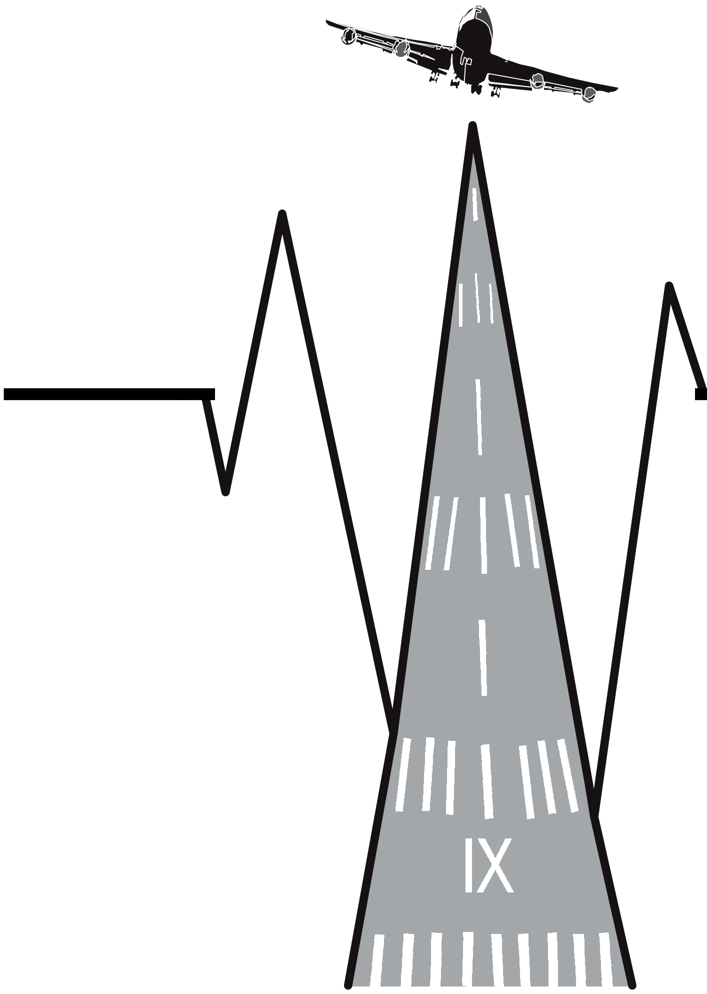
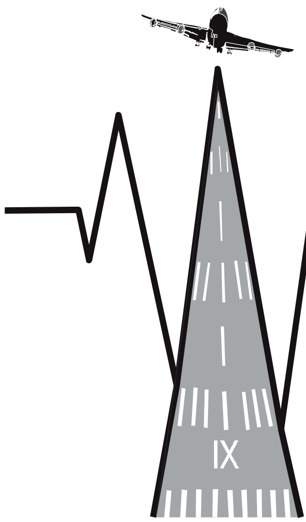


Don’t Wing It

Airports and Bay Area Earthquakes

DECEMBER 2000

ASSOCIATION OF BAY AREA GOVERNMENTS



Don’t Wing It

Airports and Bay Area Earthquakes

Using Airport Vulnerability Data and Response Capability to Improve Planning for Post-Earthquake Transportation Disruptions in the San Francisco Bay Region

DECEMBER 2000

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FAA AIRPORTS PROGRAMS
BUILDING GATEWAYS TO THE SKY

MTC METROPOLITAN TRANSPORTATION COMMISSION

ABAG ASSOCIATION OF BAY AREA GOVERNMENTS

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TABLE OF CONTENTS ...

BACKGROUND AND OBJECTIVES ...

These materials build on two reports on the vulnerability of the region's transportation system to earthquakes published by ABAG –

- ***Riding Out Future Quakes –*** October 1997
- ***Riding Out Future Quakes – Ideas for Action –*** March 1999

The ***Riding Out Future Quakes*** project was initiated by ABAG and Caltrans following the Northridge and Loma Prieta earthquakes. We learned that we need our transportation systems to be functional after earthquakes for two principal reasons:

- Emergency responders need to use transportation systems, including airports, after earthquakes.
- Transportation system disruptions, including disruptions to airports, can have a severe impact on a region's economy for months, if not years.

As a second step in the planning process, ABAG held a series of five subregional workshops discussing hypothetical road and rail closures resulting from selected scenario earthquakes in October and November 1998. "Tabletop" disaster drills and extensive discussion led to identification of the major issues, interagency dependencies, and areas of potential conflict likely to face transportation providers, governments, utilities and businesses as they struggle to address the transportation impacts after a large earthquake. The ***Riding Out Future Quakes – Ideas for Action*** report is both the proceedings of those workshops, as well as a tool to inspire innovative planning for minimizing transportation disruption following future earthquakes. One conclusion of these workshops was the importance of airports in the region's response and recovery to earthquakes.

At the same time, MTC is continuing to test and refine the Trans Response Plan (TRP) which integrates response and recovery efforts among all modes of transportation. The TRP coordinates the activities of MTC, Caltrans, State and local Offices of Emergency Services, and other transportation providers, including transit agencies and airports.

Our work on airports and earthquakes has five principal overall ***objectives***:

- To develop a ***long-term partnership*** among air transportation providers, users, the earthquake research community, and earthquake responders to foster cooperation for response and recovery.
- To assess the ***vulnerability of our air transportation system*** to liquefaction and land-side access issues given the scenario earthquakes considered likely Bay Area.
- To assist in ***collaborative planning for emergency response*** among the airports, emergency responders, and cargo and passenger carriers. Emergency responders are depending on our airports for delivering disaster cargo and disaster relief workers.
- To identify methods for ***minimizing long-term impacts*** of reduced land-side access and airport damage following future earthquakes, thereby minimizing impacts on airport business, the cargo industry, and our regional economy.
- To ***increase public awareness*** and support of emergency planning activities at and among airports.

As a first step in this process, ABAG has been actively involved in the discussion of earthquake issues as part of the ***Regional Airport System Plan (RASP) Update 2000*** process. In addition, ABAG held a workshop on October 10, 2000, to discuss the potential problems outlined in this report and to begin the process of developing strategies to cope to earthquake-related disruptions to airports.

- What are the options for bringing relief aircraft into the region if all runways at one or more major airports are damaged beyond immediate repair?
- What kinds of concerns should airport safety managers be addressing? What specific Bay Area earthquake issues should be included in their earthquake plans?
- What are the potential problems and solutions related to land-side access?
- How should emergency plans be improved to deal with areas likely to be damaged in an earthquake?
- If an airport lifeline network is established, what are the critical land-side components of that network (control towers, runways, key access routes, etc.)?

FINDINGS – EARTHQUAKES AND AIRPORTS

What Are the Threats to Airport Operations Following Future Earthquakes in the Bay Area?

Based on past experience in California and other recent earthquakes, the threats to Bay Area airport operations following future earthquakes fall into four general categories:

- liquefaction damage to airport runways, particularly at San Jose (until the new runways are completed), Oakland, San Francisco, and, perhaps, Moffett Federal Airfield;
- shaking damage to air control and terminal facilities, particularly older facilities that may be present at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan, and Livermore airports;
- power and communications disruptions; and
- disruptions to the transportation systems serving the airports.

Our Airport Systems Can and Should Be Made More Earthquake-Ready!

1. **We need to better understand and mitigate the liquefaction hazard to runways.** Thus, we need to expand on the liquefaction analysis conducted for the runways at the three major airports (OAK, SFO, and SJC) to:
   - gain further information on the vulnerability of other major airports, particularly Moffett Federal Airfield on the Peninsula and Travis Air Force Base in Solano County, and, if feasible, Buchanan, Hayward, and Livermore in the East Bay; and
   - incorporate more recent geotechnical information becoming available for OAK, SJC and SFO.

   We need to ensure that the design of new runways also mitigates liquefaction hazards associated with the connections to the existing runway system. Any runway expansions at SFO and OAK that tie into sections of existing runways which are vulnerable to liquefaction will make the expansions vulnerable as well. Current runway work at SJC is designed to minimize the liquefaction hazard.

2. **We need to improve emergency planning at individual airports and to better coordinate emergency planning among airports and with other forms of transportation.** Some ideas focusing on employees and operations at individual airports are listed at the end of this report. However, airport participation in coordinated emergency planning is also essential. MTC is starting this planning as part of the integrated Trans Response Plan (TRP) for earthquakes.

3. **We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should Bay Area commercial airports loose capacity due to road transportation system disruptions, runway damage, or structural damage.** Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

The Issue – Why Worry About Airport Disruptions Following Future Earthquakes in the Bay Area?

Airports Are Part of Our Transportation System

We need our transportation systems to be functional after earthquakes for two principal reasons:

1. Emergency responders need to use transportation systems, including airports, after earthquakes.
2. Transportation system disruptions, including disruptions to airports, can have a severe impact on a region's economy for months, if not years (Brady and Perkins, 1998).

Airports as Intersections

Airports are critical points in our transportation system because they function as intersections, not between two freeways, but between our air space and our land-side transportation. Yet, just as damage to a major interchange or bridge in an earthquake can have impacts far beyond the local area, so can damage to an airport, particularly one of the principal international airports in the Bay Area.

Focus on Major Airports

Although the focus of this report is on the three major airports, other airports are also discussed in the context of the potential problems at these facilities in comparison to the three international airports.

Other Emergency Planning Efforts

ABAG held a series of five subregional workshops discussing hypothetical road and rail closures resulting from selected scenario earthquakes in October and November 1998. "Tabletop" disaster drills and extensive discussion led to identification of the major issues, interagency dependencies, and areas of potential conflict likely to face transportation providers, governments, utilities and businesses as they struggle to address the transportation impacts after a large earthquake. The ***Riding Out Future Quakes – Ideas for Action*** report (Perkins and others, 1999b) is both the proceedings of those workshops, as well as a tool to inspire innovative planning for minimizing transportation disruption following future earthquakes. One conclusion of these workshops was that airports are critically important in the region's response and recovery to earthquakes.

