Seismic Monitoring Advisory Committee Meeting

01 April 2020 to 30 September 2020 Reporting Period

Virtual Meeting Due to COVID-19 Concerns

09 November 2020

Craig Hartline Senior Geophysicist Geysers Power Company, LLC The Geysers

Presentation Agenda

- Geysers Geothermal Field and Nearby Communities
- Geothermal Baseload Renewable Power
- Seismic Monitoring Networks
    - USGS / Northern California Seismic Network
    - LBNL/ Geysers Power Company, LLC Seismic Monitoring Network
        - Fieldwide Seismicity Analysis *
        - Field-wide Water Injection and Seismicity
        - Water Injection and Induced Seismicity Animations
    - LBNL/Calpine Strong Motion Network
        - Strong Motion Data Access and Analysis
        - Community Hotline
- 3D Structural Model
    - Fault/Fracture Analysis
- Additional Seismic Monitoring and Research
- New Water Injection Wells and Induced Seismicity Response

* All Presentation Seismicity Analysis Animations Disabled To Minimize Virtual Meeting Data Transfer Issues

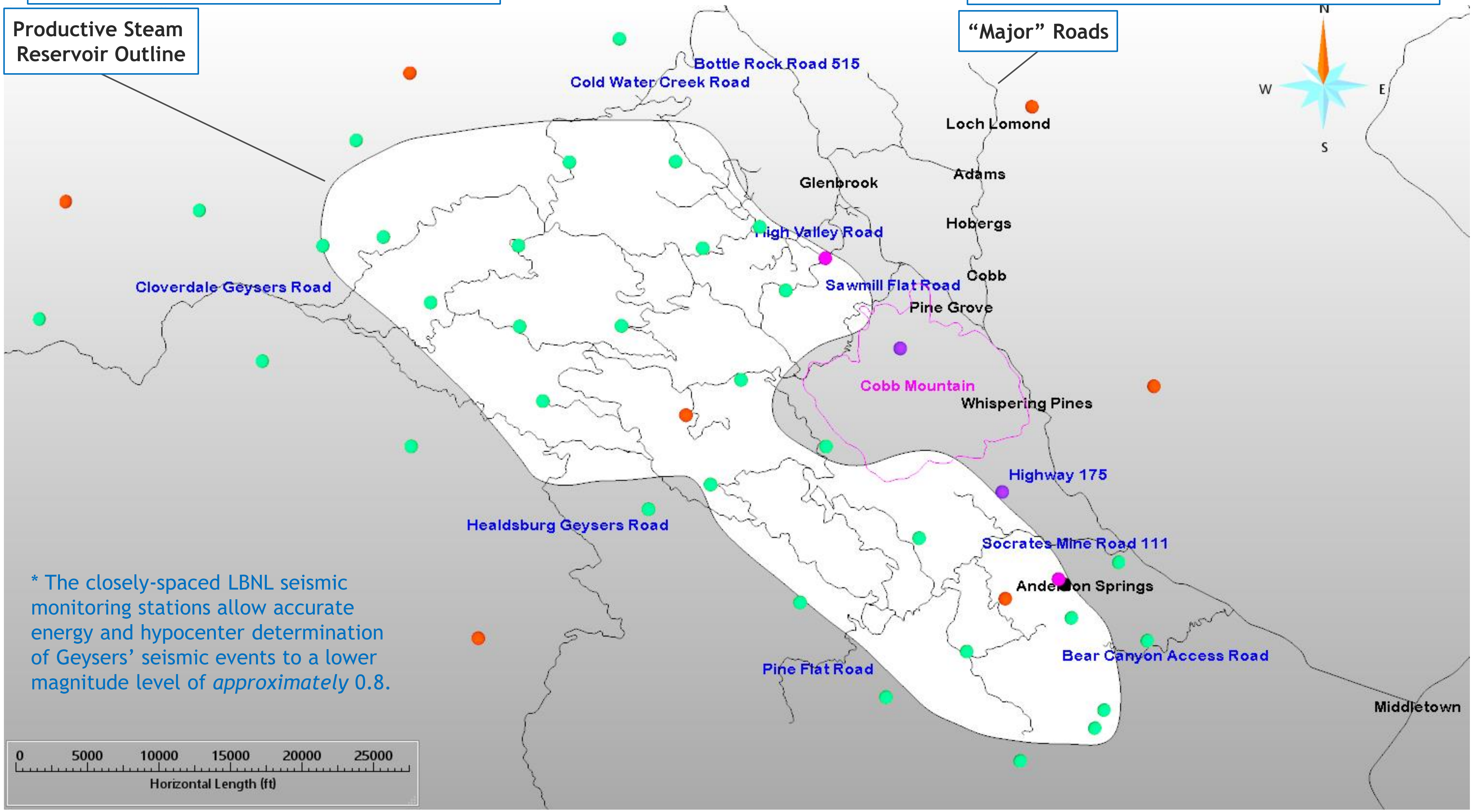
Seismic Monitoring Advisory Committee Meeting

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



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

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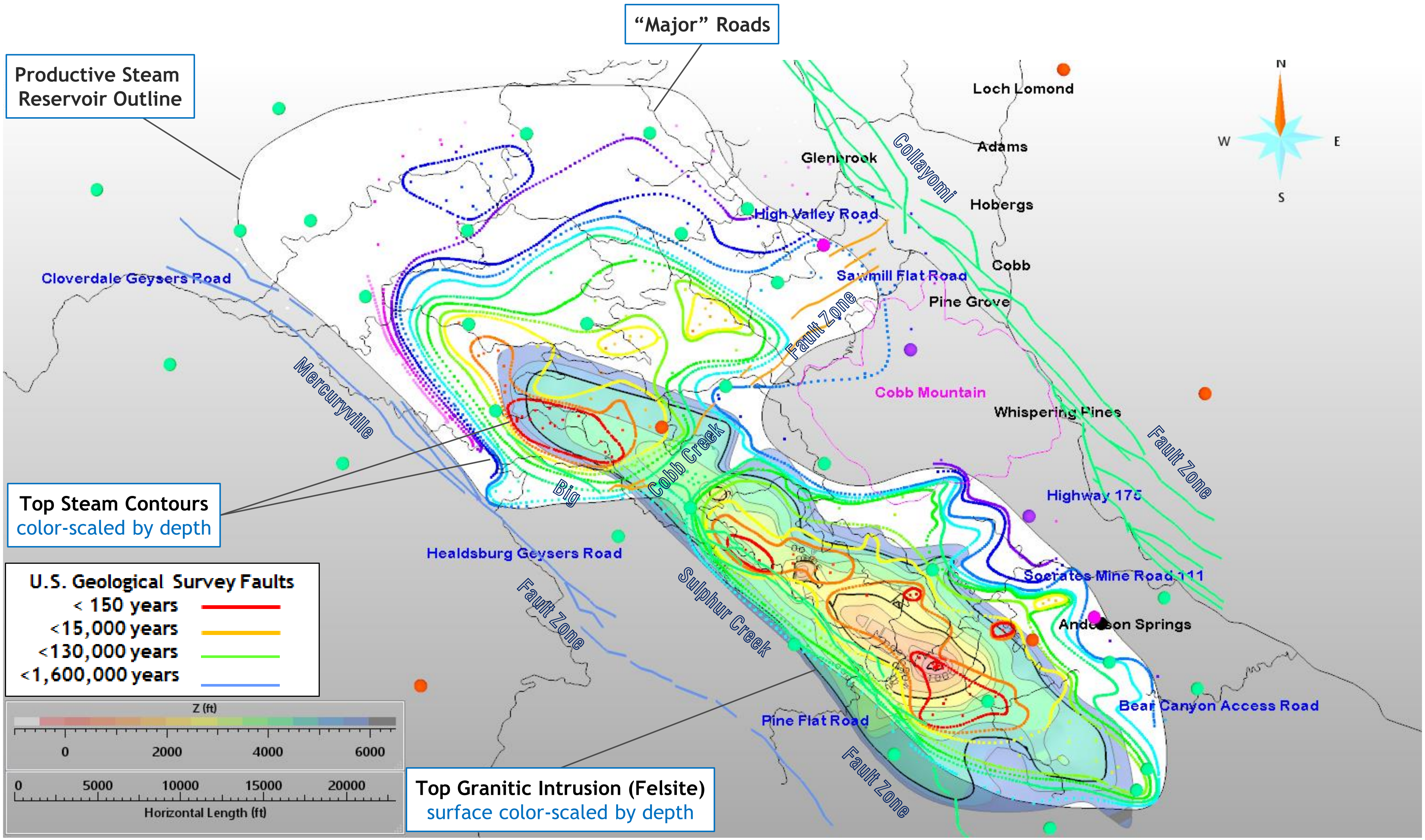
Geysers Geothermal Field, Top Granitic Intrusion and Top Steam Reservoir



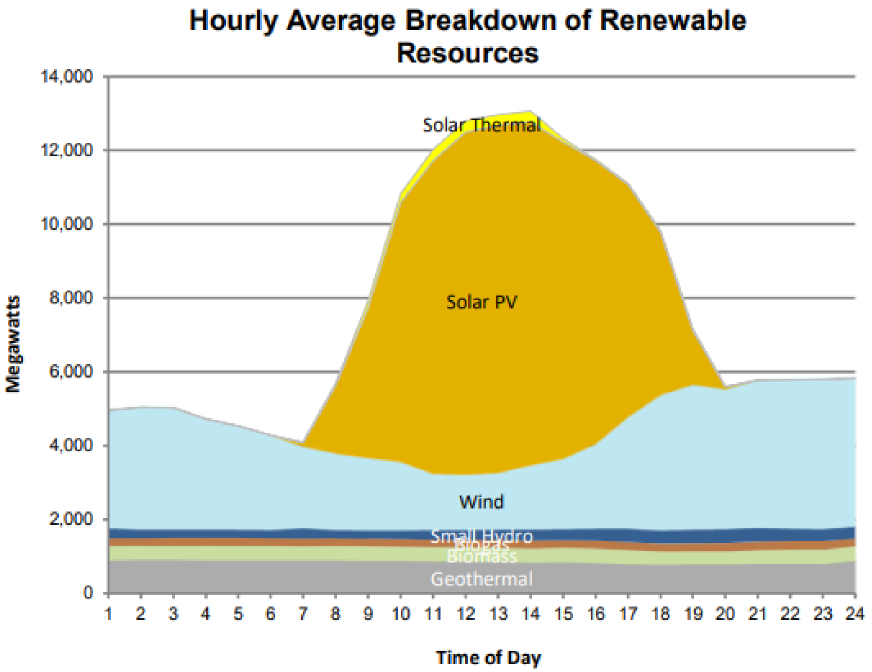
Wednesday August 19 2020 Example

Geothermal Electricity is Reliable and Renewable Baseload Power

24-Hour Renewables Production

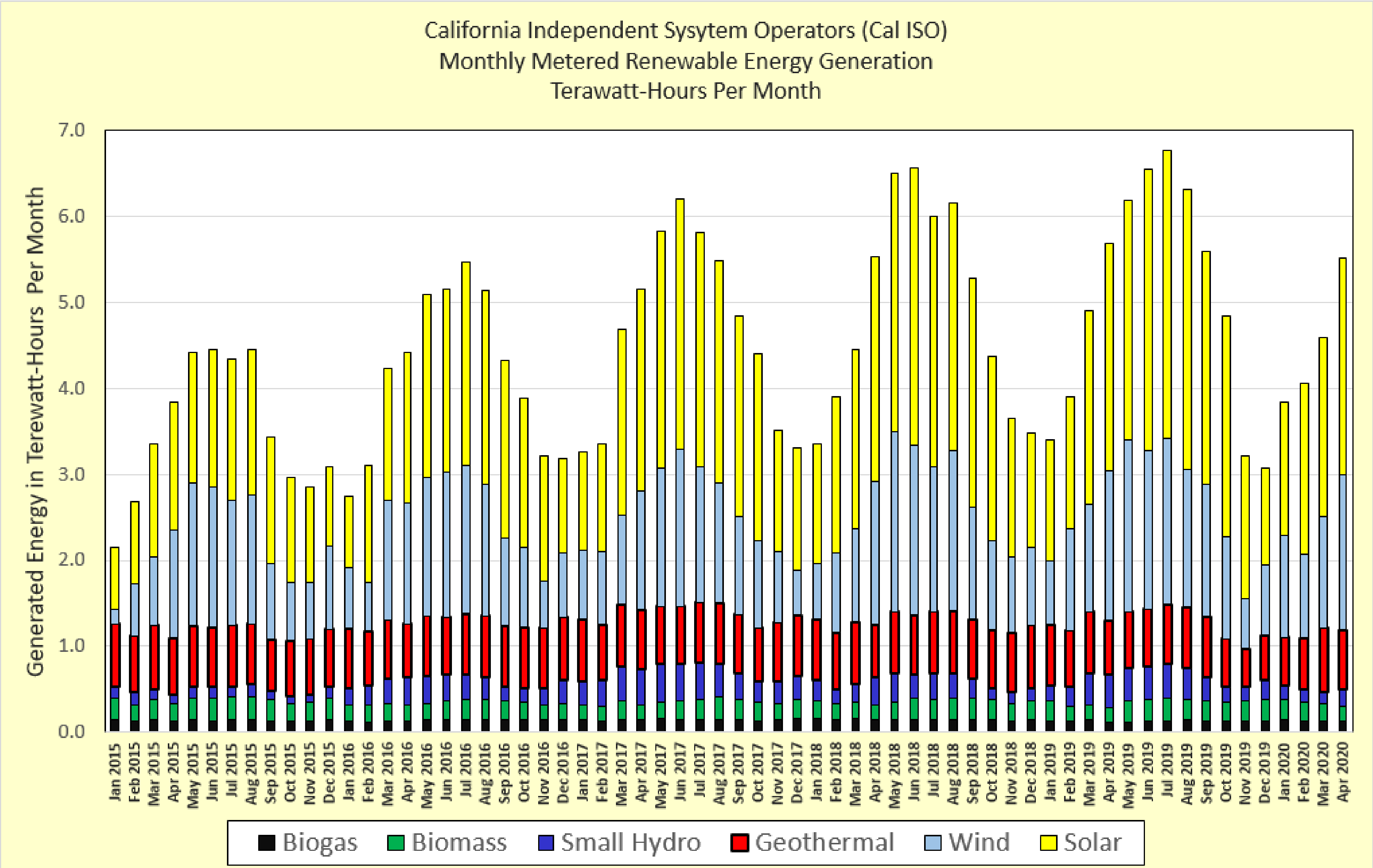
Renewable Resources	Peak Production Time	Peak Production (MW)	Daily Production (MWh)
Solar Thermal	12:16	331	1,853
Solar	12:32	9,439	78,045
Wind	20:35	4,146	66,847
Small Hydro	19:24	399	7,369
Biogas	21:18	213	4,957
Biomass	16:26	385	8,896
Geothermal	1:56	920	20,894
Total Renewables			**188,861**

Total 24-Hour System Demand (MWh): *888,701*



California Independent System Operators Monthly Metered Renewable Energy Generation

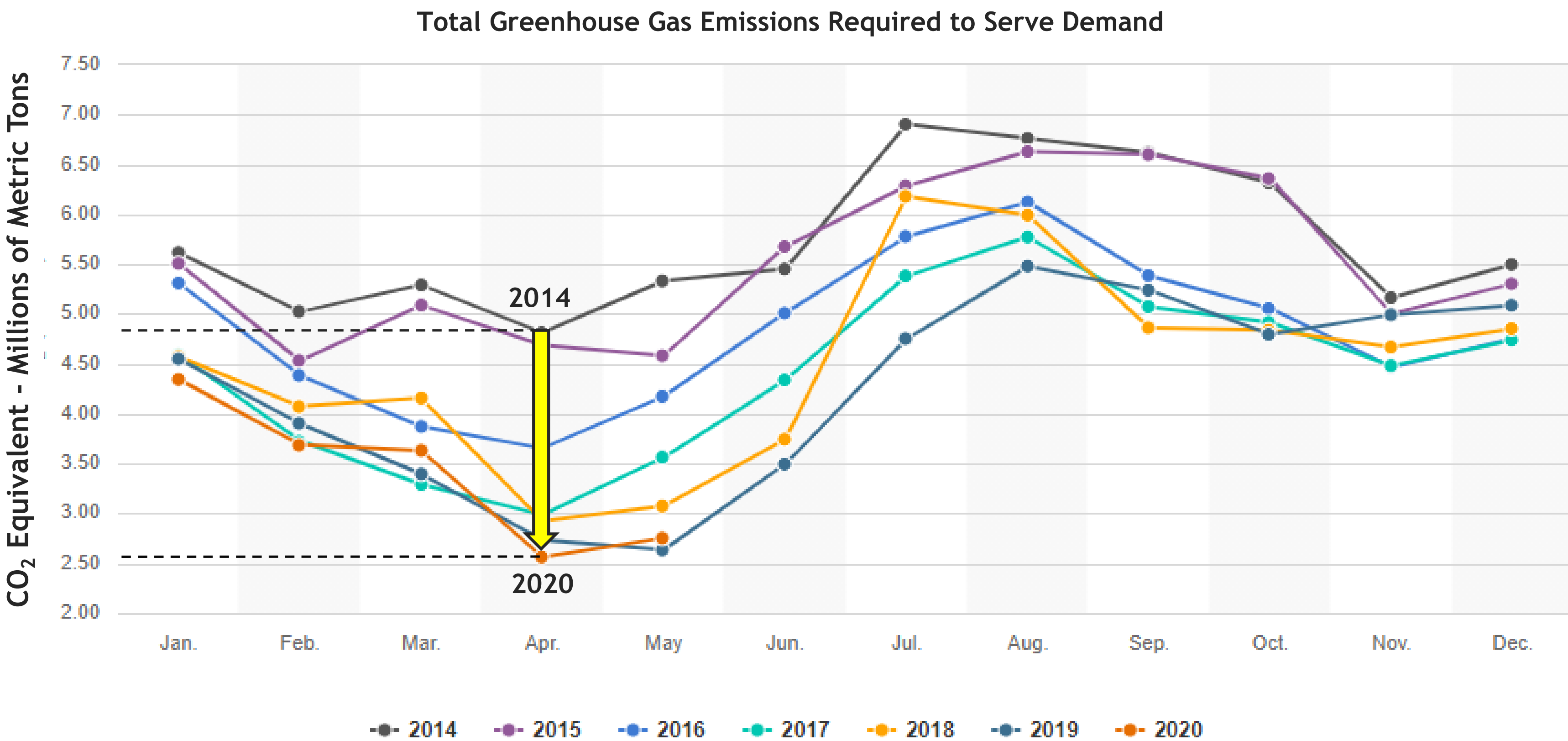
Geysers Power Company, LLC Geothermal Facility Generates Nearly Six Terawatt-Hours* Per Year Of Renewable Energy



* Nearly Six Trillion Watt-Hours Per Year

California Independent System Operators Electrical Energy Greenhouse Gas Emissions

April 2014 vs. 2020: 47% CO_2 Equivalent Emission Reduction Since 2014



Induced Seismicity at The Geysers

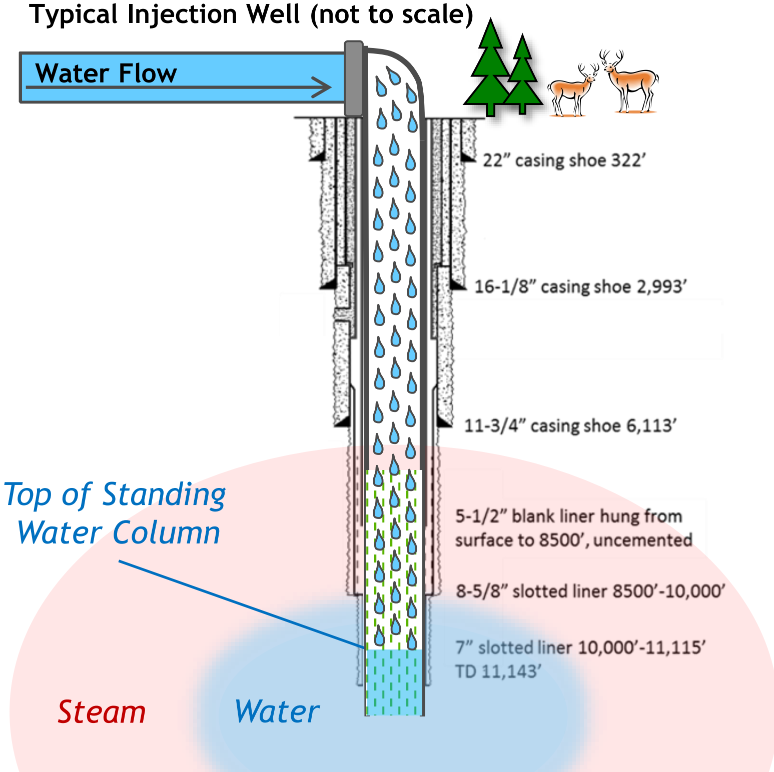
Cobb, California 8.0 km (5.0 mi) W
Anderson Springs, California 11.0 km (6.8 mi) WNW
Cloverdale, California 18.0 km (11.2 mi) E
Santa Rosa, California 41.0 km (25.5 mi) NNW

Induced Seismicity

- Cool water “free falls” into hot rock and reactivates fractures (thermal contraction)
- Modest pressure increases also reactivate fractures

Mechanism	Nodal Plan 1 Strike, Dip, Rake	Nodal Plan 1 Strike, Dip, Rake
	(339°, 80°, 175°)	(70°, 85°, 10°)

Geysers Power Company, LLC has well-developed community relations programs and worldwide seismicity research collaborations to address induced seismicity at The Geysers.

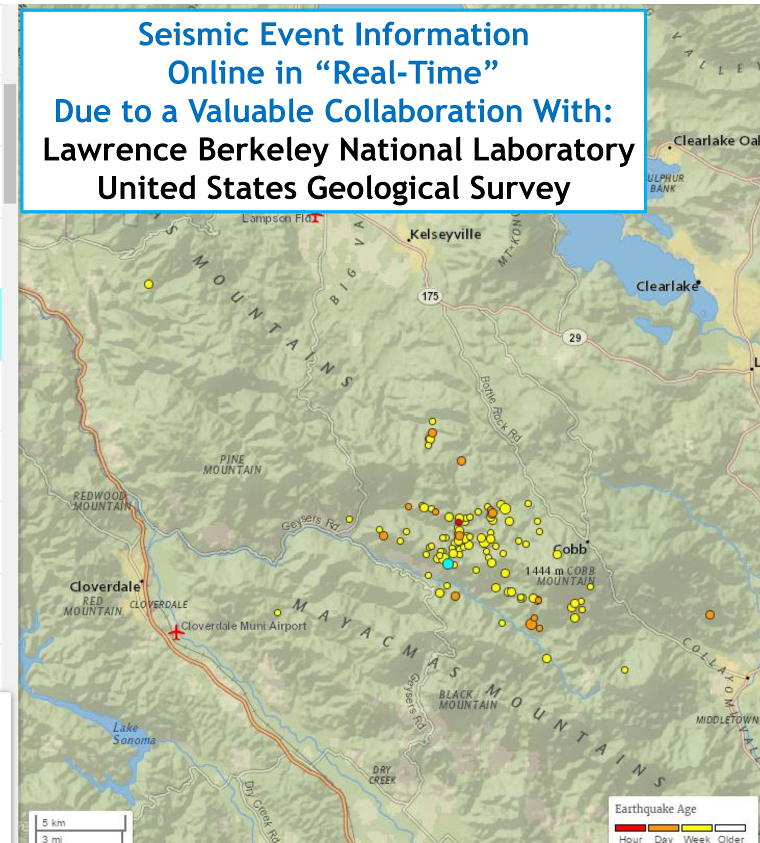


2.5	5km W of Cobb, California	2016-09-25 06:36:54 (UTC)	1.2 km
0.6	5km WNW of Cobb, California	2016-09-25 01:50:15 (UTC)	1.5 km
1.6	2km ENE of The Geysers, California	2016-09-25 00:16:00 (UTC)	1.2 km
0.9	6km WNW of The Geysers, California	2016-09-24 19:14:27 (UTC)	2.1 km
2.6	6km NW of The Geysers, California	2016-09-24 18:56:14 (UTC)	1.4 km
1.7	12km SW of Lakeport, California	2016-09-24 18:07:36 (UTC)	5.5 km
1.6	1km N of The Geysers, California	2016-09-24 18:04:31 (UTC)	0.4 km
1.9	6km NW of The Geysers, California	2016-09-24 16:06:05 (UTC)	2.4 km
2.4	4km WNW of Cobb, California	2016-09-24 11:55:41 (UTC)	-0.8 km
0.9	6km W of Cobb, California		

M 2.6 – 6km NW of The Geysers, California

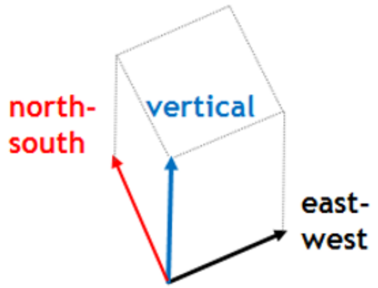
Time 2016-09-24 18:56:14 (UTC)
Location 38.811°N 122.813°W
Depth 1.4 km

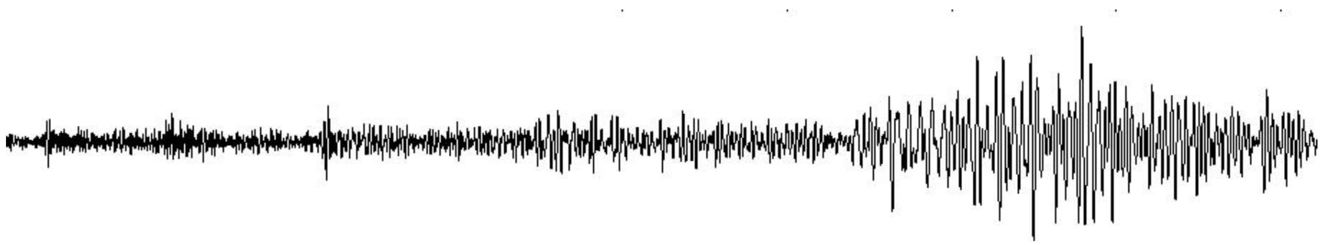
Seismic Event Information Online in “Real-Time” Due to a Valuable Collaboration With:
Lawrence Berkeley National Laboratory
United States Geological Survey



The USGS and collaborating agencies provide services of significant value to The Geysers.
The USGS Regional Seismic Network provides:

Seismic Data	
Acquisition	Six three-component USGS seismic stations contribute to seismicity determinations within The Geysers.
Processing	Seismic waveforms are intially compiled and p-wave arrival times calculated at the USGS "Waveserver"located within the Geysers Administration Center (and adjacent to the LBNL seismic data server).
Transfer	Merged LBNL/USGS station waveforms and arrival times are forwarded by a Northern California Seismic Network radio link to their Geysers Peak microwave hub, then transmitted to the USGS facility at Menlo Park.
Integration	LBNL/USGS P-wave arrival times are integrated with P-wave arrival times from other monitoring networks operated by the USGS, UC Berkeley, the California Geological Survey, and the California Department of Water Resources.
Analysis	Automatic determination of seismic event magnitude, hypocenter, first-motion mechanisms, and moment tensor solutions/shake maps (for seismic events with magnitude > 3.5). Seismologists complete reviews of more significant events.
Distribution	The USGS Eartquake Hazards Program website (https://earthquake.usgs.gov/) is the starting point for access to almost unlimited seismicty information, including nearly "real-time" availability of earthquake information (https://earthquake.usgs.gov/earthquakes/map/).
Archival	Waveforms and event determinations retrieved hourly for archival at the UC Berkeley Northern California Earthquake Data Catalog. Data derived from this catalog, including tomographic double-difference refined seismicty hypocenter determinations, contributes to Calpine/NCPA seismicity analysis, along with worldwide seismic research collaborations.





* United States Geological Survey

Funding Transition For LBNL / Geysers Power Company, LLC Seismic Monitoring Network

The Department of Energy's Geothermal Technologies Office shifted their research efforts to these programs:

FORGE

Frontier Observatory for Research in Geothermal Energy   Milford, Utah
https://utahforge.com/

EGS Collab

Geothermal technology research by eight national laboratories, six universities, and industrial partners.
https://eesa.lbl.gov/projects/the-egs-collab-project/

Why is this important?

Department of Energy funding for The Geysers seismic monitoring network ended May 2019.
Geysers Power Company, LLC now contributes $110,000 for yearly maintenance and upgrades.

Ramsey Haught was previously contracted to LBNL for seismic monitoring network installation and maintenance.
This highly-experienced seismic specialist is now contracted directly by Geysers Power Company, LLC.
Jarpe Data Solutions* is also being contracted for data flow management tasks related to transition.

Primary Seismic Monitoring Network Goal

Optimize LBNL network functionality, accuracy and reliability.
Optimize data flow from seismic data recovery, through data processing, and to efficient seismic data archival.

