Magna M 5.7 2020

John Eidinger, G&E
eidinger@geEngineeringSystems.com
www.geEngineeringSystems.com
October 23 2020

Acknowledgements: Pete McDonough, PG&E, Dominion Energy, Enstar provided
information about the performance of gas systems in the Magna and various other earthquakes in California and Alaska.
Mobile home information provided by Bruce Maison.

Agenda

- Magna M 5.7, March 18 2020
- Gas Pipes in Ridgecrest 2019, Alaska 2018, Napa 2014, Eureka 2010, Northridge 1994, Imperial Valley 1979, San Fernando 1971, Long Beach 1933, and others
- Data analysis (fragility)
- The issue of mobile homes and gas meters

Magna
Natural Gas System

Magna M 5.7

- M 5.7 4 km NNW of Magna
- Depth 11.9 km
- Wednesday March 18 2020 7:09:31 am local time

Natural Gas Operations

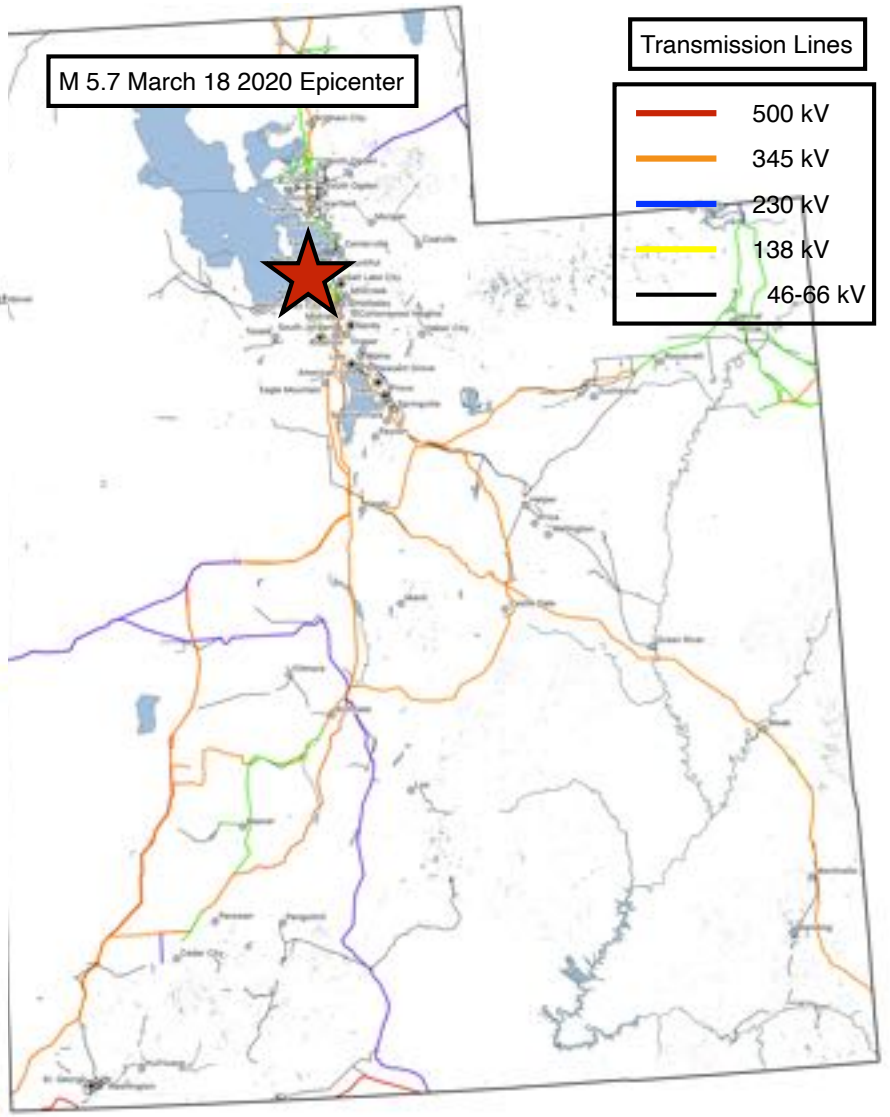
- Questar was the operator for many years
- Dominion Energy bought Questar in Utah
- The Transmission System was spun off Dominion Energy
- Dominion includes: local sub-transmission, distribution for Salt Lake City, Park City and other areas

Gas Leaks, March 18 2020

- Very minor damage (items falling, etc.)
- No structural damage (moment frame building designed in 1990s) designed to remain operational during a worst case EQ
- 48% of customers who turned off their gas at the meter actually had leaks. This compares with 1994 Northridge (10%) and 1987 Whittier Narrows (22%)

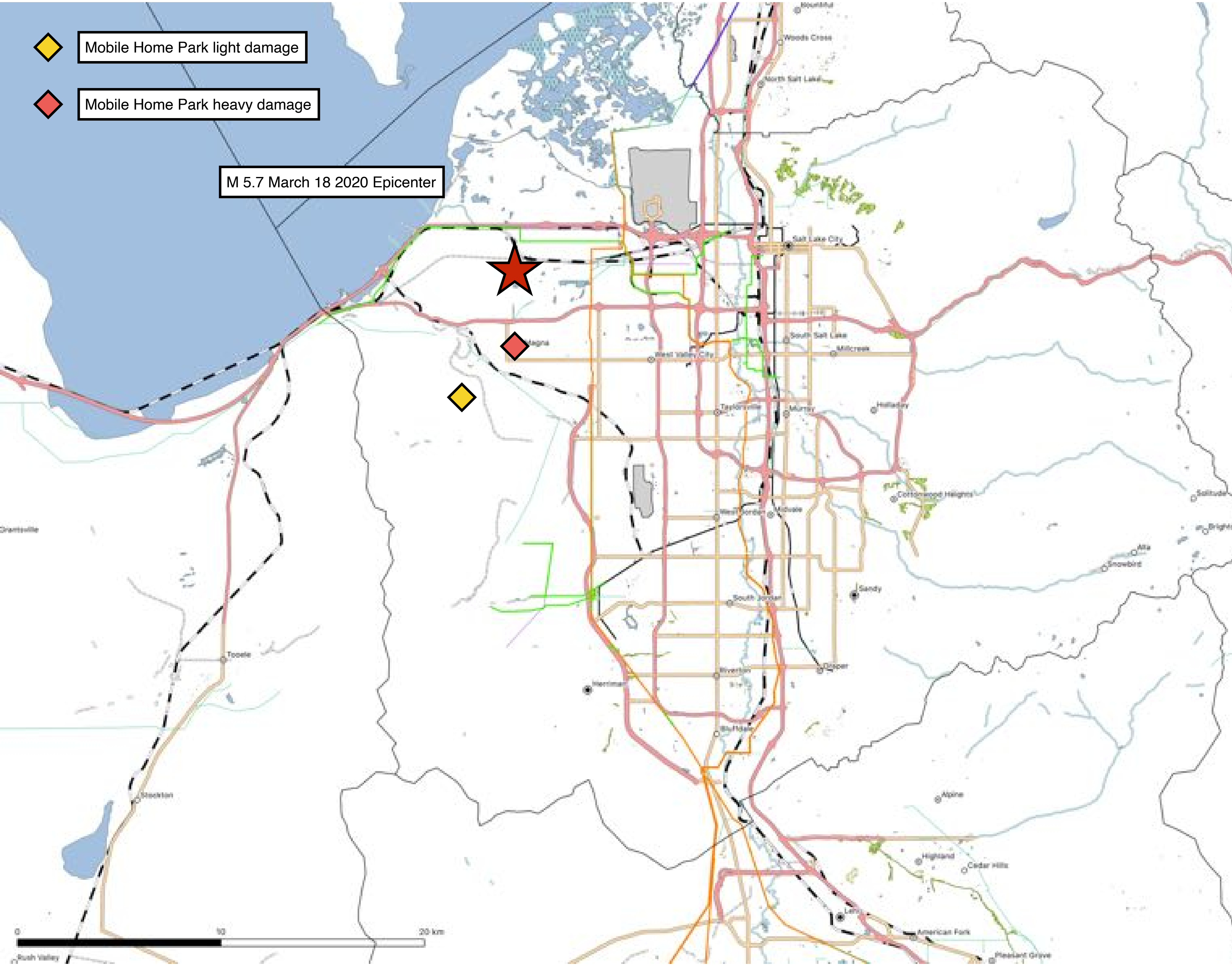
Gas

- Significant trailer park damage (about 49 trailers at MMI VII). There were no fires at the trailer parks (unlike Northridge)
- No main leaks. Dominion uses MDPE extensively for distribution pipes
- 9 earthquake valves activated within MMI VI and VII zones. These appear to have been activated above the ANSI standards of PGA = 0.16g. These are valves in service lateral lines.
- 391 leaks. 97% were on meter sets. 3% were on underground service laterals: 4 tap-to-main leaks; 1 corroded steel service
- 113 leaks on customer piping: 21% were water heater related (compared to 75% for Whittier). Most new water heaters are installed with seismic straps, which is something that Dominion has stressed.

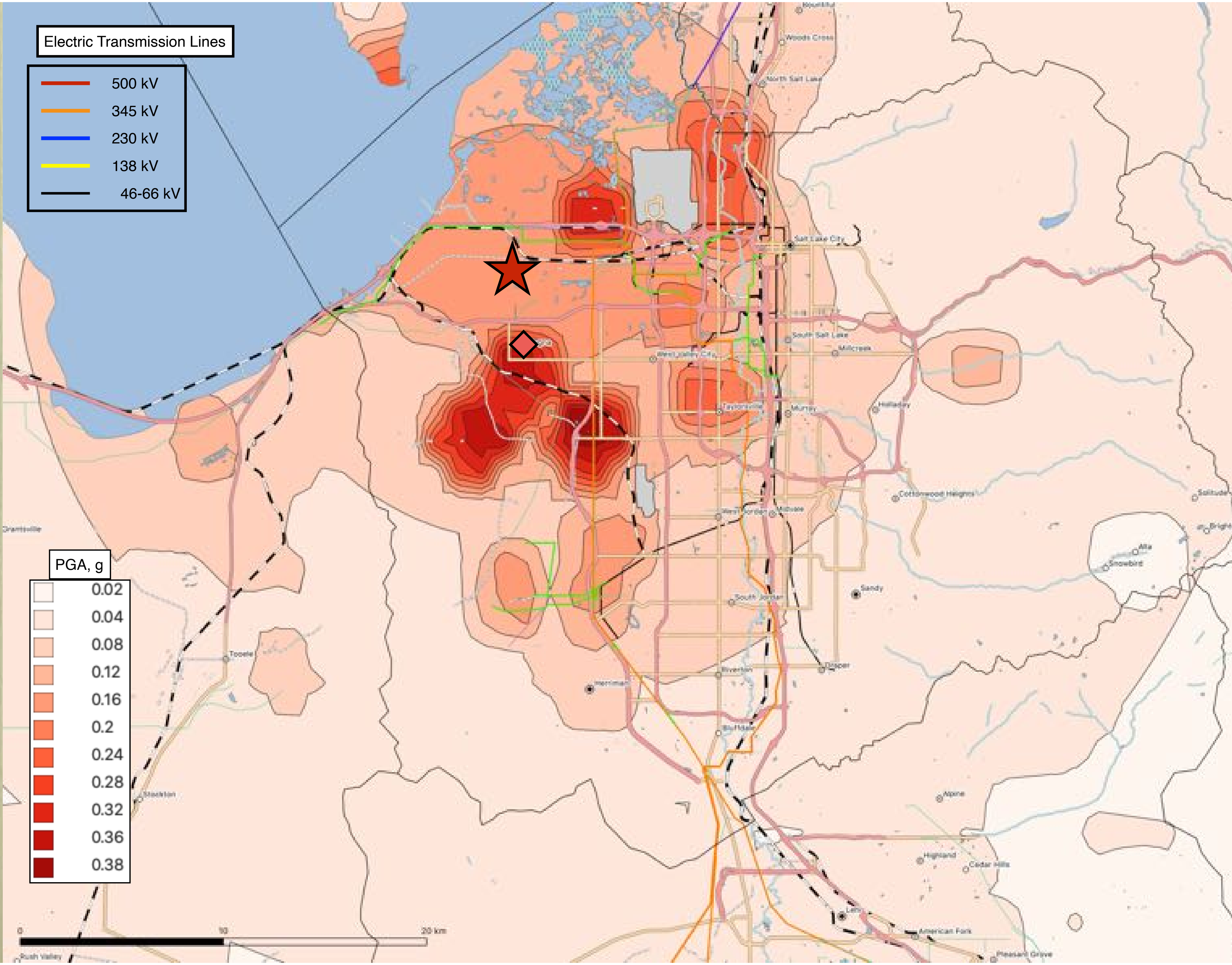


Earthquakes in 2020

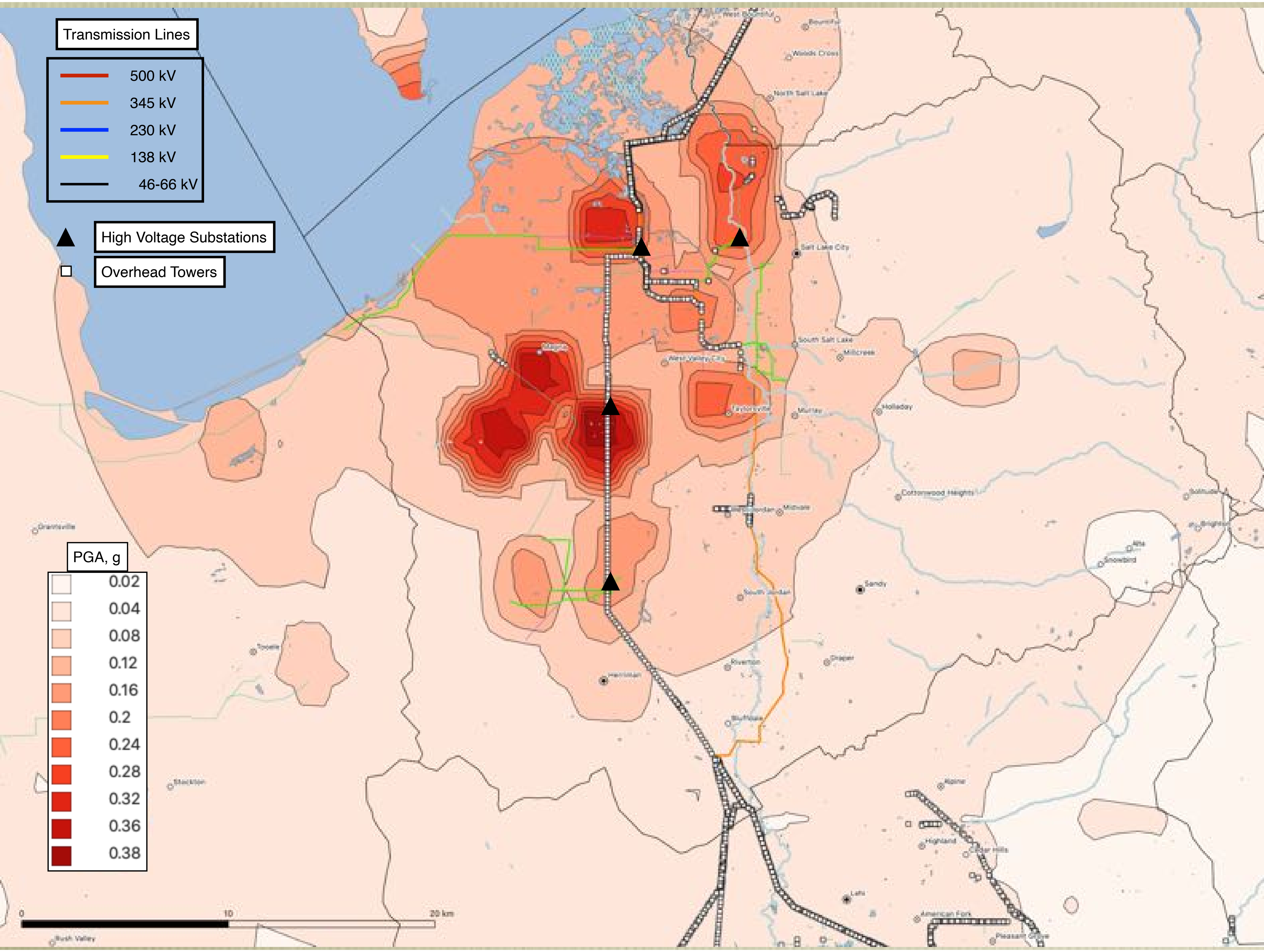
impacts to gas
impacts to power

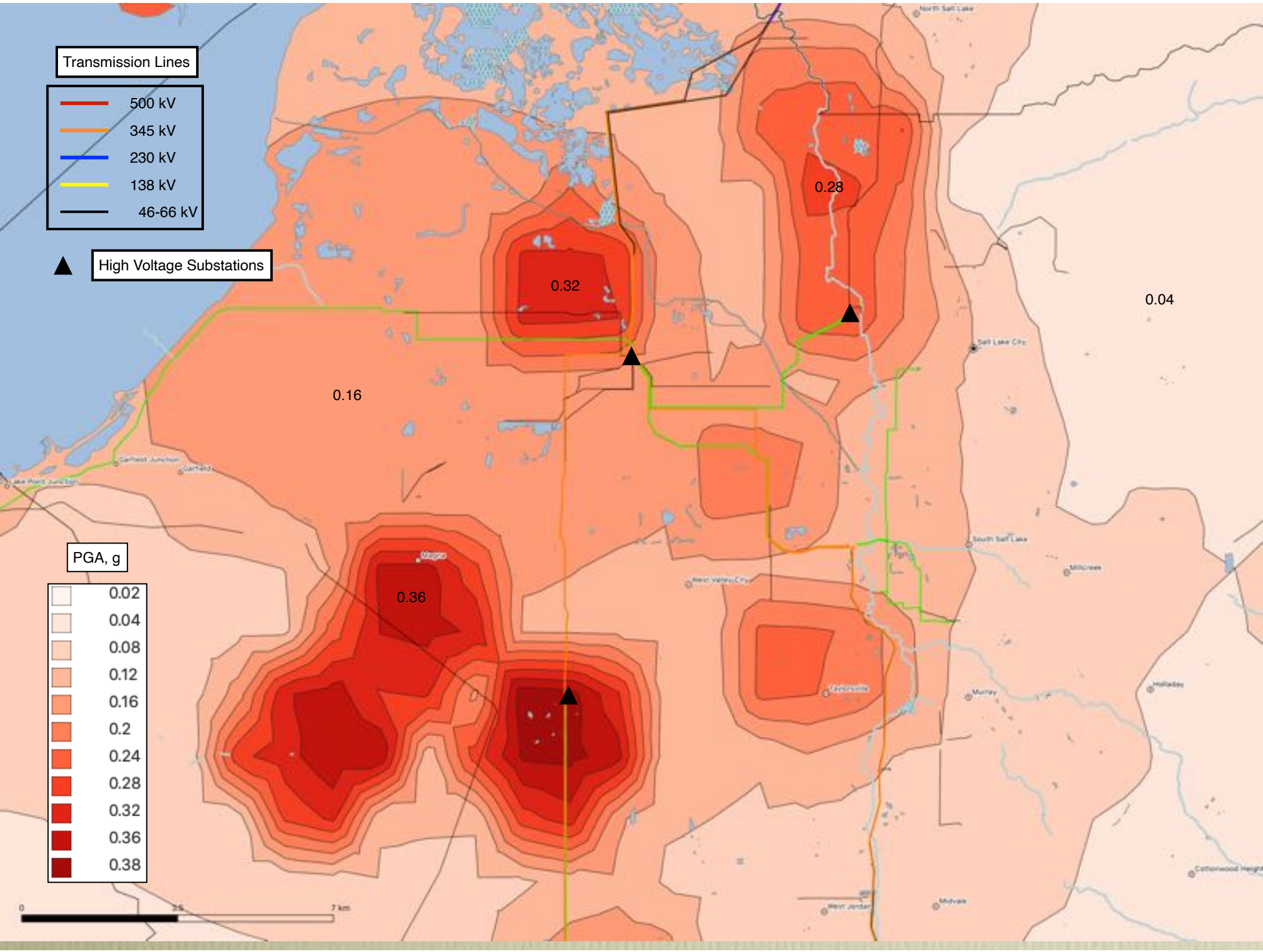


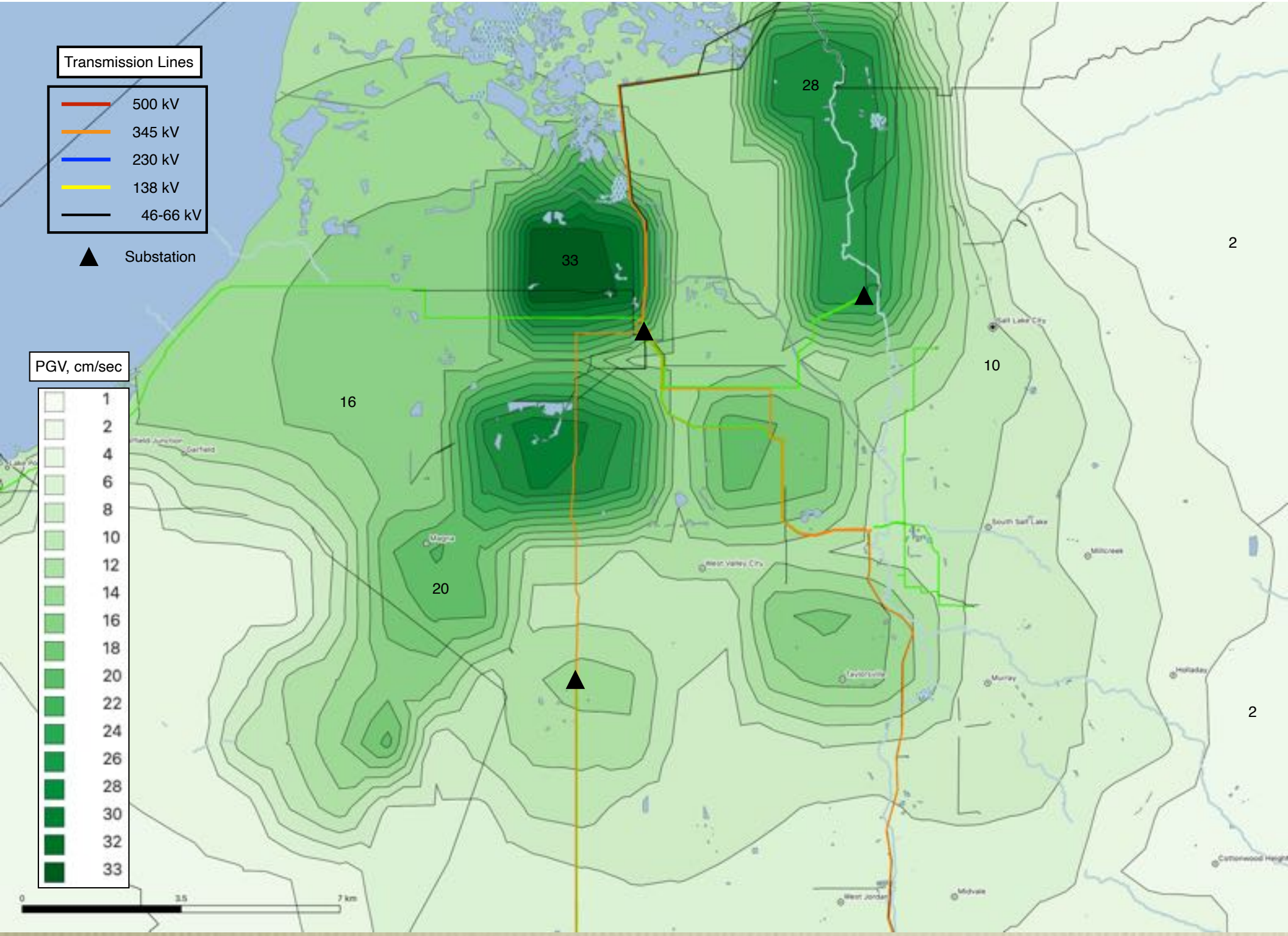
Mobile Home Park light damage
Mobile Home Park heavy damage
M 5.7 March 18 2020 Epicenter
Bountiful
Woods Cross
North Salt Lake
Salt Lake City
Magna
West Valley City
South Salt Lake
Millcreek
Taylorsville
Murray
Holladay
Cottonwood Heights
West Jordan
Midvale
Grantsville
Tooele
South Jordan
Sandy
Riverton
Draper
Herriman
Bluffdale
Stockton
Alpine
Highland
Cedar Hills
Lehi
American Fork
Pleasant Grove
Solitude
Brighton
Alta
Snowbird
Rush Valley
0
10
20 km