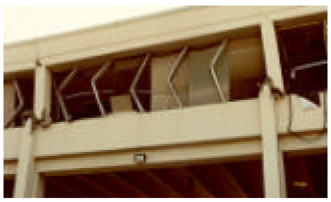
At the same time, MTC is continuing to test and refine the Trans Response Plan (TRP) which integrates response and recovery efforts among all modes of transportation. The TRP coordinates the activities of MTC, Caltrans, State and local Offices of Emergency Services, and other transportation providers, including transit agencies and airports.

The information in this report will hopefully serve to improve earthquake emergency planning at and among airports.

PAST EARTHQUAKES – WHAT HAPPENED LAST TIME?

1989 Loma Prieta Earthquake

The magnitude 6.9 Loma Prieta earthquake occurred in the Santa Cruz mountains near the border of Santa Cruz and Santa Clara counties on October 17, 1989. Because the earthquake source fault was far south of the main urban center of the Bay Area, it only serves as a wake-up call for what might happen in a closer or larger magnitude earthquake. Thus, it is inappropriate to assume that since a problem did not occur in this earthquake, it will not occur in the future.



source – SFO – R. Wiggins

San Francisco International Airport (SFO) was over 35 miles from the fault source for the Loma Prieta earthquake. Although operations at SFO officially halted for one night, this was not due to any significant damage to the facilities or the runways. The control tower sustained window and non-structural damage, and some unanchored equipment was broken, but this did not prevent the tower from operating. ***The primary reason for the shutting down of flights during that night was that not enough controllers were available to operate the tower safely.*** The runways (built on fill), navigational equipment, runway lights, fuel tanks, and piping were mostly unaffected. However, liquefaction (a process where loose water-saturated sands temporarily behave like a liquid when shaken) shifted some small support structures. Lost power was restored within 3 hours, well before the time the airport was reopened. Non-structural damage occurred in the terminals, but did not cause the airport to be shut down. Damage to an air cargo building was significant, and problems transpired with a power transformer, but these were remedied over time without air operations being affected. ***There were no problems with access road failures or freeway closures within the immediate vicinity of this airport that contributed to closure. However the ability of the controllers to travel to work safely and quickly was an issue*** (EERI, 1990).

source – Geomatrix Consultants

Oakland International Airport (OAK) was also affected by the Loma Prieta earthquake, in spite of its location over 40 miles from the fault source for the earthquake. OAK and adjacent Port of Oakland lands, however, experienced peak ground accelerations of almost 0.3 g. These problems affected airport operations. Its main 10,000-foot runway, built on hydraulic fill over Bay mud, was severely damaged by liquefaction; 3,000 feet of the runway sustained cracks, some of them were a foot wide and a foot deep. Spreading of the adjacent unpaved ground resulted in cracks up to 3 feet wide. Large sand boils appeared on the runway and adjacent taxiway, a few as wide as 40 feet (EERI, 1990). As a result, OAK was immediately shut down to evaluate runway damage. A shorter 6,212-foot general aviation runway was used to accommodate diverted air traffic for a couple of hours before the main runway was reopened with a usable length of only 7,000 feet. This shorter runway length impacted cargo loads during takeoff. Over the next 30 days, 1,500 feet of the 3,000 foot damaged section of the runway was repaired using an emergency repair order for resurfacing and crews already present during the earthquake. An adjacent taxiway was also damaged by liquefaction. Repairs of this taxiway segment and the final 1,500 feet of the main runway were completed six months later, after a competitive bidding process (T. LaBasco, S. Kopacz, and J. Serventi, Port of Oakland, personal communications, Sept. 2000). Post-earthquake communications were difficult at OAK, as both telephone service and the usable radio frequency became quickly overloaded, affecting both cleanup crews and the public on-site at the time of the earthquake. Other damage was limited – for example, the control tower lost three windows, a walkway between terminals was damaged, and a water main ruptured causing a service road to collapse (EERI, 1990). Repair costs totaled approximately $6.8 million, including $3.5 million for runway repairs, $2.2 million for taxiway repairs, and $1.1 million for repair of other damage. FAA funded approximately $5.5 million of the repairs, with the remainder funded by OAK (T. LaBasco and I. Osantowski, Port of Oakland, and J. Rodriguez, FAA, personal communications, Sept. 2000).

San Jose International Airport (SJC) was located approximately 15 miles from the fault source of the Loma Prieta earthquake. The airport immediately closed for inspection of runways, taxiways, associated lighting systems, and aircraft parking ramps. The operational status of the Air Traffic Control (ATC) tower, other ATC facilities, and aircraft navigational aids were verified. Both terminals, automobile parking garages, and lots were also inspected. The inspection showed that there was no damage that might affect operations, so the airport reopened and was fully operational 40 minutes after the earthquake. The airport also determined the status of the three principal access routes, as well as of SFO and OAK. The status of the airport was then communicated to the City Emergency Response Center (C. Herrera, SJC, in Perkins and others, 1999b). The control tower lost a window and had non-structural problems; other cosmetic damage occurred at the terminal. Commercial power was lost for over 5 hours, but backup generators worked well. The airport was considered as an alternative airfield if flights needed to be diverted from San Francisco or Oakland. The main reason this did not occur was the lack of refueling capabilities at San Jose (rendering takeoff of most of those planes impossible) rather than damage due to the earthquake. No road failures at or near the airport were reported (EERI, 1990). The emergency plan for natural disasters, in place at the time of the earthquake, clearly spelled out procedures relating to duties, communications and inspection procedures. The airport staff feel that the plan worked well, although the minimal damage did not give the plan a thorough test. The staff, therefore, are continuing to use this plan and procedures (D. Chubbic, SJC, personal communication, Sept. 2000).

source –
J. Bray – University of California, Berkeley and U.S. Geological Survey

Significant damage also occurred to the Alameda Naval Air Station. Substantial liquefaction led to the closure of both the 8,000-ft. and 7,200-ft. runways. The terminal building had structural damage and was closed. Other damage occurred to piers, railroad tracts on piers, and the water- and gas-distribution system. The power was not disrupted. The helicopter pads were not damaged and were used during the emergency operation. The two runways were repaired and reopened (one in December 1989 and the second expected in January 1990) (EERI, 1990). However, the facility was closed in 1995 and is now scheduled for non-airport reuse.

source –
J. Villarin,
for California Pilots Association

The Watsonville airport, with two 4,000-ft. runways, had a loss of power and no emergency generators. Thus, flights could not depart at night due to lack of runway lights. Some hanger doors fell from their support rails. However, this airport became a key player in the emergency relief effort. For example, there was an average of 25 military flights per day. In addition, approximately 300 flights were made by light planes on the weekend of October 28-29 (EERI, 1990). A total of about 300,000 pounds of emergency supplies were flown to Watsonville and Hollister during the week following the earthquake utilizing over a hundred small aircraft (J. White, California Pilots Association, personal communication, 2000).

Because of problems at the three commercial airports, flights were diverted to outside of the Bay Area. Sacramento Airport was notified to expect diversions from the Bay Area. It had 256,000 gallons of jet fuel on hand. An emergency recall of fueling staff was ordered to help facilitate fueling aircraft, escorting of vehicles and handling of paperwork (flight plans and fueling paperwork). The second runway and some taxiways were used to park incoming aircraft. No domestic flights at Sacramento were cancelled. Some international flights landed and fueled, these had to keep people onboard the aircraft due to no international facilities available. The airport accepted a total of 40 diversions in the first five hours, at which time Chevron topped off the jet fuel tank farm. There were later occasional fuel diversions during the following week.(S. Soto, Sacramento County Airport System, personal communication, 2000).

No significant damage was reported at smaller airports in the region. Smaller amounts of damage would be expected because these airfields generally have fewer facilities.

1994 Northridge Earthquake

Van Nuys Control Tower had gashes in its siding caused when ¾" thick windows fell.
source –
A. Schiff, 1995

The magnitude 6.7 Northridge earthquake occurred on a fault buried beneath the San Fernando Valley of Los Angeles on January 17, 1994. The three airports in the area with most severe shaking in the Northridge earthquake were closed for runway and taxiway inspections. However, all three were reopened quickly when the inspections were completed and showed no significant damage.

Van Nuys Airport, the general aviation airport closest to the area of highest shaking intensity, had window glass breakage in the control tower (EERI, 1995a). Equipment in that tower slid up to 4 inches. Damage to FAA facilities at the airport control tower totaled about $160,000 (Schiff, 1995).

Burbank Airport, a commercial airport located just east of the fault source zone, was closed for approximately five minutes while the runways and taxiways were inspected. The terminal building was closed for approximately two hours for inspection and to allow cleanup of fallen ceiling tiles (EERI, 1995a).

The Los Angeles International Airport (LAX), located almost 20 miles south of the fault source zone, was closed down for several hours for inspection. Due to a power loss of approximately one hour, the emergency generator power backup was used and functioned. Some ceiling tiles fell, and there were some water leaks at pipe joints (EERI, 1995a).

