

**Seismic Monitoring
Advisory Committee Review**

**14 November 2011
Geothermal Visitors Center
Middletown, California**

**Reporting Period:
1 April 2011 to 30 September 2011**



Seismic Monitoring Advisory Committee Meeting

Strong Motion Instruments / EQ Hotline



Anderson Springs Strong Motion

Power loss on 3 June 2011 (mistakenly removed by local utility provider)

Power fully restored 29 June 2011

Attempted to keep system active on battery power during repair period

However, data loss for 4 June 2011 to 22 June 2011

Cobb Strong Motion

Station went offline 3 Sept 2011

Power failure repaired by Calpine facilities expert

Data loss for 3 Sept 2011 to 13 Sept 2011

Site Selection for Additional Strong Motion Stations

URS Corporation contracted for study in progress

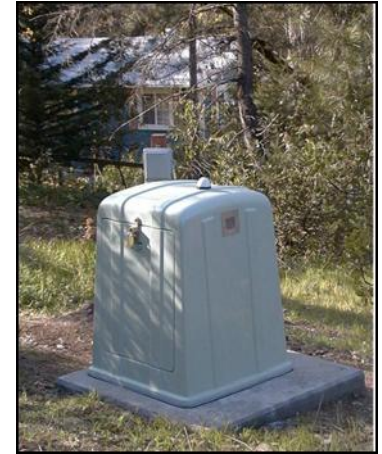
Analysis of EQ Hotline and existing reports

On-site assessment of structures and local conditions

Toll-free seismic hotline (1-877-4GEYSER)

Continues operation

26 voicemails transcribed and reviewed 1 April 2011 to 30 September 2011



Anderson Springs ETNA
Strong Motion Station

Seismic Monitoring Advisory Committee Meeting

Additional Seismic Monitoring



GFZ Potsdam GEISER Project

GFZ (*GeoForschungsZentrum*) German Research Centre for Geosciences
30 broadband and continuous monitoring autonomous seismic stations

Program and Goals

Cleared customs last week; seismic instruments now at The Geysers
Installation in late 2011 for a one year deployment
Improved understanding of seismic velocity and seismic attenuation
Track possible seismic velocity changes with subsurface fluid variations

Participants:

Calpine (USA)
Array Information Technology (USA)
BRGM (France)
GFZ Potsdam (Germany)

NW Geysers EGS Demonstration

14 temporary LBNL stations (discussed on next slide)



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Seismic Monitoring Networks

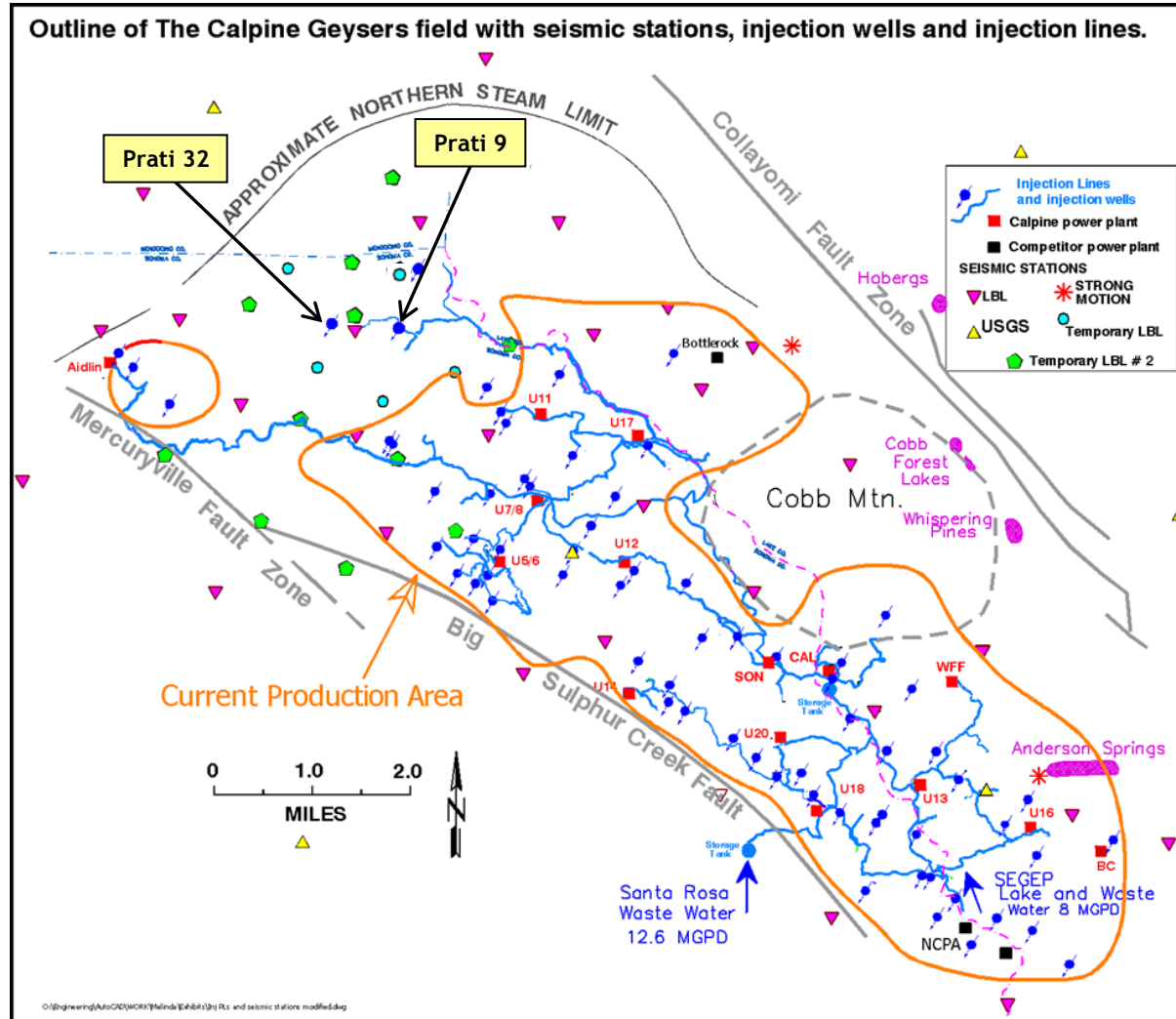


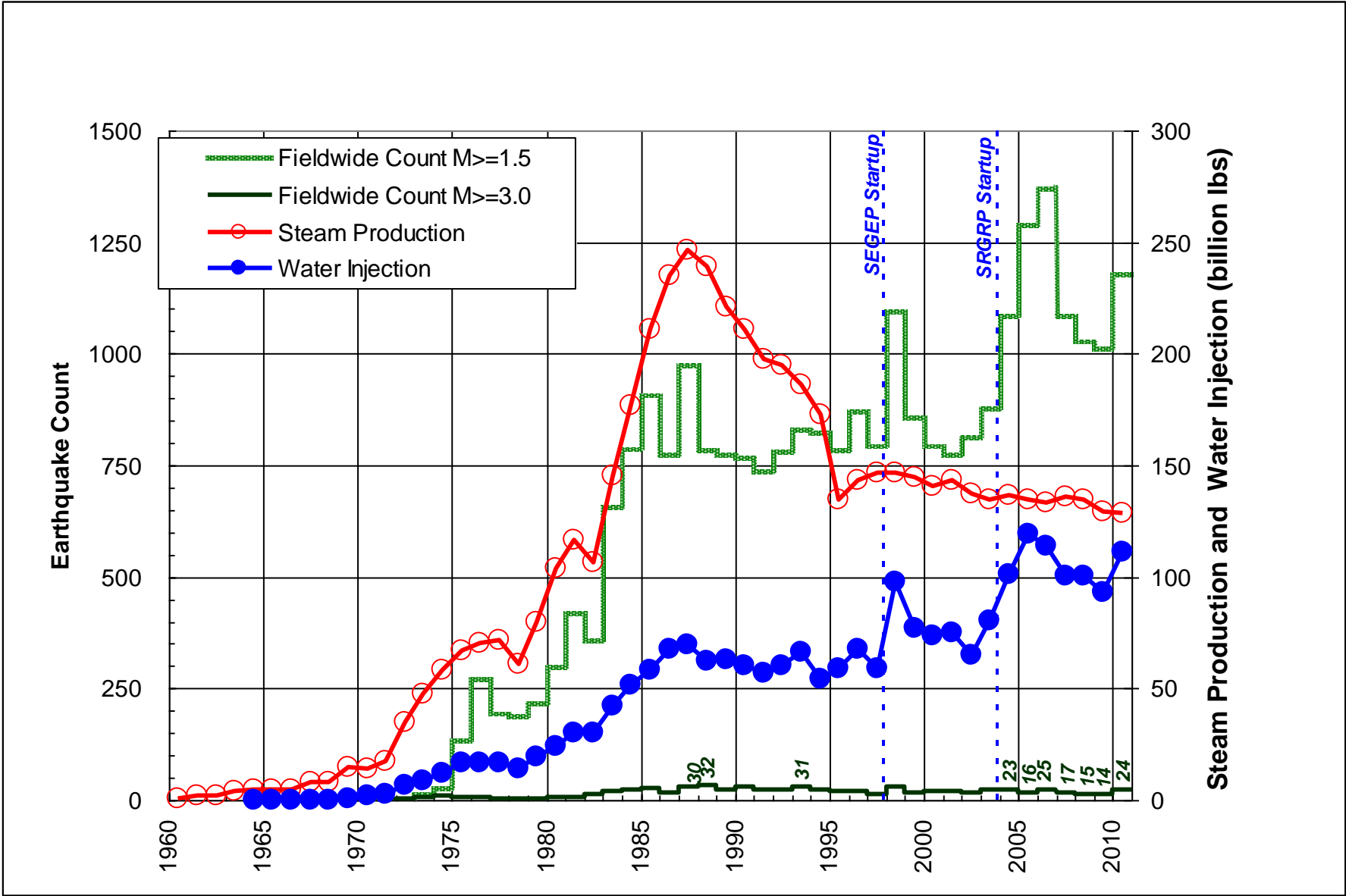
Permanent Monitoring / Real-Time Processing

