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

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. 24018-24020, 24025

APPLICATION OF GOODNIGHT PERMIAN MIDSTREAM, LLC FOR APPROVAL OF A SALTWATER DISPOSAL WELL, LEA COUNTY, NEW MEXICO.

DIVISION CASE NO. 22626
ORDER NO. R-22869-A
COMMISSION CASE NO. 24123

SELF-AFFIRMED SUR-REBUTTAL STATEMENT OF JAMES A. DAVIDSON

1. My name is James A. Davidson. I work for Netherland, Sewell & Associates, Inc. ("NSAI") as Vice President and Senior Technical Advisor. I have been with NSAI since 1998.

2. I provided direct written and rebuttal testimony in these cases that were filed with the Commission on August 26, 2024, and February 6, 2025, respectively, on behalf of Goodnight Midstream Permian, LLC ("Goodnight"). I have been asked to prepare sur-rebuttal testimony in

BEFORE THE OIL CONSERVATION COMMISSION
Santa Fe, New Mexico
Sur-Rebuttal Exhibit No. D
Submitted by: Goodnight Midstream Permian, LLC
Hearing Date: February 24, 2025
Case Nos. 23614-23617, 23775,
24018 – 24020, 24025, 24123

response to Empire's additional petrophysical models and analyses regarding the potential for a productive residual oil zone ("ROZ") in the EMSU submitted by OPS Geologic.

3. This sur-rebuttal statement 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.

SUMMARY

- OPS Geologic's testimony implies that the better-quality rock types are not allowed to be present in the San Andres interval in NSAI's model and that oil saturation was largely independent of the resistivity measurements. This simply is not true. The individual rock types are identified based on all of the available well log measurements and the oil saturations are predicted based on resistivity and interpreted porosity.
- NSAI obtained the well log data for the R. R. Bell 4 drilled in 1982 from the OCD files. The cored interval was digitized and interpreted with the NSAI model. A good match was obtained between the porosity and oil saturation estimates derived from the model and the core measurements, supporting the reliability of the NSAI model.
- Digital well log data was provided for the NMGSAU 522 by OPS. Interpretation results obtained with NSAI's model are in agreement with the conclusions outlined in NSAI's rebuttal statement.
- The computed n values used by OPS do not correlate well with either porosity or permeability. The n values varied by half an order to over two orders of magnitude for each porosity value. The San Andres and Grayburg formations are comprised of rock types with a variety of pore structures and multimodal pore-size distributions. It is highly unlikely

that electrical characteristics in these disparate rock types can be reasonably represented with a porosity-based correlation of Archie's saturation exponent. The limitations of the standard Archie model for the analysis of complex carbonate formations are addressed in my original direct and rebuttal testimonies.

- OPS consistently interprets the highest oil saturations in the lower San Andres in intervals with low porosity. OPS postulates that a continuous ROZ might exist from the top of the Glorietta to the base of the Grayburg. It is unreasonable to believe that elevated oil saturations approaching 80 percent could exist in the low-porosity intervals floating within higher porosity intervals above and below that are 100 percent water saturated. In contrast, NSAI's interpretation, which takes into account the expected rock type for low-porosity, high carbonate mud content intervals, is reasonable.
- By overestimating shale volume and including anhydrite in the dolomite endpoint, OPS is not able to identify intervals where the anhydrite volumes may be high. NSAI believes that the identification of intervals containing elevated levels of anhydrite is important for the proper identification of potential vertical flow barriers. NSAI prepared lithology calculations for wells occupying a cross-section from the northwest to the southeast boundaries of the EMSU from well logs provided by OPS. This cross section shows multiple beds of elevated anhydrite content that provide barriers to vertical communication in the interval from the high gamma ray ("GR") peak to the top of the water disposal interval.
- The oil saturation versus depth profile observed in the core from EMSU 679 does not match the profiles from the SSAU and Tall Cotton ROZs. The profile observed in the EMSU 679

core more closely resembles the profile expected in an oil migration pathway where oil migrates through the best quality reservoir rock at levels just above residual levels.

- It has not been argued that intervals containing oil at residual and lower saturation levels are not present in the interval between the top of the high GR marker and the oil-water contact within the Grayburg. There is nothing preventing Empire from pursuing CO2 recovery operations in this interval. Goodnight's water disposal operations are occurring in the water disposal zone well below, and isolated from, the interval containing residual oil.

I. OPS description of NSAI's model leads to a deceptive impression of the model's applicability in the San Andres interval below the high GR marker.

4. All the rock types present in the Grayburg were also interpreted to be present in the San Andres in the NSAI model. No rock types were excluded, and the oil saturations were computed based on the interpreted rock type, porosity, and measured resistivity.

5. A noticeable shift in the GR baseline occurs for all of the wells reviewed by NSAI in the EMSU under a high GR marker as noted in **Figure 1**. As discussed in my direct testimony, the clay content is low throughout the Grayburg-San Andres interval and variations in gamma ray amplitude are primarily the result of changes in the uranium content of the rock. Available potassium measurements from natural gamma ray spectroscopy (NGS) measurements indicate that feldspar content is very low (see **Figure 2**). Uranium is present in sea water and precipitates onto rock surfaces in areas with low wave energy. The amount of precipitated uranium is proportional to the surface area of the rock. The smaller the grain size, the higher the surface area. The higher the surface area, the higher the uranium content. The higher gamma ray values indicate that the grainstones in the San Andres likely have smaller grain sizes than those in the Grayburg and there

is a higher mud-sized particle content in the packstones. This suggests that deposition in the San Andres was in deeper water where the wave energy was lower. Lucia (1995) has shown that reservoir quality decreases with decreasing carbonate grain size and increasing mud content. This situation was observed at the San Andres outcrop located in the Guadalupe Mountains west of the EMSU studied by Kerans et al. (1994) and is applicable to the San Andres at EMSU.

6. Uranium is concentrated when evaporation occurs in a restricted body of water such as a lagoon and increases in GR readings are often associated with the presence of evaporites. Many of the GR spikes consistently found in the Grayburg-San Andres interval can be associated with beds of elevated anhydrite content.

7. All of the rock types present in the Grayburg are present in the San Andres. However, the relative abundance of the various rock types differs between the two formations. The intervals with the lowest GR readings are interpreted to be grainstones in both the Grayburg and San Andres. Wackestones are not included as an interpreted rock type in either the Grayburg or San Andres. OPS implied that the better-quality rock types are not allowed to be present in the San Andres interval and that oil saturation was largely independent of the resistivity measurements. This simply is not true. The individual rock types are identified based on all of the available well log measurements and the oil saturations are predicted based on resistivity and interpreted porosity.

II. NSAI did not understand that there are two wells named R.R Bell 4.

8. There are two wells associated with the EMSU which are named R.R. Bell 4. NSAI located the data in the OCD files for the well drilled in 1949 and found no available log

measurements. The logs without headers included in Empire's original testimony were assumed to be from this 1949 well and would not have been of sufficient quality for rigorous interpretation.

9. The mistake was realized when the OPS rebuttal document was provided on Feb. 10, 2025. Sufficient well log data was available in the OCD files for the R. R. Bell 4 drilled in 1982 for a rigorous interpretation. Raster images of the well logs were available. The cored interval was digitized and interpreted with the NSAI model, and a good match was obtained between the porosity and oil saturation estimates derived from the model and the core measurements, supporting the reliability of the NSAI model. The match between the corrected core measurements and the porosity and water saturation estimates derived from the NSAI model are shown in **Figure 3**.

III. Analysis results from the open-hole log measurements from NMGSAU 522 are consistent with NSAI's earlier observations.

10. Digital well log data became available for NMGSAU 522 with the deliverables associated with the OPS rebuttal to NSAI's model. Interpretation results obtained with NSAI's model are in agreement with the conclusions outlined in the rebuttal document provided by NSAI on Feb. 10, 2025 that oil saturations measured in the core from NMGSAU 522 do not appear to be representative of true reservoir conditions as the result of the documented presence of lease crude in the drilling mud used during the coring operations. A comparison between the porosity and water saturation estimated from the model and the core measurements is shown in **Figure 4**.