* Jarpe Data Solutions has long-term relationship with LBNL concerning seismic acquisition testing and seismic databases

Improvements To LBNL / Geysers Power Company, LLC Seismic Monitoring Network

- **Geospace 2Hz Seismic Sensor Upgrades**
  - Upgrade of 24 seismic monitoring stations to Geospace 2Hz sensors
- **Strong Motion Station Installation**
  - Installation of four on eastern perimeter near communities
- **Battery Replacement and Recycle**
  - Replacement Of 30 batteries At 15 LBNL seismic monitoring stations
  - 2 Sunlyte / MK deep cycle batteries per station (36 purchased)
- **Hardware and Data Security**
  - Replacement of outdated Taurus/Janus digitizers
  - Two LBNL servers now in Geysers Administration Center (one a back-up unit)
  - Uninterrupted Power Source at Geysers Administration Center
  - Uninterrupted Power Source at three radio repeater sites
    - *DX Radio Repeater, Socrates Container, Microwave Tower*
- **Software Upgrades**
  - Improvements to web-based strong motion data interface
  - Improvements to strong motion waveform visualization software
- **Data Quality and Continuity**
  - Primary data transfer, processing and storage by Jarpe Data Solutions
  - Eliminate noise spikes on 2 Hz sensor data (grounding issue)
  - Replacement of cable for MIT-installed continuous GPS monitoring site TCH;
  - Restoring data flow for three continuous GPS monitoring sites
  - Conducted software trial for Applied Seismology InSite Geo Software for refined seismic waveform analysis

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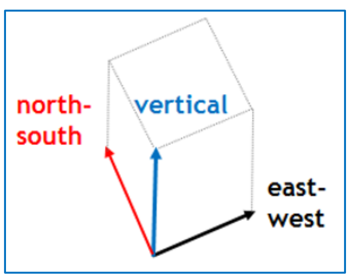
Improvements To LBNL / Geysers Power Company, LLC Seismic Monitoring Network

Recent Improvements
- Geysers Power Company, LLC
- Purchased 24 Three-Component Geospace 2 Hz Sensors
- Completed Installation By July 2020

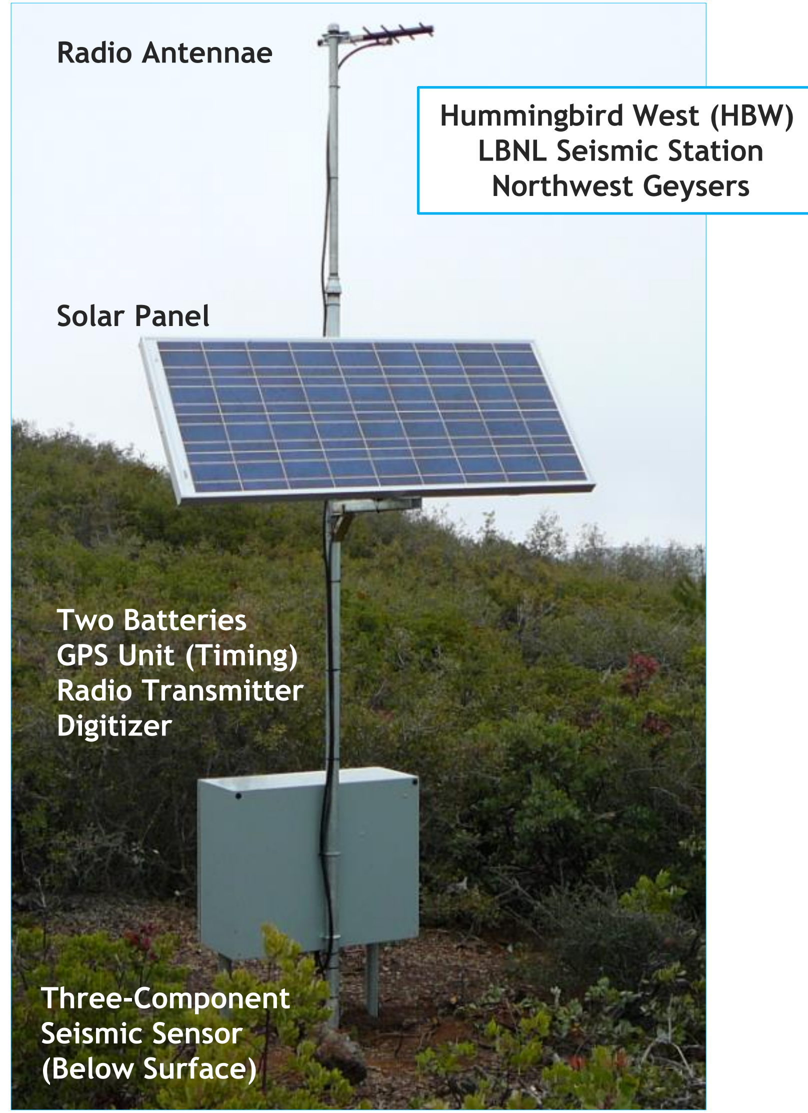
Geospace HS-1 3C arrays and cables
- Equipment: $2,400 per sensor station
- Installation: $ 500 per sensor station
- Total: $2,900 per sensor station

"ideally suited for seismological, engineering, and scientific applications where passive, low noise, short period, tri-axial sensors are required"



GEOSPACE Technologies

HS-1 3 Component Array



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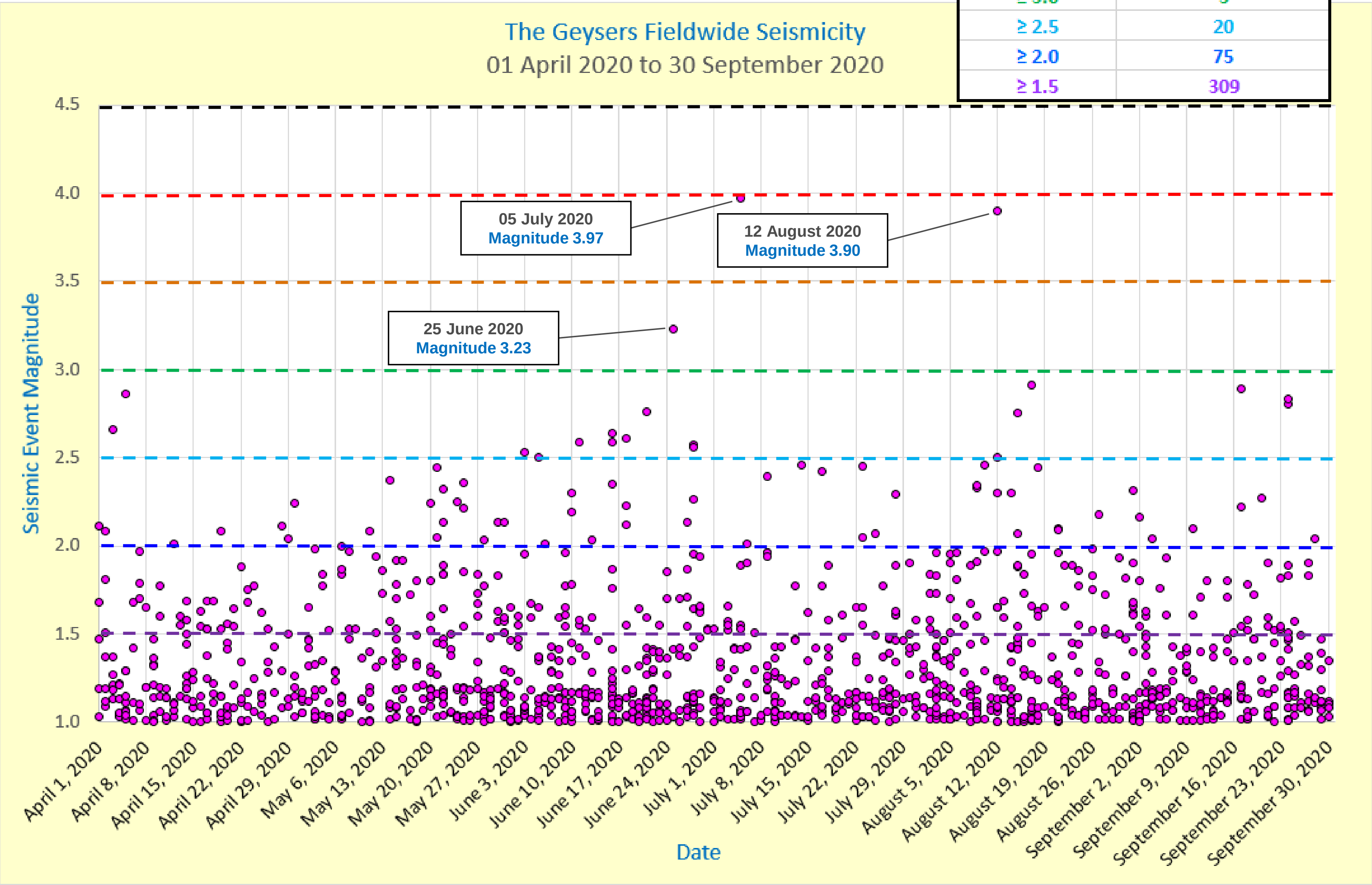
Field-wide Seismicity Analysis

01 April 2020 to 30 September 2020

Magnitude	Number of Events
≥ 4.5	0
≥ 4.0	0
≥ 3.5	2
≥ 3.0	3
≥ 2.5	20
≥ 2.0	75
≥ 1.5	309



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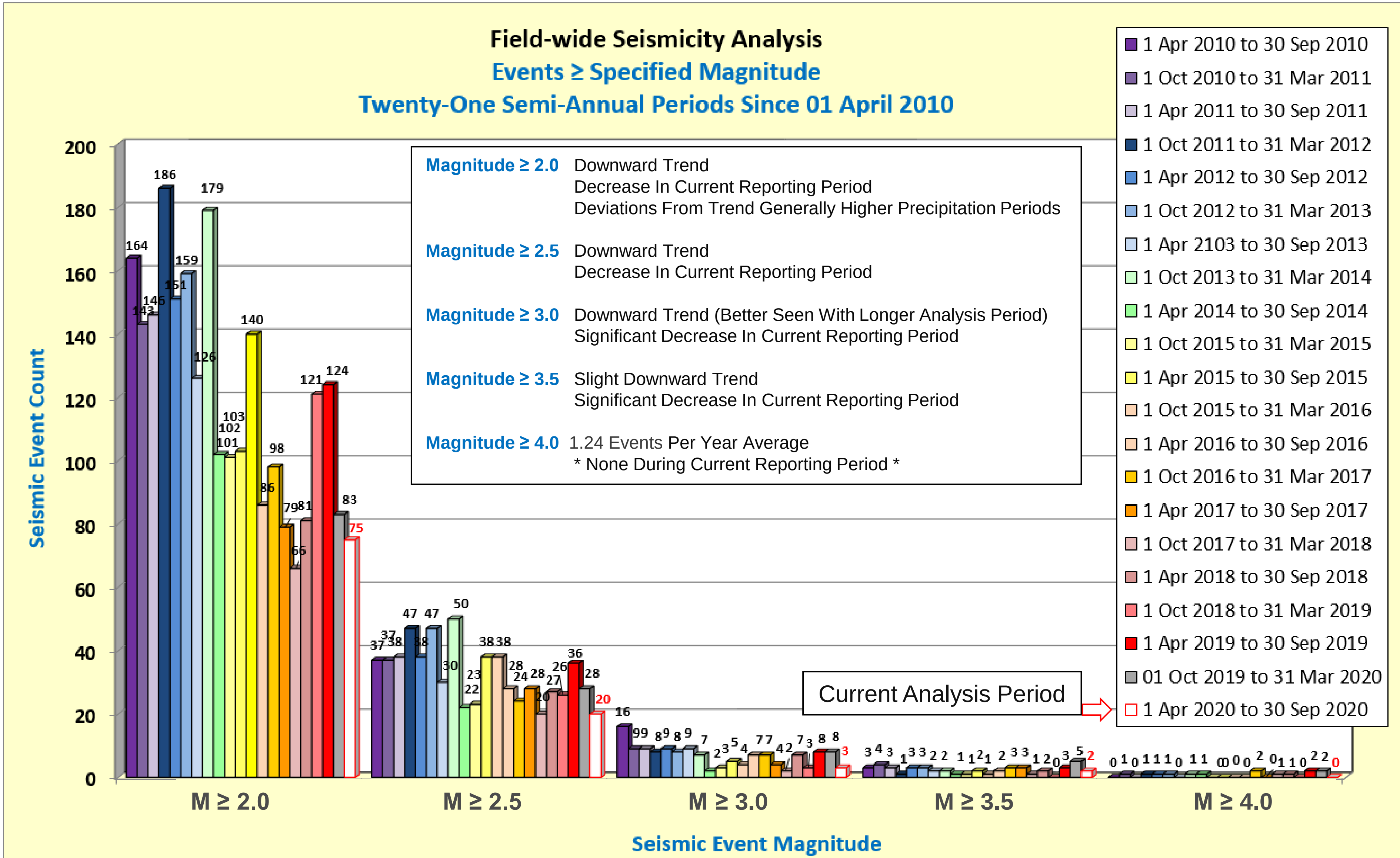
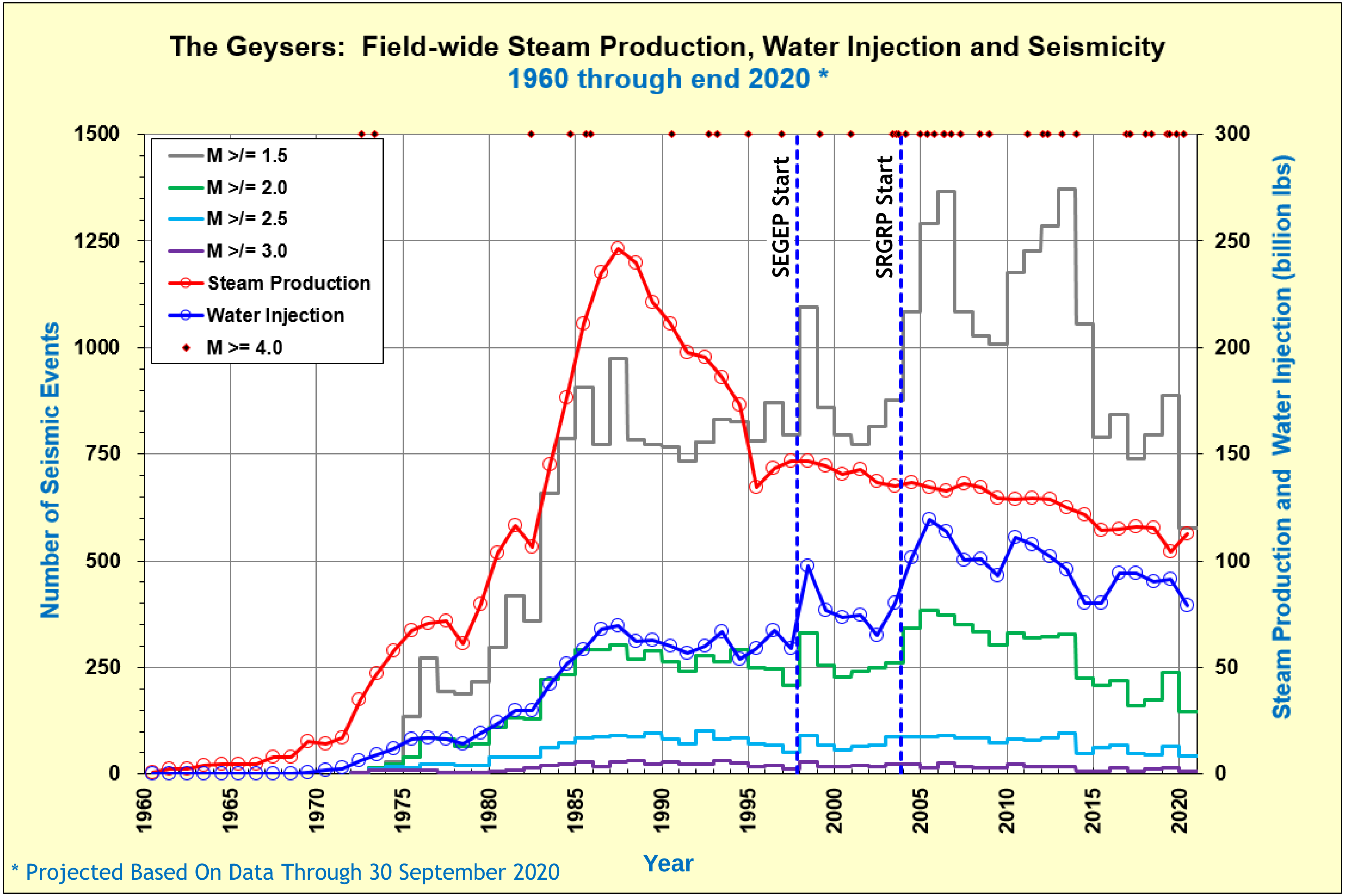
Field-wide Seismicity Analysis

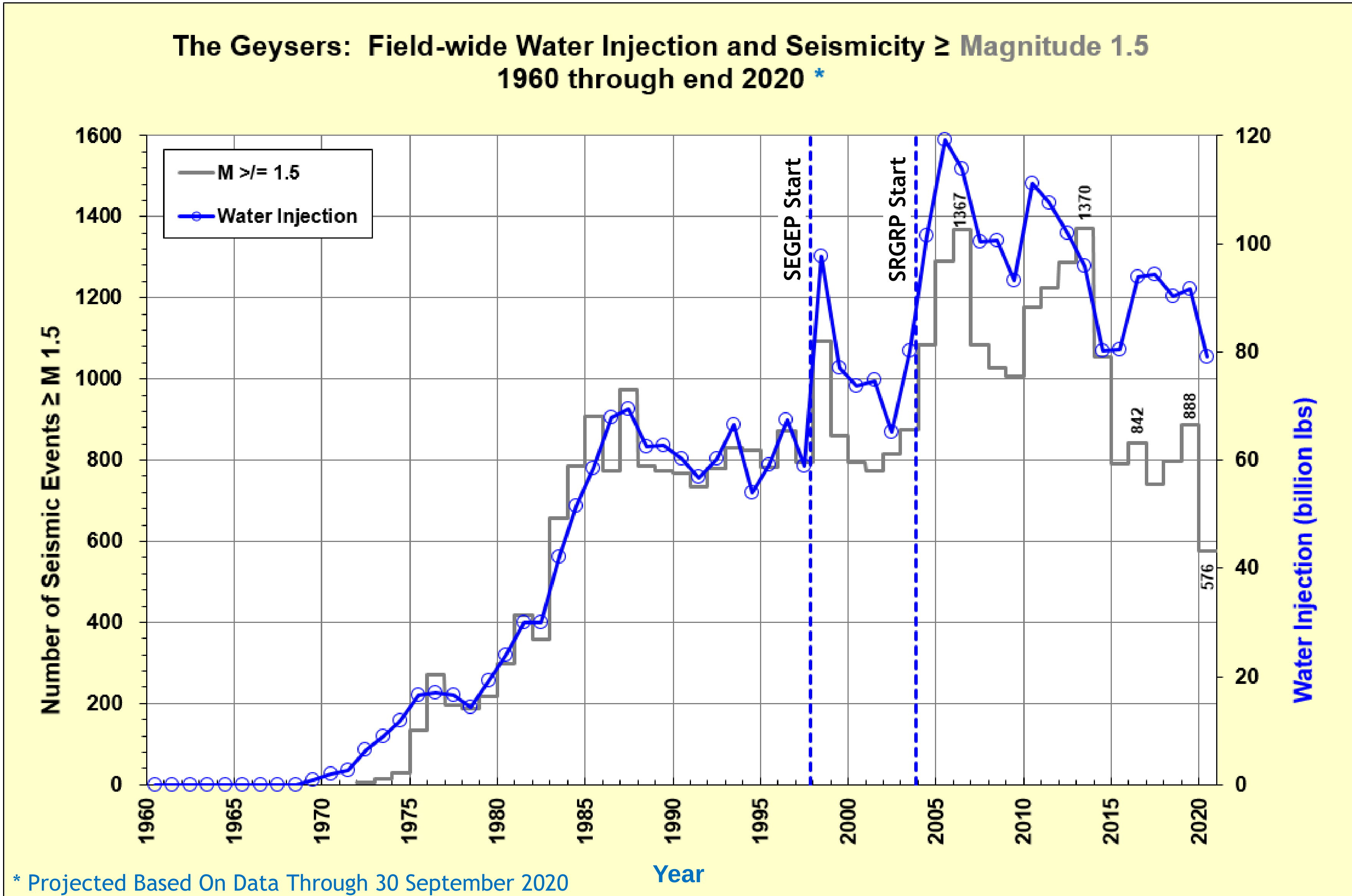
Comparison of Twenty-One Semi-annual Reporting Periods Since 01 April 2010



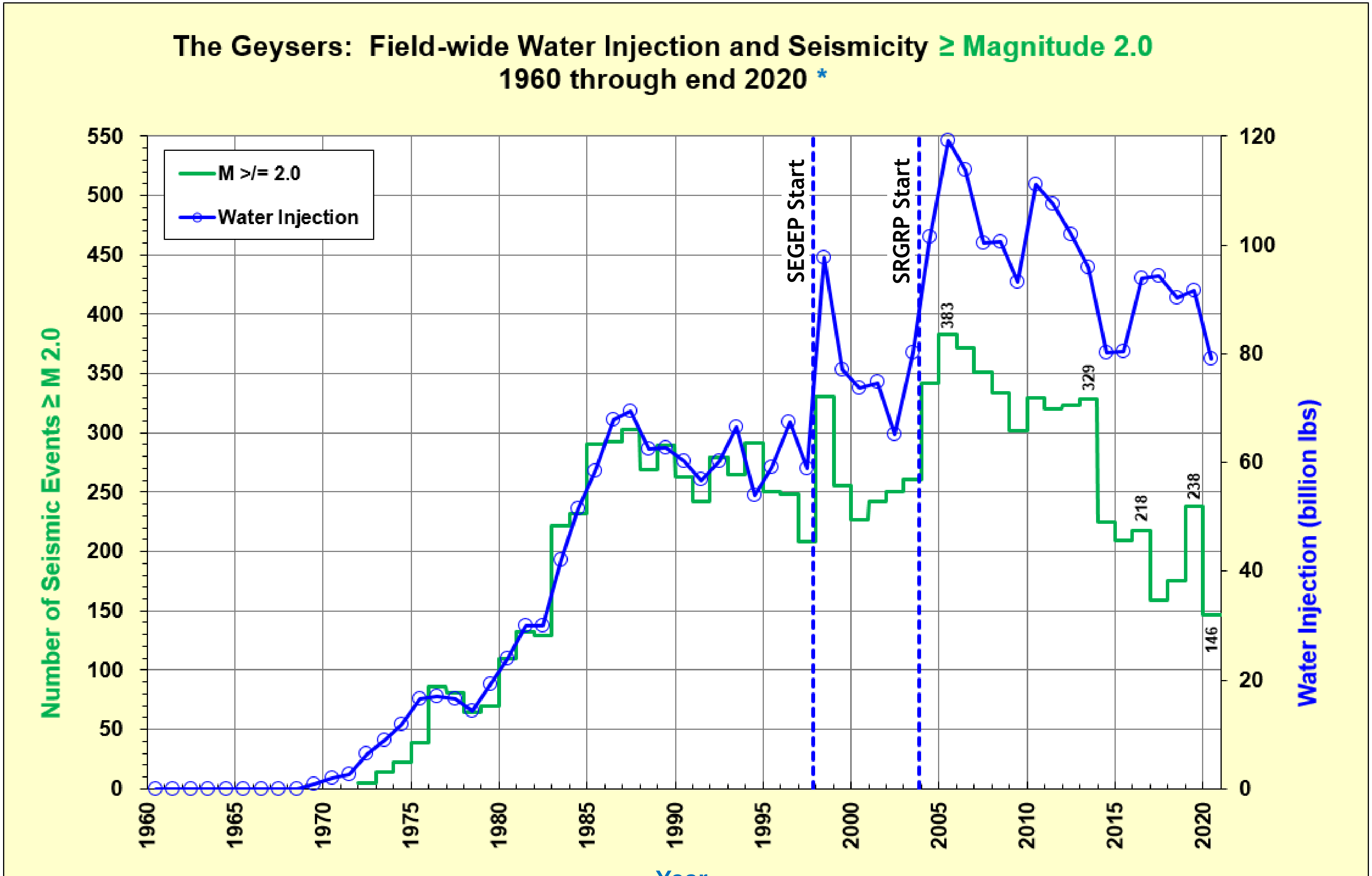
Yearly Field-wide Steam Production, Water Injection and Seismicity



Yearly Field-wide Water Injection and Seismicity ≥ Magnitude 1.5

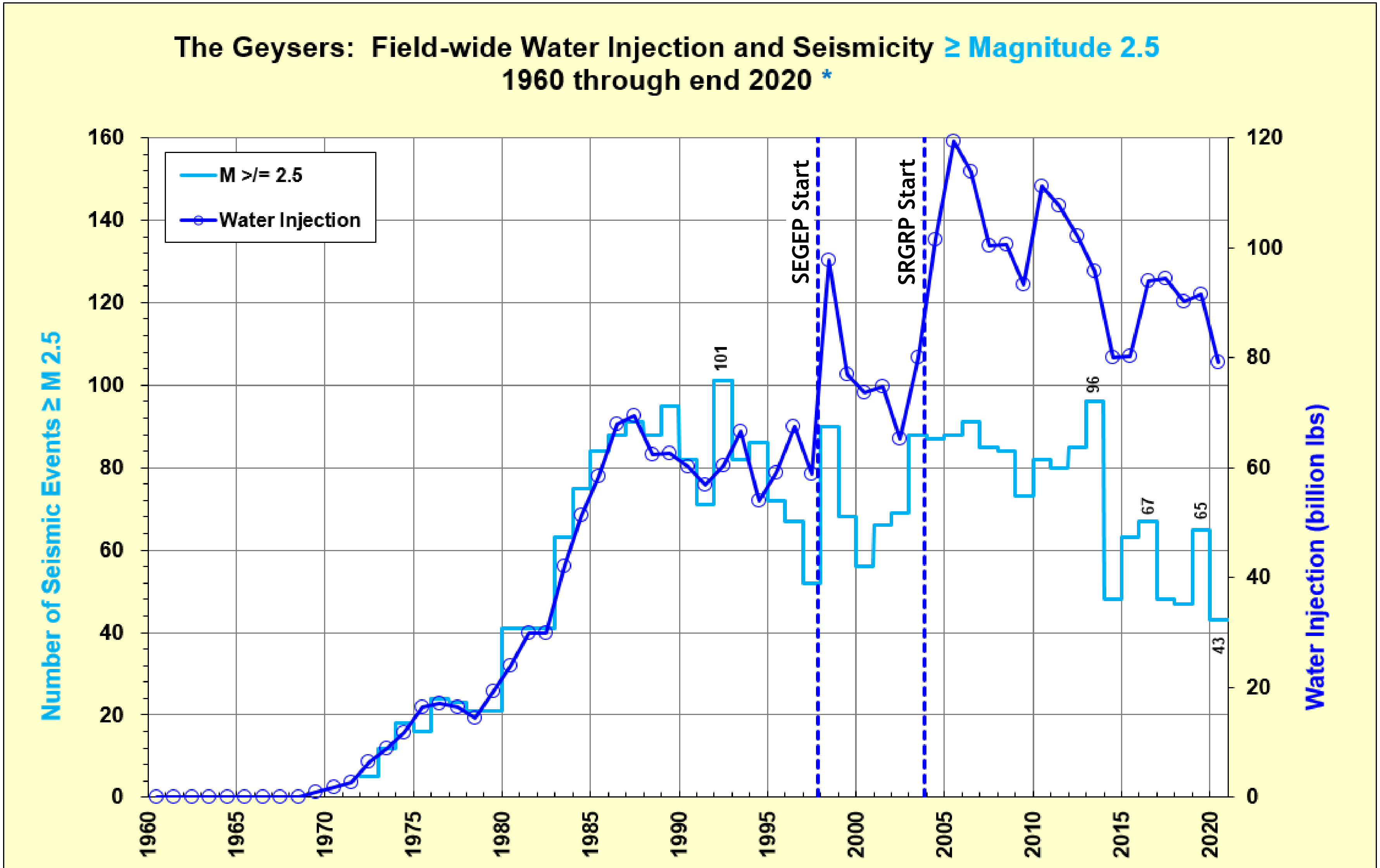


Yearly Field-wide Water Injection and Seismicity ≥ Magnitude 2.0



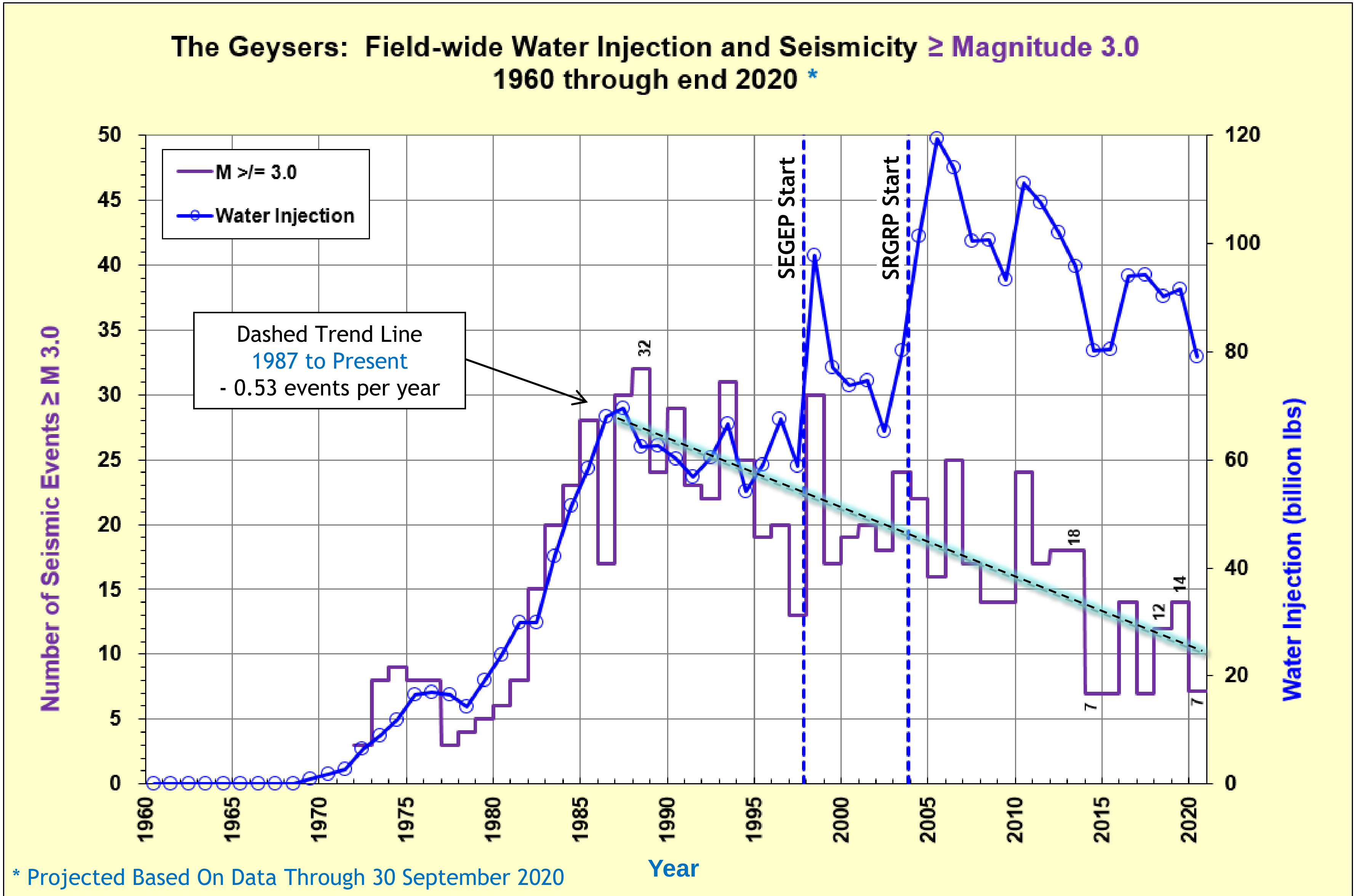
* Projected Based On Data Through 30 September 2020

