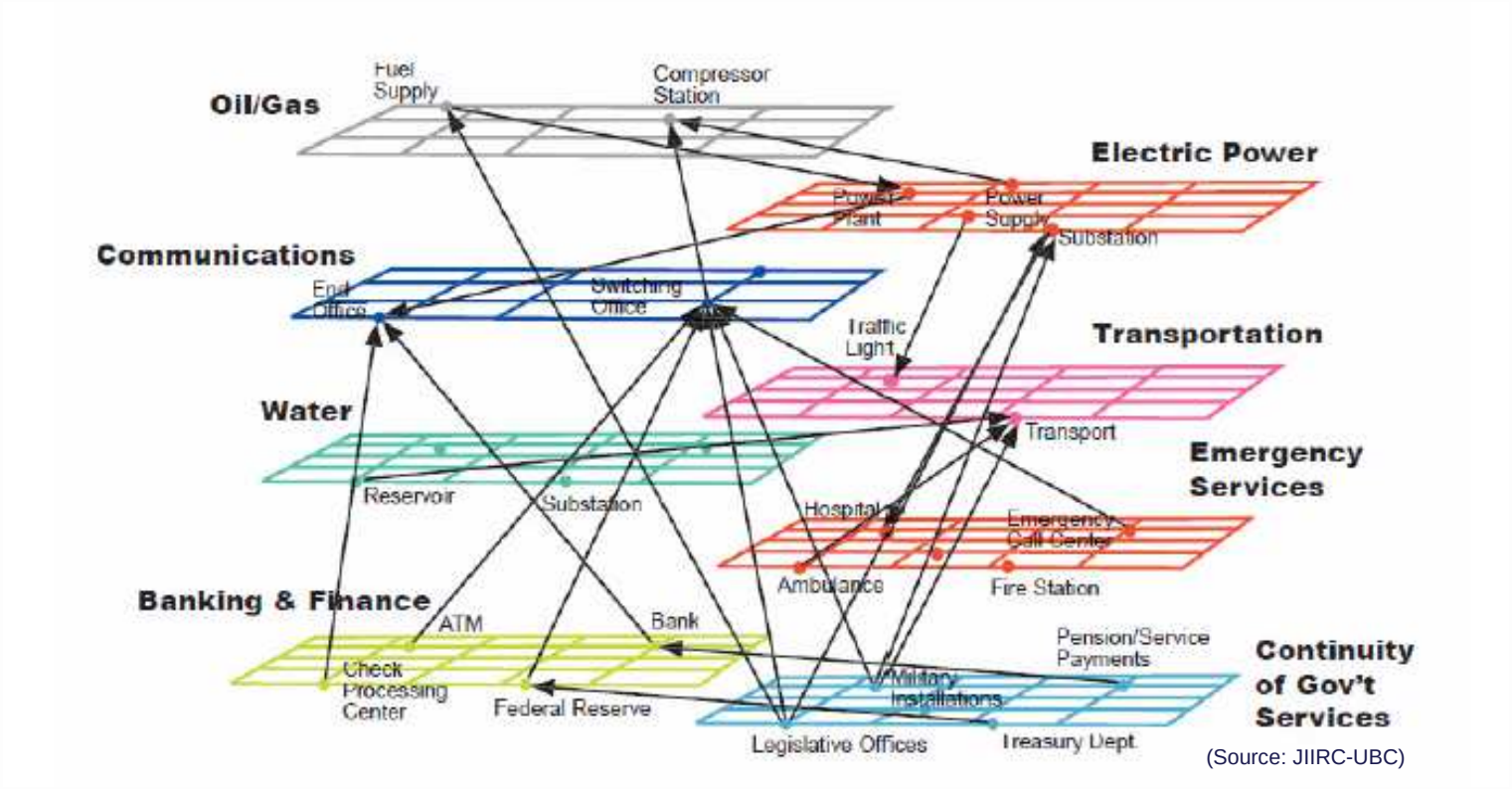
Progress Report:
CCSF Lifelines Council Interdependency Study



(Source: JIIRC-UBC)

Lifelines Council Meeting #8

April 25, 2012

Lifelines Council's Objectives

- Develop and improve collaboration in the City and across the region by regularly convening a group of Executive Officers and Senior-level operational deputies of local and regional lifelines providers
- Understand inter-system dependencies to enhance planning, restoration and reconstruction.
- Share information about recovery plans, projects and priorities.
- Establish coordination processes for lifeline restoration and recovery following a major disaster event.

Interdependency Study Goals (Near-term 2 – 5 years)

- Build a workable understanding of system interdependencies, and consequences of existing conditions ,to help expedite response and restoration planning among agencies
- Identify key assets and restoration priorities/schemes to prioritize post-disaster restoration and reconstruction activities for the city, and ultimately the region
- Develop a collective set of lifelines performance expectations under current conditions

Interdependency Study
Desired Outcomes

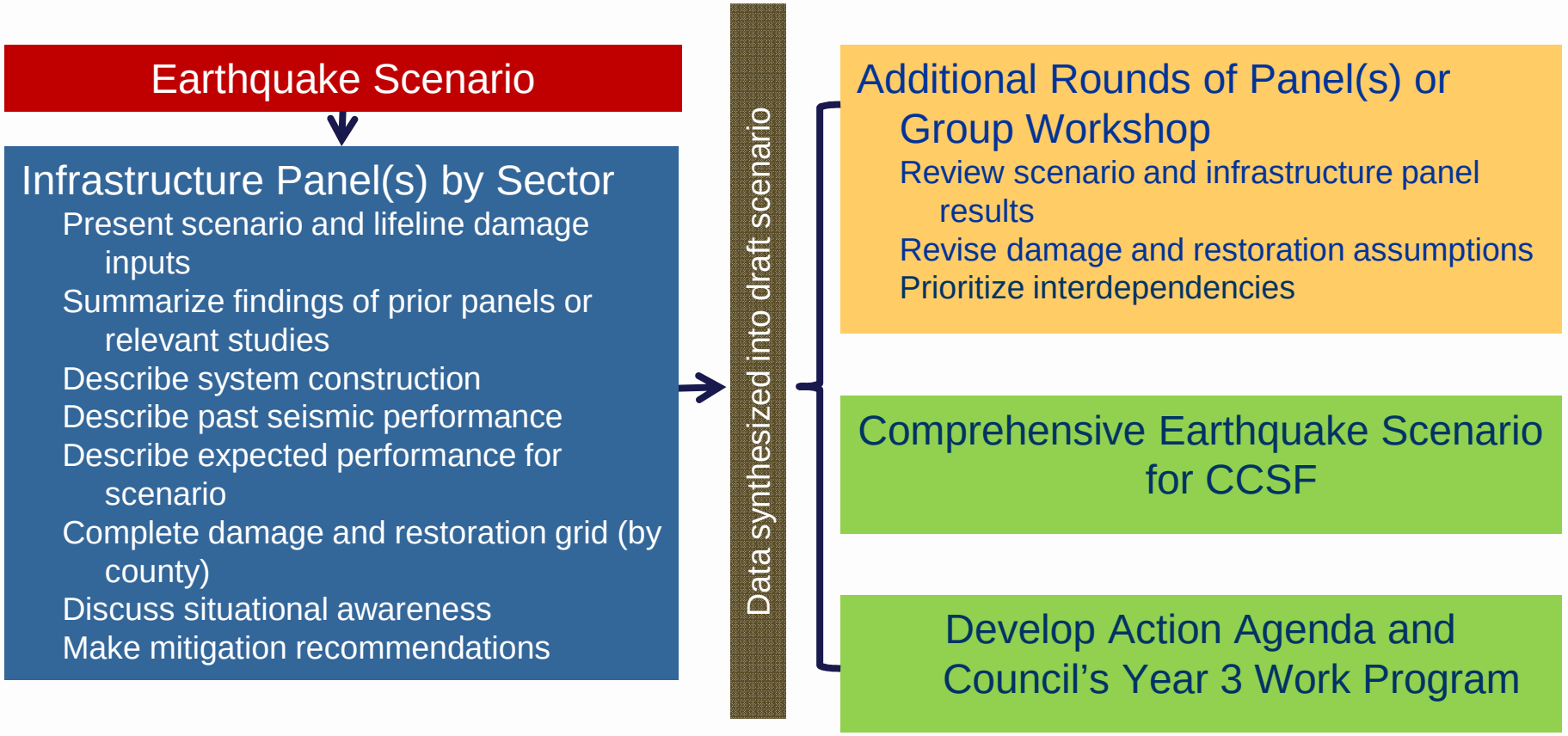
- Development of a more detailed and comprehensive scenario of lifeline system impacts and restoration assumptions, for agencies to use in emergency response planning, table-top exercises
- Development of a economic loss model that reflects lifeline system impacts and restoration assumptions
- Identify key critical nodes and chokepoints in system interdependencies for continued work on inter-agency coordination and reducing lifeline interdependencies between sectors and systems

Interdependency Study
Desired Outcomes

- Identify priorities for public funding (e.g. city bonds, infrastructure financing districts) necessary to underwrite or encourage correcting choke points that affect multiple systems
- Identify priorities for legislative and regulatory changes, and barriers that need to be overcoming for utilities to improve lifeline post-disaster performance and restoration
- Obtain credentialing for personnel to work on system restoration and recovery
- Launch a regional lifelines interdependency study
- Publish updated expectations so business and community partners know results of gap analysis and understand how their dependencies will be affected.

