



America's Premier Competitive Power Company
... Creating Power for a Sustainable Future



Seismic Monitoring Advisory Committee Meeting

01 October 2021 to 31 March 2022 Reporting Period

Calpine Geothermal Visitor Center

Thursday 12 May 2022

Craig Hartline
Senior Geophysicist
Geysers Power Company, LLC



Seismic Monitoring Advisory Committee Meeting

Presentation Agenda

- Seismic Monitoring Networks
 - USGS / Northern California Seismic Network
 - LBNL / Geysers Power Company Seismic Monitoring Network
 - LBNL / Geysers Power Company Strong Motion Network
 - Upgrades to Radio Telemetry Systems
- Fieldwide Water Injection
- Fieldwide Induced Seismicity Analysis
- Water Injection and Induced Seismicity Animation Analysis
- Community Hotline
 - Seismic Events of Concern
- Strong Motion Data Analysis
 - Peak Ground Acceleration vs. Hypocentral Distance
 - Anderson Springs Site Amplification
- Water Injection Goals
 - 3D Pre-Drilling Project Analyses
 - Injection Well Planning
- Applied Seismology InSite Geo Software

Geysers Geothermal Field, Nearby Communities and Seismic Monitoring Networks

● Lawrence Berkeley National Laboratory
2003 installation; continuing upgrades
34 stations

Magnitude 0.8 Threshold *

Primary Contacts: Dr. Seiji Nakagawa
Dr. Ernie Majer

● Strong Motion Accelerometers

● 2017/18 Nanometrics installation (2)
● 2020 Q1 Nanometrics installation (2)

0.1% of Gravitational Acceleration Threshold

Primary Contacts: Ramsey Haught
Jarpe Data Solutions

● US Geological Survey Regional Network
1970's installation; several upgrades
7 contributing stations

Magnitude 1.5 Threshold *

Primary Contacts: Dr. Lind Gee / Lynn Dietz
Dr. David Oppenheimer

Productive Steam Reservoir Outline

"Major" Roads

Northwest Geysers
Radio Repeater Relocation/Upgrade
Q4 2021 to Q4 2022

Upgrades In Progress:

New Weatherproof 8'x10' Container
Ethernet Communication Lines
Intuicom Broadband Radio Pairs
Antenna Mounts, Masts and Antennas
High Quality Gears-Pacific HVAC Unit
Back-Up Power Systems
480V Transfer Switch
~ \$22000 equipment and labor

Goals:

Improved Seismic Data
Quality And Reliability

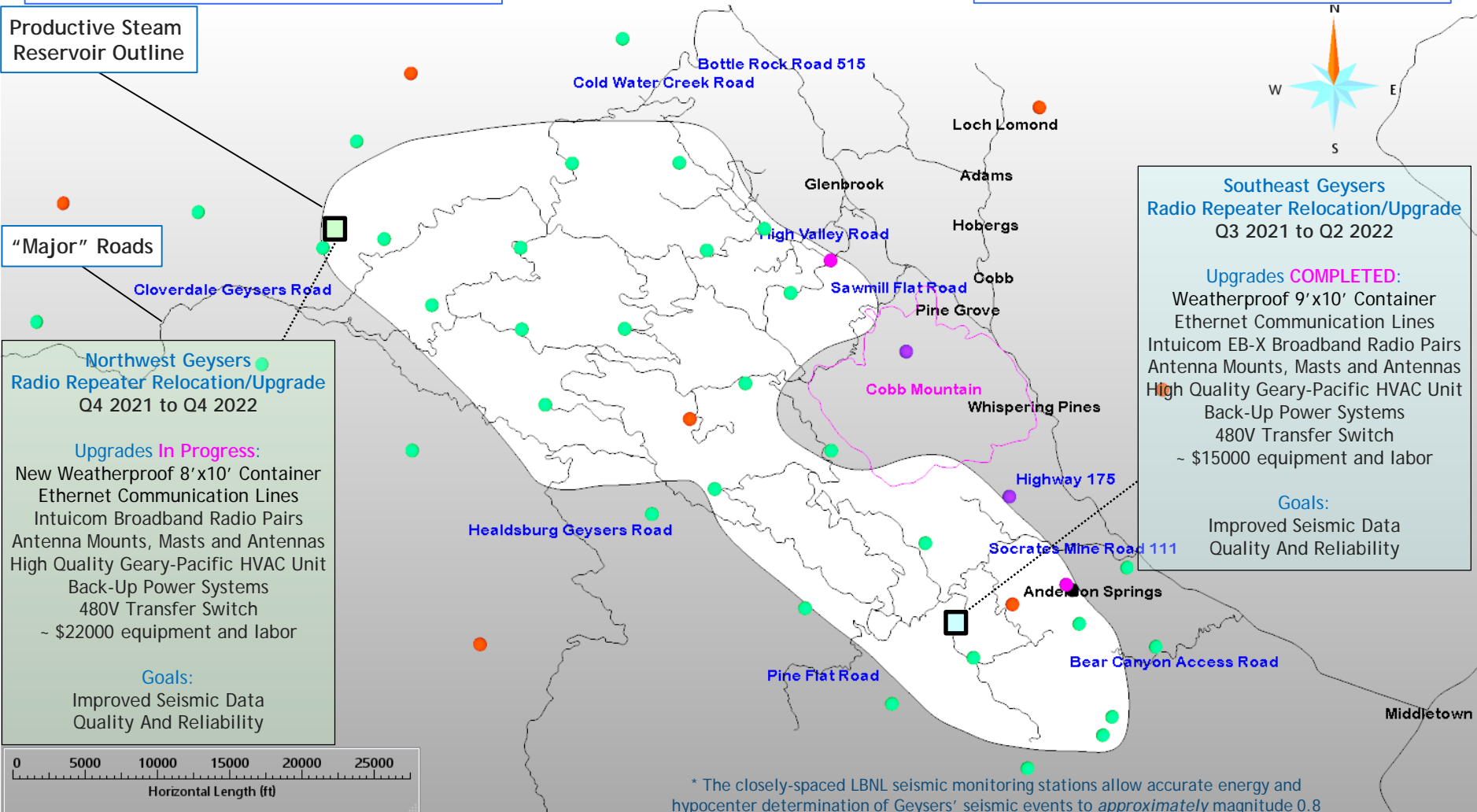
Southeast Geysers
Radio Repeater Relocation/Upgrade
Q3 2021 to Q2 2022

Upgrades COMPLETED:

Weatherproof 9'x10' Container
Ethernet Communication Lines
Intuicom EB-X Broadband Radio Pairs
Antenna Mounts, Masts and Antennas
High Quality Gears-Pacific HVAC Unit
Back-Up Power Systems
480V Transfer Switch
~ \$15000 equipment and labor

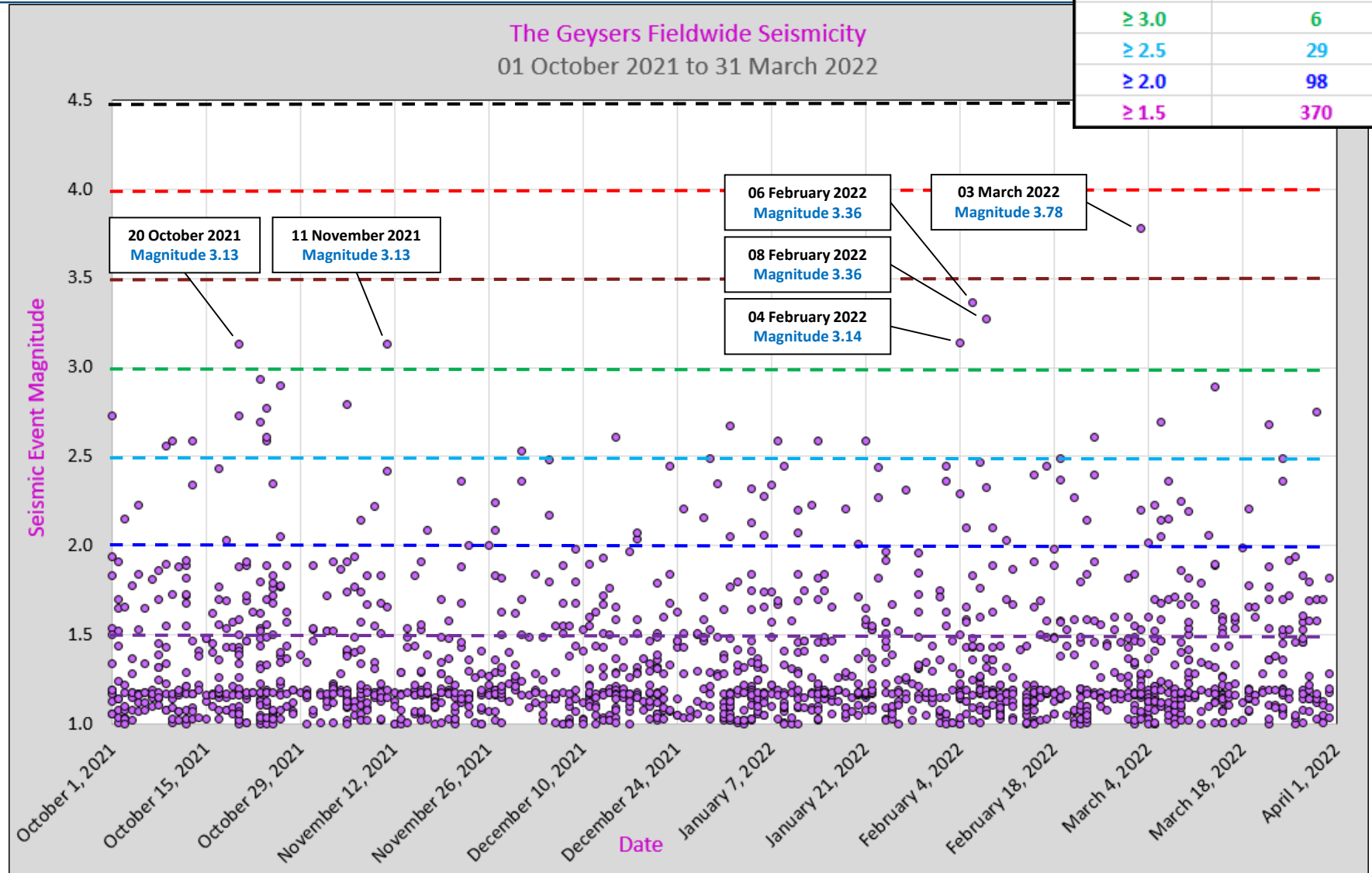
Goals:

