STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION COMMISSION

APPLICATION OF GOODNIGHT MIDSTREAM PERMIAN, LLC FOR APPROVAL OF SALTWATER DISPOSAL WELLS LEA COUNTY, NEW MEXICO — **CASE NOS. 24123**

APPLICATIONS OF GOODNIGHT MIDSTREAM PERMIAN, LLC FOR APPROVAL OF SALTWATER DISPOSAL WELLS LEA COUNTY, NEW MEXICO — **CASE NOS. 23614-23617**

APPLICATION OF GOODNIGHT MIDSTREAM PERMIAN LLC TO AMEND ORDER NO. R-22026/SWD-2403 TO INCREASE THE APPROVED INJECTION RATE IN ITS ANDRE DAWSON SWD #1, LEA COUNTY, NEW MEXICO. — **CASE NO. 23775**

APPLICATIONS OF EMPIRE NEW MEXICO LLC TO REVOKE INJECTION AUTHORITY, LEA COUNTY, NEW MEXICO — **CASE NOS. 24018-24027**

GOODNIGHT MIDSTREAM'S NOTICE OF REVISED TESTIMONY: WILLIAM KNIGHTS

Goodnight Midstream Permian, LLC ("Goodnight Midstream"), through undersigned counsel, respectfully provides notice pursuant to the agreement of the parties, that it is filing a revised self-affirmed statement for William J. Knights.

While preparing his rebuttal testimony, Mr. Knights determined that his initial self-affirmed statement filed in these matters on August 26, 2024, included an inadvertent calculation omission rendering his original oil in place ("OOIP") estimates incorrect. Specifically, Mr. Knights determined that his OOIP calculations were based on the incorrect assumption that the petrophysical data prepared by Dr. James Davidson were on one-foot increments when, in fact, the data were in half-foot increments. The estimates in Mr. Knights' self-affirmed statement should have been half the values of what he originally provided. This calculation error has been corrected in the revised self-affirmed statement.

In addition, Mr. Knights' used a "practical threshold" of 30% oil saturation ("S_o") in preparing his initial analysis in his original self-affirmed statement based on his determination that that cutoff "more closely represents an average to better-than-average reservoir quality of existing CO_2 projects." *See* Goodnight Exhibit E, Testimony of William J. Knights, filed August 26, 2024. However, Mr. Knights has determined that a cutoff of S_o of greater than 20% "more closely aligns with a minimal saturation . . . to define an ROZ [residual oil zone]," according to Empire's expert witnesses Dr. Melzer and Dr. Trentham. Mr. Knights decided his analysis should use a 20% cutoff following his deposition on December 12, 2024, when Empire counsel queried him on the basis for his 30% cutoff and after some consideration. Accordingly, Mr. Knights' revised testimony includes a revised calculation for OOIP using the correct petrophysical data increments and summing hydrocarbon pore volumes values using a 20% S_o cutoff rather than a 30% S_o cutoff.

No other changes or updates were made to Mr. Knights' original analysis or testimony. A redline version of Mr. Knights' revised self-affirmed statement showing all the revisions is attached as **Exhibit A**. A clean version of his revised testimony has been filed with the Commission and served on all parties as Goodnight *Revised* Exhibit E.

DATED: January 21, 2025

Respectfully submitted,

HOLLAND & HART LLP

/s/ Adam G. Rankin
By: ______________________________

Michael H. Feldewert
Adam G. Rankin
Nathan R. Jurgensen
Paula M. Vance
Post Office Box 2208
Santa Fe, NM 87504
505-988-4421
505-983-6043 Facsimile
mfeldewert@hollandhart.com
agrankin@hollandhart.com
nrjurgensen@hollandhart.com
pmvance@hollandhart.com

ATTORNEYS FOR GOODNIGHT MIDSTREAM PERMIAN, LLC

CERTIFICATE OF SERVICE

I hereby certify that on January 21, 2025, I served a copy of the foregoing document to the following counsel of record via Electronic Mail to:

Ernest L. Padilla
Padilla Law Firm, P.A.
Post Office Box 2523
Santa Fe, New Mexico 87504
(505) 988-7577
padillalawnm@outlook.com

Dana S. Hardy
Jaclyn M. McLean
HINKLE SHANOR LLP
P.O. Box 2068
Santa Fe, NM 87504-2068
(505) 982-4554
dhardy@hinklelawfirm.com
jmclean@hinklelawfirm.com

Sharon T. Shaheen
Daniel B. Goldberg
Spencer Fane LLP
Post Office Box 2307
Santa Fe, New Mexico 87504-2307
(505) 986-2678
sshaheen@spencerfane.com
dgoldberg@spencerfane.com
ec: dortiz@spencerfane.com

