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A GENERATION AHEAD, today

Seismic Monitoring Advisory Committee Review

19 November 2012
Geothermal Visitors Center
Middletown, California

Reporting Period:
01 April 2012 to 30 September 2012

Craig Hartline Senior Geophysicist Calpine Corporation

CLEAN MODERN EFFICIENT FLEXIBLE POWER GENERATION

Calpine Presentation Agenda

Reporting Period 01 April 2012 to 30 September 2012

- Southeast Geysers Water Injection and Seismicity
- Seismicity Hotline
- Strong Motion Sensor Stations and Data Analysis
- URS Corporation Strong Motion Siting Recommendations
- Field-Wide Water Injection and Seismicity

SRGRP #18 Report Summary

- Reporting Period 01 March 2012 to 31 August 2012

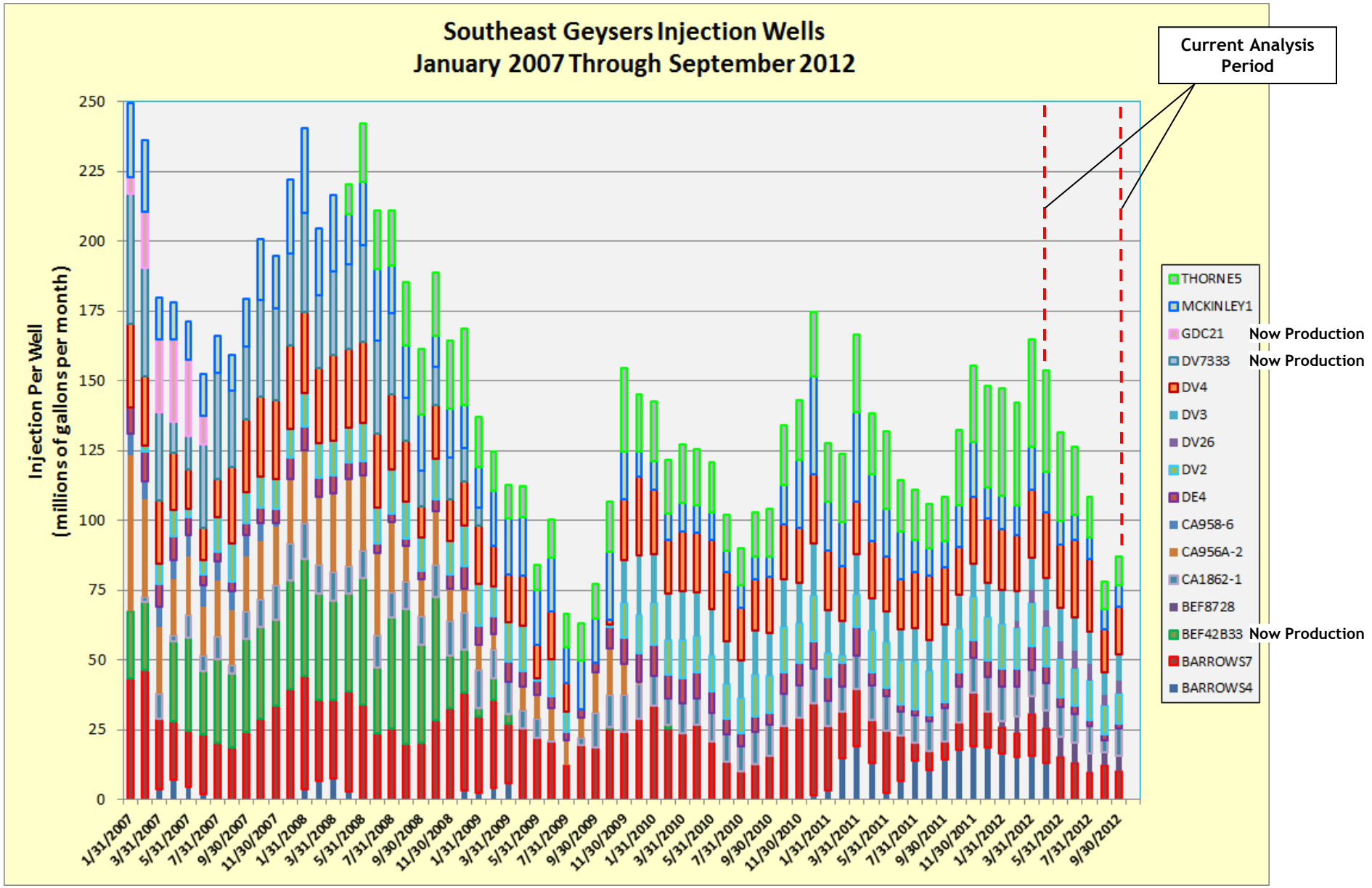
Historical M > 4.0 Seismicity Analysis

Ongoing Seismicity Research Collaborations

- University of California Berkeley
- Lawrence Berkeley National Laboratory
- GEISER Consortium
- Seismic Warning Systems
- United States Geologic Survey
- Seismic Warning Systems

Calpine's Communication and Public Relations

Seismic Monitoring Advisory Committee Meeting
Calpine's Southeast Geysers Injection Wells
01 April 2012 to 30 September 2012



Seismic Monitoring Advisory Committee Meeting
Southeast Geysers Injection Totals Per Well
Current and Previous Reporting Period

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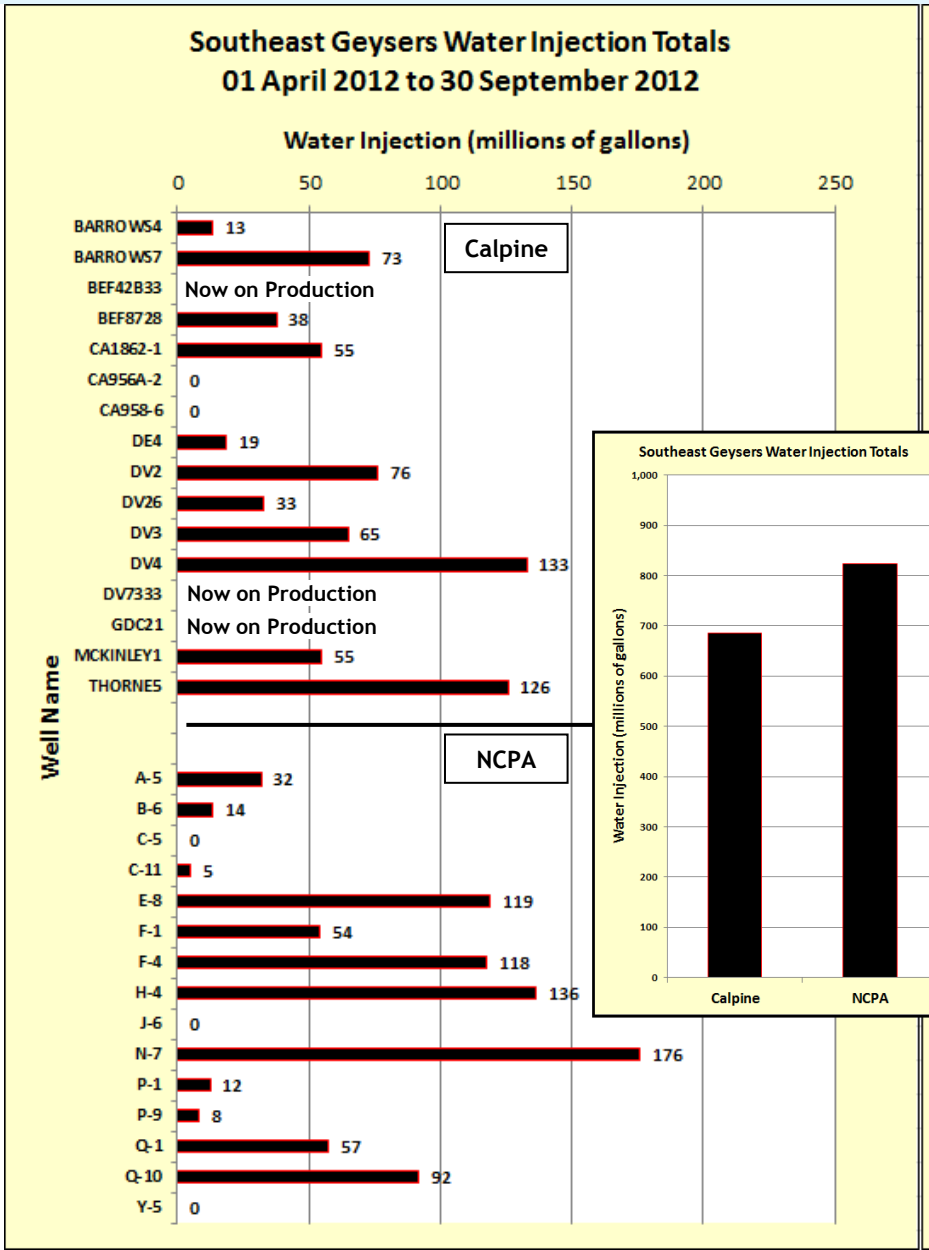
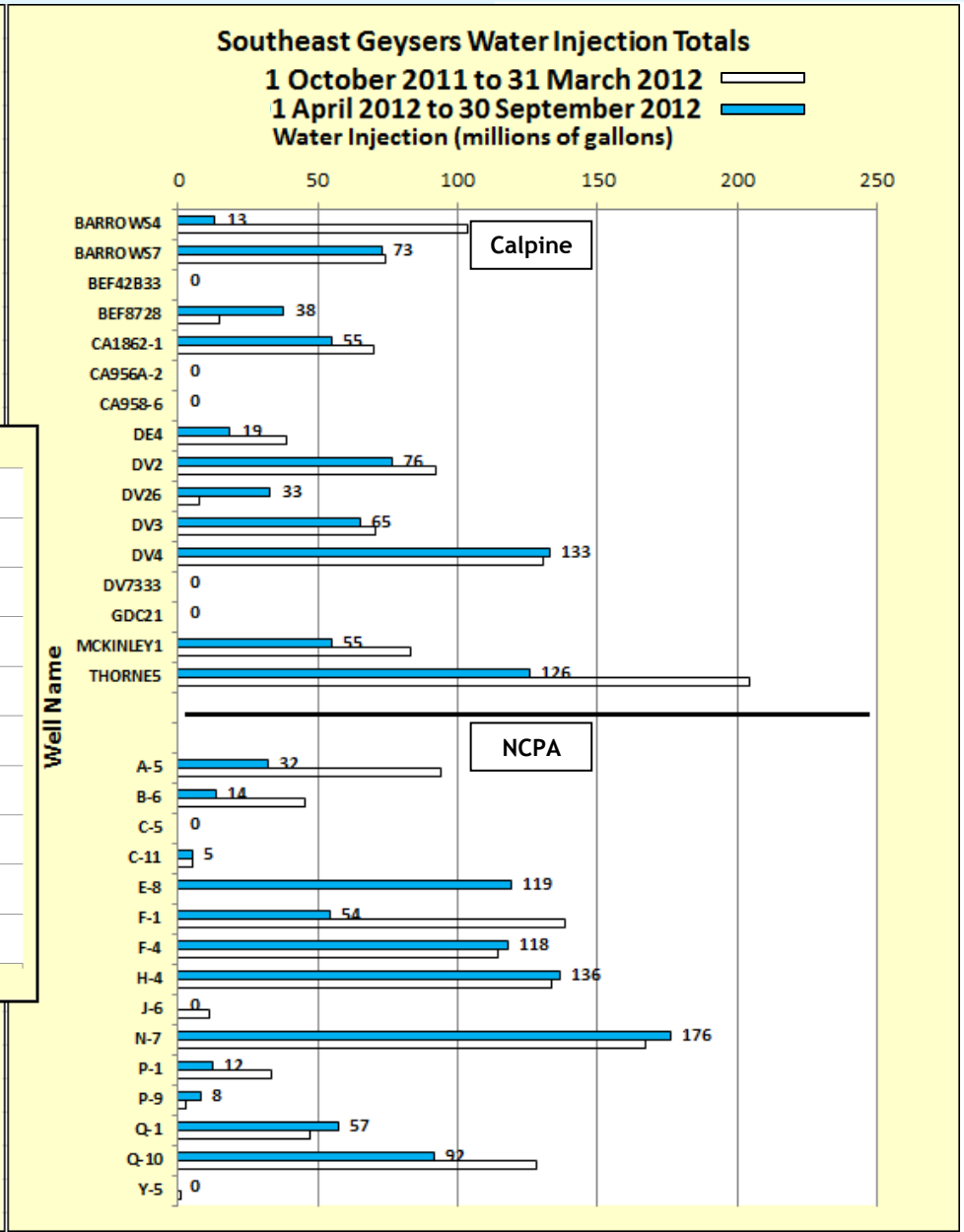
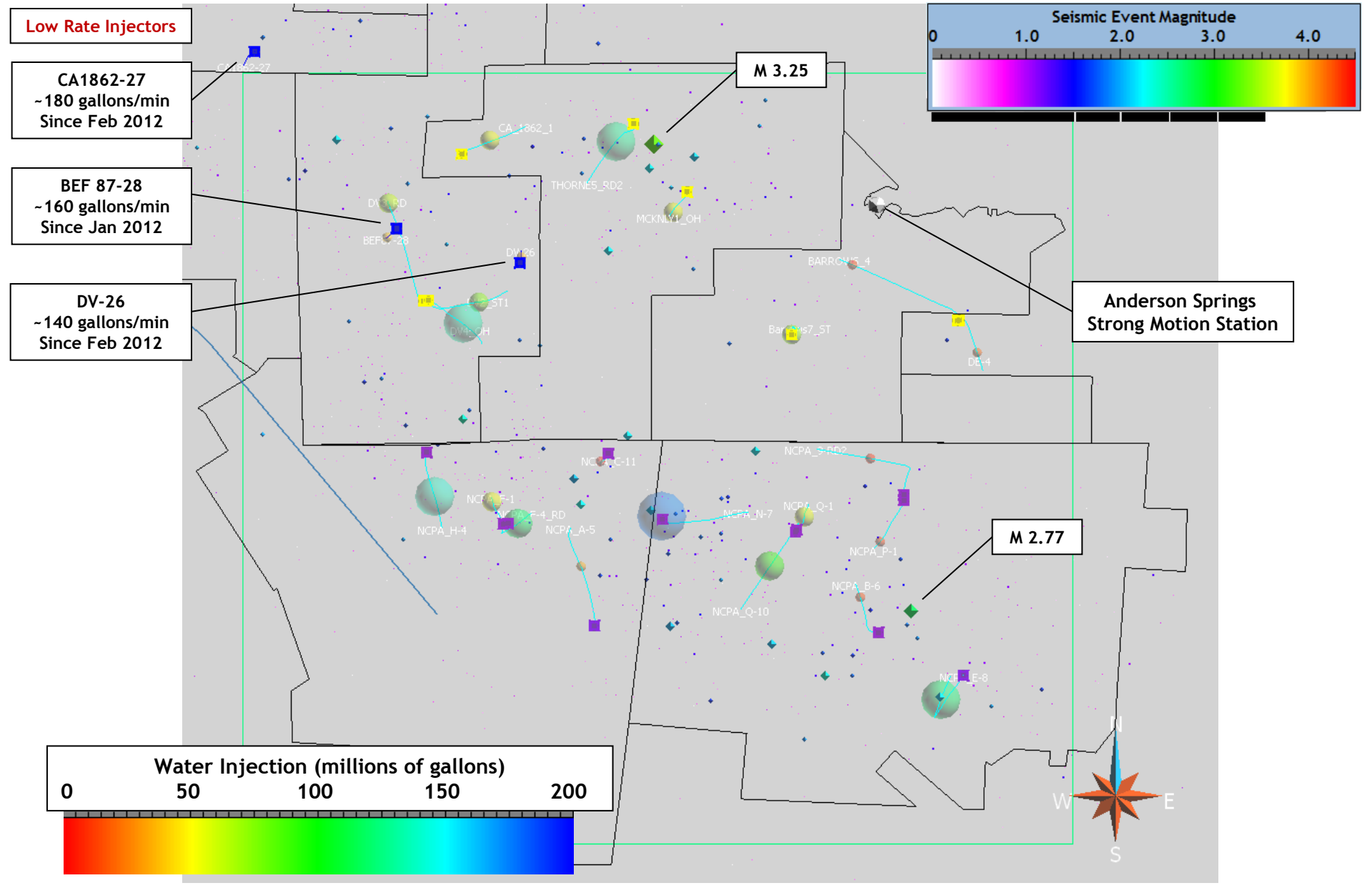




Seismic Monitoring Advisory Committee Meeting
Southeast Geysers Seismicity and Water Injection
01 April 2012 to 30 September 2012



Seismic Monitoring Advisory Committee Meeting
Southeast Geysers Seismicity and Injection
Thorne 5 Vicinity - Seismic Events Since January 2008

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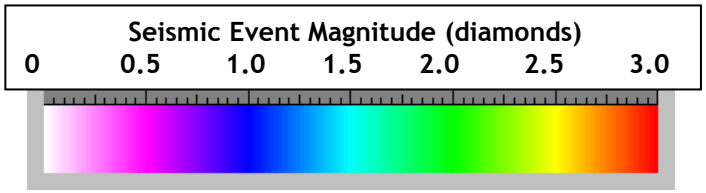