Improved Seismic Data
Quality And Reliability



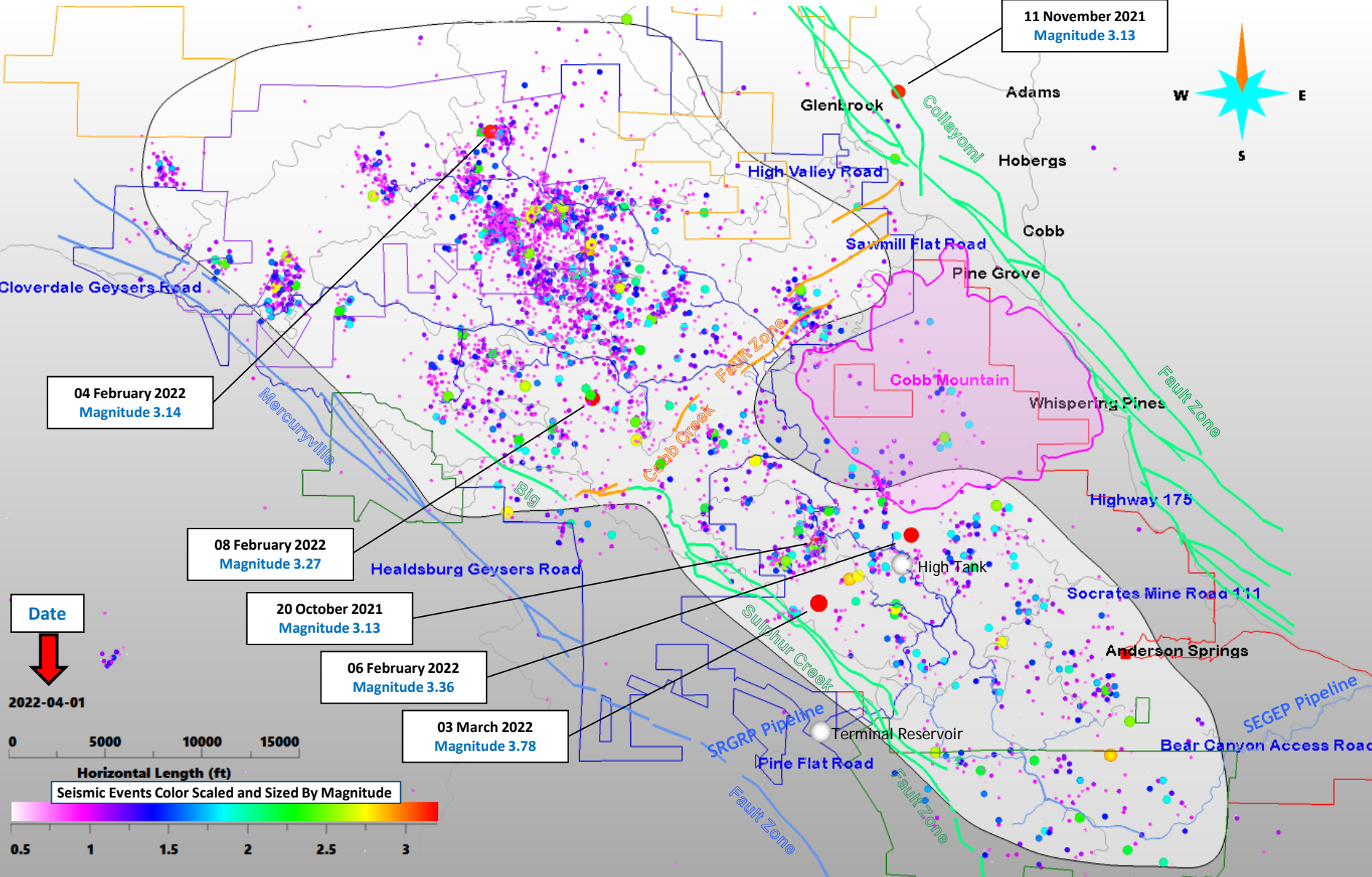
* The closely-spaced LBNL seismic monitoring stations allow accurate energy and hypocenter determination of Geysers' seismic events to approximately magnitude 0.8

Magnitude	Number Of Events
≥ 4.5	0
≥ 4.0	0
≥ 3.5	1
≥ 3.0	6
≥ 2.5	29
≥ 2.0	98
≥ 1.5	370



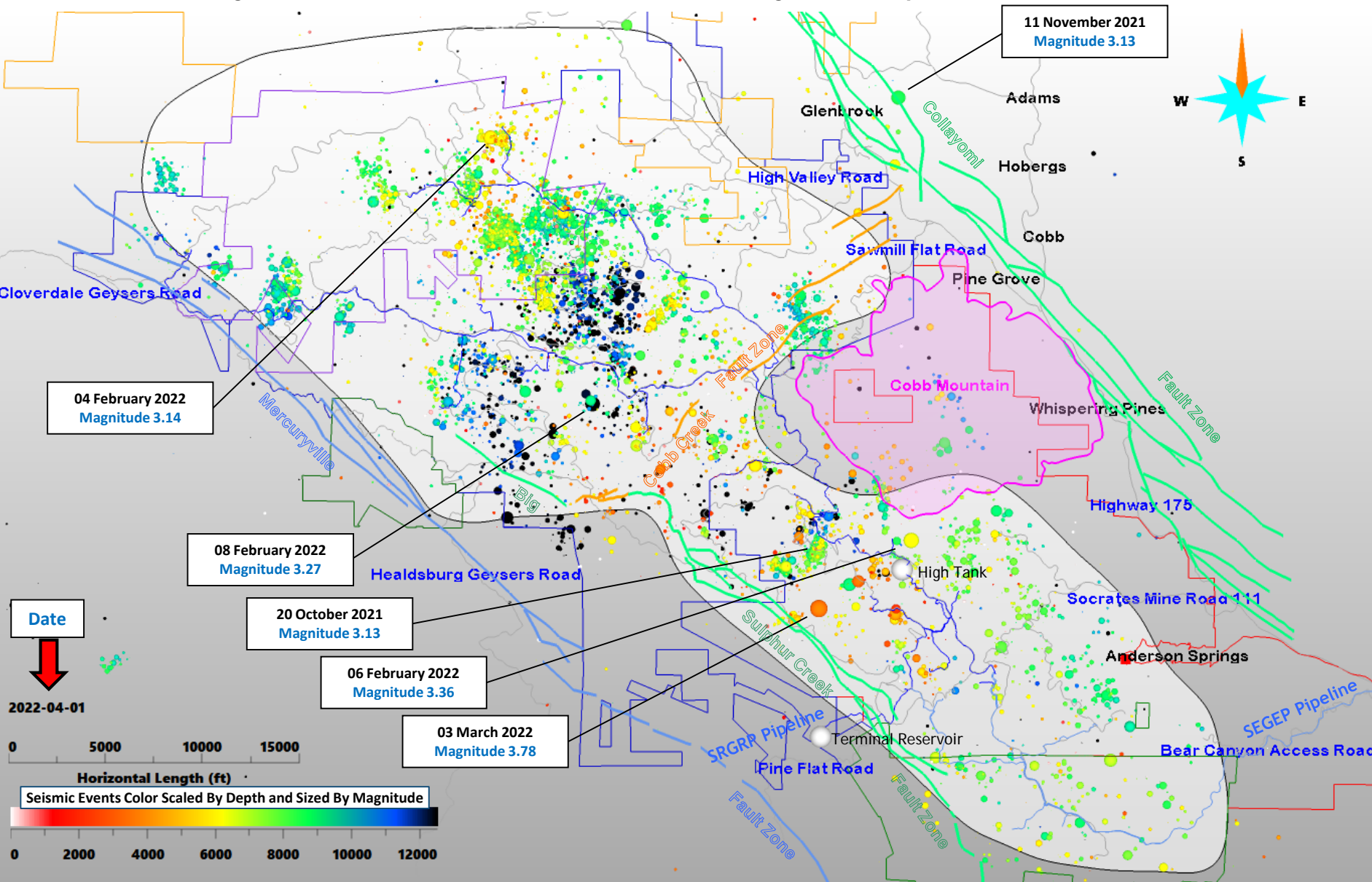
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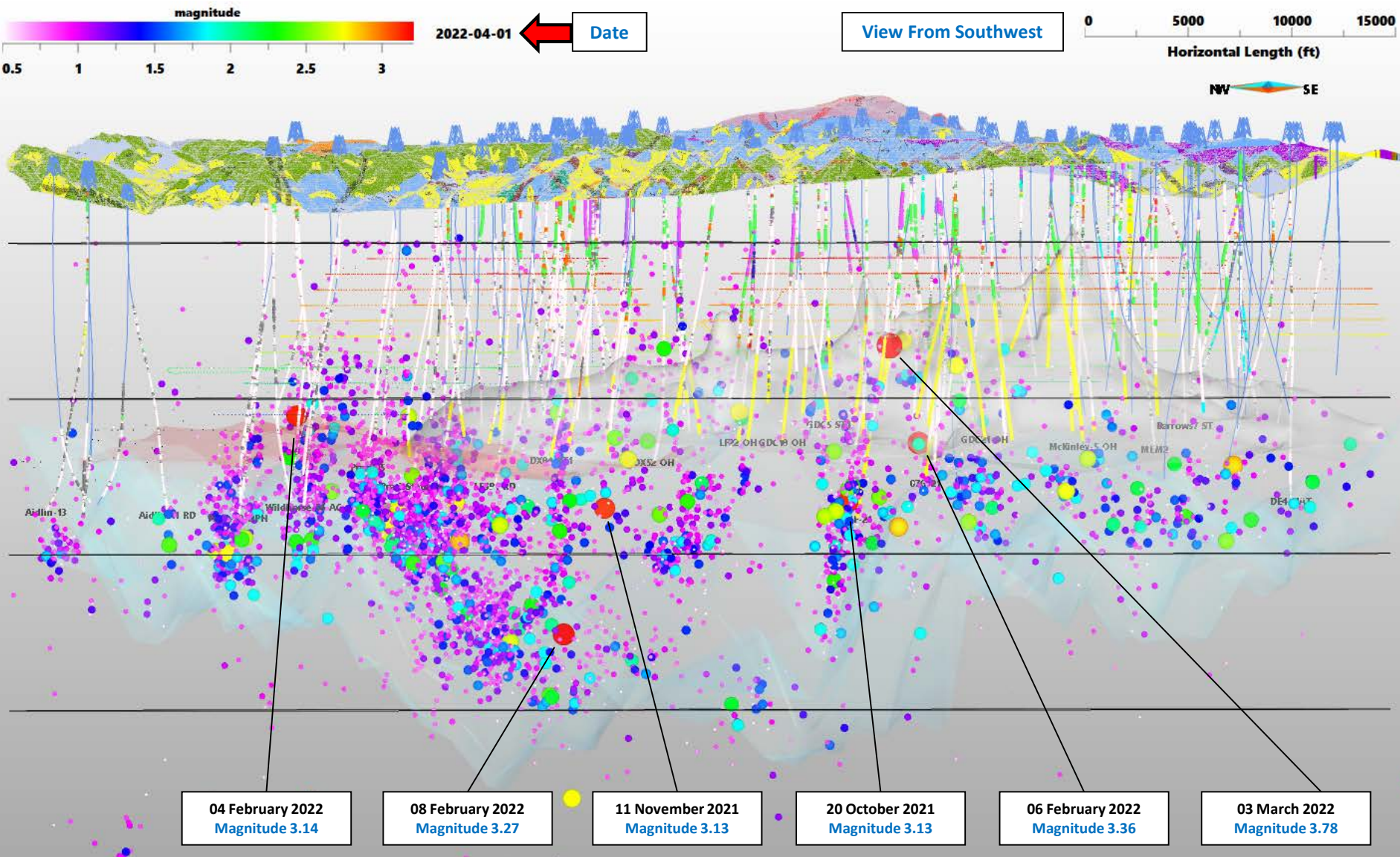
Field-wide Seismicity Animation At Two Week Interval - Color Scaled By Magnitude