Lifelines Council Interdependency Study Approach

(modeled after Chang et al (Vancouver) and Porter et al (Southern California))

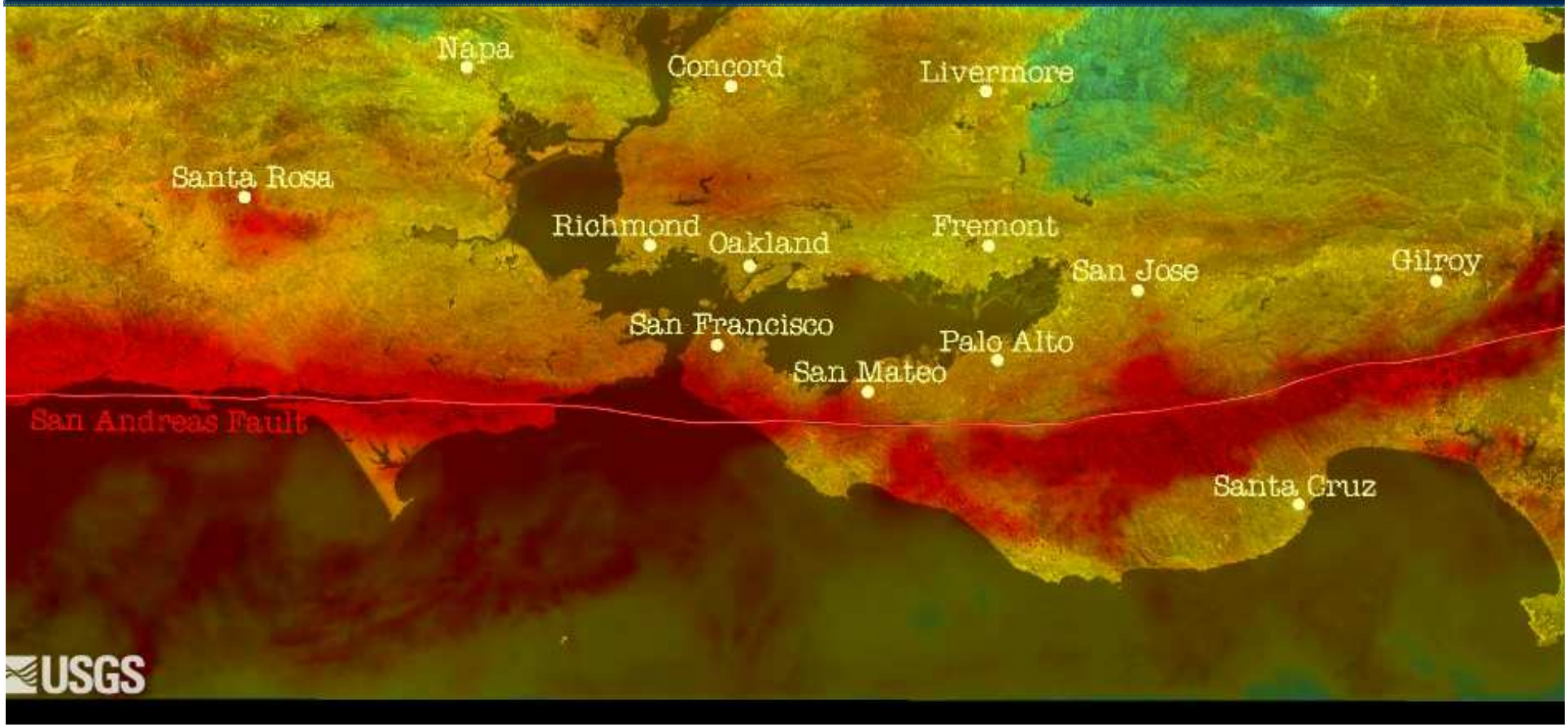


Interdependency Study Progress to Date and Next Steps

- √ Launch study with presentation on interdependency issues and study approaches (April 2011)
- √ Council member working group and other partners/advisors to design and advise on the study (May – July 2011)
- √ Develop system strawman methodology approach (vetted in discussion groups on August 11)
- √ Scenario selection and discussion guide development (Sept – Oct)
- √ Pilot testing of scenario and finalize discussion guide (Nov 2011 –Jan 2012)
- ❑ Infrastructure operator and panel discussions (January – August 2012)
- ❑ Synthesize discussions into integrated scenario and interdependency insights; operator review and approval (September – October 2012)

M7.9 San Andreas Earthquake Scenario affecting19-counties in Northern California

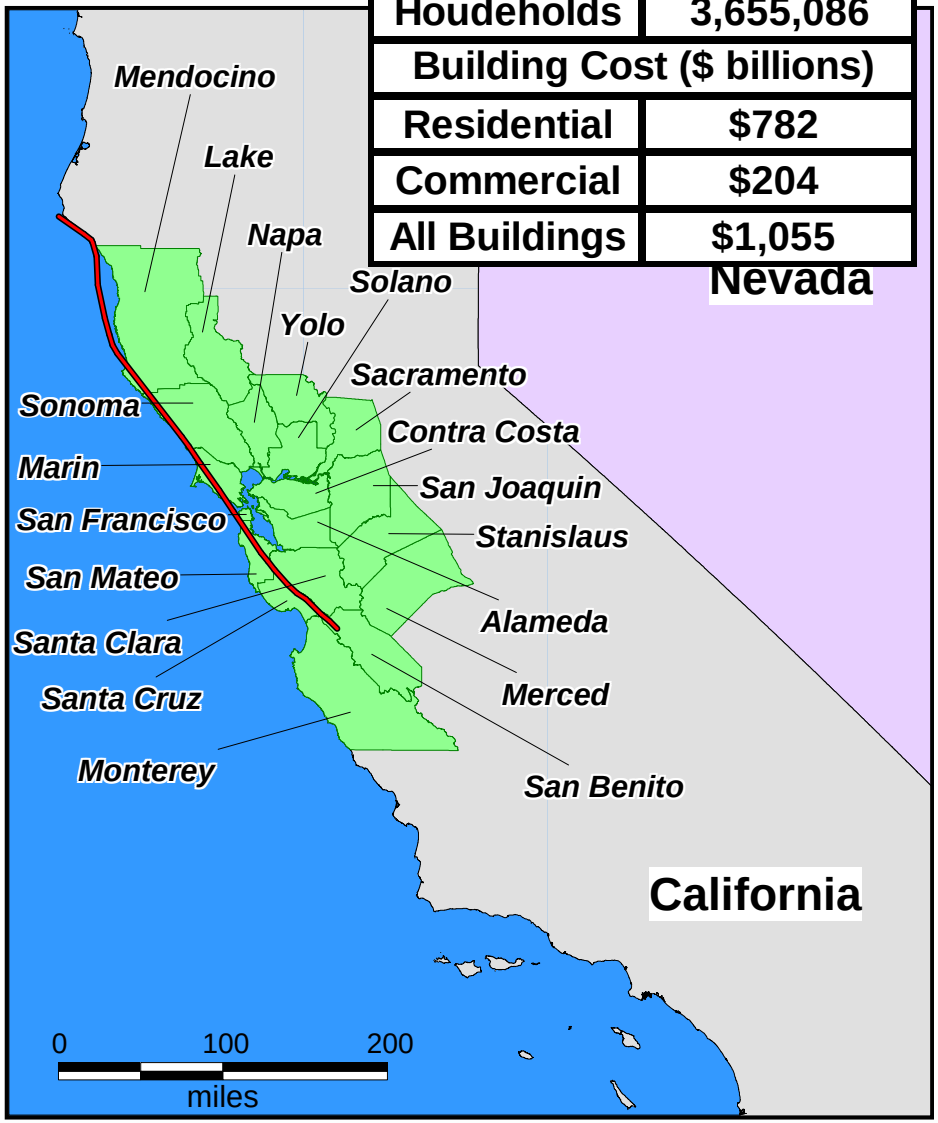
(EERI, Charles A. Kircher et al. 2006)



Study Region

County	Population	Exposure ($ in millions)
Alameda	1,443,741	$155,700
Contra Costa	948,816	$102,807
Lake	58,309	$4,796
Marin	247,289	$36,050
Mendocino	86,265	$7,285
Merced	210,554	$12,901
Monterey	401,762	$33,773
Napa	124,279	$14,579
Sacramento	1,223,499	$110,562
San Benito	53,234	$4,136
San Francisco	776,733	$100,179
San Joaquin	563,598	$42,756
San Mateo	707,161	$84,301
Santa Clara	1,682,585	$183,312
Santa Cruz	255,602	$28,383
Solano	394,542	$34,820
Sonoma	458,614	$50,858
Stanislaus	446,997	$33,828
Yolo	168,660	$14,479

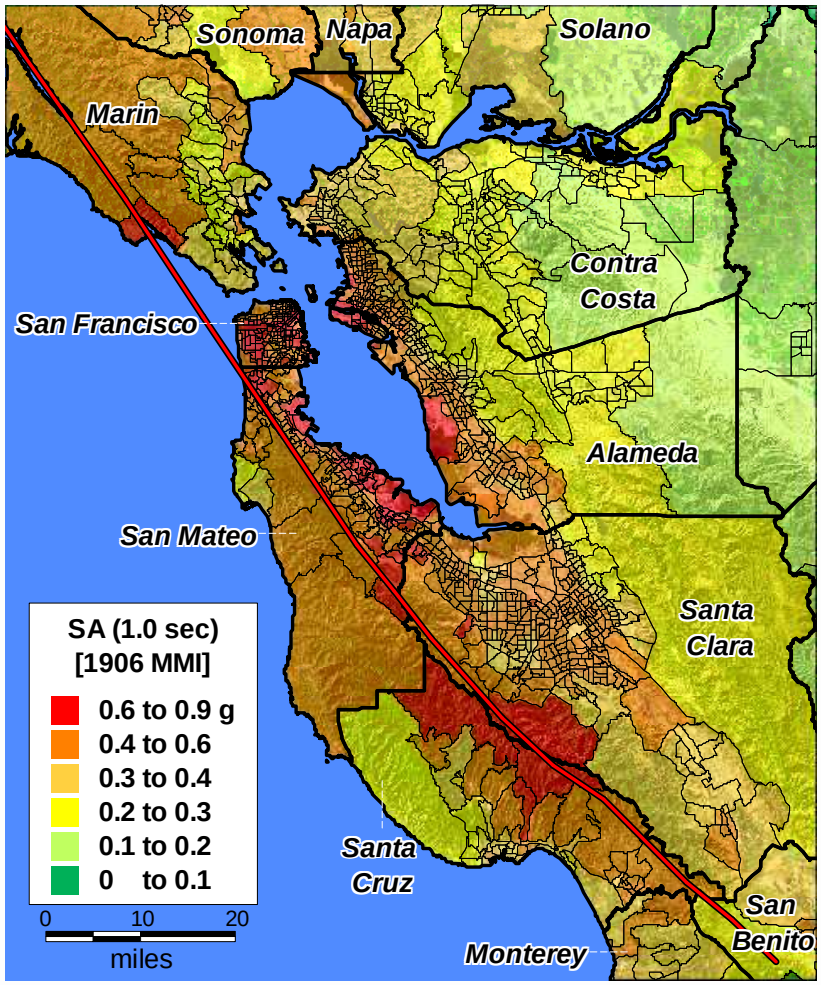
19-County Study Region	
Population	10,252,240
Houdeholds	3,655,086
Building Cost ($ billions)	
Residential	$782
Commercial	$204
All Buildings	$1,055