Attorneys for Empire New Mexico, LLC

Miguel A. Suazo
BEATTY & WOZNIAK, P.C.
500 Don Gaspar Ave.
Santa Fe, NM 87505
Tel: (505) 946-2090
msuazo@bwenergylaw.com

Attorneys for Pilot Water Solutions SWD, LLC

Jesse Tremaine
Chris Moander
Assistant General Counsels
New Mexico Energy, Minerals, and Natural Resources Department
1220 South St. Francis Drive
Santa Fe, New Mexico 87505
(505) 741-1231
(505) 231-9312
jessek.tremaine@emnrd.nm.gov
chris.moander@emnrd.nm.gov

Attorneys for New Mexico Oil Conservation Division

Matthew M. Beck
PEIFER, HANSON, MULLINS & BAKER, P.A.
P.O. Box 25245
Albuquerque, NM 87125-5245
Tel: (505) 247-4800
mbeck@peiferlaw.com

Attorneys for Rice Operating Company and Permian Line Service, LLC

Adam G. Rankin
Adam G. Rankin

EXHIBIT A

NETHERLAND, SEWELL & ASSOCIATES, INC.

INTRODUCTION

Netherland, Sewell & Associates, Inc. (NSAI) has been retained by Goodnight Midstream Permian, LLC (Goodnight) to (1) conduct a geologic study of the lands in and around the Eunice Monument South Unit (EMSU) and in particular the San Andres Formation; (2) evaluate and confirm the presence of geologic barriers isolating the San Andres Formation from the overlying Grayburg Formation; and (3) prepare an oil-in-place (OIP) assessment for the San Andres Aquifer within the EMSU.

SUMMARY OF QUALIFICATIONS

My name is William J. Knights. I work for NSAI as a Vice President and Senior Technical Advisor. I have been with NSAI since 1991. I earned my Bachelor and Master of Science degrees from Texas Christian University in 1981 and 1984, respectively. I am a licensed Professional Geoscientist in the State of Texas since 2003, license number 1532. I am also an AAPG Certified Petroleum Geologist since 1994, license number 5188, and have over 40 years of experience in the oil and gas industry. My Curriculum Vitae is attached herein as Appendix A.

Before joining NSAI, I worked as an independent petroleum geologist, evaluating domestic and international exploration and development projects. Since 2002, I have had extensive experience in all of the productive and emerging unconventional shale plays in the United States and Canada, as well as in many prospective unconventional plays internationally. I have been involved in the estimation and classification of hydrocarbon volumes from prospective and contingent resources through proved, probable, and possible reserves in both unconventional and conventional reservoirs. I have extensive experience preparing and reviewing oil and gas reserves reports and performing due diligence reviews for financial transactions in the oil and gas industry. My responsibilities include structural/stratigraphic analysis using geophysical, geological, and petrophysical data interfaced with reservoir modeling to determine reservoir quality and in-place hydrocarbon volumes. With respect to tertiary recovery projects, I have worked the Altura property divestiture (Occidental Petroleum Corporation acquisition of BP and Shell Permian Basin assets), Yates Field (specifically, the Grayburg and San Andres Formations oil field), and Cantarell Field in southern offshore Mexico (the largest nitrogen injection project in the world). I have not previously testified before the New Mexico Oil Conservation Commission as an expert witness in petroleum geology.

SUMMARY

The San Andres Formation is a laterally extensive, high-permeability aquifer. Any injected water can be displaced over large lateral areas, and, since the San Andres Formation is in a migration pathway, oil saturations (S_o), while not unexpected, are not concentrated enough to be considered a target for recovery. Four separate depth intervals have been evaluated based on their evidence of movable fluids, yet no evidence of significant movable hydrocarbons is demonstrated below -500 feet (ft) true vertical depth subsea (TVDSS). Water being injected into the deeper San Andres Aquifer is vertically separated from the producing Grayburg Reservoir and from any potential residual oil zones (ROZs) by numerous vertical permeability barriers that extend across the EMSU. When evaluating potential OIP targets for tertiary recovery, the producing Grayburg Reservoir is the only interval above -500 ft TVDSS that has sufficient OIP concentration to warrant an economic evaluation to determine viability. Reservoirs below -500 ft TVDSS in the EMSU have insufficient OIP concentration to warrant economic evaluation.

NETHERLAND, SEWELL & ASSOCIATES, INC.

