



# Establishing CO<sub>2</sub> Utilization, Storage and Pipeline Systems for the Eastern Gulf of Mexico

Prepared for:

**Southeast Offshore Storage Resource Assessment (SOSRA)**

U.S. Department of Energy | National Energy Technology Laboratory

Project Number: DE-FE0026086

Prepared By:

**Vello A. Kuuskraa**, President

**Advanced Resources International, Inc.**

Atlanta, GA

March 8, 2017

# Establishing CO<sub>2</sub> Utilization, Storage and Pipeline Systems for the Eastern Gulf of Mexico

---

**As part of our scope of work, Advanced Resources conducted a pre-feasibility study of the volumes of CO<sub>2</sub> that could be utilized and stored in offshore Eastern Gulf of Mexico Federal waters oil fields as part of CO<sub>2</sub> enhanced oil recovery.**

We then used the CO<sub>2</sub> utilization and storage data to establish two CO<sub>2</sub> pipeline systems (one for the shallow water and one for the deep water) in the Eastern Gulf of Mexico that would deliver CO<sub>2</sub> from onshore to oil fields for use by CO<sub>2</sub>-EOR.

- The study established the location of the technically viable oil fields, including the volumes of CO<sub>2</sub> expected use and storage and the oil recovery potential for each oil field.
- A preliminary CO<sub>2</sub> pipeline system was specified and costed for delivering CO<sub>2</sub> to these offshore oil fields.

# **Eastern GOM Shallow Water CO<sub>2</sub> Pipeline System for Utilization and Storage of CO<sub>2</sub>**

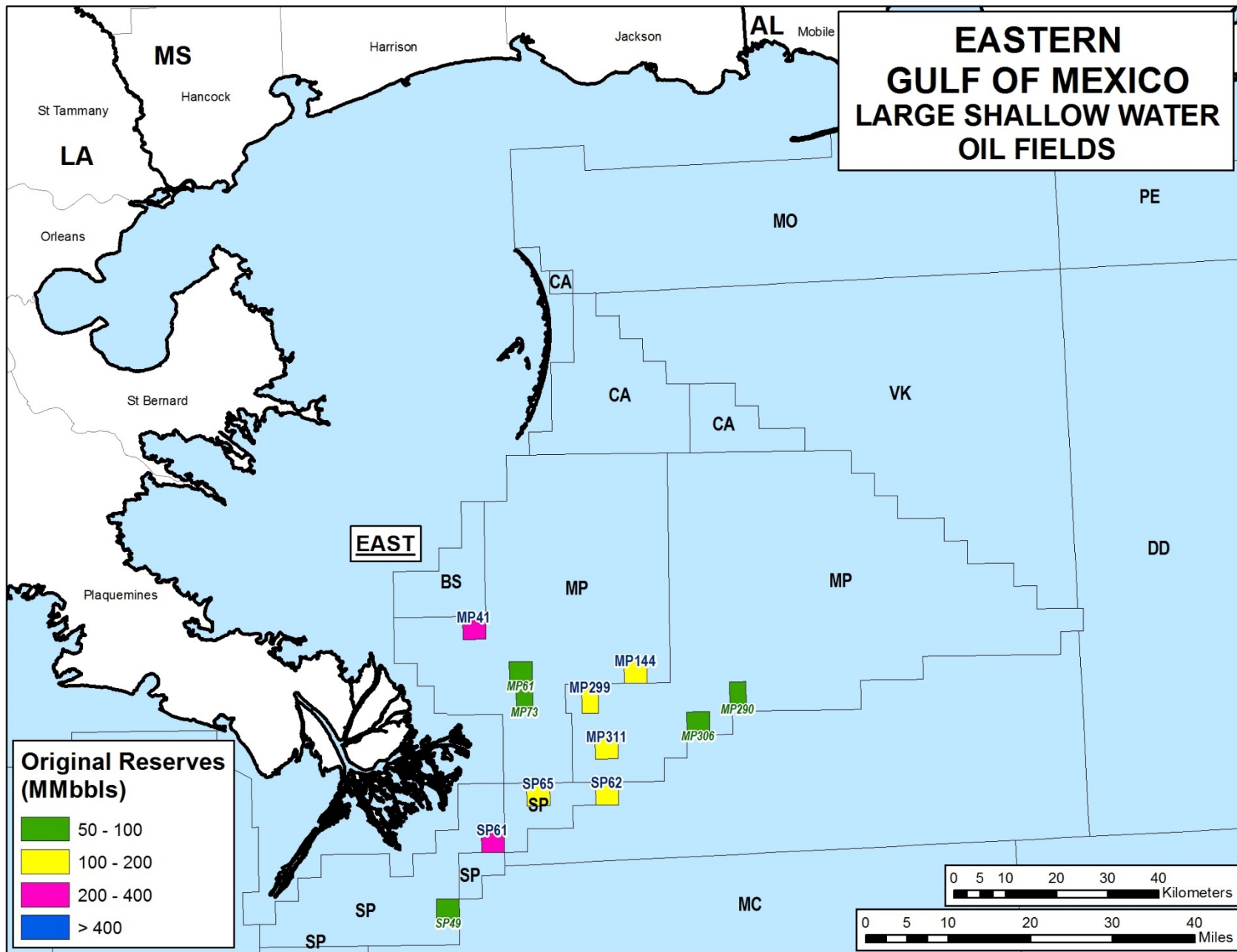
# Pipeline System for Delivering CO<sub>2</sub> to Eastern GOM Shallow Water Oil Fields