Yearly Field-wide Water Injection and Seismicity ≥ Magnitude 2.5



* Projected Based On Data Through 30 September 2020

Yearly Field-wide Water Injection and Seismicity ≥ Magnitude 3.0



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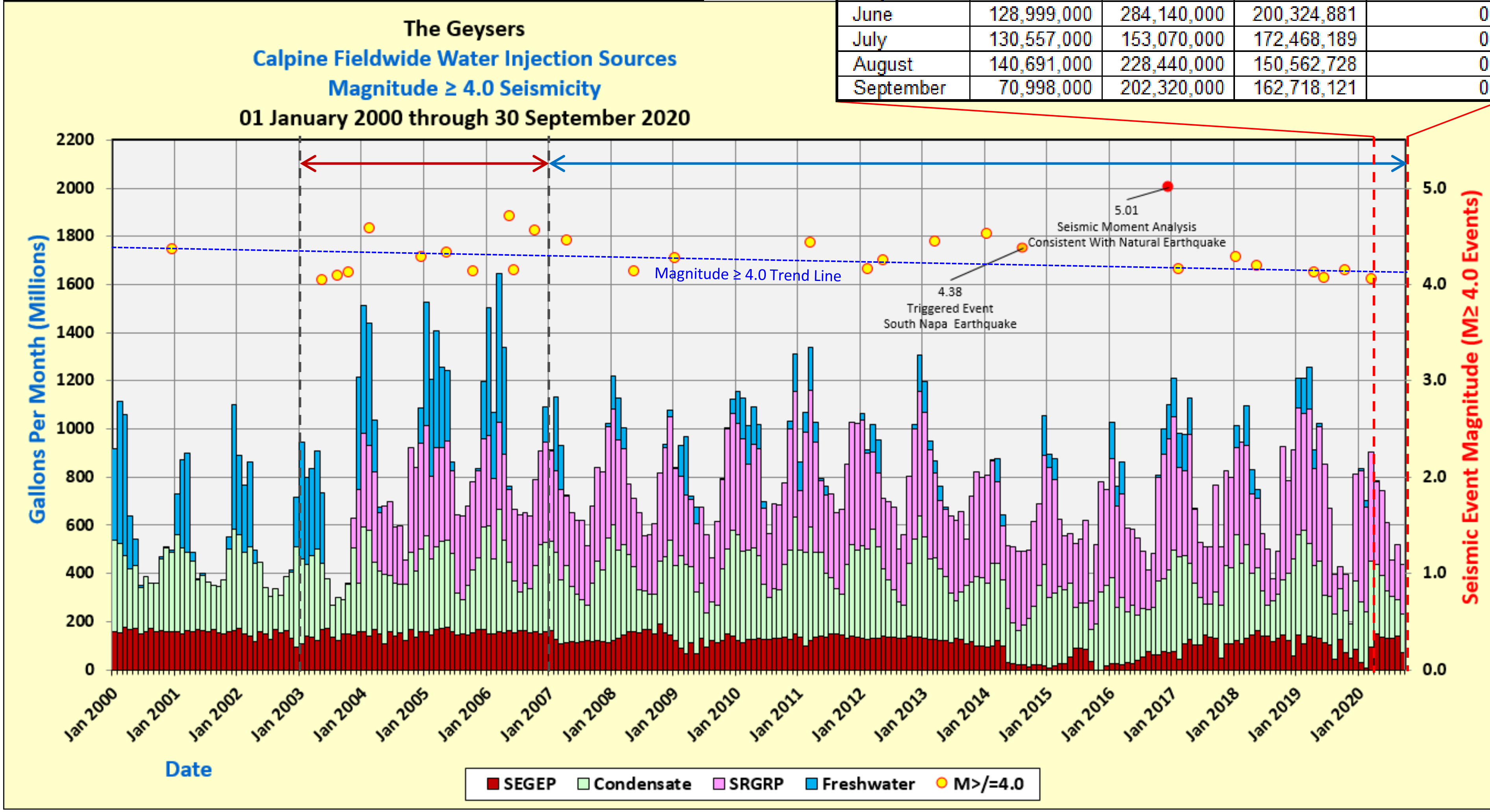
Monthly Field-wide Water Injection By Water Source vs. Magnitude ≥ 4.0 Seismicity

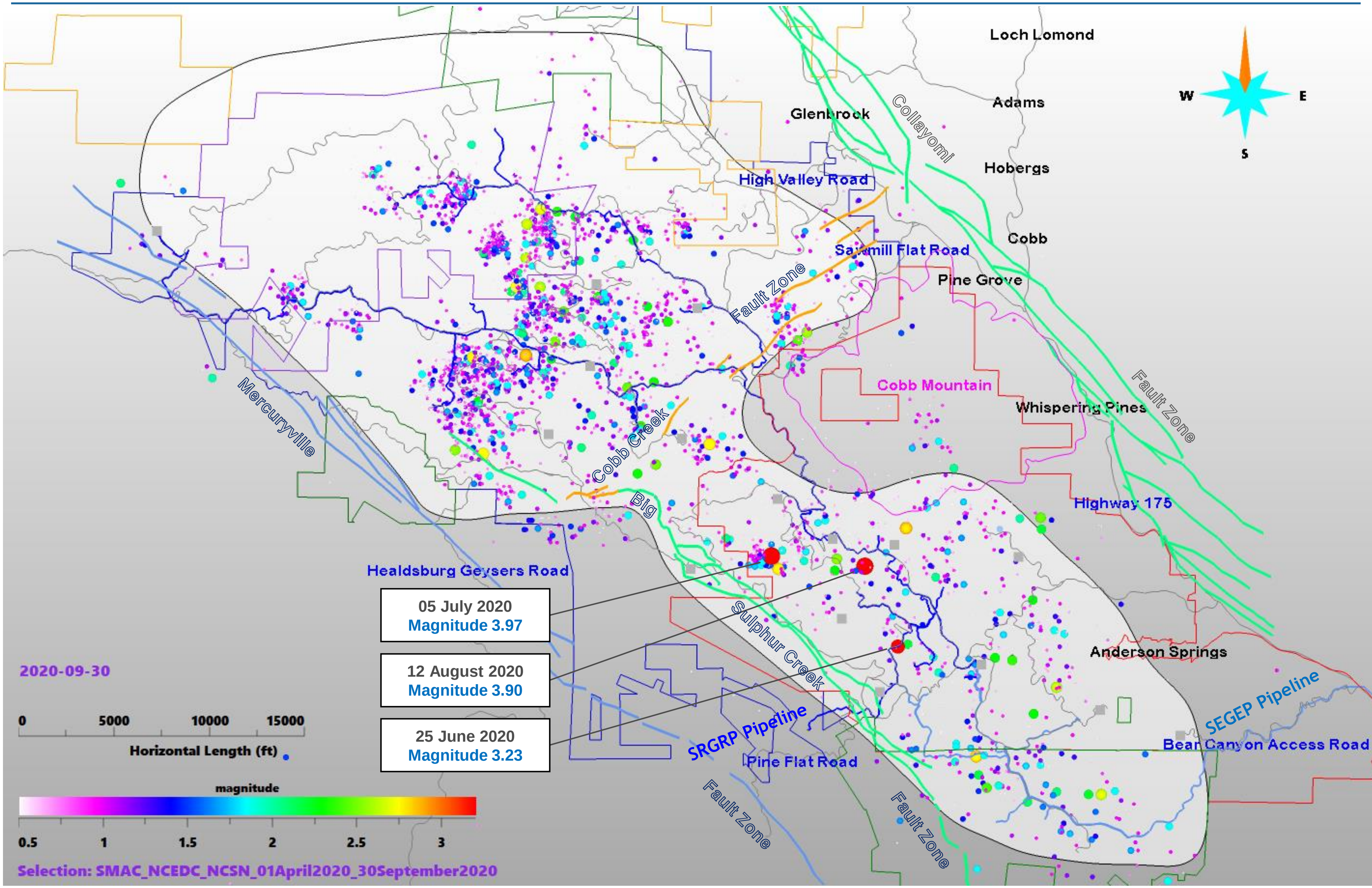
Average Number of Magnitude ≥ 4.0 Events Since January 2007 is 1.24 Per Year

Time Period	Magnitude ≥ 4.0 Seismic Events
January 2003 through December 2006	2.50 per year
January 2007 through September 2020	1.24 per year

Water Supply for Reporting Period (Six Months)				
Water Injection Sources (Gallons)				
Month	SEGEP	SRGRP	Condensate	Fresh Water
April	149,259,000	340,640,000	290,238,463	3,174,631
May	135,788,000	351,160,000	257,146,252	0
June	128,999,000	284,140,000	200,324,881	0
July	130,557,000	153,070,000	172,468,189	0
August	140,691,000	228,440,000	150,562,728	0
September	70,998,000	202,320,000	162,718,121	0



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



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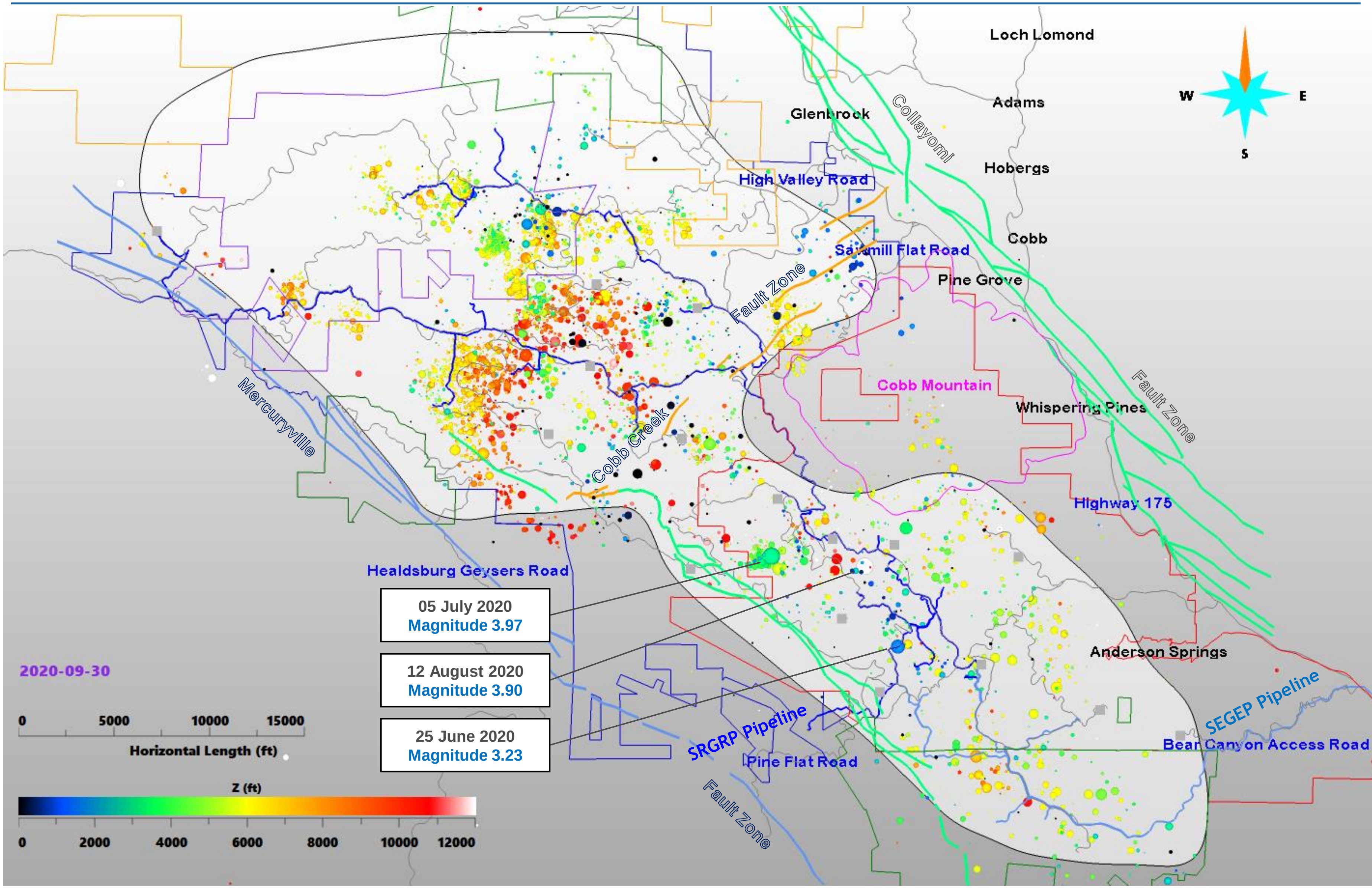
Field-wide Seismicity
Seismic Events Color Scaled By Depth



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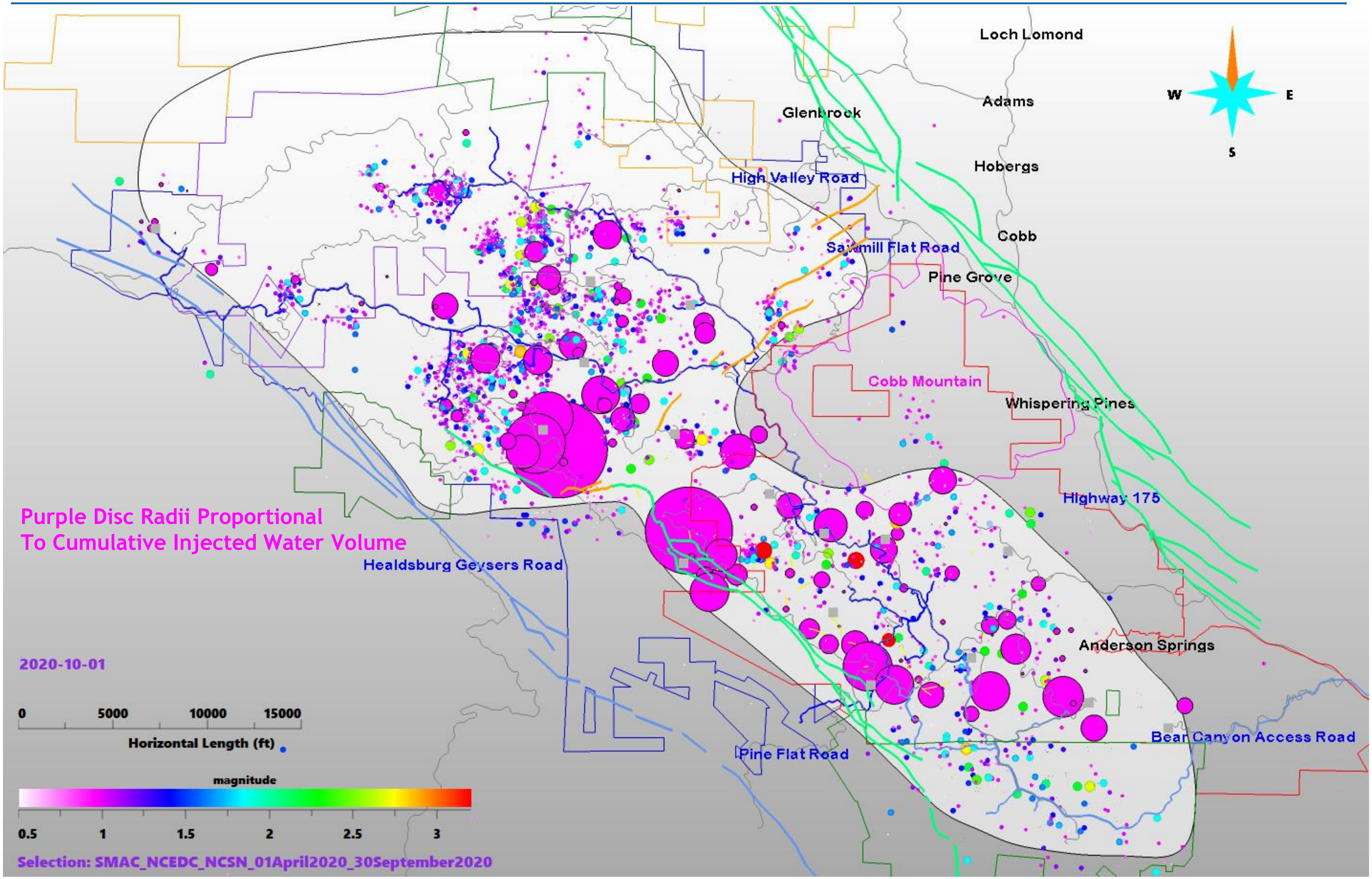
Field-wide Seismicity

Seismic Events Color Scaled By Magnitude And Cumulative Historical Injection Volume



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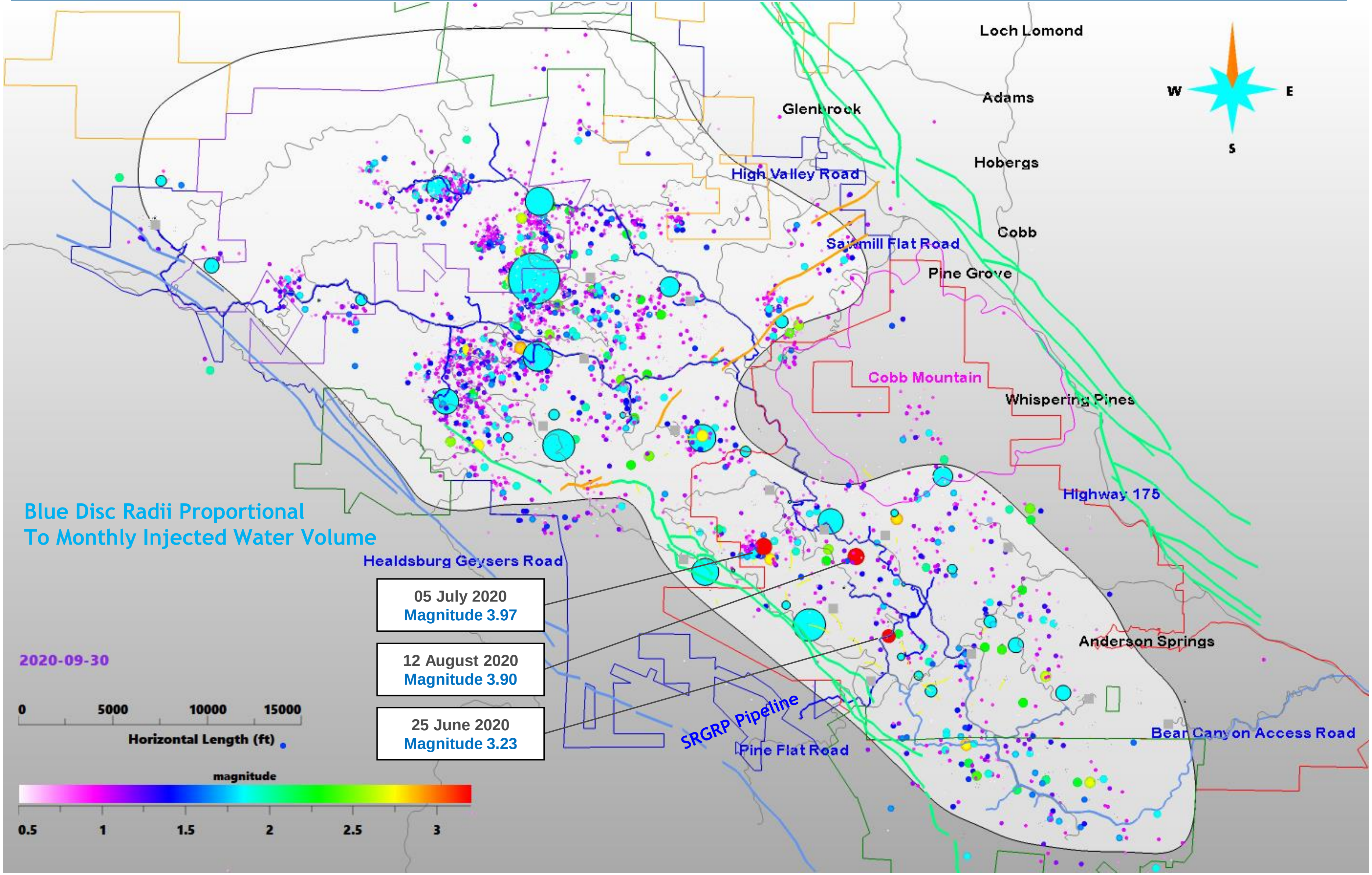
Field-wide Seismicity Animation At One Month Interval
Seismic Events Color Scaled By Magnitude and Monthly Injection Volume



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Improvements To LBNL / Geysers Power Company, LLC Strong Motion Network

ACCELEROMETER TECHNOLOGY AND PERFORMANCE

Topology: Triaxial, horizontal-vertical
Feedback: Force balance with capacitive displacement transducer
Centering: Electronic offset zeroing via user interface or control line
Full-scale Range: Electronically selectable range: ±4*g*, ±2*g*, ±1*g*, ±0.5*g*, and ±0.25*g* (peak)
Bandwidth: DC to 430 Hz (-3 dB point)
Dynamic Range: (Integrated RMS)
- 166 dB @ 1 Hz over 1 Hz bandwidth
- 155 dB, 3 to 30 Hz

Offset: Electronically zeroed to within ±0.005*g*
Non-linearity: < 0.015% total non-linearity
Hysteresis: < 0.005% of full scale
Cross-axis Sensitivity: < 0.5% total
Offset Temperature Coefficient:
- Horizontal sensor: 60 µ*g*/°C, typical
- Vertical sensor: 320 µ*g*/°C, typical

Recent Improvements
- Geysers Power Company, LLC Purchased Four Nanometrics Titan Accelerometer Stations
- All Now Installed And Operational Along Eastern Perimeter Of Geysers Geothermal Field
- State-Of-The-Art Sensors Provide Improved Data Accuracy And Reliability

Nanometrics Titan Three- Component Accelerometer
- Equipment: $4,800 per sensor station
- Installation: $2,500 per sensor station
- Total: $7,300 per sensor station

Power
- Solar Panels

Communications
- LBNL Radio Telemetry

Data Reliability Concerns Related To Previous Generation ETNA Strong Motion Stations Greatly Reduced

No Rural …
- AC Power
- Phone-Line Communication

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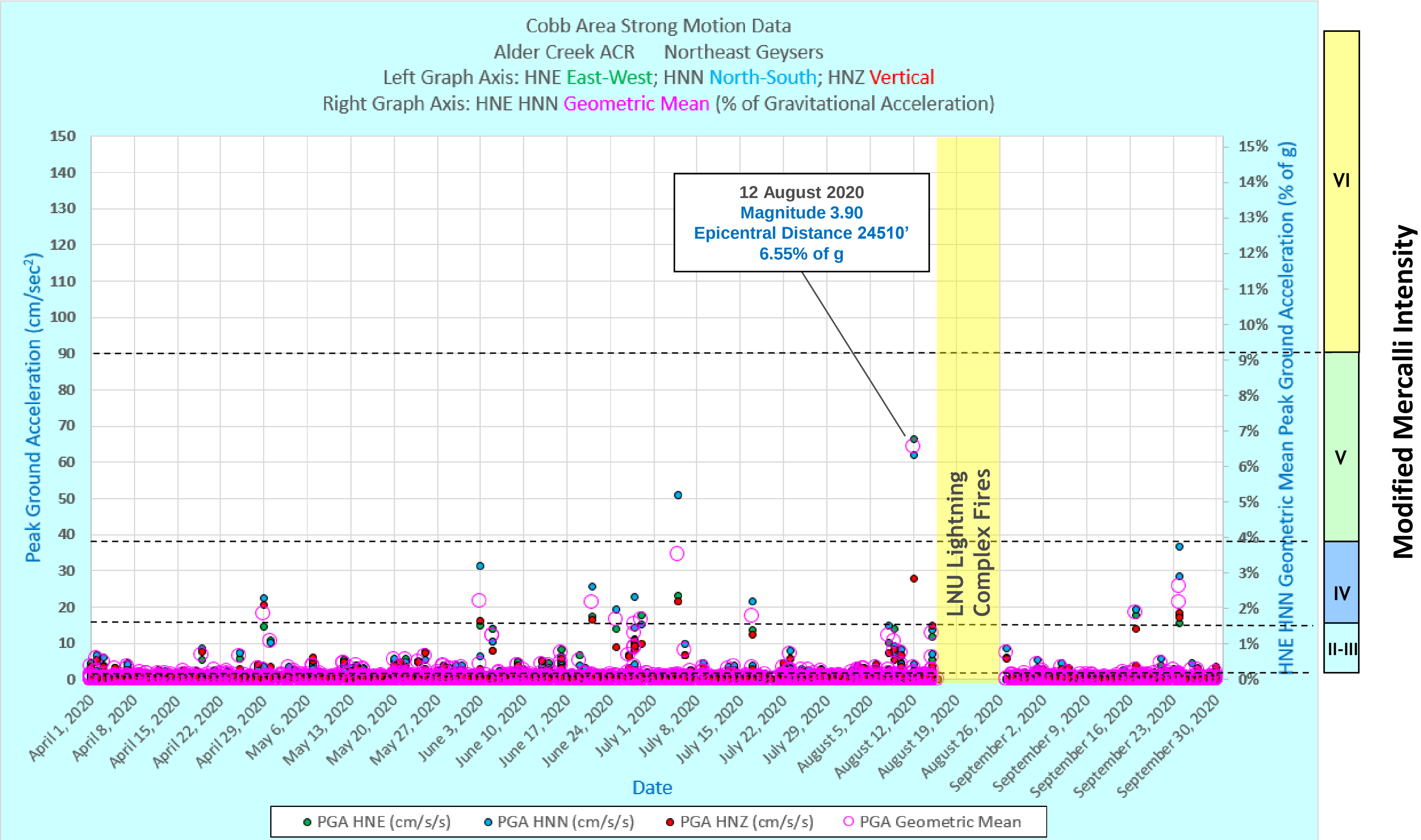
Cobb Area Alder Creek Strong Motion ACR



Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (cm/sec)	< 0.10	0.1 - 1.1	1.1 - 3.4	3.4 - 8.1	8.1 - 16.0	16.0 - 31.0	31.0 - 60.0	60.0 - 116.0	> 116.0
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X

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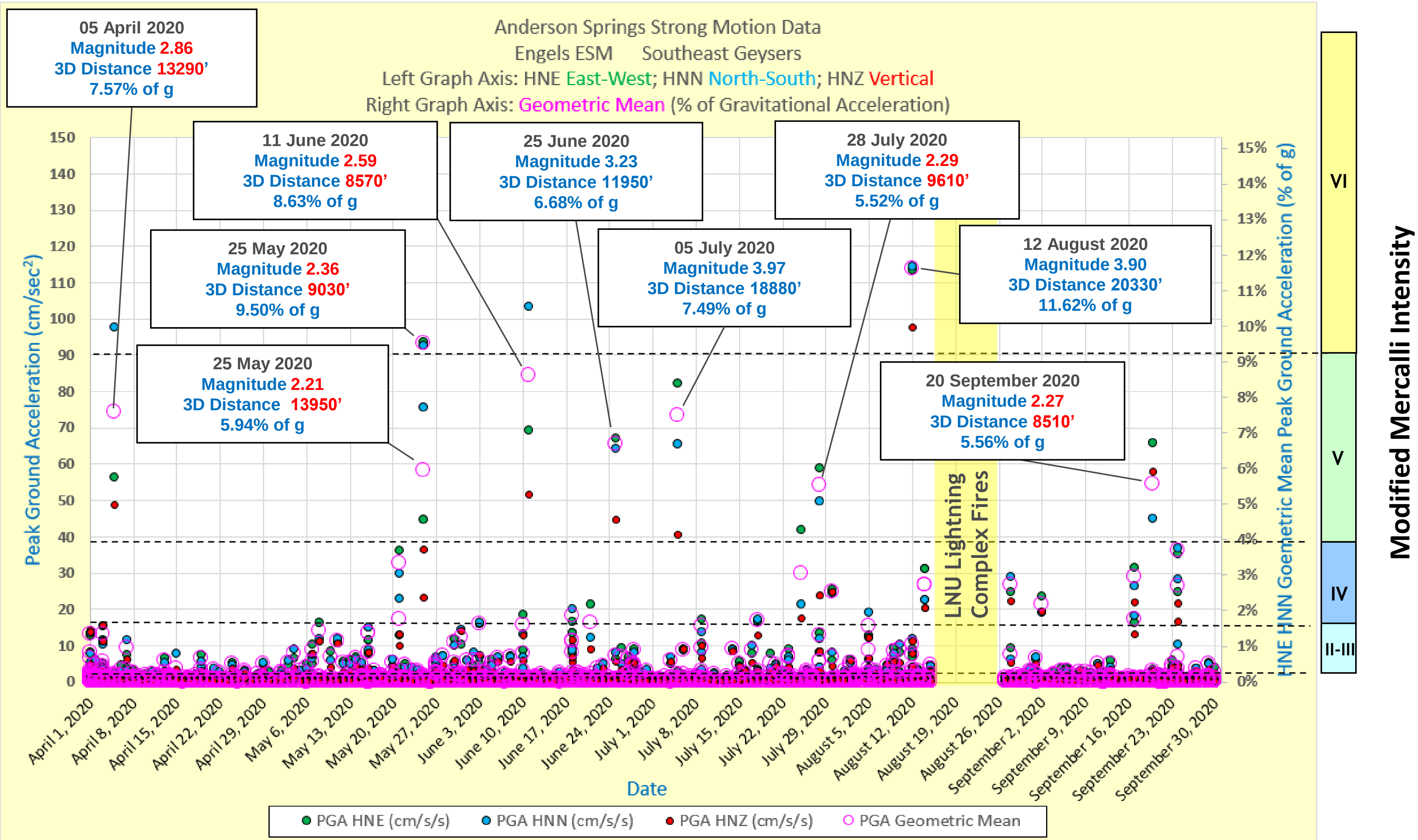
Anderson Springs Engels Strong Motion ESM



Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (cm/sec)	< 0.10	0.1 - 1.1	1.1 - 3.4	3.4 - 8.1	8.1 - 16.0	16.0 - 31.0	31.0 - 60.0	60.0 - 116.0	> 116.0
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X

Several relatively low magnitude seismic events near the community of Anderson Springs, plus encouragement to utilize the community hotline, resulted in a total of 15 calls during the reporting period of 01 April 2020 to 30 September 2020.

