# Surface Seismic Monitoring Report
# Sulphur Mines Salt Dome Broadband Seismic Array

Report Period : January 16-31, 2024

Report Date: February 5, 2024

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Using results from Nanometrics

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**Summary**


- No seismic detections or locations were reported from January 16-31, 2024.
- All five broadband stations were operational from January 16-31, 2024.


**Broadband Trillium Compact Seismic Array**

Nanometrics (https://nanometrics.ca/home) operates and processes data for the broadband array. The broadband array was fully functional from January 16-31, 2024.

The broadband station locations are show in Figure 1 and listed in Table 1. Figure 2 shows the broadband network amplitude over time from January 16-31, 2024 (background noise plot). The background noise is similar to the previous reporting, the noisiest stations are SUL01 and SUL02, while the quietest stations in this time period were stations SUL03 and SUL05.

As mentioned in the previous reports, the plan for the seismic network is to move station SUL01 approximately 2400 feet to the WNW (Figure 1, labeled SUL01 Trillium NEW LOC) and add an additional station to the east of the dome, SUL06 (labeled "SUL06 PROPOSED TRILLIUM"). The station moves will likely occur sometime in Q1 2024.

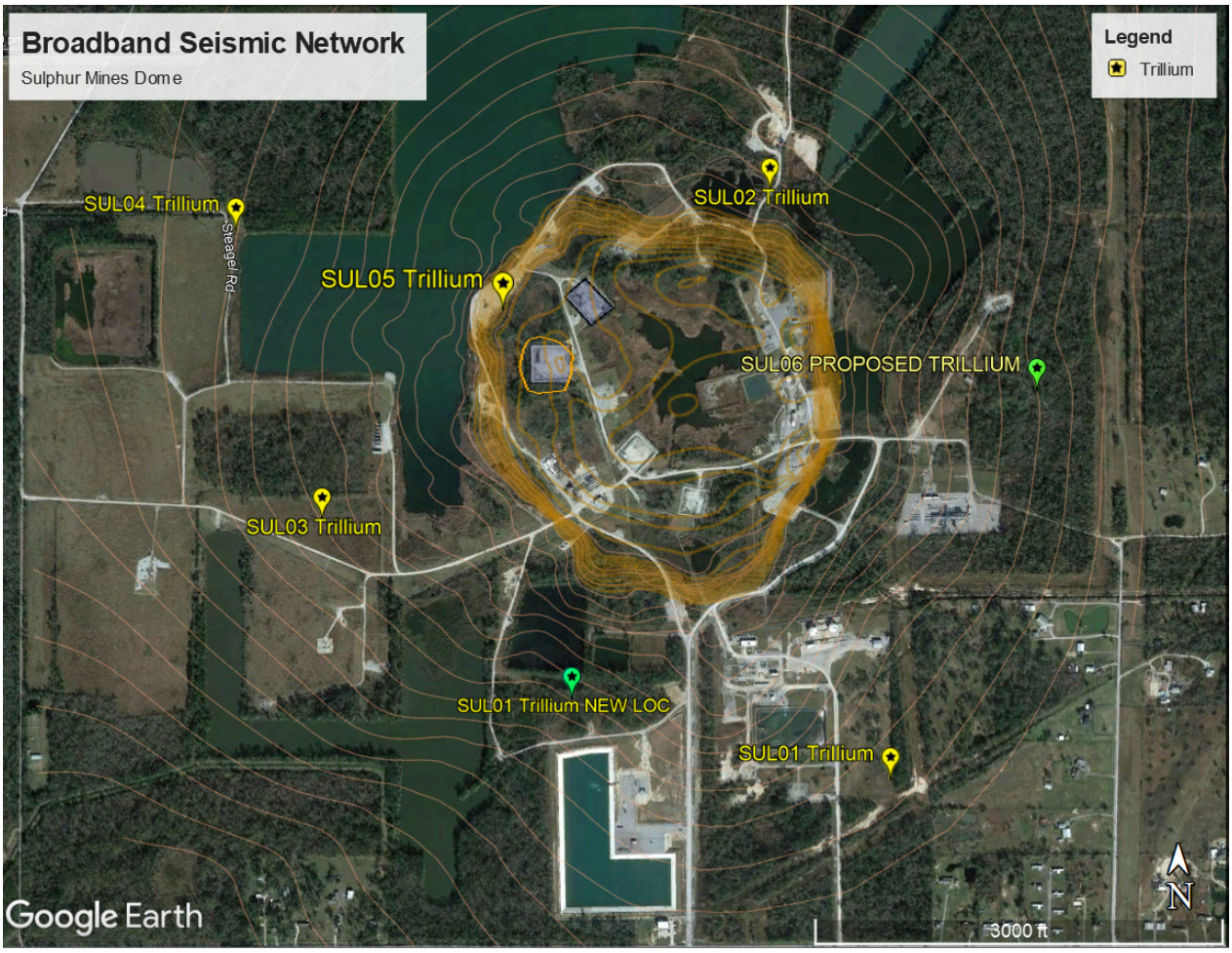



*Figure 1. Google Earth map image showing the location of the broadband seismic (Trillium Compact Sensors, yellow symbols and labels) stations near and at the Sulphur Mines Salt Dome. The contours are the salt and cap rock elevations, the orange circle is the general outline of Cavern 7. Two new stations are shown in green symbols, SUL01 Trillium NEW LOC is the proposed approximate location for moving SUL01, and a new station SUL06 PROPOSED TRILLIUM is the approximate location for a new seismic station.*

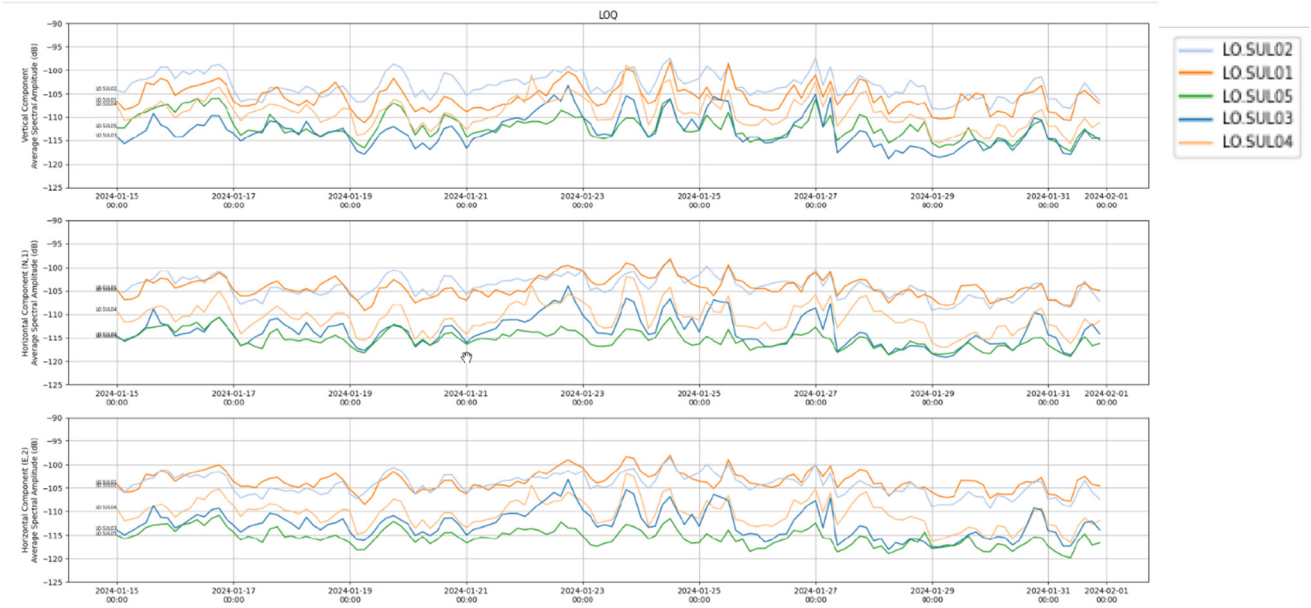



*Figure 2. Average spectral amplitudes in decibels on the five broadband sensor from January 16-31, 2024. The upper plot is the vertical component, the middle and lower plots are the horizontal component (middle is north-south and lower plot is east-west component).*

