Chemical EOR:
Powder River Basin Field Screening

Final Report

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Cover Letter

This report details the process of enhanced oil recovery field screening of the Powder River Basin for potential chemical flooding candidates. The report outlines the entire process, including: planning, preliminary screening, indexing, filling in data, recognizing the top 5 fields, and finally performing a field history on each of the top 5 to determine recommended chemical flooding techniques.

The project was divided into 3 phases: a planning phase, a screening and indexing phase, and a field history phase. The planning phase began in August of 2015 and continued until December 2015. The planning detailed the process our corporation was to follow, and included a linked Gantt Chart for scheduling purposes, with project completion anticipated in April of 2016.

The second phase included screening, indexing, and filling in data blanks. The preliminary screening used parameters also used by the Enhanced Oil Recovery Institute, as well as parameters to narrow our focus to the Powder River Basin and high producing fields (to make our endeavor profitable). An indexing method employed using 6 field values to quickly identify the top 20 fields, and the filling in of the blanks was used primarily for more accurate field histories, discussed next.

The final phase involved accessing the EORI's Interactive Data Platform for infrastructure, field values, and other pertinent information for chemical flooding recommendations. The top 5 fields were identified, and this detailed field analysis was performed. A recommendation was made for each field as for the particular EOR method recommended, and this report details the process and the results of that research.

Executive Summary

The Powder River Basin (PRB) in NE Wyoming contains over 4,300 fields that the Enhanced Oil Recovery Institute (EORI) of the University of Wyoming (UW) has determined to be active producers of oil or gas, and require a thorough screening and ranking process to determine the top candidates for enhanced oil recovery (EOR) methods for improved production. Operators of these fields do not actively search for appropriate EOR methods of their respective fields, and the EORI accesses public databases such as the Wyoming Oil and Gas Conservation Commission (WOGCC) and the Energy Information Administration (EIA) along with their own database to locate Wyoming candidates for specific EOR methods in order to aid in boosting Wyoming's economy.

The high number of potential fields in the PRB prove quite a challenge to screen through, and SACAN Corporation uses a unique screening and ranking method to efficiently and accurately find the top potential fields for this area by screening for only chemical flooding candidates and fields that have produced over 10,000 bbls of oil (cumulative) as of 2008. Using a screening table provided by the EORI, SACAN first reduced the high number of fields to potential candidates for chemical flooding. We then accessed public databases as mentioned before and the EORI's Interactive Data Platform (IDP) powered by a software program called esri to locate pertinent field information such as porosity, permeability, oil saturation, density, viscosity, depth and temperature.

Using our filled in data and an indexing method to rank the fields, we narrowed our search to the top 5 fields; Thompson Creek, Greasewood, Scott, Crawford Draw, and Taylor. Using EORI's IDP, a detailed field analysis was performed to analyze in-place infrastructure and compatibility for chemical flooding techniques. Due to the ideal values for density, viscosity, permeability, depth and temperature of Thompson Creek, Greasewood, and Taylor, all three fields were recommended for Alkali-Surfactant-Polymer (ASP) flooding. The Scott field, due to the low permeability was recommended for Alkali-Surfactant (AS) flooding. Crawford Draw, due to the high temperature and depth, and low viscosity was found to have escaped our indexing screening; instead of eliminating the field as a potential candidate, SACAN instead used the field and performed a field analysis to determine it was indeed a good candidate for Surfactant (S) flooding.

Future work on this project should involve the following changes. First, a detailed literature search on the area of interest should occur first, as that allows for the proper EOR technique to be screened for initially. Second, a preliminary indexing method such as that used in this report should be employed to identify the top 50 fields. This reduces the number of fields to fill in data for substantially. Third, a data review on which values can easily be found should be conducted. This will allow for maximum effectiveness; once these easily-found values are acquired, an update to the screening and indexing can eliminate more fields before more difficult parameters are searched for.

Table of Contents

List of Figures and Tables

Figures:

Tables:

Nomenclature

BBLS	Barrels
BPD	Barrels per day
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EORI	Enhanced Oil Recovery Institute
EORI IDP	EORI's Interactive Data Platform
ESRI	A software Wyoming database program created by the EORI
EUR	Enhanced Ultimate Recovery
PWB	Powder River Basin
SACAN	Saudi Arabian, Canadian, American, and Nigerian
UW	University of Wyoming
WOGCC	Wyoming Oil and Gas Conservation Commission

1 – Introduction

The Powder River Basin within Wyoming contains in excess of 4,830 different fields, ranging from the NE corner of Wyoming, SW to fields surrounding Casper. The basin employs a standard method of oil recovery, typically beginning with primary pressure drainage, and then commencing with water flooding when production begins to drop off. There are currently multiple EOR techniques used when a field nears the end of commercial production, from CO_2 injection to chemical flooding. The major formations are sandstone with conventional permeability.

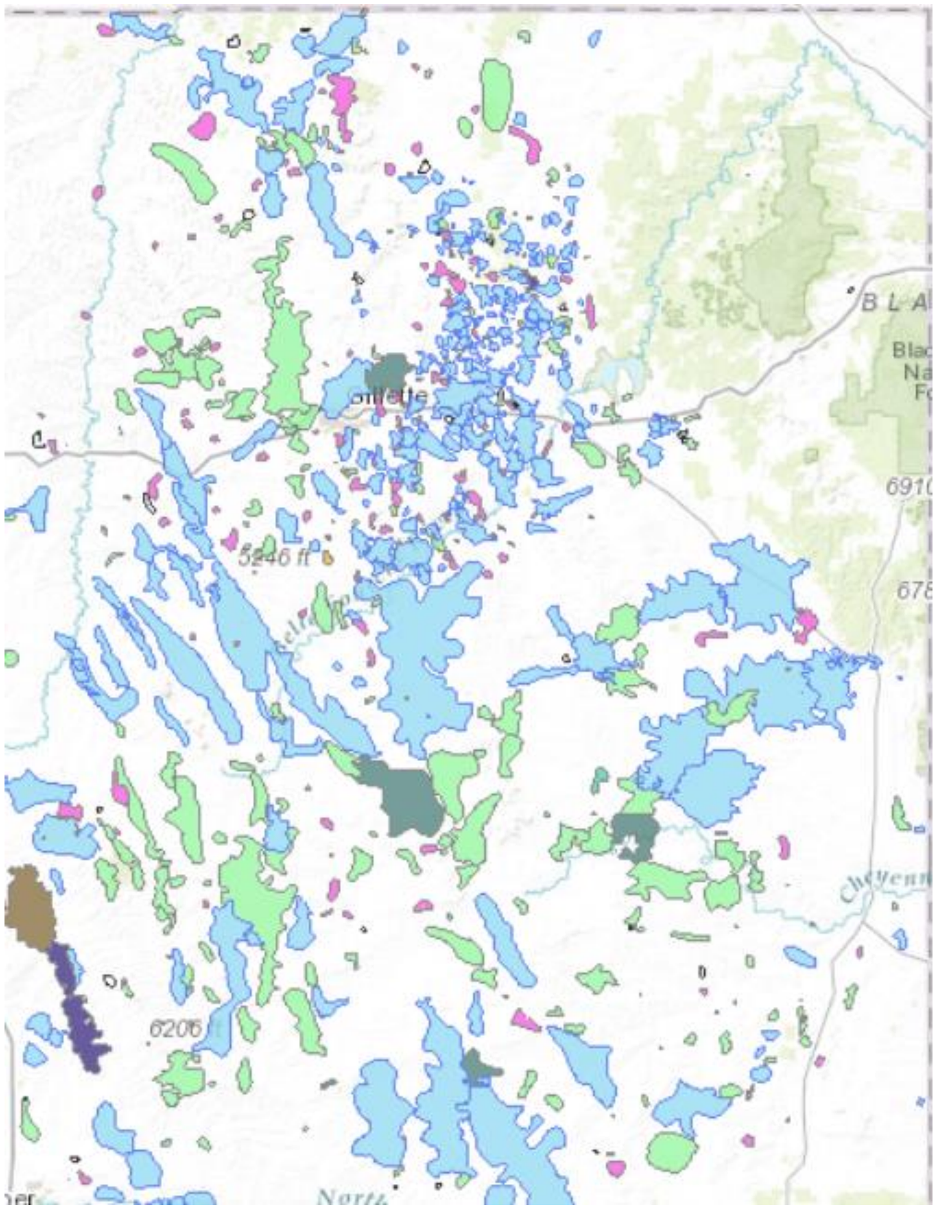


Figure 1: Field areas in the Powder River Basin. Image pulled from EORI's Interactive Data Platform

The EORI accesses the (WOGCC) database to locate potential field candidates in Wyoming for EOR techniques. They then approach the field operators and relay that information so that maximum enhanced ultimate recovery (EUR) is achieved, helping Wyoming's economy. The current EORI Wyoming database has 4,867 fields, with most missing data of one form or another. Aside from locating potential EOR candidates, the EORI accesses public databases for information on the fields in order to fill in the missing data.

Similar to the EORI, our company screens through the same data packet to locate EOR fields by comparing field values to look-up tables, and fills in the missing data. We however have focused our screening to include only good candidates for chemical flooding techniques, took the top 5 of those fields by performing a basic ranking, and used the EORI's IDP to identify field histories for the purpose of a preliminary chemical injection implementation plan.

Chemical EOR methods involve the injection of a fluid (usually water) in addition to additives that are designed to affect either the rock properties, fluid properties, or both. Polymer flooding affects the water mobility ratio by introducing large polymer chains to increase the viscosity of water, increasing mobility ratio and therefore sweep efficiency. Surfactants decrease the interfacial tension between oil and water, and helps water displace more oil. Alkali flooding is injected to generate in situ natural surfactants for reservoirs with low API gravity crude oils, and if used in conjunction with surfactants acts a sacrificial agent to increase the salinity of the water (aiding in injected surfactant performance).

2 – Planning

2.1 – Reference of Used Symbols

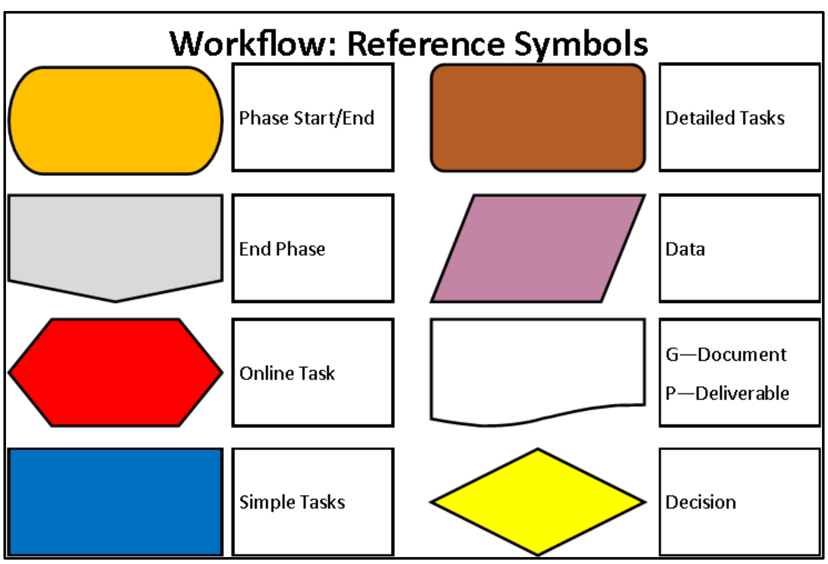


Figure 2.1.1: These symbols were the ones used in our flowchart; G means the icons were green, and P means the icons were purple.

2.2 – Work Task Flow and Gantt Chart

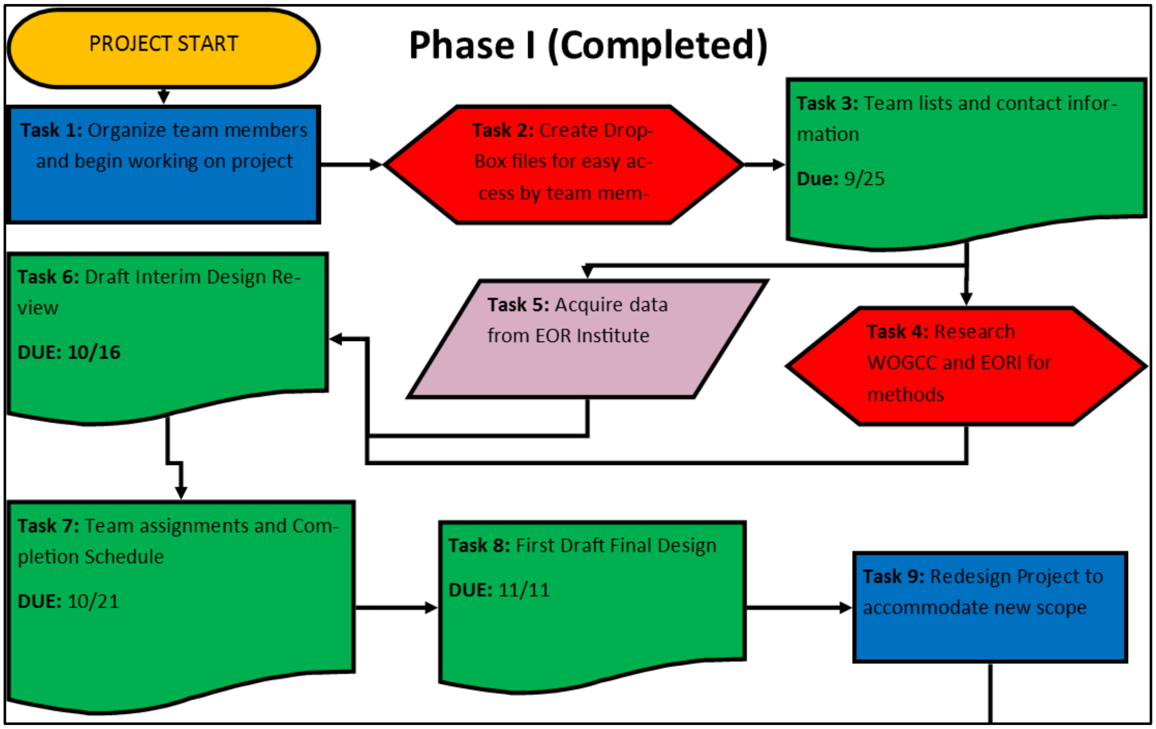


Figure 2.2.1: First half of Phase I of our planning phase, showing the acquisition of data and the creation of our first draft final design