IV. Analysis of the core measurements from R. R. Bell 4 and EMSU 679 shows that the Archie saturation exponent, n does not correlate well with porosity.

11. NSAI followed the model calibration procedures outlined by Mr. Birkhead in his testimony. The Archie cementation exponent, m values were computed using the correlations

proposed by Focke and Munn (1987) using the core porosity and permeability values. The measured resistivity at each core plug depth was used to calculate the resistivity index for each plug. The saturation exponent, n was calculated for each plug using the Archie equation and the core oil saturation measurement. It was found that the computed n values did not correlate well with either porosity or permeability. The n values varied by half an order to over two orders of magnitude for each porosity value. For example, for a porosity value of 5 percent, the value of n was found to vary from around 0.3 to 150. At 10 percent porosity, n varied from around 3 to 130. The San Andres and Grayburg formations are comprised of rock types with a variety of pore structures and multimodal pore-size distributions. It is highly unlikely that electrical characteristics in these disparate rock types can be reasonably represented with a porosity-based correlation of Archie's saturation exponent. I have discussed the limitations of the standard Archie model for the analysis of complex carbonate formations in my original written testimony and the subsequent rebuttal testimony prepared for the Feb. 23, 2025 hearing.

V. The OPS model seems to consistently interpret high oil saturations in low-porosity intervals in the Lower San Andres.

12. Review of the interpreted well logs provided by OPS indicates that the highest oil saturations in the lower San Andres are consistently interpreted in intervals with low porosity. When the porosity of a carbonate rock gets low, the conductive pathways through the pore network can get very tortuous. Pressure solution can cause pore throats to become occluded, creating isolated porosity within the rock. High resistivities often reflect poor pore system continuity rather than the presence of hydrocarbons. **Figure 5** shows the OPS interpretation for Meyer B 4-34 in the Lower San Andres. OPS has postulated that a continuous ROZ might exist from the top of the Glorietta to the base of the Grayburg. It seems unreasonable to believe that elevated oil saturations

approaching 80 percent could exist in the low-porosity interval from 4810 ft. to 5140 ft. floating within the higher porosity, 100 percent water saturated intervals above and below. The same is true of the interval from 4690 ft. to 4740 ft. This phenomenon can be observed in most every OPS interpretation.

13. The high gamma ray readings through the low-porosity interval suggests that the grain size of the sediments is very small. This would suggest that the pore throats are very small and susceptible to occlusion by pressure solution. **Figure 6** shows a comparison of the OPS interpretation for Meyer B 4-34 and NSAI's interpretation which takes into account the expected rock type for low-porosity, high carbonate mud content intervals. The NSAI solution seems to be more physically reasonable.

VI. The mineralogy modeling employed by OPS misses some important features of the San Andres.

14. **Figure 7** shows a section of the OPS interpreted lithology for J. A. Akens 10. It appears as though the shale volume has been calculated from the raw gamma ray measurements. The shale volumes appear to be way too high based on the clay contents derived from available natural gamma ray spectroscopy measurements for the Grayburg-San Andres interval (see **Figure 2**). The interpreted lithology track does not include anhydrite. Apparently, OPS included a 20 percent anhydrite content in their dolomite mineral endpoint used in the lithology model and did not break out the anhydrite content individually. By overestimating shale volume and including anhydrite in the dolomite endpoint, OPS is not able to identify intervals where the anhydrite volumes may be high. NSAI believes that the identification of intervals containing elevated levels of anhydrite is important for the proper identification of potential vertical flow barriers.

15. In the wells interpreted by NSAI, multiple intervals with beds of elevated anhydrite content have been identified between the water disposal interval employed by Goodnight and the high GR marker (for example, see **Figure 8**). The presence of elevated anhydrite beds has been confirmed using well log crossplot techniques developed by Lucia and Ruppel (1996). Based on loss circulation events observed by Goodnight during the drilling of the water disposal wells, I believe that these beds of elevated anhydrite provide multiple barriers between Goodnight's disposal operations and Empire's waterflood operations in the Grayburg. I have not seen evidence that water withdrawals from the Grayburg waterflood significantly exceed water injection volumes in Empire's injection wells.

16. The OPS rebuttal document contained well log interpretations for 17 wells that were previously unavailable for interpretation by NSAI. Lithology calculations were performed for wells occupying a cross-section from the northwest to the southeast boundaries of the EMSU. A cross section composed of the gamma ray and bulk density measurements from the selected wells is shown in **Figure 9**. Flags indicating the locations of the beds of elevated anhydrite are shown in the track containing the bulk density measurements. The yellow highlighted interval extends from the high GR peak to the top of the water disposal interval. Note that in every well there are multiple beds of elevated anhydrite content to provide barriers to vertical communication.

VII. OPS concept of a "spectrum" of oil saturation within an ROZ does not fit well with the definition of both "brownfield" and "greenfield" ROZs.

17. Brownfield ROZs have been defined by Trentham and Melzer to be associated with an overlying trap, while greenfield ROZs have been defined as zones containing residual oil that are not associated with an overlying trap. In both cases, it is theorized that the zones had once been saturated with oil to above-residual levels and had been subsequently swept by multiple pore

volumes of meteoric water to the present residual saturation condition. The ROZ associated with the Seminole San Andres Unit has often been cited as an example of a brownfield ROZ and the ROZ associated with the Tall Cotton Field has been cited as an example of a greenfield ROZ. Data from the core wells from each of these projects is not publicly available. However, well log data is available for a few of the ROZ development wells.

18. The University of Texas Bureau of Economic Geology conducted an integrated study of the well log and core measurements from the Seminole San Andres Unit which was published in 1998 (Wang et al.). As a part of that study, residual oil saturations were reported for each of the rock types found to be present. The reported residual saturations are summarized in the table below.

Rock Type	Sorw
Grainstone	0.25 – 0.35
Moldic Grainstone	0.4
Grain-Dominated Packstone	0.35
Mud-Dominated Packstone	0.4
Wackestone	0.4

19. An ROZ that was originally saturated with oil to levels above residual levels would be expected to contain oil near the expected residual saturation determined for each rock type. The calculated values from NSAI's model for oil saturations for SSAU 4113R are displayed in **Figure 17** from my rebuttal testimony of Feb. 10, 2025. Note that the computed oil saturations generally range from 10 to 45 percent, and intervals of high oil saturations are generally present from the base of the ROZ to the top. These saturation levels are in agreement with those reported from pressure and sponge coring operations (Honarpour, et al. 2010). The residual oil saturations generally fall within the range that would be expected based on the core measurements summarized in the table above.

20. **Figure 10** shows the results of oil saturation calculations with NSAI's model for Kinder Morgan Bergen P 02 which was drilled during the infill program for CO2 flooding in the Tall Cotton ROZ. Again, oil saturations ranged from 10 to 45 percent with intervals of high oil saturations present from the base of the ROZ to the top.

21. It is my understanding that the Tall Cotton ROZ produced much less oil than originally projected and the project was not likely an economic success. The poorer than expected recovery may be the result of the overestimation of oil in place within the ROZ resulting from the reliance on simplified Archie modeling procedures.

22. The oil saturation versus depth profile observed in the core from EMSU 679 does not match the profiles from the SSAU and Tall Cotton ROZs. In my opinion, the profile observed in the EMSU 679 core more closely resembles the profile expected in an oil migration pathway where oil migrates through the best quality reservoir rock at levels just above residual levels and not an ROZ (see **Figure 11**). During migration, oil enters into the portions of the lower quality rock with the largest pore throats at sub-residual saturation levels. Intervals of low oil saturation are present at the top and base of the core with the higher oil saturations generally existing in the middle of the core interval.

