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MEMORANDUM

June 17, 2011

To: Wyoming Enhanced Oil Recovery Commission

From: Wyoming Enhanced Oil Recovery Institute (EORI)

Re: Facts Regarding Future Development of Enhanced Oil Recovery in the Bighorn Basin

This document provides information developed by the Enhanced Oil Recovery Institute (EORI) at the direction of the Enhanced Oil Recovery Commission (EORC) regarding future development of Enhanced Oil Recovery (EOR) projects in oil reservoirs located in the Bighorn Basin (BHB) of Wyoming.

Note that eight of the largest twelve oil fields developed in Wyoming are located in the BHB. Cumulative oil production from the BHB through 2010 totals over 2 billion barrels of oil. This equals approximately 28 percent of the more than 7 billion barrels of oil that have been produced in the state of Wyoming. See Table 1 and Figure 1 for a summary of the largest oil fields in the BHB.

EORI estimates that another 1.3 to 2 billion barrels of oil can be recovered from the BHB as a result of enhanced oil recovery operations using carbon dioxide to displace stranded oil. CO_2 EOR may proceed as soon as a source(s) of CO_2 are made available to local operators, and a new pipeline is built to transport the CO_2 from the source to the identified fields. Numerous new sources of anthropogenic and natural CO_2 are currently being developed. These sources are associated with insitu coal gasification, ex situ coal liquification, and expanded recovery of CO_2 from gas production operations within the state.

Summary

The following text provides an overview of EORI evaluations regarding future development of EOR using CO_2 in both mature reservoirs and residual oil zones (ROZ's) in the BHB of Wyoming.

Enhanced Oil Recovery Institute

1. BHB would result in an additional 500 to 800 million barrels of additional oil production over the next 40 years.

2. Based on experience with development of ROZ's in the Permian Basin I Texas and New Mexico, and upon preliminary reservoir evaluations in the BHB, EORI estimates that between 800 and 1,200 million barrels of additional oil may be produced from ROZs in the BHB over the next 40 years.

3. Implementation of EOR will utilize a majority of the estimated 2,000 existing wells drilled through the Tensleep and Madison formations in the BHB. Existing infrastructure including roads, well pads, and production and injection facilities will be used to implement the EOR projects.

4. Additional facilities will be required for implementation of CO_2 EOR, including regional CO_2 transmission lines, gas compression facilities, construction of additional injection and production wells, injection and production lines, and gas treatment facilities.

5. Large quantities of CO_2 will be sequestered into the oil reservoirs as a result of implementation of CO_2 EOR. EORI estimates that between 12 and 18 TCF CO_2 can be sequestered in the petroleum reservoirs.

The financial benefit to Wyoming counties in the state of Wyoming will be substantial. The ad valorem and severance taxes on 1 billion barrels of oil production are estimated to total $9.2 billion, based on an average oil price of $80 per barrel. Note that many additional economic benefits will be realized in addition to increased revenue to counties and the state.

Estimated CO_2 EOR Oil Production from Historically Produced Reservoirs

The BHB has some of the largest oil reservoirs in Wyoming that are technically feasible for CO_2-based EOR. Sixty three BHB reservoirs pass the screening criteria for miscible CO_2 flooding and 42 reservoirs for immiscible CO_2 flooding (Wo, et al, 2008). By assuming an average recovery factor of 12% OOIP for miscible CO_2 floods and 6.5% for immiscible CO_2 floods, it is estimated that 500 to 800 million barrels of additional oil might be recovered from the BHB reservoirs by CO_2 EOR.

Estimated CO_2 EOR Production from Residual Oil Zones

Due to the complex migration and accumulation history of the Tensleep reservoir oil in the (BHB), the residual oil zone (ROZ) below the oil/water contact contains large amounts of residual oil. Initial evaluation indicates this oil can be recovered with use of CO_2 EOR from under historically produced reservoirs as well as "green field" reservoirs that have never been produced (Melzer, 2010). Oil in ROZs

could not be produced with primary or secondary recovery techniques because oil saturations were not sufficiently high (ARI, 2006). This residual oil can be produced using tertiary techniques. Preliminary work indicates that potential oil reserves in the Tensleep ROZ in the BHB are greater than those

contained within the historically produced zones. ROZ production has been successfully developed in Permian Basin reservoirs using CO_2 EOR, and contributes proportionally large amounts of production in those reservoirs (Honapour, et al, 2010).

