Establishing CO_2 Utilization, Storage and Pipeline Systems for Oil Fields in Shallow and Deep Waters of the Gulf of Mexico

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Presentation Outline

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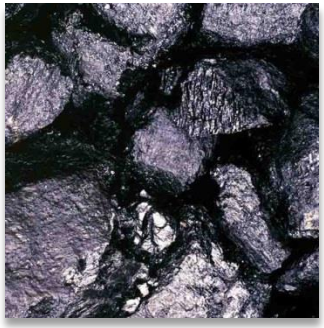
2	Eastern and East Central GOM Deepwater CO_2 Pipeline System
3	Next Steps

Executive Summary

The large oil fields in the Eastern and East Central GOM offshore offer significant opportunities for productively utilizing and storing CO_2 while helping increase domestic oil production and Federal revenues.

- The 52 moderate to large oil fields in the shallow Federal waters of the GOM will need a three CO_2 pipeline system to deliver 40 million metric tons per year (2.1 Bcfd) for use and storage by CO_2 enhanced oil recovery,
- The 63 large oil fields in the deep Federal waters of the GOM will need a three CO_2 pipeline system to deliver 57 million metric tons per year (2.9 Bcfd) for use and storage by CO_2 enhanced oil recovery,
- The capital costs for these six CO_2 pipelines is estimated at nearly $6 billion,
- The Federal royalties provided from the recovery of 7.3 billion barrels by CO_2 enhanced oil recovery (assuming all 7.3 B bbls would be economically viable to develop) would equal $104 billion dollars, assuming an $80 per barrel (WTI) oil price, as estimated by EIA for Year 2025.



1. Eastern and East Central GOM Shallow Water CO_2 Pipeline System

Pipeline Systems for Delivering CO_2 to Shallow Water Eastern and East Central GOM Oil Fields

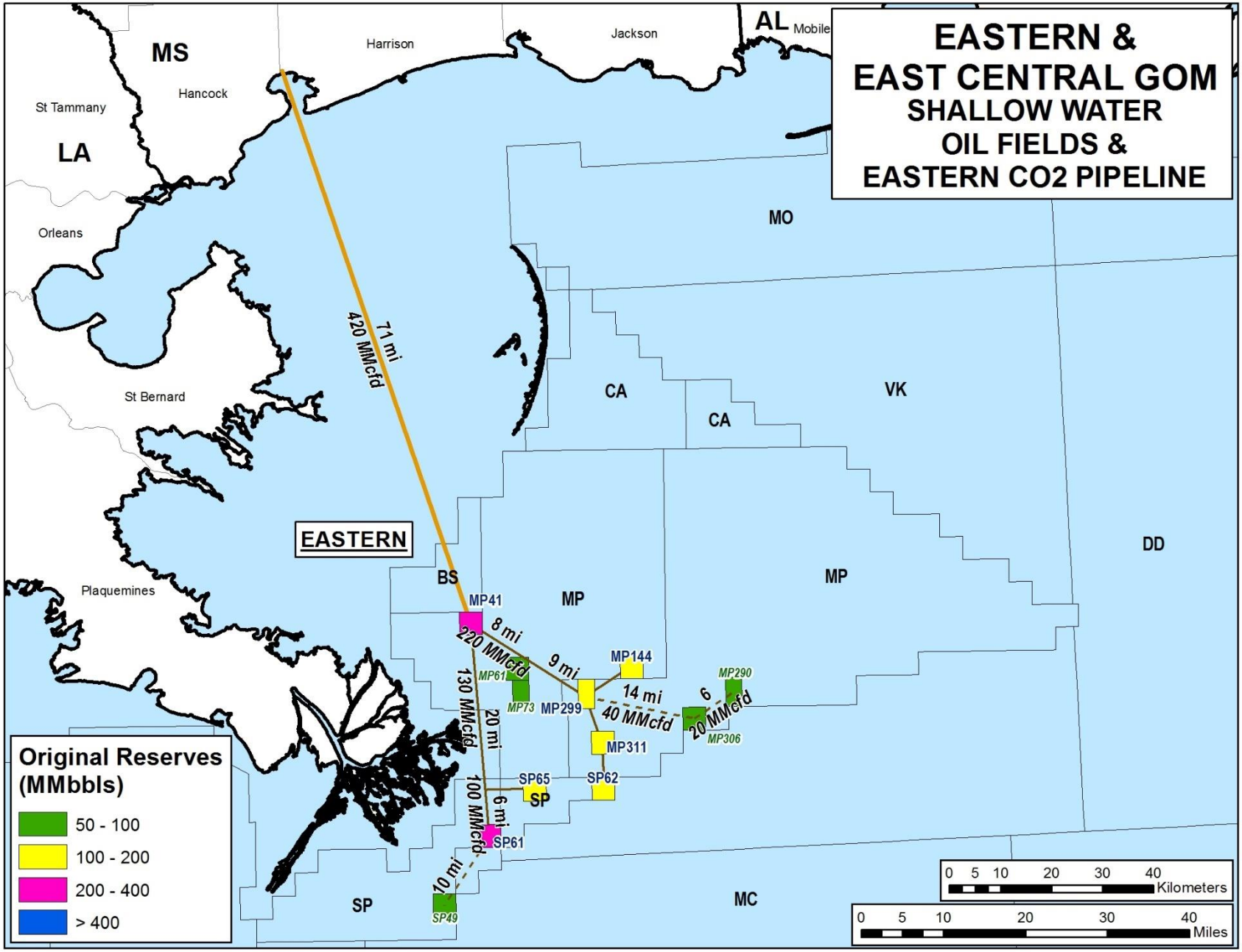
The Eastern and East Central portions of the Gulf of Mexico (GOM) shallow water offshore hold 52 moderate- to large-size oil fields. These oil fields contain 8.2 billion barrels of original oil reserves, with 97% of these original reserves already produced.