The four seismic events of primary concern were:

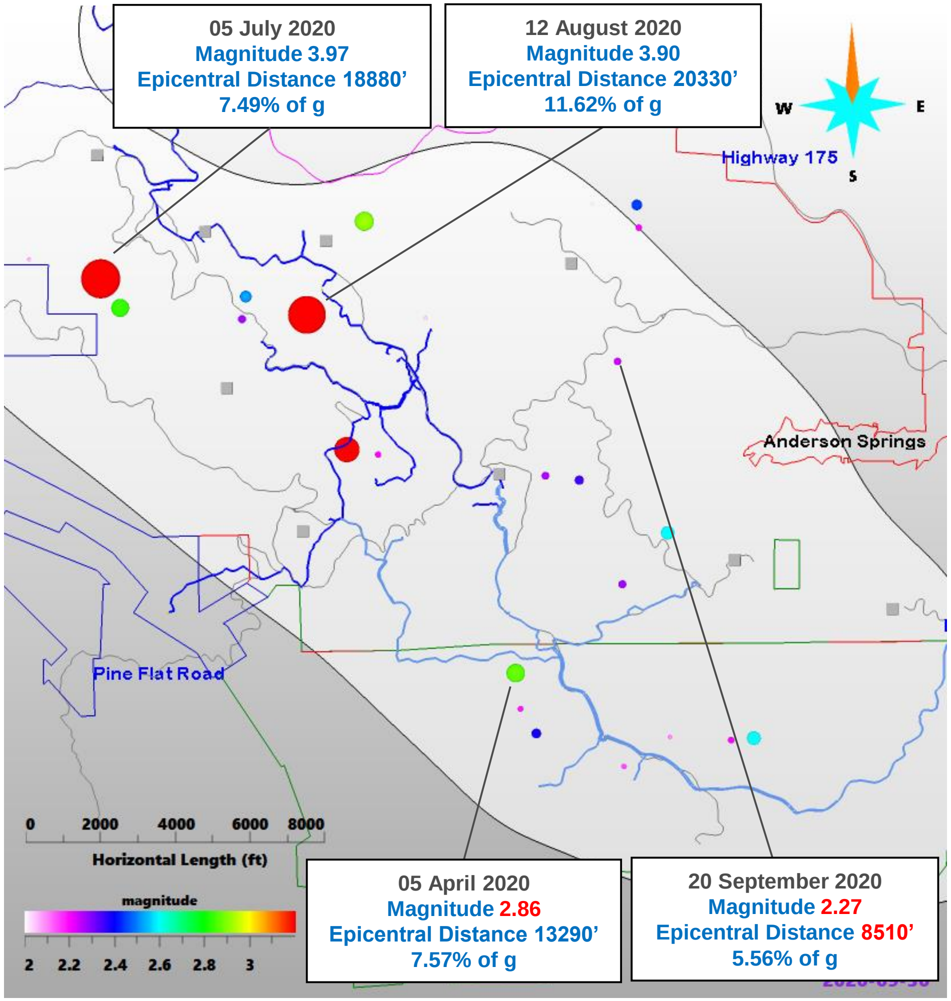
05 April 2020 Magnitude 2.86 at 04:06:39 UTC
13,290' Southwest of Anderson Springs
3 calls

05 July 2020 Magnitude 3.97 at 04:09:07 UTC
18,750' Northwest of Anderson Springs
3 calls

12 August 2020 Magnitude 3.90 at 11:45:43 UTC
20,330' Northwest of Anderson Springs
1 call

20 September 2020 Magnitude 2.27 at 01:48:53 UTC
8,510' Northwest of Anderson Springs
2 calls

The 25 April 2020 and 20 September 2020 seismic events were of magnitude 2.86 and 2.27 respectively, but had a relatively limited epicentral distances.
(energy *and* distance are important criteria)



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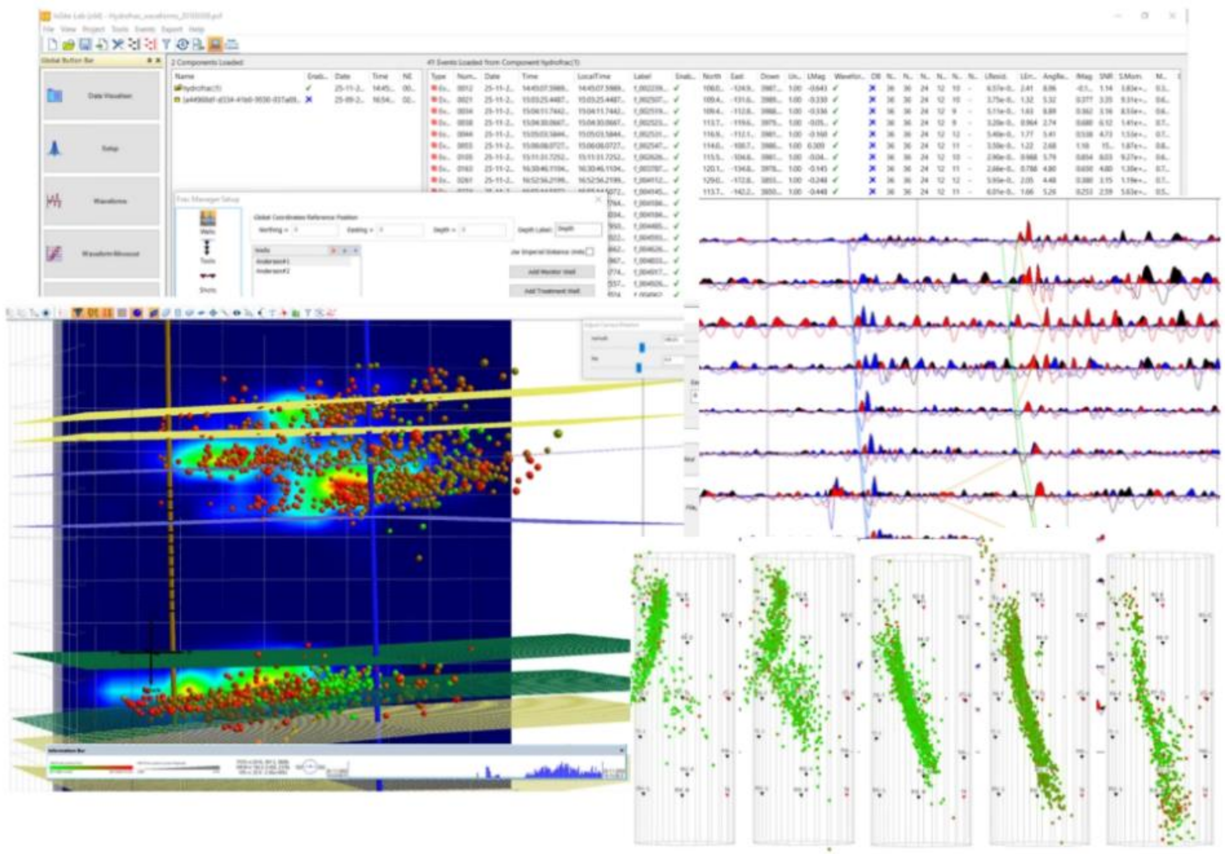
Applied Seismology / Itasca InSite-Geo Software Testing

Geysers Power Company, LLC has conducted on-site testing of this well-developed software to assist with detailed seismicity analysis at The Geysers and is currently arranging for an early 2021 software purchase.

InSite Seismic Processor

ITASCA

- Itasca's seismic software integrating data management, processing, analysis and interpretation
- Developed over the past 20 years incorporating tools from internal R&D and collaboration projects with clients and partners
- Used at all scales of seismic and acoustic monitoring, from laboratory rock deformation tests to processing of local and regional seismicity
- Latest version 3.16.1 released March 2020

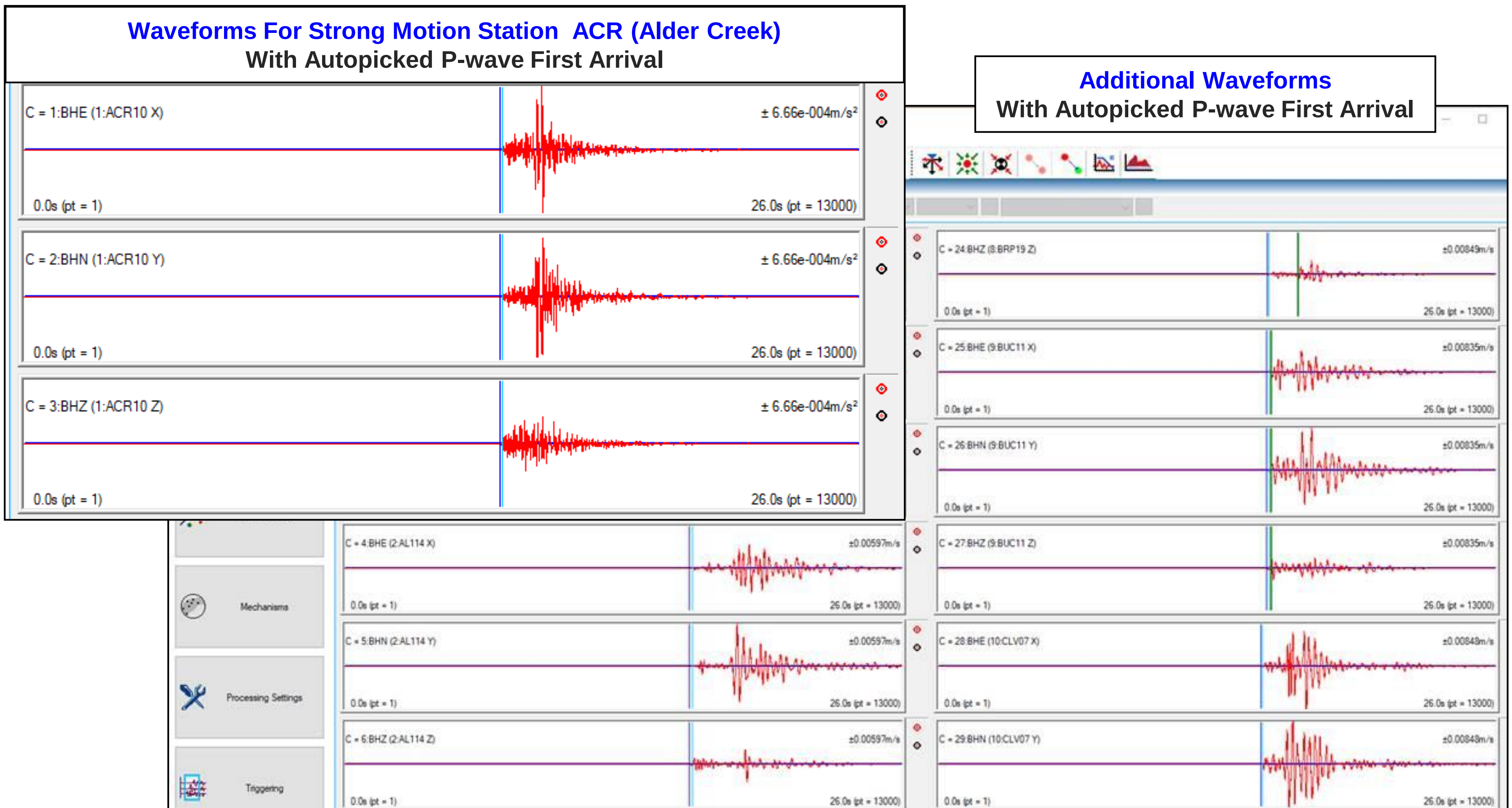


GEOMECHANICS • HYDROGEOLOGY • APPLIED SEISMOLOGY : MINING • CIVIL • ENERGY 2

Applied Seismology / Itasca InSite-Geo Software Testing

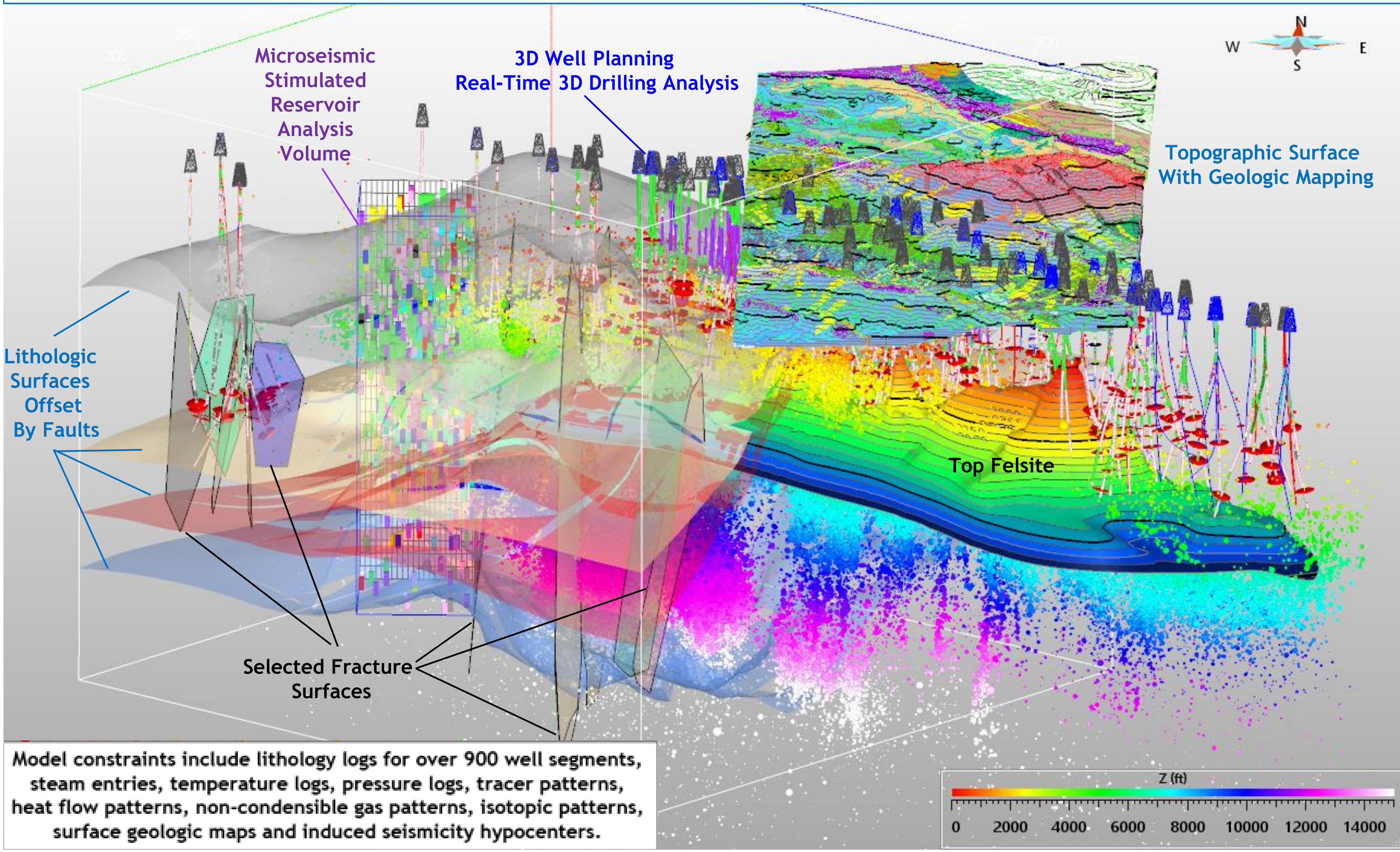
Seismic events exceeding threshold criteria were isolated from The Geysers continuous waveform data and processed within the Applied Seismology / Itasca InSite-Geo software. Waveforms for the East-West, North-South and Vertically oriented sensors are shown for a 12 August 2020 magnitude 3.9 seismic event processed on a Geysers Power Company, LLC workstation.

Larger seismic events typically have usable waveforms (with signal well above the noise floor) for the majority of the 38 three-component LBNL / Calpine seismic stations.



Current Status Of 3D Structural Model Development

A refined understanding of The Geysers' fluid flow paths, fluid boundaries, reservoir heterogeneity and reservoir compartmentalization *assists* with well planning / targeting, real-time drilling analysis, reservoir management and provides the potential for improved seismicity mitigation at The Geysers.



Model constraints include lithology logs for over 900 well segments, steam entries, temperature logs, pressure logs, tracer patterns, heat flow patterns, non-condensible gas patterns, isotopic patterns, surface geologic maps and induced seismicity hypocenters.

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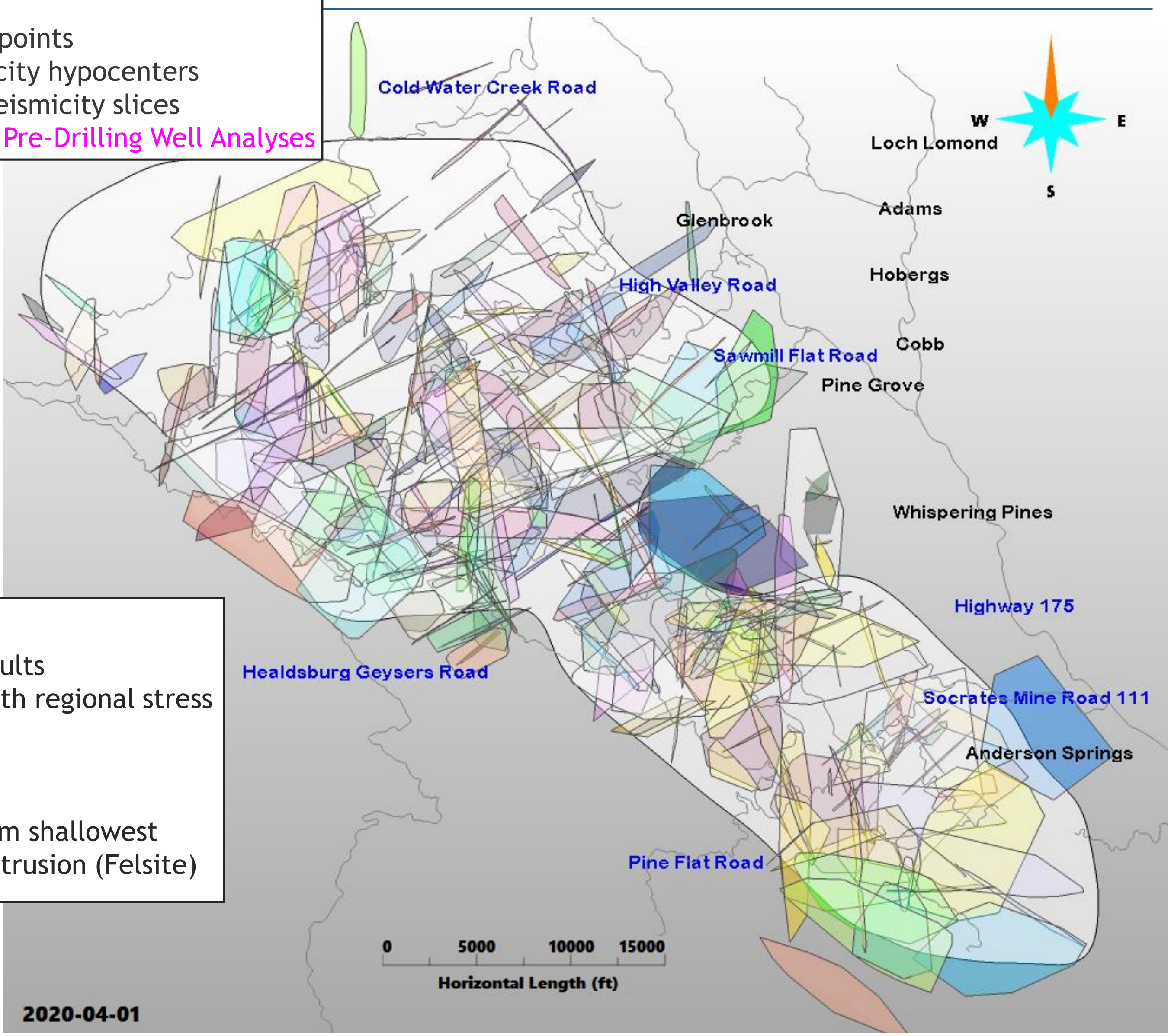
Fault/Fracture Interpretation Surfaces Based on Seismicity Patterns/Alignments

357 Fault/Fracture Surfaces
- Greater than 42,000 interpreted points
- Picked directly on aligned seismicity hypocenters
- Picked using variously-oriented seismicity slices
- Continual Refinements during 3D Pre-Drilling Well Analyses



Northwest Geysers
- Primarily near-vertical faults
- Orientation consistent with regional stress

Southeast Geysers
- More non-vertical faults
- Several faults radiate from shallowest penetration of granitic intrusion (Felsite)

Accepted Proposal

High-Resolution Micro-Earthquake Imaging of Flow Paths Using a Dense Seismic Network and Fast-Turnaround, Automated Processing * * Additional funding for this effort approved by the California Energy Commission in March 2020 *

Program Goal

Development of advanced, low-cost, microseismic imaging for high-resolution spatial and temporal images of subsurface fluid flow, flow barriers and heterogeneity in producing geothermal fields. The project will focus on microseismicity imaging challenges that are unique to geothermal reservoirs.

Improved 3D and time-lapse subsurface resolution is anticipated to assist with seismicity mitigation efforts at The Geysers.

Applicant

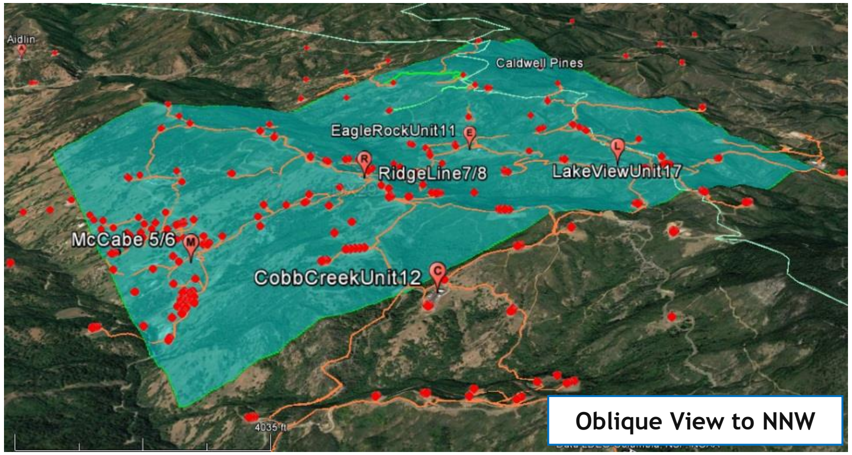
Lawrence Berkeley National Laboratory

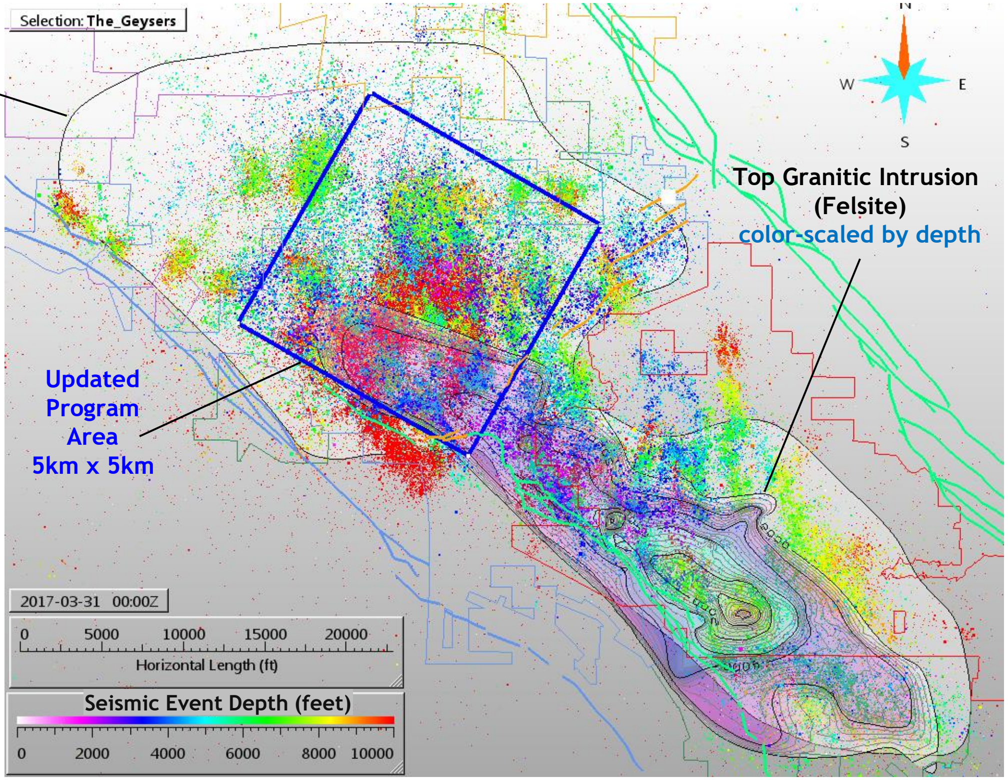
Project Partners

Geysers Power Company, LLC
Array Information Technology

California Energy Commission Funds Recommended

$1,672,639





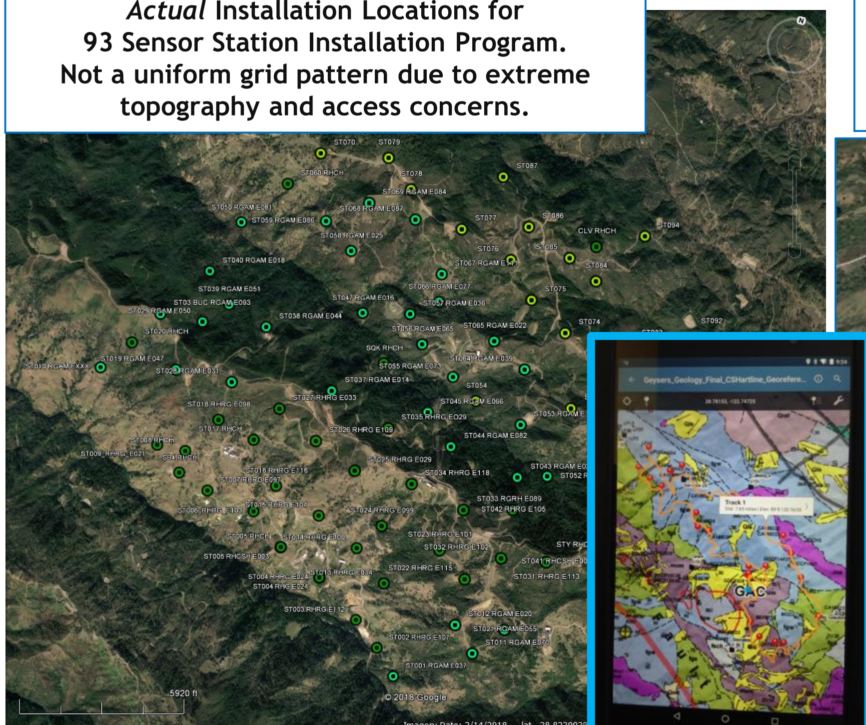
An extensive seismic sensor test program was planned and is being conducted with the project scientists. Additional funding for this effort approved by the CEC in March 2020.

Geysers Power Company, LLC has provided:

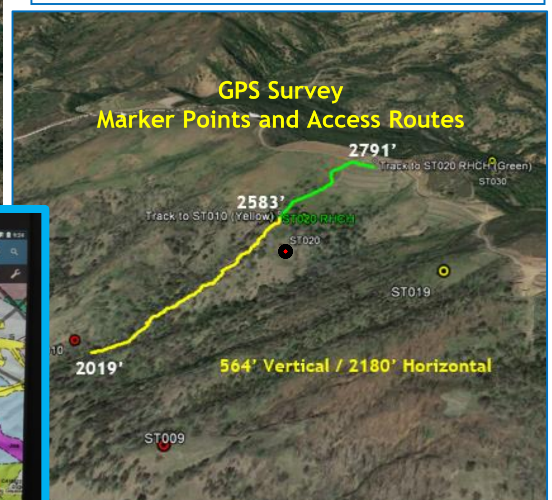
- The field location for this program.
- Technical support with survey design planning.
- On-site assessments including GPS surveying with updated equipment and techniques.
- Assistance to LBNL Contractor Ramsey Haught during 17 seismic sensor test installations.
- Coordination and updating of GPS surveys/maps data recovery at 2-3 month intervals.