1995 Kobe, Japan Earthquake

The magnitude 6.9 Hanshin-Awaji (Kobe) earthquake occurred on January 17, 1995 on a 30 – 50 km segment of the Nojima and associated faults (EERI, 1995b). There were three airports in the region affected by the earthquake: the Osaka International Airport, the Kansai International Airport, and the Yao Airport. The Yao Airport is a small general aviation airport and was undamaged in the earthquake. Both the Osaka and Kansai International Airports were slightly damaged. More importantly, they had a large role in the rescue and emergency response phase of the earthquake, particularly due to damage to the main bullet train connecting eastern and western Japan. The following description is summarized from a report prepared by the Editorial Committee on the Hanshin-Awaji Earthquake Disaster (2000). This Committee consisted of the Architectural Institute of Japan, the Japanese Geotechnical Society, the Japan Society of Civil Engineers, the Japan Society of Mechanical Engineers, and the Seismological Society of Japan.

source – Kansai International Airport Web Site

The Kansai International Airport, completed in 1994, serves the Kobe and Osaka region. It was less than a year old at the time of the earthquake. It lies approximately 19 miles (30 km) from the epicenter on a man-made island. Although there was no damage on the outside levees, some cracks were observed on the apron of the water access base. Runways, access ways, and asphalt maintenance aprons had minor cracks approximately 1/8" (2-3 mm) wide. At the time of the earthquake (5:46 am) there was a plane preparing to land. Immediately, the runway was inspected and determined to be safe in spite of the cracking, so that plane was allowed to land at 6:15 am. The cracks were sealed the following night to prevent rainwater from seeping into them. The fuel supply system is equipped for automatic shutoff when shaking exceeds 80 gal (0.08 g). After inspection confirmed the system was safe, it was restarted. Airport buildings had damage to ceilings, hallways and water lines. The rail of the shuttle in the passenger terminal was slightly bent, but service was quickly restored. Minor damage occurred to terminal walkways, expansion joints, escalators, water tanks and light fixtures.

The Itami (Osaka) Airport, the former international airport for the region, now handles domestic flights. It is approximately 6 miles from the most heavily damaged area. Immediately after the earthquake, runways were inspected and many cracks of less then an inch (a few mm) wide were observed. The airport was not closed; the cracks were sealed the following night to prevent rainwater seepage. The control tower and the fire department and power generation buildings had cracks in glass, as well as other areas. The passenger terminal had fallen concrete panels, broken wall panels, damaged roof and ceiling sections, and broken glass. Water lines, toilets, sprinklers, air conditioners, and boarding bridges were damaged. There was some damage to the runway lighting system, but this system was quickly restored.

Due to damage to the rail lines and roads, the number of flights increased significantly between January 17th and April 14th. Additional flights were added at the Itami Airport until 10 p.m. during this period. (Airport service had stopped at 8 p.m. prior to the earthquake.) Helicopters transported emergency relief goods. Those goods were mainly food and drinking water during the first 4-5 days, followed by tents, portable toilets, blankets and heaters for the next 6-10 days, and then clothes and goods for infants. The Itami Osaka Airport accepted domestic relief goods and distributed them via trucks and helicopters to the disaster area. The Kansai Airport accepted both domestic and international relief goods, which were then distributed via trucks, helicopters and ships to the disaster area. Between January 19th and May 10th, about 1,722 tons of goods were transported. The sky over the disaster area was crowded with airplanes from the Japanese self-defense forces, police, fire fighters, and media groups. NATM was provided to control them. The process of obtaining permits to land in non-equipped areas was simplified in order to speed up the transportation of relief goods by helicopter.

The Kobe report notes that the role of air transportation is to provide emergency and alternate transportation, and to contribute to the recovery of the disaster area. Recommendations included:

- seismic reinforcement of current facilities;
- alternate or redundancy for aircraft control facilities;
- establishment of air emergency response and recovery systems; and
- research on earthquake investigation methods.

1999 Turkey Earthquake

source – Istanbul Ataturk Airport Web Site

The magnitude 7.4 Kocaeli earthquake occurred in northwest Turkey, rupturing an approximately 70 mile (110 km) length of the North Anatolian fault system on August 17, 1999. The epicenter was approximately 60 miles (95 km) from Istanbul and 70 miles (110 km) from the Istanbul Ataturk International Airport (IST). The closest extension of the source fault rupture was approximately 50 miles (80 km) from the city center and 60 miles (95 km) from the airport. The peak ground acceleration at the strong motion station nearest the airport was only 0.09 g (USGS, 2000). Because the earthquake source fault was relatively far away and because IST likely experienced low shaking levels, there was minimal damage. Stronger shaking would have damaged the emergency power system (J. Eidinger, personal commications, Sept. 2000). Thus, one should not assume that since a problem did not occur in this earthquake, problems will not occur in the future.

Airport personnel conducted inspections of all runways and aprons following the earthquake prior to allowing any planes to land. When no damage was found, airport operations continued without major delays (A. Tang, personal communication, Sept. 2000). Although more damage to runways might have occurred with higher shaking levels, the runways are ***not*** located in a general area of high liquefaction susceptibility (unlike the Oakland and San Francisco airports on the margins of San Francisco Bay) (J. Bachhuber, personal communication, Nov. 2000).

IST handled over 14 million passengers in 1998 on over 184 thousand flights. In August 1999, international flights were highest on the 19th and 20th with a smaller rise on the 26th and 27th, probably due to international rescue and relief efforts. Cargo operations were also increased due to the increase in foreign aid (A. Tang, personal communication, Sept. 2000). In addition, during the month following the earthquake, there was a significant drop in inbound passenger arrivals over historical seasonal trends, reflecting the 30% to 50% reduction in tourism for the month following the post-earthquake. Outbound departures may have increased after the earthquake, reflecting the shortened vacation plans of tourists and the departure of displaced people (J. Eidinger, personal communication, Sept. 2000).

A new $305 million terminal was under construction when the earthquake occurred. As a result of the earthquake, the decision was made to review the design for the terminal, although construction was 90% complete at the time of the earthquake. Needed changes were made and it was opened in January 2000 (Eng. News Record, 1-17- 2000).

Much less information is available on the performance of the Cengiz Topel Military Airport in Izmit. It appears that there was significant damage to the control tower rendering it unusable. It was further reported that airport operations were reduced as a result of the damage (A. Tang, personal communication, Sept. 2000).

1999 Taiwan Earthquake

The magnitude 7.6 Chi-Chi earthquake occurred in central Taiwan on September 21, 1999. The international airport is located approximately 75 miles (120 km) from the earthquake epicenter and approximately 50 miles (90 km) from the fault source. It was undamaged and functional following the earthquake, enabling it to serve a critical role in the earthquake response and recovery effort.

THE AIRPORT SYSTEM – HOW DOES IT OPERATE?

The Airports

The airport system in the Bay Area consists of three commercial international airports –

- San Francisco International Airport (SFO),
- Oakland International Airport (OAK), and
- San Jose International Airport (SJC).

There are also two military/federal airfields –

- Travis Air Force Base, and
- Moffett (NASA).

In addition, there are several general aviation airports that vary greatly in size. The principal general aviation airports include –

- Hayward (in Alameda County)
- Livermore (in Alameda County)
- Oakland – North Field (in Alameda County)
- Buchanan – Concord (in Contra Costa County)
- Napa County
- Half Moon Bay (in San Mateo County)
- Rio Vista (in Solano County)
- Nut Tree (in Vacaville in Solano County)
- Sonoma County – Santa Rosa

Other significant general aviation airports include –

- Byron (in Contra Costa County)
- Marin County (Gnoss Field)
- San Carlos (in San Mateo County)
- Reid Hillview (in San Jose in Santa Clara County)
- South County (in Gilroy in Santa Clara County)
- Palo Alto (in Santa Clara County)

Airport Usage Statistics

The three major commercial airports serviced 56.6 million passengers on 639,000 total flights in 1999, for an average of 1,750 flights per day. In addition, there were 71,000 cargo flights, or 195 flights per day. SFO handled 66% of the passengers, while OAK handled 76% of the cargo flights (MTC, 2000a). The current airport usage statistics and projections for that usage in the future are shown on Figure 1.