We started our study by targeting the largest 29 of these oil fields, each with original oil reserves of over 100 million barrels.

We plotted the location of each of these 29 oil fields, estimated their technically viable oil recovery potential and CO_2 injection requirements, and then designed three CO_2 pipelines that would connect these 29 oil fields with CO_2 supply from onshore Louisiana and Mississippi.

- Eastern GOM CO_2 Pipeline System
- East Central GOM CO_2 Pipeline System #1
- East Central GOM CO_2 Pipeline System #2

Finally, we prepared an initial estimate of the capital costs of installing these three CO_2 pipeline systems in the shallow waters of Eastern and East Central GOM.



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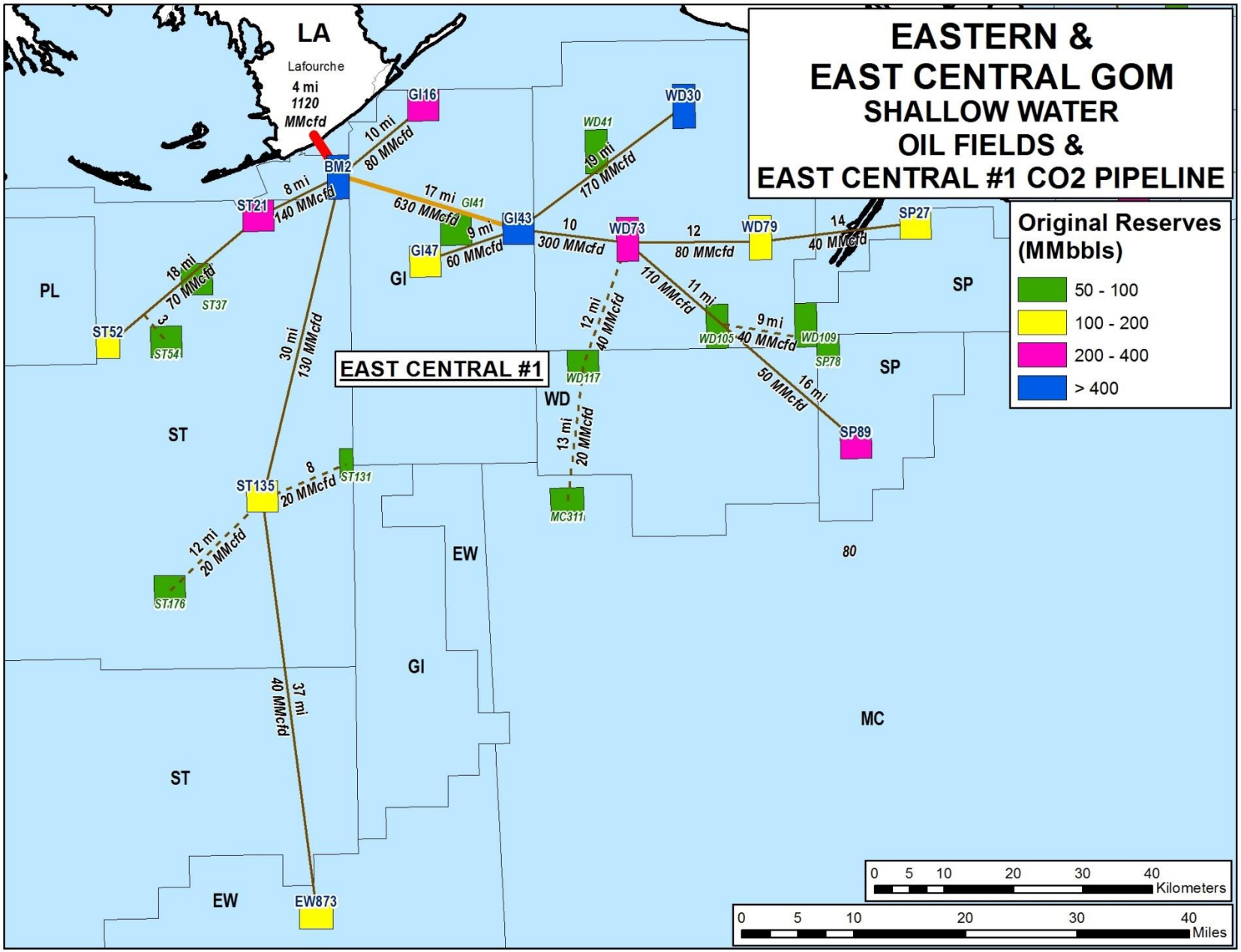