Generation Three Sensor Station

Green Labeled Points
Actual Installation Locations for
93 Sensor Station Installation Program.
Not a uniform grid pattern due to extreme topography and access concerns.



Surveying of 23 Test Sensor Station Locations and Access Routes Completed By Calpine With Samsung Nexus 7 Tablet and Paired Garmin GLO Device.



Sensor Installation on Rock Outcrop

Correlation of Imaging Results to 3D Reservoir Model

Four Following Summary Slides Concerning California Energy Commission Funded Collaborative Seismicity Research Were Provided By:
Dr. Roland Gritto
Array Information Technology

Correlation to Reservoir Data

CALIFORNIA ENERGY COMMISSION

BERKELEY LAB
Lawrence Berkeley National Laboratory

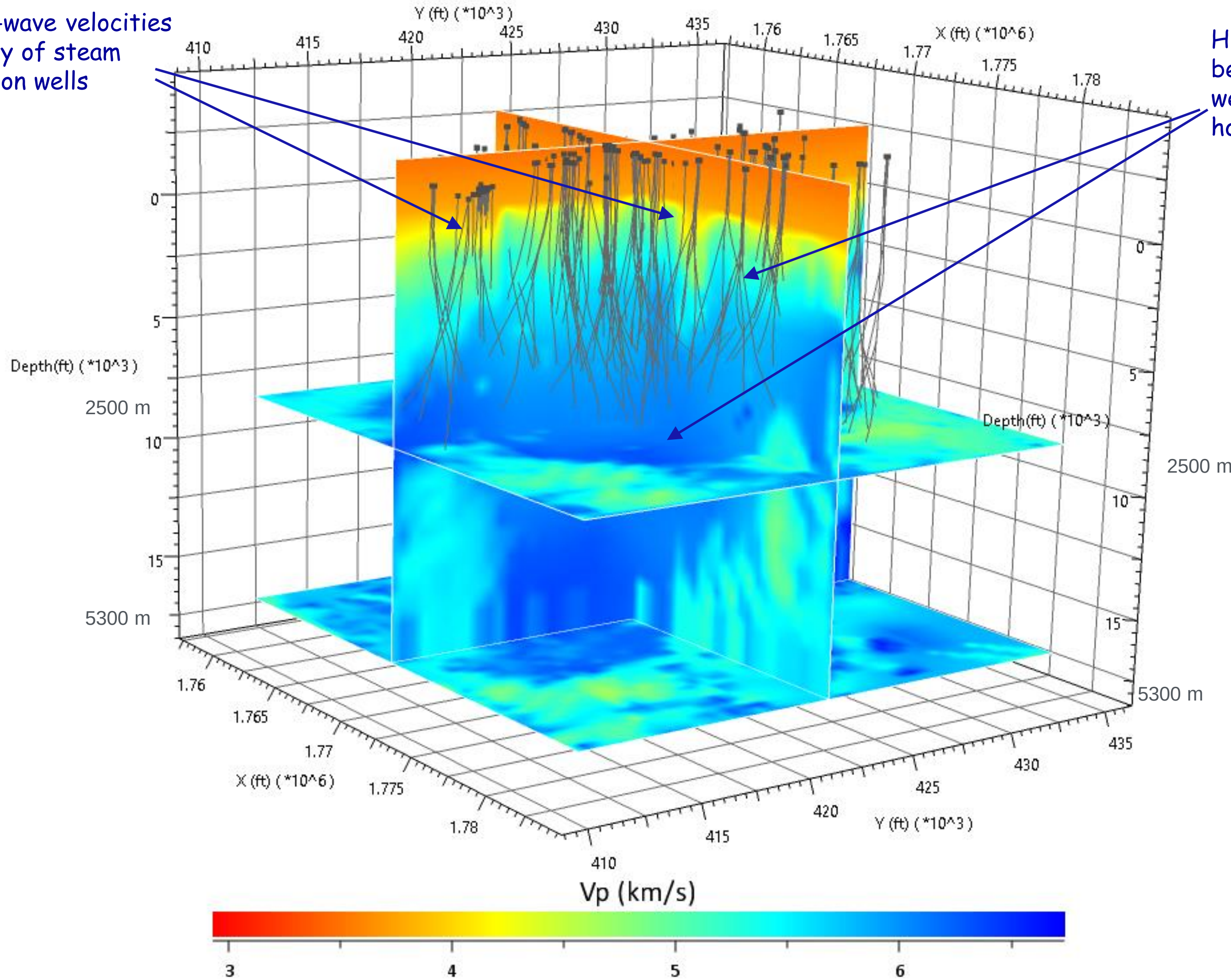
ARRAY
applied innovation · driving mission success

JDS

P-Wave Velocity Estimates

Lower P-wave velocities in vicinity of steam production wells

Higher P-wave velocities below water injection wells and around open hole sections

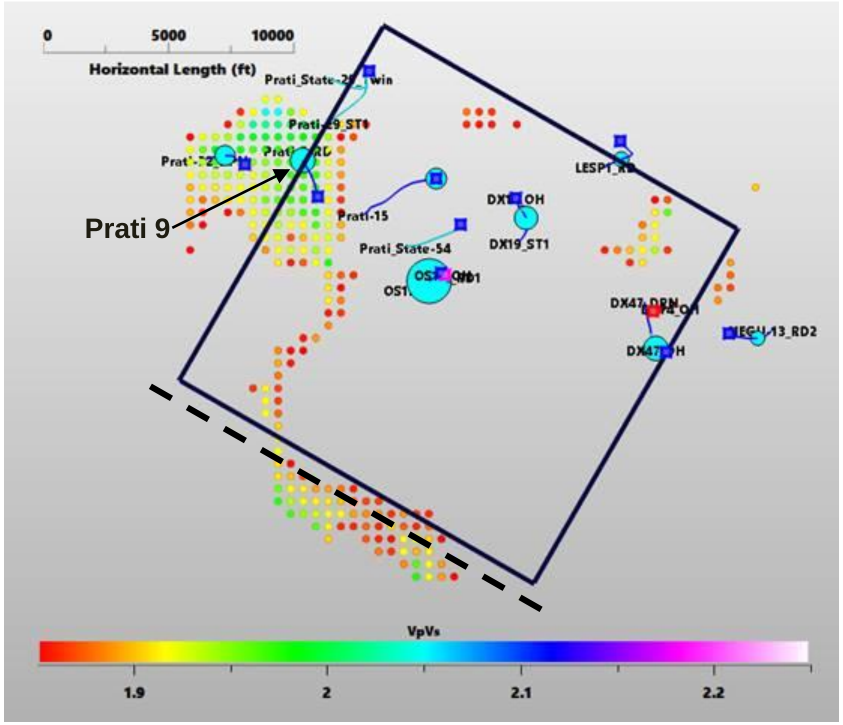


Correlation to 3D Reservoir Model

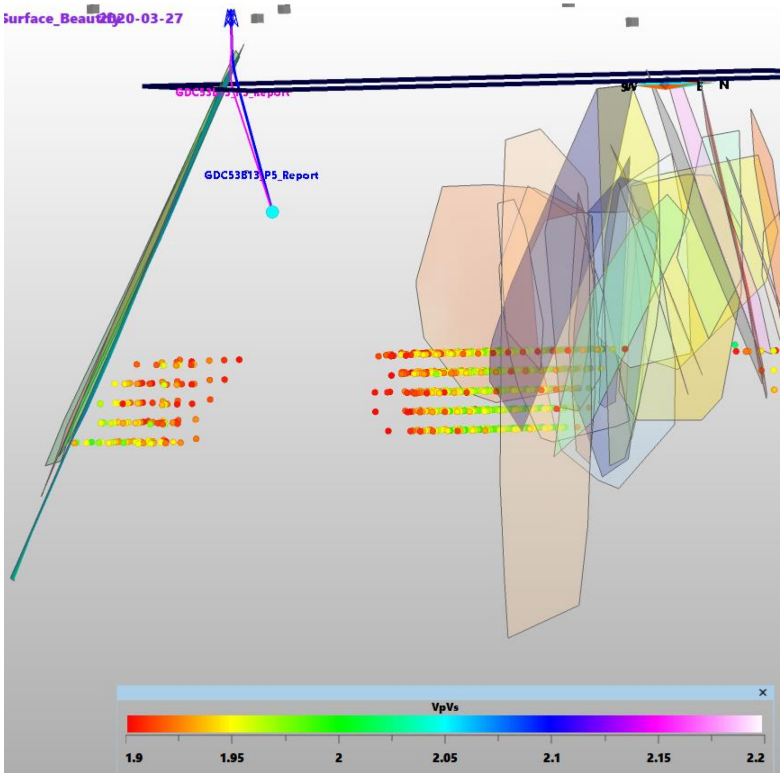
CALIFORNIA ENERGY COMMISSION | BERKELEY LAB | ARRAY applied innovation · driving mission success | JDS

Can we Image Fluid Pathways?

Map view of Vp/Vs-Ratio at 2440 m depth



Vertical cross section of Vp/Vs-Ratio View from SE

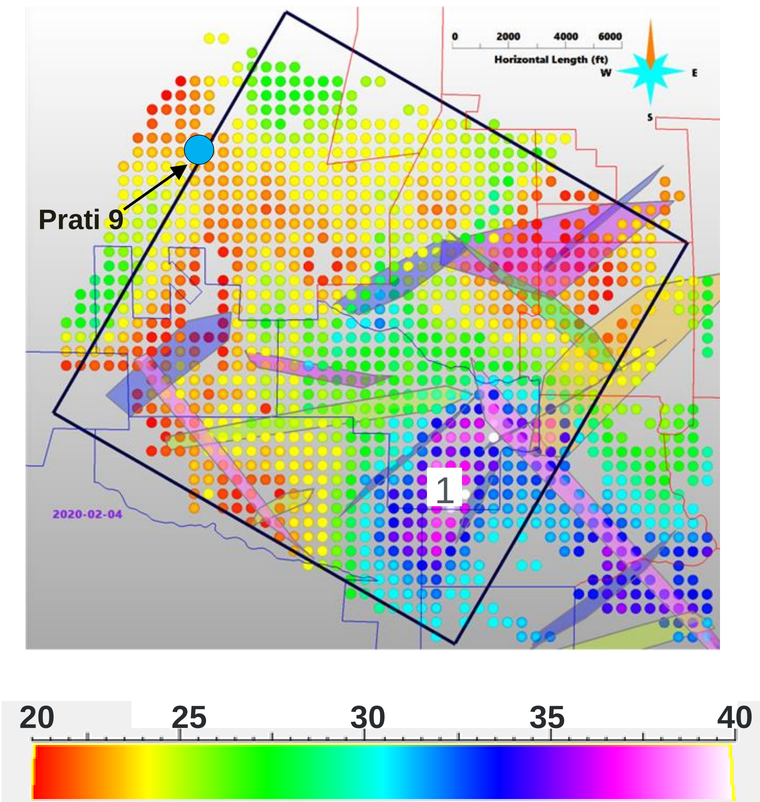


Correlation to 3D Reservoir Model

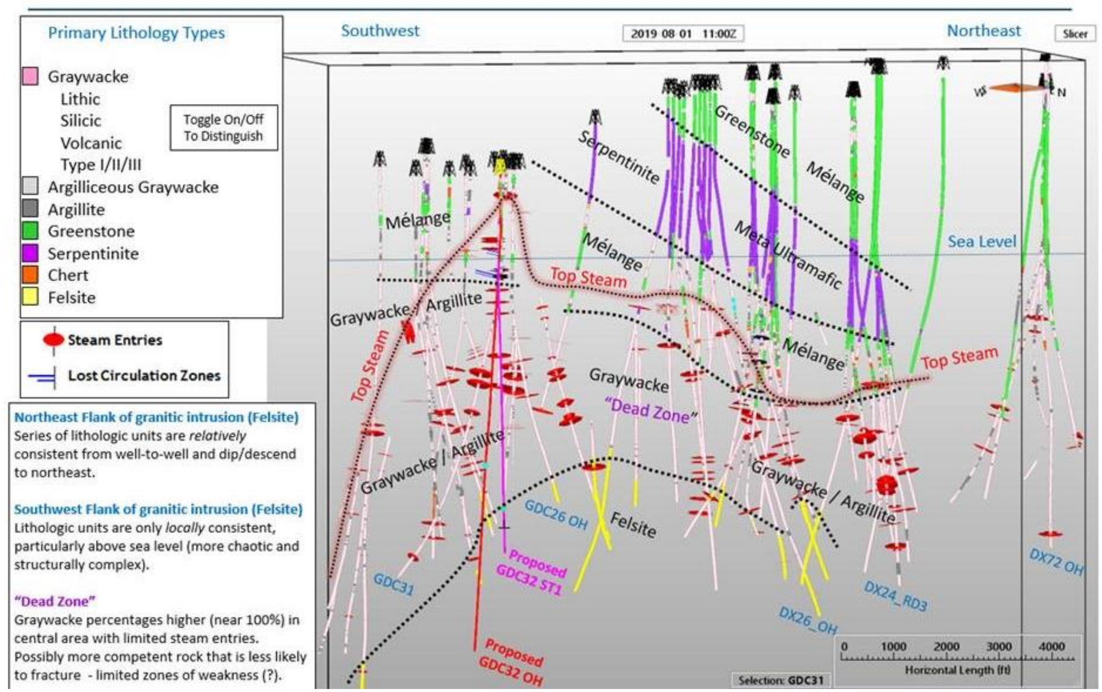
CALIFORNIA ENERGY COMMISSION | BERKELEY LAB | ARRAY | JDS

Imaging Rock Properties

Map view of Shear Modulus at 2440 m depth

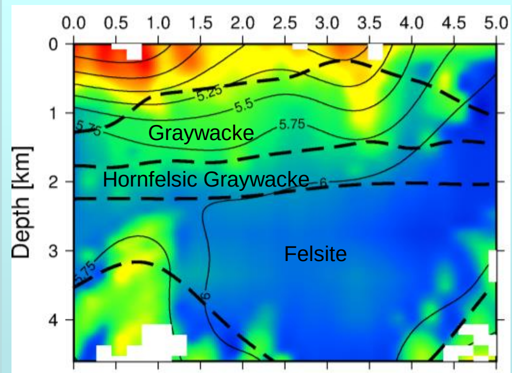


Steam Production Wells Cross Section SW to NE

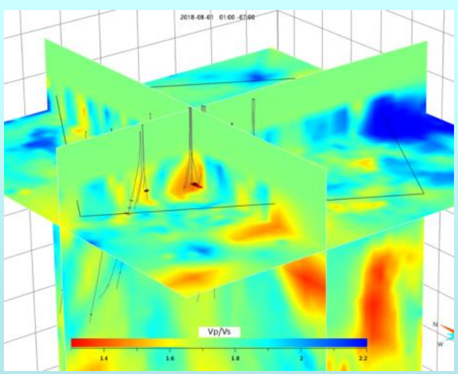


Conclusions High-Resolution Imaging

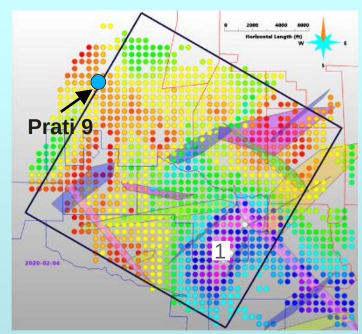
Availability of cost-effective sensors make operation of dense networks affordable



P- and S-wave velocities useful for imaging large-scale reservoir structure



Vp/Vs-ratio useful for interpretation of injection and production operations and to support drilling program of geothermal operators



Comparison to reservoir model provides confidence in seismic results and allows borehole data to be interpolated between wells

Geysers Power Company, LLC Geysers Water Injection Goals

Improve Injection Distribution

- Expansion to northwest and away from communities
- **Additional injection wells**
- Shallow low-rate injectors (~150 gallons/minute)

Minimize Injection Rate Variations

- Individual wells and field-wide
- Emphasis on limited variation for wells nearest communities
- Designed any tests concerning injection rate variability far from communities
- More gradual transition of SRGRP water for injection
- Suitable injection rates per well continually evaluated (dependent on local geology)

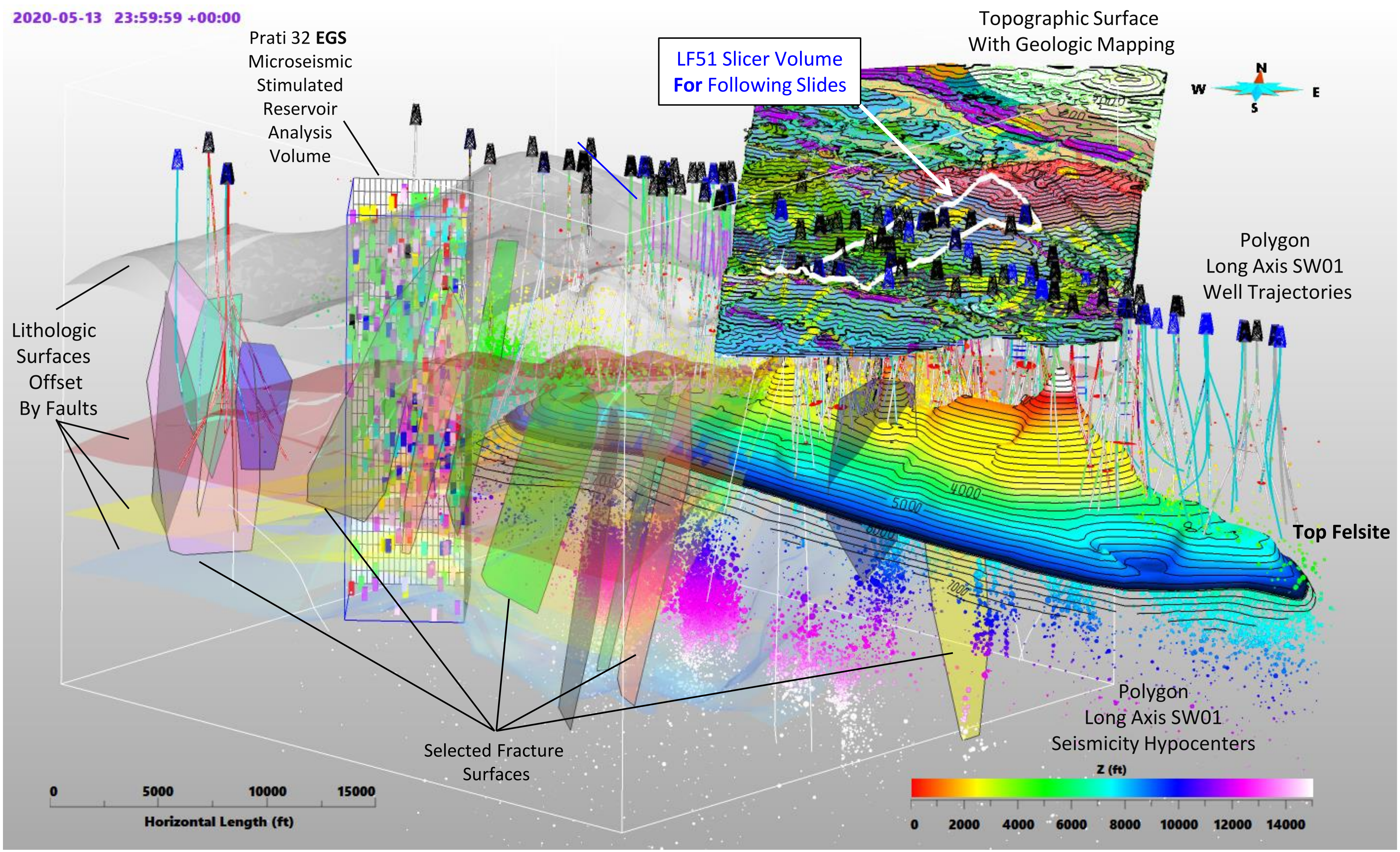
A broadly distributed and uniform "rainfall" of water throughout the reservoir volume would be preferred solution for seismicity mitigation and reservoir mass recharge.

The remaining slides provide images from recent well planning, drilling and seismicity monitoring for the following water injection wells:

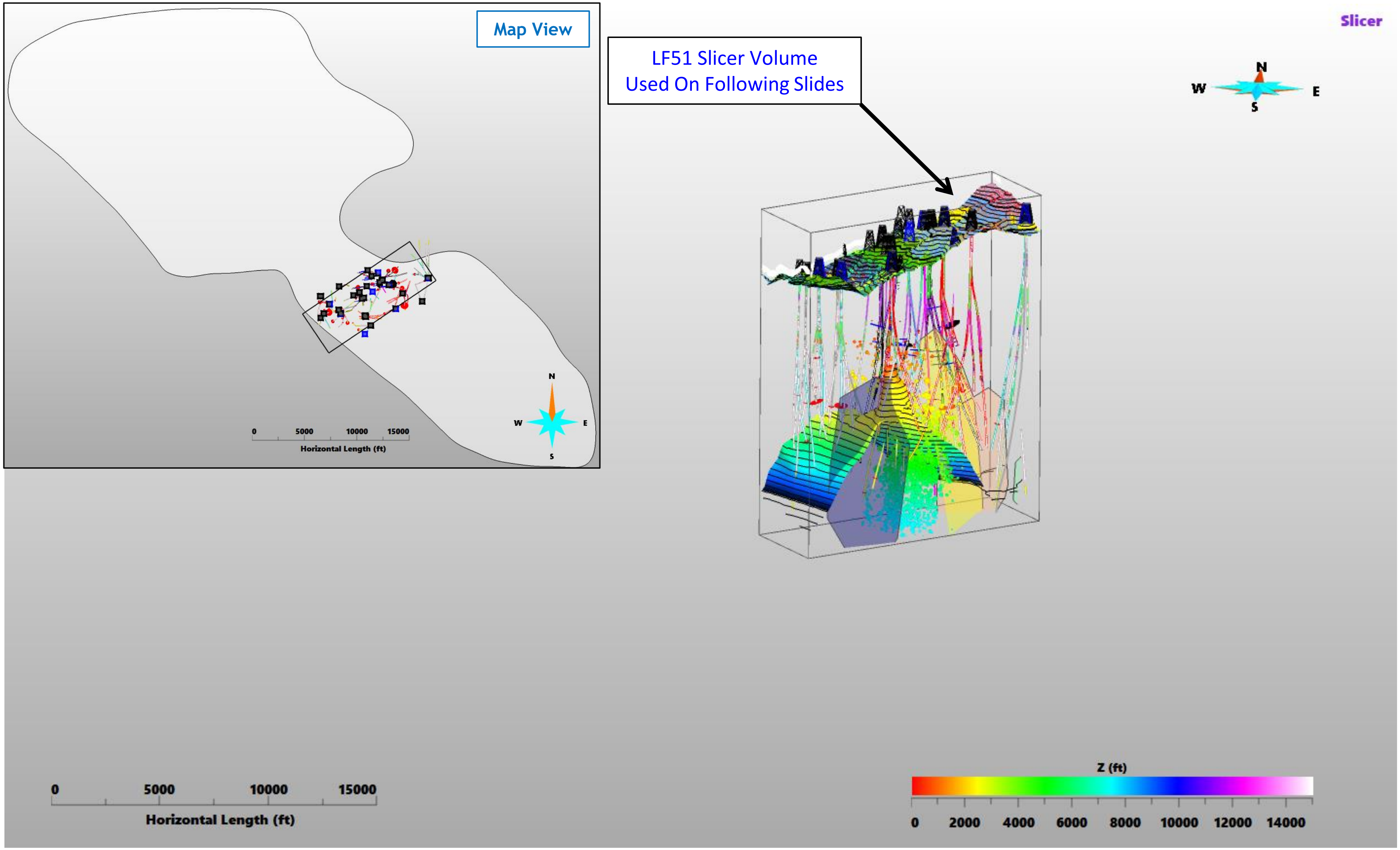
LF-51
74F-21
GDC-34
Prati-15

Fieldwide Structural Model and LF51 Water Injection Well Slicer Volume Location

Oblique View From South

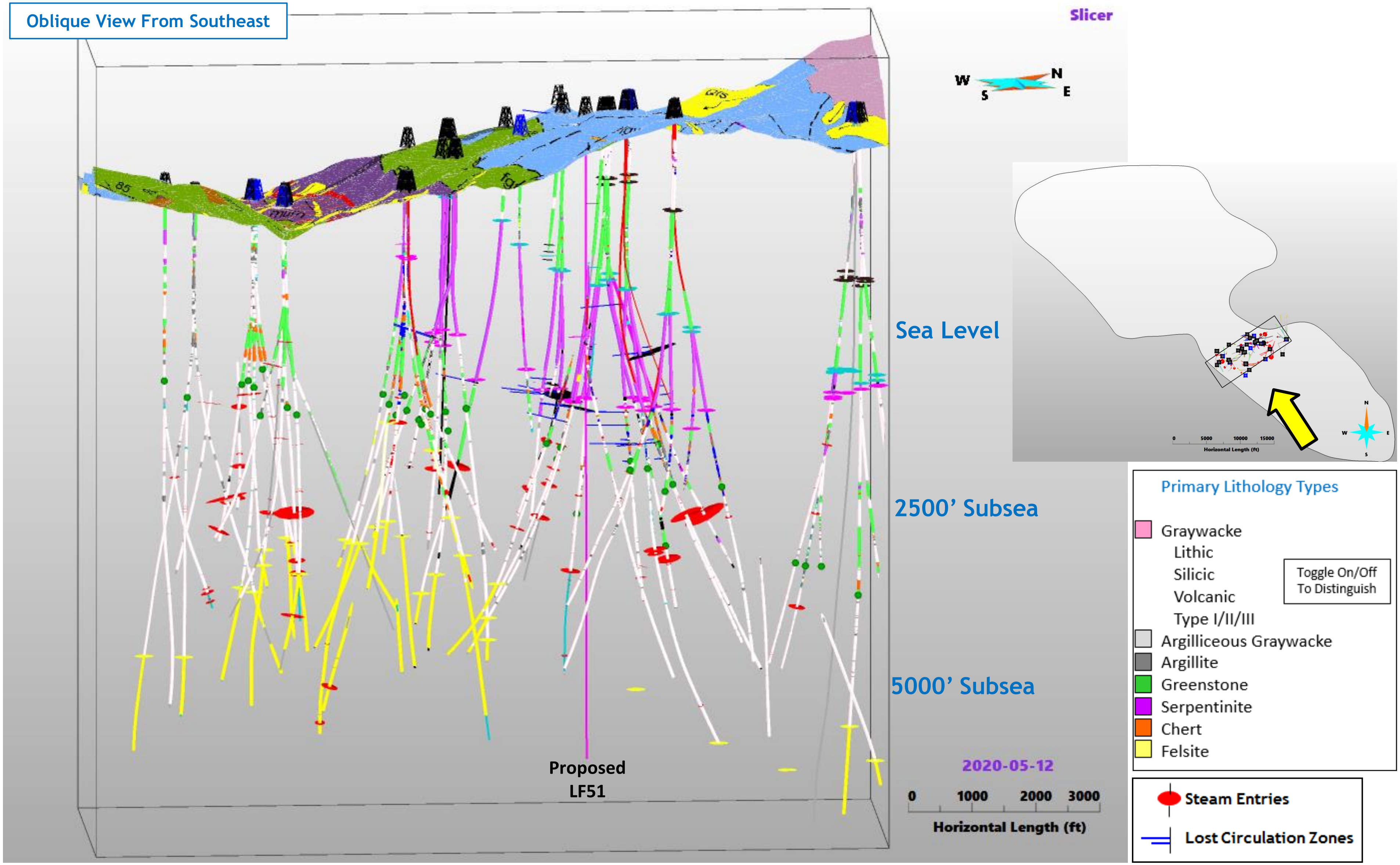


Fieldwide Structural Model and LF51 Water Injection Well Slicer Volume Location



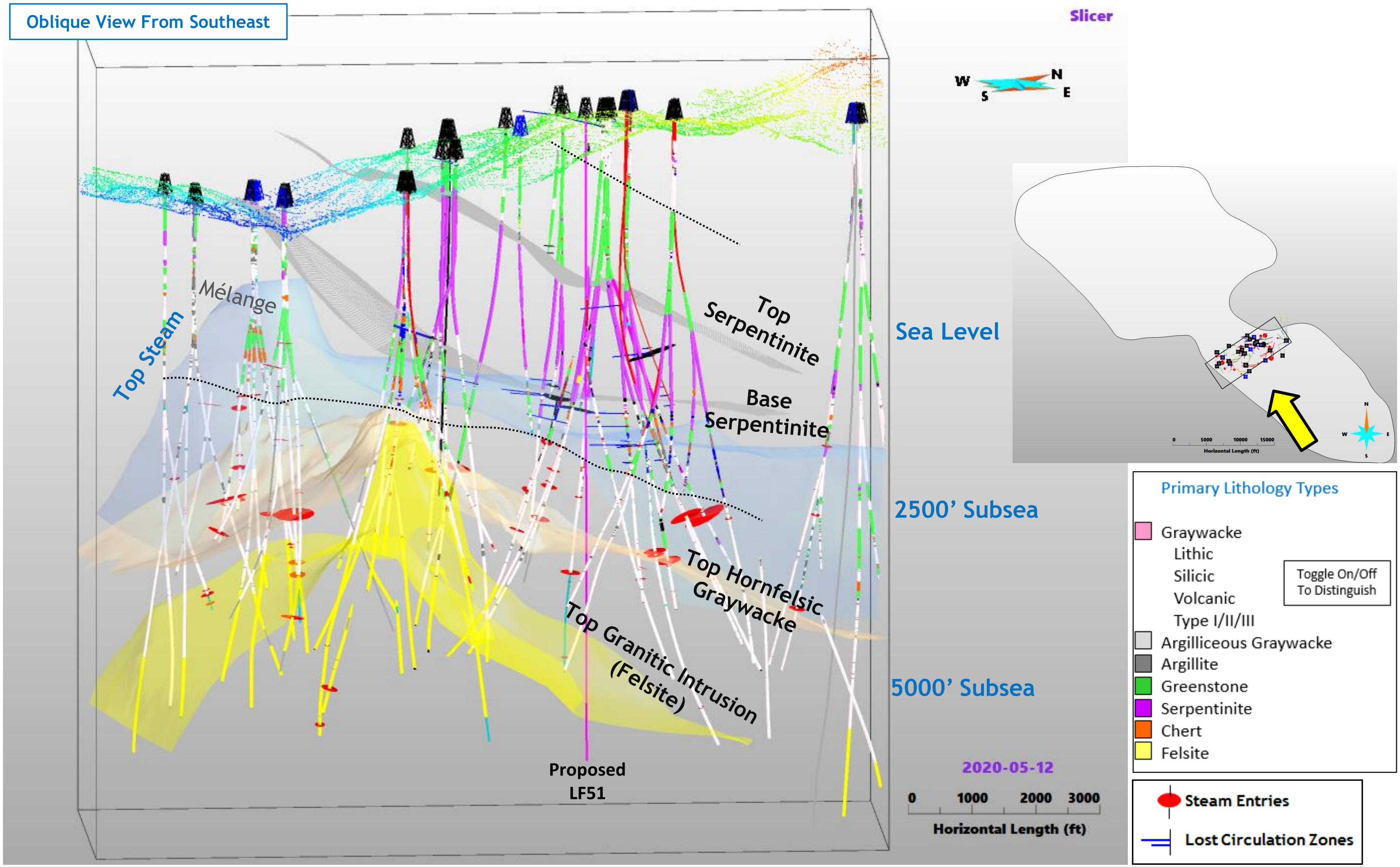
Seismic Monitoring Advisory Committee Meeting