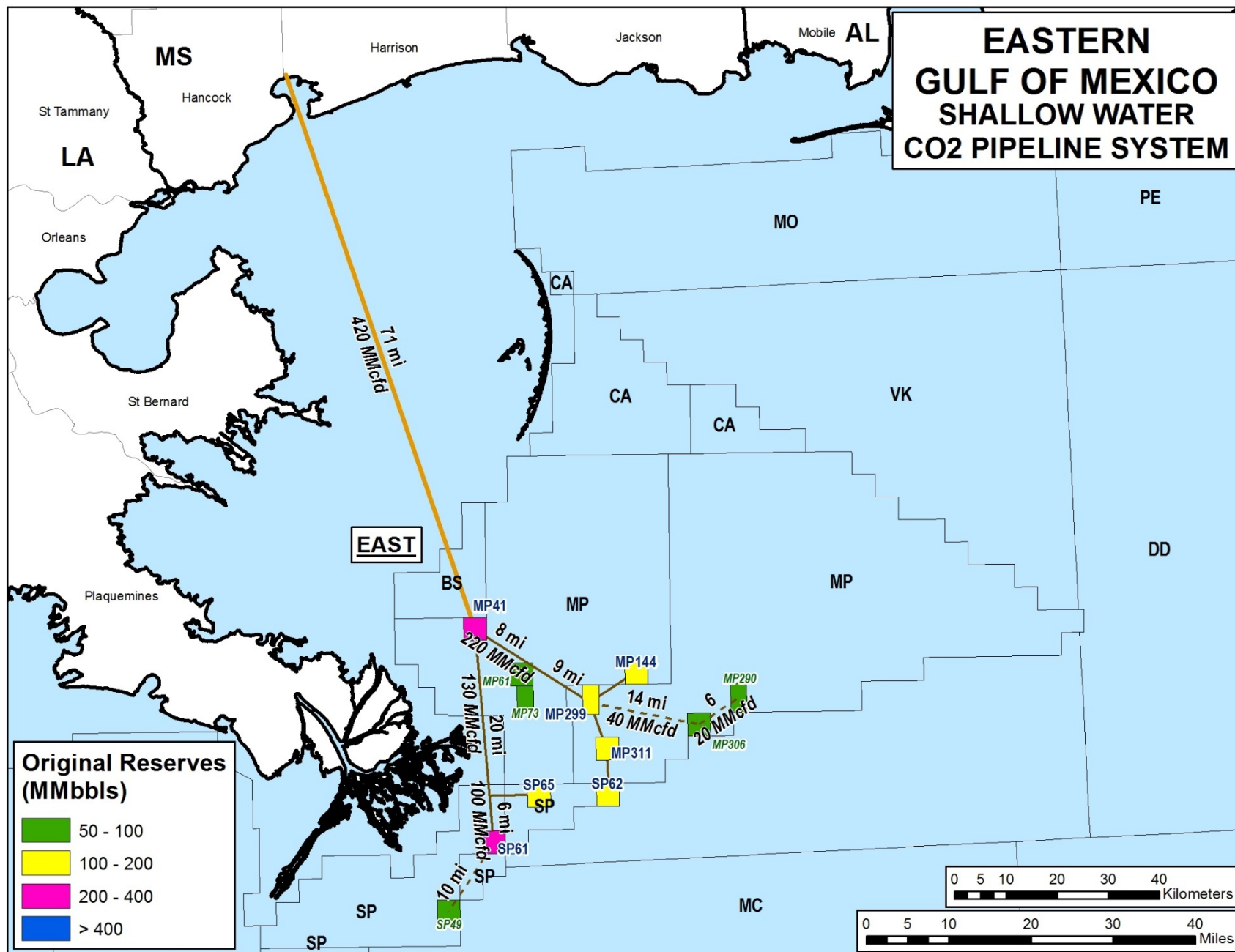
---

**We assembled data on the largest 12 shallow water GOM oil fields (each with original oil reserves of 50 million barrels or more) in the Federal waters of the Eastern Gulf of Mexico.**

For the initial CO<sub>2</sub> pipeline design, we plotted the location of each of the 12 shallow water oil fields. We then estimated the oil recovery potential and CO<sub>2</sub> injection requirements for each oil field for CO<sub>2</sub> enhanced oil recovery.

Then, we established an offshore pipeline system that would optimally connect these 12 shallow water oil fields with CO<sub>2</sub> supply delivered from an onshore location.





# Eastern GOM Shallow Water CO<sub>2</sub> Pipeline System

**The Eastern Gulf of Mexico CO<sub>2</sub> pipeline system would deliver 6,110 Bcf of CO<sub>2</sub> (equal to 323 million metric tons of CO<sub>2</sub>) for utilization and storage with CO<sub>2</sub>-EOR.**

## Eastern GOM Shallow Water CO<sub>2</sub> Pipeline System

No. of Fields	CO <sub>2</sub> -EOR Oil Recovery	Total CO <sub>2</sub> Requirements		CO <sub>2</sub> Flow Requirements	