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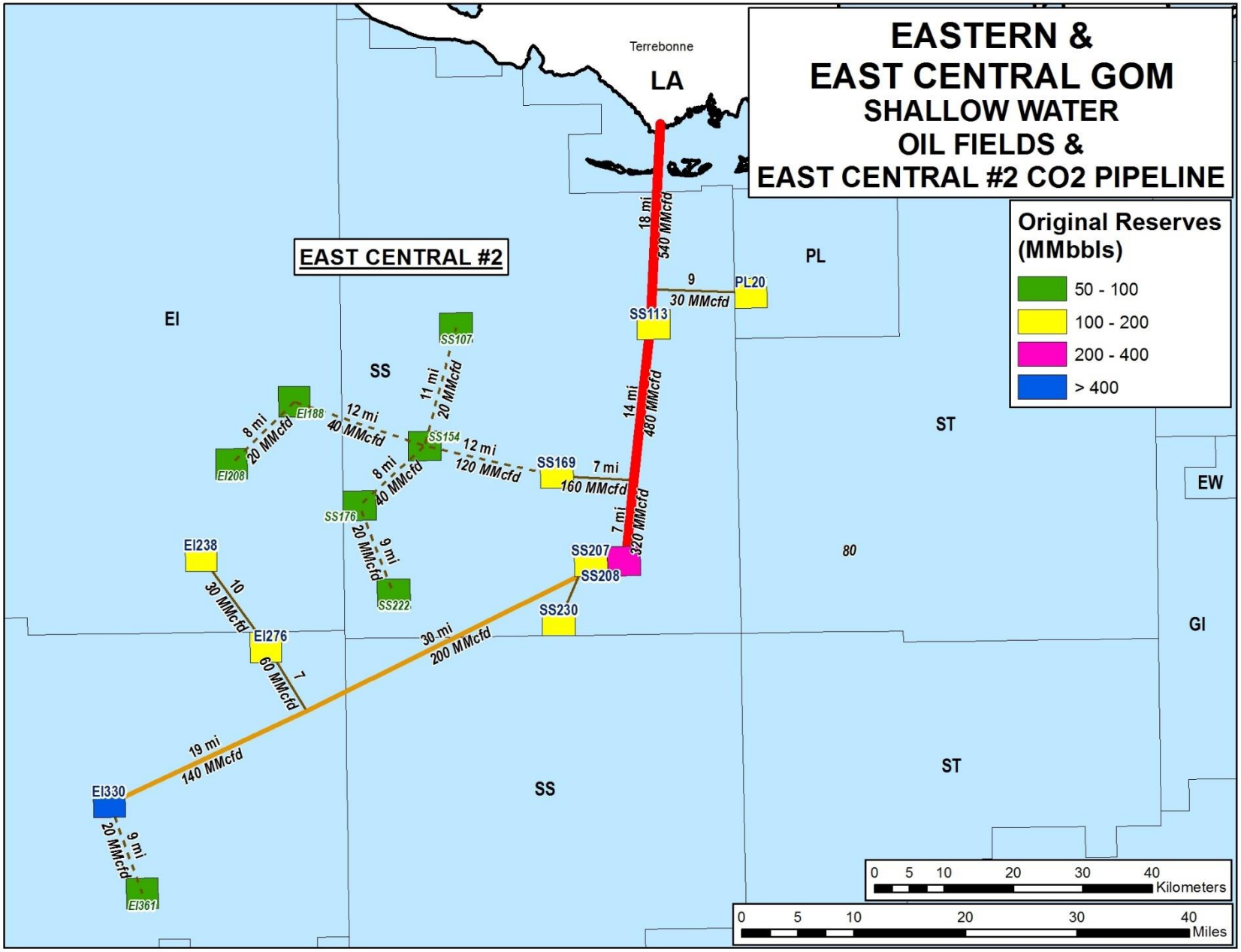

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Final Eastern and East Central GOM Shallow Water CO_2 Pipeline System

Including both the 29 "targeted" oil fields and the 23 "opportunity" oil fields, the three pipelines would deliver about 2.1 Bcfd of CO_2 (40 million tons per year) to 52 shallow water GOM oil fields.

Pipeline System	No. of Fields	CO_2-EOR Oil Recovery	Total CO_2 Requirements		CO_2 Requirements	
	(#)	(MMB)	(Bcf)	(MMmt)	(MMcfd)	(MMmt/yr)
Eastern	**12**	**610**	**6,110**	**323**	**420**	**8.1**
East Central #1						
▪ Part 1	6	520	5,220	276	360	6.9
▪ Part 2	7	650	6,530	346	450	8.7
▪ Part 3	6	240	2,380	126	160	3.2
▪ Part 4	5	220	2,150	114	150	2.8
Total	**24**	**1,630**	**16,280**	**862**	**1,120**	**21.6**
East Central #2						
▪ Part 1	12	500	5,040	267	350	6.8
▪ Part 2	4	290	2,840	150	190	3.7
Total	**16**	**790**	**7,880**	**417**	**540**	**10.5**
Total	**52**	**3,030**	**30,270**	**1,602**	**2,080**	**40.2**

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- The Eastern CO_2 pipeline system remains modest in size, transporting 420 MMcfd (8.1 MMmt/yr) of CO_2.
- The East Central #1 CO_2 pipeline system remains the dominant CO_2 system, with 1,120 MMcfd (21.6 MMmt/yr) of capacity.
- The East Central #2 CO_2 pipeline system would have 540 MMcfd (10.5 MMmt/yr) of transportation capacity.

Eastern and East Central GOM Shallow Water CO_2 Pipeline Investment Costs

Our estimate of installing the three CO_2 pipelines in the shallow waters of the Eastern and East Central Gulf of Mexico is about $1.7 billion.

Pipeline System	CO_2 Requirements		Pipeline Requirements	Capital Costs*
	(MMcfd)	(MMmt/yr)	(in-mi)	($MM)
Eastern	420	8.1	2,478	$600
East Central #1	1,120	21.6	2,512	$600
East Central #2	540	10.5	2,074	$500
Total	**2,080**	**40.2**	**7,064**	**$1,700**

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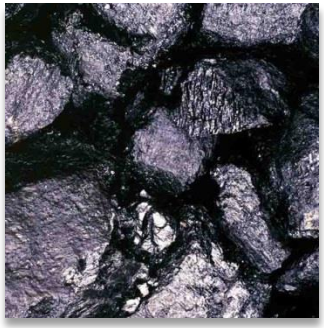
*We assume $240,000 per inch-mile for shallow water.