LF51 Water Injection Well Proposed Trajectory Within Geological Cross Section



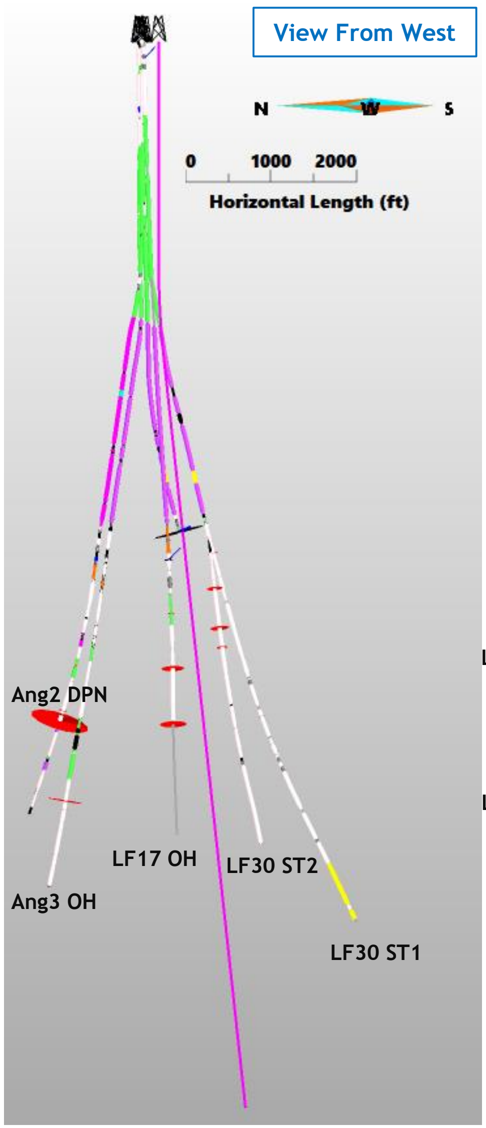
Seismic Monitoring Advisory Committee Meeting

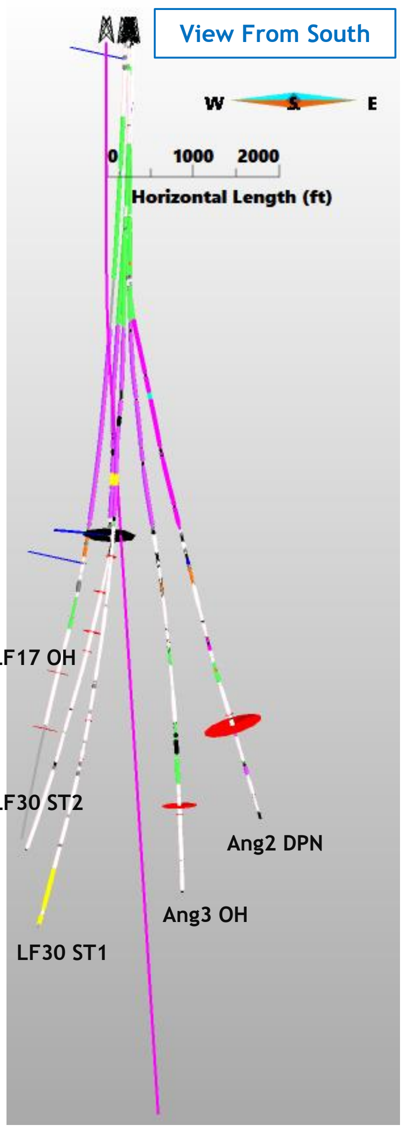
LF51 Water Injection Well Proposed Trajectory Within Geological Cross Section



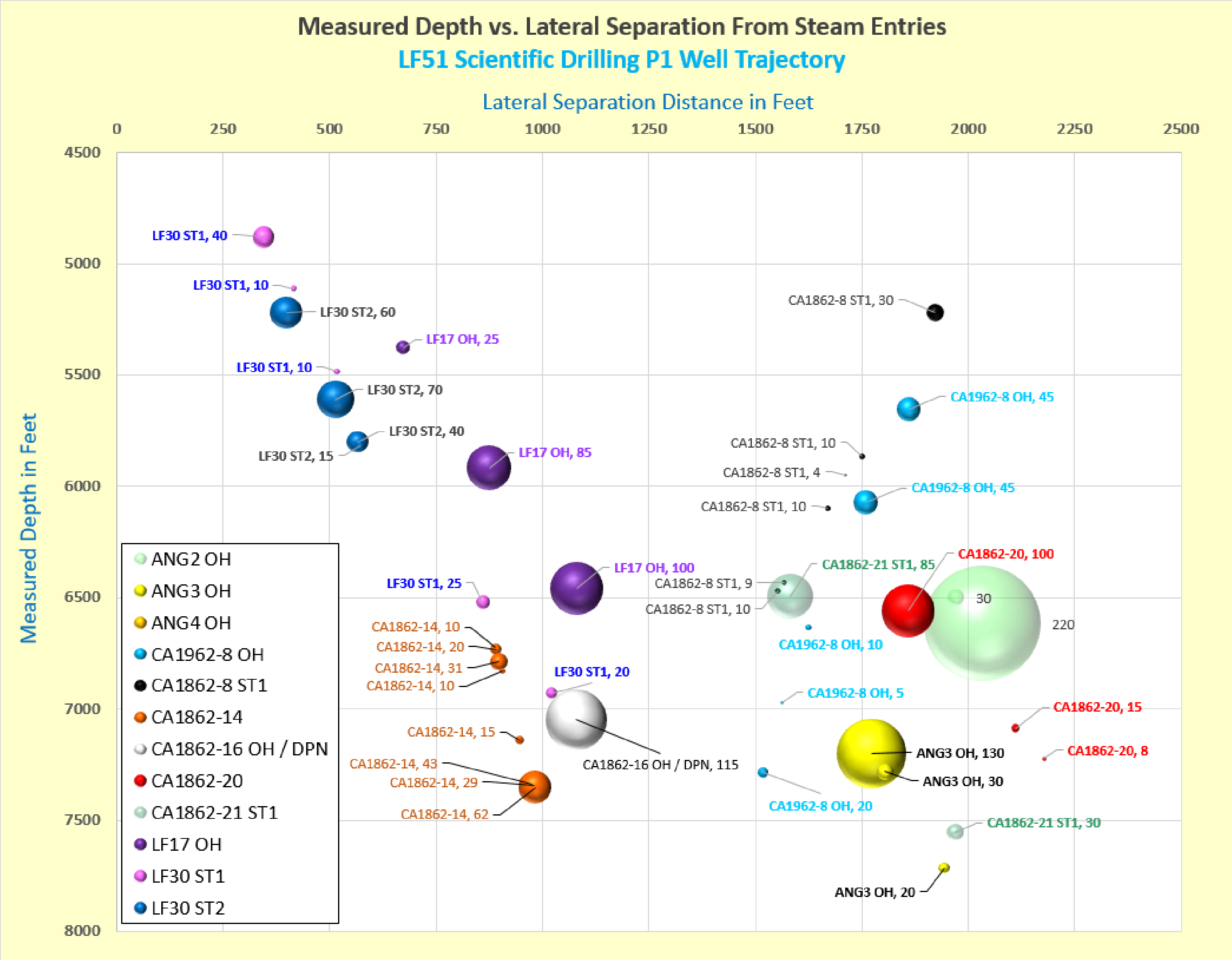
LF51 Water Injection Well Estimated Depths To Lithological Transitions and Top Steam Reservoir

Proposed LF51 Water injection Well		
Intersection	Measured Depth	TVDSS
Kelly Bushing	0	-3434
Surface	32	-3402
Graywacke / Argillite (Top)	32	-3402
Graywacke / Argillite (Base)	659	-2775
Greenstone Complex (Top)	659	-2775
Greenstone Complex (Base)	2667	-767
Serpentinite (Top)	2667	-767
Serpentinite (Base)	4425	969
Greenstone / Graywacke / Chert Melange (Top)	4425	969
Top Steam Reservoir	**4976**	**1513**
Greenstone / Graywacke / Chert Melange (Base)	5339	1872
Main Graywacke / Argillite (Top)	5339	1872
Main Graywacke / Argillite (Base)	6725	3241
Hornfelsic Graywacke (Top)	6725	3241
Hornfelsic Graywacke (Base)	9129	5615
Felsite (Top)	9129	5615

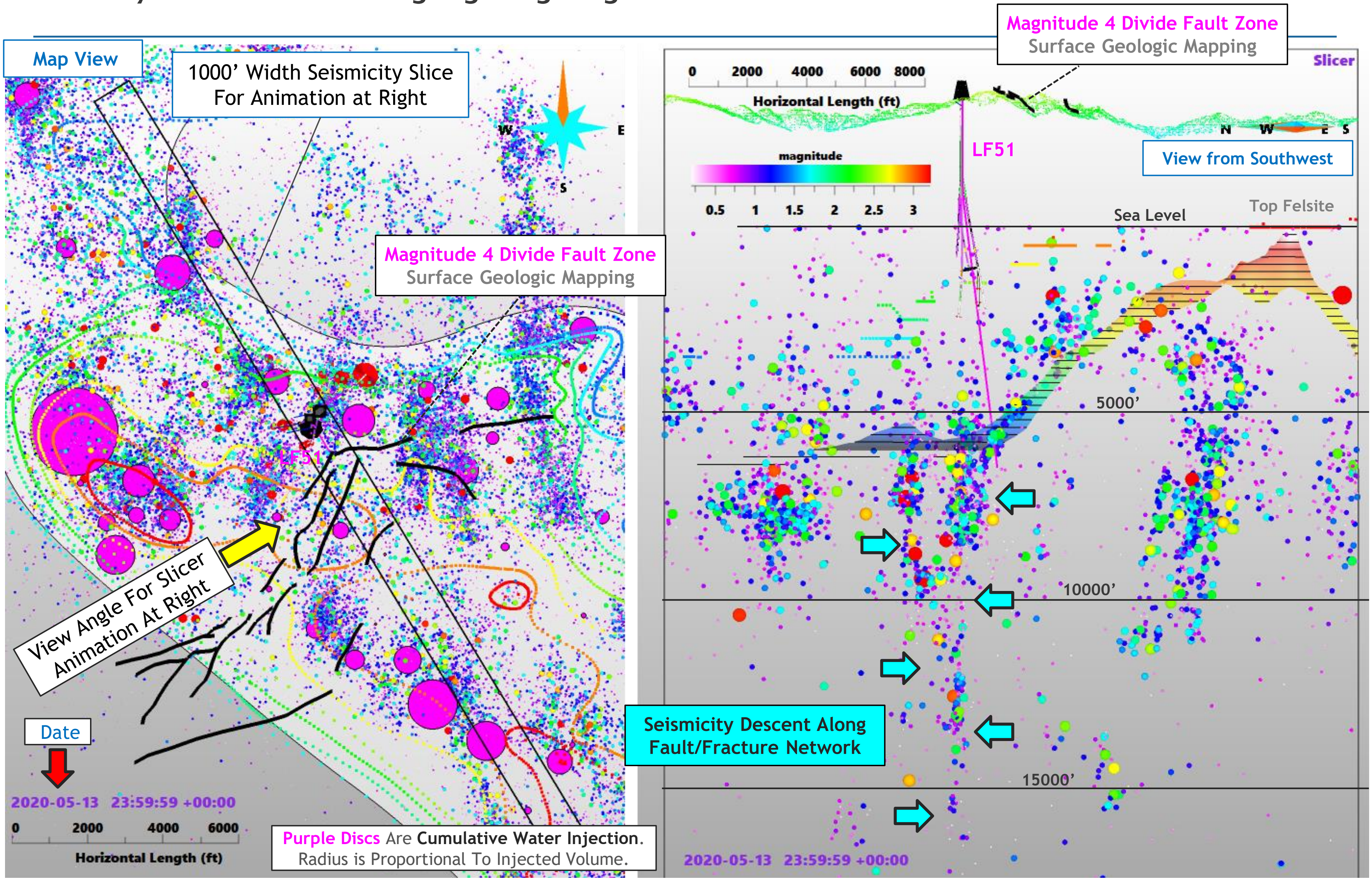




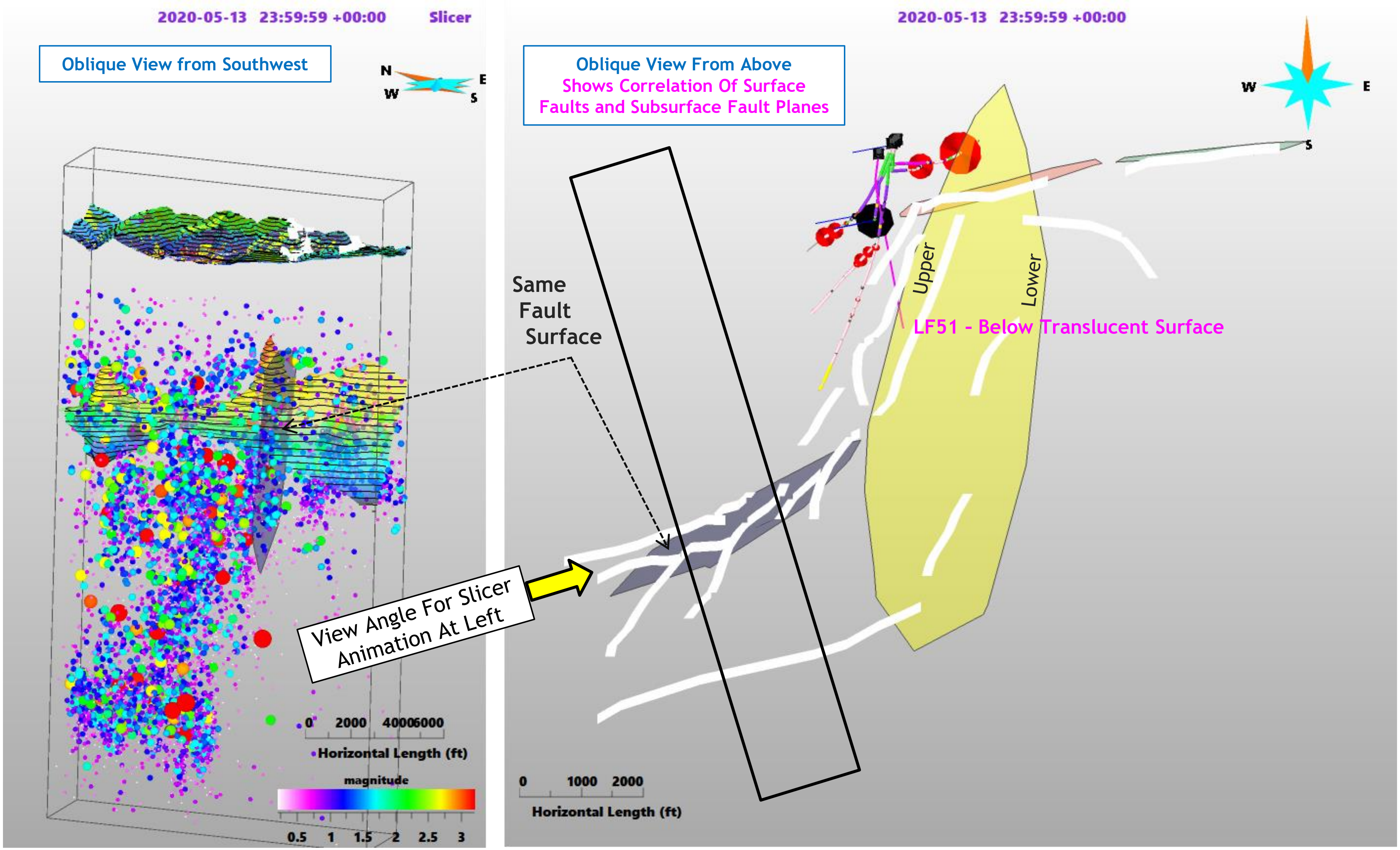
LF51 Proposed Water Injection Well Lateral Separation From Steam Entries



Seismic Monitoring Advisory Committee Meeting
LF51 Proposed Water Injection Well
Seismicity Slice Animation Highlighting Magnitude 4 Divide



Seismic Monitoring Advisory Committee Meeting
LF51 Proposed Water Injection Well
Magnitude 4 Divide Fault Zone; Correlation of Surface Fault Zones And Seismicity Slice Fracture Interpretation



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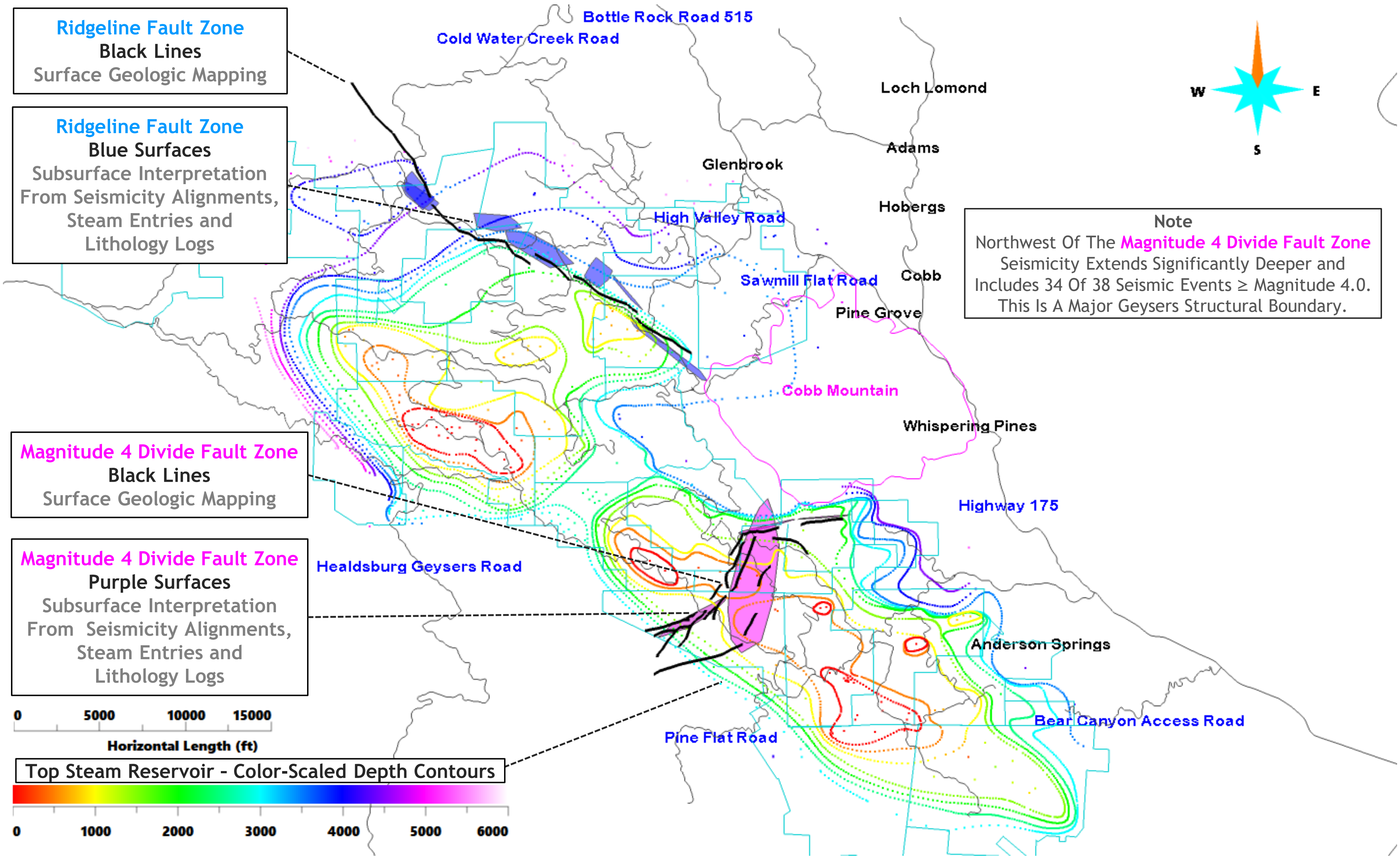
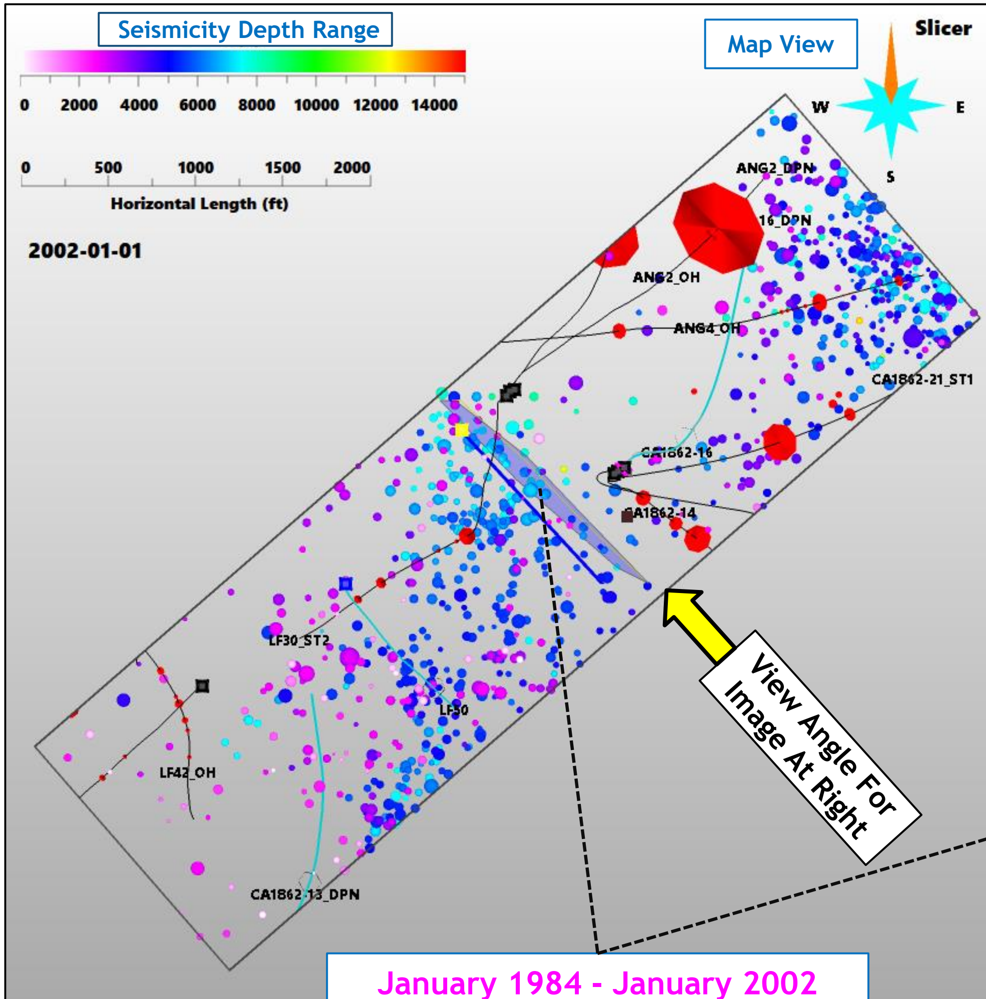
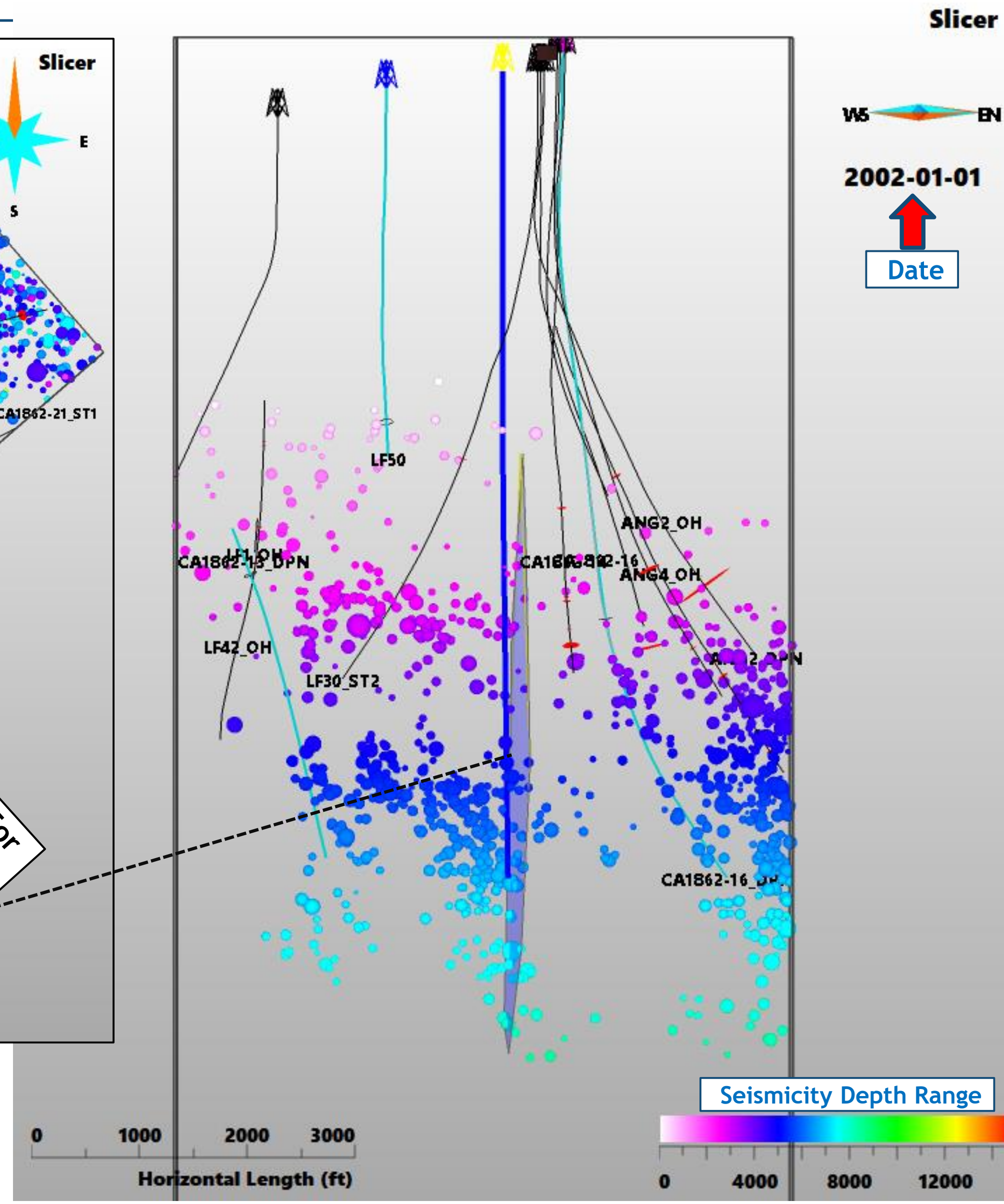
Correlation of Surface Fault Zones And Seismicity Slice Fracture Interpretation
Magnitude 4 Divide Fault Zone and Ridgeline Fault Zone



Seismic Monitoring Advisory Committee Meeting
LF51 Water Injection Well Water Injection and Induced Seismicity Animation

January 1984 - January 2002
Two Year Interval





January 1984 - January 2002
Seismicity Progression Related To Water Injection From South/Southwest Appears To Be Inhibited At Interpreted Surface.

