# Appendix 5

# Porosity Distribution Maps & Workflow

Geostock Sandia

**POROSITY DATA AND HISTOGRAMS**

Thirty-one wells in the vicinity of the Project Blue injection site were found to have sufficient log data to calculate a total porosity (**Figure 1 and Table 1 in this appendix**). The method of calculation used for porosity is described in Section 3.2 of the "*Area of Review and Corrective Action Plan"* technical report. The calculated logs were then imported into Petrel for the purposes of distributing the porosity property over the entire modeled extent of the two injection intervals, the lower Hosston and Cotton Valley Sand Complex.

**Figures 2 thru 6** are histograms of the Total Porosity data in three states, that of the raw well log data, the range in the upscaled cells and the range in the model populated property. Over the Lower Hosston Injection Zone the histogram shows that the Total Porosity well log data spans a range of 0.00% to 43.1% porosity, with an average of 20.0%. (**Table 2**) For the Cotton Valley Injection Zone, the Total Porosity well log data spans a range of 0.18% up to a maximum of 57.2% porosity units and an average of 18.7% porosity. (**Table 3**) For the Cotton Valley 3 interval, the Total Porosity well log data spans a range of 0.40% up to a maximum of 57.2% porosity and an average of 17.3% porosity. (**Table 4**) For the Cotton Valley 2 interval, the Total Porosity well log data spans a range of 0.52% up to a maximum of 48.8% porosity and an average of 16.8% porosity. (**Table 5**) For the Cotton Valley 1 interval, the Total Porosity well log data spans a range of 0.00% up to a maximum of 39.5% porosity and an average of 15.3% porosity. (**Table 6**) All of the data for these three injection intervals can be found in the Tables accompanying the Porosity Data Histograms (**Tables 2 - 6**).

**It should be noted that minimum and maximum values for the Total Porosity Logs are the far ends of the distribution and are not reflective of the mean or true statistical distribution of porosity. The histograms in Figures 2-6 demonstrate the distribution for porosity for each of the injection intervals**

This wide data range is the result of log porosity being the total porosity, as there is not sufficient data to calculate an effective porosity currently. However, a future test well will be designed with this in mind, and the appropriate data will be collected so that an effective porosity can be calculated.

The porosity logs for each of the Injection Zones (Lower Hosston and Cotton Valley Formations) were upscaled using a simple arithmetic average, with the log data sampled by treating the log as lines and neighbor cell used for the process in the cells penetrated by wells were sampled for the upscaling process. Through this process of well log upscaling, the range of porosity values over the injection intervals are tightened. Upscaling is done using the same method in both confining and injection units however the cell layers are 10 feet and 2 feet respectively. With the thicker vertical layering there will be a more dramatic smoothing or tightening of porosity ranges in the confining intervals. The Lower Hosston and Cotton Valley Injection Zones have two rock types of sand, and shale respectively. Due to the presence of shale facies the range of porosity values for these intervals is wide and approaches or is near 0.00%. The upscaled cells and resulting model populated total porosity values for the Hosston injection interval were truncated at a minimum of 0.00% and maximum of 40.7% porosity, with an average of 20.3%. (**Figure 2 and Table 2**).

The upscaled cells and resulting model populated total porosity values for the Cotton Valley were truncated at a minimum of 0.04% and a maximum of 41.9%, with an average of 19.2%. The upscaled cells and resulting model populated total porosity values for the Cotton Valley 3 were truncated at a minimum of 0.02% and a maximum of 41.5%, with an average of 17.5%. The upscaled cells and resulting model populated total porosity values for the Cotton Valley 2 were truncated at a minimum of 0.00% and a maximum of 43.9%, with an average of 16.8%. The upscaled cells and resulting model populated total porosity values for the Cotton Valley 1 were truncated at a minimum of 0.00% and a maximum of 40.2%, with an average of 15.5%. (**Figure 3 to 6 and Table 3 to 6**)

It should be noted that while the porosity distribution in the Lower Hosston yielded what appears to be a normal single distribution, the Cotton Valley Formation indicates the possibility of a bimodal porosity distribution. This will need to be investigated thoroughly in the collection of data for a site specific well to be drilled in the future.

Once the wells had been upscaled, the porosity property was then distributed across the entire model extent. For all layers, Total Porosity was modeled using *Gaussian random function simulation.* Due to the spatial distribution of available well data the major and minor trends for the

variogram analysis were set at 045 and 315 orientations respectively **Figure 7.** With the spatial distribution of the data (specifically wells with Total Porosity Logs) when using a North-South (000) orientation for the variograms there is limited data that is captured; this is the primary driver for variogram changes. Additionally, as observed in the structure maps (**Appendix 2 to the technical report**) the dip direction is Southwest at approximately 045 orientation also fitting the major and minor direction for the variograms. For populating the model with the porosity property, the specific variogram settings can be found in **Figures 8 to 12** (for the Lower Hosston and Cotton Valley Formations). With additional data collected at the proposed injection site, the methodology behind property distribution will be re-evaluated. Full size porosity maps can be found in the Module B document. **Figures 13 and 14** demonstrate the spatial distribution of porosity modeled. It can be observed that the higher porosity values are generally associated with the sand facies when compared with the 3D cube visualizations in *Appendix 4*.