- ▼ **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)

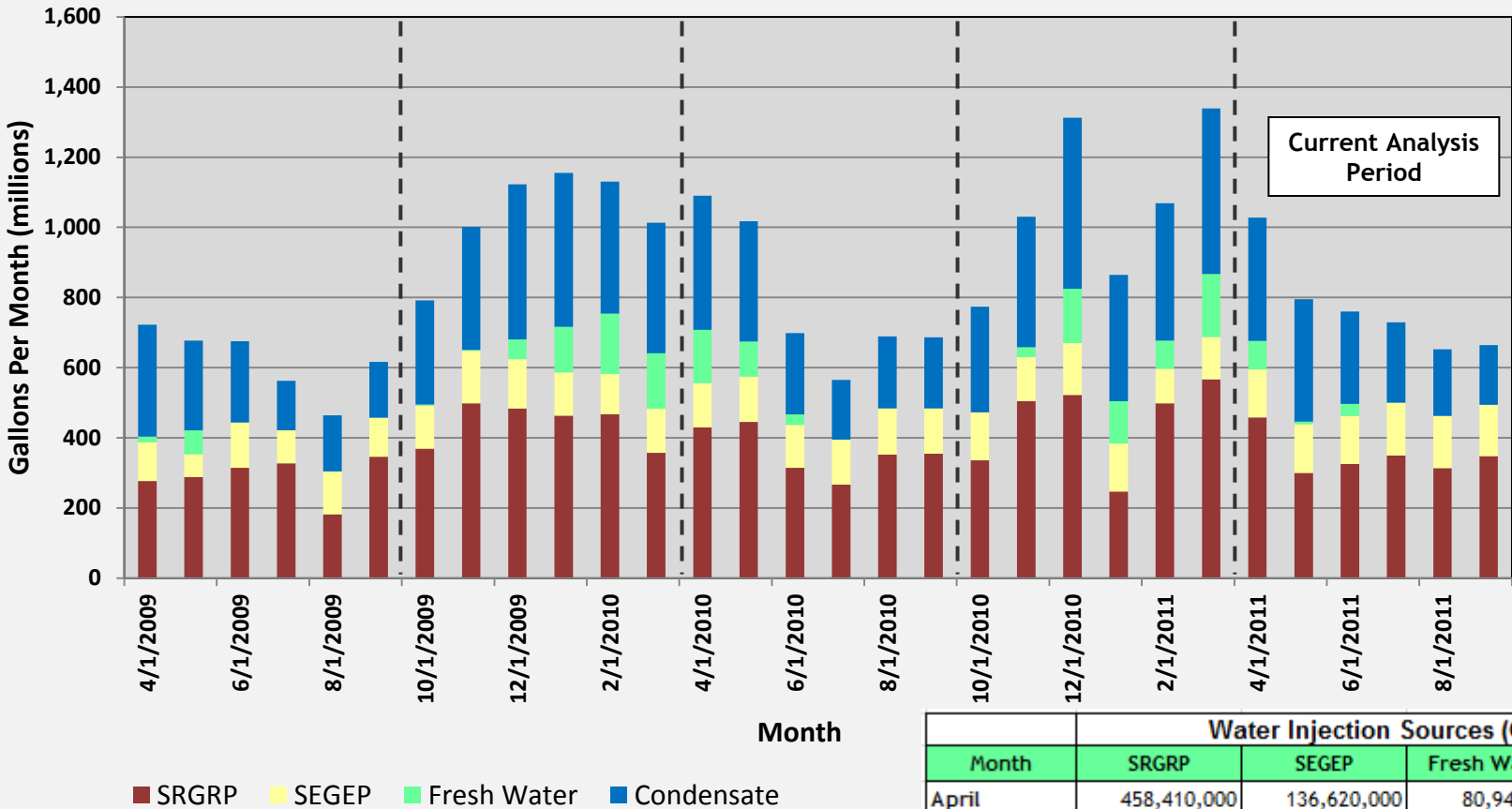
Project Dedicated Temporary Monitoring

- **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)





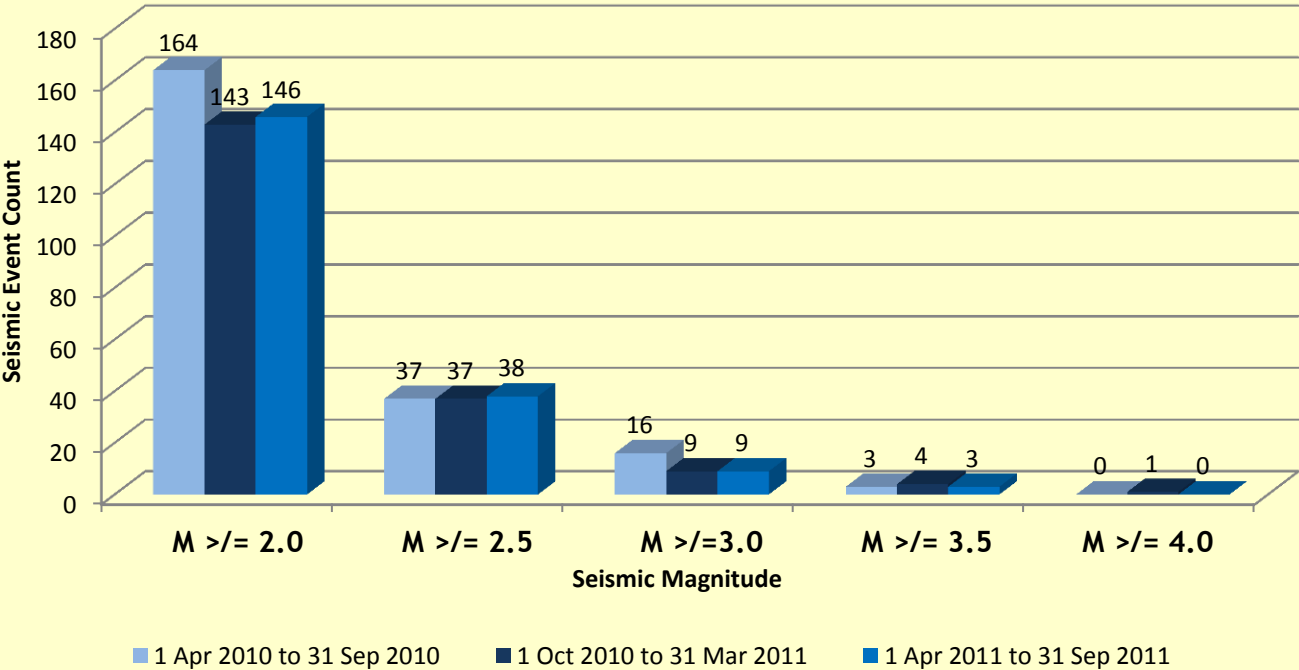
Water Injection Sources
1 April 2009 to 30 Sept 2011



SRGRP water injection shutdown during the past reporting period:
08/15/2011 (ramping down on this day) to 08/19/2011 (ramping up on this day)

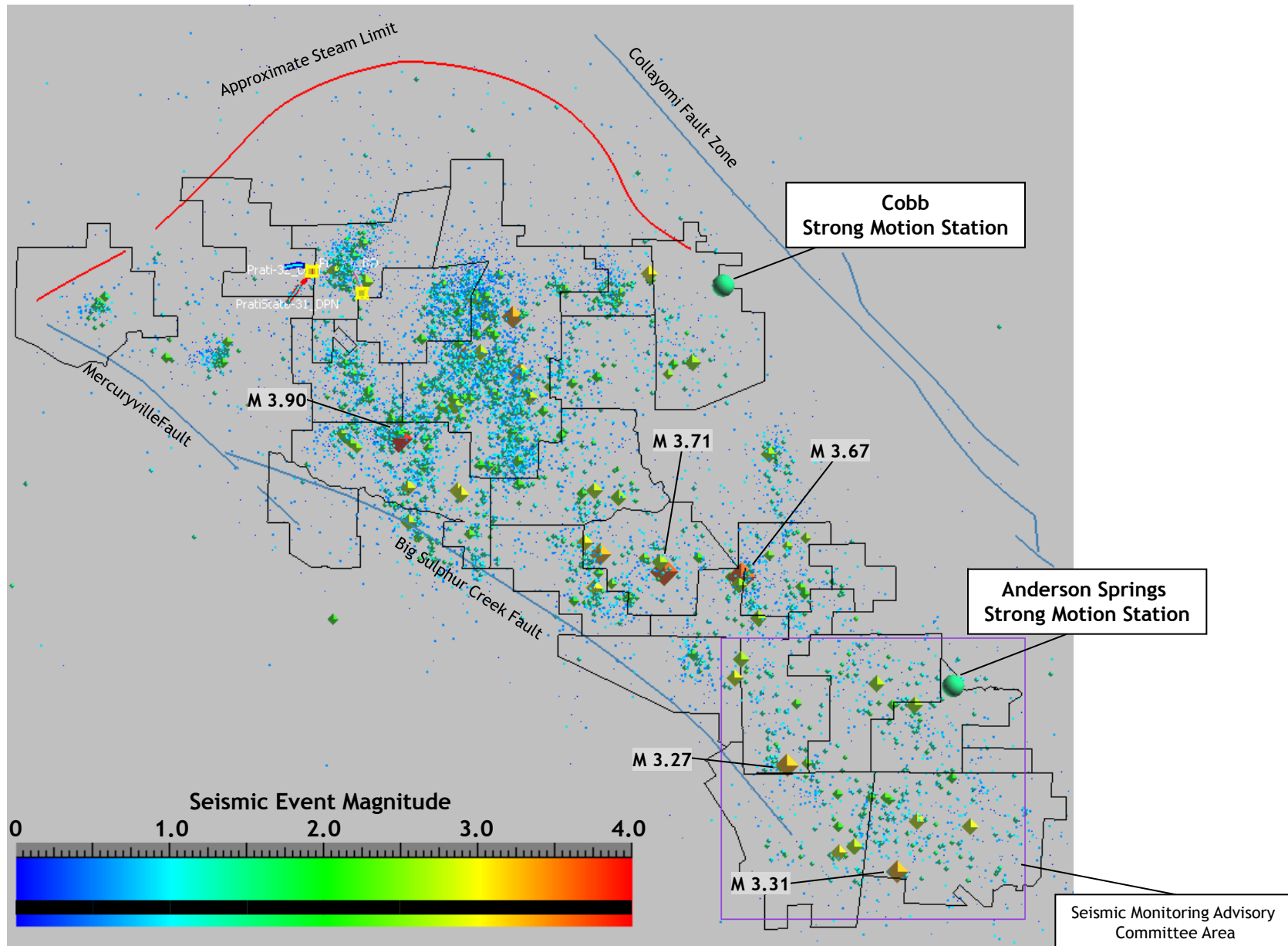
Water Injection Sources (Gallons)				
Month	SRGRP	SEGRP	Fresh Water	Condensate
April	458,410,000	136,620,000	80,941,388	351,850,869
May	299,620,000	138,571,000	8,406,956	348,233,834
June	325,390,000	137,243,000	34,246,940	263,271,300
July	349,190,000	150,462,000	-	229,824,775
August	313,500,000	149,180,000	-	189,361,615
September	348,180,000	146,024,000	-	169,966,697

