Report on the Napa - American Canyon Earthquake of 8.24.2014 Mw 6.0 - Performance of Lifelines

Bay Area Center for Regional Disaster Resilience

Dublin, CA, February 20 2015

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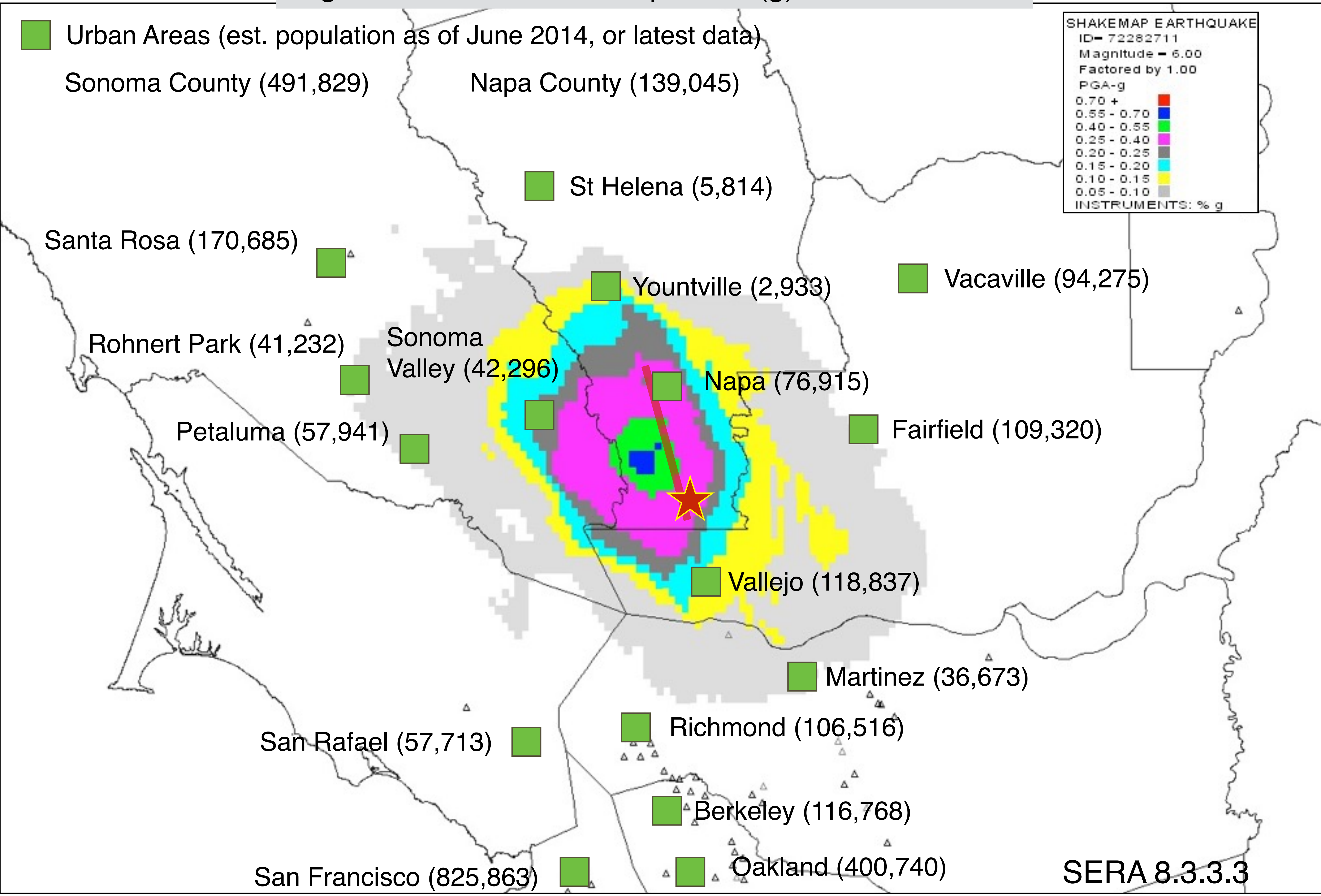
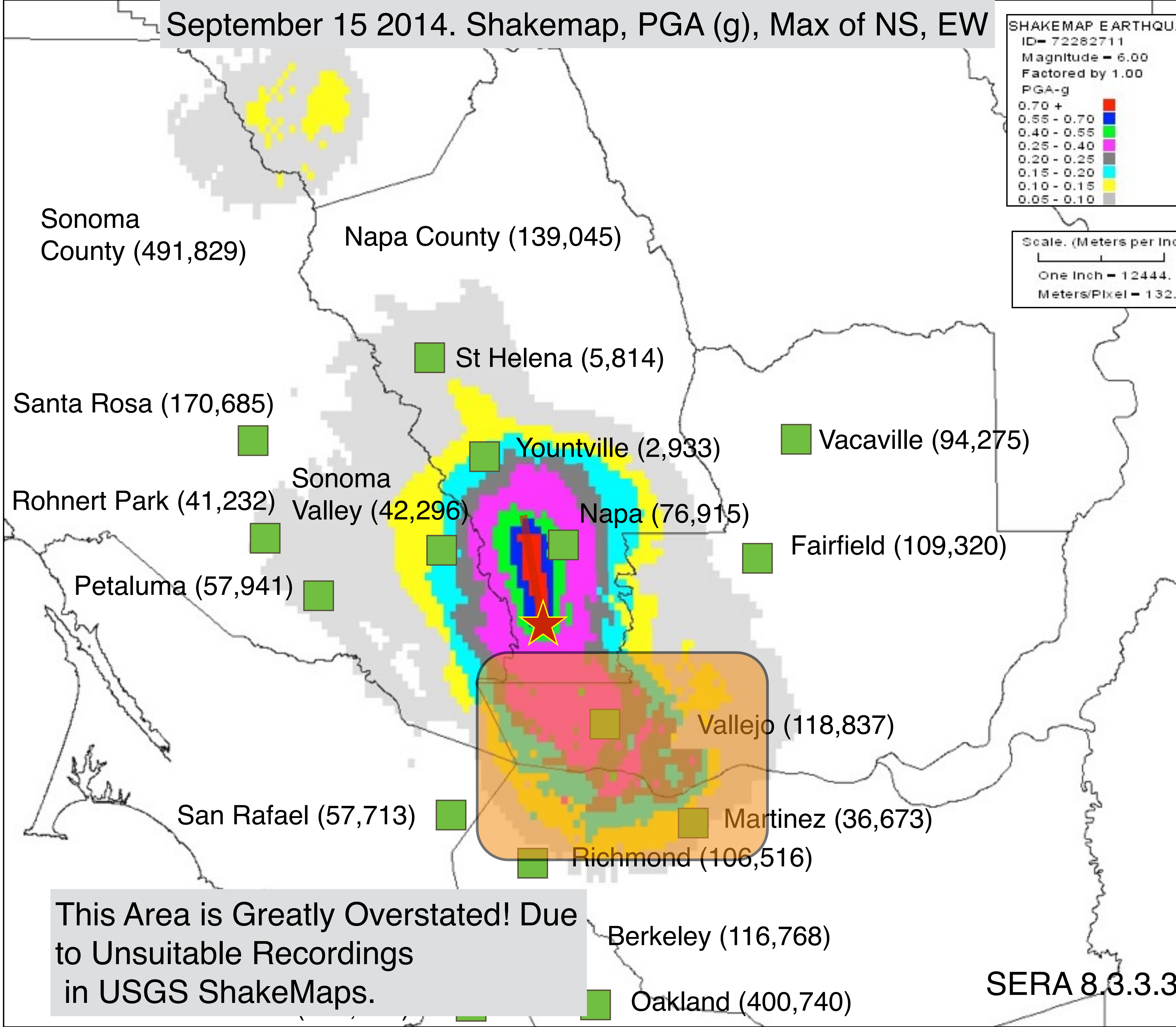
Agenda

- What Broke?
- What worked well?
- Why?
- DO Lifelines DO or NOT DO seismic mitigation?