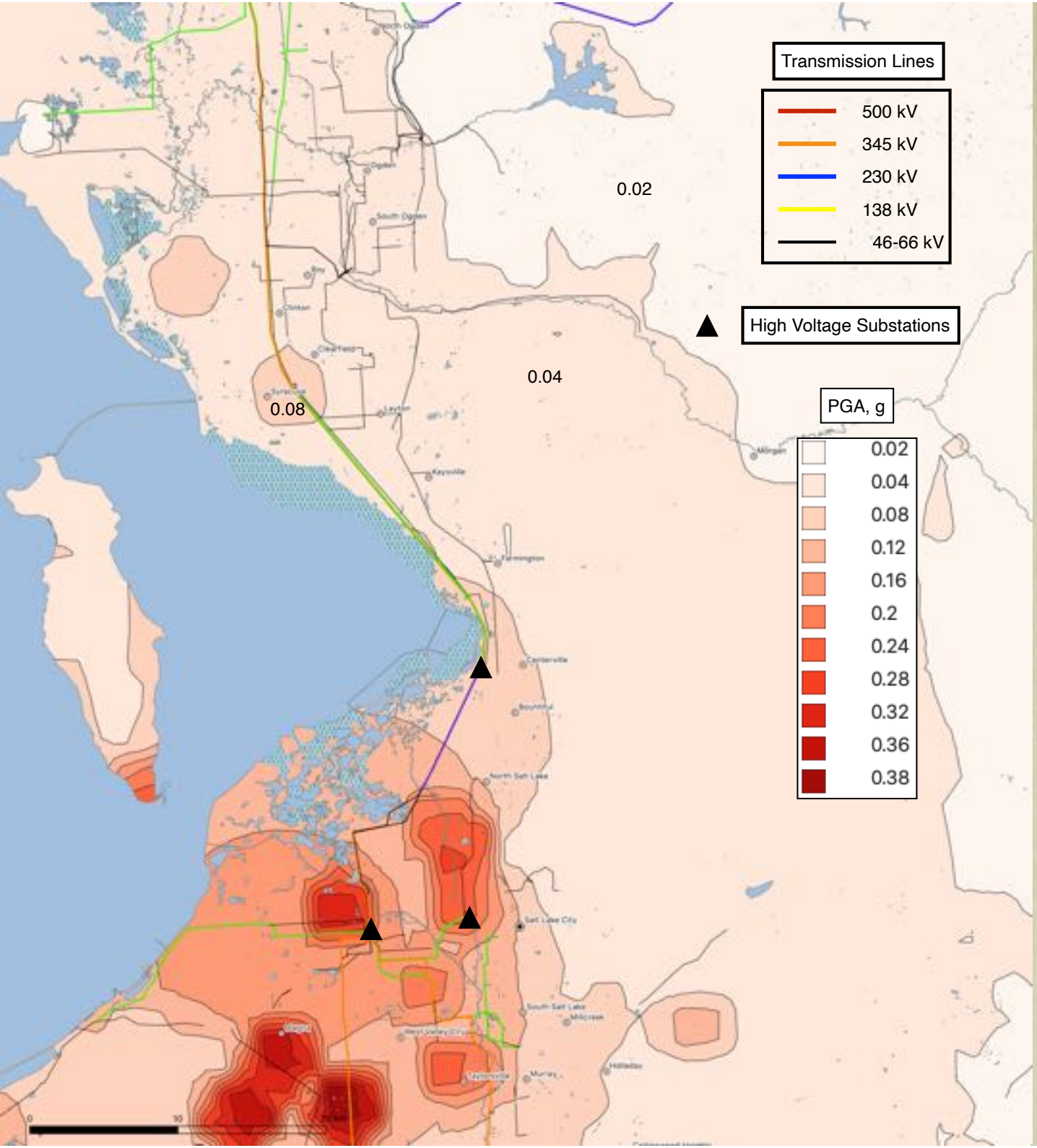


Electric Transmission Lines
500 kV
345 kV
230 kV
138 kV
46-66 kV
PGA, g
0.02
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.38

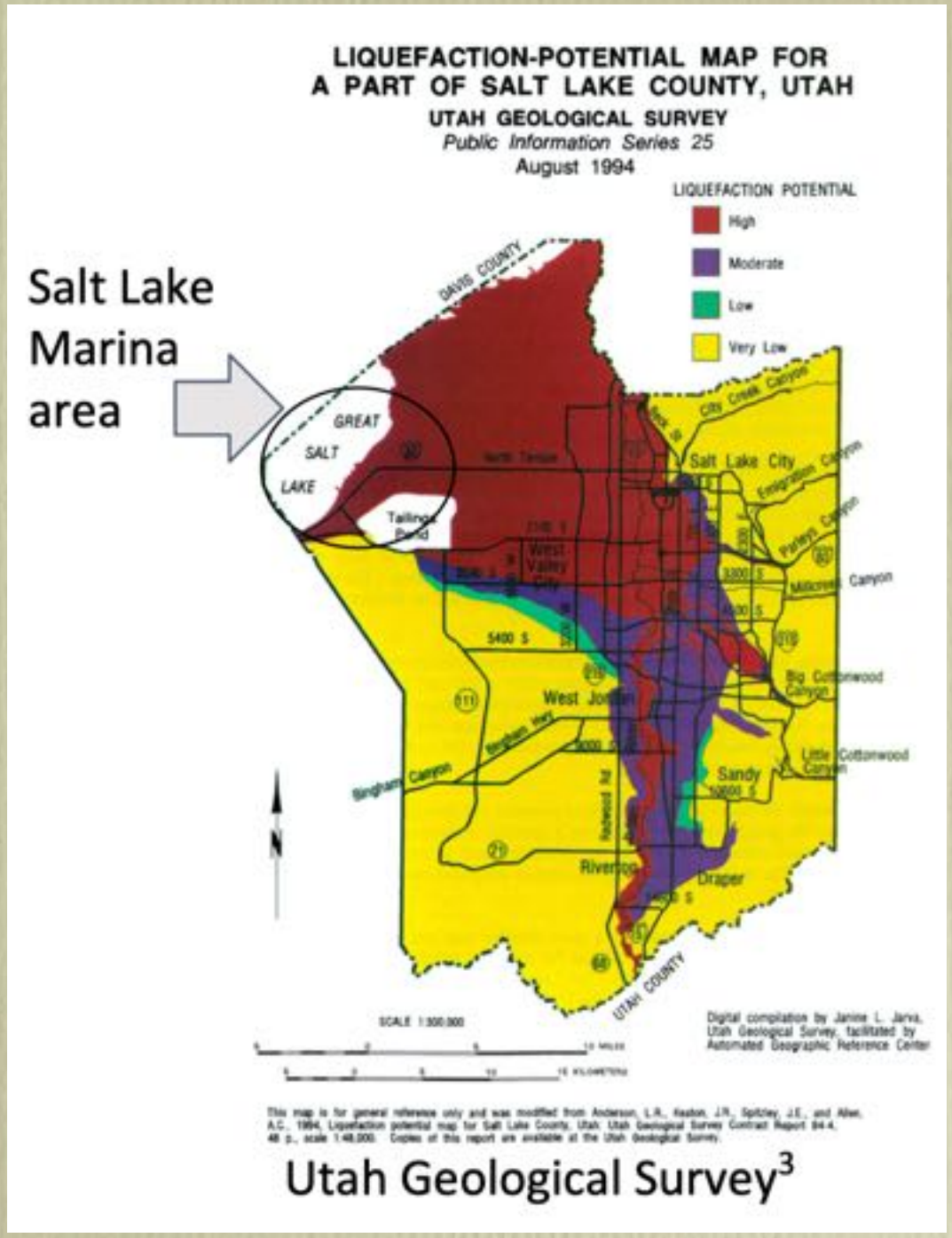

Transmission Lines
500 kV
345 kV
230 kV
138 kV
46-66 kV
High Voltage Substations
Overhead Towers
PGA, g
0.02
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.38
0
10
20 km


Transmission Lines
500 kV
345 kV
230 kV
138 kV
46-66 kV
High Voltage Substations
PGA, g
0.02
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.38
0.16
0.32
0.28
0.04
0.36
0
3.5
7 km


Transmission Lines
500 kV
345 kV
230 kV
138 kV
46-66 kV
Substation
PGV, cm/sec
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
33
0
3.5
7 km
28
33
16
20
10
2
2

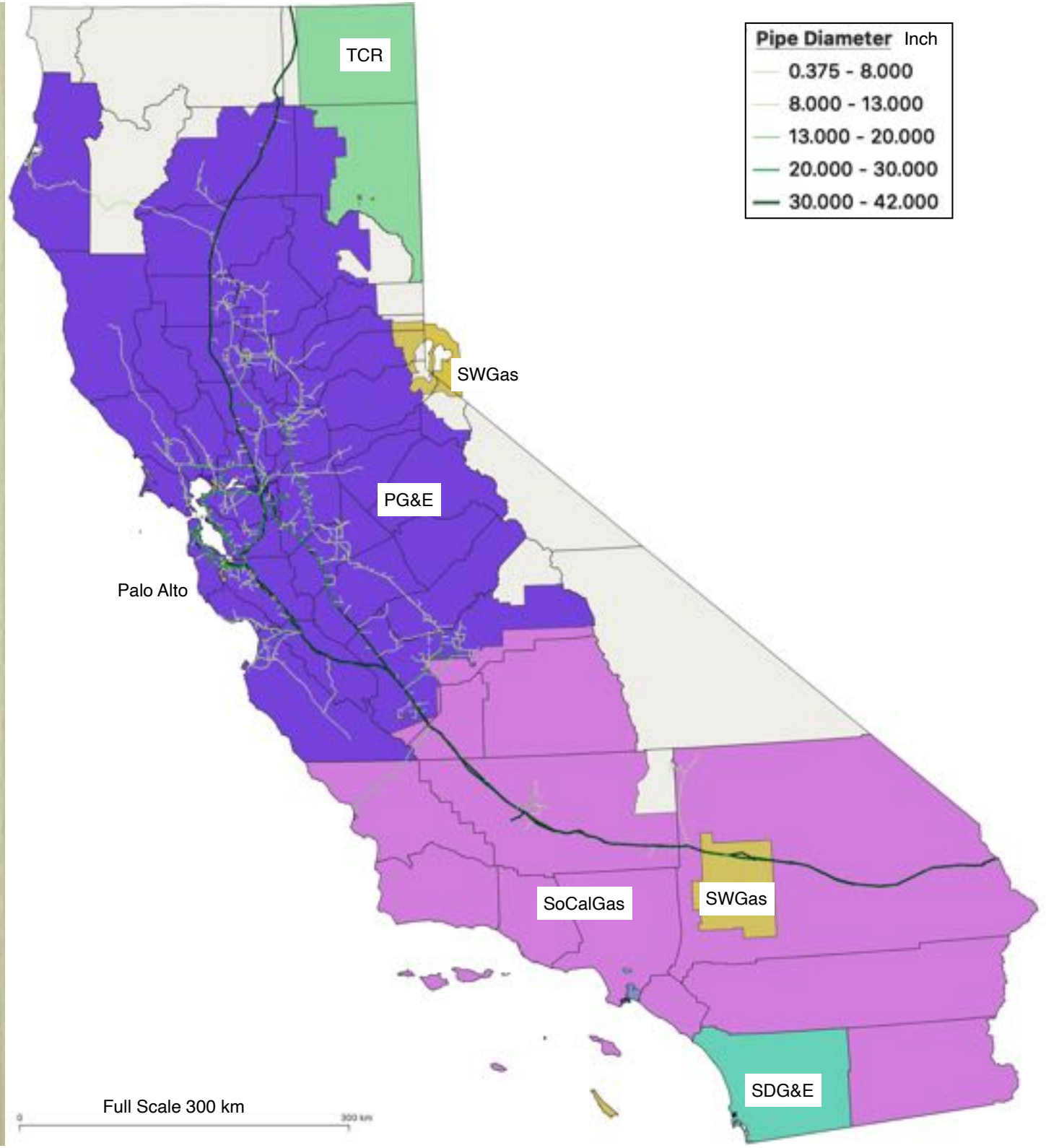

Transmission Lines
500 kV
345 kV
230 kV
138 kV
46-66 kV
High Voltage Substations
PGA, g
0.02
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.38
0.02
0.04
0.08

Salt Lake Marina area

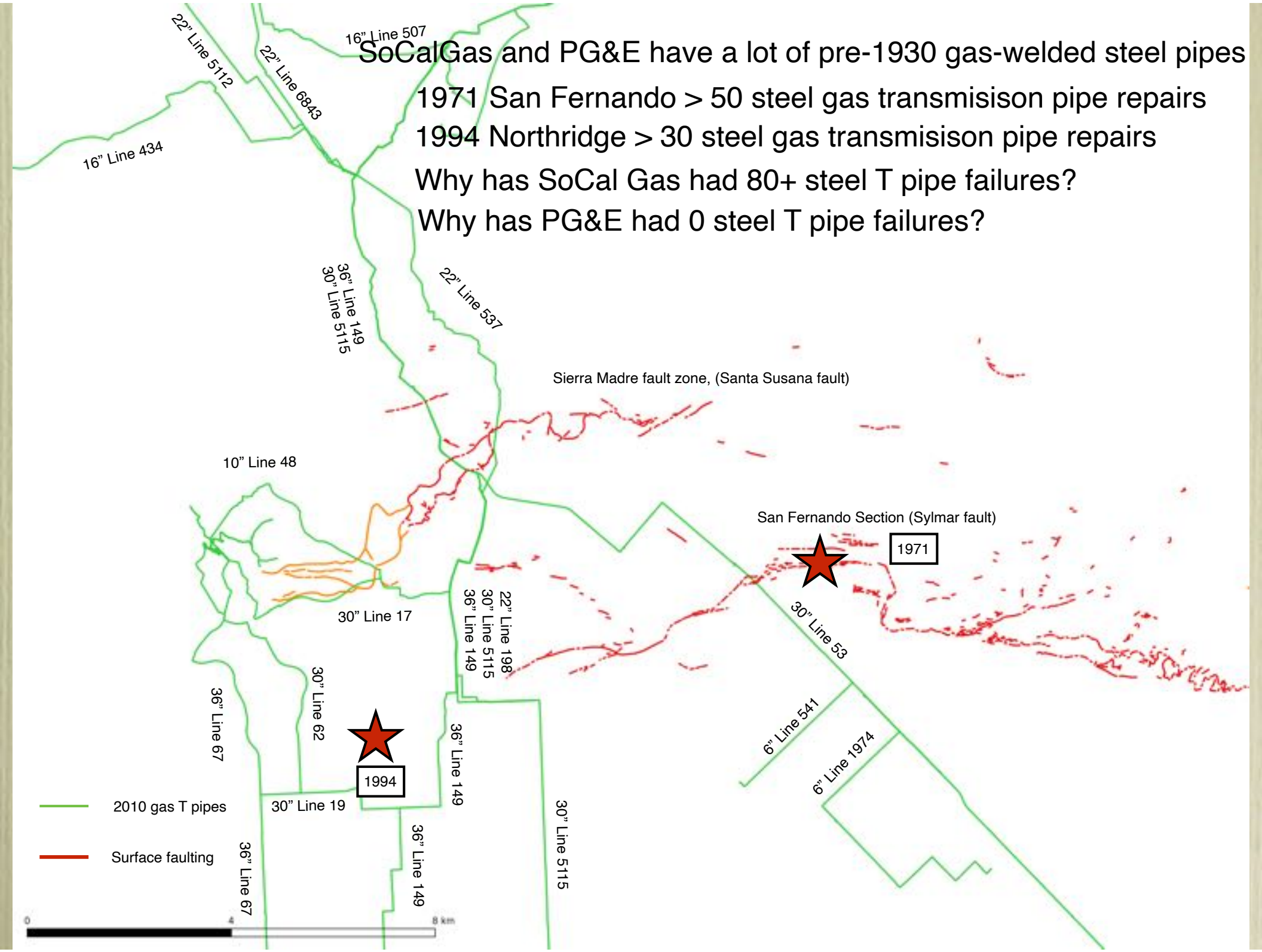


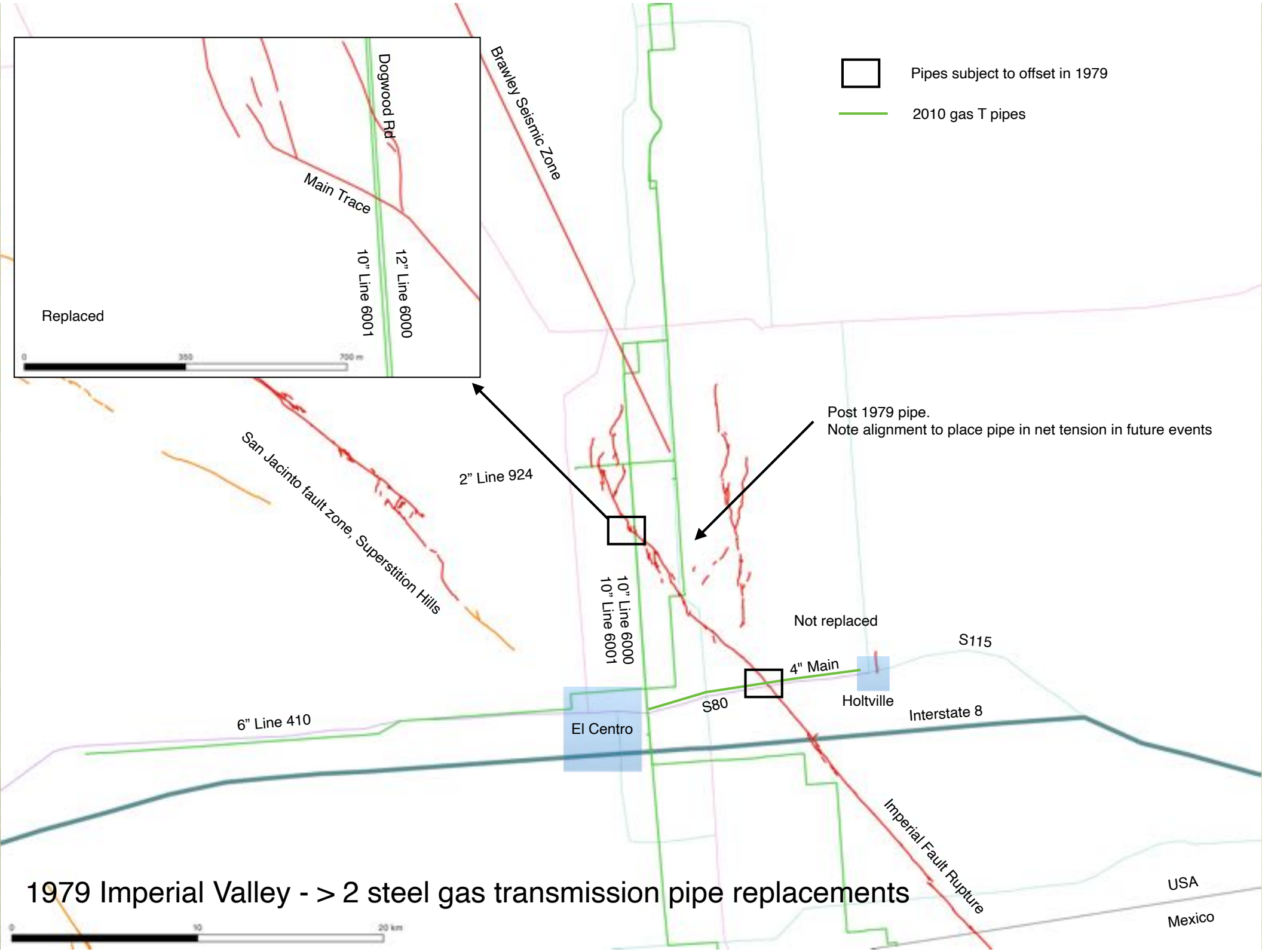
Utah Geological Survey[3]

California, Anchorage


Pipe Diameter Inch
0.375 - 8.000
8.000 - 13.000
13.000 - 20.000
20.000 - 30.000
30.000 - 42.000
TCR
SWGas
PG&E
Palo Alto
SoCalGas
SWGas
SDG&E
Full Scale 300 km
0
300 km


