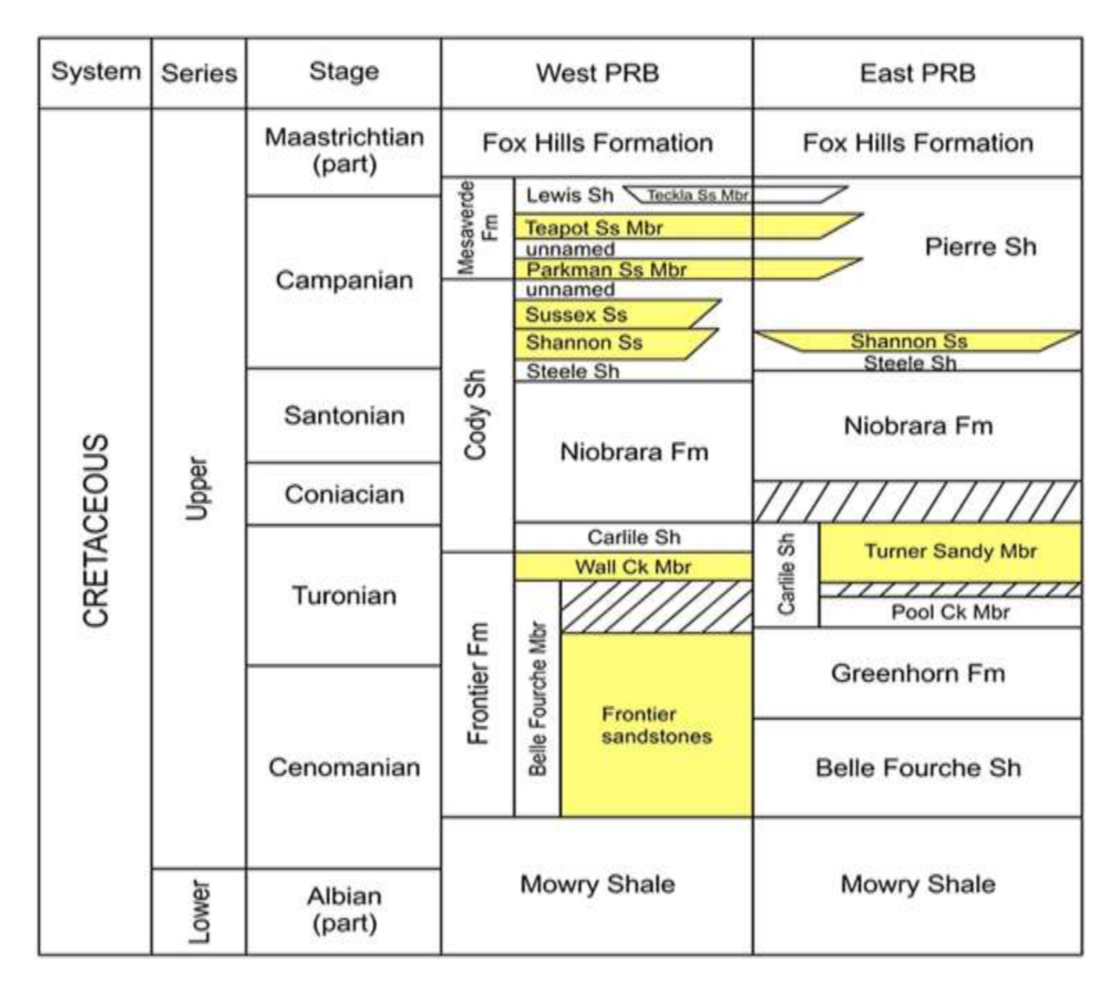
Top Five Fields

1) Taylor Field in the Minnelusa Formation
2) Crawford Draw Field in the Frontier Formation
3) Scott Field in the Teapot-Parkman Formation
4) Thompson Creek Field in the Muddy Formation
5) Greasewood Field in the Morrison Formation



Methods for Finding Permeability and Oil Saturation

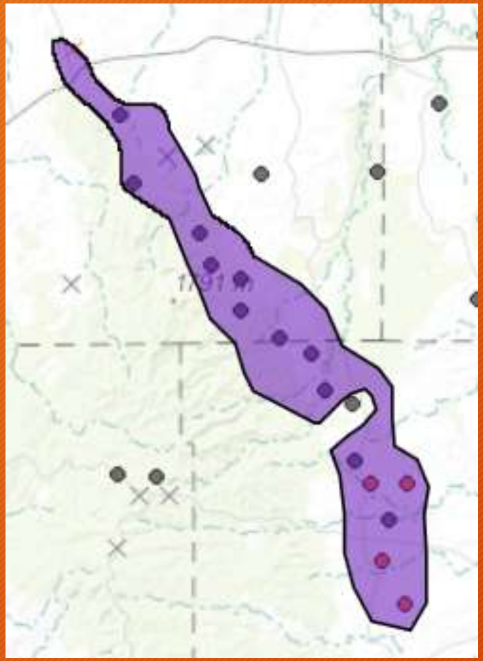
Method 1: Literature search

- Analogous fields (same formation and nearby fields); formation information; nearby fields

Method 2: Well Logs combined with Equations and Graphs

- Permeability: Porosity and Density logs than using Formation Porosity vs Permeability Graph Trend lines
- Oil Saturation: Attempted to read Resistivity Logs and Use Basic Archie Equation (unable to read resistivity logs adequately)

Crawford Draw Field: (New Field Index: 0.38)



Formations: Frontier and Mesaverde

Field Status: Injecting Water

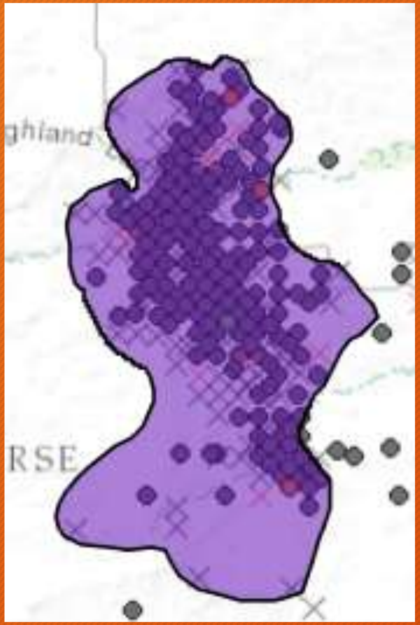
Production: Oil (primary) and Gas

EOR: None proposed

Variables	Values
Porosity (%)	15
Permeability (mD)	20
API Gravity (°)	42
Depth (feet)	11972.62
Temperature (°F)	208
Viscosity (cP)	1.75
Oil Saturation (%)	15

Recommended: Surfactant flooding; depth + viscosity/API Gravity

Scott Field: (New Field Index: 0.58)



Formations: Fox Hills, Lewis, Teckla, Teapot, Parkman, Sussex, Niobrara

Primary Production: Parkman

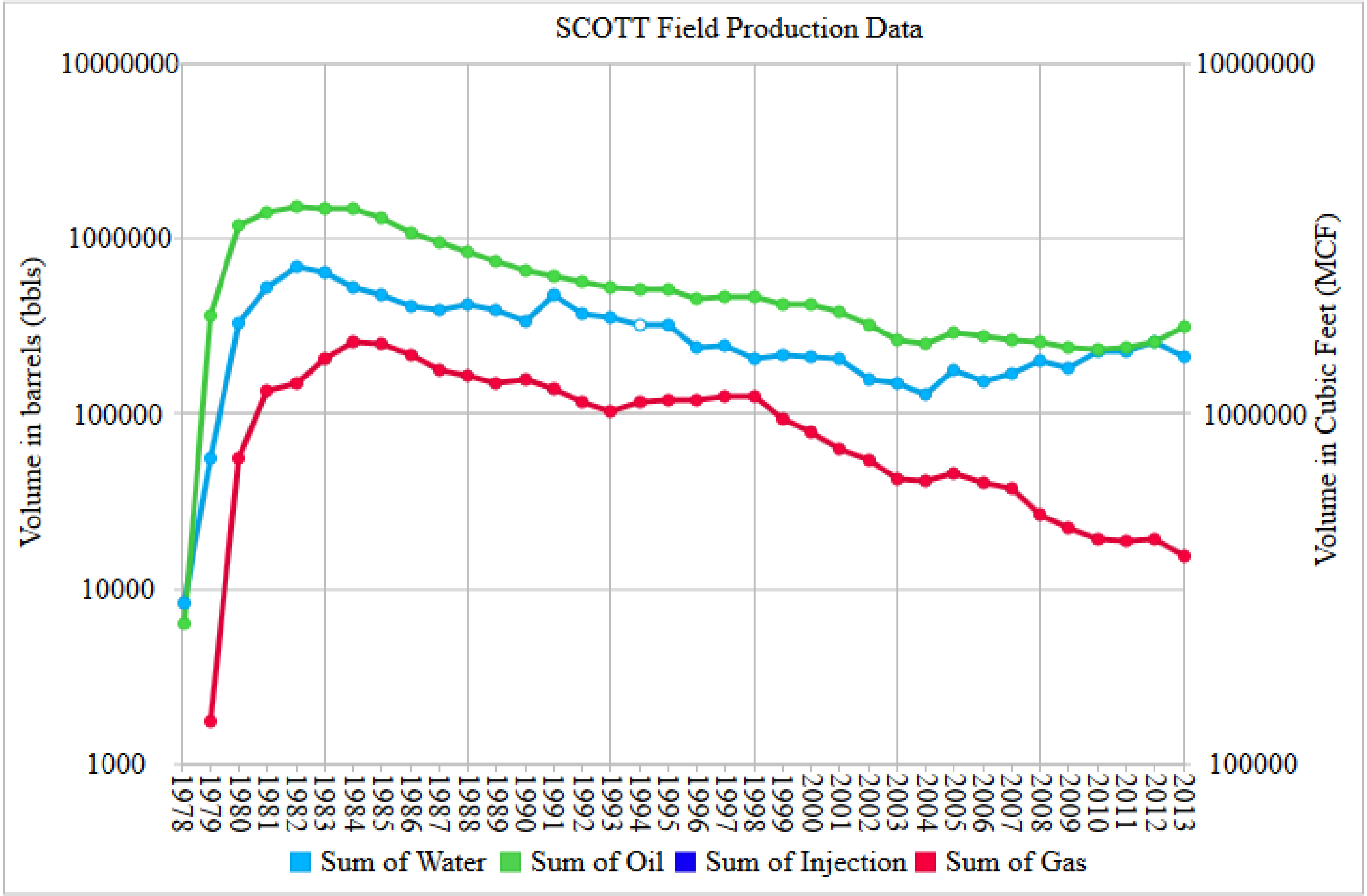
No EOR Projects

Field Status: Injecting Water (idle)