August 24 2014. Shakemap, PGA (g), Max of NS, EW

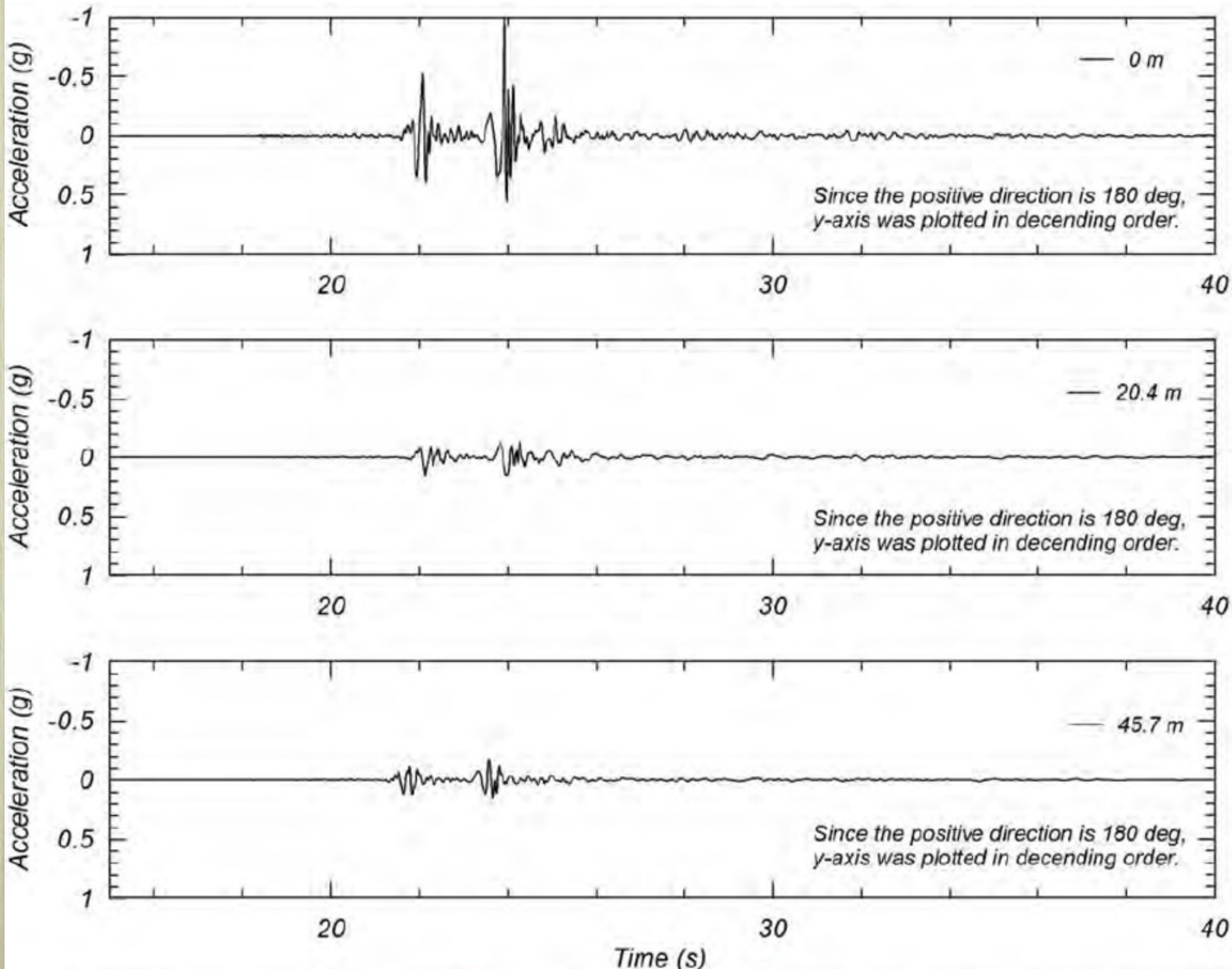


Place Names and Populations


September 15 2014. Shakemap, PGA (g), Max of NS, EW
SHAKEMAP EARTHQUAKE
ID= 72282711
Magnitude = 6.00
Factored by 1.00
PGA-g
0.70 +
0.55 - 0.70
0.40 - 0.55
0.25 - 0.40
0.20 - 0.25
0.15 - 0.20
0.10 - 0.15
0.05 - 0.10
Scale. (Meters per Inch)
One Inch = 12444.
Meters/Pixel = 132.
Sonoma County (491,829)
Napa County (139,045)
St Helena (5,814)
Santa Rosa (170,685)
Yountville (2,933)
Vacaville (94,275)
Sonoma Valley (42,296)
Rohnert Park (41,232)
Napa (76,915)
Fairfield (109,320)
Petaluma (57,941)
Vallejo (118,837)
San Rafael (57,713)
Martinez (36,673)
Richmond (106,516)
Berkeley (116,768)
Oakland (400,740)
This Area is Greatly Overstated! Due to Unsuitable Recordings in USGS ShakeMaps.
SERA 8.3.3.3

Two Giants Next to the Offending Ground Motion Instrument

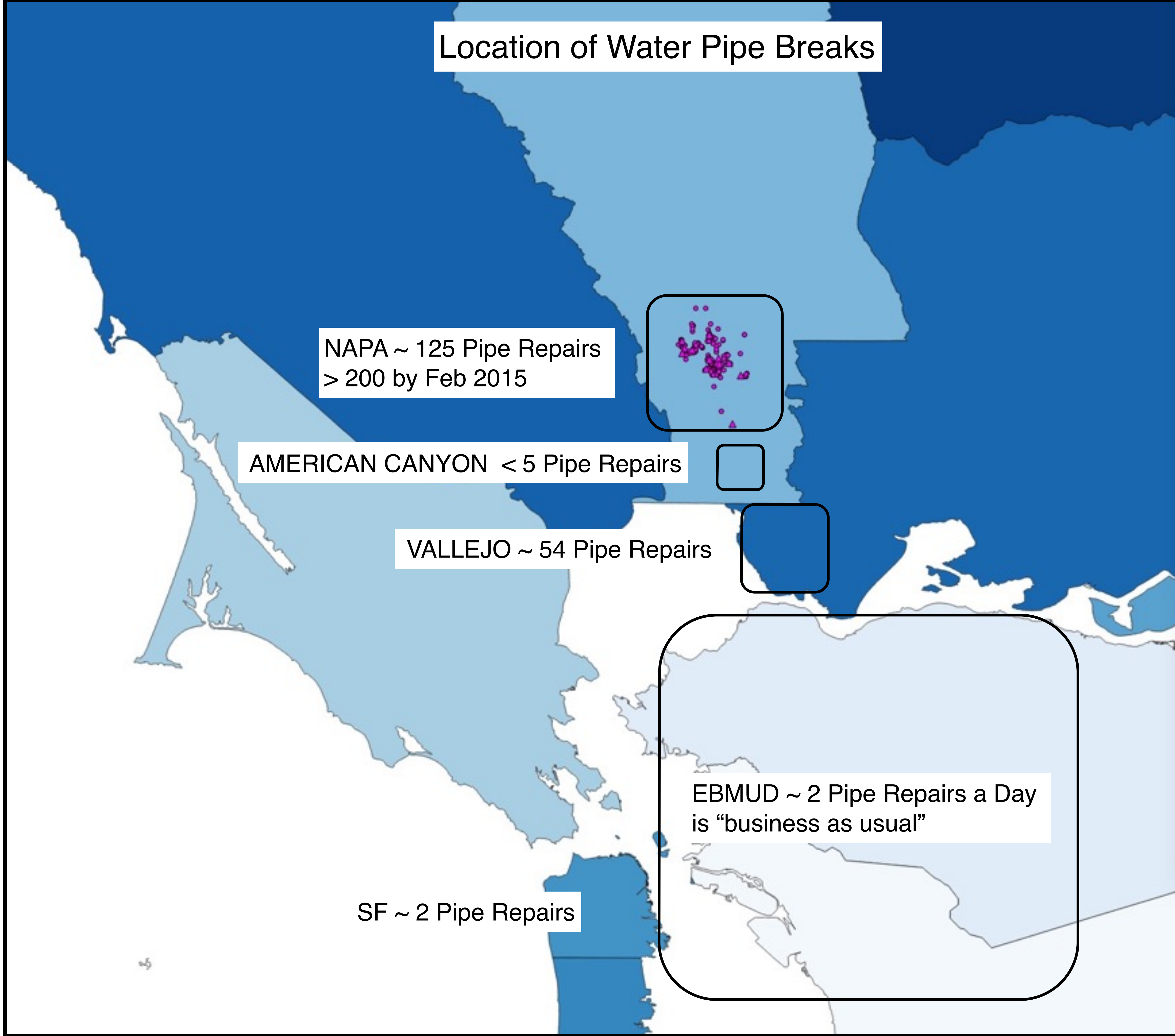
Charlie Scawthorn John Eidinger



-1
-0.5
0
0.5
1
Acceleration (g)
— 0 m
Since the positive direction is 180 deg,
y-axis was plotted in decending order.
20
30
40
— 20.4 m
Since the positive direction is 180 deg,
y-axis was plotted in decending order.
— 45.7 m
Since the positive direction is 180 deg,
y-axis was plotted in decending order.
Time (s)