The concept of the presence of floating, areally continuous greenfield ROZs in the lower San Andres does not seem physically reasonable. NSAI's modeling does not predict their presence. From a practical point of view, whether the oil in the cores above the GR marker in R. R. Bell 4 and EMSU 679 is associated with an ROZ or with paleo migration paths is academic. It has not been argued that intervals containing oil at residual and lower saturation levels are not present in the interval between the top of the GR marker and the oil-water contact within the Grayburg. There is nothing preventing Empire from pursuing CO2 recovery operations in this interval. Goodnight's water disposal operations are occurring in the water disposal zone well below, and isolated from, the interval containing residual oil.

CONCLUSION

- Individual rock types are identified in NSAI's model based on all of the available well log measurements and the oil saturations are predicted based on resistivity and interpreted porosity.
- A good match was obtained between the porosity and oil saturation estimates derived from NSAI's model and the core measurements for the R.R. Bell 4, supporting the reliability of the NSAI model.
- Interpretation results obtained with NSAI's model for the NMGSAU 522 are in agreement with the conclusions outlined in NSAI's rebuttal statement.
- It is highly unlikely that electrical characteristics in the disparate rock types in the San Andres and Grayburg formations can be reasonably represented with a porosity-based correlation of Archie's saturation exponent, as OPS has attempted to do.
- OPS postulates that a continuous ROZ might exist from the top of the Glorietta to the base of the Grayburg, but it is unreasonable to believe that elevated oil saturations approaching 80 percent could exist in the low-porosity intervals floating within higher porosity intervals above and below that are 100 percent water saturated.
- By overestimating shale volume and including anhydrite in the dolomite endpoint, OPS is not able to identify intervals where the anhydrite volumes may be high. NSAI has identified multiple beds of elevated anhydrite content that provide barriers to vertical communication in the interval from the high GR peak to the top of the water disposal interval.

- The oil saturation versus depth profile observed in the core from EMSU 679 does not match the profiles from the SSAU and Tall Cotton ROZs, but more closely resembles the profile expected in an oil migration pathway where oil migrates through the best quality reservoir rock at levels just above residual levels.
- Goodnight's water disposal operations are occurring in the water disposal zone well below, and isolated from, the interval containing residual oil. There is nothing preventing Empire from pursuing CO2 recovery operations in this interval.

23. 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.

James A. Davidson — March 18, 2025

James A. Davidson | Date

REFERENCES

Focke, J. and Munn, D., 1987. Cementation exponents in Middle Eastern carbonate reservoirs. *SPE formation evaluation*, *2*(02), pp.155-167.

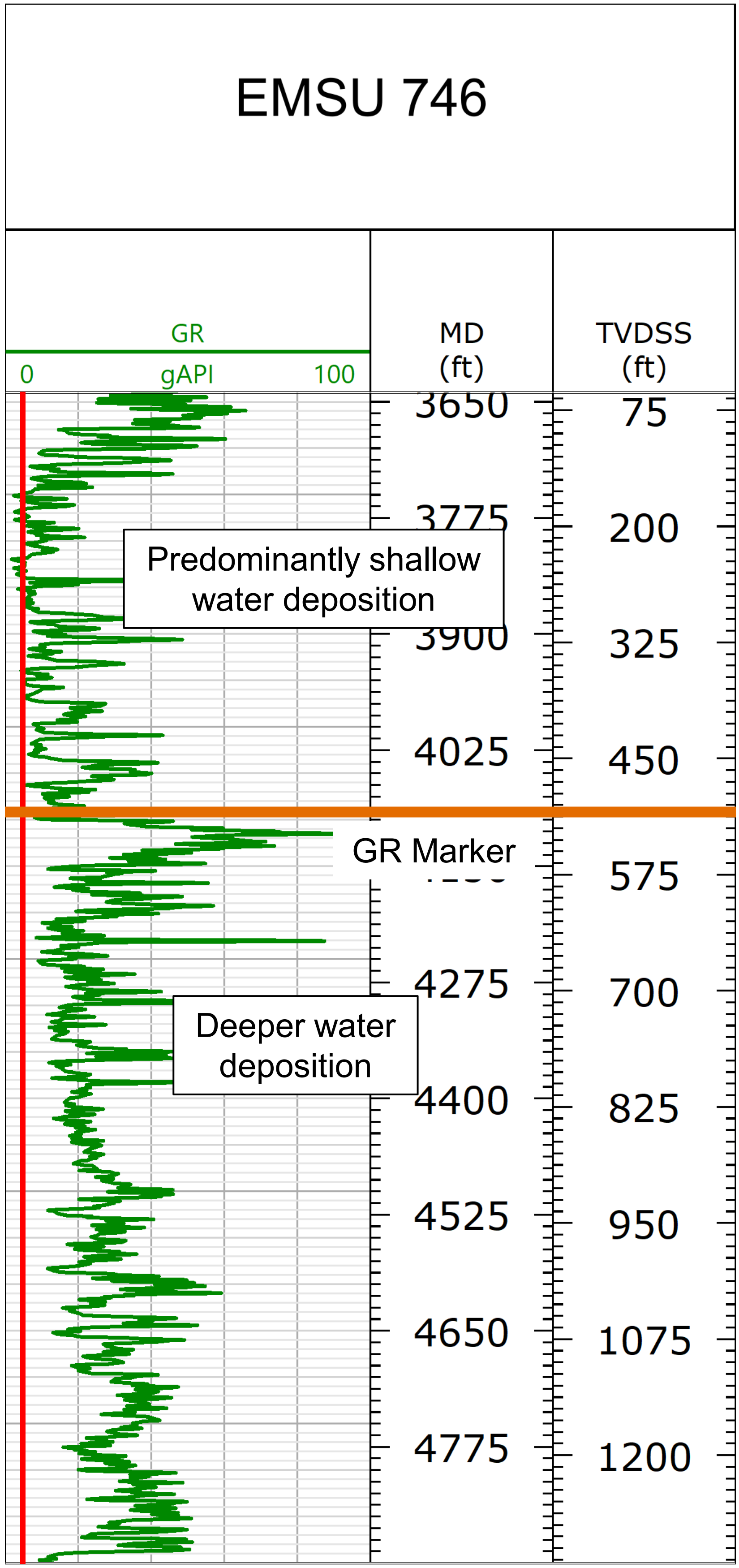
Honarpour, M.M., Nagarajan, N.R., Grijalba, A.C., Valle, M. and Adesoye, K., 2010, September. Rock-fluid characterization for miscible CO2 injection: residual oil zone, Seminole Field, Permian Basin. In *SPE Annual Technical Conference and Exhibition* (pp. SPE-133089). SPE.

Kerans, C., Lucia, F.J. and Senger, A.R., 1994. Integrated characterization of carbonate ramp reservoirs using Permian San Andres Formation outcrop analogs. *AAPG bulletin*, *78*(2), pp.181-216.

Lucia, F.J., 1995. Rock-fabric/petrophysical classification of carbonate pore space for reservoir characterization. *AAPG bulletin*, *79*(9), pp.1275-1300.

Lucia, F.J. and Ruppel, S.C., 1996, October. Characterization of diagenetically altered carbonate reservoirs, South Cowden Grayburg reservoir, west Texas. In *SPE Annual Technical Conference and Exhibition* (pp. SPE-36650). SPE.

NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.



All estimates and exhibits herein are part of this NSAI report and are subject to its parameters and conditions.

Figure 1

NETHERLAND, SEWELL & ASSOCIATES, INC.