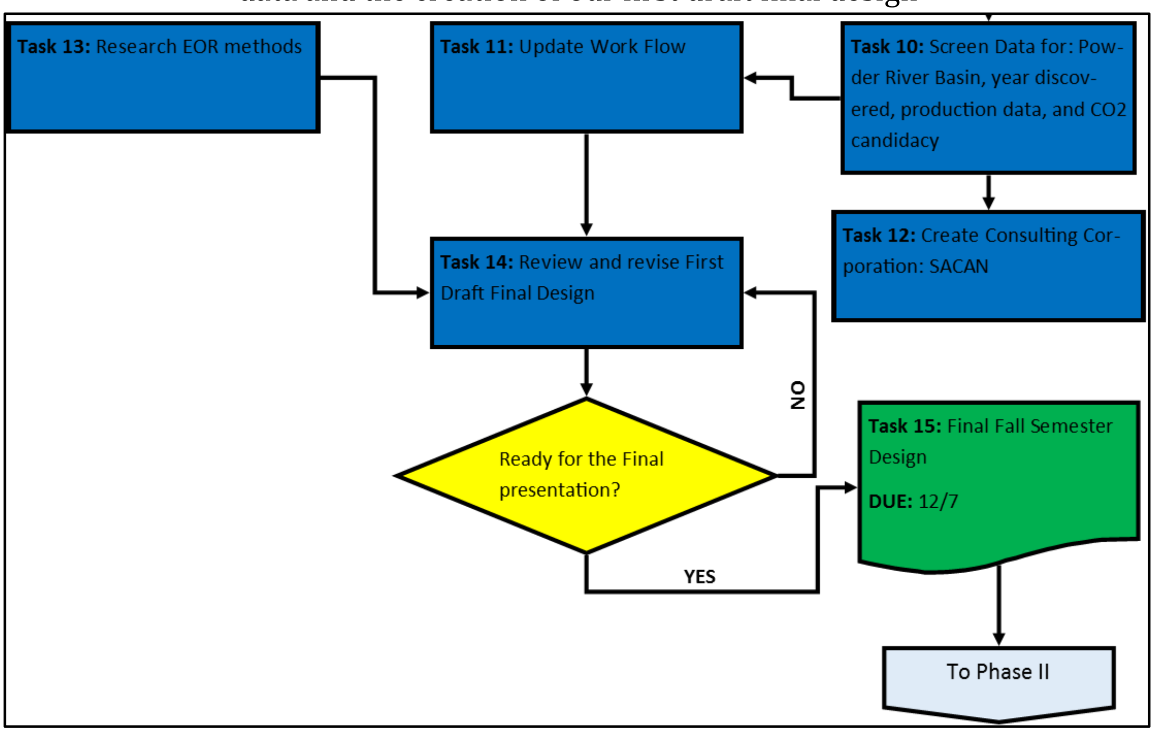


Figure 2.2.2: Second half of Phase I detailing the creation of SACAN, fine-tuning the Workflow and the preparation of our final presentation

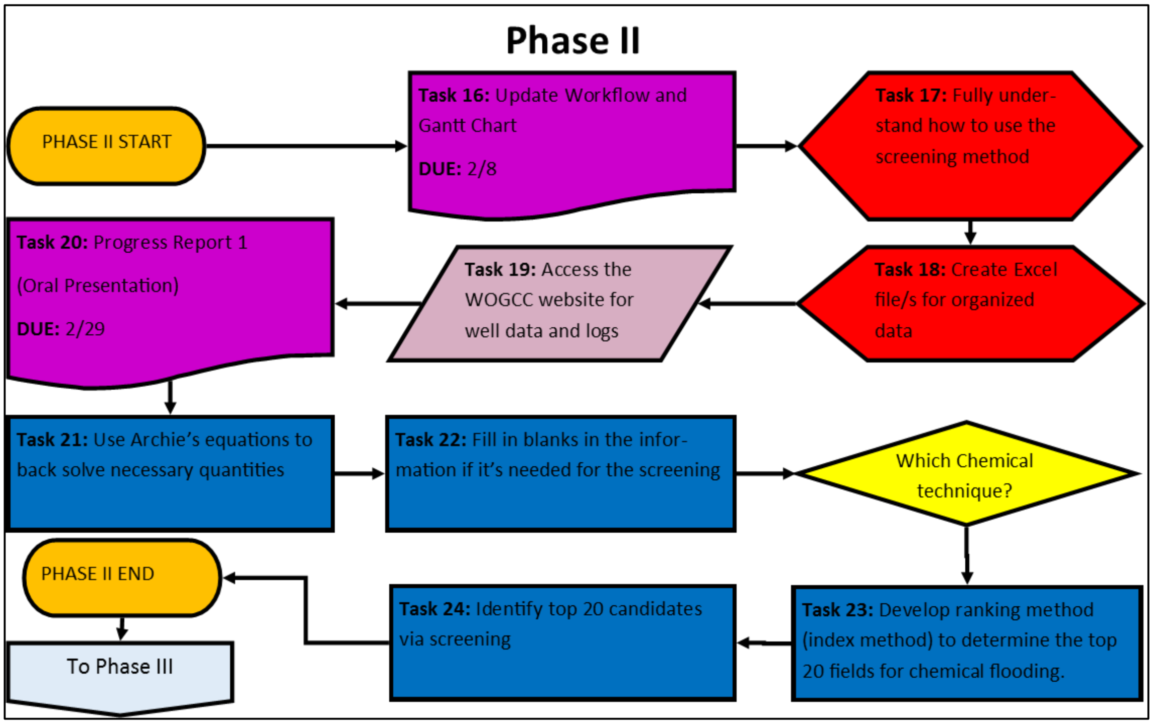


Figure 2.2.3: Phase II showing the screening, indexing method creation, and filling in the data blanks before indentifying the top 20 candidates

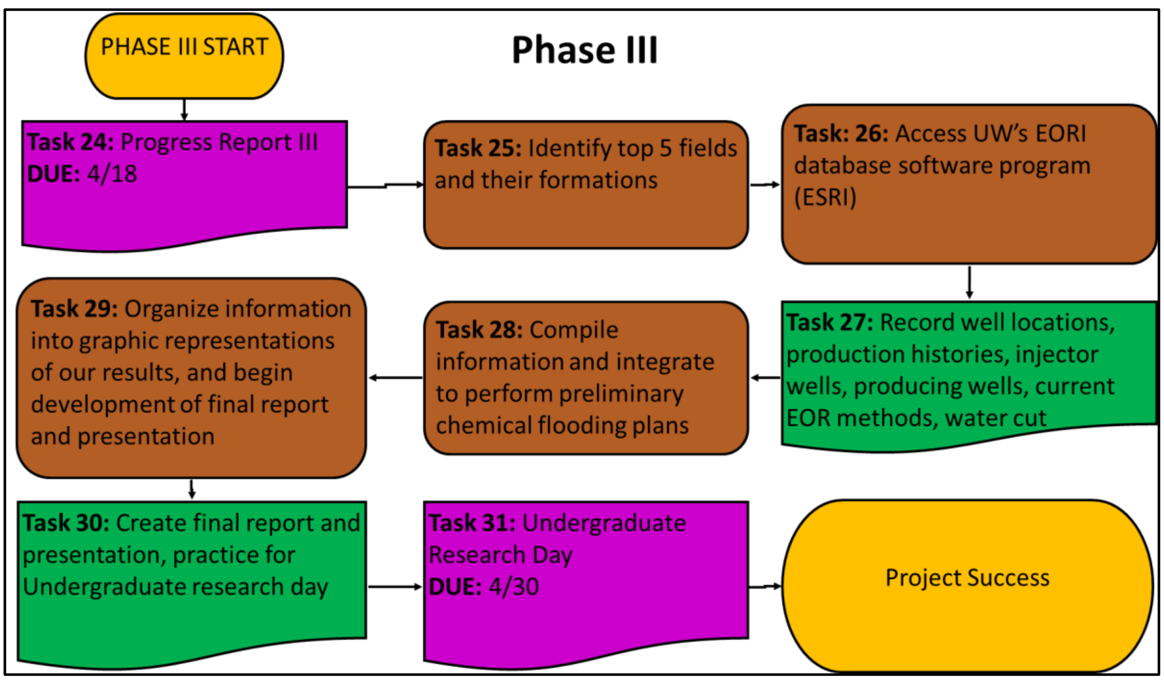


Figure 2.2.4: Phase III detailing identification of the top 5 fields and the verification and analysis of which chemical flooding those fields would best be suited for by performing field histories

Gantt Chart: Phase I							
Task #	Task Name	Team Member	Duration		Start	Finish	Predecessors
1	Organize Team	All	16	days	243	259	
2	DropBox	S	2	days	260	262	1
3	Team List and Contacts	All	6	days	263	269	2
4	Research WOGCC	M	4	days	270	274	3
5	EORI Data	T	2	days	270	272	3
6	Draft Interim Design Review	All	13	days	275	288	4,5
7	Team Assignments and Completion Schedule	T	2	days	273	275	6
8	First Draft Final Design	All	7	days	276	283	7
9	Redesign	All	4	days	284	288	8
10	Preliminary Screening	T	2	days	289	291	9
11	Update Workflow	T	15	days	292	307	10
12	Create SACAN	All	15	days	292	307	10
13	EOR methods	All	3	days	288	291	
14	Review First Draft Final Design	All	6	days	307	313	11,13
15	Final Fall Semester Design	All	1	days	314	315	14

Table 2.2.5: Gantt Chart Phase I showing the scheduling of our first semester. The starting and finish days are number of the year (used in excel for ease of mathematical formulas).

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

Table 2.2.6: Gantt Chart Phase II shows the second phase of our project, and the scheduling that we ended up following for the rest of the semester.

Gantt Chart: Phase III						
Task #	Task Name	Team Member	Duration	Start	Finish	Predecessors
25	Progress Report III	All	1 days	108	108	24
26	Top 5 Fields	All	1 days	109	109	24
27	ESRI	T	3 days	110	112	26
28	Field Histories	T	3 days	113	115	27
29	Integration	M	2 days	116	117	27,28
30	Graphic Representations	T	1 days	118	118	27
31	Final Report and Presentation	All	2 days	119	120	-
32	Undergraduate Research Day	All	1 days	120	120	-

Table 2.2.7: Gantt Chart Phase III showing the ending of our project beginning with our final progress report to the preparation of our final presentation and report.

3 - Data Review

In order to better understand how we should proceed with our project, we performed multiple data reviews. These reviews occurred at each stage of our project, and our workflow and schedule were adjusted to better suit the results of our data review.

3.1 - Initial Data Review:

The initial data received from the EORI (Enhanced Oil Recovery Institute) contained information about numerous fields (4867) across the state of Wyoming. The information provided in the data packet included geology and location, reservoir and oil properties as well as some production data. Our initial assessment of the data showed a significant number of gaps. Before beginning a more detailed analysis of our data, we needed to narrow the data set so that we would only review relevant data for fields in which we were interested in. These fields were included in our lookup table; API gravity, viscosity, permeability, oil saturation, oil composition, net thickness, depth, porosity, and temperature. Our understanding of the WOGCC website was that we could access these parameters without too much issue (perhaps reading well logs and back-solving for Oil Saturation would have been the most difficult); we therefore moved forward with our project with no adjustments.

3.3 – Post Preliminary Screening:

To initiate our indexing equation, we needed to assess which variables were critical in screening a field for chemical EOR. This required a literature search for variables that affected chemical EOR to determine which variables –rock and fluid properties- we needed. Chemical EOR has several variables to determine if the field is suitable; however, each individual chemical EOR method needs a slightly different list of required variables for screening. For now, we use several general variables that are needed for most chemical EOR methods:

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

- Porosity (logs)
- Production Data
- Lithology
- Pressure Data
- Viscosity
- Oil API
- Oil Saturation
- History of EOR applied to the field
- Soft variables

3.4 – Post Indexing Method:

After determining the top 20 fields that we determined from our indexing, we accessed the WOGCC website and analyzed the data that we could obtain from the website. Based on our analysis we can obtain data from the WOGCC website for the following variables:

- Depth (logs)
- Temperature (correlation)
- Fracture Pressure (correlation)
- Permeability (logs)
- Porosity (logs)
- Production Data
- Lithology

Some of these variables could be obtained directly from logs while data for the other variables must be correlated. Some of the logs have also been downloaded, but the file sizes are very large, and require a computer at UW.

3.5 - Additional Data Needed:

Unfortunately, to analyze the potential of chemical EOR in these fields we need additional data that is not easily accessible from the WOGCC website. They are:

- Pressure Data
- Viscosity
- Oil API
- Oil Saturation
- History of EOR applied to the field
- Soft variables

To access these types of variables, the EORI's IDP was analyzed. It was found that well locations, some soft variables, pressure data, and a general field history could easily be found for any field. The values that we determined were possible via this software database moved our project forward to perform field histories with these variable included.

4 – Methods

Our project objective was to perform a field screening of Powder River Basin fields for chemical flooding EOR methods and then perform a ranking analysis on the remaining fields before taking the top 5 and performing a detailed field history for each field. This project had 4 major parts to accomplish this: a preliminary screening, our indexing method, data gathering and acquisition, and finally a field history.

4.1 – Part I: Preliminary Screening

In order to reduce the number of our fields drastically, we performed a preliminary screening. The parameters that were used to screen were based on several factors. The first criteria eliminated all fields not in the PRB. This did not reduce the number of fields very much, as a lot of the fields within the Wyoming EORI database are in the PRB. The second screening eliminated all fields that had a production value less than 10,000 in 2008; this ensured that any fields which we screened for had a) high enough production values to make our endeavor profitable and b) to ensure that the proper infrastructure could be afforded by the operators. After these two criteria were put into the data filter, the next parameters included API gravity, permeability, depth, temperature, oil saturation and viscosity. These values were ensured to follow the lookup table criteria values as shown in Figure 4.1.1, and a summary for the chemical field screening is shown in Figure 4.1.2.