FIELD OVERVIEW

The EMSU is a secondary recovery project in the Permian Grayburg Formation reservoir. The Grayburg Formation is part of the large Permian Grayburg and San Andres Formation petroleum system that extends across the Delaware Basin and the Central Basin Platform (CBP) as shown in Figure 1. The Grayburg and San Andres Formations on the CBP are created by the migration of oil from the deeper Delaware Basin source rocks and into updip stratigraphic and structural traps as shown in Figure 2. Because of its thickness and lateral extent, the San Andres Formation is the more prolific of the two. The San Andres fields are located on the eastern edge of the CBP, while the Grayburg fields are more prevalent on the flanks of both the eastern and western edges of the CBP. These are depletion drive reservoirs with weak water drive, requiring additional pressure support from water injection to increase recovery. In some fields, additional recovery can be achieved by injecting carbon dioxide (CO_2) as an additional drive mechanism to improve residual oil mobility. Economic recovery from secondary and tertiary methods typically occurs in rocks with very little variation in permeability and porosity. This allows a large portion of the oil to be contacted by the injectant. Poor secondary and tertiary recoveries would occur in formations with significant variations in permeability and porosity. Oil concentration in the interval targeted for secondary and tertiary recovery methods is a key component for economic viability. In other words, the higher the oil concentration, the more likely it is to achieve economic recovery. The concentration of oil in a formation is calculated using hydrocarbon pore volume (HCPV) estimates from a combination of both S_o and porosity. Enhanced secondary and tertiary recovery methods require sources of water or gas for injection and a formation suitable for the disposal of any excess nonhydrocarbons produced. EMSU is a complete secondary recovery, economic hydrocarbon system in a concentrated oil reservoir with significant volume of primary oil recovery. The high-permeability and nonhydrocarbon aquifer in the San Andres Formation provides a source for injection water and can be used to dispose of excess fluids.

EMSU FIELD HISTORY

Eunice Field was discovered in March 1929. The field was initially slow to develop because of a lack of infrastructure, but by January 1, 1939, 474 wells had been completed across the field's 18,960 acres at approximately 40-acre spacing. Recovery in the field continued until a waterflood program was initiated in 1986 by Chevron Corporation (Chevron). Much of the early reservoir data reviewed in this report came from the 1983 Technical Committee Report on the proposed EMSU secondary recovery project.

The EMSU in Eunice Field is currently developed across 14,190 acres. The drive mechanism is characterized by a rapid decline in reservoir pressure without a rise in water production, leading to the conclusion that it is a solution gas drive reservoir. Early water encroachment from the south and east areas of the field supplied only a minor amount of aquifer pressure support. In the 1983 study, it was found that the primary oil production through October of 1982 amounted to 120 millions of barrels of oil (MMBO), the estimated ultimate recovery was 134 MMBO, the water-to-oil production ratio was four-to-one, the oil cut was 20 percent, and an original oil-in-place (OOIP) was estimated at 671 MMBO, based on an assumed 20 percent recovery factor. Chevron became the primary operator in February 1985. Initial water injection began in 1986 at a rate of about 85,000 barrels (BBL) of water per day and is still continuing as a waterflood project as of July 2024.

Opinions discussed herein are based on my review of electric logs, sample logs, core descriptions, core analysis, completion reports, and production data associated with the EMSU and in the surrounding area, as shown in Figure 3. NSAI collected data from public sources for 461 wells in the immediate EMSU area along with additional nearby wells, to create TVDSS cross sections of the well bore paths and perforated intervals. Core data for the EMSU 679 well were only available below the current producing interval. Additional representative core samples describing the lithology, porosity, and permeability in the EMSU area were presented in the Reservoir Characteristics of the Eunice Oil Field report by Anderson, Hinson, and Schroeder, which was prepared for the U.S Bureau of Mines. There are seven wells with mudlog data that we also reviewed that relate to lithology and fluid saturation depths in the EMSU area. These are the EMSU 577, 628, 658, 660, 673, 713, and 746 wells. NSAI performed petrophysical analysis for eight wells: EMSU 628, 658, 660, 673, 679, 713, 746, and Ryno (previously Snyder). We also reviewed two area wells with spectral gamma ray logs: SEMU BTD 123 and Central Drinkard Unit 441. The EMSU 679 is the only one of these wells to have both core and log data below the producing oil-water contact (OWC) of -350 ft TVDSS, so it was used to calibrate the NSAI petrophysical model. We used these data for an analysis of porosity, permeability, fluid saturations, and OIP estimates in the EMSU.

We examined ten historical water supply wells that have produced water from reservoirs below the producing Grayburg Reservoir in the San Andres Formation, with six of these wells within the EMSU. These are the EMSU 457, 458, 459, 460, 461, and 462 wells, operated by Chevron. The other four water supply wells are located to the south of the EMSU in the Arrowhead Grayburg Units: the AGU 600 and 601, the Janda 060, and the State 060. The performance of the San Andres Formation water supply wells indicates both the size and permeability of the formation.

