March 27, 2020

SECARB Offshore GoM Project Updates and Discussion

9:45 AM – 10:00 AM
Log In and Trouble Shooting

10:00 AM – 11:00 PM
Status of Risk Characterization Activities and Data Development – Michael Godec, Advanced Resources International, Inc.

11:00 AM – 11:15 AM | BREAK

11:15 AM – 12:15 PM
Status on Work on Characterizing Legal and Regulatory Frameworks and Key Considerations – Michael Godec, Advanced Resources International, Inc., and Ingvild Ombudstvedt, IOM Law
Overview of Offshore CO2-EOR/Storage Case Studies – Vello Kuuskraa, Advanced Resources International, Inc.

12:15 PM – 1:15 PM | LUNCH BREAK

1:15 PM – 2:05 PM
Risk Assessment Gas Hydrates – Camelia Knapp, Oklahoma State University
SECARB Offshore evaluating the salt structures and deep-water reservoirs in the central Gulf of Mexico – Jack Pashin, Oklahoma State University

2:05 PM – 2:20 PM | BREAK

2:20 PM – 3:00 PM
Offshore Well Integrity – Andrew Duguid, Battelle Memorial Institute
45Q – Brian Hill, Crescent Resource Innovation

3:00 PM – 3:15 PM
Wrap up and Comments

Experiencing Technical Difficulties?
Emily Moskal
Emily.Moskal@beg.utexas.edu
(281) 796-9834
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Presentations are available online.

gulfcoastcarbon.org/news/2020


After March 27: https://www.sseb.org/news-and-events/past-events/
Characterization of Offshore CO₂ EOR Resource Potential

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace, Project Manager
Advanced Resources International, Inc.

March 26-27, 2020
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purpose of Study</td>
</tr>
<tr>
<td>2</td>
<td>Offshore GOM OCS Oil Resources</td>
</tr>
<tr>
<td>3</td>
<td>Offshore Oil Field Database</td>
</tr>
<tr>
<td>4</td>
<td>Offshore CO\textsubscript{2} EOR Resource Potential</td>
</tr>
<tr>
<td>5</td>
<td>Next Steps</td>
</tr>
</tbody>
</table>
The primary purpose of this resource characterization is to identify the Offshore GOM OCS oil resource that is potentially viable for CO₂ enhanced oil recovery (CO₂ EOR).

This study includes characterization of oil fields in both the Shallow Water Lease Areas and Deep Water Protraction Areas in the Central Planning Area of the GOM OCS.

This resource characterization included several tasks:

1. **Offshore GOM OCS Oil Resource.** Establish the oil resource in-place and remaining reserves for oil fields in the GOM OCS Central Planning Area.

2. **Offshore Oil Field Database.** Develop a database of Offshore GOM OCS oil reservoirs viable for CO₂ EOR.

3. **Offshore CO2 EOR Resource Potential.** Calculate the remaining oil reserves and resource in place for Shallow and Deep Water oil fields that are likely candidates for CO₂ EOR.
Offshore GOM OCS Oil Resource
Status of Offshore GOM OCS Oil Production

Offshore GOM: Crude Oil Production

Oil production from offshore GOM OCS oil fields has increased for the last several years, enabling production to reach 1.9 MMB/D in 2019.

We expect oil production to continue to grow in 2020 as new deep water oil fields come on-line and existing fields, like Thunder Horse South and Atlantis, undergo expansion.

Given the increased production from offshore oil resources, many leases nearing depletion will require advanced production practices (like CO$_2$ EOR) to extend their productive life.
This Offshore CO$_2$ EOR resource characterization focuses on Shallow and Deep Water resources in the GOM OCS Central Planning Area.

As of EOY 2017 the Central Planning Area contains 966 of the 1,319 total GOM OCS oil and gas fields.

These 966 fields contain 51,850 MMBOE of the 59,380 MMBOE in the GOM OCS (87%).
Offshore Oil Field Database
The foundation for establishing the ARI Offshore Oil Reservoir Database is the Bureau of Ocean Management (BOEM) 2018 Oil Sands database.

This data set includes production history, well counts, volumetric data, and reservoir characteristic data for all Offshore oil and gas reservoirs.

Of the 966 fields in the Central Planning Area 241 are designated oil fields. These 241 oil fields contain 23.4 billion barrels of Original Reserves, with only 3.7 billion barrels of Remaining Reserves.

### Central Planning Area Oil Resources

<table>
<thead>
<tr>
<th>CPA Resources</th>
<th>Oil Resources (MMBbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Fields</td>
<td>241</td>
</tr>
<tr>
<td>Original Reserves</td>
<td>23,410</td>
</tr>
<tr>
<td>Cumulative Production</td>
<td>19,660</td>
</tr>
<tr>
<td>Remaining Reserves</td>
<td>3,750</td>
</tr>
</tbody>
</table>

### Central Planning Area Remaining Reserves

- **Cumulative Production**: 19.7 MMBbl
- **Remaining Reserves**: 3.7 MMBbl

16% of Original Reserves Remaining
Building the ARI Offshore Oil Field Database

The 2018 BOEM Sands reservoir data provided the foundation for the ARI Offshore Oil Field Database, however a number of updates were required to adapt the data for evaluating CO₂ EOR viability.

1. **Volumetric Consistency** – The 2018 Sands Database includes a reservoir OOIP, however this value is not always consistent with the reported reservoir volumetric data (area, net pay, porosity, So, and Bo). ARI adjusted the OOIP value to be volumetrically consistent, which added a significant volume of resource to the database.

2. **Additional Reservoir Data** – The 2018 Sands Database includes primarily volumetric and reservoir characteristic data, however ARI calculated a number of additional reservoir data points required for modeling CO₂ EOR in the future. These data points include:
   - Current formation volume factor (Bo)
   - Residual oil saturation (Sor)
   - Dykstra-Parsons co-efficient of heterogeneity
   - Reservoir Sweep Efficiency
The 2018 Sands Database was screened to identify oil fields in the Central Planning Area that are likely candidates for CO₂ EOR. Screening criteria included:

- Resource Size: Minimum Original Oil In-Place >= 20 MMBbl
- API Gravity: Minimum of 20 degrees
- Depth: TVD > 2,500 ft to meet minimum miscibility requirements
- Shallow Water Fields: < 1,000 ft water depth
- Deep Water Fields: >= 1,000 ft water depth
Of the 241 CPA oil fields in the 2018 BOEM Sands database, 168 oil fields met the screening criteria for inclusion in the ARI Offshore Oil Field Database.

These 168 oil fields include 572 reservoirs, which hold 49.7 billion barrels of original oil in-place and 15.3 billion barrels of original reserves (approximately 65% of the 2018 Sands Database total of 23.4 billion barrels).

While the Shallow Water lease areas contain more oil fields and reservoirs, the Deep Water resource contains approximately 70% of the total oil resource in the CPA.

### ARI Offshore DB -- Central Planning Area Oil Resources

<table>
<thead>
<tr>
<th></th>
<th>Oil Fields</th>
<th>Reservoirs</th>
<th>OOIP (BBbl)</th>
<th>Orig. Reserves (BBbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow Water</td>
<td>90</td>
<td>310</td>
<td>14.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Deep Water</td>
<td>78</td>
<td>262</td>
<td>35.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Total</td>
<td>168</td>
<td>572</td>
<td>49.7</td>
<td>15.3</td>
</tr>
</tbody>
</table>
Offshore CO₂ EOR Resource Potential
Central Planning Area CO₂ EOR Resource Potential

Central Planning Area CO₂ EOR Oil Resources

The CPA holds 34.3 billion barrels of remaining oil in-place available for targeting by CO₂ EOR.

The shallow water area has only 100 million barrels of remaining reserves, and many fields are effectively depleted. However, there are 8.6 billion barrels of remaining oil in-place available for targeting by CO₂ EOR.

The deep water area has 3 billion barrels of remaining reserves, however it holds a significant volume of remaining oil in-place of 25.7 billion barrels that could be targeted by CO₂ EOR.
Shallow Water Lease Areas

The ARI Offshore Oil Field Database includes oil resources for eleven shallow water lease areas.
Characterization of Offshore CO₂ EOR Resource Potential

Viable Shallow Water CO₂ EOR Resources

The shallow water lease areas contain just over 100 million barrels of remaining reserves. Original reserves in each lease area are nearing depletion, particularly in South Pass, West Delta, and South Timbalier which have produced over 99% of original reserves.

South Timbalier, which includes the large Bay Marchand field, has over 1 billion barrels of ROIP and is particularly attractive for CO₂ EOR.

### Viable Shallow Water CO₂ EOR Resources

<table>
<thead>
<tr>
<th>Area</th>
<th>OOIP</th>
<th>Resources (Million Barrels)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Original Reserves</td>
</tr>
<tr>
<td>South Pass</td>
<td>1,902</td>
<td>702</td>
</tr>
<tr>
<td>West Delta</td>
<td>1,790</td>
<td>859</td>
</tr>
<tr>
<td>South Timbalier</td>
<td>1,975</td>
<td>998</td>
</tr>
<tr>
<td>South Marsh</td>
<td>1,160</td>
<td>435</td>
</tr>
<tr>
<td>Main Pass</td>
<td>2,270</td>
<td>817</td>
</tr>
<tr>
<td>Ship Shoal</td>
<td>1,272</td>
<td>597</td>
</tr>
<tr>
<td>Grand Isle</td>
<td>1,573</td>
<td>645</td>
</tr>
<tr>
<td>Eugene Island</td>
<td>1,769</td>
<td>774</td>
</tr>
<tr>
<td>Other*</td>
<td>999</td>
<td>320</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14,709</td>
<td>6,147</td>
</tr>
</tbody>
</table>

*Ewing Bank, Vermillion, East Cameron
This diagram represents a theoretical offshore CO₂ pipeline network connecting oil fields to onshore sources of CO₂ for CO₂ EOR.

The large Bay Marchand field, which is located close to shore, would serve as a “hub” location distributing CO₂ through smaller transportation lines.
Deep Water Oil Field Resource
Deep Water Protraction Areas

The ARI Offshore Oil Field Database includes oil resources for eight whole or partial deep water protraction areas.
Viable Deep Water CO₂ EOR Resources

The deep water protraction areas contain just over 3 billion barrels of remaining reserves. Original reserves in several lease areas, like Viosca Knoll, are nearing depletion while others, like Mississippi Canyon and Green Canyon, have significant volumes of remaining reserves.