Scenario Earthquake Ground Motions

1906 MMI Ground Motions

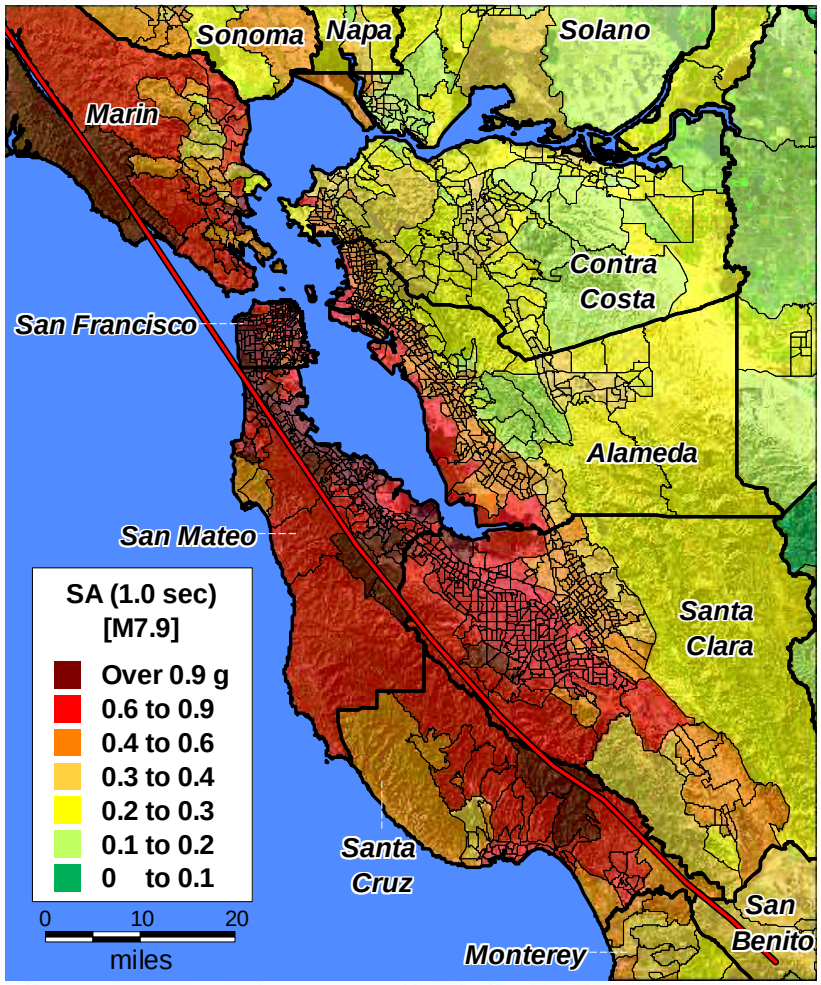
- Best available estimate of how the ground shook in 1906
- MMI ShakeMaps (USGS)
  - Boatwright, Bundock and Seelins, 2006, "Using Modified Mercalli Intensities to Estimate Acceleration Response Spectra" (EERI, *Earthquake Spectra*)



Scenario Earthquake Ground Motions

M7.9 Ground Motions

- Best estimate of how the ground will shake next time
- Same methods as those of Seismic Codes (USGS)
  - Frankel et al., 2002, "Documentation for the 2002 Update of the national Seismic Hazards Maps, (USGS OFR 02-420)
- High-Resolution Soil (Site Class) Map
  - California Geological Survey



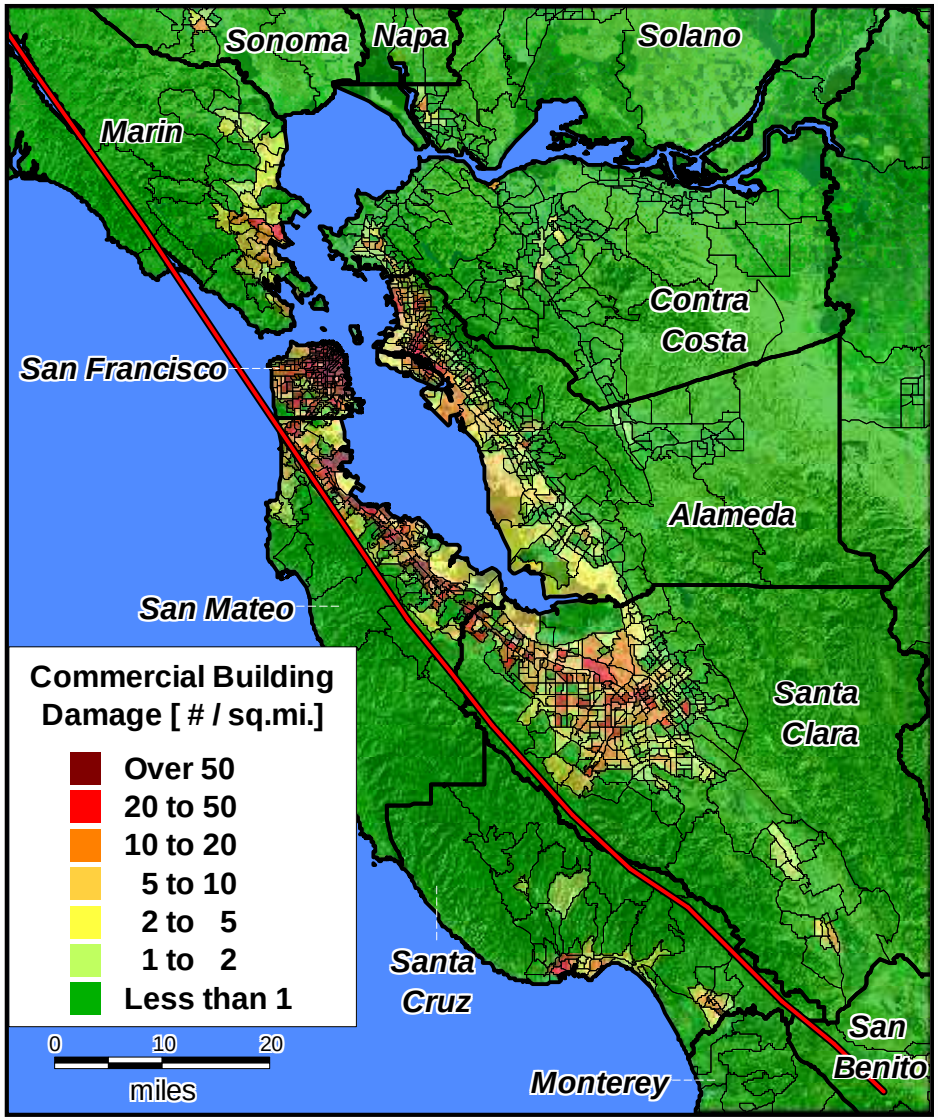
Summary of Building Damage and Loss Results Due to Ground Shaking and Ground Failure – Total Study Region

Damage or Loss Parameter	Population or Exposure	Scenario Earthquake	
		1906 MMI	M7.9
Number of Severely Damaged Buildings			
Residential Buildings	2,800,000	80,000	120,000
Commercial Buildings	70,000	7,000	10,000
Social Losses due to Building Damage			
Displaced Households	3,700,000	170,000	250,000
Serious Injuries - Nighttime	10,300,000	4,000	8,000
Serious Injuries - Daytime		6,000	13,000
Immediate Deaths - Nighttime	10,300,000	800	1,800
Immediate Deaths - Daytime		1,600	3,400
Direct Economic Losses due to Building Damage (Dollars in Billions)			
Structural System	$300	$15	$20
Nonstructural Systems	$800	$57	$75
Contents and Inventory	$500	$14	$17
Business Interruption (BI)	NA	$8	$11
Total Building and Contents	$1,500	> $90	> $120