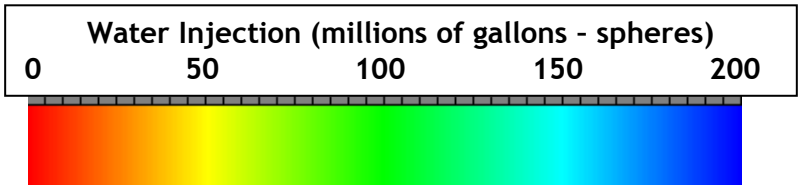

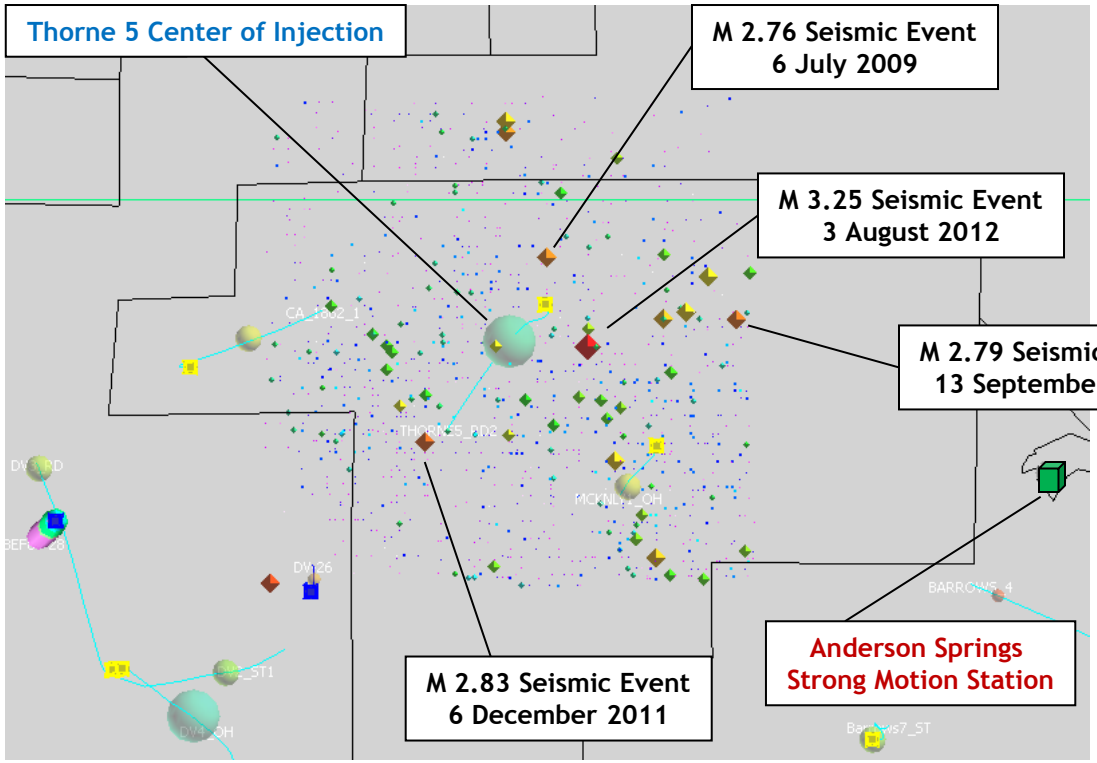

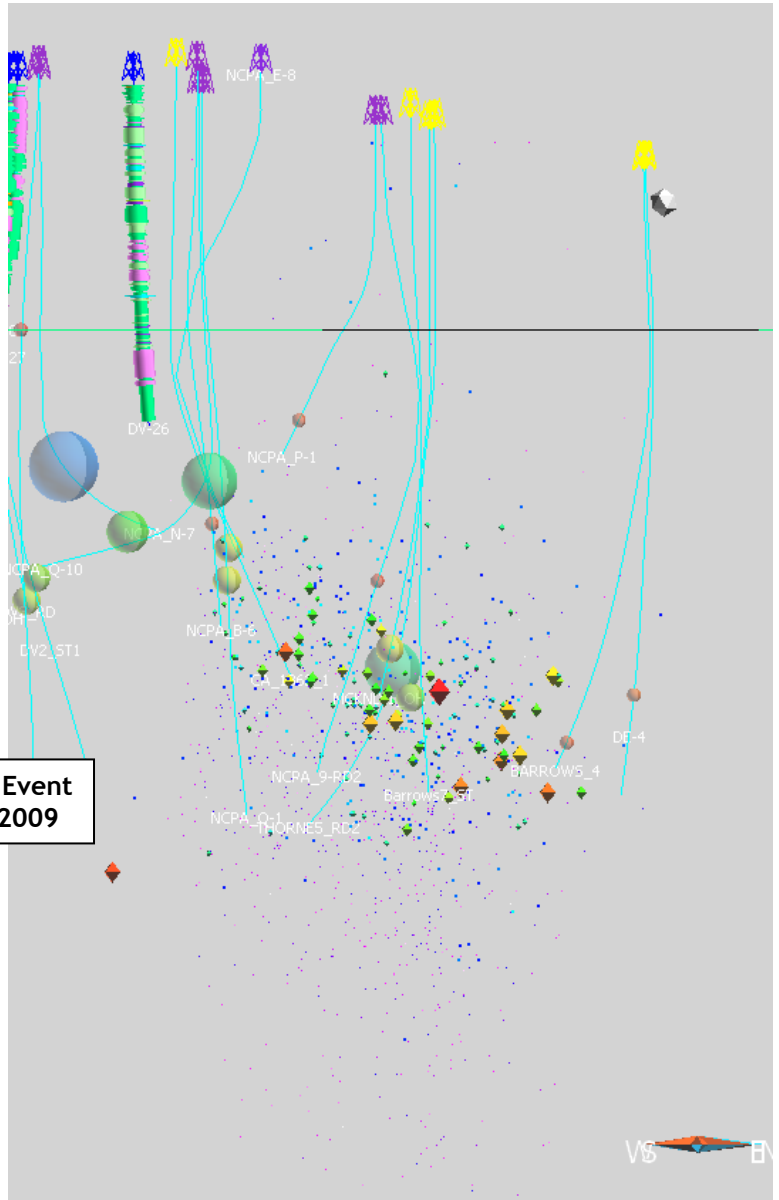

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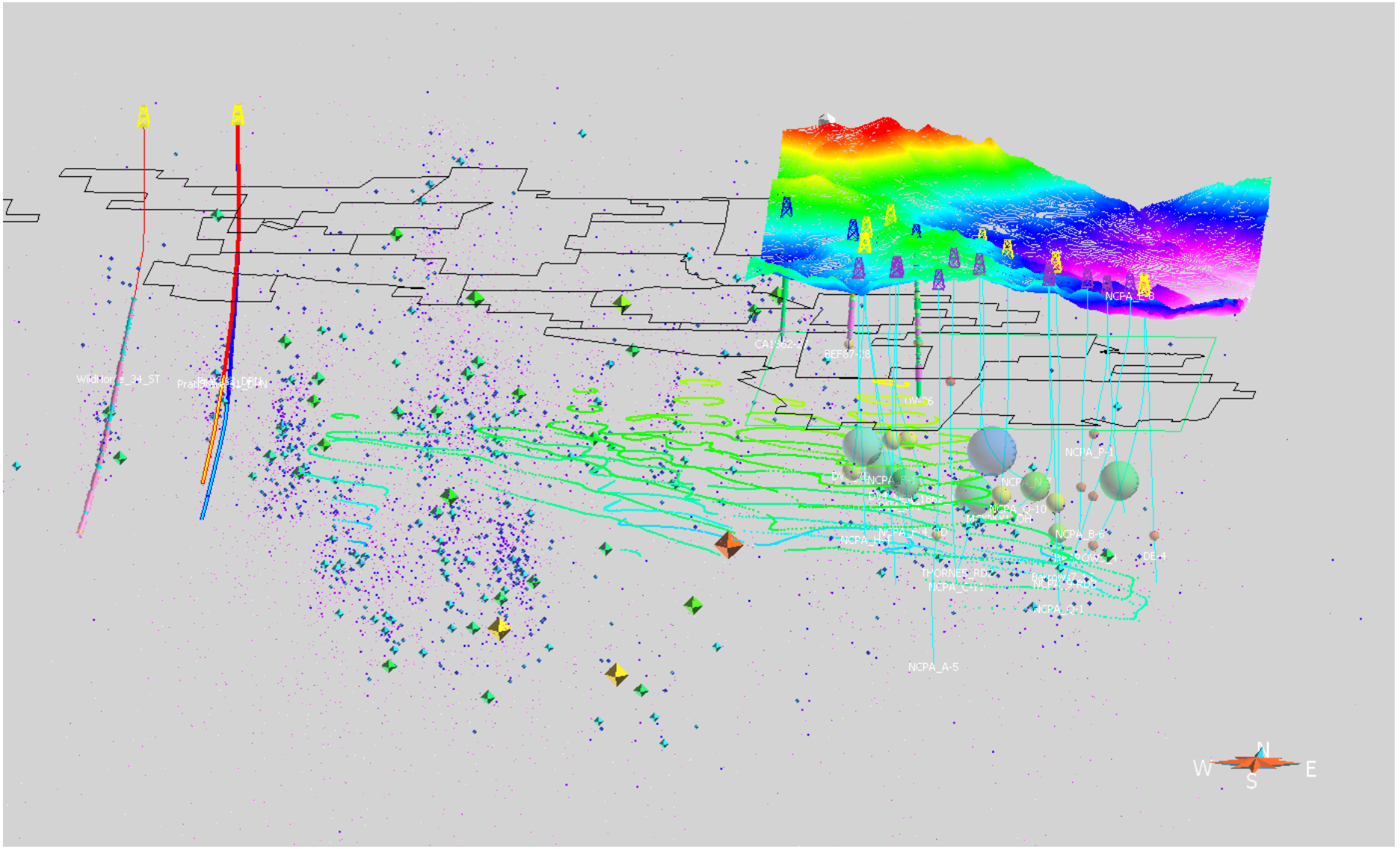
Southeast Geysers Seismicity and Injection

01 April 2012 to 30 September 2012



Seismic Monitoring Advisory Committee

Southeast Geysers Seismicity and Injection

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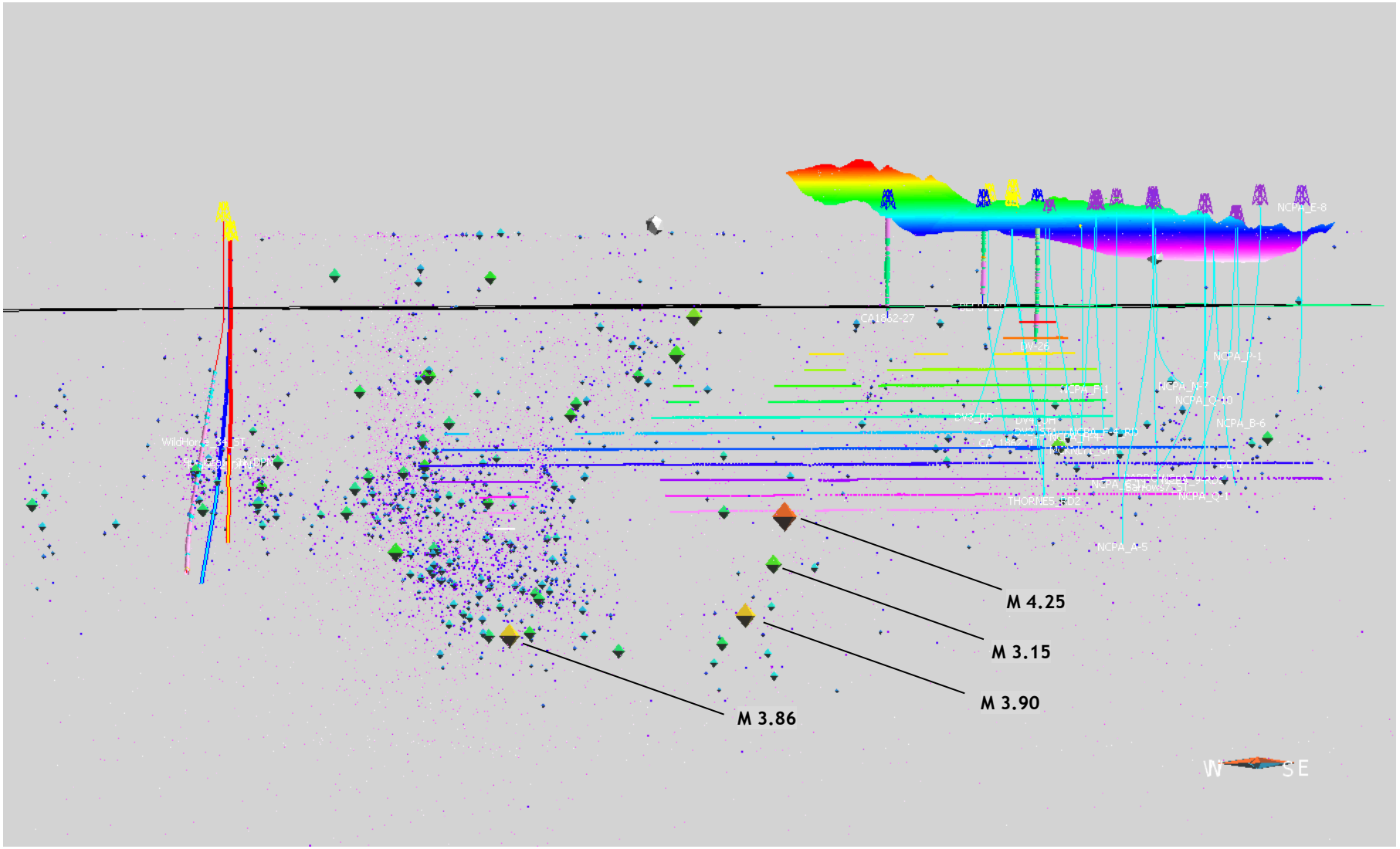
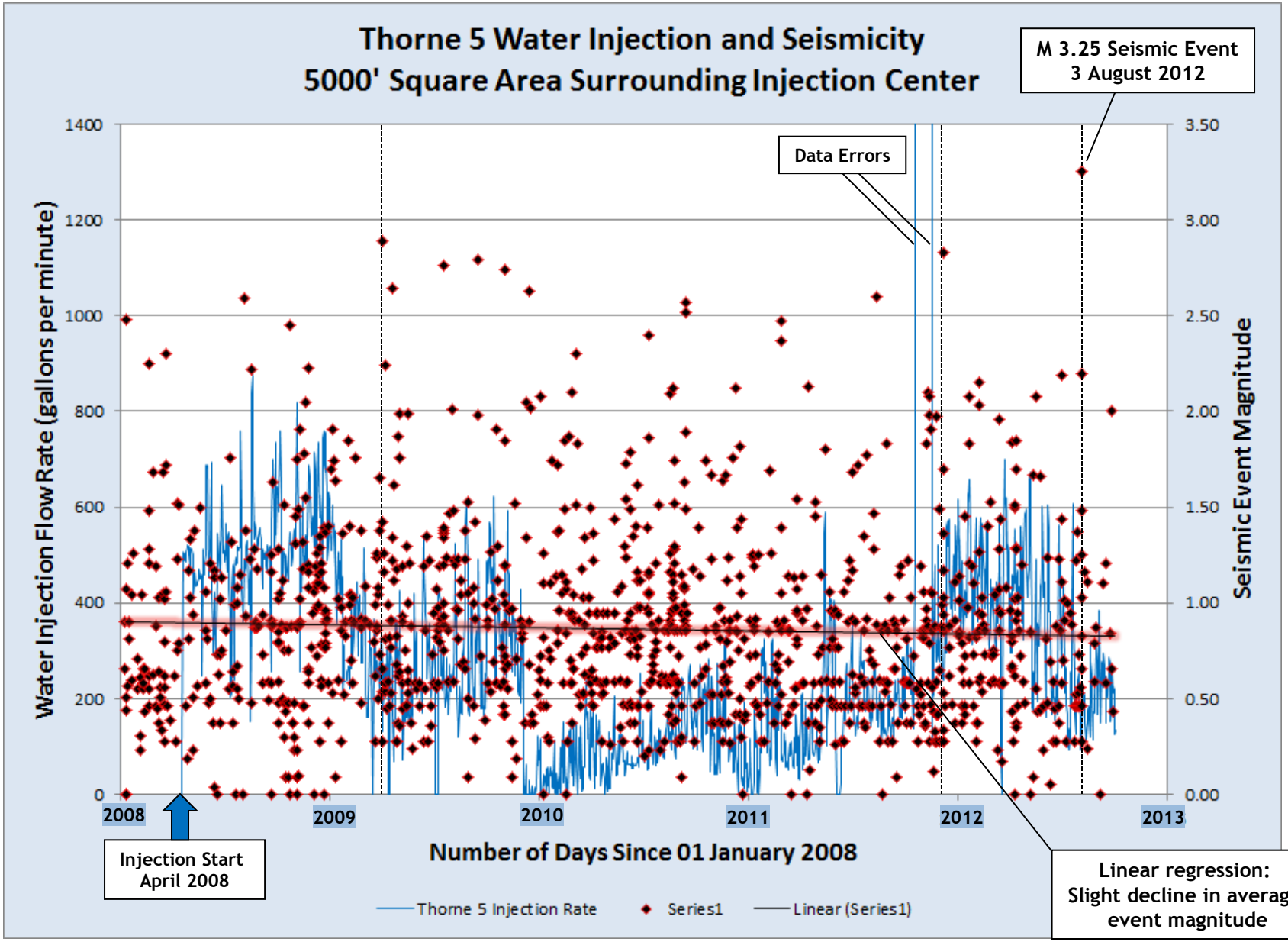


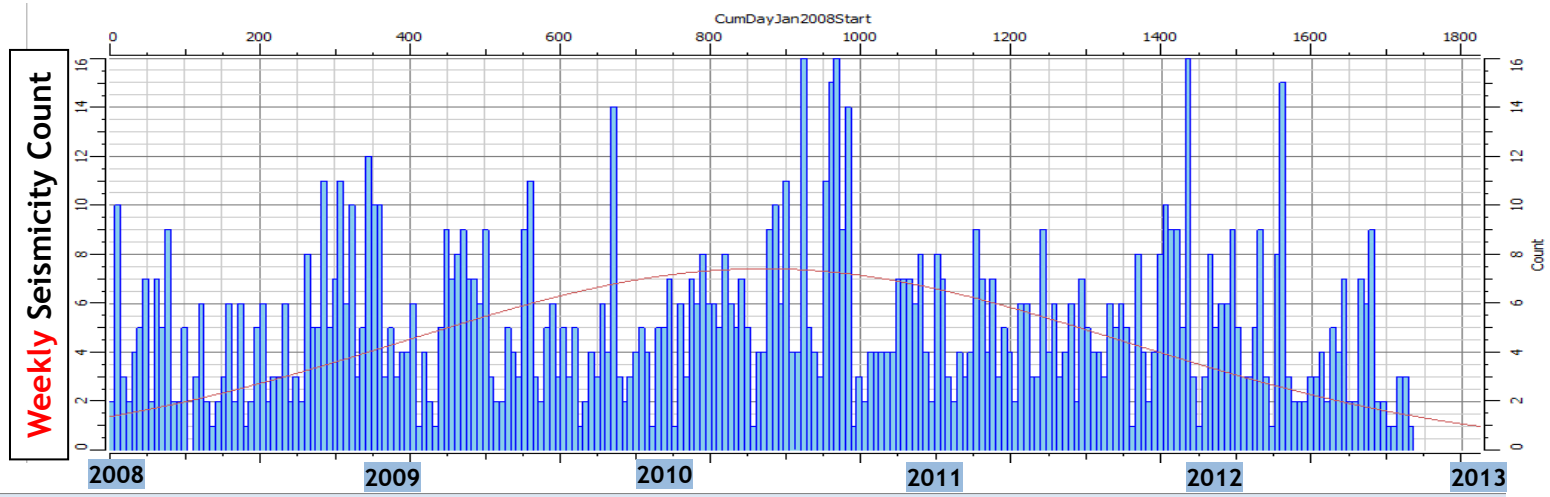
Seismic Monitoring Advisory Committee Meeting

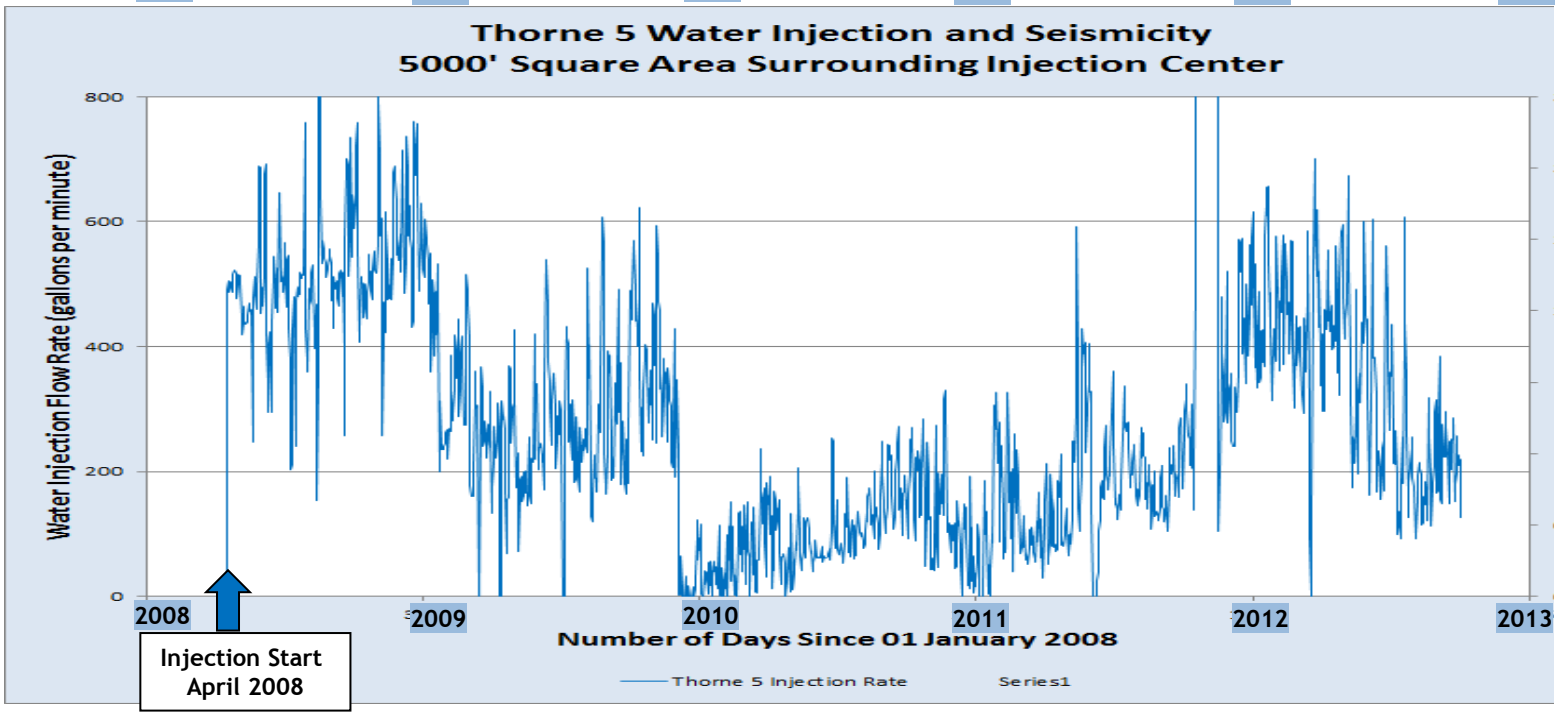
Southeast Geysers Seismicity and Injection

Thorne 5 Water Injection and Seismicity



Seismic Monitoring Advisory Committee Meeting
Southeast Geysers Seismicity and Injection
Thorne 5 Water Injection and Seismicity





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Southeast Geysers Seismicity and Injection
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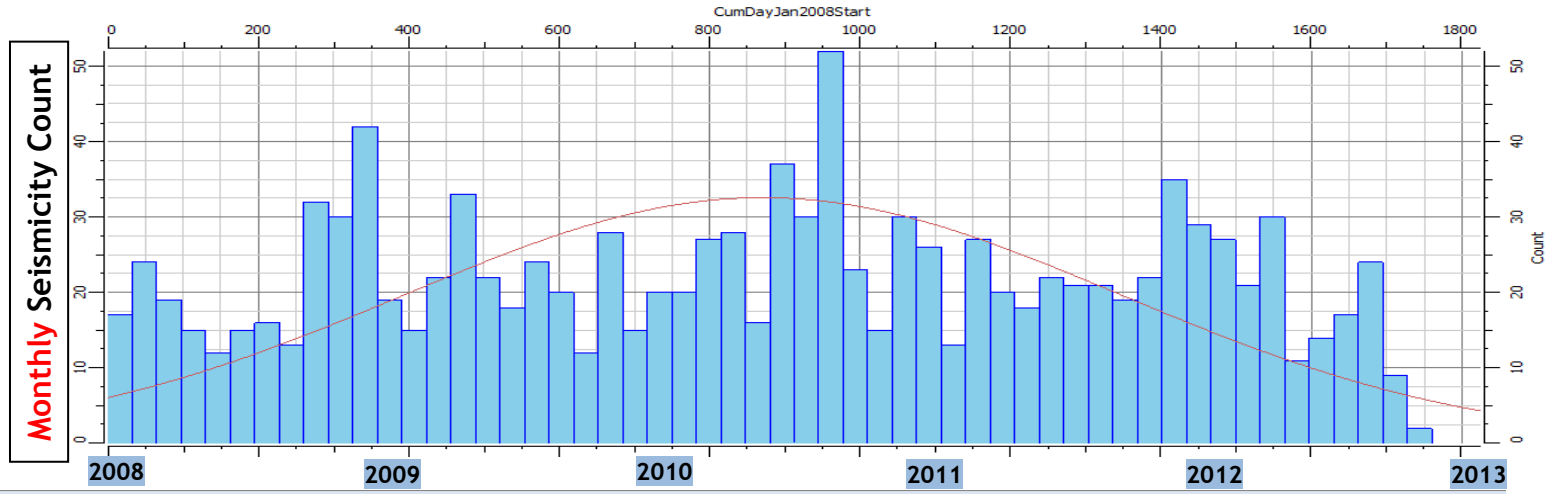

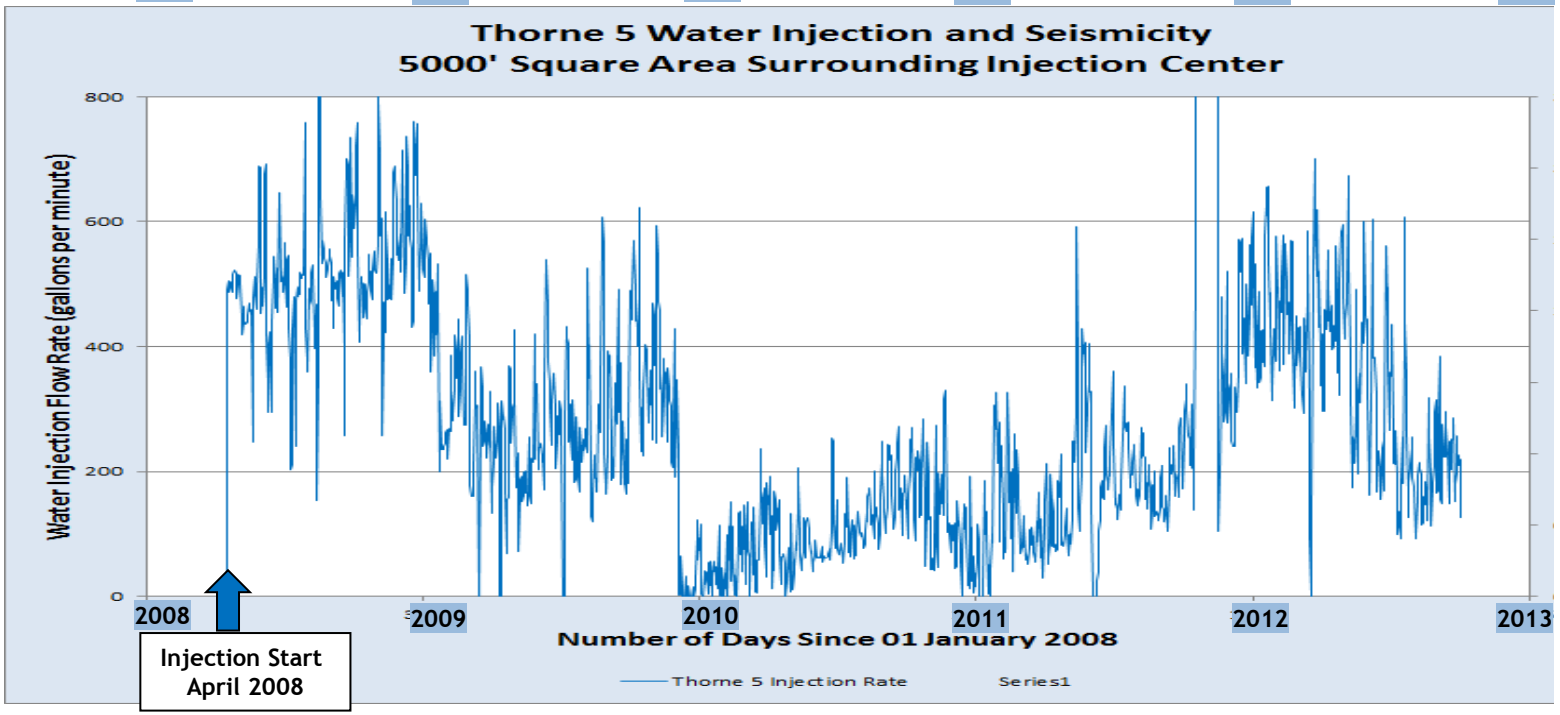

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Northern California Seismic Network
Seismicity Data