	CE.68206	CE.68259
Latitude	38.0540	38.0548
Longitude	-122.2250	-122.2264
Distance to Epicenter (km)	20.0	19.9
PGA (NS) g	0.979 g	0.424 g
PGV (NS) cm/sec	22.2 cm/sec	19.8 cm/sec
SA (NS 0.3 sec, 5%) g	1.322 g	0.948 g
SA (NS 1.0 sec, 5%)	0.082 g	0.102 g
SA (NS 3.0 sec, 5%)	0.010 g	0.012 g
PGA (EW) g	0.517 g	0.177 g
PGV (EW) cm/sec	10.4 cm/sec	11.0 cm/sec
SA (EW 0.3 sec, 5%) g	0.432 g	0.323 g
SA (EW 1.0 sec, 5%)	0.115 g	0.122 g
SA (EW 3.0 sec, 5%)	0.010 g	< 0.01 g
PGA (V) g	0.316 g	0.172 g
PGV (V) cm/sec	7.42 cm/sec	6.33 cm/sec
SA (V 0.3 sec, 5%) g	0.518 g	0.360 g
SA (V 1.0 sec, 5%)	0.236 g	0.045 g
SA (V 3.0 sec, 5%)	0.003 g	0.004 g

Table 2-1. Instrument Recordings


Location of Water Pipe Breaks
NAPA ~ 125 Pipe Repairs
> 200 by Feb 2015
AMERICAN CANYON < 5 Pipe Repairs
VALLEJO ~ 54 Pipe Repairs
EBMUD ~ 2 Pipe Repairs a Day
is “business as usual”
SF ~ 2 Pipe Repairs

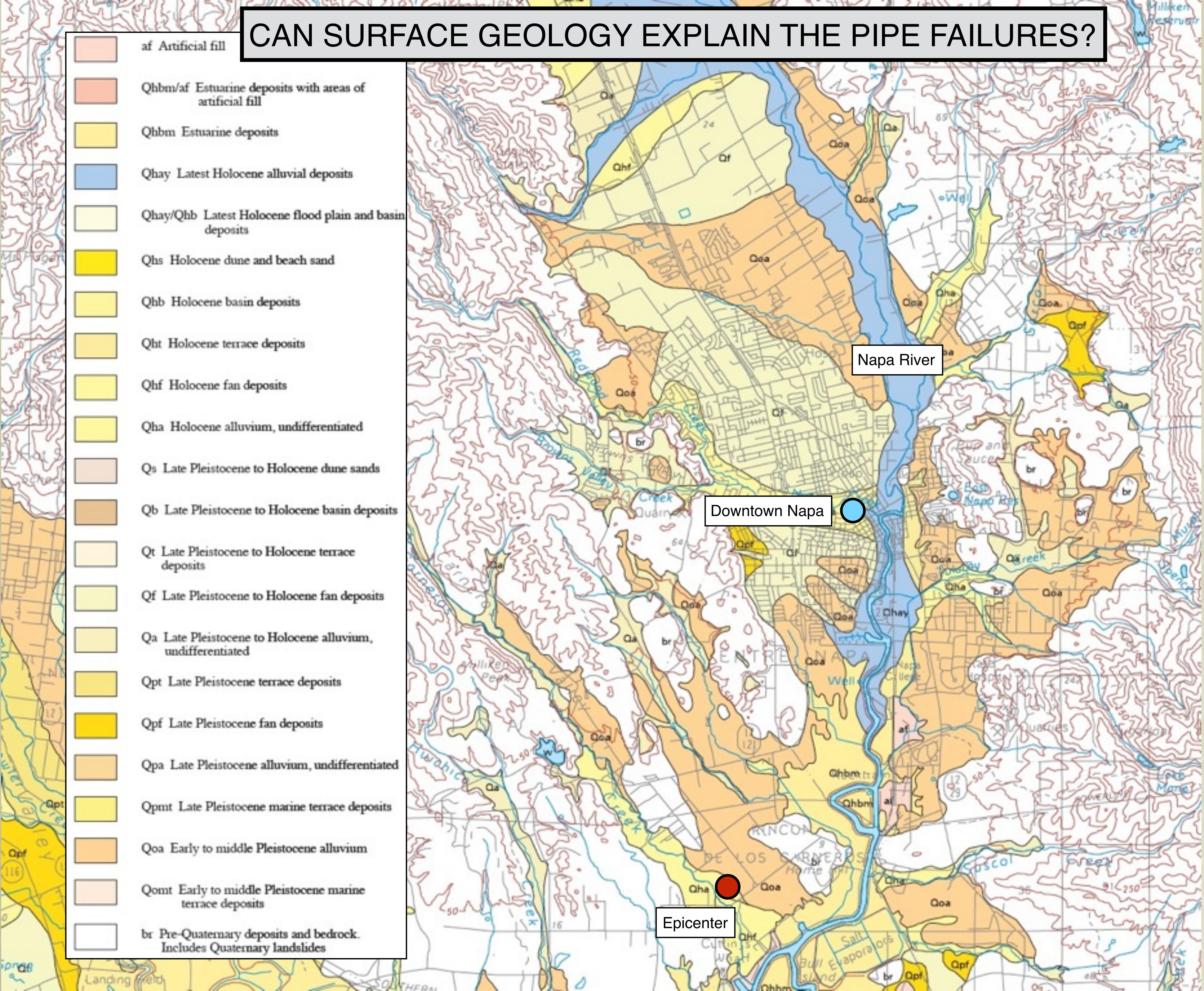
Age (years)	PVC	DI	CI	AC	RCCP	STL	Total	Pct of Total
< 20	6,600	225,600				100	232,300	13%
20-40	24300	370,500	83,400	14,100		100	492,400	28%
40-60		12,300	466,700	167,200	9,900	59,800	715,900	40%
60-80			173,100			100,400	273,500	15%
80-100			55,100				55,100	3%
> 100			10,300				10,300	1%
Total	30,900	608,400	788,500	181,300	9,900	160,400	1,779,500	100%
	2%	34%	44%	10%	1%	9%	100%	

Table 4-1. Length of Water Pipe Mains – Napa (Feet)

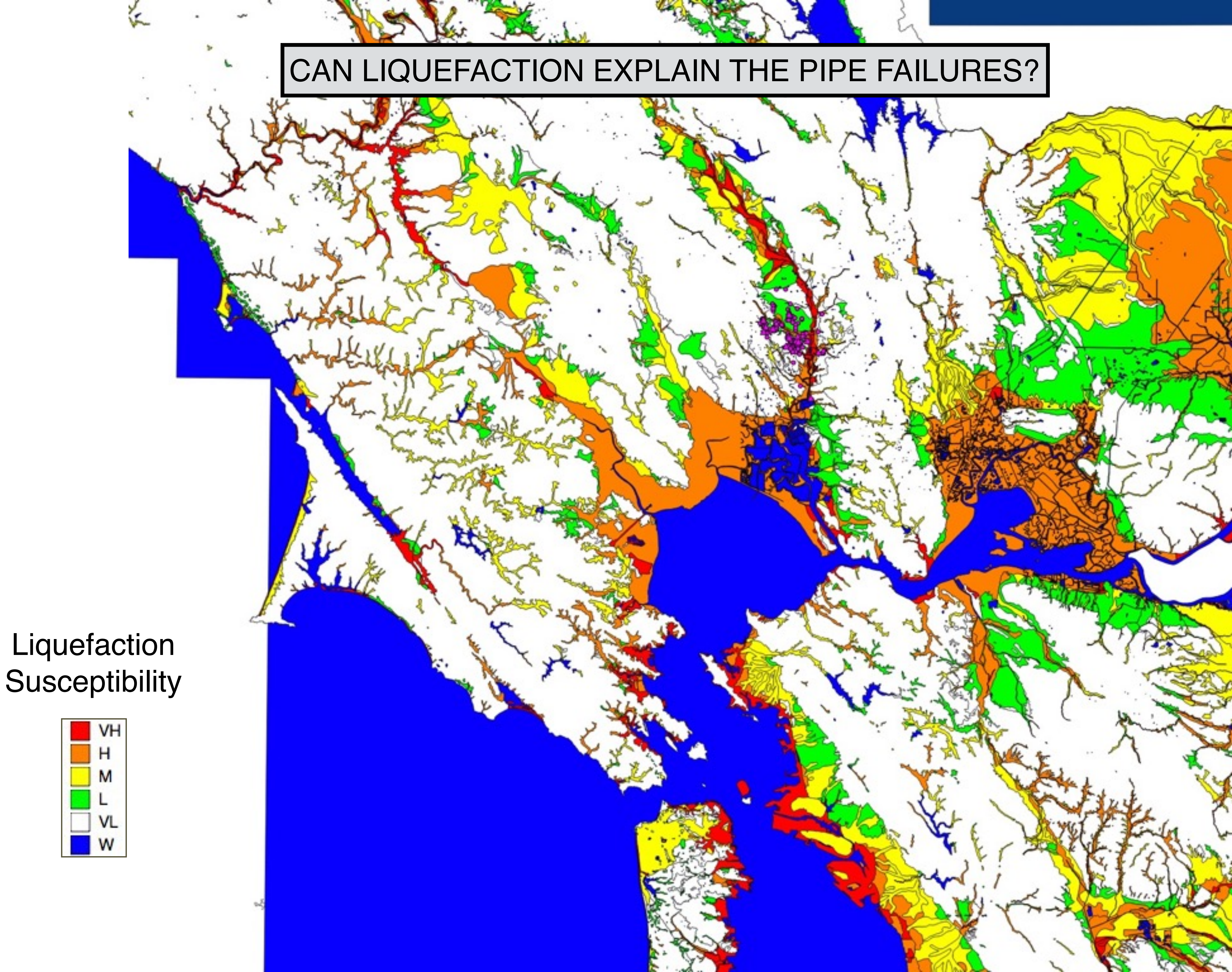
Material	Repairs	% Repairs	% Pipe	Repair per Mile
AC	8	5%	10%	0.23
PVC	2	1%	2%	0.34
CI	123	75%	44%	0.82
DI	18	11%	34%	0.16
Steel	3	2%	9%	0.10
Other / unk	7	4%		
Total	163	100%		

Table 4-2. Repair Rates for Water Pipe

CAN SURFACE GEOLOGY EXPLAIN THE PIPE FAILURES?



