PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Coordinated Planning and Preparedness for Fire Following Major Earthquakes

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EXECUTIVE SUMMARY

This report documents activities of a project entitled “Coordinated Planning and Preparedness for Fire Following Major Earthquakes” which built on a previous project entitled “Water Supply in regard to Fire Following Earthquake”.

Voluntary Performance Guidelines for post-earthquake reliability of water supply for firefighting were developed so as to focus the attention of high-risk urban regionis on this problem while placing as little demand as possible on fire or other agencies. The Guidelines recommend that incorporated jurisdictions with population exceeding 100,000 and having significant seismic hazard develop quantitative estimates of the number and locations of fires that are likely to occur given the same pattern of earthquake shaking hazard as used in the California Building Code. The Guidelines also recommend that jurisdictions should also develop and maintain a written Plan for reducing, responding to and fighting such fires, with particular attention paid to supply of water from Normal and Alternative sources of firefighting water taking into account earthquake damage to such supplies.

Several interactions with the fire service were undertaken to highlight and disseminate the Guidelines – working with FIRESCOPE has proven most effective, and FIRESCOPE has taken this issue on as a task, with this project indicating its readiness to support FIRESCOPE in any way needed. A related issue is water supply reliability for California’s hospitals, which is currently of concern. The same PWSS technology that can enhance water supply for post-earthquake fires can also enhance water supply for hospitals following an earthquake. A meeting was held with representatives of the California Hospital Association to inform them of this project.

Fires following earthquake vis-à-vis carbon emissions were also examined. Carbon emissions are a significant factor in global warming, which is a concern for California. Fires in general produce almost 300 million metric tons of CO_2 per year. Major urban earthquakes in Southern California or the San Francisco Bay Area may result in CO_2 emissions approaching 4 million metric tons, or perhaps 15% of CO_2 production due to wildland fires in the same year.

In order to continue support and to foster actions to improve post-earthquake reliability of water supply for fighting fires and serving hospitals, a project is recommended involving the convening of four workshops in 2014, two each in northern and southern California, in which the fire and water services, and perhaps the health service, would participate. The goal of these workshops would be to reach consensus on the Guidelines, for their implementation by the fire and water services.

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1 Introduction

1.1 PURPOSE AND BACKGROUND OF THIS REPORT

This report documents activities of a project entitled “Coordinated Planning and Preparedness for Fire Following Major Earthquakes” which builds on a previous project entitled “Water Supply in regard to Fire Following Earthquake”.

The previous project was summarized in PEER report 2011/08, which provided background on fire following earthquake, and which found that this risk in California is very significant:

> Los Angeles Metropolitan Area: Given a Mw 7.8 on the San Andreas Fault was the focus of the ShakeOut Scenario, it is estimated that 1,600 ignitions and 2,700 pipeline repair locations (for the LADWP system only) will occur, versus about 2,000 fire engines in the entire affected area. Taking these factors into account, estimates of losses are about $40 billion (structure only).
>
> San Francisco Bay Area: The entire Bay Area has not been modeled for fire following earthquake, but approximate rules of thumb indicate that for a major earthquake on either the Hayward or San Andreas event, that as many as five hundred ignitions would occur, which will be initially fought by resources from approximately 280 fire stations. Hundreds to thousands of pipe breaks will quickly drain the distribution network, and also perhaps many hillside tanks, leaving hydrants dry.
>
> The situation in San Diego has not been examined, but undoubtedly has many parallels.
>
> Lastly, in all these locations there are many high-rise buildings. Experience in previous events as well as discussions with senior fire officers in Northern and Southern California indicate their anticipated response in an earthquake to high-rise fires will be attempt to assure safe evacuation, but not to commit to firefighting, given the other demands on their resources.

The previous project examined readiness for this risk, finding:

> Excepting a few special measures undertaken by a few fire departments discussed above, earthquake readiness in most urban California fire and water departments is much less than it could be. This is not to say nothing is being

done. Most major water utilities in California have completed or are in the midst of significant seismic improvement programs intended to assure reliable potable water following an earthquake (and some initial limited disruption). However, surveys of fire and water departments found that in most cases water utility seismic improvement programs focus on reservoirs, transmission lines, pump stations – that is, facilities other than the distribution network[1]. Distribution networks, which serve the hydrants firefighters rely on for water, are not typically addressed due to the immensity of the challenge (hundreds to thousands of miles of buried pipe) and the strategy of not trying to prevent any breaks but rather to quickly repair them. While this is justified from some perspectives, this means that immediately following the earthquake, breaks will result in many hydrants (especially in the more heavily damaged areas) being dry. That is, the agreement of most fire and water departments that they will lose firefighting water supply from the normal distribution system is justified**.**

Based on these findings, it was recommended that efforts should be made to (i) highlight the problem to the California Fire Service; (ii) enlist the Water Community; and (iii) develop state-wide guidelines. Additionally, a program of measures for the San Francisco and Los Angeles regions, and certain state-wide measures, was recommended:

San Francisco Bay Area: development of a regional Portable Water Supply System (PWSS) system should be explored, using standardized hose and equipment, that would be adopted by most fire departments in the Bay Area.

Los Angeles Region: development of a regional high pressure / PWSS system should be explored. Most of the high risk regions would be covered. While the cost of such a network would be in the many tens of millions of dollars, this is perhaps equivalent to several dozen houses, far less than the losses that would likely be prevented with such a system.

State-wide Urban Equipment Caches: Los Angeles, San Francisco and many other fire departments have trained thousands of disaster volunteers. However, these volunteers are currently only trained and equipped for light search and rescue and minimal fire extinguishment. It was suggested that a standardized equipment container cache be developed for California, that would equip trained neighborhood volunteers to assist firefighters in fighting conflagrations.

[1] See http://ebmud.com/sites/default/files/pdfs/sip_annual_2005.pdf for a good description of an excellent seismic improvement program that however does not mention the distribution network.

1.2 SCOPE OF WORK

The scope of work for this project consisted of:

1. Contact key fire and water agencies in Northern and Southern California, to identify key representatives.
2. Attend and present this issue at a meeting of the California Metro Fire Chiefs, in conjunction with the Seismic Safety Commission and CalEMA, with the goal of obtaining their concurrence and support for this issue.
3. Attend and present this issue at a meeting of the California chapter of the Association of Metropolitan Water Agencies, in conjunction with the Seismic Safety Commission and CalEMA, with the goal of obtaining their concurrence and support for this issue.
4. Form and support a fire-water agency joint task force for development of state-wide guidelines and implementation plan for post-earthquake firefighting water supplies, with the goal that water and fire agencies would develop and submit plans for measures intended to achieve these goals.
5. A project report documenting these activities, findings and Recommendations, including (as appropriate) draft guidelines, regulations and/or legislation.

Subsequently, an additional element was added, having to do with the estimated carbon cost of fire following earthquakes.

1.3 OUTLINE OF THE REPORT

The next section of this report discusses development of Voluntary Performance Guidelines and agency outreach activities of the project. Section 3 then presents an analysis of the carbon cost of fire following earthquake. Lastly, Section 4 summarizes our findings and presents recommendations for future work. References, a glossary and other materials conclude the report.

2 Agency Outreach

2.1 VOLUNTARY PERFORMANCE GUIDELINES

The initial step in the project was the development of draft Voluntary Performance Guidelines ("Guidelines"), as a basis for defining how to improve post-earthquake water supply reliability, and for what fire and water agencies could do in this regard. The approach taken for framing the Guidelines was similar to that taken by the Commission in the 1980s in addressing the unreinforced masonry (URM) building problem – that is, as framed in SB 547, develop a voluntary program and guidance which each California jurisdiction could follow in its own way. That approach worked well for addressing the URM problem.

Towards this objective, a set of Guidelines was drafted and discussed with several fire and water officials. Following several revisions, the Guidelines were presented to the Commission at its 14 March 2013 meeting, and comments received. The Guidelines were revised based on these comments, and are presented in Appendix A. In summary, the Guidelines consist of a Preamble, the Guidelines themselves, Definitions of terms, a Commentary to explain the reasoning and utilization of the Guidelines, and References. The Guidelines themselves are brief, and provide:

- That only incorporated Cities with population exceeding 100,000 and having significant seismic hazard need consider this problem;
- Such Cities should develop quantitative estimates of the number and locations of fires that are likely to occur given the same pattern of earthquake shaking hazard as used in the California Building Code;
- Such Cities should develop and maintain a written Plan for reducing, responding to and fighting such fires, with particular attention paid to supply of water from Normal and Alternative sources of firefighting water, taking into account earthquake damage to such supplies;
- The estimates and Plan should be published and presented to Mayors and other senior officials.

- The Plan may consider other mitigation actions, such as seismic shut-off switches or valves for energy sources

Commentary provides further detail and an example that illustrates how the number and location of fires following the scenario earthquake can be readily quantified using a table that is provided.

As indicated during the presentation to the Commission on 14 March, the Guidelines are drafted as voluntary guidelines, with the intent to focus the attention of a city's fire and water agencies on this issue. Again, the intent is to focus attention, not to mandate specific improvements or compliance. The specific degree to which the city seeks to mitigate this problem is that city's decision.

2.2 OUTREACH ACTIVITIES

Initial meetings were held with senior personnel of several larger fire departments, including San Francisco, Oakland, Berkeley, Los Angeles City and Los Angeles County departments. The purpose of these meetings was several-fold: to present findings of the previous project, to again confirm concurrence (and/or differences) with these findings vis-à-vis the specific department, and to ascertain the interest of the department in joining in regional cooperation as envisioned in the previous project's recommendations.