Earthquakes that damaged Gas pipes (year)
Reference: Seismic Fragility of Natural Gas Transmission Pipelines and Wells, by G&E Engineering Systems Inc, Report R130.01.01,259 pages, Revision 3, July 15 2020. Available at: www.geEngineeringSystems.com
2010
2014
1906
1957
2007
1952
1994
1971
1987
1933
1979


SoCalGas and PG&E have a lot of pre-1930 gas-welded steel pipes
1971 San Fernando > 50 steel gas transmisison pipe repairs
1994 Northridge > 30 steel gas transmisison pipe repairs
Why has SoCal Gas had 80+ steel T pipe failures?
Why has PG&E had 0 steel T pipe failures?
22" Line 5112
22" Line 6843
16" Line 507
16" Line 434
36" Line 149
30" Line 5115
22" Line 537
Sierra Madre fault zone, (Santa Susana fault)
10" Line 48
San Fernando Section (Sylmar fault)
1971
30" Line 17
22" Line 198
30" Line 5115
36" Line 149
30" Line 53
36" Line 67
30" Line 62
6" Line 541
6" Line 1974
1994
36" Line 149
30" Line 19
30" Line 5115
36" Line 149
36" Line 67
2010 gas T pipes
Surface faulting
0
4
8 km



1979 Imperial Valley - > 2 steel gas transmission pipe replacements

Anchorage M 7.0
Nov 30 2018

ANCHORAGE, ALASKA, M_w 7.1 EARTHQUAKE OF NOVEMBER 30, 2018 LIFELINE PERFORMANCE

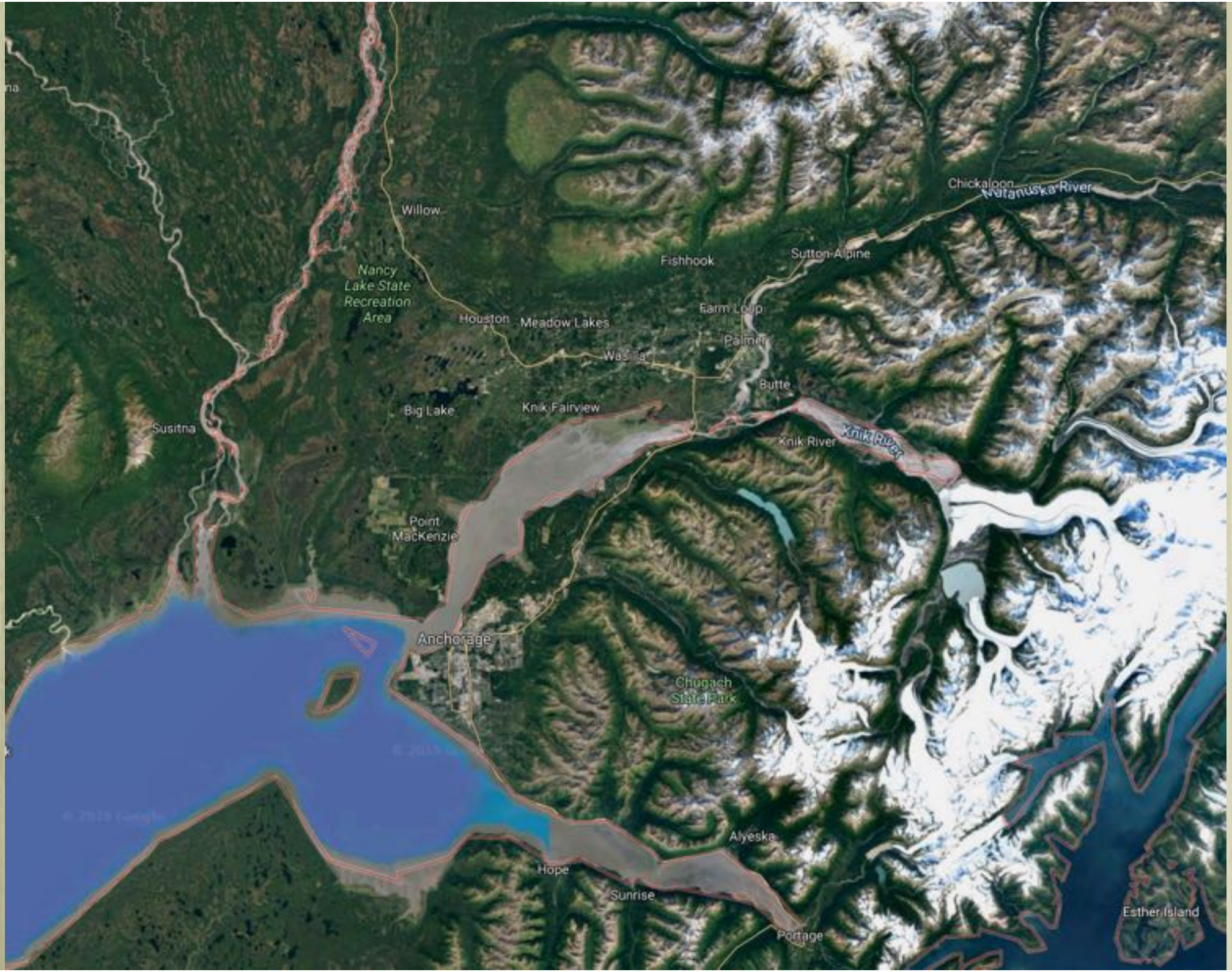
By

JOHN M EIDINGER and JOHN DAI

The Council of Lifeline Earthquake Engineering
TCLEE No: 5

Revision A, June 27 2019


Susitna River
Willow
Nancy Lake State Recreation Area
Houston
Meadow Lakes
Wasilla
Fishhook
Sutton-Alpine
Matanuska River
Farm Loop
Palmer
Butte
Big Lake
Knik-Fairview
Eklutna
Knik River
Epicenter of M 7.1 Earthquake
Knik Arm
Eagle River
Pt MacKenzie
Anchorage
Beluga
Turnagain Arm
Hope

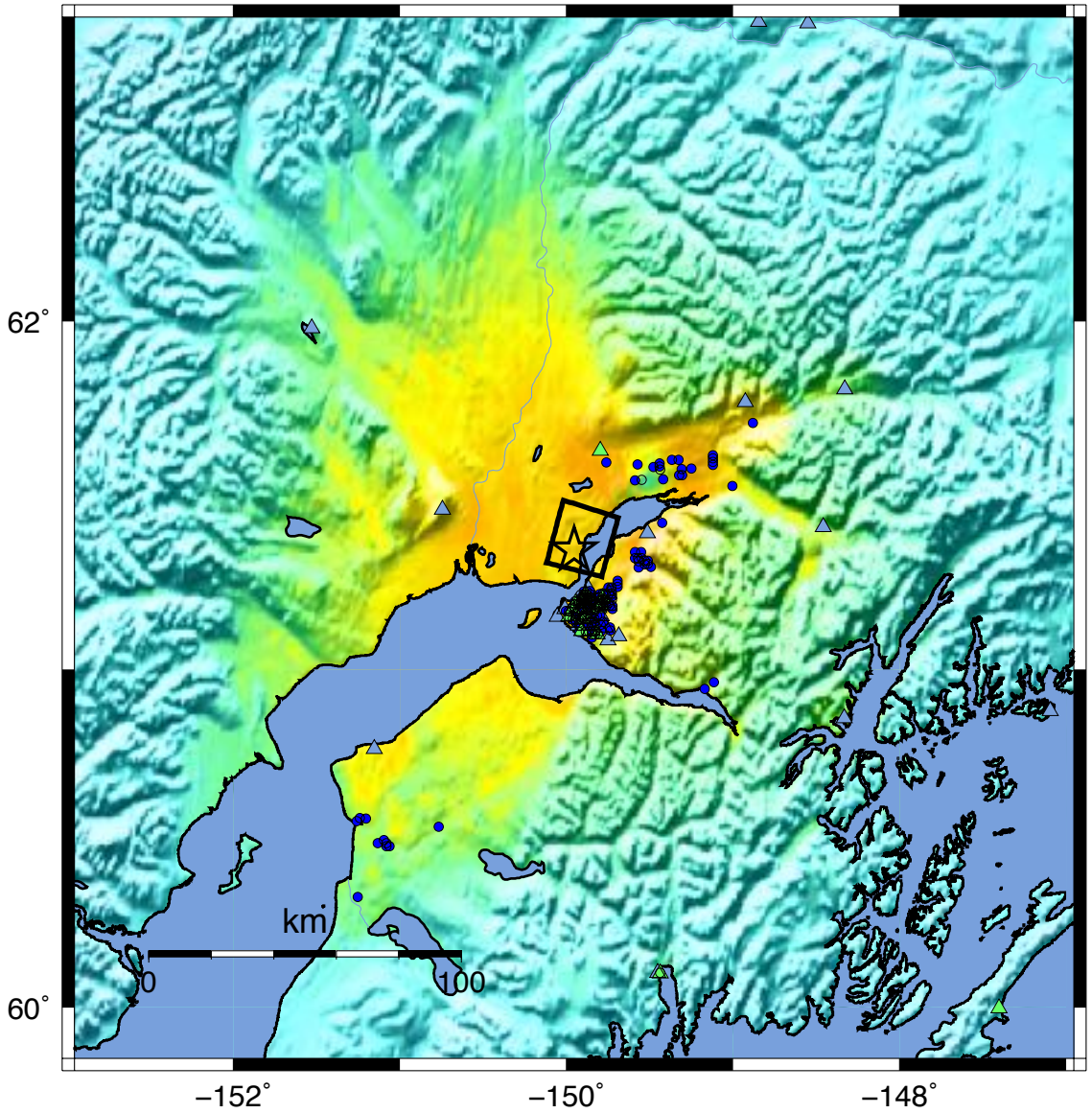

Willow
Nancy Lake State Recreation Area
Houston
Meadow Lakes
Wasilla
Big Lake
Knik Fairview
Susitna
Point MacKenzie
Anchorage
Chugach State Park
Fishhook
Sutton-Alpine
Chickaloon
Matanuska River
Farm Loop
Palmer
Butte
Knik River
Knik River
Alyeska
Hope
Sunrise
Portage
Esther Island

ENSTAR

- Natural Gas Company for Anchorage and area (1961)
- 440 miles of transmission pipes
- 3,200 miles of distribution pipes (1,000 Cu laterals, 100 replacements per year)
- 15 repairs in Nov 30 2018 earthquake (to date) 12 corrosion 3 EQ
- 2,000 customer calls for re-light: Enstar asked public NOT to turn off valves unless they smelled gas
- $1 million in repair cost
- A longer duration event would have been MUCH worse (PGDs)

AEC ShakeMap : 7 miles NW of Elmendorf AFB

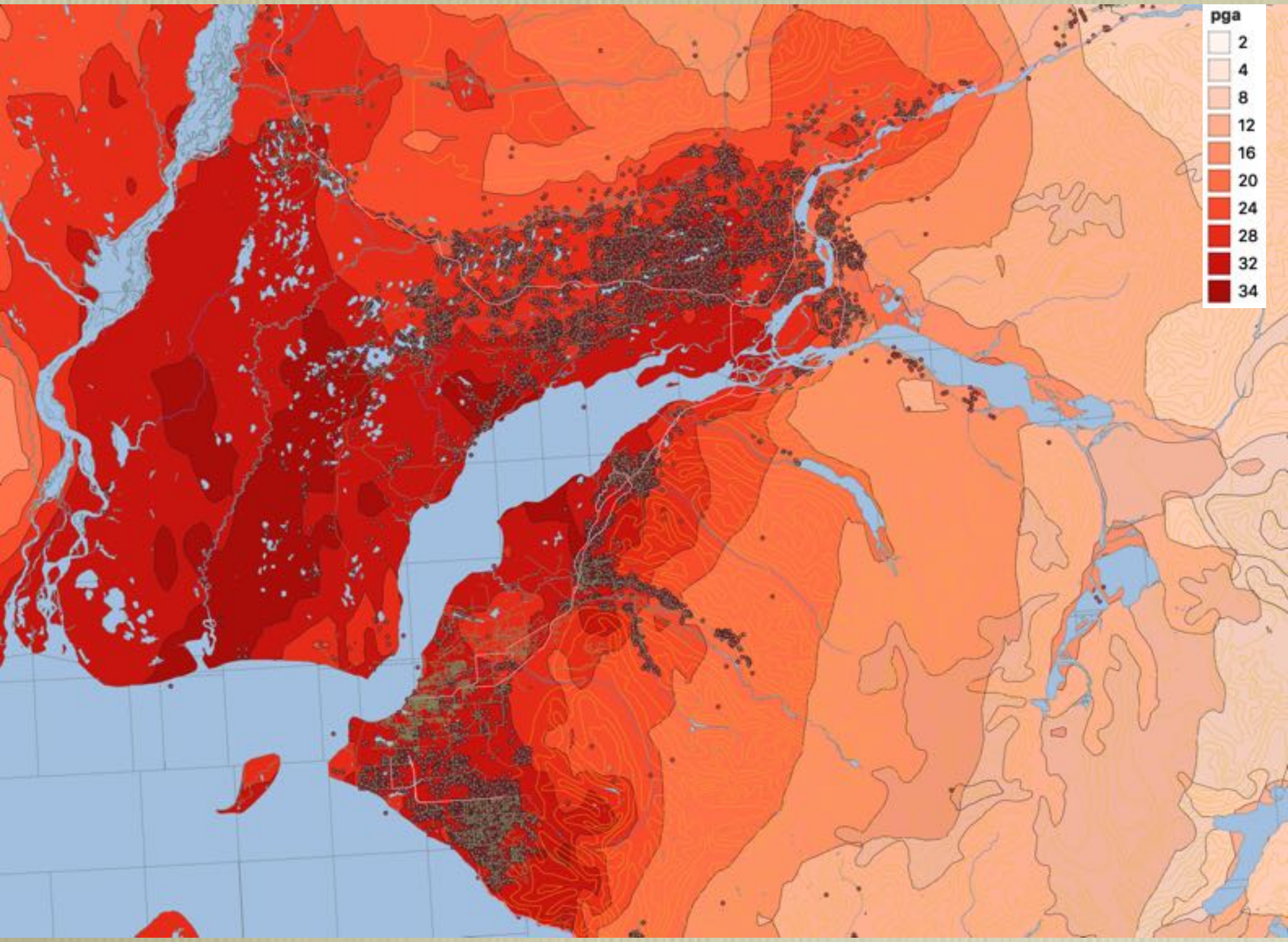
Nov 30, 2018 08:29:29 AM AKST M 7.1 N61.35 W149.96 Depth: 46.7km ID:20419010

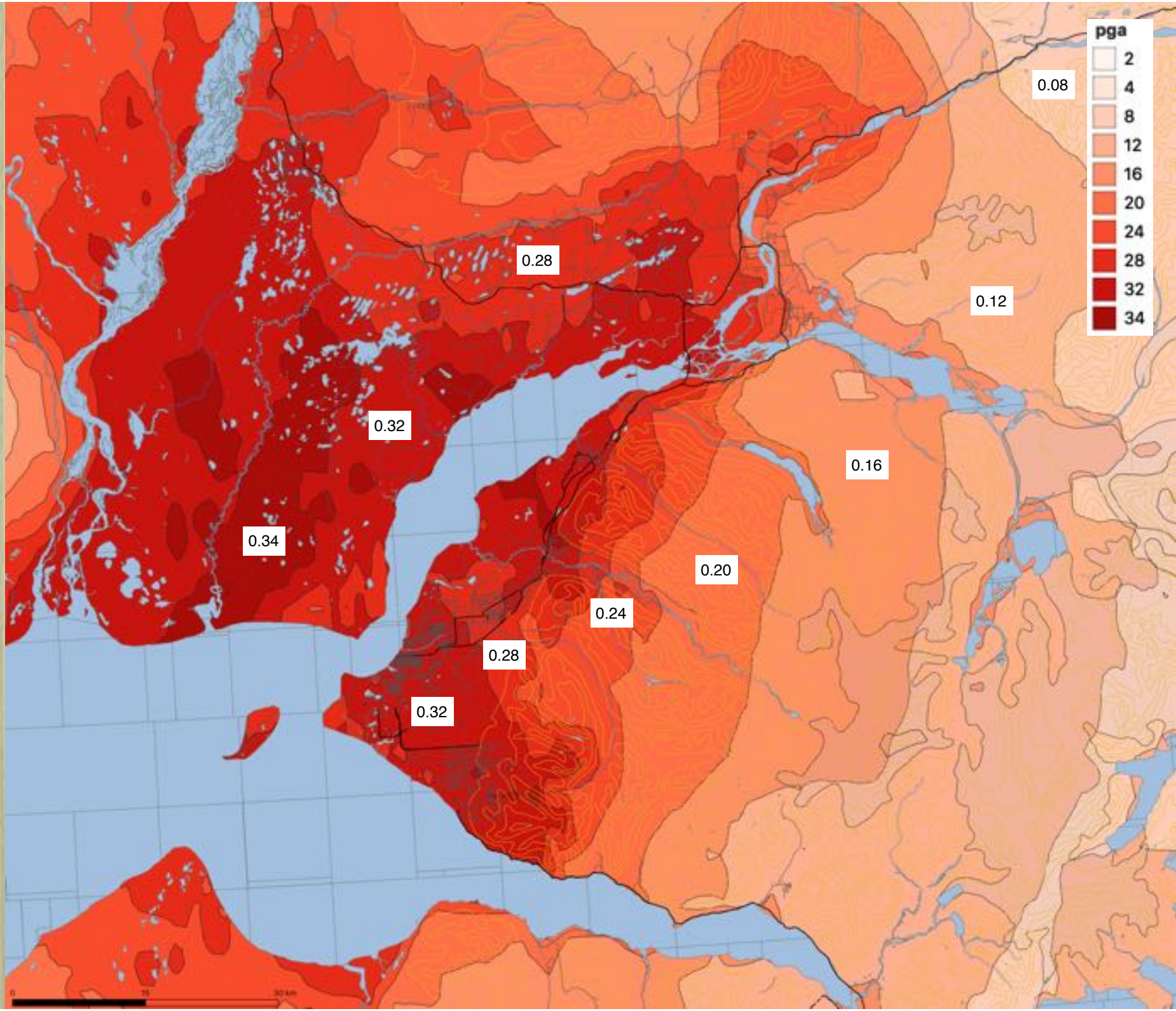


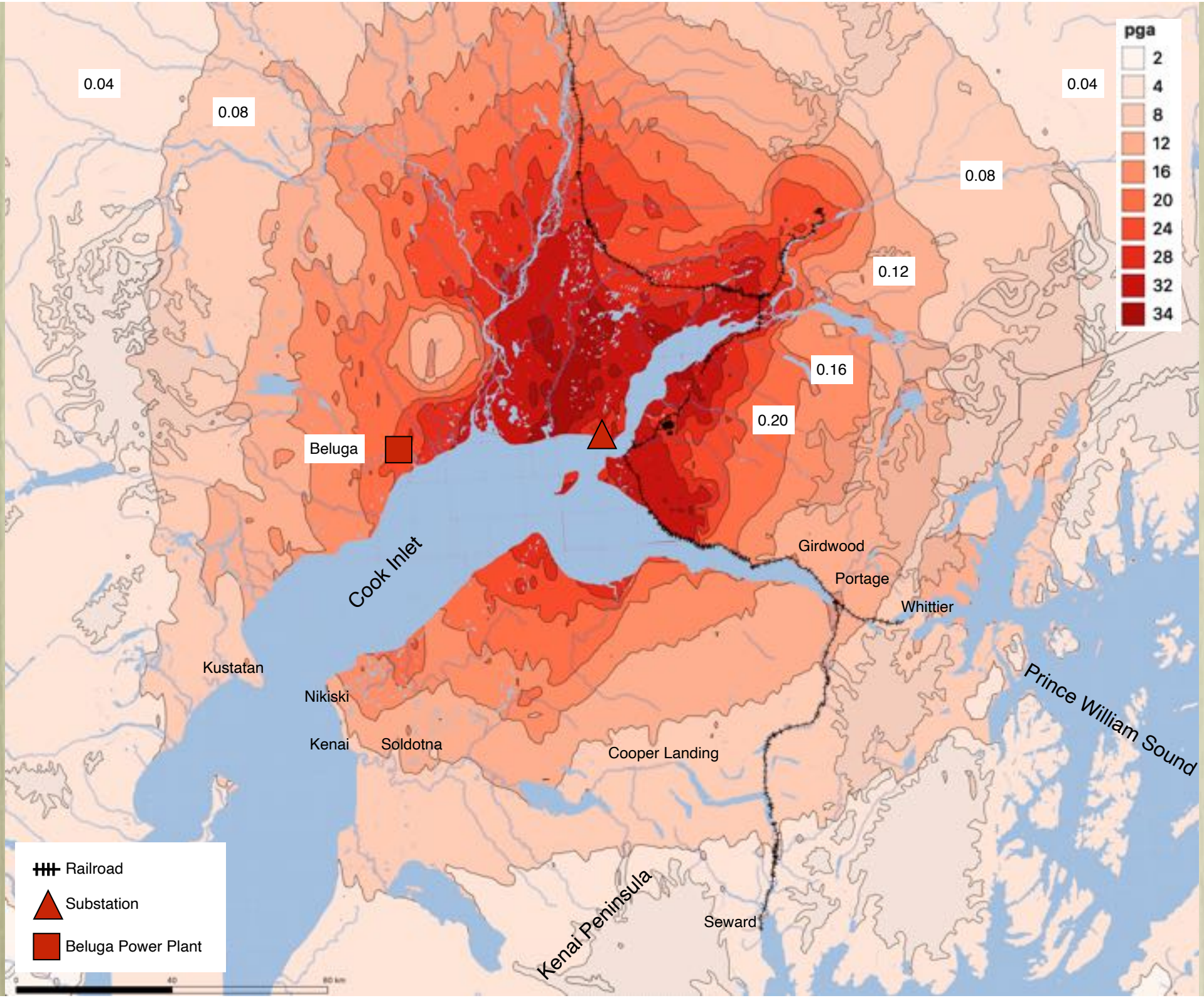
Map Version 8 Processed 2019−03−08 10:12:17 AM AKST