There are 18 water disposal wells in the area injecting into the San Andres Aquifer below the producing Grayburg Formation, of which 8 are on EMSU acreage. The Dawson, Sosa, Snyder, and Banks wells are operated by Goodnight; the Rice N11 and EME 21 (also known as the Rice 21) wells are operated by Permian Line Service, LLC; the Owl P15 well is operated by Pilot Water Solutions; and the Empire 1 well is operated by Empire Petroleum Corporation (Empire). Outside the EMSU, Goodnight operates the Piper, Ted Williams, Nolan Ryan, Yaz, Scully, and Pedro wells; Rice Operating Company operates the Rice N7, EME 33 (also known as the Rice 33), and the State E Tract 27 (also known as Rice E27) wells; and Parker Energy Support operates the Parker well.

A list of materials relied upon for this analysis is included in Appendix B. Other resources used in the analysis for this report are listed in Appendix C, and a list of abbreviations is included in Appendix D.

GEOLOGIC CONCLUSIONS

I. San Andres Regional Geologic Setting - Regional Aquifer

The San Andres Formation is a laterally extensive, high-permeability aquifer. Any injected water can be displaced over large lateral areas, and, since the Sand Andres Formation is in a migration pathway, S_o, while not unexpected, are not concentrated enough to be considered a target for recovery.

The San Andres Formation can be up to 1,600 ft thick and has depositional trends based on historical bathymetry. These trends include a deepwater depositional environment generating low-permeability carbonates, a nearshore ramp environment creating high-porosity carbonates, and a shallow tidal depositional environment producing low-porosity carbonates. Depositional environments have changed over time creating distinct stratigraphic pay intervals that can be correlated from the Guadalupe Mountains in the west to the CBP in the east. There are five regional pay units that are productive along the oil migration pathways: Holt, McKnight, Intermediate, Judkins, and Lovington (Trentham, 2012). Most of the oil that migrated through the San Andres Formation in the New Mexico portion of the CBP continued to move updip and into the eastern flank of the CBP in Texas. The five regional pay units were sourced by oil generated in the deeper Delaware Basin to the west.

Oil entered the San Andres Aquifer and migrated through a complicated porosity system to create several isolated reservoirs with varying compositions of salinity and hydrocarbon saturation. These reservoirs include both mobile oil in productive fields across the CBP and residual oil scattered along the migration pathways. A map of the migration in the EMSU is shown in Figure 4. Subsequent structural movement has caused some secondary flushing of previously trapped oil. This leaves behind more continuous ROZs associated with conventional traps that are predominantly on the east side of the CBP. There are 15 major updip San Andres fields that have produced over 1.9 billion BBL of oil, as of March 2024, from the San Andres Formation reservoirs, as shown in Figure 5. The

EMSU is along the downdip migration pathways and is not a part of a major structural or stratigraphic trap in the San Andres Formation. The major San Andres Formation reservoirs are distributed across the updip portions of the CBP. These reservoirs are the result of the regional extent of the aquifer and migration pathways and indicate that any withdrawal or injection volumes into these reservoirs could be displaced across large areas.

The San Andres Formation in the EMSU has been used as a source for water injection operations and is currently being used as a water disposal interval by numerous companies including Empire. Chevron developed one of these isolated and permeable San Andres Formation reservoirs beneath the EMSU as a source for injection water. The six Chevron-operated water supply wells have produced over 340 millions of barrels (MMBBL) of water from 1987 to the present.

The significant withdrawal of water volumes from the EMSU water supply wells over the 30 years of production history has not diminished their ability to produce at high rates. Although 340 MMBBL of water was extracted from this aquifer, no oil was reported to have been produced from these wells. These large volumes of water are an indication of both the extent of the connected reservoir and the good permeability throughout the reservoir, establishing this as a large aquifer rather than an oil reservoir. Our well log analysis and review of mud log data do indicate some scattered areas of elevated S_o in these water production intervals, but not at S_o levels high enough or laterally continuous enough to be a target for oil production.

More recently, seven water disposal wells that Goodnight drilled to the south of the Chevron water supply wells found a consistent zone of lost circulation below the producing Grayburg Reservoir. The lost circulation zones encountered by Goodnight while drilling its water disposal wells are in the same stratigraphic interval as the Chevron water supply wells that extracted over 340 MMBBL of water. These lost circulation zones are typically caused by extremely high permeability and/or lower pressure relative to the surrounding strata. This evidence suggests that the current Goodnight water injection intervals in the aquifer are most likely injecting into the same extensive reservoir from which the water supply wells produced. The similar stratigraphic interval of the lost circulation zones across all seven Goodnight water injection wells also indicates that this is a laterally extensive, high-permeability zone. The large volumes of water extracted from the EMSU, and the indications of laterally extensive, high-permeability zones from the recent San Andres injection wells, suggest that any injected water will be displaced over a large lateral area.

II. Evidence of Movable Hydrocarbons

Four separate depth intervals have been evaluated based on their evidence of movable fluids, yet no evidence of movable hydrocarbons is demonstrated below -500 ft TVDSS.