Overall, the results of these meetings were positive – departments recognized the need for improved water supply, and were interested in regional cooperation. However, in virtually all cases, department resources were stretched and active leads from the fire service for this activity could not be identified. While the problem was being highlighted to the fire service, department-by-department conversations were not leading to enlisting their active participation in a regional effort.

This status was presented to the Commission at its 14 March 2013 meeting (held at CSU, Monterey Bay). Commission member (and CalEMA Secretary) Mark Ghilarducci recommended the offices of the FIRESCOPE[2] Board of Directors as a channel for communicating with the California fire service.

The outcome of this was a presentation (see Appendix B) to the FIRESCOPE Board of Directors at the Burbank Fire Training Center on 10 April 2013, Figure 1. The presentation was facilitated by Cal EMA State Fire and Rescue Chief Kim Zagaris. The purpose of the presentation was to present the FIRESCOPE Board with the draft Voluntary Performance Guidelines and to ask their support (support = considering, modifying as needed, adopting and

[2] Under Health and Safety Code Section 13070, the Office of Emergency Services (OES), California Department of Forestry and Fire Protection (Cal Fire) and the State Fire Marshal (SFM) jointly administer the FIRESCOPE (**FI**refighting **RES**ources of **C**alifornia **O**rganized for **P**otential **E**mergencies) Program, which represents all facets of local, rural, and metropolitan fire departments, in order to unify these various fire agencies together into one voice and direction. See http://www.firescope.org/ for more information.

promoting the Guidelines) with FIRESCOPE members, particularly the larger urban fire agencies. The presentation was well received and was followed by a good discussion and Recommendation to support the Guidelines. Subsequent discussions with Chief Zagaris confirm that FIRESCOPE has taken this on as a task, and this project has indicated its readiness to support FIRESCOPE in any way needed.

Figure 1 FIRESCOPE Board of Directors Meeting 10 April 2013.

2.3 HEALTH PROVIDERS

A new dimension was added to the project with a meeting with representatives of the California Hospital Association on 29 April, arranged by Director McCarthy. CHA's members represent a large segment of California hospitals and are concerned that they don't have an adequate and reliable post-earthquake supply of potable water. The project's concept of a state-wide standardized Portable Water Supply System (PWSS) was presented, and the CHA representatives indicated their understanding of its ability to play a key role in improving this situation. The project indicated its readiness to support this concept in any way needed.

2.4 SUMMARY

Voluntary Performance Guidelines were drafted and improved based on several rounds of discussions with fire service officials and comments from the Commission. The Guidelines are framed as voluntary and so as to focus high-risk city's attention on this problem while placing as little demand as possible on fire or other agencies. Several approaches were made to the fire service to highlight this issue and build a critical mass. The most positive approach has been in working with FIRESCOPE, which has taken this on as a task, and this project has indicated its readiness to support FIRESCOPE in any way needed. A related issue is water supply reliability for California's hospitals, which is currently of concern. The same PWSS technology that can enhance water supply for post-earthquake fires can also enhance water supply for hospitals following an earthquake. A meeting was held with representatives of the California Hospital Association to inform them of this project.

3 Carbon Cost of Fire Following Earthquake

3.1 WHAT IS CARBON COST AND WHY IS IT IMPORTANT?

Carbon cost is defined as the total amount of greenhouse gases produced as the result of an activity. Carbon 'footprint' is synonymous with carbon cost and is often used when referring to the greenhouse gases produced by human activities. Carbon cost is usually expressed in terms of equivalent tons of carbon dioxide (CO_2) – at atmospheric pressure and room temperature, a metric ton of CO_2 occupies about 556 m^3 or 19,634 cu. ft (i.e., a cube about 27 ft. on a side).

"Produced" includes direct as well as indirect production. When you drive a car, the engine burns fuel which creates a certain amount CO_2, depending on its fuel consumption and the driving distance – for example, the rate of CO_2 produced per gallon of gasoline burned is 19.2 lbs. However, the total carbon cost for this activity is not only the direct production of CO_2 produced by fuel consumption, but also the indirect costs – that is, the prorated fraction of the CO_2 produced in drilling, refining and transporting the fuel, the prorated fraction of CO_2 produced in producing, manufacturing and transporting the tires, the engine, the car chassis etc[3].

Why is carbon cost important? As summarized in Global Climate Change Impacts in the United States:

> Observations show that warming of the climate is unequivocal. The global warming observed over the past 50 years is due primarily to human-induced emissions of heat-trapping gases. These emissions come mainly from the burning of fossil fuels (coal, oil, and gas), with important contributions from the clearing of forests, agricultural practices, and other activities… Reducing emissions of carbon dioxide would lessen warming over this century and beyond… Climate-related changes have already been observed globally and in the United States. These include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice…. (Karl, Melillo, & Peterson, 2009)

In other words, heat-entrapping gases ('greenhouse gases', or GHG), of which CO_2 is the most important, are causing global warming, which is leading to climate change. If we could easily

[3] Clearly, these indirect costs should be included only if they are not accounted for under their own activities.

adapt to climate change it wouldn't be a problem, but our cities, croplands and other fixed investments are not easily adaptable, so climate change is a big problem. While burning of fossil fuels is the number one source of greenhouse gases, burning of biomass is a significant source, so that the question arises of *how significant a source of CO_2 are fires following earthquake*?

3.2 METHODS FOR ESTIMATING CARBON COST OF CONFLAGRATIONS

Until recently "…there was no published literature quantifying the impact of green house gas emissions from house fires…." (Robbins, Page, & Jaques, 2010), and only a few investigators (Blomqvist & McNamee, 2009; Robbins et al., 2010) have addressed the problem to date, while none have addressed the larger issue of conflagrations.

The general equation for emissions estimation is (Seiler & Crutzen, 1980; US EPA, 2009; Wiedinmyer et al., 2006)

$$E = A \text{ x } EF \text{ x } (1\text{-}ER/100) \qquad (1)$$

where:

E = emissions;
A = activity rate;
EF = emission factor, and
ER = overall emission reduction efficiency, %

This general equation has been expanded by (Robbins et al., 2010), see Table 1 to Table 3, and (Blomqvist & McNamee, 2009) to estimation of GHG emissions from house fires, for New Zealand and the Nordic countries, respectively, to examine annual emissions due to dwelling fires.

The New Zealand study involves housing with 'sheet steel' roofing, which differs from most California housing, but is otherwise relatively similar. An average value of GHG emissions from that study is approximately 190 kg CO_2 per sq. meter of building, due to burning of the building and interior (including furnishings) materials.

The Nordic study found an average of approximately 218 kg CO_2 per sq. meter of building, due to burning of the building and interior (including furnishings) materials. The larger value for the Nordic study is likely due to heavier and wooden roofing materials in the Nordic countries versus New Zealand. The Nordic study also examined schools, finding an average of about 156 kg CO_2 per sq. meter of school building, and cars, finding an average of about 378 kg CO_2 per vehicle.

3.3 CARBON COST OF FIRE FOLLOWING EARTHQUAKE

A detailed analysis of conflagration losses using Equation 1 as elaborated for example in Table 1 to Table 3 is beyond the scope of the present project, although it would be more accurate and informative than use of average values. Using average values dwellings of 218 kg CO_2 per sq.

meter of wood framed [e.g., Type 5 per (IBC, 2006)] building, 156 kg CO_2 per sq. meter of Types 1~4 ("non-combustible) building, and 378 kg CO_2 per vehicle, per (Blomqvist & McNamee, 2009), we can estimate losses due to fire following earthquake.

Taking the Shakeout scenario of a hypothetical M7.8 earthquake occurring at 10am on 13 November 2008 on the Southern segment of the San Andreas Fault, (Scawthorn, 2011) found a mean loss of approximately 200 million sq. ft. of residential and commercial building floor area. Applying the above rates for CO_2 generation by source, we find that building fires will generate about 3.7 million metric tons of CO_2:

Building Type	sq ft	sq m / sq ft	%	kg/sq m	metric tons
Type 5	200,000,000	0.093	75%	218	3,037,929
Type 1~4	200,000,000	0.093	25%	156	724,644
				Total	**3,762,573**

Estimation of CO_2 generation due to vehicle fires is more problematic as, on the one hand, people will probably use vehicles to escape the fires while, on the other hand, resulting traffic jams may cause numerous vehicles to be abandoned. Given 200 million sq. ft. of building loss, perhaps 100,000 vehicles may be at risk. If 50% of these are consumed by fire, the total additional CO_2 production is about 19,000 tons, or only 0.5% of the CO_2 produced due to building fires.

As noted in the previous project, a study comparable to the Shakeout study is not available for other major California urban regions. Simply pro-rating the Shakeout losses by population for the San Francisco Bay Area or San Diego regions neglects the higher ground motions likely to occur due to closer faults in the former, and the relatively lower seismicity of the latter. As a simple approximation, a major earthquake in the San Francisco Bay Area may produce fire following earthquake losses comparable to the Shakeout study, while estimation for the San Diego region is more problematic.