Southeast Geysers Seismicity Results as of 30 September 2012

Comparison of pre-SEGEP and post-SEGEP (equivalent annual rates in parentheses)

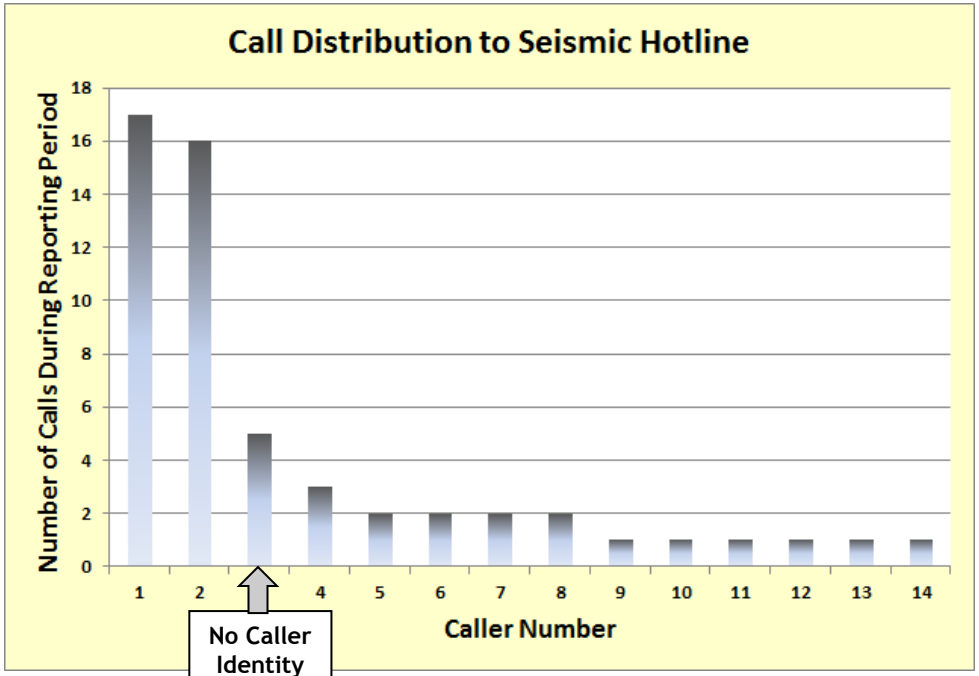
Time Period	Pre-SEGEP	SEGEP	Current Period
Dates	Nov 1995 - Oct 1997	Nov 1997 - Mar 2012	Apr 2012- Sep 2012
Time Span (yrs)	2	14.91	0.5
Seismic Events:			
M>=1.2	330 (165)	4637 (311)	129 (258)
M>=2.0	46 (23)	661 (44)	17 (34)
M>=3.0	10 (5)	36 (2.4)	1 (2)
M Maximum	3.7	4.3	3.3

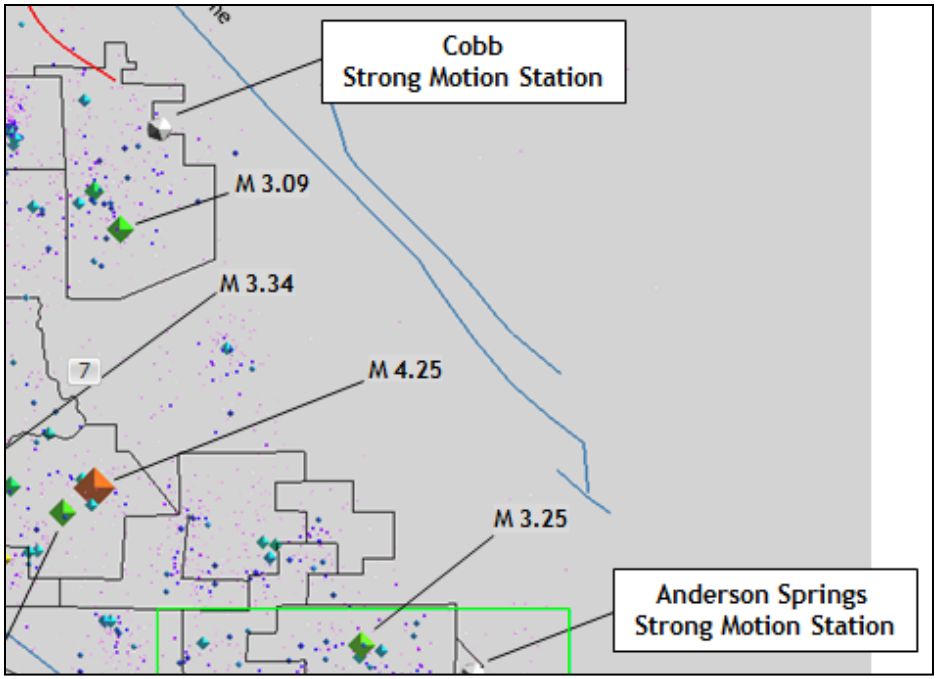
Calls are now transcribed and distributed daily, as requested by the community.

55 voicemails transcribed and reviewed 01 April 2012 to 30 September 2011

15 of these calls were from a limited number of callers concerning noise / vibration

8 calls were received for the Saturday, 05 May 2012 M 4.25 seismic event





Seismic Monitoring Advisory Committee Meeting
Strong Motion Instruments
01 April 2012 to 30 September 2012

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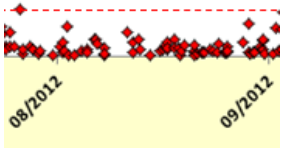
Anderson Springs Strong Motion

No reported disk, power or communication problems
However, no triggered events for 10-12 August 2012



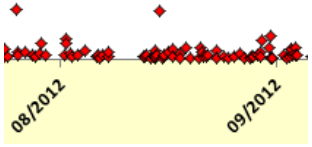
Anderson Springs ETNA Strong Motion Station

Cobb Strong Motion

Data loss from 15 April 2012 to 22 April 2012
Instrument continued to trigger, but no event files were being recorded.

22 April 2012: Cobb Strong Motion fully operational by 10:35 am local time.
The memory card failed and no data was recoverable.
Memory cards have been a persistent problem.
Jim Cullen is now keeping three new spare memory cards.

No other reported disk, power or communication problems
However, no triggered events for 09-13 August 2012



Strong Motion System Reliability Limitations:

- Rural Power
- Rural Communications
- Lightning Strikes
- Downed Lines

Site Selection for Additional Strong Motion Instruments
Anderson Springs

Contracted evaluation completed with URS Corporation

- On-site assessment of structures and local conditions (including some discussions with property owners)
  - Ivan Wong: Principal Seismologist; Seismic Hazards Group; URS Corporation
  - Melinda Wright: Senior Geologist; Calpine Corporation
  - Craig Hartline: Senior Geophysicist; Calpine Corporation
- URS review of existing geologic maps (McLaughlin, 1978*) and reports
- URS detailed analysis of EQ Hotline calls from January 2004 to March 2011
- URS final recommendations for additional instrument siting provided 21 May 2012:
  Evaluation of Ground Shaking Intensities in Anderson Springs and Recommendations for Strong Motion Instrument Sites
  Ivan Wong and Fabia Terra

* McLauglin, R,J, 1978, Preliminary geologic map and structural sections of the Central Mayacamas Mountains and The Geysers Steam Field, Sonoma, Lake and Mendicino Counties, California: U.S. Geological Survey Open File Report OF78-389

Seismic Monitoring Advisory Committee Meeting
Site Selection for Additional Strong Motion Instruments
Anderson Springs

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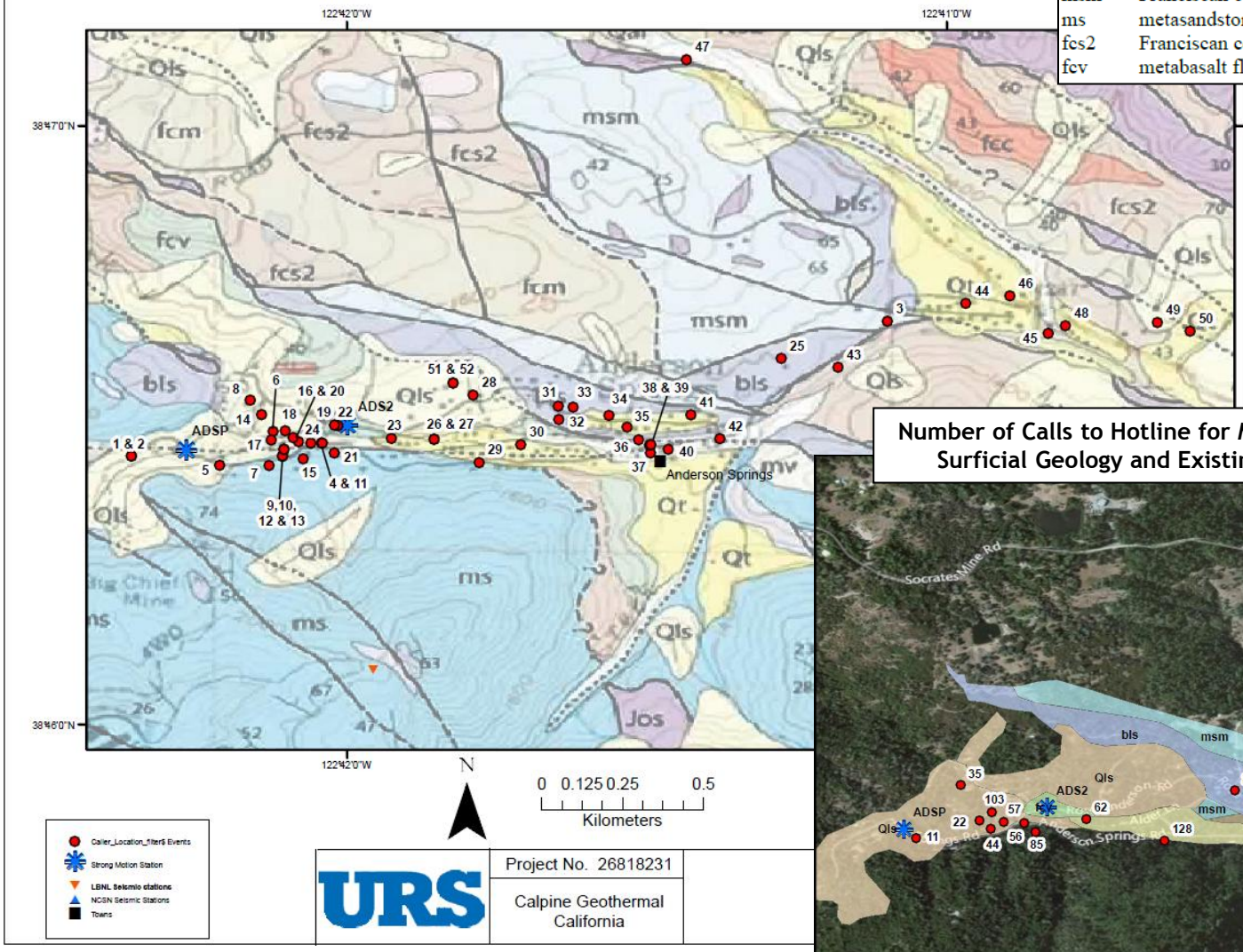
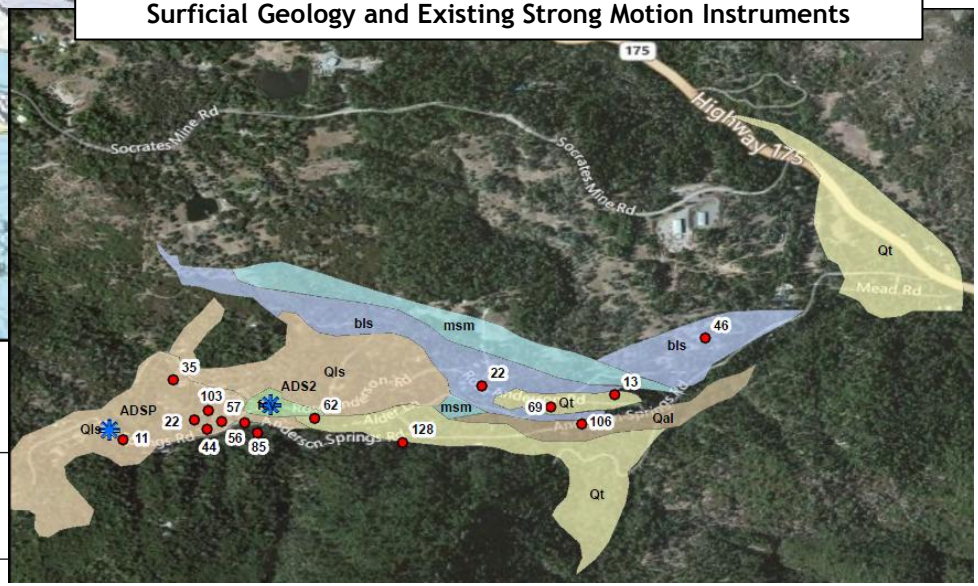
Qls	landslide deposits
Qal	alluvium
Qt	terrace deposits
bls	Franciscan complex, blueschist and ecologite block in melange
msm	Franciscan complex, metamorphosed mélange
ms	metasandstone
fcs2	Franciscan complex, metasandstone
fcv	metabasalt flows and flow breccias

Numbered Hotline Caller Locations and Surficial Geology



Number of Calls to Hotline for Most Sensitive Sites (> 10 Calls), Surficial Geology and Existing Strong Motion Instruments



URS	Project No. 26818231
	Calpine Geothermal California

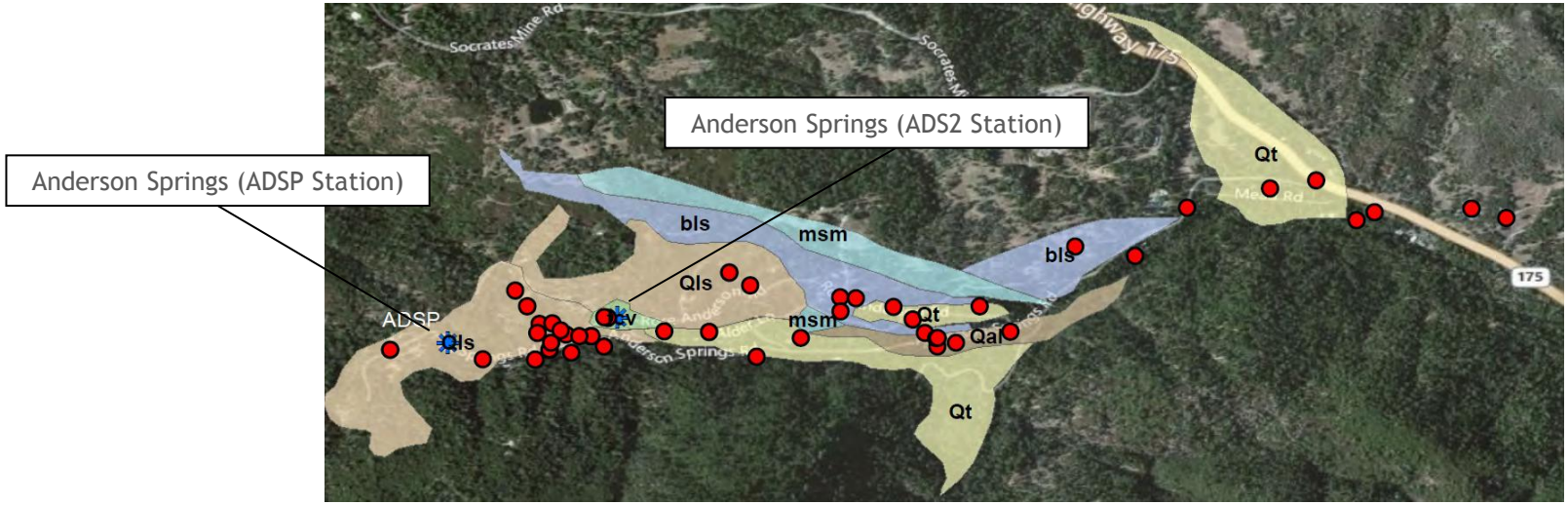
Seismic Monitoring Advisory Committee Meeting
Site Selection for Additional Strong Motion Instruments
Anderson Springs

Analysis based on a correlation of reported intensities with surficial geology and topography.
Nine events with largest number of calls to hotline analyzed in detail.

Majority of hotline callers have residences on landslide deposits (Qls) at the western end of the community.

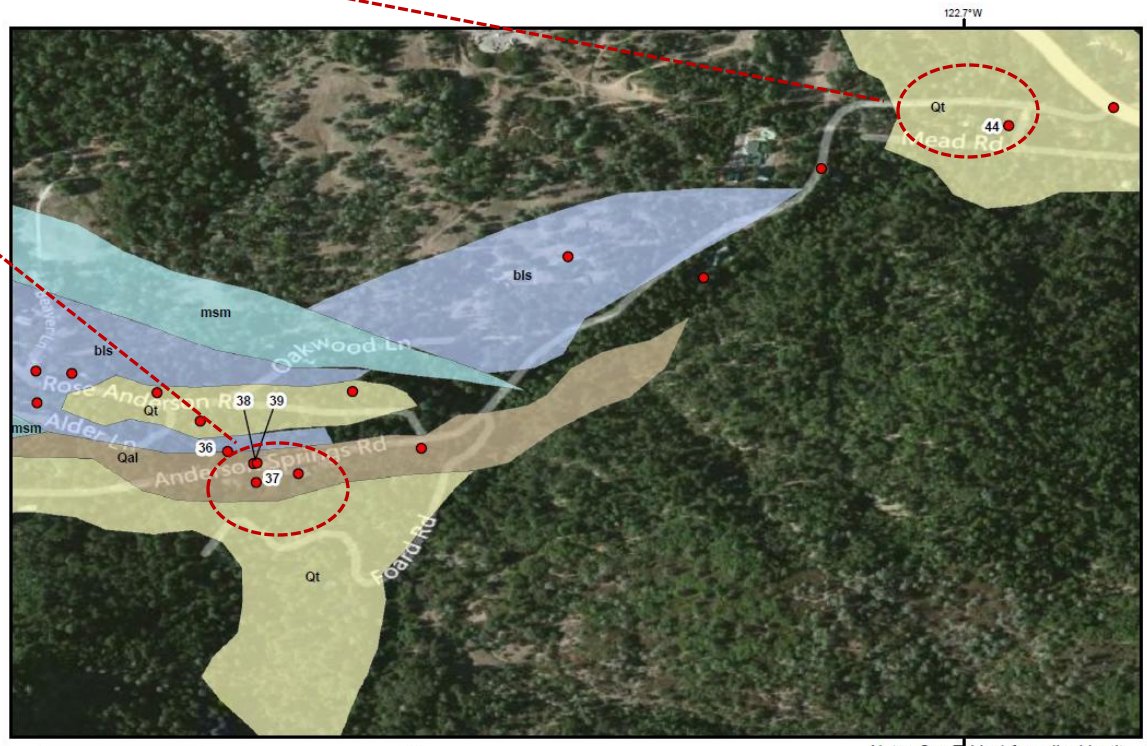
Anderson Springs (ADSP Station):
- Instrument also on relatively thin landslide deposits (Qls) overlying rock
- Low shear wave velocities
- Leads to site amplification at short to moderate periods

Anderson Springs (ADS2 station):
- Located on metabasalt (fcv)
- Consistently and significantly lower peak ground accelerations and peak ground velocities



Site Selection for Additional Strong Motion Instruments
Anderson Springs

Recommend placement of any additional stations:
Eastern portion of Anderson Springs
On Quaternary “soft” geologic units (other than Qls) with site amplification potential
Near callers 36-39 (Qal / Qt) and near caller 44 (Qt)



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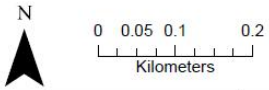

URS | Project No. 26818231 | Calpine Geothermal California | RECOMMENDED RESIDENTIAL LOCATIONS FOR FUTURE STRONG MOTION SITES | Figure 16

Seismic Monitoring Advisory Committee Meeting
Anderson Springs Peak Ground Acceleration
01 April 2012 to 30 September 2012