Field-wide Seismicity Analysis
Current and Previous Two SMAC Reporting Periods



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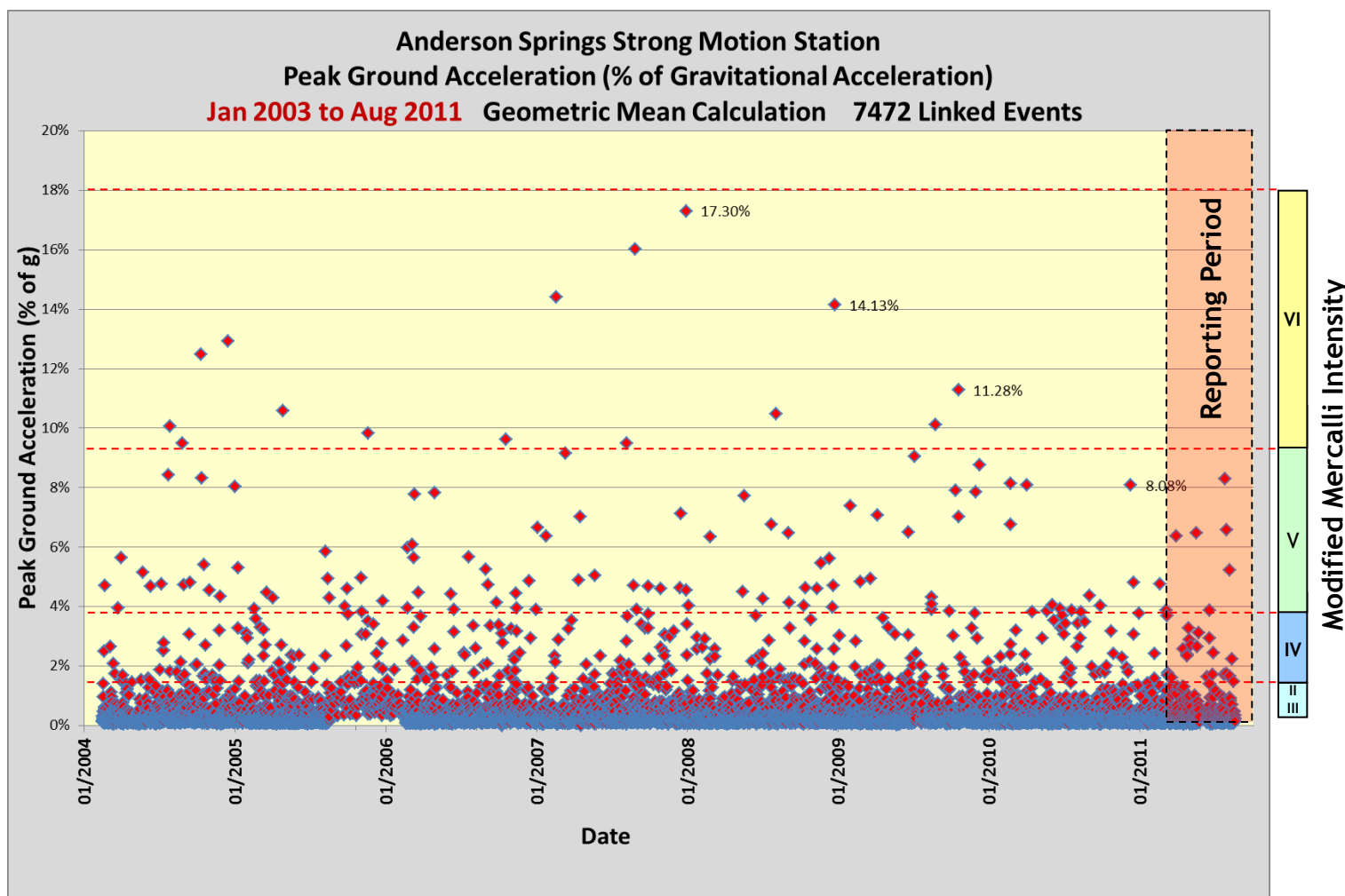
Field-wide Seismicity Analysis



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Strong Motion Analysis

Anderson Springs Peak Ground Acceleration

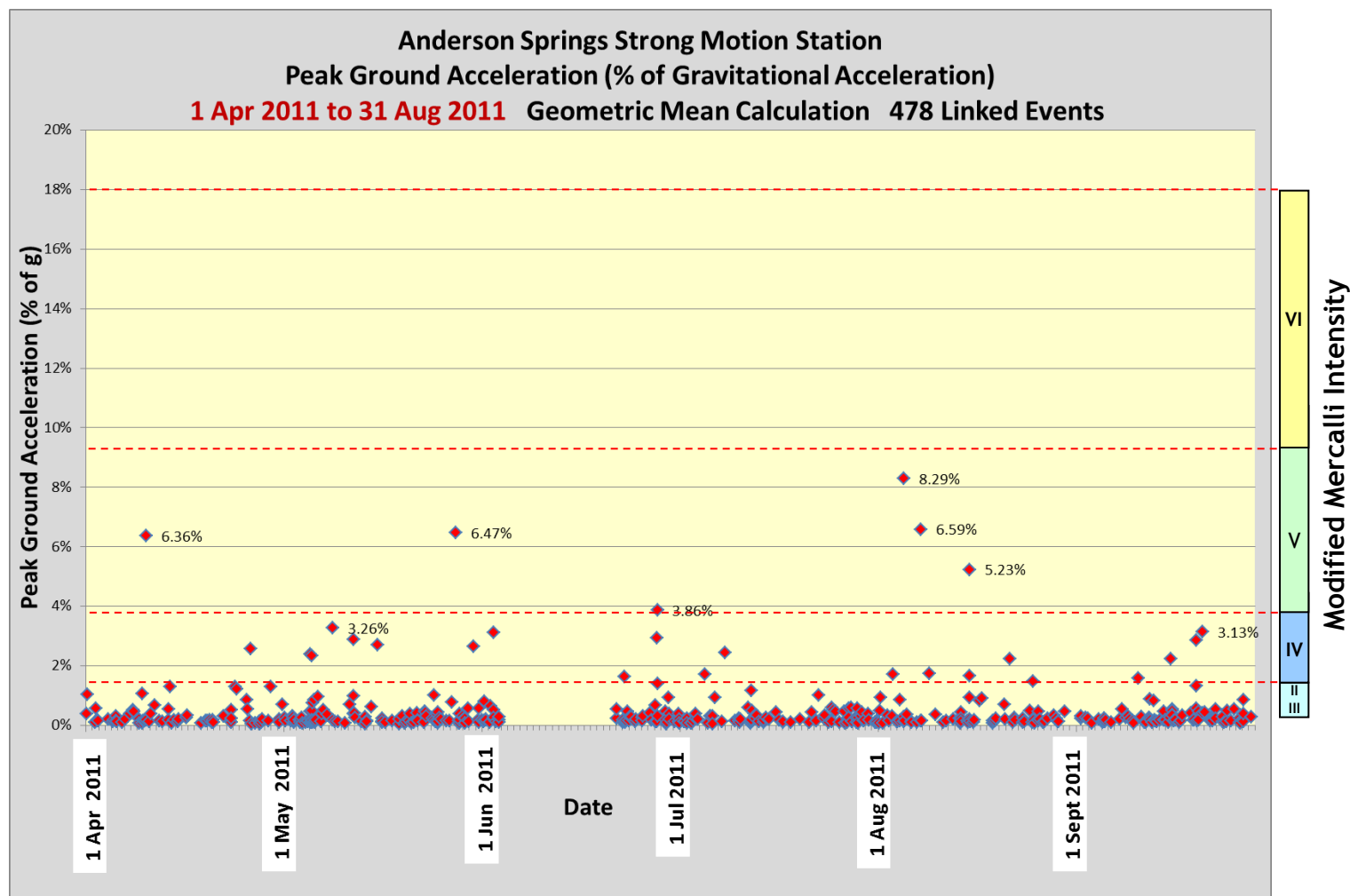


Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity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