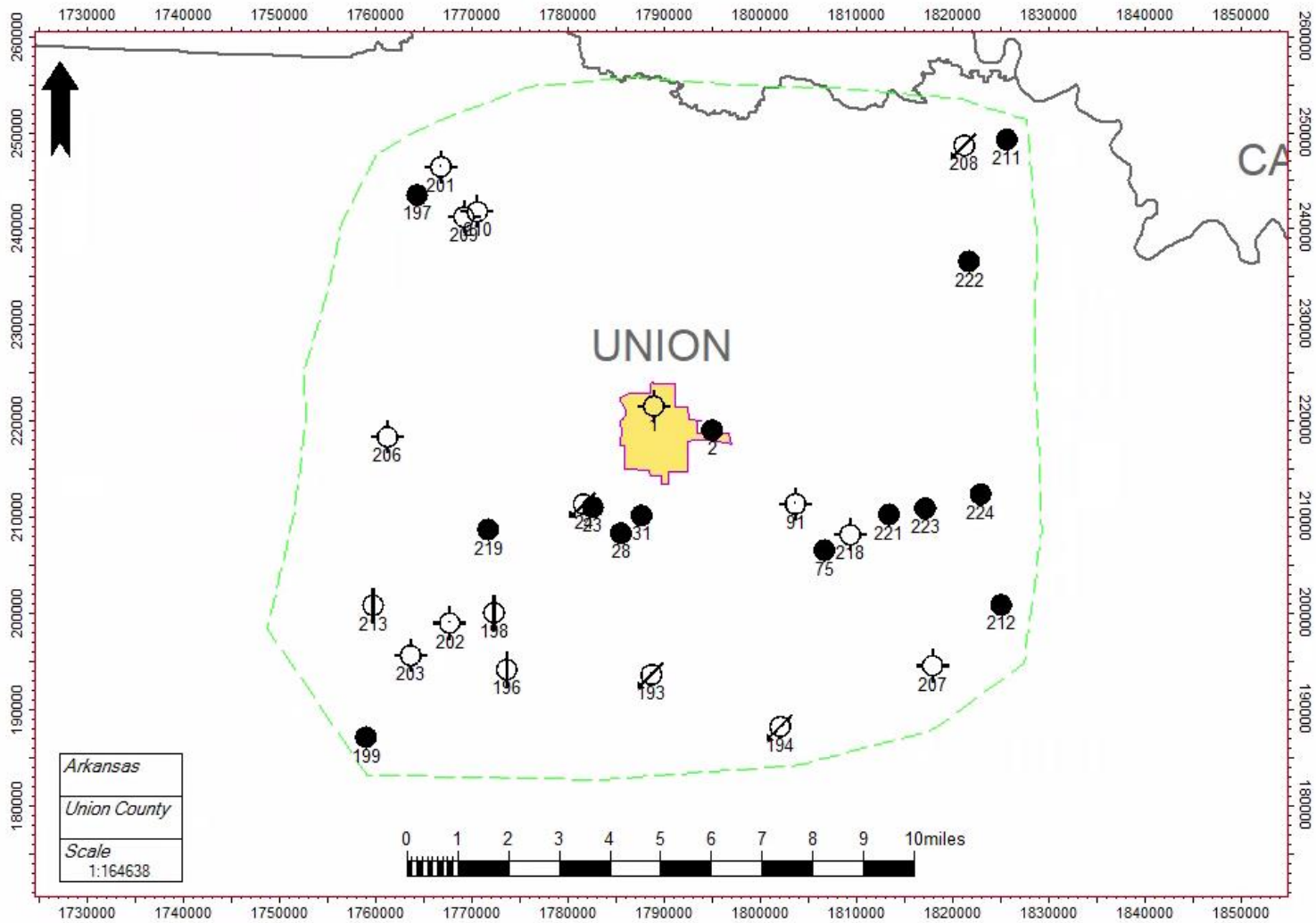


**Figure 1: Location of wells with Total Porosity Logs.**

| Map Number | Name | UWI | Well symbol | Surface X | Surface Y | Latitude | Longitude | Well datum | Well datum value | Total Depth (feet-TVDSS) | Total Depth (feet-MD) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 193 | SWD 5 | 03139104520000 | Active | 1788686 | 193803 | 33.1973 | -92.69072 | DF | 262.50 | -7131.5 | 7380 |
| 194 | SWD 8 | 03139105300000 | Active | 1802088 | 188411 | 33.1827 | -92.6468 | DF | 216.80 | -7237.2 | 7440 |
| 196 | BRINE SUPPLY | 03139108200000 | P&A | 1773631 | 194322 | 33.1984 | -92.73994 | KB | 242.80 | -7274.2 | 7503 |
| 197 | DELTIC FARM & TIMBER | 03139110100000 | P&A | 1764317 | 243642 | 33.3338 | -92.7716 | KB | 210.10 | -5927.9 | 6124 |
| 198 | BRINE SUPPLY WELL 11 | 03139110630000 | P&A | 1772316 | 200253 | 33.2147 | -92.74438 | KB | 238.30 | -7142.7 | 7367 |
| 199 | NATURAL RESOURCES | 03139110720000 | Active | 1758991 | 187305 | 33.1789 | -92.78762 | KB | 180.50 | -7504.5 | 7671 |
| 31 | HAMMOND, IRIS G ET AL UNIT 1 | 03139114150000 | P&A | 1787644 | 210331 | 33.2427 | -92.69449 | KB EST | 193.88 | -6820.12 | 7000 |
| 201 | SAXON, C H TR 1 | 03139115030000 | P&A | 1766795 | 246562 | 33.3419 | -92.76356 | KB | 180.00 | -5918 | 6084 |
| 202 | WINGFIELD 1 | 03139115350000 | P&A | 1767699 | 199162 | 33.2116 | -92.75945 | KB | 262.00 | -6910 | 7158 |
| 203 | J & M POULTRY PACKING 1 | 03139115770000 | P&A | 1763650 | 195787 | 33.2023 | -92.7726 | KB | 228.00 | -7196 | 7410 |
| 206 | HARRELL 1 | 03139117360000 | P&A | 1761229 | 218493 | 33.2646 | -92.78108 | KB | 267.00 | -6697 | 6950 |
| 207 | HARPER, W L 1 | 03139117460000 | P&A | 1817931 | 194731 | 33.2004 | -92.59515 | KB | 230.90 | -6593.1 | 6810 |
| 208 | LANGLEY | 03139117550000 | Active | 1821238 | 248783 | 33.349 | -92.58535 | KB | 89.00 | -2713 | 2788 |
| 209 | ARMSTRONG EST. 1 | 03139118800000 | P&A | 1769183 | 241345 | 33.3276 | -92.75562 | KB | 174.70 | -5939.3 | 6100 |
| 28 | MCMAHAN 1 | 03139119110000 | P&A | 1785513 | 208483 | 33.2376 | -92.70142 | KB EST | 204.00 | -6545 | 6735 |
| 210 | JOHNSON 1 | 03139119620000 | P&A | 1770579 | 241908 | 33.3292 | -92.75106 | KB | 151.80 | -5906.2 | 6044 |
| 211 | IPRC | 03139120730000 | P&A | 1825648 | 249402 | 33.3507 | -92.57092 | KB | 82.00 | -5202 | 5270 |
| 212 | SMITH ET AL | 03139122150000 | P&A | 1825057 | 201043 | 33.2178 | -92.57197 | KB | 243.00 | -6422 | 6651 |
| 91 | SEAMSTER, B 1 | 03139124220000 | P&A | 1803670 | 211530 | 33.2463 | -92.64211 | KB EST | 181.72 | -6349.28 | 6517 |
| 2 | GOODWIN, WALTER | 03139126790000 | P&A | 1794990 | 219205 | 33.2672 | -92.67066 | KB EST | 186.00 | -3377 | 3545 |
| 213 | BSW 13 | 03139127790000 | Active | 1759737 | 200991 | 33.2165 | -92.78552 | KB | 236.00 | -7378 | 7600 |
| 23 | PARNELL, JOHN ETAL | 03139128020000 | P&A | 1782599 | 211190 | 33.245 | -92.71101 | KB | 248.00 | -6564 | 6800 |
| 75 | WILSON ESTATE | 03139128150000 | P&A | 1806670 | 206737 | 33.2332 | -92.6322 | KB EST | 256.00 | -4617 | 4855 |
| 24 | PARNELL, JOHN | 03139128440000 | P&A | 1781621 | 211526 | 33.2459 | -92.71422 | KB EST | 267.00 | -5748 | 6001 |
| 218 | MAHONEY CORPORATION 1 | 03139129590000 | P&A | 1809368 | 208343 | 33.2376 | -92.62341 | KB | 251.00 | -6363 | 6600 |
| 1 | EDC 1 | 03139129790000 | P&A | 1788937 | 221703 | 33.274 | -92.69052 | KB EST | 217.00 | -6361 | 6564 |
| 219 | DUMAS | 03139131850000 | P&A | 1771702 | 208885 | 33.2384 | -92.7466 | KB | 203.40 | -6660.6 | 6850 |
| 221 | FROST "C" | 03139133030000 | Active | 1813393 | 210444 | 33.2435 | -92.61029 | KB | 220.40 | -5796.6 | 6003 |
| 222 | BARKER | 03139133780000 | Active | 1821716 | 236739 | 33.3159 | -92.58356 | KB | 156.70 | -5357.3 | 5500 |
| 223 | EZZELL | 03139135060000 | Active | 1817172 | 211080 | 33.2453 | -92.59794 | KB | 210.40 | -6053.6 | 6250 |
| 224 | PAMCO-MOODY | 03139135610000 | Active | 1822932 | 212554 | 33.2494 | -92.57913 | KB | 204.00 | -6024 | 6214 |