CAN LIQUEFACTION EXPLAIN THE PIPE FAILURES?

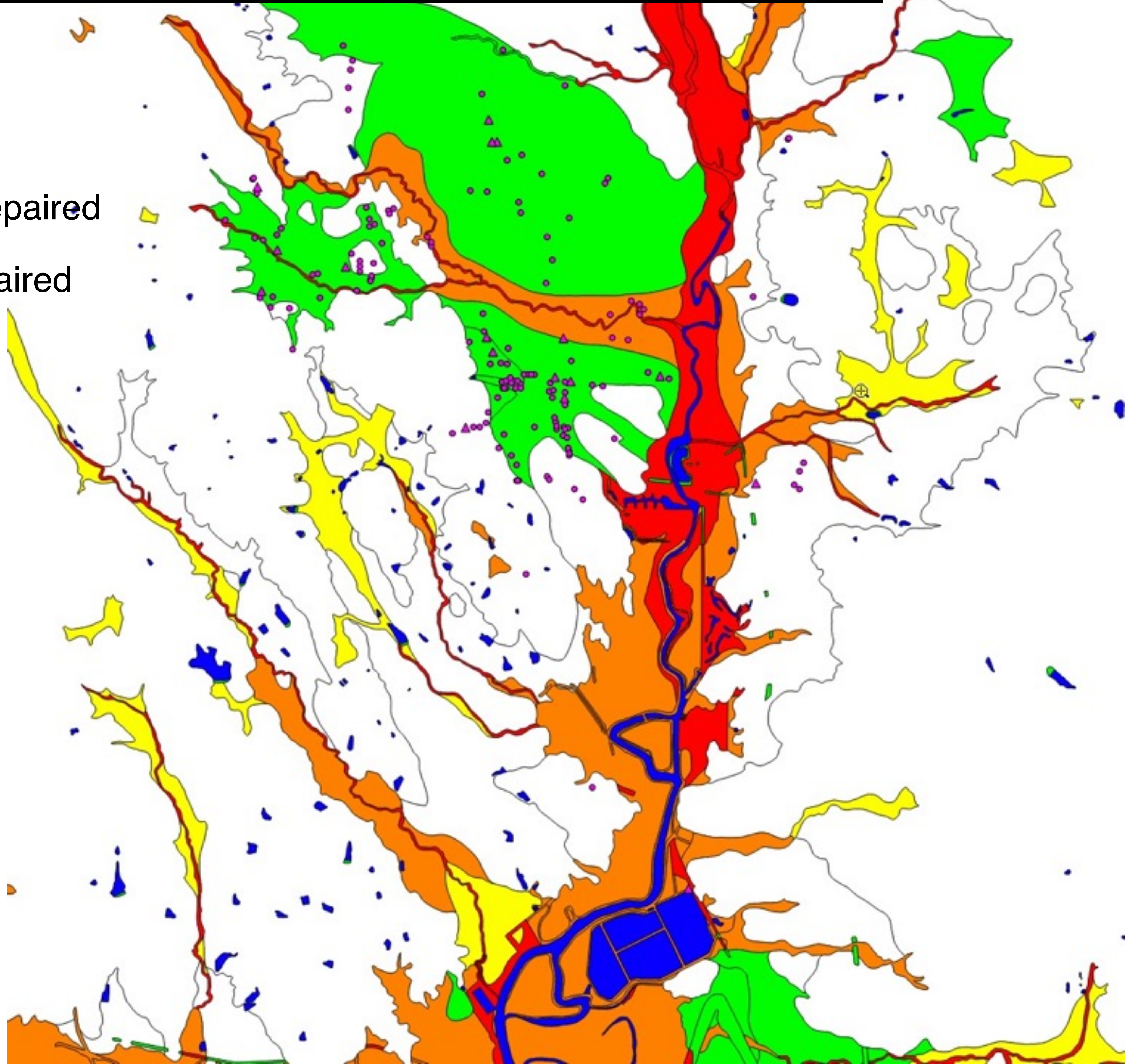


CAN LIQUEFACTION EXPLAIN THE PIPE FAILURES?

- ● Pipes Already Repaired
- ▲ Pipes To Be Repaired

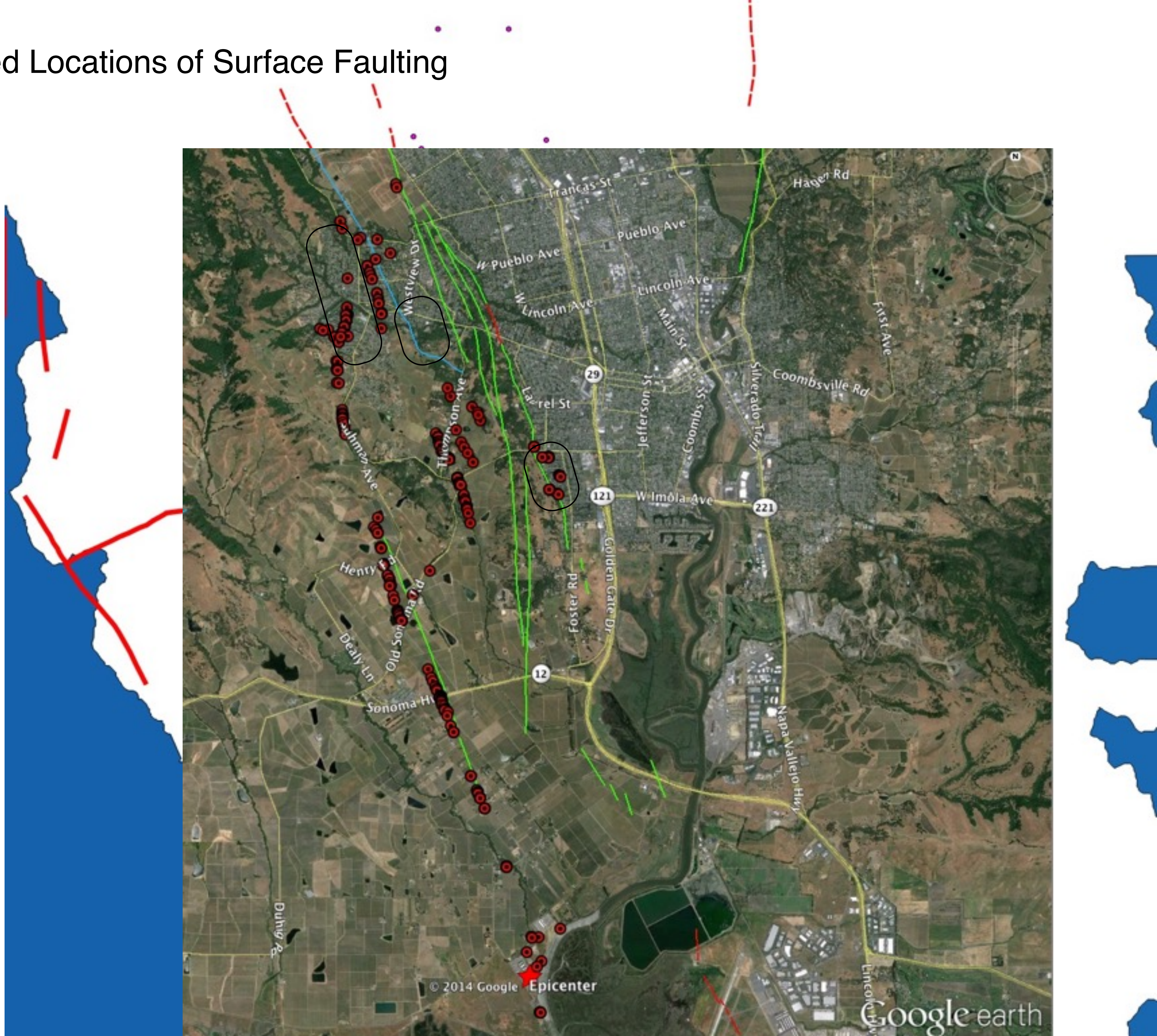
Liquefaction Susceptibility

- VH
- H
- M
- L
- VL
- W



CAN SURFACE FAULTING EXPLAIN THE PIPE FAILURES?