Opportunities for lowering these costs would involve further optimizing the CO_2 pipeline systems and selectively using existing, empty offshore natural gas pipelines, where possible.

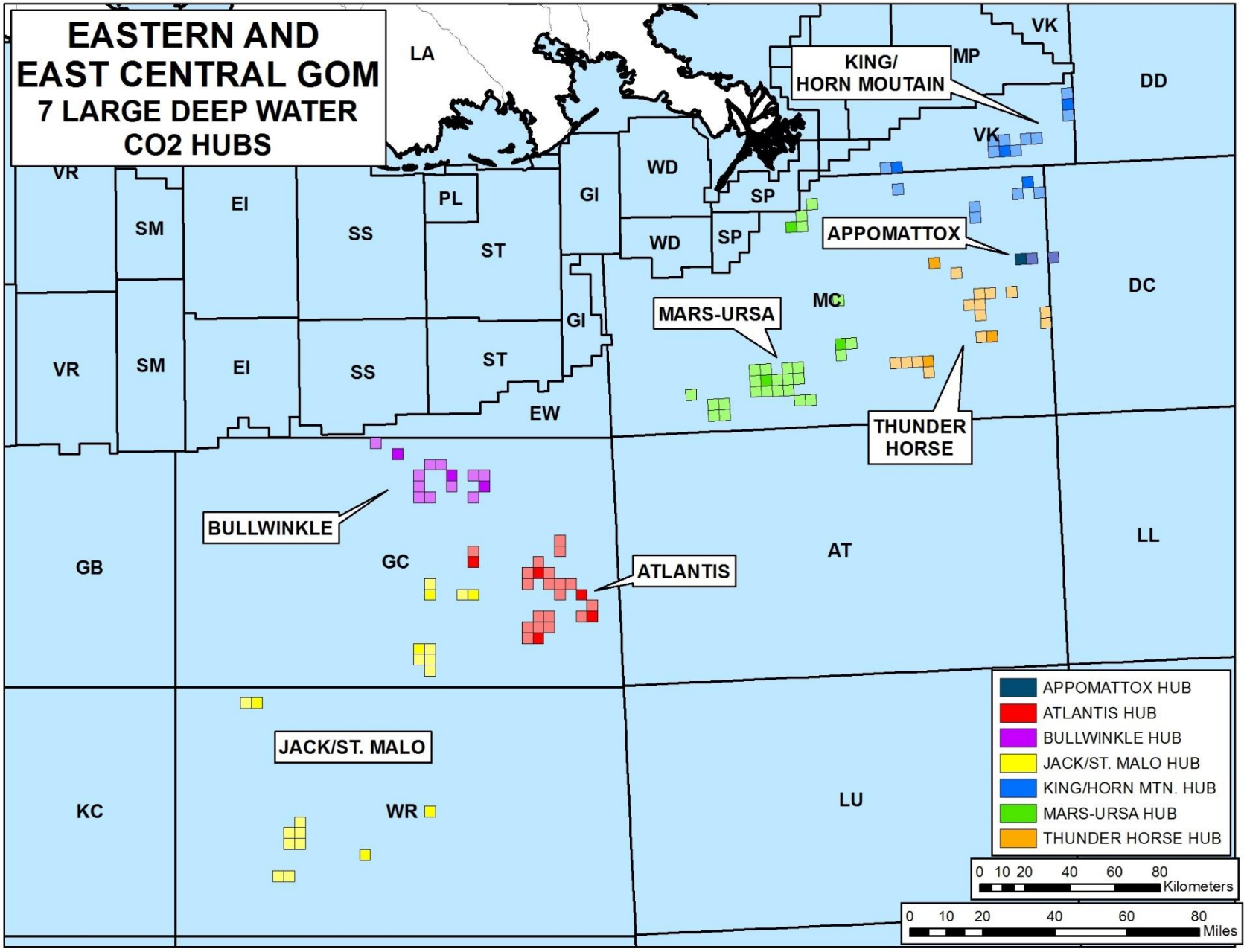


2. Eastern and East Central GOM Deepwater CO_2 Pipeline System

Pipeline Systems for Delivering CO_2 to Deepwater Eastern and East Central GOM Oil Fields

The 63 large deepwater Eastern and East Central GOM oil fields, concentrated in Green Canyon and Mississippi Canyon, offer considerable potential for CO_2 storage and technically viable oil recovery using CO_2-EOR.

- These 63 large deepwater oil fields contain 8.6 billion barrels of original oil reserves, with about half of these original reserves already produced.
- We plotted the location of these 63 large deepwater oil fields and 26 Production Complexes (central platforms). We then estimated their oil recovery potential and CO_2 requirements for CO_2-EOR.
- We established seven major CO_2 Hubs served by three Deepwater CO_2 Pipeline Systems to link these 63 large oil fields with CO_2 supplies delivered from onshore Louisiana, Mississippi and Alabama.