Once this initial screening was performed, we ended up with 193 fields that met all of these criteria. One of the major decisions we had to make was what to do with the blanks in the data packet before the preliminary screening occurred. None of the fields were eliminated during this screening process because they had a blank for those values, and only if that field did not pass another screening criterion did it get eliminated from the final list of 193 fields.

From this point, our group needed to get some results faster, which is why we went forward with our indexing method, as detailed below.

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.

Figure 4.1.1: The lookup table as provided by Taber in his 1997 paper; the lookup table shows various parameters for several EOR methods.

Chemical Flooding Screening Criteria (Recommended by the EORI)								
EOR Method	**Gravity (API)**	**Viscosity (cp)**	**Composition**	**Oil Saturation (% PV)**	**Lithology**	**Average Permeability (md)**	**Depth (ft)**	**Temperature (F)**
Micellar/ Polymer, ASP, and Alkaline Flooding	>20↗36↗	<35↘13↘	Light, intermediate, some organic acids for alkaline floods	>35↗53↗	Sandstone Preferred	>10↗450↗	>9,000↘3,250	>200↘80
Polymer Flooding	>15	<150, >10	NC	>50↗80↗	Sandstone Preferred	>10↗800↗	<9,000	>200↘140

Figure 4.1.2: This is a summary of the information in the screening table provided by Taber, and as is used by the EORI at UW.

4.2 – Part II: Indexing Method

Initially we had planned to complete the screening after we had gathered additional data about the fields in the Powder River Basin. However, due to limitation in time and resources we decide to complete an initial screening with the data only partially filled in or completed. Once we had more data we planned to complete additional screening.

In our development of our screening method, we examine the variable in which our screening would be based on. Our literature search resulted in several possible screening tables used in screening chemical flooding. Many of the screening tables have similar values. After a careful review of the literature we selected the same screening table for the indexing method as we used for the preliminary screening.

Figure 4.2.1 is a screenshot of a second paper that Taber came out with to explain in further detail Micellar/Polymer, ASP, and alkaline flooding information. In addition to information about chemical flooding of these sorts, the table also shows the absolute lowest/highest limits for each of the parameters that have been used in the research performed by Taber. It also explains the median values of each field that has undergone chemical flooding techniques; these median values are what were used in our indexing equation.

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.

Figure 4.2.1: Detailed information about Micellar/Polymer, ASP, and Alkaline flooding provided by Taber in his follow up paper explaining the screening table used by the EORI.

Our first problem with the indexing method was to determine which parameters to use in the indexing equation. We analyzed all possible parameters, and came up with the following conclusions. First the lithology of fields in the Powder River Basin is relatively uniform, with the vast majority of fields to be considered being sandstone. This meant that indexing for lithology in the Powder

River Basin would do little in helping us distinguishing which fields would be best for chemical flooding.

Secondly, information about the composition of the petroleum products produced was not available in our initial data set. Our initial analysis of the major data source, the WOGCC, did not produce any information about the composition of hydrocarbon produced. Furthermore, to properly screen the composition would require the developing a system or method to grade each possible component. It was therefore decided to not screen using this variable.

With these two variables eliminated, we could index using the following six variables:

- API gravity
- Viscosity
- Oil saturation
- Average permeability
- Depth
- Temperature

This method (screening values from left to right) is what's recommended by the source of the table but altered to fit the unique features of the Powder River Basin and the available data.

While several different pre-existing indexing methods exist, we decided to create our own indexing method to best fit our situation. This indexing method was based on the fact that the six remaining variables could be divided into two groups, with 1) one group of variables being better suited to chemical flooding if their values were higher; and 2) another group of variables in which chemical flooding would be better suited if they were lower.

Several different pre-existing indexing methods exist, but we decided to create our own indexing method to fit our situation. This indexing method was based on the fact that the six variables could be divided into two groups, with 1) one group of variables being better suited to chemical flooding if their values were higher; and 2) another group of variables in which chemical flooding would be better suited if they were lower. The following is the actual equation used in our calculations of the field indices.

Legend:

Field Value, FV = Value of rock or fluid property in the field of interest
Lower Limits, LL = Lowest Acceptable Value of Rock or Fluid Property for Chemical Flooding
Upper Limits, UL = Highest Acceptable Value of Rock or Fluid Property for Chemical Flooding
Median Value, MV = Median Value of Rock or Fluid Property for Chemical Flooding as determined by Taber's research repertoire.

Preferred Higher Values for Chemical EOR:

$$Parameter\ Index, PI = \frac{Field\ Value, FV - Lower\ Limit, LL}{Median\ Value, MV - Lower\ Limit, LL}$$

For example, API has a Median Value of 35° and a Lower Limit of 20°, therefore the equation used to rank this variable would be:

$$Parameter\ Index, PI = \frac{FV - 20°}{35° - 20°}$$

If the API gravity in a field was 30°, then:

$$Parameter\ Index, PI = \frac{30° - 20°}{35° - 20°} = \frac{10}{15} = 0.667$$

If the API gravity in a field was 40°, then:

$$Parameter\ Index, PI = \frac{40° - 20°}{35° - 20°} = \frac{40}{15} = 2.667$$

However, if the API gravity in a field was less than the lower limit of 15°, then the Parameter Index, PI would automatically be set to zero.

$$Parameter\ Index, PI = \frac{15° - 20°}{35° - 20°} = \frac{-5}{15} = 0$$

If any of the Parameter Indices are negative then our screening algorithm would reset it to zero. There are however two exceptions.
Based on our literature the depth and temperature have absolute limit, that is if the depth is greater than 9000 feet (>9000 ft.) or the temperature is greater than 200°F (>200°F). Chemical flooding is not possible regardless of the index value of the other variables. Thus, any field that exceeds these limits were given a zero value for the Total or Overall Index value.

Preferred Lower Values for Chemical EOR:

$$Parameter\ Index, PI = \frac{Upper\ Limits, UL - \ Field\ Value,\ FV}{Upper\ Limit, UL - \ Median\ Value,\ MV}$$

For example, viscosity has an upper limit of 150 [cp] and a median value of 13 [cp], therefore the equation used to rank the fields is:

$$Parameter\ Index, PI = \frac{150\ [cp] - \ FV}{150\ [cp] - \ 13\ [cp]}$$

If the viscosity of the oil in the field is 100 [cp], then

$$Parameter\ Index, PI = \frac{150\ [cp] - \ 100[cp]}{150\ [cp] - \ 13\ [cp]} = \frac{50\ [cp]}{137\ [cp]} = 0.365$$

If the viscosity of the oil in the field is less than the median value of 13 [cp] say 10 [cp] then,

$$Parameter\ Index, PI = \frac{150\ [cp] - \ 10[cp]}{150\ [cp] - \ 13\ [cp]} = \frac{140\ [cp]}{137\ [cp]} = 1.022$$

If the viscosity of the oil in the field is greater than the lower limit of 150 [cp] say 200 [cp] then the Parameter Index resets to zero.

$$Parameter\ Index, PI = \frac{150\ [cp] - \ 200[cp]}{150\ [cp] - \ 13\ [cp]} = \frac{-50\ [cp]}{137\ [cp]} = 0$$

If no data is available for that rock or fluid property our algorithm gives that Parameter Index value a presumptive value of zero.

After each Parameter Index, PI was determined, they were averaged.
Total Index Value for Chemical EOR:

$$Total\ Index = \frac{1}{i}\sum_{i=1}^{6} PI_i$$

For example,

$$Total\ Index = \frac{1}{6}\sum_{i=1}^{6}(0.1 + 0.2 + 0.3 + 1.0 + 0.5 + 0) = 0.35$$

Results:

After completing our initial indexing of the 114 fields by indexing each of the six parameters and finally averaging the index of the 6 parameters for the 114 fields, we began ranking the fields in terms of the Total Index. Once we completed the ranking of the fields, we looked at the top 20 fields and attempted gathering more information about the field. From these top 20 fields we were able to choose the top 5 fields.

Table 4.2.2 - Top 20 Fields:

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
11	OTTIE DRAW	0.45849
12	TUIT DRAW	0.44767
13	TRIANGLE U EAST	0.43768
14	BEAVER HOLE	0.43548
15	FISH	0.42343
16	COLLINS	0.40121
17	KICKEN DRAW	0.39524
18	MALMQUIST	0.38534
19	SIDNER DRAW	0.38534
20	GREASEWOOD	0.37000

Table 4.2.3 - Top 5 Fields:

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

4.3 – Data Gathering Methods

Our literature revealed several possible sources of data. Generally, they are divided into two major sources: 1) public data; and 2) private data. Public data is accessible to the public or to students at University of Wyoming via subscription through the UW library. Private data can only be accessed by paying a private subscription. For example, the Wyoming Geological Association only offer its "Wyoming Oil and Gas Fields Symposium Powder River Basin" reports for a fee of $200, funds which were not available to us.

Public Data Sources:

- WOGCC (Wyoming Oil and Gas Conservation Commission) (Original Method)
- 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.+)
- UW Libraries (COE library and

Private Sources of Data

- IHS (Information Handling Services): Infrastructure and Marketing Database
- Wyoming Geological Association: Wyoming Oil and Gas Fields Symposium Powder River Basin (2000 A.D.+)

Further analysis and review of the Public Data sources showed that each source limitations and issues.

Data Source	**Information Available**	**Issues or Limitations**
WOGCC	Logs, Cored Wells, Reports	Miss-filed Limited well given by operator
AAPG	Full assessment of fields (All required rock and fluid properties)	Few fields fully assessed by geologists
SPE	Full assessment of fields (All required rock and fluid properties)	Few fields fully assessed by petroleum engineers

NETL	Assessment of Crude Oil in Fields (API gravity)	Limited to formation based data and field studies funded by federal government
EORI	Core Analysis, Reports, (Depth, Well location)	Limited data directly accessible via website; miss-labelled and miss-filed fields and wells
WGA	(API gravity)	Limited number of fields described and limited rock and fluid properties described

Archie Equation

Based on our literature search the most widely available data is well logs. The WOGCC website possesses a large well logging database that covers the entire state of Wyoming including the Powder River Basin. We determined that for many of the rock or fluid properties that make up our Indexing Variables, we would need to use well log data to fill in that information. After a literature review and discussion from experts at the University of Wyoming, it was determined that the basic Archie equation was best suited to our needs. Most of our formation were sandstone and as screening data we would use the standard Archie Equation with the standard cementation exponent, *m* value of 2.0 and the standard saturation exponent, *n* of 2.0. Since fields in the Powder River Basin are typically sandstone we used a touristy, *a* value of 0.6 for our equation. Thus our version of Archie Equation is:

$$C_t = \frac{1}{a} C_w \varphi^m S_w^n = \frac{1}{0.6} C_w \varphi^2 S_w^2$$

We also considered using the Simandoux Equation for shaley-sand but none of our formation were of this type so the equation was not used.

$$R = \frac{1}{S_w^n \left(\frac{\varphi^m}{R_w} + \frac{C}{R_{clay}} \right)}$$

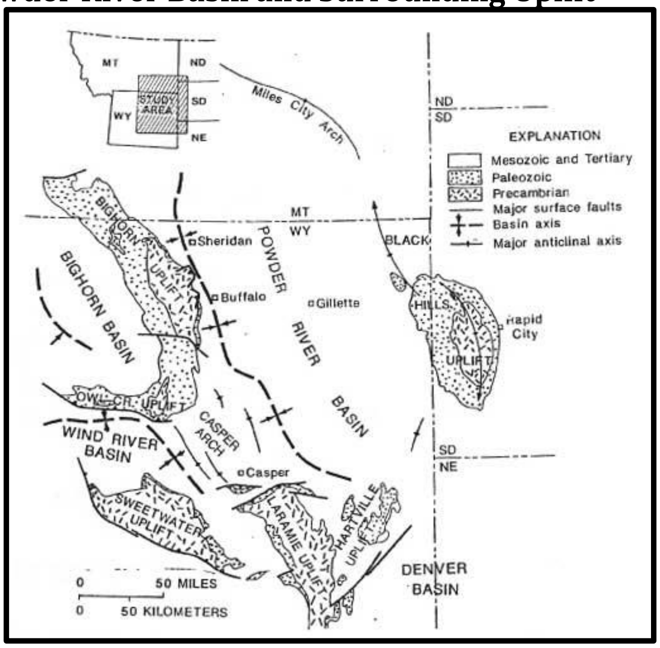
The porosity, ϕ is determine using a combination of Density Logs and Neutron Logs. This combination, plus the resistivity logs allow us determine saturation purely from the logs –if no other source of information is available.

5 – Field History

5.1 – General Geology of the Powder River Basin

The Powder River Basin is a geological structurally unified as a basin. The thickest section of the Powder River Basin is made of Cretaceous Period rock, dating from 145 Ma to 66 Ma ago.