**Magnitude Detectability.** The magnitude detectability of the network for three representative noise periods is shown in Appendix 2. The modeling was updated to show the magnitude of completeness for three different attenuation values from high attenuation (Q= 100) to lower attenuation (Q=200).

## Appendix 1. Seismic Station Locations

*Table 1. Seismic Station locations and operational dates at Sulphur Mines Dome (to January 31, 2024). Temporary Station locations and start and end dates provided by Westlake. Trillium station locations provided by Nanometrics.*

| Station | LAT WGS84 | LON WGS84 | Date start | Date end |
|---|---|---|---|---|
| Temp_1a | 30.2575 | -93.4123 | 1/30/2023 | 2/9/2023 |
| Temp_1b | 30.2534 | -93.4135 | 2/9/2023 | 4/3/2023 |
| Temp_2a | 30.2570 | -93.4097 | 1/30/2023 | 2/9/2023 |
| Temp_2b | 30.2555 | -93.4132 | 2/9/2023 | 2/27/2023 |
| Temp_2c | 30.2547 | -93.4138 | 2/27/2023 | 4/5/2023 |
| Temp_3a | 30.2533 | -93.4091 | 1/30/2023 | 2/9/2023 |
| Temp_3b | 30.2563 | -93.4146 | 2/9/2023 | 4/5/2023 |
| Temp_4a | 30.2486 | -93.4123 | 1/30/2023 | 2/27/2023 |
| Temp_4b | 30.2507 | -93.4121 | 2/27/2023 | 3/8/2023 |
| Temp_4c | 30.2506 | -93.4100 | 3/8/2023 | 3/15/2023 |
| Temp_4d | 30.2503 | -93.4119 | 3/15/2023 | est 4/3/2023 |
| Temp_5a | 30.2502 | -93.4156 | 1/30/2023 | 2/27/2023 |
| Temp_5b | 30.2507 | -93.4153 | 2/27/2023 | 3/15/2023 |
| Temp_5c | 30.2504 | -93.4140 | 3/15/2023 | est 4/3/2023 |
| Temp_6a | 30.2532 | -93.4166 | 1/30/2023 | 3/15/2023 |
| Temp_6b | 30.2529 | -93.4161 | 3/15/2023 | 4/4/2023 |
| Temp_7a | 30.2547 | -93.4161 | 1/30/2023 | 4/3/2023 |
| Semi Perm S01 | 30.2453 | -93.4073 | 4/4/2023 | 11/2/2023 |
| Semi Perm S02 | 30.2571 | -93.4098 | 4/6/2023 | 11/2/2023 |
| Semi Perm S03 | 30.2536 | -93.4091 | 4/6/2023 | 11/2/2023 |
| Semi Perm S04 | 30.2470 | -93.4213 | 4/5/2023 | 5/12/2023 |
| Semi Perm S04_1 | 30.2506 | -93.4204 | 5/12/2023 | 11/2/2023 |
| Semi Perm S05 | 30.2564 | -93.4224 | 4/5/2023 | 11/2/2023 |
| Semi Perm S06 | 30.2532 | -93.4167 | 4/5/2023 | 11/2/2023 |
| Semi Perm S07 | 30.2547 | -93.4162 | 4/5/2023 | 11/2/2023 |
| SUL01 trillium | 30.2452 | -93.4071 | 9/13/2023 | |
| SUL02 trillium | 30.2570 | -93.4099 | 9/13/2023 | |
| SUL03 trillium | 30.2504 | -93.4203 | 9/12/2023 | |
| SUL04 trillium | 30.2562 | -93.4223 | 9/12/2023 | |
| SUL05 trillium | 30.2546 | -93.4161 | 9/13/2023 | |