(#)	(MMB)	(Bcf)	(MMmt)	(MMcfd)	(MMt/yr)
12	610	6,110	323	420	8.1

- The flow requirements, over 40 years of operation, are 420 million cubic feet per day, equal to 8.1 million metric tons per year.
- The oil recovery potential from these 12 oil fields using CO<sub>2</sub>-EOR is 610 million barrels.

# Eastern GOM Shallow Water CO<sub>2</sub> Pipeline Investment Costs

Our prefeasibility estimate of installing the Eastern Shallow Water GOM CO<sub>2</sub> Pipeline System is about \$1.2 billion. This estimate is based on 2,412 inch-miles of pipeline with capital costs of \$500,000 per inch-mile.

## Eastern GOM Shallow Water CO<sub>2</sub> Pipeline System

Pipeline Segment	CO <sub>2</sub> (MMcfd)	Length (mi)	Diameter (in)	Pipeline (in-mi)	Water Depth (ft)	Pipeline Costs (\$MM)	End Field
1	420	71	20	1,420	43		MP41
2	220	8	16	128	220		MP61/MP73
3	190	9	16	144	209		MP299
4	70	6	10	60	253		MP311
5	40	6	8	48	336		SP62
6	40	7	8	56	213		MP144
7	40	14	8	112	247		MP306
8	20	6	6	36	339		MP290
9	130	20	12	240	295		X
10	100	6	12	72	220		SP61
11	40	6	8	48	295		SP65
12	20	10	6	60	354		SP49
<b>Total</b>				<b>2,424</b>		<b>1,212</b>	