Figure 5.1.1 – Powder River Basin and Surrounding Uplift



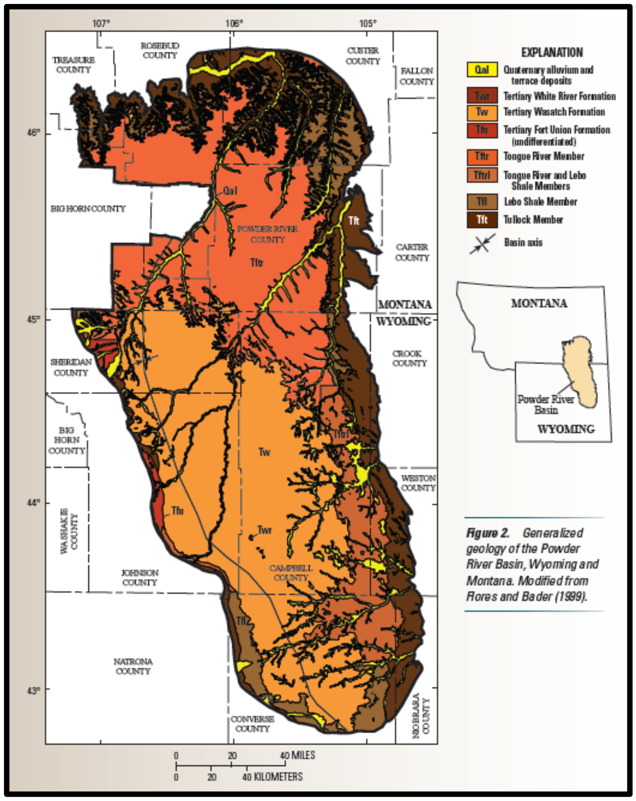


Figure 5.1.2 – General Geology of the Powder River Basin

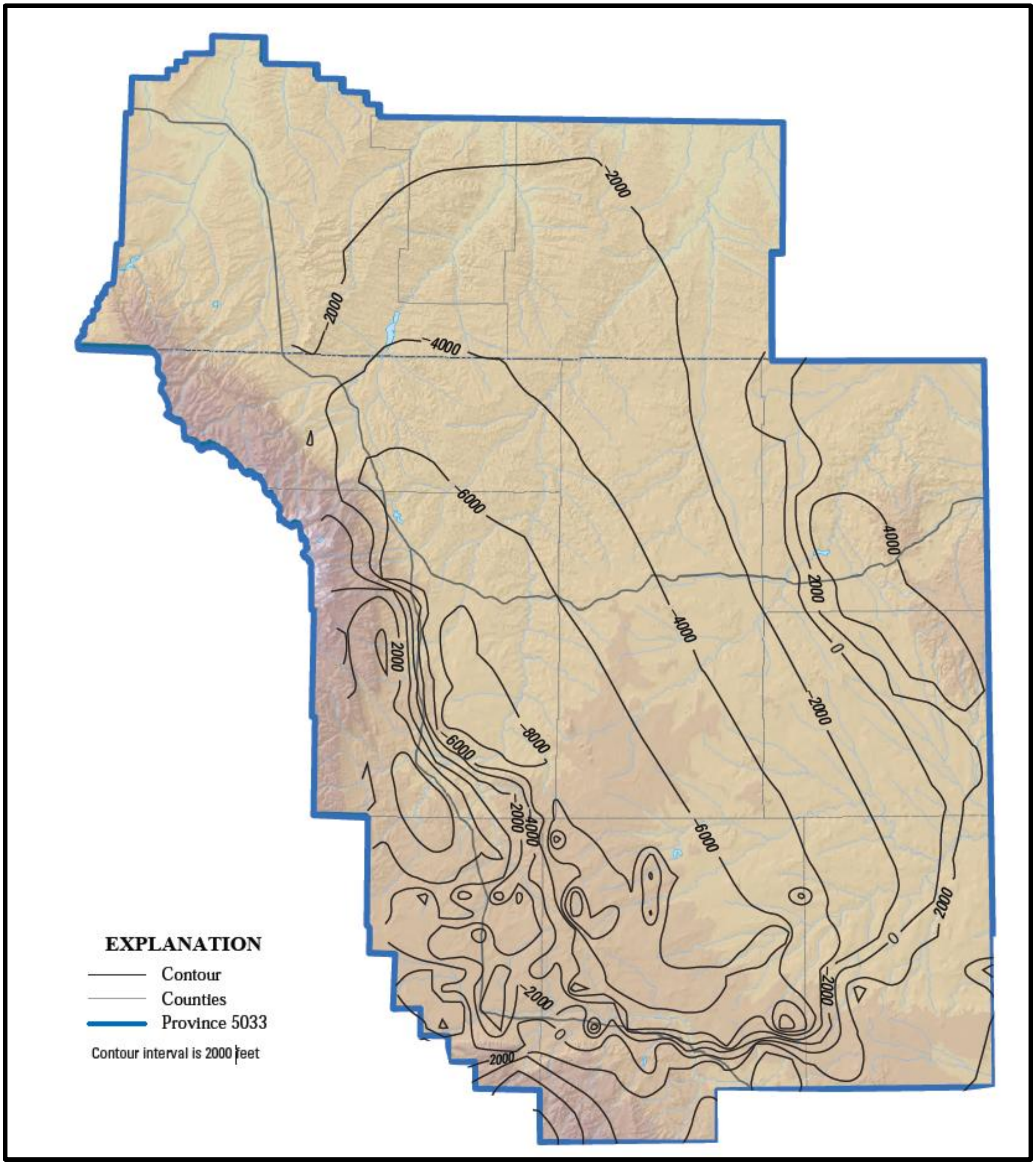


Figure 5.1.3 – Contour Map of the Powder River Basin

5.2 – Stratigraphy of the Powder River Basin

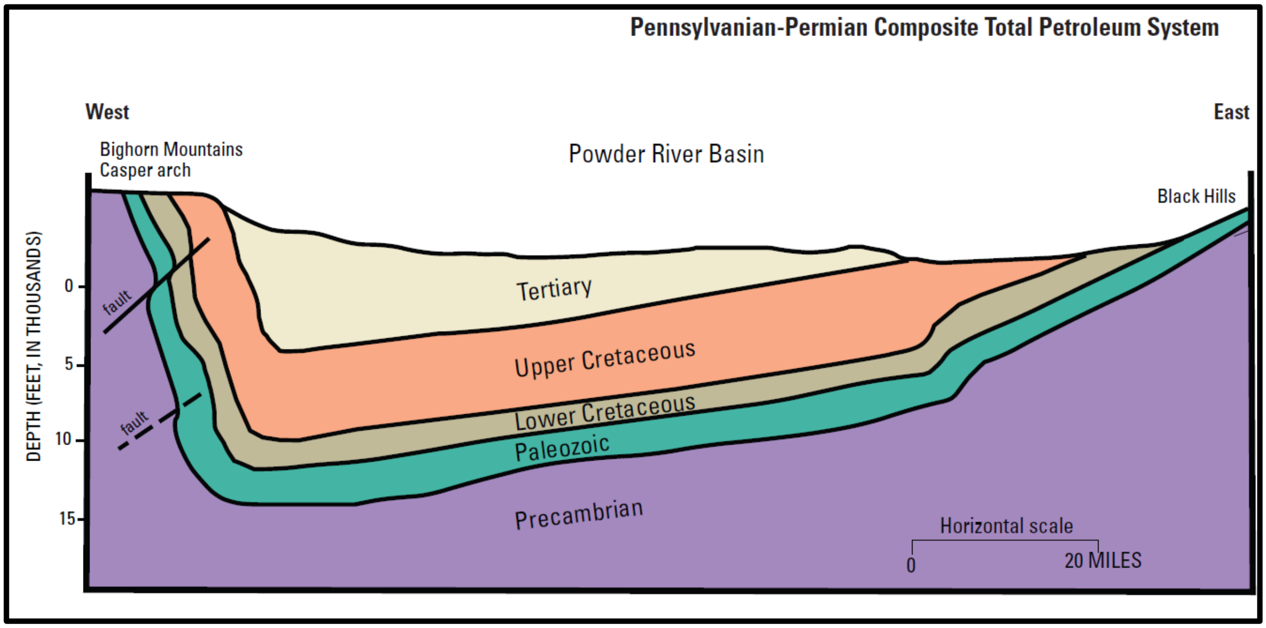


Figure 5.2.1 – Cross-Sectional Map (West to East) of the Powder River Basin

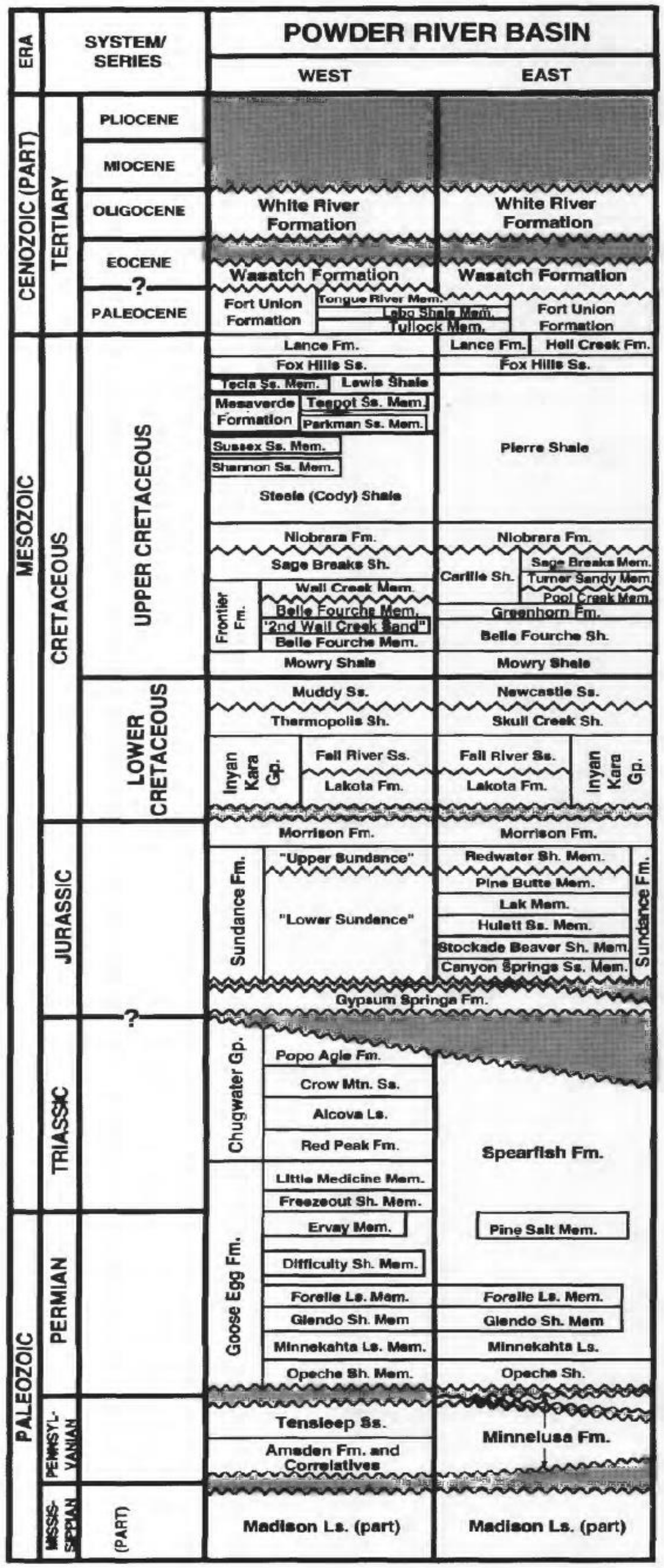


Figure 5.2.2 – Complete Stratigraphic Column of the Power River Basin

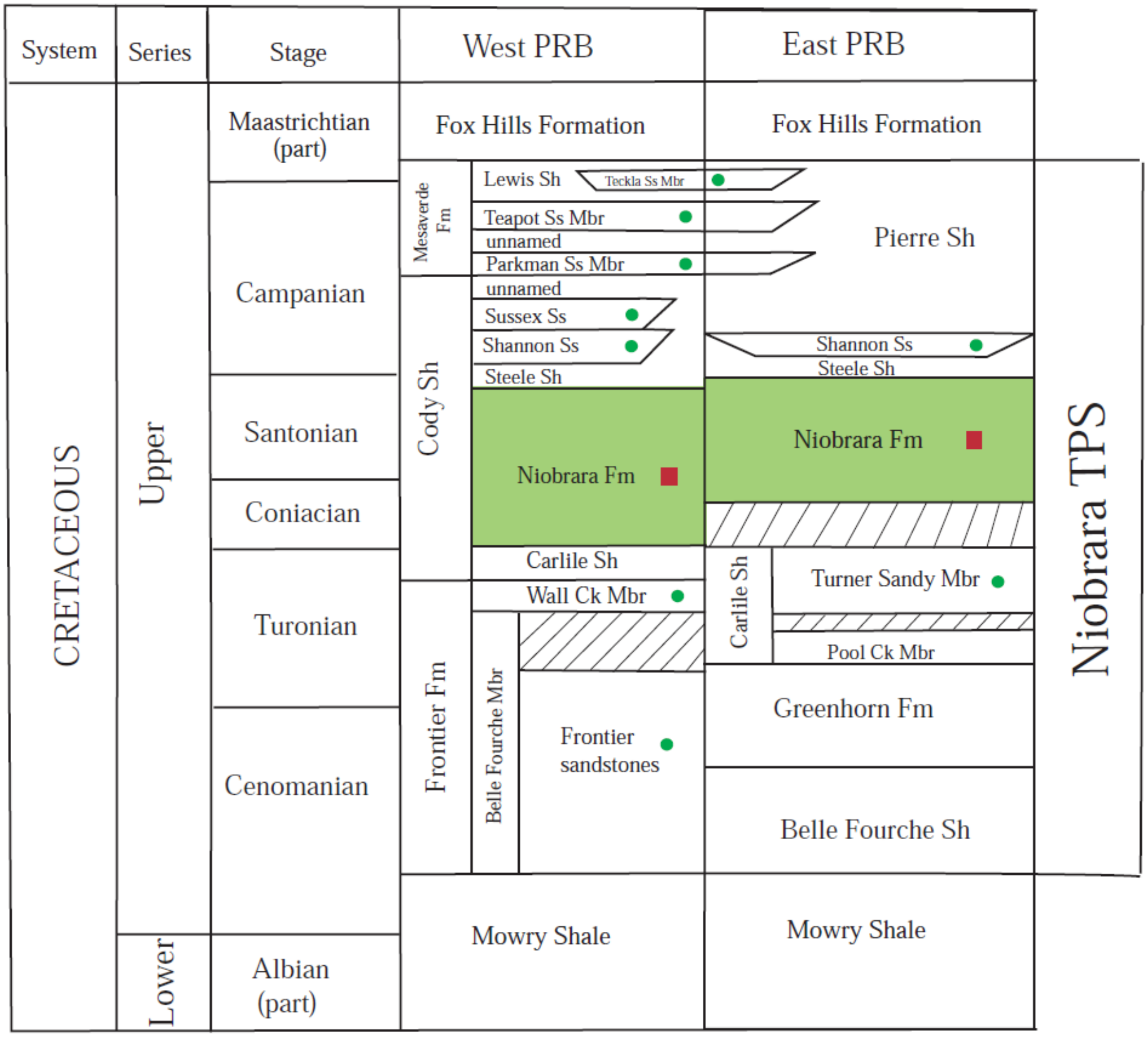


Figure 5.2.3 – Stratigraphic Map of the Powder River Basin of the Cretaceous System