Table 1 **House fire GHG emissions framework algorithms excerpted from (Robbins et al., 2010), where input variables are listed in Table 2 and output variables in Table 3.**

Name	Calculation Method
GHG emissions from total loss of the structure of an exemplar house	$E_{exe\_struct,i} = \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \left(m_{i,j} p_{100\%,j} Y_{gas,j} G_{gas}\right)$ $[\text{kg}_{CO2}]$
GHG emissions from total loss of the contents of an exemplar house	$E_{exe\_cont} = \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \left(n_k m_k p_{100\%,k} Y_{gas,k} G_{gas}\right)$ $[\text{kg}_{CO2}]$
GHG emissions released by house fires	$E_{house,total} = \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\frac{1}{H_{all,t}} \left(\frac{F_t \sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fires} Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + F_t \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%lost,k} A_{\%lost} p_{A\%lost,fires} Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{household}/\text{year}]$ $= \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\left(\frac{\sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fires} Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%lost,k} A_{\%lost} p_{A\%lost,fires} Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{fire}/\text{year}]$ $= \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\left(\frac{F_t \sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fires} Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + F_t \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%lost,k} A_{\%lost} p_{A\%lost,fires} Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{year}]$
GHG emissions saved from being released by house fires where home sprinkler systems are effective	$S_{sprink,total} = \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\frac{1}{H_{all,t}} \left(\frac{F_t \sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fire} \left(\eta_{sprink} + p_{fire,\text{NZS 4517}} - 1\right) Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + F_t \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%,k} A_{\%lost,fires} p_{A\%lost,fires} \left(\eta_{sprink} + p_{fire,\text{NZS 4515}} - 1\right) Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{household}/\text{year}$ $= \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\left(\frac{\sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fire} \left(\eta_{sprink} + p_{fire,\text{NZS 4517}} - 1\right) Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%,k} A_{\%lost,fires} p_{A\%lost,fires} \left(\eta_{sprink} + p_{fire,\text{NZS 4515}} - 1\right) Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{fire}/\text{year}]$ $S_{sprink,total} = \frac{1}{Y_{analysis}} \sum_{t=1}^{Y_{analysis}} \left(\left(\frac{F_t \sum_{type=A}^{F} \left(H_{type,t} \sum_{j=1}^{j_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(m_{type,j} p_{A\%lost,j} p_{A\%lost,fire} \left(\eta_{sprink} + p_{fire,\text{NZS 4517}} - 1\right) Y_{gas,j} G_{gas} \right) \right)}{H_{all,t}} + F_t \sum_{k=1}^{k_{max}} \sum_{gas=1}^{gas_{max}} \sum_{A\%lost=0}^{100\%} \left(n_k m_k p_{100\%,k} A_{\%lost,fires} p_{A\%lost,fires} \left(\eta_{sprink} + p_{fire,\text{NZS 4515}} - 1\right) Y_{gas,k} G_{gas} \right) \right) \right)$ $[\text{kg}_{CO2}/\text{year}]$

Table 2 **List of house fire GHG emissions framework input parameters excerpted from (Robbins et al., 2010).**

Name	Symbol	Brief Description
Initial number of house structure fires per year	F_0	The current number of house fires per year. The number of house fires each year is assumed to be proportional to the number of houses, $F_t = \frac{H_{t,all}}{H_{0,all}} F_0$
Floorarea of house lost to fire	$A_{\% lost}$	The percentage of floorarea lost to fire of the exemplar house.
Current number of households	$H_{0,all}$	The current number of houses. The number of houses is assumed to increase at a uniform rate, $H_t = H_{0,all}\, tr_{house}$
Increase in households per year	r_{house}	An estimate of the average percentage increase of the number of house per year over the chosen analysis period.
Discount rate	$r_{discount}$	Estimated discount rate. Similar as typically used for money. A value is not included in this study, but this parameter is included in the framework, so that if at a effective value is recommended for the use of CO_2 Equivalent then it can be utilised within this framework.
Inflation rate	$r_{inflation}$	Estimated inflation rate. Similar as typically used for money. A value is not included in this study, but this parameter is included in the framework, so that if at an effective value is recommended for the use of CO_2 Equivalent then it can be utilised within this framework.
Analysis period	$Y_{analysis}$	Number of years considered for this analysis.
Global Warming Potential of Species	G_{gas}	The Global Warming Potential of the gas (gas), as listed in Table 2.
Species yield	$Y_{gas,x}$	Mass yield of a gas species (gas, e.g. CO_2, etc.) per unit of mass of fuel for each material or item (x).
Mass of house structural component	$m_{i,j}$	Estimated mass of each structural component (j) for each combination (i) of foundation, wall and roof cladding exemplar house. The structural components are listed in Table 12 and Table 13.
Number of house contents item	n_k	Estimated number of each item of house contents (k) in the exemplar house. The estimated numbers of items of house contents are listed in Table 15.
Mass of house contents item	m_k	Estimated mass of each contents item (k) for the exemplar house. The items of house contents and the associated estimated mass distribution are listed in Table 26.
Proportion of material burnt	$p_{A\% lost,x}$	Estimated proportion of each material, proxy material, item or proxy item (x) burnt for a particular amount of house floorarea burnt ($A_{\%, lost}$).
Proportion of fires with specific proportion of floorarea burnt	$p_{A\% lost,fires}$	Estimated proportion of fires with a particular amount of house floor area burnt ($A_{\%, lost}$).
Maximum number of gas species	gas_{max}	The maximum number for the counter used for the gas species (gas).
Maximum number of materials considered	j_{max}	The maximum number for the counter used for the materials, proxy materials, items or proxy items for structural components (j).
Maximum number of items considered	k_{max}	The maximum number for the counter used for the materials, proxy materials, items or proxy items for structural components (k).

Table 3 **List of house fire GHG emissions framework output parameters excerpted from (Robbins et al., 2010).**

Name	Symbol	Brief Description
GHG emissions from total loss of the structure of an exemplar house	$E_{exe\_struct,i}$	CO_2 Equivalent release for the total loss of the structure of the exemplar house for each combination (i) of foundation, wall and roof cladding.
GHG emissions from total loss of the contents of an exemplar house	E_{exe_cont}	CO_2 Equivalent release for the total loss of the contents of the exemplar house.
GHG emissions released by house fires	$E_{house,total}$	CO_2 Equivalent release due to house fires. The results are presented in terms of three units: 1. Equivalent CO_2 per household per year 2. Equivalent CO_2 per fire per year 3. Equivalent CO_2 per year
GHG emissions saved from being released by house fires where home sprinkler systems are effective	S_{sprink}	CO_2 Equivalent saved from being released due to house fires by an effective home sprinkler system. The results are presented in terms of three units: 1. CO_2 Equivalent per household per year 2. CO_2 Equivalent per fire per year 3. CO_2 Equivalent per year

3.4 FIRE FOLLOWING EARTHQUAKE VERSUS OTHER CARBON FOOTPRINTS

Comparison of the above CO_2 production with other sources requires comparable temporal frameworks – that is, normalization to an annual CO_2 production. Many CO_2 sources such as electricity production or vehicles are chronic and occur constantly whereas earthquakes are rare events. As a simple approximation, if we take the total CO_2 production from a large Southern California earthquake to be about 3.7 million metric tons, and assume the same for a large San Francisco Bay Area event, and assume both are likely to occur sometime in the next 100 years (most estimates are that these events are more likely than that), then we have an annualized CO_2 production due to fire following California earthquakes of about 74,000 metric tons of CO_2. Given the uncertainty associated with the probability of these two earthquakes, this estimate may more reasonably be expressed as in the range of perhaps 50,000 to 100,000 metric tons of CO_2 per year.

Emissions of CO_2 due to US fires has been examined by (Wiedinmyer & Neff, 2007), who find:

> Average annual CO_2 emissions from fires in the lower 48 states from 2002–2006 are estimated to be 213 (± 50 std. dev.) million metric tons CO_2 yr-1 and 80 (± 89 std. dev.) million metric tons CO2 yr-1 in Alaska.

and

> Annually, for the continental US (not including Washington D.C.), the average CO_2 emissions from all fossil fuel burning (FFB) sources from 2000 – 2003 were 5,738 million metric tons CO2 [31]. Annual average CO2 emissions for 2002 – 2006 from fires in the continental US was 293 million

metric tons CO_2, corresponding to the equivalent of 5.1% of the annual FFB emissions from 2000–2003 (and 5.4% of the average from 1990–2003). Depending on the year, emissions from fires for the entire Continental US were equivalent to as little as 4% of the FFB emissions, and as much as 6%. However, this is for the entire U.S; on a state-level, the importance of fire emissions of CO_2 relative to FFB emissions is much different. There are eight states (Alaska, Idaho, Oregon, Montana, Washington, Arkansas, Mississippi, and Arizona) where the annually-averaged (2002– 2006) fire emissions are equal to more than 10% of the state-level FFB CO_2 emissions, and eleven other states whose fire emissions equal more than 5% of the state level CO2 emissions.

In essence, all fires (almost entirely wildland fires) produce about 293 million metric tons of CO_2 annually, corresponding to a small fraction (4–6%) of anthropogenic (vehicles, electric generation, etc) emissions at the national level. For California, wildland fire CO_2 production is approximately 25 million metric tons per year, corresponding to 5~10% of anthropogenic sources.

Fire following earthquake causes in the range of perhaps 50,000 to 100,000 metric tons of CO_2 per year, which is perhaps 1% of wildland fire CO_2 production in the year a major earthquake occurs, and 1% of 1% of wildland CO_2 production on an annualized basis, for the nation. Considering only California, a major earthquake may produce CO_2 emissions corresponding to 15% of that year's wildland CO_2 emissions.