2/2/2017



# **Eastern GOM Deepwater CO<sub>2</sub> Pipeline System for Utilization and Storage of CO<sub>2</sub>**

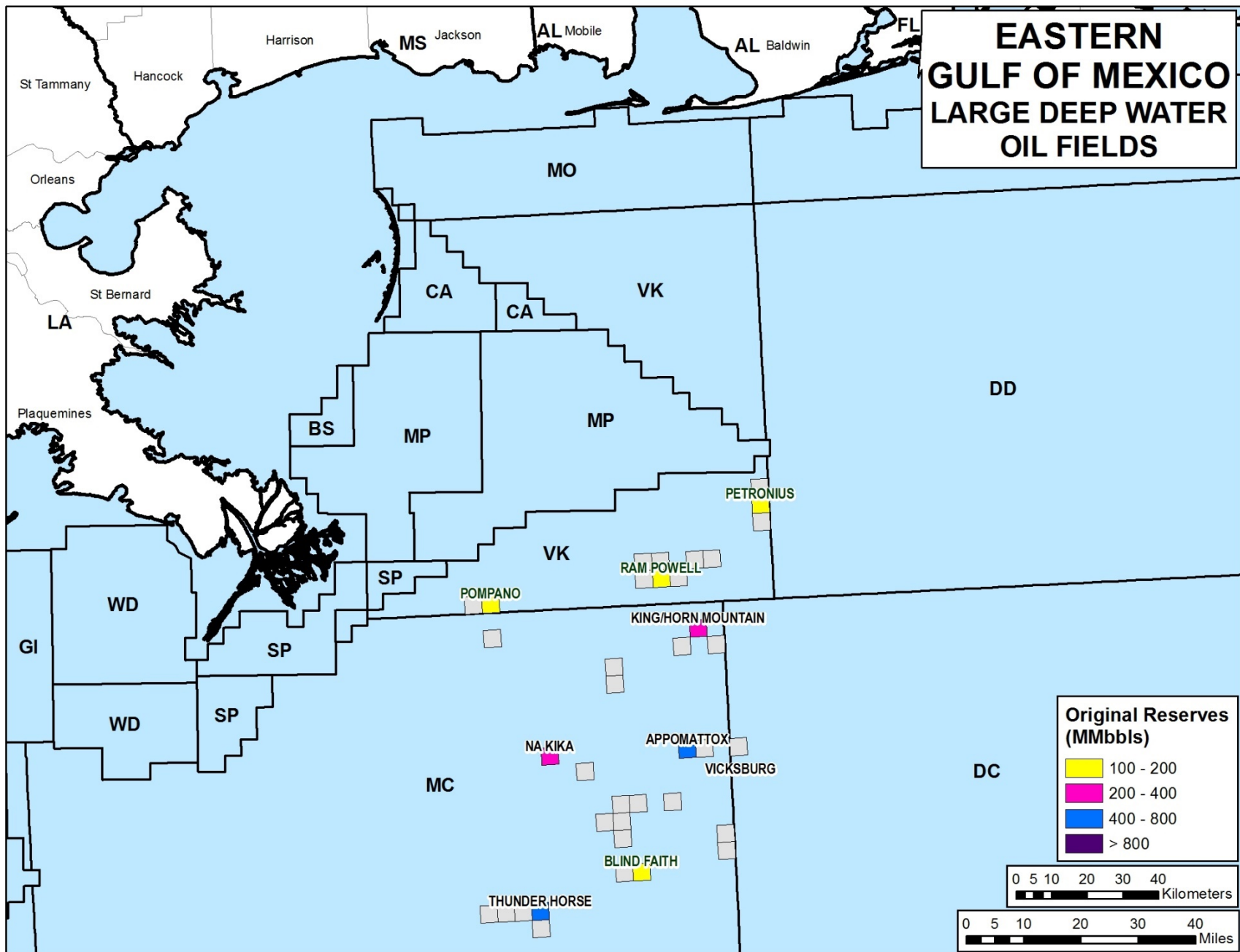
# Pipeline System for Delivering CO<sub>2</sub> to Deepwater Eastern GOM Oil Fields