Viosca Knoll, which includes several large fields like Ram Powell and Petronius that are located relatively close to shore, holds 700 million barrels of ROIP that could be targeted for CO₂ EOR.

<table>
<thead>
<tr>
<th>Area</th>
<th>Original OIP</th>
<th>Resources (Million Barrels)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Original Reserves</td>
</tr>
<tr>
<td>Viosca Knoll</td>
<td>1,193</td>
<td>461</td>
</tr>
<tr>
<td>Garden Banks</td>
<td>1,729</td>
<td>662</td>
</tr>
<tr>
<td>Walker Ridge</td>
<td>4,837</td>
<td>591</td>
</tr>
<tr>
<td>Mississippi Canyon</td>
<td>12,549</td>
<td>4,002</td>
</tr>
<tr>
<td>Green Canyon</td>
<td>14,280</td>
<td>3,393</td>
</tr>
<tr>
<td>Other*</td>
<td>384</td>
<td>154</td>
</tr>
<tr>
<td>Total</td>
<td>34,972</td>
<td>9,262</td>
</tr>
</tbody>
</table>

*Keathley Canyon, Atwater Valey, De Soto Canyon
A number of large deep water oil fields that are viable for CO2 EOR are located relatively near shore – particularly in the Viosca Knoll and Mississippi Canyon protraction areas. Cognac, Petronius, Horn Mountain, and Mars Ursa, among a number of other fields, are located within 80 miles of shore and have a combined ROIP of 3.5 billion barrels.
**Emerging Deep Water CO₂ EOR Technology**

Significant advancements in technology have moved CO₂ EOR in the Deep Water GOM OCS protraction areas closer to reality. Aker Solutions is currently developing a network of sea floor processing equipment for CO₂ injection and recycling for CO₂ EOR.

*Source: Journal of Petroleum Technology, Aker Sea Floor CO2 Injection Project*
Next Steps
The next step for modeling Offshore CO₂ EOR potential is to determine the technically viable CO₂ EOR resources and overall CO₂ demand.

With availability of appropriate data, the CO₂-PROPHET Model can be used to model CO₂-EOR potential in GOM oil reservoirs. The data required for running CO₂-PROPHET would be assembled from the latest BOEM Sands database, augmented by a variety of estimates and calculations.
The economically viable Offshore CO$_2$ EOR oil resource and CO$_2$ demand would be determined using a modified CO$_2$ EOR Cost Model. The model will include separate costs for developing offshore CO$_2$ EOR oil fields in either shallow or deep water areas, and will include several technology options for CO$_2$ delivery, injection, and recycling.

The Offshore GOM OCS resource contains significant potential for increased volumes of domestic oil production and secure storage of CO$_2$, yet the technical challenges will require significant collaboration from multiple stakeholders.
Characterization of Offshore CO₂ EOR Resource Potential
Building the Foundation for Assessing GOM Offshore CO$_2$ EOR and Associated CO$_2$ Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020
Outline of Presentation

1. Purpose of the Case Studies
2. Petronius Offshore Oil Field Case Study
3. Cognac Offshore Oil Field Case Study
4. Observations and Findings
The primary purpose of the “Offshore Oil Field Case Studies” is to assess the ability of the NETL CO₂ PROPHET Model to represent the performance of an offshore CO₂ flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.

2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.

3. **Field Development.** Establish the locations of the existing oil/gas production wells producing from the oil reservoir.
4. **History Matching Using Compositional Simulations.** Use GEM compositional simulator to provide a “first-order” history match of fluid production from the oil reservoir.

5. **Assessing CO₂ Flooding Using Compositional Simulation.** With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO₂ EOR project in the oil reservoir using the GEM compositional simulator.

6. **Assessing CO₂ Flooding Using CO₂ PROPHET.** In parallel with the GEM compositional simulator, use the NETL CO₂ PROPHET Model to appraise the performance of a post-primary CO₂ EOR project in the oil reservoir.

7. **Comparing GEM and CO₂ PROPHET Modeling.** Compare the results of GEM and CO₂ PROPHET modeling of CO₂ EOR to determine whether the NETL CO₂ PROPHET model could reasonably represent the performance of the CO₂ flood compared to the more sophisticated GEM compositional simulator.
Petronius Offshore Oil Field Case Study
Petronius Offshore Oil Field Case Study

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico

Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.
The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

Source: Duan, 2013
The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

### Petronius Original Oil Resources, Production and Remaining Reserves

<table>
<thead>
<tr>
<th>Sands</th>
<th>Area (Acres)</th>
<th>Original Oil In-Place (MMB)</th>
<th>Cumulative Oil Production (MMB)</th>
<th>Remaining Oil Reserves (MMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Major Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-1</td>
<td>3,438</td>
<td>124.8</td>
<td>69.6</td>
<td>4.0</td>
</tr>
<tr>
<td>▪ J-2</td>
<td>5,288</td>
<td>104.7</td>
<td>52.0</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>2. Minor Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-3</td>
<td>1,352</td>
<td>24.5</td>
<td>6.1</td>
<td>1.0</td>
</tr>
<tr>
<td>▪ J-4</td>
<td>1,398</td>
<td>39.2</td>
<td>17.8</td>
<td>0.9</td>
</tr>
<tr>
<td>▪ J-5</td>
<td>389</td>
<td>18.2</td>
<td>7.8</td>
<td>1.5</td>
</tr>
<tr>
<td>▪ Other (13)</td>
<td>-</td>
<td>0.7</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11,865</strong></td>
<td><strong>312.1</strong></td>
<td><strong>153.5</strong></td>
<td><strong>8.7</strong></td>
</tr>
</tbody>
</table>

*As of end of 2016.
# Volumetric and Other Reservoir Properties: Petronius J-2 Sand

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Area</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5,288 Acres</td>
</tr>
<tr>
<td>Quarter*</td>
<td>1,290 Acres</td>
</tr>
<tr>
<td>Porosity</td>
<td>30%</td>
</tr>
<tr>
<td>Depth</td>
<td>10,900 to 11,100 ft</td>
</tr>
<tr>
<td>Permeability</td>
<td>398 mD</td>
</tr>
<tr>
<td>Net Pay</td>
<td>16.5 ft</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>31 API</td>
</tr>
<tr>
<td>Swi</td>
<td>0.24</td>
</tr>
<tr>
<td>Boi</td>
<td>1.45</td>
</tr>
<tr>
<td>OOIP</td>
<td>104 MM bbls</td>
</tr>
<tr>
<td>Initial Pressure</td>
<td>5,287 psia</td>
</tr>
<tr>
<td>Pressure Gradient (@ 10,560 ft)</td>
<td>0.5 psi/ft</td>
</tr>
<tr>
<td>Initial Temperature</td>
<td>182 °F</td>
</tr>
</tbody>
</table>

*After including gas cap area.

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.
After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.
The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.
Excellent history matched results were obtained for oil production, gas production and water production.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Actual Data</th>
<th>History Matched Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>53 MM bbl</td>
<td>52.4 MM bbl</td>
</tr>
<tr>
<td>Gas</td>
<td>53 Bcf</td>
<td>51.4 Bcf</td>
</tr>
<tr>
<td>Water</td>
<td>28.5 MM bbl</td>
<td>29.4 MM bbl</td>
</tr>
</tbody>
</table>

Source: Advanced Resources International, 2019
An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.
GEM Compositional Modeling of the Performance of the CO\textsubscript{2} Flood, Petronius J-2 Sand

CO\textsubscript{2} Flood Design. Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO\textsubscript{2} flood was as follows:

- Drill an updip CO\textsubscript{2} injection well on the crest of the fault block.
- Inject continuous CO\textsubscript{2} at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO\textsubscript{2} flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO\textsubscript{2} flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.
CO$_2$ PROPHET Modeling of the NETL CO$_2$ Flood, Petronius J-2 Sand

In parallel with the GEM compositional simulator, the study modeled the CO$_2$ flood in the Petronius J-2 Sand using NETL CO$_2$ PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO$_2$ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO$_2$ producer and operate the CO$_2$ flood using a quarter of a five-spot pattern.
- Inject continuous CO$_2$ at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO$_2$ of 365 Bcf, equal to CO$_2$ injected in the GEM Model.
Comparative Analysis of GEM and CO\(_2\) PROPHET Modeling of CO\(_2\) Flood, J-2 Sand

The CO\(_2\) PROPHET streamtube model was able to reasonably represent the performance of the CO\(_2\) flood compared to the GEM compositional simulator.

<table>
<thead>
<tr>
<th></th>
<th>CO(_2) Flood Performance GEM Compositional Simulator</th>
<th>CO(_2) Flood Performance CO(_2) PROPHET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP of 0.75</td>
<td>DP of 0.5</td>
</tr>
<tr>
<td>OOIP (million Barrels)</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>CO(_2) Injection (Bcf)</td>
<td>365</td>
<td>365</td>
</tr>
<tr>
<td>CO(_2) Production (Bcf)</td>
<td>226</td>
<td>238</td>
</tr>
<tr>
<td>CO(_2) Storage (Bcf)</td>
<td>139</td>
<td>127</td>
</tr>
<tr>
<td>Cumulative Oil Recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(million barrels)</td>
<td>14.3</td>
<td>10.8</td>
</tr>
<tr>
<td>% of OOIP</td>
<td>13.5%</td>
<td>10.2%</td>
</tr>
<tr>
<td>CO(_2)/Oil Ratio (Mcf/B)</td>
<td>25.5</td>
<td>33.8</td>
</tr>
<tr>
<td>Gross</td>
<td>9.7</td>
<td>11.8</td>
</tr>
</tbody>
</table>

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO\(_2\) PROPHET model) provide results that bracket the performance of the CO\(_2\) flood from the GEM compositional simulator.
The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.
The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.
The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

### Cognac Original Oil Resources, Production and Remaining Reserves

<table>
<thead>
<tr>
<th>Sands</th>
<th>Oil Area (Acres)</th>
<th>Original Oil In-Place* (MMB)</th>
<th>Cumulative Oil Production** (MMB)</th>
<th>Remaining Oil Reserves (MMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Major Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ I</td>
<td>3,560</td>
<td>191.5</td>
<td>91.7</td>
<td>0.1</td>
</tr>
<tr>
<td>▪ J</td>
<td>2,240</td>
<td>135.6</td>
<td>56.9</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,540</td>
<td>350.4</td>
<td>171.2</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>2. Minor Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-1</td>
<td>1,740</td>
<td>23.3</td>
<td>6.6</td>
<td>***</td>
</tr>
<tr>
<td>▪ Others</td>
<td>n/a</td>
<td>n/a</td>
<td>16.0</td>
<td>3.2</td>
</tr>
</tbody>
</table>

*Volumetrically adjusted by Advanced Resources Int'l., **As of end of 2016.