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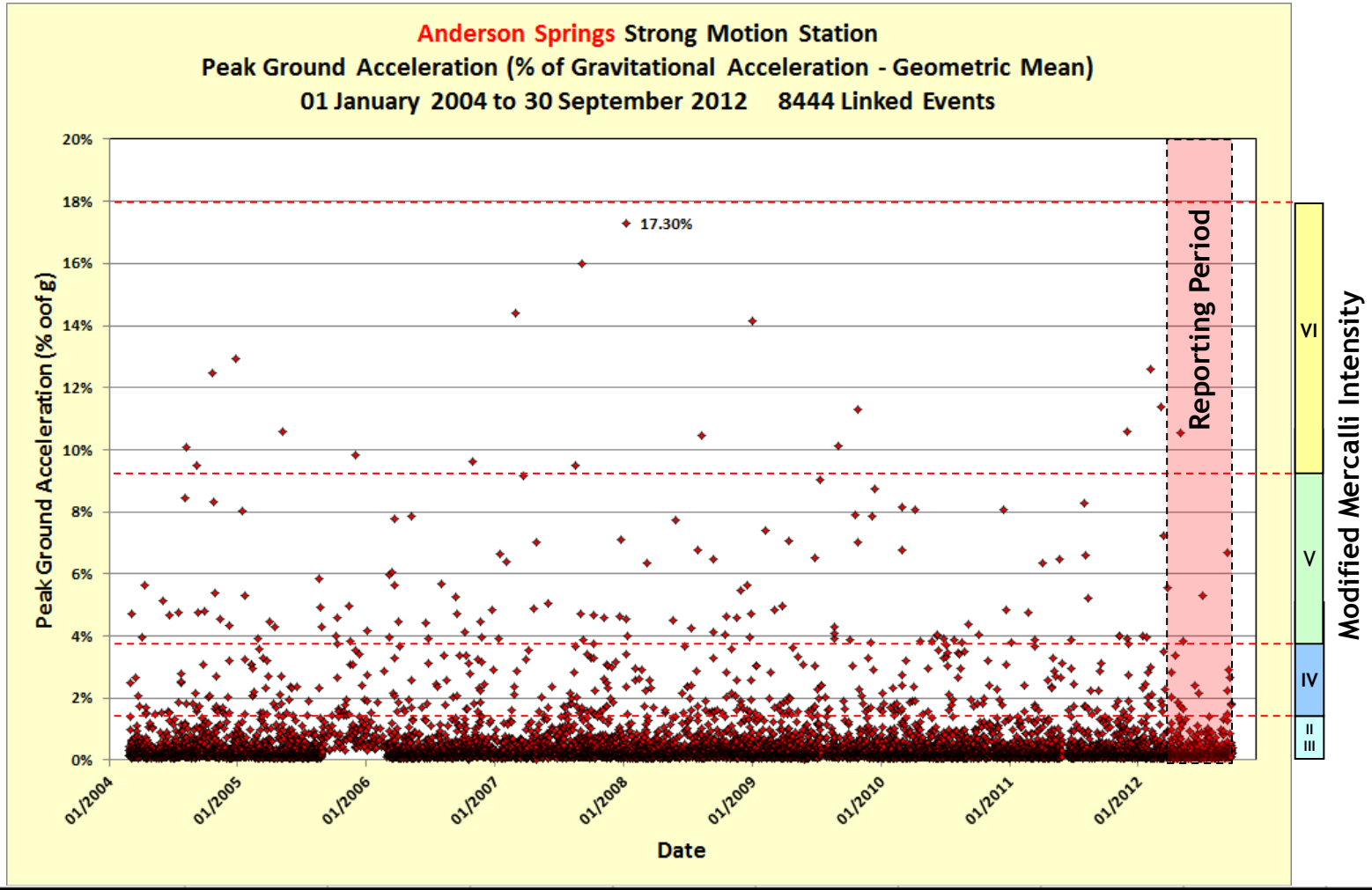
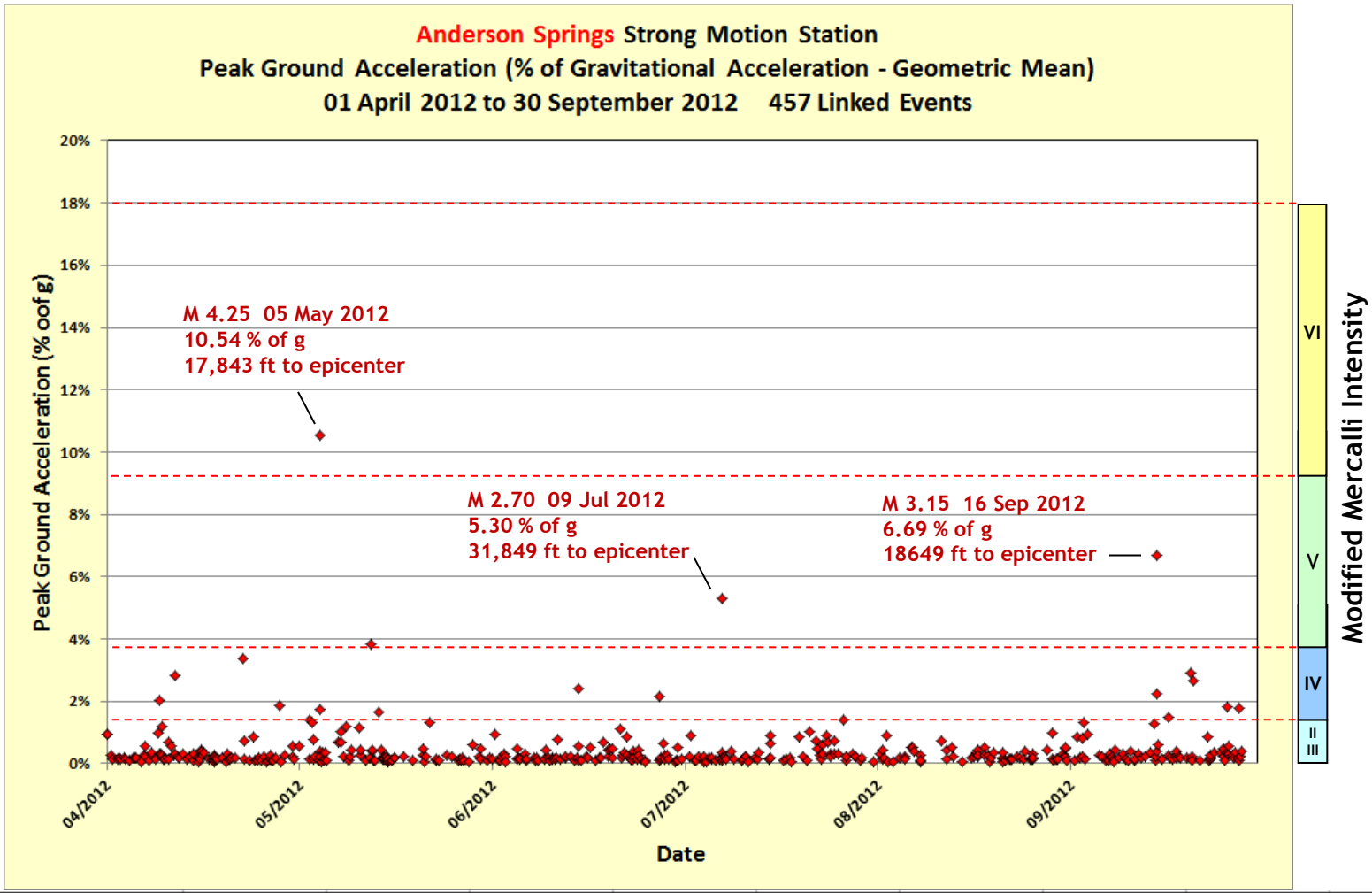


Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (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

Seismic Monitoring Advisory Committee Meeting
Anderson Springs Peak Ground Acceleration
01 April 2012 to 30 September 2012

CALPINE NYSE CPN



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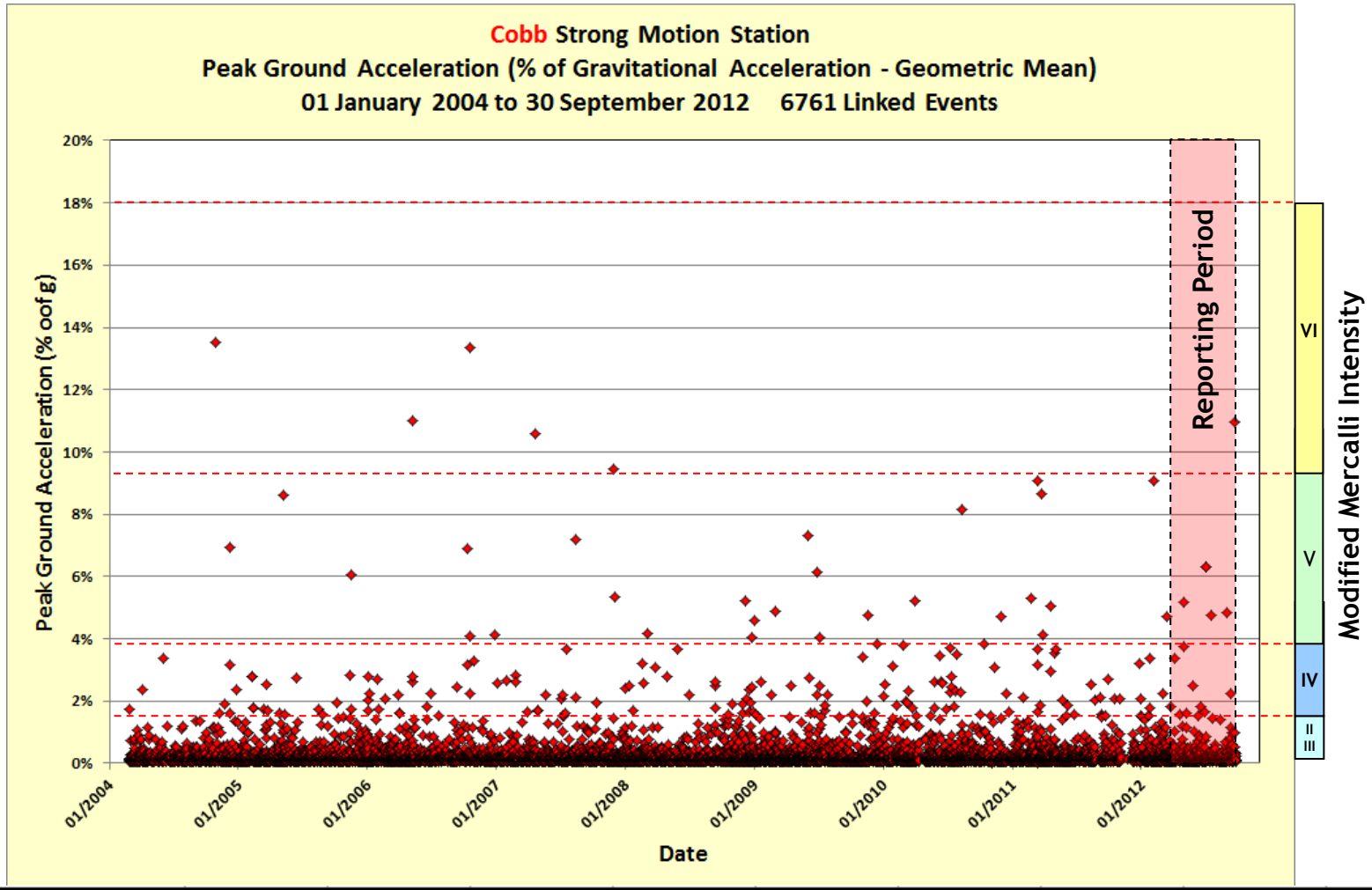
Seismic Monitoring Advisory Committee Meeting

Cobb Peak Ground Acceleration

01 April 2012 to 30 September 2012



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Seismic Monitoring Advisory Committee Meeting
Cobb Peak Ground Acceleration
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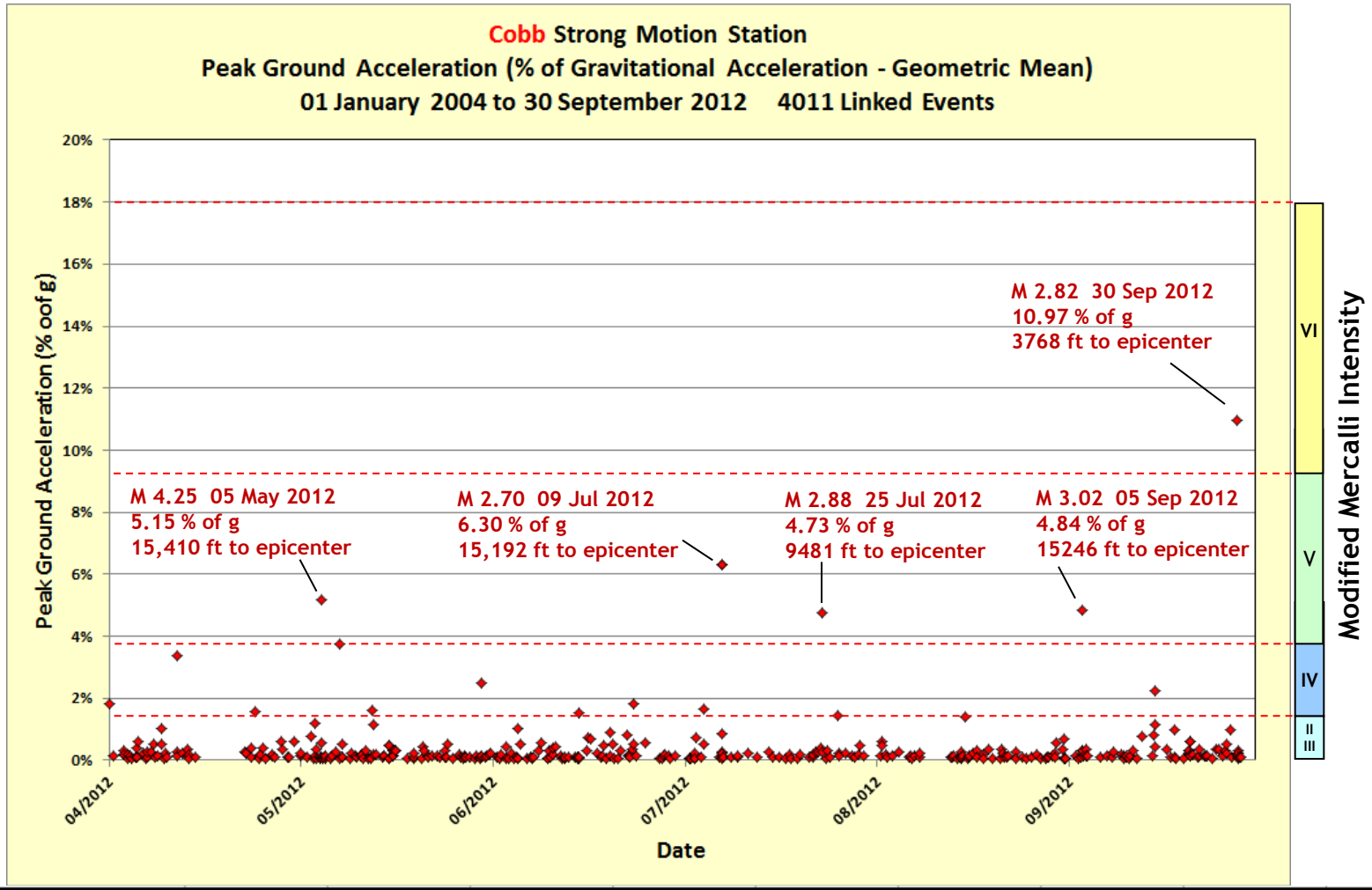

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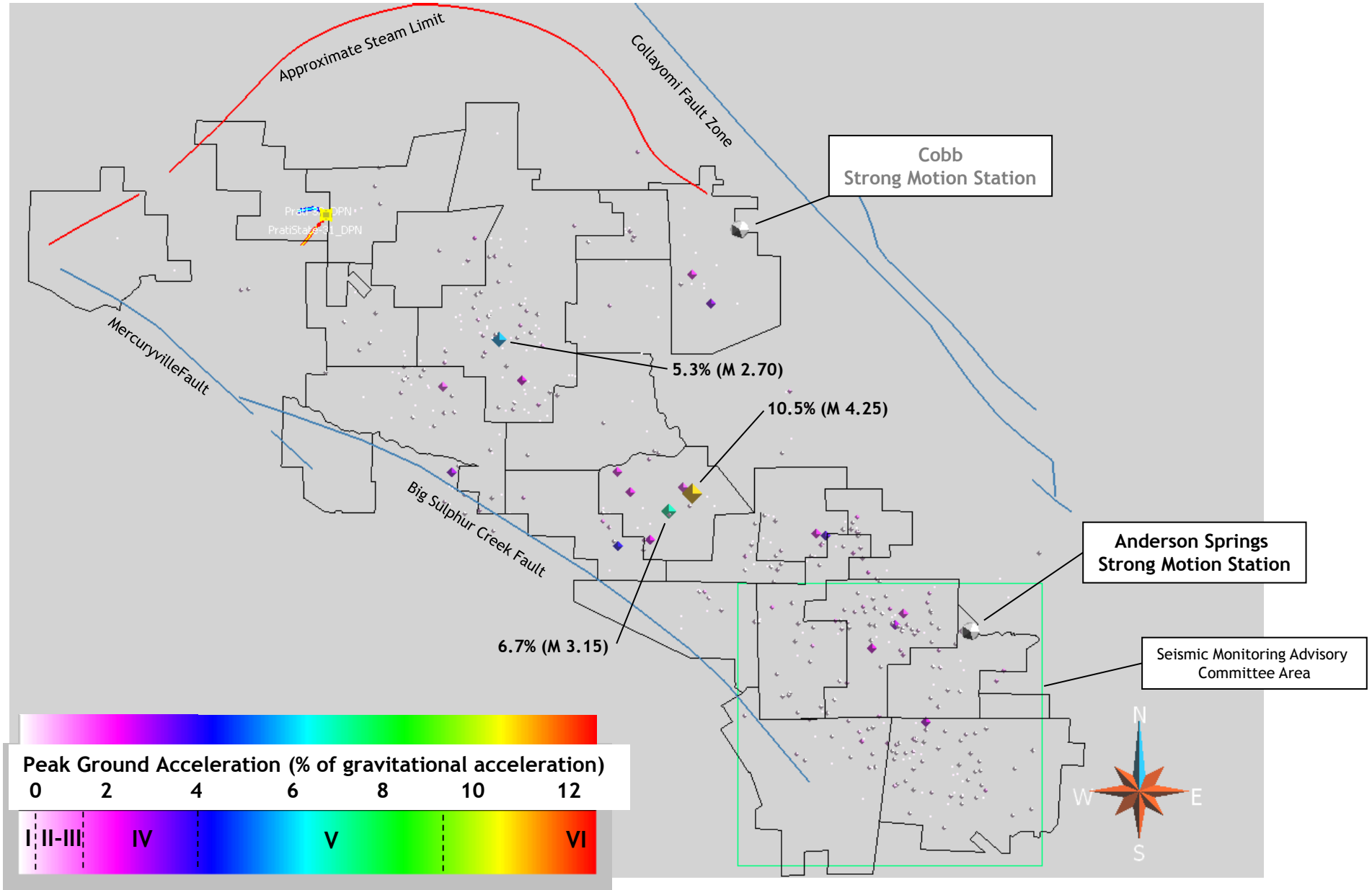
Seismic Monitoring Advisory Committee Meeting
Anderson Springs Peak Ground Acceleration
01 April 2012 to 30 September 2012



Seismic Monitoring Advisory Committee Meeting
Cobb Peak Ground Acceleration
01 April 2012 to 30 September 2012

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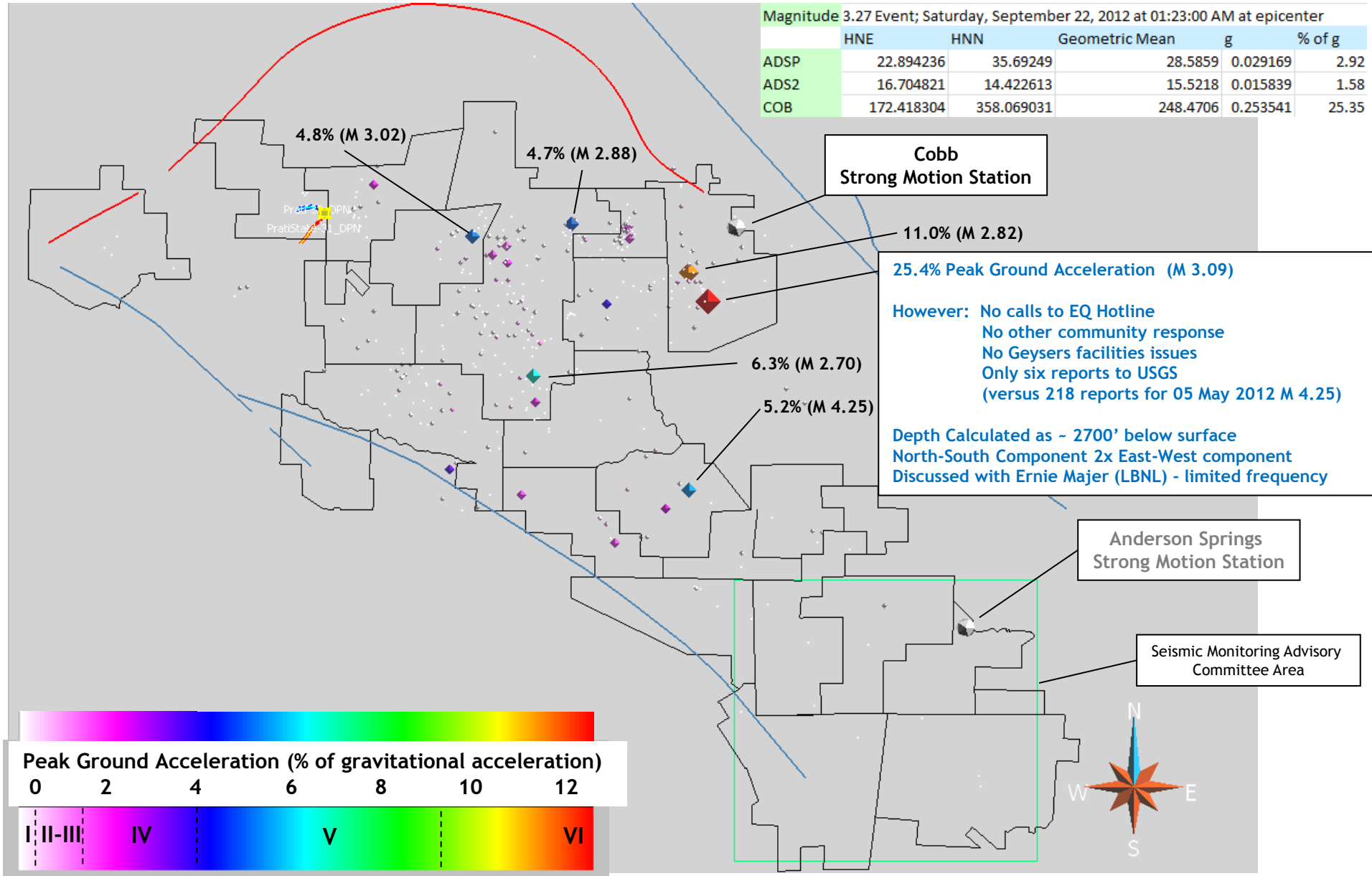