## Appendix 2. Broadband Array Magnitude of Completeness ($M_c$)

A magnitude of completeness, Mc, is the minimum magnitude locatable on a network. For the Sulphur Mines broadband array, Nanometrics modeled three Mc scenarios for the array based on three noise levels, high, median and low noise recorded from September 20 to 27, 2023 (Figure 3). The magnitude of completeness model assumes 4 stations are triggered to compute a location. The Mc events are modeled at 3000 ft depth, near the base of Cavern 7, using three different noise levels based on the noise recorded on the array. The percentile used are $10^{th}$ (low noise), $50^{th}$ (median noise) and $90^{th}$ (high noise) (Figure 3).

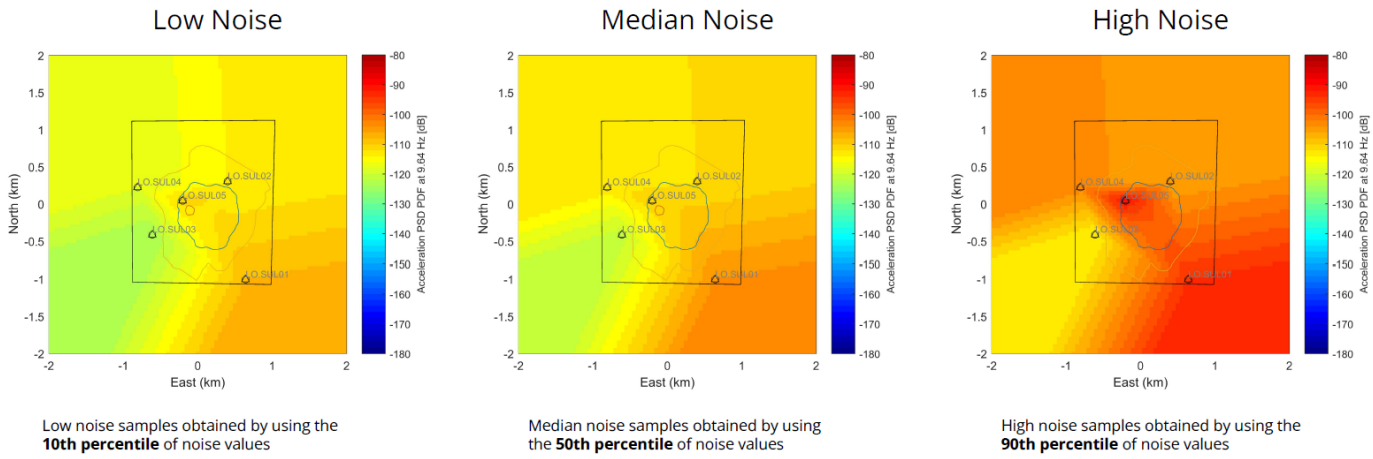



*Figure 3. Map of the noise levels modeled for the magnitude of completeness figures. Left most is the low noise, middle median noise and right is high noise.*

The map of the magnitude of completeness modeled by Nanometrics for the three noise levels is shown in Figure 4 for the Sulphur Mines dome area. The Mc will vary spatially (Figure 4) depending on the station geometry and the event location and depth.