● Observed Locations of Surface Faulting



Quaternary Faults (as of 2010)

Well Constrained

Moderately Constrained

Inferred Constrained

NAPA 2014. This map based on 160 known repairs as of September 2014.

Zones with Many Observations of Surface Faulting

Pipes Already Repaired

Pipes To Be Repaired

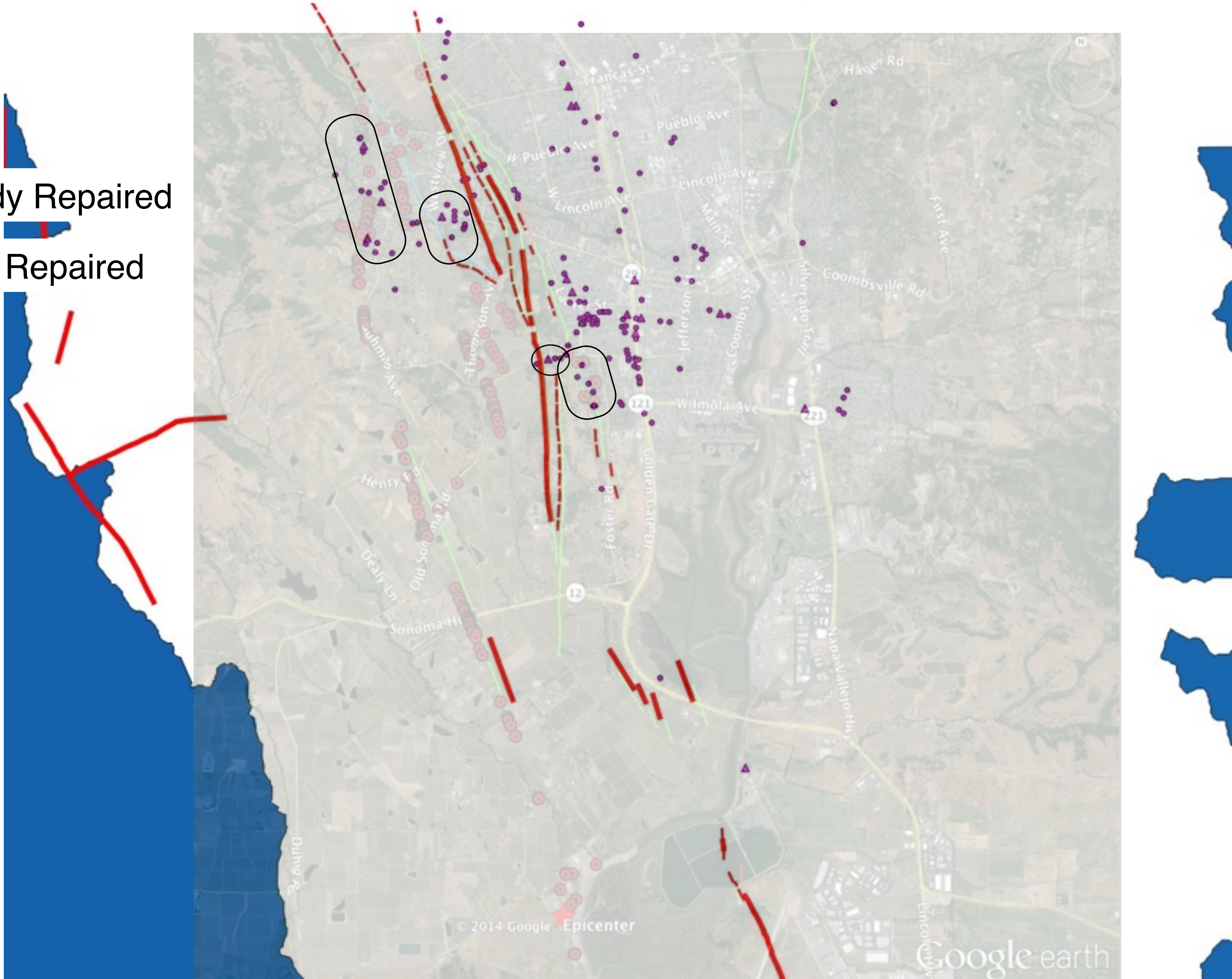
Previously Mapped Quaternary Faults (as of 2010)

Well Constrained

Moderately Constrained

Inferred Constrained

Mapped by others



Water Pipe Damage due to Shaking (excl. faulting or liquefaction)

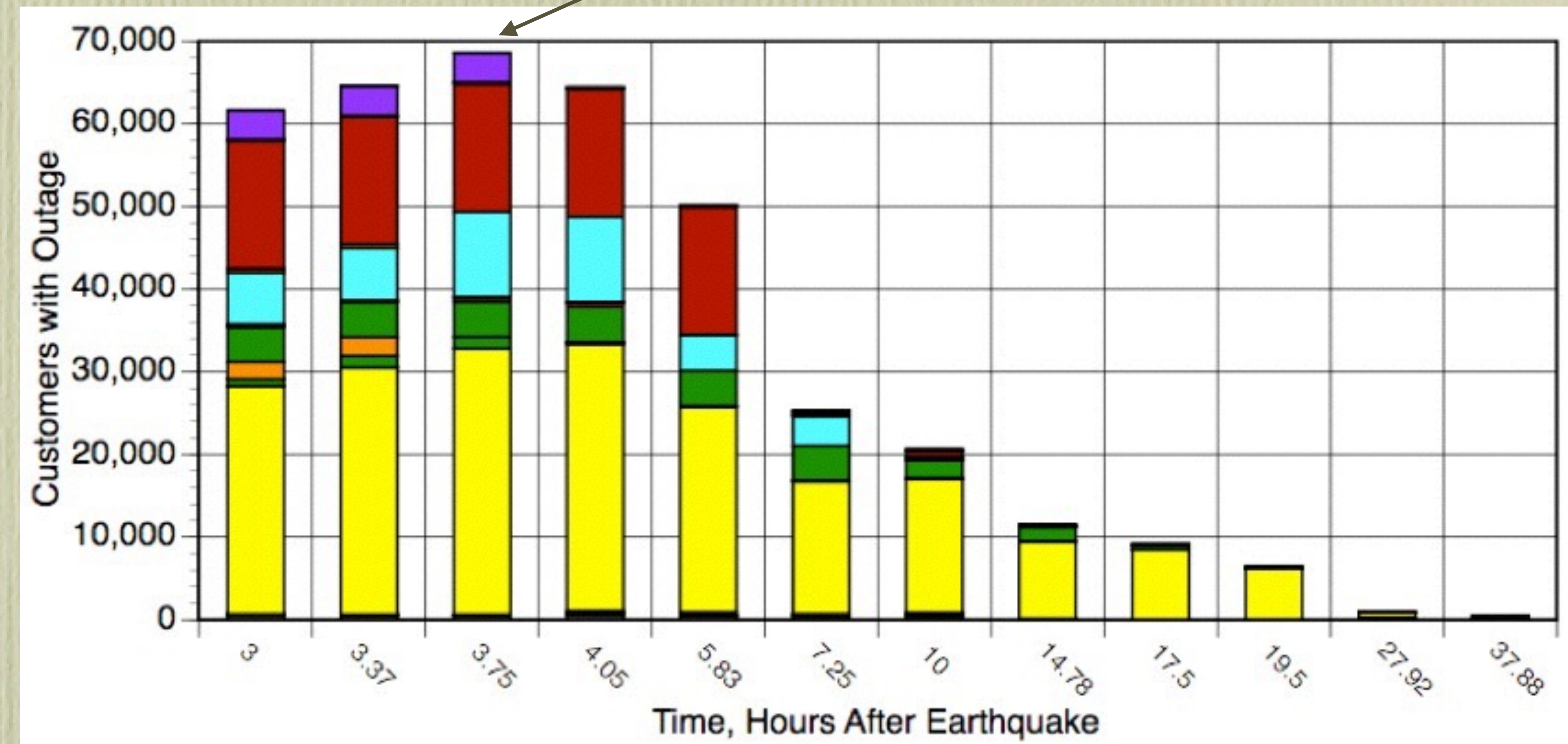
- ALA 2001 models: RR = 0.00187 * PGV, Adjust for pipe type; estimated soil corrosivity, pipe diameter, pipe age.