5.3 – Top 5 Field Histories

Crawford Draw Field (New Field Index: 0.38)

Background Information:
Discovered: 1985
General Location: 41N-77W
EOR: Currently there are no EOR Projects
Field Status: Injecting Water (? No Injection well)

Geology:
Formations: Frontier, Muddy, Sussex
Primary Production: Frontier
Lithology: Sandstone

Production Data (Total):
Oil: 3,462,296 [BBLS] (as of 01/2016)
Gas: 19,352,929 [MCF] (as of 01/2016)

Table 5.3.1.1 – Crawford Draw Field Screening Data

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

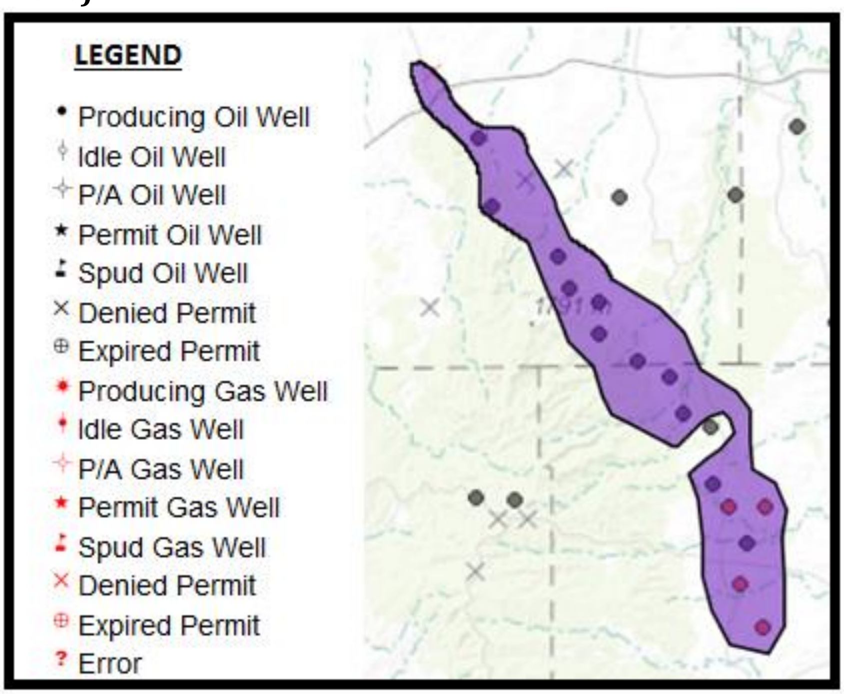
New Field Index: 0.38

Infrastructure:

Table 5.3.1.2 - Crawford Draw Field Well Data

	Federal	Fee or State	Total
PA'd	2	2	4
Dormant Wells	0	0	0
Complete Wells	13	4	17
Injection Wells	0	0	0
Monitoring Wells	0	0	0
NIA's	0	0	0
Spuds	0	0	0
Denied Permits	0	0	0
Expired permits	5	0	5
Permit To Drill	0	4	4
Waiting on Approval	0	0	0
Total Confidential	0	0	0
Total	20	10	30

Figure 5.3.1.3 - Crawford Draw Field - Well Map (Production and Injection Wells)



Summary:

We screened the reservoir in the Crawford Draw field producing out of the Frontier Formation. According to our screening method the Crawford Draw field has a very low screening field index number of 0.38 when all six variables are used. After review the data again, we suspect that an incorrect number was entered for its depth during the initial screening process allowing it get past our initial screening.

The reservoir in the Frontier Formation is far too deep and too hot for it to be well suited for chemical flooding, particularly for polymer flooding since the polymer, which would degrade at such great depths and temperature. The oil saturation and permeability of this reservoir is also relatively low and not best suited for chemical flooding.

The Crawford Draw produces a light crude and natural gas. In terms of infrastructure it has not injection wells that could be easily converted to chemical flooding.

Recommendations:

We would recommend a surfactant flooding without polymers or alkali agents due to the Frontier Formation in the Crawford Draw being so deep and hot.

Scott Field (New Field Index: 0.58)

Background Information:
Discovered: 1979
General Location: 36N-71W
EOR: Currently there are no EOR Projects
Field Status: Injecting Water
Production: Oil and Gas

Geology:
Formations: Fox Hills, Lewis, Teckla, Teapot, Parkman Sussex, Niobrara
Primary Production: Parkman
Lithology: Sandstone

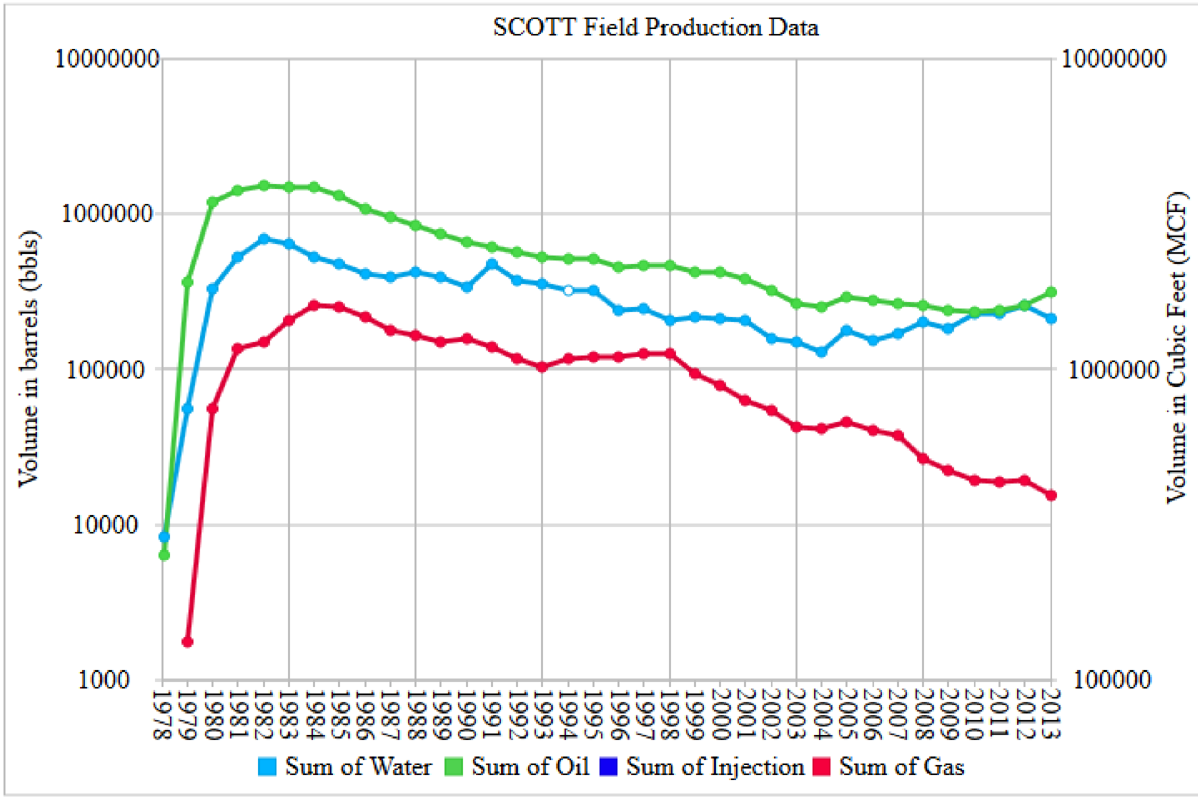
Production Data:
Oil: 21,801,166 [BBLS] (as of 01/2016)
Gas: 32,918,686 [MCF] (as of 01/2016)

Table 5.3.2.1 – Scott Field Screening Data

VARIABLES	VALUES
Porosity (%)	10
Permeability (mD)	2
API Gravity (°)	40
Depth (feet)	8753
Temperature (°F)	169
Viscosity (cP)	6.7
Oil Saturation (%)	5

New Field Index: 0.58

Figure 5.3.2.2 - Scott Field Production Data



Infrastructure:

Table 5.3.2.3 - Scott Field Well Data

	Federal	**Fee or State**	**Total**
PA'd	31	37	68
Dormant Wells	0	3	3
Complete Wells	93	77	170
Injection Wells	2	0	2
Monitoring Wells	0	0	0
NIA's	0	3	3
Spuds	1	0	1
Denied Permits	2	3	5
Expired permits	26	38	64
Permit To Drill	22	49	71
Waiting on Approval	0	0	0
Total Confidential	0	0	0
Total	177	210	387

Figure 5.3.2.4 - Scott Field - Well Map (Production and Injection Wells)

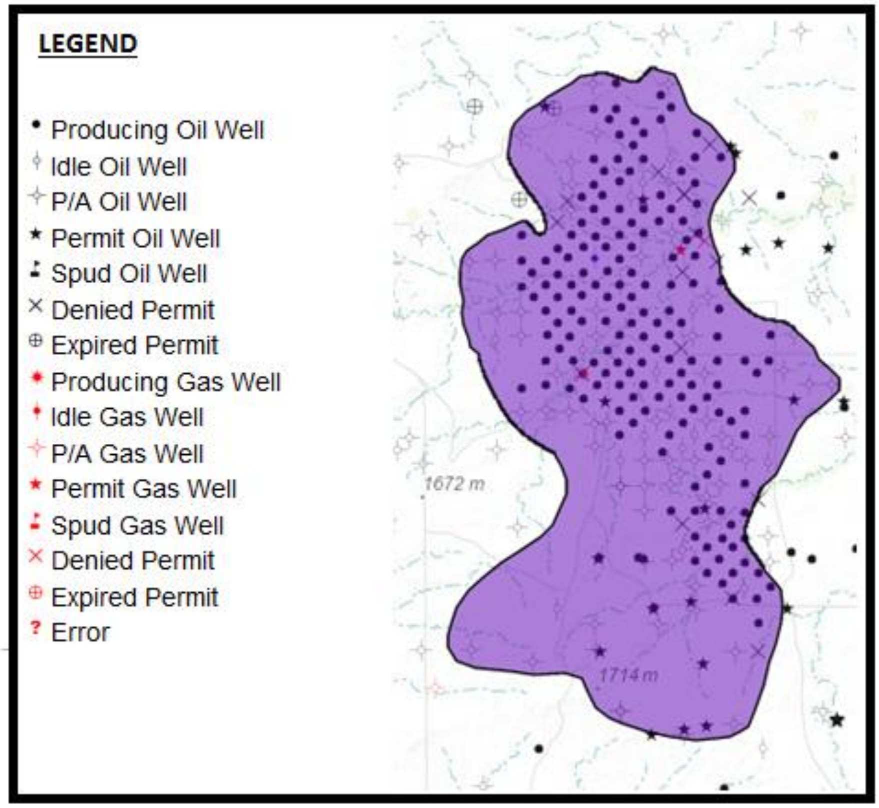
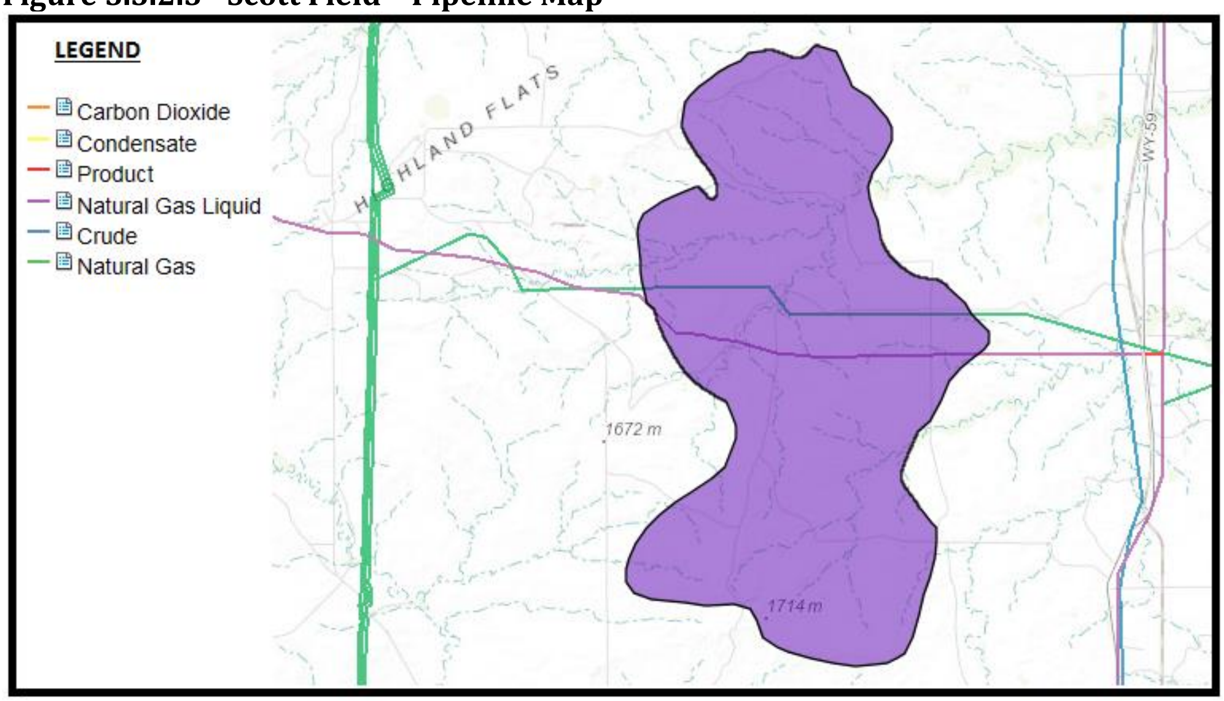


Figure 5.3.2.5 - Scott Field – Pipeline Map



Summary:

Based on our screening index, the Scott field has a screening index number of 0.58 based on all six variable we used. This is a reasonable number for chemical flooding.

The Scott field produces from numerous formation with our screening focusing on production from the Parkman Formation. The reservoirs in the Parkman Formation produces both oil and gas. The oil produced from this formation is slightly higher in viscosity than the Crawford Draw but is still quite suitable for chemical flooding.

Currently there are two idle water injection wells om the Scott field that could be converting into injection wells for chemical flooding. The Scott Field has excellent infrastructure available in terms of pipe lines to transfer both oil and gas to market.