Seismic Monitoring Advisory Committee

Field-wide Injection Sources

01 April 2012 to 30 September 2012

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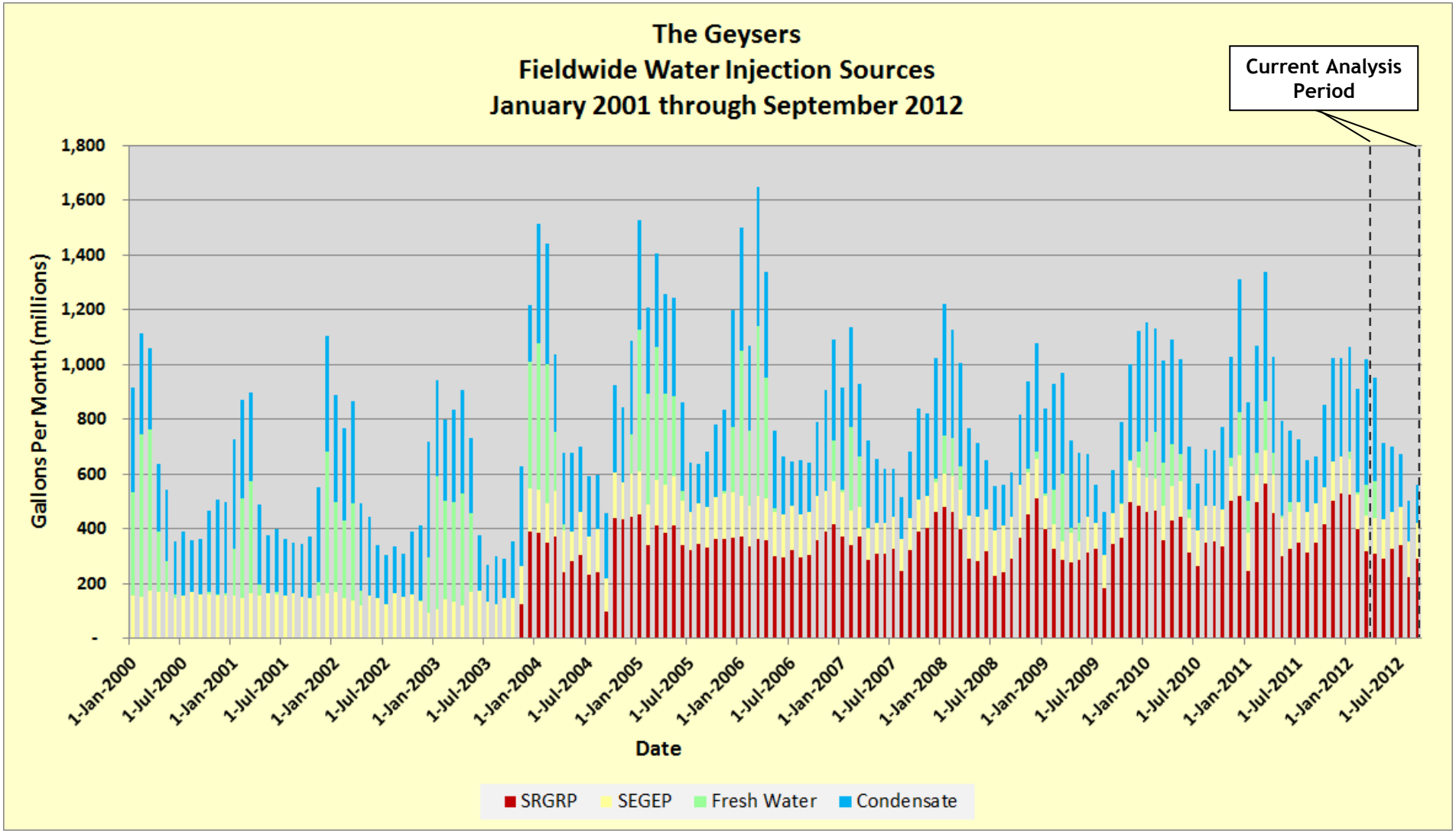

Seismic Monitoring Advisory Committee
Field-wide Injection Sources
01 April 2012 to 30 September 2012

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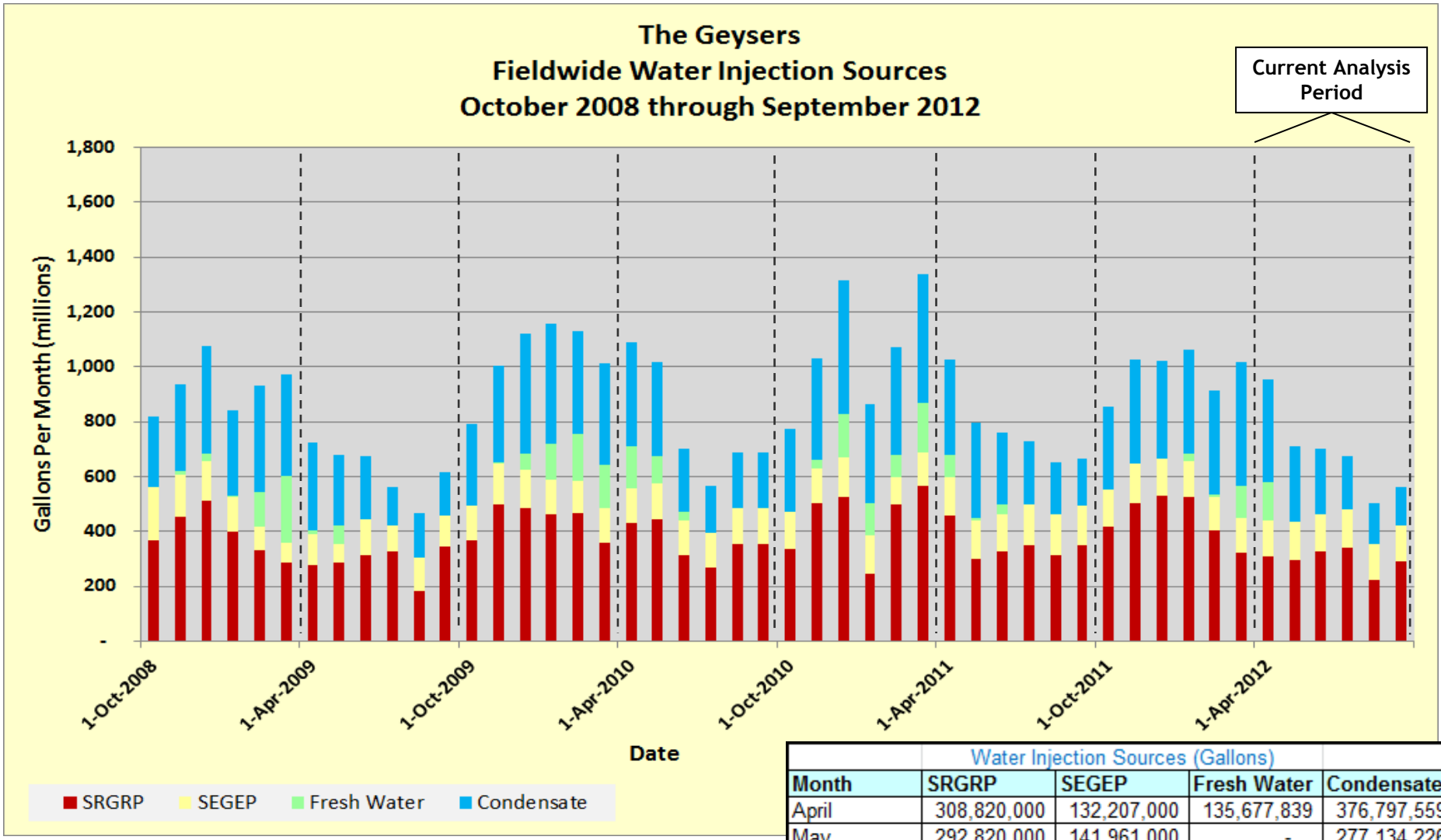

	Water Injection Sources (Gallons)			
Month	SRGRP	SEGEP	Fresh Water	Condensate
April	308,820,000	132,207,000	135,677,839	376,797,559
May	292,820,000	141,961,000	-	277,134,226
June	326,070,000	135,054,000	-	238,716,815
July	340,720,000	137,449,000	-	195,145,500
August	222,230,000	132,151,000	-	149,081,374
September	292,289,430	128,572,219	-	139,797,900

Seismic Monitoring Advisory Committee Meeting
01 April 2012 to 30 September 2012
Seismic Monitoring Networks

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Permanent Monitoring / Real-Time Processing

- **Lawrence Berkeley National Laboratory**
  Installed in 2003; continued upgrades
  31 stations; M 1.0 threshold
  Primary Contact: Dr. Ernie Major (LBNL)

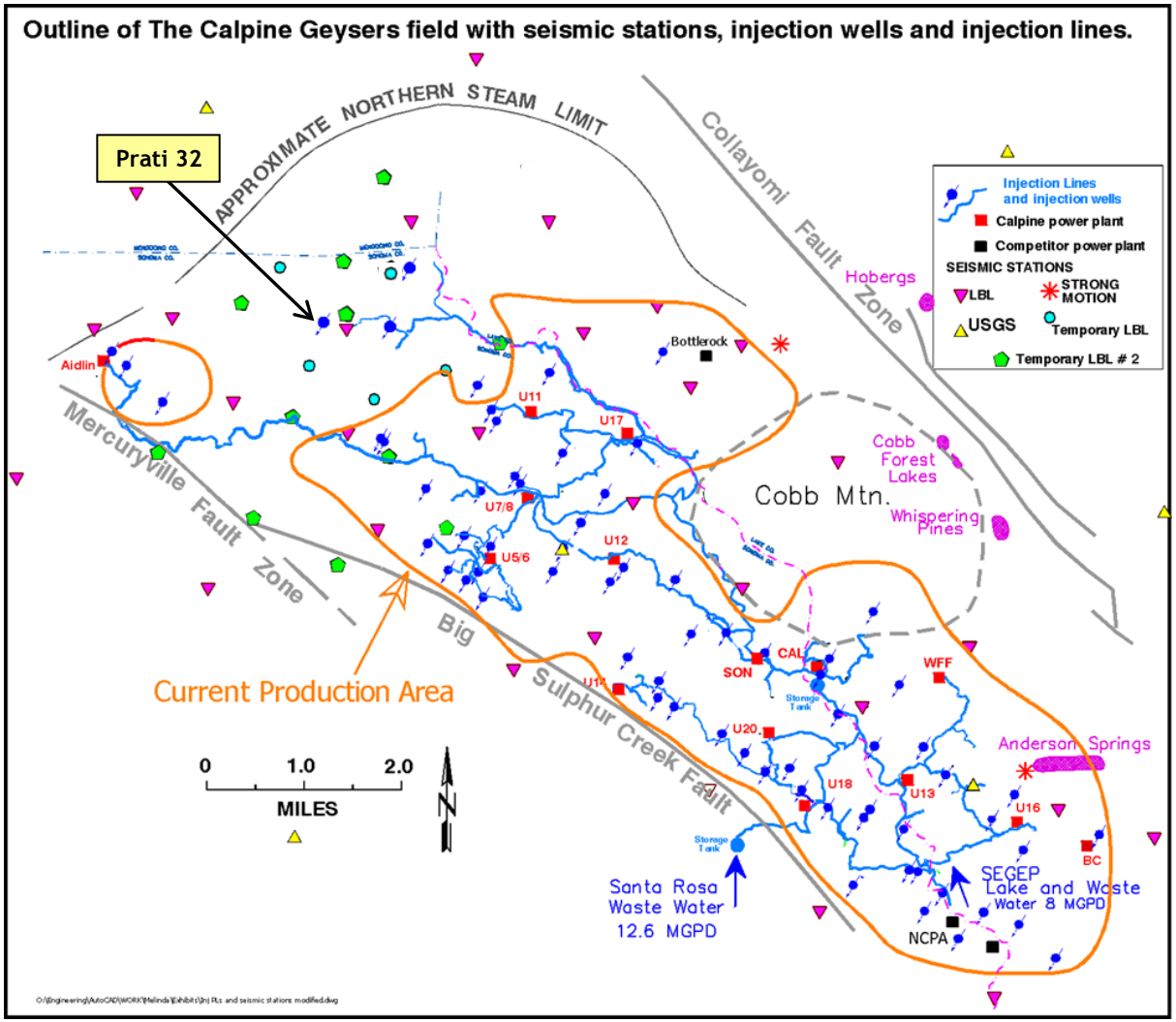
- **US Geological Survey**
  Installed in 1970's; some upgrades
  5 stations; M 1.5 threshold
  Primary Contact: David Oppenheimer (USGS)

- **Strong motion instruments: 3**
  Installed in 2003; perceived shaking
  3 stations; ~0.1% g threshold
  Primary Contact: Jim Cullen (USGS contracted)

Project Dedicated Temporary Monitoring

- **Lawrence Berkeley National Laboratory**
  Installed in 2010, ~ M1.0 threshold
  5 stations; 4-6 months storage
  Primary Contact: Dr. Ernie Major (LBNL)

- **Lawrence Berkeley National Laboratory**
  Installed in 2011, ~ M1.0 threshold
  9 stations; 3-4 weeks storage
  Primary Contact: Dr. Lawrence Hutchings (LBNL)



Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
01 April 2012 to 30 September 2012

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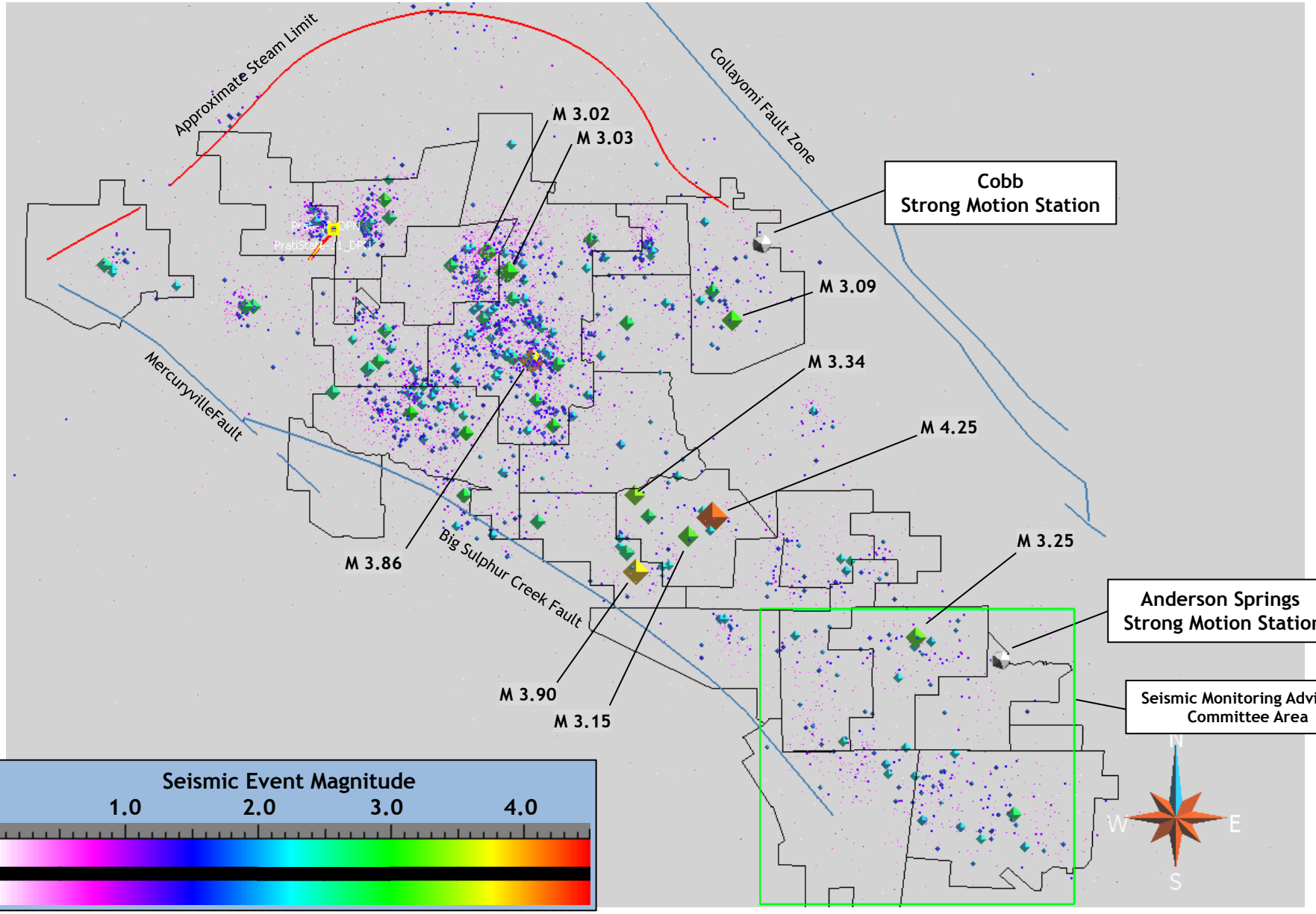

Seismic Monitoring Advisory Committee Meeting

Field-wide Seismicity Analysis
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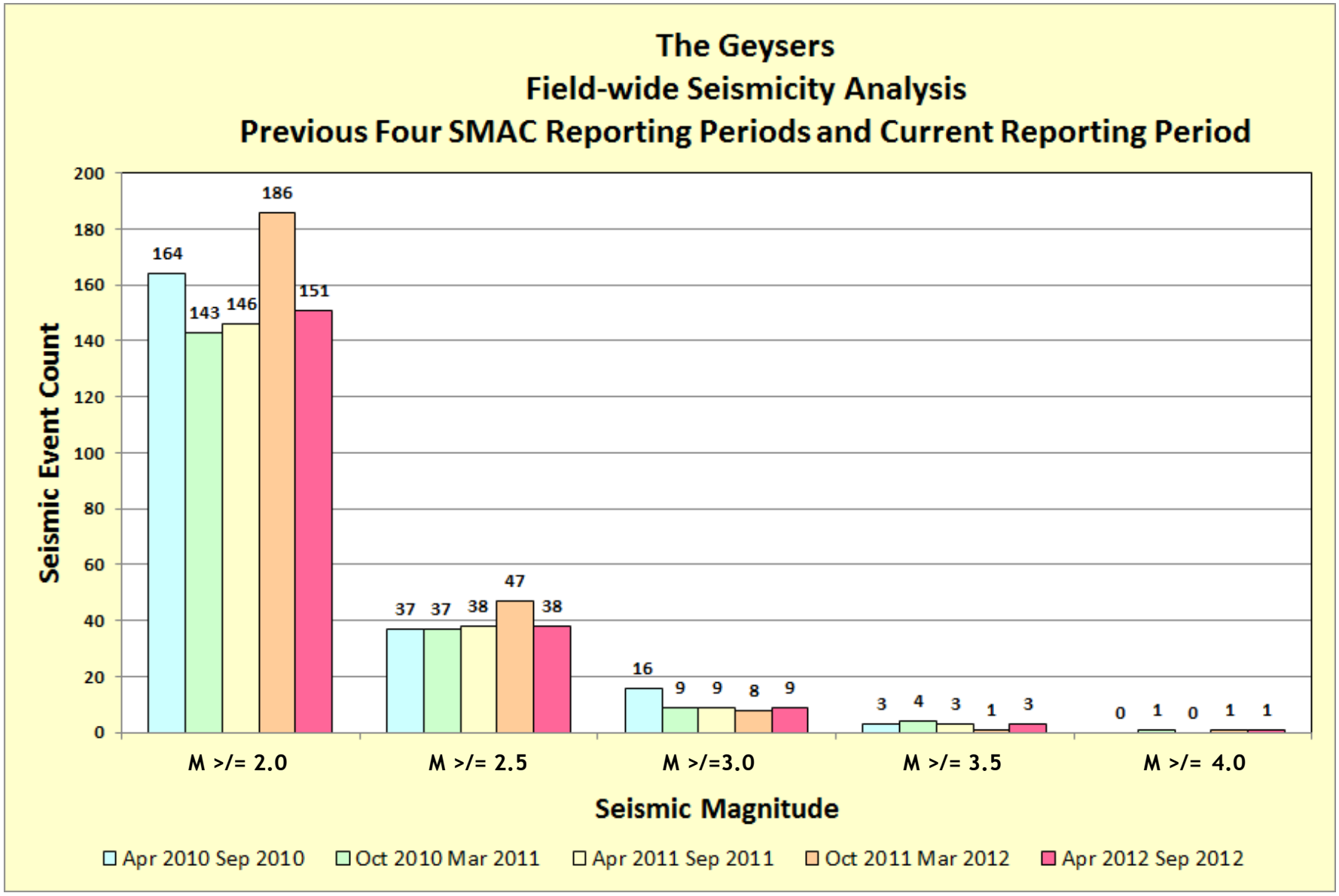

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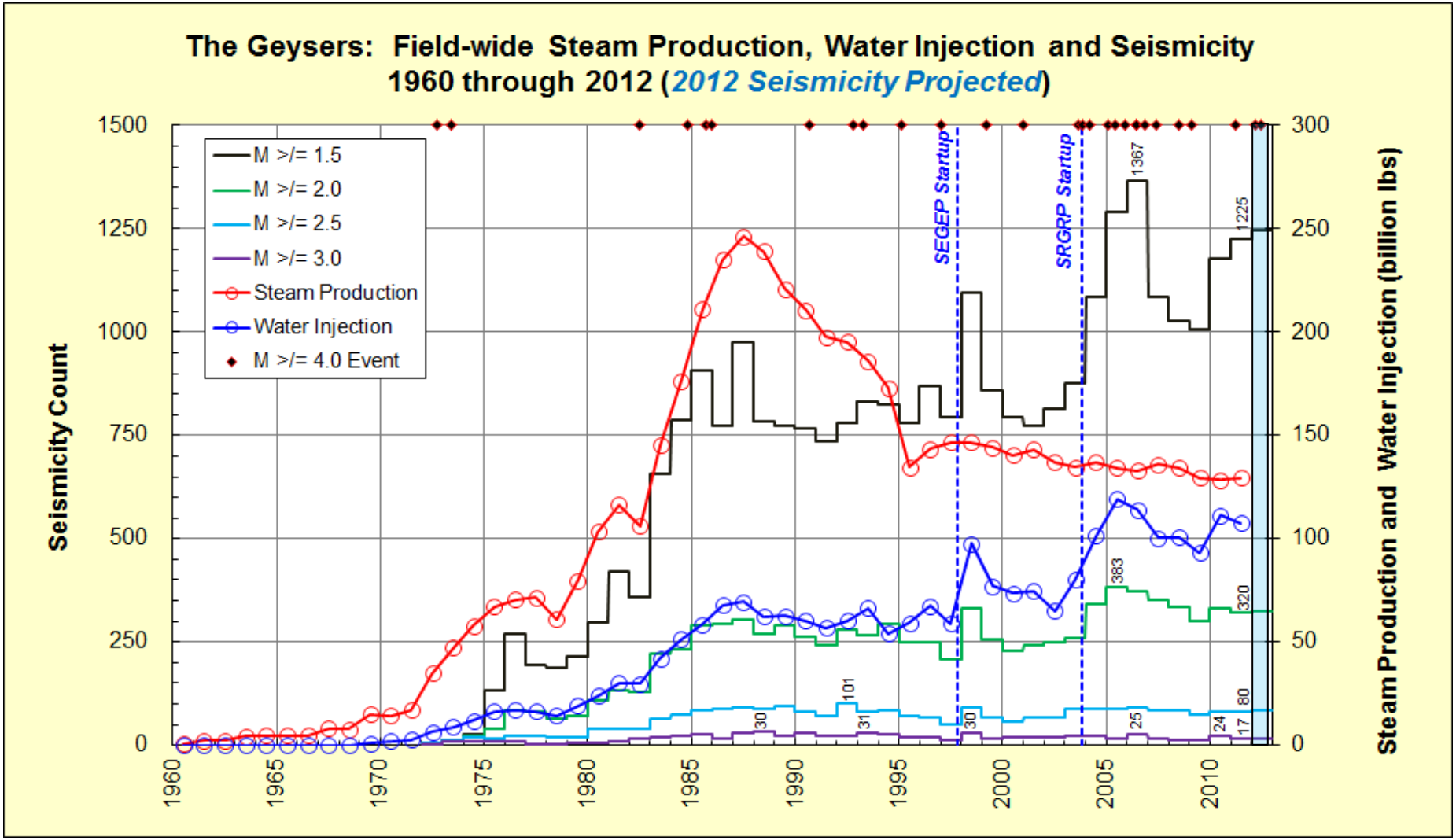
The Geysers 1960 through 2011
Field-wide Steam Production, Water Injection and Seismicity



Calpine
The Geysers 1960 through 2011
Field-wide Water Injection and M >/= 3.0 Seismicity