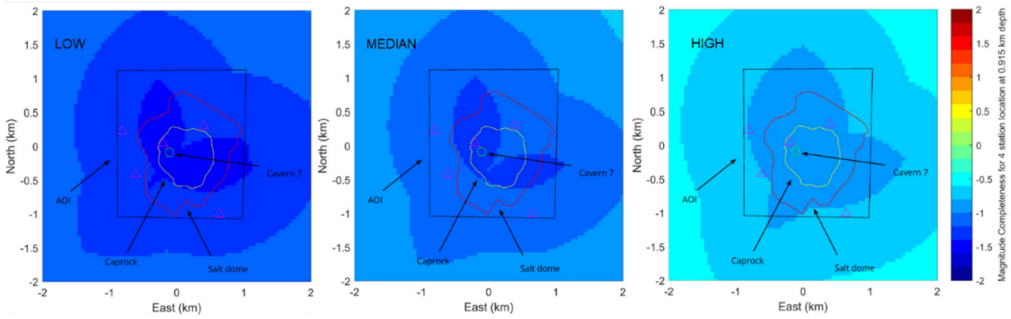
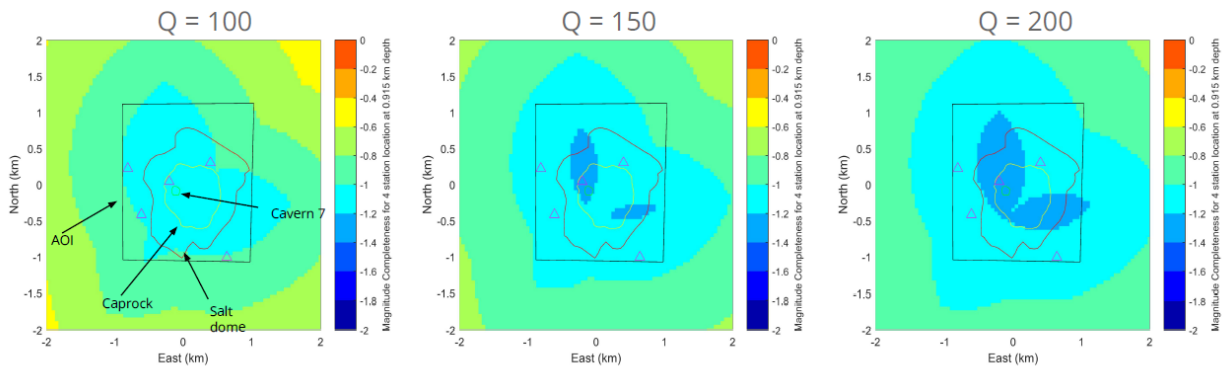



*Figure 4. Modeled magnitude of completeness (Mc, lowest magnitude detectable) for the Sulphur Mines salt dome and vicinity using the broadband array. Three noise models are shown: the high noise model shown on the right, median noise level in the middle and low noise model on the left, as labeled. The outline of the Sulphur Mines dome and caprock and the outline of Cavern 7. The color bar shows the Mc values for each model.*

**Modeling with Seismic Attenuation**. Seismic attenuation will result in a modification of the magnitude detectability across the array. If seismic attenuation is high, more energy is dissipated therefore is more difficult to record seismic waveforms on the surface. Figure 5 shows magnitude of completeness for the median noise level for three seismic attenuation values.




- **Range:** M-1.18 to M-0.81
- **Median:** M-1.05
- **Cavern 7:** M-1.15

- **Range:** M-1.24 to M-0.93
- **Median:** M-1.13
- **Cavern 7:** M-1.21

- **Range:** M-1.27 to M-0.99
- **Median:** M-1.17
- **Cavern 7:** M-1.25

*Figure 5. Modeled magnitude of completeness (Mc, lowest magnitude detectable) for the Sulphur Mines salt dome and vicinity using the broadband array for three different seismic attenuation values for a median noise level. The three seismic attenuation values are on the top of each plot: Q=100 (high attenuation), left most plot, Q=150 (medium attenuation, middle plot) and Q=200,( lower attenuation, right plot). The outline of the Sulphur Mines dome and caprock and the outline of Cavern 7. The color bar shows the Mc values for each model.*

The modeling results for Mc computed by Nanometrics at Cavern 7 location at 3000 ft depth suggests:

- The low noise model shows a Mc of about magnitude -1.4
- The median noise level Mc is magnitude -1.3.
- For the median noise level and accounting for seismic attenuation:
    - With Q= 100 seismic attenuations (highest attenuation modeled), the estimate is M -1.15
    - With Q=150 seismic attenuation, the estimate is M -1.13
    - With Q=200 seismic attenuation (lowest attenuation modeled), the estimate is M -1.25
- The high noise level Mc is magnitude -0.9.