Central Drinkard Unit #441

30-025-39805

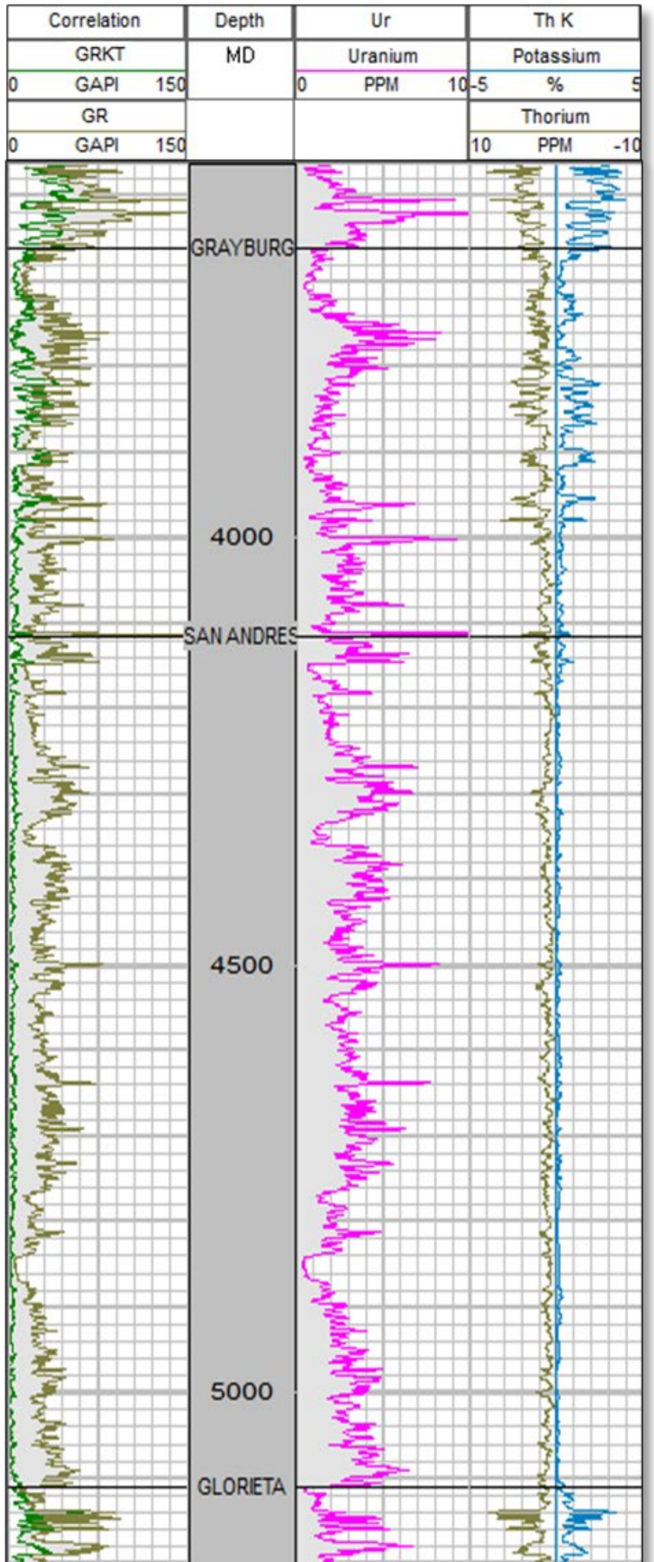


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Figure 2

NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.

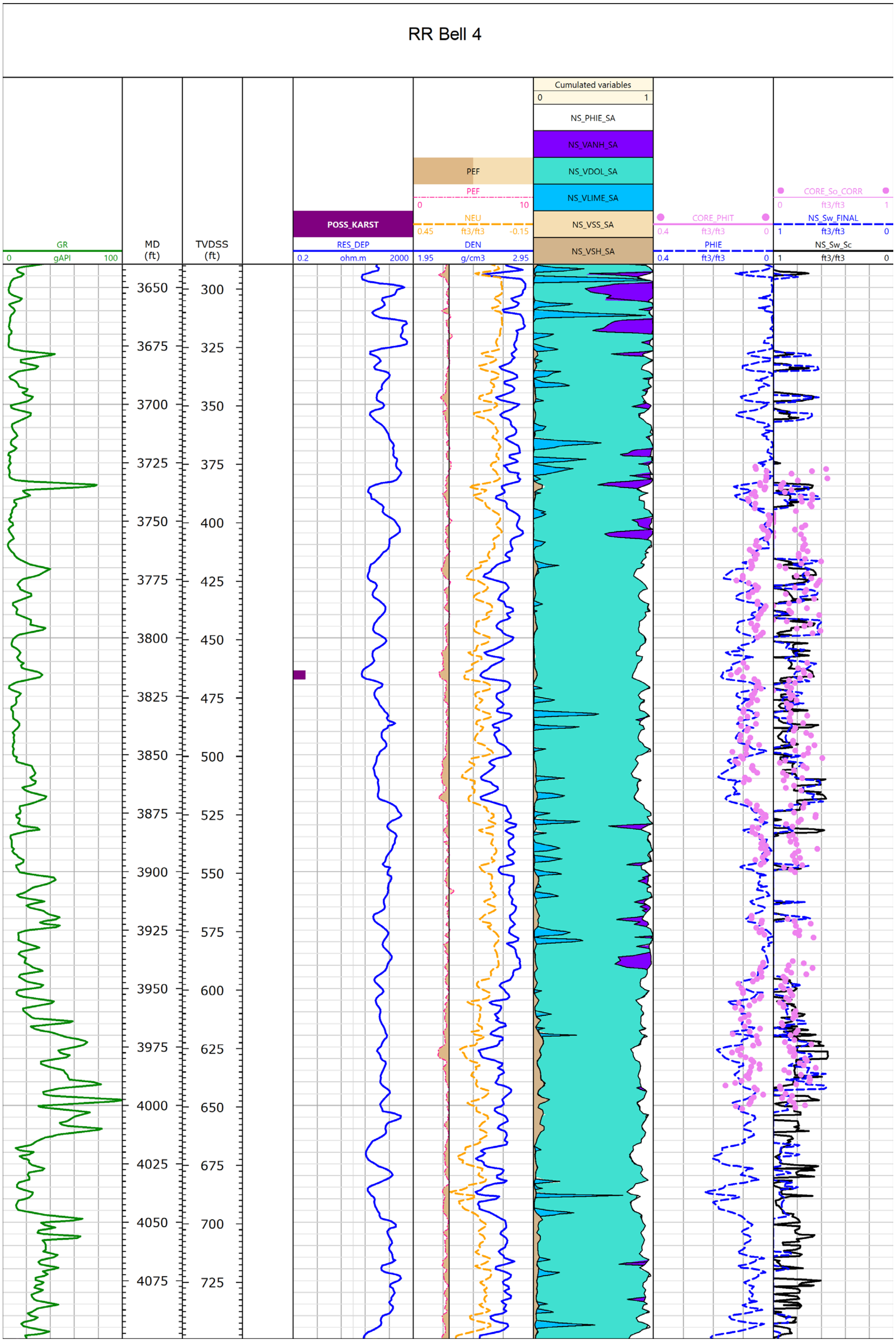

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Figure 3

NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.