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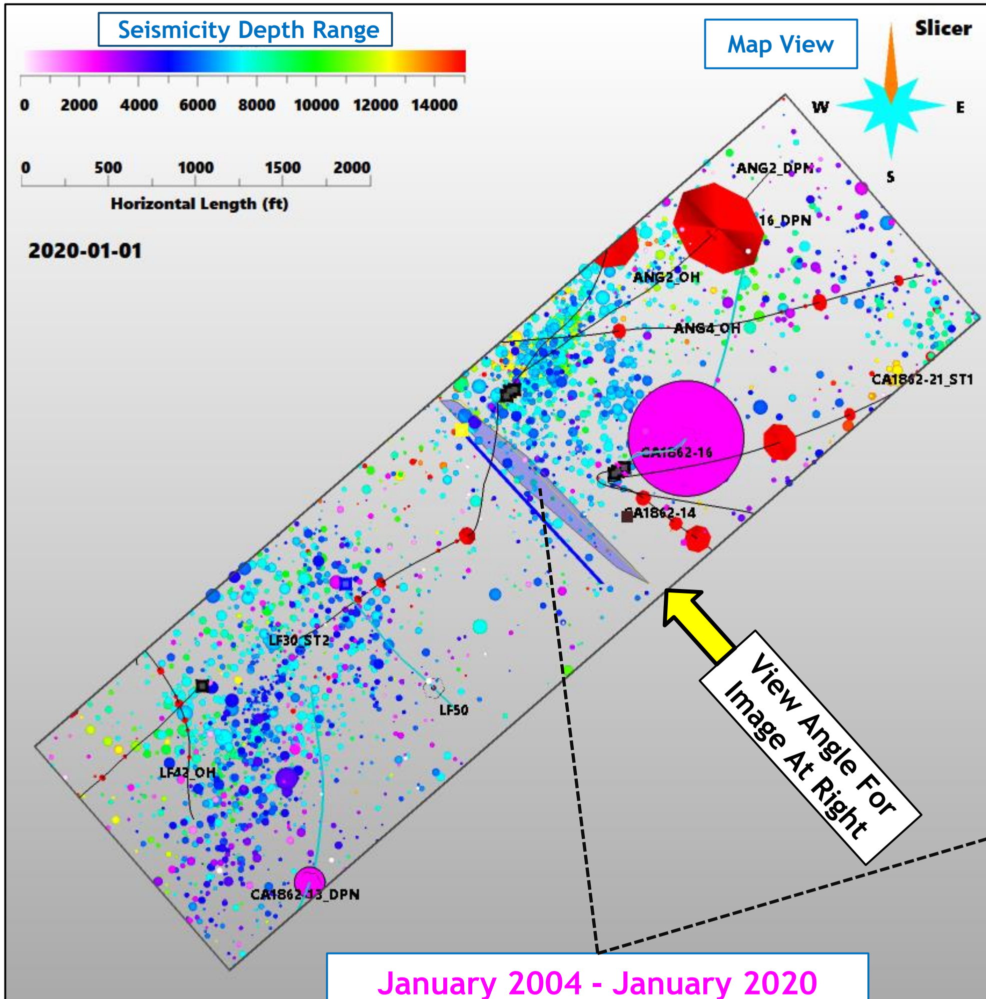
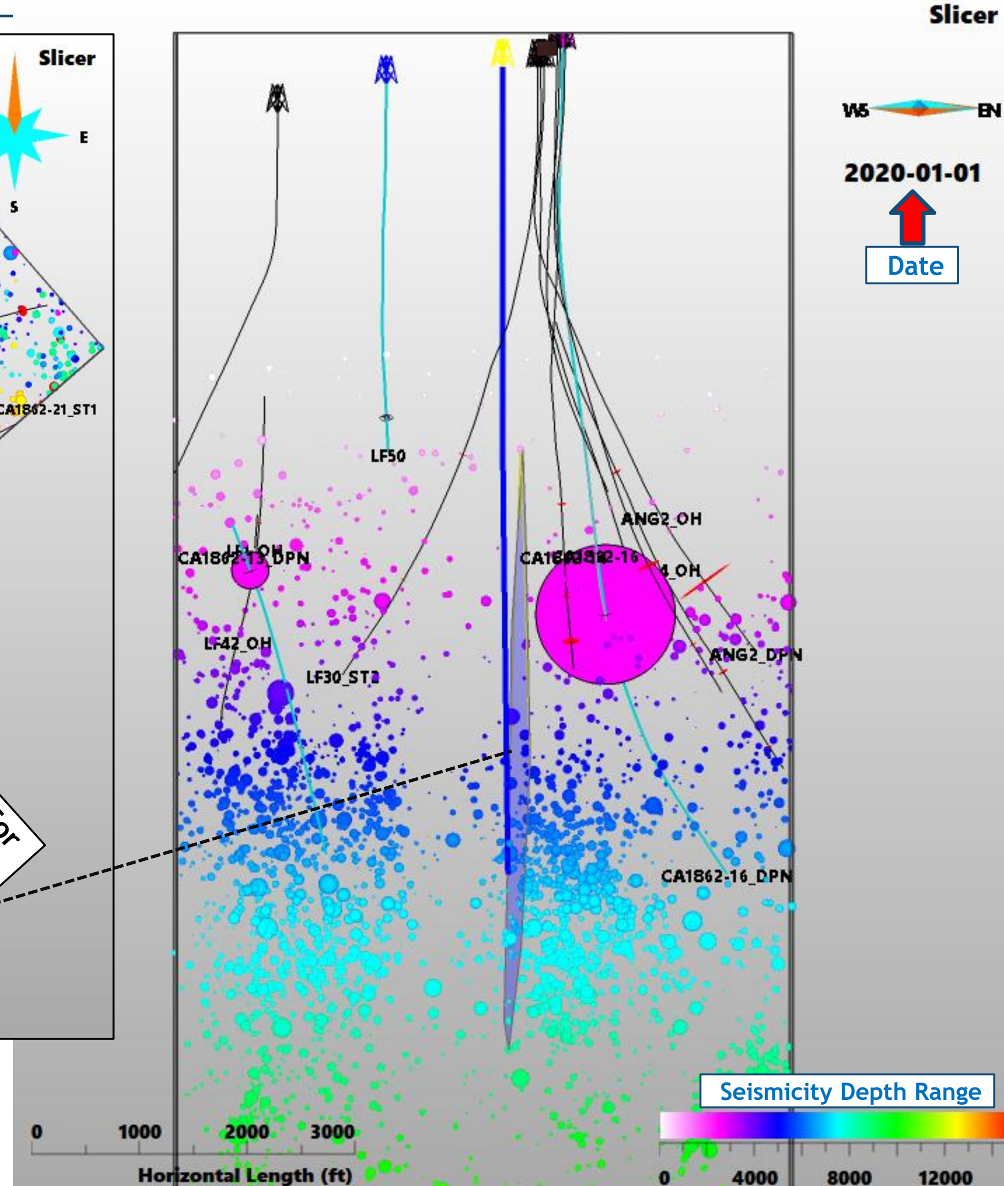
LF51 Water Injection Well Water Injection and Induced Seismicity Animation

January 2004 - January 2020
Two Year Interval



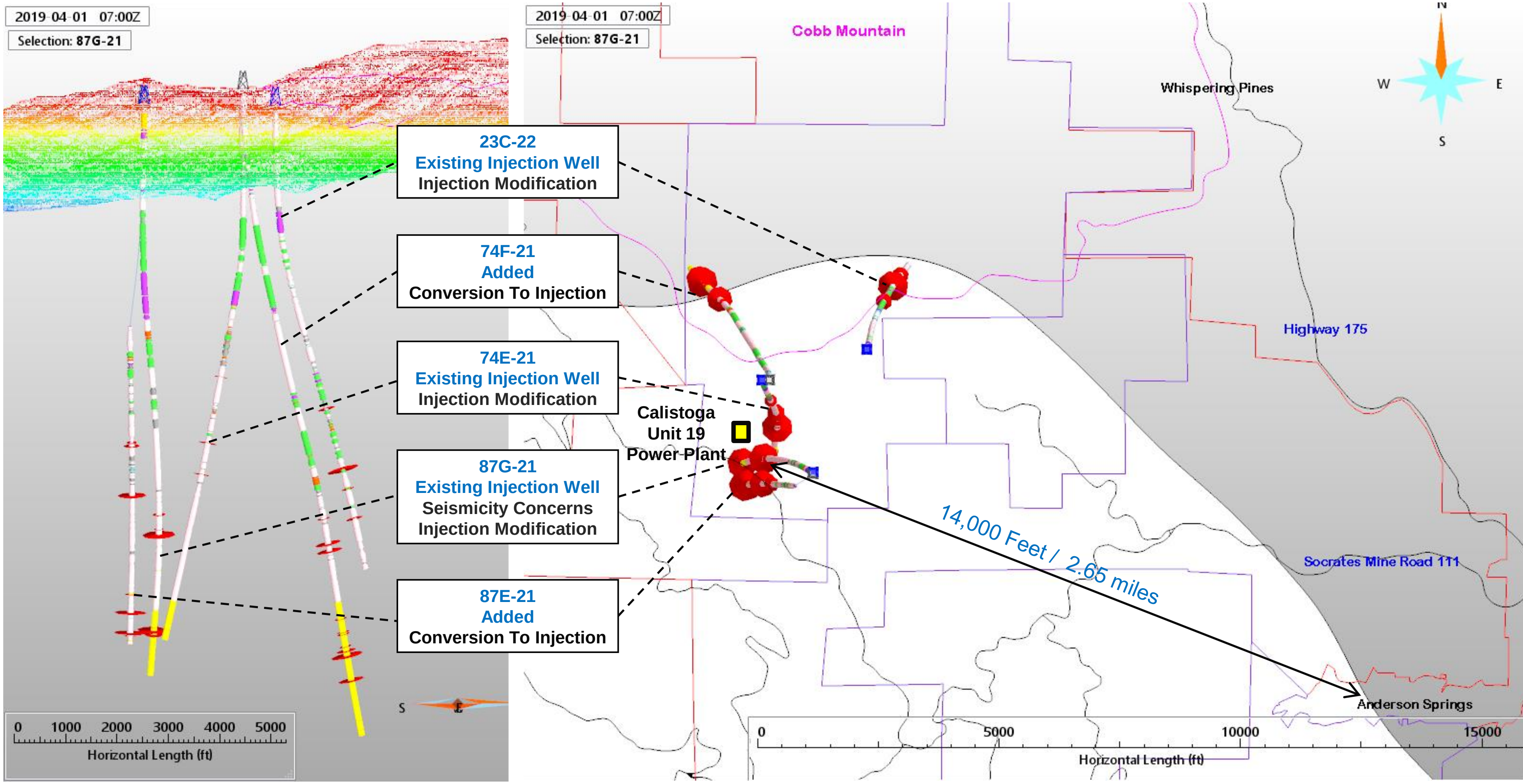


January 2004 - January 2020
Seismicity Progression Related To Water Injection From North/Northeast Appears To Be Inhibited At Interpreted Surface.

Seismic Monitoring Advisory Committee Meeting
Improved Water Distribution for Seismicity Mitigation
Conversion-To-Injection Drilling Program

Calistoga Power Plant Area

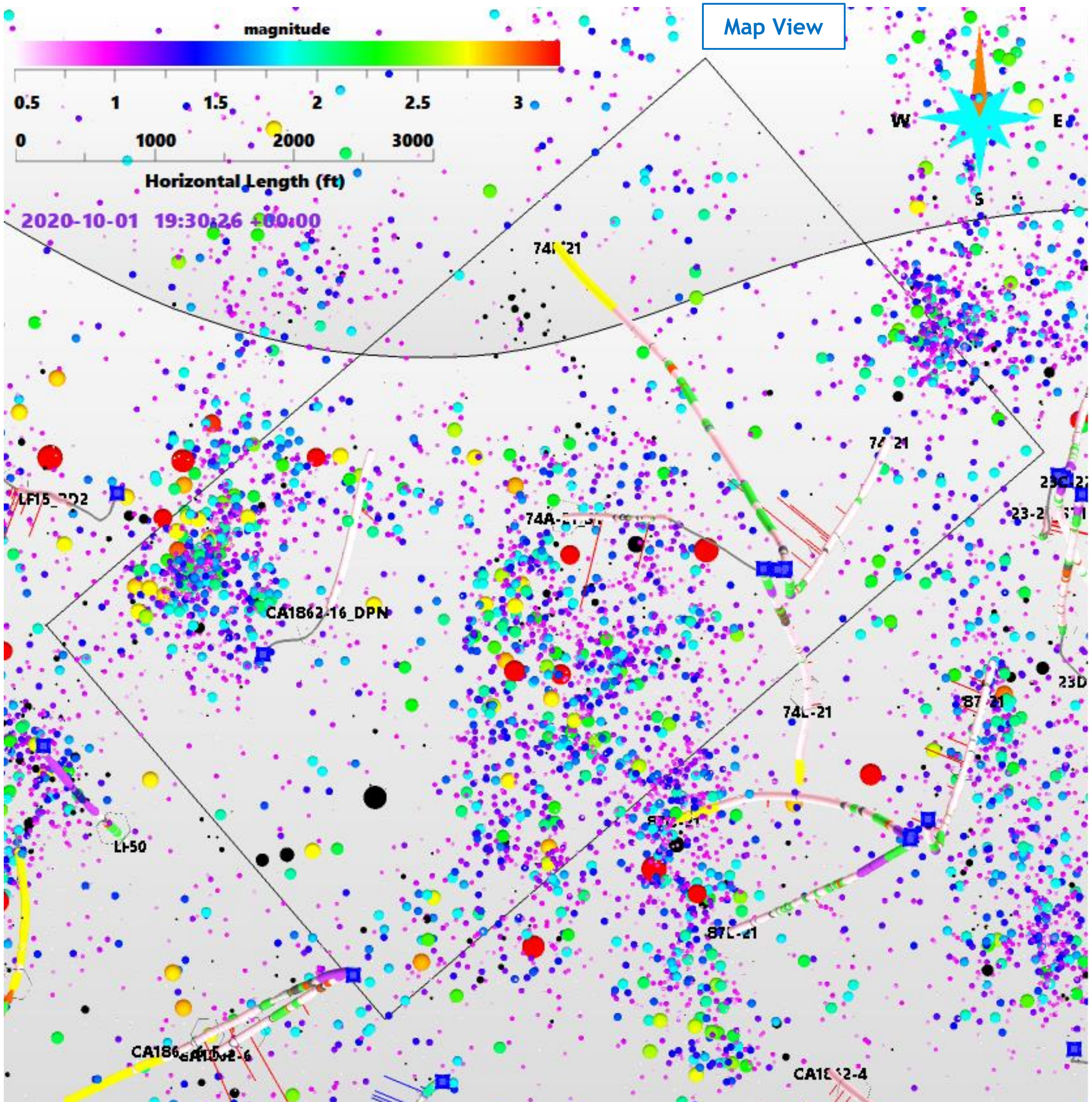
- 74F-21 October 2019 Conversion of Steam Production Well to Injection
- 87E-21 November 2019 Conversion of Steam Production Well to Injection
- 23C-22 Early 2020 Modification to Existing Water Injection
- 74E-21 Early 2020 Modification to Existing Water Injection
- 87G-21 Early 2020 Modification to Existing Water Injection

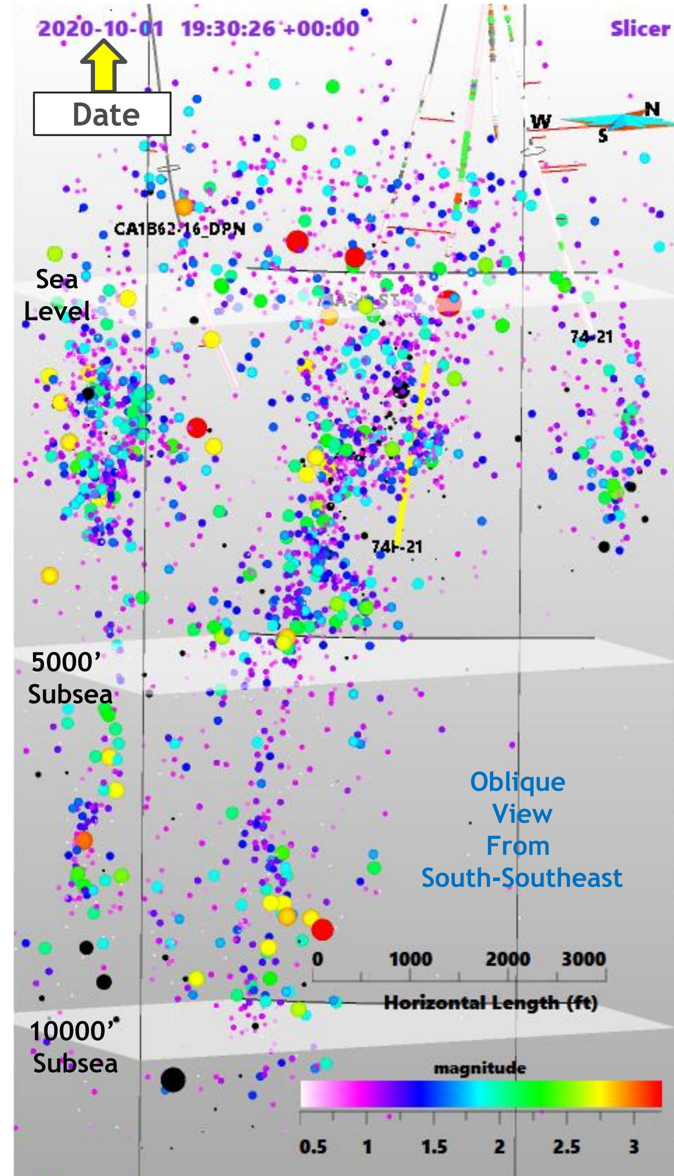


Seismic Monitoring Advisory Committee Meeting

74F-21 Water Injection Well And "Background" Induced Seismicity 01 January 2005 – 01 January 2020

01 January 2020 Through October 2020 Added As Black Symbols

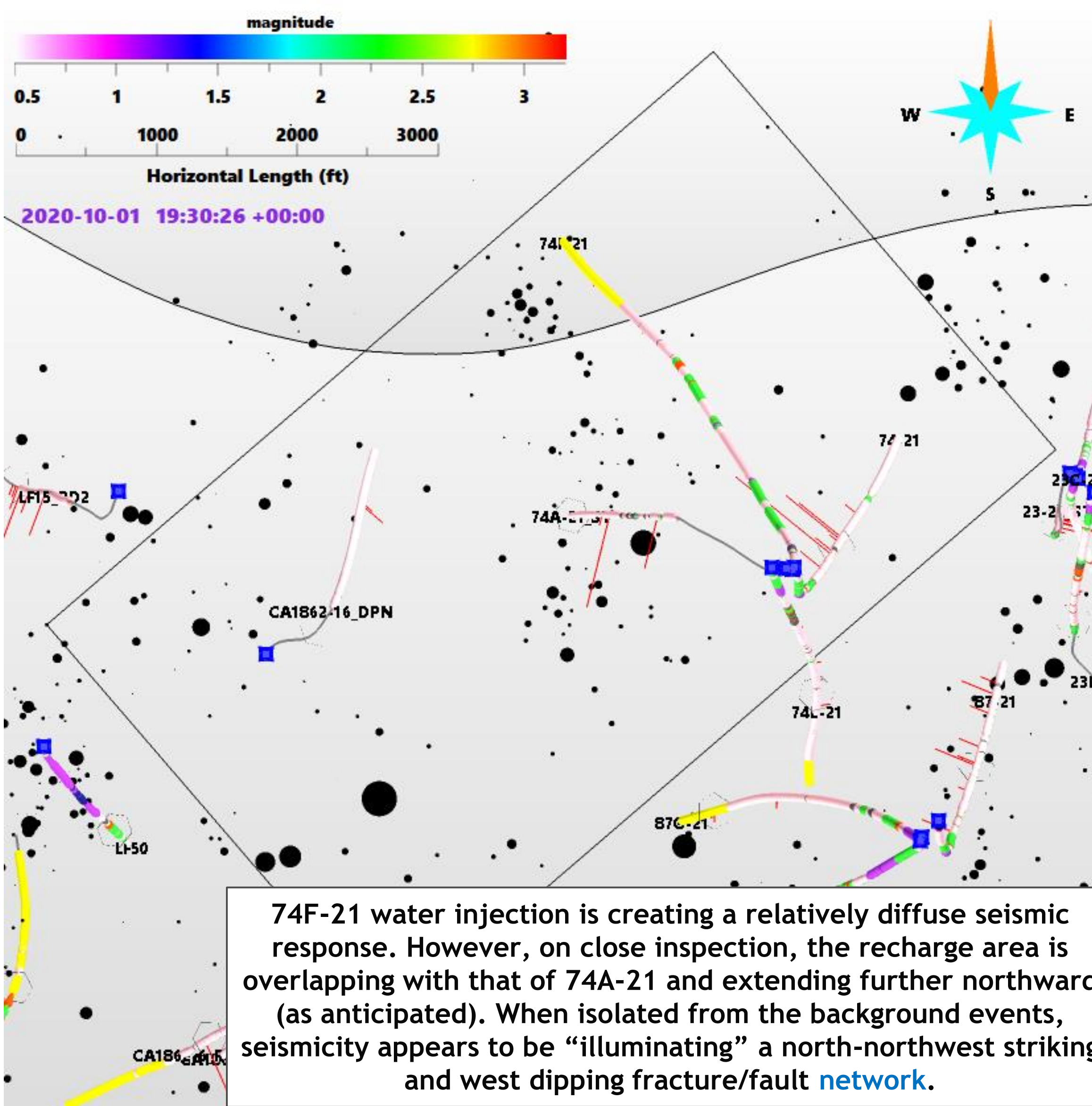




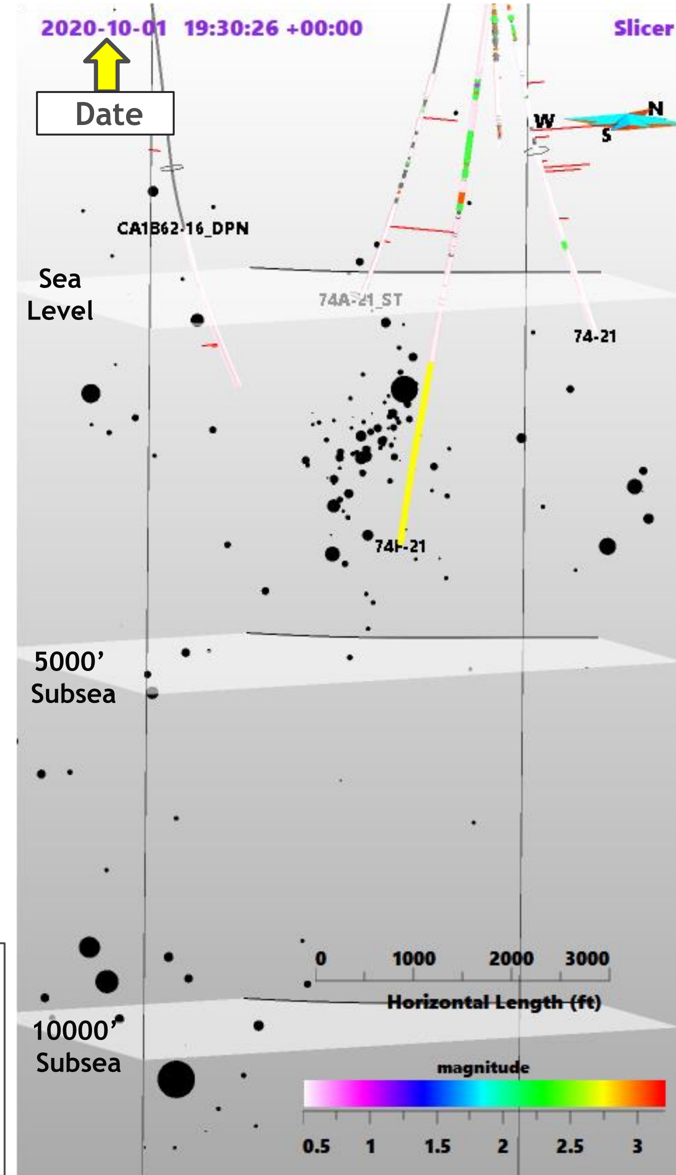
Seismic Monitoring Advisory Committee Meeting

74F-21 Water Injection Well Induced Seismicity 01 January 2020 Through 01 October 2020 ONLY As 2x Increased Radius Black Symbols

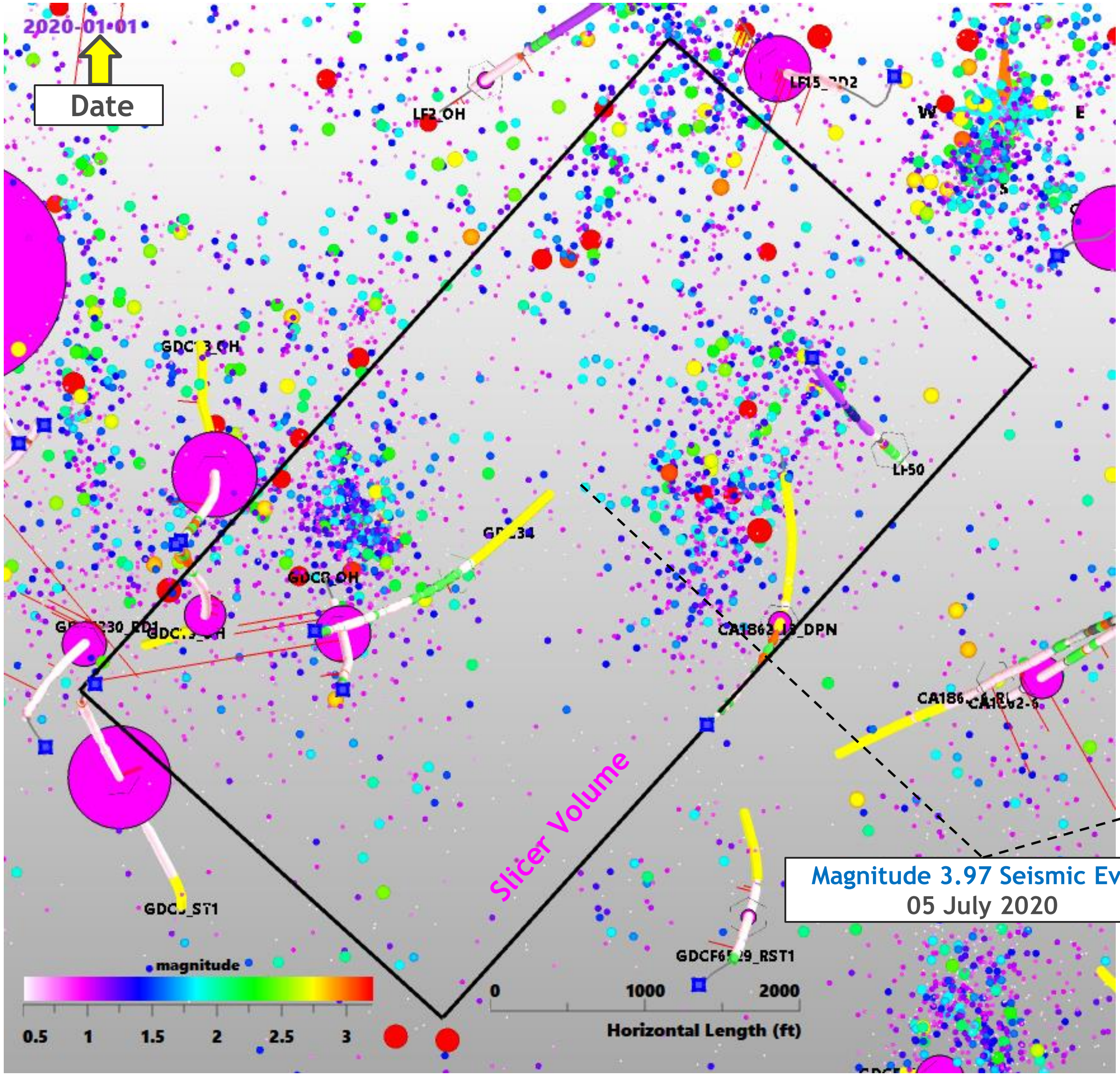
Oblique View From South-Southeast

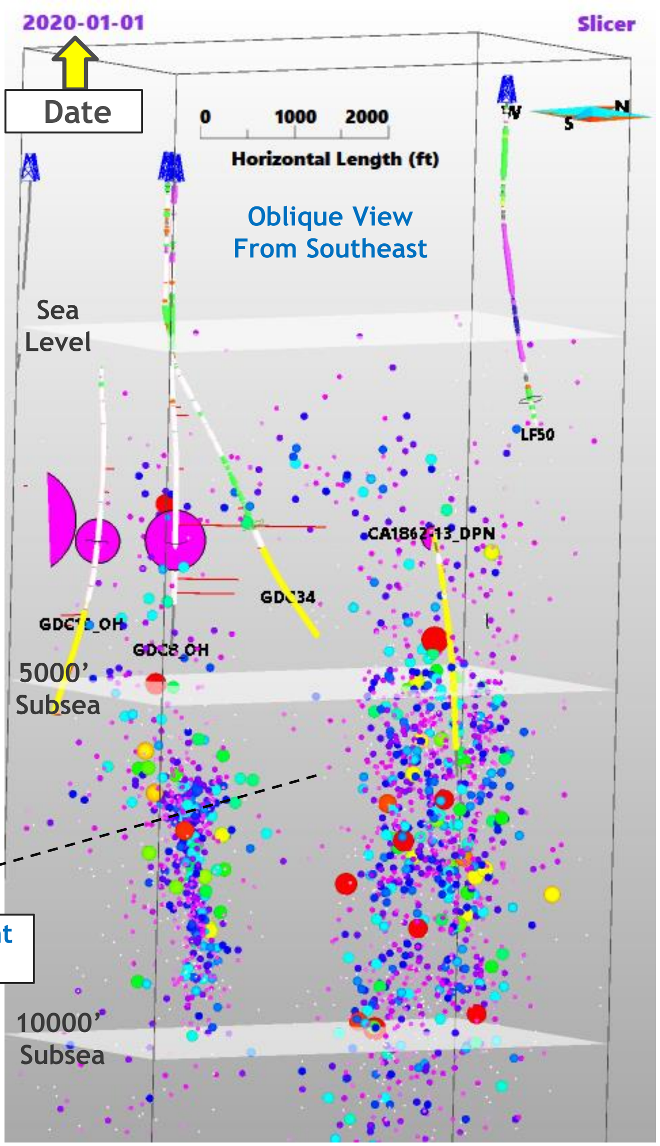


74F-21 water injection is creating a relatively diffuse seismic response. However, on close inspection, the recharge area is overlapping with that of 74A-21 and extending further northward (as anticipated). When isolated from the background events, seismicity appears to be "illuminating" a north-northwest striking and west dipping fracture/fault network.