Anderson Springs Peak Ground Acceleration

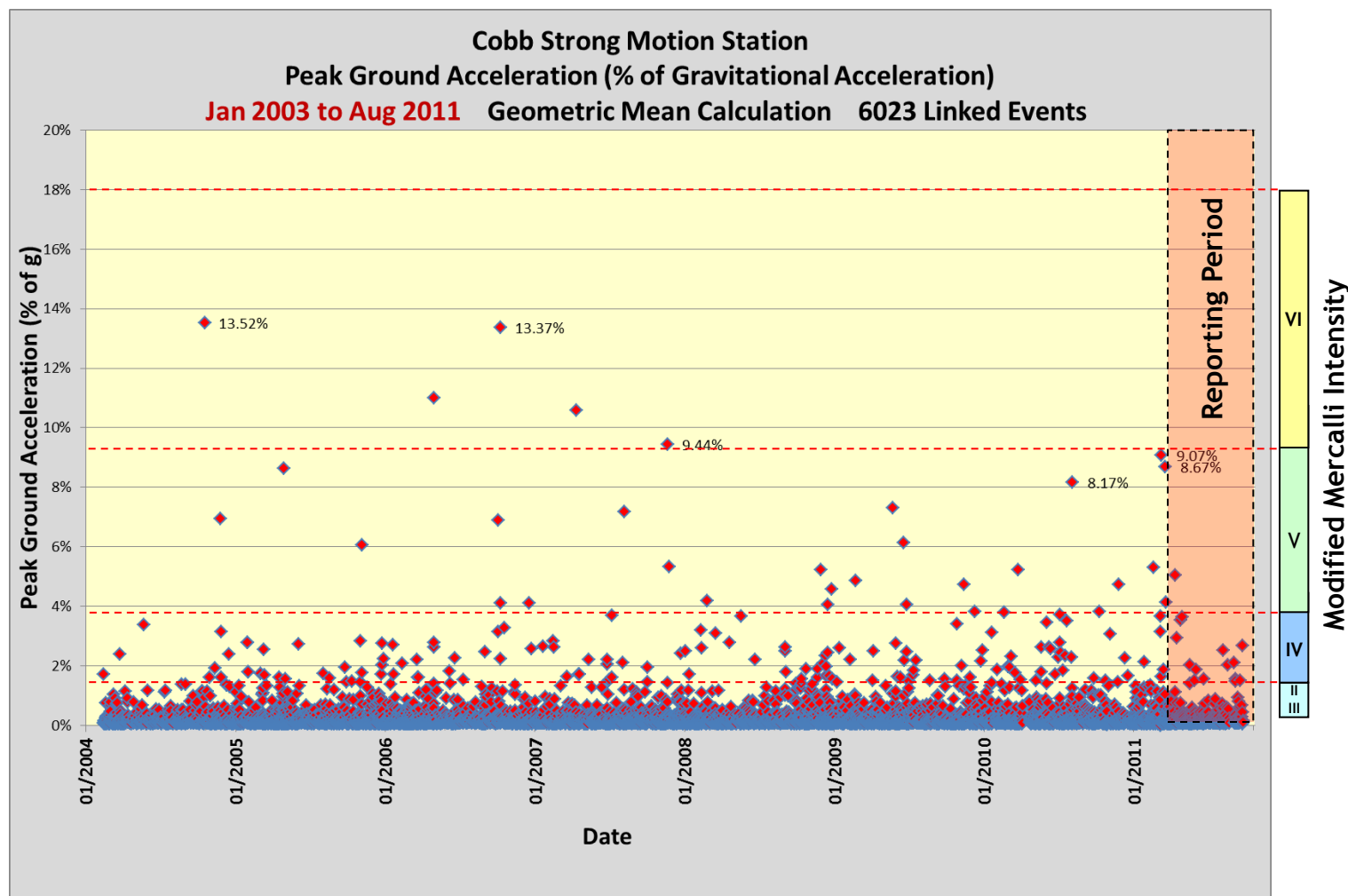


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Strong Motion Analysis

Cobb Peak Ground Acceleration

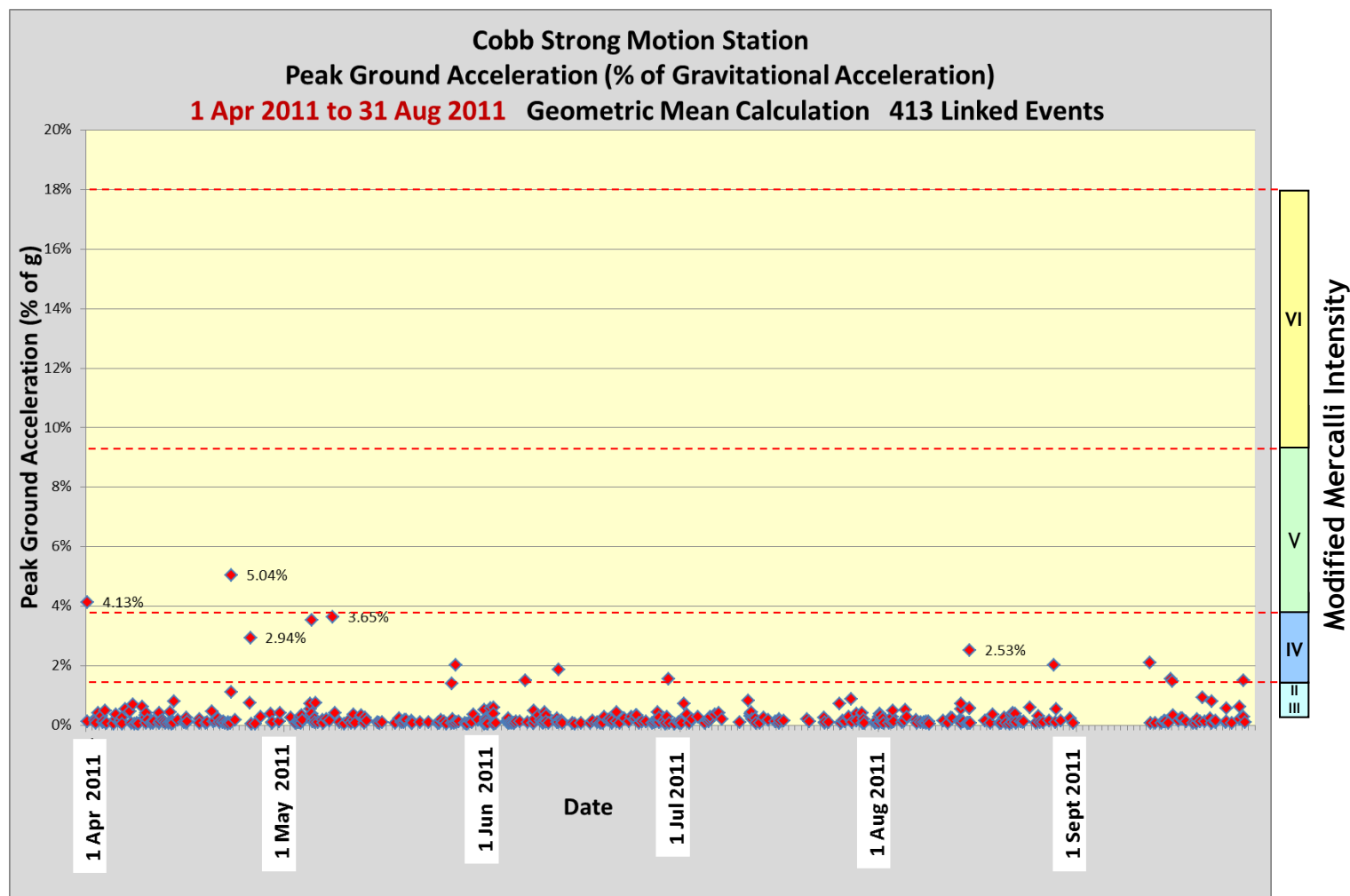


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Strong Motion Analysis