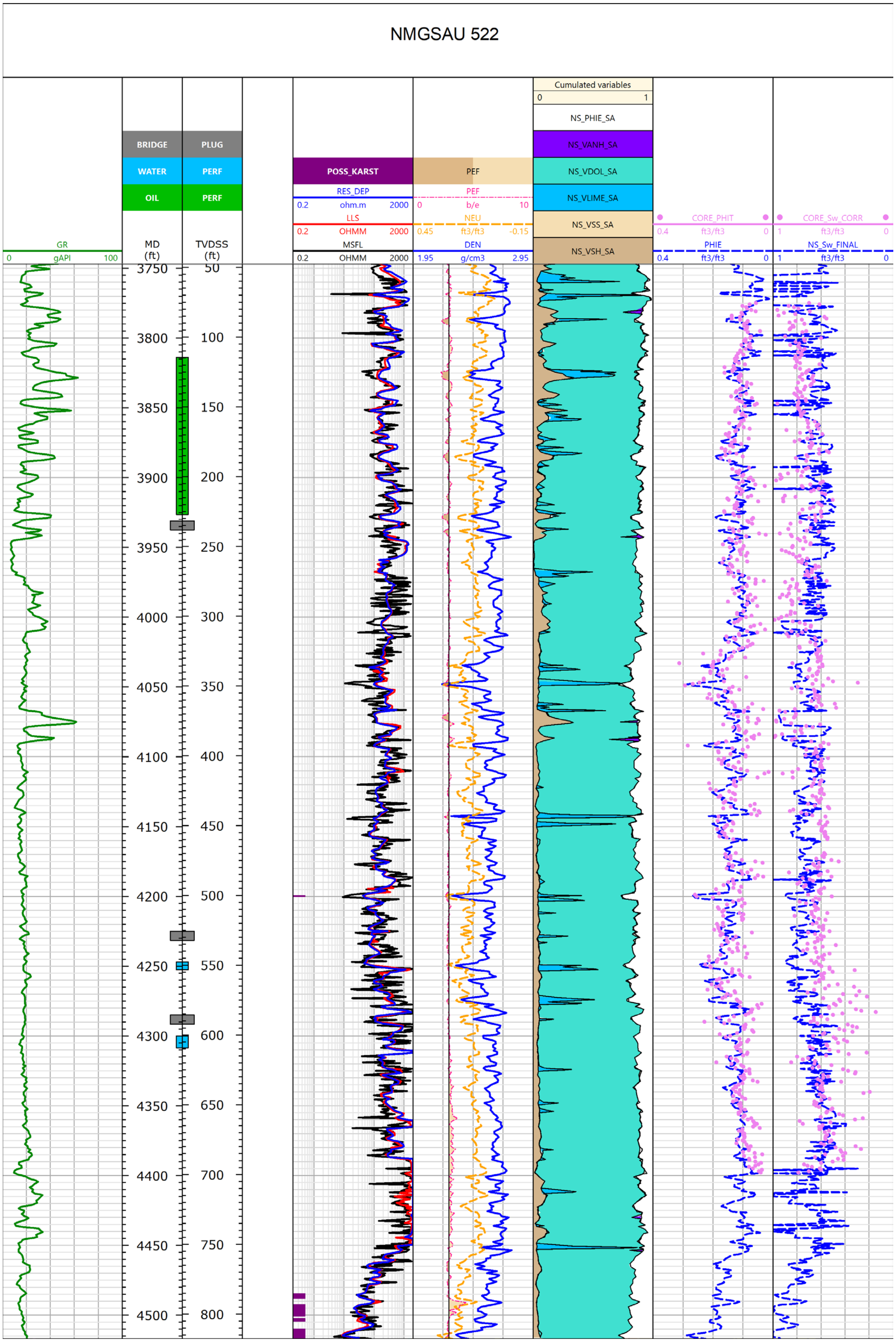

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Figure 4

NETHERLAND, SEWELL & ASSOCIATES, INC.

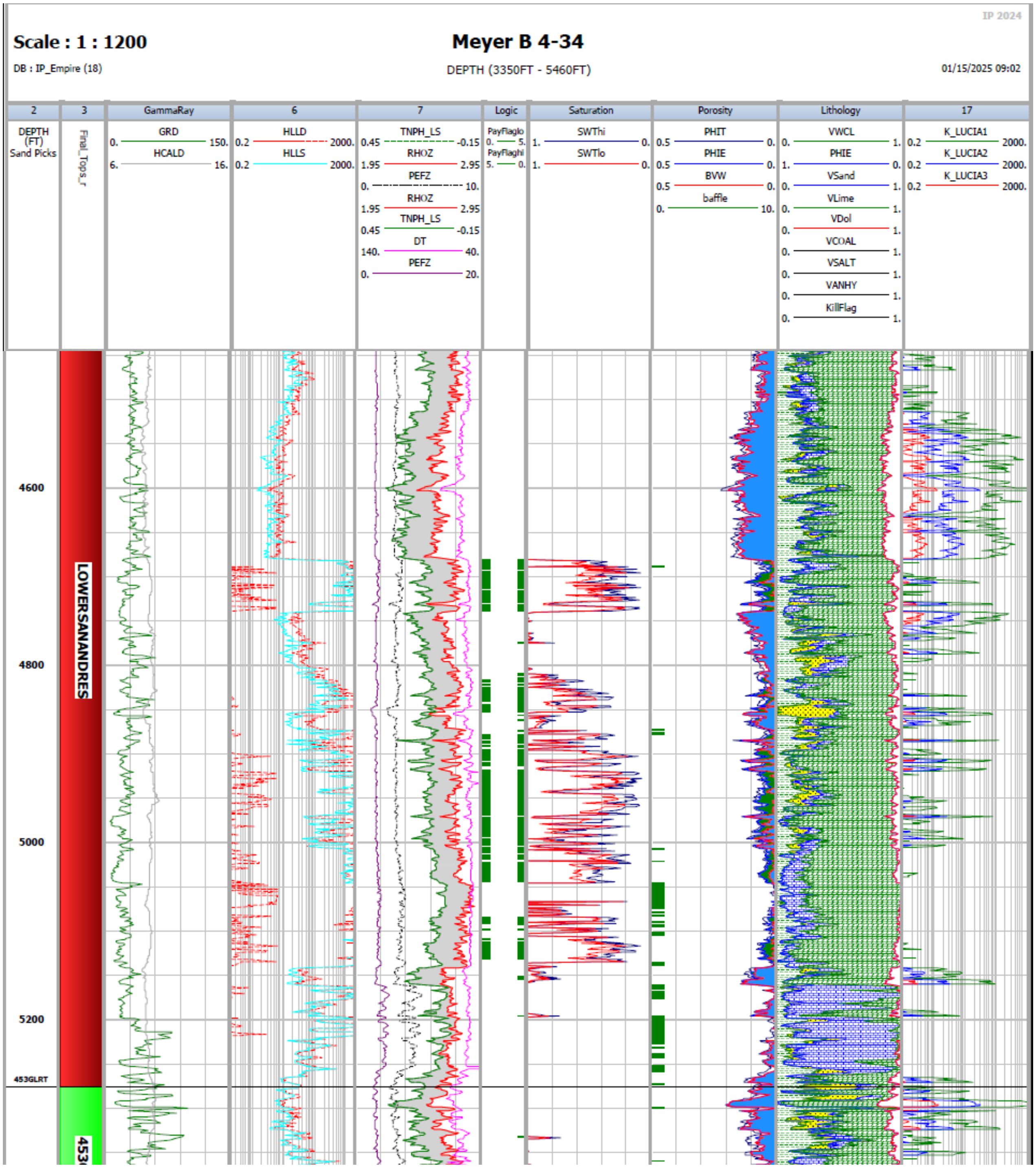

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Figure 5

NETHERLAND, SEWELL & ASSOCIATES, INC.