***Less than 0.05 MMB.
Volumetric and Other Reservoir Properties
Cognac J Sand/NE Fault Block

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessible Oil Area</td>
<td>384 Acres</td>
</tr>
<tr>
<td>Porosity</td>
<td>32%</td>
</tr>
<tr>
<td>Permeability</td>
<td>794 mD</td>
</tr>
<tr>
<td>Net Pay</td>
<td>42 ft</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>34.6 API</td>
</tr>
<tr>
<td>Soi</td>
<td>0.73</td>
</tr>
<tr>
<td>Sor</td>
<td>0.45</td>
</tr>
<tr>
<td>Boi</td>
<td>1.21</td>
</tr>
<tr>
<td>OOIP</td>
<td>24.2 MMbbls</td>
</tr>
<tr>
<td>Initial Pressure (@ 8,297 ft)</td>
<td>4,412 psia</td>
</tr>
<tr>
<td>Initial Reservoir Temperature</td>
<td>130 °F</td>
</tr>
</tbody>
</table>

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.
Cognac J Sand/NE Fault Block

As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.

Source: Advanced Resources Int'l using DrillingInfo data, 2019
The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.
History Match of Fluid Production, Cognac J Sand, NE Fault Block

**Cumulative Oil Production**: Modeled: 9.2 MMbbl
Reported: 9.2 MMbbl

**Cumulative Gas Production**: Modeled: 4.2 Bcf
Reported: 4.1 Bcf

**Cumulative Water Production**: Modeled: 2.7 MMbbl
Reported: 2.8 MMbbl
An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.
CO₂ Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO₂ flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO₂ breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO₂ flood.
In parallel with the GEM compositional simulator, the study modeled the CO$_2$ flood in the Cognac J Sand, NE Fault Block, using NETL CO$_2$ PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block’s J Sand were modeled (with CO$_2$ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO$_2$ producer and operate the CO$_2$ flood in a two well line drive configuration.
- Inject continuous CO$_2$ at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO$_2$ of 88 Bcf equal to CO$_2$ injected in the GEM Model (a HCPV of 1.2).
Comparative Analysis of GEM and CO₂ PROPHET Model of CO₂ Flood, NE Fault Block J Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

<table>
<thead>
<tr>
<th></th>
<th>CO₂ Flood Performance</th>
<th>CO₂ Flood Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GEM Compositional</td>
<td>CO₂ PROPHET</td>
</tr>
<tr>
<td></td>
<td>Simulator</td>
<td>DP of 0.75</td>
</tr>
<tr>
<td>OOIP (million Barrels)</td>
<td>24.2</td>
<td>24.4</td>
</tr>
<tr>
<td>CO₂ Injection (Bcf)</td>
<td>89.5</td>
<td>87.7</td>
</tr>
<tr>
<td>CO₂ Production (Bcf)</td>
<td>52.3</td>
<td>55.7</td>
</tr>
<tr>
<td>CO₂ Storage (Bcf)</td>
<td>37.2</td>
<td>32.0</td>
</tr>
<tr>
<td>Cumulative Oil Recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(million barrels)</td>
<td>8.18</td>
<td>6.33</td>
</tr>
<tr>
<td>% of OOIP</td>
<td>33.8%</td>
<td>26.2%</td>
</tr>
<tr>
<td>CO₂/Oil Ratio (Mcf/B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td>10.9</td>
<td>13.9</td>
</tr>
<tr>
<td>Net</td>
<td>4.5</td>
<td>5.1</td>
</tr>
</tbody>
</table>

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.
Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.
- By defining the location and status of existing production and injection wells, reasonable spacing and CO₂ flooding designs can be established for offshore oil fields.
- Miscible CO₂ EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO₂.
- The NETL CO₂ PROPHET Model can provide realistic estimates of oil recovery and CO₂ storage in offshore oil reservoirs.
Initial Risk Characterization and Data Development Activities

Presented at:
SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting

Presented by:
Michael Godec
Caroline Skidmore
Advanced Resources International

New Orleans, Louisiana, USA
March 25 – 27, 2020
Task 4.0
Risk Assessment, Simulation, and Modeling

- Under Task 4.0, one activity is focused on assessing site-specific risks and developing mitigation strategies in the offshore GOM environment.
  - Involves reviewing published efforts to evaluate onshore and offshore (North Sea, Australia, and Brazil) risk assessment and mitigation strategies and adapt or tailor them to our case.

- Based on this, the project team will:
  - Develop and/or adapt geologic and dynamic flow models that evaluate multiple physical and chemical processes
  - Describe the effects of the processes on CO₂ movement within the storage reservoir and potentially through the caprock, overburden, and water column, defined for representative prospects.

- Among other objectives, the results of these modeling efforts will be used to identify and characterize potential geologic and CO₂ permanence risks and design monitoring programs.
Proposed Approach for Risk Characterization

- In this effort, we build on two previous risk assessment approaches.
  - The CarbonSAFE ECO$_2$S Project Risk Assessment
  - The Shell Goldeneye “Bow-Tie” Risk Assessment
- From these we have developed a proposed combination process that involves aspects of both.
Project ECO$_2$S Approach

- Compile an initial risk register (pre-workshop)
  - Project ECO$_2$S used the SECARB Anthropogenic Test CCS project’s risk register as their initial risk register.
- Identify and discuss project values (pre-workshop)
- Divide identified risks into topic groups (pre-workshop)
- Identify the elements of the project that fall under the “5 W’s and H” -- Who, What, When, Where, Why, and How. (workshop)
- Evaluate each risk scenario in terms of Severity and Likelihood
- Determine a “risk” value for each risk scenario
- Develop plan for a monitoring program
In October 2017, a workshop was conducted to identify and evaluate the principal risks to the Project ECO\textsubscript{2}S storage site

- 18 project participants

102 unique risk scenarios were developed

- Encompassed five specific topic groups: 1) Geologic; 2) Monitor-Model; 3) Operations; 4) Project-Program Management; and 5) Public Acceptance

Discussion centered on known risks as well as unknowns that could potentially impede the achievement of project goals.

Participants provided semi-quantitative risk-evaluation data for analysis and reporting

- Comprising ‘Likelihood’ and ‘Severity’ values measured on 5-point scales.
- Aggregated values were displayed in real time during the workshop.

Scenarios not evaluated during the workshop were later completed through emailed correspondence.
Project ECO$_2$S Results

- 102 scenarios were ranked by risk. Strong group consensus identified five to seven program-management scenarios related to CO$_2$ supply as main sources of project risk.

- Technical risks ranked lower, with concerns about seal (caprock) continuity ranking highest (#23 out of 102, in the “most familiar with the topic” ranking).

- Induced seismicity risks were ranked low.

- Highest monitoring-modeling risks (ranked around #30) focused on prospect that the CO$_2$ plume might not be confidently observable using available monitoring techniques.

- Overall, risk rankings differed little among participants regardless of familiarity with the subject matter of specific scenarios.
### How to select risks to treat? Multiple Screens

<table>
<thead>
<tr>
<th>Scen ID</th>
<th>Risk</th>
<th>Rank by Risk (all)</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>12.17</td>
<td>1</td>
<td>Changes in the operational status or commercial viability of CO₂ source plant prevent meeting project objectives.</td>
</tr>
<tr>
<td>P09</td>
<td>12.16</td>
<td>2</td>
<td>Kemper energy facility does not become a source of CO₂.</td>
</tr>
<tr>
<td>P18</td>
<td>11.48</td>
<td>3</td>
<td>Insufficient CO₂ supply commitments to support regional storage hub.</td>
</tr>
<tr>
<td>U03</td>
<td>11.13</td>
<td>4</td>
<td>Changes in U.S. government personnel or policies result in removal of government support of the CarbonSAFE program.</td>
</tr>
<tr>
<td>O15</td>
<td>10.90</td>
<td>5</td>
<td>Operational problems at CO₂ source plant prevent delivering the CO₂ needed to show commercial-scale geological storage.</td>
</tr>
<tr>
<td>P13</td>
<td>10.10</td>
<td>6</td>
<td>MPC / SOPO management not interested in supporting a regional storage hub.</td>
</tr>
<tr>
<td>P12</td>
<td>10.06</td>
<td>7</td>
<td>MPC / SOCO management do not continue to support project during next 2-50 years.</td>
</tr>
<tr>
<td>P04</td>
<td>9.92</td>
<td>8</td>
<td>Existing pipeline network not designed to be used as a regional hub.</td>
</tr>
<tr>
<td>P14</td>
<td>9.43</td>
<td>9</td>
<td>Pore space rights are insufficient for the project.</td>
</tr>
<tr>
<td>P15</td>
<td>9.43</td>
<td>10</td>
<td>Potential CO₂ sources believe that no mature capture technology is available, so will not commit to project.</td>
</tr>
<tr>
<td>P11</td>
<td>9.09</td>
<td>11</td>
<td>Loss of pore space access (due to land sale or other cause) limits the overall storage capacity of the hub.</td>
</tr>
<tr>
<td>O14</td>
<td>8.88</td>
<td>12</td>
<td>Oilfield boom drives up project costs and increases lead time for equipment and services.</td>
</tr>
<tr>
<td>U11</td>
<td>8.75</td>
<td>13</td>
<td>Local animosity toward MPC leads to vocal opposition of ECO₂S project.</td>
</tr>
<tr>
<td>O10</td>
<td>8.48</td>
<td>14</td>
<td>Loss of surface access rights in area of existing or planned injection well.</td>
</tr>
<tr>
<td>U16</td>
<td>8.30</td>
<td>15</td>
<td>Permitting of a Class VI UIC permit for storage is delayed.</td>
</tr>
<tr>
<td>P07</td>
<td>8.17</td>
<td>16</td>
<td>Infrastructure development costs are considerably higher than expected.</td>
</tr>
<tr>
<td>O21</td>
<td>8.16</td>
<td>17</td>
<td>Uncertainty in CO₂ source(s) delays pipeline specifications (sizing, materials, pressure rating).</td>
</tr>
</tbody>
</table>
Example Severity-Likelihood Grid
Live Poll Results (High-Risk Scenario)
102 Scenarios Ranked By Risk

(average of all participants' risk values)
Shell Goldeneye “Bow-Tie” Approach

- Identify and describe risks (pre-workshop)
  - Based on risk identification workshops, experience, past project reviews, regular engagement with key external stakeholders

- Conduct workshop where project members come together and discuss/create an initial bow-tie risk assessment

- Identify the top hazard event(s)
  - Using initial risk register, identify ‘threats, based on ways CO₂ could be released
  - Identify the consequence(s) for each threat
  - Identify ‘barriers’ that can prevent the ‘threats’ from causing CO₂ leakage
  - Identify ‘controls’ that can mitigate the consequences if CO₂ leakage does occur

- Conduct initial bow-tie risk assessment

- Perform evaluation of risks

- Expand initial bow-tie risk assessment as monitoring program progresses
Bow-Tie Model for Goldeneye Project
Goldeneye’s Risk Assessment Matrix
The primary objective of this initial risk characterization workshop is to ensure that initial data acquisition and analysis activities are being conducted to ensure the best possible characterization.