3.5 SUMMARY

Carbon emissions are a significant factor in global warming, which is a significant concern for California. Fires in general produce almost 300 million metric tons of CO_2 per year. Major urban earthquakes in Southern California or the San Francisco Bay Area may result in CO_2 emissions approaching 4 million metric tons, or perhaps 15% of CO_2 production due to wildland fires in the same year.

4 Summary and Recommendations

4.1 SUMMARY

This report documents activities of a project entitled "Coordinated Planning and Preparedness for Fire Following Major Earthquakes" which built on a previous project entitled "Water Supply in regard to Fire Following Earthquake".

Voluntary Performance Guidelines were drafted and improved based on several rounds of discussions with fire service officials and comments from the Commission. The Guidelines are framed as voluntary and so as to focus high-risk city's attention on this problem while placing as little demand as possible on fire or other agencies. The Guidelines provide:

- That only incorporated Cities with population exceeding 100,000 and having significant seismic hazard need consider this problem;
- Such Cities should develop quantitative estimates of the number and locations of fires that are likely to occur given the same pattern of earthquake shaking hazard as used in the California Building Code;
- Such Cities should develop and maintain a written Plan for reducing, responding to and fighting such fires, with particular attention paid to supply of water from Normal and Alternative sources of firefighting water, taking into account earthquake damage to such supplies;
- The estimates and Plan should be published and presented to Mayors and other senior officials;
- The Plan may consider other mitigation actions, such as seismic shut-off switches or valves for energy sources.

Several approaches were made to the fire service to highlight this issue and build a critical mass. The most positive approach has been in working with FIRESCOPE, which has taken this on as a task, and this project has indicated its readiness to support FIRESCOPE in any way needed. A related issue is water supply reliability for California's hospitals, which is currently of concern. The same PWSS technology that can enhance water supply for post-earthquake fires can also enhance water supply for hospitals following an earthquake. A meeting was held with representatives of the California Hospital Association to inform them of this project.

Fires following earthquake vis-à-vis carbon emissions were examined. Carbon emissions are a significant factor in global warming, which is a concern for California. Fires in general produce almost 300 million metric tons of CO_2 per year. Major urban earthquakes in Southern California or the San Francisco Bay Area may result in CO_2 emissions approaching 4 million metric tons, or perhaps 15% of CO_2 production due to wildland fires in the same year.

Recommendations for Future Work

In order to support FIRESCOPE in its consideration of the Voluntary Performance Guidelines, and to foster in general actions to improve post-earthquake reliability of water supply for fighting fires and also for serving hospitals, continued discussion supported by technical analysis will be needed. A productive scenario for such discussions would be several workshops in northern and southern California, co-sponsored by the Commission, CalEMA, FIRESCOPE and PEER, which would bring together first the fire service, and then the water service, for the purpose of considering the Guidelines. Comparable workshops could also be held with the health and water services. These discussions will raise technical questions, for which PEER can serve as a resource, perhaps with working groups from the fire and water services. We therefore recommend a project consisting of:

- Two workshops to be held in the second quarter of 2014, one each in northern and southern California, to be attended by representatives of fire agencies in these two regions, for presentation and consideration of the Guidelines, with emphasis on fire aspects.
- Two subsequent to be held in the third quarter of 2014, one each in northern and southern California, to be attended by representatives of the fire and water agencies in these two regions, for presentation and consideration of the Guidelines, with emphasis on water aspects. An option to be considered would be to also invite representatives of the health service to attend.

The goal of these workshops would be reach consensus on the Guidelines, for their implementation by the fire and water services.

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GLOSSARY

ASCE	American Society of Civil Engineers
Cal Fire	California Department of Forestry and Fire Protection
CalEMA	California Emergency Management Agency (formerly Governor's Office of Emergency Services)
FEMA	[United States] Federal Emergency Management Agency
FFE	Fire following earthquake
GHG	Greenhouse gases
HAZUS	A multi-hazard loss-estimation methodology and software package developed by FEMA
M_w	moment magnitude scale for earthquakes
NSHMP	National Seismic Hazard Mapping Project
OES	see CalEMA
PEER	Pacific Earthquake Engineer Research Center (see http://peer.berkeley.edu)
PWSS	Portable Water Supply System (ISO methodology)
USGS	United States Geological Survey

APPENDIX A: Voluntary Performance Guidelines for Post-Earthquake Firefighting Water Supply

Preamble

California is earthquake-prone and its cities consist predominantly of wood frame buildings, so that the risk of fire following earthquake in urban areas is very high. In order to reduce that risk, the Seismic Safety Commission and the California Emergency Management Agency are working to improve the availability of water for fires following major earthquakes in California. A first step towards reducing this risk are voluntary performance guidelines for assured post-earthquake firefighting water supply.

Voluntary Performance Guidelines

Incorporated cities in California with a population exceeding 100,000 and having at least a portion of their jurisdiction subject to a Maximum Considered Earthquake (MCE, as defined below) may seek to meet the following Guidelines:

1. By XX[4] and updated each five years thereafter:
   a. Develop a quantitative estimate of the median and 90th percentile upper bound number and locations of fires that are likely to occur given the pattern of earthquake shaking hazard as, as shown in Figure A -1. The estimates should consider variability in time of day, season, occupancy and other key factors.
   b. Develop and maintain a written plan for reducing, responding to and fighting such fires, to be termed the Fire Following Earthquake Water Supply Plan (the "Plan"). The Plan should consider:
      i. Variability in wind, humidity, access and other relevant factors.
      ii. Supply of water from Normal and Alternative sources of firefighting water. Estimation of water quantity and pressure from such sources should take into account earthquake damage and their resulting reliability. Sources of water should only be considered available when

[4] XX = a date to be determined

the ability to transport the water from the source to the likely fire location in adequate volume and pressure has been demonstrated.

iii. Non-firefighting demands on the Department's resources, such as EMS and USAR.

iv. Assistance by Automatic and Mutual Aid only after HH[5] hours following the MCE event.

c. Based on the Plan, publish and present to the Mayor, City Manager, City Council and other senior officials, a quantitative estimate of the median and 90th percentile upper bound number and zipcode location of buildings and property likely to be damaged and/or destroyed due to the fires determined in 1a., taking into account the mitigation due to the Plan in 1b. In addition to water supply needs, the Plan may consider other mitigation actions, such as seismic shut-off switches or valves for energy sources.

2. Exercise the Plan at least one time per year.

[5] On a preliminary basis, 12 hours is recommended for HH hours

Guidelines Definitions

Maximum Considered Earthquake (MCE)	the pattern of peak ground acceleration of 0.50g or greater with associated probability of 2% in 50 years, as shown on the most recent National Seismic Hazard Maps prepared by the U.S. Geological Survey
Fires	Fires refer to the ignitions likely to occur following an MCE earthquake, and the subsequent fire spread given buildings and other combustibles.
Normal Water Supply	Refers to water supply normally used by firefighters under non-earthquake conditions, such as hydrants supplied from underground potable water mains.
Alternative Water Supply	Refers to sources of water not typically used by firefighters for water supply, but which can be used in an emergency when Normal water supply sources fail. Examples include swimming pools, ponds and lakes, streams and rivers, the ocean, water reservoirs and industrial water tanks.
EMS	Emergency Medical Service
USAR	Urban Search and Rescue
Median	50^{th} percentile confidence level
Upper bound	90^{th} percentile confidence level
X percentile (%) confidence level	That number of occurrences that are likely not to be exceeded with X% probability under the stated conditions.

Guidelines Commentary

Nature of the Guidelines: The Guidelines do not arbitrarily specify a maximum permitted level of fire loss given an earthquake, but rather allow local governments to individually determine their acceptable risk of loss due to fire following earthquake. It is anticipated this will be facilitated by having:

- a clear estimate of the fires that are likely to occur following a major earthquake,
- a Plan for suppressing those fires,
- the public understand the likely fire losses (given the actions assumed to occur in the Plan)
- the Plan exercised annually, and it and the loss estimates updated every five years.

It is anticipated that, if the losses due to fire following earthquake are known to the public, a public debate will occur as to their acceptability. The outcome of that debate will either be acceptance of the risk, or implementation of mitigation measures to reduce the fire following earthquake risk to an acceptable level.

Currently, most cities lack an estimate of their potential losses due to fire following earthquake, and only have general plans lacking a quantitative basis for dealing with fires following a major earthquake.

> Size of Cities: Only cities with populations more than 100,000 are recommended to meet the Guidelines. Smaller cities are less likely to have an overwhelming number of fires.
>
> Maximum Considered Earthquake (MCE): The Guidelines are drafted to only apply to the highly seismic part of California – that is, only to cities where some portion of the city's earthquake shaking exceeds a specific value.

The specific value is expressed technically in terms of peak ground acceleration (PGA), since this is the parameter employed in the California Building Code. **For non-technical persons, the proposed value (PGA = 0.5g) is approximately equivalent to shaking intensity 9 (MMI IX).**

The pattern of ground motions has been selected so as to represent a large but possible earthquake that would affect a city. These are the same ground motions that are used in design of buildings. Cities with smaller ground motions will probably have fewer ignitions and be able to cope, and are more likely to receive mutual aid more quickly.