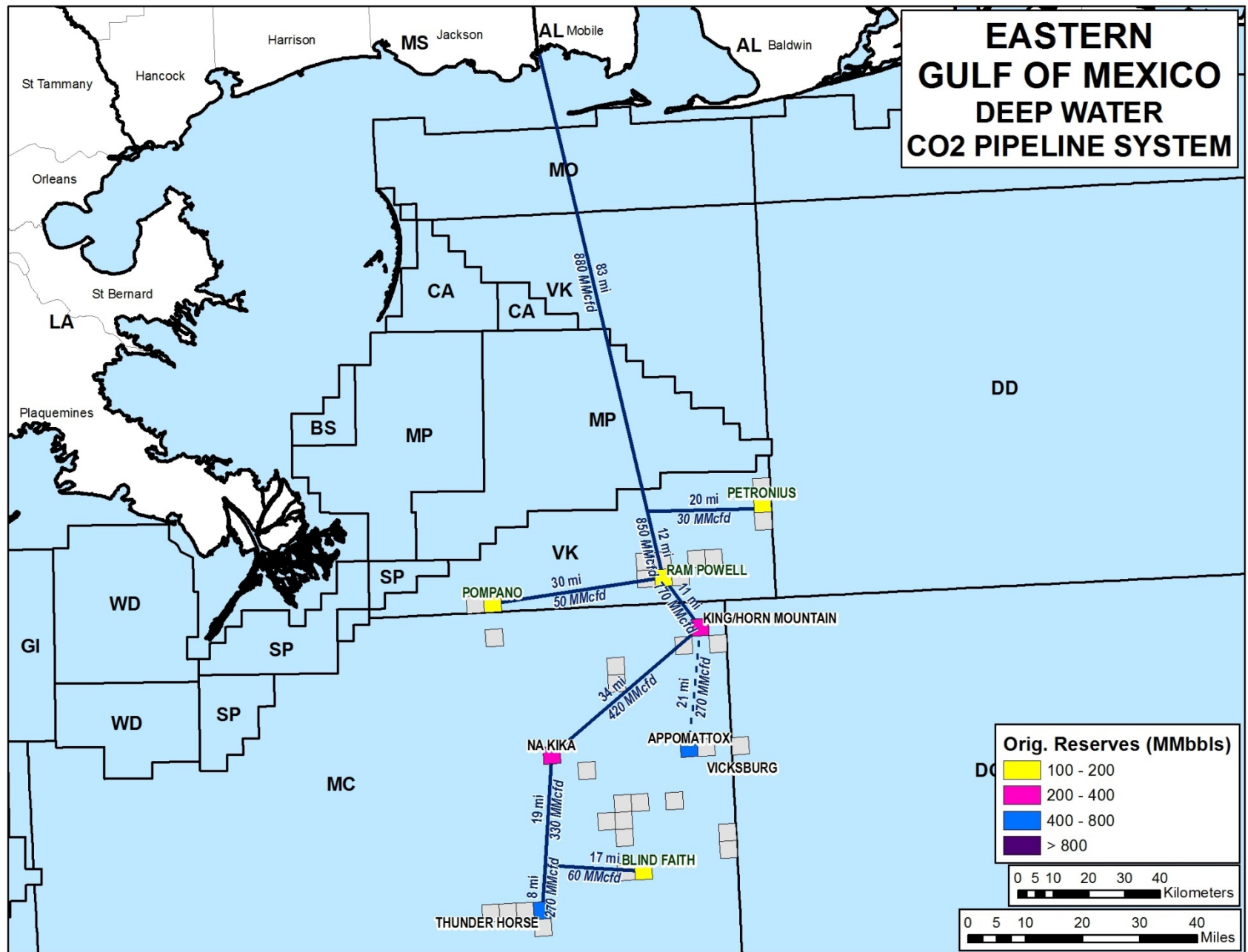
---

**We assembled data and then evaluated eight large deepwater GOM Production Complexes, each with original oil reserves of 50 million barrels or more in the Eastern Portion of the Federal waters of the Gulf of Mexico.**

We plotted the location of each of the eight Production Complexes, estimated their oil recovery potential, and calculated their CO<sub>2</sub> injection requirements for CO<sub>2</sub>-EOR.

Then, we established an offshore pipeline system that would optimally connect these eight Production Complexes (containing 23 large oil fields) with CO<sub>2</sub> supply delivered from an onshore location.





# Eastern Deepwater GOM CO<sub>2</sub> Pipeline System

The Eastern Deepwater Gulf of Mexico CO<sub>2</sub> Pipeline System links three deepwater CO<sub>2</sub> Hubs: (1) King/Horn Mt. CO<sub>2</sub> Hub (including the King/Horn Mt., Petronius, Pompano and Ram-Powell Production Complexes); (2) Thunder Horse CO<sub>2</sub> Hub (including the Thunder Horse, Blind Faith and NaKita Production Complexes); and (3) the future Appomattox CO<sub>2</sub> Hub and Production Complex.