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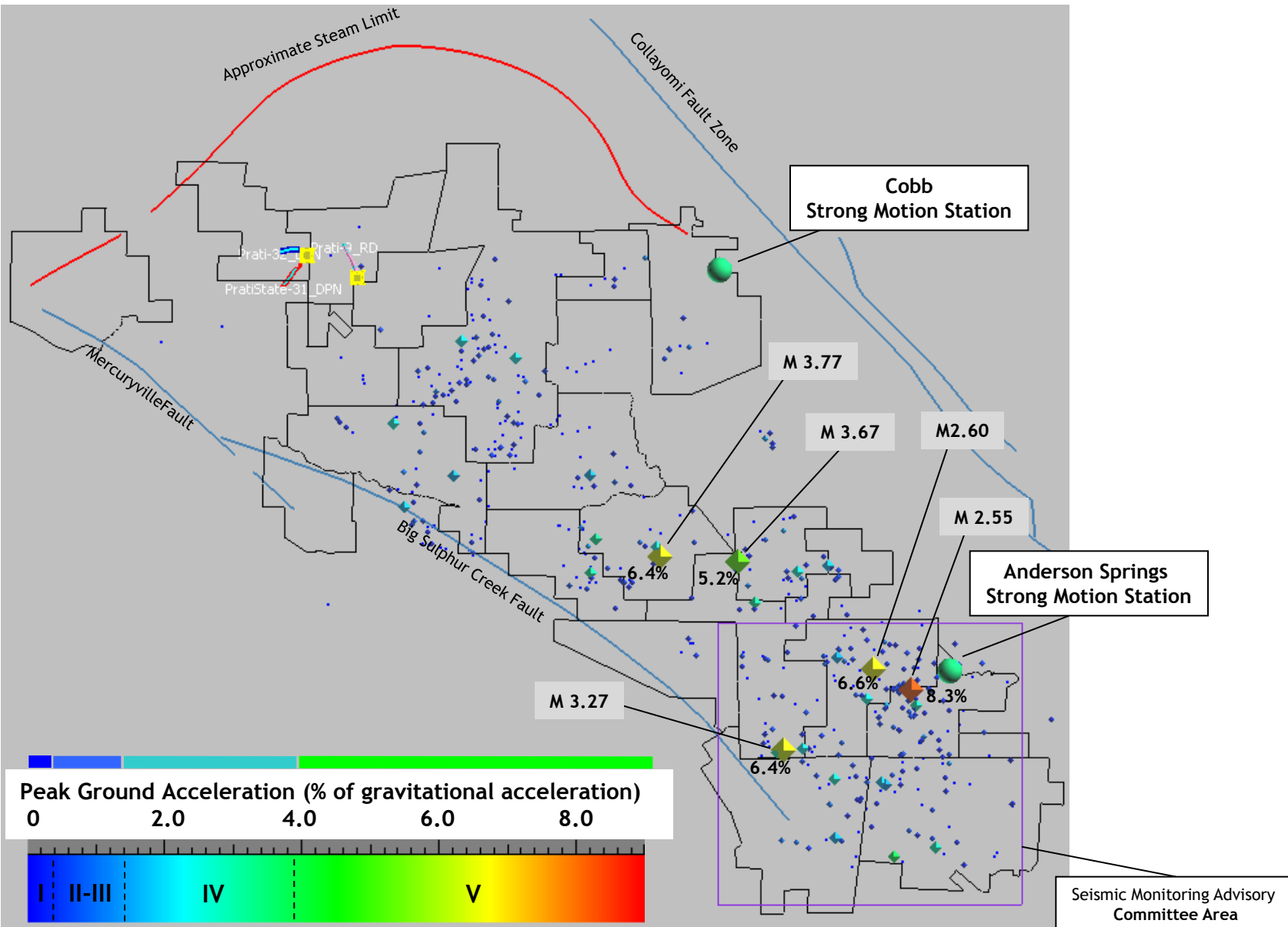


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Strong Motion Analysis

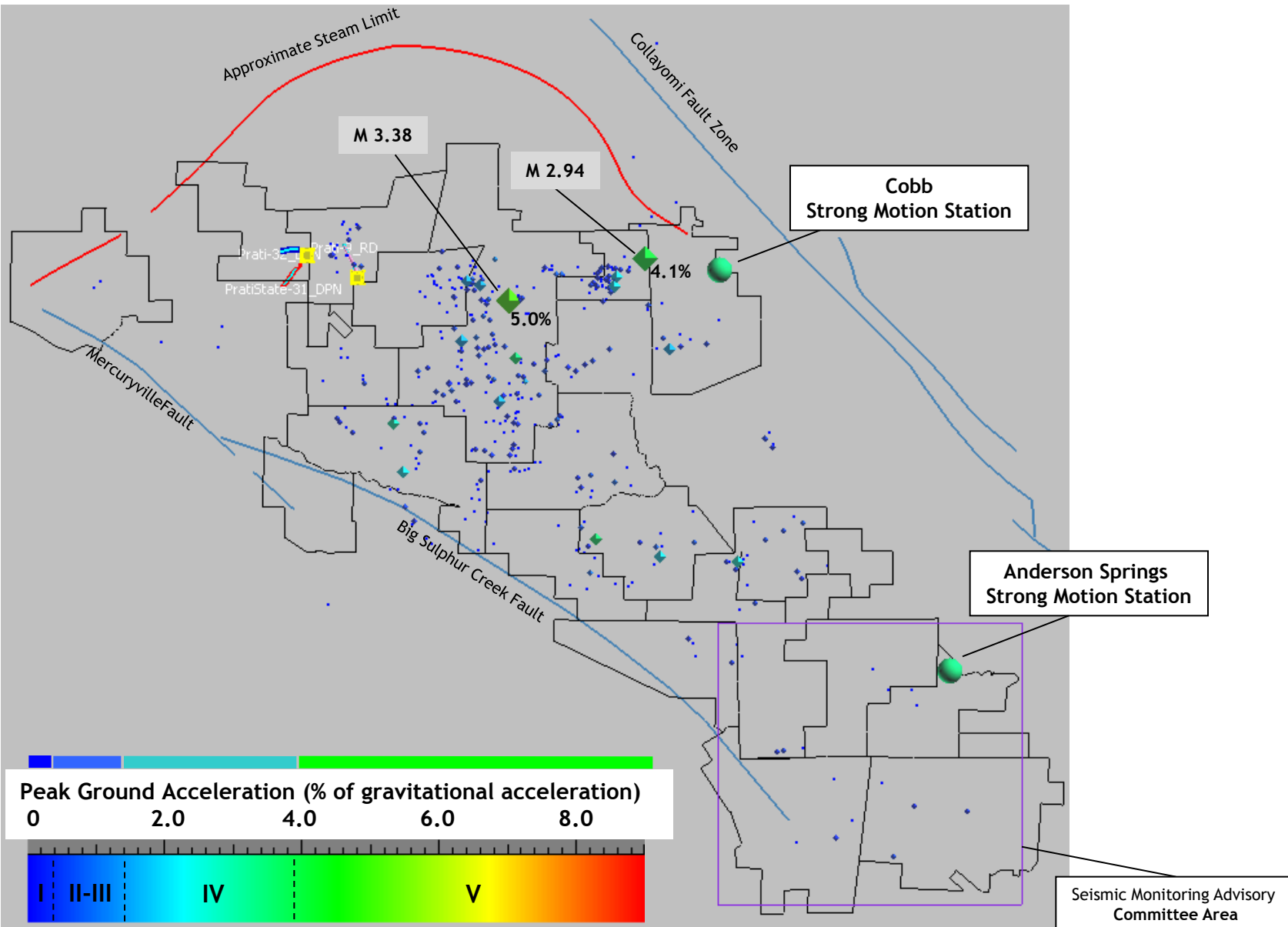
Anderson Springs Peak Ground Acceleration



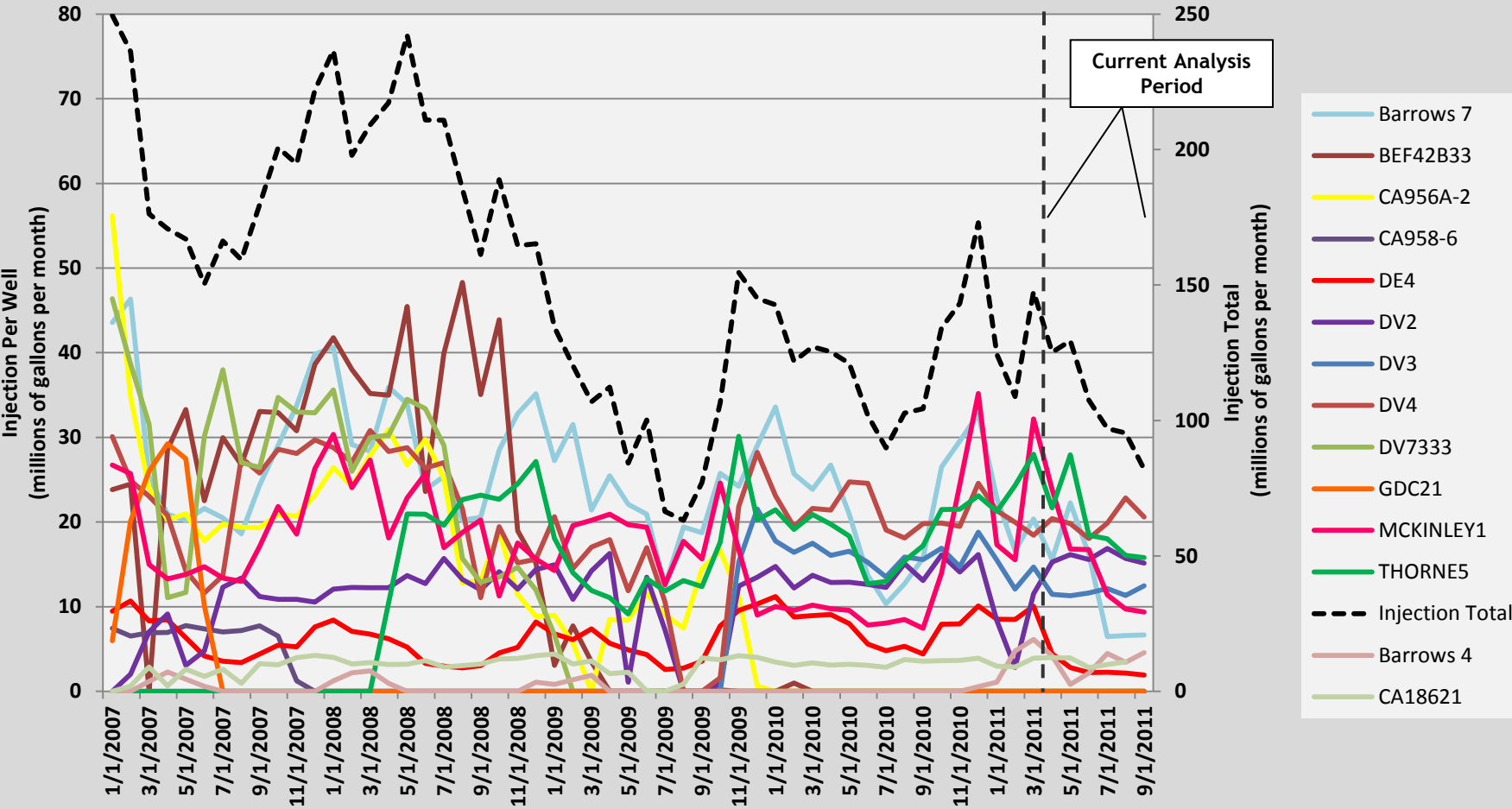
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Strong Motion Analysis