**Table 1: Detailed Information for wells identified in Figure 1.**

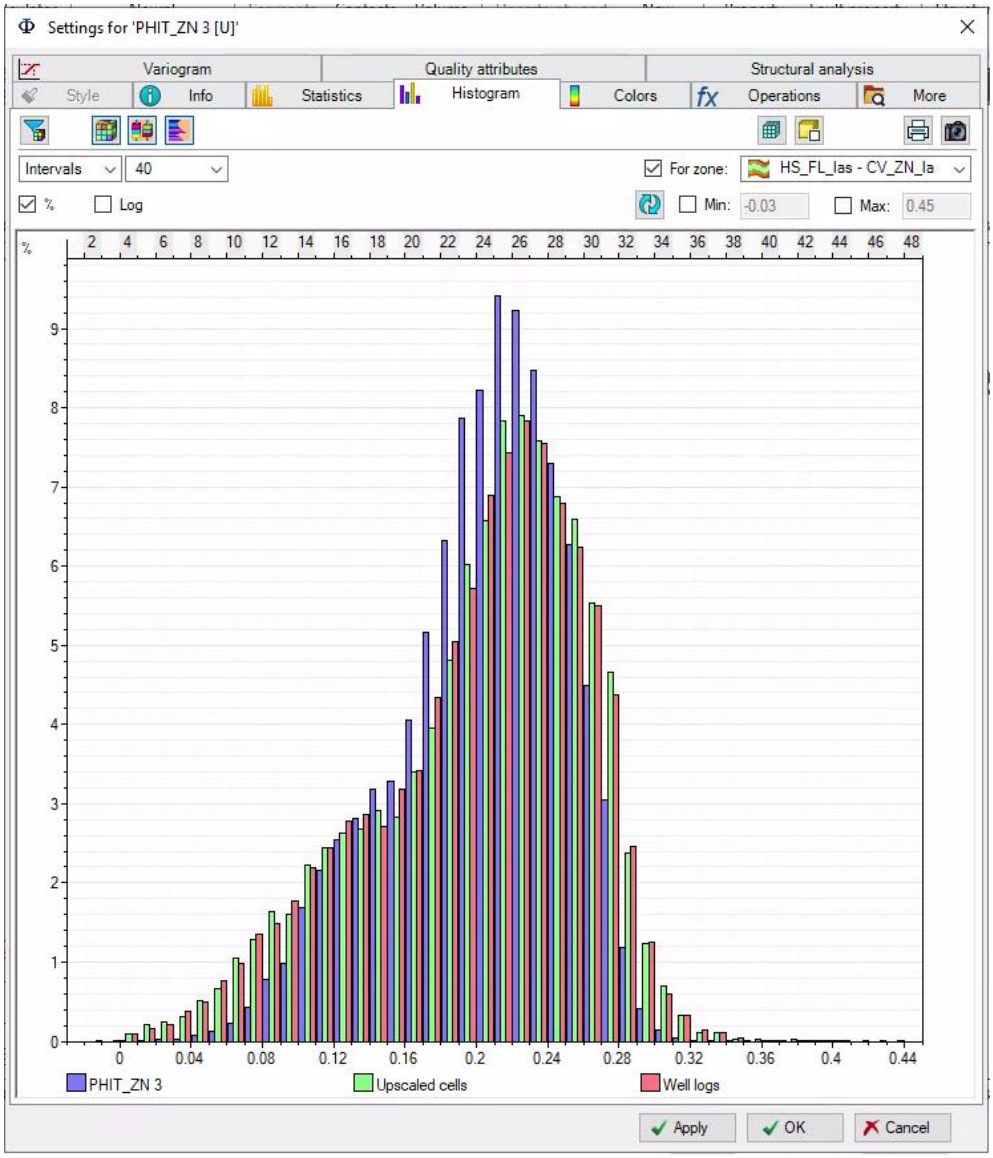


**Figure 2: Histogram of data and table of data for Well Logs, Upscaled Cells and Modeled Property over the Lower Hosston Injection Zone.**

| TYPE | MIN | MAX | DELTA | N | MEAN | STD | VAR | SUM |
|---|---|---|---|---|---|---|---|---|
| Modeled Property | 0.0000 | 0.4068 | 0.4068 | 56560000 | 0.2031 | 0.0472 | 0.0022 | 1148563 |
| Upscaled Cells | 0.0000 | 0.4000 | 0.4000 | 6565 | 0.2009 | 0.0603 | 0.0036 | 1318 |
| Well Logs | 0.0000 | 0.4301 | 0.4446 | 25325 | 0.2000 | 0.0604 | 0.0036 | 5063 |

**Table 2: Table of data for Well Logs, Upscaled Cells and Modeled Property over the Lower Hosston Injection Zone.**

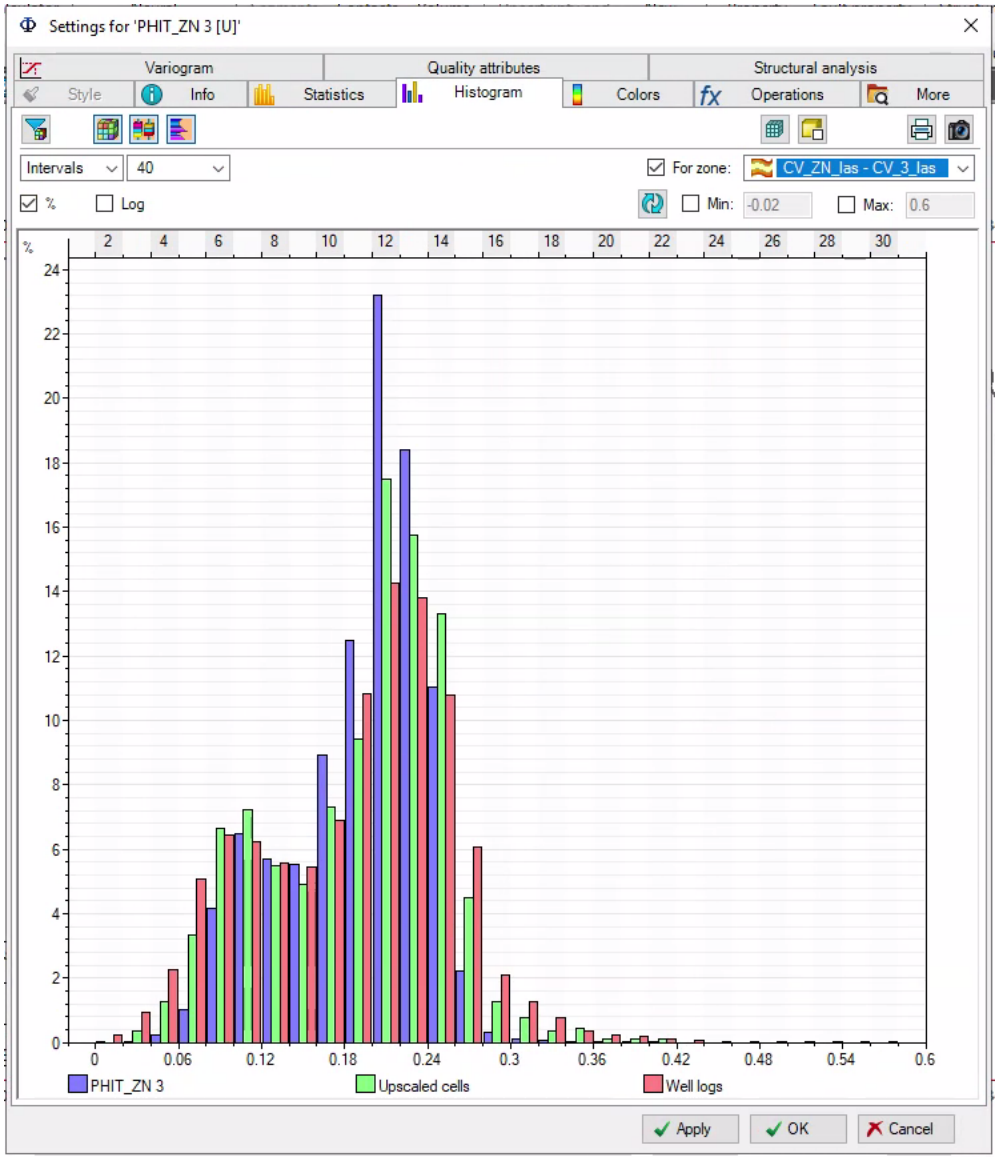


**Figure 3: Histogram of data and table of data for Well Logs, Upscaled Cells and Modeled Property over the Cotton Valley Injection Zone**

| TYPE | MIN | MAX | DELTA | N | MEAN | STD | VAR | SUM |
|---|---|---|---|---|---|---|---|---|
| Modeled Property | 0.0004 | 0.4190 | 0.4186 | 969600 | 0.1924 | 0.0481 | 0.0023 | 186589 |
| Upscaled Cells | 0.0269 | 0.4000 | 0.3731 | 1201 | 0.1895 | 0.0617 | 0.0038 | 227 |
| Well Logs | 0.0018 | 0.5772 | 0.5754 | 25796 | 0.1869 | 0.0694 | 0.0048 | 4821 |

