ASSOCIATION OF BAY AREA GOVERNMENTS

Representing City and County Governments of the San Francisco Bay Area

ABAG

Date: October 1, 2014

To: Regional Planning Committee

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Subject: **Infrastructure Resilience Overview**

This fall the Earthquake & Hazards program will release an Infrastructure Vulnerability and Interdependencies Study. The study provides a regional perspective of the transportation, fuel, electric, and water systems and their seismic vulnerability. This memo frames the motivation of the study. The attachment includes drafts of the study introduction, and a short chapter on Bay Area Airports.

The Bay Area region's resilience is largely dependent upon both building and infrastructure performance in seismic events. Our homes and businesses are only active when they are safe to be inside and when they are connected to the services they are reliant on: water, sewer, electricity, communications, natural gas, fuel, transportation. In an earthquake, building and infrastructure damage will be confined primarily to areas of strong shaking. Infrastructure outages will cascade outward beyond areas of strong shaking and liquefaction, impacting areas downstream of the failures. Infrastructure outages following an earthquake can impact the entire region at once. Some infrastructure repairs will be quick, while others will take months and years, leaving some communities without service for an unacceptable length of time.

The study maps airports, transportation (highways & passenger rail), fuel, electricity, and water systems, and highlights their interaction with seismic hazards. Publicly available information illustrates at a high level how the systems operate, and the potential consequence should the system be damaged. The report focuses on the seismic exposure of infrastructure systems and the significant consequences of failures. The key findings warrant keen attention from local, regional, and state actors.

Functional infrastructure systems are necessary for achieving community resilience. While it is unrealistic to expect systems to be earthquake proof, knowing what to expect provides the users of infrastructure systems the information they need to take measured preparedness actions. Currently the vulnerability of many publicly and privately operated infrastructure systems is not well known or not well communicated to the public. With a lack of information stakeholders have no baseline for predicting the benefits of possible preparedness or mitigation strategies. Going forward the region must understand and communicate the vulnerability of infrastructure systems to inform stakeholders on what to expect so that they can make informed decisions to limit their impacts should the system fail.

This study is a first step in understanding the risks to airports, transportation, fuel, electric, and water systems. The study should be used to inform actions in the present, and also as a call for greater attention of the regions infrastructure systems, and their impact on Bay Area Stakeholders.

CHAPTER 1
Introduction

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Ground failures in the 1994 Northridge Earthquake.

A future large earthquake will impact the entire Bay Area region. Ground shaking near the fault and liquefaction of loose soils along the bay will cause severe damage to buildings and infrastructure systems in all nine counties that touch the Bay. Many homes and businesses will be severely damaged, displacing residents and businesses. Even in the largest scenarios individuals in seismically designed buildings or those not exposed to strong shaking will walk away with minimal damage to their home and workplace; however, they are likely to be severely impacted by infrastructure interruption. Damage to roads and water pipelines elsewhere will decrease the habitability of undamaged homes, close undamaged businesses, and test the operability of critical facilities like airports. A resilient region is reliant on functional infrastructure systems to keep key societal services operational to help damaged areas rebuild, to keep undamaged homes habitable, and businesses open during recovery. This report examines the interaction of Bay Area infrastructure systems with seismic hazards and the interdependence between mutually dependent systems.

This work builds off of past Bay Area infrastructure studies:

- *Earthquake Engineering Research Institute: Scenario for a Magnitude 7.0 Earthquake on the Hayward Fault (EERI, 2010)*
- *Urban Areas Security Initiative: Regional Catastrophic Earthquake Logistics Response Plan, Appendix G Critical Lifelines (UASI, 2014)*
- *City & County of San Francisco Lifelines Council: Lifelines Interdependencies Study I (2014)*

It will also be joined by other similar work scheduled for release over the next 18 months:

- *FEMA Region 9: Bay Area Earthquake Plan*
- *USGS: Haywired*
- *City & County of San Francisco Lifelines Council: Regional Coordination of Lifelines Restoration Working Group*
- *City & County of San Francisco Lifelines Council: Post-Disaster Fuel*

Supplies Working Group

Infrastructure systems can be interrupted by any number of natural or manmade events. This study examines infrastructure systems through the lens of earthquakes. In past California earthquakes and recent global earthquakes infrastructure systems have been severely damaged, testing the resilience of regions. Earthquake hazards and three Bay Area earthquake scenarios are defined in:

- Chapter 2: Earthquake Hazards & Scenarios

While this assessment is focused on seismic events, the background research on each studied infrastructure system can be a resource to examine system performance in other hazard events.