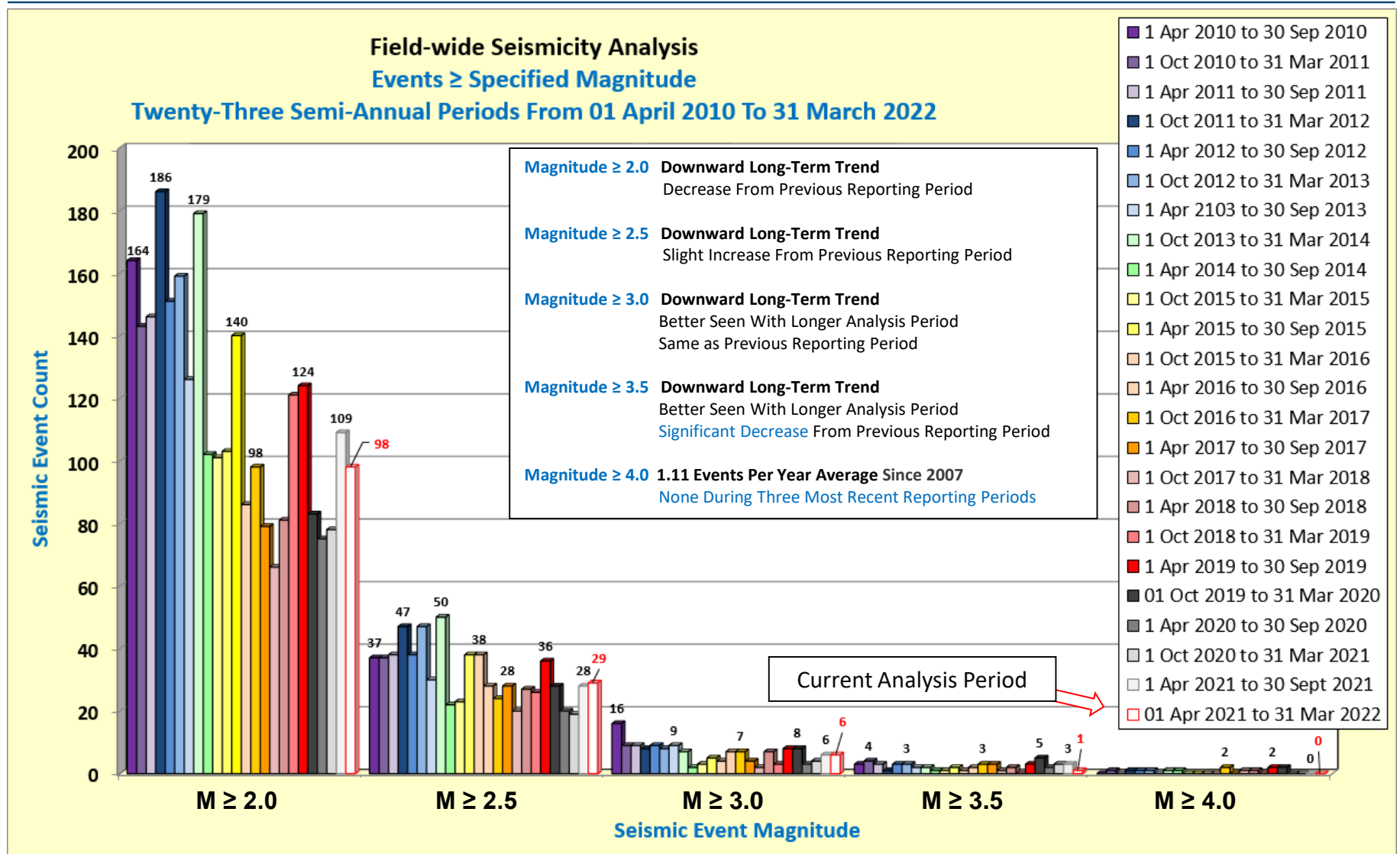


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Field-wide Seismicity Animation At Two Week Interval - Color Scaled By Subsea Depth







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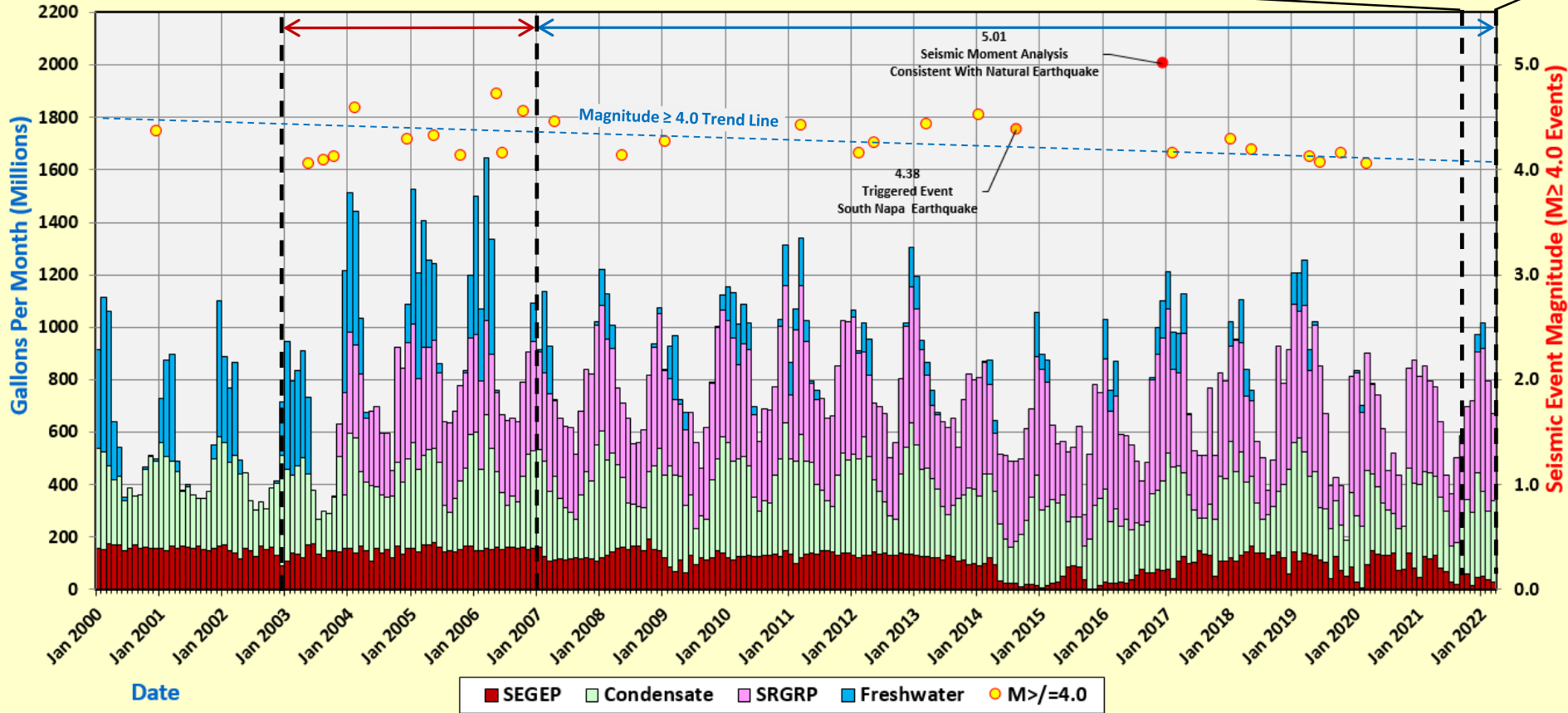
Monthly Field-wide Water Injection By Water Source And Magnitude ≥ 4.0 Seismicity