Estimated Carbon Dioxide Demand

The estimated total CO_2 demand for CO_2 EOR ranges from 5 to 7 TCF for the historically produced reservoirs in the Bighorn basin. By assuming a similar flooding efficiency, an additional 7 to 11 TCF of CO_2 could be required to flood the ROZs in the basin. Note that the estimated total CO_2 demand only takes account of the net CO_2 volume that needs to be purchased, which is the volume of sequestered CO_2 in the reservoir after CO_2 flooding is complete. As given in Equation 2 of SPE 122921, a 70% CO_2 re-injection rate, 1:1 WAG ratio and a total WAG injection of 2.5 HCPV are assumed in the estimate of total CO_2 demand. In addition, Equation 4 of SPE 122921 is used to provide an estimate of the required initial CO_2 volume for a candidate reservoir.

Sequestration of Carbon Dioxide

It is estimated that between 12 and 18 trillion cubic feet of CO_2 can be sequestered as a result of CO_2 EOR operations in the BHB. It is assumed in this memorandum that carbon dioxide demand equals the carbon dioxide that will be sequestered. Please see the brief explanation of the estimation method in the previous paragraph.

Existing Infrastructure

Substantial existing infrastructure in the BHB will be used to develop CO_2 EOR projects. EORI estimates that more than 2,000 existing wells are available for use in injection and production operations based on current Wyoming Oil and Gas Conservation Commission data.

Other existing infrastructure includes:

- Field gathering system
- Field injection systems,
- Oil production and water treatment facilities,
- Gas treating facilities,
- Oil and water storage facilities,
- Regional road systems,
- Electrical power distribution systems,
- Facilities that support oil field service and product companies, and
- Regional petroleum transportation facilities.

Implementing CO_2 EOR operations in the near future, while existing infrastructure is still in place and operational, will lower the required capital investment for new EOR projects.

New Infrastructure

New infrastructure will have to be built to accommodate:

- Transportation of carbon dioxide into the BHB and to individual fields,
- Gas treatment and compression facilities to allow reuse of produced gases,
- Additional wells for injection and production of oil produced from both the historically produced zones and the newly developed residual oil zones.
- Additional roads and facilities to support new development.

Note that the footprint of new production facilities will be much smaller than that required for facilities constructed prior to the 1990s, due to development of directional drilling, and development of completion techniques for horizontal wells.

Estimated Financial Benefit to Wyoming Counties and the State of Wyoming

The economic benefits generated by the Wyoming oil and gas industry are many and include:

- Severance taxes paid to the state,
- Ad valorem taxes paid to individual counties,
- Generation of primary and downstream or secondary jobs,
- Property taxes,
- Mineral royalties paid to individual land owners and the state, and
- Sales and use taxes.

Wyoming Enhanced Oil Recovery Institute

The Enhanced Oil Recovery Commission (EORC) was created by the Wyoming legislature in 2004 to support and encourage use of advanced oil technology to recover oil stranded in Wyoming reservoirs by funding programs at the University of Wyoming's Enhanced Oil Recovery Institute (EORI). EORI's mission includes completion of applied research, technology transfer to Wyoming operators, and demonstration of innovative technology in real work environments. EORI is currently characterizing and evaluating development of EOR in mature oil reservoirs in the Bighorn and Wind River Basins of Wyoming. EORI is also working with operators to characterize and develop residual oil zones in the BHB. For more information on EORI please access our web site at www.uwyo.edu/eori.

FIELD	OIL CUMS (bbls) AS OF 12/2010	BIGHORN BASIN OIL CUMS (bbls) AS OF 12/2010	# OF WELLS (PO, SI, AI)
SALT CREEK	689,450,823		
OREGON BASIN	478,319,450	478,319,450	486
ELK BASIN	471,260,706	471,260,706	283
HAMILTON DOME	267,548,289	267,548,289	289
LOST SOLDIER	268,019,963		
GRASS CREEK	215,040,600	215,040,600	346
GARLAND	200,189,313	200,189,313	240
LITTLE BUFFALO BASIN	138,770,672	138,770,672	199
BYRON	133,971,153	133,971,153	84
LANCE CREEK	120,712,409		
WERTZ	121,048,774		
FRANNIE	119,244,704	119,244,704	83
HARTZOG DRAW	115,419,827		
STEAMBOAT BUTTE	99,381,733		
WINKLEMAN	94,278,189		
BIRCH CREEK	90,626,845		
HILIGHT	79,894,666		
GLENROCK SOUTH	75,708,969		
PAINTER RESERVOIR EAST	73,591,521		
SUSSEX	72,764,692		
TOTALS	3,925,243,298	**2,024,344,887**	2,010
Located in Bighorn Basin, WY			
In Tertiary Recovery			

Table 1) The 20 largest oil fields in Wyoming and those located in the Big Horn Basin or in Tertiary recovery mode.