Pipe Type	*ALA Model*	*Napa Actual*	*Comment*
CI	61.9	93	Very low R? Very Old? Pulse? Basin Effects? Shrink-swell? low c?
PVC	0.6	1	
AC	3.4	5	
DI	11.4	13	
RCCP	0.3	0	
STL	4.2	2	
TOTAL	81.8	114	

PRELIMINARY. Pending PGD, PGV Model Updates, GIS Maps

PG&E Customers without Power

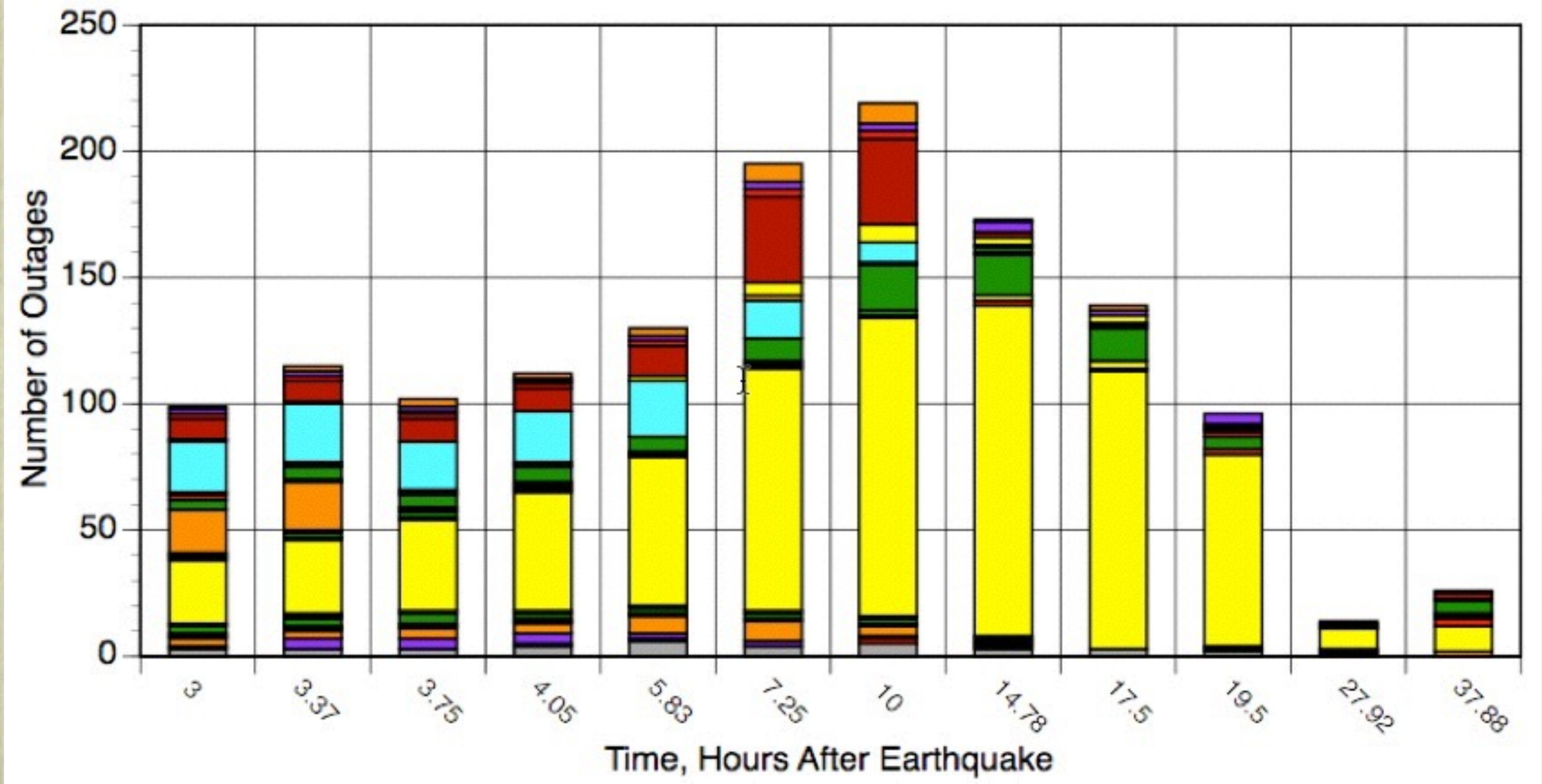
1.4% of PG&E's 5,100,000 Customers



Yellow: Napa
Orange: Rohnert Park
Green: Saint Helena
Cyan: Santa Rosa

Red: Sonoma Valley
Grey: American Canyon
Blue: Vallejo

Number of Power Outages
(number of faulted feeders, or part thereof)



Yellow: Napa
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PG&E Power Outages

- High Voltage Transmission. Most had been seismic upgraded between 2000 and 2012, many $millions. No material damage. No outages.
- Low Voltage Distribution. Pretty good performance. Why? Lessons learned in 1952 led PG&E to modify the way transformers are attached to wood poles: all through bolted, none on cross arms, none resting on platforms.

Distribution Outages

- 166 overhead, 3 underground
- 52 fuse related
- 41 wire related
- 10 equipment related
- 6 pole / cross arm / insulator related

Modern Control Building…. “many times stronger than code”

Old Control Building (Behind). Why replace it if it still plenty strong?
and Battery Enclosure (Front). Why build a Tesla when a Prius will do?

Everything OK at PGA = 0.30g.

Modern Transformer 230 kV - 60 kV (built 2010).
Anchorage capacity was sufficient so that PGA = 0.30g was small enough to not overcome sliding / rocking.
Modern composite bushings.
Lots of cable slack.
No damage.

Modern Circuit Breaker 230 kV (built 2010).
Shake Table Tested to PGA = 0.5g.
Steel supports are elastic to PGA >> 1.0g. (No “R” values allowed like for regular buildings)
Lots of cable slack.
No damage.

230 kV Horizontal Break switch atop heavily braced frame.

Lots of cable slack.

No damage.

Anshel Schiff, August 26, 2014

Prof Schiff is the “father” of seismic design of high voltage equipment.

Behing him is a modern circuit switcher (1999) (no damage) and a vintage power transformer (minor oil leaks)

115 kV - 12 kV Bank 1

Oil leaks appears to be from top pipe connections (as expected / common)

Modern Battery Racks.

No damage.

230 kV. Wave trap supported buy two post-insulators, on same stand with Trench CCVT (composite)

Station Service Transformers. Heavy braced. No damage.

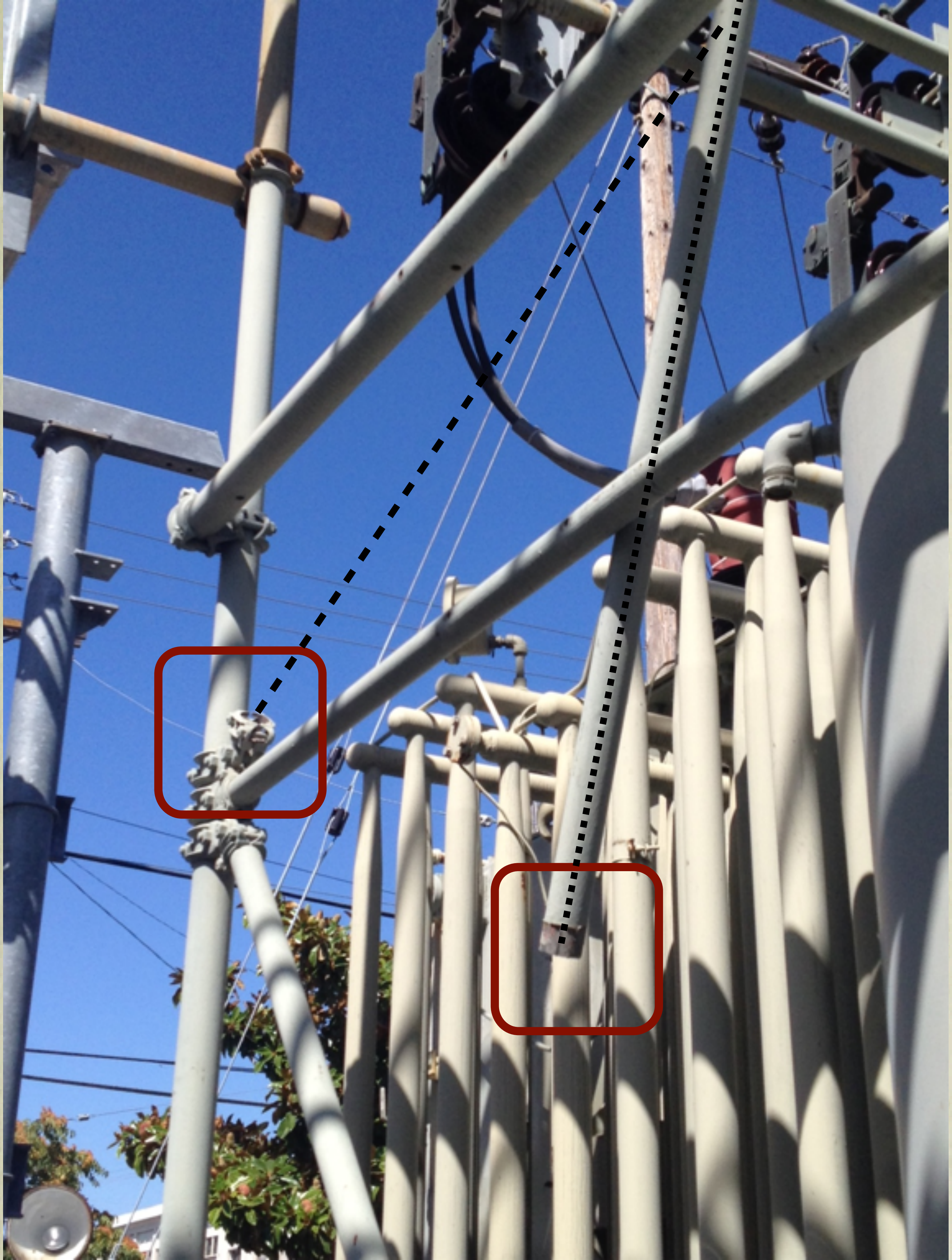
Vintage transformers. No damage at PGA ~0.30g. Well anchored.
A new parallel transformer bank was installed so these are somewhat “Redundant”