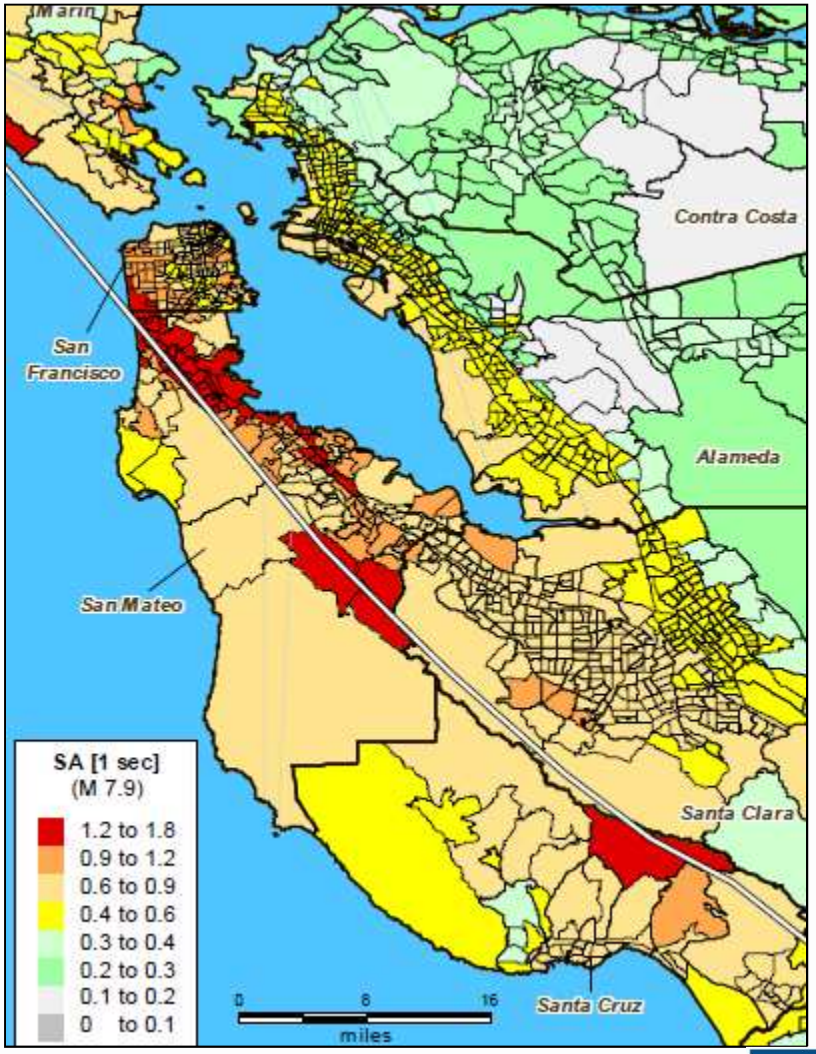
Commercial Building Damage (M7.9 Scenario)

- Over 10,000 commercial buildings likely to be closed or to have restricted use until repairs are made due to structural damage

Commercial Buildings with at least Extensive Structural Damage		
County	**Number**	**Fraction**
Alameda	1,307	12%
San Francisco	3,560	37%
San Mateo	2,054	41%
Santa Clara	2,059	19%
Other Counties	1,271	7%
All Counties	10,251	15%



Residential Impacts (San Francisco)



- 15,000 – 24,000 single family dwellings with extensive or complete damage (12% to 20% of 125,000 total)
- 7,000 – 11,000 other residential buildings with extensive or complete damage (19% to 30% of 37,000 total)
- 60,000 – 88,000 households initially displaced (18% to 27% of ~330K)
- 14,000 – 22,000 people seeking shelter (out of ~800K)

Fatalities (M7.9 Scenario)

- **3,400 Daytime Fatalities**

1/1,000 Fatality rate
(San Francisco County)

County	Daytime Deaths	
	Number	Rate[1]
By County		
Alameda	378	26
San Francisco	823	106
San Mateo	1,013	143
Santa Clara	802	48
All Others	394	7
By Building Type		
Typical	2,232	23
"Bad" Types[2]	1,179	329

1. Deaths per 100,000 of population
2. Soft-story wood, un-reinforced masonry and non-ductile concrete

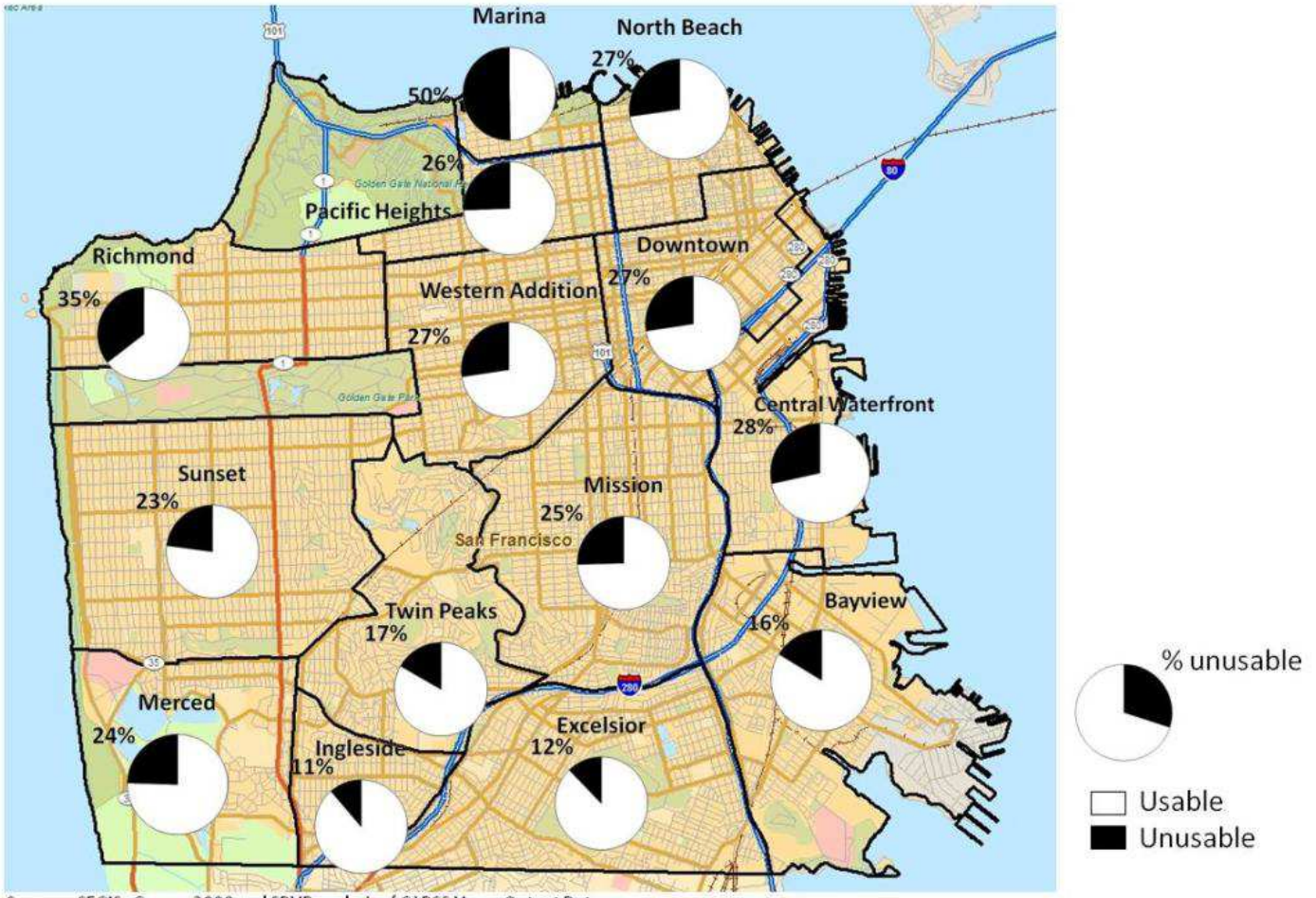
- **1,800 Nighttime Fatalities**

One-half due collapse of "bad" building types

County	Nighttime Deaths	
	Number	Rate[1]
By County		
Alameda	269	19
San Francisco	574	74
San Mateo	370	52
Santa Clara	361	21
All Other	271	5
By Building Type		
Typical	892	9
"Bad" Types[2]	954	266

1. Deaths per 100,000 of population
2. Soft-story wood, un-reinforced masonry and non-ductile concrete

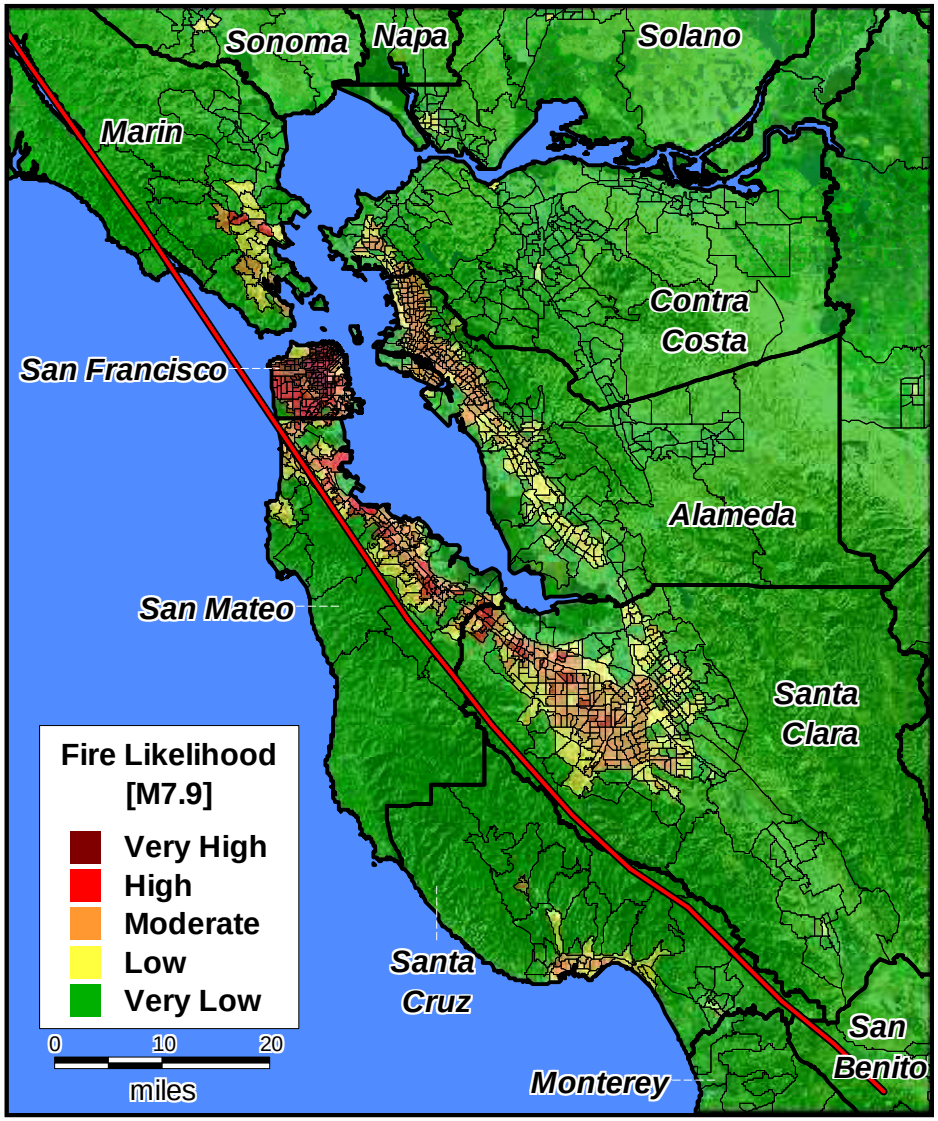
Housing Units Usable and Unusable after a M7.2 San Andreas Earthquake (SPUR/CAPSS)