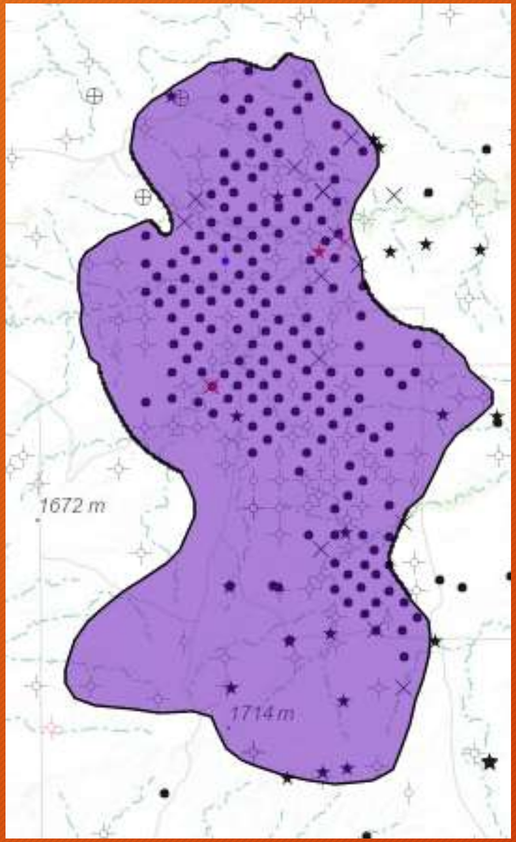
Production: Oil and Gas

Variables	Values
P`orosity (%)	10
Permeability (mD)	2
API Gravity (°)	40
Depth (feet)	8753
Temperature (°F)	169
Viscosity (cP)	6.7
Oil Saturation (%)	5

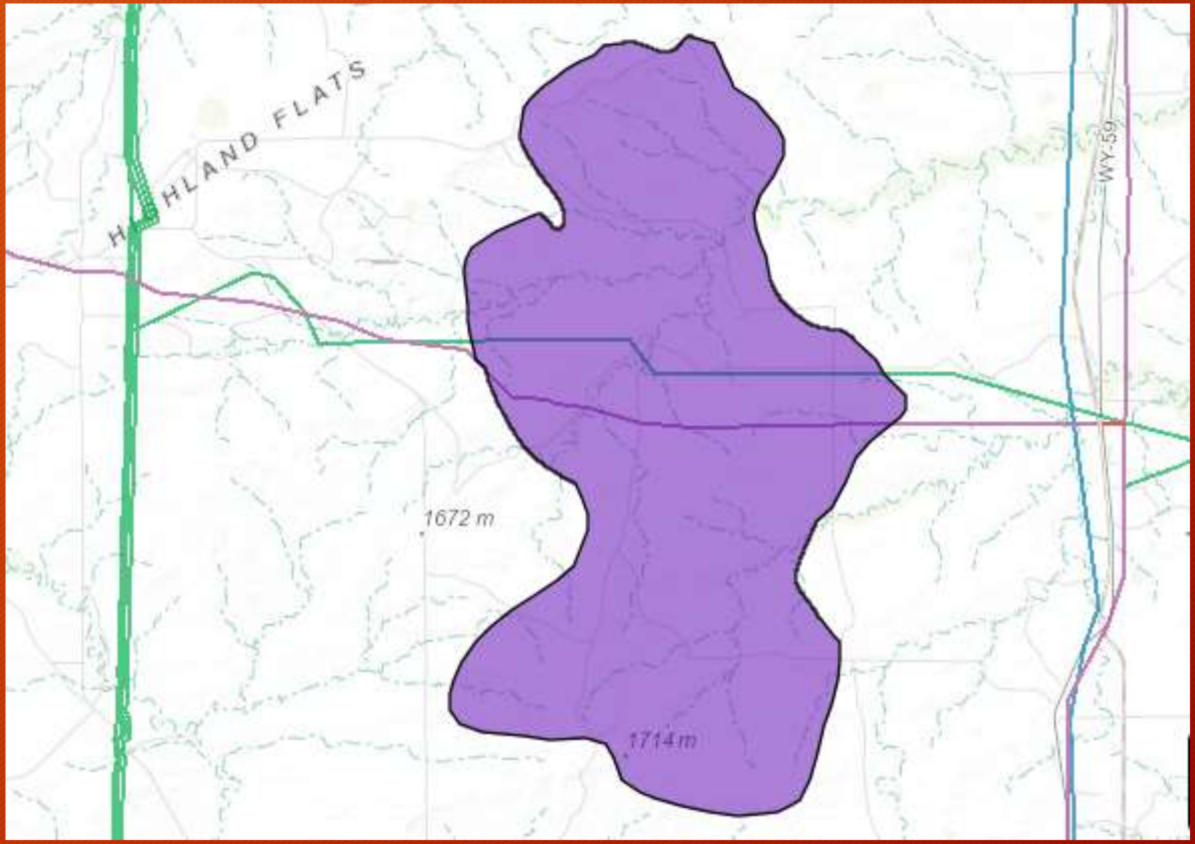
Recommended: SP flooding; k too low, high viscosity/low API Gravity


SCOTT Field Production Data
Volume in barrels (bbls)
Volume in Cubic Feet (MCF)
10000000
1000000
100000
10000
1000
10000000
1000000
100000
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Sum of Water
Sum of Oil
Sum of Injection
Sum of Gas

Scott Field Maps: Infrastructure

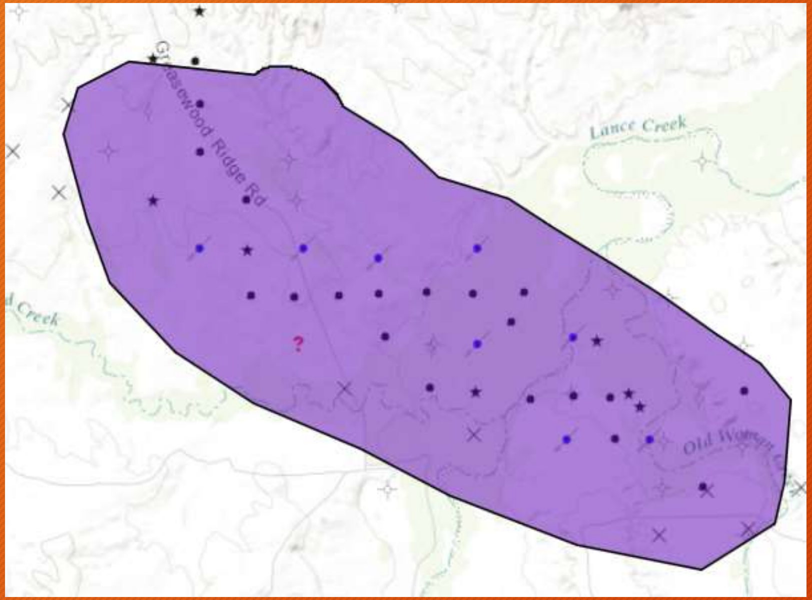


Injection and Production Wells



Pipeline Map: Gas lines through Field

Greasewood Field: (New Field Index: 0.73)