Replacing these surge arrestors would be a good thing; but there is redundancy. They did not fail in this earthquake.

115 kV CCVT Composite.

Upgrades of heavily loaded scaffolding might be a good thing.

Diagonal in scaffolding that was damaged in earthquake



12 kV Circuit Breaker and switches
some settlement

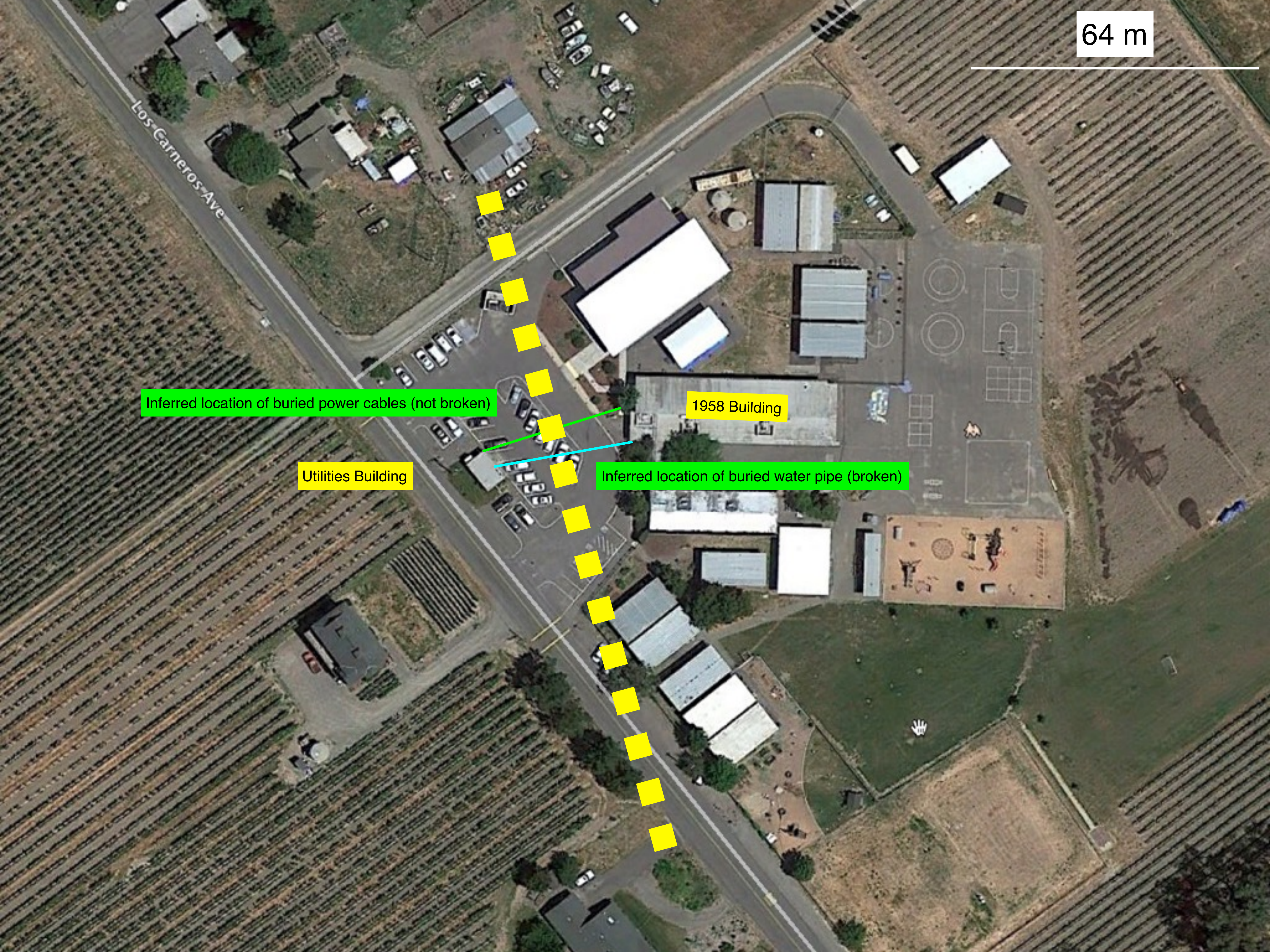
12 kV Circuit Breaker and switches
some settlement

115 kV SA (Composite) and
Pot Head (XLPE type)

Unanchored Cabinets rocked to these positions (formerly cabinets were tight against each other).


Gas Issues

- 160 loss of service due to damage to customer facilities
- PG&E responded to >8,000 service "tags" (report of gas odor, leak, safety check, ...)
- Total relights, appliance checks > 2,500 (926 in Napa, 110 in Vallejo)
- PG&E has replaced 200 feet of 26-inch diameter Steel pipe that underwent some fault offset. No damage in old pipe. New pipe is ~2 times tougher.
- PG&E is replacing 7,000 feet of 12-inch diameter PE pipe located in the fault zone (the pipe had no leak or apparent damage, but might be prone to pre-mature cracking)


64 m
Los Carneros Ave
Inferred location of buried power cables (not broken)
1958 Building
Utilities Building
Inferred location of buried water pipe (broken)


Line 021A.
Surface Cracking
North
South

AT&T - Communications

Wall Panel Fell. Was held by 4 tabs, for future expansion. Building racking damaged the tabs.
Panel fell onto HVAC equipment, damaging cooling system.
PG&E power equipment was also damaged by the falling wall.
Emergency generator failed to start.
Back up batteries worked well. But, batteries need to be recharged…. a priority to get a generator to recharge the batteries.
No real loss of service, as AT&T was able to respond.

Sewer

WWTP did well.
Why? founed on clay (no liquefaciton)