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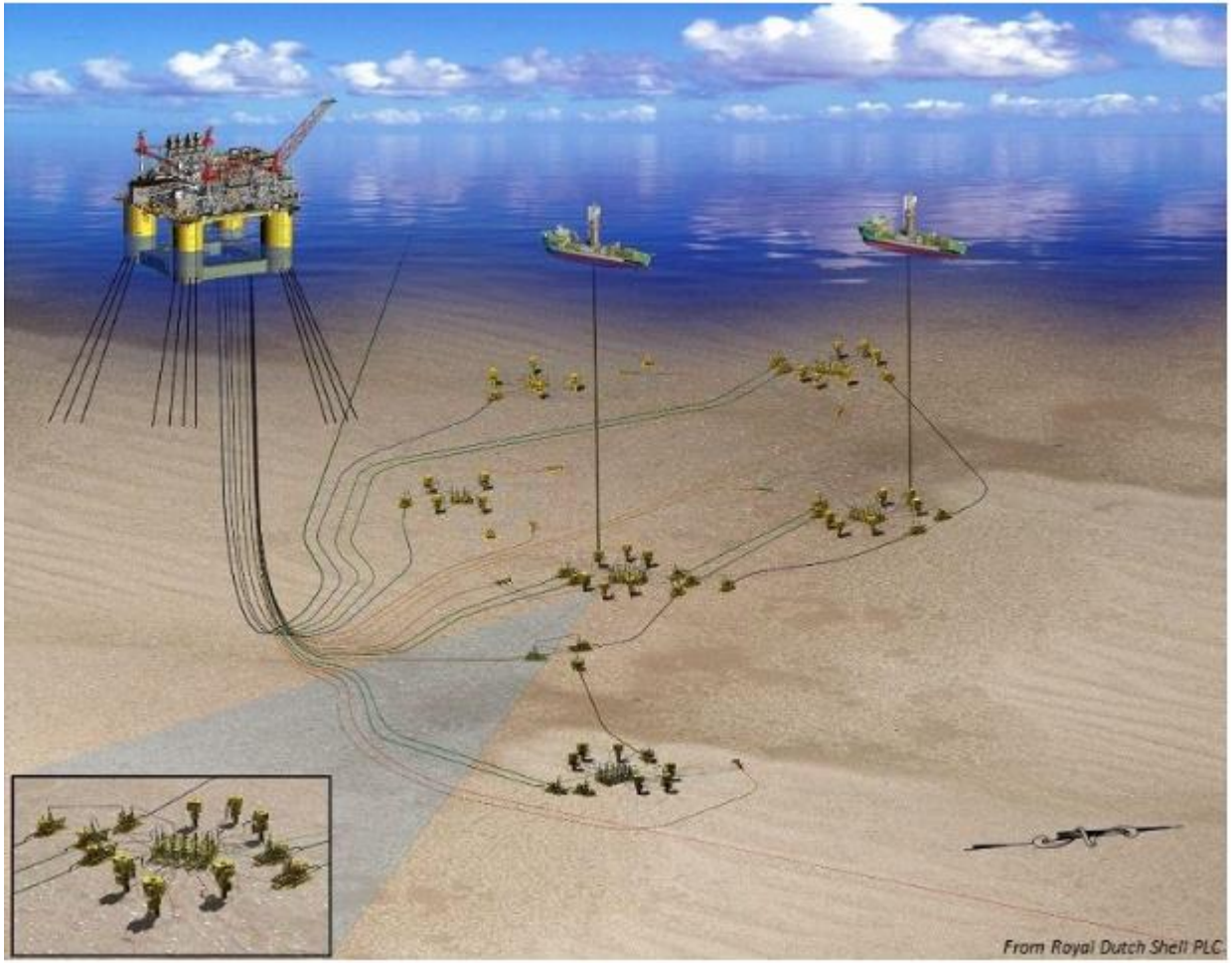
Appomattox CO_2 Hub and Production Complexes

The Appomattox CO_2 Hub and Production Complex is linked to the Appomattox (MC391) and Vicksburg (DC353) oil fields located in about 7,300 feet of water depth. Vicksburg was discovered by Shell in 2013 with Appomattox discovered, also by Shell, in 2016. Both fields are projected to be placed on production in 2020.

Subsequently, Shell announced the Appomattox deepwater platform would also provide tieback opportunities for the nearby Gettysburg, Ryberg and other prospects.

Shell has proposed building a 24-inch pipeline, called the Mattox Pipeline, to transport crude oil from the Appomattox host platform to a shallow water offshore structure and from there to the onshore using existing infrastructure.