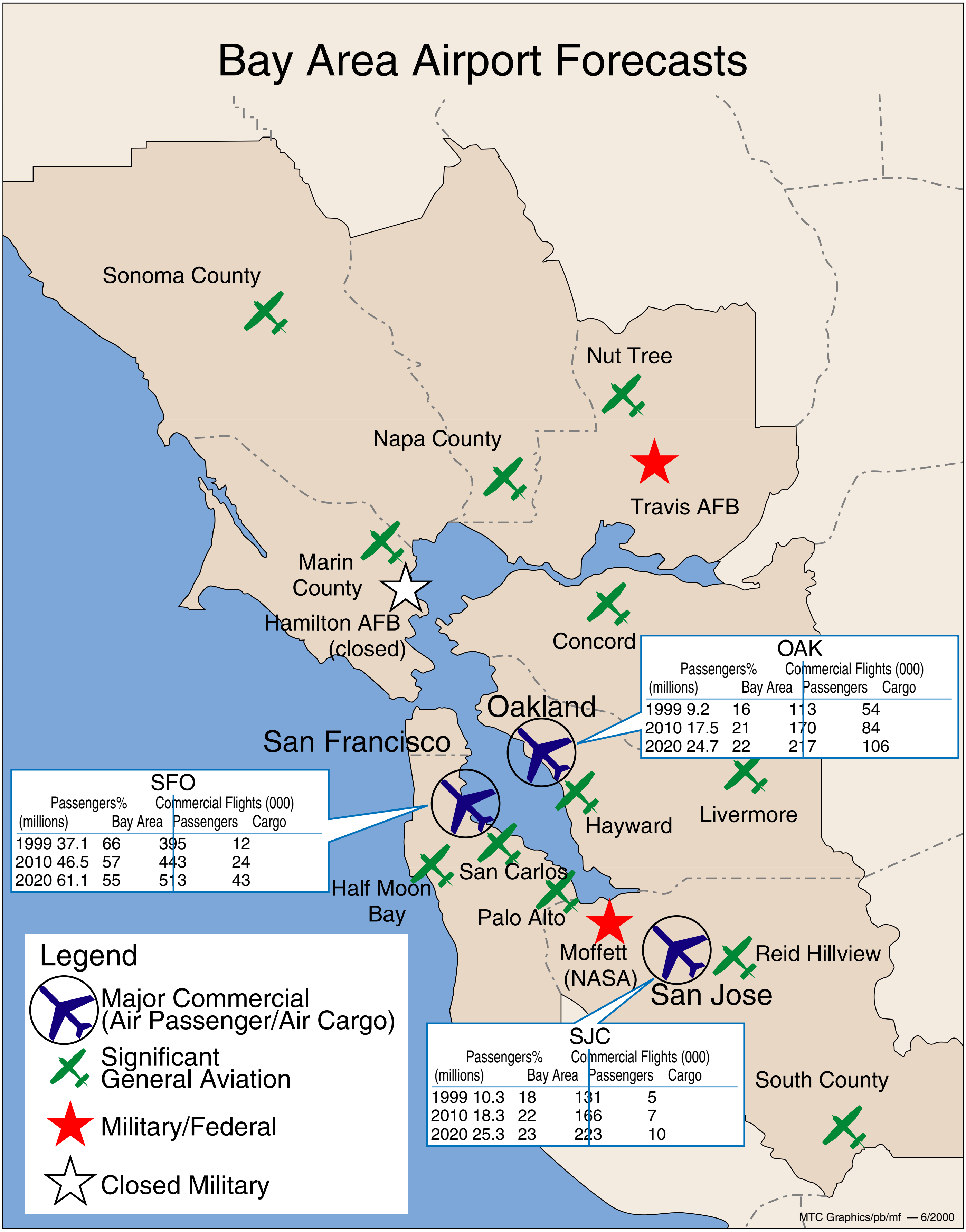
Airport Area Employee Access

Thousands of people work at the region's airports. Table 1, below, provides estimates of airport employees for 1998 – 2020 (MTC, 2000b).

Table 1: Bay Area Airport Employees

	Year		
Airport Name	**1998**	**2010**	**2020**
OAK – Oakland	18,600	21,600	23,000
SFO – San Francisco	29,900	33,100	35,800
SJC – San Jose	13,600	18,300	19,100

Figure 1


Bay Area Airport Forecasts
Sonoma County
Nut Tree
Napa County
Travis AFB
Marin County
Hamilton AFB (closed)
Concord
OAK
Passengers% Commercial Flights (000)
(millions) Bay Area Passengers Cargo
1999 9.2 16 113 54
2010 17.5 21 170 84
2020 24.7 22 217 106
Oakland
San Francisco
SFO
Passengers% Commercial Flights (000)
(millions) Bay Area Passengers Cargo
1999 37.1 66 395 12
2010 46.5 57 443 24
2020 61.1 55 513 43
Hayward
Livermore
San Carlos
Half Moon Bay
Palo Alto
Moffett (NASA)
Reid Hillview
San Jose
SJC
Passengers% Commercial Flights (000)
(millions) Bay Area Passengers Cargo
1999 10.3 18 131 5
2010 18.3 22 166 7
2020 25.3 23 223 10
South County
Legend
Major Commercial (Air Passenger/Air Cargo)
Significant General Aviation
Military/Federal
Closed Military
MTC Graphics/pb/mf — 6/2000

According to the ***Regional Airport System Plan – Update 2000 Airport Access Report*** (MTC, 2000b):

> Currently, the majority of airport employees drive alone to work (71%). The remaining employees either share rides (14%), take public transit (11%) or bike or walk to work (4%). By 2020, the percentages of employees taking these transportation modes are projected to look essentially the same as today.

Thus, any disruption of the road transportation system could seriously impact the commute patterns of airport employees, as well as their availability after an earthquake.

Airline Passenger Access

Similarly, the majority of air passengers get to the three major commercial airports by private car (72%). The vast majority of the remainder take a door-to-door shuttle or taxi (17%), or a private bus, chartered bus, or hotel shuttle (9%). Only 2% ride public transit (MTC, 2000b). The completion of BART to SFO in approximately 2002 may change this pattern. Disruptions of the road transportation system or of BART could seriously impact the ability of these passengers to get to the airport.

Cargo Access Patterns

The third source of airport-related traffic is air cargo trucking. According to the ***Regional Airport System Plan – Update 2000 Airport Access Report*** (MTC, 2000b):

> On an average work week (Monday through Friday) the three airports generate 33,456 air cargo related truck trips to and from the airport… . Daily truck trips were highest at SFO (17,348), followed by OAK (11,765) and SJC (4,344).

Thus, any disruption of the road transportation system also could be expected to seriously impacts air cargo truck traffic and associated flights.

See Appendix A for More Information

A table listing runway facilities for the various airports within the nine Bay Area counties is included as Appendix A. In addition, because of the focus of this project on emergency planning, the table also includes the larger airport facilities in adjacent counties.

THE VULNERABILITIES – WHAT PROBLEMS DO WE EXPECT?

Based on the past experiences described in the previous section, the principal problems that can disrupt airport operations after a future earthquake are:

1. liquefaction damage to airport runways;
2. damage to air control and terminal facilities;
3. power and communications disruptions; and
4. disruptions to the transportation and fuel systems serving the airports.

These problems can result from any of a number of earthquake scenarios on faults shown on Figure 2.

ISSUE 1 – Liquefaction Damage to Airport Runways

When the ground liquefies, sandy materials saturated with water can behave like a liquid, instead of like solid ground. The ground appears to sink or pull apart. Sand boils, or sand "volcanoes," can appear. When this ground "failure" occurs, it can cause damage to paved areas, pipelines, and building foundations. These failures take the form of:

- ✈ flows and lateral spreads (essentially landslides on flat or nearly flat ground next to rivers, harbors, or drainage channels);
- ✈ ground oscillations (or movement of the liquefied layer of ground separately from the surrounding layers);
- ✈ loss of bearing strength (to hold up buildings or hold tanks underground); and
- ✈ settlement and differential (uneven) settlement.

ABAG earthquake hazard maps show portions of all three commercial airports in areas with very high liquefaction susceptibility. Thus, ABAG contracted with William Lettis & Associates (WLA) to prepare a preliminary assessment of the susceptibility of runways at the three major Bay Area airports to earthquake-induced liquefaction – ***Evaluation of Earthquake-Induced Liquefaction Hazards at the San Francisco Bay Area Commercial Airports*** (WLA, 1999). The distribution and magnitude of liquefaction-induced settlement and differential settlement estimated by WLA varies from facility to facility, and across each facility. ABAG staff have assumed that the size of these estimated differential settlements are sufficient to close runways in at least one likely earthquake. These analyses have been supplied to the three commercial airports to aid them when they conduct further studies to characterize the limits and amount of liquefaction-related deformation and to plan for disruptions.

WLA developed preliminary liquefaction hazard maps for each airport (Figures 3 – 5). These maps show areas susceptible to liquefaction and the amount of potential liquefaction-induced settlement (in feet). The hazard maps are based on a separate maximum likely earthquake event for each individual airport, and incorporate conservative assumptions regarding liquefaction susceptibility and subsurface conditions. Therefore, the estimated settlement values likely represent a maximum for any realistic earthquake event in the San Francisco Bay Area based on our current knowledge of how Bay Area faults behave. Additional subsurface information would allow

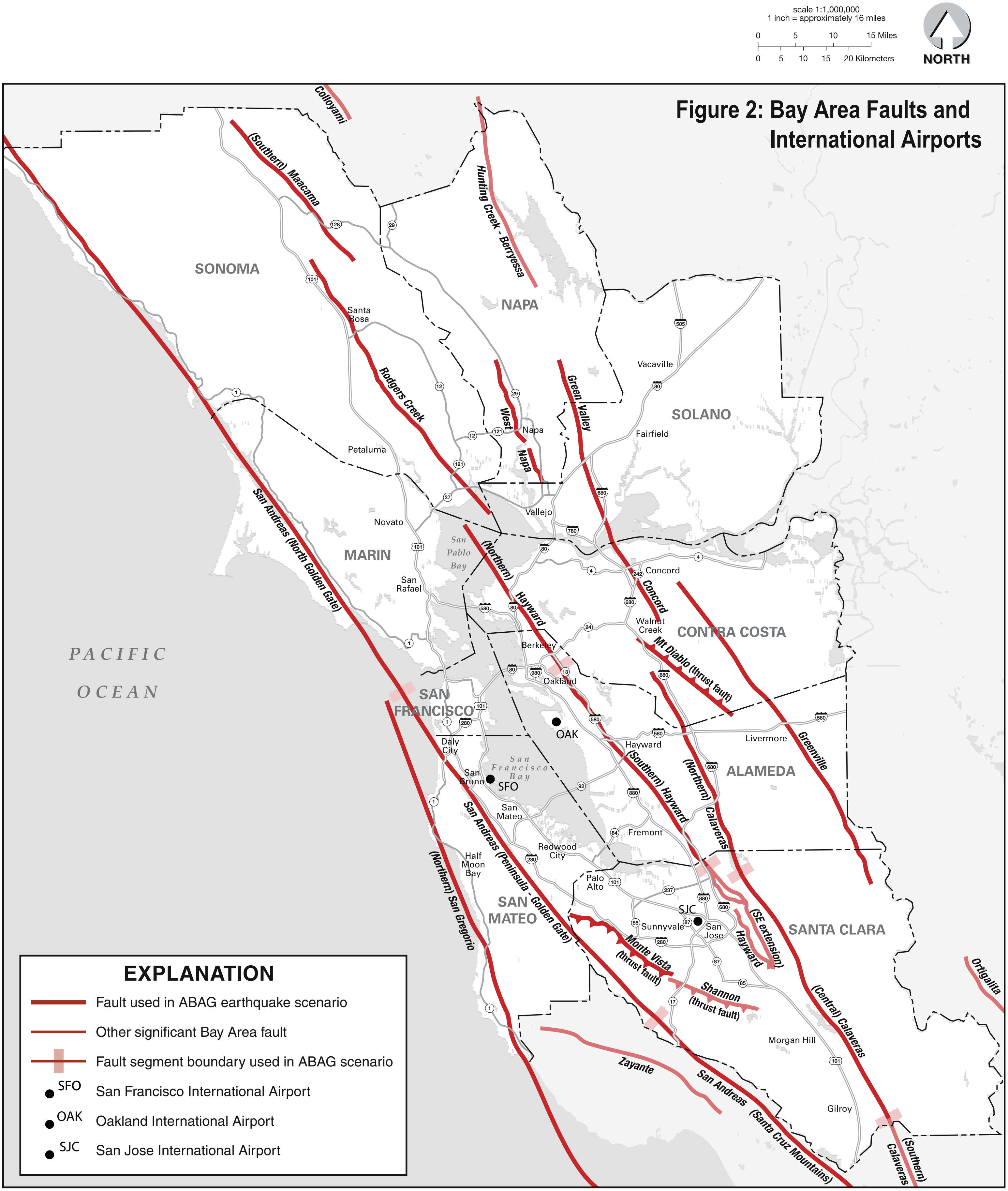


Figure 2: Bay Area Faults and International Airports

ABAG
Source: Association of Bay Area Governments- 2000

Oakland International Airport Liquefaction Susceptibility Due to Particularly Sandy Fill on Bay Mud

