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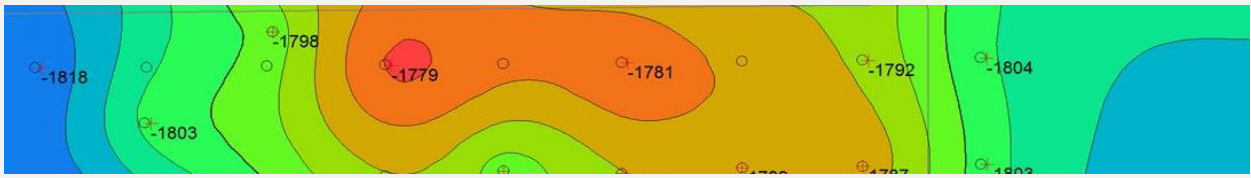

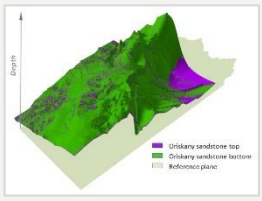

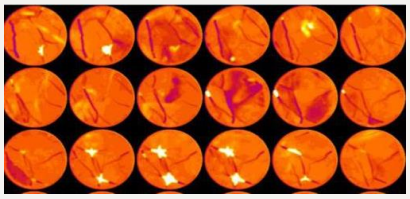

Eight County Permian Basin San Andres Residual Oil Zone (ROZ) Database

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Eight County Permian Basin San Andres Residual Oil Zone (ROZ) Database

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ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ARI	Advanced Resources International, Inc.
CO_2	Carbon dioxide
cp	Centipoise
DOE	Department of Energy
EOR	Enhanced oil recovery
FE	Fossil energy
ft	Foot, Feet
GOR	Gas to Oil Ratio
HCPV	Hydrocarbon pore volume
kg	Kilogram
md	Millidarcy
MESA	Mission Execution and Strategic Analysis
mg	Milligram
MMP	Minimum Miscibility Pressure
NETL	National Energy Technology Laboratory
ppm	Parts per million
psi	Pounds per square inch
res bbl/STB	Ratio of volume of oil in the reservoir (at reservoir temperature and pressure) to the volume of oil at standard conditions
ROZ	Residual oil zone
Scf/STB	Standard cubic feet per barrel of oil at standard conditions
U.S.	United States
°F	Degrees Fahrenheit

1 INTRODUCTION

The Eight County Permian Basin Residual Oil Zone (ROZ) Database contains reservoir information for individual ROZ reservoir units located in seven counties (Andrews, Martin, Winkler, Ector, Crane, Upton, and Ward) in the San Andres formation of the Permian Basin of West Texas. An eighth county, Midland County, was included in the study, but no San Andres ROZ resources were found in this county.

The reservoir property information in this database was compiled as part of a greater effort to establish the ROZ resource in the Permian Basin.

This study is a collaborative effort between Advanced Resources International, Inc. (ARI) and the National Energy Technology Laboratory (NETL) to conduct a baseline estimation of the CO_2 storage capacity and by-product oil recovery from conducting CO_2 injection-based enhanced oil recovery (EOR) in the ROZ "fairway" resources of the Permian Basin.

The database discussed in this document is found in an Excel® spreadsheet named ROZ_SanAnd_8.xlsx. The data in the sheet labeled 8_County_SanAndres_ROZ_DB are the data described in this report.

The sheet labeled OilFldData has much of the same information that is included in sheet 8_County_SanAndres_ROZ_DB, but OilFldData is accessed by the FE/NETL Onshore CO_2 EOR Evaluation Tool (Evaluation Tool) which is a Python script developed by NETL that runs StrmtbFlow and the FE/NETL Onshore CO_2 EOR Cost Model.[a] OilFldData has the structure that the Evaluation Tool requires. StrmtbFlow, which is part of the FE/NETL CO_2 Prophet Model, is a stream tube model that simulates oil recovery and CO_2 storage with CO_2 EOR. The FE/NETL Onshore CO_2 EOR Cost Model is a techno-economic model of a CO_2 EOR operation.

The sheet labeled ROZ_DB_OilVol has calculations of original oil in place and oil in place using data from the sheet named 8_County_SanAndres_ROZ_DB. This sheet and the sheet labeled OilFldData are not discussed further.

[a] The FE/NETL CO_2 Prophet Model (including StrmtbFlow) and the FE/NETL Onshore CO_2 EOR Cost Model are being posted to the NETL website at the same time this document is being posted. The FE/NETL Onshore CO_2 EOR Evaluation Tool will eventually be posted to the NETL website. Until this resource is posted, a copy can be obtained by contacting David Morgan or Derek Vikara at NETL.

2 DATABASE METHODOLOGY

The Eight County Permian Basin San Andres ROZ Database is used to estimate the oil in-place in seven counties (Andrews, Martin, Winkler, Ector, Crane, Upton, and Ward) in the San Andres formation in the Permian Basin of West Texas. (The eighth county, Midland, was found to contain no San Andres ROZ resources). To make these estimates, the ROZ resource in the San Andres formation in each county was divided into one-to-three geographically distinct areas called partitions. Each partition was then subdivided into a higher-quality and a lower-quality resource layer. The database provides central Latitude and Longitude values in decimal degrees that identify the central point of each partition.