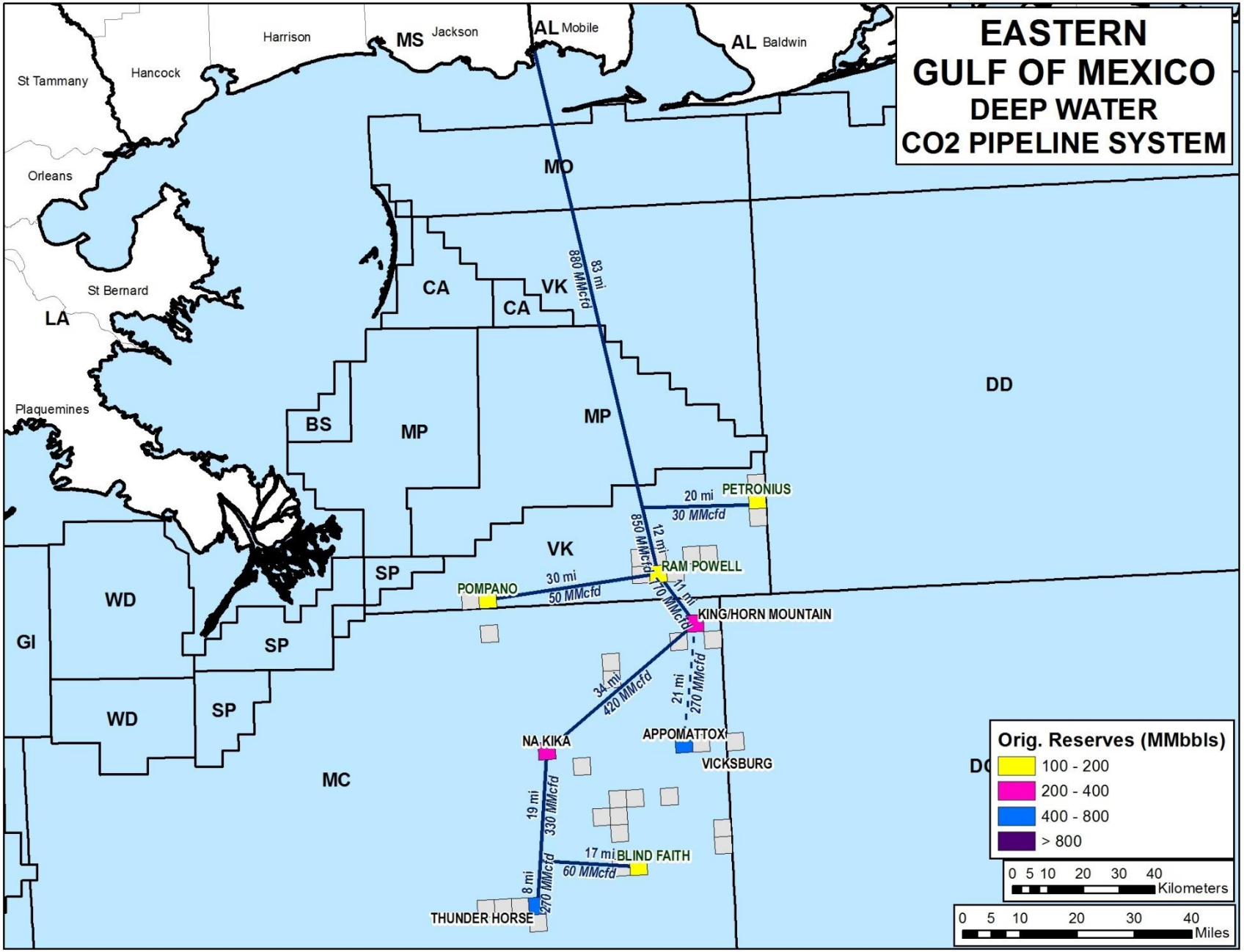
Appomattox CO_2 Hub



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 is scheduled to be placed on-stream in 2020.