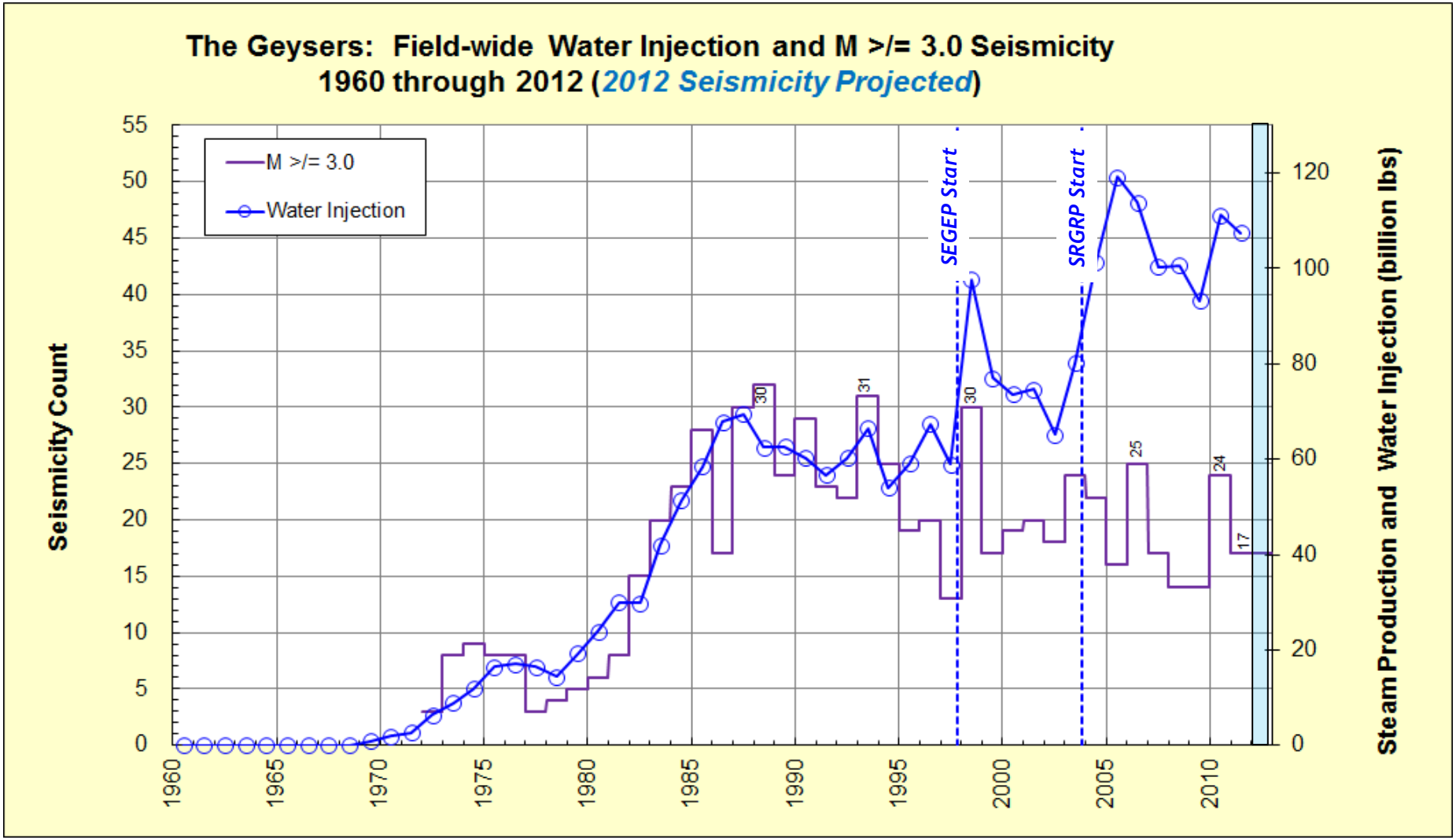


TABLE 2. EARTHQUAKE-CORRELATED STRONG-MOTION TRIGGERS.

Comparison of Peak Horizontal Acceleration (PGA) incidences during three time periods:

1. Pre-SRGRP (11 July to 18 November 2003)
2. During SRGRP (19 November 2003 to 29 February 2012)
3. Most recent biannual reporting period (1 March 2012 to 31 August 2012)

Red = Previous Reporting Period Values

		MM Intensity→	I	II -- III	IV	V	VI
			PGA (g)	0.0017	0.014	0.039	0.092
Quantity	Station	Time Period	<=0.0017	to 0.014	to 0.039	to 0.092	to 0.18
Seismicity Count	Anderson Springs	Pre-SRGRP	87	207	19	4	1
		During SRGRP	2908	4523	439	127	19
		3/1/12-8/31/12	202	238	17	3	3
Seismicity Count	Cobb	Pre-SRGRP	89	46	6	3	0
		During SRGRP	3754	2148	183	32	6
		3/1/12-8/31/12	233	150	13	4	0
Annualized Seismicity Count	Anderson Springs	Pre-SRGRP	243	577	53	11.2	2.8
		During SRGRP	382**	558	54	15.7	2.3
		3/1/12-8/31/12	454 ⇩ 401	629 ⇩ 472	54 ⇩ 34	14.5 ⇩ 6	4.2 ⇧ 6
Annualized Seismicity Count	Cobb	Pre-SRGRP	266	138	18	9.0	0.0
		During SRGRP	480	274	23	4.1	0.8
		3/1/12-8/31/12	505 ⇩ 481	256 ⇧ 310	44 ⇩ 27	2.6 ⇧ 8.3	0.0 = 0.0

Accounts for ADSP station outage 20 July 2009 to 15 August 2009, 5 to 9 August 2010, 3 to 29 June 2011, 26 to 29 Dec 2012, and 8 to 11 February, 2012.

** Corrected for 1 September 2005 to 28 February 2006 when no events were recorded in this category because the ADSP trigger threshold was set at 0.002g.

* Accounts for COB station outage 10 November 2003 to 28 January 2004, 12 October 2009 to 6 November 2009, 3 to 10 February 2010 and 18 April 2010 to 3 May 2010, 7 to 10 September, 2010, and 3 to 12 September 2011 and 20 Novemeber 2011 to 12 December 2011.

† Accounts for COB station outages for 15 to 21 April 2012.

Seismic Monitoring Advisory Committee
SRGRP Report for 1 March 2011 to 31 August 2012
Summary

CALPINE NYSE CPN

Field-wide data for 1 March 2011 to 31 August 2012 provided by Calpine to URS Corporation

- LBNL / USGS Seismicity
- Strong Motion Measurements
- SRGRP Well Monthly Injection Volumes
- Earth Quake Hotline Reports

Draft report completed by 10 October 2012

Final report with minor Calpine/URS revisions complete by 23 October 2012

Seismicity results consistent with Environmental Impact Report projections

Since SRGRP initiation: 50% increase in NCSN seismicity of magnitude >=1.5

Since SRGRP initiation: *slight decrease* in NCSN seismicity of magnitude >=3.0

Most recent seismic events of magnitude >= 4.0:

M 4.25 05 May 2012 (within reporting period #18)

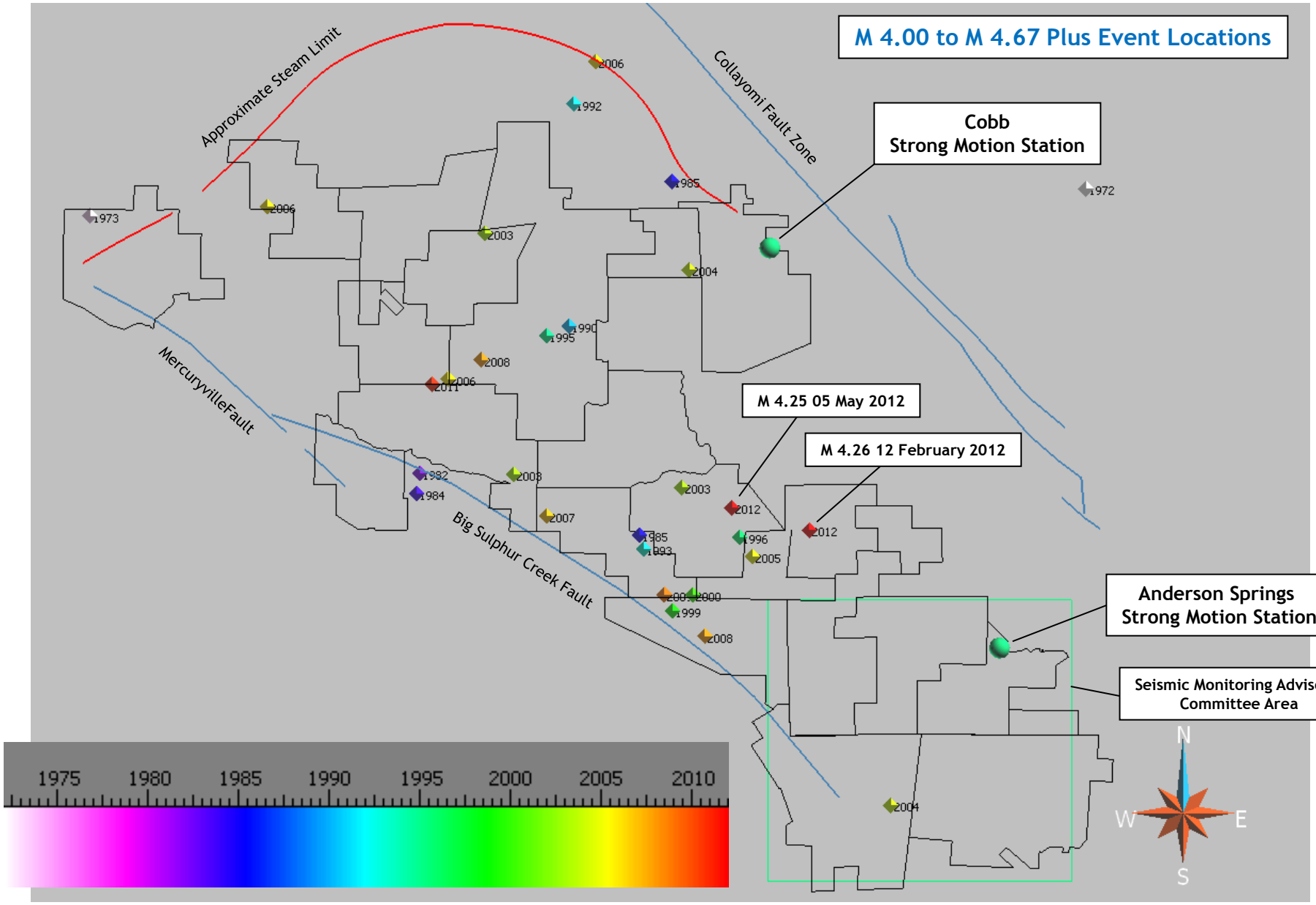
M 4.26 13 February 2012 (within reporting period #17)

M 4.46 01 March 2011

M 4.30 04 January 2009 (nearly four years ago)

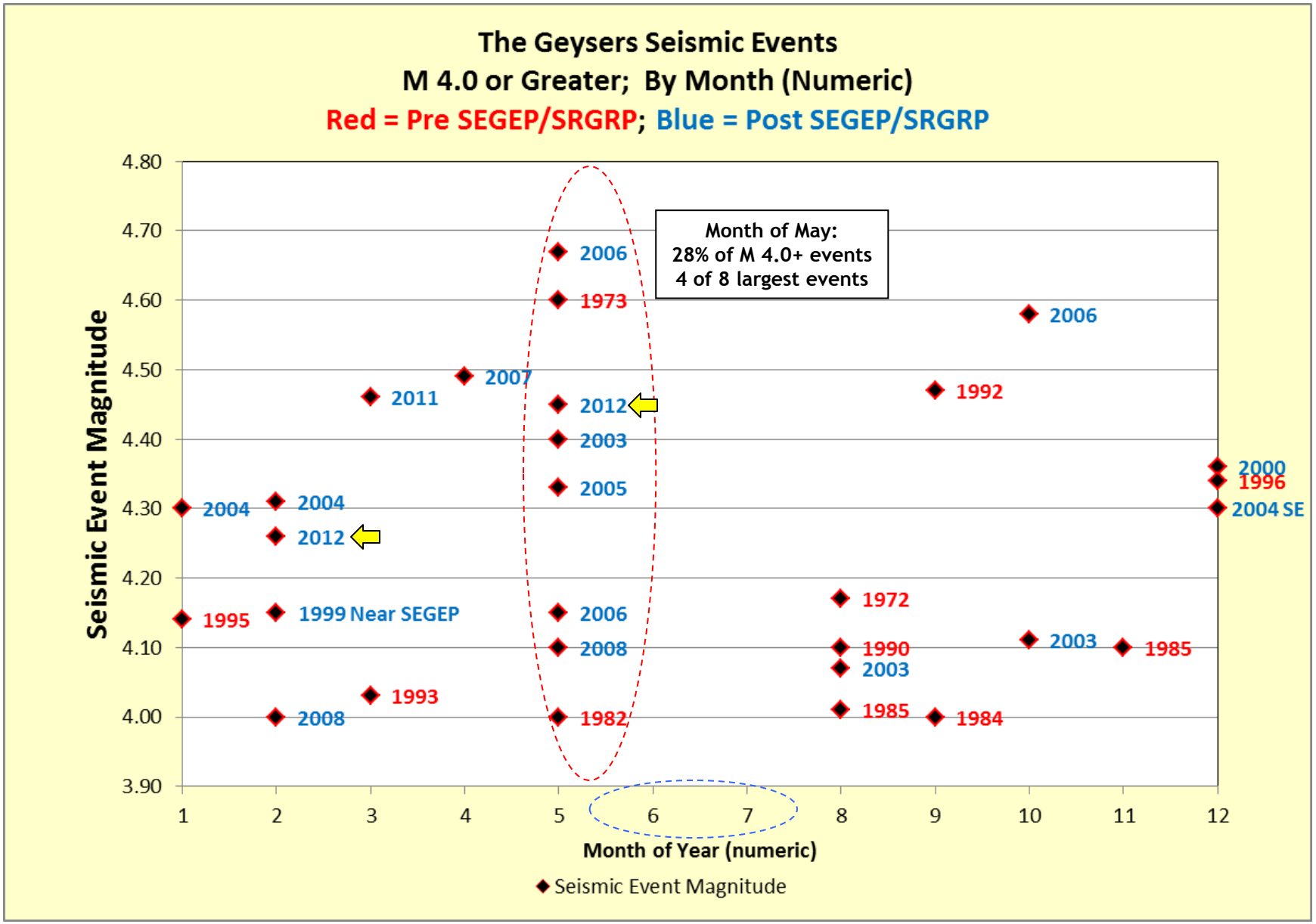
Seismic Monitoring Advisory Committee Meeting
Historical Field-wide Seismicity Analysis
Through 07 May 2012

CALPINE
NYSE CPN

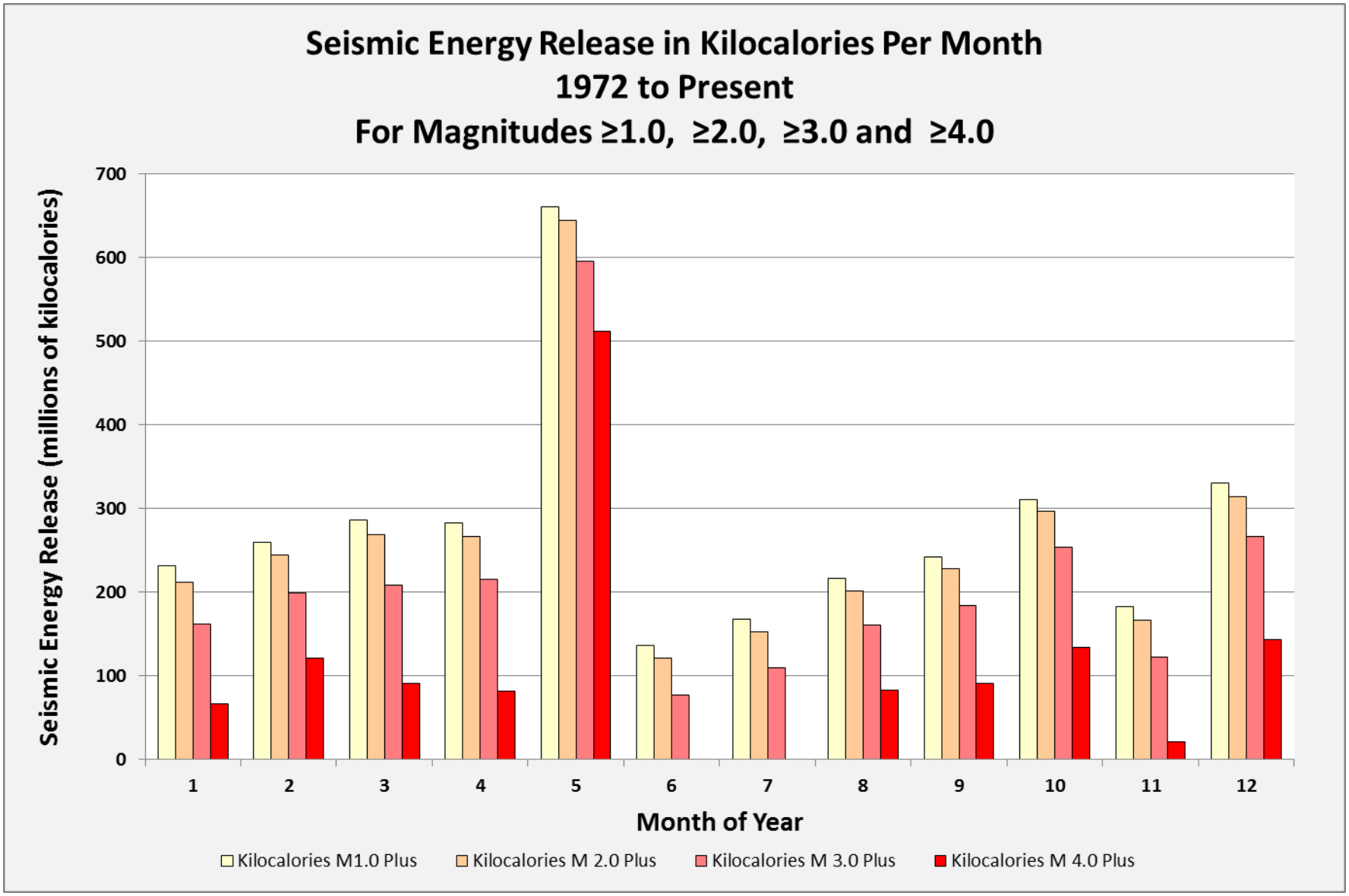


Seismic Monitoring Advisory Committee Meeting
Historical Field-wide Seismicity Analysis
Seismic Events M >/= 4.0

CALPINE NYSE CPN

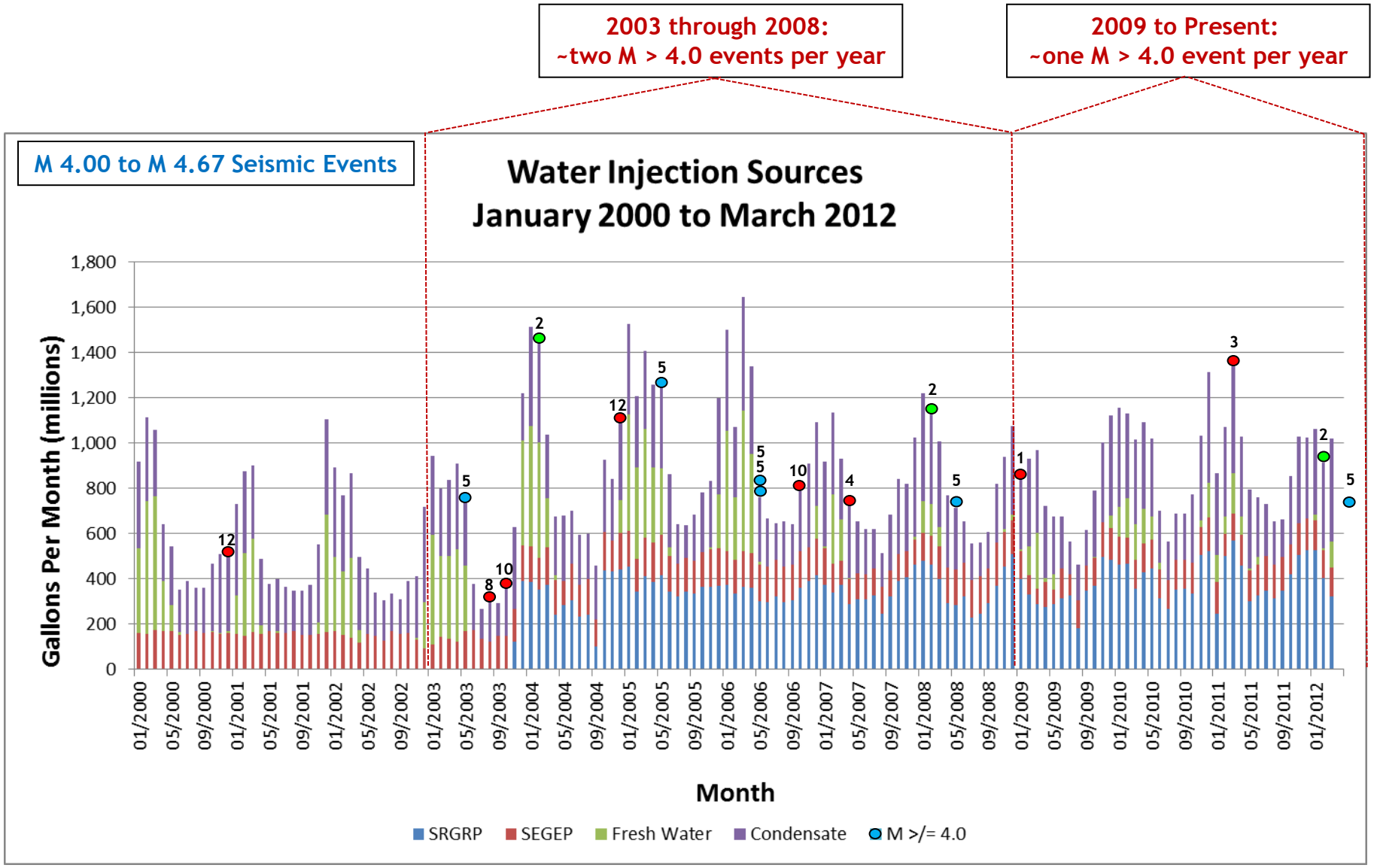


Historical Field-wide Seismicity Analysis
Seismic Events M >/= 4.0



Seismic Monitoring Advisory Committee Meeting
Historical Field-wide Seismicity Analysis
Seismic Events M >/= 4.0

CALPINE NYSE CPN



The Geysers
Additional Seismic Monitoring and Research
Moment Tensor Analysis

CALPINE NYSE CPN

In Collaboration With:
Array Information Technology - Dr. Roland Gritto
University of California Berkeley – Dr. Douglas Dreger; Sierra Boyd

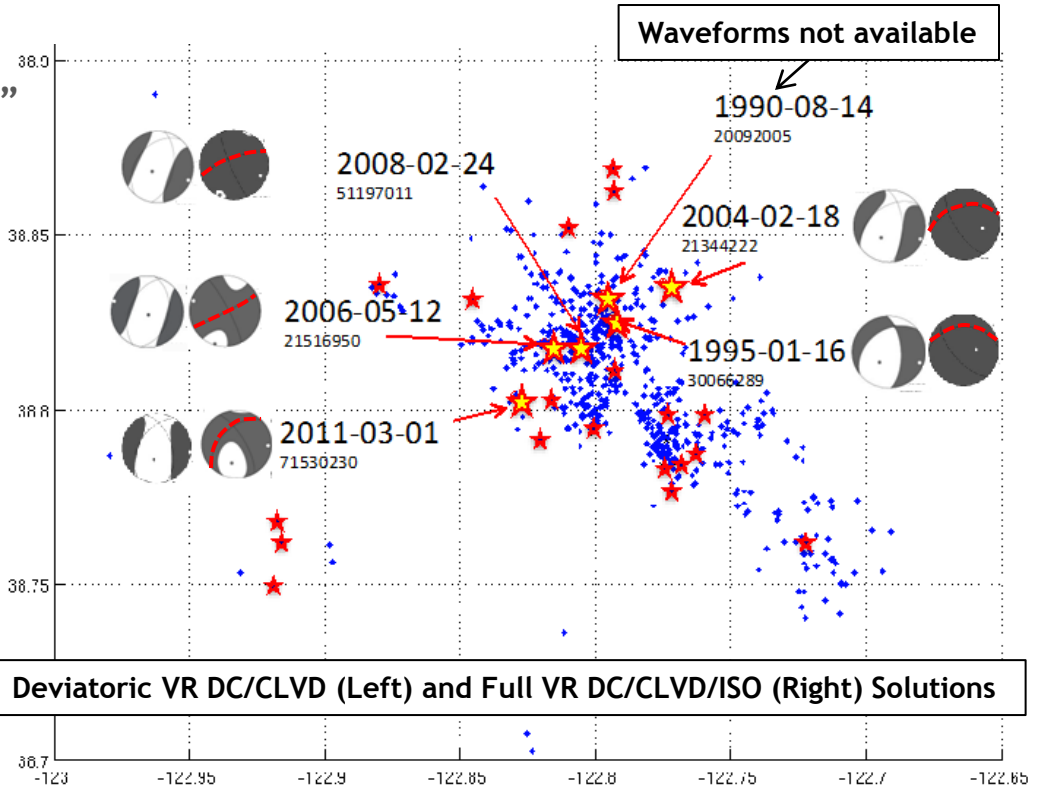
Goal:
Understand initiation and sense of movement of larger seismic events in north central Geysers
Five events greater of M_W 3.94 to 4.65 analyzed

Preliminary Results:

Best solution includes a "volumetric component" (related to thermal contraction)

SW to NE oriented high angle slip planes

Event likely initiated by thermal contraction
Shear movement occurs along SW to NE planes



Deviatoric VR DC/CLVD (Left) and Full VR DC/CLVD/ISO (Right) Solutions

Red/Yellow stars are analyzed events
labeled with date and event number

Smaller red stars (smaller) are M > 4 events.
Blue plus signs are M > 3 seismicity.