**Table 3: Table of data for Well Logs, Upscaled Cells and Modeled Property over the Cotton Valley Injection Zone.**

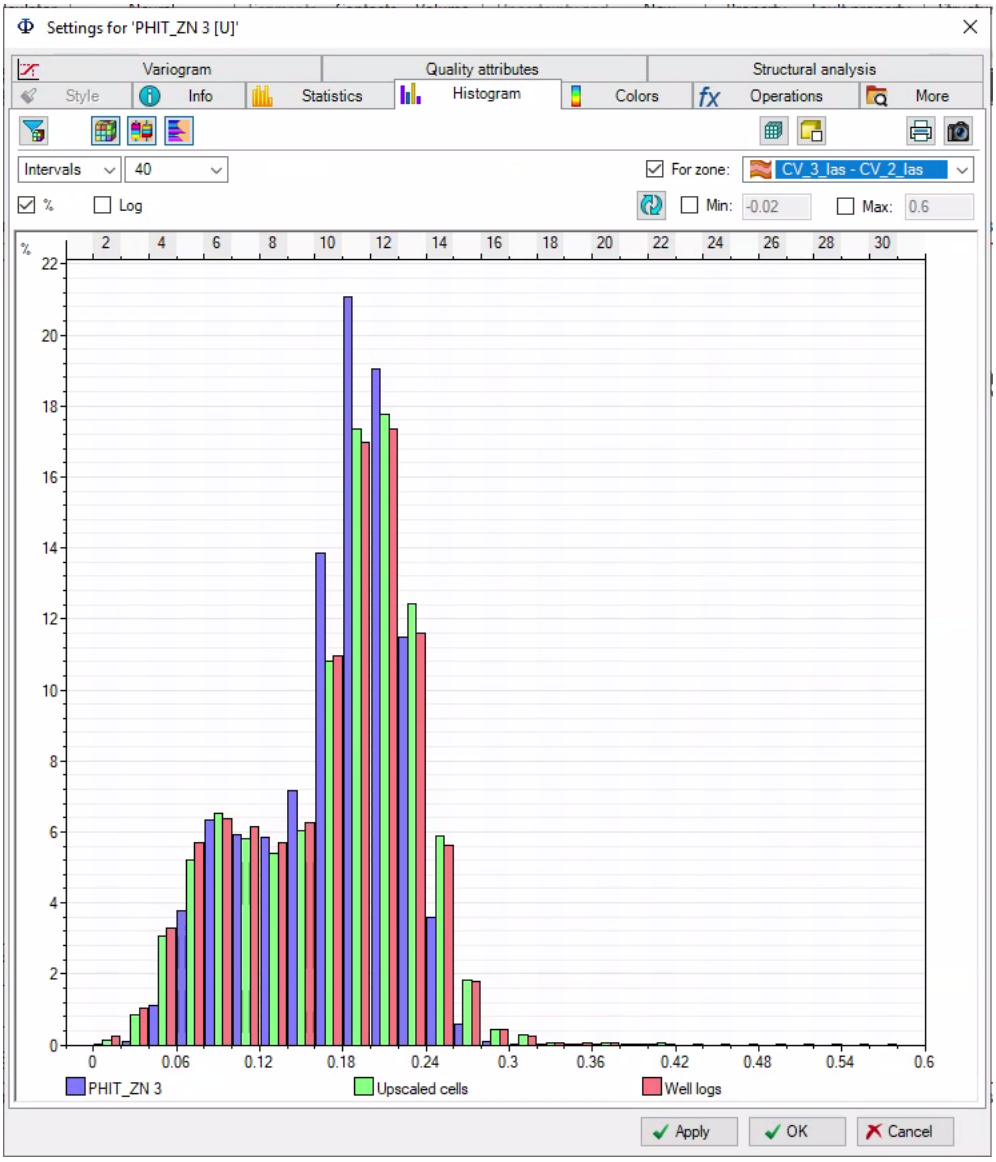


**Figure 4: Histogram of data and table of data for Well Logs, Upscaled Cells and Modeled Property over the CV3 interval.**

| TYPE | MIN | MAX | DELTA | N | MEAN | STD | VAR | SUM |
|---|---|---|---|---|---|---|---|---|
| Modeled Property | 0.0002 | 0.4151 | 0.4149 | 6565000 | 0.1748 | 0.0486 | 0.0024 | 1147795 |
| Upscaled Cells | 0.0060 | 0.4000 | 0.3940 | 8135 | 0.1736 | 0.0586 | 0.0034 | 1412 |
| Well Logs | 0.0040 | 0.5716 | 0.5675 | 33855 | 0.1713 | 0.0600 | 0.0036 | 5799 |

**Table 4: Table of data for Well Logs, Upscaled Cells and Modeled Property over the CV3 interval.**

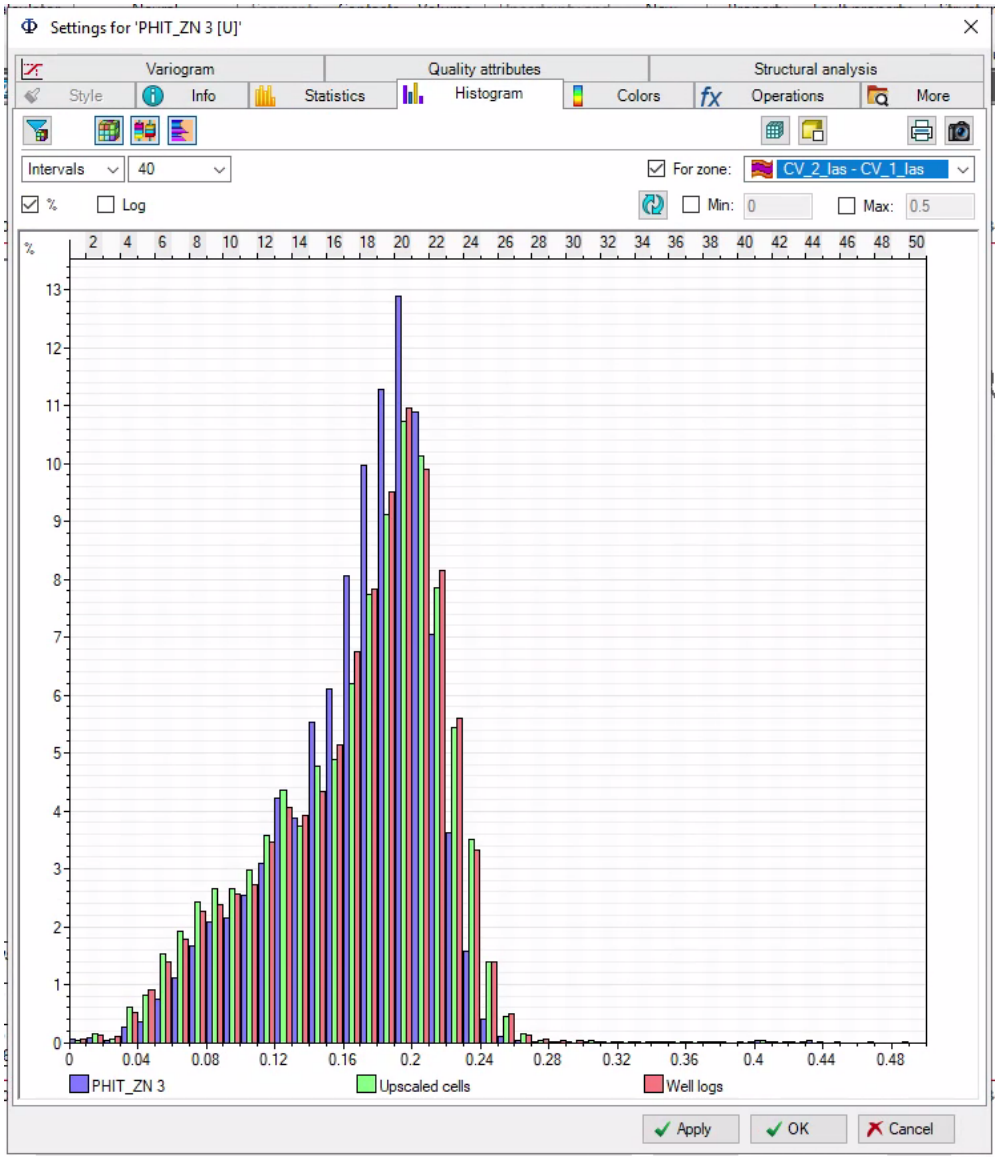


**Figure 5: Histogram of data and table of data for Well Logs, Upscaled Cells and Modeled Property over the CV2 interval.**

| TYPE | MIN | MAX | DELTA | N | MEAN | STD | VAR | SUM |
|---|---|---|---|---|---|---|---|---|
| Modeled Property | 0.0000 | 0.4393 | 0.4393 | 4242000 | 0.1688 | 0.0429 | 0.0018 | 716212 |
| Upscaled Cells | 0.0075 | 0.4000 | 0.3925 | 5329 | 0.1668 | 0.0502 | 0.0025 | 888 |
| Well Logs | 0.0052 | 0.4884 | 0.4832 | 21983 | 0.1680 | 0.0498 | 0.0025 | 3693 |