NSAI's independent petrophysical analysis does not indicate any significant S_o below -661 ft TVDSS, which corroborates the low S_o observations in core data and lack of any oil recovery from the water supply wells. In the EMSU, the original gas-oil contact (GOC) in the Grayburg Formation reservoir is defined at -100 ft TVDSS, and the OWC is estimated between -325 to -350 ft TVDSS, as defined in the unitization document. We have defined -350 ft TVDSS as the producing oil-water contact (POWC). We reviewed the three deepest wells with perforations in the EMSU below -500 ft TVDSS: the EMSU 577, 658, and 660. The EMSU 577 well tested the interval from -457 to -588 ft TVDSS, in which 220 BBL of water and 1 BBL of oil were swabbed on February 22, 2006, with an oil cut of 0.5 percent. Later, it tested with an oil cut of 6.6 percent with 45 BBL of oil, 636 BBL of water, and 63 thousands of cubic feet of gas produced with an electrical submersible pump (ESP) on February 26, 2006. Eighteen days later, on March 14, 2006, a cast iron bridge plug was set above these perforations at -422 ft TVDSS. The EMSU 577 well is the deepest indication of any movable oil in the EMSU. The next two intervals perforated in the EMSU 577 well were above the POWC, and these intervals produced both oil and water. The EMSU 658 well tested the interval from -395 to -576 ft TVDSS and recovered 667 BBL of salt water with no indications of oil on February 9, 2006. This interval was then tested using an ESP and produced 1,856 BBL of water and 2 BBL of oil on March 10, 2006, resulting in an oil cut of 0.1 percent. The EMSU 658 well was then perforated above the POWC and tested oil and water on June 4, 2006. From December 2005 to January 2006, the EMSU 660 well tested the interval from -548 to -661 ft TVDSS. The well was acidized, then pump tested 4,056 BBL of water and 7 BBL of oil with an oil cut of 0.2 percent. A cast iron bridge plug was set at -422 ft TVDSS on March 3, 2006, then the well was perforated above the POWC from -206 to -334 ft TVDSS and tested oil and water on March 10, 2006. The average oil cut for these three deep tests was 0.8 percent, which is significantly lower than the 20 percent oil cut obtained in the period from 1980 to 1981, after 40 years of primary production and prior to waterflood. Oil cut and water cut for the deep well tests and the pre-waterflood EMSU are summarized in Figure 6. Data for key wells and their completion intervals are shown in Figure 7.

The six water supply wells within the EMSU have produced over 340 MMBBL of water from below the producing Grayburg Formation reservoir with no reported oil production. The upper perforations in these wells are at -500 ft TVDSS in the EMSU 458 well and they have no indications of produced oil. This establishes an upper limit of the aquifer at -500 ft TVDSS at this location.

Our analysis of core data suggests that the deepest continuous S_o above 20 percent is in the EMSU 679 well at -650 ft TVDSS. The NSAI log analysis in the EMSU 679 well has consistent S_o greater than 20 percent down to -660 ft TVDSS and scattered S_o as deep as -704 ft TVDSS. These data could indicate a possible base of a ROZ at this well location. The EMSU 679 well was completed from -256 to -500 ft TVDSS and produced oil and water. Additional log analysis in the EMSU 713 and EMSU 746 wells indicated continuous S_o greater than 20 percent down to -450 and -524 ft TVDSS, respectively. Additionally, the EMSU 713 and EMSU 746 wells indicated scattered S_o greater than 20 percent at -486 ft TVDSS and -672 ft TVDSS, respectively. An S_o comparison for the EMSU 679 core analysis to log analysis for the EMSU 679, EMSU 713, and EMSU 746 wells are shown in Figure 8. These S_o intervals indicate an uneven base of possible ROZ with a variability in depth for a minimal ROZ depth target between -450 and -704 ft TVDSS. Figure 9 shows the interpreted depth of deepest potential ROZ, based on a continuous S_o greater than 20 percent in the EMSU. Therefore, based on our analysis, any targeted oil recovery above -450 ft TVDSS would have the best chance to extend across a larger area, but S_o below -450 ft TVDSS would be restricted to the local area around the EMSU 679 and 746 wells to a maximum depth of -660 ft TVDSS.

Our review of available mud log data had indicated S_o and/or oil staining in intervals below -661 ft TVDSS down to as deep as -1,036 ft TVDSS. The seven wells with mud logs we reviewed had various oil staining and fluorescence. These shows of oil are not indications of any likely economic oil recovery targets based on the POWC at -350 ft TVDSS, a highest test of water without any oil at -500 ft TVDSS, and the lowest indication of scattered S_o above 20 percent at -704 ft TVDSS based on log and core data. The lack of data supporting significant movable oil below the POWC makes these depth intervals questionable for any significant oil recoveries. The highest upper perforations in the Goodnight injection wells are at -720 ft TVDSS, which is below both the estimated POWC, the highest water only test, and the lowest indication of oil. We have found no data to support that the current disposal intervals in the EMSU, or any interval below the highest water only test at -500 ft TVDSS, as being a reasonable target for economic oil recovery.