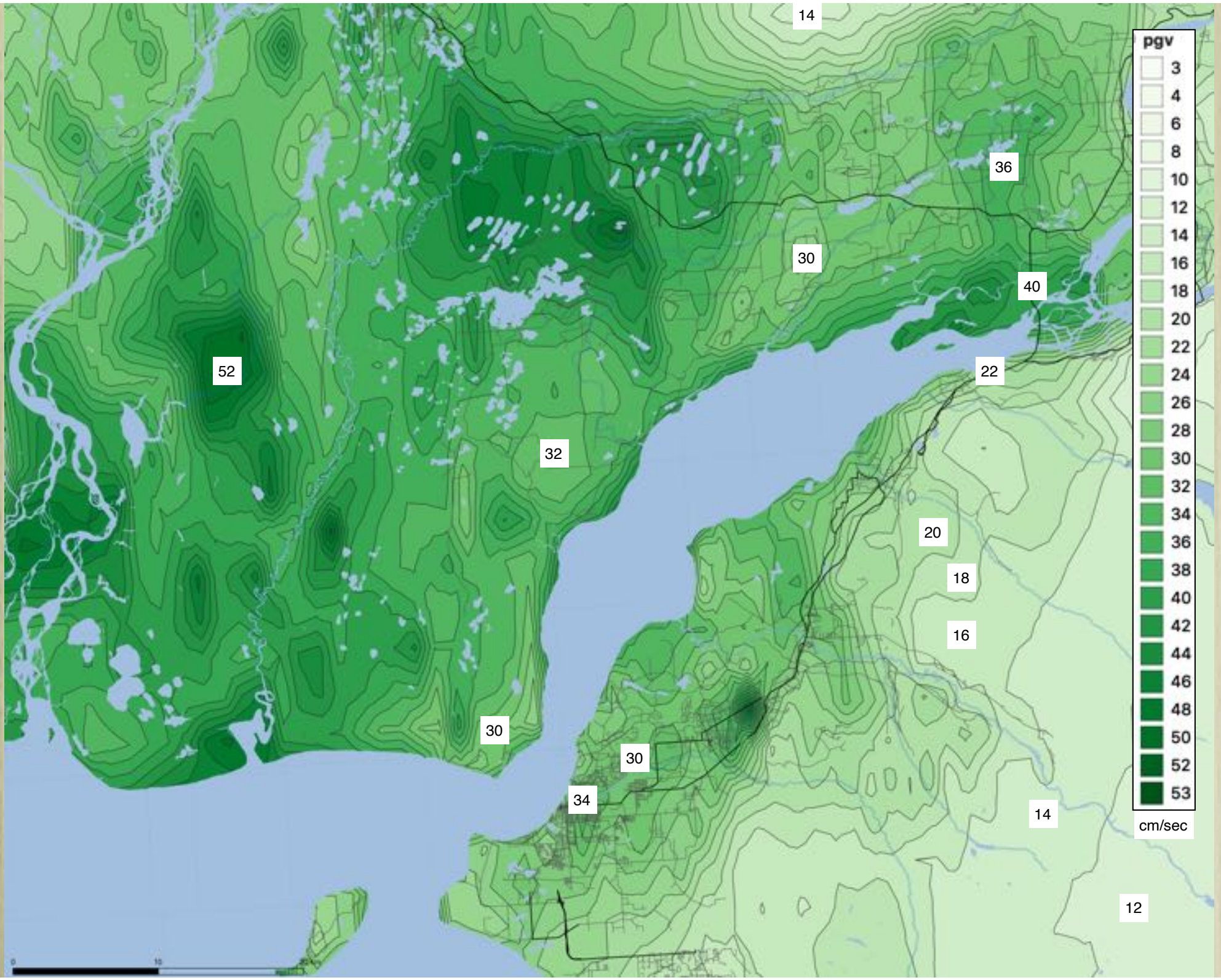
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	***<0.02***	***0.1***	***1.4***	***4.7***	***9.6***	***20***	***41***	***86***	***>178***
INSTRUMENTAL INTENSITY	**I**	**II−III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X+**

Scale based upon Worden et al. (2012)


pga
2
4
8
12
16
20
24
28
32
34


pga
2
4
8
12
16
20
24
28
32
34
0.08
0.28
0.12
0.32
0.16
0.34
0.20
0.24
0.28
0.32


pga
2
4
8
12
16
20
24
28
32
34
0.04
0.08
0.04
0.08
0.12
0.16
0.20
Beluga
Cook Inlet
Girdwood
Portage
Whittier
Kustatan
Nikiski
Kenai
Soldotna
Cooper Landing
Prince William Sound
Kenai Peninsula
Seward
Railroad
Substation
Beluga Power Plant


14
36
30
40
52
22
32
20
18
16
30
30
34
14
12
pgv
3
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
53
cm/sec

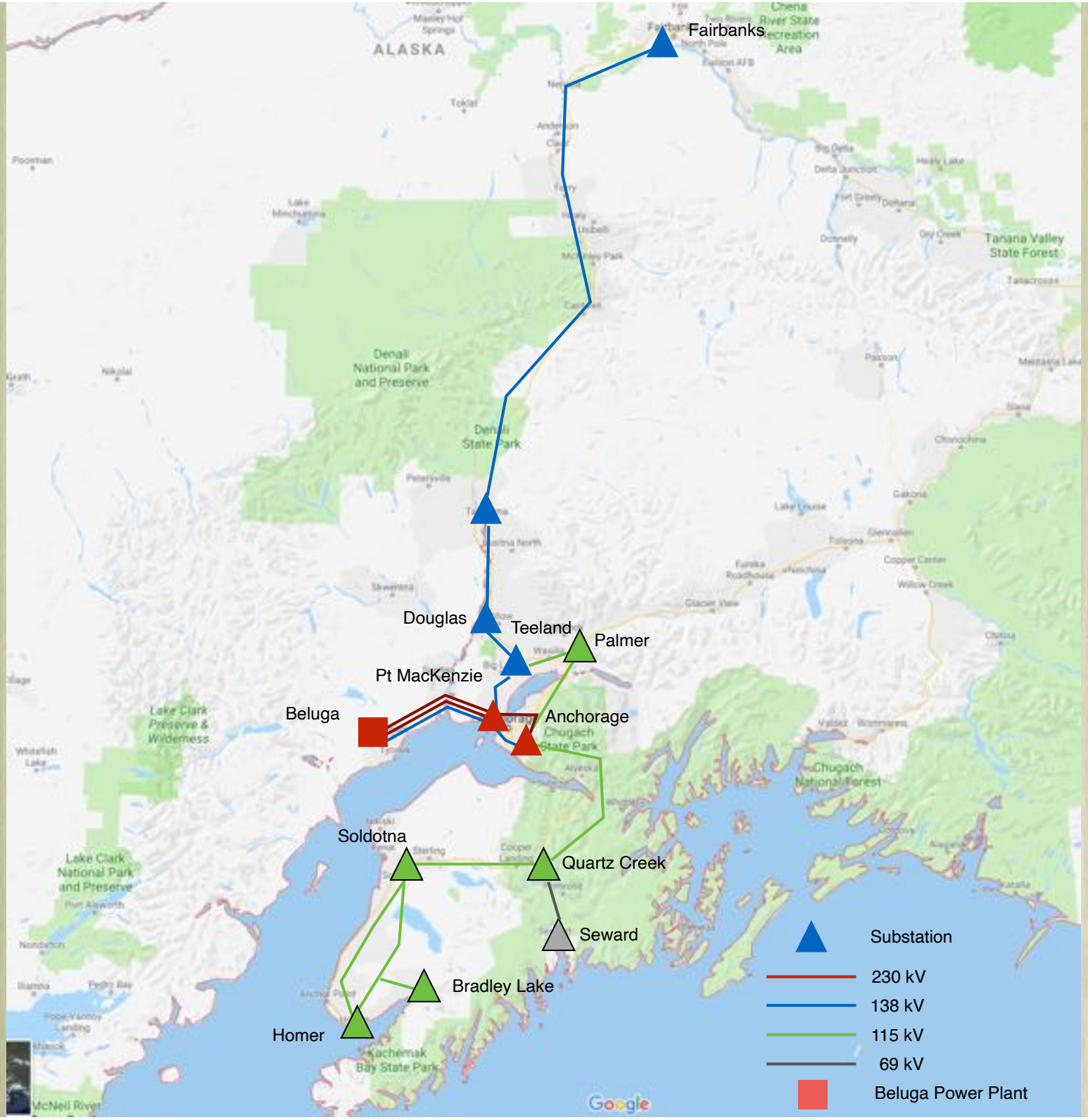
Chugach Electric Assocation (CEA)

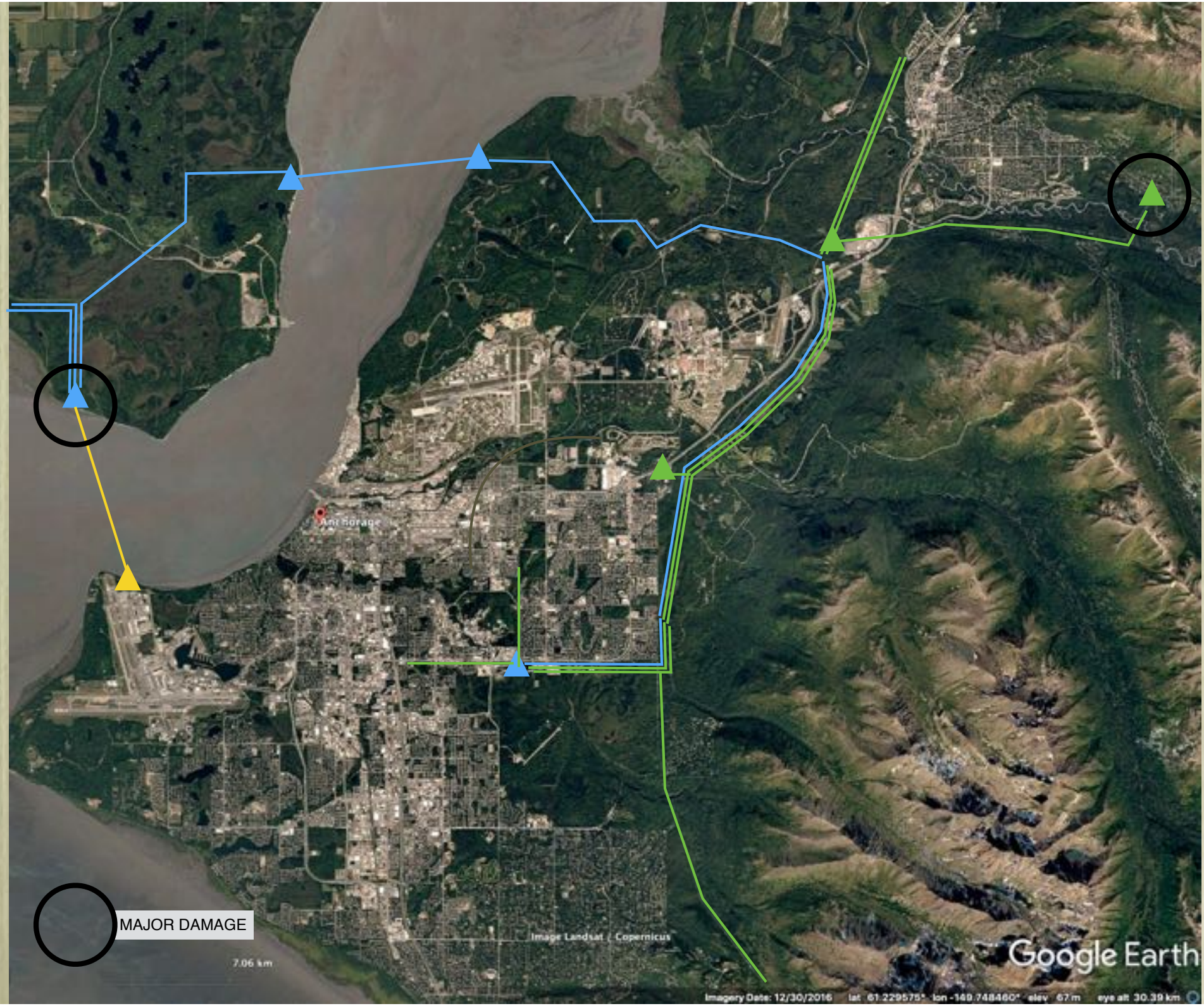
Matanuska Electric Assocation (MEA)

Seward Electrical System (SES)

Golden Valley Electric Assocation (GVEA)

Anchorage Municipal Light & Power (ML&P)

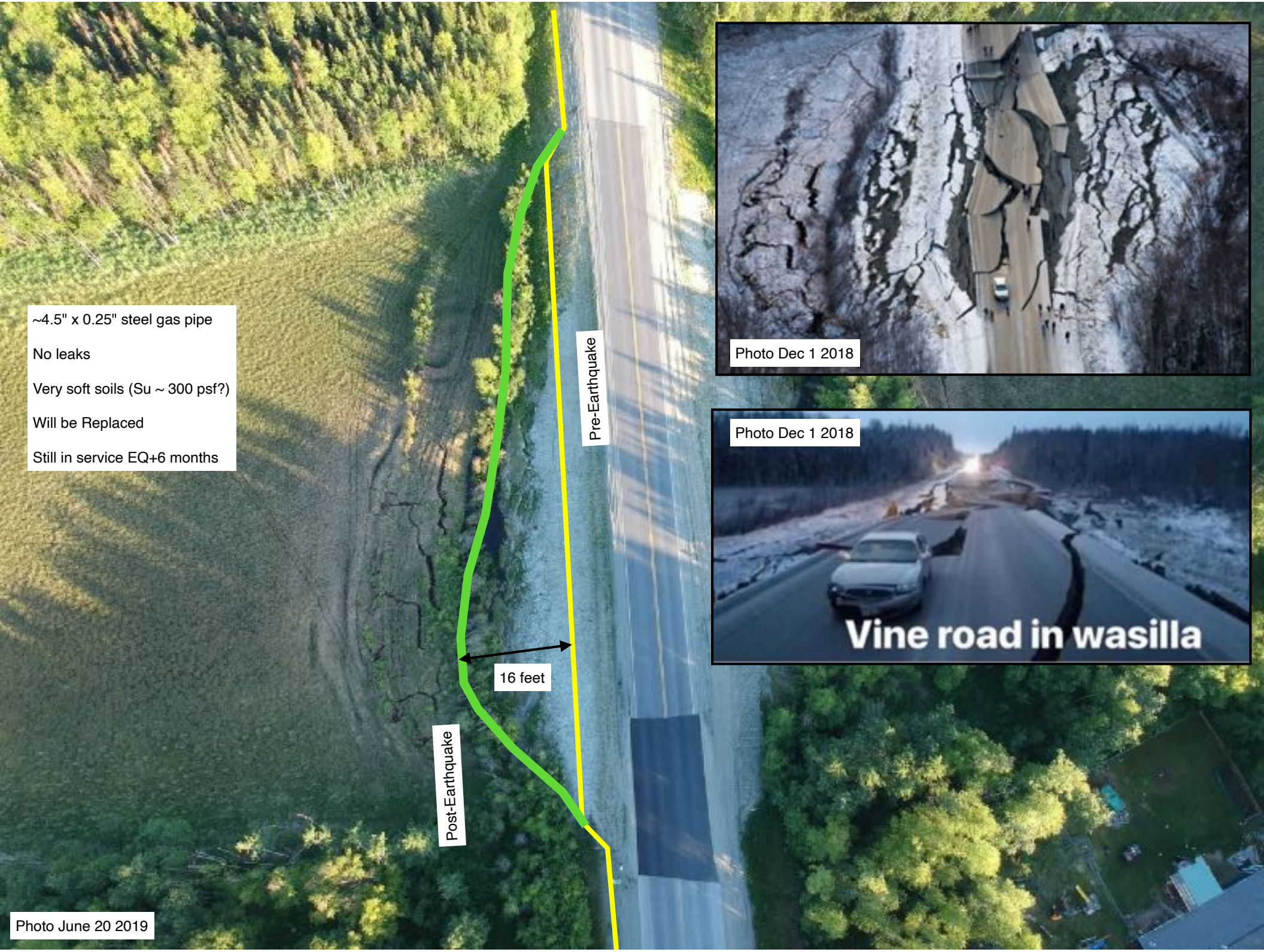



MAJOR DAMAGE
Image Landsat / Copernicus
Google Earth

Chugach Electric Association
Point MacKenzie Substation
Photo Pre-EQ, July 2018
230 138 kV
Lat 61.2496
Long -150.0268

230 kV Yard
17/22 swtiches collapse
Rigid bus with plungers
$2 M to $8 million to re-build
1+ Year re-build


Diam. 4-inch t = 0.25 inch steel gas pipe
No leaks
Very soft soils (Su ~ 300 psf?)
Will be Replaced
Still in service June 2019
Alignment: Based om Enstar survey.
Yellow and green lines approximate
Pre-Earthquake
350 feet
16 feet
Post-Earthquake
Photo June 20 2019


~4.5" x 0.25" steel gas pipe
No leaks
Very soft soils (Su ~ 300 psf?)
Will be Replaced
Still in service EQ+6 months
Pre-Earthquake
16 feet
Post-Earthquake
Photo June 20 2019
Photo Dec 1 2018
Photo Dec 1 2018
Vine road in wasilla

California - Ridgecrest 2019

SERA Forecast Leaks and Repairs Ridgecrest M 7.1

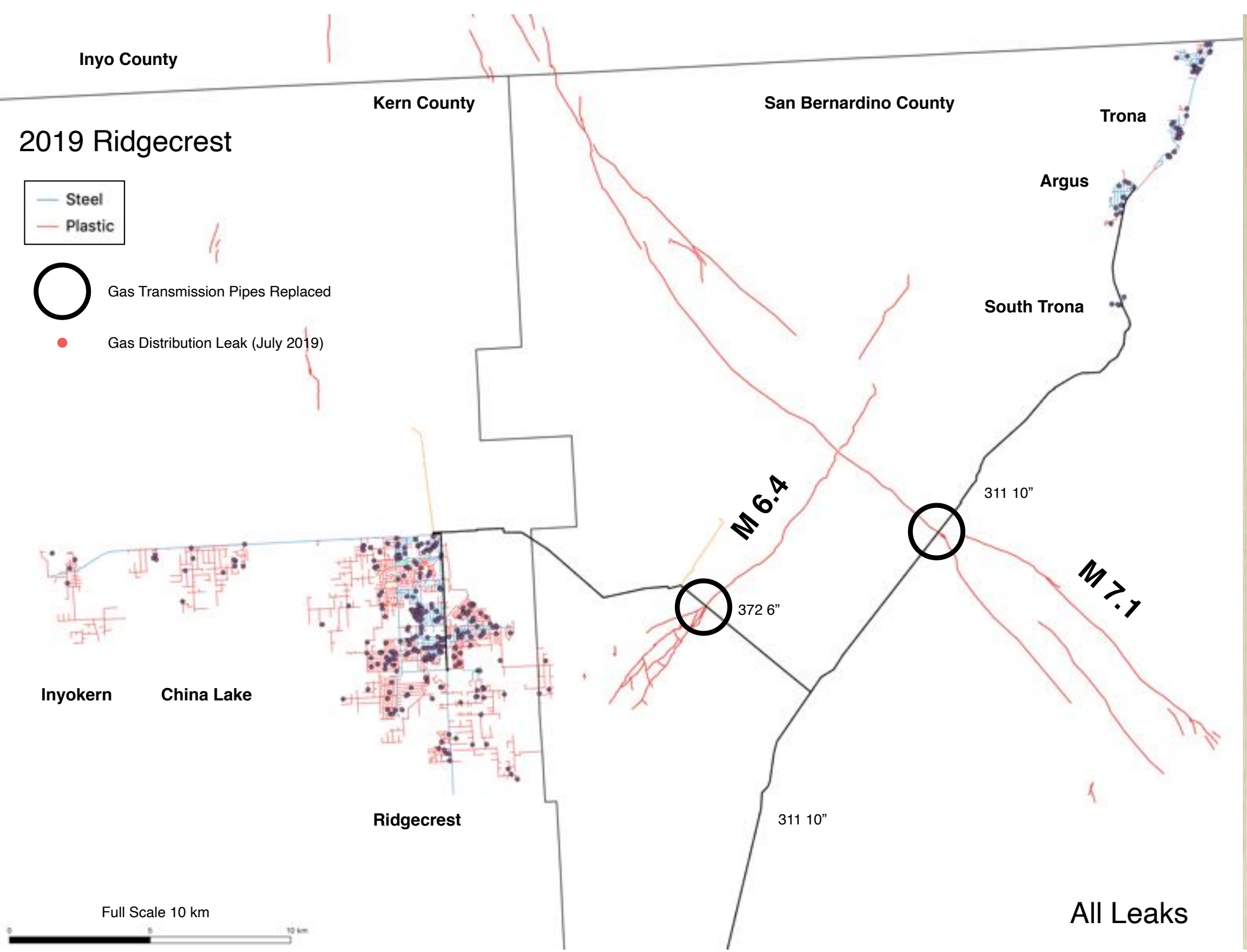
Category	Entire System Inventory length (km)	M 7.1 Repairs	Pct of All Repairs	Actual
Transmission	10,703	2	3%	2
Distribution	69,551	12	16%	11
Service Laterals	41,266	59	81%	~ 300 1 week ~ 540 1 year
Total		73	100%	

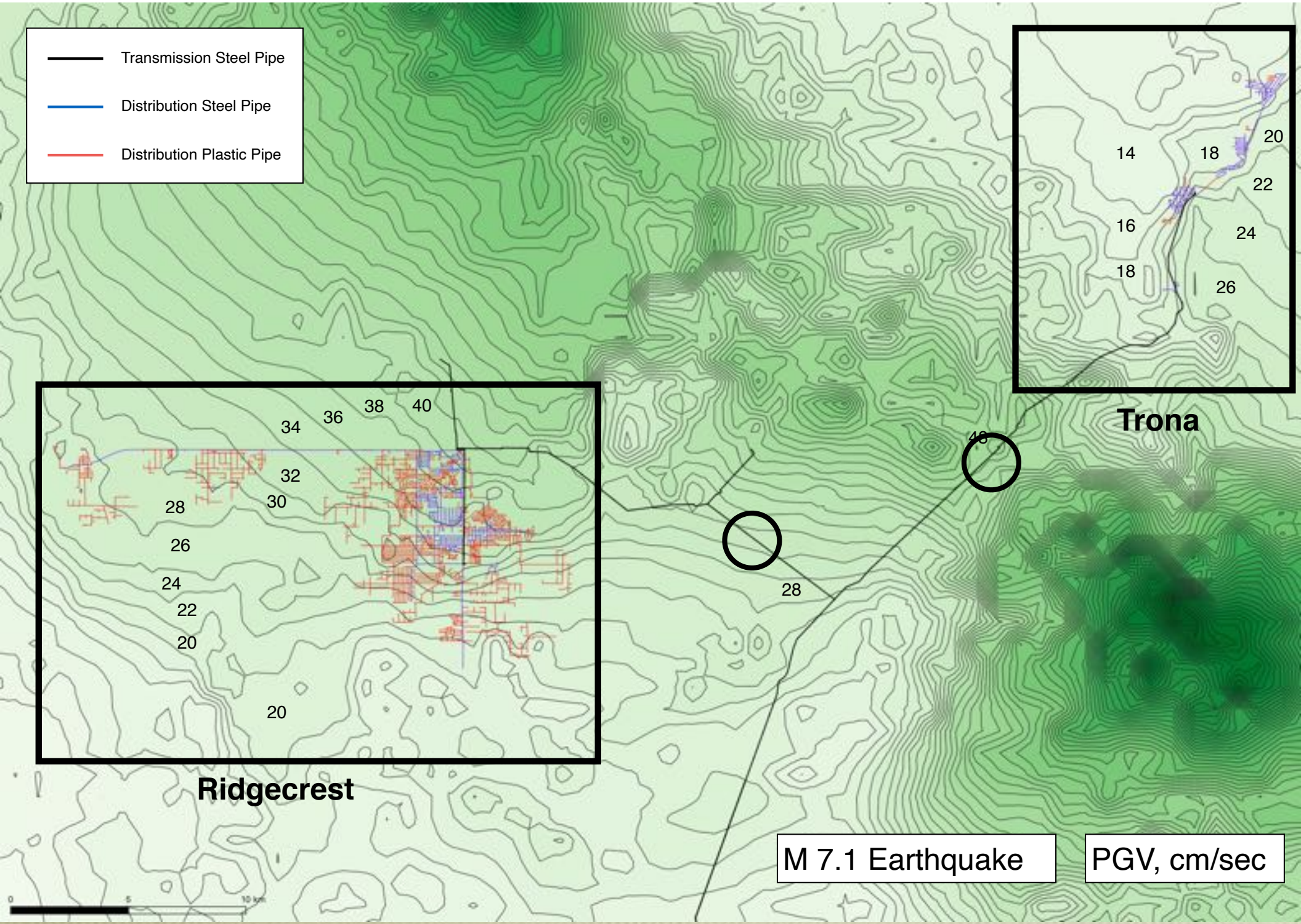
General Approach

- Examine Historic Gas Leaks After Earthquakes
  - Ridgecrest 2019, Napa 2014, Alum Rock 2007, Eureka 2010, Loma Prieta 1989.
- Develop Fragility Models based on this data

Discussion

- What is a Leak?
  - 10± parts per Million? (Background rate)
  - 10± parts per Billion
  - Smell Test? (Serious)
  - Ignition: > 50,000 parts per Million
- Different Utilities do this differently!