**Table 5: Table of data for Well Logs, Upscaled Cells and Modeled Property over the CV2 interval.**

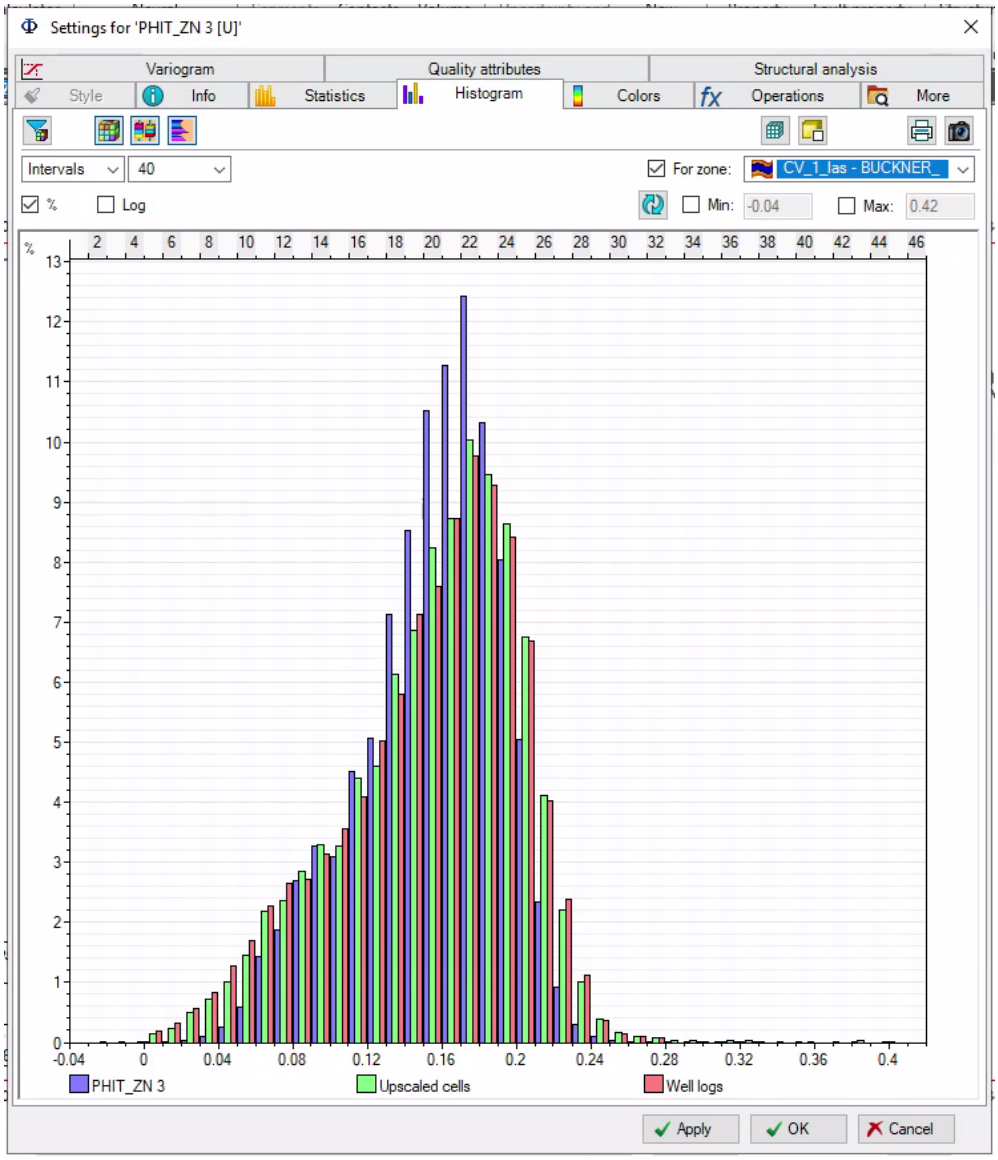


**Figure 6: Histogram of data and table of data for Well Logs, Upscaled Cells and Modeled Property over the CV1 interval.**

| TYPE | MIN | MAX | DELTA | N | MEAN | STD | VAR | SUM |
|---|---|---|---|---|---|---|---|---|
| Modeled Property | 0.0000 | 0.4018 | 0.4018 | 3333000 | 0.1550 | 0.0374 | 0.0014 | 516718 |
| Upscaled Cells | 0.0000 | 0.3806 | 0.3806 | 4294 | 0.1542 | 0.0468 | 0.0022 | 662 |
| Well Logs | 0.0000 | 0.3947 | 0.4231 | 16342 | 0.1527 | 0.0482 | 0.0023 | 2495 |

**Table 6: Table of data for Well Logs, Upscaled Cells and Modeled Property over the CV1 interval.**

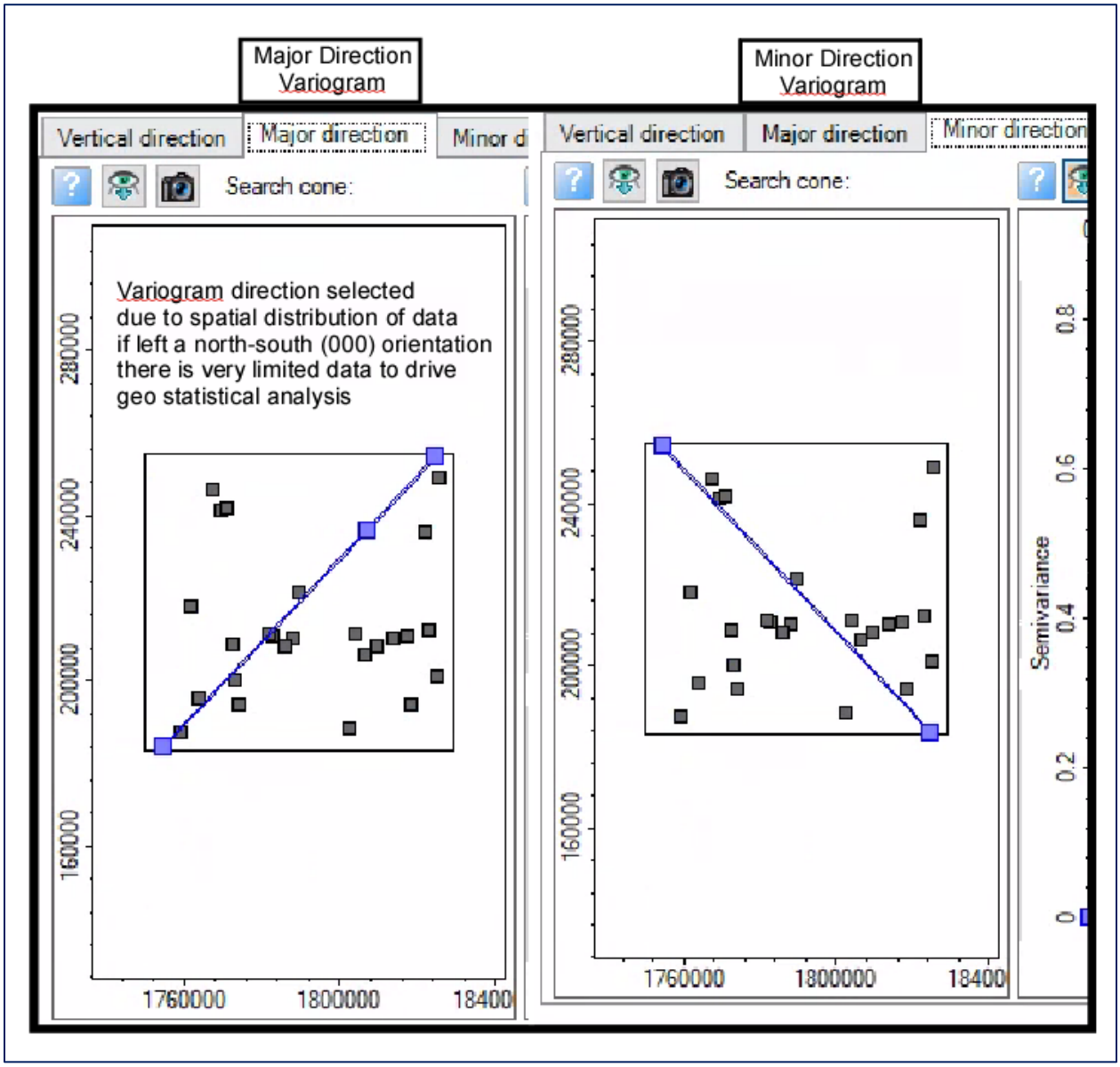


**Figure 7: Settings for major and minor direction for variogram analysis based upon spatial distribution of well data.**