The Oakland International Airport (OAK) is susceptible to liquefaction due to its particularly sandy artificial fill overlying Bay mud. In the event of a large earthquake on the Hayward fault, liquefaction-related settlement is estimated to be at least 0.5 ft. across runways, and potential settlement could exceed 1 foot over the northernmost 30-40% of the main runways. Significant differential settlement at OAK is expected along the south and north margins of the runways. Differential settlement likely will be most severe at fill boundaries and along Bay margin levees. This assessment is partly supported by the liquefaction-related damage documented at OAK following the Loma Prieta earthquake.

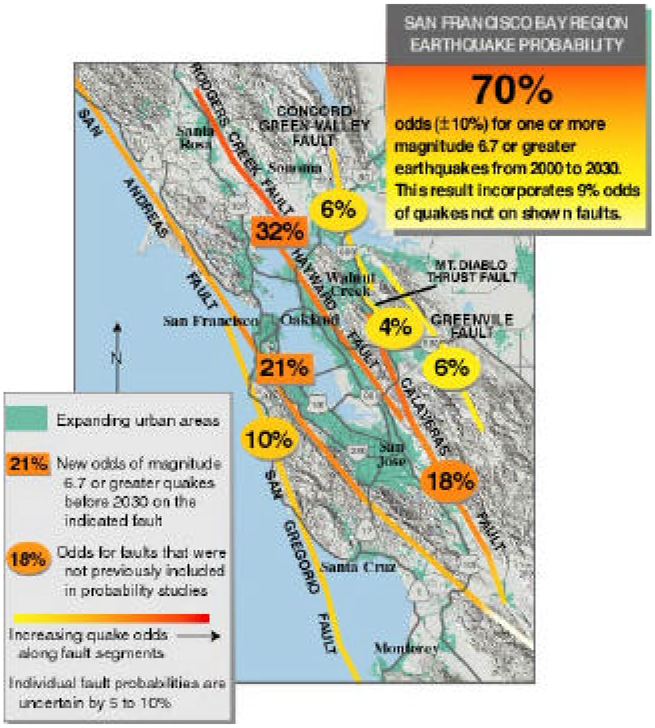
San Francisco International Airport Liquefaction Susceptibility Due to Particularly Thick Fill on Bay Mud

The San Francisco International Airport (SFO) is built on artificial fill that is potentially susceptible to liquefaction. In the event of a repeat of the 1906 San Francisco earthquake, settlement of 0.5 ft. may occur across the entire runway field, and settlements of between 1 and 1.5 ft. may occur under the southeast part of the field. Thickness changes in liquefiable fill are relatively broad at SFO, suggesting that settlement may be spread out, and that the runway field may undergo a general southeastward tilt. The areas that likely present the greatest hazard to the operation of the runways are the fill boundaries crossing the central and southeastern part of the runways, where differential settlement is most likely to occur. ***The SFO liquefaction hazard map (Figure 4) is based on more limited borehole data than the maps for OAK and SJC.***

San Jose International Airport Liquefaction Susceptibility Due to Buried Stream Channels

The liquefaction hazards at San Jose International Airport (SJC) are related primarily to naturally occurring ancient stream channel deposits and localized fills, unlike OAK and SFO that are underlain by broad artificial fills susceptible to liquefaction. A large earthquake on either the San Andreas (such as a repeat of the 1906 San Francisco earthquake) or the Hayward faults could cause total settlements of at least 0.5 feet under the northwestern 20-25% of the runways, with possible localized settlement between 1 and 2 feet under the extreme northern end of the field. The northwesternmost parts of the airport and runways may experience up to 2 ft. of settlement related to liquefaction, and the westernmost runway may settle as much as 1 ft. Extensive differential settlement is expected in the extreme northernmost part of the runways. Lesser amounts of differential settlement may occur over buried creek channels in the north-central and southern parts of the runways.

Likelihood of Liquefaction Damage to Airport Runways



Even airport runways in areas with very high susceptibility to liquefaction will not have a problem unless shaken long and hard enough in an earthquake to trigger liquefaction. Thus, when evaluating the liquefaction hazard, it is extremely important to understand the likelihood of a major earthquake on a fault that is close enough to trigger liquefaction. Using published and unpublished USGS data, ABAG staff estimated the closure probabilities for each commercial airport in the next 30 years as shown in Table 2. Note that these probabilities of closure are approximate.

In addition, for comparison, ABAG estimated the probabilities of closure due to liquefaction for the other airports in the region. The information for the other airports able to accommodate moderate-sized aircraft is also shown in Table 2. With the exception of the three international airports and Oakland Airport's North Field, the liquefaction analysis is based on regional, rather than site-specific information, however. ***The three major airports are among the most vulnerable to liquefaction of any airports in the Bay Area.***

Table 2: Liquefaction Disruption Information

Airport Name	Liquefaction Susceptibility of Runway Area	Approximate Probability of at Least One Airport Closure Due to Liquefaction in the Next 30 Years
OAK – Oakland	**Very High**, somewhat less for shorter North Field runway	**61 %** (Main runways ***and*** longest North Field runway; somewhat less for other North Field runways)
SFO – San Francisco	**Very High**	**18 %**
SJC – San Jose	**Very High**	**33 %** (due to buried stream channels)
Travis Air Force Base	**Low**	Less than **2 %**
Moffett Federal Airfield	**Very High**, somewhat less for inland portion a south end	From less than **2%** (S end) to **50 %** (N end of longer runway)
Hayward	**Moderate**	Less than **2 %**
Livermore	**High**	**4 %**
Buchanan	**High**	**6 %**
Napa Co	**Low**	Less than **2 %**
Half Moon Bay	**Low**	Less than **2 %**
Rio Vista – Solano	**Very High**	Less than **2 %**
Nut Tree – Solano	**Moderate**	Less than **2 %**
Santa Rosa – Sonoma	**Very Low**	Less than **2 %**

TABLE NOTES – See Appendix B for data on other Bay Area airports. **Liquefaction information –** Variations in liquefaction susceptibility at individual airports can be quite large, particularly at Moffett Field. **Probability information –** In 1999, the U.S. Geological Survey (USGS) released revised estimates of the overall probability of a magnitude 6.7 earthquake in the region, as well as the probabilities of earthquakes on each fault system, but not on each fault segment. ABAG used additional preliminary USGS information on the probability of earthquakes occurring on each fault segment(s) to perform this analysis (personal communication, David Schwartz, USGS).

Can Runways Be Made More Liquefaction

The engineering measures usually used to mitigate potential problems due to liquefaction typically require closing runways to perform major ground improvement work. Such efforts are usually not cost effective or feasible unless undertaken as part of a larger runway construction or reconstruction project, such as that underway at San Jose International Airport.

> ***Runway Program at the San Jose International Airport***
>
> SJC is currently extending a shorter runway to create a new full-length (11,000 ft) runway (30R/12L) that should be far less vulnerable to damage because the new pavement section is sufficient to "bridge" the stream channels. Upon completion of this project, the existing full-length runway (30L/12R) will be taken out of service and reconfigured in a similar fashion. Both projects should be completed by 2004.

Is Funding Available for Making Runways More Liquefaction Resistant?

The FAA has funding for assisting airports in various capital improvements. Airport Capital Improvement Plan (AIP) funding is described in U.S. Department of Transportation Federal Aviation Administration Order 5100.38A. Additional information on how priorities are established for distribution of these funds is provided in Order 5100.39A. Although there are no special funds set aside for making runways more liquefaction resistant, FAA will evaluate improvements critical for pavement service life and continued operation of the runways, particularly for SFO, OAK, and SJC. Federal AIP funds pay for 75% of eligible expenses at SFO, and 80.56% of eligible expenses at OAK and SJC. Improvements at the commercial service airports of Buchanan and Santa Rosa/Sonoma are of a lower priority, while funding improvements at general aviation airports are the lowest priority. The FAA will fund 90% of eligible expenses at these other airports, however, if the improvements are deemed a high priority in competing for the limited funds. AIP funds cover 90% of the eligible cost, with emphasis placed on runway rehabilitation projects at general aviation reliever airports. The FAA would review all funding requested following a major earthquake, or at sites suffering from major storm damage due to heavy rains that resulted n subsurface damage or erosion.

For more information, contact Fernando Yanez of the FAA San Francisco Airports District Office at 650/876-2803 or see **http://www.faa.gov/arp/app500/acip/fedfinal.htm**.