Formation: Morrison Primary Production

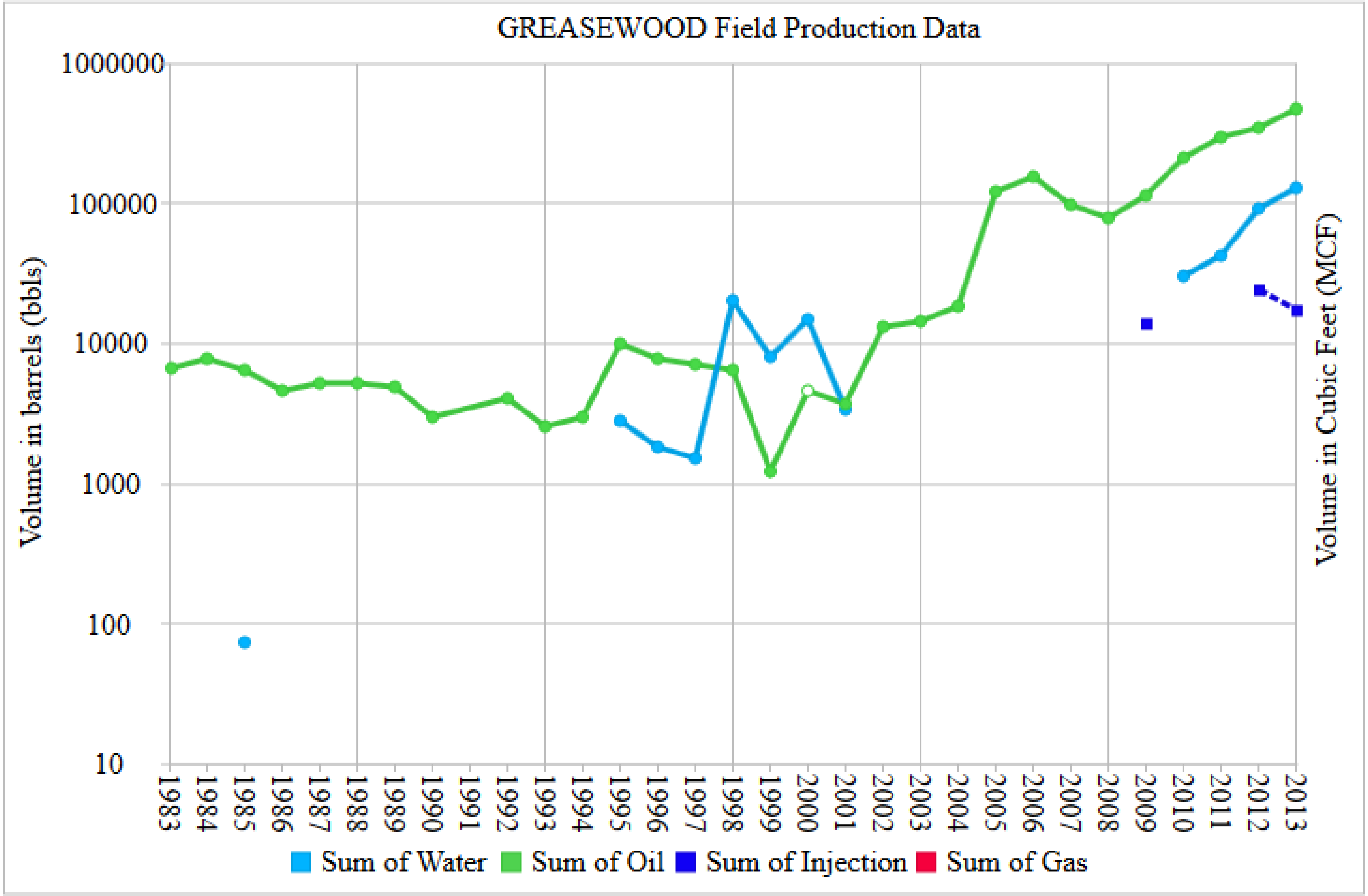
No EOR Projects

Field Status: Injecting Water

Production: Oil

Variables	Values
Porosity (%)	16
Permeability (mD)	40
API Gravity (°)	34
Depth (feet)	5913
Temperature (°F)	134
Viscosity (cP)	8.71
Oil Saturation (%)	?

Recommended: ASP flooding (dependent on saturation) with low MW Polymer


GREASEWOOD Field Production Data
Volume in barrels (bbls)
Volume in Cubic Feet (MCF)
1000000
100000
10000
1000
100
10
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Sum of Water
Sum of Oil
Sum of Injection
Sum of Gas

Greasewood Field: Infrastructure

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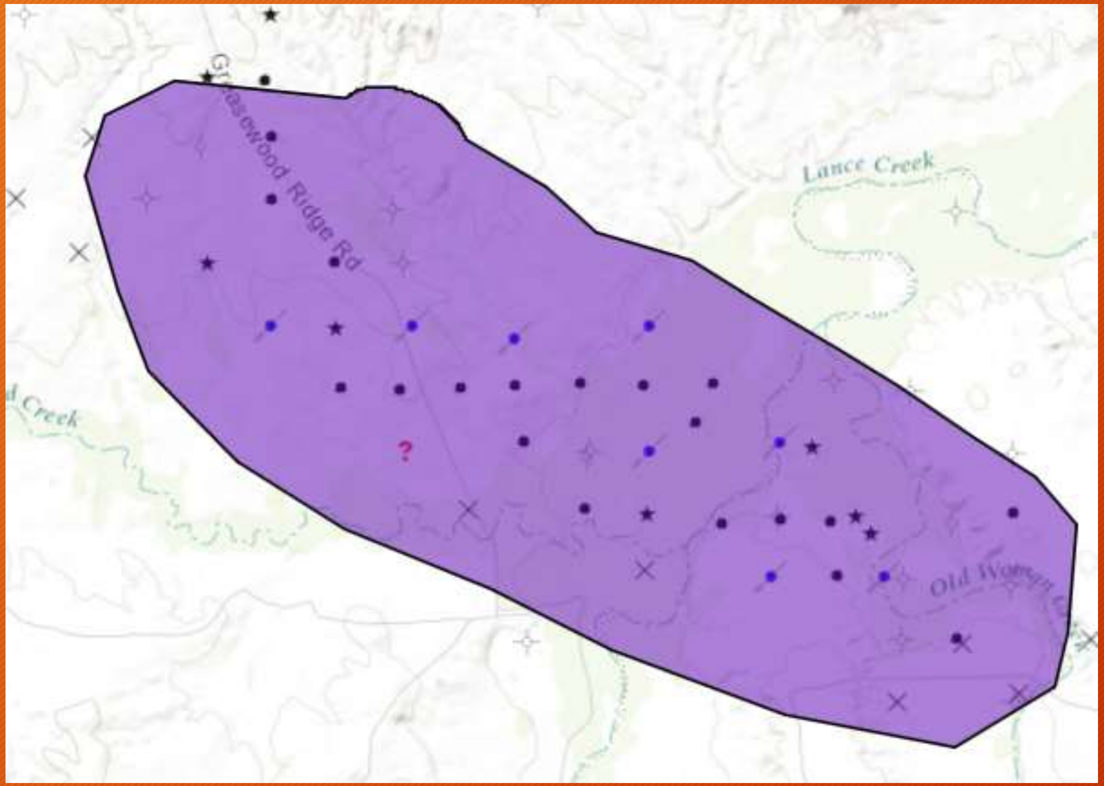
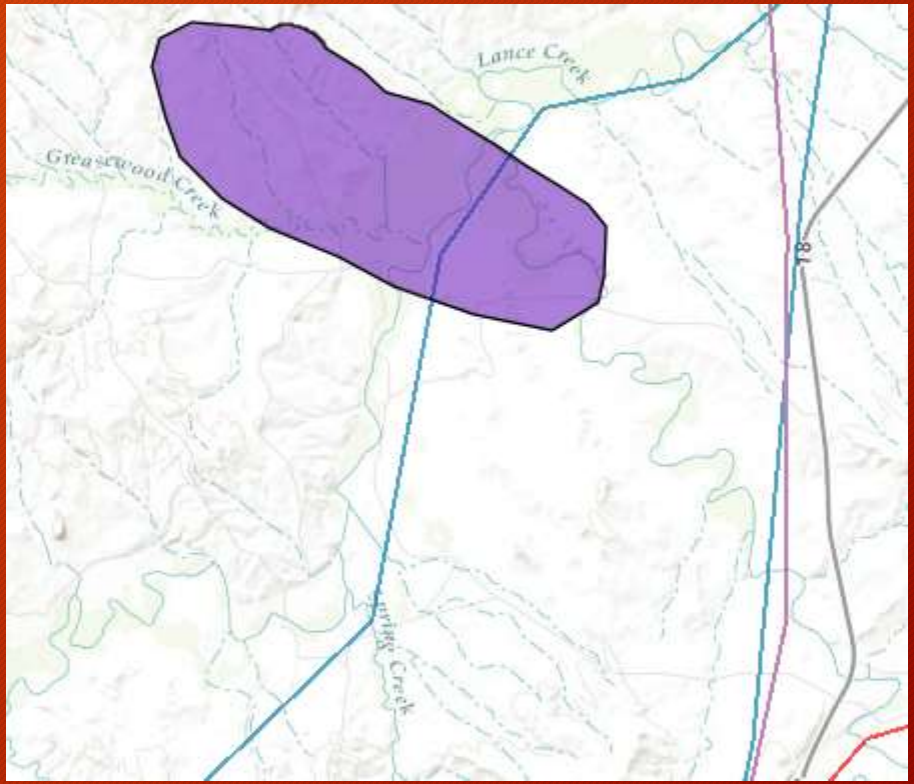


Injection and Production Wells



Pipeline Map (crude oil line through field)

Thompson Creek Field: (New Field Index: 0.78)

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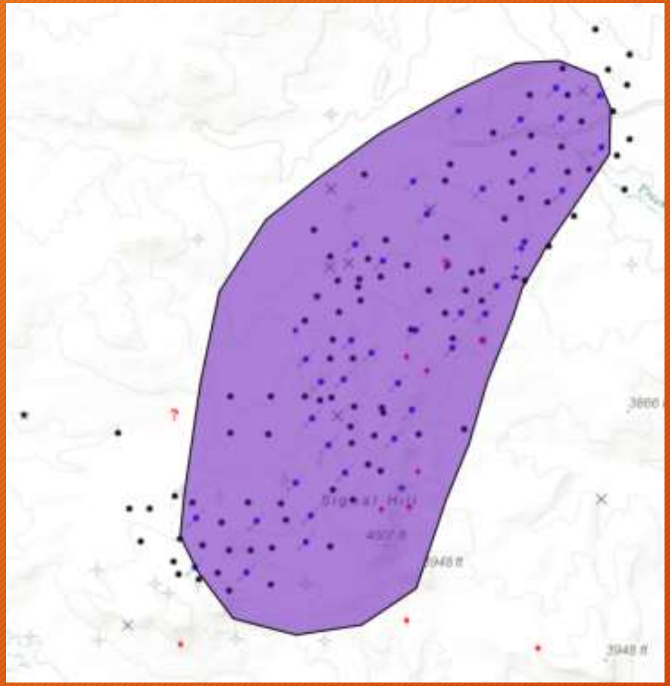


Formation: Muddy (Newcastle)