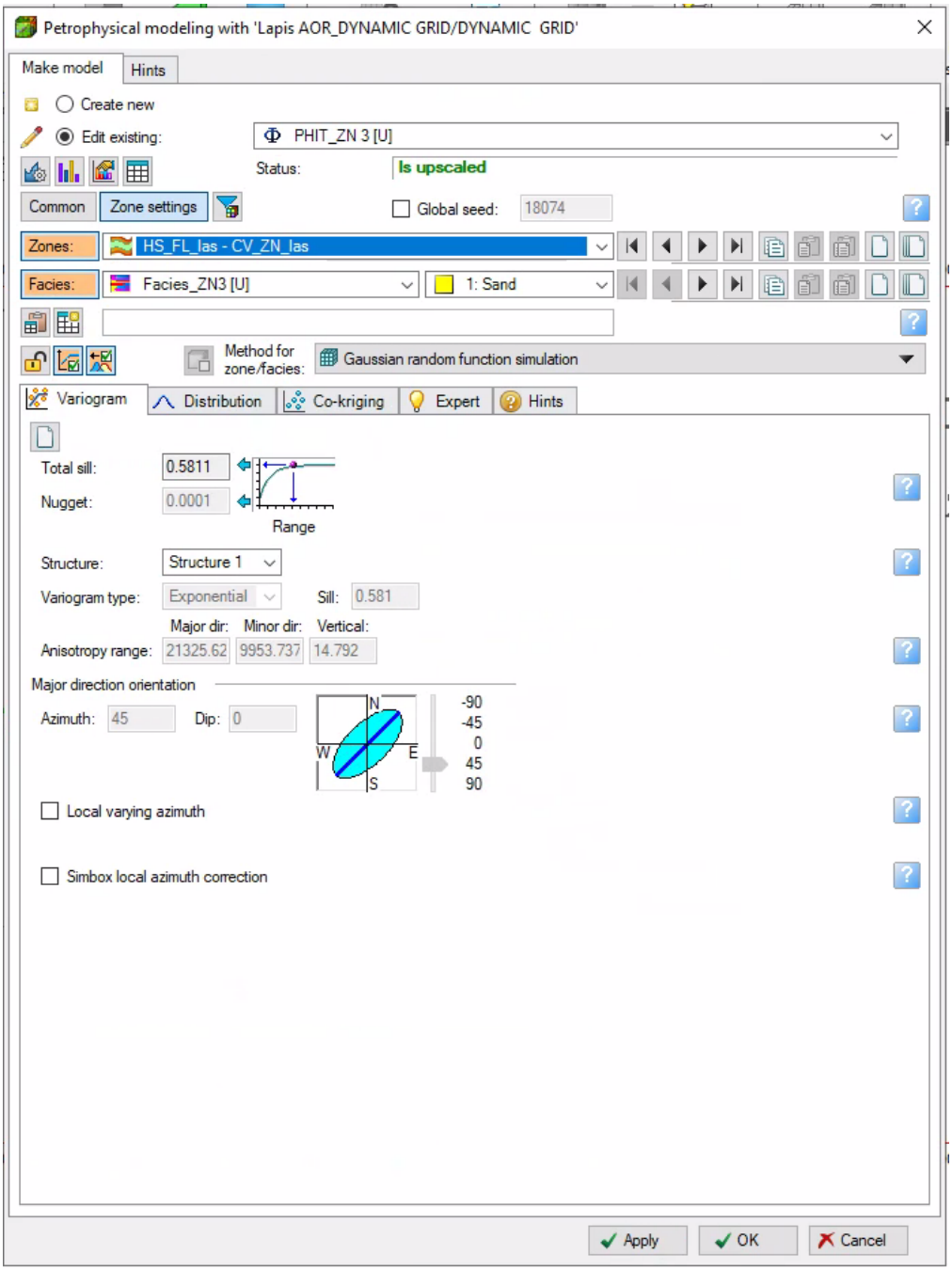


**Figure 8: Settings dialog for the petrophysical modeling of Total Porosity over the Lower Hosston Injection Zone.**

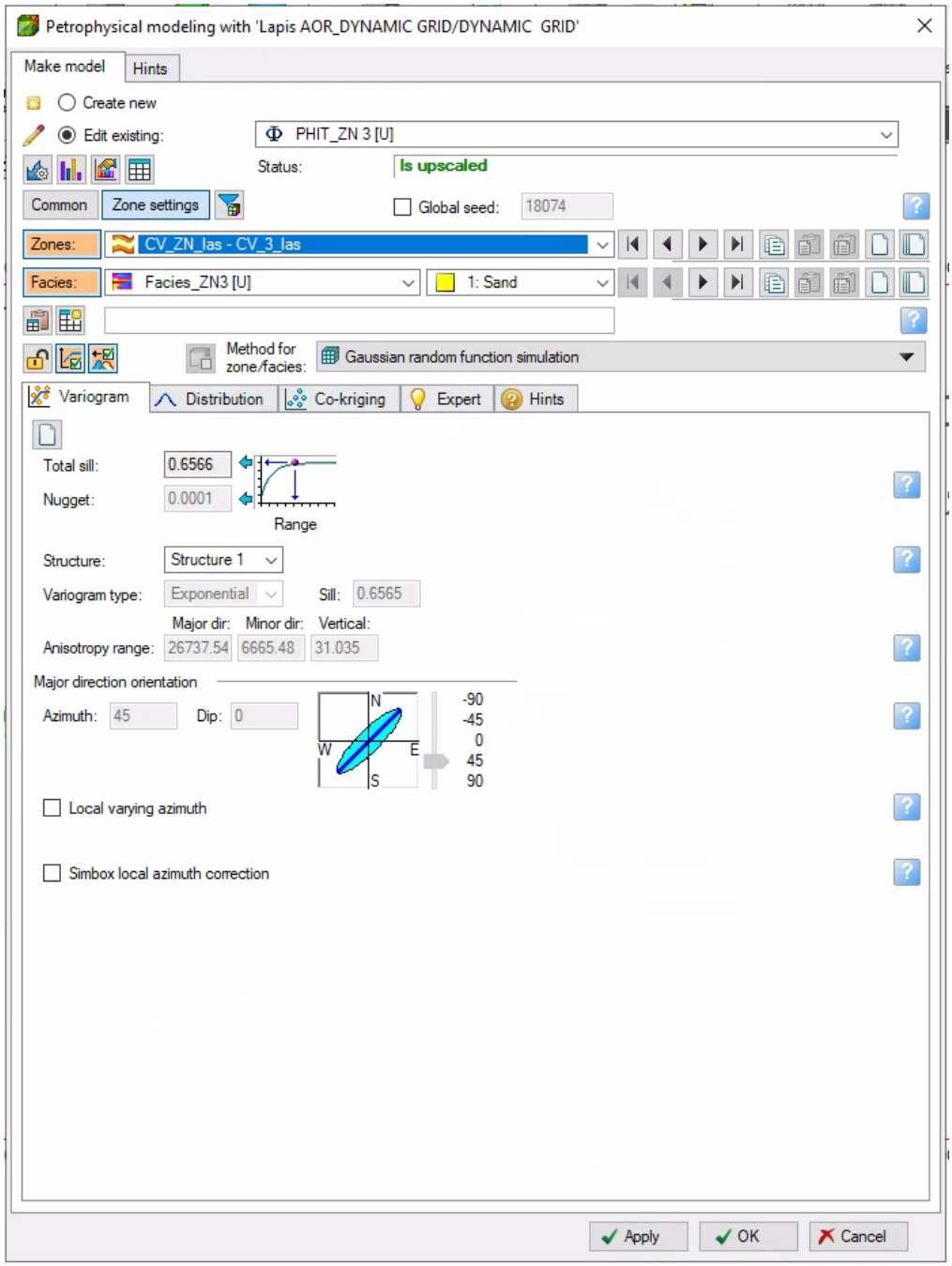


**Figure 9: Settings dialog for the petrophysical modeling of Total Porosity over the Cotton Valley Injection Zone**

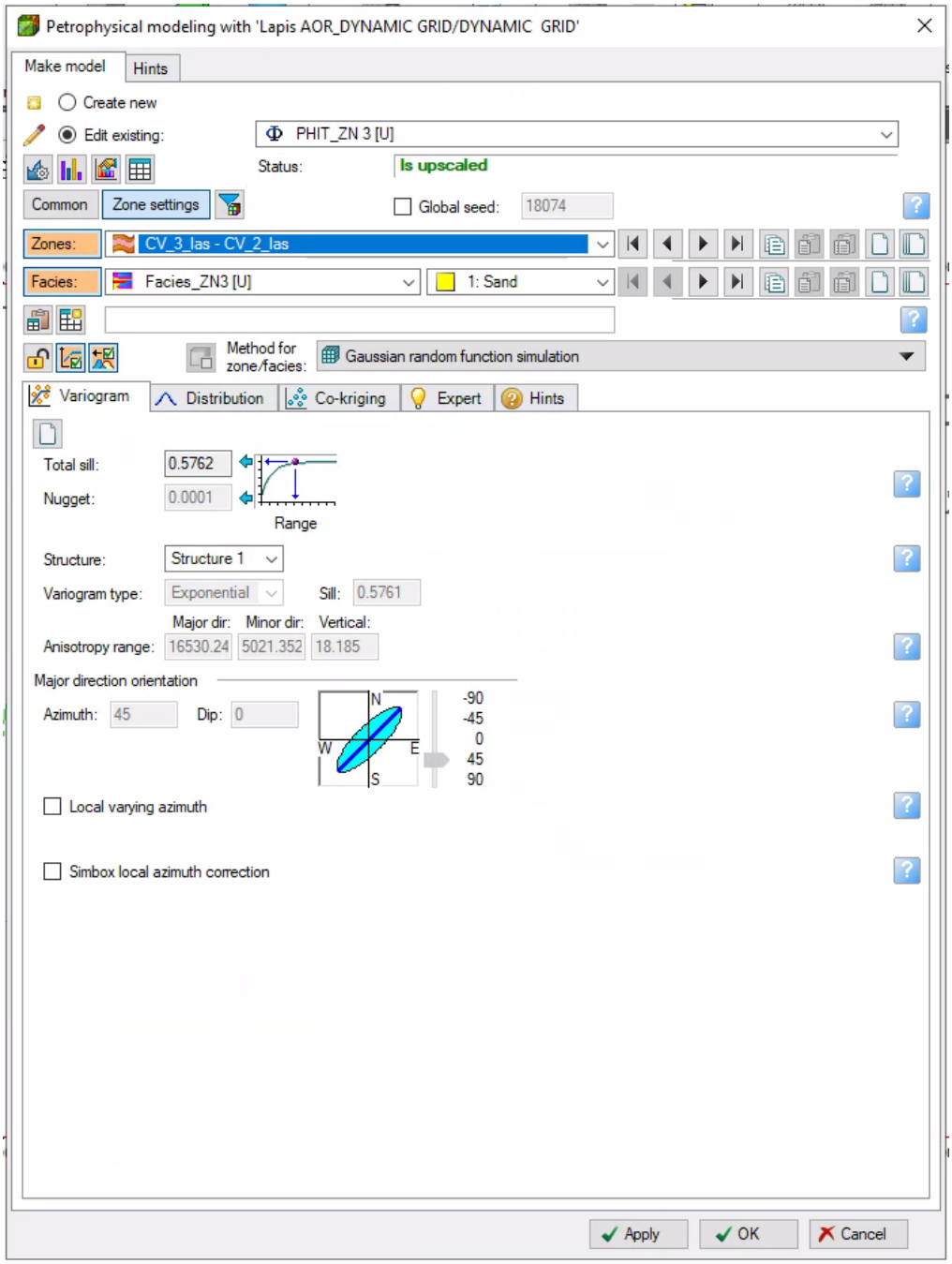