The study draws from publically available data sets for each lifeline system, and when possible, provides a regionally complete perspective of the system. The information presented will be a useful tool for a number of Bay Area stakeholders, but Bay Area airports are the primary audience for this report. The 24 airports in the region are geographically distributed and are unlikely to all be damaged in a single event, but these regional air assets are all reliant on the same infrastructure systems which are vulnerable to interruption in a future earthquake. Airports and individuals are directly reliant on a number of publically and privately provided infrastructure services to maintain operability. The study focuses on:

- Chapter 3: Airports
- Chapter 4: Transportation - Roads & Passenger Rail
- Chapter 5: Fuel System
- Chapter 6: Electric System
- Chapter 7: Water System

This list is not a comprehensive review of all infrastructure systems but recognizes the limitations of a single study. Other systems deserving of future study are (freight rail, natural gas, waste water, communications, bio-fuels). In Chapters 3 through 7 individual systems are overlaid regional earthquake scenarios identified in Chapter 2. A seismic vulnerability assessment of each system provides only an initial evaluation of system performance under earthquake loading.

Each system is dependent on other infrastructure systems which may have also been damaged. The interdependence between systems can result in cascading outages, an increased repair time, or can limit the utility of functional systems (i.e. functional roadways, but disrupted fuel system). Including study of the interdependence between lifeline systems reveals a more complete picture of system performance. These interactions are discussed in:

- Chapter 8: Interdependencies

GIS mapping, case studies, technical reports, planning documents, and interviews were used to develop profiles of the Bay Area's infrastructure. GIS was used to map infrastructure systems and hazards, highlighting features of interaction. This analysis by itself provides an infrastructure exposure analysis. When fragility attributes about the system were known the analysis was expanded to consider these features. Case studies of past earthquakes and earthquake engineering research were used to highlight components of each system that were most likely to fail in various seismic hazard loadings, and which system components were most likely to govern the restoration of each system. The likelihood of failure, time required to repair given failure, and consequence of failure were the attributes used to focus analysis on the most important system components. Lastly, interviews with experts who are familiar with the Bay Area's infrastructure and hazards provided additional knowledge into the past performance of infrastructure, their dependence on other systems, and expert guidance.

CHAPTER 3
Airports

KEY FINDINGS

- Airports are well distributed around the region.
- In San Andreas and Hayward scenario events the three international airports will simultaneously experience strong to violent shaking. 17 of 24 Bay Area airports are within five miles of an active Alquist-Priolo mapped fault, and 21 of 24 are within ten miles.
- Of the 16 airports that completed the Caltrans Division of Aeronautics Emergency Plan Survey, 15 have an Airport Emergency Plan, 13 of which have sections that cover earthquakes.

Bay Area airports provide residents and businesses the ability to travel and conduct business across the globe. The airports support the regional economy by providing airport sector jobs, economic access to domestic and global markets, air cargo services, and tourism access. Among the many important every day benefits of Bay Area airports, after a major earthquake they become key nodes to support both the response and recovery of the region. The accompanying report, *Roles of Airports in Regional Disasters* (2013) highlights the important resource airports provide in both short-term disaster recovery and long-term economic recovery of the Bay Area region.

In the Bay Area there are 24 public airports, three of which have international service. The airports are well distributed throughout the region, with airports in all counties except San Francisco and Marin. Eleven of the airports are within 1.5 miles of Highway 101 along the 175 miles between Cloverdale and San Juan Baustista. The majority of the airports in the region are classified by the FAA as supporting only medium to small aircraft (FAA, 2013). There are a number of factors that influence necessary runway lengths: wheel type, weight, site elevation, temperature, and others, but the FAA categorizes Bay Area airports as shown in Figure X.