Recommendation:

We recommend AS (Alkali-Surfactant) flooding for the Scott field. The low permeability of the Parkman Formation in the Scott field eliminates the possibility of using polymer. However, Alkaline can still be used as a sacrificial agent to reduce the amount of surfactant used.

Greasewood Field (New Field Index: 0.73)

Background Information:
Discovered: 1983
General Location: 39N-63W
EOR: Currently there are no EOR Projects
Field Status: Injecting Water (currently inactive)
Production: Oil

Geology:
Formations: Dakota, Morrison, Turner
Primary Production: Morrison
Lithology: Sandstone

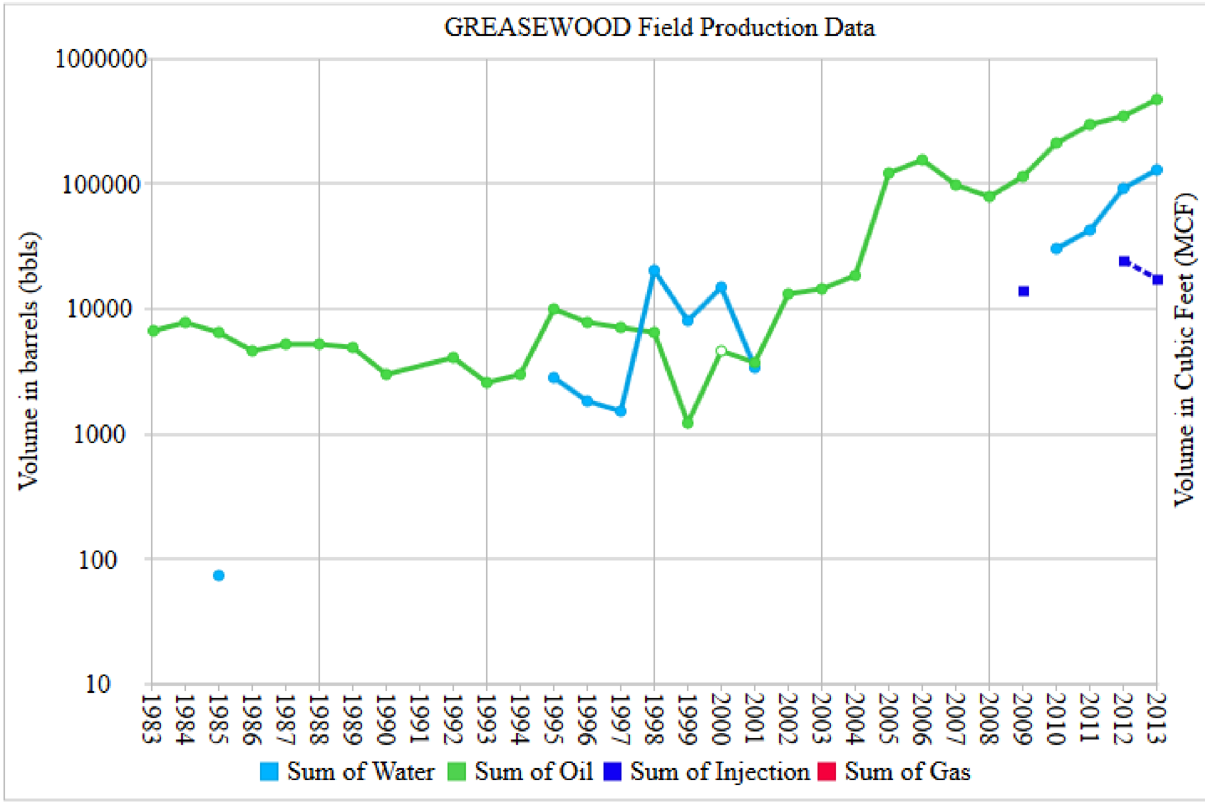
Production Data:
Oil: 3,175,372 [BBLS] (as of 01/2016)
Gas: 0 [MCF] (as of 01/2016)

Table 5.3.3.1 – Greasewood Field Screening Data

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

New Field Index: 0.73

Figure 5.3.3.2 - Greasewood Field Production Data



Infrastructure:

Table 5.3.3.3 - Greasewood Field Well Data

	Federal	**Fee or State**	**Total**
PA'd	7	1	8
Dormant Wells	2	0	2
Complete Wells	19	13	32
Injection Wells	3	5	8
Monitoring Wells	0	0	0
NIA's	0	0	0
Spuds	3	1	4
Denied Permits	0	0	0
Expired permits	18	6	24
Permit To Drill	1	0	1
Waiting on Approval	0	0	0
Total Confidential	0	0	0
Total	53	26	79

Figure 5.3.3.4 - Greasewood Field - Well Map (Production and Injection Wells)

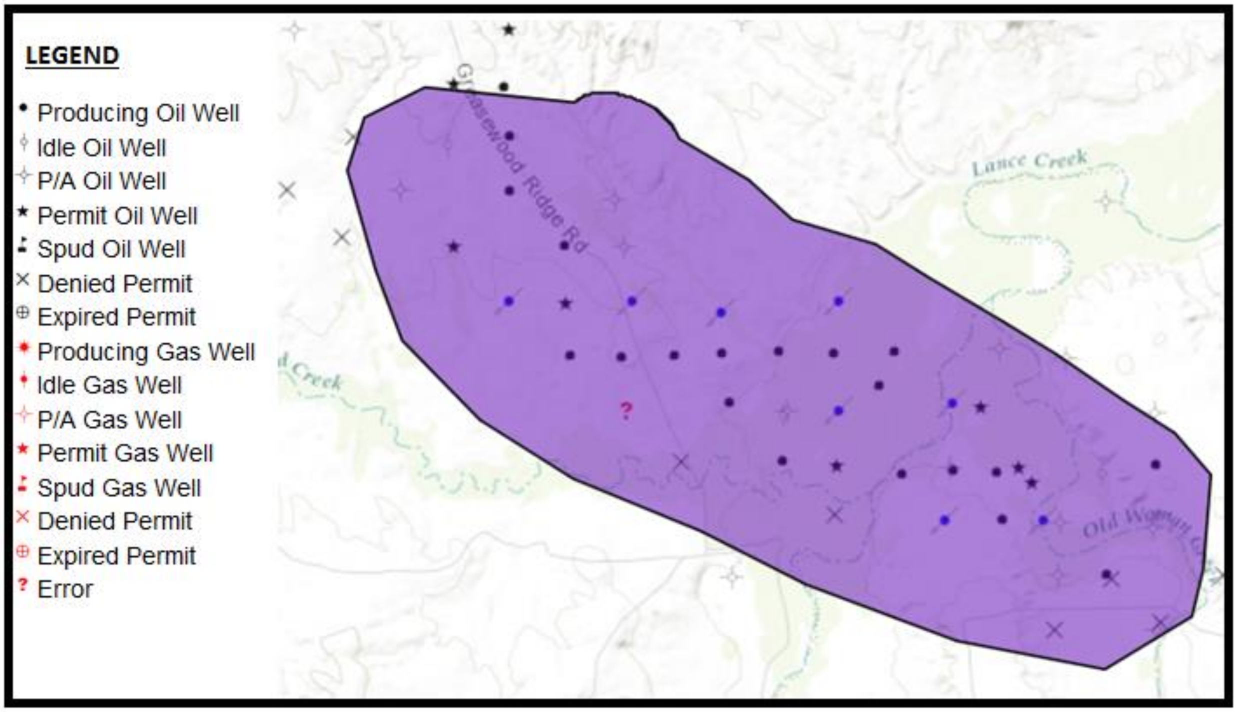
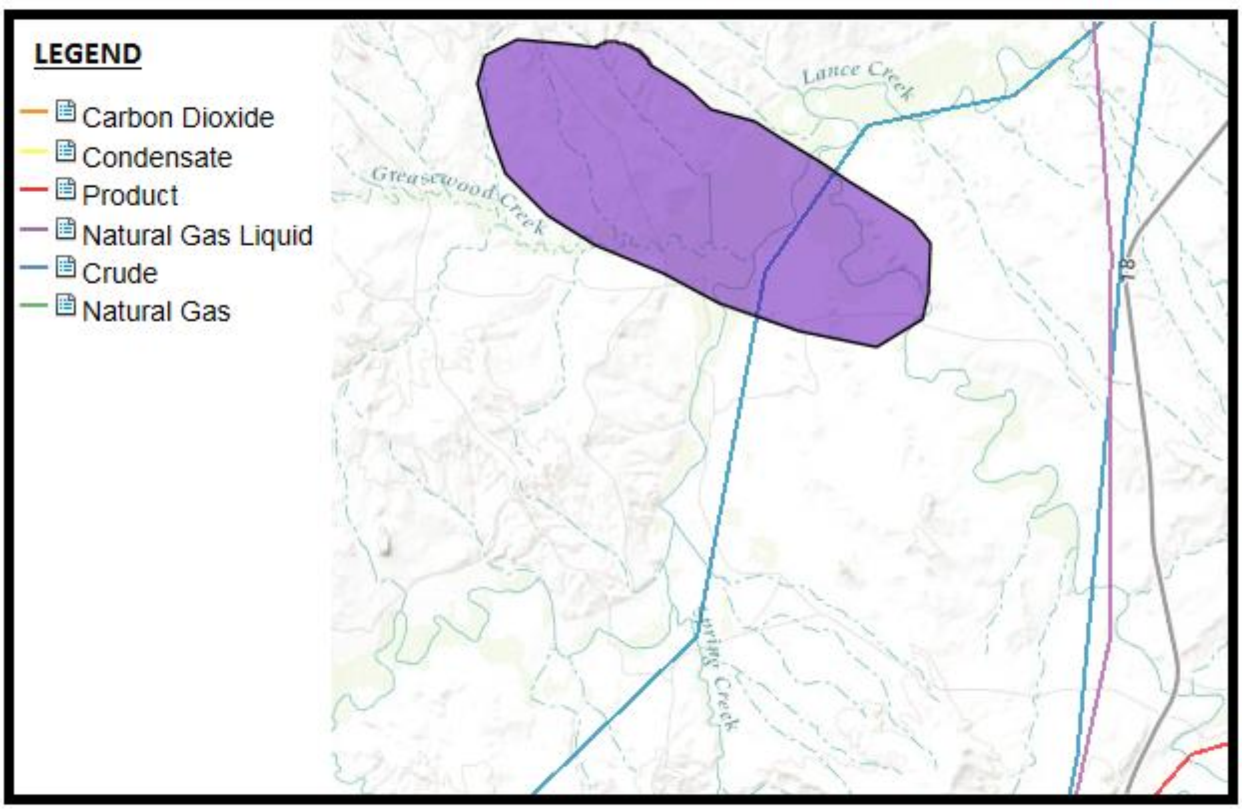


Figure 5.3.3.5 - Greasewood Field – Pipeline Map



Summary:
Our screening method determined that the Greasewood field has a screening index number of 0.73 based on the data available, which does not include oil saturation. This is a reasonable number for chemical flooding however because oil saturation is still missing we cannot be certain of its suitability for chemical flooding.
The Greasewood field we screened, produces primarily from the Morrison formation and produces only light crude. The formation has relatively good permeability for chemical flooding.
The Greasewood field current has water injection wells that could be converted into chemical flooding. It has easy access to a crude oil pipeline to transport production to market.
Recommendation:
Depending on the oil saturation, which is unknown, we would recommend ASP flooding. The components of ASP flooding (Alkali, Surfactant and Polymer) work synergistically to greatly increase own production and would effective in the Greasewood field. We would recommend low molecular weight polymer as it is best suited to the Greasewood field.

Thompson Creek Field (New Field Index: 0.78)

Background Information:
Discovered: 1985
General Location: 58N-67W
EOR: Currently there are no EOR Projects
Field Status: Injecting Water
Production: Oil and Gas

Geology:
Formations: Dakota, Morrison, Turner
Primary Production: Muddy (Newcastle)
Lithology: Sandstone

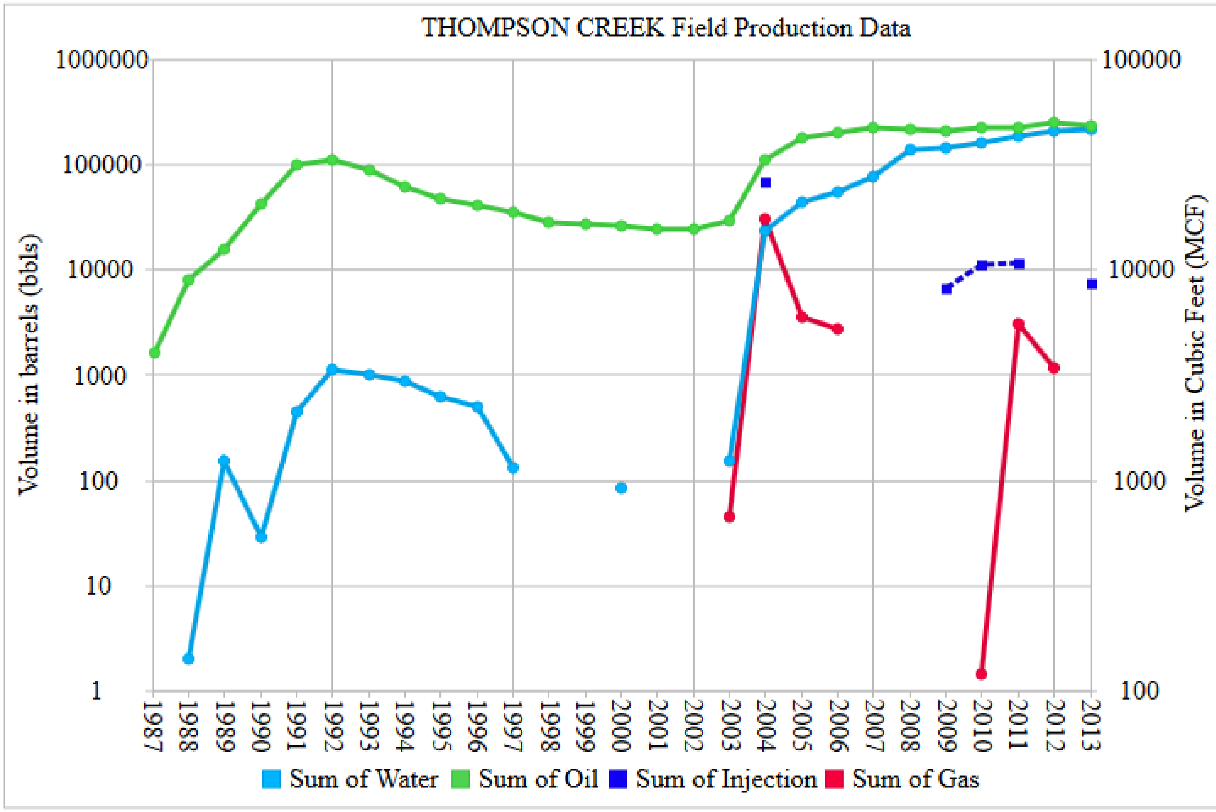
Production Data:
Oil: 3,185,791 [BBLS] (as of 01/2016)
Gas: 385,612 [MCF] (as of 01/2016)