**Figure 10: Settings dialog for the petrophysical modeling of Total Porosity over the CV3 interval.**

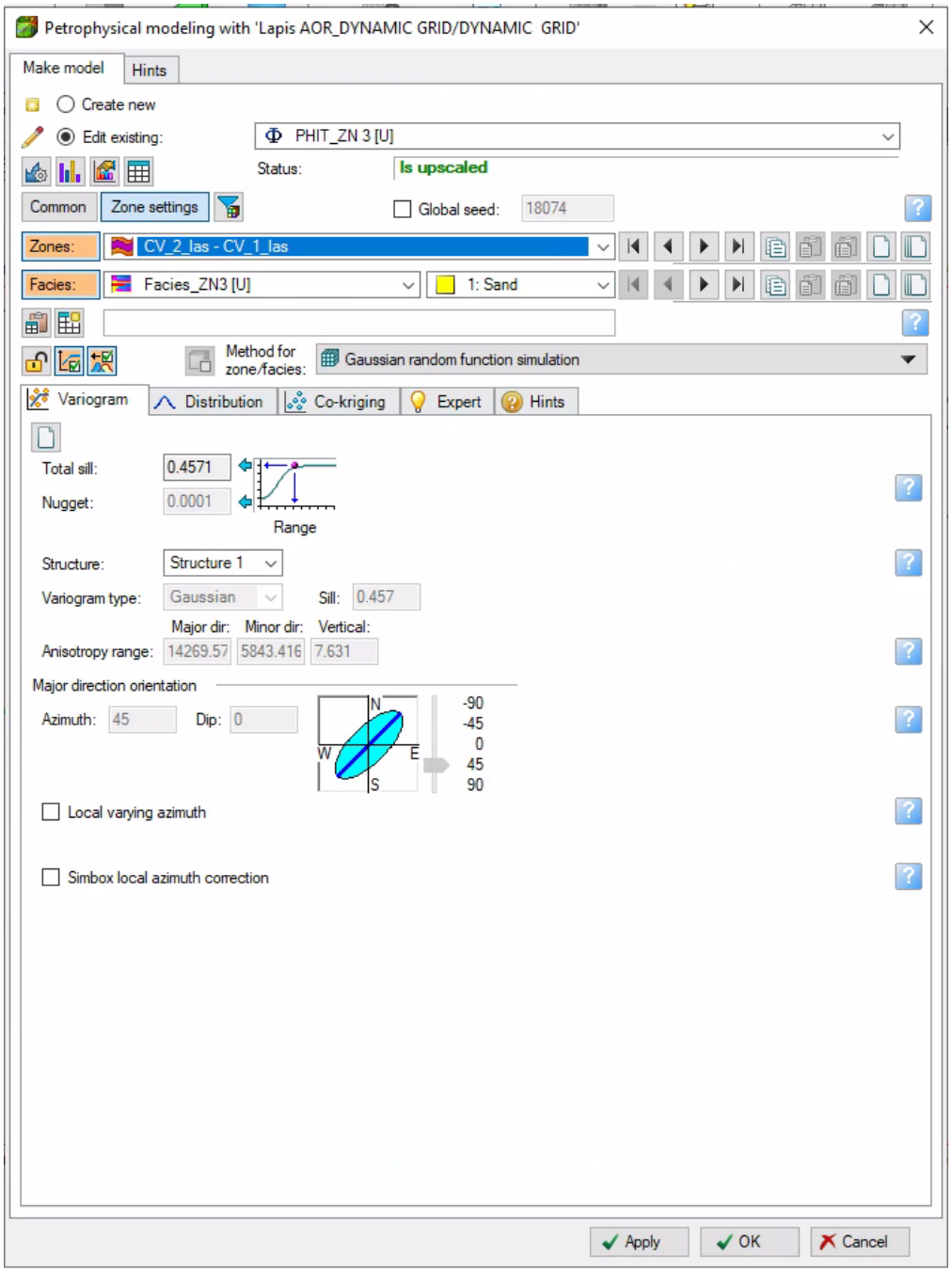


**Figure 11: Settings dialog for the petrophysical modeling of Total Porosity over the CV2 interval.**

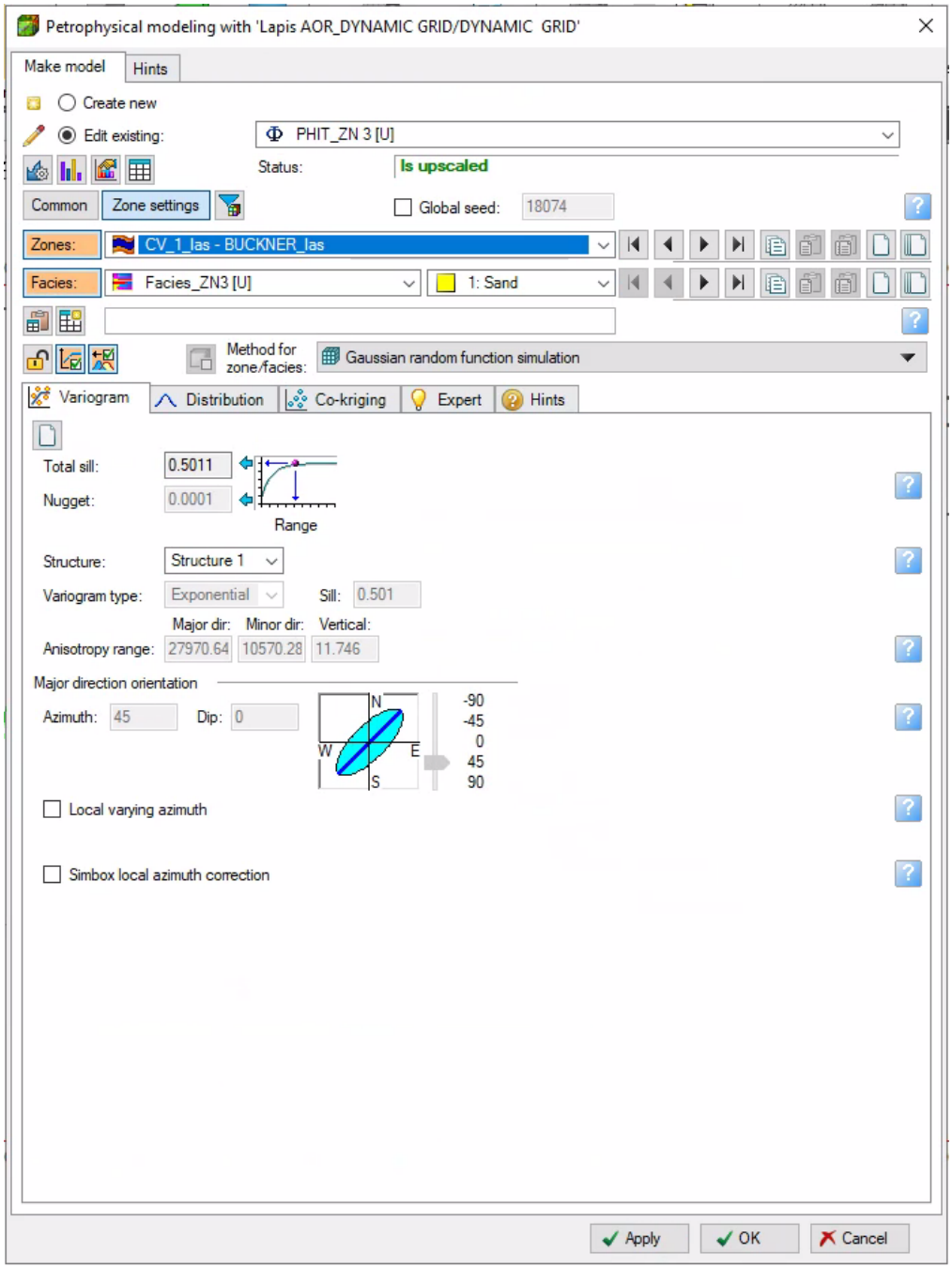


**Figure 12: Settings dialog for the petrophysical modeling of Total Porosity over the CV1 interval.