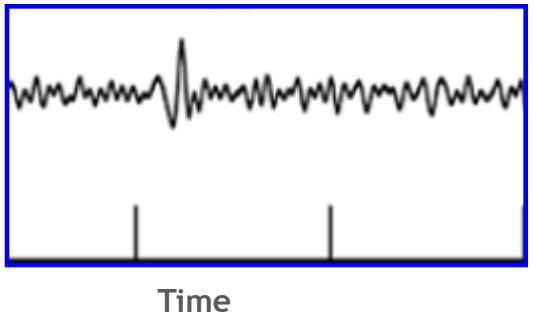
The Geysers
Additional Seismic Monitoring and Research
LBNL Sensors – Conversions from Surface to Borehole Monitoring

CALPINE NYSE CPN

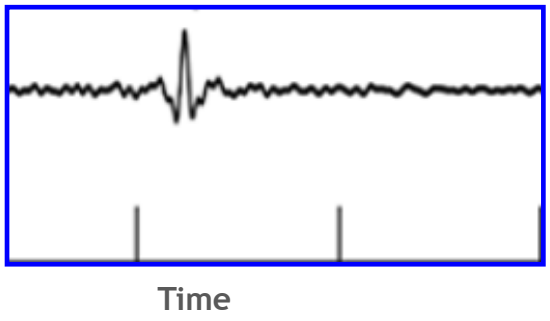
Several existing boreholes allow recording of less near-surface noise (wind, rain, machinery, …)

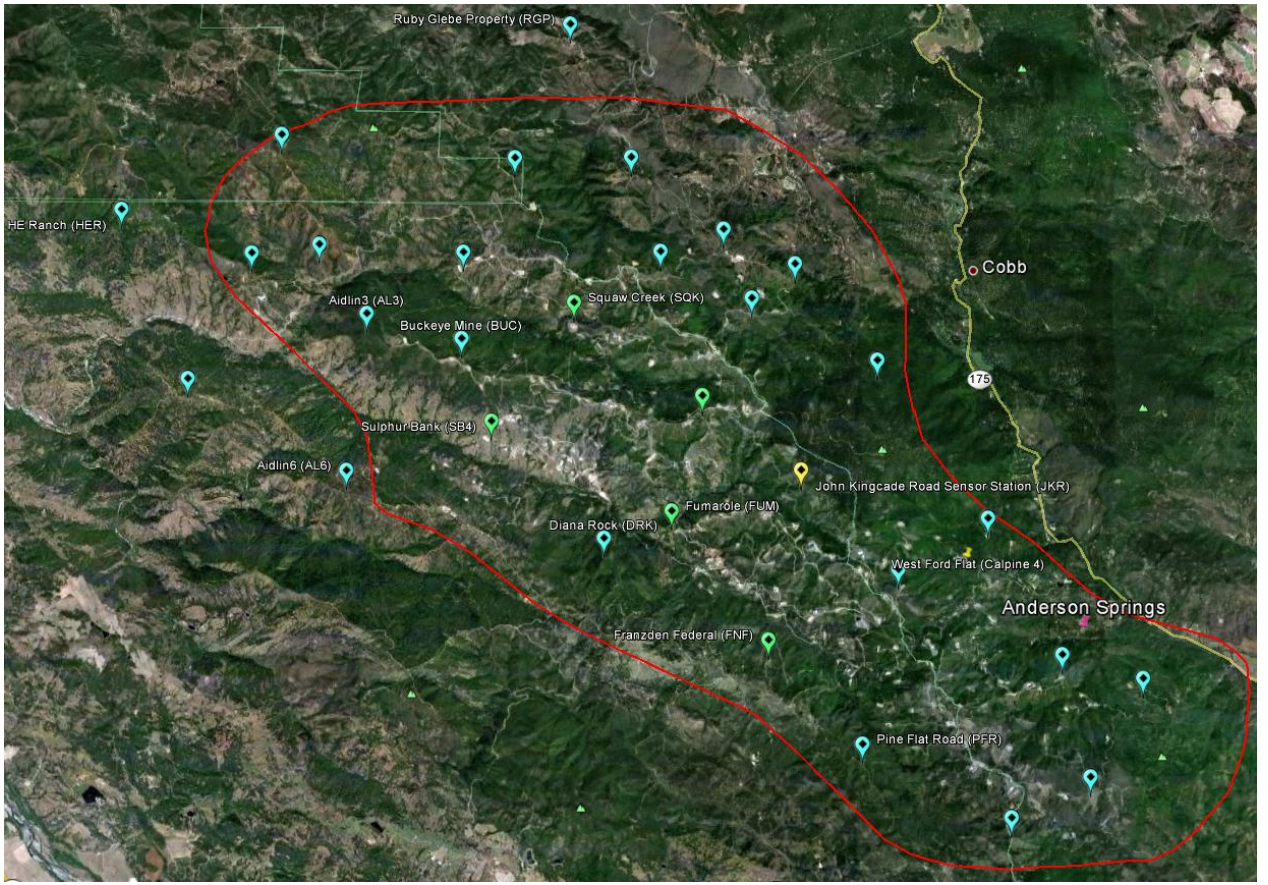
Yellow	Borehole sensor installed and evaluated
Green	Conversion to borehole sensor in late 2012 (permits received)
Blue	Remaining LBNL stations

Surface Sensor – More noise



Borehole Sensor – Less noise





The Geysers
Additional Seismic Monitoring and Research
AltaRock Microseismic Array

AltaRock has offered to transfer 8 existing AltaRock seismic monitoring boreholes to Calpine. Transfer to Calpine is likely, but is dependent on an ongoing borehole assessment.

Calpine collaboration with LBNL for additional borehole seismic monitoring would then occur.

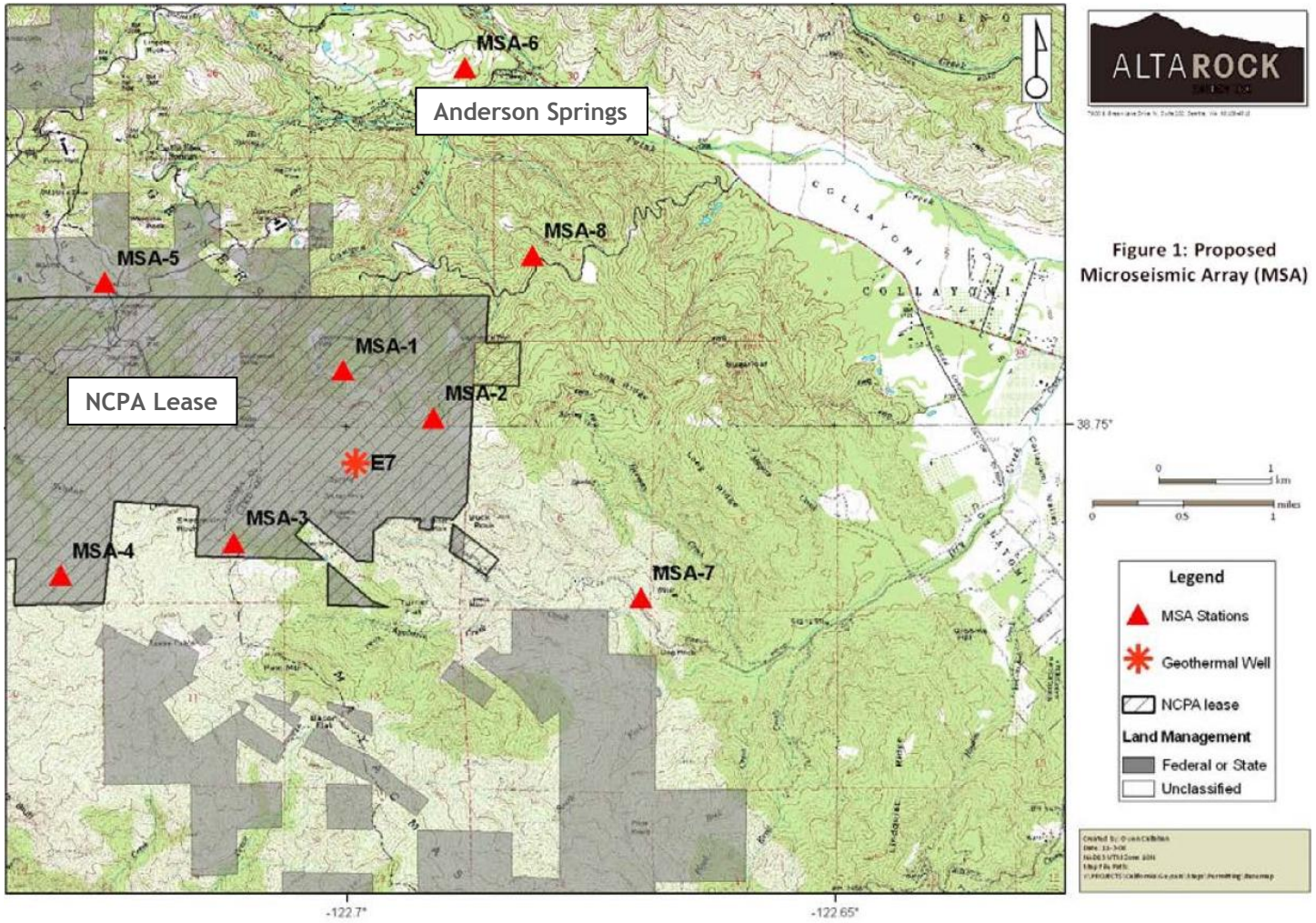


Figure 1: Proposed Microseismic Array (MSA)

The Geysers
Additional Seismic Monitoring and Research

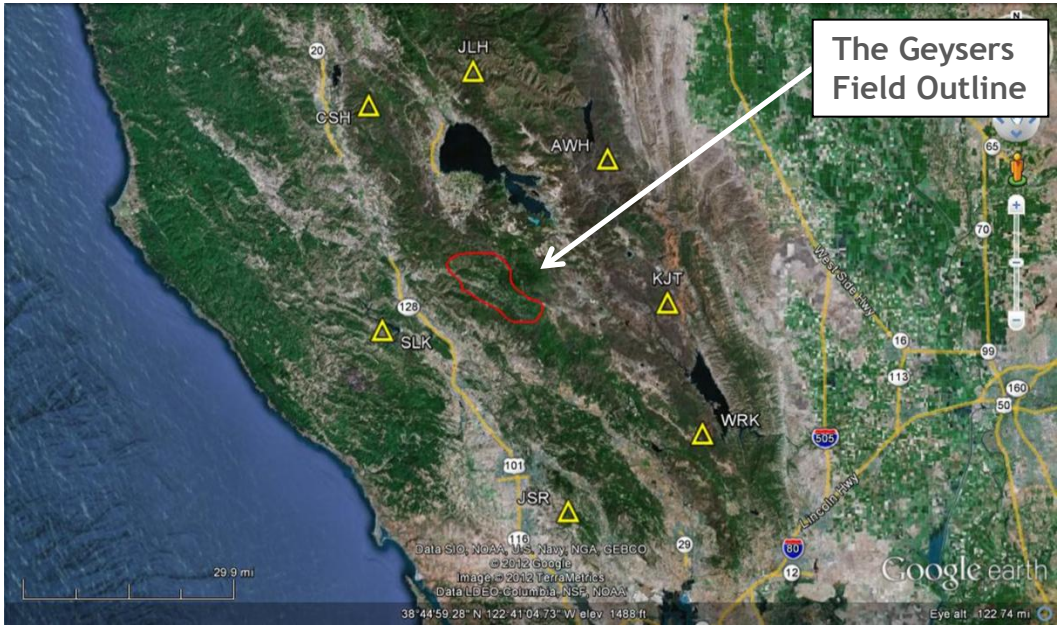
CALPINE NYSE CPN

Research Collaboration with European GEISER Project
GFZ Potsdam, Germany
Coordinated with Dr. Roland Gritto; Array Information Technology

GEISER — Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs

At The Geysers:
- 33 stations installed in early 2012:
- 26 within field boundary
- 7 beyond field boundary

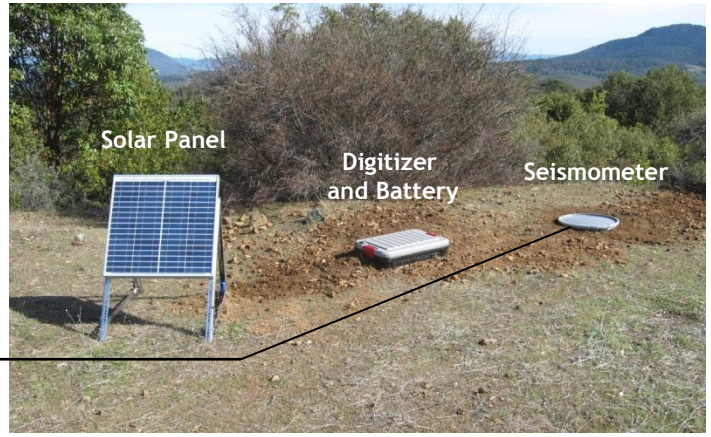
- Continuous monitoring
- Broadband
- Within and beyond geothermal field



This seismic monitoring network contributes to worldwide GEISER consortium goals:

World-wide acquisition and analysis of induced seismicity data
Understand induced seismicity and geomechanical processes
Understand consequences of induced seismicity
Strategies for the mitigation of induced seismicity

Trillium Triaxial
Seismometer
120 second to 120 Hz

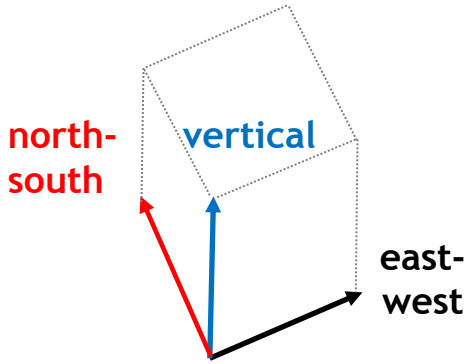


Additional Seismic Monitoring and Research

Research Collaboration with the United States Geological Survey
Primary Contact: Dr. David Oppenheimer

Traditional orthogonal seismometers

- record three components of linear motion



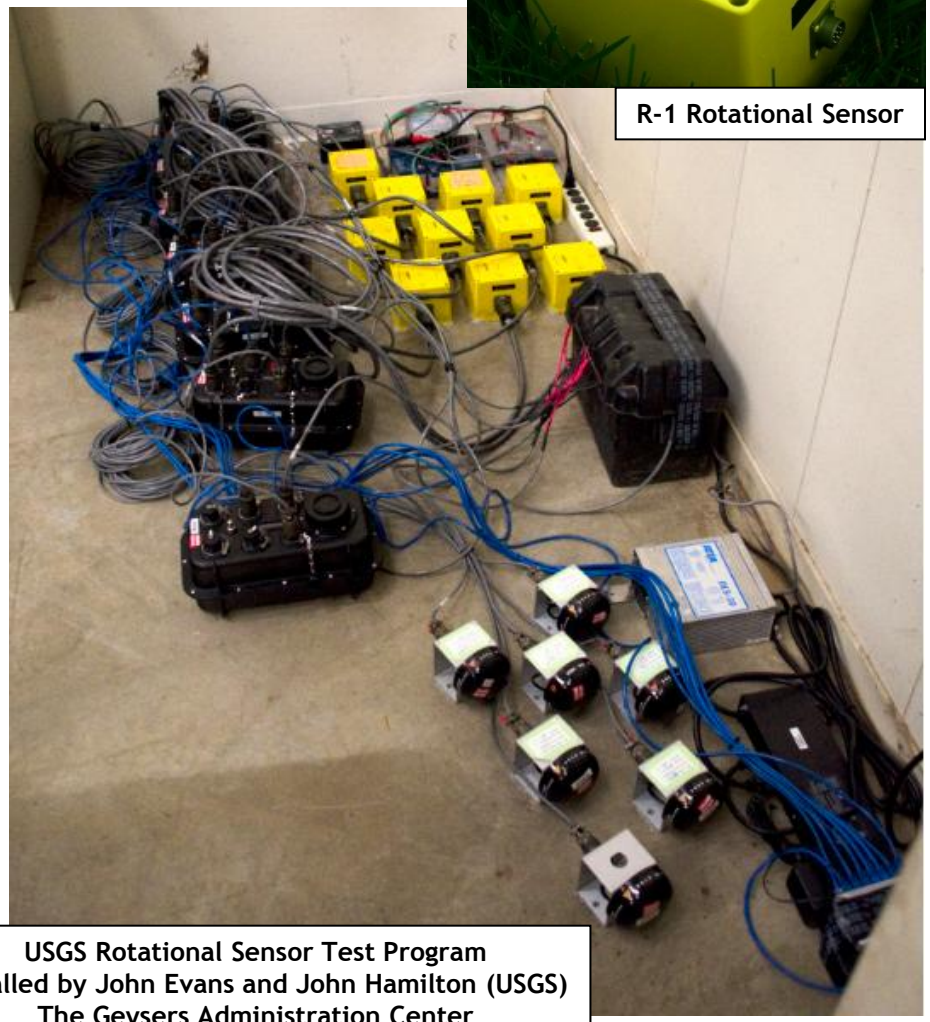
Next generation "rotational" sensors

- record six components of motion (6DOF)
- three linear + three rotational
- important for larger events involving tilt
- more faithfully recover the true ground motion

Installed 03 May 2012

- 10 *eentec Services* rotational seismometers
- 1 traditional accelerometer
- 7 dataloggers
- 7 GPS repeaters and GPS antenna (event timing)
- Real-time data recovery - USGS network

R-1 Rotational Sensor



USGS Rotational Sensor Test Program
Installed by John Evans and John Hamilton (USGS)
The Geysers Administration Center

Additional Seismic Monitoring and Research

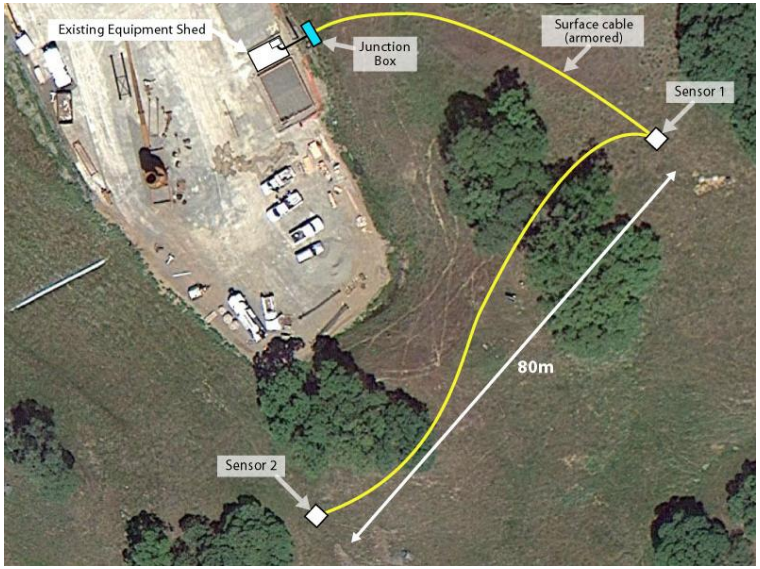
CALPINE
NYSE CPN

Research Collaboration with Seismic Warning Systems
Early Detection and Warning System for Natural Earthquakes

SEISMIC WARNING SYSTEMS

Primary goal:
Automated control (and shutdown) of natural gas, electricity and water supply for refineries, chemical plants, public schools, medical facilities, …

Two test sensors at The Geysers Prati 32 well pad.
Tied in to Calpine power and communications.