The King/Horn Mt., Thunder Horse and Appomattox CO<sub>2</sub> Hubs offer the potential for: (1) 1,280 million barrels of CO<sub>2</sub>-EOR based oil recovery; (2) 12,840 Bcf (679 MMmt) of CO<sub>2</sub> use and storage; and (3) CO<sub>2</sub> requirements of 880 MMcfd (17 MMmt/yr) of CO<sub>2</sub> (for 40 years).

## Eastern GOM Deepwater CO<sub>2</sub> Pipeline System

CO <sub>2</sub> Hubs	No. of Fields	CO <sub>2</sub> -EOR Oil Recovery	Total CO <sub>2</sub> Demand/Storage		CO <sub>2</sub> Flow Requirements	
	(#)	(MMB)	(Bcf)	(MMmt)	(MMcfd)	(MMmt/yr)
King/Horn Mt.	9	280	2,820	149	190	3.7
Thunder Horse	12	600	6,030	319	410	8.0
Appomattox	2	400	3,990	211	280	5.3
<b>Total</b>	<b>23</b>	<b>1,280</b>	<b>12,840</b>	<b>679</b>	<b>880</b>	<b>17.0</b>

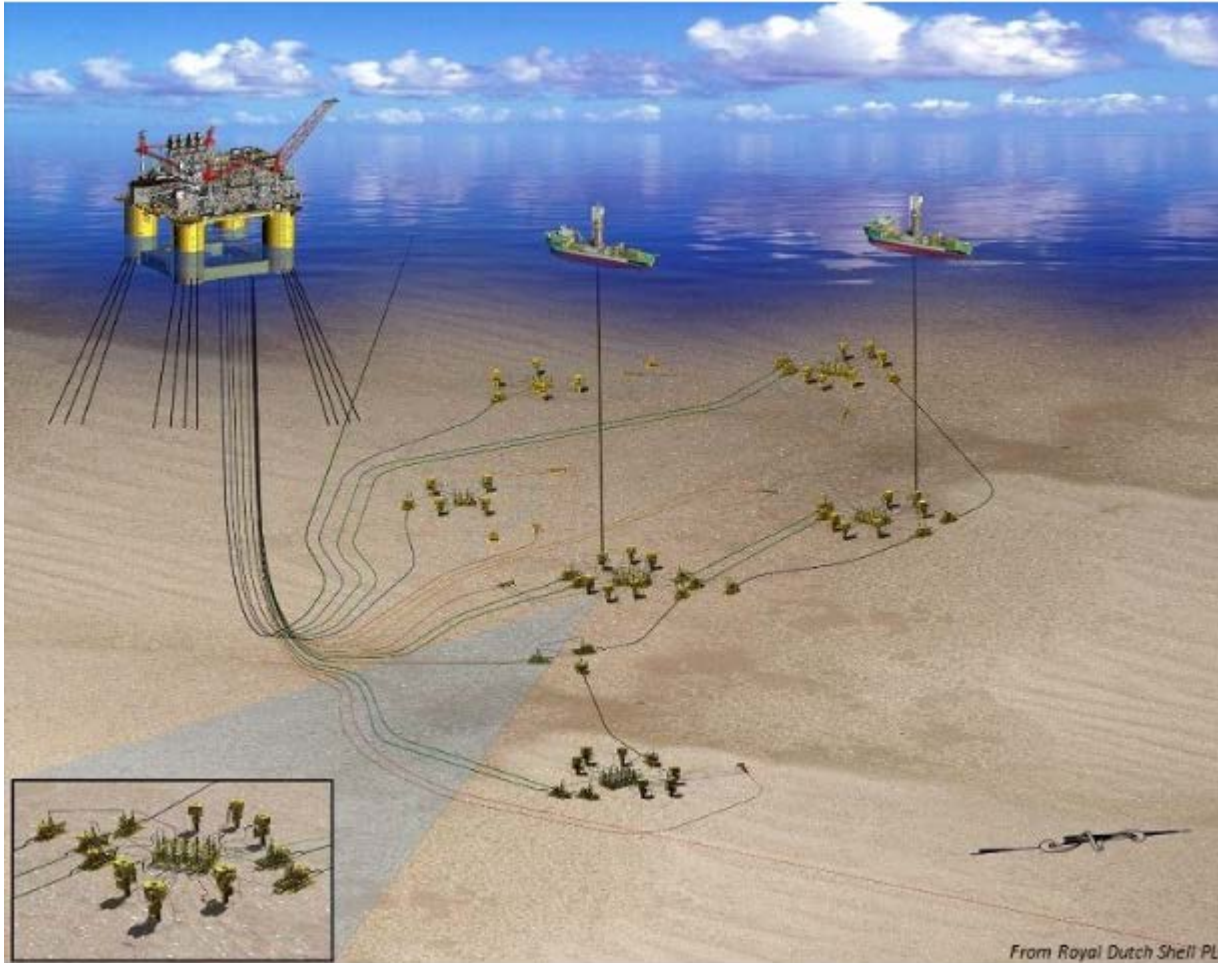
JAF2017\_007.XLS

# Oil Recovery and CO<sub>2</sub> Requirements for Eastern Deepwater GOM Production Complexes and CO<sub>2</sub> Hubs

PRODUCTION COMPLEXES AND CO2 HUBS	Water Depth  (feet)	Original Reserves			2014 Annual Production			Cumulative Production through 2014			Reserves			Resource In-Place		CO2 Parameters			Sands #	Sub-Sea Depth (feet)
		Oil	Gas	BOE	Oil	Gas	BOE	Oil	Gas	BOE	Oil	Gas	BOE	Oil	Gas	Oil Rec.	CO2	Flow		
		(MMbbl)	(Bcf)	(MMbbl)	(MMbbl)	(Bcf)	(MMbbl)	(MMbbl)	(Bcf)	(MMbbl)	(MMbbl)	(Bcf)	(MMbbl)	(MMbbl)	(Bcf)	MMbbl	Bcf	MMcfd		
KING/HORN MOUNTAIN	4,597	330	643	444	14	15	16	268	539	364	62	104	81	771	882	116	1,157	79	11	11,063