The full set of ROZ partitions and quality layers results in 23 distinct ROZ analytic units for the seven counties in the Permian Basin, which hold all the ROZ resource oil in-place. To calculate the oil in-place, the following parameters were estimated:

- ROZ Analytic Unit Area (acres) – The total surface area of each ROZ partition or analytic unit.
- Net Pay (ft) – The net width or thickness of oil-producing zones of each ROZ analytic unit.
- Porosity (%) – The reservoir pore space, as a percentage of the total volume of each ROZ analytic unit.
- Current Oil Saturation (%) – The current oil saturation in each ROZ analytic unit as a percent of the total pore space (So_cur).
- Oil Formation Volume Factor (res bbl/STB) – The ratio of volume of oil in the reservoir (at reservoir temperature and pressure) to the volume of oil at standard surface conditions. The volume of oil at standard conditions does not include any hydrocarbon gases that may have volatilized from the oil as it equilibrated to standard temperature and pressure.

These volumetric reservoir parameters are sufficient to calculate the current resource oil in-place. However, additional reservoir parameters are needed to estimate the potential oil production and volumes of CO_2 that could be stored using CO_2 EOR. These estimates are made using StrmtbFlow.

3 ESTIMATED RESERVOIR DATA

To run StrmtbFlow, additional parameters were estimated by ARI for each ROZ analytic unit:

- Latitude and Longitude (degrees) – The latitude and longitude of the centroid of each analytic unit.
- ROZ Analytic Unit Depth (ft) – The depth from the surface to the top of each ROZ analytic unit.
- Gross Pay (ft) – The total width or thickness of each ROZ analytic unit.
- Original Oil Saturation (%) – The original saturation of oil in the ROZ analytic unit before natural water flooding occurred (So_ooip) as a percentage of the total pore space. Estimating a value for this parameter is very difficult, if not impossible, since the condition of the ROZ analytic unit millions of years ago before natural water flooding began is not known. However, StrmtbFlow uses this parameter to calculate the hydrocarbon pore volume (HCPV) and the model uses HCPV in several calculations, such as the volume of CO_2 and/or water injected during each injection period. Consequently, an estimate of this parameter is needed, but the estimated value just needs to be reasonable when compared to values for conventional oil fields. Two values are provided for this parameter. The parameter labeled Initial Oil Saturation is the value for each ROZ analytic unit borrowed from nearby conventional oil fields. The other parameter is labeled Resource Initial Oil Saturation. In some instances, the value for the Initial Oil Saturation may be low compared to more typical values for this parameter. In those instances, the value assigned to the Resource Initial Oil Saturation should be increased to make it more consistent with typical values for the initial oil saturation. For this dataset, the values assigned to the Resource Initial Oil Saturation are the same as the values in the Initial Oil Saturation. The Resource Initial Oil Saturation values are considered more realistic choices for calculating the original oil in place and better choices for the variable So_ooip in StrmtbFlow.
- Residual Oil Saturation to Water Flood (%) – The average residual oil saturation to a water flood (Sorw) in the ROZ analytic unit as a percentage of the total pore space. In principle, the oil in the ROZ has been naturally water flooded for millions of years, so there should be very little oil in the ROZ that will move during a water flood. Thus, the current oil saturation (So_cur) should be equal to or less than the residual oil saturation to a water flood. Consequently, Sorw was set equal to So_cur.
- Permeability (md) – Average reservoir permeability value. This is the horizontal permeability or the permeability in the direction of fluid flow.
- Dykstra-Parsons Coefficient (dimensionless) – A parameter with a value between 0 and 1 that provides a measure of the heterogeneity of permeability in the vertical direction. This is a measure of how the horizontal permeability varies with depth. A value of 0 indicates no variation in permeability or a perfectly homogeneous formation with respect to permeability. A value of 1 indicates an infinitely heterogeneous reservoir or a

reservoir where the standard deviation of permeability is infinite. The Dykstra-Parsons coefficient for oil reservoirs is generally measured between 0.50 and 0.93.

- Reservoir Temperature (°F) – Reservoir temperature in degrees Fahrenheit.
- Reservoir Pressure (psi) – Reservoir pressure in pounds per square inch.
- Oil Gravity (°API) – Reservoir oil gravity in degrees API.
- Hydrocarbon Gas to Oil Ratio (GOR) (scf/STB) – The ratio of hydrocarbon gas in solution in reservoir oil to the volume of oil at stock tank conditions. The hydrocarbon gas dissolved in reservoir oil gas comes out of solution when the oil is produced and equilibrates to standard conditions.
- Specific Gravity of Hydrocarbon Gas – The measure of the density of hydrocarbon gas associated with oil relative to the density of air at standard conditions.
- Oil Viscosity (cp) – Oil viscosity measured at reservoir conditions.
- Water Salinity (ppm) – The measure of the reservoir water salinity in parts per million or mg of salt per kg of solution.
- Water Viscosity (cp) – Water viscosity measured at reservoir conditions. If the water viscosity is not known, then FE/NETL CO_2 Prophet will calculate a value based on the temperature, pressure, and salinity of the reservoir.
- Minimum Miscibility Pressure (MMP) (psi) – The minimum reservoir pressure that will allow for oil and CO_2 to combine as a miscible mixture. A miscible mixture of two components is one where each component is completely soluble at all proportions in the other component. MMP was estimated using an algorithm presented by ARI: [1]