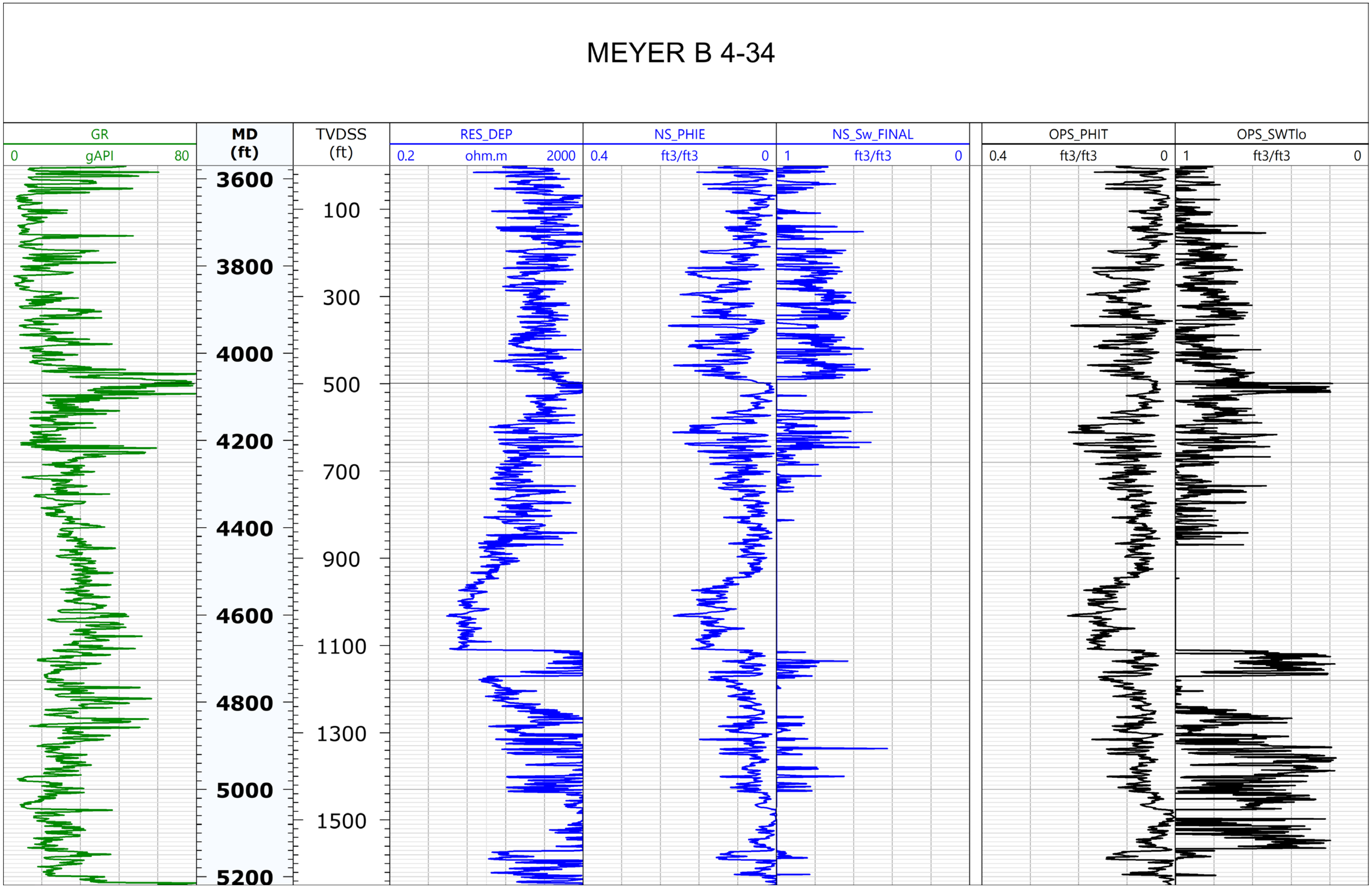

Figure 6

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NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.

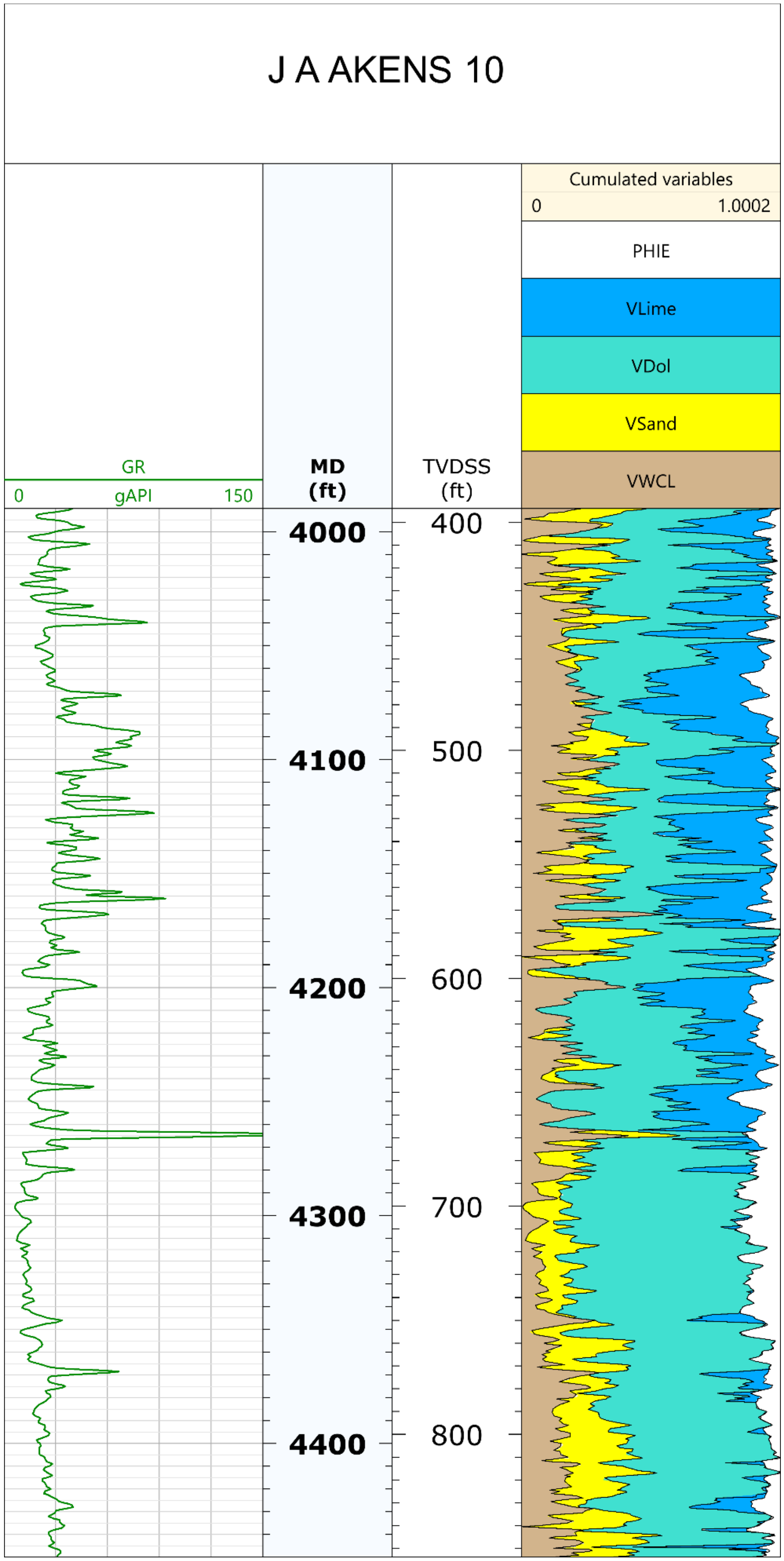

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Figure 7

NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.