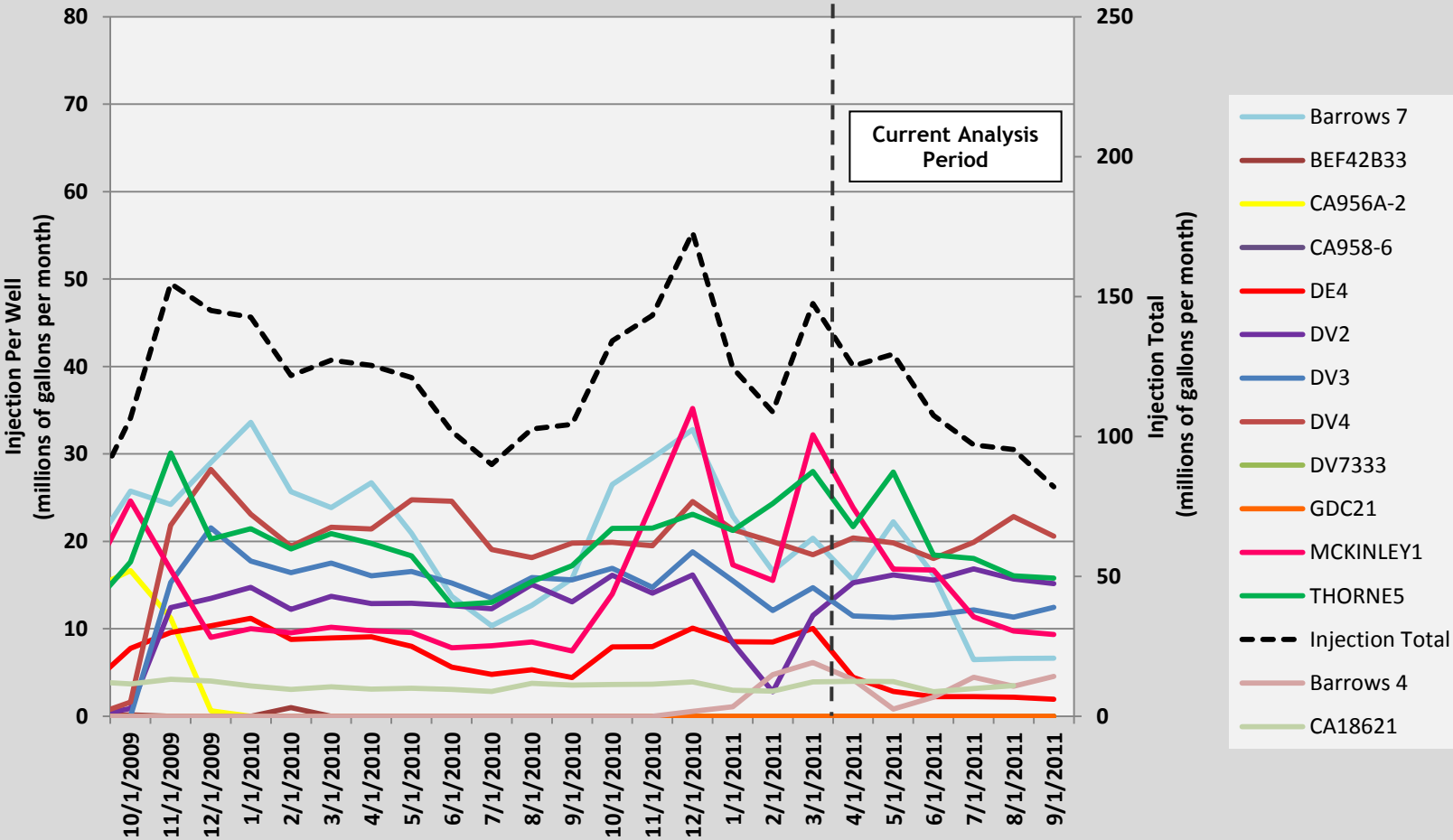
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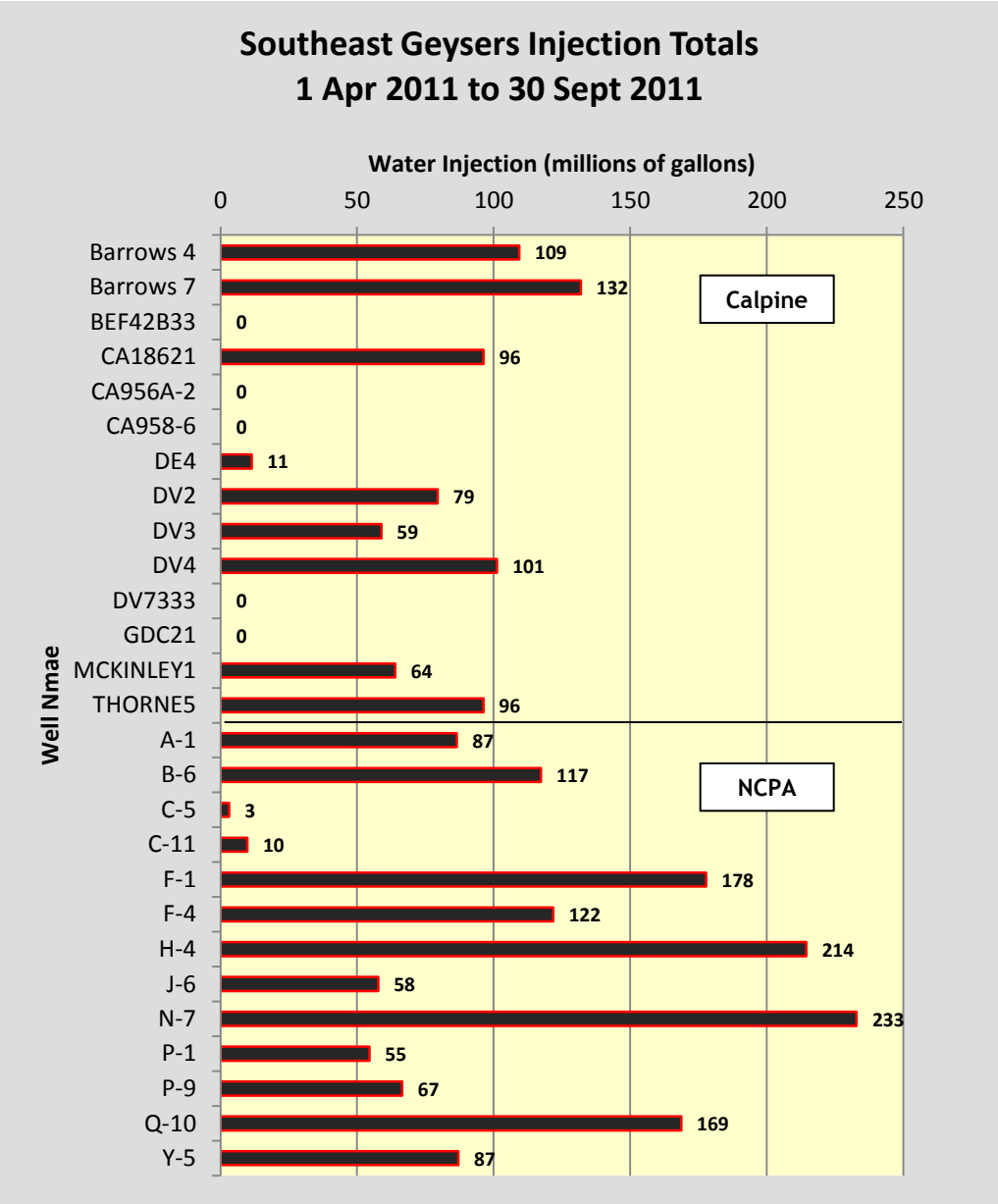