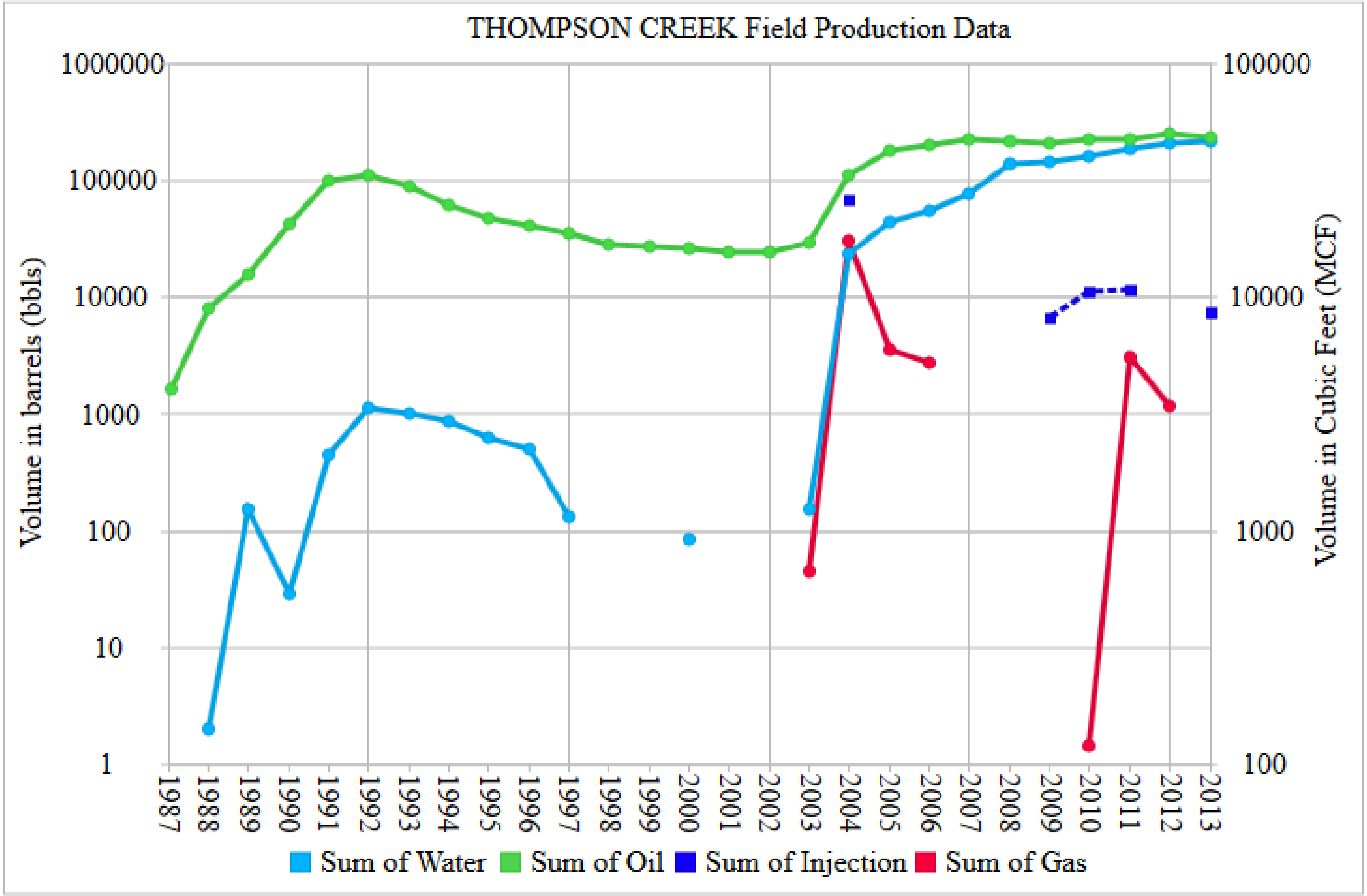
No Current EOR Projects

Field Status: Injecting Water

Production: Oil (Primary) and some Gas

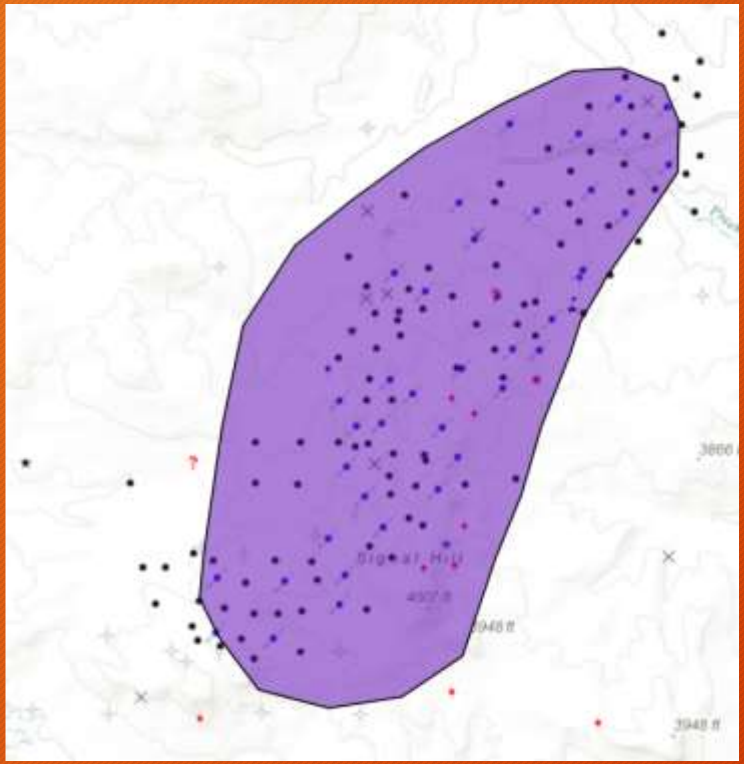
Variables	Values
Porosity (%)	15
Permeability (mD)	50
API Gravity (˚)	20
Depth (feet)	1593
Temperature (˚F)	81
Viscosity (cP)	78
Oil Saturation (%)	?

Recommended: ASP flooding (dependent on saturation); viscosity + API = Alkali

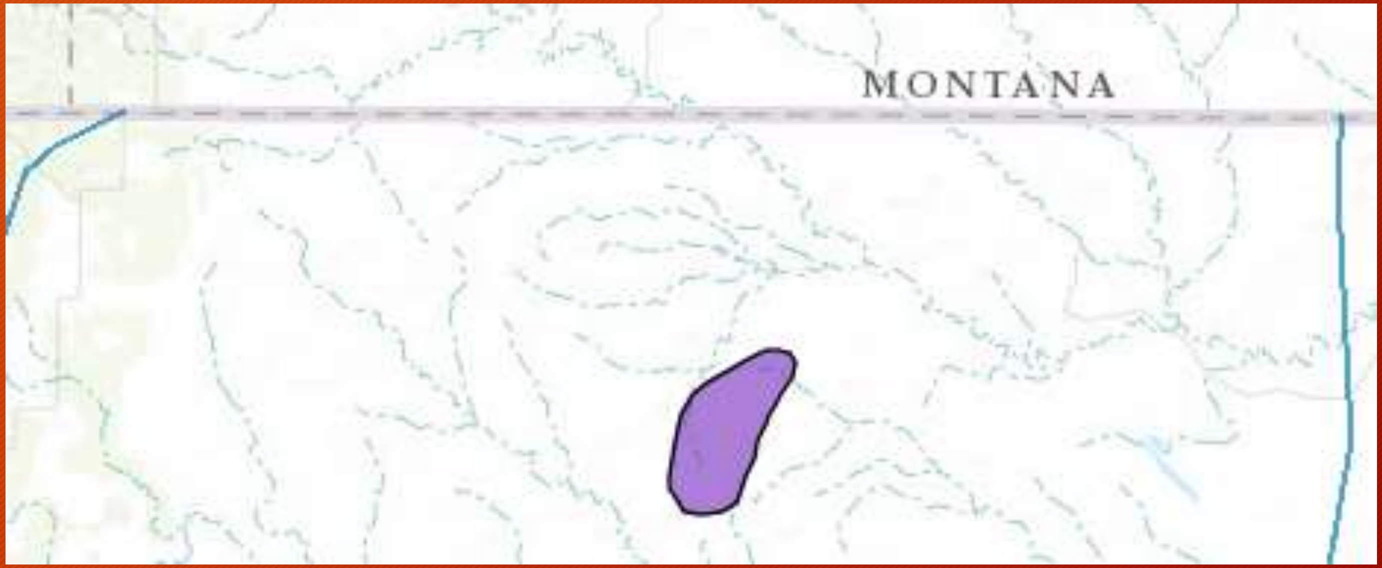


THOMPSON CREEK Field Production Data
Volume in barrels (bbls)
Volume in Cubic Feet (MCF)
1000000
100000
10000
1000
100
10
1
100000
10000
1000
100
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Sum of Water
Sum of Oil
Sum of Injection
Sum of Gas

Thompson Creek Maps

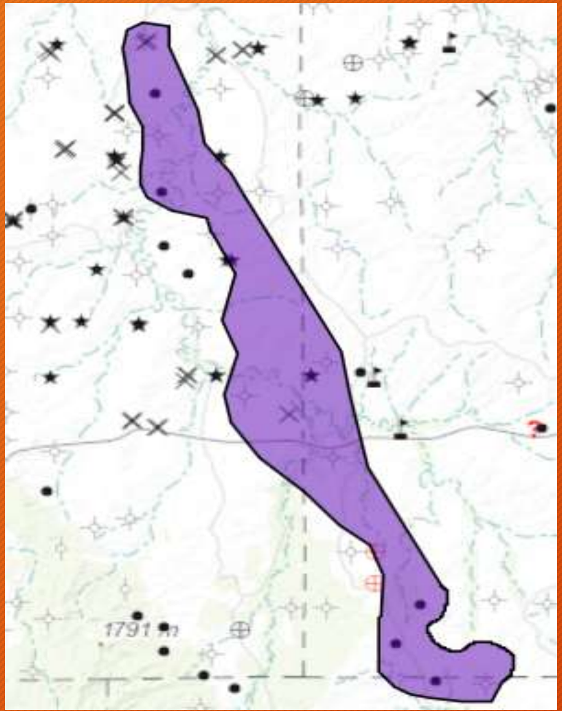


Injection and Production wells



Pipeline Map (Crude Oil Line East and West)