PETRONIUS	2,739	160	198	195	4	9	5	151	178	182	9	21	13	310	216	47	466	32	8	10,665
POMPANO	1,731	156	280	206	1	6	2	140	263	187	16	17	19	440	557	66	661	45	14	9,176
RAM POWELL	3,238	99	897	259	2	6	3	95	881	252	4	16	7	326	1,393	49	489	33	7	12,096
KING/HORN MTN. CO2 HUB		744	2,017	1,103	20	36	26	654	1,861	985	91	157	119	1,848	3,048	277	2,772	190	40	
BLIND FAITH	6,952	127	98	144	3	3	4	68	53	78	59	46	67	599	151	90	899	62	6	22,371
NA KIKA	6,590	345	989	521	27	52	36	271	833	419	74	156	102	851	1,641	128	1,276	87	19	14,543
THUNDER HORSE	5,873	496	440	575	30	26	34	274	245	318	222	195	257	2,573	677	386	3,859	264	23	21,381
THUNDER HORSE CO2 HUB		968	1,527	1,240	60	80	74	613	1,131	815	355	397	425	4,023	2,469	603	6,035	413	48	
APPOMATTOX CO2 HUB	7,395	797	1,541	1,063	0	0	0	0	0	0	797	1,541	1,063	2,657	2,371	399	3,985	273		
KING/HORN MT./ APPOMATTOX/ THUNDER HORSE CO2 HUB		2,510	5,086	3,406	80	115	101	1,267	2,991	1,799	1,243	2,095	1,607	8,528	7,888	1,279	12,792	876	88	
2/3/2017																				



# Appomattox CO<sub>2</sub> Hub



Source: OGJ On-Line, 07/01/2015

The Appomattox deepwater semi-submersible production platform will be located in 7,200 feet of water, 80 miles south of Mobile, Alabama. It will contain six drill centers, 15 producing sub-sea wells and five water injection wells.

The production platform and associated oil fields (Appomattox and Vicksburg) are scheduled to be placed on-stream in 2020.