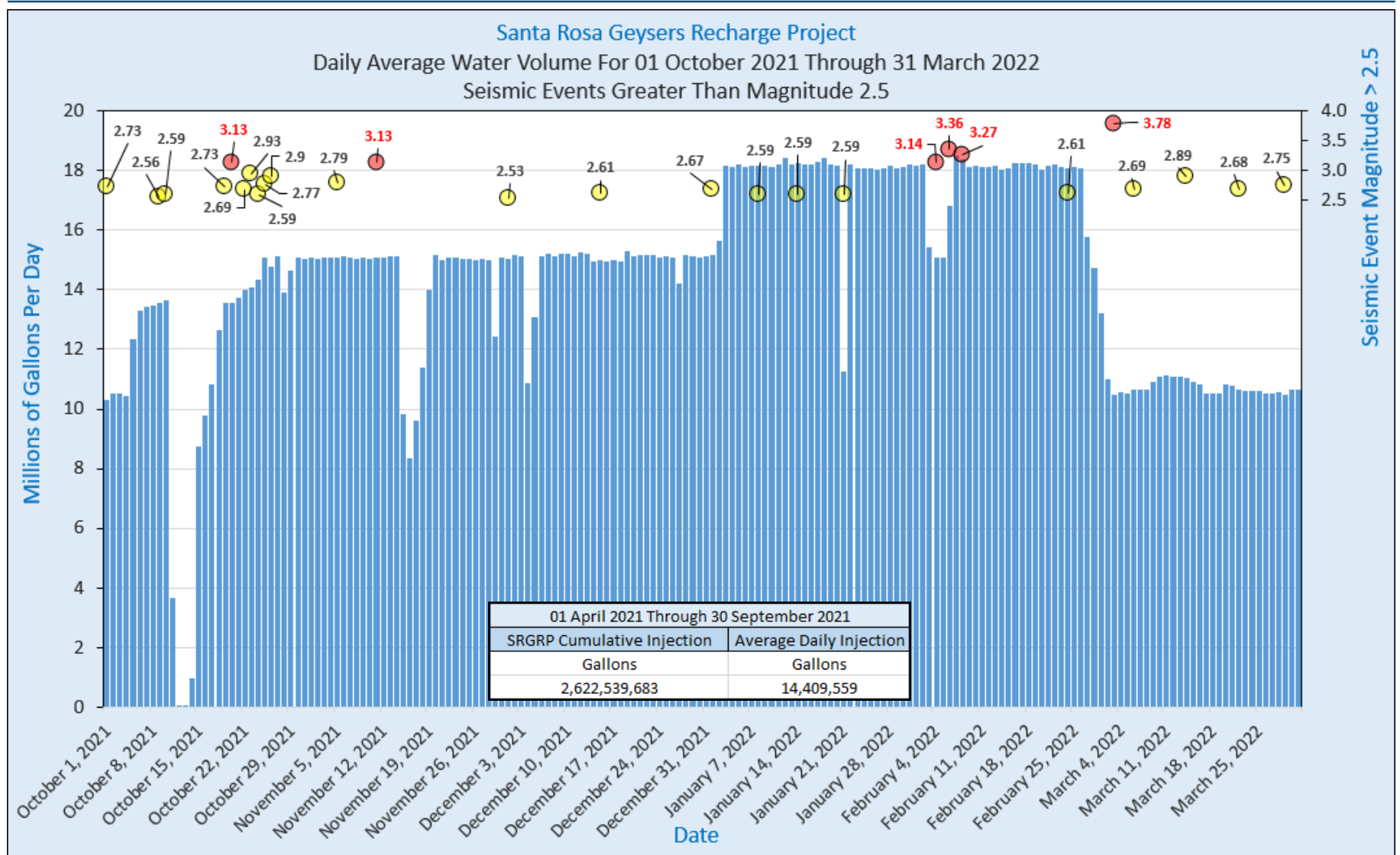
Average Number of Magnitude ≥ 4.0 Events Since January 2007 is 1.11 Per Year

Time Period	Magnitude ≥ 4.0 Seismic Events
January 2003 through December 2006	2.50 per year
January 2007 through September 2021	1.11 per year

Water Supply for Six Month Reporting Period				
Water Injection By Source (Gallons)				
Month	SEGEP	SRGRP	Condensate	Fresh Water
October	58,564,000	352,410,000	285,967,428	0
November	14,394,000	426,020,000	281,473,874	0
December	46,627,000	459,680,000	397,818,486	70,292,359
January	48,858,000	545,940,000	324,444,766	96,614,355
February	37,965,000	494,120,000	261,188,957	0
March	30,889,000	336,170,000	306,267,323	0

The Geysers
Calpine Fieldwide Water Injection Sources
Magnitude ≥ 4.0 Seismicity
01 January 2000 through 31 March 2021

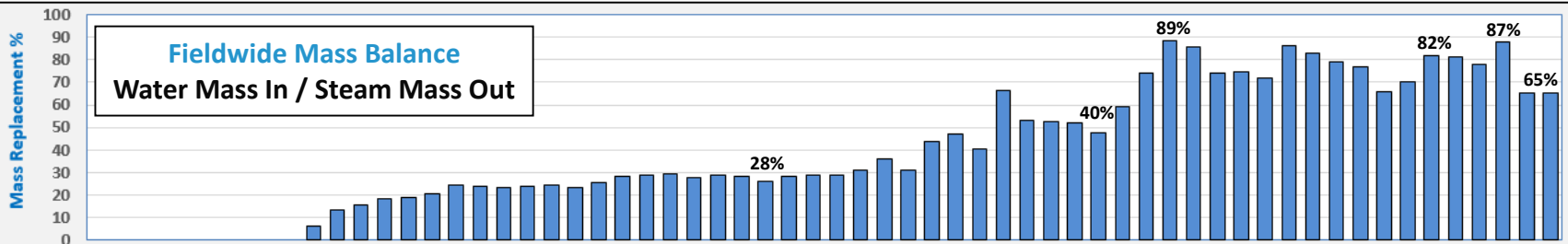
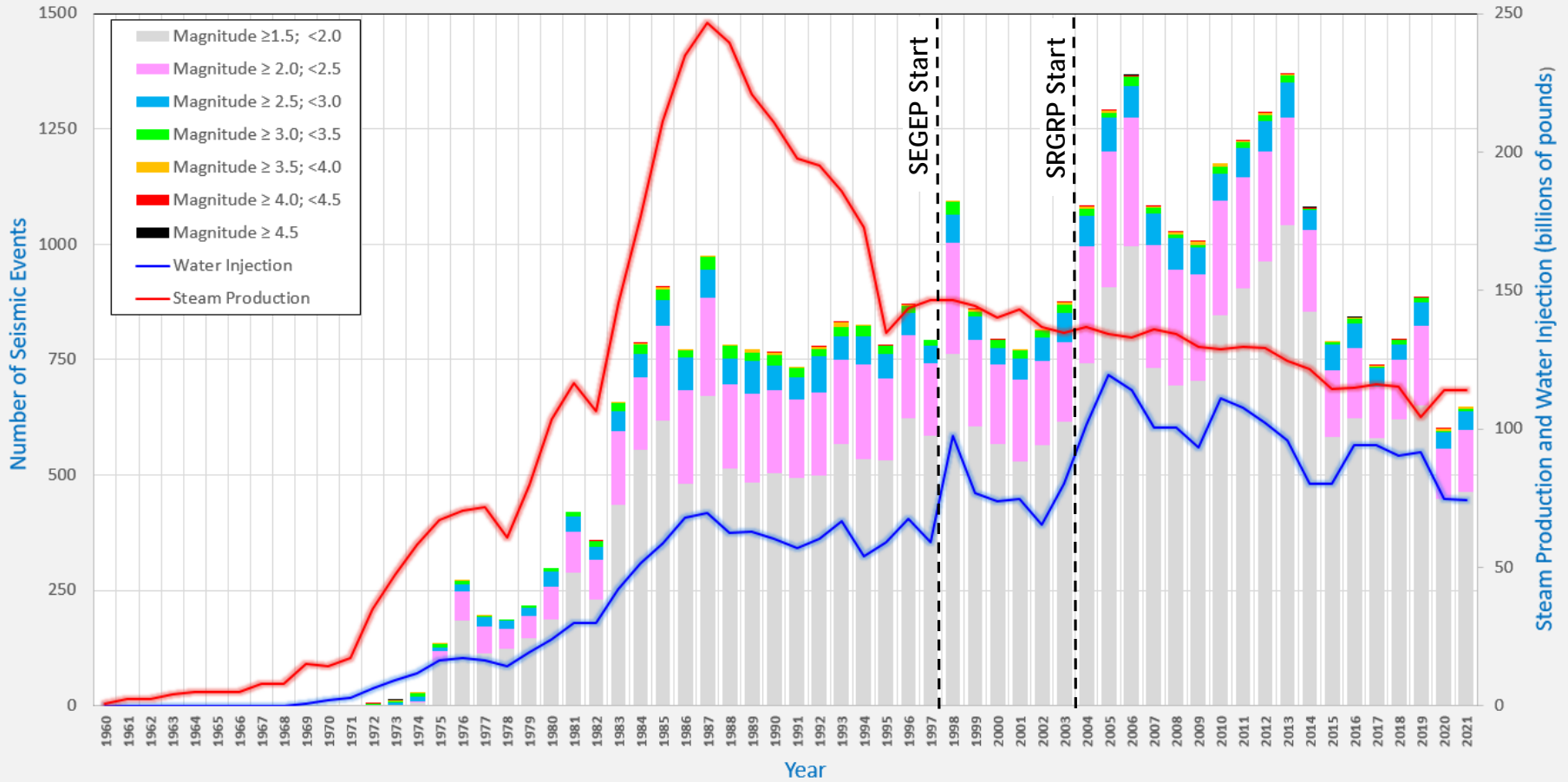




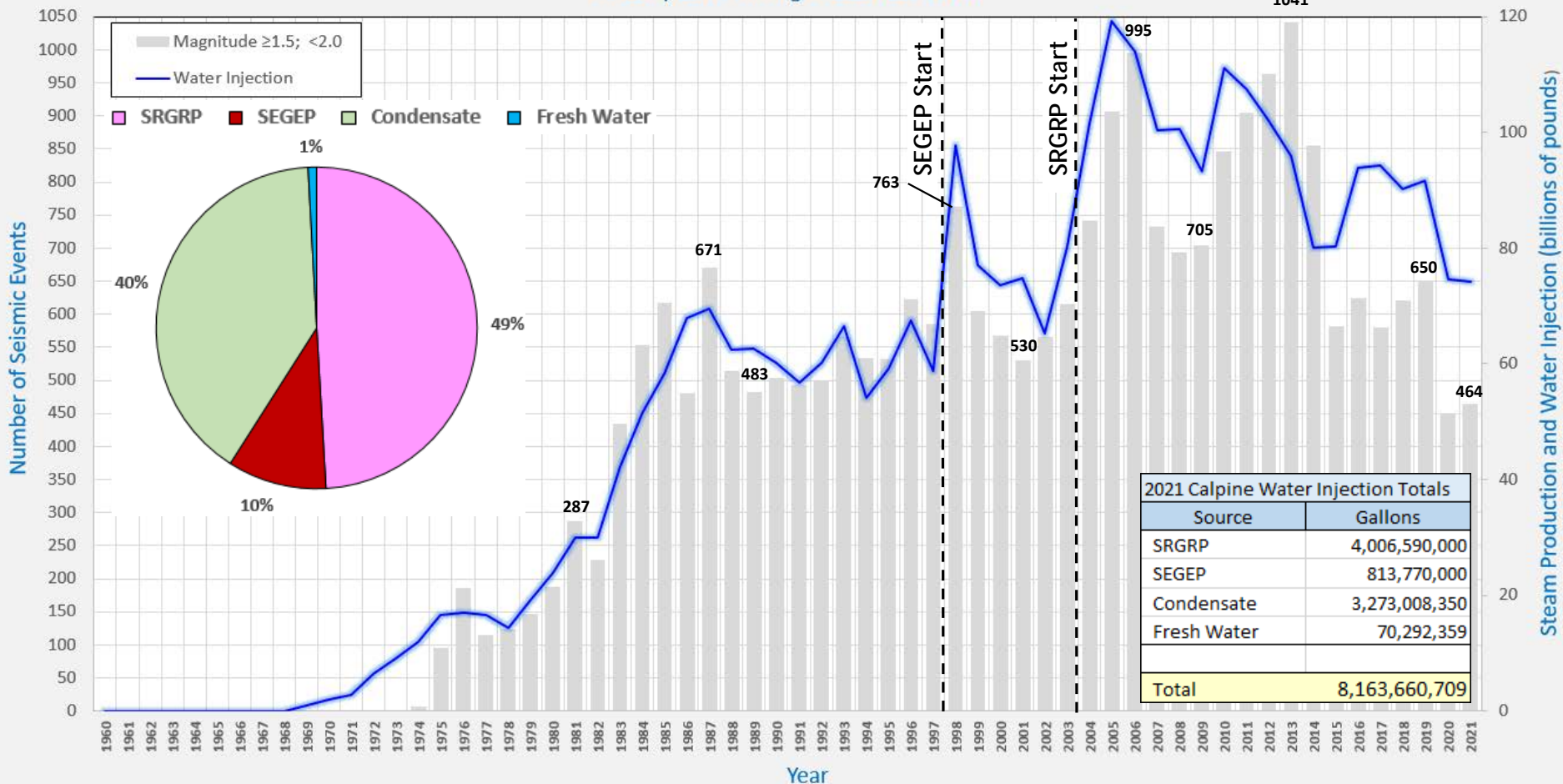
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Yearly Field-wide Steam Production, Water Injection and Seismicity