Taylor Field: (New Field Index: 0.95)



Formation: Frontier

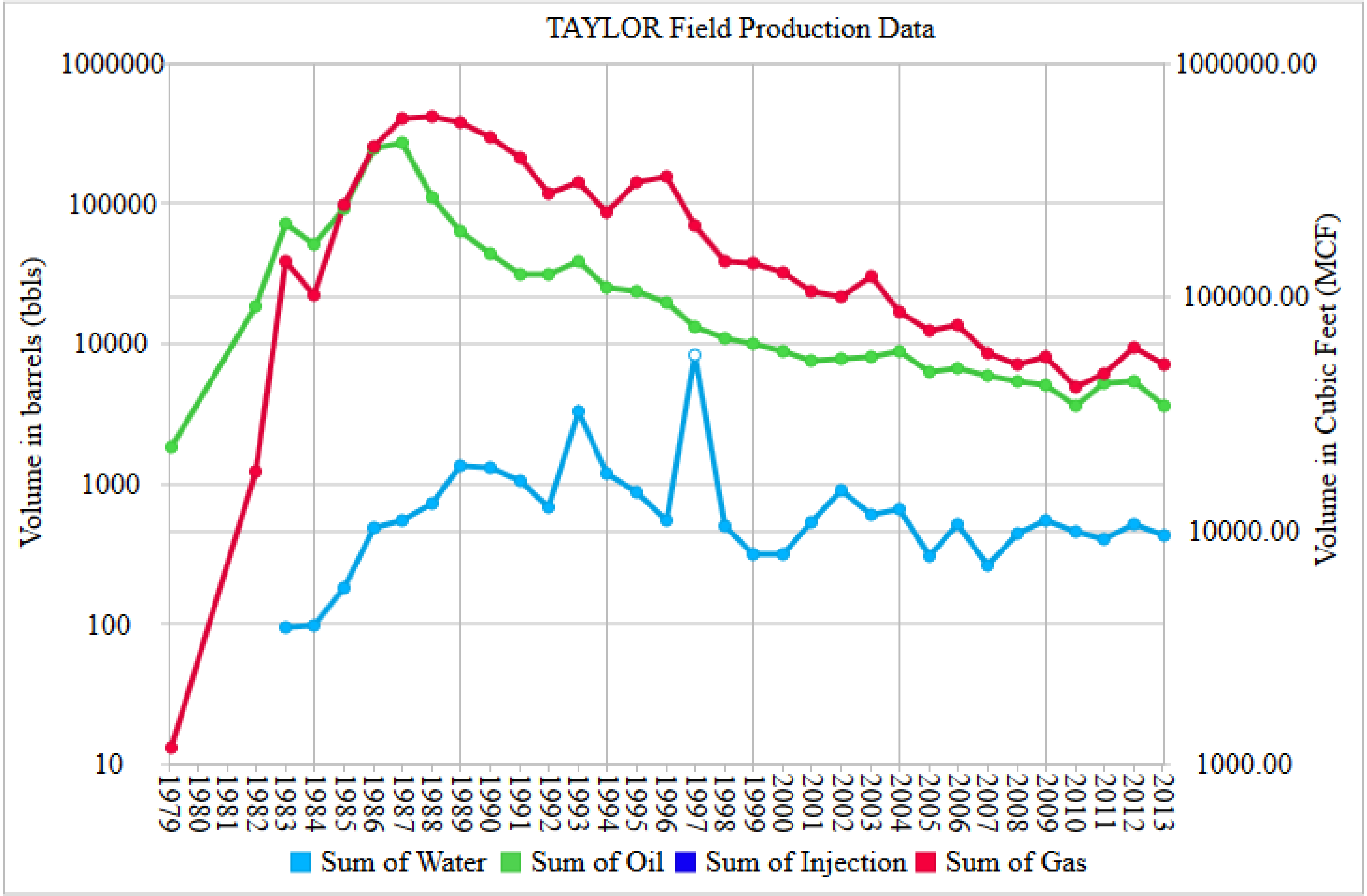
No EOR Project

Field Status: Primary Recovery

Production: Oil and Gas

Variables	Values
Porosity (%)	9
Permeability (mD)	70
API Gravity (°)	25
Depth (feet)	1555
Temperature (°F)	80
Viscosity (cP)	15
Oil Saturation (%)	?

Recommended: ASP flooding (dependent on saturation)


TAYLOR Field Production Data
Volume in barrels (bbls)
Volume in Cubic Feet (MCF)
1000000
100000
10000
1000
100
10
1000000.00
100000.00
10000.00
1000.00
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Sum of Water
Sum of Oil
Sum of Injection
Sum of Gas

Taylor Field Maps

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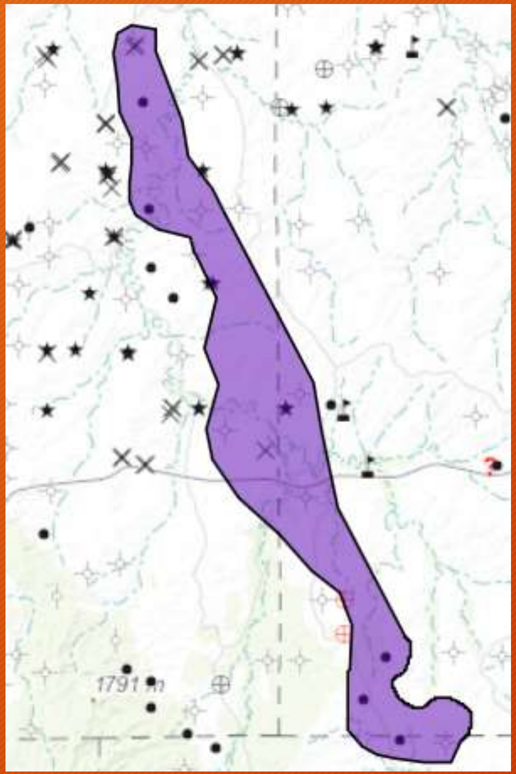
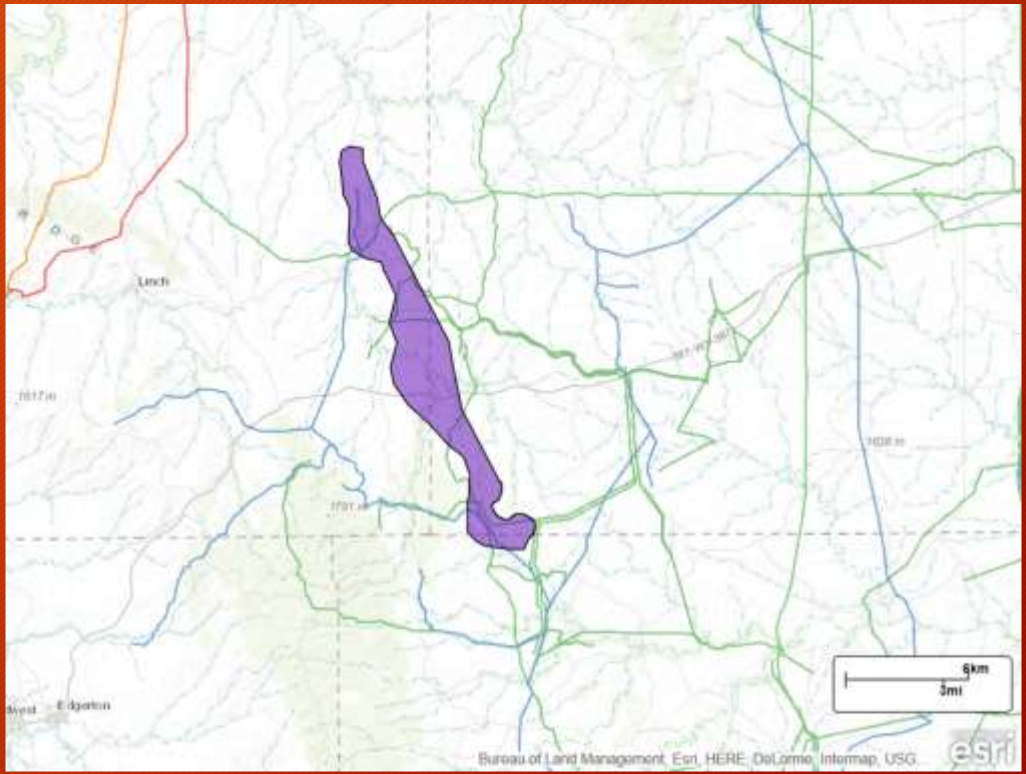


Injection and Production Wells



Pipeline Map (Crude and Gas Lines through field)

SUMMARY

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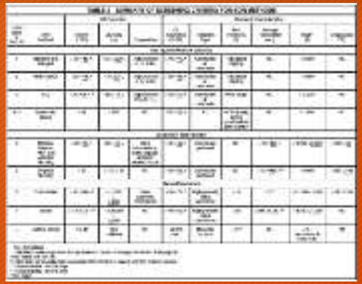
Project Overview