Southeast Geysers Injection
1 January 2007 to 30 September 2011



Southeast Geysers Injection
1 October 2009 to 30 September 2011





Northern California Seismic Network
Seismicity Data

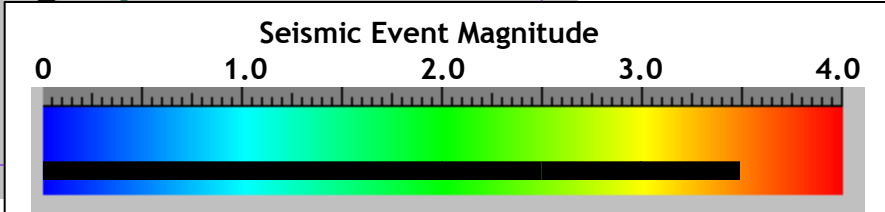
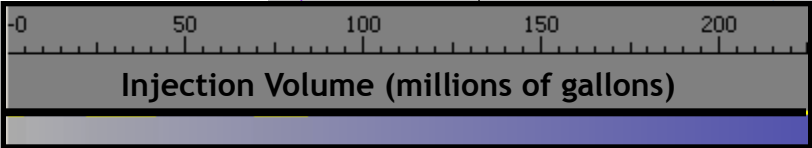
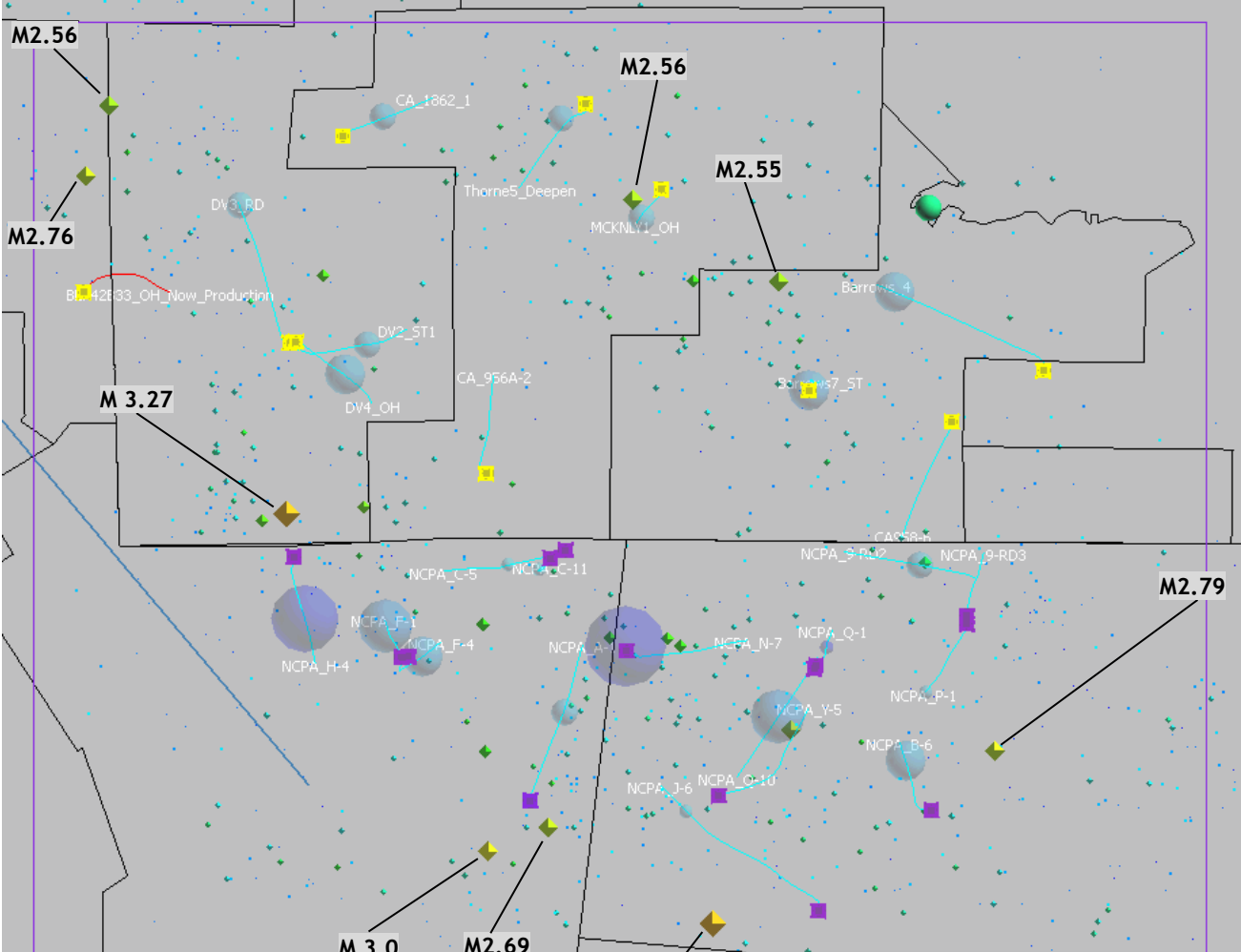
Southeast Geysers Seismicity Results as of September 30, 2011

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

<u>Time Period</u>	<u>Pre-SEGEP</u>	<u>SEGEP</u>	<u>Current Period</u>
Dates	Nov 1995 - Oct 1997	Nov 1997 - Mar 2011	Apr 2011- Sep 2011
Time Span (yrs)	2	13.33	0.5
<u>Seismic Events:</u>			
M>=1.2	330 (165)	4378 (329)	134 (268)
M>=2.0	46 (23)	624 (47)	20 (40)
M>=3.0	10 (5)	33 (2.5)	2 (4)
M Maximum	3.7	4.3	3.31

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Southeast Geysers Seismicity and Injection



Field-wide data for **1 Mar 2011 to 31 Aug 2011** 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 24 October 2011

Final report with Calpine/URS revisions completed by 9 November 2011

Seismicity results consistent with Environmental Impact Report projections

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

Since SRGRP initiation: no increase in NCSN seismicity of magnitude ≥ 3.0

Most recent seismic events of magnitude ≥ 4.0 :

M 4.46 01 March 2011

M 4.30 04 January 2009 (two years prior)

One event \geq M 4.0 in the past 34 months

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Strong Motion Trigger Analysis

SRGRP Report for 1 March 2011 to 31 August 2011



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 28 February 2011)
3. Most recent biannual reporting period (1 March 2011 to 31 August 2011)

124 March
83 April
77 May
82 June
57 July
73 August
38 September

		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
Count	ADSP	Pre-SRGRP	87	207	19	4	1
Count	ADSP	During SRGRP	2465	3984	383	113	17
Count	ADSP	3/1/11-8/31/11	224	236	30	7	0
Count	COB	Pre-SRGRP	89	46	6	3	0
Count	COB	During SRGRP	3258	1868	152	25	6
Count	COB	3/1/11-8/31/11	301	181	14	6	0
Annualized Rate	ADSP	Pre-SRGRP	243	577	53	11.2	2.8
Annualized Rate#	ADSP	During SRGRP	368**	554	53	15.7	2.4
Annualized Rate&	ADSP	3/1/11-8/31/11	↑ 524	↓ 553	↑ 70	↑ (March) 16.4	↓ 0.0
Annualized Rate	COB	Pre-SRGRP	266	138	18	9.0	0.0
Annualized Rate*	COB	During SRGRP	469	269	22	3.6	0.9
Annualized Rate	COB	3/1/11-8/31/11	↑ 604	↑ 363	↑ 28	↑ (March) 12.0	↓ 0.0

Accounts for ADSP station outage 20 July 2009 to 15 August 2009 and 5 to 9 August 2010.

** 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 ADSP station outage 3 June to 29 June, 2011.

* 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.

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 $M \geq 4.0$ (or $M \geq 3.5$; $MMI \geq 5$; $PGA \geq 3.9\%$)

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

Expansion to include Enhanced Geothermal System exhibits

Geysers Field Tours

Approximately monthly tour groups (Spring to Fall)

Community Newsletter

2-3 publications yearly by mail

Northwest Geysers EGS Demonstration Community Updates

August 18th; November 4th



Reference

Seismic Monitoring Advisory Committee

Field-wide Injection Sources



Magnitude >= 2.0

Year	Month	Count Of USGS Events
2011	4	26
2011	5	22
2011	6	28
2011	7	24
2011	8	28
2011	9	18

Magnitude >= 3.0

Year	Month	Count Of USGS Events
2011	4	3
2011	5	3
2011	6	1
2011	8	1
2011	9	1

Magnitude >= 4.0

None

Magnitude >= 2.5

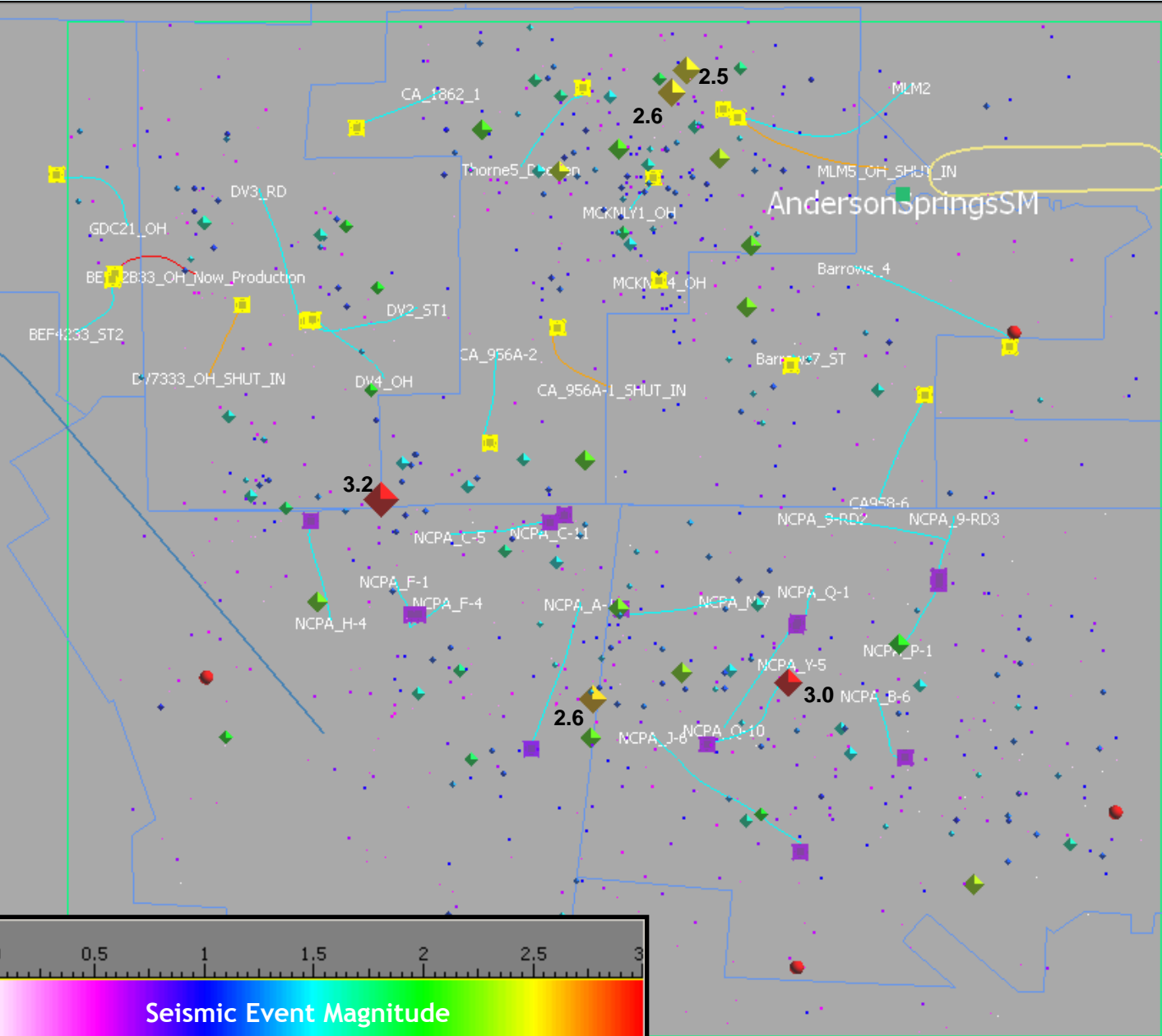
Year	Month	Count Of USGS Events
2011	4	8
2011	5	5
2011	6	8
2011	7	2
2011	8	7
2011	9	8