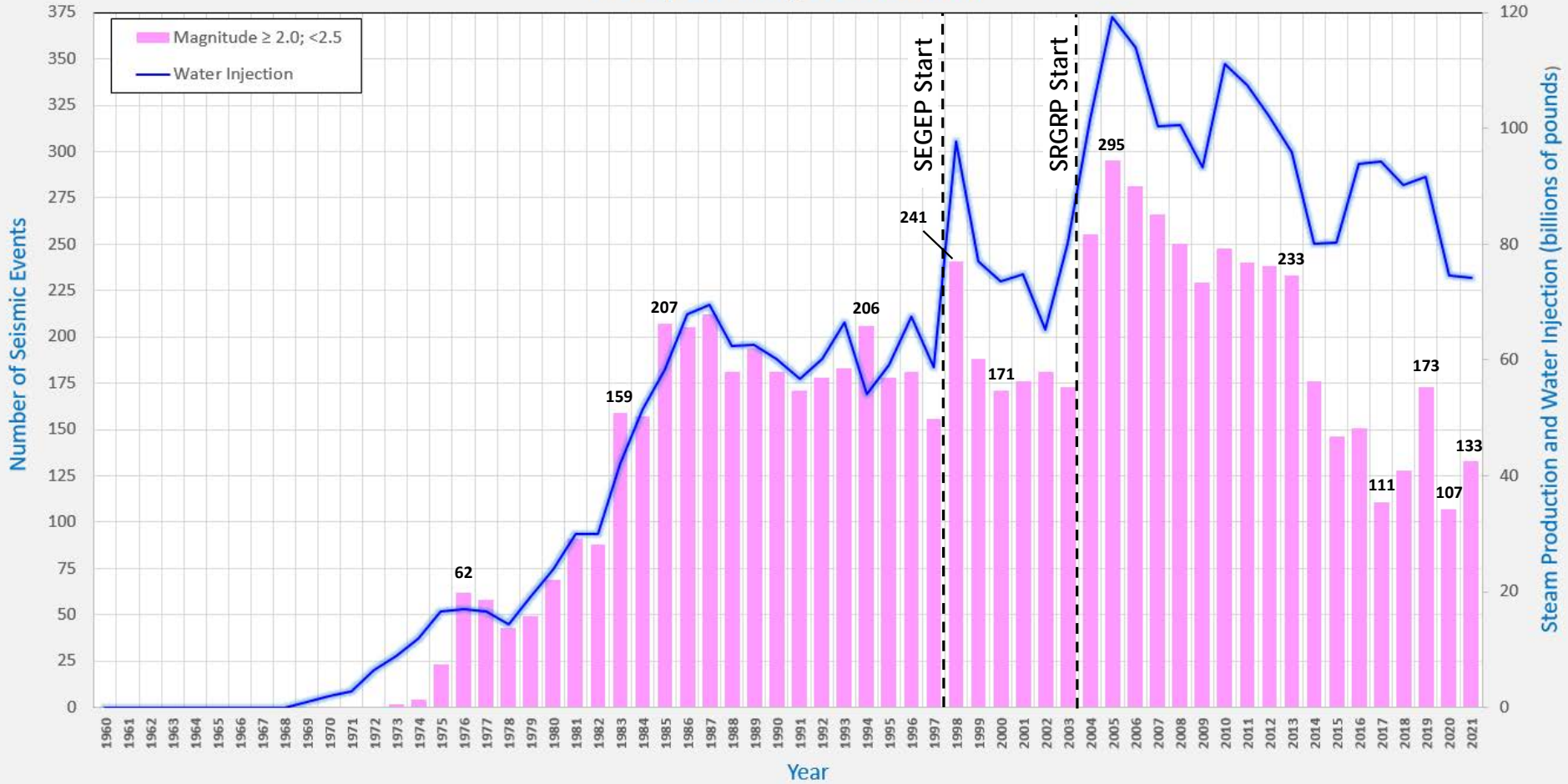
The Geysers Fieldwide Water Injection, Steam Production And Induced Seismicity
January 1960 Through December 2021



The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 1.5 and < 2.0
January 1960 Through December 2021



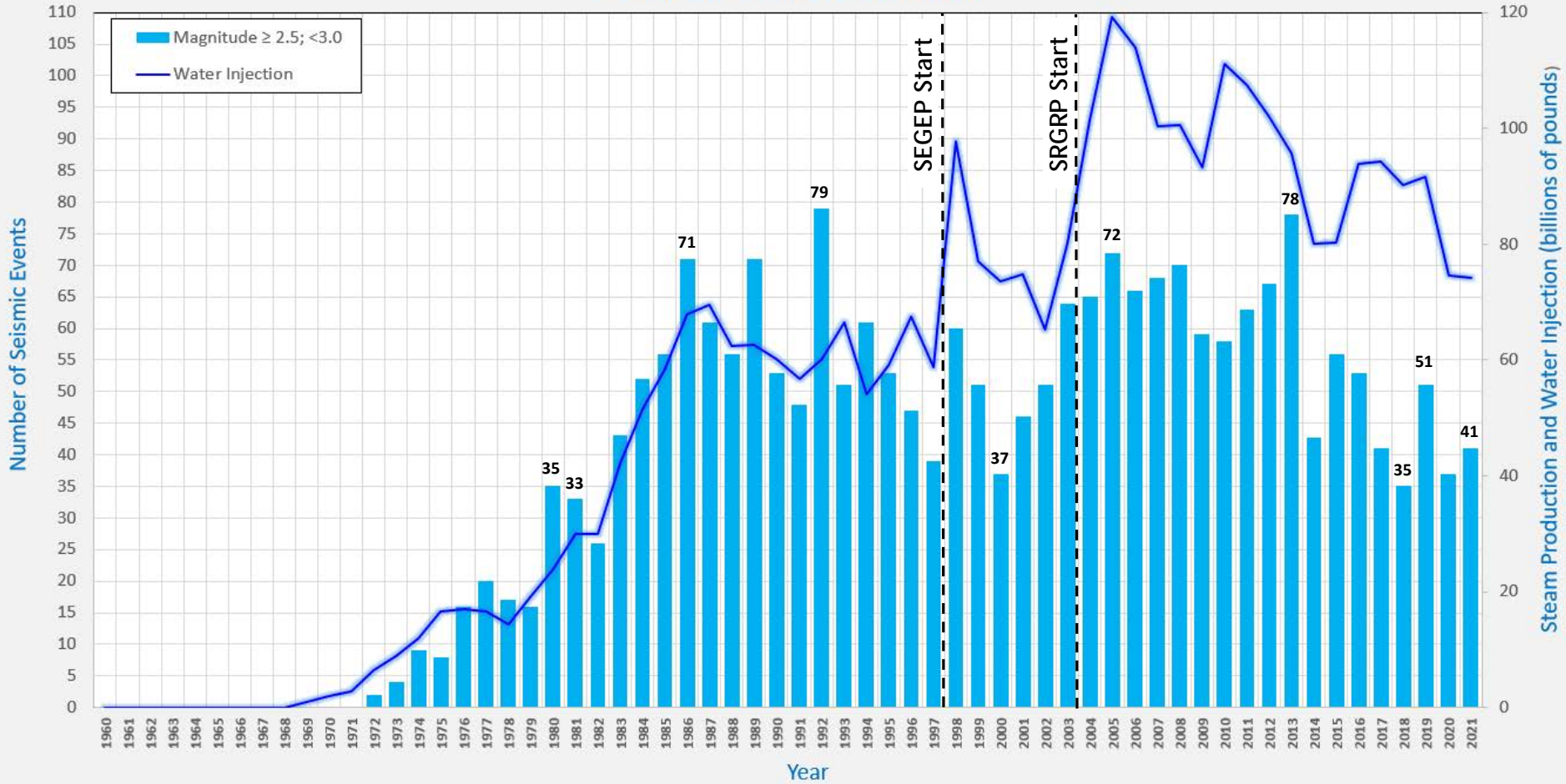
The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 2.0 and < 2.5
January 1960 Through December 2021



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Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 2.5 and < 3.0