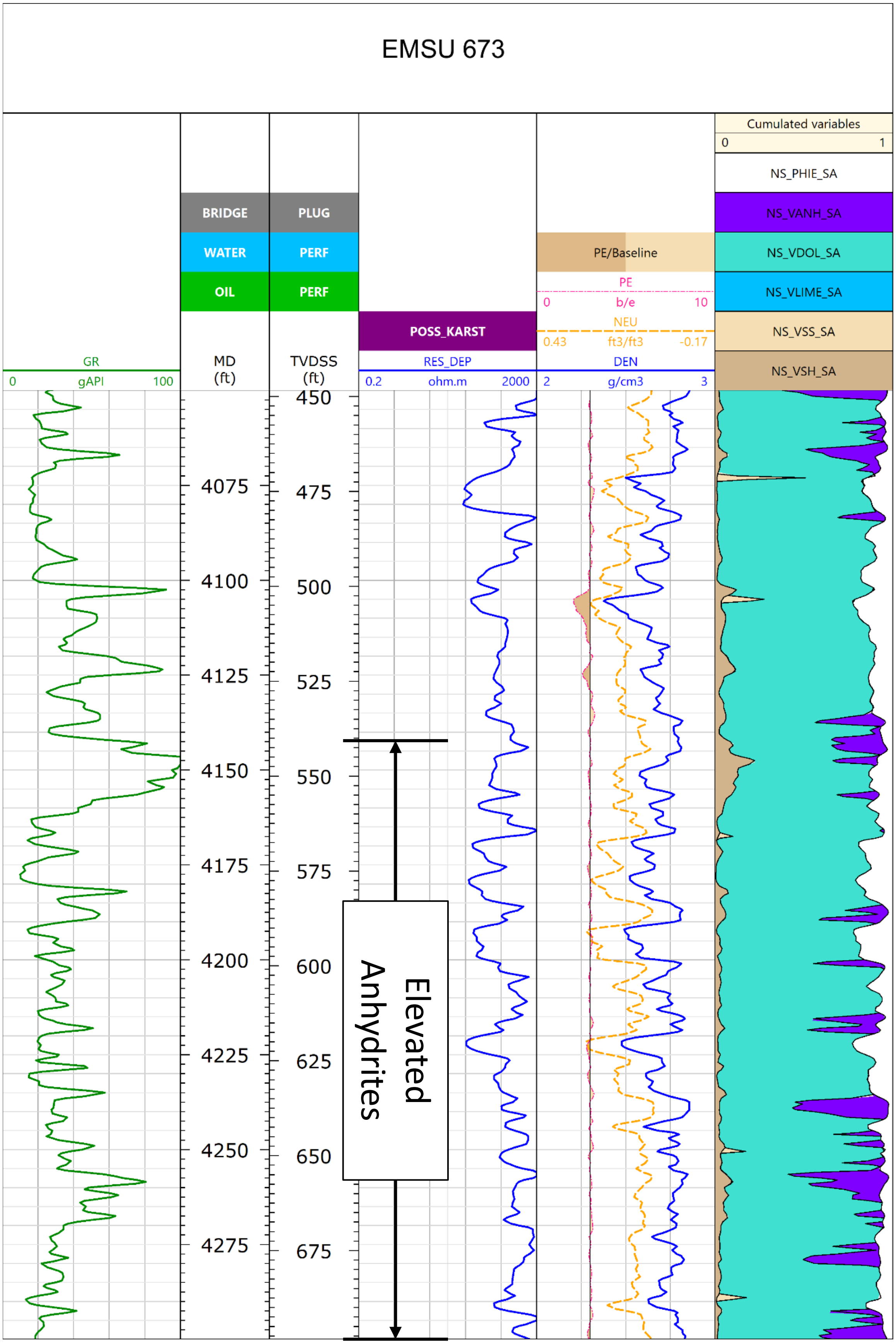

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Figure 8

NSAI NETHERLAND, SEWELL & ASSOCIATES, INC.