See Appendix B for More Information

A table listing general liquefaction hazard information for the runway facilities at the various airports within the nine Bay Area counties is included as Appendix B.

The types of liquefaction hazard information for airport runways provided in this report are more useful for planning purposes than

for design of specific mitigation programs. The information is also useful to provide a comparative analysis of hazards among airports, rather than specific to an individual airport.

ISSUE 2 – Potential Damage to Air Traffic Control and Terminal Facilities

source – Control tower at Anchorage International Airport collapsed in 1964 earthquake – Steinbrugge Collection, Earthquake Engineering Research Center, University of California, Berkeley

source – SFO terminal damage due to Loma Prieta earthquake – R. Wiggins

A second major potential source of airport disruption is damage to air traffic control and terminal facilities. ***A structural analysis of these facilities is beyond the scope of this plan. In general, prior to constructing control and terminal facilities, seismic factors are investigated and new facilities are designed to resist shaking damage.***

However, structural damage in past earthquakes is clearly correlated with the measured intensity of shaking. Thus, for emergency planning purposes, it is useful to know the probability that Bay Area airports may be subject to very violent or violent ground shaking (modified Mercalli intensity (MMI) IX or greater) in the next 30 years. The shaking intensity information is based on the latest version of ABAG's ground shaking maps (Perkins and Boatwright, 1995; Perkins, 1998; Perkins and others, 1999a). As mentioned in the discussion of liquefaction issues, the scenario-specific USGS probability information is preliminary at this time. ***Facility managers at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan and Livermore all need to be particularly concerned about the potential for violent ground shaking when designing new facilities. In addition, a structural assessment of older existing facilities may be warranted.***

In addition, even if the airport itself is not damaged, damage to buildings in the surrounding area may make the functioning of the airport particularly useful immediately after earthquakes, such as for airlifting in critical medical supplies or search and rescue teams. This makes conservative design of facilities at these seven airports particularly important.

Table 3: Shaking Exposure Information

Airport Name	Approximate Probability of Airports Being Exposed to Violent or Very Violent Shaking in the Next 30 Years
OAK – Oakland	**24 %**
SFO – San Francisco	**12 %**
SJC – San Jose	Less than **2 %**
Travis Air Force Base	Less than **2 %**
Moffett Federal Airfield	**23 %**
Hayward	**13 %**
Livermore	**4 %**
Buchanan	**6 %**
Napa Co	Less than **2 %**
Half Moon Bay	**7 %**
Rio Vista – Solano	Less than **2 %**
Nut Tree – Solano	Less than **2 %**

Santa Rosa – Sonoma	Less than **2 %**

TABLE NOTES – See Appendix B for data on other Bay Area airports. **Probability information** – As stated on page 17, ABAG used a combination of published and unpublished probability information as a basis for these estimates.

ISSUE 3 – Power and Communications Disruptions

Another potential threat to airport operations is disruptions to power and communications systems. ***An analysis of the vulnerability of these facilities is beyond the scope of this plan.*** However, as noted earlier, problems with these systems were among the most common in past earthquakes.

One of the reasons for these problems is the complexity of the systems, particularly at large airports. Another is that airports are constantly changing, with various buildings, maintenance facilities, passenger terminals, and operational structures being expanded, moved, and torn down. Thus, the nonstructural and lifeline components of airports, though originally designed to function after an earthquake, may be vulnerable today. A third problem is that these complex systems may have remnants of systems that were designed to standards in effect at the time they were installed, but that would not meet current standards. The system is as vulnerable as its weakest link.

Problems with power and communications systems are particularly disruptive, but can also be easily mitigated, using many of the techniques on page 27.

ISSUE 4 – Disruptions to the Transportation and Fuel Systems Serving the Airports

The final major potential source of airport disruption is damage to the road and highway transportation system that serves the airports. Critical staff (including air traffic controllers) needed to operate the airport may not be able to get to work. Crews and materials (such as gravel and concrete) necessary for airport runway and other repairs may be prevented from or delayed in reaching the airport. After the emergency, airport customers (including travelers and shipping companies) may not be able to get to and from the airport. Transportation disruptions that may impact airport operations are varied.

- ✈ The Oakland International Airport (OAK) is expected to be affected by numerous road closures servicing its facilities in a number of different earthquake scenarios. These scenarios include earthquakes on various segments of the Hayward fault system in the east Bay, as well as on more distant faults. As the highway interchanges in the vicinity of the airport are retrofitted, access problems are being reduced. Remaining critical structures in the vicinity of the airport that are still being retrofitted or waiting for replacement include the I-980 East Connector Viaduct, the Hwy. 24 West Connector Viaduct, the I-880 Distribution Structure, and the I-880/Rte.77/High St./SP Railroad Structure (personal communication, Rebecca Franti, Caltrans, Office of Earthquake Engineering). However, access routes to OAK will continue to be subject to disruption even after all structural retrofits are completed. For example, pipelines are more likely to rupture in areas subjected to liquefaction, and these pipeline ruptures can cause roads to be closed. In addition, OAK access roads are subjected to the threat of increased road closures indirectly due to the effects of amplified ground shaking on buildings, sites containing hazardous materials, and other problems which will continue to affect access to the airport.

- Similarly, the San Francisco International Airport (SFO) is expected to be affected by numerous road closures servicing its facilities in a number of different earthquake scenarios. Since the highway interchanges in the vicinity of the airport have been retrofitted, access problems are reduced. In addition, since most of the faults in the Bay Area are closer to OAK than SFO, the access problems in the immediate vicinity of the airport are less. On the other hand, many of those traveling to SFO cross one or more toll bridges in route to the airport. Thus, to the extent that retrofits on those bridges have not been completed, access problems will remain. Potential road disruptions due to amplified ground shaking will affect access to SFO, but probably not to the extent that OAK is impacted. As with OAK, those problems may include road closures due to building damage, hazardous materials spills, broken pipelines, and other reasons.

- Hayward Airport and Moffett Field, while not experiencing quite as many closures as OAK and SFO, will probably still be affected by several road closures.

- Livermore, Buchanan, and Half Moon Bay airports are only affected by major numbers of road closures should faults immediately adjacent to these facilities rupture. Thus, problems are most severe when the potential role of these airports for emergency response is most critical.

- Roads in the vicinity of San Jose International are also potentially affected, particularly from larger earthquakes on the Hayward and San Andreas faults. However, the extent of these problems is much less severe, and the nature of the road network in the vicinity of the airport makes using alternate routes more practical. Thus, particularly after the completion of the runway improvements discussed on page 18, SJC should be considered a more likely to be functional than either SFO or OAK after a major Bay Area earthquake.

We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should road transportation system disruptions make access to some airports difficult. Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

source –
J. Villarin

One major problem may be fuel. Both SFO and OAK have jet fuel delivered to their facilities via the ***same*** jet fuel pipeline. SJC, however, depends on fuel being trucked to the facility over roads which may be damaged. General aviation airports also have fuel trucked to their facilities. Disruptions in truck-based refueling over damaged roads, as well as with disruptions to fuel pipelines, should be considered in emergency planning. These plans should also discuss jet fuel supply issues should refinery sources be disrupted. Again, implementing many of the mitigation strategies on page 27 may be useful.

THE AIRPORT SYSTEM IN AN EMERGENCY – WHAT ARE OUR CURRENT PROCEDURES?

By definition, an earthquake, like any disaster, disrupts the normal way in which business is conducted. There are, however, plans by various airports and airport users on how airports will and should be used after an earthquake. The current system contains plans, both formal and informal, of:

- the Federal Aviation Administration;
- the three major international airports;
- other airports (including general aviation, out-of-region, and military/federal airports); and
- airport users (including passenger carriers, air cargo carriers, disaster services providers, and businesses).

This section summarizes the extent of those activities in 2000.

Federal Aviation Administration (FAA)

The Federal Aviation Administration (FAA) has responsibility for the management of the nation's air traffic system. The Airports Division of FAA works with the Air Traffic, Flight Standards, Airways Facilities and Logistics Divisions to provide for the installation and maintenance of federal navigational equipment and Air Traffic Control facilities. FAA works with City and county governments to construct airport runways, taxiways, and airport terminal facilities, and provides for the management of airport transportation on a daily basis (J. Rodriguez, FAA, personal communication, 2000).

The Airports Division of the FAA keeps a record of airport facilities and emergency services contacts. In the event of a serious earthquake, the San Francisco Airports District Office will conduct a survey of the airport facilities to assess damages and the need for federal funding for repairs for runways/taxiways, airport access roads, and terminal/cargo facilities. The public agencies that own and operate airports will be requested to submit grant applications for reconstruction projects. Funding priority will be given to runway/taxiway repairs and terminal areas needed to move passengers, airfreight, and the U.S. mail (J. Rodriguez, FAA, personal communication, 2000).

Bay Area International Airports

The three international airports are required by the Federal Aviation Administration to prepare emergency plans. These three plans include earthquake procedures. The specificity of those procedures, and the exact nature of those procedures, varies from airport to airport. In one case, the plan contains extensive checklists for use by airport personnel. The checklists streamline the decisions of personnel as they confirm the operational status of the FAA air traffic control tower, fire station, runway surfaces and lighting, taxiway surfaces and lighting, signage, utilities (power, gas, propane, communications, water, generators, and fuel farm), access routes, and medical support resources. In another case, the plan focuses on coordination with other agencies, administrative procedures, procedures for the care and sheltering of passengers and employees, and medical issues. In the third case, the emphasis of the earthquake portion of the plan is on duck-cover-hold procedures, as well as on evacuation procedures.