Goal:
Refinement of event detection software to:
- **Avoid false positives (caused by human activity)**
- **Distinguish between:**
  - **smaller earthquakes**
    - **(which should be ignored)**
  - **larger earthquakes**
    - **(warning and automated shutdowns)**

The Geysers

SEISMIC WARNING SYSTEMS

CALPINE NYSE CPN

Seismic wave energy travels at different speeds and different energy levels
P-waves arrive first, are rarely damaging, and may provide advance notice of damaging earthquakes

Body Waves (travel through earth's interior)

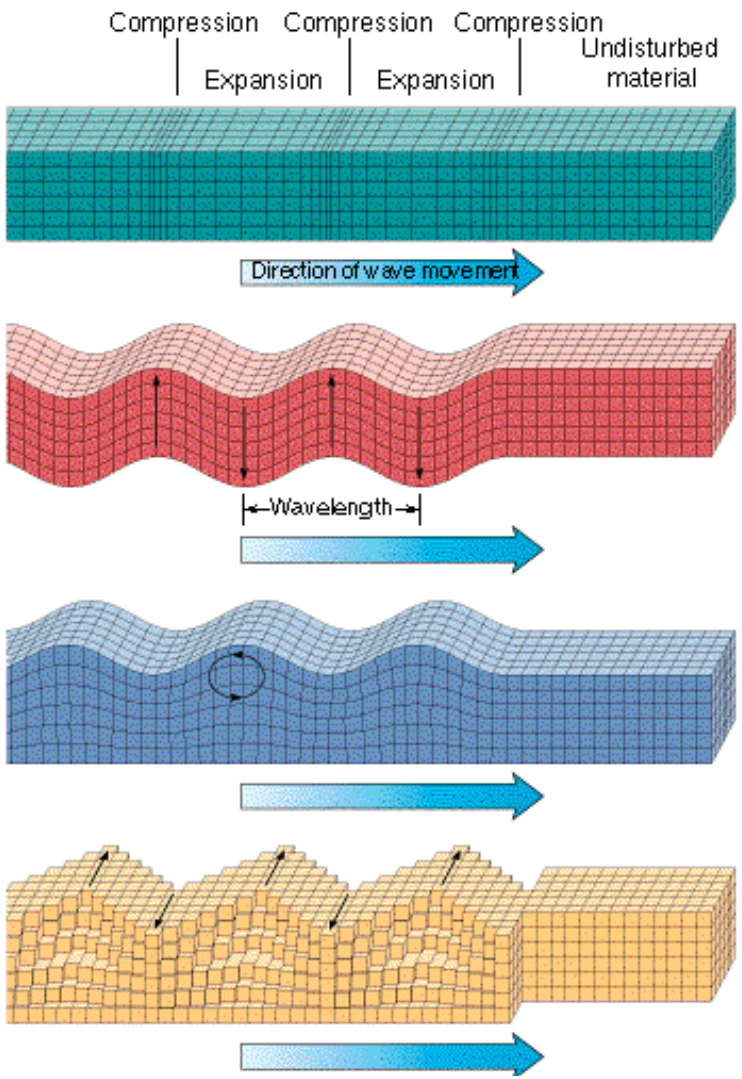
Longitudinal P-waves →
compression/rarefaction
fastest; ~ 5-7 km/sec

Transverse S-waves →
shear motion
~ 60% of P-wave velocity ~ 3-4 km/sec

Surface Waves (confined to the near surface)

Rayleigh Waves →
retrograde ellipse motion
~ 90% of S-wave velocity

Love Waves →
horizontally polarized (guided) shear motion
~ 90% of S-wave velocity
largest amplitude



Seismic Monitoring Advisory Committee

Calpine Communication and Public Relations

CALPINE
NYSE CPN

Voicemail Hotline (877) 4-GEYSER
- Calls transcribed and reviewed weekly since 12/16/2003
- Compared with strong-motion measurements for Cobb and Anderson Springs stations

Detailed Reporting of Events of M>/= 4.0 (or M >/=3.5; MMI >/= 5; PGA >/= 3.9%)
- Provided to Calpine employees, community leaders, industry and academic representatives

Biannual Reporting to the City of Santa Rosa
- SRGRP injection and seismicity relationships
- URS Corporation geophysicists perform independent data analysis and report generation

Biannual Meeting with Seismic Monitoring and Advisory Committee
- Field activity and seismicity update to community leaders, industry and academic representatives

Geothermal Visitors Center
- Wednesday – Saturday
- Updated Expansion Including Enhanced Geothermal System (EGS) exhibits

Geysers Field Tours
- Free group tours approximately monthly spring through fall (www.geysers.com)

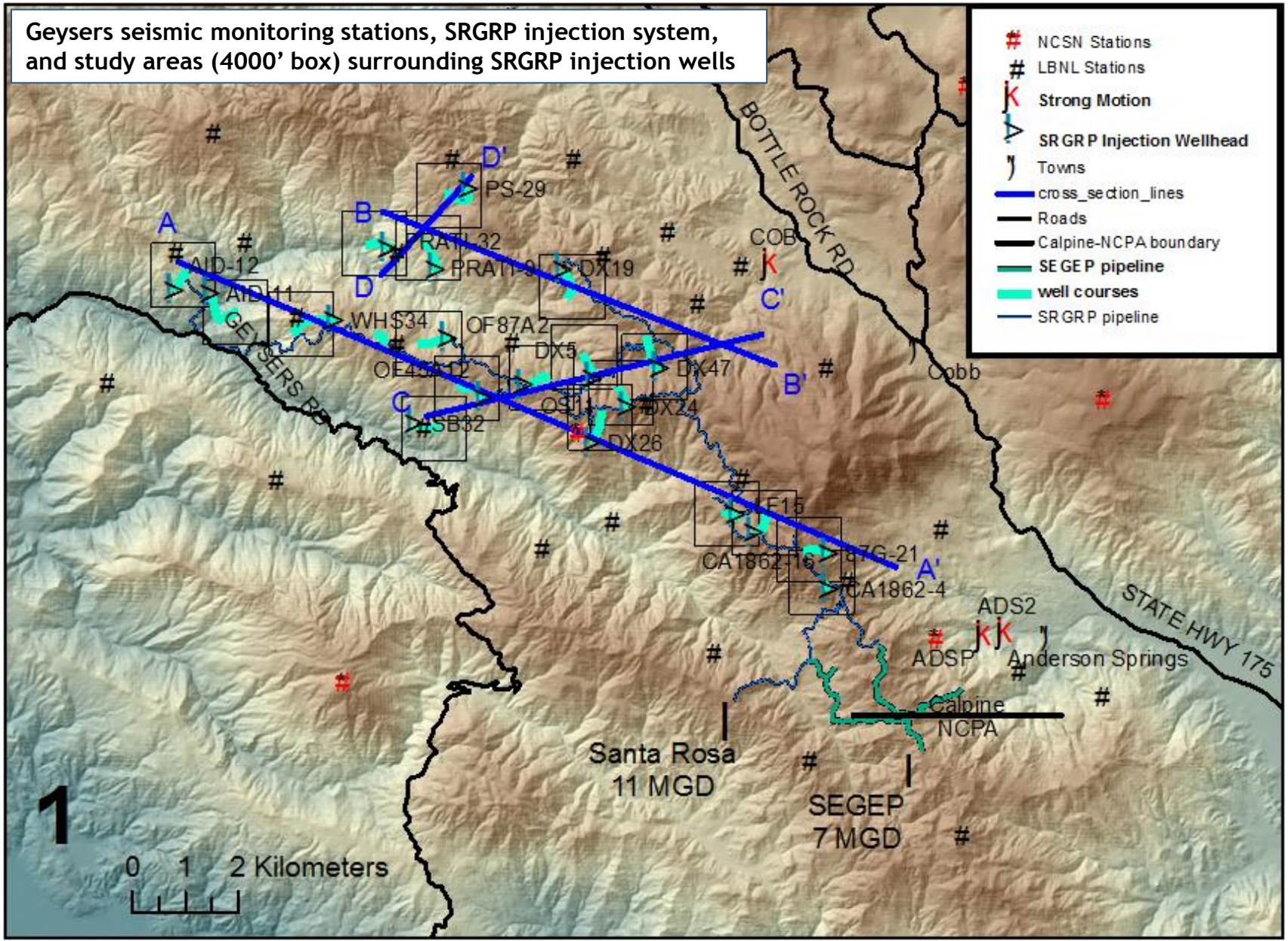
Community Newsletter
- 2-3 publications yearly by email and posted to www.geysers.com

Northwest Geysers ENHANCED GEOTHERMAL SYSTEM Demonstration Community Updates
- Five Community Updates since Oct 2011 Project Start-up

CALPINE®

NYSE CPN

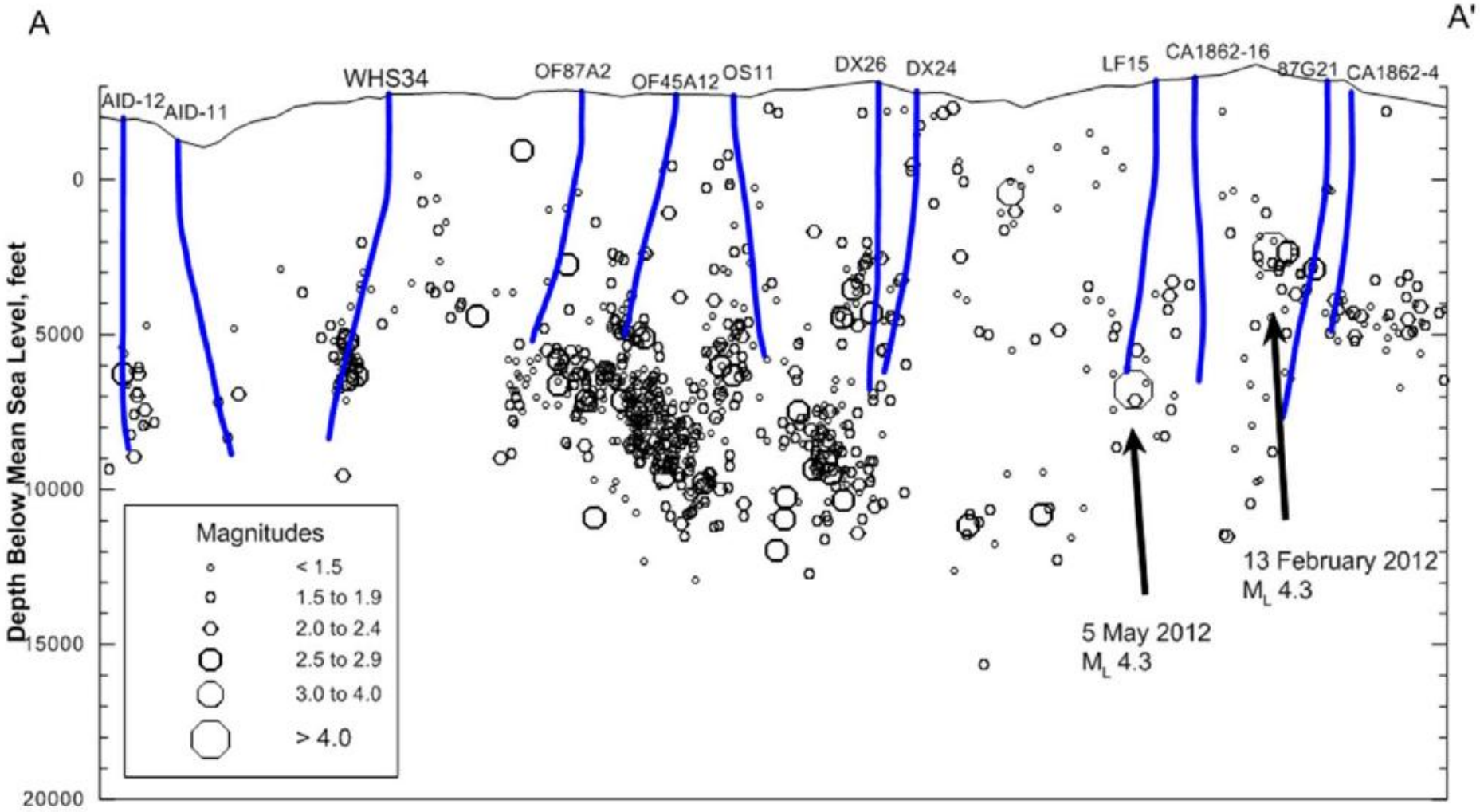
Seismic Monitoring Advisory Committee
Seismicity Analysis
SRGRP Report for 1 March 2012 to 31 August 2012



Seismic Monitoring Advisory Committee
Seismicity Analysis
SRGRP Report Seismicity Cross Section for Previous Full Year

CALPINE
NYSE CPN

1 September 2011 to 31 August 2012

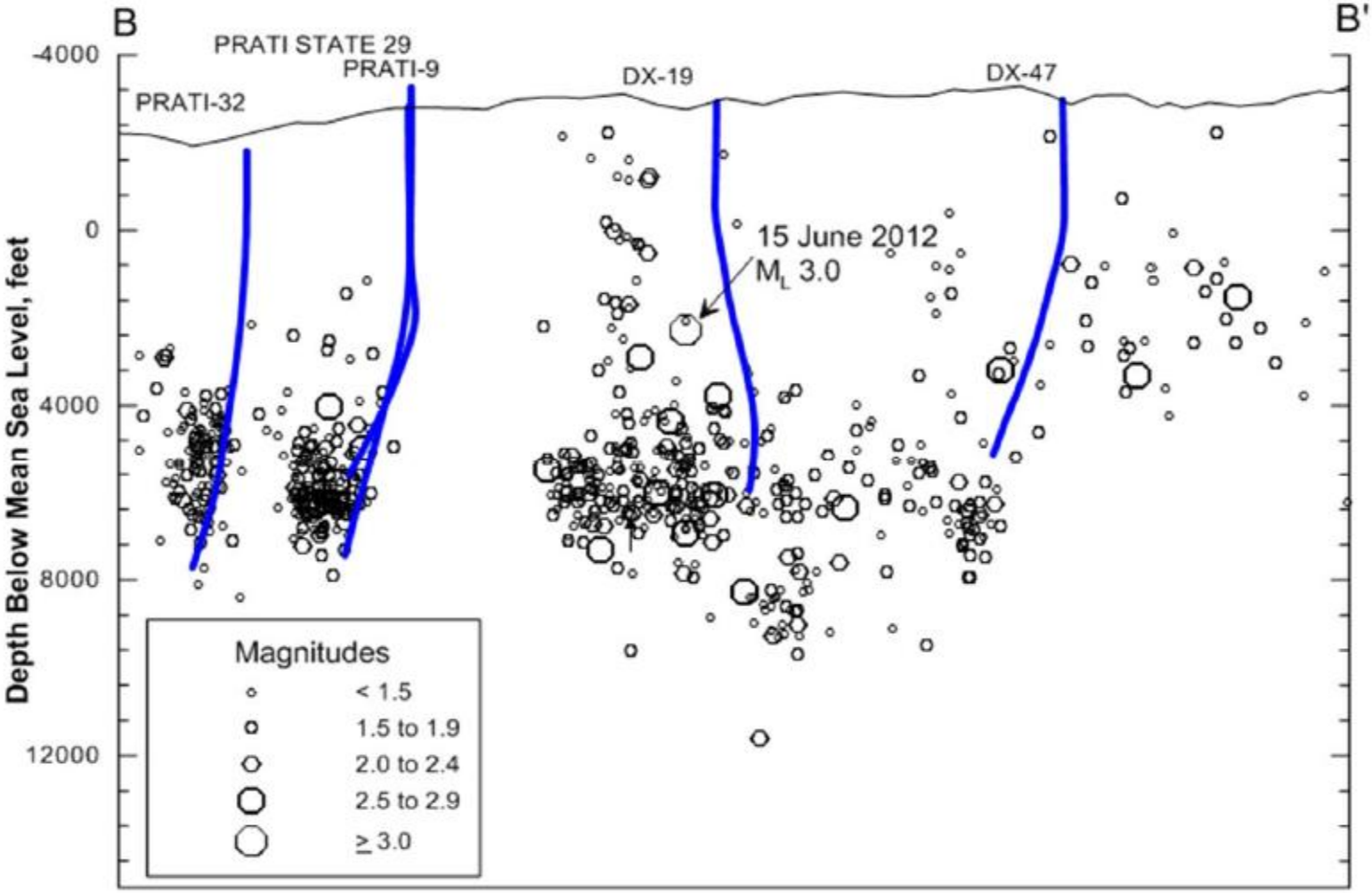


Cross-section A-A' showing SRGRP injection well courses and earthquakes 1 September 2011 – 31 August 2012

Seismic Monitoring Advisory Committee
Seismicity Analysis
SRGRP Report Seismicity Cross Section for Previous Full Year

CALPINE
NYSE CPN

1 September 2011 to 31 August 2012

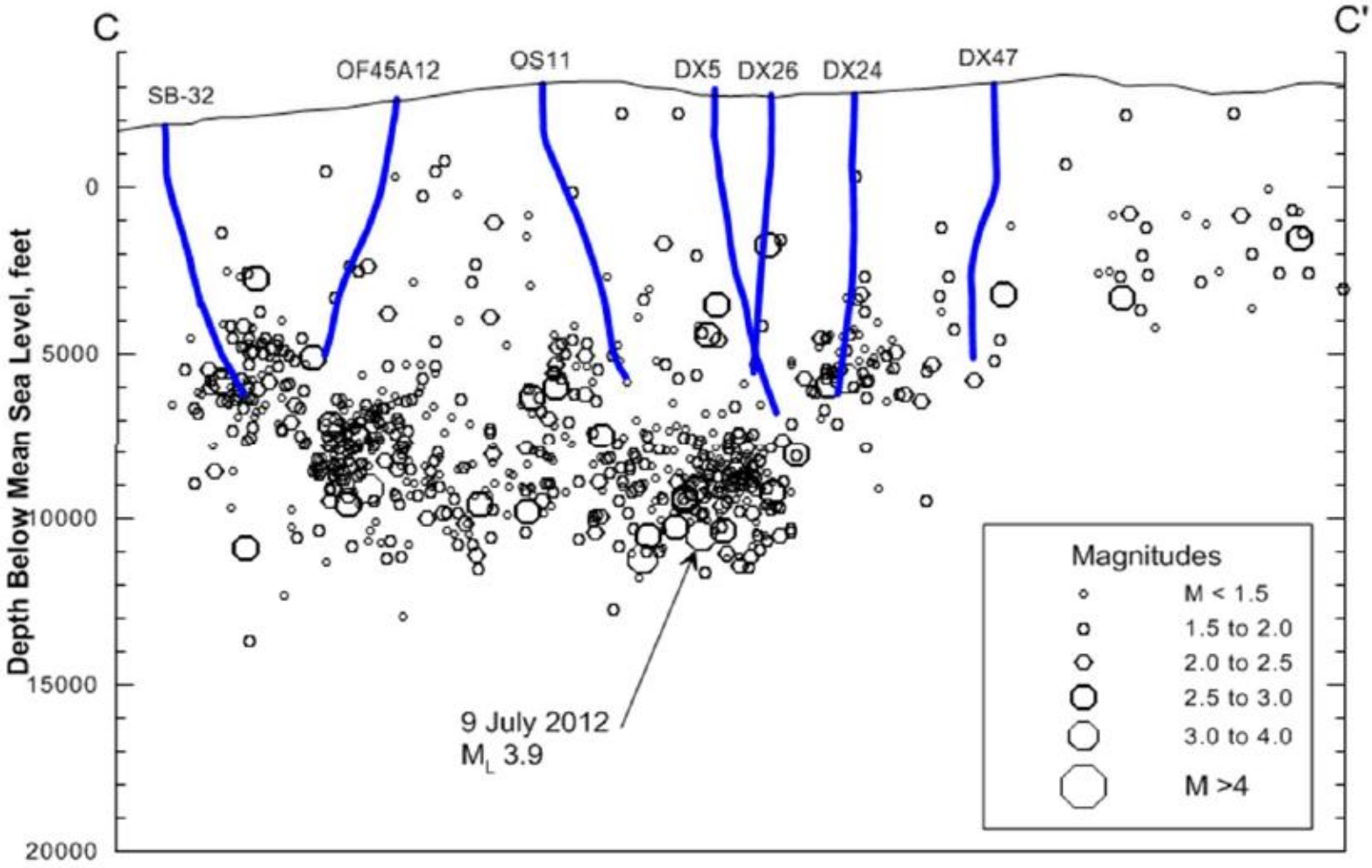


Cross-section B-B' showing SRGRP injection well courses and earthquakes 1 September 2011 – 31 August 2012

Seismic Monitoring Advisory Committee
Seismicity Analysis
SRGRP Report Seismicity Cross Section for Previous Full Year

CALPINE
NYSE CPN

1 September 2011 to 31 August 2012

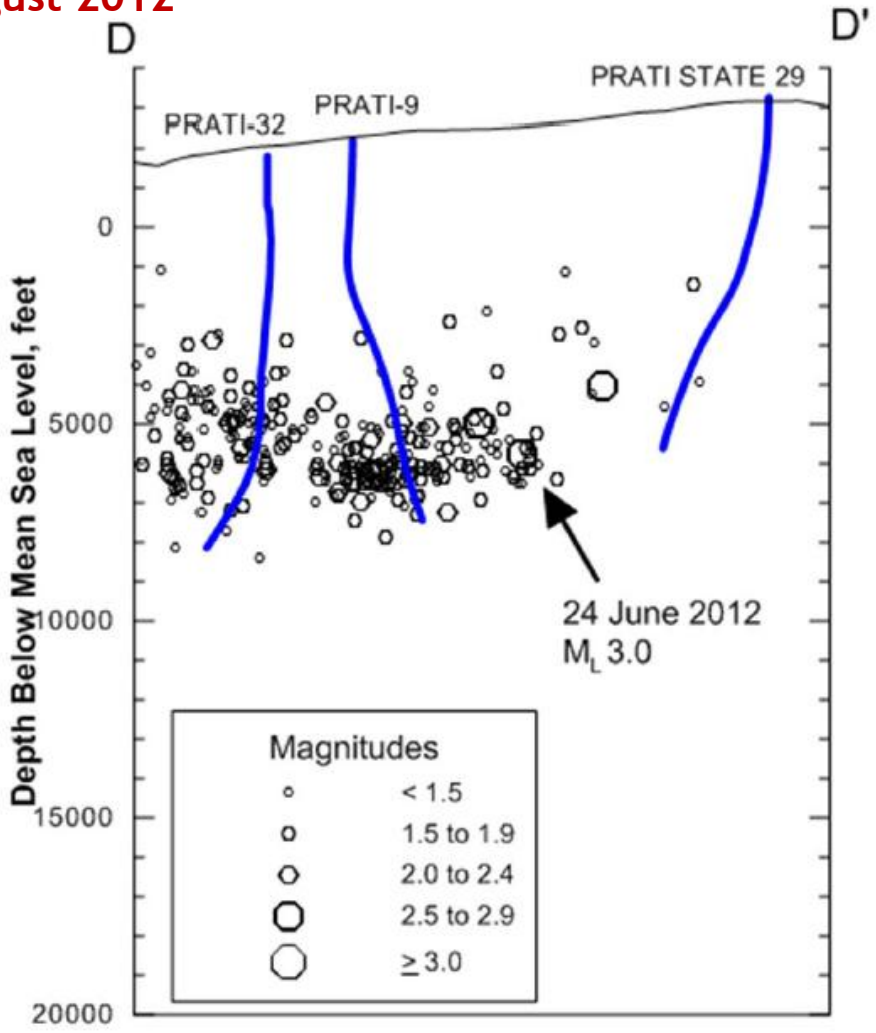


Cross-section C-C' showing SRGRP injection well courses and earthquakes 1 September 2011 – 31 August 2012

Seismic Monitoring Advisory Committee
Seismicity Analysis
SRGRP Report Seismicity Cross Section for Previous Full Year

CALPINE
NYSE CPN

1 September 2011 to 31 August 2012



Cross-section D-D' showing SRGRP injection well courses and earthquakes 1 September 2011 to 31 August 2012