Cross Section Showing Intervals with Beds of Elevated Anhydrite Content

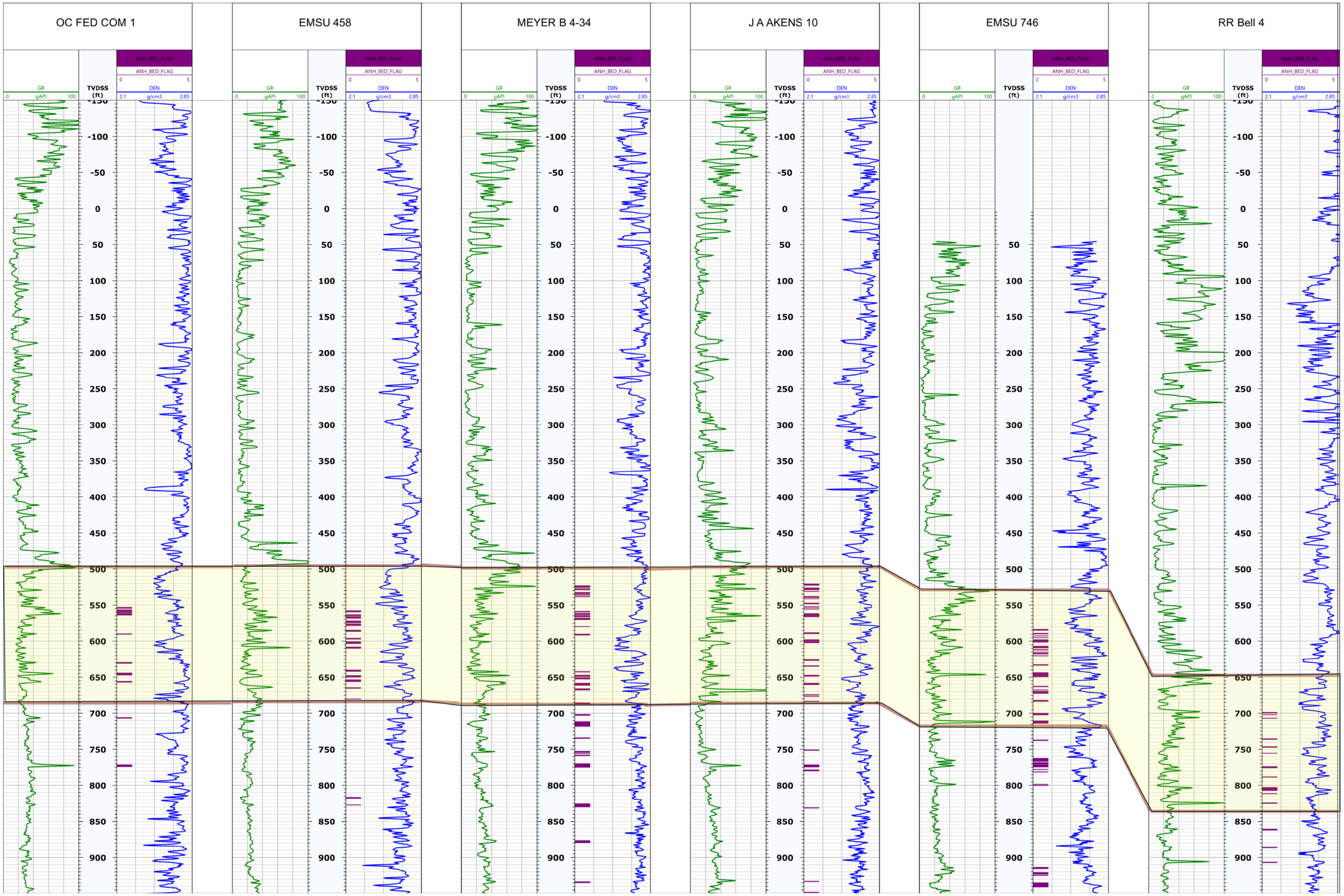

Figure 9

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Kinder Morgan Bergen P 02

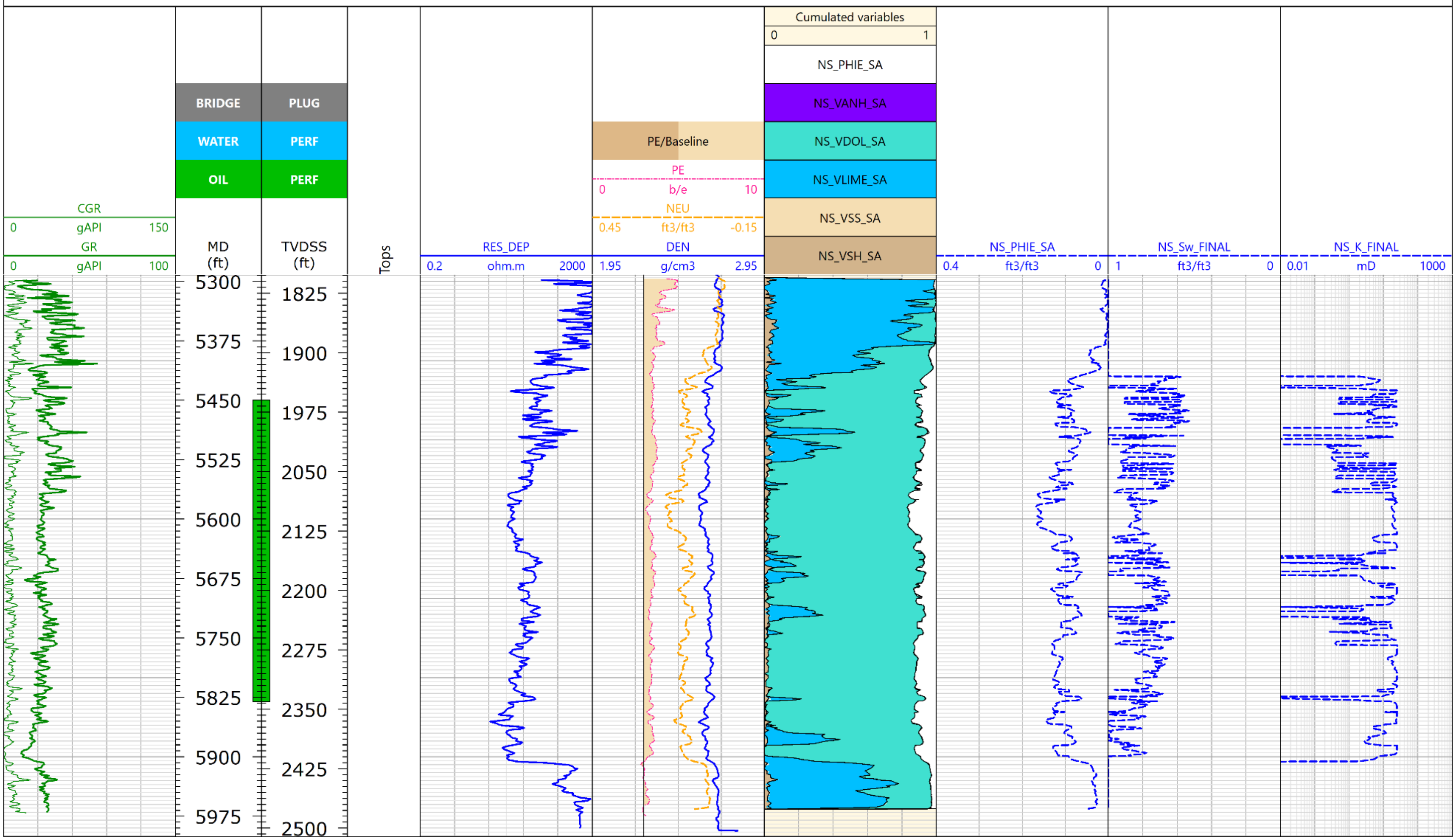

Figure 10

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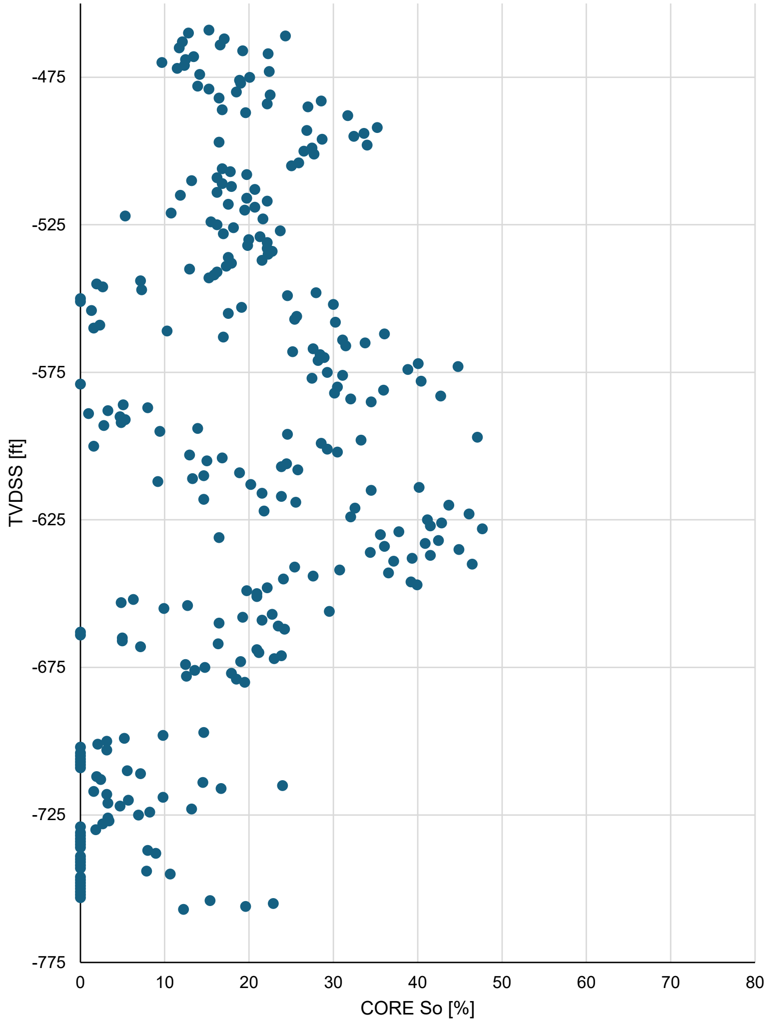
NETHERLAND, SEWELL & ASSOCIATES, INC.

EMSU 679
Core Oil Saturation Profile

EMSU 679



Trentham & Melzer ROZ Profile

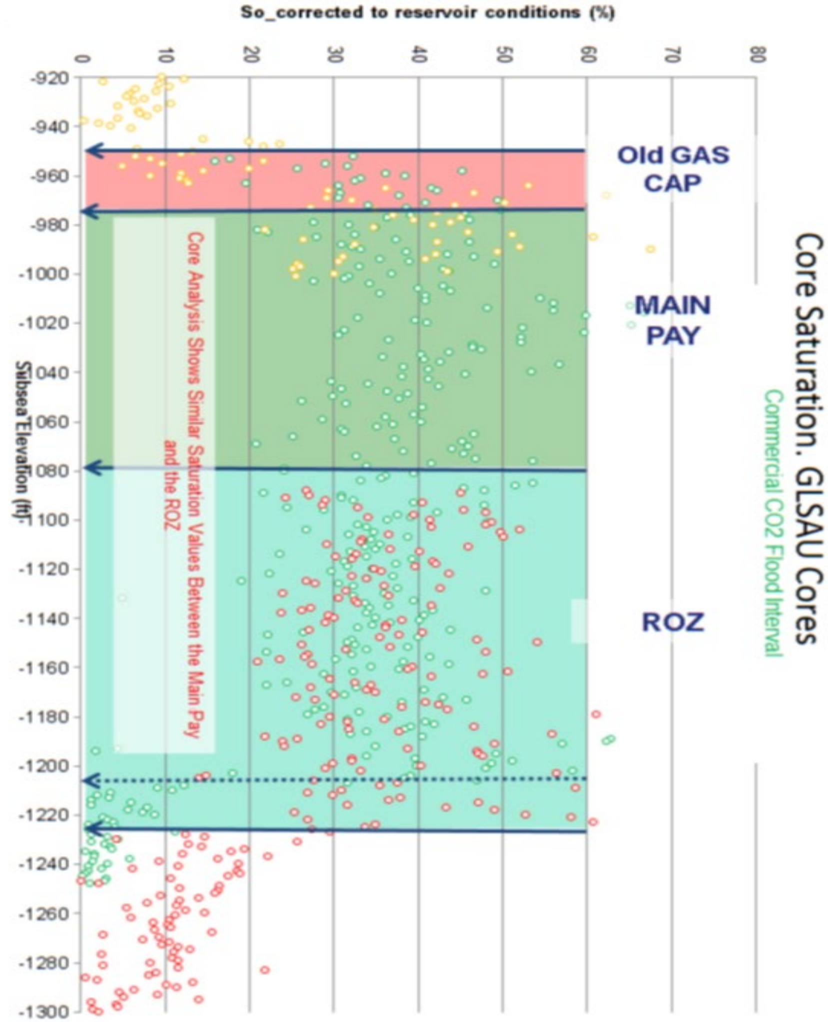


Figure adapted from Trentham, R. and Melzer, S., 2016.

Figure 11

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