The difficulty in writing an emergency plan results, in part, from the four roles of that planning in an earthquake disaster:

- to protect employee and public safety during an earthquake (such as by the use of duck-cover-hold emergency procedures);
- to provide for employee and public safety in the immediate aftermath of the earthquake (such as plans for the medical care, feeding and sheltering on site of airport employees and passengers);
- to ensure the most rapid return of the airport to a status where the airport can be used for the dispatch and delivery of emergency personnel and materials; and
- to ensure the most rapid return to full operational status by the airport.

The existing plans could all be improved and expanded with more extensive coordination among the three Bay Area airports, as well as with airport users, general aviation airports, military and federal airports, and airports outside the Bay Area.

General Aviation Airports

General aviation airports are not subject to the same requirements for emergency plans that FAA requires of the commercial airports. However, as facilities owned and operated by local governments, they are, or should be, involved in emergency planning with the local government that owns them. There is typically not a separate emergency plan prepared for the airport facility. These airports, however, have a longer history of collaborative planning with other general aviation airports than the larger airports. Thus, they understand the benefits of working together to define creative solutions for mutual problems.

source –
J. McCloud
for California Pilots Association

These airports have nighttime staffing issues that are more significant than with larger commercial airports (G. Petersen, San Mateo County Airports Manager, personal communication, 2000).

In addition, several Bay Area general aviation airports have been involved in airlift operations in past earthquakes and are familiar with the process. For example, after the 1989 Loma Prieta earthquake, approximately 300,000 pounds of emergency supplies were flown to the Watsonville and Hollister airports from the Hamilton Field, Buchanan, and Reid Hillview airports (J. White, California Pilots Association, personal communication, 2000).

Out-of-Region Airports

Out-of-region commercial airports include Sacramento International Airport (SMF), Mather Field (MHR), Stockton, and Monterey. Sacramento County handles both SMF and Mather Field MHR. SMF is commercial airport with limited customs and immigration services. MHR, however, is not certified to handle passenger aircraft. Five major cargo companies use it. These two airfields, even when combined with Stockton Airport, do not have the capability of handling the 80 – 100 flights per hour currently handled by the three major Bay Area airports (OAK, SFO, and SJC). Depending on the time of day, these out-of-region airports could expect to be saturated within the first two hours of a major earthquake in the Bay

Area. Thus, major airport closures could expect to cause flight changes throughout the western portions of the country (S. Soto, Airport Firefighting and Airports Operations, Sacramento County, personal communication, 2000).

In an emergency, the first actions of these airports will be to ensure that they can be safely operated. Thus, they plan to move emergency equipment into open areas, dispatch units to survey damage, and prepare for aftershocks. If damage occurs, priority will be given to lifesaving efforts, call for medical help as needed, and fire suppression action. As victims are searched for, they anticipate that they may be involved in light rescue operations and may need to call for heavy equipment to rescue trapped victims. The airports will use mutual aid as needed, and use the airport paging systems for self-help instructions. Finally, the airports plan to establish access controls, organize multi-purpose staging areas, and set up for cargo aircraft relief operations.

Travis Air Force Base

At Travis Air Force Base, the priority is their wartime mission to support military operations. However, a commercial aircraft declaring an in-flight emergency may land at Travis AFB. In addition, civil authorities may designate Travis AFB as a base support installation and FEMA Mobilization Center. The rail lines servicing the base enhance the usefulness of the facility. In these instances, the facility will respond to a top-down request for support from FEMA. The AFB has begun to participate in disaster exercises. This has been a change in directive from the top air force command at the base (Lt. Col. R. Sandico, Travis Air Force Base, personal communication, 2000).

Air Cargo Carriers

The cargo carriers are challenged even on a normal business day to get goods delivered in the Bay Area due to the overstressed transportation network. An earthquake would make many transit corridors unavailable. Given the “just-in-time” nature of business, companies now count on their cargo carriers to be a “mobile warehouse” for them. The package is not in the back room, but in the back of a truck coming to them. Thus, it is that much more important for cargo carriers to be in business after a disaster. Cargo carriers use the full transportation network, including airports, roads, and rail lines.

UPS has been a leader in developing a plan for earthquake response and recovery. Their first priority is to protect employees and their families through drills, communications networks, meeting and evacuation points, and training for safety. The communications system includes radios for communications with employees at airports in and outside the region. Their second priority is to protect business assets, including securing computers to desktops, retrofitting hazardous older buildings, and working with customers to minimize their business disruption. Their third priority is to help the community they serve. In northern California, UPS plans to assist the Red Cross in logistics and with emergency support vehicles for the first 7 – 10 days after a major earthquake. An unprepared business may join the list of victims of the disaster. UPS plans to be a prepared business and to be a resource for the community in time of need (D. Bullert, UPS, personal communication, 2000).

The principal concern of a cargo carrier should an airport be shut down is how that carrier can get to their equipment so that they can go to an alternate airport. A secondary concern is setting up an alternate service network using a combination of alternate airports (such as Mather), alternative rail yards (such as Stockton rather than Richmond), and ground transportation.

Airline Passenger Carriers

The passenger carriers have goals similar to the cargo carriers, for they want to protect their employees and their assets, as well as to serve the community. However, they have the additional concern that their "cargo" is people. The disaster created by an earthquake may be one of the most stressful, emotionally challenging, and physically exhausting events we will ever experience. The stresses on carrier employees are particularly intense as they struggle to meet the needs of the passengers. Thus, carriers such as Southwest Airlines have developed guidelines for making the necessary decisions in an emergency. These guidelines have been provided to all carrier employees (C. Enriquez, Southwest Airlines, personal communication, 2000).

Some airlines view their responsibility to deliver passengers to an airport, not to care for and feed those passengers if they are stranded. This issue needs to be addressed with collaborative planning among airports, passenger carriers, and disaster relief agencies.

To the extent that passenger flights are diverted to other airports, these carriers may be dependent on road-based transit to deliver passengers to their destination.

Bay Area Red Cross and Other Disaster Service Providers

source – American Red Cross, Bay Area Chapter

The disaster service providers currently expect the airports and airlines to service the needs of stranded passengers and employees, particularly for the first few days. For a Hayward scenario event, they will need to move about 10,000 people into the affected area for logistics, mass care, mental health, family services, public affairs, and health services support in the first 7 – 10 days. In addition, they plan to move medical supplies, communications equipment, computer equipment, and mass care support supplies into the area (J. Cahill, American Red Cross – Bay Area, personal communication, 2000).

Major airport and road closures are also assumed. Therefore, initially, local logistics workers inside the Bay Area will support the Red Cross effort to the best of their ability and operate autonomously. Marshalling is planned to occur in Reno next to the airport, with a closer material mobilization center and staging area in the Sacramento area. A staff mobilization center is planned for the Stockton area. The Red Cross plans to open a staff reception area in the vicinity of Los Angeles area airports, and then people would be bused to Stockton if airports at Stockton and Sacramento were unavailable. East Bay activities might be supported with a mobilization center in the Stockton-Tracy area, for this area has both port and airport facilities which might be used. At the present time, West Bay activities might be supported by opening a logistics center at Moffett Federal Airfield. In past disasters, the Red Cross has brought in supplies by air to

Moffett and stored them there until they can be separated and redistributed. However, as the air museum at Moffett expands, this space may not be readily available. In addition, potential problems with runways discussed earlier may make use of this facility impractical. Travis AFB is being looked at as an alternate. The Red Cross is dependent on commercial shipping; food and other materials are typically trucked. The Red Cross hopes to continue to develop planning relationships with the airports, developing a liaison network which is useful to both the airports and the Red Cross, and integration of the American Red Cross needs into airport priorities (J. Cahill, American Red Cross – Bay Area, personal communication, 2000).

Business Users

As stated earlier when describing the role of cargo carriers, businesses have concerns about building and shipping and products. A typical manufacturing business relies on supplies from multiple companies that are trucked to the manufacturing facility. In the high-tech business environment of the San Francisco Bay Area, many of those parts are delivered as airfreight. That facility then adds value by creating a more complex and complete product. Those products are then sent throughout the world for distribution. Thus, there is a highly complex "supply chain" network system just to build and distribute one product. Typical disruptions in this network include:

- problems with information (such as data inconsistencies);
- operational delays (such as a delay in delivery of parts similar to the world-wide impact of the 1999 Taiwan earthquake on computer circuits); and
- strategic issues (such as how to set up a design system to meet customer demands).

Information technology businesses in the Bay Area get supplies from all over the world, and distribute product throughout the world. Airport cargo is an integral part of the logistical system. Companies such as Agilent Technologies have a plan for what to do after a disaster, such as an earthquake, but realize that the success of that plan is highly dependent on the particular affects of any earthquake (M. Ronstadt, Agilent Technologies, personal communication, 2000). Back-up shipping systems include use of barges to get product to and from airports, use of helicopters, and use of alternate airports outside of the region, such as Sacramento. Smaller businesses are typically not as sophisticated with their emergency planning as larger companies. They may easily experience disruptions in communications that cause them to be unable to contact airports, their suppliers, and their distributors.

Businesses have several concerns after an earthquake related to product being shipped. Where is the product in the distribution channel? Can the product be expected to reach the customer? What kind of shape is the product in? If it is damaged, can you get it back to the manufacturer? Where will the product be held? Although there will be some delay that is expected in the distribution system, it will not be long before cargo customers will expect service to return to normal to allow the economy to return to normal.

IDEAS FOR ACTION – HOW CAN WE BETTER PLAN?

The following checklist is expanded from recommendations contained in ABAG's report, ***Riding Out Future Quakes – Ideas for Action*** (Perkins and others, 1998). The recommendations focus on ways to keep providing transportation services following earthquakes, as well as how to plan around expected transportation interruptions. As such, they are useful in airport operations.