Location: Powder River Basin

Production: 2008 Oil Production > 10,000

API Gravity: > 22

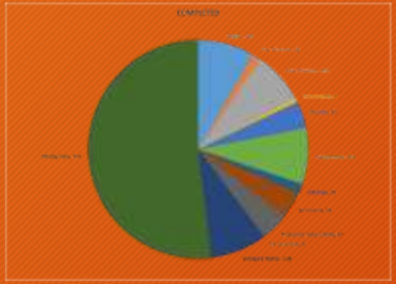
Viscosity: < 10 cp

Depth: >2500

Temperature: No screening

Chemical Flooding

- API Gravity > 15
- Viscosity < 35,150 cp
- K > 10 mD
- Depth < 9000 ft
- Temperature < 200



API Gravity	
Median	35
Low	20
Field Median	20
Index	0

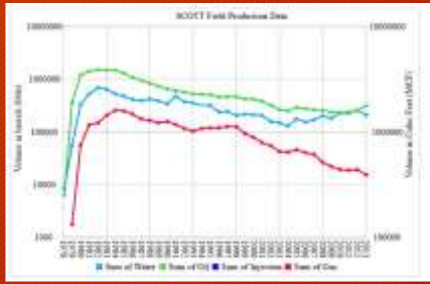
Viscosity	
Median	12
High	150
Field Median	78
Index	0.5256

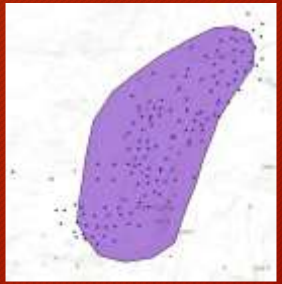
Oil Saturation	
Median	53
Low	35
Field Median	
Index	0

Average K	
Median	450
Low	10
Field Median	50
Index	0.09091

Depth	
Median	3250
High	9000
Field Median	1593
Index	1.288

Temperature	
Median	140
High	200
Field Median	81
Index	1.9833





Major Challenges

- ~5000 Fields → Preliminary Screening
- Missing Data → Public Databases
- CO_2 flooding to Chemical Flooding → Re-Screen all fields
- Lack of results → Quick method of indexing
- Indexing equation → Human Error, Top fields?
- Field History → EORI's IDP difficult to use

- TIME CONSTRAINTS!

Results and Recommendations

5 fields:

- Crawford Draw – Surfactant flooding
- Greasewood – ASP flooding
- Taylor – ASP flooding
- Scott – SP flooding
- Thompson Creek – ASP flooding

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Questions?

Thank You!

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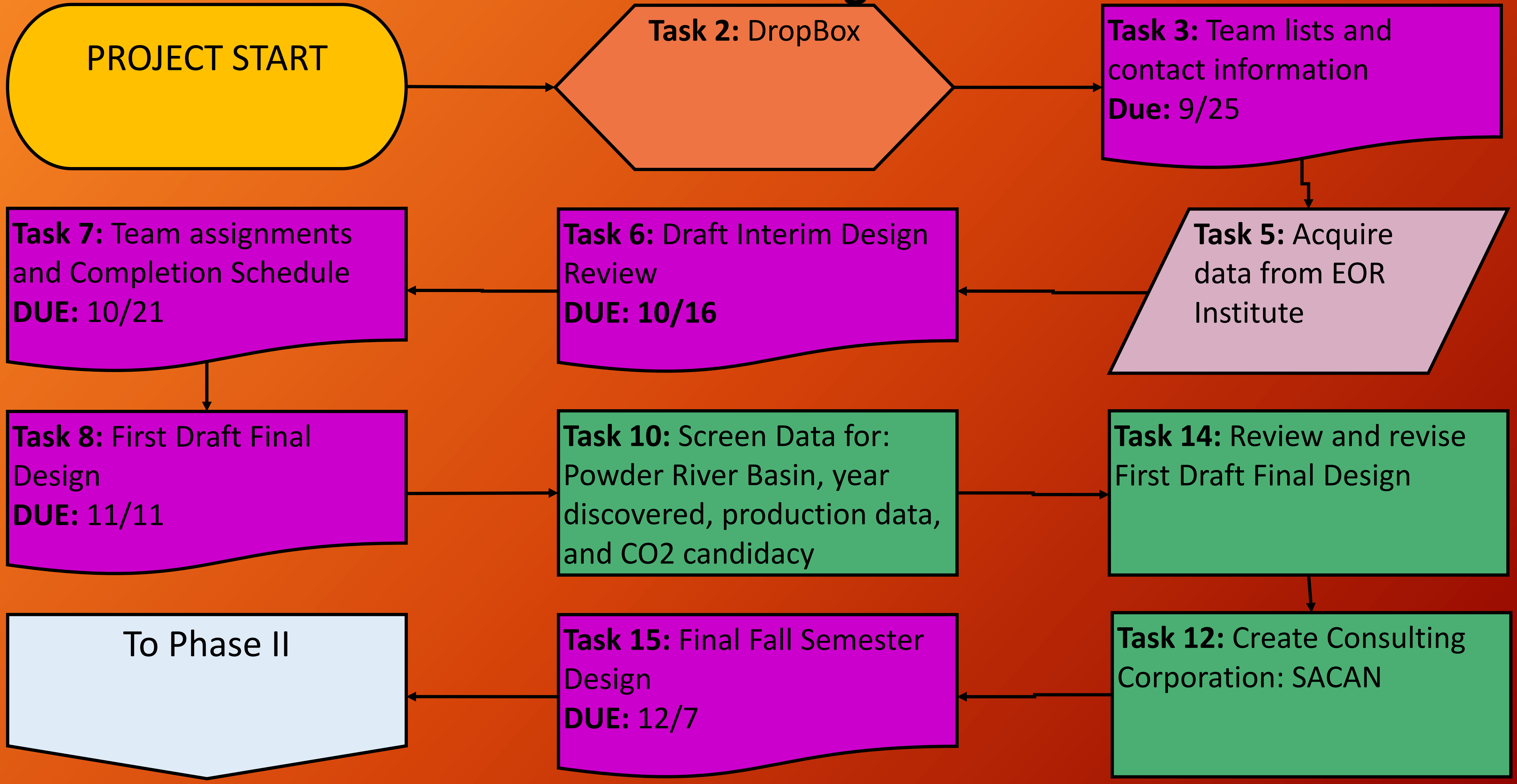
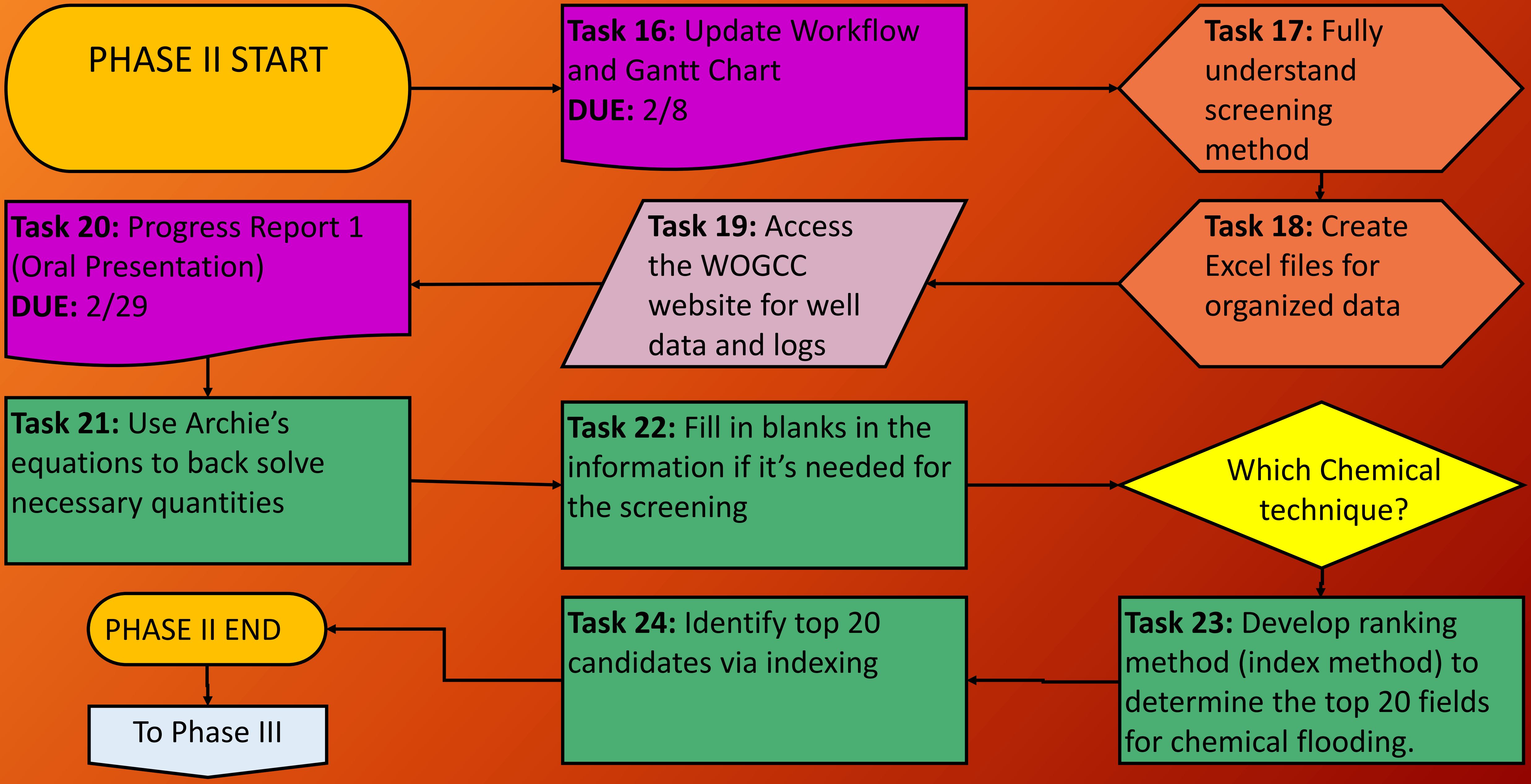
Bringing you STELLAR EOR Consultation