Inyo County
Kern County
San Bernardino County
2019 Ridgecrest
Steel
Plastic
Gas Transmission Pipes Replaced
Gas Distribution Leak (July 2019)
Trona
Argus
South Trona
M 6.4
311 10”
M 7.1
372 6”
Inyokern
China Lake
Ridgecrest
311 10”
Full Scale 10 km
All Leaks


Transmission Steel Pipe
Distribution Steel Pipe
Distribution Plastic Pipe
14
18
20
22
16
24
18
26
Trona
38
40
36
34
32
30
28
26
24
22
20
20
Ridgecrest
28
M 7.1 Earthquake
PGV, cm/sec

Calibration Earthquake
2019 Ridgecrest

PGV (cm/sec)	Mains	Service Laterals	Regulators
0 – 1			
1 – 2			
2 – 4			
4 – 6		1	
6 – 8			
8 – 10			
10 – 12		1	
12 – 14		9	
14 – 16		11	
16 – 18	6	13	
18 – 20	3	12	
20 – 22	2	11	
22 – 24		4	1
24 – 26		21	
26 – 28	1	11	
28 – 30	1	32	
30 – 32	1	32	
32 – 34	2	60	
34 – 36	9	73	
36 – 38	5	25	
38 – 40	1	8	
Total	31	324	

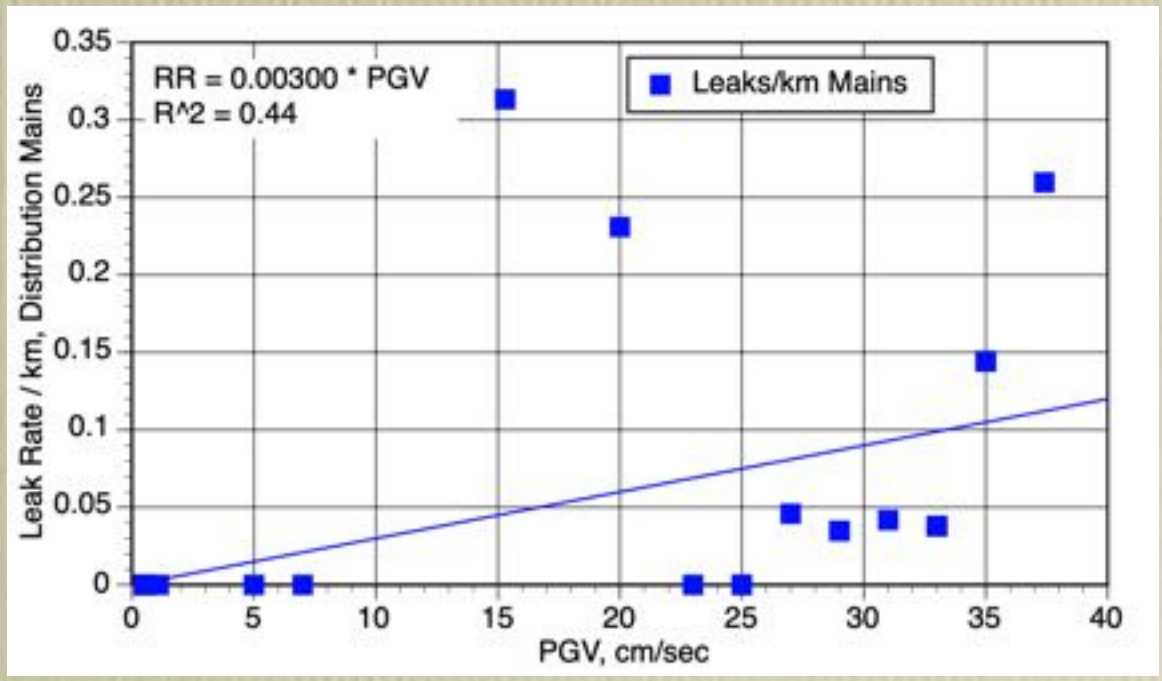
Initial Survey, July 2019

Note

PGV
Based on ShakeMap

There are some serious
Issues with the ShakeMap
Motions for Trona area

Some adjustment for PGDs



Leak Cause	Ridgecrest	Systemwide
Undetermined	15.0%	24.3%
Atmospheric Corrosion	0.2%	1.9%
Construction Defect	5.1%	4.7%
Compression Coupling	0.2%	0.1%
Damage by Earth Movement	0.4%	0.2%
Digin/Excavation	0.9%	2.7%
Damage by Third Party (non-digin)	0.4%	0.1%
Earthquake	0.5%	0.0%
External Corrosion	0.7%	0.4%
Fire or Explosion on Customer Facility	0.2%	0.0%
Leak - Unknown	33.8%	45.3%
Material Failure	8.8%	1.3%
No/Deteriorated Pipe Dope	31.6%	15.9%
Other	0.5%	0.9%
Other Natural Forces	0.2%	0.3%
Previously Damaged	0.4%	0.1%
Plastic Embrittlement	0.7%	0.3%
Unknown (Replaced Facility)	0.4%	0.4%
Weld Failure	0.2%	0.2%

Notable differences. Why?

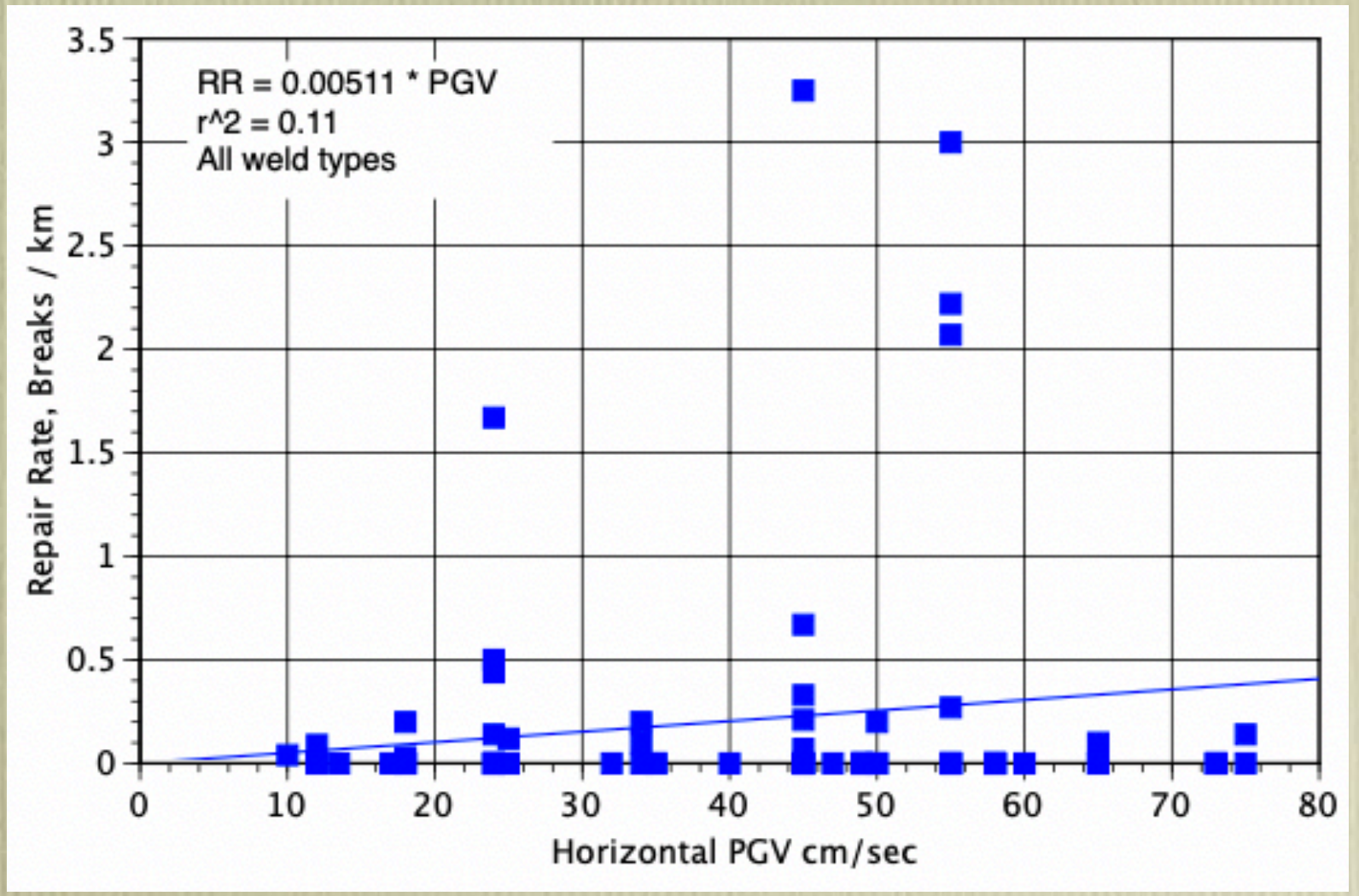
Material failures: earthquake adds stress to buried pipe: leading to higher material failure rate
(Most to riser insert kits or plastic tee caps. Pipe age might also have something to do with this
(Trona pipes are old)

Shaking of house impacts service riser / aggravates pipe dope at threaded connections
(Leaks through threads not genreally hazardous)