Sources: SFGIS , Census 2000 and SPUR analysis of CAPSS Hazus Output Data

Fire Following (M7.9 Scenario)

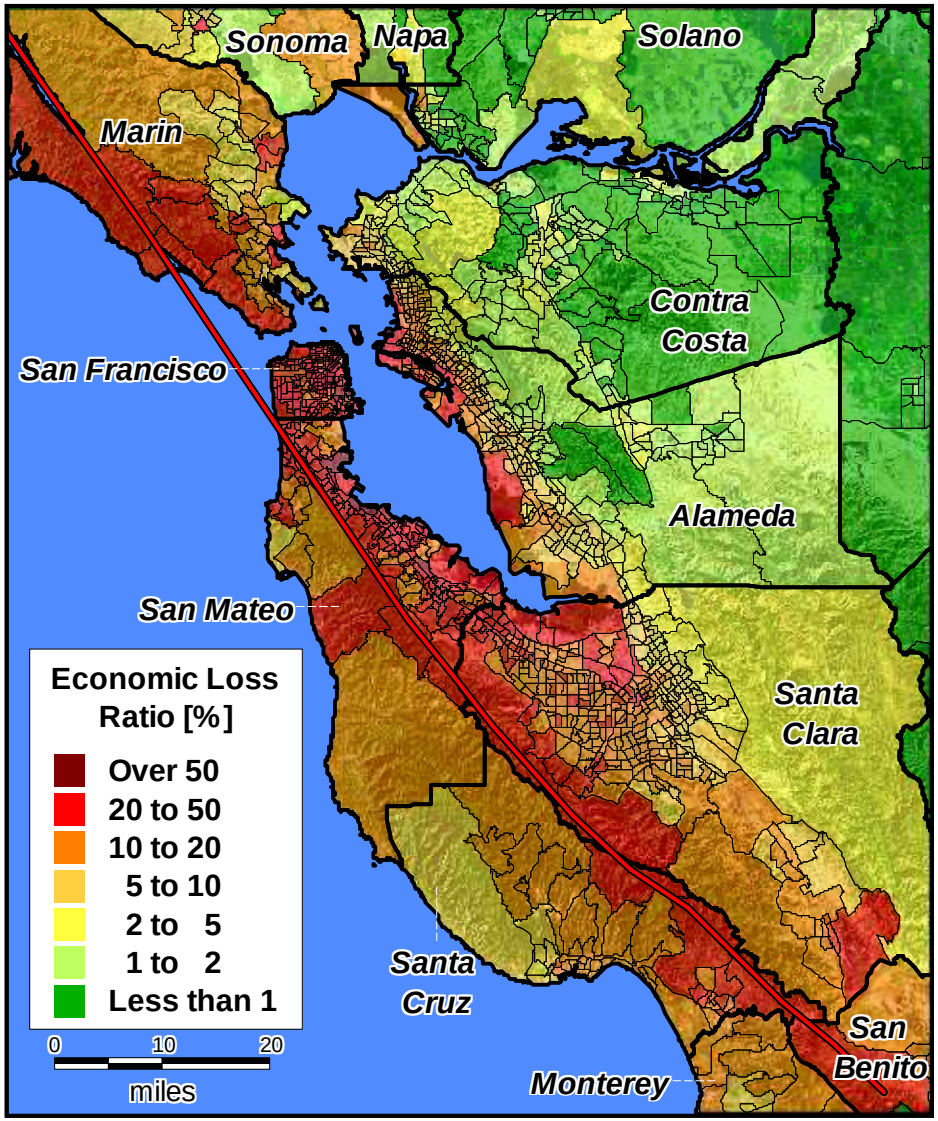
- Fire Following Concepts
  - Ignitions
  - Spread
  - Suppression
- 300 - 600 fire ignitions estimated
  - 30 – 60 San Mateo
- Fire Likelihood Map
  - Areas with older, denser buildings and stronger ground motions



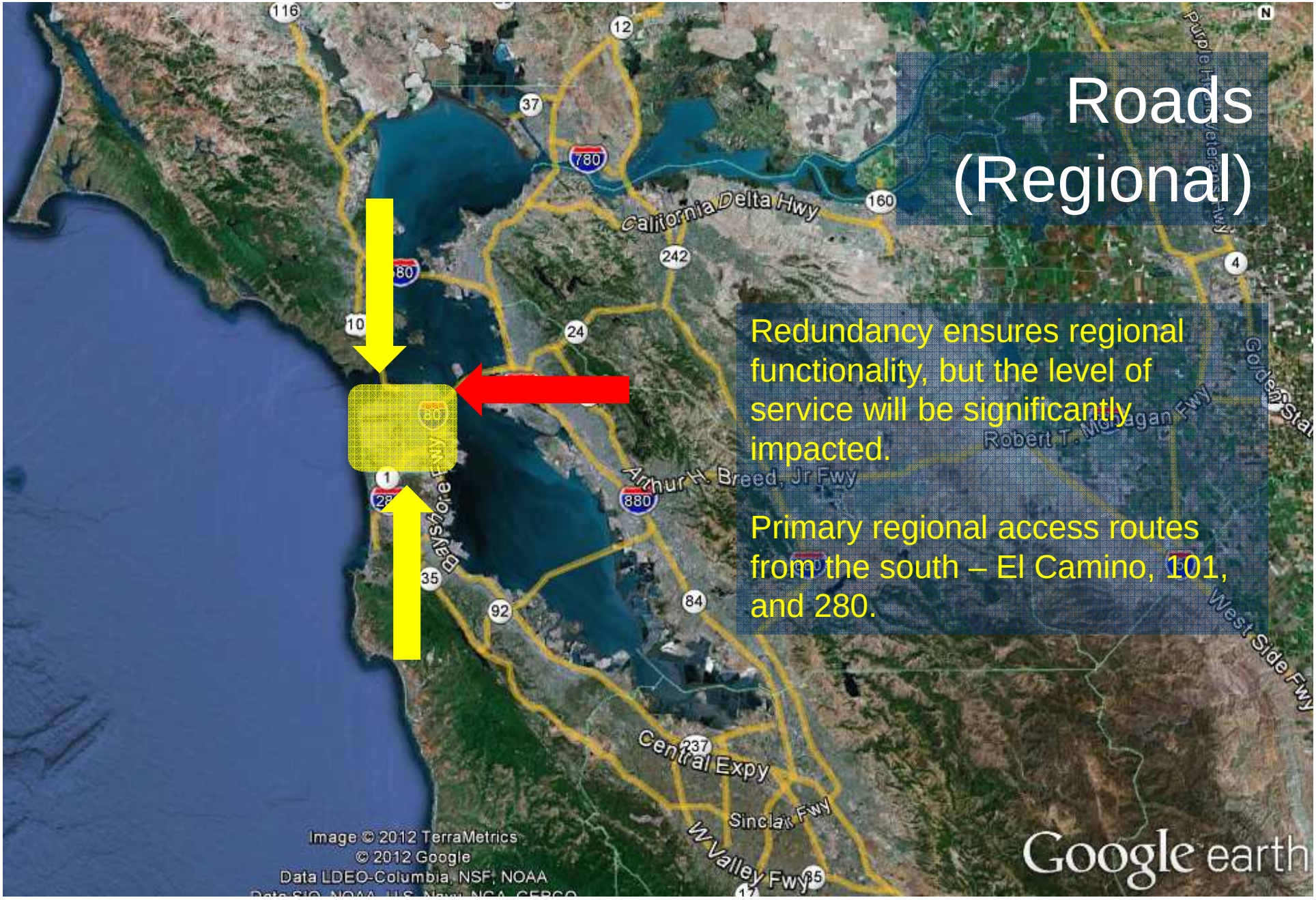
Total Direct Economic Loss

Direct Economic Building Loss due Ground Shaking/Failure (M7.9)	
County	**Loss Ratio**
Alameda	7.4%
San Francisco	25.9%
San Mateo	24.6%
Santa Clara	11.9%
Other Counties	2.7%
All 19 Counties	9.0%

- Fire - Plus 5% - 15%
- Lifelines - Plus 5% - 15%
- Total Loss: **$150 billion**



Roads (Regional)



Roads (Regional)

- N-S: 101-Doyle Drive, 280-Crystal Springs damage. Other damage along 101, 280, El Camino Real, and Highway 1.
- E-W: Bay Bridge damage. Retrofit bridges will not collapse but may not be functional.
- CalTrans and CHP staff will provide damage/ functionality reports; 12 – 18 hours to get picture
- Structures maintenance group does inspections. Shakecast used to prioritize inspections.