It should be noted that the Guidelines define the event in terms of a probabilistic pattern of shaking, rather than a specific event. For fire following earthquake analysis, use of one or more deterministic scenario events would be technically preferred. However, the size of most incorporated cities in California is typically such that the difference between the probabilistic pattern of Maximum Considered Earthquake Ground Motions, and the pattern of ground motions for an individual earthquake that would closely replicate those probabilistic ground motions, is negligible.

Estimation of Fires: Table A – 1 provides a quick reference for estimating the number of ignitions as a function of population and MCE ground motions. Taking The City of Berkeley as an example (population 114,000), from Figure A – 3 we see that the City is likely to be subjected to about 1g PGA so from Table A – 1 we see that Berkeley will on average have about 14 ignitions (1.14*12= 13.7), which is a significant challenge for that jurisdictions' Fire Department (7 fire stations and 7 fire engines plus 3 reserve engines).

Table A – 1 is only a quick reference and the analysis should consider variability due to wind, humidity, season, time of the earthquake and other factors. In this regard (TCLEE, 2005) is a useful resource. The analysis should actually be performed at a smaller resolution (e.g., zipcode) taking into account the variation of ground motions as a function of soil conditions and other factors. For larger cities, such as Los Angeles, a more detailed analysis is particularly important.

It is not sufficient to estimate the average (mean) number of ignitions – an upper bound (90^{th} percentile) as well as their location and subsequent fire growth should also be estimated, in order to arrive at an estimate of the mean and upper bound quantities of firefighting water and other resources that will be required. In this regard (TCLEE, 2005) is a useful resource.

Sources of Water: In every large earthquake, underground water mains typically sustain a significant number of breaks, due to the earthquake shaking and, even more so, the failure of the ground in soft soil areas, due to liquefaction, land sliding and other forms of permanent ground failure. The estimation of the residual capacity of the Normal water supply system given these breaks is a complex matter, which the local water agency is best qualified to do. In some jurisdictions, local water agencies have been aware of and responding to this problem (for example, the East Bay Municipal Utility District, EMBUD, which serves Berkeley and other communities, has had a major seismic retrofit program). Nevertheless, the potential for all breaks, particularly in the distribution system, cannot be eliminated, and it should be expected that portions of the Normal water supply will not provide the required firefighting water following the earthquake. Again, which portions will fail and what their impact will be on the remaining capacity is best estimated by the water agency.

Fire departments understand that Normal water supplies may sometimes fail, so that they make contingency plans for Alternative water supplies. The Guidelines envision that both the Normal and the Alternative water supply sources be reviewed, regarding their ability to reliably provide adequate supplies of firefighting water.

However, even if they are adequate to the demands, it is not sufficient to simply identify supplies of water. The Guidelines envision that the Plan be developed which identifies

- where the likely locations of fires will be, and their growth,
- as each fire grows, from where the required firefighting water will be supplied, and
- how the water will be transported from the source to the fire

The latter aspect is crucial. Under non-earthquake conditions, the typical contingency plan for transporting firefighting water from the source to the fire is a 'relay' system, in which the water is pumped through hose. Because of friction in the hose, the water pressure drops and has to be boosted by 'relay' pumpers placed along the hose line, for example at about 1,000 ft. spacing. To move a significant quantity of firefighting water a mile therefore requires perhaps six fire engines, which may all or most of the engines in a jurisdiction – for one fire! If there are several fires, there won't be enough fire engines, and other means have to be found. The Guidelines call for a Plan to identify what these means are, and annual practicing of such means.

Lastly, water supply is one element, albeit a crucial element, of the overall fire following earthquake problem. At each City's option, other aspects of the fire following earthquake problem such as reducing ignitions via seismic shut-off switches or valves on energy sources, may also form part of the Plan.

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Table A - 1 Average number of Ignitions as a function of PGA and Population (source SPA Risk, 2009).

	Peak Ground Acceleration (g)								
Populaton	0.5	0.6	0.7	0.8	0.9	1	1.2	1.4	1.6
100,000	3	4	6	7	10	12	17	24	31
200,000	6	8	11	15	19	24	34	47	62
300,000	8	12	17	22	29	36	52	71	93
400,000	11	16	23	30	38	47	69	94	124
500,000	14	21	28	37	48	59	86	118	155
600,000	17	25	34	45	57	71	103	141	185
700,000	20	29	40	52	67	83	120	165	216
800,000	22	33	45	60	76	95	138	188	247
900,000	25	37	51	67	86	107	155	212	278
1,000,000	28	41	57	75	95	118	172	236	309
1,500,000	42	62	85	112	143	178	258	353	464
2,000,000	56	82	113	150	191	237	344	471	618
2,500,000	70	103	142	187	238	296	430	589	773
3,000,000	84	123	170	224	286	355	516	707	927
3,500,000	98	144	198	262	334	414	602	824	1,082
4,000,000	112	164	227	299	381	474	688	942	1,236

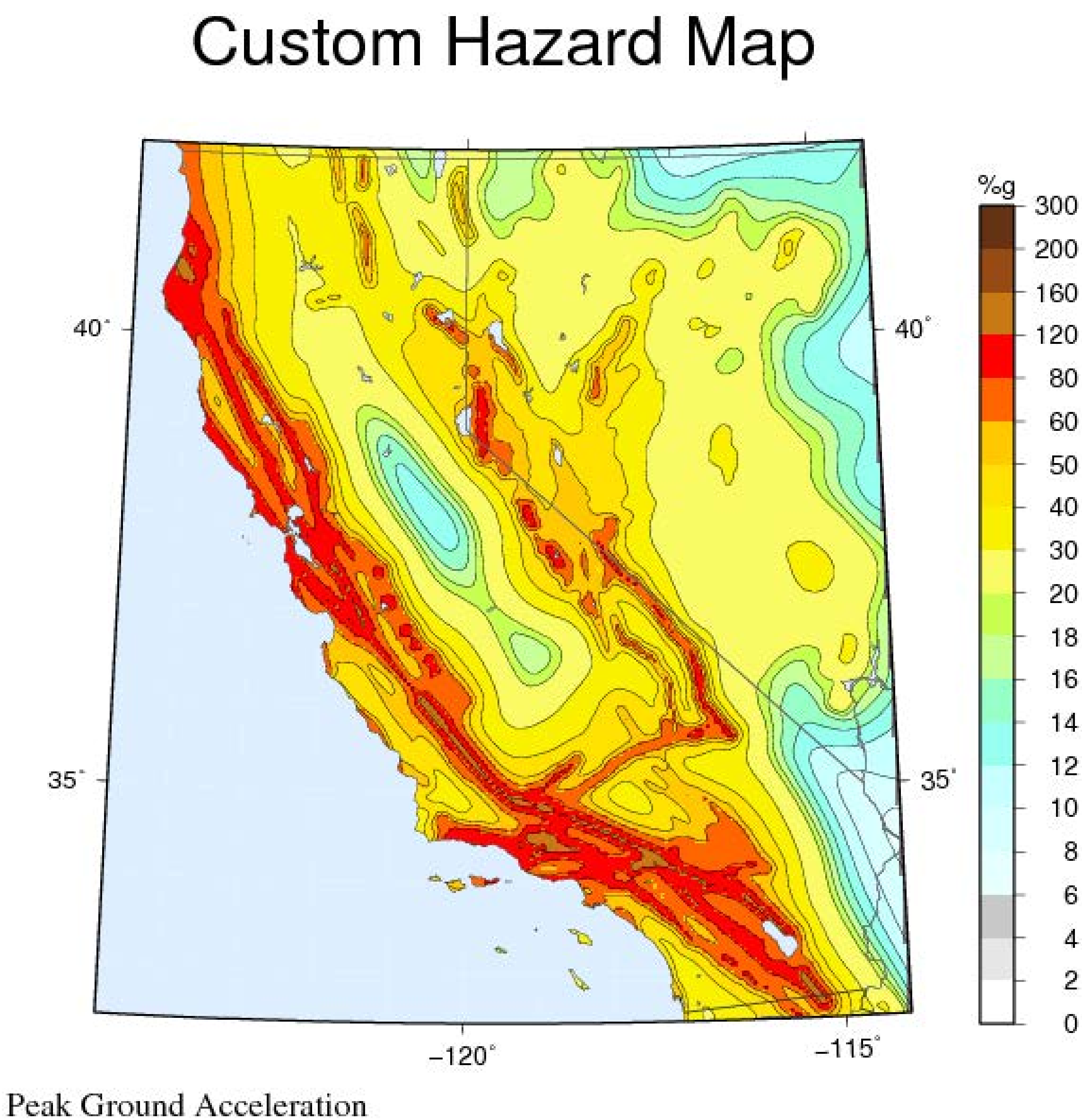


Figure A - 1 Peak ground acceleration in California with a 2% probability of exceedance in 50 years (source: https://geohazards.usgs.gov/hazards/apps/cmaps/).