$$MMP\ (psi) = 15.988 * TRES^{(0.744206 + 0.0011038 * C5+)}$$

In this expression, TRES is the reservoir temperature in °F and C5+ is the molecular weight of a specific fraction of the oil in the reservoir, where C5+ refers to the fraction of the oil with pentanes and heavier hydrocarbons. C5+ can be estimated from the API gravity with the following equation, also found in ARI: [1]

$$C5+ = 4247.98641 * API^{-0.87022}$$

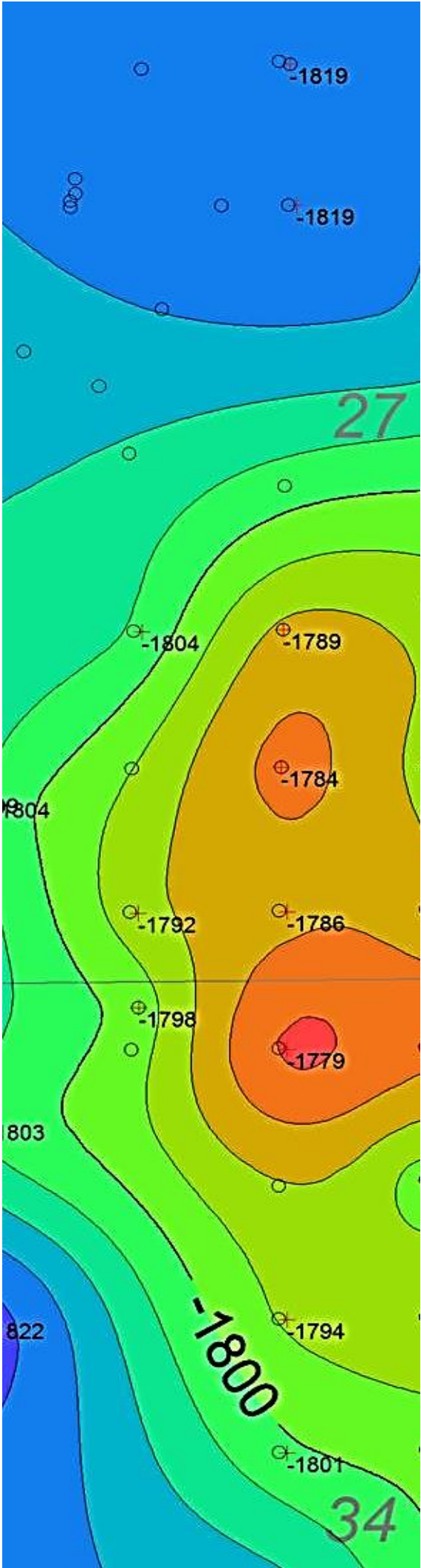
Exhibit 3-1 provides the ranges of the individual parameters for the 23 analytic units with ROZ resource oil in-place contained in the Eight County Permian Basin San Andres ROZ Database. The latitude and longitude are not included in the table since the ranges are not particularly meaningful.

Exhibit 3-1. ROZ partition reservoir parameters and data ranges

Reservoir Parameter	Data Range
ROZ Analytic Unit Area (acre)	14,800 – 236,500
ROZ Analytic Unit Depth (ft)	2,380 – 4,950
Gross Pay (ft)	120 – 621
Net Pay (ft)	47 – 377
Porosity (%)	7.5 – 12.1
Current Oil Saturation (%)	15 – 37
Oil Formation Volume Factor (res bbl/STB)	1.08 – 1.40
Initial Oil Saturation (%)	60 – 80
Resource Initial Oil Saturation	60 – 80
Residual Oil Saturation to a Water Flood (%)	15 – 37
Permeability (md)	5 – 10
Dykstra-Parsons Coefficient	0.75
Reservoir Temperature (°F)	80 - 118
Reservoir Pressure (psi)	1,020 – 2,090
Reservoir Oil Gravity (°API)	28 – 35
Hydrocarbon Gas-Oil Ratio (scf/STB)	120 – 760
Hydrocarbon Specific Gas Gravity	0.75
Oil Viscosity (cp)	0.98 – 4.50
Reservoir Water Salinity (ppm)	15,000 – 140,000
Reservoir Water Viscosity (cp)	0.61 – 1.05
Minimum Miscibility Pressure (psi)	1,162 – 1,666

4 REFERENCES

[1] Advanced Resources International, Inc. (ARI), "Basin Oriented Strategies for CO2 Enhanced Oil Recovery: Permian Basin," prepared for U.S. Department of Energy, Office of Fossil Energy – Office of Oil and Natural Gas, 2006.



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