- Compile an initial risk register
- Establish one or more workshop working groups
- Assess risks that represent potential ‘real impacts’
- Determine data needs to characterize potential “real impacts,” possibly creating a bow-tie model
  - That includes the risks, the mitigation/controls and consequences that were discussed during their assessment of the risks as material impacts.
  - The overarching main concern initially will be release of CO₂ from the storage complex.
Evaluate potential risks in terms of Severity and Likelihood

- To discuss the highest-ranked risks and discuss if other risks should be ranked higher or vice versa.
- These discussions will help pinpoint the data gaps and how those data gaps could be filled and which monitoring efforts would be the best to explore to ensure gaps are filled.
- Discussions of risk evaluations are likely to continue after the workshop between project members as they determine the appropriate monitoring efforts.

Discuss possible additional data acquisition activities

Discuss possible monitoring plans and activities
An excel file has been created to document all potential risks that members of the SECARB Offshore project team identify as initial risks that should be looked into.

The table will look similar to the table below.

<table>
<thead>
<tr>
<th>Potential Risks</th>
<th>Severity of Risk</th>
<th>Likelihood of Risk</th>
<th>Data to Characterize Risk</th>
<th>Possible Monitoring Methods</th>
<th>Possible Mitigation Approaches</th>
<th>Links to Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Initial Risk Registry (Cont.)

- **Potential Risks**: identify potential risks from experience, past project reviews, and expertise.

- **Severity**: If the risk were to occur how serious are the impacts?

- **Likelihood**: The probability that the potential risk will occur.

- **Data to Characterize**: What data is already available to the project? And what data does the project team need to obtain to better characterize potential risks?

- **Monitoring Methods**: From past experiences and expertise what are the monitoring efforts that could be put in place for the potential risk?

- **Mitigation Methods**: What are the possible mitigation efforts that can diminish the negative impacts if the potential did occur?

- **Links to Sources**: If you have any PDFs, journal article, etc that could be helpful to better explaining/understanding your responses, please include the link(s).
We have chosen to use the Severity and Likelihood Scales from Project ECO$_2$S.

Each potential risk’s severity and likelihood should be evaluated in terms scales featured in the next slides, a 1 through 5 scale.

After the severity and likelihood values have been determined, those two values will be added together to create the overall potential hazard score.

Risks with potential hazard score of 7 or greater are considered to have the highest risk potential.

As the project progresses and more data is collected, we expect the hazard scores to change.
# Generic Likelihood Scale

<table>
<thead>
<tr>
<th>LIKELIHOOD of Impact or Failure Occurring (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Very Unlikely</td>
</tr>
</tbody>
</table>

| In 50 ECO₂S-like commercial projects, might happen once. | Probably won't happen during this project. In ten such projects, once per decade. | May or may not happen during the project, with roughly equal likelihood. | Probably would occur during the pilot or commercial-scale ECO₂S Project. Once per several years. | Nearly sure to occur during the pilot or commercial-scale ECO₂S Project. Could happen yearly. |
# Generic Severity Scale

<table>
<thead>
<tr>
<th>Health &amp; Safety</th>
<th>Environment</th>
<th>Regulatory</th>
<th>Economic-Financial</th>
<th>Reputation</th>
<th>CCS Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> First aid. Minor health effects. Public nuisance.</td>
<td>Insignificant and temporary impact. Small but recordable release of hazardous material.</td>
<td>Nonconformance with stringent industry practice standards (e.g. ISO, API, ANSI).</td>
<td>Equipment damage or production costs &lt;$5k.</td>
<td>Isolated individual concerns.</td>
<td>Temporary / fixable low injectivity. Ineffectiveness of one monitoring technique.</td>
</tr>
<tr>
<td><strong>2</strong> Medical aid, restricted work. Hospital visit. Temporary disability. 1-10 lost person-days. Brief facility evacuation or stand-down.</td>
<td>Reportable release of hydrocarbons or hazardous materials. Minor or one-time cleanup.</td>
<td>Equipment damage or production costs &lt;$5k.</td>
<td>$5k-100k</td>
<td>Local media coverage. Multiple informal complaints. Landowner or community concern.</td>
<td>Capacity somewhat limited for commercial CCUS. Moderate uncertainty in proving containment.</td>
</tr>
<tr>
<td><strong>3</strong> Intensive care. 10-100 lost days. Facility evacuation to 2 days.</td>
<td>Onsite release, large or with prolonged cleanup. Offsite release with quick cleanup.</td>
<td>Nonconformance with specific Regional or business unit requirements. Threat of sanctions.</td>
<td>$100k-1m</td>
<td>Broad media coverage or community concern. Repeated and/or formal complaints.</td>
<td>Injection takes 50% more wells. Models or monitoring questionably demonstrate creditable storage.</td>
</tr>
<tr>
<td><strong>4</strong> Permanent injury or disability. Lost days &gt;100. Facility evacuation &gt;2 days.</td>
<td>Offsite release, large or with long cleanup.</td>
<td>Nonconformance with operating company standards and/or rqmts. License suspension.</td>
<td>$1m-10m</td>
<td>Regional media coverage. Broad community outrage. Litigation.</td>
<td>Injection takes many wells. Suspected leakage; lack of data to show containment.</td>
</tr>
<tr>
<td><strong>5</strong> Fatality. Severe health effects. Facility and community evacuation.</td>
<td>Release on, to, or across moving water, potable water, wildlife, national park, state border.</td>
<td>Serious or flagrant nonconformance with regulations or license conditions. License revoked.</td>
<td>&gt;$10m</td>
<td>National media coverage.</td>
<td>Persistent CO₂ leak to potable water or surface. Few wells usable at commercial rate.</td>
</tr>
</tbody>
</table>
Next Steps

- Our initial plan was to conduct a preliminary risk characterization workshop among the SECARB Offshore project team as part of this meeting.
  - Of course, that plan has been overtaken by events

- This was to use an initially developed risk registry, for participants to react to, add to, comment on, etc.

- We are in the process of evaluating options for continuing.
  - Delay the preliminary workshop until we can get together again.
  - Conduct the preliminary workshop virtually via a webinar-type format
  - Facilitate input solicitation and data gathering via email communications.
Characterizing Legal and Regulatory Frameworks

Presented at:
SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting

Presented by:
Michael Godec, Vice President
Advanced Resources International

New Orleans, Louisiana, USA
March 25 – 27, 2020
“The Recipient will communicate with BOEM, BSSE, the Coast Guard and other Federal and State regulatory agencies to keep them informed on current project activities, to facilitate a dialogue on permitting requirements, and to compare and contrast with experience/lessons learned elsewhere.

The project team also will engage with experts on regulatory oversight on offshore CO₂ storage projects from North Sea (UK and Norway and EU), Brazil, Japan.

Further, the team will coordinate with BOEM, BSSE, DOE, Internal Revenue Service and other Federal and State agencies to develop recommendations to remove barriers and streamline the regulatory process to encourage subsea storage with or without enhanced hydrocarbon recovery and to enable projects to take advantage of any Federal or State incentives.”
Advantages of CO2 Injection
Offshore vs. Onshore?

- May allow surface discharge of produced water.
- Avoids populated areas (minimal NIMBY concerns).
- Minimal issues with surface, pore space, and mineral rights ownership in federal or state waters.
- Avoids issues pertaining to potentially impacting underground sources of drinking water, at a minimum in federal waters.
- Regulatory processes could be more straightforward and expeditious in federal waters (may not be quite the case in state waters)
- E.g., Class VI regulatory requirements are not applicable in federal waters.
## BBA Enhancements to IRC Section 45Q -- Highlights

<table>
<thead>
<tr>
<th>Previous 45Q</th>
<th>Bipartisan Budget Act of 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 million metric ton cap</td>
<td>Eliminates 75 million metric ton cap; applies to new facilities that “break ground” by EOY 2023.</td>
</tr>
<tr>
<td>Credit based on “captured qualified CO₂”</td>
<td>After enactment, credit based on captured “qualified carbon oxide” (CO₂ and other carbon oxides). Allows for the transfer of qualified credits</td>
</tr>
<tr>
<td>$20/metric ton for CO₂ stored and not used for EOR</td>
<td>$50/mt for geologic storage and $35/mt for EOR (each rate phases up over 10-year period from 2017 to 2026). Existing qualified facilities would continue to receive the original inflation adjusted $20 and $10 credit rates.</td>
</tr>
<tr>
<td>$10/metric ton for CO₂ stored and used for EOR</td>
<td></td>
</tr>
<tr>
<td>Available to facility with capture equipment capturing at least 500,000 metric tons CO₂/year.</td>
<td>Capture &gt; 500,000 metric tons CO₂/year for electric generating units; &gt; 100,000 metric tons CO₂/year for other. Credit goes to the <strong>owner of the capture equipment</strong>. Available to “<strong>direct air capture</strong>” and “<strong>beneficial use</strong> (with 25,000 metric ton threshold)”</td>
</tr>
<tr>
<td>Credit available until the 75-million-ton cap is reached.</td>
<td>Credit available for 12 years from the date the carbon capture equipment is placed in service.</td>
</tr>
</tbody>
</table>
On 5/20, IRS issued Request for Comments on 45Q enhancements.