III. Separation of Reservoir from Aquifer - Permeability Barriers

Water being injected in the deeper San Andres Formation is vertically separated from the producing Grayburg Reservoir and any potential ROZ by numerous vertical permeability barriers.

The EMSU is located along the northwestern edge of the CBP, as shown in Figure 1. The unit is composed of the producing Grayburg Reservoir and the underlying San Andres Aquifer. These formations were deposited in typical marine and restricted-marine environments, with most of the EMSU deposition occurring in a predominantly shallow-water, carbonate ramp environment. These carbonate deposits are controlled by water depths that change over time with short-term tidal action and longer-term eustatic sea level changes. These changes cause the various carbonate rock types to change positions both vertically and laterally. In general, the shallower the water, the more the carbonate rock types will change over shorter distances. The best reservoirs are deposited in shallow, higher-energy environments (e.g., grainstones), which transition to lower-energy environments. Lower-quality carbonate reservoirs deposited in slightly deeper water (e.g., packstones and wackestones) are generally thicker and more laterally extensive. Porosity is highest in the grainstones and packstones, with mud-rich wackestones forming low-permeability barriers. The higher gamma ray response in the underlying San Andres Formation, caused by the retention of uranium, indicates that these carbonates were deposited in slightly deeper waters relative to the producing Grayburg Reservoir and are more likely to be low-permeability barriers. Early diagenesis, caused by periodic variation in sea level, has further complicated reservoir distribution by allowing for dissolution, dolomitization, and the deposition of pore-filling secondary calcite, dolomite, and anhydrite in the producing Grayburg Reservoir.

The initial deposition and subsequent diagenetic activity created the stratigraphic variability and compartmentalization that define the eastern trapping mechanism in the EMSU producing Grayburg Reservoir. A northwest-to-southeast-trending anticline creates an oil trap on the southern and western portions of the field. A representative set of 12 core plugs in the EMSU Grayburg Formation was described and included a variety of lithologies, including porous oolitic dolomite, fine-grained dolomitic sandstone, dolomites with local dark streaks, and oolitic dolomites embedded in sandy dolomite (Anderson, 1939). The significant amount of fine-grained sand, oolites, and dolomite all indicate a very shallow-water, nearshore environment in the Grayburg Formation reservoir. It was noted by Anderson that these lithologies cut across structures, making correlations using lithology or log character difficult. Oil production in the EMSU is restricted to higher-permeability carbonates above the POWC. These complex carbonate environments make it difficult to estimate fluid saturations and permeabilities using a simple petrophysical model with standard values and to explain why actual oil production is a key component in any analysis of future potential.

In addition to petrophysical models, various publications have presented evidence of permeability barriers throughout the Grayburg Formation as an indication of the type of barriers that exist within and below the producing Grayburg Reservoir. Early initial potential (IP) tests showed variable gas-oil ratios at similar subsea depths, which indicates vertically isolated completions within the producing Grayburg Reservoir. Based on lithology and performance, three potential isolated reservoirs, called Zone A, Zone B, and Zone C, were interpreted. Cross sections showing lithologies, perforations, shows, IP test results, and casing seat points across the EMSU are shown in Figures 10 and 11. The highlighted permeability barriers (Anderson, 1939) were interpreted early in the analysis of the field and range from 20 to 40 ft thick and extend laterally across the field.

A 1998 Society of Petroleum Engineers (SPE) paper (Love, McCarty, Miller, and Semmelbeck, 1998) was published and attempted to diagnose the poor performance in the EMSU. This paper identified the main issue as poor vertical conformance primarily due to extensive horizontal permeability streaks, indicating that low-permeability streaks confined movement of fluids along horizontal layers. This confined movement caused a good portion of the oil in lower-permeability rock to be bypassed with water cycling mainly through the high-permeability layers. As shown in Figure 12, the complex stratigraphy and horizontal layering are exemplified by a stratigraphic cross section showing up to 82 separate depositional cycles, simplified into seven practical zones for the EMSU Grayburg Formation (Lindsay, 2014). The 1998 SPE paper described the EMSU as having six zones, similar to Lindsay's description, and described Zone 4 as a clastic-rich (sandy/silty) rock that forms a pressure barrier. "It is vertically impermeable, can have good porosity zones, and the upper surface of this zone is described as a karsted surface" (Love, et al., 1998).