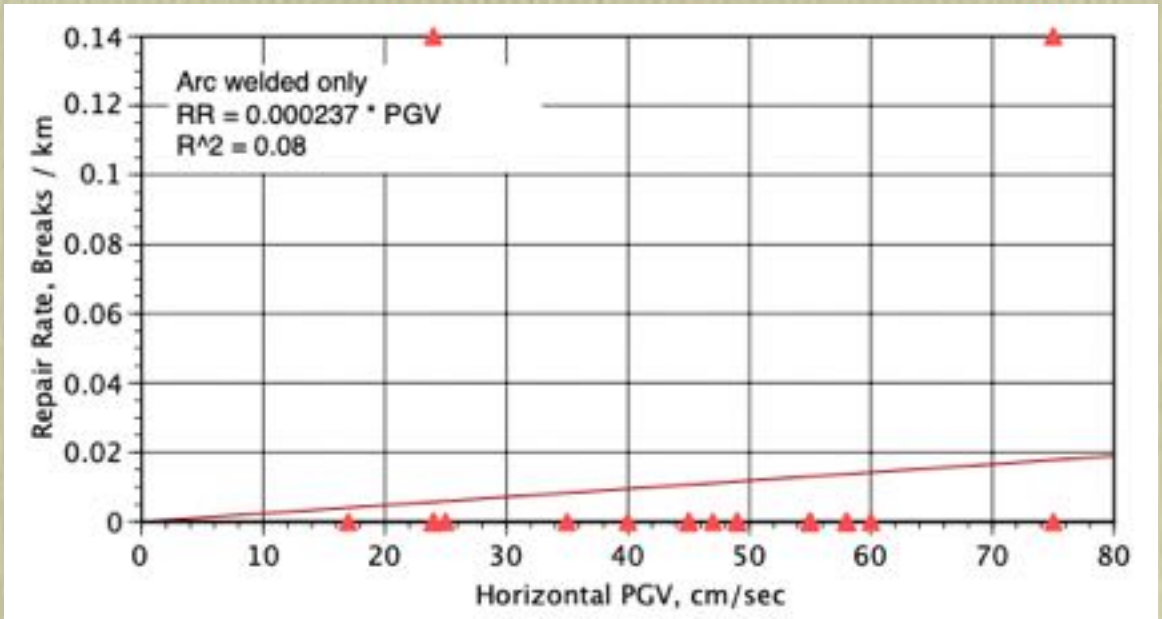
Updated Survey, July 2020

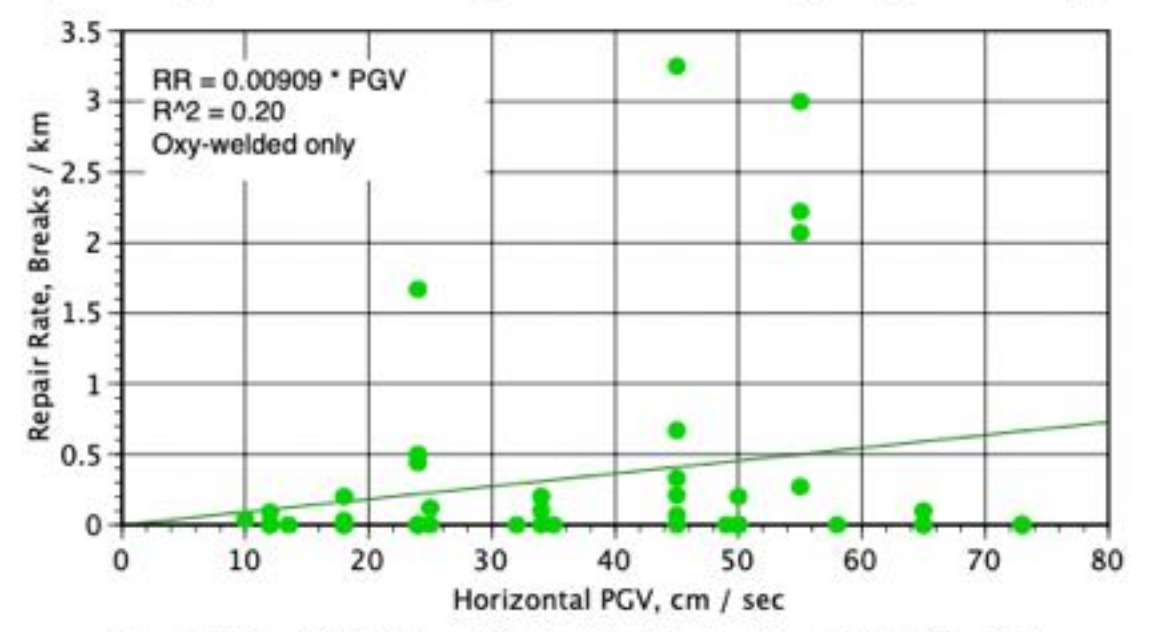
Transmission Pipes

SoCalGas Transmission Pipes

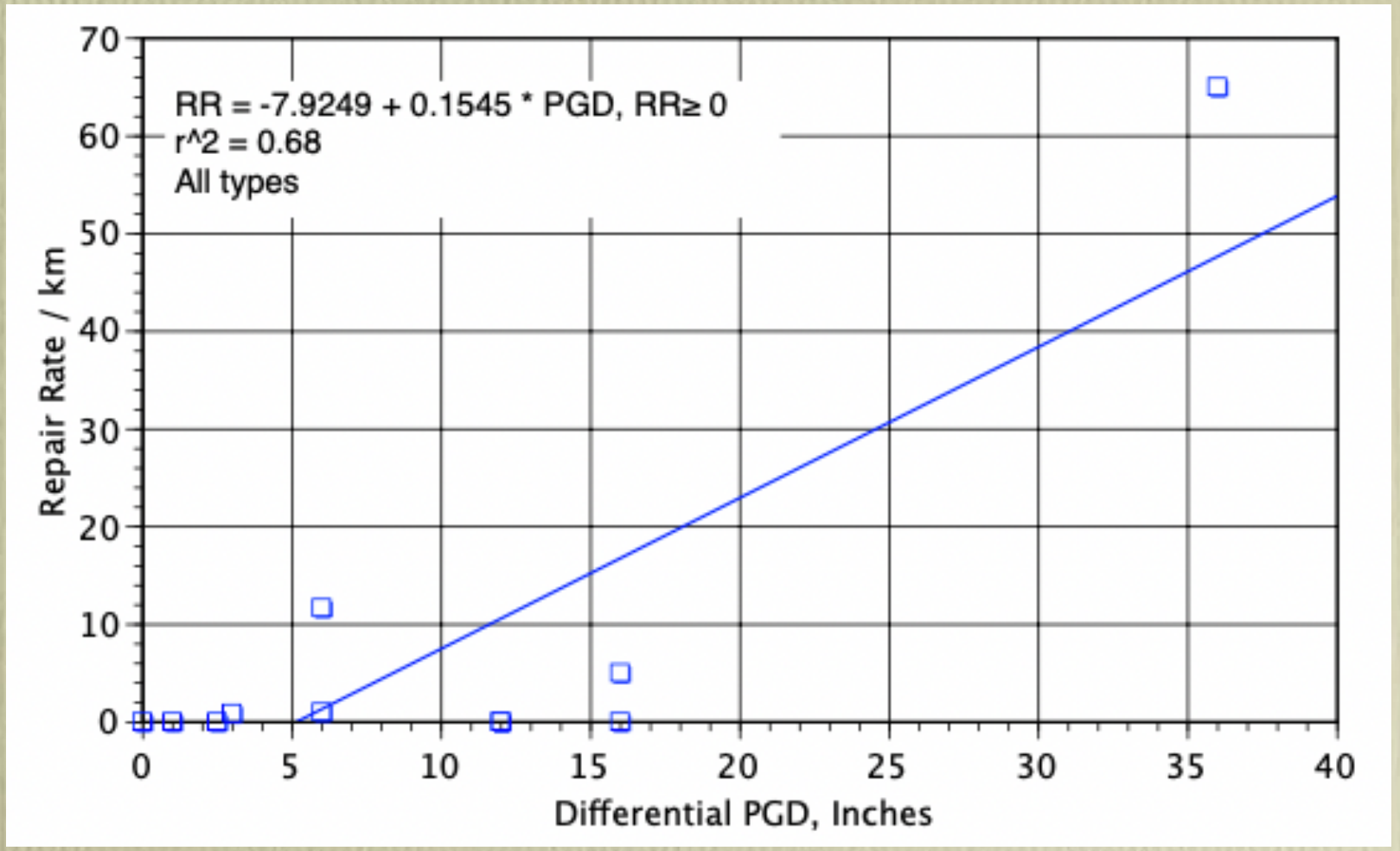


SoCalGas Transmission Pipes





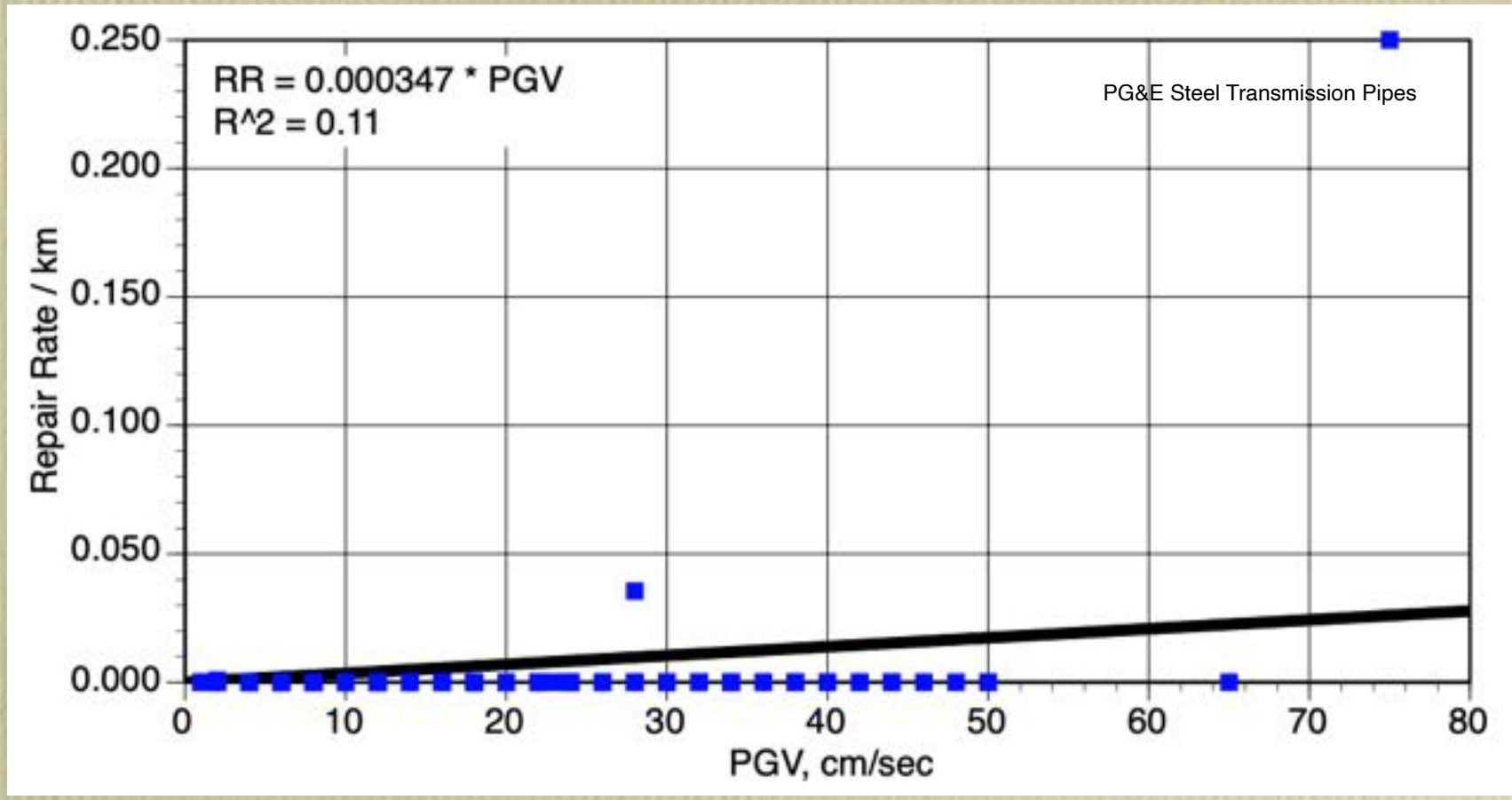
SoCalGas Transmission Pipes



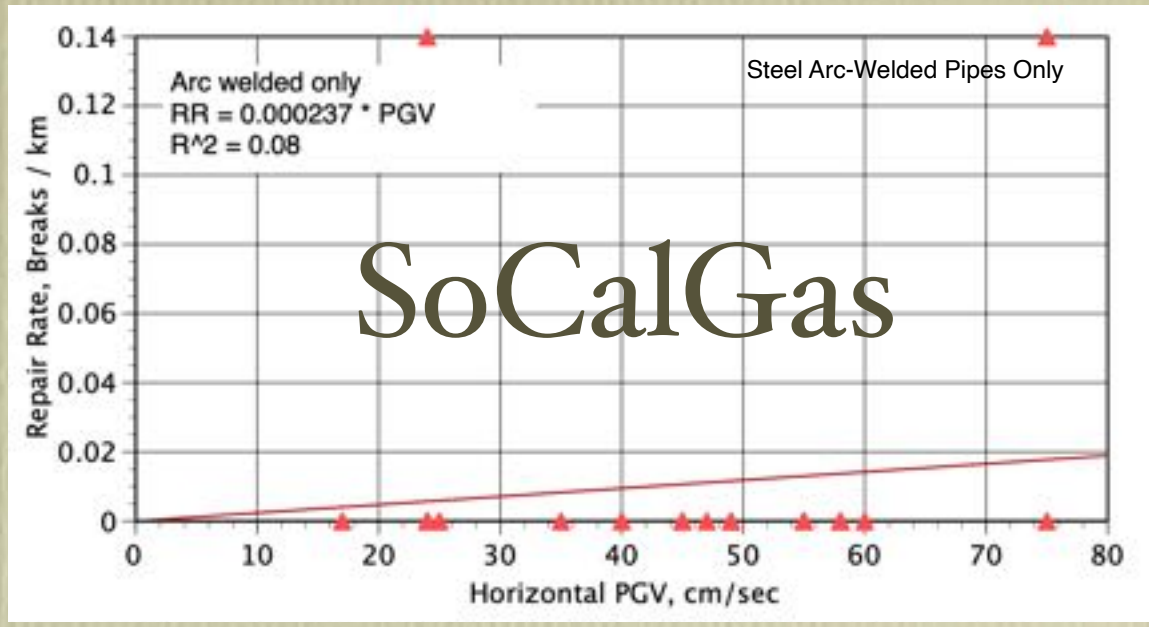
PG&E Transmission Pipes

Earthquake	M	Year	Repair History Quality	No. Transmission Repairs Reported L = Likely P = Possible	No. Transmission Pipes Replaced for Stress Relief
San Francisco	7.9	1906	Marginal	Many	N.A.
Kern County	7.3	1952	Very good	1 L	2
Daly City	5.7	1957	Poor	Some	0?
Greenville	5.8	1980	Poor	None ?	?
Coalinga	6.3	1983	Poor	Some	?
Morgan Hill	6.2	1984	Marginal	1 P	0
Ridgemark	5.4	1986	Marginal	0	0
Calaveras	5.6	1986	Marginal	0	0
Fort Tejon	5.2	1988	Marginal	0	0
Loma Prieta	6.9	1989	Marginal	0	0
Cape Mendocino	7.2	1992	Poor	Some ?	0
Salinas	5.1	1998	Marginal	1 P	0
Yountville	5.0	2000	Marginal	0	0
San Simeon	6.5	2003	Good	0	0
Alum Rock	5.6	2007	Marginal	1 L 2 P	0
Eureka	6.5	2010	Good	1 L	0
Napa	6.0	2014	Good	2 P	2
Ridgecrest	7.1	2019	Very good	0	2
Total				3 L, 6P	6

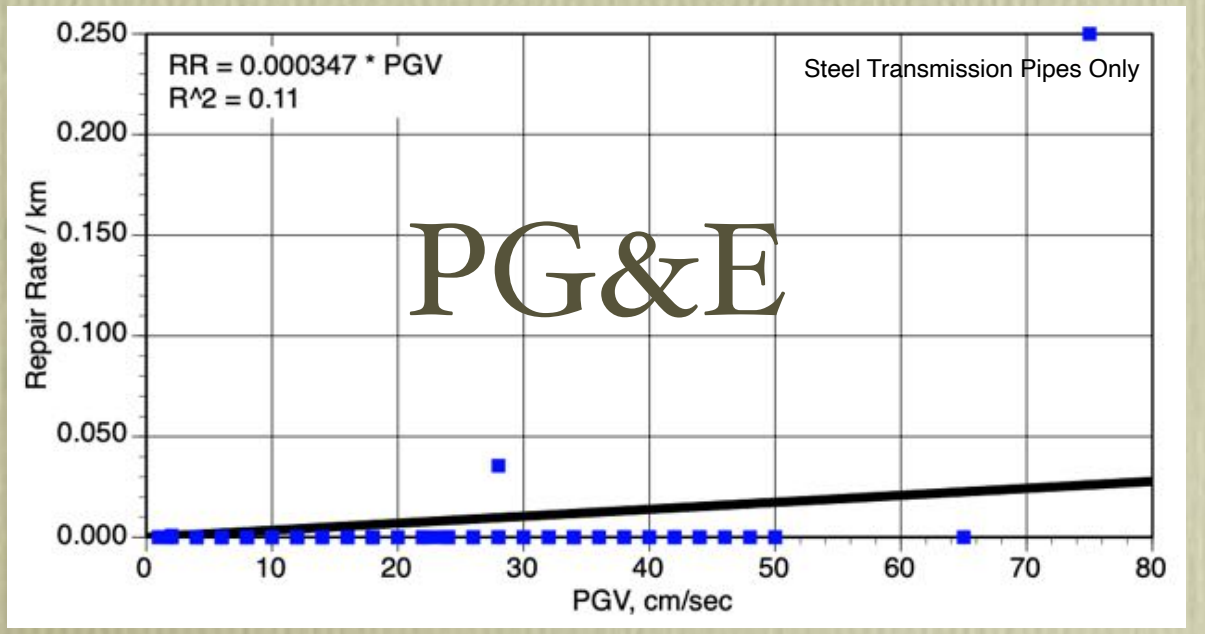
PG&E Transmission Pipes



PG&E / SoCalGas
Steel Transmission Pipes
(excluding pre-1930 SoCal pipes)



SoCalGas: repairs to pipe barrels



PG&E: all repairs to appurtenances

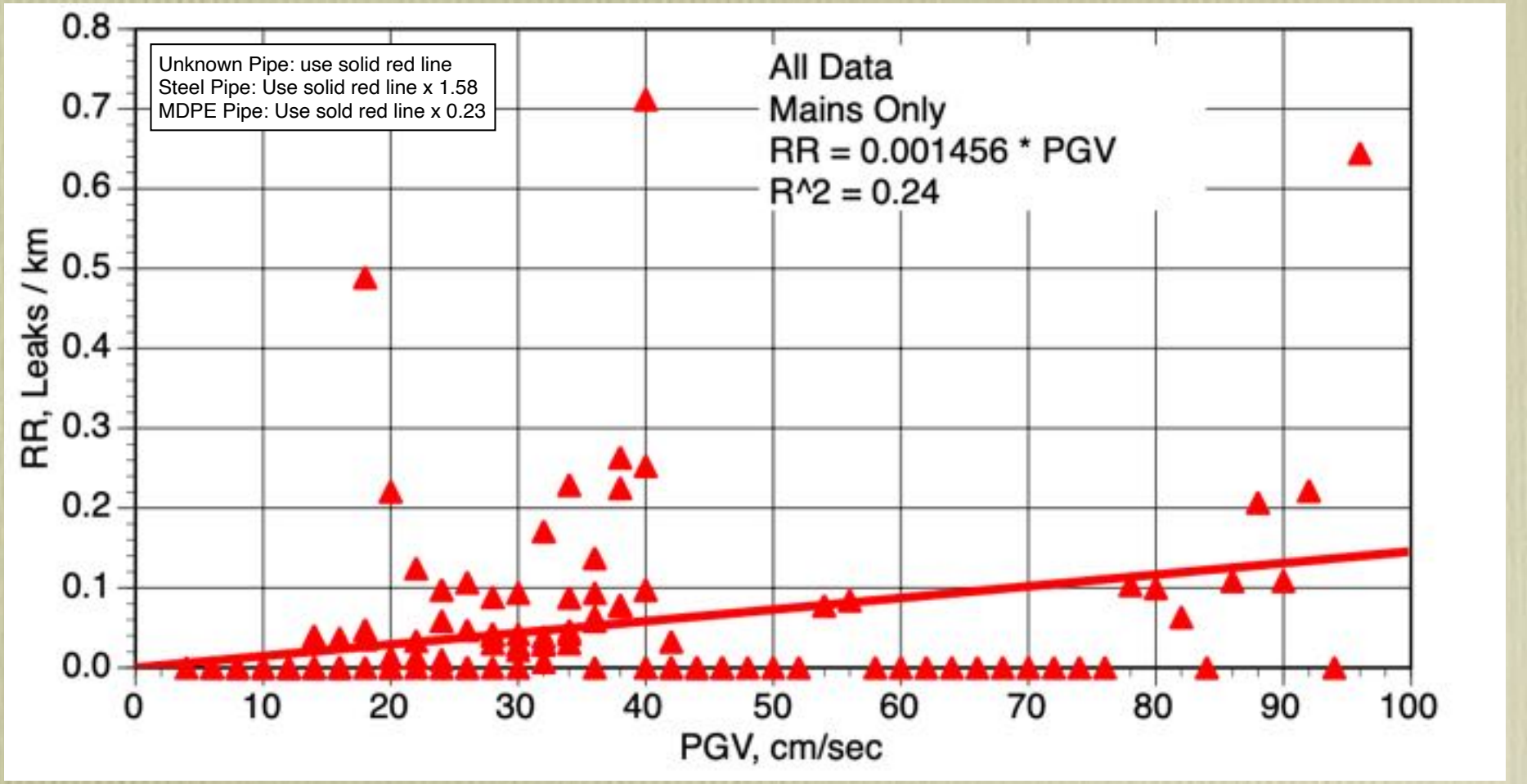
Distribution Pipes

Earthquake	M	Year	Repair History Quality	No. Distribution Repairs Reported
San Francisco	7.9	1906	Marginal	Many
Kern County	7.3	1952	Very good	Unknown
Daly City	5.7	1957	Poor	Some
Greenville	5.8	1980	Poor	None reported
Coalinga	6.3	1983	Poor	Some
Morgan Hill	6.2	1984	Marginal	None reported
Ridgemark	5.4	1986	Marginal	None reported
Calaveras	5.6	1986	Marginal	?
Fort Tejon	5.2	1988	Marginal	No data
Loma Prieta	6.9	1989	Marginal	270
Cape Mendocino	7.2	1992	Poor	Some likely
Salinas	5.1	1998	Marginal	None
Yountville	5.0	2000	Marginal	A few?
San Simeon	6.5	2003	Good	0
Alum Rock	5.6	2007	Good	0
Eureka	6.5	2010	Very good	279
Napa	6.0	2014	Very good	388
Ridgecrest	7.1	2019	Very good	356
Total				1,293

270 count excludes an additional ~300 Leaks in San Francisco

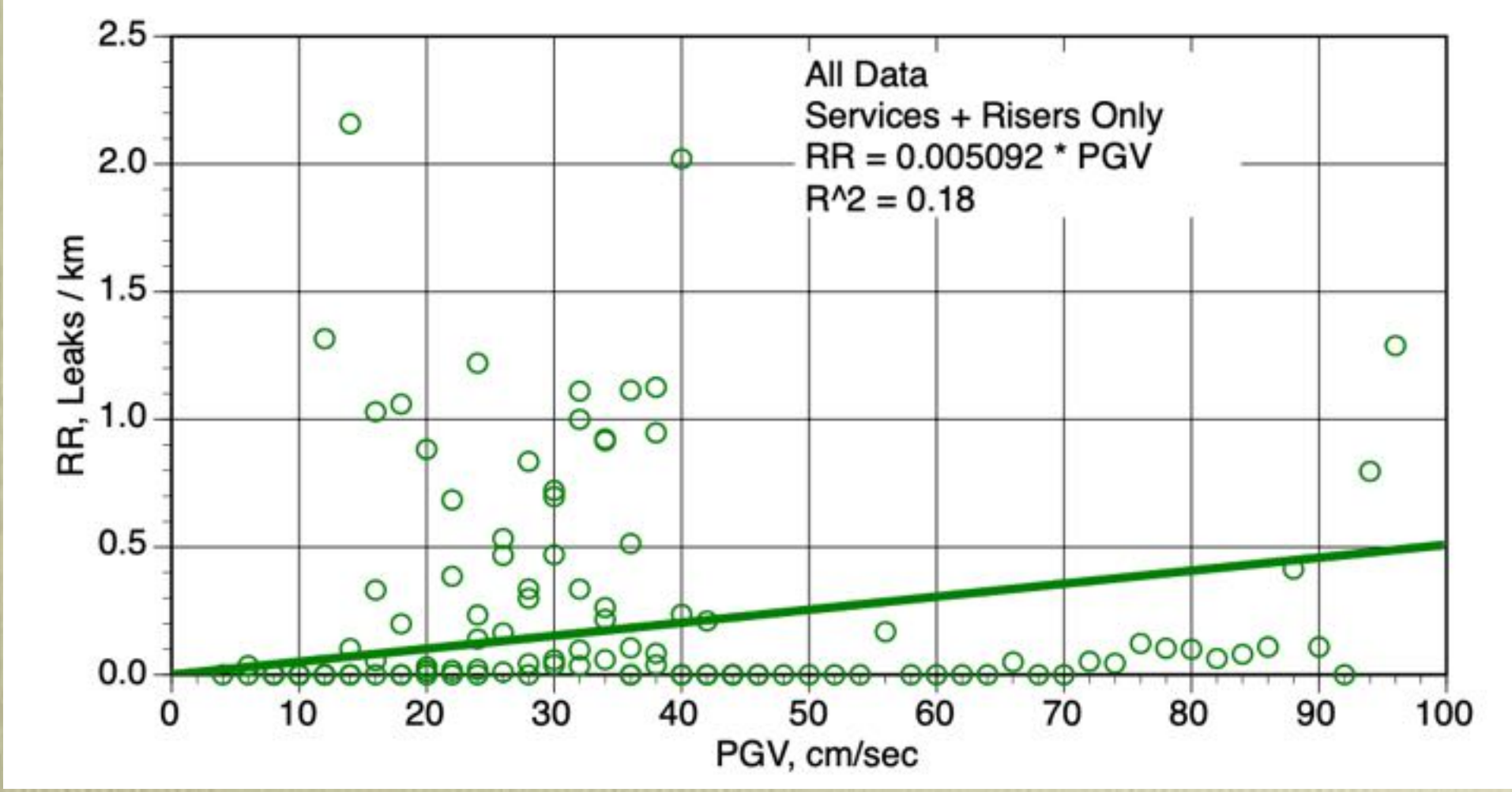
Distribution Gas Pipes (including Service Laterals and Meters)

Includes: Mains Only. Red Line = Backbone Curve



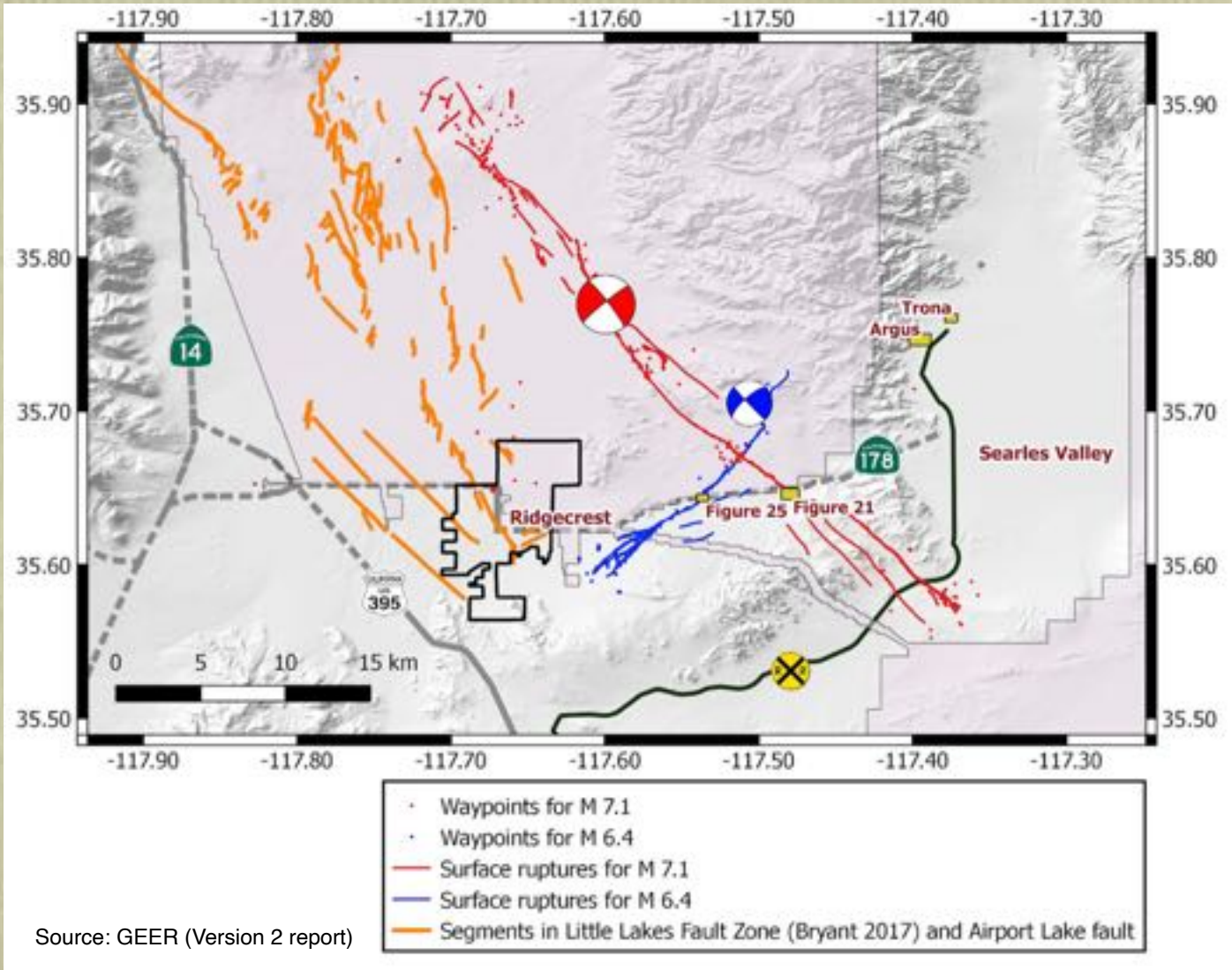
Includes: Loma Prieta 1989, Eureka 2010, Napa 2014, Ridgecrest 2019