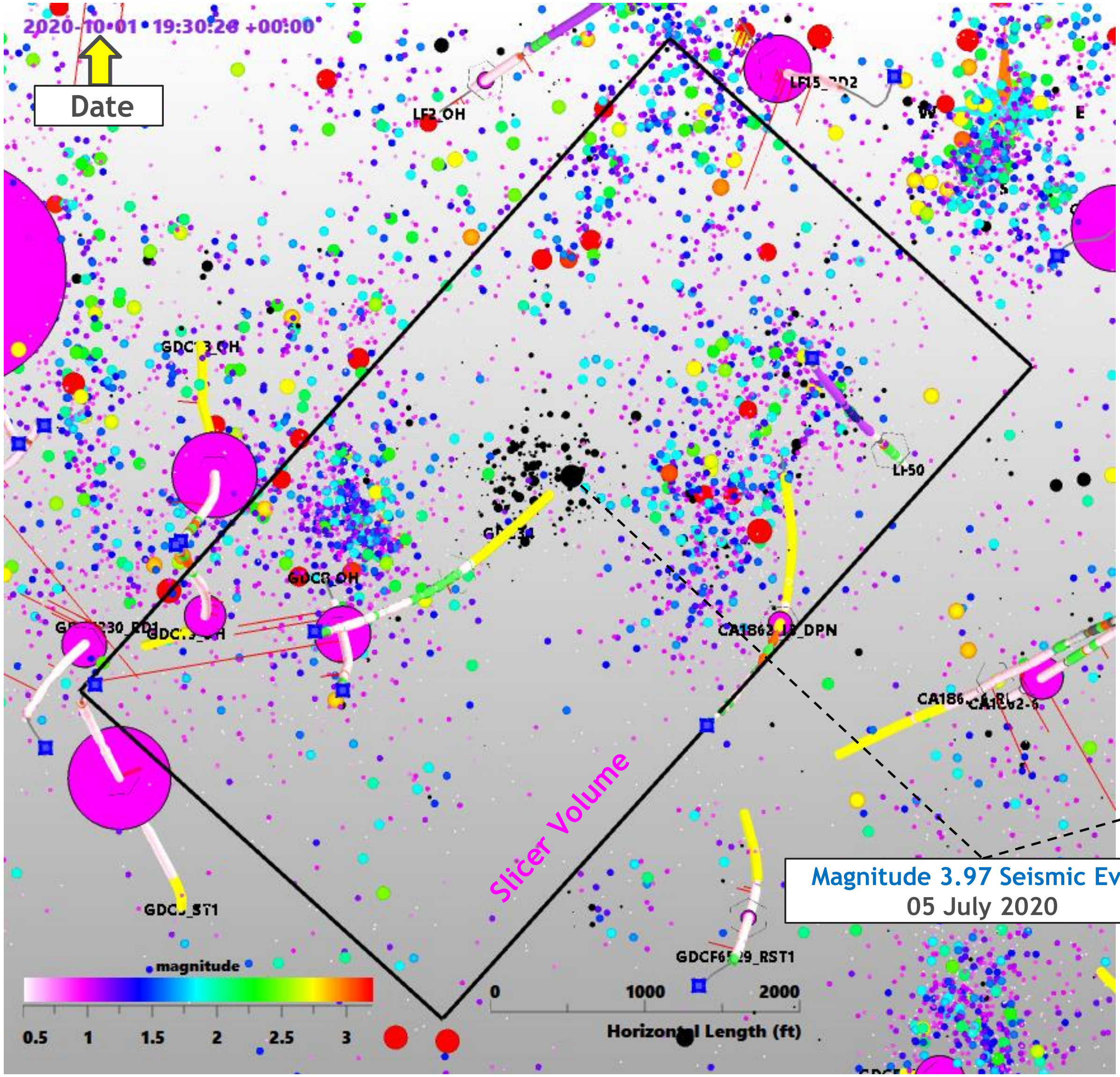
GDC34 Water Injection Well Induced And "Background" Seismicity 01 January 2005 – 01 January 2020

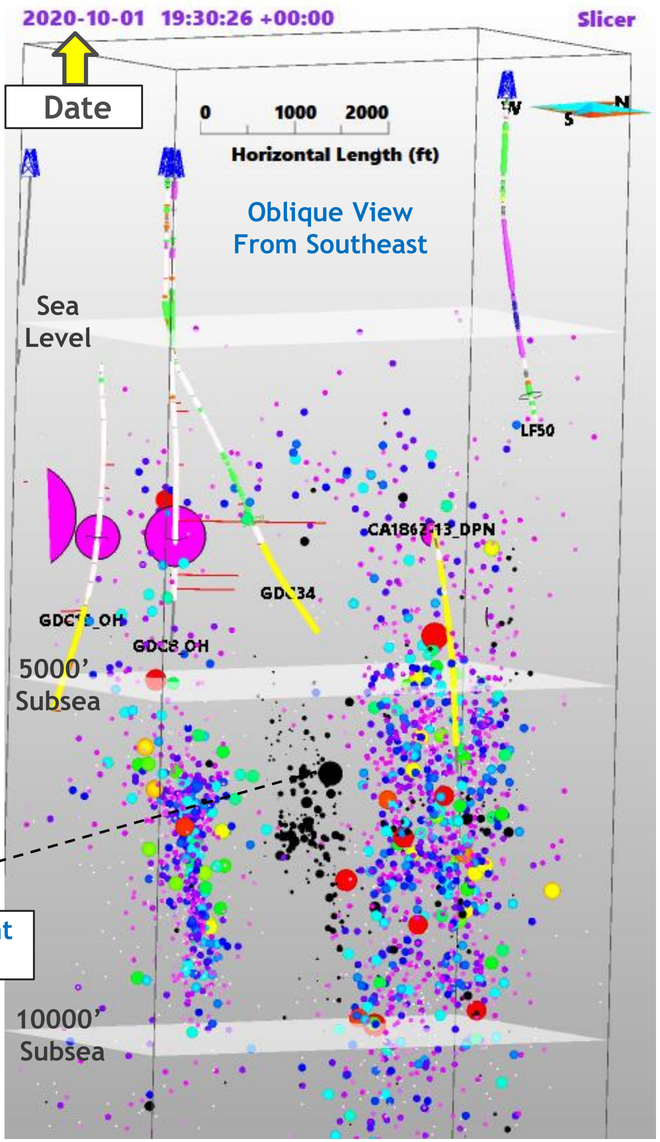




Magnitude 3.97 Seismic Event
05 July 2020

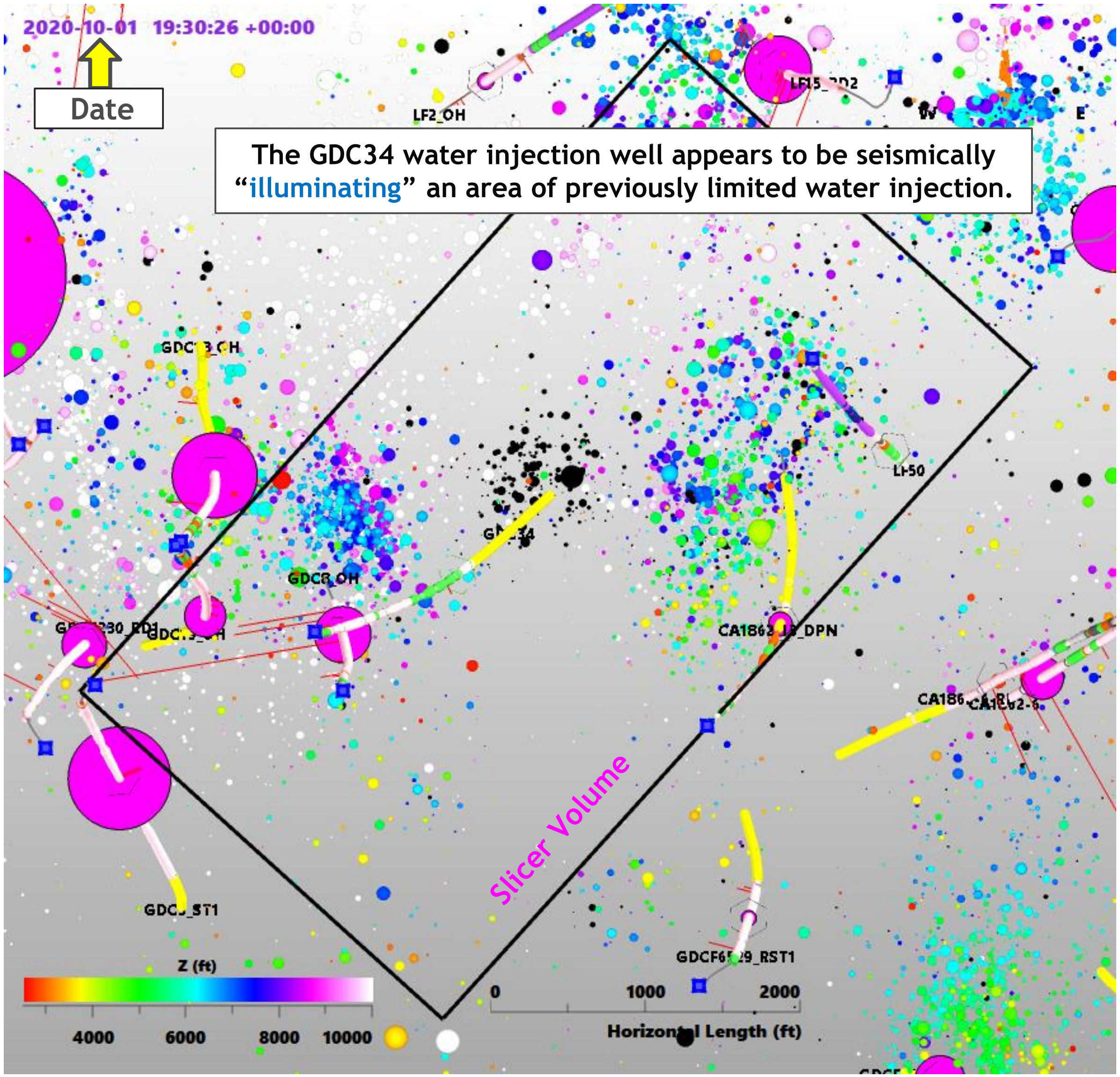
GDC34 Water Injection Well Induced And "Background" Seismicity 01 January 2005 – 01 January 2020 Through 01 October 2020 Added As Black Symbols

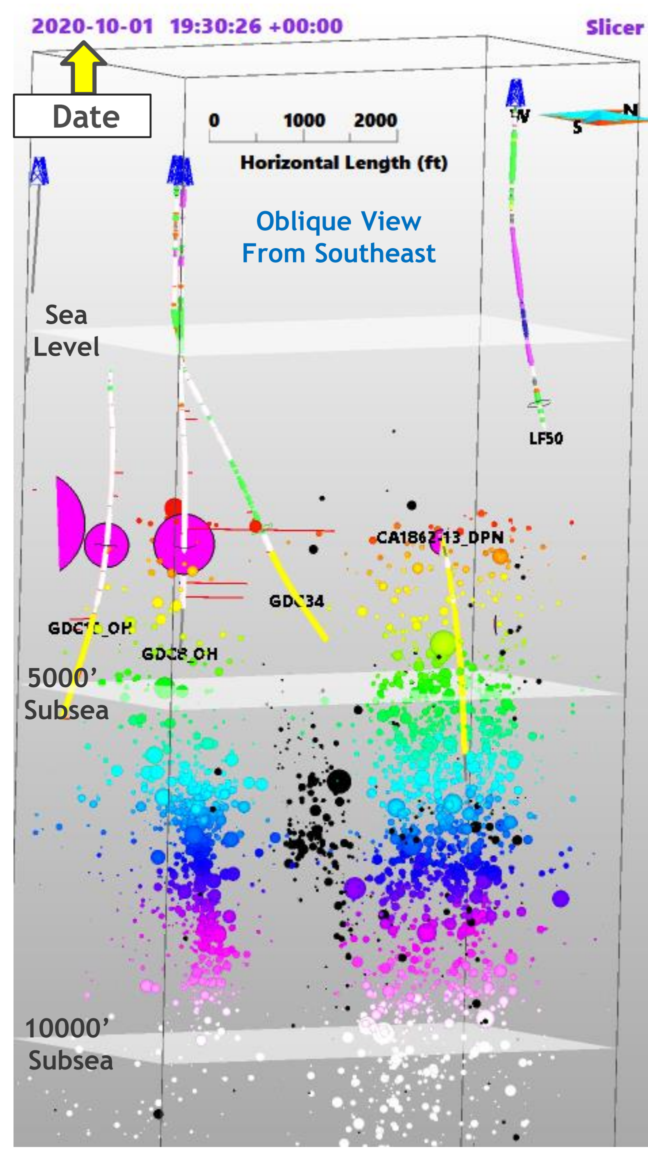




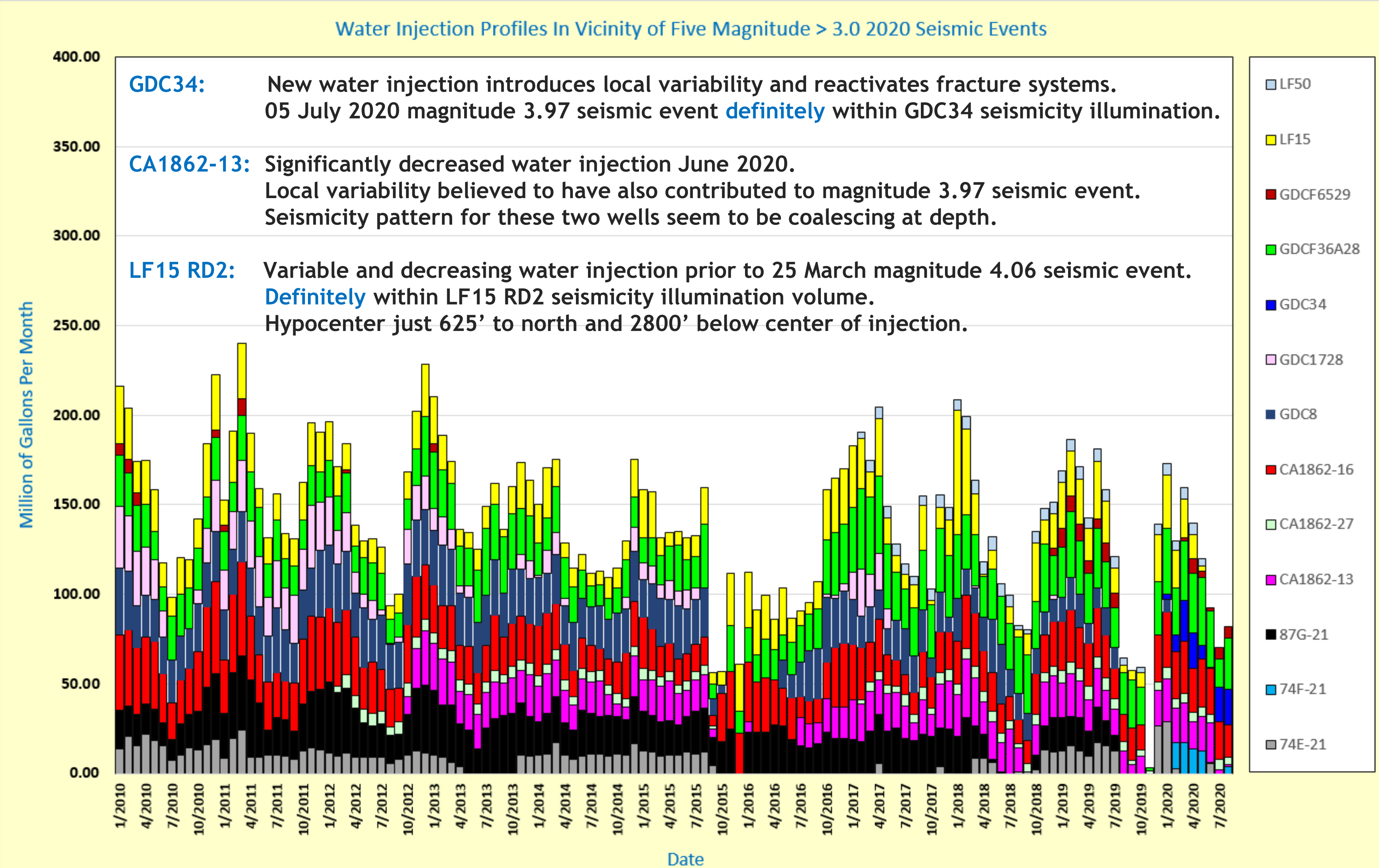
Seismic Monitoring Advisory Committee Meeting

GDC34 Water Injection Well Induced And "Background" Seismicity 01 January 2005 – 01 January 2020 Through 01 October 2020 Added As Black Symbols

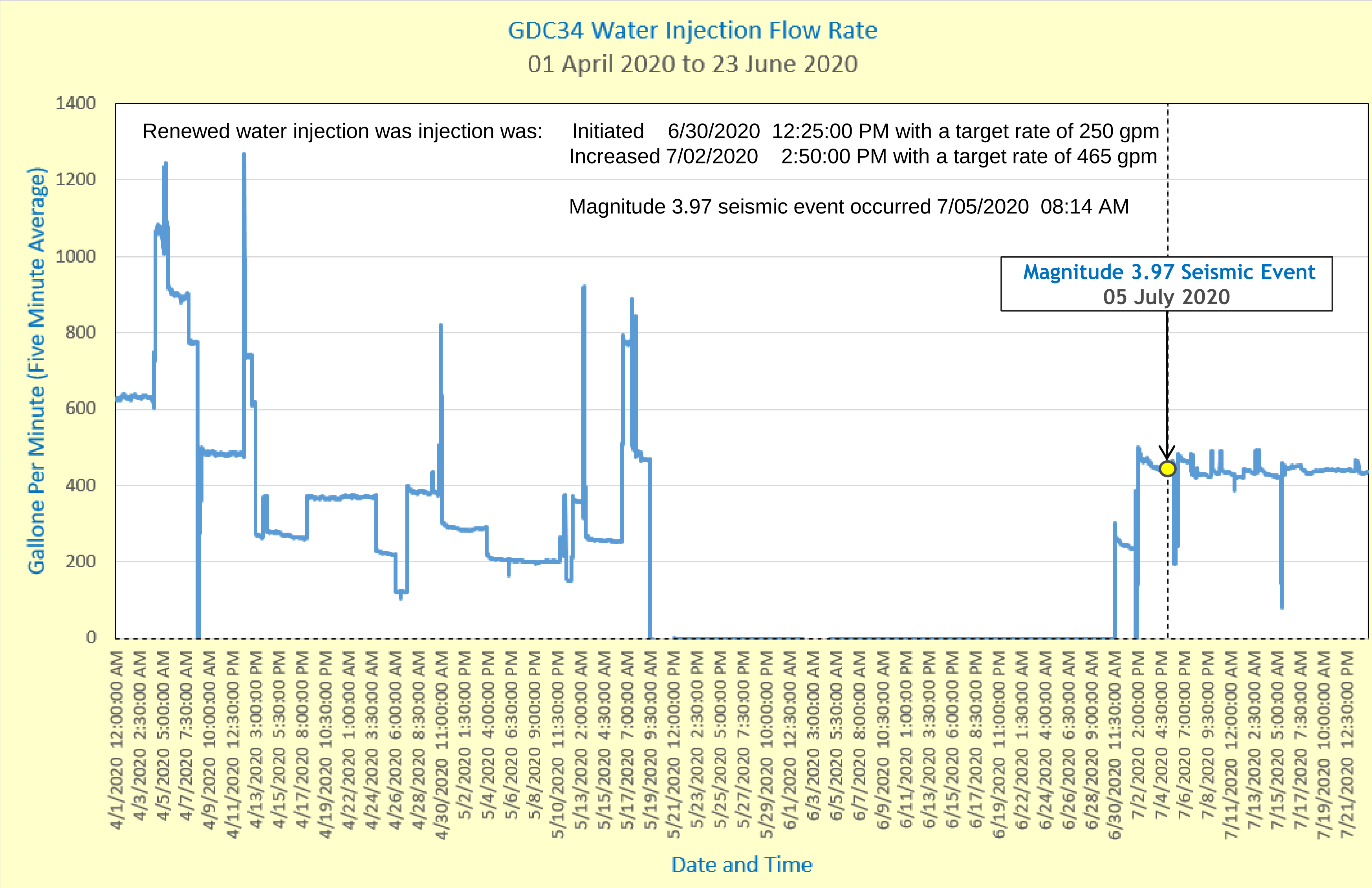




Seismic Monitoring Advisory Committee Meeting
GDC34 Water Injection Well
Monthly Water Injection For Wells In Vicinity



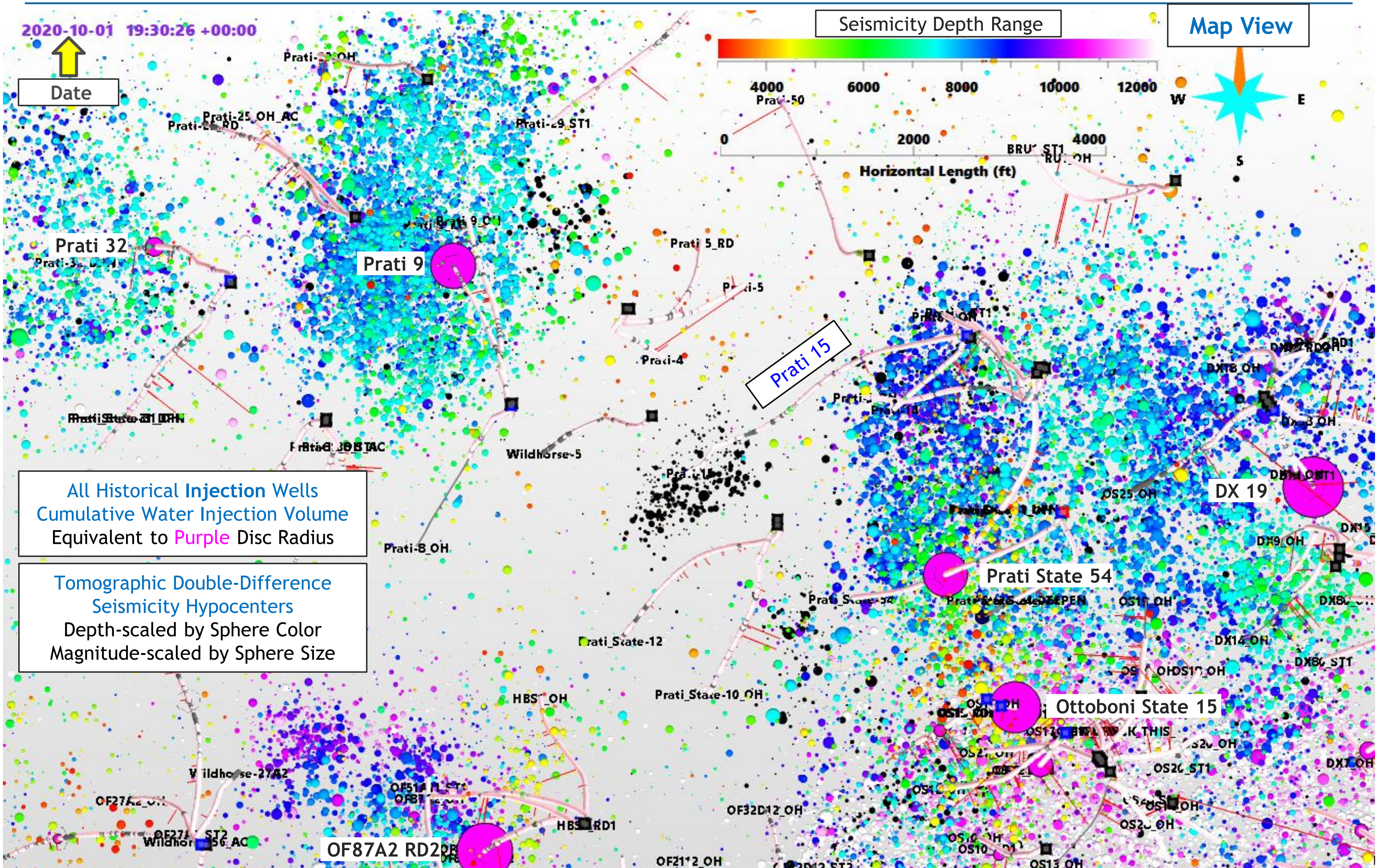
GDC34 Water Injection Flow Rates And Induced Seismicity



2020/07/05 16:14:07.71 38.78800 -122.76633 0.920 3.97 Mw 113 48 2 0.07 NCSN 73421981

Seismic Monitoring Advisory Committee Meeting

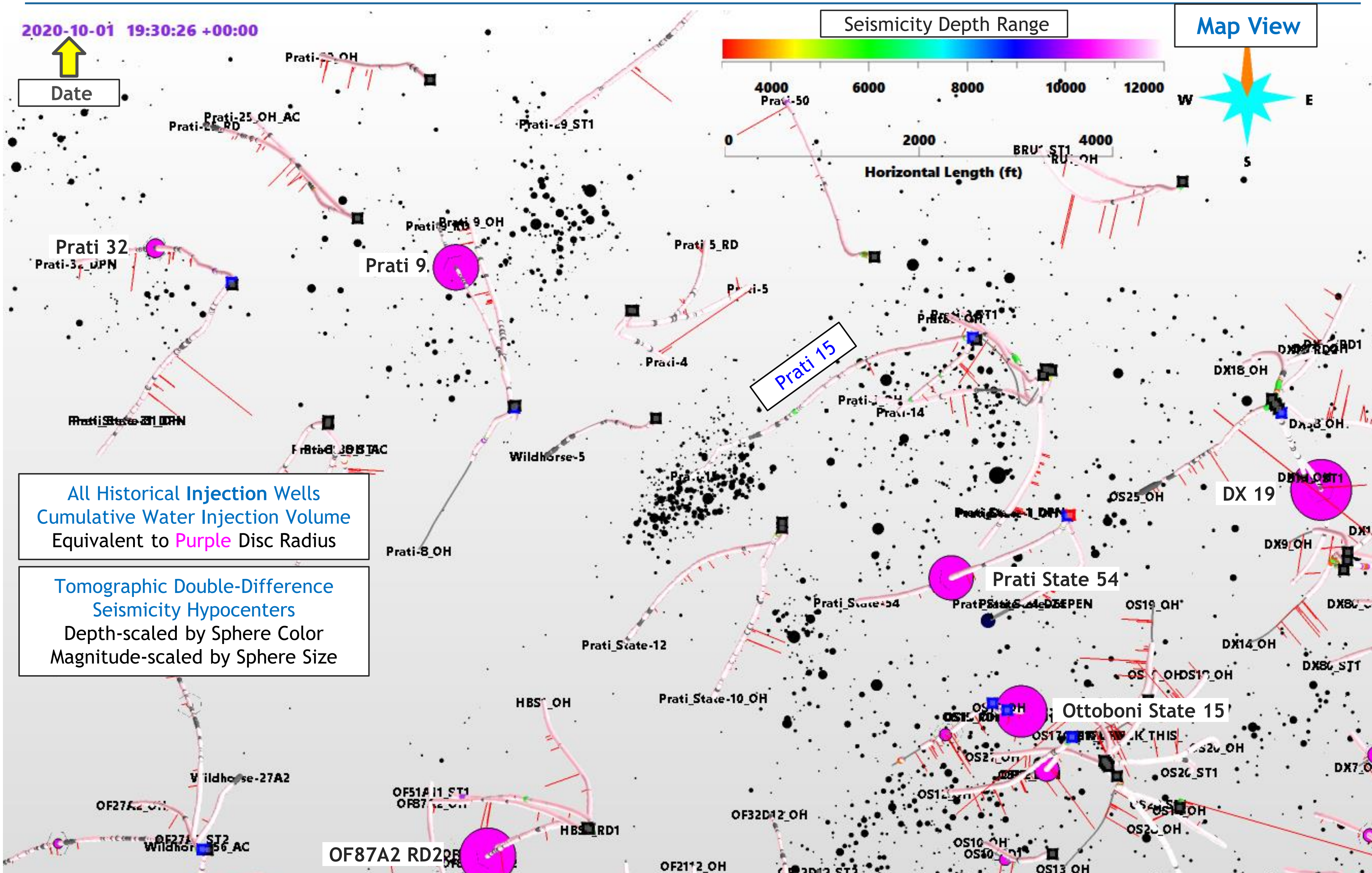
Prati 15 Water Injection Well And "Background" Seismicity 01 January 2005 - 01 January 2020 Color-Scaled By Depth 01 January 2020 - 01 October 2020 As Black Symbols



All Historical Injection Wells
Cumulative Water Injection Volume
Equivalent to Purple Disc Radius

Tomographic Double-Difference
Seismicity Hypocenters
Depth-scaled by Sphere Color
Magnitude-scaled by Sphere Size

Seismic Monitoring Advisory Committee Meeting
Prati 15 Water Injection Well
Seismicity 01 January 2020 - 01 October 2020 ONLY As Black Symbols



Seismic Monitoring Advisory Committee Meeting

Prati 15 Water Injection Well Seismicity 01 January 2020 Through 01 October 2020 ONLY

Color-Scaled By Event Magnitude