Based on our review of spectral gamma ray logs, there is an interval of increasing gamma ray at the base of the Grayburg Formation correlated across the EMSU, as shown in Figure 13. This interval correlates across the EMSU and could act as a permeability barrier between the overlying reservoir and the underlying aquifer. NSAI petrophysical analysis of permeability in three Goodnight injection wells on the south end of the EMSU shows a significant number of vertical permeability barriers in the same correlative interval at the base of the Grayburg section. Additional permeability barriers are present throughout the interval as shown on Figure 14. The dark blue line on the logs identifies the depth of lost circulation while drilling. These indicate a significant change in the

NETHERLAND, SEWELL & ASSOCIATES, INC.

reservoir characteristics from the overlying strata with both higher permeability and lower pressure at that depth. The red bar in the center of the wells in Figure 14 represents the perforated interval where the current water injection occurs. The key, continuous, thick permeability barrier above the Goodnight San Andres water injection intervals and above the lost circulation zones is also shown. Multiple vertical permeability barriers can be seen throughout the Grayburg Formation that clearly show separation between the water-injection and oil-producing intervals.

The permeability barriers in the 1939 Anderson analysis, the spectral gamma ray cross section, and the loss circulation intervals in the NSAI petrophysical analysis all indicate that the interval between the producing Grayburg Reservoir and the San Andres Aquifer is a consistent permeability barrier across the EMSU area.

IV. Concentration of Hydrocarbons - Quality of Potential

When evaluating potential OIP targets for tertiary recovery, the producing Grayburg Reservoir is the only interval above -500 ft TVDSS that has sufficient OIP concentration to warrant an economic evaluation to determine viability. Reservoirs below -500 ft TVDSS in the EMSU have insufficient OIP concentration to warrant economic evaluation.

After reviewing data across the area, NSAI evaluated four potential future oil recovery targets using an HCPV model. The four intervals evaluated include the currently developed EMSU producing Grayburg Reservoir extending from the GOC down to POWC, the potential ROZ extending below the POWC to the highest water only tested based on the water supply wells, the transition zone spanning from the base of potential ROZ to -700 ft TVDSS used to approximate the lowest indication of S_o from log analysis, and below the transition zone is designated as an aquifer. The saturation profiles reviewed in the EMSU did not conform to the continuous gradational ROZ models proposed in various articles by Trentham and Meltzer. Instead, I have defined four intervals to evaluate hydrocarbon potential with slightly different nomenclature. These intervals were evaluated based on indicators of reservoir quality such as gross OIP, the size of the target, and oil concentration. The EMSU producing Grayburg Reservoir is a reasonable target for tertiary recovery. The potential ROZ in the Grayburg Formation has no indications of significant movable hydrocarbons but does have a reasonable OIP concentration that could possibly be targeted for tertiary recovery. The transition interval below that zone has significantly less OIP distributed across a much larger rock volume and would not make a reasonable target for oil recovery. The deeper aquifer that serves as Goodnight's disposal interval has no potential as an oil recovery target since there is no significant indication of OIP.

A. Summary of OOIP Distribution Above ~~30~~20 Percent Oil Saturation

Economic viability is dependent on a number of factors, especially the defining of a continuous concentration of S_o. The higher the concentration of S_o, the more likely a development is to be economic. Since any secondary or tertiary recovery project has to develop the entire available gross rock volume, a large OIP spread across a thick interval is significantly less attractive from an economic perspective. The ability to identify areas of potentially recoverable oil is determined by calculating porosity and S_o, with higher porosity and S_o indicating that the hydrocarbons are more concentrated and movable. We used HCPV estimates to determine OIP per unit volume, which is an indicator of reservoir quality that is directly related to potential recovery factors.

To estimate the HCPV within the EMSU, we used the NSAI petrophysical model results to analyze the potential quantity of the OIP in each of the four potential future oil recovery intervals. While Meltzer has defined ROZ S_o to be as low as 20 percent, typically, mean S_o ranges from 27 to 39 percent in carbonate reservoirs at the start of CO_2 projects (Olea, 2017; Verma, 2017). For the purposes of our initial analysis, we used the more practical threshold of 30 percent S_o, which more closely represents an average to better-than-average reservoir quality of existing CO_2 projects. The 30 percent OOIP was created by summing the hydrocarbon pore volume values, but the calculations did not adjust for petrophysical data presented in ½-foot increments. Therefore, the correct estimates should have been half of the values in the previous report. For our updated analysis, we used a cutoff of S_o greater than 20 percent, which aligns more closely with a minimal saturation used by Meltzer to define an ROZ. The NSAI model calculated HCPV across the entire stratigraphic section and subdivided it into three reservoir quality groups. Tier 1 was based on standard industry water saturation cut-offs of 60 percent or greater than 40 percent S_o. Tier 1 reservoirs represent the highest concentration of oil that can be targeted for conventional primary recovery and an optimum target for secondary or tertiary recovery. Tier 2 reservoirs have between 40 and 30 percent S_o. These are generally not targets for primary recovery and in certain circumstances have been targeted for tertiary recovery by use of CO_2, steam, or nitrogen injection. Tier 3 reservoirs are between 30 and 20 percent S_o. Intervals with scattered S_o above 20 percent are defined as aquifers. Intervals with less than 20 percent S_o and are best described as "oil-stained." These reservoirs are not a reasonable target for oil recovery by primary or tertiary means and are well below the threshold for consideration as an ROZ.