Areas of comment included:
- Establishing “secure geologic storage”
- Leakage after credit award – “recapture”
- Defining “qualifying facilities”
- Defining “commence construction”
- Credit transferability, timing, flexibility
- Allowable structures/partnerships
- 90+ comments received

Some limited guidance recently released; more pending

Key question -- is 45Q, as it stands, enough for the offshore GOM?
Regulatory Oversight of CO₂ Storage in the Federal Offshore -- DOI

- Outer Continental Shelf Lands Act (OCSLA), Dept. of Interior (DOI), Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) have authority to regulate development of mineral resources on the OCS:
  - Authority to permit the use and storage of CO₂ for EOR activities on existing oil and gas leases on the OCS.
  - Authority to permit the storage of CO₂ for certain types of projects; though the authority to issue leases for storage remains unclear.
  - No facilities/operations permitted to date

- BOEM finalized research on Best Management Practices (BMPs) for CO₂ offshore transportation and storage on the OCS
  - We are using some of the as a starting point for our study.
  - Specific categories of offshore issues (potential regulatory gaps) were identified.
Under Section 8(p)(1)(C) of the OCSLA (43 U.S.C. 1337)(p)(1)(C)), BOEM may issue leases, easements, and rights-of-way for activities that:

- “produce or support production, transportation, or transmission of energy from sources other than oil and gas”

In certain circumstances, Section 8(p)(1)(C) allows BOEM to issue leases for sub-seabed CO₂ storage...

- Only for CO₂ generated as a by-product of electricity production from an onshore coal-fired power plant.

In 2010, the Presidential Interagency Task Force on CCS examined the existing U.S. regulatory framework and recommended the development of a comprehensive U.S. framework for leasing and regulating sub-seabed CO₂ storage operations on the OCS

However, this comprehensive framework has yet to be established; therefore, the existing regulatory framework is shared across multiple Federal agencies, and there are several gaps.
Legal and regulatory analysis

Joint GoMCarb and SECARB Offshore meeting -- 26-27 March 2020

Ingvild Ombudstvedt, IOM Law
Approach

- Starting point: previous legal analysis of U.S framework
- Desktop review of recent developments
- Comparison with other legal and regulatory frameworks
- Test findings on SECARB Offshore case studies
- Recommendations
Previous legal analysis

• Storage of Carbon Dioxide in Geologic Structures: A Legal and Regulatory Guide for States and Provinces, 2007

• Interagency Task Force on Carbon Capture and Storage, 2010

• Preliminary evaluation of offshore transport and storage of carbon dioxide, 2013

• Best management practices for offshore transportation and sub-seabed geologic storage of carbon dioxide, 2017

• Overcoming Impediments to Offshore Carbon Dioxide Storage: Legal Issues in the U.S and Canada, 2019
The focus of our analysis

- Prioritized relevant barriers identified in the earlier cited reports
  - Lack of comprehensive legal and regulatory framework
  - Fragmentism
  - Monitoring, reporting, and verification pursuant to subparts RR and UU
  - Liability and long-term stewardship
  - CO$_2$ as hazardous waste
Legal Framework for CCUS
Some of the most relevant instruments

• Outer Continental Shelf Lands Act
  • Oil and Gas Leasing Program

• Coastal Zone Management Act

• Submerged Lands Act

• National Environmental Policy Act

• Safe Drinking Water Act
  • Underwater Injection Control (UIC) Program

• Clean Air Act
  • Greenhouse Gas Reporting Rules
Comparison with International Legal Framework

- The United Nations Convention on the Law of the SEA (UNCLOS)
- The London Convention
- The London Protocol
- OSPAR
Comparison with European Framework

• EU legal framework
  • CCS Directive (2009)
    • Guidance Document 2 (Characterization of the Storage Complex, CO₂ Stream Composition, Monitoring and Corrective Measures)
    • Guidance Document 3 (Criteria for Transfer of Responsibility to the Competent Authority)
    • Guidance Document 4 (Financial Security (Art. 19) and Financial Mechanism (Art. 20))

• Norwegian legal framework
  • Continental Shelf Act (1969)
    • Storage Regulations (2014)
    • Regulations related to safety and working environment in relation to transport and injection of CO₂ on the Norwegian Continental Shelf (2020)
  • Petroleum Act (1996)
    • Petroleum Regulations (1997)
  • Pollution Control Act (1981)
    • Pollution Control Regulations (2004)
      • Guidelines for financial security (2016)
EU liability framework for CO₂ storage at a glance
Other Documents

• EPA Guidance Documents for Class II and Class VI

• IEA Model Regulatory Framework

• ISO TC 265 documents

• European Commission opinions on draft permits for the Netherlands and the United Kingdom

• Norwegian exploitation permit for CO₂ storage (awarded January 2019)
ISO TC265 Carbon Dioxide Capture, Transportation and Geological Storage
General principles of the TC265 standards

- Technology neutrality
  - No patented rights
  - No explicit descriptions of technology or product
  - Fits both onshore and offshore

- Regulatory neutrality
  - Performance-based rather than descriptive
  - No time periods specified
  - No criteria for reporting
  - No criteria for decommissioning
  - No explicit references to, e.g., transfer of liability

- Complements other standards
  - TC265 standards
  - Other ISO standards
  - Specific technical standards from other standardization bodies
ISO standard for CO₂-EOR

• Standard for CO₂-EOR published 31 January 2019

• Provides important tools to
  • assuring containment
  • unlocking access to allowances under e.g. ETS
  • replacing natural with anthropogenic CO₂

• Applies to quantification and documentation of total CO₂ being stored in association with CO₂-EOR

• Contains background data and information about CO₂-EOR globally

• Allows for quantification calculation of natural, anthropogenic and in-situ CO₂
Process for considering recommendations

• Contrast and compare previous work on legal analysis and recommendations
• Compare and contrast with other legal and regulatory frameworks
• Taking new legal and technical developments into consideration
• Taking policy considerations
• Filling gaps using technical international standards
• Reusing known models and mechanisms under US legal framework
• Consultation
Thank you for your attention!
Building the Foundation for Assessing GOM Offshore CO$_2$ EOR and Associated CO$_2$ Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020
**Outline of Presentation**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purpose of the Case Studies</td>
</tr>
<tr>
<td>2</td>
<td>Petronius Offshore Oil Field Case Study</td>
</tr>
<tr>
<td>3</td>
<td>Cognac Offshore Oil Field Case Study</td>
</tr>
<tr>
<td>4</td>
<td>Observations and Findings</td>
</tr>
</tbody>
</table>

_This work was completed under DOE NETL Contract Number DE-FE0025912. This work was performed under MESA Activity 205.002._
The primary purpose of the “Offshore Oil Field Case Studies” is to assess the ability of the NETL CO₂ PROPHET Model to represent the performance of an offshore CO₂ flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.

2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.

3. **Field Development.** Establish the locations of the existing oil/gas production wells producing from the oil reservoir.
4. **History Matching Using Compositional Simulations.** Use GEM compositional simulator to provide a “first-order” history match of fluid production from the oil reservoir.

5. **Assessing CO₂ Flooding Using Compositional Simulation.** With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO₂ EOR project in the oil reservoir using the GEM compositional simulator.

6. **Assessing CO₂ Flooding Using CO₂ PROPHET.** In parallel with the GEM compositional simulator, use the NETL CO₂ PROPHET Model to appraise the performance of a post-primary CO₂ EOR project in the oil reservoir.

7. **Comparing GEM and CO₂ PROPHET Modeling.** Compare the results of GEM and CO₂ PROPHET modeling of CO₂ EOR to determine whether the NETL CO₂ PROPHET model could reasonably represent the performance of the CO₂ flood compared to the more sophisticated GEM compositional simulator.
Petronius Offshore Oil Field Case Study
Petronius Offshore Oil Field Case Study

Background

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico

Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.
The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

Source: Duan, 2013
The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

### Petronius Original Oil Resources, Production and Remaining Reserves

<table>
<thead>
<tr>
<th>Sands</th>
<th>Area (Acres)</th>
<th>Original Oil In-Place (MMB)</th>
<th>Cumulative Oil Production* (MMB)</th>
<th>Remaining Oil Reserves* (MMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Major Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-1</td>
<td>3,438</td>
<td>124.8</td>
<td>69.6</td>
<td>4.0</td>
</tr>
<tr>
<td>▪ J-2</td>
<td>5,288</td>
<td>104.7</td>
<td>52.0</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>2. Minor Sands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-3</td>
<td>1,352</td>
<td>24.5</td>
<td>6.1</td>
<td>1.0</td>
</tr>
<tr>
<td>▪ J-4</td>
<td>1,398</td>
<td>39.2</td>
<td>17.8</td>
<td>0.9</td>
</tr>
<tr>
<td>▪ J-5</td>
<td>389</td>
<td>18.2</td>
<td>7.8</td>
<td>1.5</td>
</tr>
<tr>
<td>▪ Other (13)</td>
<td>-</td>
<td>0.7</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11,865</strong></td>
<td><strong>312.1</strong></td>
<td><strong>153.5</strong></td>
<td><strong>8.7</strong></td>
</tr>
</tbody>
</table>

*As of end of 2016.
Volumetric and Other Reservoir Properties: Petronius J-2 Sand

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Area</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5,288 Acres</td>
</tr>
<tr>
<td>Quarter*</td>
<td>1,290 Acres</td>
</tr>
<tr>
<td>Porosity</td>
<td>30%</td>
</tr>
<tr>
<td>Depth</td>
<td>10,900 to 11,100 ft</td>
</tr>
<tr>
<td>Permeability</td>
<td>398 mD</td>
</tr>
<tr>
<td>Net Pay</td>
<td>16.5 ft</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>31 API</td>
</tr>
<tr>
<td>Swi</td>
<td>0.24</td>
</tr>
<tr>
<td>Boi</td>
<td>1.45</td>
</tr>
<tr>
<td>OOIP</td>
<td>104 MM bbls</td>
</tr>
<tr>
<td>Initial Pressure</td>
<td>5,287 psia</td>
</tr>
<tr>
<td>Pressure Gradient (@ 10,560 ft)</td>
<td>0.5 psi/ft</td>
</tr>
<tr>
<td>Initial Temperature</td>
<td>182 °F</td>
</tr>
</tbody>
</table>

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.