Magnitude >= 3.5

Year	Month	Count Of USGS Events
2011	4	1
2011	5	1
2011	8	1

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Seismicity for Previous Period: 1 Apr 2010 to 30 Sep 2010



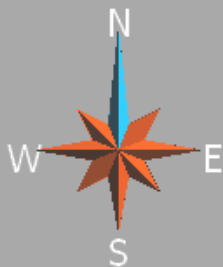
Seismic Events
magnitude proportional
to size and color
(see color bar)

LBNL Stations

Well Tracks
Active injectors.....blue
Now Production.....red
Shut-In.....orange

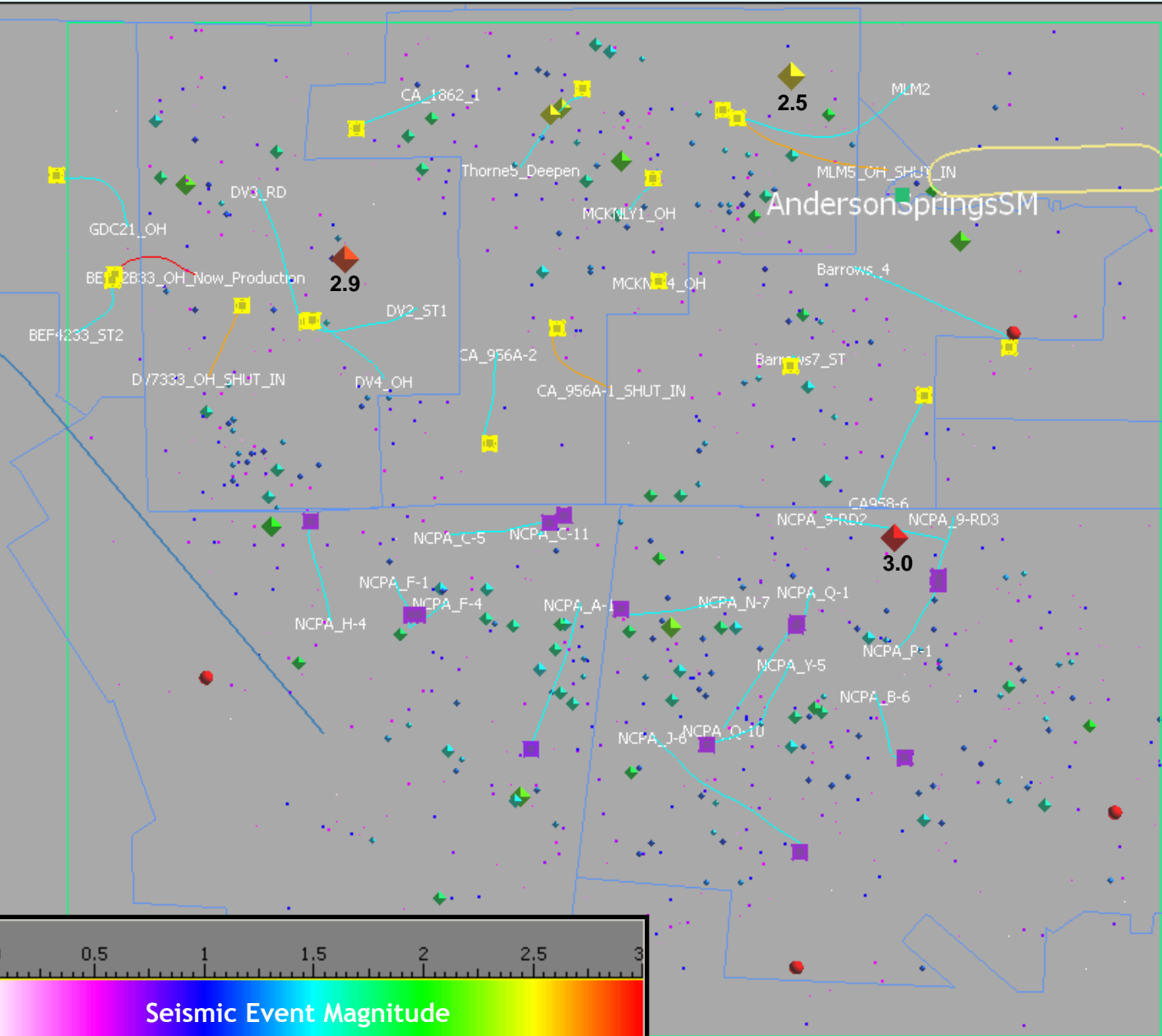
Derrick Symbols
Calpine.....yellow
NCPA.....purple

Outlines
SMAC Area.....green
Leases.....blue



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Seismicity for Current Period: 1 Oct 2010 to 31 Mar 2011



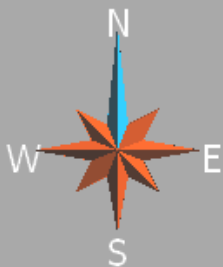
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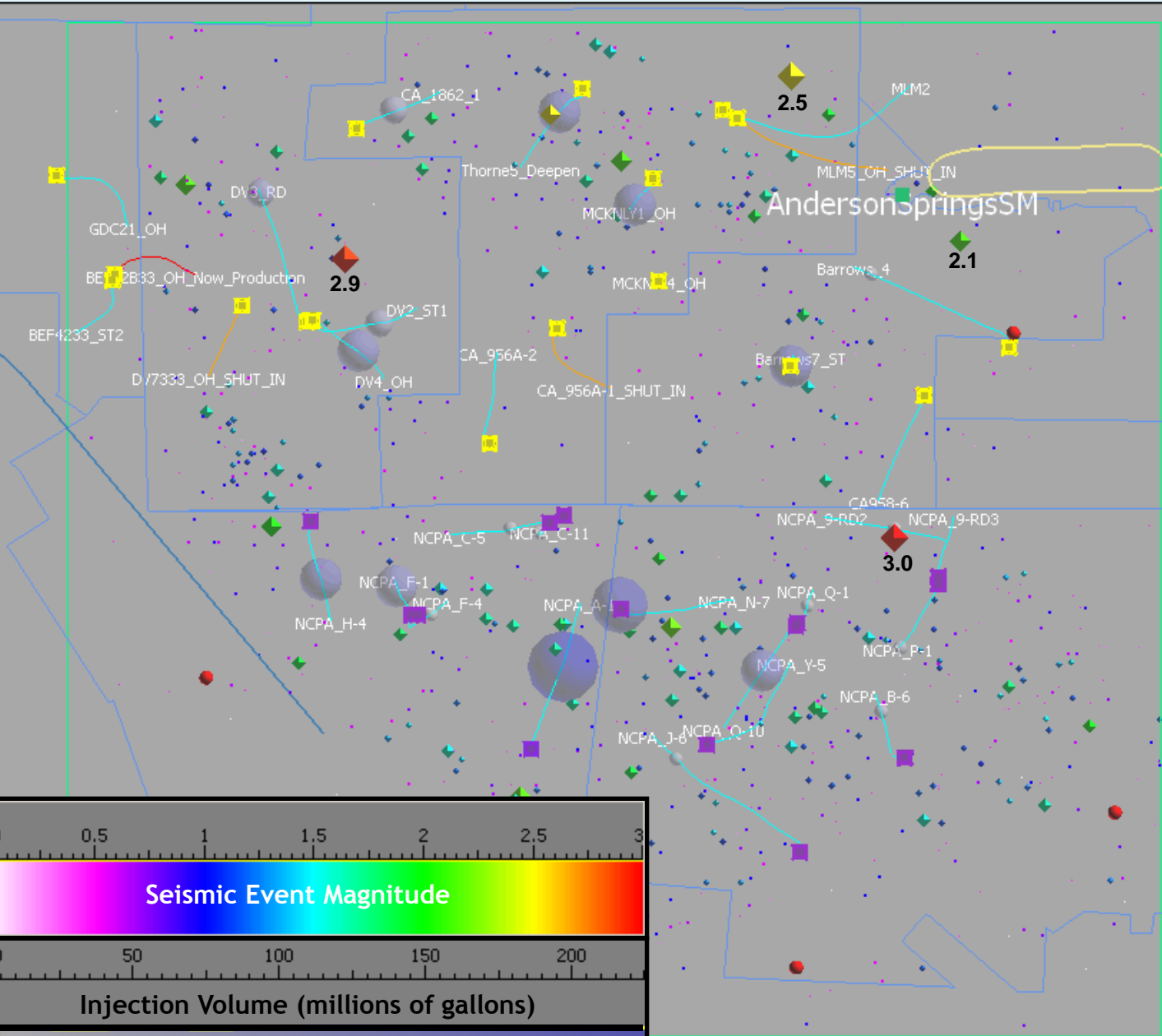
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Seismic Monitoring Advisory Committee

Seismicity/Injection for Current Period: 1 Oct 2010 to 31 Mar 2011



Seismic Events
magnitude proportional to size and color (see color bar)

LBNL Stations

Well Tracks
Active injectors.....blue
Now Production.....red
Shut-In.....orange

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Outlines
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Injection Volumes
volume proportional to:
size
color saturation (see color bar)