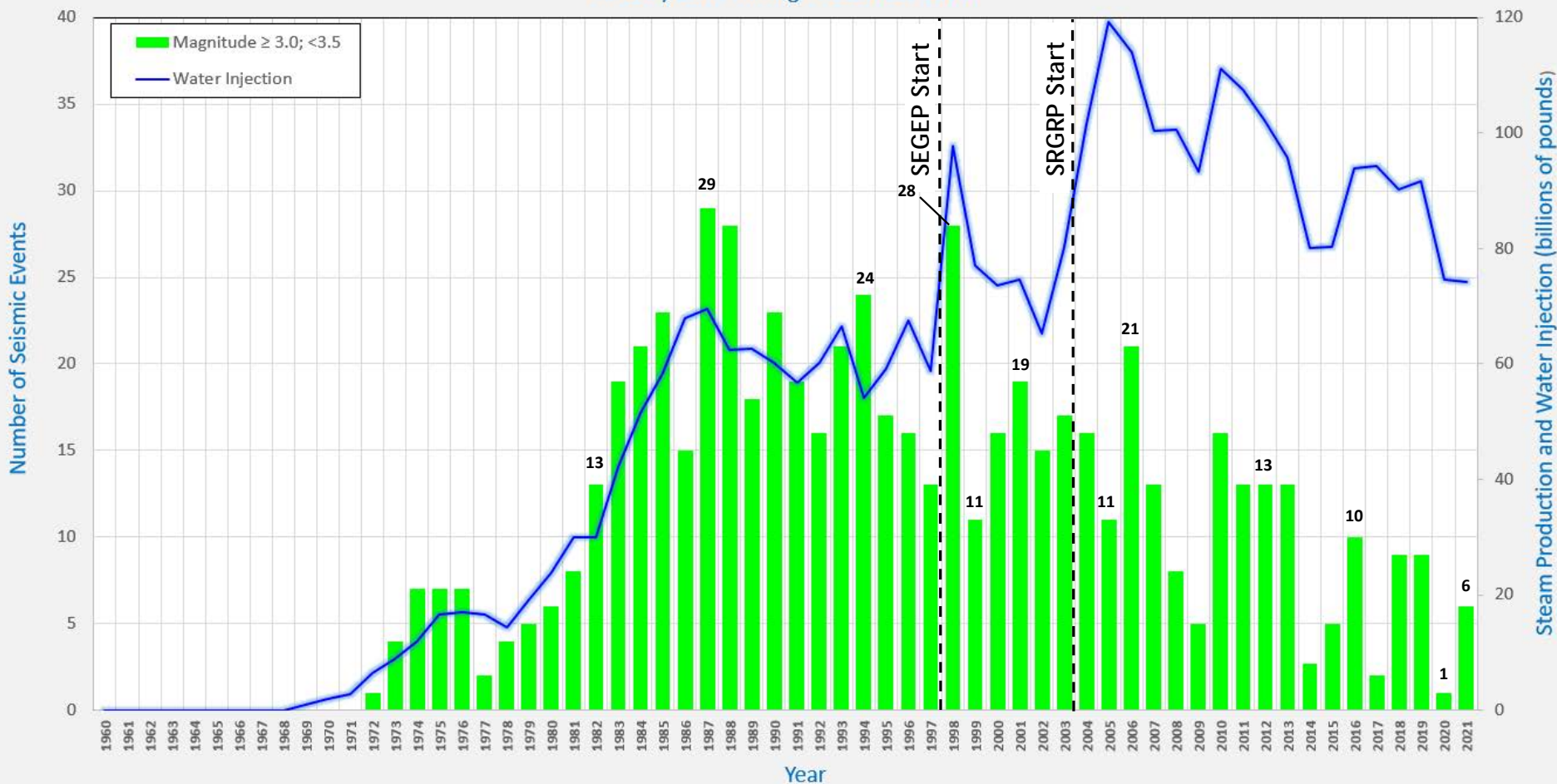
The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 2.5 and < 3.0
January 1960 Through December 2021



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Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 3.0 and < 3.5

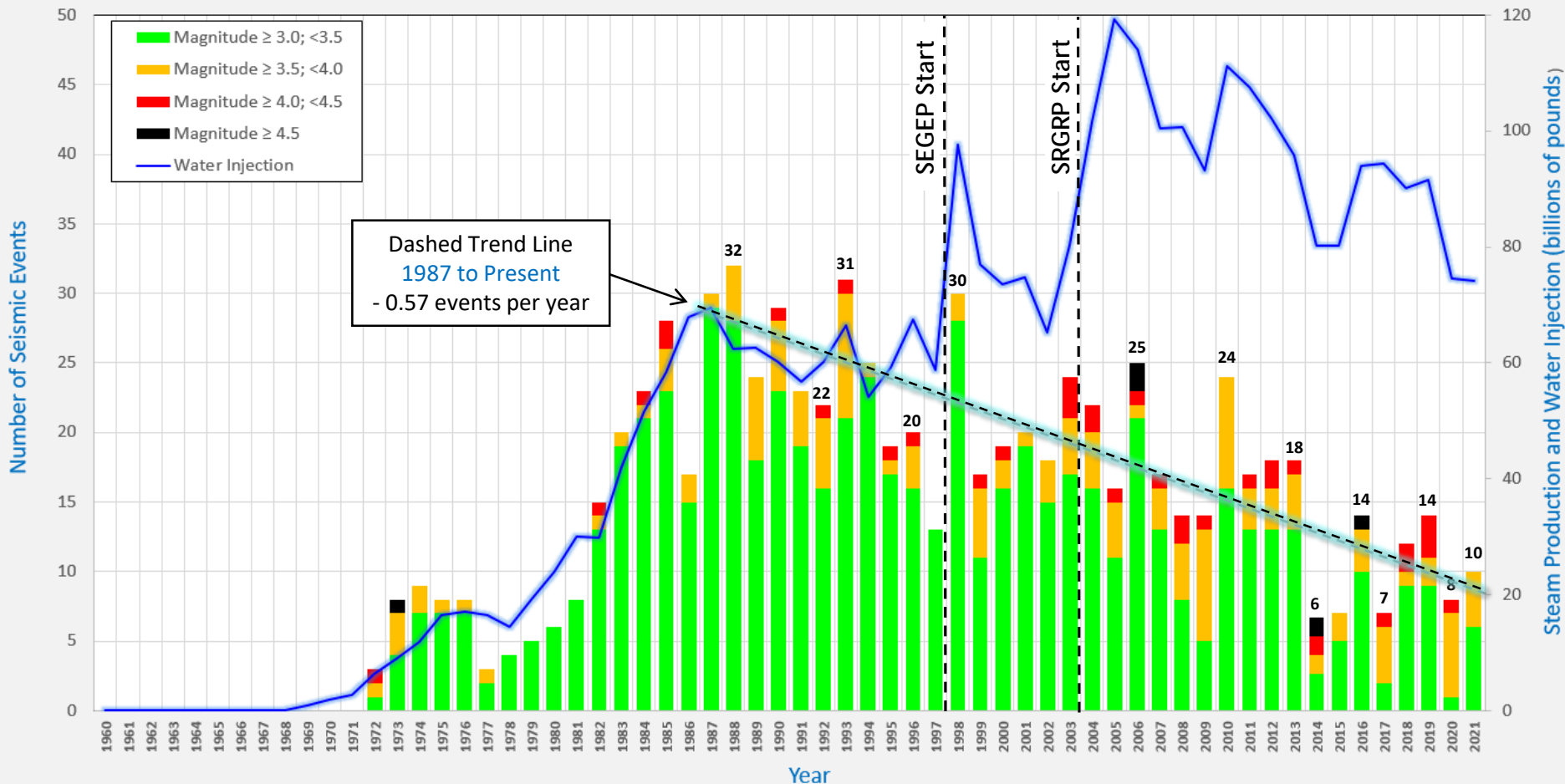
The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 3.0 and < 3.5
January 1960 Through December 2021



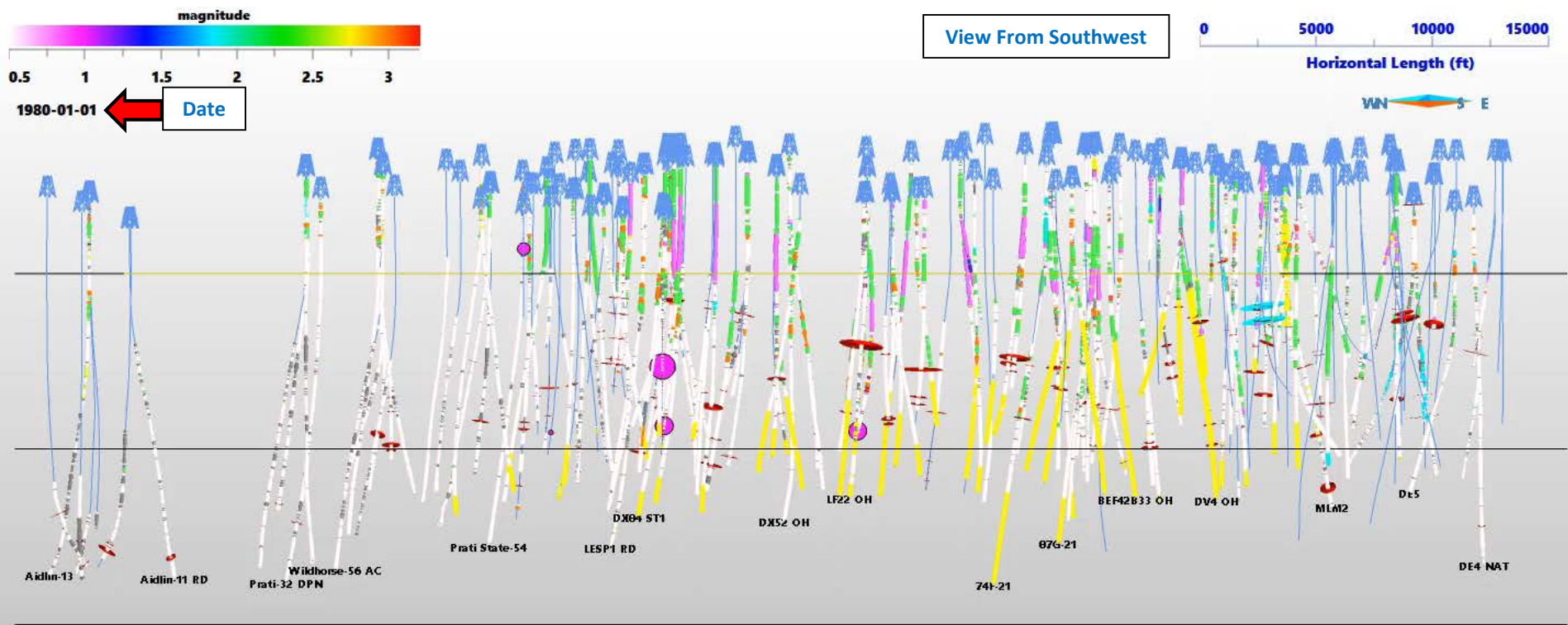
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Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 3.0