*After including gas cap area.
After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.
Reservoir Model for Petronius J-2 Sand

The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.
Excellent history matched results were obtained for oil production, gas production and water production.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Actual Data</th>
<th>History Matched Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>53 MM bbl</td>
<td>52.4 MM bbl</td>
</tr>
<tr>
<td>Gas</td>
<td>53 Bcf</td>
<td>51.4 Bcf</td>
</tr>
<tr>
<td>Water</td>
<td>28.5 MM bbl</td>
<td>29.4 MM bbl</td>
</tr>
</tbody>
</table>

Source: Advanced Resources International, 2019
An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.
GEM Compositional Modeling of the Performance of the CO$_2$ Flood, Petronius J-2 Sand

**CO$_2$ Flood Design.** Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO$_2$ flood was as follows:

- Drill an updip CO$_2$ injection well on the crest of the fault block.
- Inject continuous CO$_2$ at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO$_2$ flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO$_2$ flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.
In parallel with the GEM compositional simulator, the study modeled the CO₂ flood in the Petronius J-2 Sand using NETL CO₂ PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO₂ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO₂ producer and operate the CO₂ flood using a quarter of a five-spot pattern.
- Inject continuous CO₂ at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO₂ of 365 Bcf, equal to CO₂ injected in the GEM Model.
Comparative Analysis of GEM and CO₂ PROPHET Modeling of CO₂ Flood, J-2 Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.

<table>
<thead>
<tr>
<th></th>
<th>CO₂ Flood Performance GEM Compositional Simulator</th>
<th>CO₂ Flood Performance CO₂ PROPHET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP of 0.75</td>
<td>DP of 0.5</td>
</tr>
<tr>
<td>OOIP (million Barrels)</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>CO₂ Injection (Bcf)</td>
<td>365</td>
<td>365</td>
</tr>
<tr>
<td>CO₂ Production (Bcf)</td>
<td>226</td>
<td>238</td>
</tr>
<tr>
<td>CO₂ Storage (Bcf)</td>
<td>139</td>
<td>127</td>
</tr>
<tr>
<td>Cumulative Oil Recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(million barrels)</td>
<td>14.3</td>
<td>10.8</td>
</tr>
<tr>
<td>% of OOIP</td>
<td>13.5%</td>
<td>10.2%</td>
</tr>
<tr>
<td>CO₂/Oil Ratio (Mcf/B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td>25.5</td>
<td>33.8</td>
</tr>
<tr>
<td>Net</td>
<td>9.7</td>
<td>11.8</td>
</tr>
</tbody>
</table>

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.
Cognac Offshore Oil Field Case Study
Background

The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Location of Cognac Oil Field, Eastern Gulf of Mexico

Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.
Cognac J Sand/NE Fault Block Geologic Model

The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.
Cognac J Sand

The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

### Cognac Original Oil Resources, Production and Remaining Reserves

<table>
<thead>
<tr>
<th>Sands</th>
<th>Oil Area (Acres)</th>
<th>Original Oil In-Place* (MMB)</th>
<th>Cumulative Oil Production** (MMB)</th>
<th>Remaining Oil Reserves (MMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Major Sands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ I</td>
<td>3,560</td>
<td>191.5</td>
<td>91.7</td>
<td>0.1</td>
</tr>
<tr>
<td>▪ J</td>
<td>2,240</td>
<td>135.6</td>
<td>56.9</td>
<td>0.3</td>
</tr>
<tr>
<td>2. Minor Sands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ J-1</td>
<td>1,740</td>
<td>23.3</td>
<td>6.6</td>
<td>***</td>
</tr>
<tr>
<td>▪ Others</td>
<td>n/a</td>
<td>n/a</td>
<td>16.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Total</td>
<td>7,540</td>
<td>350.4</td>
<td>171.2</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*Volumetrically adjusted by Advanced Resources Int'l., **As of end of 2016. ***Less than 0.05 MMB.
Volumetric and Other Reservoir Properties
Cognac J Sand/NE Fault Block

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessible Oil Area</td>
<td>384 Acres</td>
</tr>
<tr>
<td>Porosity</td>
<td>32%</td>
</tr>
<tr>
<td>Permeability</td>
<td>794 mD</td>
</tr>
<tr>
<td>Net Pay</td>
<td>42 ft</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>34.6 API</td>
</tr>
<tr>
<td>Soi</td>
<td>0.73</td>
</tr>
<tr>
<td>Sor</td>
<td>0.45</td>
</tr>
<tr>
<td>Boi</td>
<td>1.21</td>
</tr>
<tr>
<td>OOIP</td>
<td>24.2 MMbbls</td>
</tr>
<tr>
<td>Initial Pressure (@ 8,297 ft)</td>
<td>4,412 psia</td>
</tr>
<tr>
<td>Initial Reservoir Temperature</td>
<td>130 °F</td>
</tr>
</tbody>
</table>

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.
As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.
The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.
History Match of Fluid Production, Cognac J Sand, NE Fault Block

- Cumulative oil prd. Modeled: 9.2 MMbbl, Reported: 9.2 MMbbl
- Cumulative gas prd. Modeled: 4.2 Bcf, Reported: 4.1 Bcf
- Cumulative water prd. Modeled: 2.7 MMbbl, Reported: 2.8 MMbbl
History Match of Fluid Production, Cognac J Sand, NE Fault Block

An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.
CO₂ Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO₂ flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO₂ breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO₂ flood.
In parallel with the GEM compositional simulator, the study modeled the CO$_2$ flood in the Cognac J Sand, NE Fault Block, using NETL CO$_2$ PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block’s J Sand were modeled (with CO$_2$ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO$_2$ producer and operate the CO$_2$ flood in a two well line drive configuration.
- Inject continuous CO$_2$ at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO$_2$ of 88 Bcf equal to CO$_2$ injected in the GEM Model (a HCPV of 1.2).
The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

<table>
<thead>
<tr>
<th>CO₂ Flood Performance</th>
<th>CO₂ Flood Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM Compositional</td>
<td>CO₂ PROPHET</td>
</tr>
<tr>
<td>Simulator</td>
<td>DP of 0.75</td>
</tr>
<tr>
<td>DP of 0.5</td>
<td></td>
</tr>
<tr>
<td>OOIP (million Barrels)</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>24.4</td>
</tr>
<tr>
<td></td>
<td>24.2</td>
</tr>
<tr>
<td>CO₂ Injection (Bcf)</td>
<td>89.5</td>
</tr>
<tr>
<td></td>
<td>87.7</td>
</tr>
<tr>
<td></td>
<td>87.7</td>
</tr>
<tr>
<td>CO₂ Production (Bcf)</td>
<td>52.3</td>
</tr>
<tr>
<td></td>
<td>55.7</td>
</tr>
<tr>
<td></td>
<td>45.3</td>
</tr>
<tr>
<td>CO₂ Storage (Bcf)</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>32.0</td>
</tr>
<tr>
<td></td>
<td>42.4</td>
</tr>
<tr>
<td>Cumulative Oil Recovery</td>
<td></td>
</tr>
<tr>
<td>(million barrels)</td>
<td>8.18</td>
</tr>
<tr>
<td></td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>8.67</td>
</tr>
<tr>
<td>% of OOIP</td>
<td>33.8%</td>
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The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.
Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.

- By defining the location and status of existing production and injection wells, reasonable spacing and CO₂ flooding designs can be established for offshore oil fields.

- Miscible CO₂ EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO₂.

- The NETL CO₂ PROPHET Model can provide realistic estimates of oil recovery and CO₂ storage in offshore oil reservoirs.
RISK ASSESSMENT GAS HYDRATES

CAMELIA KNAPP, JIM KNAPP, GOKCE ASTEKIN, SAIFUL ALAM
Boone Pickens School of Geology
Oklahoma State University
Task 4.0
Task 4.0

• Risk Assessment, Simulation, and Modeling. Going beyond the traditional NRAP process, this Task encompasses activities related to the refinement and adaption of existing data mining, analysis, and machine learning tools (SAS Viya decision system; Subtask 3.2), simulation tools, geologic models, and risk assessment and mitigation strategies for site-specific assessments of storage prospects in the offshore environment. To aid in a formalized process for characterizing prospects with high potential for commercial CO2 storage development, supported, to the extent possible and practical, by the SAS Viya platform, the project team will perform a robust characterization of risk, geologic, technical risk, operational risk, and commercial risk related to the full, integrated system (source, transport, and storage/utilization). Results will be used to highlight possible physical regulatory and/or commercial barriers, and mechanisms to overcome those barriers. This activity is directly dependent on the outcome of Task 3.0, namely the defined characteristics of representative storage opportunities.

• Subtask 4.3.2: Seismic Hazard Assessment and Earthquake Risk Analysis. Perform seismic hazard assessment and earthquake risk analysis in the study area, assess the evolution of gas hydrate-bearing systems and their temporal and spatial response to natural perturbations, based on lessons learned from the active Woolsey Mound cold seep at Mississippi Canyon 118.
Woolsey Mound - CSHS

- 900 m WD on the N continental slope of the GOM.
- Slope highly discontinuous, intersected by slumping, folding and faulting mainly driven by salt tectonics and sediment load delivered by the Mississippi River.
- Deepwater Horizon rig, Mississippi Canyon 252, April 22, 2010.
Woolsey Mound Hydrates

- Do not exhibit the classic regional BSRs on seismic sections.
- Seem to form around salt-related faults that provide likely migration pathways for the thermogenic hydrocarbons.
- Other methods need to be implemented in order to detect them and provide estimates of their volumetric extent.

MC 118, (Lutken et al., 2011)
Woolsey Mound: Fault-Controlled, Transient, Thermogenic Hydrate System

- Mid-slope of GOM
- Salt tectonically driven cold seep
- Gas venting at the seafloor
- Outcropping hydrate chemosynthetic communities, carbonate mounds, and bubble plumes
- Chemosynthetic communities
- Relatively shallow water depth (<1000 m).