HISTORIC SYSTEM PERFORMANCE

Airport facilities are susceptible to fault rupture, liquefaction, and ground shaking. Fault rupture and liquefaction can cause damage to runways requiring the re-grading and asphalting of the runway. The above ground components of airports (terminals, hangers, air traffic control towers, etc.) are vulnerable to all three hazards. Damage to facilities can be both structural or non-structural. In many earthquakes structural damage can be minimal, but poorly anchored heating and cooling equipment, architectural elements, and mechanical systems can result in closure. The accompanying report *Roles of Airports in Regional Disasters* has nine case studies of recent domestic disasters, and international earthquakes and their impacts to airports. It also highlights the services these facilities can provide in both response and recovery for their regions.

BAY AREA VULNERABILITY ASSESSMENT

In the Bay Area there are two airports that have a known risk of fault rupture, Napa County Airport, and Buchanan Field. In the region there are 15 airports with portions of their facility in high or very high liquefaction susceptibility zones. The airports near the bay are especially susceptible, but many have taken some level of mitigative action to address the liquefaction potential. An accompanying study to this report

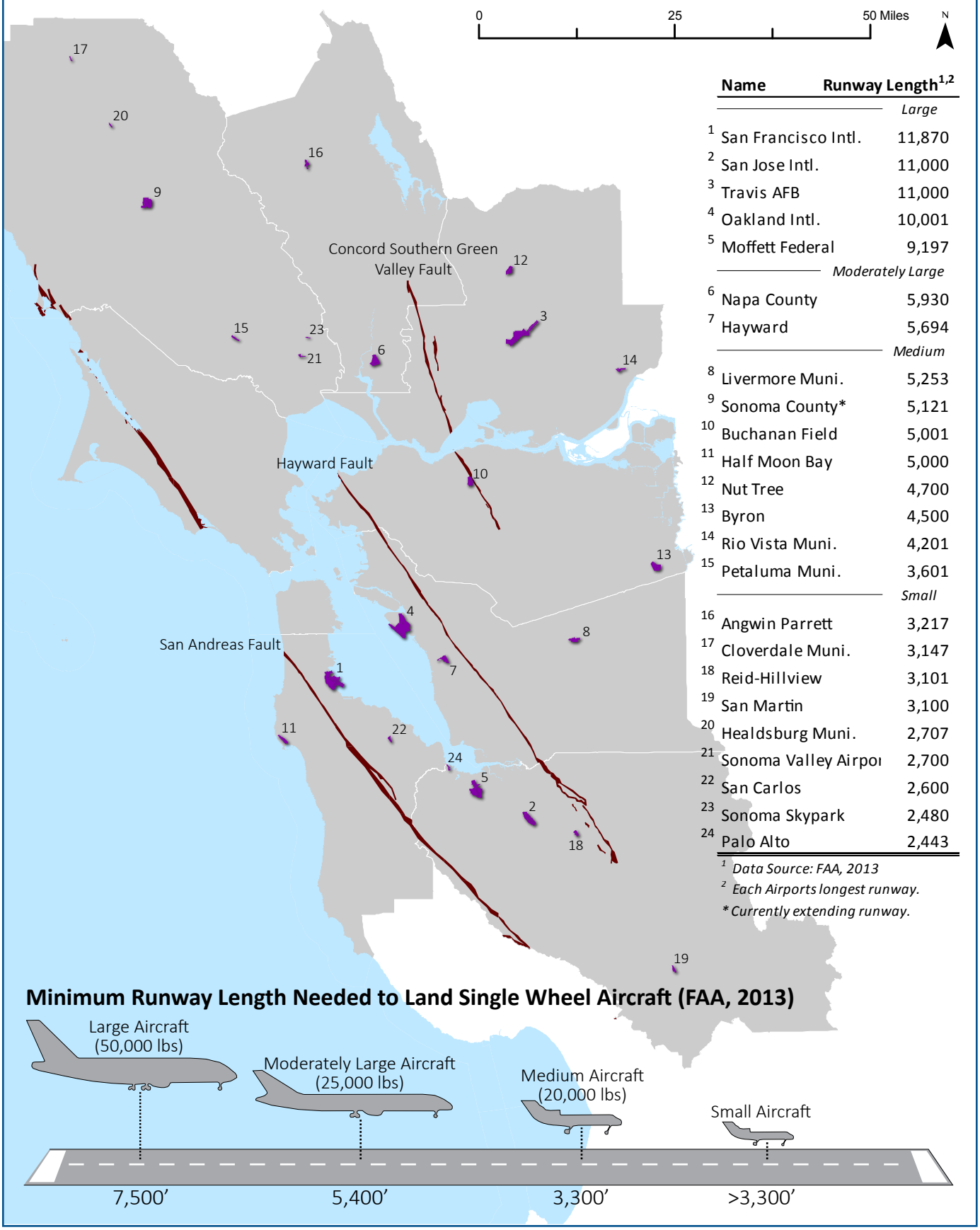
Accompanying Reports Specific to Airports.