# Eastern GOM Deepwater CO<sub>2</sub> Pipeline Investment Costs

Our prefeasibility estimate of installing the Eastern Deepwater CO<sub>2</sub> Pipeline System is about \$2.74 billion. This estimate is based on 1,992 inch-miles in shallow water with costs of \$500,000 per inch-mile and 2,496 inch-miles in deepwater with costs of \$700,000 per inch-mile.

## Eastern GOM Deepwater CO<sub>2</sub> Pipeline System

Pipeline Segment	CO <sub>2</sub> (MMcfd)	Length (mi)	Diameter (in)	Pipeline (in-mi)	Water Depth (ft)	Pipeline Costs (\$MM)	End Field
1	880	83	24	1,992	984		X
2	30	20	6	120	1,795		VK786
3	850	12	24	288	3,238		VK956
4	50	30	8	240	1,436		VK990
5	770	11	24	264	5,285		MC84
6	420	34	20	680	5,741		MC383
7	330	19	16	304	5,576		X
8	60	17	8	136	6,952		MC696
9	270	8	16	128	6,077		MC778
10	270	21	16	336	7,333		MC391
Total				4,488		2,743	



# Summary of Findings

---

**The prefeasibility study of the Eastern Gulf of Mexico CO<sub>2</sub> Pipeline System provides the following findings:**

- 1. Time Urgency for the CO<sub>2</sub> Pipeline System.** The majority of the 12 large shallow water Eastern Gulf of Mexico oil fields, as well as several of the deepwater fields (Ram-Powell, Pompano and Petronius), are close to abandonment.

Once these fields are abandoned and their platforms removed, the feasibility of conducting CO<sub>2</sub>-EOR and storing CO<sub>2</sub> in the offshore becomes much more challenging and costly.

# Summary of Findings (Cont'd)

2. **The Eastern GOM Shallow Water CO<sub>2</sub> Pipeline System.** The \$1.21 billion Eastern GOM shallow water CO<sub>2</sub> pipeline systems would facilitate implementation of CO<sub>2</sub>-EOR and CO<sub>2</sub> storage in 12 large oil fields.
  - Potential oil recovery of 610 million barrels,
  - CO<sub>2</sub> demand and storage of 6,110 Bcf (323 million metric tons), and
  - CO<sub>2</sub> delivery (and storage) of 0.42 Bcf per day, equal to 8.1 million metric tons per year, over a 40 year time period.
3. **The Eastern GOM Deepwater CO<sub>2</sub> Pipeline System.** The \$2.74 billion Eastern GOM deepwater CO<sub>2</sub> pipeline systems would facilitate implementation of CO<sub>2</sub>-EOR and CO<sub>2</sub> storage in nine large GOM Production Complexes containing 23 oil fields.
  - Potential oil recovery of 1,280 million barrels,
  - CO<sub>2</sub> demand and storage of 12,280 Bcf (670 million metric tons), and
  - CO<sub>2</sub> delivery (and storage) of 0.88 Bcf per day, equal to 17 million metric tons per year, over a 40 year time period.

# Summary of Findings (Cont'd)

---

- 4. Benefits of Establishing CO<sub>2</sub> Utilization, Storage and Pipeline Systems for the Eastern Gulf of Mexico.** With oil recovery of 1.89 billion barrels, an oil price of \$72 per barrel (EIA AEO 2017 projected oil price for Year 2020), and a combined shallow and deepwater royalty rate of 18.1%, the Federal Government would receive about \$25 billion dollars of royalty revenues from the oil produced using the GOM CO<sub>2</sub> pipeline systems.

Higher oil prices, as projected by EIA for the post 2020 time period, would appreciably increase the royalty revenues to the Federal Government.



**Advanced  
Resources  
International**  
[www.adv-res.com](http://www.adv-res.com)

**Office Locations**

**Washington, DC**

4501 Fairfax Drive, Suite 910  
Arlington, VA 22203  
Phone: (703) 528-8420

**Houston, TX**

11931 Wickchester Ln., Suite 200  
Houston, TX 77043-4574  
Phone: (281) 558-9200

**Knoxville, TN**

1210 Kenesaw Ave.  
Suite 1210A  
Knoxville, TN 37919-7736