Table 5.3.4.1 – Thompson Creek Screening Data

VARIABLES	VALUES
Porosity (%)	**15**
Permeability (mD)	**50**
API Gravity (°)	**20**
Depth (feet)	**1593**
Temperature (°F)	**81**
Viscosity (cP)	**78**
Oil Saturation (%)	**?**

New Field Index: 0.78

Figure 5.3.4.2 - Thompson Creek Field Production Data



Infrastructure:

Table 5.3.4.3 - Thompson Creek Well Data

	Federal	Fee or State	Total
PA'd	18	3	21
Dormant Wells	1	0	1
Complete Wells	110	2	112
Injection Wells	50	0	50
Monitoring Wells	1	0	1
NIA's	4	1	5
Spuds	0	0	0
Denied Permits	3	0	3
Expired permits	33	3	36
Permit To Drill	12	0	12
Waiting on Approval	0	0	0
Total Confidential	0	0	0
Total	232	9	241

Figure 5.3.4.4 - Thompson Creek Field - Well Map (Production and Injection Wells)

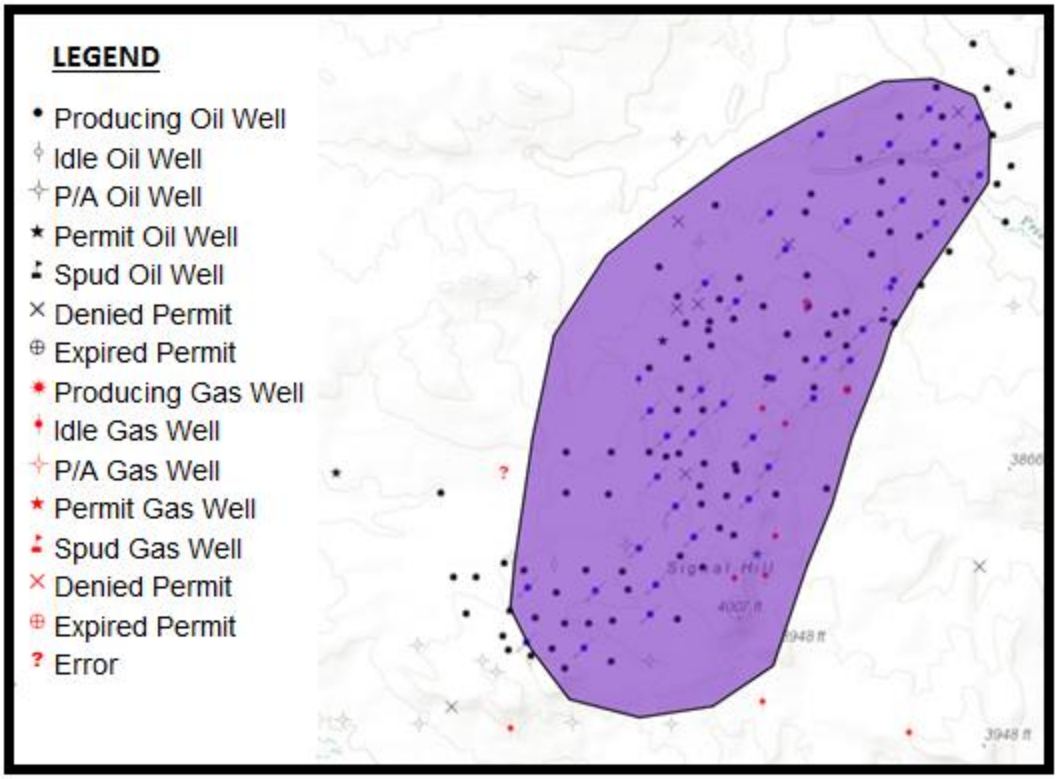
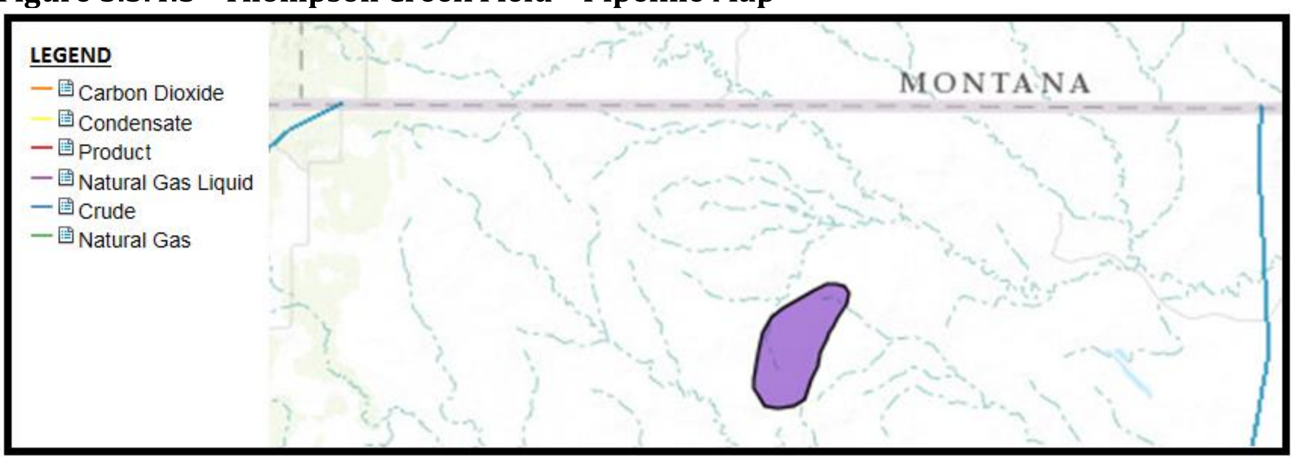


Figure 5.3.4.5 - Thompson Creek Field – Pipeline Map



Summary:

Based on our screening method the Thompson Creek field has a screening index number of 0.78 using the data from the 5 variables we had data for, which excluded oil saturation. Based on this number we believe the Thompson Creek field is suitable for chemical flooding however this dependent on the oil saturation be sufficient for chemical flooding.

The Thompson Creek Field produces out of numerous formations, with the reservoirs in the Muddy (or Newcastle) Formation being the optimal for chemical flooding based on screening method. Both oil and gas are produced from this formation, however the oil produces is heavy and has a higher viscosity. The formation itself has relatively good permeability for chemical flooding.

While the Thompson Creek Field has water injection wells that can easily be converted into injection wells for chemical flooding, pipeline access could be an issue. Currently, the two closest crude oil pipelines are far west and east of the Thompson Creek Field. Gas pipelines are even further away (not seen on map) which makes the sale of the natural gas produced unlikely and it will likely have to be flared off.

Recommendation:

We would recommend an ASP flooding for the Thompson Creek field depending on the oil saturation, which currently is still unknown. We would recommend a low molecular polymer as the oil in this field is extremely heavy. Also, Alkali would useful in decreasing the viscosity of the viscous heavy crude produced in the Thompson Creek field.

Taylor Field (New Field Index: 0.95)

Background Information:
Discovered: 1982
General Location: 41N-76W
EOR: Currently there are no EOR Projects
Field Status: Primary Recovery
Production: Oil and Gas

Geology:
Formations: Dakota, Frontier
Primary Production: Frontier
Lithology: Sandstone

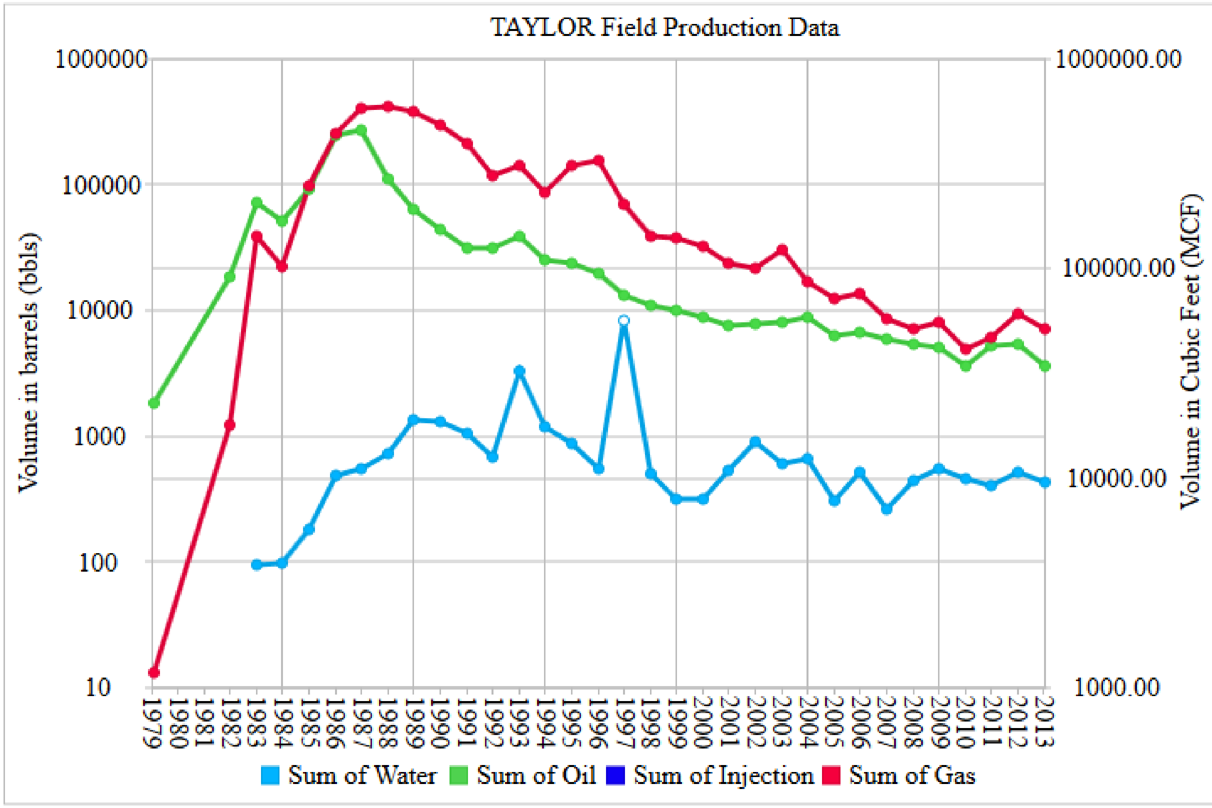
Production Data:
Oil: 1,265,881 [BBLS] (as of 01/2016)
Gas: 6,610,588 [MCF] (as of 01/2016)

Table 5.3.5.1 – Taylor Field Screening Data:

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

New Field Index: 0.95

Figure 5.3.5.2 - Taylor Field Production Data



Infrastructure:

Table 5.3.5.3 - Taylor Field Well Data

	Federal	**Fee or State**	**Total**
PA'd	4	2	6
Dormant Wells	0	0	0
Complete Wells	2	3	5
Injection Wells	0	0	0
Monitoring Wells	0	0	0
NIA's	0	0	0
Spuds	0	0	0
Denied Permits	0	0	0
Expired permits	0	1	1
Permit To Drill	0	0	0
Waiting on Approval	0	0	0
Total Confidential	0	0	0
Total	6	6	12

Figure 5.3.5.4 - Taylor Field – Well Map (Production and Injection Wells)