Macelloni et al., 2012
Hypotheses

- GH are genetically related to the salt system through active normal faults, conduits for thermogenic gas.
- GH formation and dissociation vary temporally in the vicinity of active faults, and can temporarily seal them as conduits for thermogenic fluids.
- GH at WM are controlled by a highly heterogeneous stability field leading to the general paucity of BSRs.
- AVO analysis is a good indicator of hydrates in the absence of well defined BSRs.
- Apparent temporal changes in seismic images of the subsurface are correlated with periodic fluid expulsion and hydrate dissociation.

Macelloni et al., 2012
Available Data

Standard 3-D data from TGS-Nopec, acquired in 2000; time domain data; 3 s TWTT
Standard 3-D data from Western Geco, acquired in 2003; time domain data; 10 s TWTT
Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2010; time and depth domain data; 10.4 s TWTT, 18 km depth
Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2014; time and depth domain data; 10.4 s TWTT, 18 km depth
Single-channel 2D AUV-borne Chirp Sub-bottom Profiler data, acquired in 2005;
Single-channel pseudo 3D Surface Source Deep Receiver data (SSDR), acquired in 2006.
4-D SEISMIC ANALYSIS

4-D PROCESSING SEQUENCE
(cross-equalization):
- re-sampling
- 3D geometry re-binning
- phase matching
- shaping filter
- gain x-normalization
- residual amplitude map

Time-lapse seismic monitoring involves comparing the results of 3-D seismic surveys repeated at considerable time intervals: time is the fourth dimension.
4-D seismic anomalies (time slices near the BHSZ)

Subsurface Structures (time slices near the BHSZ)

*Simonetti et al., 2015*
Inline 4365- Seismic Anomalies

- Hydrate mound
- Blanked zone
- Bright Spot
- BSR

DOE NETL SECARB Offshore Meeting, March 26-27, 2020
Crossline 9053 – Seismic Anomalies

Hydrate mound

BSR
Inline 4427 – Seismic Anomalies

Hydrate mound

Blanked zone

BSR

Bright Spot
Base of the Hydrate Layer 1 - Inline 4365

a) Variation of Reflected Amplitude with offset

b) AVO Crossplot of data- Gradient vs Intercept
Free Gas Saturated Layer 1 - Inline 4365

a) Variation of Reflected Amplitude with offset

b) AVO Crossplot of data - Gradient vs Intercept

Seafloor

Free Gas
Base of the Hydrate Layer 2 - Inline 4427

a) Variation of Reflected Amplitude with offset

b) AVO Crossplot of data- Gradient vs Intercept
Gradient vs Intercept Crossplots

Yellow cluster: Hydrate/Free Gas
Located in Quadrant 2

Red cluster: Free Gas
Located in Quadrant 3

Green cluster: Wet Sands
Follows Background Trend
Defined Zones for AVO

Zones of colors represent:
- **Red Zone**: Hydrated sediments
- **Green Zone**: Wet sands
- **Blue Zone**: Gas sands
4-D SEISMIC – RESULTS

Variance slice

Residual amplitude slice

Residual amplitude slice
4-D SEISMIC – FUTURE WORK

- Apply 4-D processing sequence on Declaration 2014 data.
- Investigate the time-lapse changes that occur between year 2000 and 2014.
- Build a 4-D model that shows Gas Hydrate destabilization in Woolsey Mound between year 2000 and 2014.
Summary

- The hydrate stability field is highly fluctuating through time and space at Woolsey Mound.
- 4-D seismic anomalies are spatially associated with faults and may represent changes in the subsurface pore-fluid content.
- AVO analysis proves to be a reliable tool to identify hydrates in the absence of clearly defined BSRs.
- Results will provide fundamental numerical parameters of the development and evolution of a gas hydrate-bearing system and its response to natural perturbations over a time window comparable to human scale processes (14 years).
Acknowledgements

- Southern States Energy Board (SSEB)
- U.S. Department of Energy (NETL)
- Gulf of Mexico Gas Hydrate Research Consortium
- Geophysical Exploration/ Tectonics and Geophysics Labs
- TGS-Nopec; WesternGeco
- Bureau of Ocean Energy Management (BOEM)
- Seismic Micro-Technology, Landmark Graphics, Veritas Hampson-Russell, Schlumberger- Petrel
SECARB Offshore Partnership
Project Number: DE-FE0031557

SALT STRUCTURES, SHELF, AND DEEP-WATER RESERVOIRS, CENTRAL GOM

Jack Pashin, Ali Al-Janabi, Seyi Sholanke, and Justin Spears
Oklahoma State University

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory. Cost share and research support are provided by the Project Partners and an Advisory Committee.

GOMCarb-SECARB Offshore Partnership Web Meeting
March 26-27, 2020
**Opening Questions**

• How do storage and enhanced recovery strategies differ between shelf and continental slope settings?

• What are the critical depositional and tectonic factors that need to be understood when developing storage strategies in salt tectonic settings?

• In what ways can depositional and structural architecture be used to evaluate geologic storage security?

• What does a decision support system look like that integrates geology, engineering, and infrastructure?
Objectives

• Geological Characterization (Stratigraphy, sedimentation, structure, hydrodynamic analysis).

• Analyze reservoir properties, storage volumetrics, potential storage mechanisms, migration pathways, and reservoir integrity.

• Understand pressure regime and implications for geologic CO₂ storage and enhanced recovery.

• Design heuristic decision support system using SAS Viya software.
SECARB Offshore Project Area

Focus areas

U.S. Bureau of Ocean Energy Management
Gulf of Mexico Deepwater Bathymetry Grid

*BOEM grid limited to colored extent
Shelf-Slope Transect

Sanford et al., 2016
Shelf Extension – Oligocene-Miocene Vicksburg Detachment, South Texas

Diegel et al., 1995
Sand-Box Model – Listric Fault, Rollover Fold, and Keystone Graben

McClay, 1990
Seismic Interpretation: Louisiana Shelf

Gas anomalies
Seismic Interpretation: Louisiana Shelf

South

North

TWT (s)

Gas anomalies
Seismic mapping

Amplitude, 3.0 s

Folds revealed

Coherency, 2.5 s

Faults revealed
Fault Modeling

Mappable faults

Regional faults

Counterregional faults
**Turbidite Systems**

1. Spillover lobes, lateral channel migration

2. Scouring and megaflute formation, channel aggradation

Keathley Canyon bathymetry

Channels, fan lobes

Minibasin

Source: BOEM
Seismic Interpretation: Submarine Channel Complexes, Mensa Region
Deep-Water Salt Tectonics

Allochthonous salt sheet with diapirs

Minibasin

Hudec et al., 2009
Salt Tectonics

Salt body geometry

Hudec and Jackson (2007)
Seismic Interpretation: Ramp-Flat Weld, Allochthonous Salt

North

South

TWT (s)

Half graben

Withdrawal basin

Salt

Chaotic zone

Rollover structure

Poor imaging
Seismic Interpretation: Ursa Structure

Graben
Horst
Salt
Ursa minibasin
Seismic Interpretation: Mars Minibasin Complex

- Angular unconformity
- Gas anomaly
- Salt
- Growth
- Pre-growth
- Salt
- Bucket weld
- Angular discordances

North

South
Reservoir Pressure Envelope

- Lithostatic gradient
- Normal hydrostatic gradient

Meckel (2010), Offshore Texas Miocene
Rock Strength (Cenozoic Strata)

Unconfined compressive stress

Mohr failure analysis

Sealing mudrock
Reservoir sandstone

Meng et al., in press
Fault Seal Analysis

Juxtaposition diagram

Meng et al., 2020

Block model

No scale intended
Heuristic Decision Support System Design

- **Geologic Information**
  - Reservoir location, dimensions
  - Rock type
  - Depth
  - Reservoir thickness
  - Structural and depositional geometry
  - Trap type

- **Reservoir properties**
  - Porosity
  - Permeability
  - Fluid composition and properties
  - Pressure
  - Storage resource

- **EOR/EGR information**
  - API gravity
  - Gas-oil ratio
  - Resource/reserve volumes
  - Production volumes
  - Production history
  - Drive type
  - Production systems

- **Considerations**
  - Quantified factors
  - Ranked factors
  - Infrastructure
  - Fluid transport options

- **What are your objectives?**
  - Saline formation storage
  - Depleted reservoir storage
  - Enhanced oil recovery
  - Pressure maintenance
Observations

• Shelf has multiple storage/enhanced recovery options; slope focus on EOR
• Shelf potential principally in fluvial-deltaic, shelf sand, slope potential in turbidites.
• Faulting central consideration on shelf; bright spots show sealing potential.
• Slope presents broad range of subsalt, salt flank, and suprasalt options.
• Pressure envelope can be limiting; pressure depletion increases options in shelf.
• Mudrock weaker than sand, although sand consolidation variable.
• Fault seal analysis critical in many settings; structural position important.
• Data well suited for heuristic decision support system; many variables required for proper decision support; operation is context sensitive.
SECARB Offshore Gulf of Mexico Project: Well Integrity Analysis

SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting
March 26 – 27, 2020

William Garnes, Laura Keister, Andrew Duguid
Battelle. Energy Division
Presentation Outline

Project Overview

- Study Area
- Initial Focus Areas

Methodology Development

- Required Data
- Data Collection
- Data Management

Next Steps

- Filling Data Holes
- Risk Assessment
Project Overview
## Gulf Study Area

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Oil and Gas Fields
Deep Saline
Initial Focus Areas

- Initial focus is on the Mobile and Viosca Knoll areas of the Gulf of Mexico.
- These areas were chosen to develop a methodology for collecting and analyzing data required for well integrity analyses.
- Once this methodology is established it can be used throughout the rest of the study area.

Required Data

- Data requirements for a well integrity analysis were established.
- Geologic data
  - Reservoir formations
  - Reservoir characteristics (depth, porosity, permeability)
  - Presence of caprock
- Well ID and Location Data
  - Well API numbers
  - Geographic location of wells
  - Longitude and latitude
- Wellbore data
  - Well construction (age, depth, borehole diameter, casing, cement, BOP, etc.)
  - Well status (producing, abandoned, cement plugs, plug depths)
  - Well history (workovers, well corrosion, blowouts)
Data Collection

• Geologic data collection
  • Developing a generic geologic stratigraphy in the initial focus areas is being completed by project partners at Oklahoma State University.