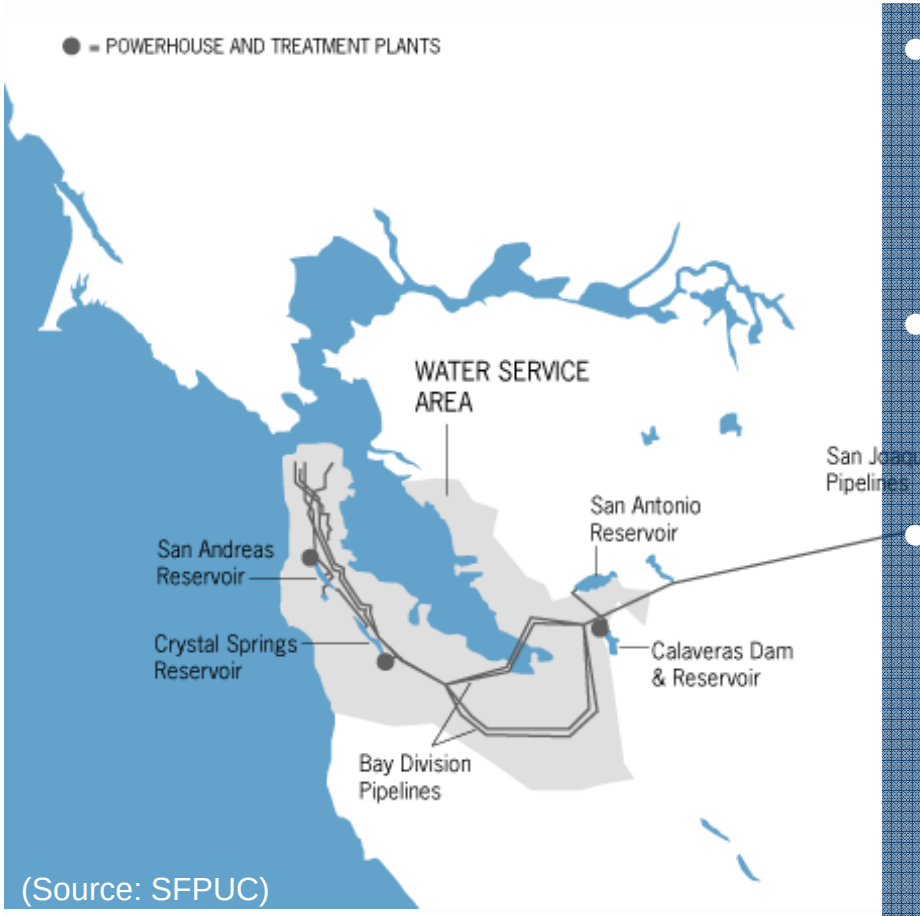
Roads (Regional) - Restoration

- System needs will change after disaster, which will affect restoration (i.e. alternate work schedules, relocations)
- Restoration initially will come organically. Start off doing a little bit everywhere. Actions determined by what happens locally.
- Major restoration priorities and communications/ decisions will come from State/region EOC.
- Restoration metrics will vary depending upon priorities, resources, and repair process:
  - "Maze" fire – 26 days; 880-Cypress reconstruction – 10 years
  - Have multi-agency regional plans and are working on regional incident mobility plan with MTC.
  - "If we are all working and cooperating, then we will likely get support."

Roads (Regional) - Interdependencies

- Regional service organization helps ensure distributed labor, equipment, and materials (particularly near construction areas). Fuel facilities throughout region (state contract)
- EOC/Caltrans communication center seismic retrofitted. Ensure water and power (UPS, generator) for 72 hours. Worst case: use CHP communications center (Vallejo)
- Upstream dependencies – telecommunications (cell phones and 800MHz radio) and power, fuel, and human needs for crews (water, food, shelter)
- Downstream dependencies – All lifelines needing regional access (labor and supplies)
  - federal staging areas (Travis, Livermore)
  - checkpoints managed by local police or CHP

Water - Transmission



(Source: SFPUC)

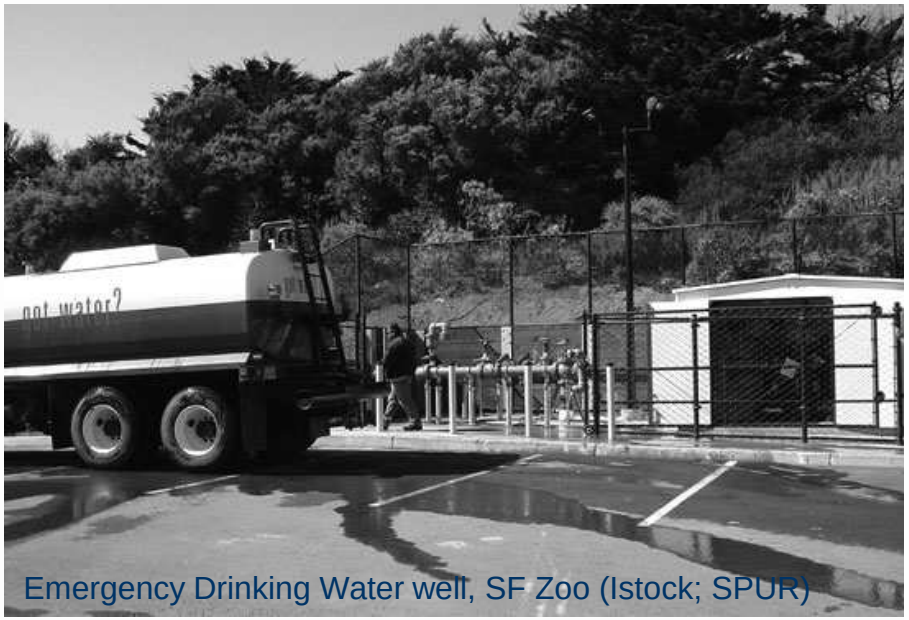
- 350 MGD* systems peak capacity; 265 MGD current delivery;
  218 MGD* from Hetch Hetchy, plus local reservoirs
- Halfway through $4.6 bn Water Seismic Improvement Program to be completed in 2016; ~$1 bn in San Francisco
- High reliability of San Francisco 5-line transmission system already.
  Performance standards:
  - 3 of 5 major "turnouts" (70%) in San Francisco within 24 hours
  - 100% in 30 days

*MGD – million gallons per day

Water - Distribution

- Distribution system (1,200 miles) generally reliability but portions will fail in major seismic event:
  - System largely gravity flow (not heavy power dependence)
  - Ductal iron pipeline replacement program underway
  - Remote distribution monitoring that will be upgraded; rely on valve shutoff
- 3 to 4 days of storage already in SF
- Emergency water program involving spigots at reservoirs, water trucks, and bagging

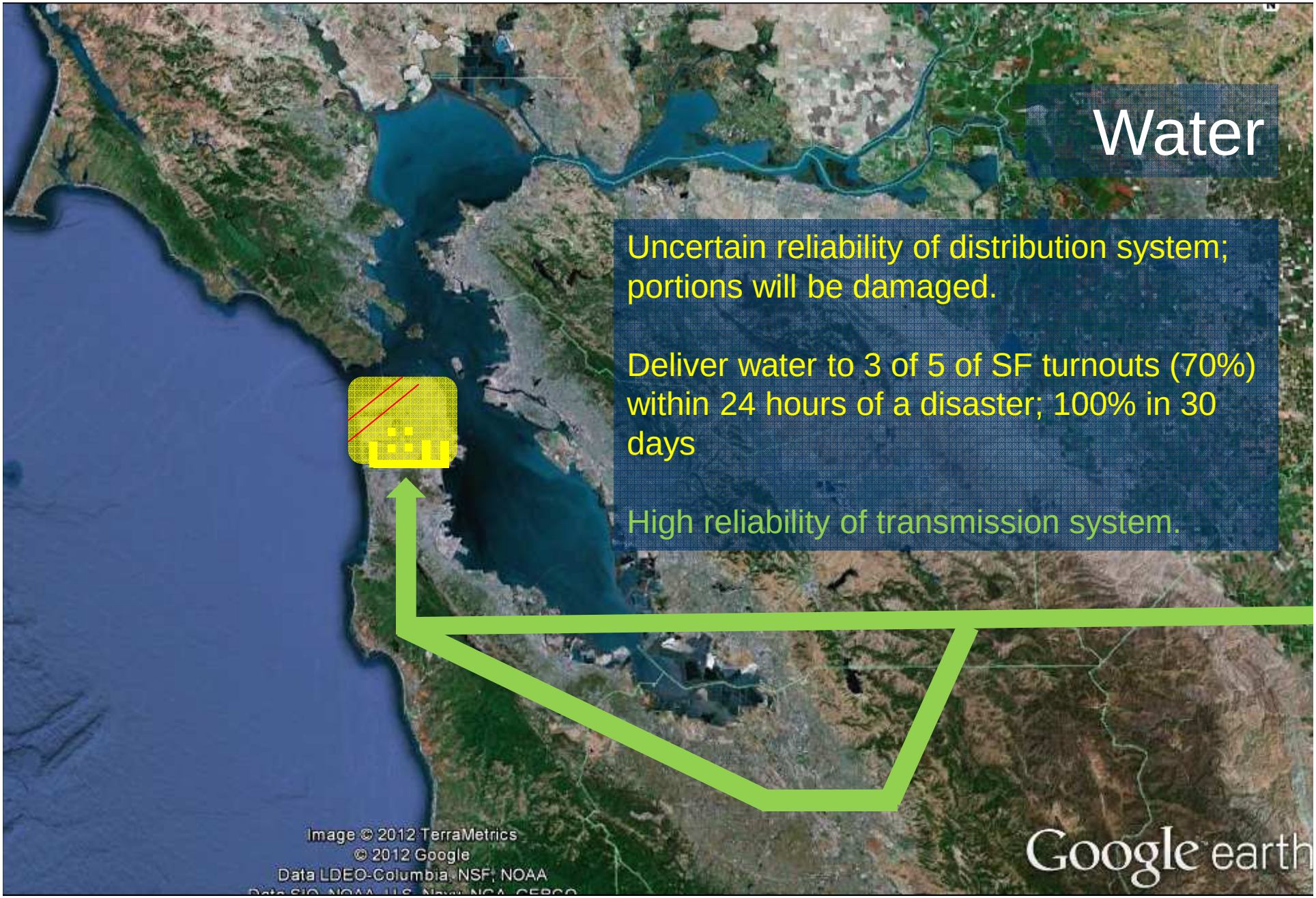
Sunset Reservoir (SFPUC)