Sewer Pipes Broke
Repaired at fault crossings

Residual pipe damage remains to be found

Zone with Concentrated Sewer Pipe Breaks

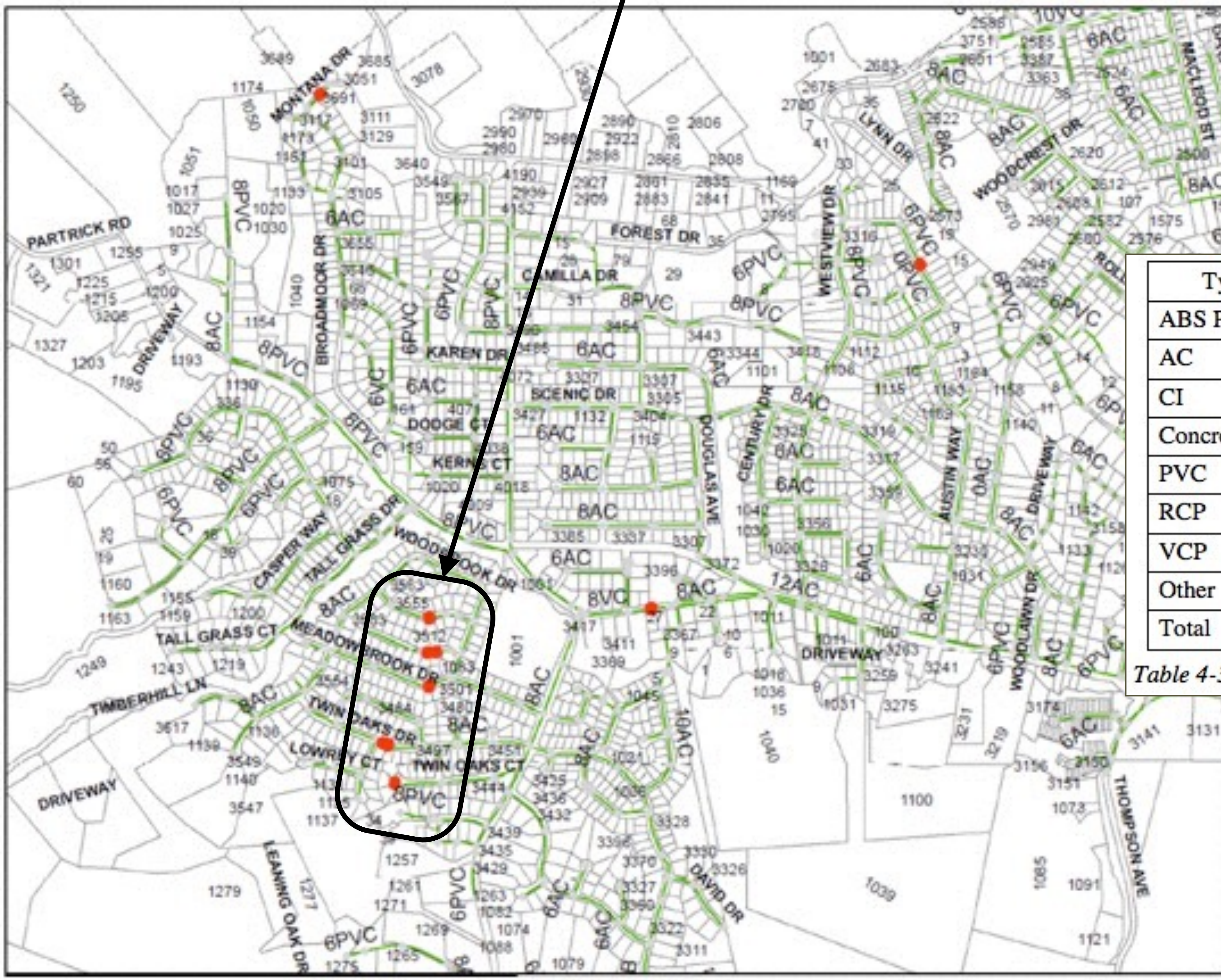


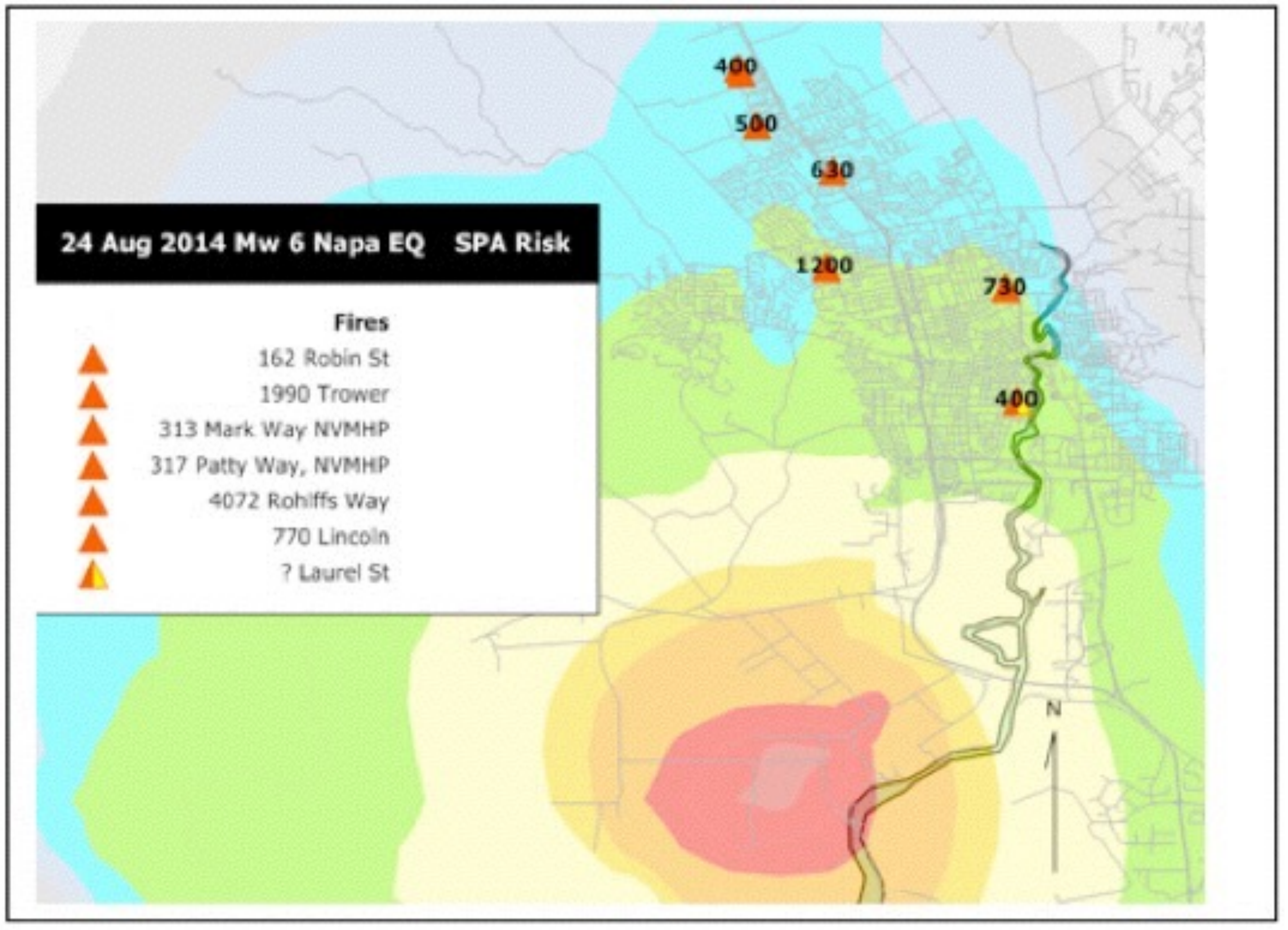
Figure 4-16. Location of Sewer Breaks

Type	Miles	Pct of Total
ABS Plastic	2	0.7%
AC	124	45.9
CI	1	0.4
Concrete	3	1.1
PVC	61	22.6
RCP	7	2.6
VCP	70	25.9
Other	2	0.7
Total	270	100%

Table 4-3. Length of Sewer Pipes – Napa (Miles)

Possible Rocking of Center Tower in Clarifier

Fire Following Earthquake



Fire Ignitions Attributed to the August 24 2014 Main Shock

No.	Time of Report (approx.)	Location	Description (see below)
1	0330	Orchard Ave	Napa Valley Mobile Home Park (NVMHP) – actually two ignitions – see narrative
2	0400	Laurel St. (no street number)	2 story, 2 unit residence, roof collapse, started fire
3	0500	162 Robin at Solano	Dbl wide home
4	0630	1990 Trower	Smoke inside structure
5	0730	770 Lincoln x Soscol	Electrical fire in substructure of a mobile home
6	1200	4072 Rohlffs Way x Fair	Kitchen fire in single story multi-unit senior housing complex

FFE

- There were several fire ignitions
- There was NO wind at the time of the earthquake
- If it had been windy (say 20 mph), with the loss of water pressure due to damage int eh water system, then a LOT of Napa would have burned to the ground

Summary -Underground

- Damage to buried utility pipes is the ELEPHANT in the room.
- If we do not install seismic-resistant pipes in a pro-active manner, some pipes are doomed in future earthquakes... Long outages.... Economic Consequences.... Loss of Water for Fire Fighting.... Raw sewage dumped into our waterways.... Gas leaks providing fuel for fires....
- ALA 2005 is a Guideline to design buried pipes. It might be time to make it a mandatory Standard.

Summary - Overhead

- Why did we do so well? IEEE 693 and Bellcore and lessons learned form past earthquakes. Thank you Anshel Schiff, Alex Tang (Nortel), Dennis Ostrom (SCE), Ed Matsuda (PG&E), Eric Fujisaki (PG&E), Leon Kempner (BPA), Lana Gilpin Jackson (BC Hydro), Ron Tognazini (LADWP), Craig Riker (SDG&E) and many others.

- These standards cost $millions, and take decades to implement.

Do Utilities Do or Not Do?

- Do-ers: Knowledge of weaknesses, followed by careful assessment, followed by capital improvements.
- Non-Do-ers: Unaware of the risks. Or, aware of the risks, but unwillingness to fund.