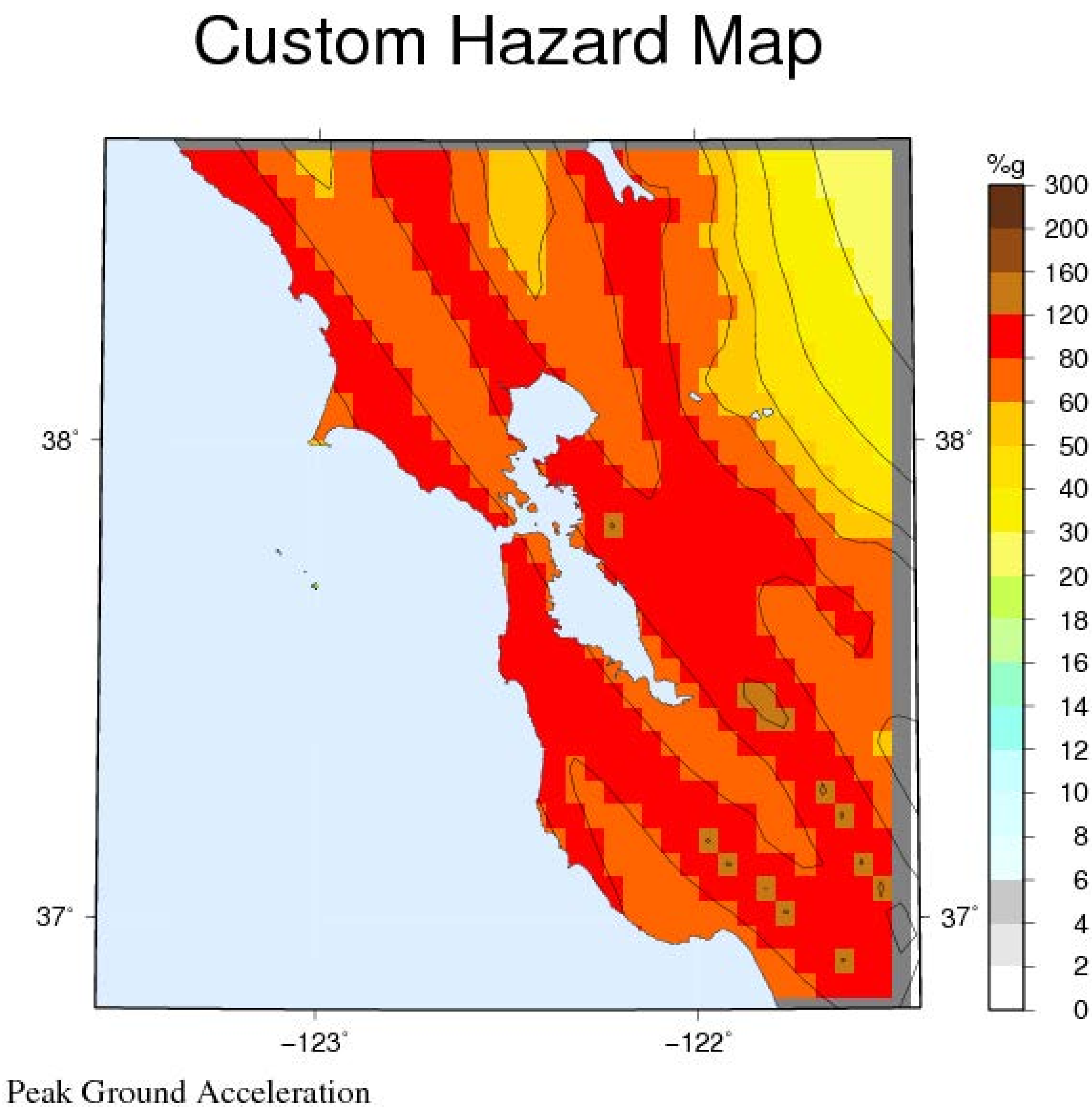


Figure A - 2 Detail of Figure A - 1 for the San Francisco Bay Area.

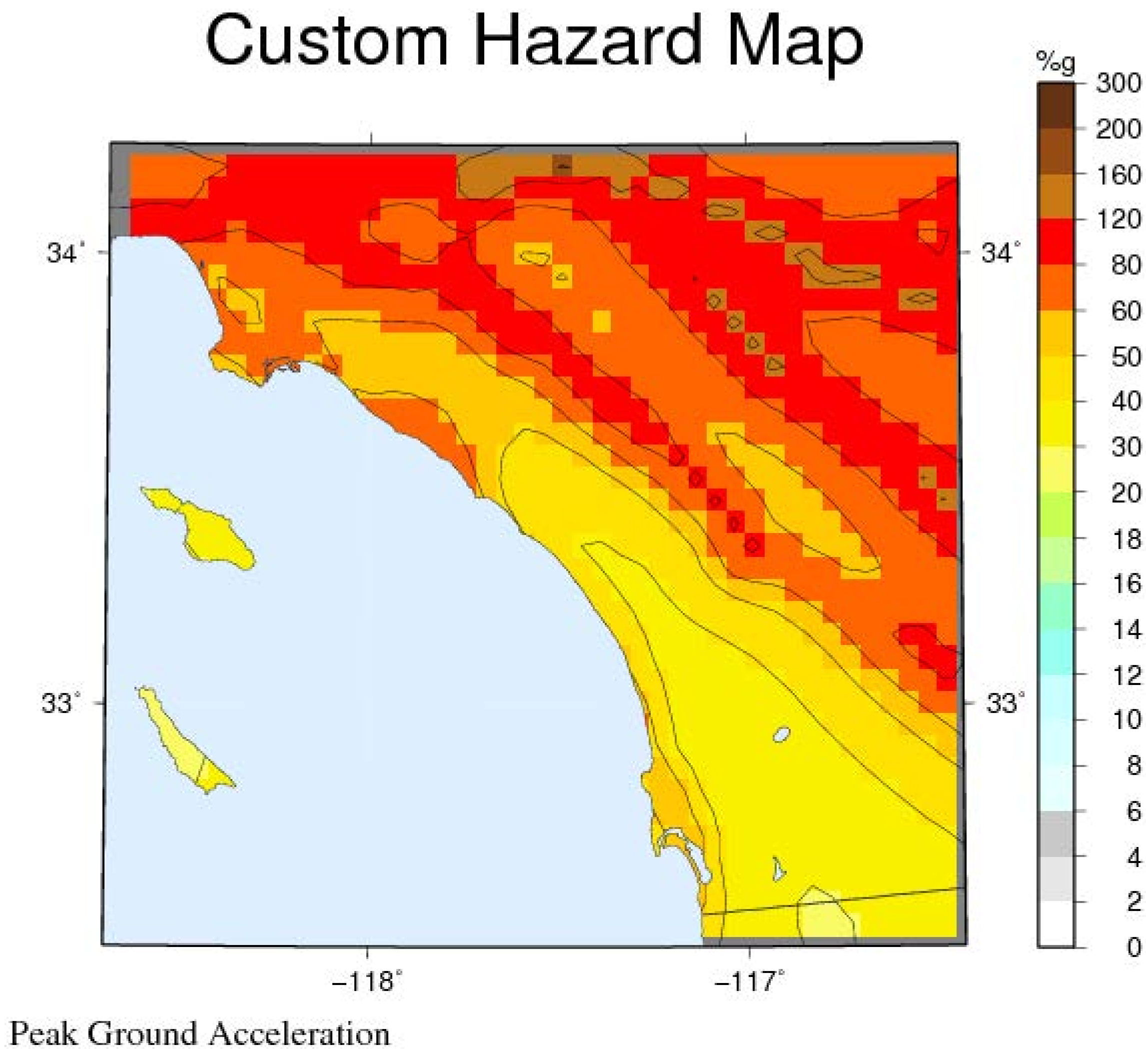


Figure A - 3 Detail of Figure A - 1 for the Los Angeles Region

Appendix B: Presentation to FIRESCOPE Board of Directors

Water Supply in regard to fire following earthquake

Firescope BOD
10 April 2013

Charles Scawthorn, S.E.

Visiting Scholar
Pacific Earthquake Engineering Research Center
University of California at Berkeley

PEER
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

1

Outline

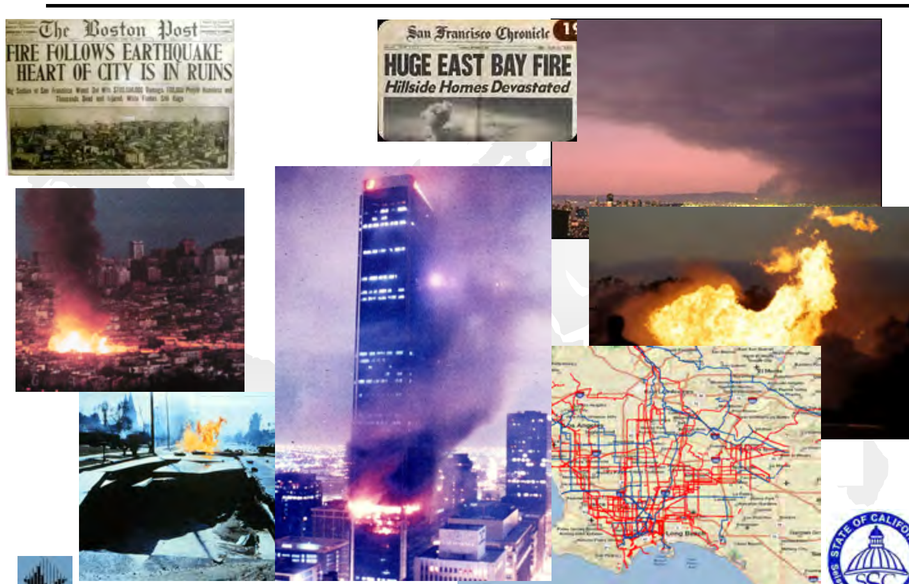
- Self-Introduction
- The Problem
- Phase 1 Method and Findings
- Phase 2 Purpose and Activities
- Next Steps
- Q&A