Airport Checklist

Employees

- ☐ work with employees to set up alternative routes from their homes to key facilities and offices in an emergency
- ☐ plan alternative shifts and/or crews since maintenance workers can be overworked
- ☐ cross-train employees to allow for some workers being unable to reach your facilities in a timely manner due to transportation disruptions
- ☐ make efforts to ensure safety to crews working on repairs, for they may be close to other damage

Operations

- ☐ *general* - evaluate the extent to which general aviation and military airports could accommodate commercial aircraft in an emergency
- ☐ *roads* - work to keep open surface roads in and out of your facility routinely maintained by your agency
- ☐ *supplies* - ensure that you have stocked your operations center with food, water and sanitation systems to allow for disruptions
- ☐ *fuel* - connect fuel pumps at vehicle yards to a backup power system
- ☐ *fuel* - ensure adequate fuel supplies should restocking of fuel supplies be delayed due to transportation disruptions, breaks in fuel pipelines, or refinery source disruptions (including fuel for ground-based vehicles)
- ☐ *power* - provide, anchor and test back-up power equipment, such as batteries
- ☐ *power* - size fuel supply tanks for emergency generators; power outages may be longer than expected
- ☐ *communications* - provide, anchor and test back-up equipment, such as portable radios and relay towers
- ☐ *water* - install back-up supplies on-site and anchor tanks
- ☐ *equipment* – work to ensure that all equipment and non-structural items are appropriately anchored, particularly in control towers
- ☐ *pipelines* - design on-site utility lines to minimize risk of pipeline breaks
- ☐ *pipelines* - create and isolate shorter segments of pipelines to facilitate repairs by installing additional valves; maintain those pipelines and valves

Site Hazards

Mitigate the exposure of your facilities to various earthquake hazards described in this plan, including:

- ☐ *liquefaction and/or differential settlement* – in particular, work to minimize the likelihood of closed runways due to pavement buckling by undertaking ground improvement mitigation as part of larger runway construction or reconstruction projects
- ☐ *violent shaking* – assess and mitigate structural deficiencies, particularly in older facilities designed and constructed using less stringent building codes

Emergency Plans

Ensure that the emergency plan for your facility covers the four roles of that planning process in an earthquake disaster:

- to protect employee and public safety during an earthquake (such as by the use of duck-cover-hold emergency procedures);
- to provide for employee and public safety in the immediate aftermath of the earthquake (such as plans for the medical care, feeding and sheltering on site of airport employees and passengers);
- to ensure the most rapid return of the airport to a status where the airport can be used for the dispatch and delivery of emergency personnel and materials; and
- to ensure the most rapid return to full operational status by the airport.

Existing airport emergency plans could be improved and expanded with more extensive coordination among the three Bay Area international airports, as well as with airport users, general aviation airports, military and federal airports, and airports outside the Bay Area.

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APPENDIX B - Airport Liquefaction Hazard and Access Vulnerability

Runway Able to Accommodate Large Aircraft
Length Over 7,500 ft; Can Accommodate Single Wheel Aircraft Over 50,000 lbs

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Alameda	Oakland	Oakland Intl Arprt, South Field	OAK	11/29	Very High	61%	24%
San Mateo	San Bruno	San Francisco International Airport	SFO	01R/19L	Very High	18%	12%
San Mateo	San Bruno	San Francisco International Airport	SFO	10L/28R	Very High	18%	12%
San Mateo	San Bruno	San Francisco International Airport	SFO	10R/28L	Very High	18%	12%
Santa Clara	San Jose	San Jose International Airport	SJC	12R/30L	Very High	33%	less than 2%
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	14L/32R	Very High	50% at Bay end	23%
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	14R/32L	Very High	50% at Bay end	23%
Solano	Fairfield	Travis Air Force Base	SUU	03L/21R	Low	less than 2%	less than 2%
Solano	Fairfield	Travis Air Force Base	SUU	03R/21L	Low	less than 2%	less than 2%

Runway Able to Accommodate Moderately Large Aircraft
Length Over 5,400 ft; Can Accommodate Single Wheel Aircraft Over 25,000 lbs

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	09L/27R	Very High	61%	24%
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	09R/27L	Very High	61%	24%
Napa	Napa	Napa County Airport	APC	18R/36L	Low	less than 2%	less than 2%
San Mateo	San Bruno	San Francisco International Airport	SFO	01L/19R	Very High	18%	12%

Runway Able to Accommodate Medium-Sized Aircraft
Length Over 3,300 ft; Can Accommodate Single Wheel Aircraft Over 20,000 lbs

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Alameda	Hayward	Hayward Executive Airport	HWD	10R/28L	Moderate	less than 2%	13%
Alameda	Livermore	Livermore Municipal Airport	LVK	07L/25R	High	4%	4%
Contra Costa	Byron	Byron Airport	C83	12/30	Low	less than 2%	less than 2%
Contra Costa	Concord	Buchanan Field	CCR	01L/19R	High	6%	6%

Runway Able to Accommodate Medium-Sized Aircraft (continued)
Length Over 3,300 ft; Can Accommodate Single Wheel Aircraft Over 20,000 lbs

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Contra Costa	Concord	Buchanan Field	CCR	14L/32R	High	6%	6%
Napa	Napa	Napa County Airport	APC	06/24	Low	less than 2%	less than 2%
San Mateo	Half Moon Bay	Half Moon Bay Airport	HAF	12/30	Low	less than 2%	7%
Santa Clara	San Jose	San Jose International Airport	SJC	11/29	Very High	33%	less than 2%
Santa Clara	San Jose	San Jose International Airport	SJC	12L/30R	Very High	33%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	07/25	Very High	less than 2%	less than 2%
Solano	Vacaville	Nut Tree - Solano County Airport	VCB	02/20	Moderate	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	01/19	Very Low	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	14/32	Very Low	less than 2%	less than 2%

Runway Able to Accommodate Small Aircraft

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Alameda	Hayward	Hayward Executive Airport	HWD	10L/28R	Moderate	less than 2%	13%
Alameda	Livermore	Livermore Municipal Airport	LVK	07R/25L	High	4%	4%
Alameda	Livermore	Meadowlark Field Airport	23Q	07/25	Low	less than 2%	6%
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	15/33	High	61%	24%
Contra Costa	Brentwood	Funny Farm Airport (Brentwood Arprt)	4CA2	17/35	High	less than 2%	less than 2%
Contra Costa	Byron	Byron Airport	C83	12/30	Low	less than 2%	less than 2%
Contra Costa	Concord	Buchanan Field	CCR	01R/19L	High	6%	6%
Contra Costa	Concord	Buchanan Field	CCR	14R/32L	High	6%	6%
Marin	Novato	Marin County Airport (Gnoss Field)	DVO	13/31	High	33%	33%
Marin	San Rafael	San Rafael (Smith Ranch Airport)	CA35	04/22	Very High	47%	23%
Napa	Angwin	Angwin-Parrett Field Airport	2O3	16/34	Very Low	less than 2%	less than 2%
Napa	Napa	Moskowite Airport	41Q	03/21	Very Low	less than 2%	less than 2%
Napa	Napa	Napa County Airport	APC	18L/36R	Low	less than 2%	less than 2%
Napa	Pope Valley	Mysterious Valley Airport	69Q	14/32	Low	less than 2%	less than 2%
Napa	Pope Valley	Pope Valley Airport	Q91	10/28	Low	less than 2%	less than 2%
San Mateo	San Carlos	San Carlos Airport	SQL	12/30	Very High	37%	12%
Santa Clara	Palo Alto	Palo Alto Airport of Santa Clara CO	PAO	12/30	Very High	50%	12%

Runway Able to Accommodate Small Aircraft (continued)

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Santa Clara	San Jose	Reid-Hillview Airport	RHV	13L/31R	Moderate	less than 2%	less than 2%
Santa Clara	San Jose	Reid-Hillview Airport	RHV	13R/31L	Moderate	less than 2%	less than 2%
Santa Clara	San Martin	South County Airport	Q99	14/32	Low	less than 2%	less than 2%
Solano	Cordelia	Garibaldi Brothers Airport	6Q2	06/24	Low	less than 2%	6%
Solano	Dixon	Maine Prairie Airport	Q33	16/34	HIgh	less than 2%	less than 2%
Solano	Fairfield	Travis AFB Aero Club	8Q0	04/22	Low	less than 2%	less than 2%
Solano	Fairfield	Travis AFB Aero Club	8Q0	16/34	Low	less than 2%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	14/32	Very High	less than 2%	less than 2%
Solano	Vacaville	Blake Sky Park Airport	CA57	17/35	Low	less than 2%	less than 2%
Sonoma	Cloverdale	Cloverdale Municipal Airport	O60	14/32	High	less than 2%	less than 2%
Sonoma	Healdsburg	Healdsburg Municipal Airport	O31	13/31	Very Low	less than 2%	less than 2%
Sonoma	Petaluma	Petaluma Municipal Arprt (Skyranch)	O69	11/29	Moderate	less than 2%	20%
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	E/W	Very Low	less than 2%	less than 2%
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	N/S	Very Low	less than 2%	less than 2%
Sonoma	Sonoma	Sonoma Skypark	0Q9	08/26	Very Low	less than 2%	less than 2%
Sonoma	Schellville	Sonoma Valley Airport	0Q3	07/25	Low	less than 2%	less than 2%
Sonoma	Schellville	Sonoma Valley Airport	0Q3	17/35	Low	less than 2%	less than 2%
Sonoma	The Sea Ranch	The Sea Ranch Airport	CA51	12/30	Very Low	less than 2%	less than 2%

Helipads

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Alameda	Hayward	Hayward Executive Airport	HWD	Helipad	Moderate	less than 2%	13%
Napa	Rutherford	River Mdw Frm Hlprt/Inglenook Rnch	7CA9	Helipad H1	Moderate	less than 2%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Helipad H1	Very High	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	Helipad	Low	less than 2%	less than 2%