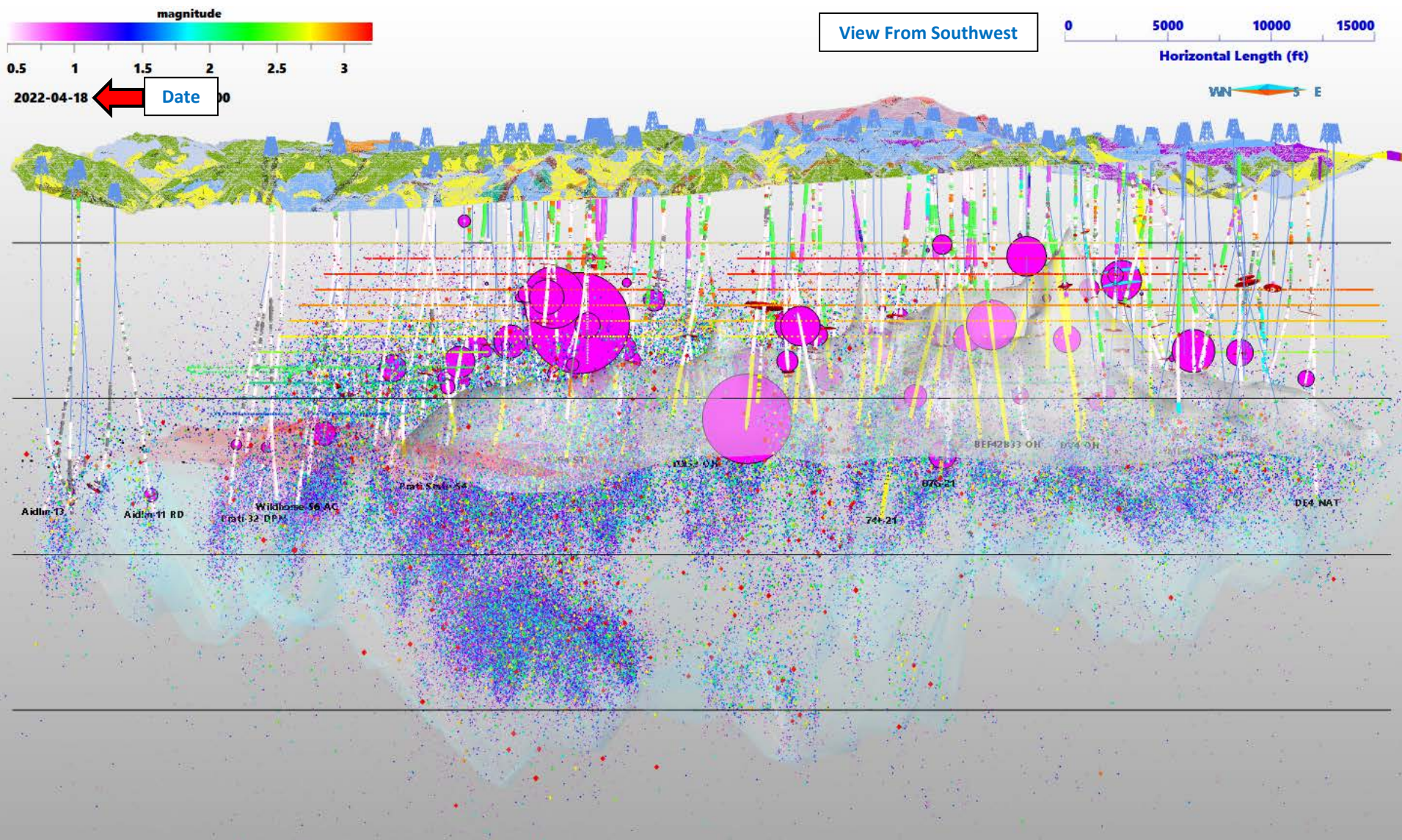
The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 3.0
January 1960 Through December 2021



Purple Disc Radii Scaled To Cumulative Water Injection Volume



Purple Disc Radii Scaled To Cumulative Water Injection Volume



Purple Disc Radii Scaled To Cumulative Water Injection Volume

View From Southwest

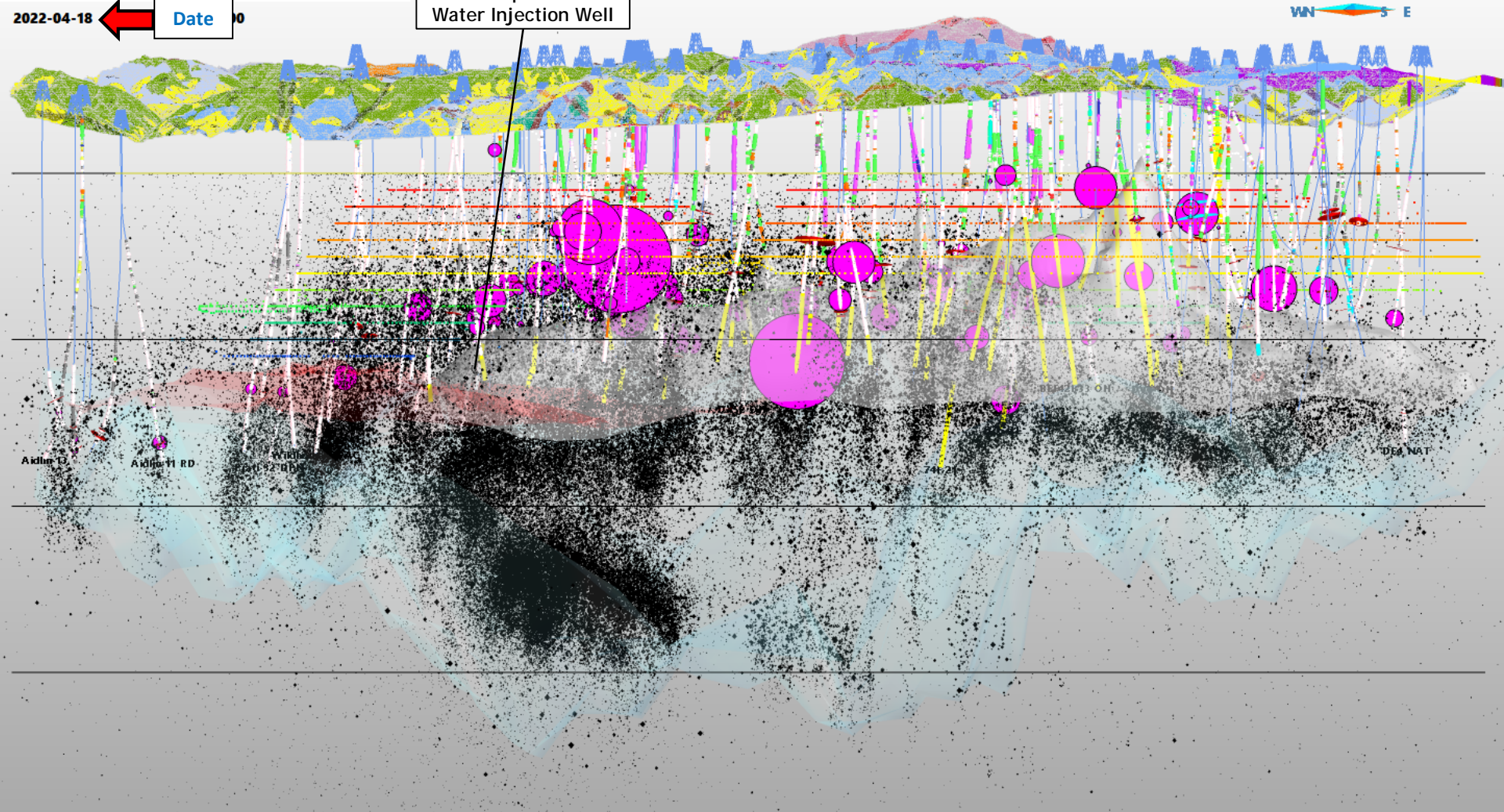
0 5000 10000 15000

Horizontal Length (ft)

WN S E

2022-04-18 ← Date → 0

Prati State-11
Proposed
Water Injection Well



VIDEO: Seismicity Animation; Half-Year Interval From October 2021 through April 2022
Volume Slicer Analysis Animation Example