Includes: Laterals + Risers Only. Green Line = Backbone Curve

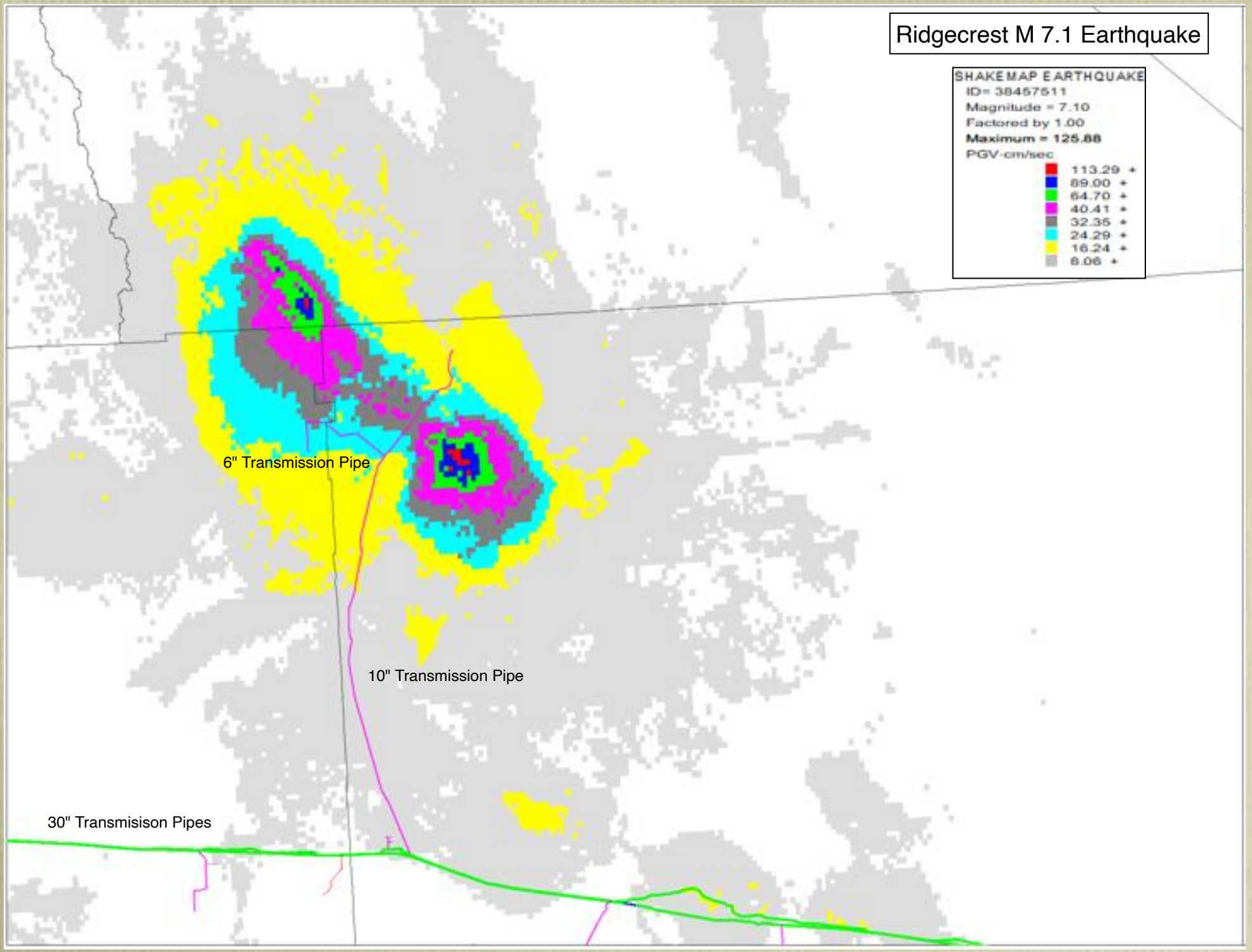


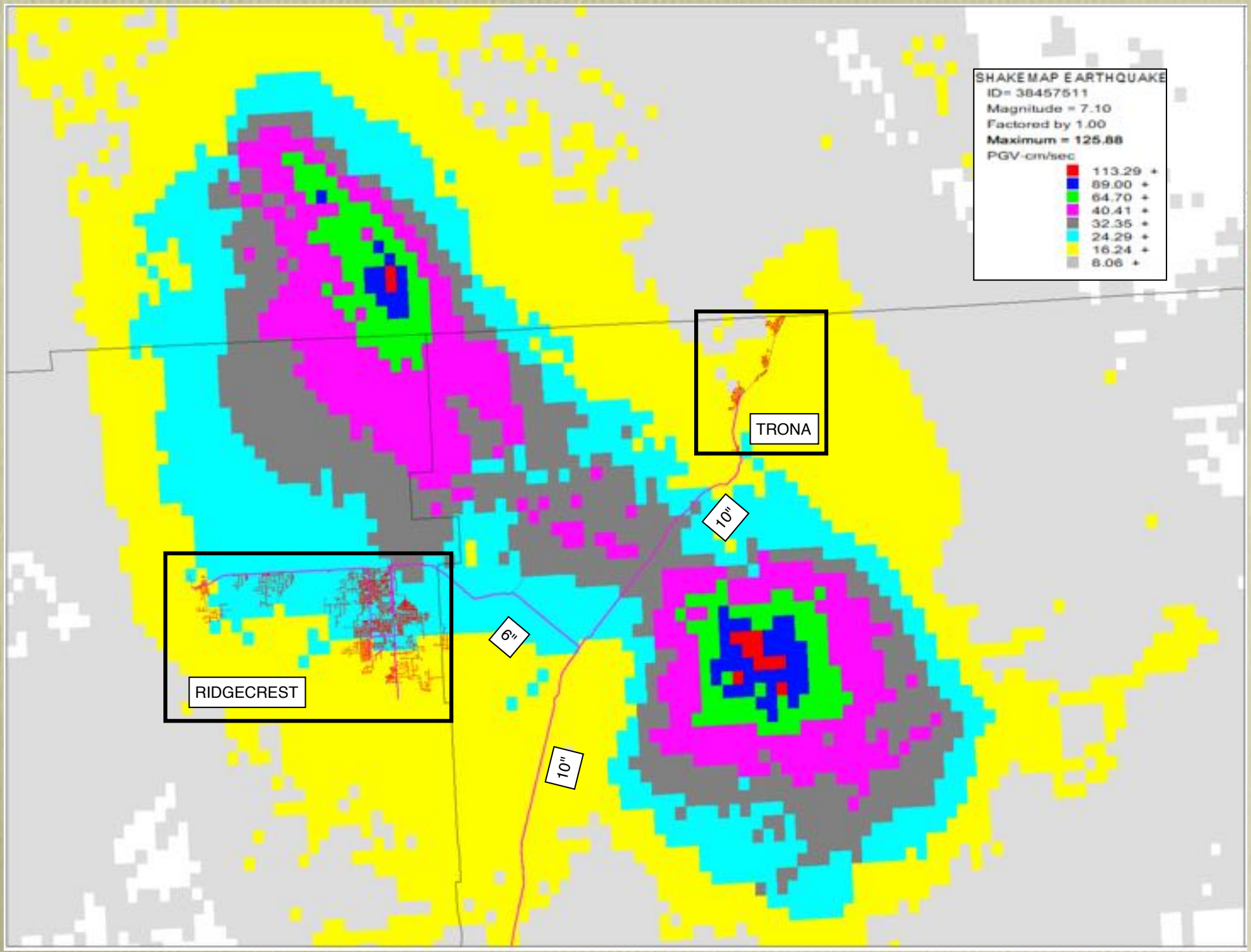
Includes: Loma Prieta 1989, Eureka 2010, Napa 2014, Ridgecrest 2019

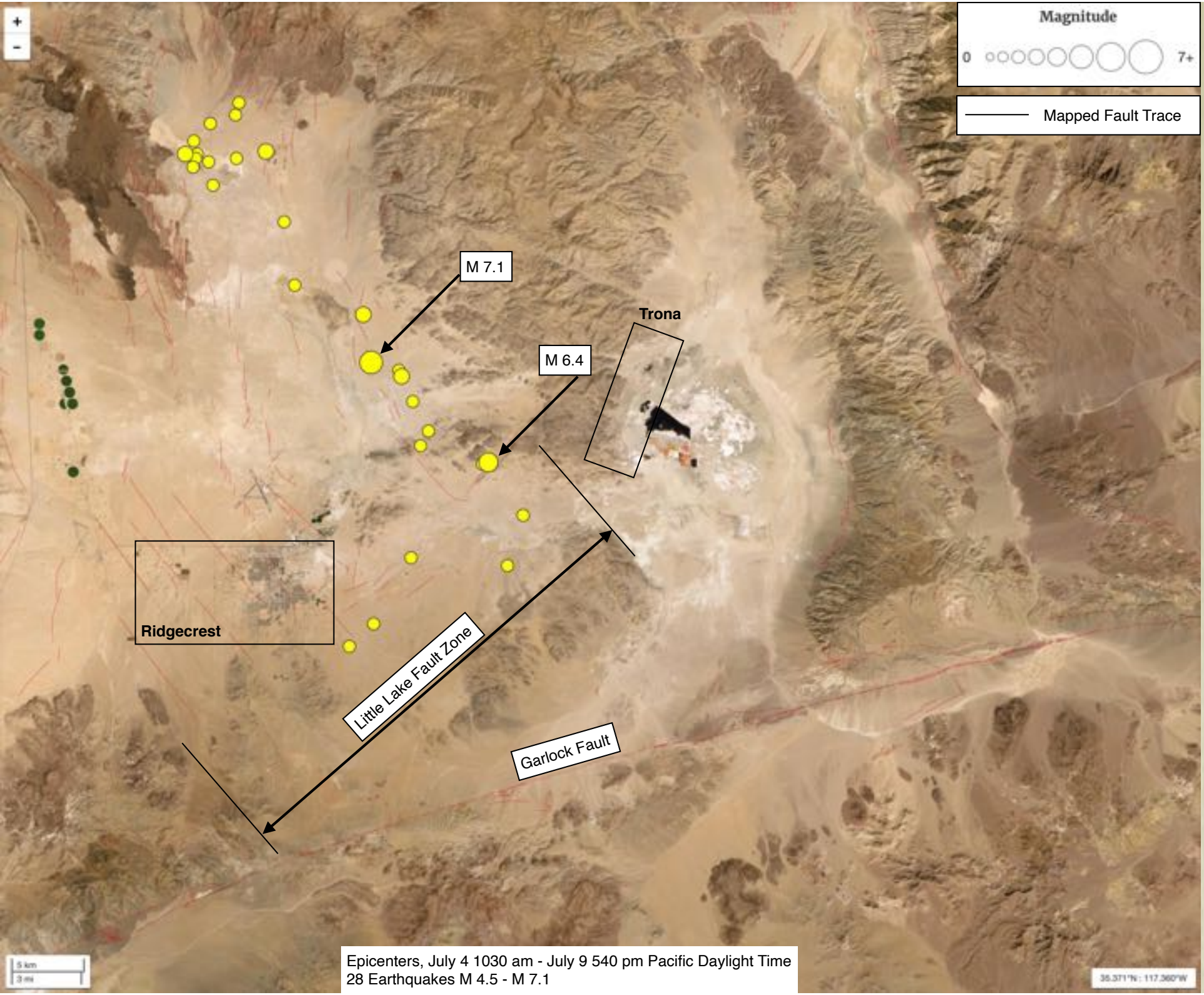
Ridgecrest

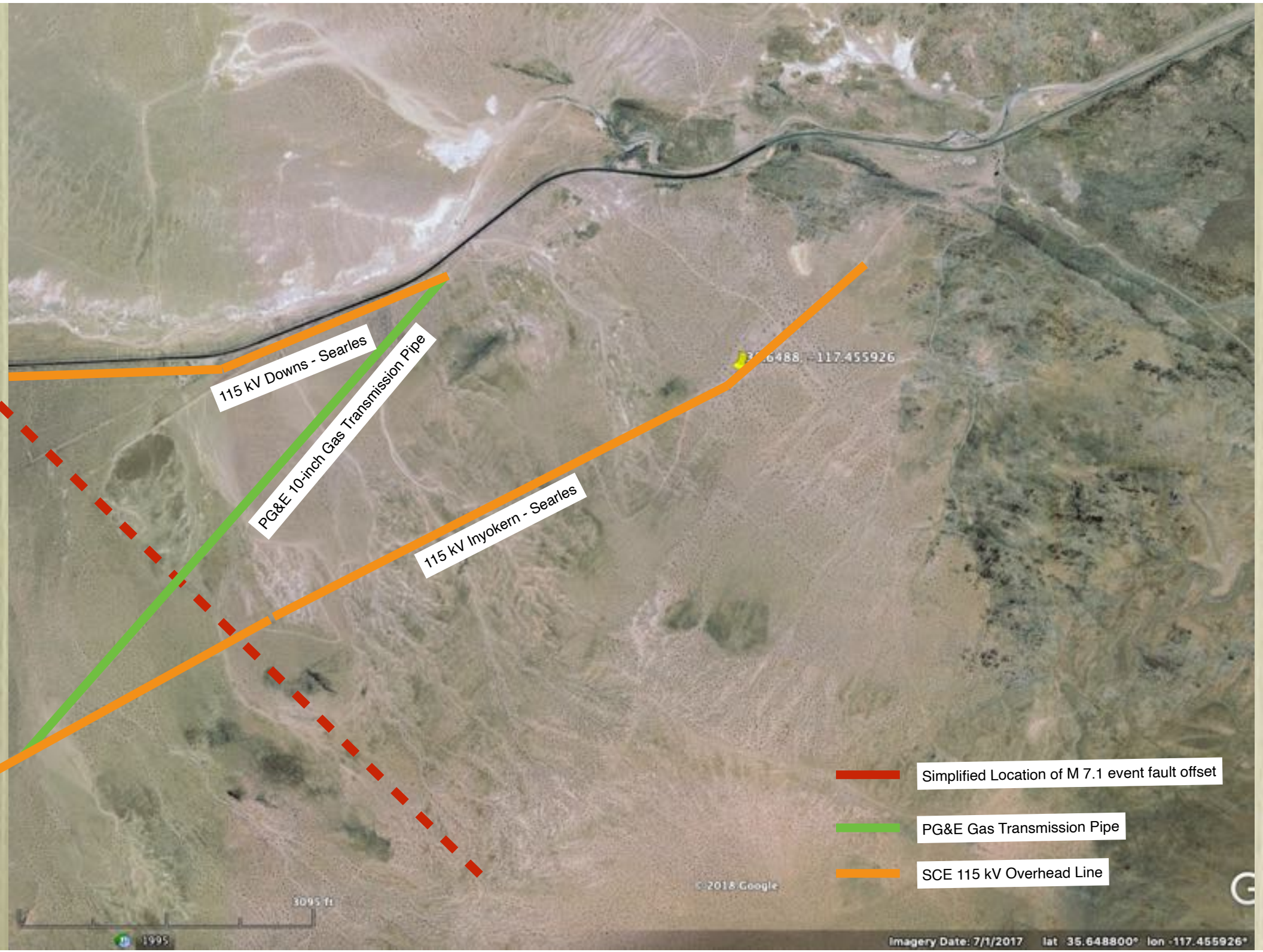


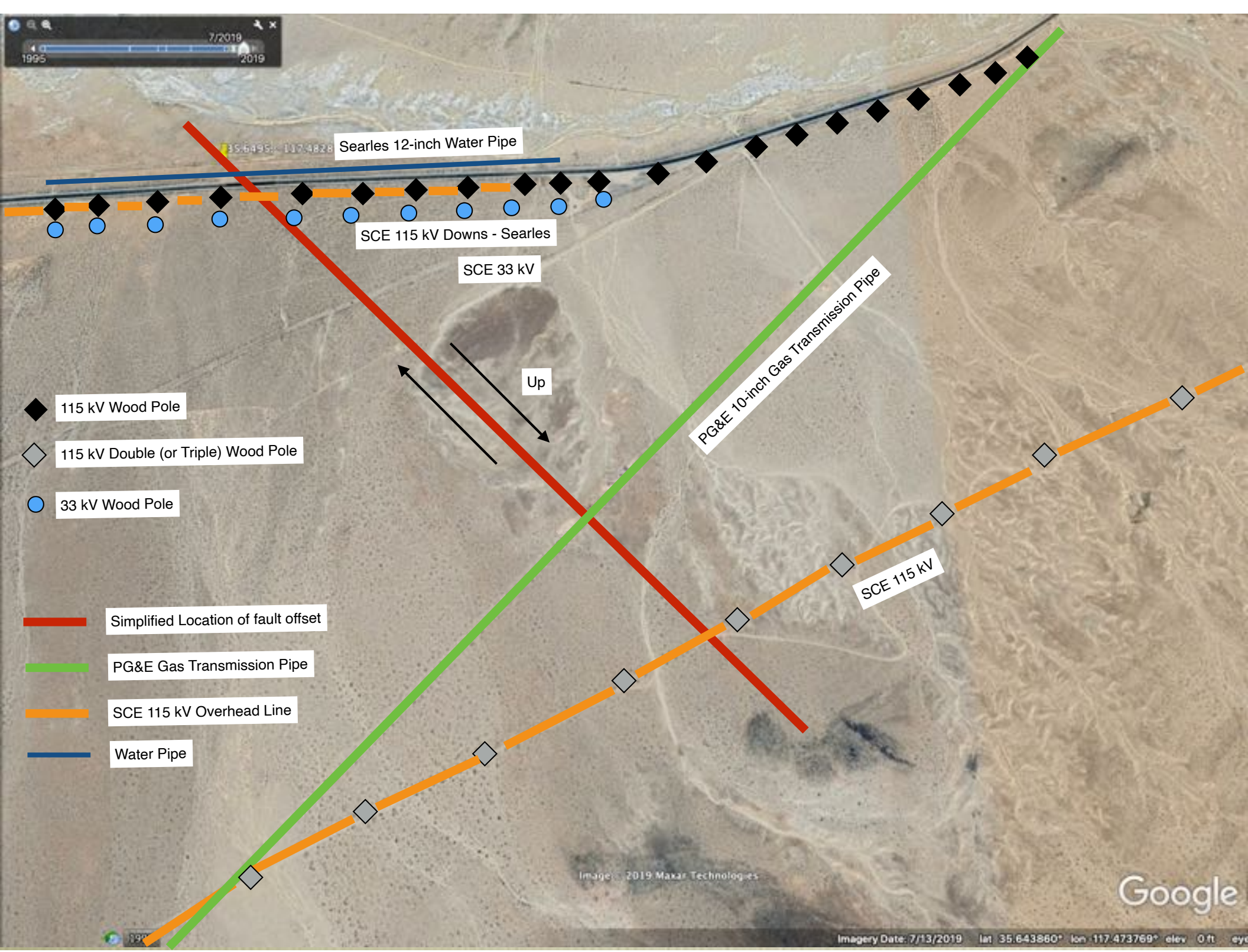
Source: GEER (Version 2 report)


Ridgecrest M 7.1 Earthquake
SHAKEMAP EARTHQUAKE
ID= 38457511
Magnitude = 7.10
Factored by 1.00
Maximum = 125.88
PGV-cm/sec
113.29 +
89.00 +
64.70 +
40.41 +
32.35 +
24.29 +
16.24 +
8.06 +
6" Transmission Pipe
10" Transmission Pipe
30" Transmisison Pipes


SHAKEMAP EARTHQUAKE
ID= 38457511
Magnitude = 7.10
Factored by 1.00
Maximum = 125.88
PGV-cm/sec
113.29 +
89.00 +
64.70 +
40.41 +
32.35 +
24.29 +
16.24 +
8.06 +
TRONA
RIDGECREST
10"
6"
10"


Magnitude
0
7+
Mapped Fault Trace
M 7.1
M 6.4
Trona
Ridgecrest
Little Lake Fault Zone
Garlock Fault
Epicenters, July 4 1030 am - July 9 540 pm Pacific Daylight Time
28 Earthquakes M 4.5 - M 7.1


115 kV Downs - Searles
PG&E 10-inch Gas Transmission Pipe
115 kV Inyokern - Searles
Simplified Location of M 7.1 event fault offset
PG&E Gas Transmission Pipe
SCE 115 kV Overhead Line
© 2018 Google
3095 ft
1995
Imagery Date: 7/1/2017 lat 35.648800° lon -117.455926°


Searles 12-inch Water Pipe
SCE 115 kV Downs - Searles
SCE 33 kV
Up
PG&E 10-inch Gas Transmission Pipe
SCE 115 kV
115 kV Wood Pole
115 kV Double (or Triple) Wood Pole
33 kV Wood Pole
Simplified Location of fault offset
PG&E Gas Transmission Pipe
SCE 115 kV Overhead Line
Water Pipe
Image © 2019 Maxar Technologies
Google
Imagery Date: 7/13/2019

Looking Southeast

10" Right Lateral Offset

Original pipe partially excavated


7/2019
1995
2019
PG&E 6-inch Gas Transmission Pipe
Simplified Location of M 6.4 fault offset
PG&E 6-inch Transmission Gas Pipe
575 feet
Aerial Photo Taken July 13 2019
Google Earth
Imagery Date: 7/13/2019

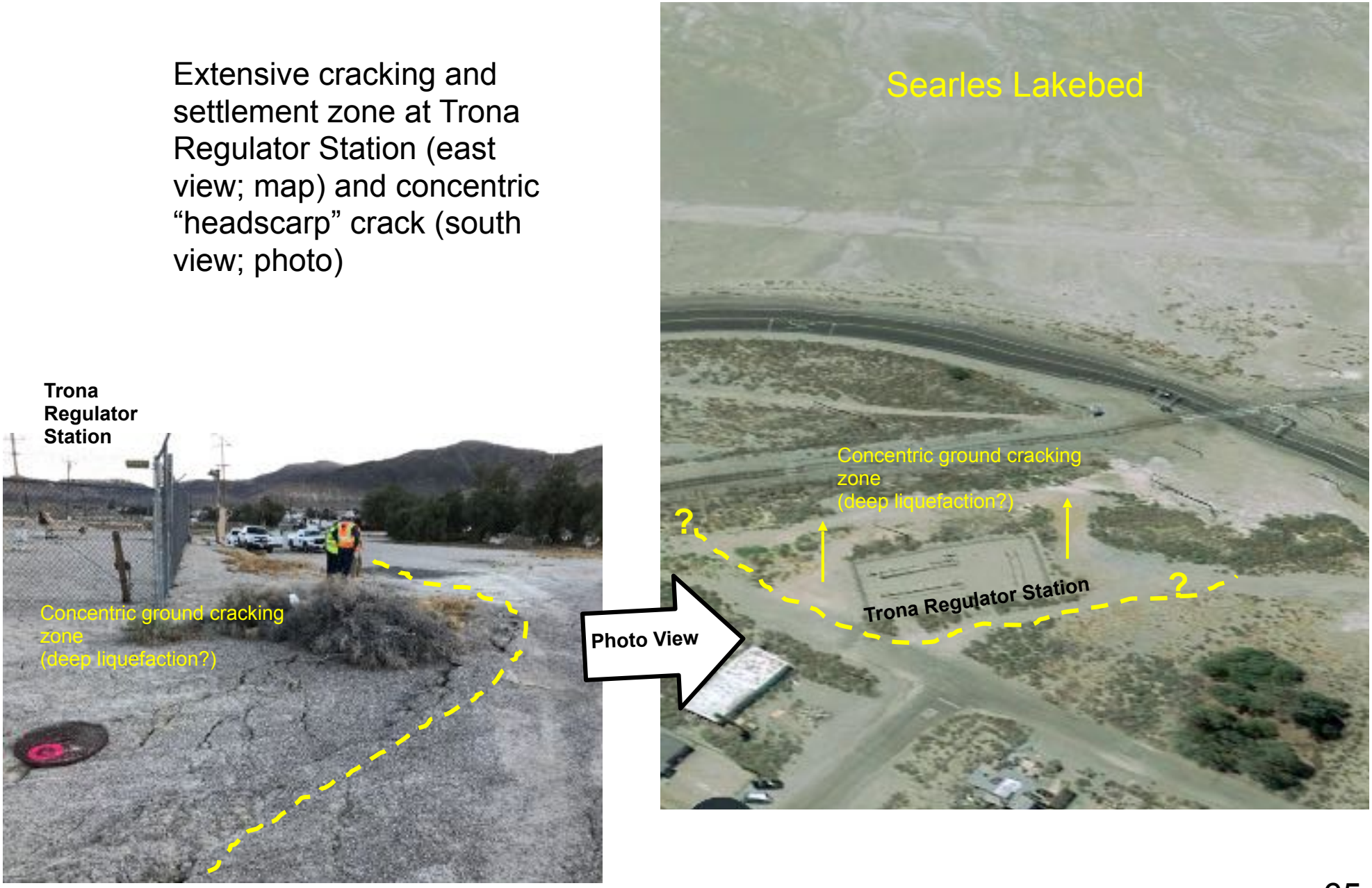
6" Pipe Left Lateral Offset

Original pipe partially excavated

Original pipe after fully excavated

Trona Gas Regulator Station Damage Assessment

Extensive cracking and settlement zone at Trona Regulator Station (east view; map) and concentric “headscarp” crack (south view; photo)



Trona Gas Regulator Station Damage Assessment

Settlement and lateral movements in station pad fills removed support for piping/valves. Settlement & lateral displacement is up to 0.5-1 foot.