Phase I: Planning Phase



Phase II: Screening, Filling in data, Indexing



Phase III: Field Histories

PHASE III START

Task 24: Progress Report III
DUE: 4/18

Task 25: Identify top 5 fields and their formations

Task: 26: Access UW's EORI database software program (ESRI)

Task 27: Record well locations, production histories, injector wells, producing wells, current EOR methods, water cut

Task 28: Compile information and integrate to perform preliminary chemical flooding plans

Task 29: Organize information into graphic representations of our results, and begin development of final report and presentation

Task 30: Create final report and presentation, practice for Undergraduate research day

Task 31: Undergraduate Research Day
DUE: 4/30

Project Success

Chemical Additive	Function(s)	EOR Mechanisms
Alkali	Increase pH to extract natural surfactants (if oil has acid number > 0.5 mg KOH/g crude) [a]	Decrease IFT
	Increase ionic strength, which alters emulsification pH profile and partition coefficient	Decrease IFT and regulates phase behavior
	Increase negative charge density on rock surface	Decrease the adsorption of anionic chemicals and makes rock more water wet
Surfactant	Adsorb at oil-water interface	Decrease IFT
	Forms mixed micelles with in-situ generated natural surfactants[a]	Broadens alkali concentration range for minimum IFT
Polymer	Increase water viscosity	Decrease water mobility
	Adsorb onto rock decrease effective water permeability	

Modified from SPE-78711

Metho

TABLE 3—SUMMARY OF SCREENING CRITERIA FOR EOR METHODS

		Oil Properties			Reservoir Characteristics					
Detail Table in Ref. 16	EOR Method	Gravity (°API)	Viscosity (cp)	Composition	Oil Saturation (% PV)	Formation Type	Net Thickness (ft)	Average Permeability (md)	Depth (ft)	Temperature (°F)
					Gas Injection Methods (Miscible)					
1	Nitrogen and flue gas	>35 ↗ 48 ↗	<0.4 ↘ 0.2 ↘	High percent of C_1 to C_7	>40 ↗ 75 ↗	Sandstone or carbonate	Thin unless dipping	NC	>6,000	NC
2	Hydrocarbon	>23 ↗ 41 ↗	<3 ↘ 0.5 ↘	High percent of C_2 to C_7	>30 ↗ 80 ↗	Sandstone or carbonate	Thin unless dipping	NC	>4,000	NC
3	CO_2	>22 ↗ 36 ↗ [a]	<10 ↘ 1.5 ↘	High percent of C_5 to C_{12}	>20 ↗ 55 ↗	Sandstone or carbonate	Wide range	NC	>2,500[a]	NC
1–3	Immiscible gases	>12	<600	NC	>35 ↗ 70 ↗	NC	NC if dipping and/or good vertical permeability	NC	>1,800	NC
					(Enhanced) Waterflooding					
4	Micellar/ Polymer, ASP, and Alkaline Flooding	>20 ↗ 35 ↗	<35 ↘ 13 ↘	Light, intermediate, some organic acids for alkaline floods	>35 ↗ 53 ↗	Sandstone preferred	NC	>10 ↗ 450 ↗	>9,000 ↘ 3,250	>200 ↘ 80
5	Polymer Flooding	>15	<150, >10	NC	>50 ↗ 80 ↗	Sandstone preferred	NC	>10 ↗ 800 ↗ [b]	<9,000	>200 ↘ 140
					Thermal/Mechanical					
6	Combustion	>10 ↗ 16 → ?	<5,000 ↓ 1,200	Some asphaltic components	>50 ↗ 72 ↗	High-porosity sand/ sandstone	>10	>50[c]	<11,500 ↘ 3,500	>100 ↗ 135
7	Steam	>8 to 13.5 → ?	<200,000 ↓ 4,700	NC	>40 ↗ 66 ↗	High-porosity sand/ sandstone	>20	>200 ↗ 2,540 ↗ [d]	<4,500 ↘ 1,500	NC
—	Surface mining	7 to 11	Zero cold flow	NC	>8 wt% sand	Mineable tar sand	>10[e]	NC	>3:1 overburden to sand ratio	NC

NC = not critical.
Underlined values represent the approximate mean or average for current field projects.
[a]See Table 3 of Ref. 16.
[b]> 3md from some carbonate reservoirs if the intent is to sweep only the fracture system.
[c]Transmissibility > 20 md-ft/cp
[d]Transmissibility > 50 md-ft/cp
[e]See depth.

TABLE 4—MICELLAR/POLYMER, ASP, AND ALKALINE FLOODING

Description

Classic micellar/polymer flooding consists of injecting a slug that contains water, surfactant, polymer, electrolyte (salt), sometimes a cosolvent (alcohol), and possibly a hydrocarbon (oil). The size of the slug is often 5 to 15% PV for a high-surfactant-concentration system and 15 to 50% PV for low concentrations. The surfactant slug is followed by polymer-thickened water. The polymer concentration often ranges from 500 to 2,000 mg/L, and the volume of polymer solution injected may be 50% PV or more.

ASP flooding is similar except that much of the surfactant is replaced by low-cost alkali so the slugs can be much larger but overall cost is lower and polymer is usually incorporated in the larger, dilute slug. For alkaline flooding much of the injection water was treated with low concentrations of the alkaline agent and the surfactants were generated in situ by interaction with oil and rock. At this time (May 1997) we are not aware of any active alkali-only floods.

Mechanisms

All surfactant and alkaline flooding methods recover oil by (1) lowering the interfacial tension between oil and water; (2) solubilization of oil in some micellar systems; (3) emulsification of oil and water, especially in the alkaline methods; (4) wettability alteration (in the alkaline methods); and (5) mobility enhancement.

Technical Screening Guides

	Recommended
Crude Oil	
Gravity, °API	>20
Viscosity, cp	<35
Composition	Light intermediates are desirable for micellar/polymer. Organic acids needed to achieve lower interfacial tensions with alkaline methods.
Reservoir	
Oil saturation, % PV	>35
Type of formation	Sandstones preferred
Net thickness	Not critical
Average permeability, md	>10
Depth, ft	<about 9,000 ft (see Temperature)
Temperature, °F	<200

Limitations

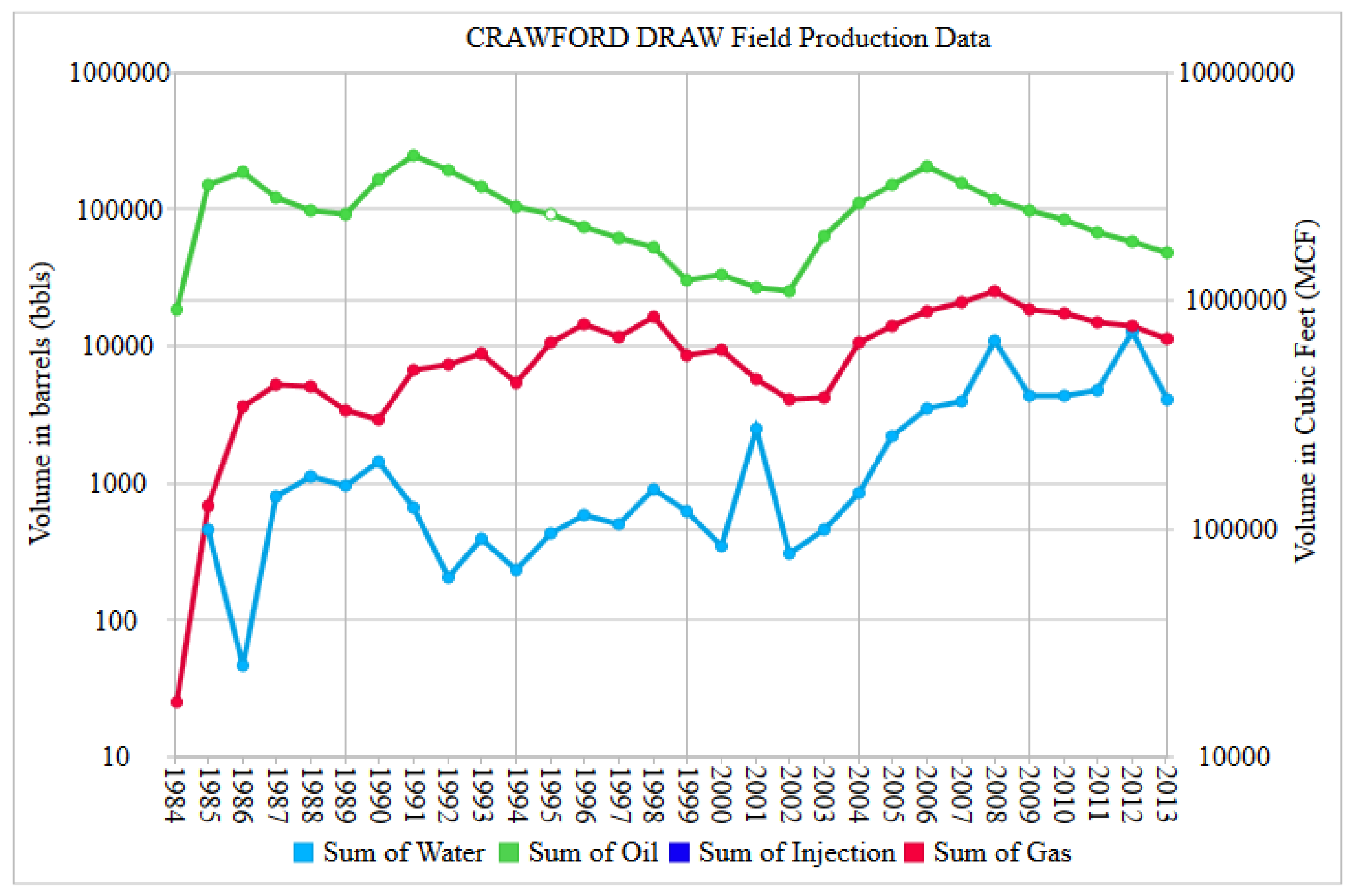
An areal sweep of more than 50% on waterflood is desired. Relatively homogeneous formation is preferred. High amounts of anhydrite, gypsum, or clays are undesirable. Available systems provide optimum behavior over a narrow set of conditions. With commercially available surfactants, formation-water chlorides should be <20,000 ppm and divalent ions (Ca^{++} and Mg^{++}) <500 ppm.