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



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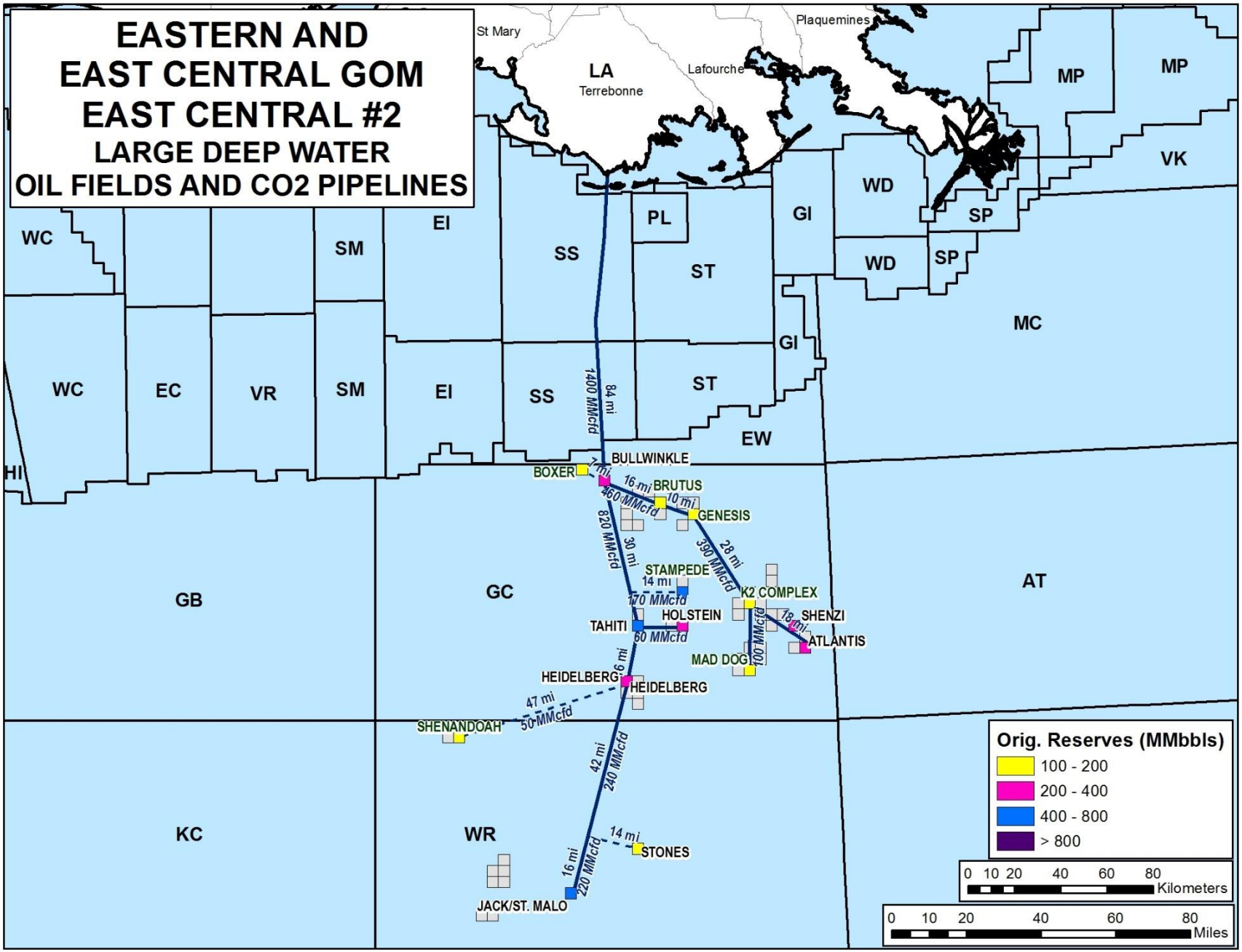
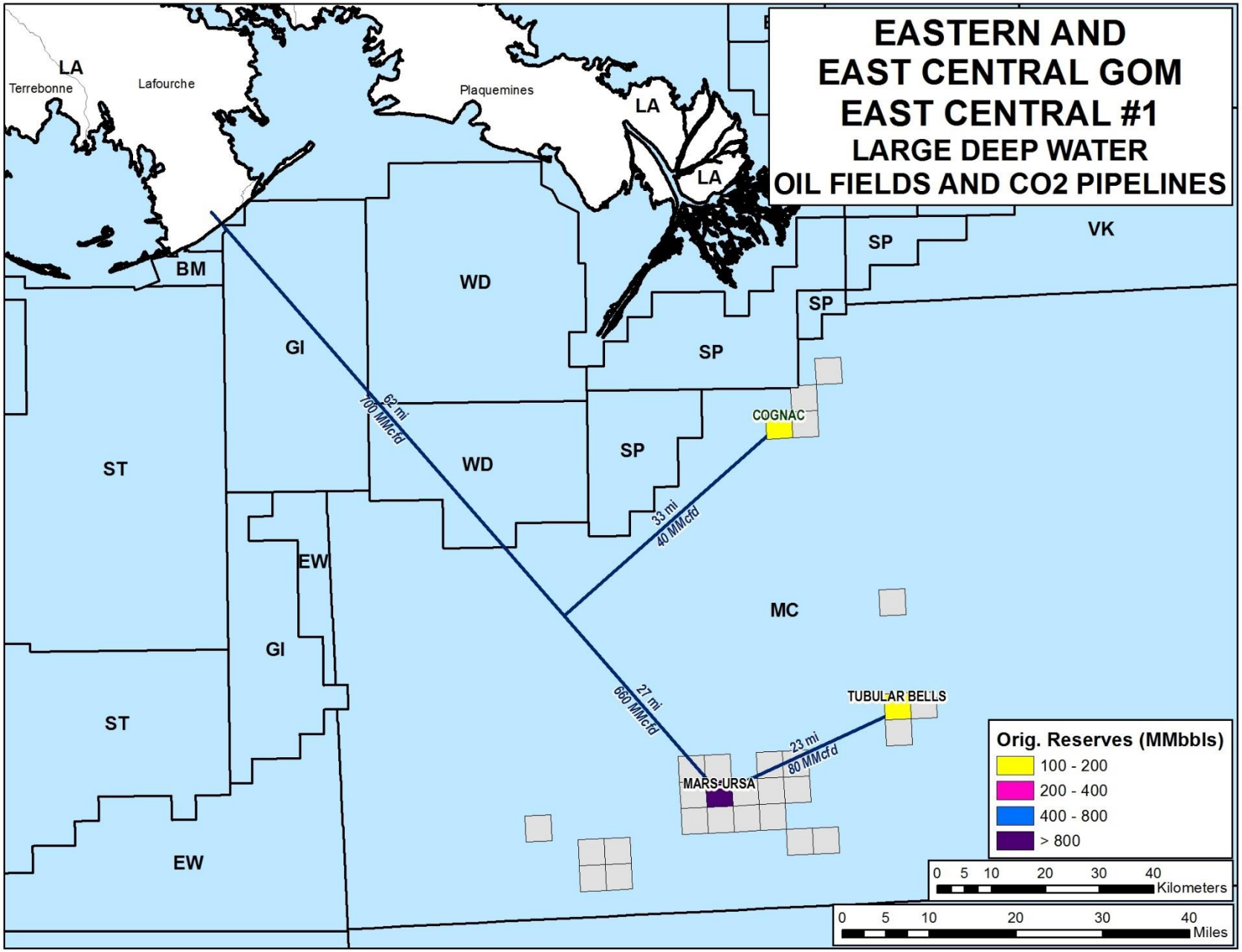

EASTERN AND
EAST CENTRAL GOM
EAST CENTRAL #2
LARGE DEEP WATER
OIL FIELDS AND CO2 PIPELINES
St Mary
LA
Terrebonne
Lafourche
Plaquemines
MP
MP
VK
WD
SP
WD
SP
GI
PL
ST
SS
EI
SM
WC
WC
EC
VR
SM
EI
SS
ST
GI
EW
MC
HI
GB
GC
AT
KC
WR
1400 MMcfd
84 mi
BULLWINKLE
BOXER
1 mi
16 mi
BRUTUS
460 MMcfd
10 mi
GENESIS
820 MMcfd
30 mi
28 mi
390 MMcfd
STAMPEDE
14 mi
170 MMcfd
K2 COMPLEX
TAHITI
HOLSTEIN
60 MMcfd
100 MMcfd
18 mi
SHENZI
ATLANTIS
MAD DOG
HEIDELBERG
6 mi
HEIDELBERG
47 mi
50 MMcfd
SHENANDOAH
42 mi
240 MMcfd
14 mi
STONES
16 mi
220 MMcfd
JACK/ST. MALO
Orig. Reserves (MMbbls)
100 - 200
200 - 400
400 - 800
> 800
0 10 20 40 60 80
Kilometers
0 10 20 40 60 80
Miles