Roles of Airports in Regional Disasters

Preliminary Assessment of Earthquake-Induced Liquefaction Susceptibility at Five San Francisco Bay Area Airports

reports are available at quake.abag.ca.gov

FIGURE 5:
Bay Area International & General Aviation Airports



	Name	Runway Length[1,2]
		Large
1	San Francisco Intl.	11,870
2	San Jose Intl.	11,000
3	Travis AFB	11,000
4	Oakland Intl.	10,001
5	Moffett Federal	9,197
		Moderately Large
6	Napa County	5,930
7	Hayward	5,694
		Medium
8	Livermore Muni.	5,253
9	Sonoma County*	5,121
10	Buchanan Field	5,001
11	Half Moon Bay	5,000
12	Nut Tree	4,700
13	Byron	4,500
14	Rio Vista Muni.	4,201
15	Petaluma Muni.	3,601
		Small
16	Angwin Parrett	3,217
17	Cloverdale Muni.	3,147
18	Reid-Hillview	3,101
19	San Martin	3,100
20	Healdsburg Muni.	2,707
21	Sonoma Valley Airpo	2,700
22	San Carlos	2,600
23	Sonoma Skypark	2,480
24	Palo Alto	2,443

[1] *Data Source: FAA, 2013*
[2] *Each Airports longest runway.*
** Currently extending runway.*

Preliminary Assessment of Earthquake-Induced Liquefaction Susceptibility at Five San Francisco Bay Area Airports (2013) used available bore hole data to quantify the potential and degree of liquefaction to five Bay Area runways.

As the region experienced recently in the 2014 South Napa Earthquake, smaller faults in the region have the potential to cause damage to individual or a small subset of regional airports. Sidebar X highlights the fortunately minimal damage at the Napa County Airport in the South Napa Earthquake.

Because the airports in the region are well distributed throughout the region there is an ability for air traffic to be rerouted in events. San Andreas and Hayward events will test the commercial travel in the region as the three international airports are between the two faults, along with Moffett Federal. Four of the regions five airports that can handle large aircraft experience strong to violent shaking in both the San Andreas and Hayward Scenario. In the event of disruption to these four airports Travis Air Force Base in Solano County would be the only airport in the region with a long enough runway for large aircraft.

SIDEBAR 2:
M6.0 South Napa Earthquake

On August 24th, 2014 an earthquake occurred on a portion of the West Napa Fault that had previously not been mapped as an active fault zone (USGS, 2014). The known section of the West Napa Fault a few miles south of the earthquake epicenter runs directly through the Napa County Airport. This section of fault did not have significant fault rupture, but rupture displacements north of the airport were greater than 1 foot (GEER, 2014).

The Napa County Airport did sustain non-structural damage to the air traffic control tower, and to shelving units elsewhere in the terminal. The airport operated without an air traffic control communications for four days until a temporary air traffic control could be set up. The tower remained unoccupied for over a month while new windows and other non-structural damage were repaired (Stockdale, 2014).

Other than a 30 minute airport closure for inspection, the airport maintained operation. The facility was without power for 12 hours and ran on backup generators during this time. PG&E used a portion of the Airport parking lot as their mobile command center, and provided additional generators to help power fixed based operator services during the short outage. Overall the earthquake was a near miss for Napa County Airport and is a reminder of the region's high earthquake risk.

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