B. Summary of the OIP and OIP Concentration Analysis

On average, the producing Grayburg Reservoir has a significant amount of OIP, with ~~31.7~~22.3 MMBO per section across a 250-ft gross interval or a concentration of ~~198~~139 BBL of oil per acre-foot (BO/ac-ft). Extrapolating this OIP across the 14,190 developed acres in the EMSU yields ~~702~~494 MMBBL of OIP. Figure 15 shows the distribution of S_o and OIP across the various depth intervals in the EMSU. In the 1983 Technical Committee Report, pre-waterflood primary recovery was estimated to be 134 MMBO, or about ~~19~~27 percent of OIP, and secondary recovery was estimated between 24 and 66 MMBO over the next 30 years. The current secondary oil recovery is based on EMSU cumulative oil. As of March 2024, the EMSU has produced 147 MMBO, or about ~~21~~30 percent of OIP. This is approximately 13 MMBO, or ~~2~~about 3 percent of OIP, more than the initial estimates of primary recovery. This low recovery factor for the waterflood can be explained by the highly variable depositional environment that can produce relatively thin beds with highly variable permeability and very limited areal extent. These reservoir characteristics would also indicate that the current EMSU Grayburg Formation reservoir would be a poor tertiary recovery candidate.

The potential Grayburg ROZ between -350 and -500 ft TVDSS has a reasonable amount of OIP. On average, this zone has ~~11.3~~9.7 MMBO per section across a 150-ft gross interval or a concentration of ~~118~~101 BO/ac-ft. Extrapolating this OIP across the 14,190 developed acres in the EMSU yields ~~252~~215 MMBBL of OIP, which is less than 50 percent of the estimated OIP in the EMSU producing Grayburg Reservoir. This potential Grayburg ROZ has lower OIP, which would make this a less desirable target for any recovery relative to the developed EMSU Grayburg Reservoir. We have found no indications of oil recovery or movable hydrocarbons across this interval that could indicate that this may be a ROZ target for tertiary recovery.

The transition zone between -500 and -700 ft TVDSS has a small amount of OIP. On average, this zone has ~~5.~~6.4 MMBO per section across a 200-ft gross interval with a concentration of ~~44~~49 BO/ac-ft. Extrapolating this OIP across the 14,190 developed acres in the EMSU yields ~~125~~141 MMBBL of OIP, which is less than ~~25~~30 percent of the developed OIP in the EMSU. The low concentration of OIP in this interval would not be a reasonable target for any type of recovery.

The aquifer below -700 ft TVDSS has a small amount of OIP. On average, the aquifer has ~~1~~3.2 MMBO per section across a 1,000-ft gross interval with a concentration of ~~2~~5 BO/ac-ft. Extrapolating this OOIP across the 14,190 developed acres in the EMSU yields ~~26~~71 MMBBL of OIP, which is less than ~~5~~15 percent of the developed OIP in the EMSU. The low concentration of OIP in the San Andres Aquifer interval would not be a reasonable target for any type of recovery.

CONCLUSION

There is a lack of significant oil concentration below -500 ft TVDSS, making it an unreasonable target for enhanced oil recovery within either the Grayburg or San Andres Formations below that depth. The producing Grayburg

Reservoir is isolated and separated from the underlying San Andres Aquifer by multiple, laterally extensive permeability barriers. The San Andres Aquifer is a regionally extensive reservoir that has data supporting pressure separation from the overlying producing Grayburg Reservoir in the EMSU. The San Andres Aquifer has a significant areal extent, with sufficient high-permeability intervals to handle a large volume of disposed water without impacting the overlying EMSU. The poor performance of the secondary recovery project within the producing Grayburg Reservoir is a strong indication of the magnitude of recovery that may occur from any tertiary project in that interval. Significant additional evaluation would be required to determine if a tertiary recovery project could be economically viable in the oil-producing EMSU.

DISCLAIMER

This report summarizes my analysis and opinions to date. I reserve the right to amend or supplement this report, if necessary, should additional information become available to me, and to rebut any related opinions reached by experts related to these cases. All the opinions and conclusions herein are rendered to a reasonable degree of professional certainty.

I affirm under penalty of perjury under the laws of the State of New Mexico that the foregoing statements are true and correct. I understand that this self-affirmed statement will be used as written testimony in this case. This statement is made on the date next to my signature below.

Sincerely,

William J. Knights, P.G. 1532
Vice President

Date Signed: ~~August 26, 2024~~January 16, 2025

WJK:LMS