2

Charles Scawthorn

3

The Problem – ***reliability of water for fire following earthquake***



4

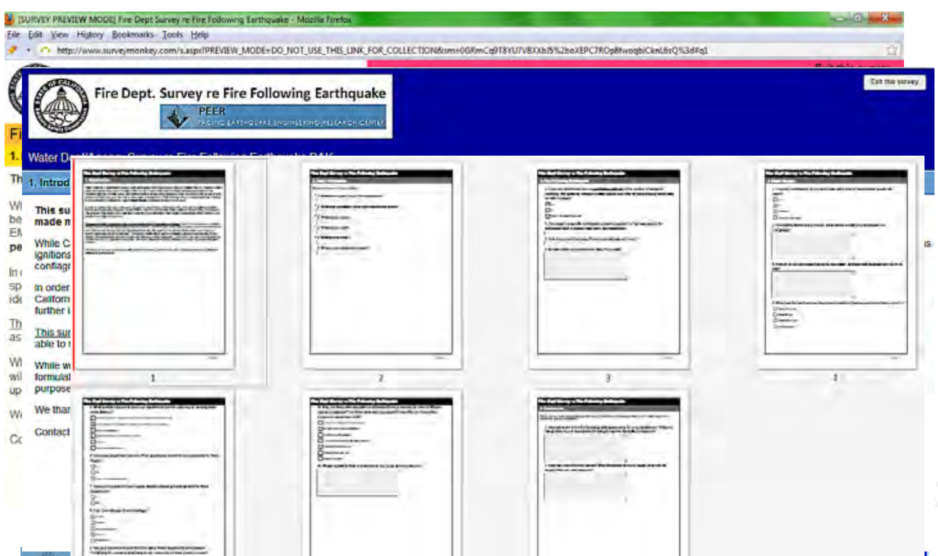
Do we have reliable water supply for FFE?

Questions:

- how well do water departments understand the potential damage to their distribution system? (focus to date has been on transmission)
- what are their current estimates of post-event firefighting water reliability?
- how well do fire departments understand this situation?
- how well are fire departments prepared for alternative water supply?
- how can this situation be improved?

5

2012 Online Surveys



6

Key Findings from the Fire Agencies Survey

- See earthquake as a very important issue.
- But, could be better informed as to earthquake risk
- Have infrequent communication with their water departments.
- Consider their normal water supp[illegible] unreliable.
- Are improving water supply ca[illegible] piecemeal, not coordinated and often are 'reinver[illegible]
- Have identified alternative water source[illegible] but [illegible] sources are often not particularly well documented, nor kept up to date nor regularly drilled.
- The very difficult task of moving water from these sources to the fire scene is in many cases not well thought out, not adequately equipped and not regularly drilled.

7

Key Findings from the Water Agencies Survey

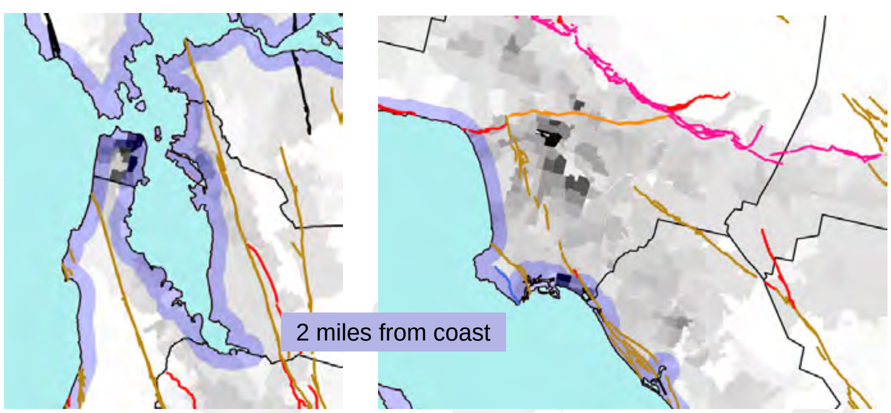
- Most larger urban water agencies not aware of the specifics of the earthquake risk they are exposed to (i.e., two thirds had had no analysis in the last ten years).
- Earthquake is seen as a key issue by most water departments, but that provision of potable water has a higher priority in some cases than firefighting.
- Even where water departments have knowledge of the vulnerabilities of their systems, this is not often (only 22%) communicated to fire departments.
- Both water and fire departments expect major loss of water supply in a major earthquake, with the water department informing the fire department of the details of this about half the time.
- Many water departments are currently addressing their seismic vulnerabilities with significant engineering programs.
- Information on when water would be restored is sparse.
- Some water departments have alternatives given loss of normal water supply, but only a fraction (~1/3) are reasonably equipped to actually move water.
- Fire and water department liaison is not very good, and are often somewhat indirect, through larger enterprise-wide coordination meetings. Emergency water supply is not a focus.

8

Solutions

9

Which solution where?

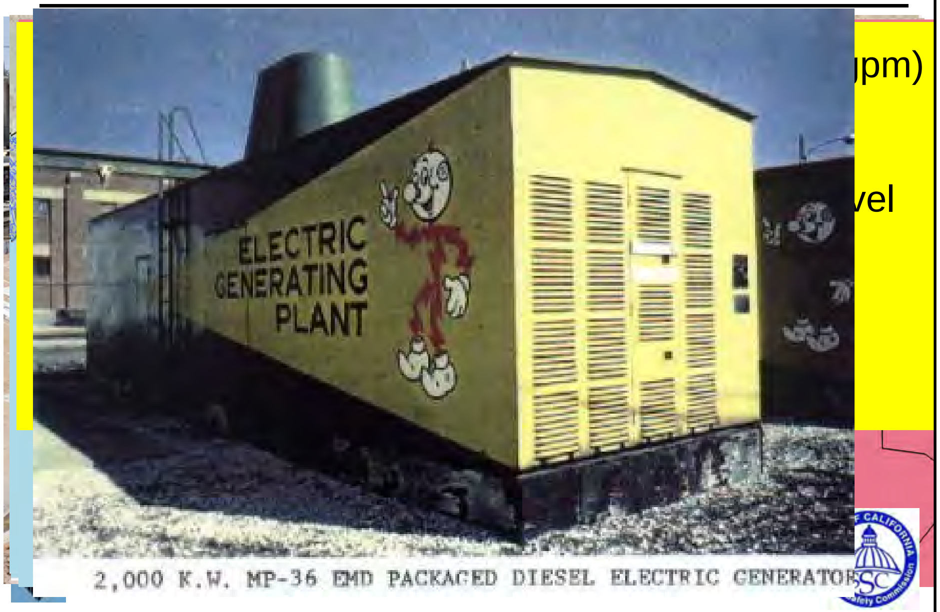


PWSS?

Salt Water HP system”

10

LA Basin HP system - feasibility



11

Phase 1 Report

12

Phase 2 Purpose / Goals

- ❑ Highlight the problem to the California Fire Service
- ❑ Enlist the Water Community via a joint meeting of key senior fire chiefs and water department managers,
- ❑ Develop state-wide requirements for development of post-earthquake firefighting water target goals

13

Goals – *Draft Concept*

URM ~ SB 547 passed in 1986 (section 8875 of the California Code)

- required jurisdictions in Zone 4 inventory URMs by 1990
- adopt a loss reduction program
  (voluntary or mandatory, per local govt.)
- report progress to the Seismic Safety Commission.

14

Draft Goals – Target / Structure

Target Fire Departments
- 70 FDs (of 789 total in state)
- Associated Water agencies
- protecting total population of 15 million

Four parts
- Preamble
- Goals
- Definitions
- Commentary

15

Draft Goals

Preamble: California is earthquake-prone and its cities consist predominantly of wood frame buildings, so that the risk of fire following earthquake in urban areas is very high. In order to reduce that risk, the Seismic Safety Commission and the California Emergency Management Agency are working to improve the availability of water for fires following major earthquakes in California. A first step towards reducing this risk is to set a goal for assured post-earthquake firefighting water supply.

16

Draft Goals

Goals: Incorporated cities in California with a population exceeding 100,000 and having at least a portion of their jurisdiction subject to a Maximum Considered Earthquake (MCE, as defined below) shall:

17

Draft Goals

c. Based on the Plan, publish and present to the Mayor, City Manager, City Council and other top officials, a quantitative estimate of the median and 90th percentile upper bound number and zipcode location of buildings and property likely to be damaged and/or destroyed due to the fires determined in 1. above.