Eastern and East Central GOM Deepwater CO_2 Pipeline Systems

We estimate technically feasible oil recovery of 4.3 billion barrels, an ultimate CO_2 demand of 43 Tcf (2,300 million metric tons), and CO_2 flows of 2.9 Bcfd (57 MMmt/yr) for the Deepwater GOM CO_2 Pipeline System.

Pipeline System	CO_2 Hub	CO_2 EOR*	CO_2 Demand**		CO_2 Flow	
		(MMbbls)	(Bcf)	(MMmt)	(MMcfd)	(MMmt/y)
Eastern						
	King/Horn Mt.	280	2,770	147	190	3.7
	Thunder Horse	600	6,040	319	420	8.1
	Appomattox	400	3,980	211	270	5.2
Eastern Sub-Total		**1,280**	**12,790**	**677**	**880**	**17.0**
East Central #1						
	Mars-Ursa	**1,030**	**10,270**	**543**	**700**	**13.5**
East Central #2						
	Bullwinkle	270	2,730	144	190	3.7
	Atlantis	770	7,650	405	520	10.0
	Jack/St. Malo	950	9,520	504	650	12.6
East Central #2 Sub-Total		**1,990**	**19,900**	**1,053**	**1,360**	**26.3**
Total		**4,300**	**42,960**	**2,273**	**2,940**	**56.8**

*Technically viable oil recovery is estimated at 15% of OOIP.

**Technically viable CO_2 requirements are estimated using 10 Mcf of CO_2 per barrel of oil recovery.

5/24/2017

Eastern and East Central GOM Deepwater CO_2 Pipeline Investment Costs

Our overall estimate of installing the three CO_2 pipeline systems in the deep waters of the Gulf of Mexico is about $4.1 billion.

Pipeline System	CO_2 Requirements		Pipeline Requirements	Capital Costs*
	(MMcfd)	(MMmt/yr)	(inch-miles)	($MM)
Eastern	880	17.0	4,862	$1,310
East Central #1	700	13.5	3,048	$820
East Central #2	1,360	26.3	7,166	$1,980
Total	**2,940**	**56.8**	**15,076**	**$4,110**

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Opportunities for lowering these costs would involve further optimizing the CO_2 pipeline system.

*We assume capital costs of $240,000 per inch-mile for shallow water and $300,000 per inch-mile for deepwater.

Summary of Findings

Our prefeasibility study of the Eastern and East Central Gulf of Mexico CO_2 Pipeline System provides the following findings:

1. **Time Urgency for the CO_2 Pipeline System**. The majority of the large shallow water oil fields are close to abandonment as are a number (18) of the large deepwater oil fields having produced 93% to 98% of their original reserves. Once these fields are abandoned and their platforms removed, the feasibility of conducting CO_2-EOR and storing CO_2 in these oil fields become much more challenging and costly.
2. **The Eastern and East Central GOM CO_2 Pipeline System**. The six GOM CO_2 pipelines would facilitate the implementation of CO_2-EOR and CO_2 storage in 115 large GOM oil fields.
   - Technically feasible oil recovery of 7.3 billion barrels,
   - CO_2 demand and storage of 73 Tcf (3,870 million metric tons),
   - CO_2 delivery (and storage) of 5 Bcf per day, equal to nearly 100 million metric tons per year, over a 40 year time period, and
   - Capital costs of $5.8 billion dollars for an all new CO_2 pipeline system.

Summary of Findings (Cont'd)

3. **Pipeline Delivery Costs for CO_2.** Using a capital cost of $1.7 billion, a 14% capital charge, and an O&M charge of 5% of capital and with annual delivery of 40 million metric tons, the CO_2 transportation costs for the GOM Shallow Water CO_2 Pipeline System would be about $8 per metric ton.

   Using a capital cost of $4.1 billion, a 14% capital charge, and an O&M charge of 5% of capital and with annual delivery of nearly 57 million metric tons, the CO_2 transportation costs for the GOM Deepwater CO_2 Pipeline System would be about $14 per metric ton.

4. **GOM Deepwater CO_2 Pipeline Benefits.** With potential oil recovery of 7.3 billion barrels, an oil price of $80 per barrel (EIA AEO 2017 projected oil price (WTI) for Year 2025, in real 2016 dollars), and a royalty rate of 16.7% to 18.75%, the Federal Government would receive in excess of $100 billion dollars of royalty revenues from the oil produced using the GOM CO_2 Pipeline System (assuming all of the technically recoverable oil is developed).

3. Next Steps

As part of our existing Scope of Work, we plan to address two additional topics.

- CO_2 utilization/storage, oil recovery and CO_2 pipeline systems for eastern Louisiana, Mississippi and Alabama state waters.
- The potential and capacity of storing CO_2 in the depleted gas fields of the Eastern and East Central GOM, including state, shallow Federal, and deep Federal waters.

A critical topic, although not within our Scope of Work, would be addressing the question - - *How much of the CO_2 demand and potential for oil recovery in the GOM offshore would be economically viable to pursue?*

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