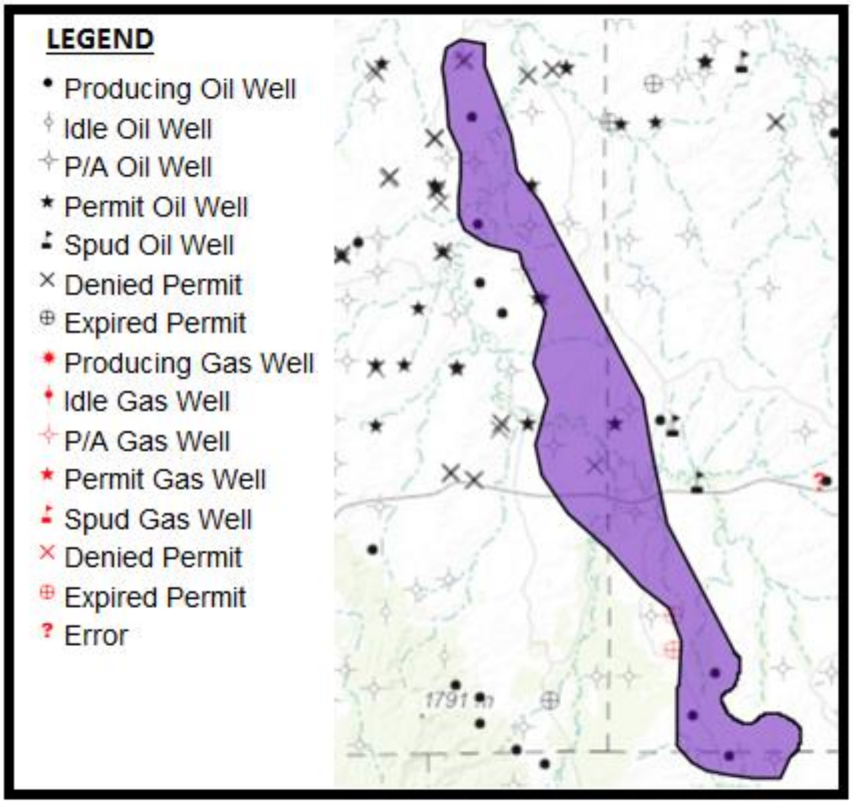
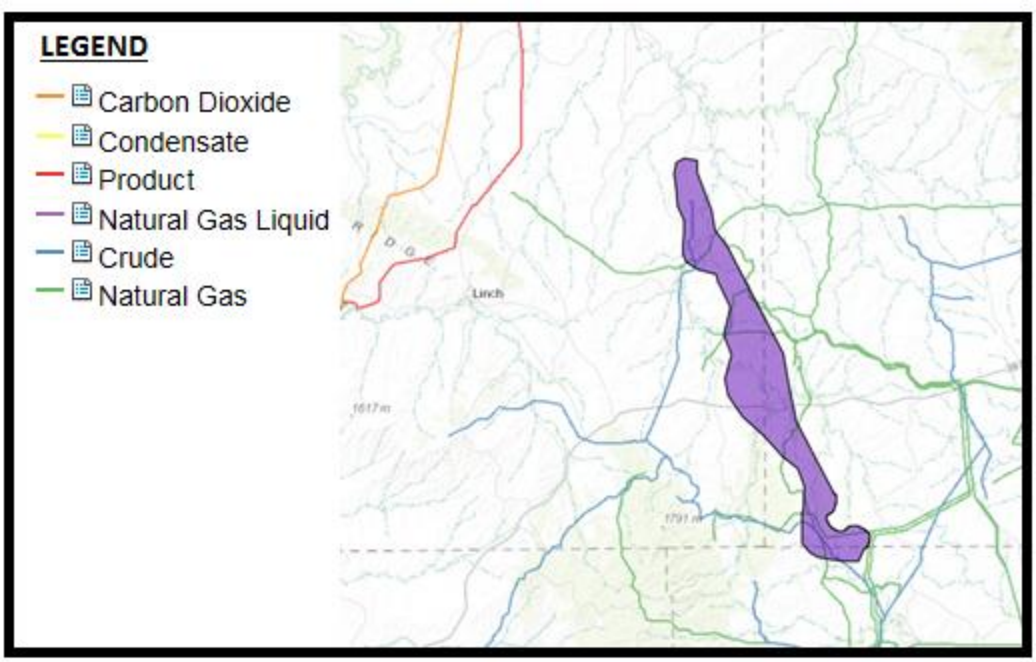


Figure 5.3.5.5 - Taylor Field – Pipeline Map



Summary:

The Taylor field has the highest score based on our screening index at 0.95, however this screening was limited to only 5 variables as oil saturation data was not available. Nonetheless we can make a preliminary recommendation for chemical flooding, assuming that the oil saturation is sufficient high enough warrant chemical flooding.

The Taylor field produces from numerous formation, with the reservoirs we screened being in the Frontier Formation and produces a medium grade oil as well as gas. The fluid and rock properties are well within the range for chemical flooding, with exception being oil saturation which we do not have data on.

Currently, the Taylor Field is producing under primary recovery and does not have any water injection wells. Thus, any chemical flooding project must first construction injection wells in the Taylor Field before chemical flooding can occur. Transportation of the produced hydrocarbon should not be issue as numerous oil and gas pipeline cross the Taylor Field.

Recommendation:

For the Taylor Field, we recommend ASP Flooding due to synergistic nature of each components and is common and prove use. However, this recommendation is still dependent on the oil saturation be sufficiently high enough to warrant chemical flooding.

6 – Discussions

Changing Direction (Carbon Dioxide Flooding to Chemical Flooding)

Perhaps the biggest challenge we face during course of this project was switching the types of EOR used, from carbon dioxide flooding to chemical flooding. Besides setting the project back in terms of scheduling, the switch underlined a major changes we needed in our process.

Our selection of carbon dioxide flooding was part of the scoping process. The type of EOR, carbon dioxide flooding was chosen along with the region we decided to focus on, the Powder River Basin during an early group meeting and decided on by the group. It is clear now that we could not fixed or chosen both the EOR method and the region or area in Wyoming to screen. The two, the EOR method and the region are interrelated and once one was chosen the other is considerably narrowed.

It is clear now, that once we had decided on the Powder River Basin, we should have complete a literature review of the area –searching through all the numerous database and determined the best EOR method for the Powder River Basin. Our determination of the EOR method used in our screening should have been based on the economics condition for that method in the specific region and viability of such a project, for example carbon dioxide requires a carbon dioxide pipeline infrastructure to be viable. Such changes in the process of our Screening Method will be and should be applied to any future project we complete.

Initial Screening Process

One of the issues complicating our screening method was whether or not we are included all possible candidates through our screening process. Due to the nature of our project –namely screening such a large geographical area like Powder River Basin in a limit amount of time- the answer is clearly no. However, we must also be concerned that we were pre-maturely eliminating any potential fields with high potential for chemical flooding. Thus, our screening filter was designed to limit this possibility as much as possible by indexing the fields only according the data we had. Based on our first screening filter, we are highly certain that no high potential fields in the Powder River Basin were left out.

Economic Scoping - Production

While we attempted to prevent the elimination of any field that we did have data for a specific criteria in our screening method, there were variable in which we purposefully used to eliminate fields. For instance, we purposefully left out fields that had smaller production values, and those values may have been updated to a more recent year or some other scenario where they are left out. While we did leave some fields out of our screening, we also understand that we are seeking the highest producing fields for economic reasons. Thus, we are not eliminating any fields that have blanks in their data set but eliminating fields because their data set clearly shows the field is not economically viable.

Screening Method – Lookup Tables

A second question we pose to ourselves is whether or not we think that our screening criteria worked. We used the lookup table provided by the EORI we believed that these lookup tables are best suited to our needs. We subsequently did a Literature Review looking for screening tables that might be suite our need. While there are many different lookup tables, based on our literature review the one provide by the EORI is best suited for Wyoming's Powder River. Quality and usefulness of a lookup tables is dependent on the experience and credibility of the expert(s) who created the lookup table and the design specification the used in making the lookup table. For example, the design of the lookup table recommend by the EORI best suited Wyoming's Powder River Basin region.

Screening Method – Missing Data and Critical Criteria

Based on the lookup table we chose, any of the fields we find that meet all of the criteria in the lookup for that EOR method are good candidates for that particular EOR. However, we are certain to encounter fields which have the majority of the parameters required, and we had to eliminate them due to only one or two parameters. This was particularly true with temperature and depth. After further research on chemical flooding we found that these parameter were particularly important to screening for chemical flooding. Thus, it was acceptable to eliminate certain fields that did not meet these very important criteria.

Also, we discovered that these two critical criteria, temperature and depth were widely available and easily accessible. Not all missing data was as easily or widely accessible as temperature and depth.

Go forward and looking at other possible projects, it would be advisable to review both the data we have, and the data that is most easily accessible (i.e. not private or corporate data, which require a fee or subscription to access) before we start our screening process.

Reviewing our Screening Process

On reviewing our initial screening process we noticed that the Crawford Draw field entered our top five field list despite being extremely deep and hot temperature for chemical flooding.

Our investigation and review of our initial screening determined that the most likely reason was data entry error. During the initial screening, it is most likely that an incorrect value was entered for depth. The data was likely entered by single individual and was not checked until later. Based on this error, going forward we would recommend for any future screening project include a review of the data entered into the screening index by another individual to prevent future errors.

Nonetheless, we were able to making a recommendation for the Crawford Draw field with respect to the type of chemical flooding. The Crawford Draw field serves as an example of the fields at the very limits of what could be considered viable for chemical flooding with current technologies and when optimal conditions are not available.

Organization and Completion

Our three-phase style project has been completed including the analysis of the top 5 fields. These fields are: the Crawford Draw field, the Scott field, the Greasewood field, the Thompson Creek Field, and the Taylor field. We feel confident that our screening was completed to the best of our abilities, and that we took into consideration some of our most important factors and we gathered and utilized all the data that was accessible.

We have narrowed down our list of almost 5000 to the top 5 fields. Of these top 5 fields we created a detailed field histories, including well information (location, production values, injecting and producing locations, etc.), we obtain data about the fields' production values, previous EOR methods already attempted (if they have already undergone water floods, chemical floods are still a viable option), and parameters accessed and calculated from the WOGCC, EORI-DP and numerous other websites. Ranking was quickly completed and our field ranking in ascending order of these fields is:

1) Crawford Draw Field (Final Screening Index: 0.38)
2) Scott Field (Final Screening Index: 0.58)
3) Greasewood Field (Final Screening Index: 0.73)
4) Thompson Creek Field (Final Screening Index: 0.78)
5) Taylor Field (Final Screening Index: 0.95)

All in all, our group feels good about the quality of our project.

7 – Conclusions

Our project was initiated when we receiving our data package from the EORI containing information on some 4500+ fields throughout Wyoming. We initially scoped our project and reduced the number of fields we needed to analyze significantly by focusing only fields in the Powder River Basin that was included in our data packet. Further narrowing our scope we looked at the economic side of the oil and production decided that we focusing on fields with high production potential. Thus we narrow our scope down by focusing on field that have 2008 production values greater than 10,000 bpd, or 2016 values greater than 500 bpd, The data for this was widely and easily available on the WOGCC website and available for all fields.

Initially we had planned to fill in the missing data for the 114 field left in our screening project however due to time limitation we decided to complete an initial screening first, using the EORI's recommended chemical (enhanced water flooding) screening criteria, which was based on paper based Martin Taber and now utilized by the EORI. We used the original data we received in data packet from the EORI and the data we were able to fill in the initially screen the 114 fields.

The results of this process was a reduction of the field to best 20 fields based on data available. We than attempted to fill in the missing data for all 20 fields. Unfortunately, this process proved quite difficult as several obstructs prevents us from obtaining the data. Some of these reason were:

1) Corporations tended to limit the data they provided to public, including to the WOGCC. Most corporation limit the data they provide to public institution like the WOGCC to what is legally required.
2) Missing or miss-placed data in the WOGCC website and well as technical issue with the EORI-DP website.
3) While database exists containing the information we needed, for example the *Wyoming Geological Association: Wyoming Oil and Gas Field Symposium Powder River Basin*, they require a fee or subscription to access.
4) The difficulty in interpreting some the information. While well logs are the most widely available information they are extremely difficult to interpret.
5) Even when useful data was available such as core analysis it could be difficult in determine whether the information is correct. Many fields had multiple formation and pay zones and often the pay zones did not match with our other information or contradicted each other.

There are other numerous reasons why we had difficulties filling in the data, including time limitations and limited personal.

7.1 - Recommendations

Based on our experience, we at SACAN Corporation would recommend several major changes to anyone considering a similar screening project.

Re-organized Project Teams

Our project group consisted of 5 petroleum engineering students. Based on our experience a screening project requires a group with wider experience and skill set. In particularly, we would recommend having a geologist or someone with experience in geology in the group. A major obstacle was the inability for our group to interpret the information from well logs. Having a more multi-disciplinary team that include a geologist would have allowed our screening project to progress further, for example a geologist would have been able to interpret well logs allowing us to utilized the most widely available data.

Earlier Literature and Data Review

A general literature and data review should have be completed as early as possible –during the first semester. A general literature review earlier would have alerted us to fact that the Powder River Basin was not suitable for carbon dioxide flooding and that we should switched EOR method much earlier.

A general data review would have determined what data was available and accessible. Knowing the limitations of the data available to us earlier we might have re-designed our project to better fit the limited data available. For example we could have changed the EOR Method our switch from the Powder River Basin to region were more public information was available. Or we could have found a way to access private data that was not available to us by talking to database companies and major institutions.

Project Approach

Additionally, our initially project focused too much on a "bottom down" approach, looking at individual fields and wells too early. An EOR screening project is by its very nature is a "top-down" project. It examines a region or location and attempt to find the best areas for EOR production. Using a "top-down" approach we would have seen that we did not need to find numbers for individual specific wells, for screening process. Instead we could focus large scale, at the Powder River Basin itself first and we would have noticed that the basin lithology is primarily made of sandstone and we didn't need to find data for lithology for each field or well.

Next we could have focused on the formations in the Powder River Basin. Many fields in the Powder River Basin produce oil from the same formation. By first screening the formation as whole we could have eliminated a lot of fields that were never going to be suitable for chemical flooding.

Utilized the Whole Data Packet

By having a "top-down" approach we would have noticed that even though much of the data packet would not be used in our final assessment of the top 5 fields, the data packet as whole could provide us with much more information. By analyze the formations instead of individual fields, we could have obtained much more information from the data packet.

For example, by looking at the formation as a whole we could have created a viscosity, porosity and permeability contour map of each formation. The data packet included numerous data points (wells in each formation) at numerous different locations that could have been utilized to create a contour map of viscosity, porosity and permeability in each formation. This would have allowed us to estimate the viscosity, porosity and permeability of certain fields based on their location in the formation. We would not have needed to search numerous databases for each individual parameter for each well or field. This would have allowed to fill in more of the data more quickly. While the values would be rough estimates this would be sufficient for a screening project.

Also, we should have created a porosity and permeability cross-plot for each formation much earlier based on the entire data packet. With so many data points in each formation we were later able to create a porosity and permeability cross-plot for the formations in which the top 5 fields were found. This allowed us to fill in all the permeability data for all 5 fields.

Had we done this earlier, we could have used the cross-plot to graphically estimated porosity if we had permeability data of a field and we could have estimated permeability if we had porosity data for field. This commonly used method for estimating porosity and permeability would have allowed us fill in more of our missing data before we screened the fields. A rough estimation of porosity and permeability would have been sufficient for our screening project.

While porosity is not part of screening criteria it is important parameter, as it could be used in estimating permeability and calculating oil saturation with Archie Equation.

Earlier Review of Infrastructure

At the end of our project we analyzed the available infrastructure for chemical flooding. However, our experience with carbon dioxide flooding has show us the importance of analyzing the available of infrastructure available. Carbon dioxide flooding requires a pipeline from a source and absent access to a pipeline, it is not economically possible to complete a carbon dioxide flooding project. The situation is similar for natural gas. Without a pipeline it is not economically viable to ship natural gas to markets and any gas produced would not economically benefit the project. In fact, it is likely that it will require additional funds to properly flare the natural gas off, which would create further environment issues for the project.

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