Emergency Drinking Water well, SF Zoo (Istock; SPUR)

Water – Restoration

- SFPUC reports into SF EOC; also have their own DOC
- SF Level of Service will need to be determined at time of disaster
- SF restoration priorities set by Mayor and incident commander
  - Transmission system repairs will have some priority
  - Distribution system repairs will consider critical facilities, largest population areas, and doable repairs. Currently replacing 9 miles of pipeline per year, ramping up to 15 miles by 2014.
- Regional restoration priorities (if choices necessary) would come through State/region EOC


Water
Uncertain reliability of distribution system; portions will be damaged.
Deliver water to 3 of 5 of SF turnouts (70%) within 24 hours of a disaster; 100% in 30 days
High reliability of transmission system.
Image © 2012 TerraMetrics
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Data LDEO-Columbia, NSF, NOAA
Google earth

Water - Interdependencies

- Regional nature of SFPUC provides high level of independence for fuel (across 7 counties), chemicals (3 to 4 days), communications (SCADA, cellular), heavy equipment, and labor
  - Draft MOU with 4 Bay Area utilities; EBMUD --> LA DWP; state water providers
  - Use SCADA system and staff inspections
- Gravity flow of system limits dependence on electricity for pumping
- Key upstream dependencies – fuel, telecommunications
- Key downstream dependencies – fire department (working on MOU) , underground utilities that might be flooded by breaks, critical facilities (hospitals already connected to 2 or 3 of the 8 pressure zones), financial services and major industries

Electricity – Transmission and Distribution

- 3 electric transmission lines come up the peninsula, a “DC line” operated by 3rd party crosses SF Bay
- Critical substation could experience significant damage, resulting loss of all 3 transmission lines
- DC line can’t provide independent service
- SF has no electric generation capacity
- Much of SF distribution system is underground, subject to significant damage
- San Mateo and Alameda County will also have significant damage

Electricity – Restoration

- PG&E headquarters expected to suffer only minor damage; relocation plan will move critical businesses out of SF if necessary
- PG&E will have regional (State-directed) and local restoration priorities (SF EOC):
  - Damaged underground distribution system will be challenging to repair
  - Electric load must be balanced during restoration to avoid system damage; unpredictable outages likely until sufficient capacity restored
  - Restoration across city will depend upon damage locations/concentrations, population concentrations (evacuated areas will likely be delayed), seasonality, and ability to expedite services to critical facilities


Electricity
Much of SF distribution system is underground, subject to significant damage, and more challenging to repair
SF has no electric generation capacity
Critical substation could experience significant damage, resulting loss of all 3 transmission lines
Transmission lines up the peninsula are pretty robust. DC line from East Bay can't provide independent service
Image © 2012 TerraMetrics
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Data LDEO-Columbia, NSF, NOAA
Google earth

Electricity – Interdependencies

- Mutual aid agreements in place
- Upstream dependencies – road clearance and access for heavy equipment; potential inundation of any underground facilities from ruptured water or sewage lines; fuel for both generators and vehicles; communications; human needs for crews (water, food, shelter)
- Downstream dependencies – most lifelines dependent on electricity; emergency shelters and other critical facilities

Gas – Transmission and Distribution

- 3 gas transmission lines come up the peninsula, and meet at a single point in San Francisco before citywide distribution
- SF gas load can be managed with only 2 of 3 lines; loss of 2 lines would result in pressure loss and potential curtailment of gas service throughout SF
- SF gas distribution lines are underground but more flexible plastic. SF gas leaks controlled through 2,200 valves that can be shut-off manually, where and when needed
- San Mateo County will also have significant damage

Gas – Restoration

- PG&E will have regional (State-directed) and local restoration priorities (SF EOC):
  - 2,200 valves across city will be shut-off, where and when needed, to isolate gas leaks in underground distribution system
  - Restoration will require entry to every property/unit to check for gas leaks and relight gas-fired equipment
  - In addition to city priorities, opportunities to quickly restore service in minimally damaged and safe areas will be taken when possible. Restoration across city will depend upon damage locations/concentrations, population concentrations (evacuated areas will likely be delayed), seasonality, and ability to expedite services to critical facilities

Gas – Interdependencies

- Mutual aid agreements in place
- Upstream dependencies – road clearance and access for heavy equipment; potential inundation of any underground facilities from ruptured water or sewage lines; fuel for both generators and vehicles; communications; human needs for crews (water, food, shelter)
- Downstream dependencies – emergency shelters and other critical facilities heavily dependent upon gas

Gas


SF gas distribution system is underground, but in flexible plastic pipe. If transmission lost, system restoration will take months
3 transmission lines up the peninsula meet at single point. If 2 lose transmission, then resulting pressure loss could curtail service citywide
Image © 2012 TerraMetrics
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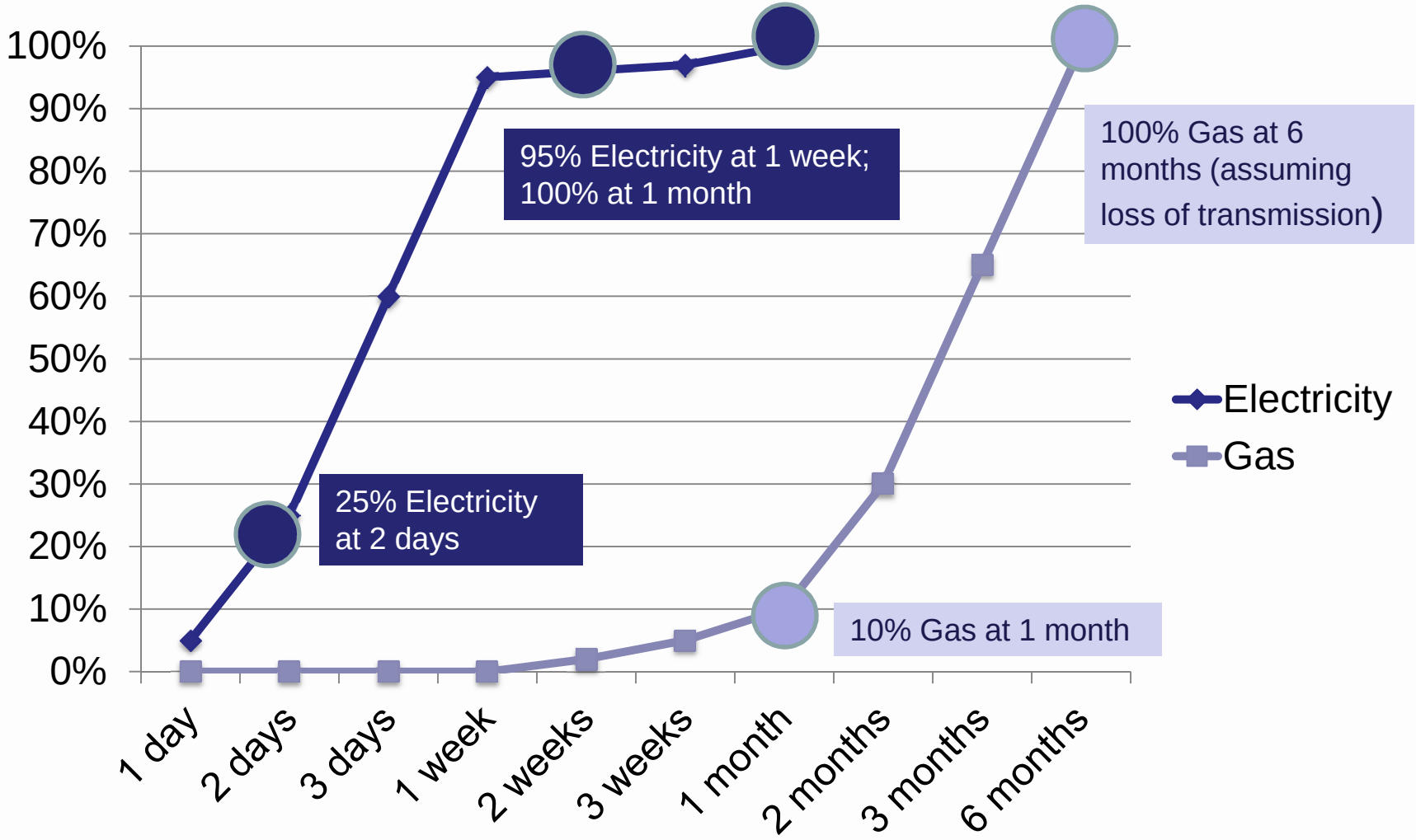
Data LDEO-Columbia, NSF, NOAA
Google earth

Electricity and Gas Restoration

(Progress Report ; April 2012)