Oblique View From SSW and Above Horizon

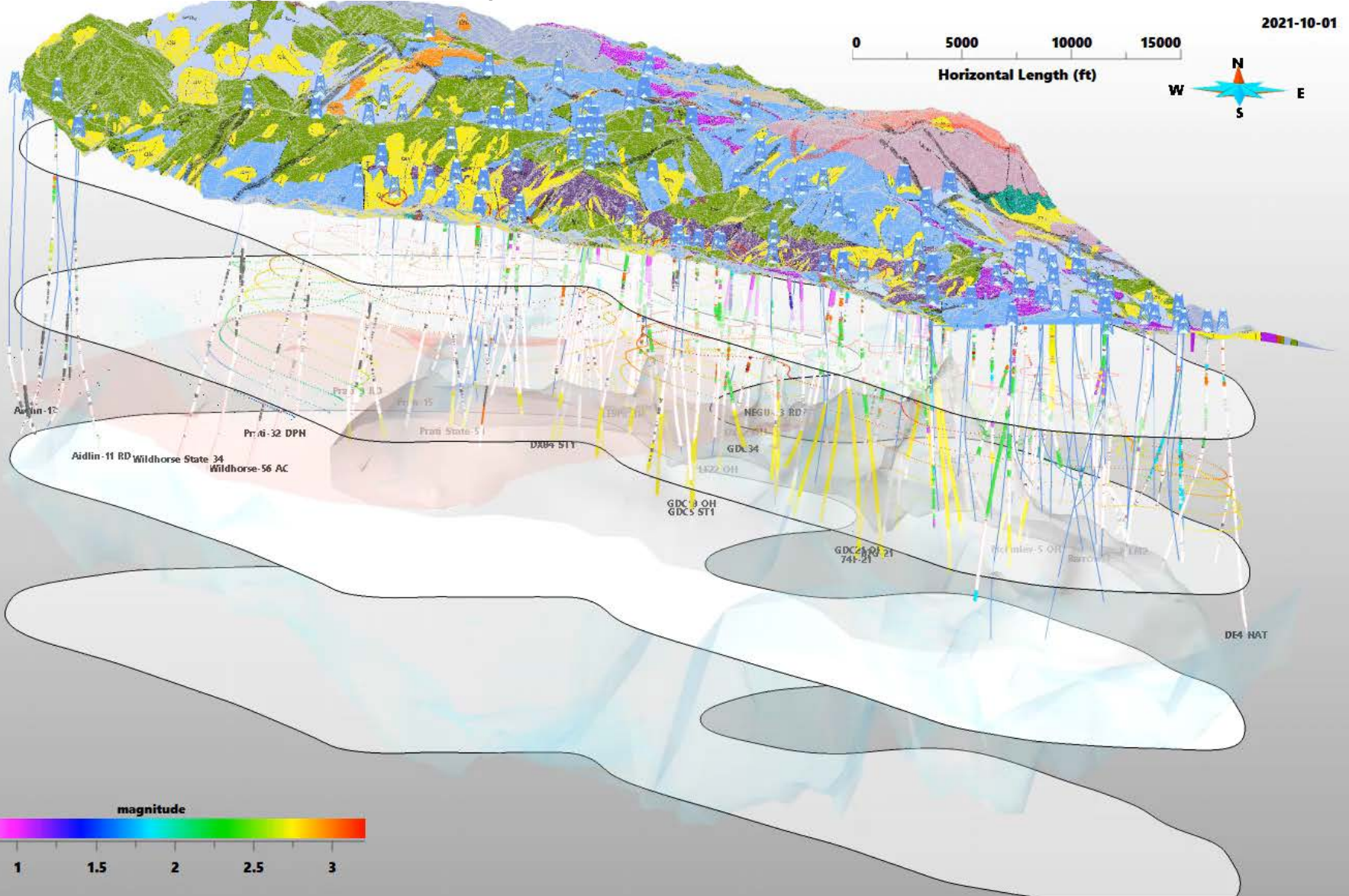
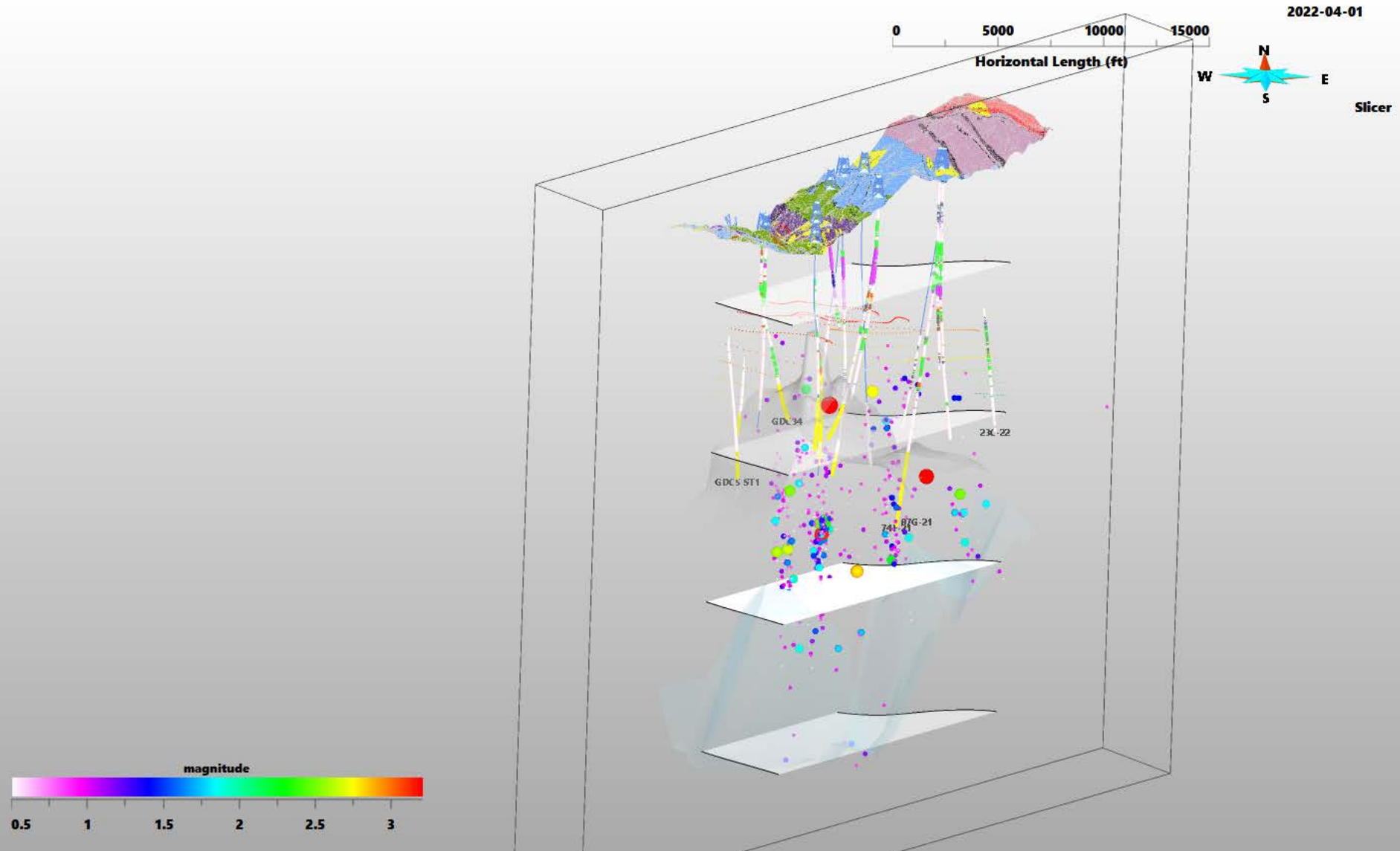


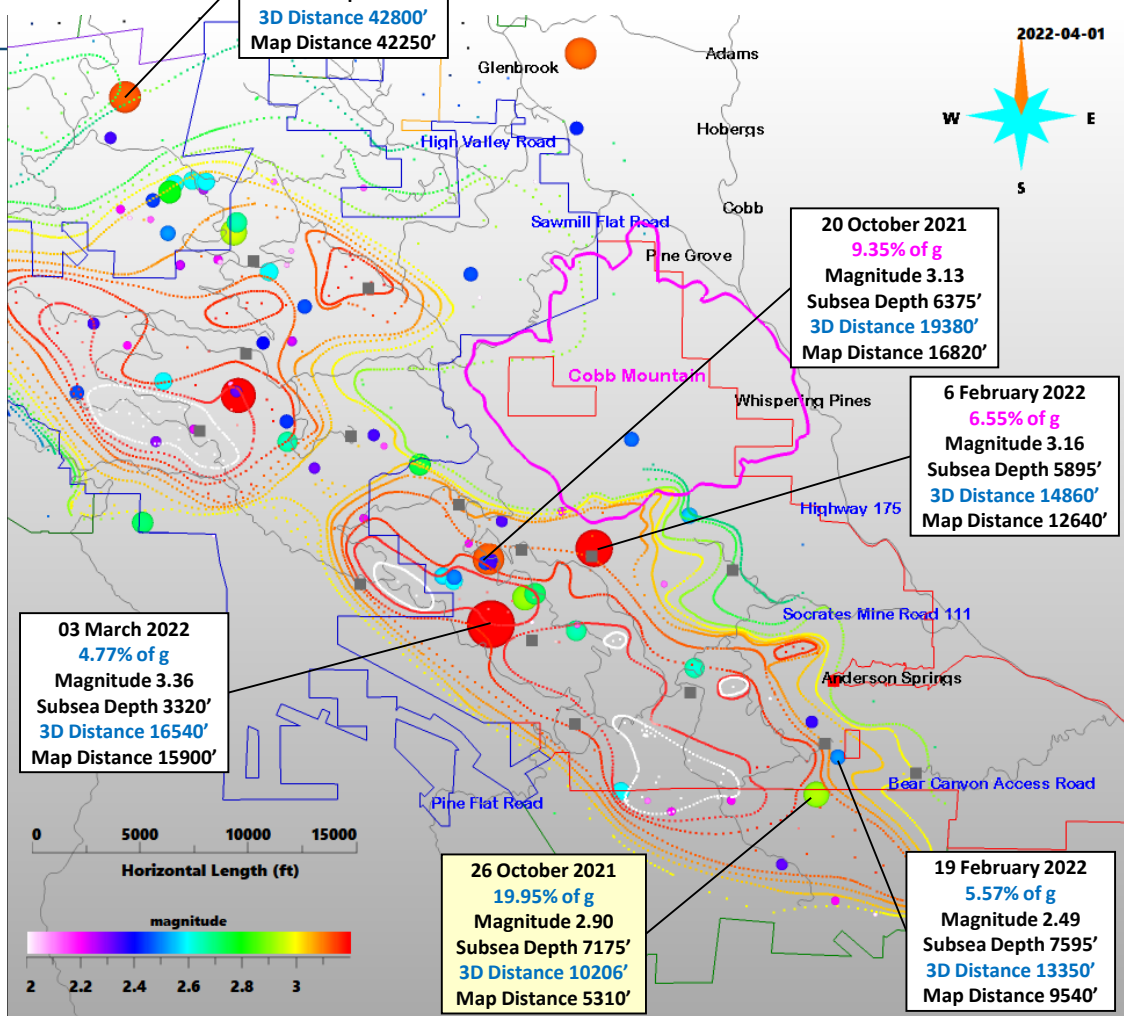
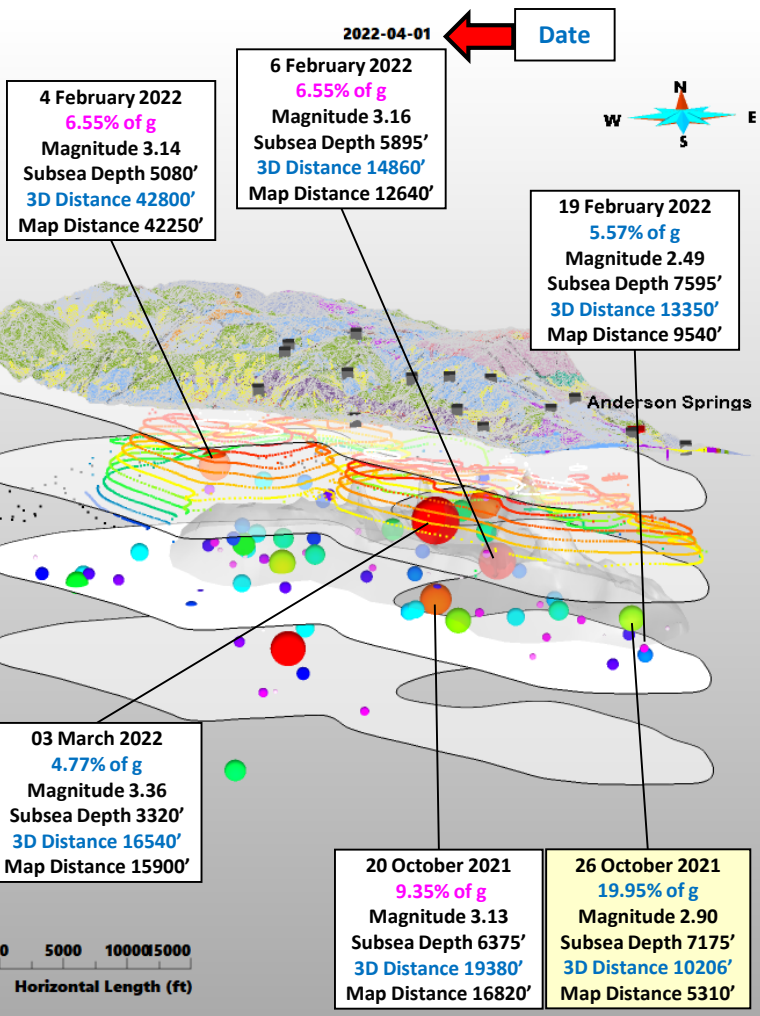
IMAGE: Seismicity Animation; Half-Year Interval From October 2021 through April 2022
Volume Slicer Analysis Animation Example

Oblique View From SSW and Above Horizon



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Community Hotline and Seismic Events of Concern



The 01 October 2021 through 31 March 2022 water injection and induced seismicity analysis determinations were **very encouraging**.

There were a total of **nine calls** from only two Anderson Springs residences to the Community Hotline.