Problems

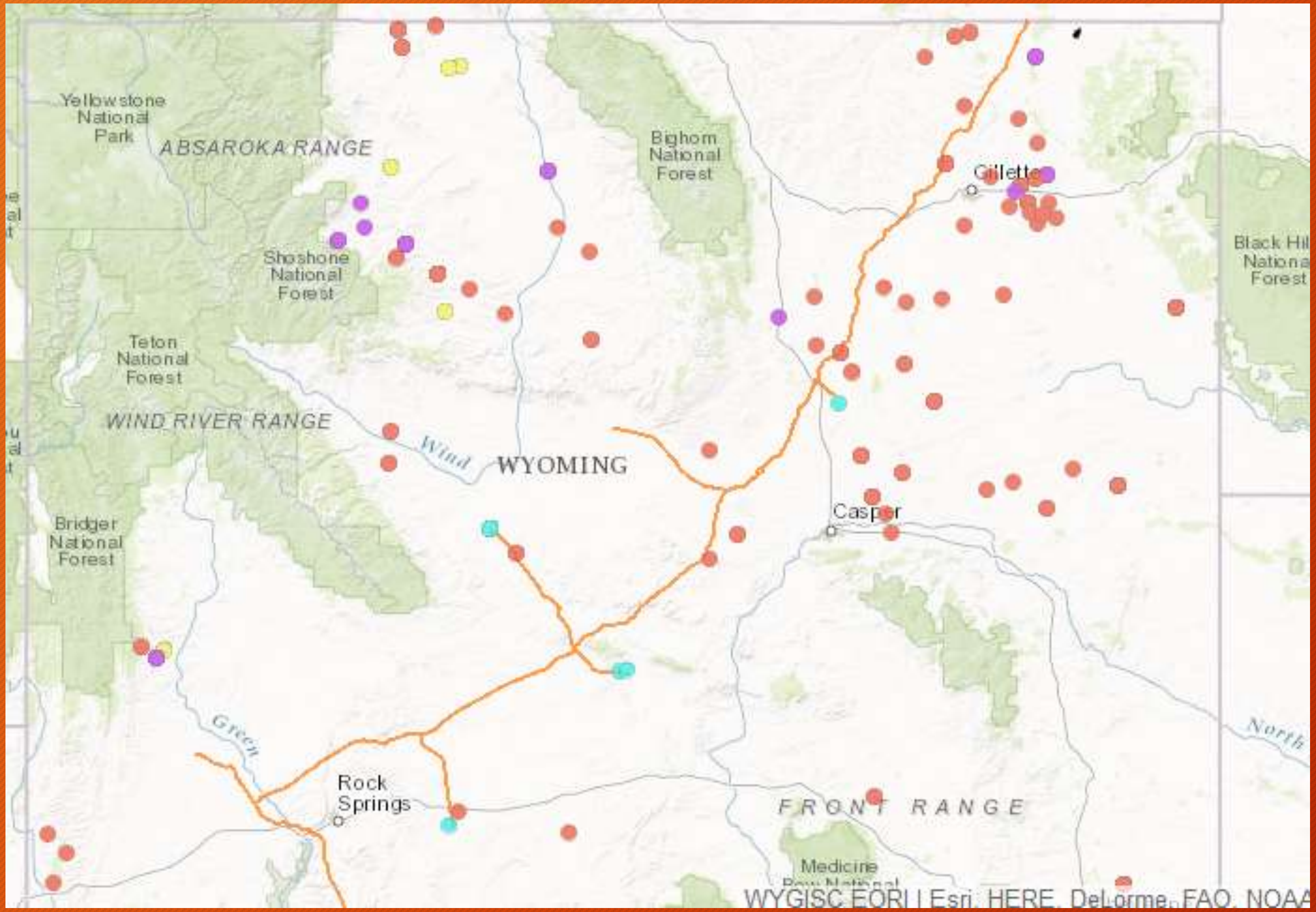
Complex and expensive systems. Possibility of chromatographic separation of chemicals in reservoir. High adsorption of surfactant. Interactions between surfactant and polymer. Degradation of chemicals at high temperature.

Crawford Draw Field Details

Field Status: Primary Recovery
Production: Oil (Primary) and Gas



Carbon Dioxide Flooding in Wyoming

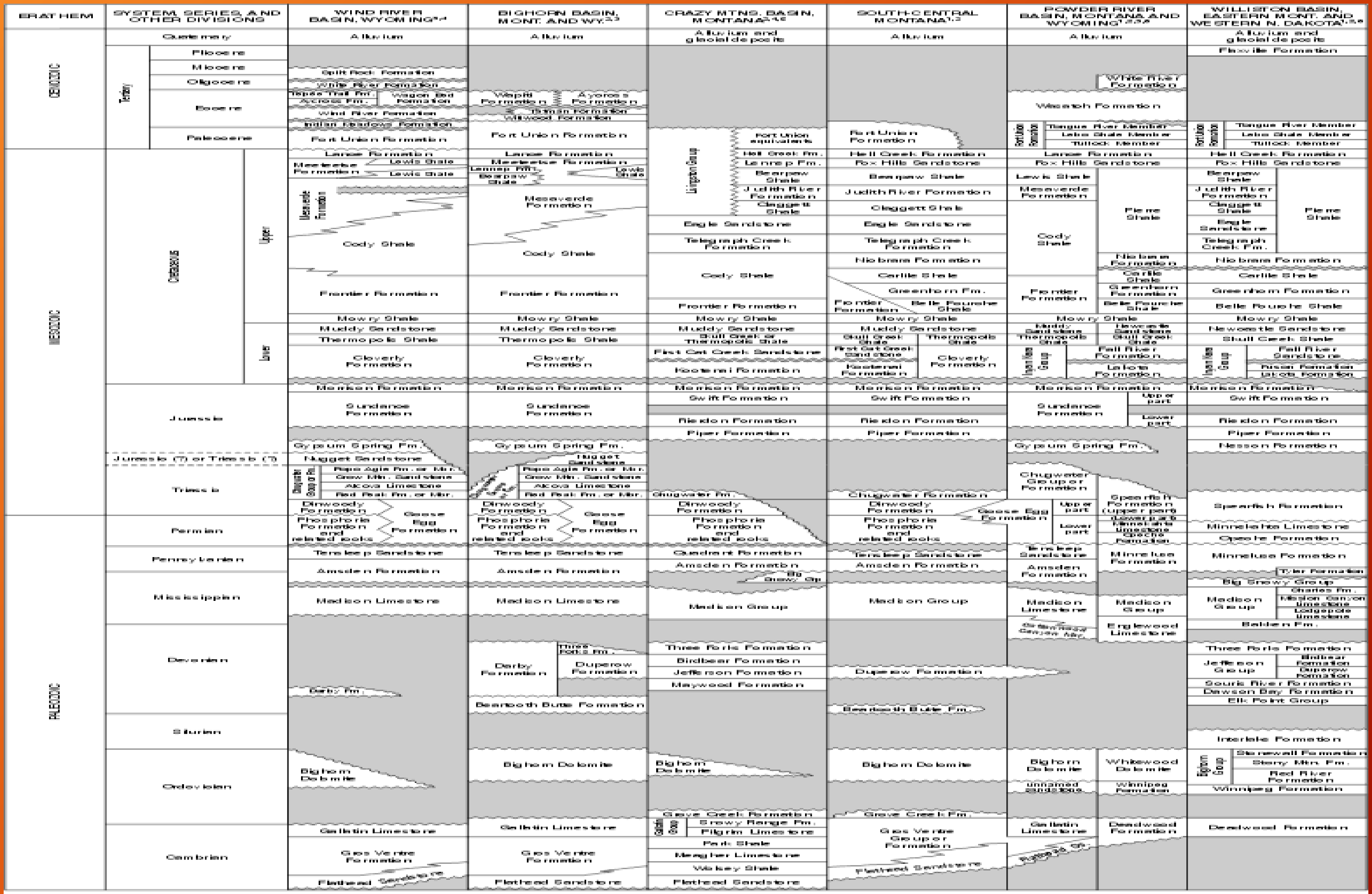


Requires Carbon Dioxide Pipeline (permit required for storage)

Current Only 5 active CO2 Floods (Light Blue)

1) Salt Creek
2) Lost Soldier
3) Wertz
4) Beaver Creek
5) Patrick Draw

Other Gas Floodings:
Immiscible Conditions (Purple)
Miscible Conditions (Red)
Mixed Conditions (Yellow)



Compiled from [1]Anna, 1986; [2]Balster, 1980; [3]Love and others, 1993; [4]McGreevy and others, 1972; [5]Robinson, 1972; and [6]Whitehead, 1996

Figure 8. Generalized correlation chart of Paleozoic, Mesozoic, and Cenozoic rocks, Yellowstone River Basin.