**

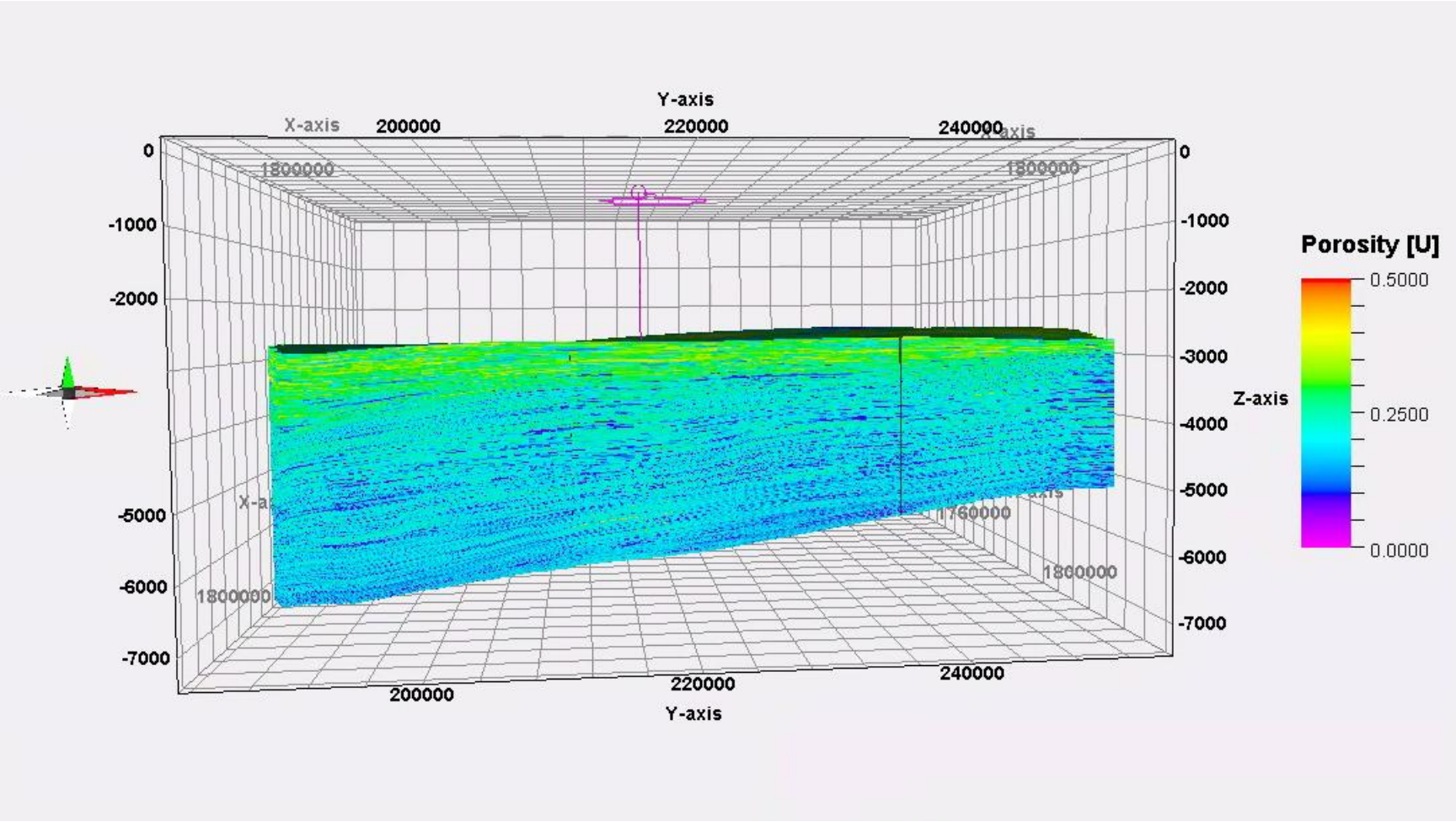


**Figure 13: View of Static Model Porosity Cube looking to the West. 5X vertical exaggeration**

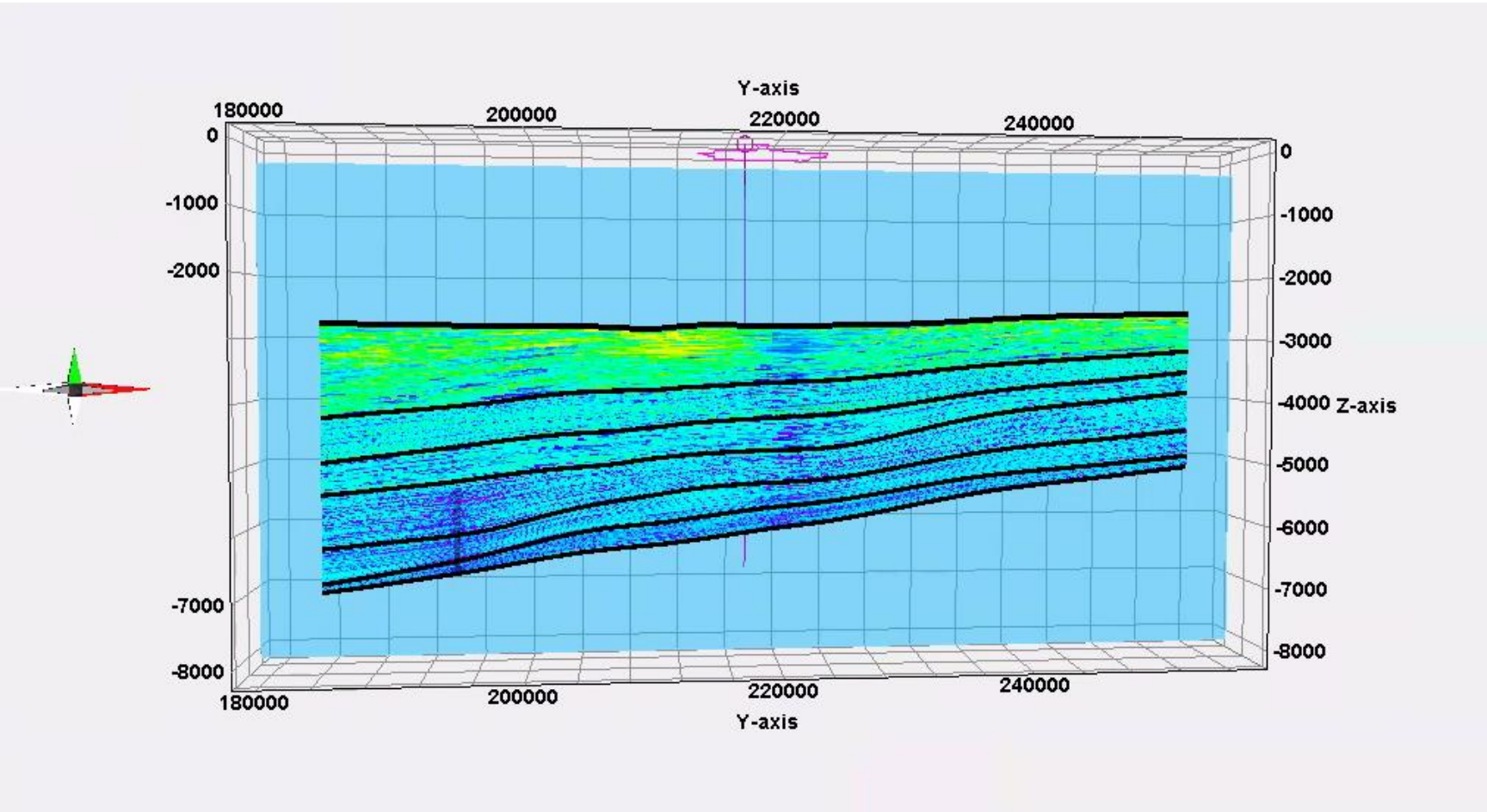


**Figure 14: N-S intersection plane view of Static Model Porosity Cube looking to the West through the proposed injection well for Project Blue. 5X vertical exaggeration**