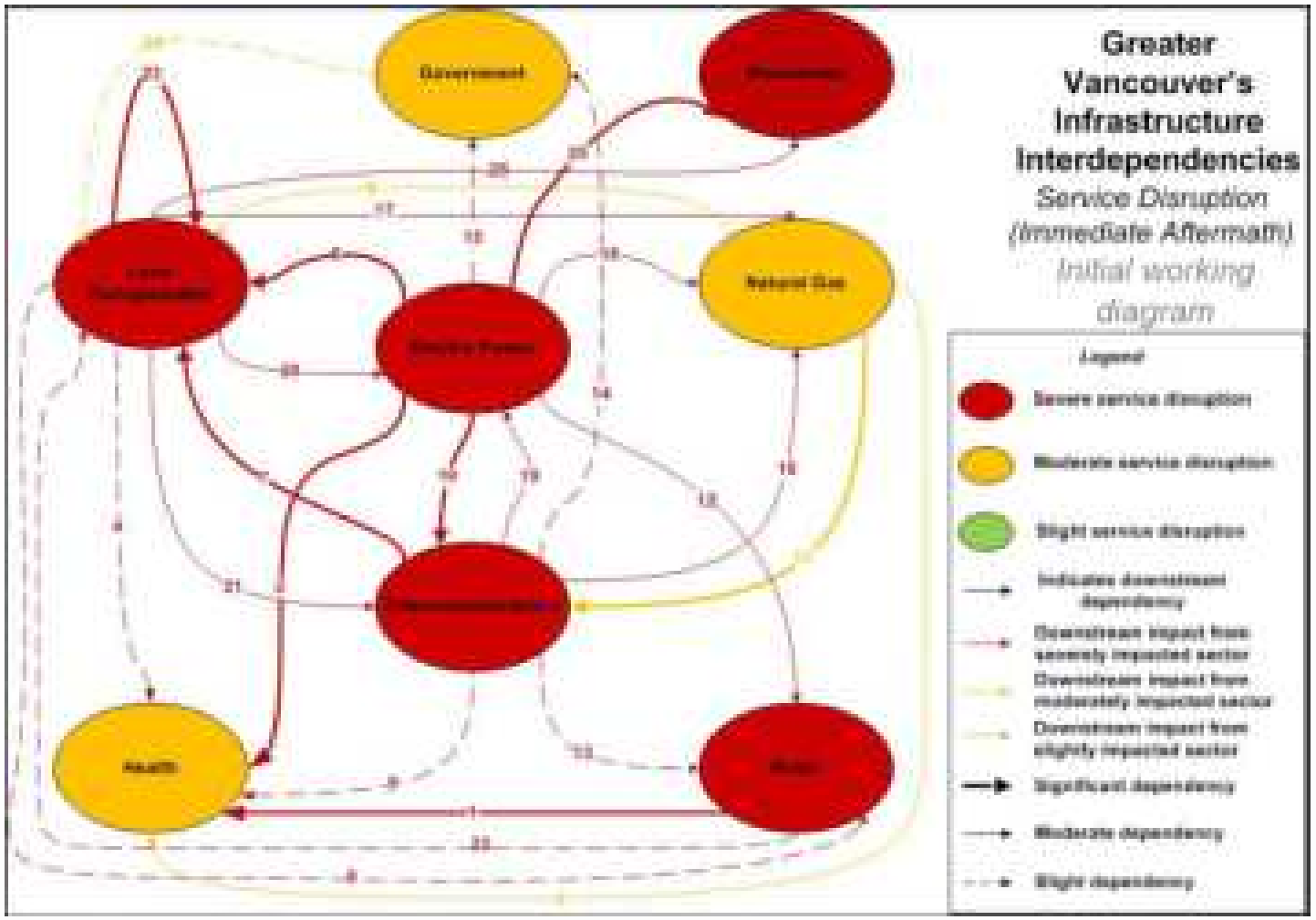
Issues/Needs
(Progress Report ; April 2012)

- Regional (multi-city, multi-operator) exercises:
  - Interdependency between different operators (Roads)
  - Mass evacuation (Roads)
  - Regional restoration policy discussions (Water)
  - Valve shut-off exercise (Water)
- Communications options/testing:
  - No radio and use CalEMA “cloud” (Roads)
  - Minus cell phones and internet (Water)
- Pre-planning of service requirements for essential facilities such as shelters (Electricity/Gas)

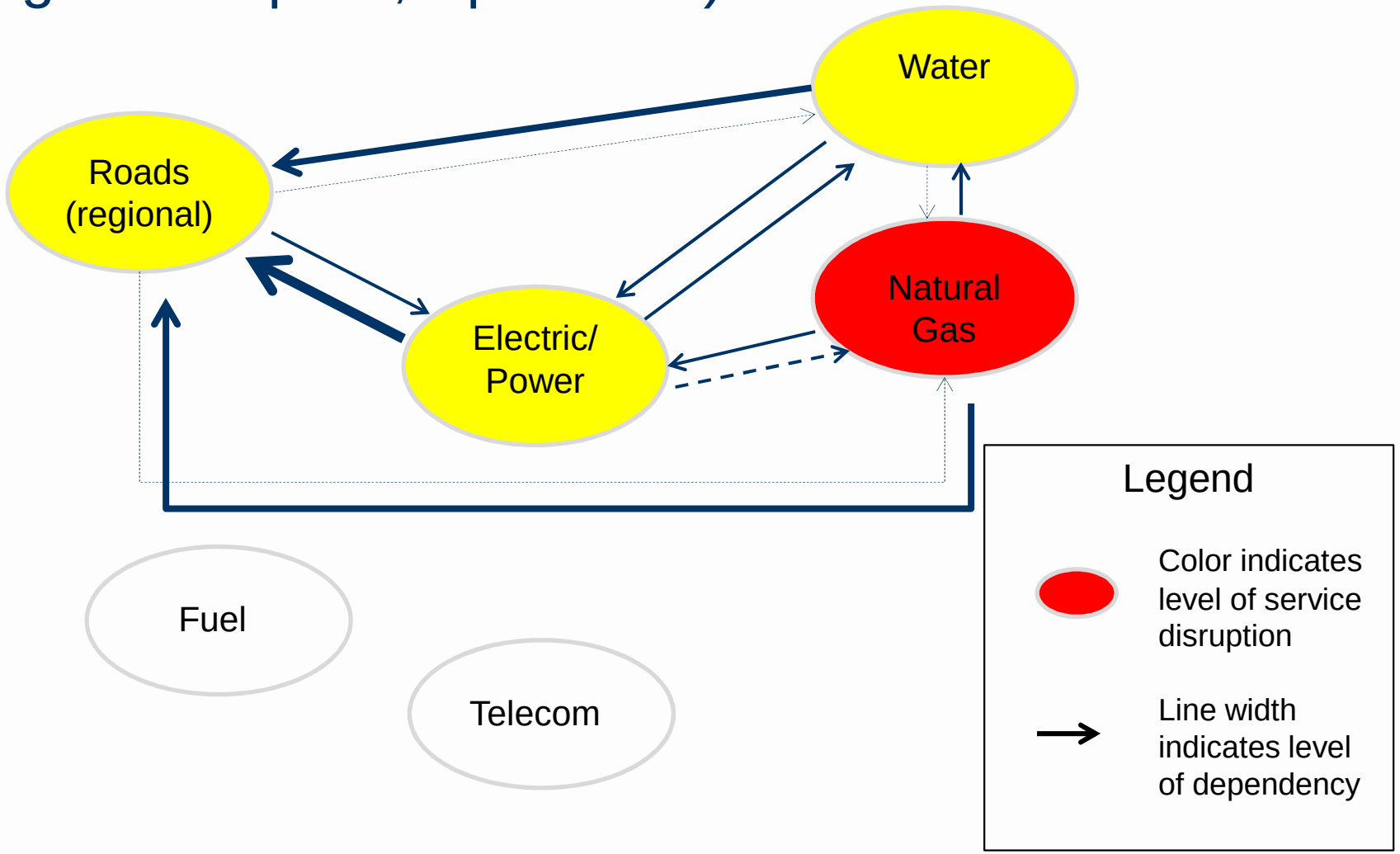
Issues/Needs
(Progress Report ; April 2012)

- Creation of new transmission routes that don't follow existing routes, such as an electric link between Embarcadero to Portrero substations (Electricity/Gas)
- Develop pre-designated lifelines routes for operators (Roads)
- Develop pre-disaster credentialing system for access that includes non-utility contractors/mutual aid providers (Electricity/Gas)
- Develop emergency medical service for lifelines restoration personnel (Electricity/Gas)
- Customer (resident, business) level scenarios of damage, restoration schemes and decision-making (Water)

Lifelines Interdependencies – Vancouver Study



Lifeline Interdependencies in San Francisco
(Progress Report ; April 2012)



Potential Interactions among San Francisco Lifelines (Progress Report ; April 2012)

(Yao et al 2005, based on Kameda, Nojima, 1992; Scawthorn 1993; and others)

- **Type A – Functional disaster propagation,** due to failure of interdependence among lifelines
  - Roads (regional) and electricity
- **Type B – Collocation interaction,** physical disaster propagation among lifeline systems
  - Underground water failures impacting underground electricity and gas
- **Type C – Substitute interaction,** influences on alternative systems
  - Electrical and gas
- **Type D – Restoration interaction**, various hindrances in the restoration stage
  - Underground water failures impacting underground electricity and gas
- **Type E – Cascade interaction,** increasing impacts on a lifeline due to initial inadequacies
  - Water impacting fire-fighting
- **Type F – General interaction**, between internal components of a lifeline system
  - Electrical substation failure, Water turnout failures

Details on Next Steps

- Infrastructure operator and panel discussions:
  - ✓ PG&E (electric and gas) (Nov 2011)
  - ✓ Caltrans (regional roads) (Nov 2011)
  - ✓ SFPUC (water) interdependency discussion (April 2012)
  - – SFPUC (wastewater) (May/June 2012)
  - – SFDPW (city roads and debris (include Recology)) (May/June 2012)
  - – BART and MUNI (June 2012)
  - – Telecommunications operators panel (July 2012)
  - – Port/airport operators (include WRDA) panel (July 2012)
  - – Fuel and refineries panel (August 2012)
- Develop integrated scenario and interdependency insights (September 2012)
- Operator review and approval (October 2012)