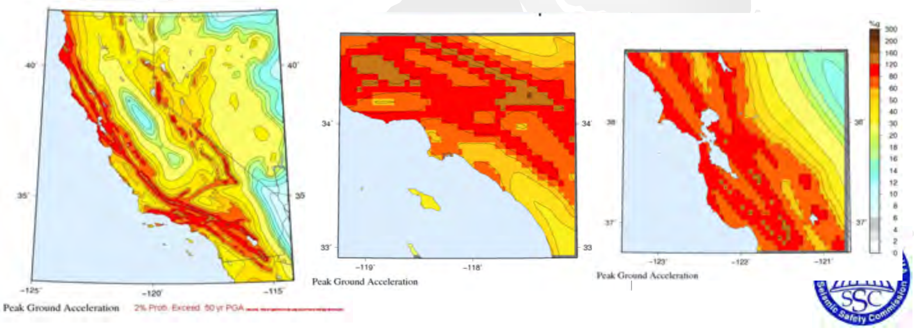
18

Definitions

Definitions

~ MMI 9

Maximum Considered Earthquake (MCE)	the pattern of peak ground acceleration of 0.50g or greater with associated probability of 2% in 50 years, as shown on the most recent National Seismic Hazard Maps prepared by the U.S. Geological Survey (see Figure 1, and commentary). *(could also be defined as the pattern of Maximum Considered Earthquake Ground Motions for the Department's protection area, as defined in Chapter 16 of the 2010 California Building Code, Title 24 Part 2, but these are older).*



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Commentary

Commentary

Nature of the Goals: The Goals do not arbitrarily specify a maximum permitted level of fire loss given an earthquake, but rather anticipate local governments will individually determine their acceptable risk of loss due to fire following earthquake. It is anticipated this will be facilitated by having:

- a clear estimate of the fires that are likely to occur following a major earthquake,
- a Plan for suppressing those fires,
- the public understand the likely fire losses (given the actions assumed to occur in the Plan)
- the Plan exercised annually, and it and the loss estimates updated every five years.

It is anticipated that, if the losses due to fire following earthquake are known to the public, a public debate will occur as to their acceptability. The outcome of that debate will either be acceptance of the risk, or implementation of mitigation measures to reduce the fire following earthquake risk to an acceptable level.

Currently, most cities have no estimate of their fire following earthquake, and only general plans lacking a quantitative basis for dealing with fires following a major earthquake.

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Commentary

Size of Cities: Only cities with populations more than 100,000 need meet the goals. Smaller cities are less likely to have an overwhelming number of fires.

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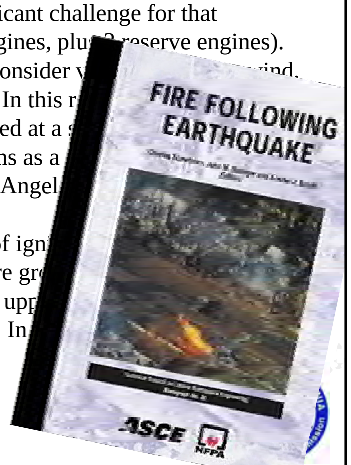
Commentary

Estimation of Fires: Table 1 provides a quick reference for estimating the number of ignitions as a function of population and MCE ground motions. Taking the City of Berkeley as an example (population 114,000), from Figure 3 we see that the City is likely to be subjected to about 1g PGA, so from Table 1 we see that Berkeley will on average have about 14 ignitions (1.14*12 = 13.7), which is a significant challenge for that jurisdiction's Fire Department (7 fire stations and 7 fire engines, plus reserve engines). Table 1 is only a quick reference, and the analysis should consider v wind, humidity, time of the earthquake, season and other factors. In this r a useful resource. The analysis should actually be performed at a zipcode) taking into account the variation of ground motions as a conditions and other factors. For larger cities, such as Los Angel analysis is particularly important.

It is not sufficient to estimate the average (mean) number of ign (90th percentile) as well as their location and subsequent fire gr estimated, in order to arrive at an estimate of the mean and upp firefighting water and other resources that will be required. In a useful resource.



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Commentary

Table 1 Average number of Ignitions as a function of PGA and Population
source (SPA Risk, 2009)

	Peak Ground Acceleration (g)								
Populaton	0.5	0.6	0.7	0.8	0.9	1	1.2	1.4	1.6
100,000	3	4	6	7	10	12	17	24	31
200,000	6	8	11	15	19	24	34	47	62
300,000	8	12	17	22	29	36	52	71	93
400,000	11	16	23	30	38	47	69	94	124
500,000	14	21	28	37	48	59	86	118	155
600,000	17	25	34	45	57	71	103	141	185
700,000	20	29	40	52	67	83	120	165	216
800,000	22	33	45	60	76	95	138	188	247
900,000	25	37	51	67	86	107	155	212	278
1,000,000	28	41	57	75	95	118	172	236	309
1,500,000	42	62	85	112	143	178	258	353	464
2,000,000	56	82	113	150	191	237	344	471	618
2,500,000	70	103	142	187	238	296	430	589	773
3,000,000	84	123	170	224	286	355	516	707	927
3,500,000	98	144	198	262	334	414	602	824	1,082
4,000,000	112	164	227	299	381	474	688	942	1,236

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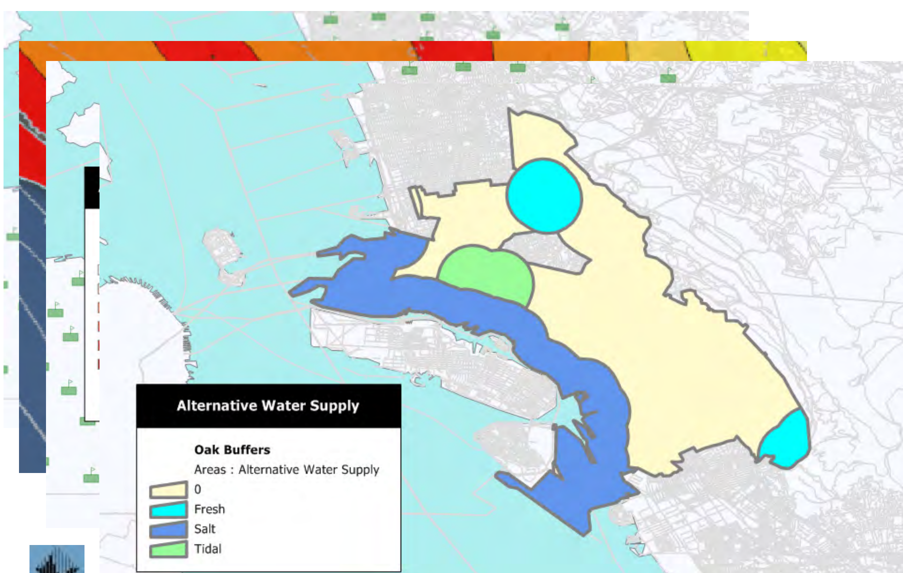
Quant. Est. Ignitions - example



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Commentary

Sources of Water: In every large earthquake, underground water mains typically sustain a significant number of breaks, due to the earthquake shaking and, even more so, the failure of the ground in soft soil areas, due to liquefaction, land sliding and other forms of permanent ground failure. The estimation of the residual capacity of the Normal water supply system given these breaks is a complex matter, which the local water agency is best qualified to do. In some jurisdictions, local water agencies have been aware of and responding to this problem (for example, the East Bay Municipal Utility District, EMBUD, which serves Berkeley, has had a major seismic retrofit program). Nevertheless, the potential for all breaks cannot be eliminated, and it should be expected that portions of the Normal water supply will not provide the required firefighting water following the earthquake. Again, which portions will fail and what their impact will be on the remaining capacity is best estimated by the water agency.

Fire departments understand that Normal water supplies may sometimes fail, so that they make contingency plans for Alternative water supplies. The Goals require that both the Normal and the Alternative water supply sources be reviewed, regarding their ability to reliably provide adequate supplies of firefighting water.

However, even if they are adequate to the demands, it is not sufficient to simply identify supplies of water. The Goals require that a Plan be developed that identifies

- where the likely locations of fires will be, and their growth,
- as each fire grows, from where the required firefighting water will be supplied, and
- how the water will be transported from the source to the fire

The latter aspect is crucial. Under non-earthquake conditions, the typical contingency plan for transporting firefighting water from the source to the fire is a 'relay' system, in which the water is pumped through hose. Because of friction in the hose, the water pressure drops and has to be boosted by 'relay' pumpers placed along the hose line, for example at about 1,000 ft. spacing. To move a significant quantity of firefighting water a mile therefore requires perhaps six fire engines, which may all or most of the engines in a jurisdiction – for one fire! If there are several fires, there won't be enough fire engines, and other means have to be found. The Goals call for a Plan to identify what these means are, and annual practicing with them.

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Initial Feedback

I like it. I'm not sure how to get the cities to buy into a mandated program like this (I guess that it depends on just what is mandated). I see this document being read by two different audiences. Engineers will understand peak acceleration, but fire chiefs will simply nod like they understand and their eyes will soon glaze over. They should understand shaking intensities.

Commentary revised to provide shaking intensities

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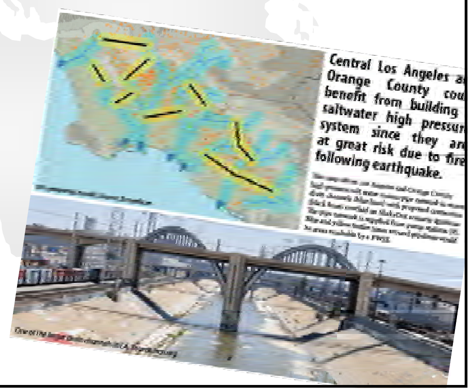
Phase 3

What will still be required:

- Continued support FD/WD community, re adoption
- Technical support
  - Plan Preparation Guidance Document (software?)
  - Implementation of Goals
  - Development of state-wide PWSS (specs…)
  - Consideration of S. Calif. water supply system



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Thank You

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Phase 1 report URLs:

173 pg Report:
http://www.seismic.ca.gov/pub/CSSC_2011-02_WaterSupply_PEER.pdf

4 pager:
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28

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