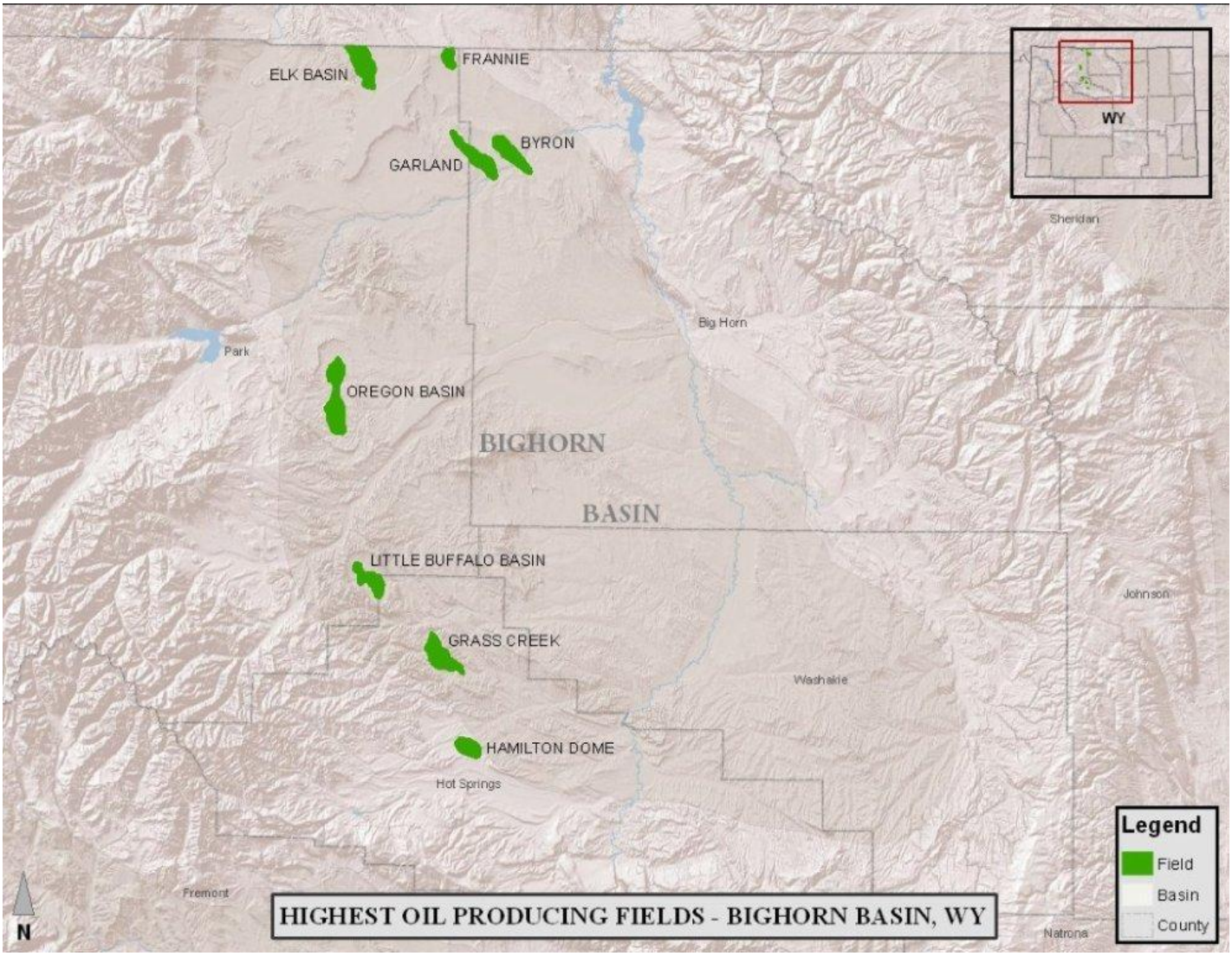

Figure 1) Map showing location of the largest oil producing fields in the Big Horn basin.

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