• Well location and construction data
  • Provided by the Bureau of Safety and Environmental Enforcement (BSEE).

• Data types and formats
  • Completion reports, drilling permits, operations reports, geophysical logs, etc.
  • Excel files, PDF files, and image files.
Data Collection

- General Well Data
  - API number, long./lat., depth, age, and status data provided by BSEE in an excel file.
- Well construction data
  - Casing, cementing, BOPs, and workover history data was provided in PDF and image files.
- Additional Data Request
  - FOIA request was sent to BSEE to see if any additional well construction data is available in an excel file.
Data Management

- Excel file well data provided by BSEE was organized by API number.

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Data Management

- Image and PDF files
  - Indexed by well API number and document type.
- Total files
  - Mobile: 7,575
  - Viosca Knoll: 23,443

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Next Steps
Filling Data Holes

- Data holes
  - Missing data needs to be added.
  - Additional digitized well construction data to be added to the database when it is received from BSEE.
  - Referencing file indices and analyzing PDF and image files to find missing information and fill in the data gaps.

<table>
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<th>Spud Date</th>
<th>BH Total MD</th>
<th>TVD</th>
<th>TD Date</th>
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Risk Assessment

- Risk = Likelihood * Impact
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Best Practices: Recent Activities

- Offshore Best Practices for CO₂ Storage & Transportation
  - SSEB and the Interstate Oil and Gas Compact Commission (IOGCC) convened an Offshore Task Force that reviewed laws and regulations for CO₂ capture and storage (2012)
  - Texas BEG prepared a report for BOEM on best management practices for offshore transportation and sub-seabed geologic storage of CO₂ (2017)
  - SSEB prepared a SOSRA T6.1 report that compared DOE/NELT onshore best practices with the BOEM best management practices for offshore CO₂ transportation and storage (2019)
**DOE/NETL and BOEM Best Practices Comparison**

*Project Management BPM not part of DOE/NETL 2017 update; Under review at SSEB (2020)*

<table>
<thead>
<tr>
<th>DOE/NETL — Best Practices Manuals (BPMs)</th>
<th>BOEM — Best Management Practices (BMPs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP-A SITE SCREENING, SELECTION &amp; CHARACTERIZATION</td>
<td>ST-1 SITE SELECTION &amp; CHARACTERIZATION</td>
</tr>
<tr>
<td>BP-B MONITORING, VERIFICATION &amp; ACCOUNTING</td>
<td>ST-4 MONITORING</td>
</tr>
<tr>
<td>BP-C RISK MANAGEMENT AND SIMULATION</td>
<td>ST-2 RISK ASSESSMENT</td>
</tr>
<tr>
<td>BP-D PUBLIC OUTREACH AND EDUCATION</td>
<td>ST-5 MITIGATION</td>
</tr>
<tr>
<td>BP-E OPERATIONS</td>
<td>ST-6 INSPECTION AND PERFORMANCE ASSESSMENT</td>
</tr>
<tr>
<td>BP-F PROJECT MANAGEMENT*</td>
<td>ST-3 PROJECT MANAGEMENT &amp; EXECUTION</td>
</tr>
<tr>
<td></td>
<td>ST-7 REPORTING REQUIREMENTS</td>
</tr>
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<td></td>
<td>ST-8 EMERGENCY RESPONSE AND CONTINGENCY</td>
</tr>
<tr>
<td></td>
<td>ST-9 DECOMMISSIONING &amp; SITE CLOSURE</td>
</tr>
</tbody>
</table>

*ST-? NO PUBLIC OUTREACH ST*
SECARB Offshore Planned Activities

• SECARB Offshore (BP1) Action Plan to Expand Available and Leading Practices Explicitly Applicable to the Gulf of Mexico (Mar 2020)
  – Create an action plan to advance offshore practices, based upon SOSRA 6.2 and BOEM work completed
  – Include existing infrastructure, logistical & regulatory obstacles, and decommissioning requirements

• SECARB Offshore (BP2) Final Report (Mar 2023)
  – Incorporate available and leading practices into a final report on “Assessment of Legal and Regulatory Frameworks”
### SECARB Offshore Planned Activities

#### INVENTORY OF AVAILABLE PRACTICES: CONCEPTUAL DESIGN

<table>
<thead>
<tr>
<th>INFRASTRUCTURE COMPONENTS</th>
<th>CHARACTERIZATION</th>
<th>RISK</th>
<th>MONITORING (Atmospheric, Aqueous, Geological, Social, Economic)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SITE SELECTION</td>
<td>INITIAL SITE EVALUATION</td>
<td>DETAILED SITE EVALUATION</td>
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<tr>
<td>Landside Connections</td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
</tr>
<tr>
<td>CO₂ Transport &amp; Corridors</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
</tr>
<tr>
<td>Platforms &amp; Sea Floor Connections</td>
<td>C7</td>
<td>C8</td>
<td>C9</td>
</tr>
<tr>
<td>Well Bores &amp; Wells</td>
<td>C10</td>
<td>C11</td>
<td>C12</td>
</tr>
<tr>
<td>Geological Seals &amp; Barriers</td>
<td>C13</td>
<td>C14</td>
<td>C15</td>
</tr>
<tr>
<td>CO₂ Storage &amp; Utilization Formations</td>
<td>C16</td>
<td>C17</td>
<td>C18</td>
</tr>
</tbody>
</table>

#### OUTREACH
- Integrate Public Outreach with Project Management
- Conduct and Apply Social Characterization
- Develop Outreach Materials Tailored to the Audiences

- Identify Outreach Goals with Project Management
- Establish an Outreach Program
- Implement and Manage the Outreach Program Needed

- Identify Key Stakeholders
- Develop Key Messages
- Assess the Performance of the Outreach Program

---

C16
## SECARB Offshore Planned Activities

### Inventory Of Available Practices – C16 CO₂ Storage and Utilization Formations

<table>
<thead>
<tr>
<th>Phase</th>
<th>Onshore Action</th>
<th>Available Practices</th>
<th>Comparison to Offshore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Identify storage reservoirs and injection zones within Selected Areas. Develop stratigraphic and structural framework diagrams that illustrate suitable storage reservoirs and injection zones of interest, using all available well and outcrop data.</td>
<td>No difference</td>
</tr>
<tr>
<td></td>
<td>Storage Reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Analyze confining zones in Selected Areas. Create stratigraphic and structural framework diagrams to illustrate areal extent, thickness, lithology, porosity, permeability, capillary pressure, and structural complexity of suitable confining zones, based on existing data.</td>
<td>No difference</td>
</tr>
<tr>
<td></td>
<td>Confining Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Establish baseline geomechanical characteristics of targeted injection and confining zones.</td>
<td>No difference</td>
</tr>
<tr>
<td></td>
<td>Trapping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Evaluate trapping mechanisms for Selected Areas using available well, outcrop, and seismic data.</td>
<td>No difference</td>
</tr>
<tr>
<td></td>
<td>Mechanism</td>
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</tr>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Establish hydrogeological characteristics of injection and confining zones to assure reliable containment of injected CO₂.</td>
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</tr>
<tr>
<td></td>
<td>Potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection</td>
<td>Subsurface Geological Data Analysis</td>
<td>- Perform initial estimate of injectivity of candidate injection zones in Selected Areas, using available production history data, hydrologic test data, and analyses of core plugs.</td>
<td>No difference</td>
</tr>
<tr>
<td></td>
<td>Injectivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection</td>
<td>Model development - Modeling parameters</td>
<td>Identify types of models and modeling parameters needed to characterize the storage reservoir, confining zone, and fluid properties for Selected Areas.</td>
<td>No difference</td>
</tr>
<tr>
<td>Site selection</td>
<td>Model development - Data Requirements and cost</td>
<td>Identify data requirements to optimize modeling results; conduct cost vs. benefit analysis to determine value of acquiring new data.</td>
<td>Data acquisition costs offshore tend to be significantly higher; data tends to be lower density due to higher cost</td>
</tr>
<tr>
<td>Site selection</td>
<td>Model development - Boundary conditions/uncertainty</td>
<td>Identify and characterize uncertainties in modeling results; select boundary conditions which minimize uncertainties in modeling results.</td>
<td>No difference</td>
</tr>
<tr>
<td>Site selection</td>
<td>Model development - Existing seismic data</td>
<td>If available, integrate existing seismic data in development of static and dynamic models for Selected Areas.</td>
<td>Offshore seismic data tends to be easier to work with due to no need for topographic corrections and easier avoidance of obstacles.</td>
</tr>
</tbody>
</table>
### SECARB Offshore Planned Activities

**Matrix of Leading Practices: Conceptual Design**

<table>
<thead>
<tr>
<th>INFRASTRUCTURE COMPONENTS</th>
<th>CHARACTERIZATION</th>
<th>RISK</th>
<th>MONITORING</th>
</tr>
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<tbody>
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<td>SITE SELECTION</td>
<td>DEVELOPMENT</td>
<td>OPERATIONS</td>
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<td>Landside Connections</td>
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<tr>
<td>CO2 Transport &amp; Corridors</td>
<td>C2</td>
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<td>M2</td>
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<td>Platforms &amp; Sea Floor Connections</td>
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<td>Well Bores &amp; Wells</td>
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<td>CO2 Storage &amp; Utilization Formations</td>
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**Outreach and Education**

- **Onshore to Offshore Relationship**
  - Very little to no difference
  - Small differences
  - Major differences
  - Not contemplated in Onshore
Challenges for Offshore

• Regulation
  – Regulation needed for offshore development
    • Bureau of Ocean Energy Management
    • Bureau of Safety and Environment Enforcement
      – Pore Space availability
      – Long term Liability
      – Monitoring requirements
    – Under the Outer Continental Shelf Lands Act (OCSLA) only CO₂ from coal fired power plants is allowed
    – Under the Marine Protection, Research, and Sanctuaries Act (MPRSA) CO₂ is considered a waste and prohibited from disposal offshore

• Timing
  – Limited window under existing 45Q
    • Commence Construction date of 12/31/2023
    • 6-year window to complete construction

• Economics
  – Higher costs to operate offshore
  – Current low oil prices
  – Economics of Storage after 45Q – only 12-year credit
THANK YOU!