Apparent settlement/lateral spread headscarp at northwest corner of station. Searles Lake is off the photo to the left (east), and crack patterns and direction of extension suggest lateral movements toward the lake.

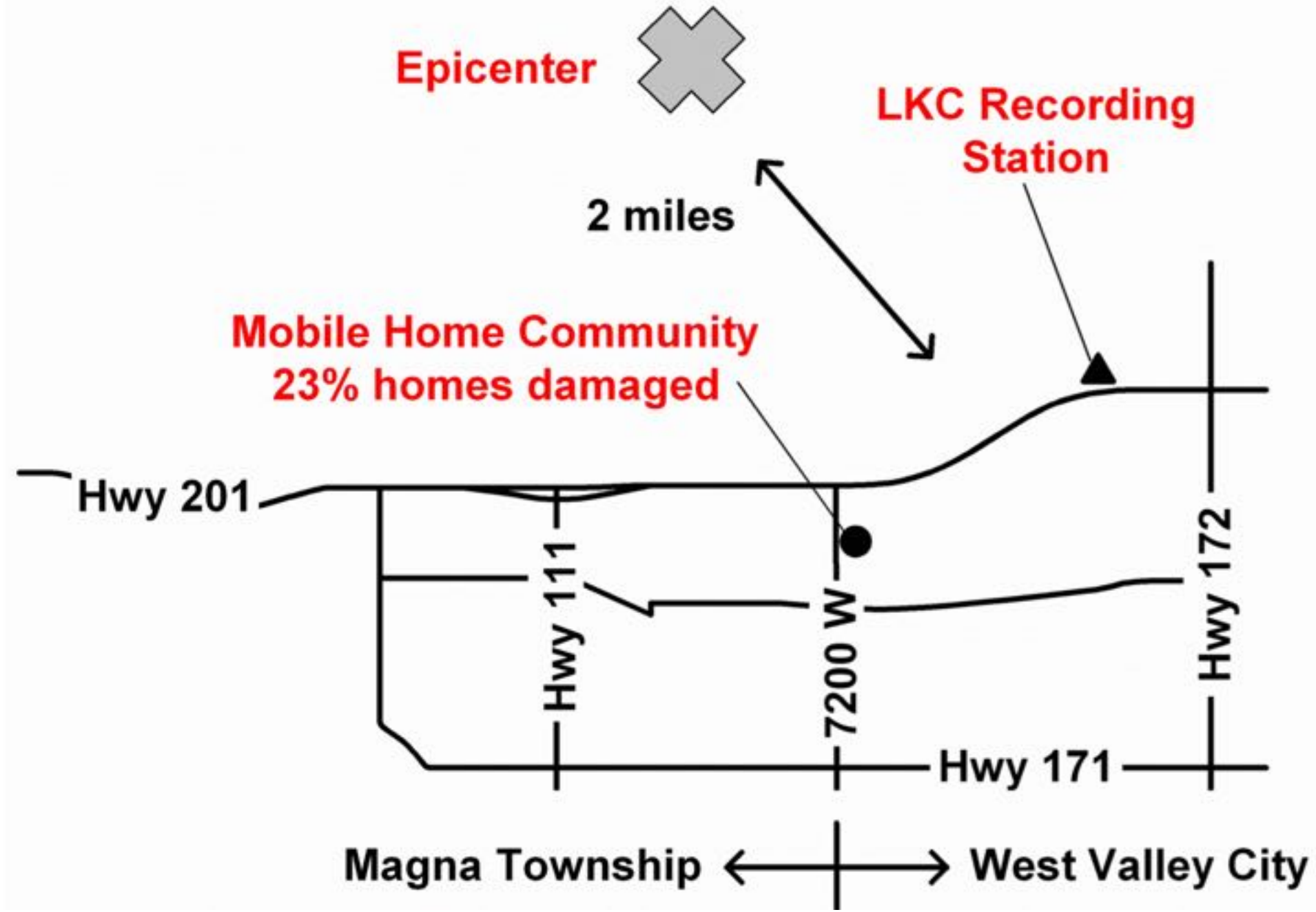
General cracking is pervasive throughout station pad fill.

Differential settlement and lateral displacement across the station pad and foundations

Risers and Meters

Is this "ideal" if the house slides off its foundation?

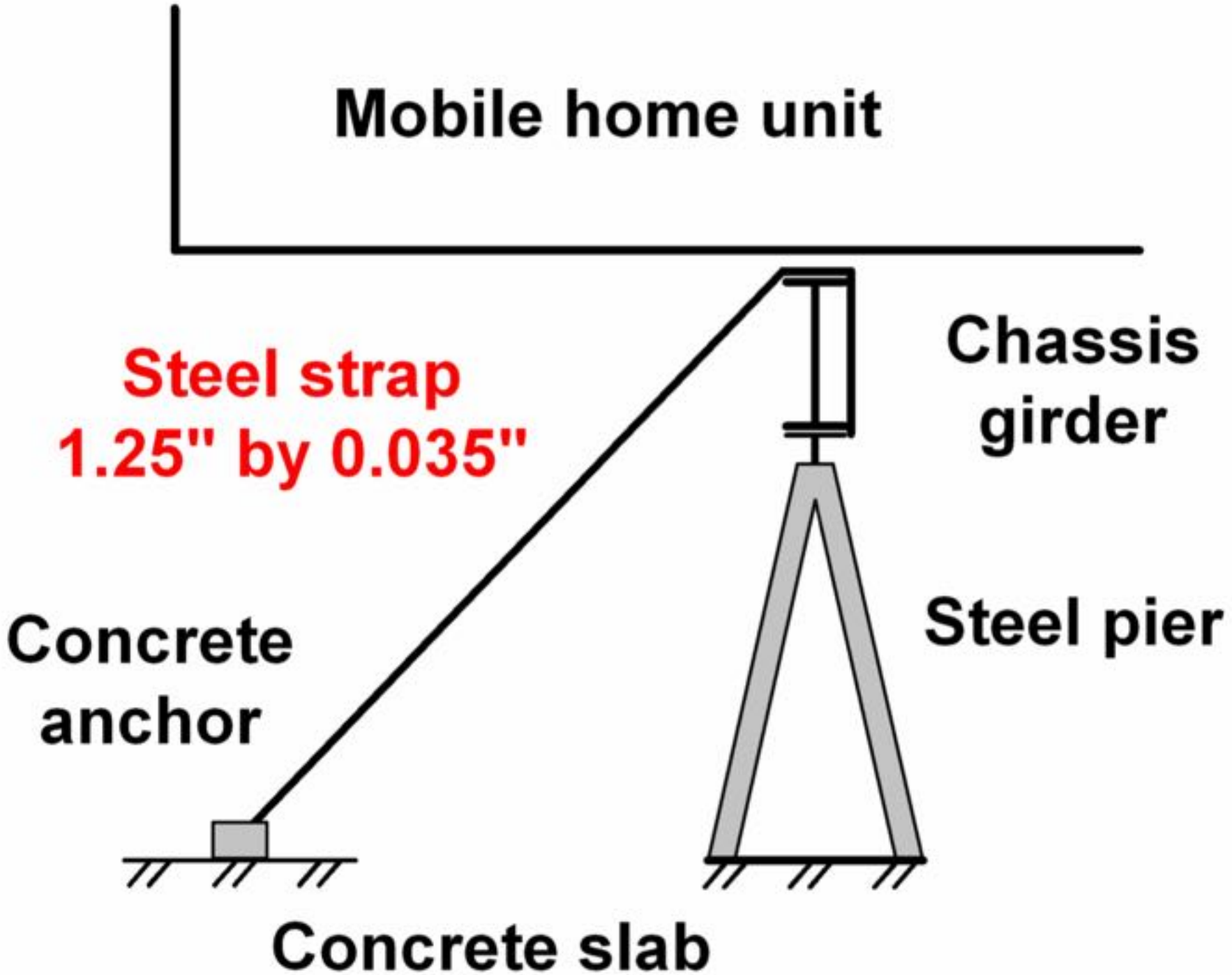
Community Close to Epicenter



Mobile Homes (MH)
(aka manufactured homes)

- One community severely affected
- 48 of 206 MHs dislodged = 23%
  - Many fell to ground
  - No fire ignitions from gas leaks
- First EQ with significant damage to MHs having ***tie-down*** *anchors*
  - CA damage mostly in ***unanchored*** MHs

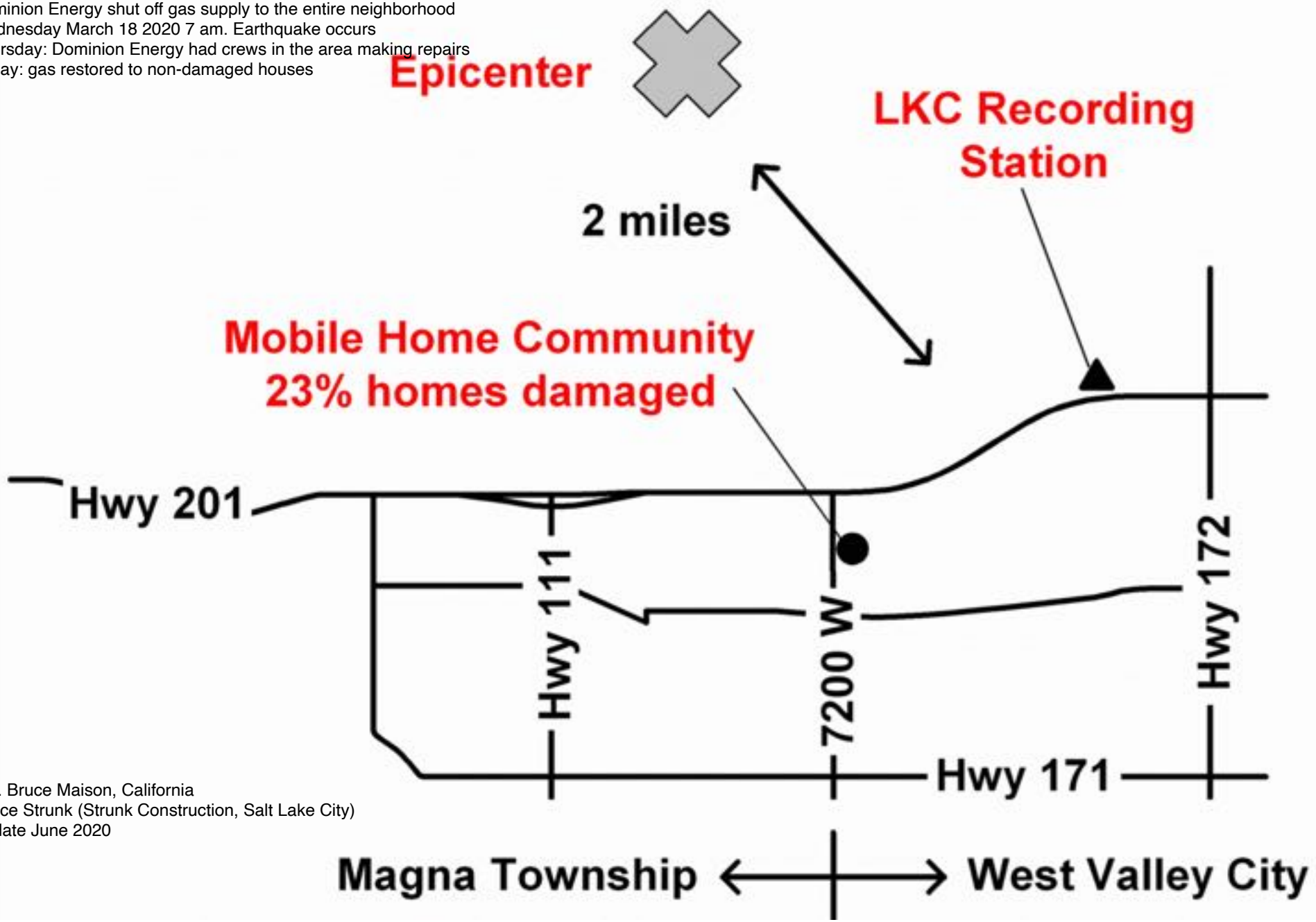
Tie-Down Lateral Bracing



Support Systems

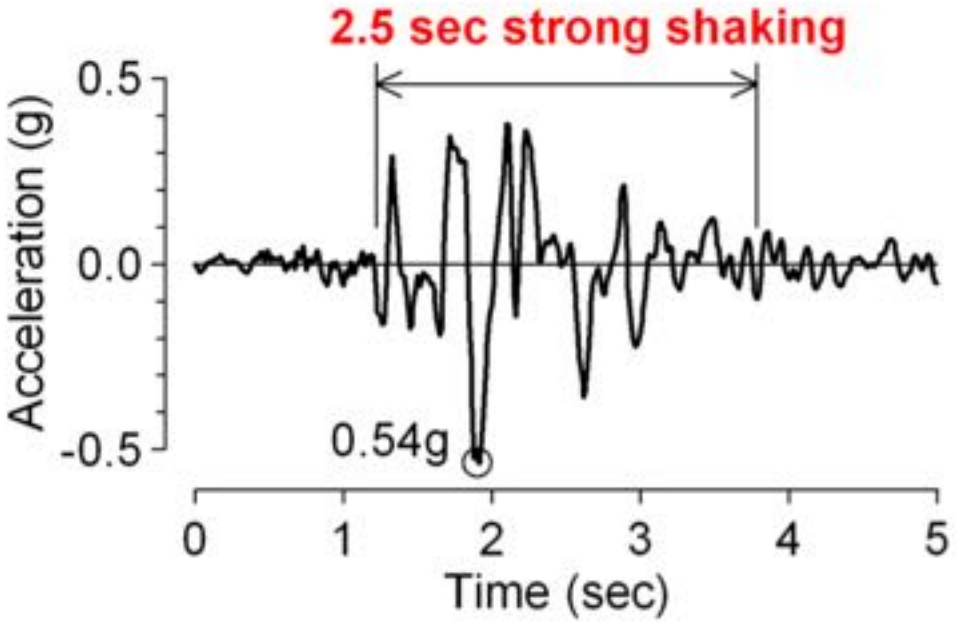
Community Close to Epicenter

Western Estates
Some damgaed gas lines in this neighborhood
Dominion Energy shut off gas supply to the entire neighborhood
Wednesday March 18 2020 7 am. Earthquake occurs
Thursday: Dominion Energy had crews in the area making repairs
Friday: gas restored to non-damaged houses

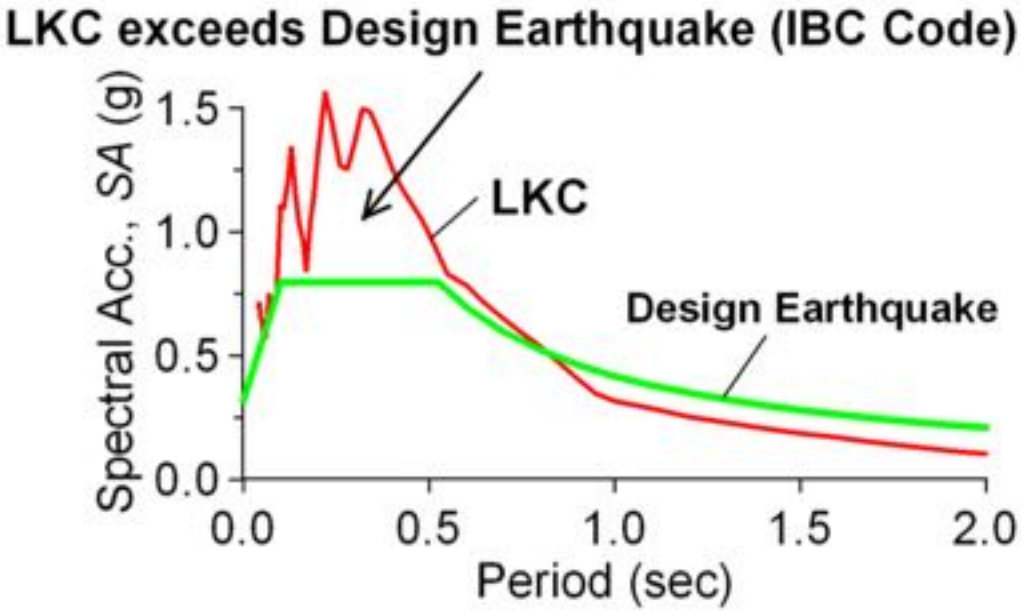


Ref. Bruce Maison, California
Vance Strunk (Strunk Construction, Salt Lake City)
Update June 2020

Short Duration & Strong Shaking



LKC acceleration in N-S direction



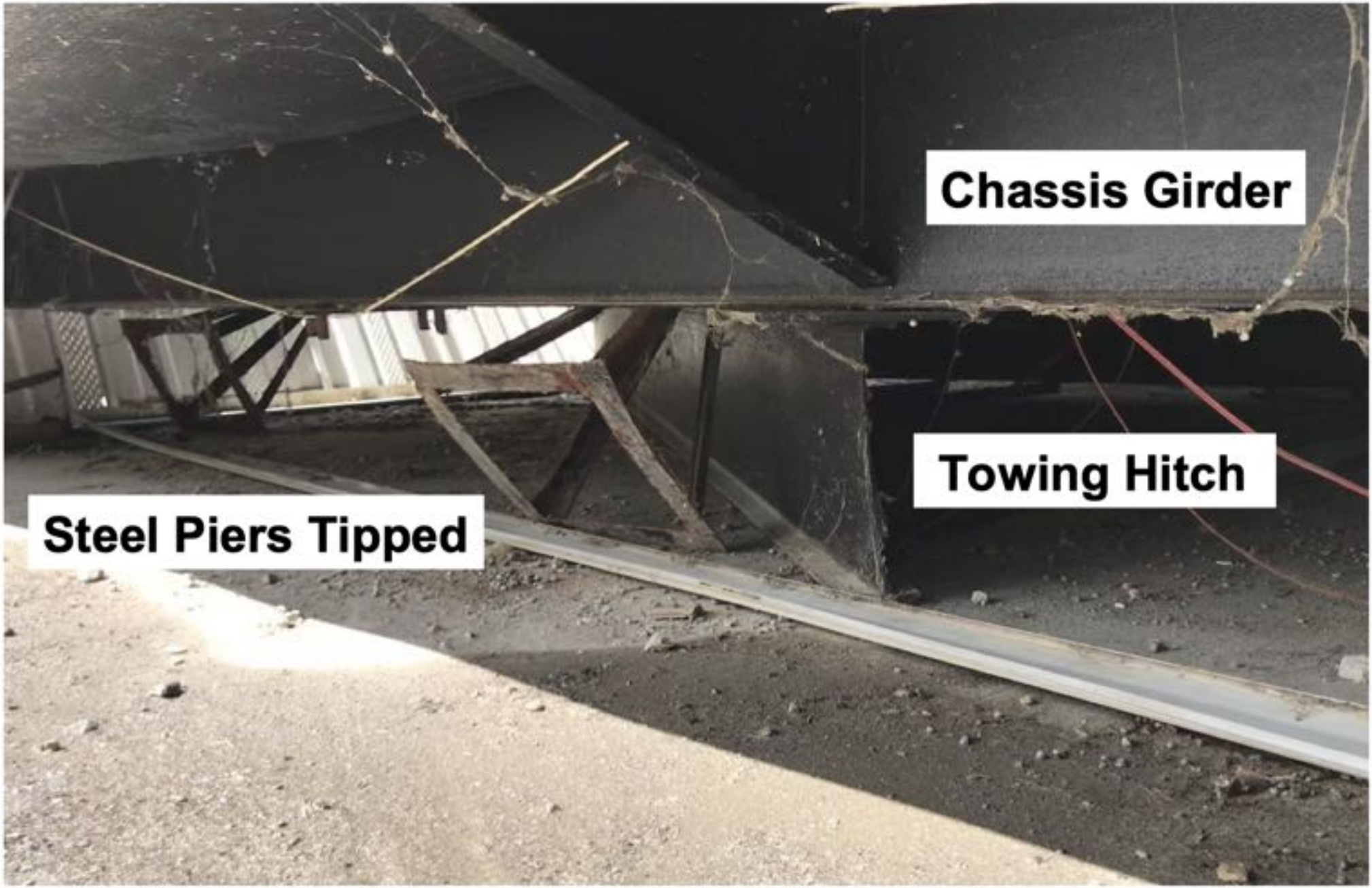
LKC versus Building Code Spectrum

Double-Wide Home

Single-Wide Home

Underneath Home

Underneath Home



Components Nearby Crushed

Corrosion Problem

Strap connection to concrete foundation

Broken Tie-Down Straps

Takeaways

- Tie-downs for wind forces ***NOT*** sufficient for EQ
  - Tension straps overloaded in EQ
- Corrosion played role in damage
  - But some collapses even with pristine tie-downs
- Detailed report in-progress
  - Available on EERI ***Learning from Earthquakes*** clearinghouse later this year

Gas Meter Sets

- Every mobile home had a gas meter set.
- Each meter set is supported by the riser and a supplementary post or pipe tube; meters are not supported by mobile homes.
- All meters had flex hose from the low pressure gas outlet to the mobile home. Commonly 1 foot± of slack in the flex hose.
- Some mobile homes impacted the meter / riser. Many meter sets were tilted. Skirts of mobile homes were damaged where impacted. Various leaks through threaded fittings.
- Some meter sets that did not have impacts with mobile homes were tilted after the earthquake.