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The San Francisco Bay Area is subject to large disasters, including earthquakes, wildfires, and floods. However, catastrophic earthquakes are the largest threat to the region (consisting of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma counties). The Bay Area airport system includes three international airports, two commercial airports, and dozens of general aviation airports. All of these airports are key resources, as well as key transportation and logistics nodes, in emergency response and recovery. These roles continue during both immediate post-disaster recovery and long-term economic recovery of the region. However, the roles will be impacted and modified based on damage to associated surface transportation systems, utilities (telecommunications, power, fuel, water, wastewater), and support personnel, equipment and supplies. Thus, it is important that airport regulators, airports, and airport users share the same understanding of what could be asked of the aviation system to support disaster response and recovery. This report describes those understandings by identifying: A potential role for commercial and general aviation airports during the three disaster phases as expressed by local government organizations operating within the Bay Area; Actual roles of airports in several recent disasters, based on a review of the literature as well as interviews with airport operators and others involved with those airports at the time of the disasters and during long-term recovery; Recommendations of actions that could be taken by airports to ensure that they can more quickly recover from an incidents, increase their value to regional response actions in future disasters using potential performance improvements, adding mechanisms to speed repair of any damage to airport facilities or to infrastructure serving those facilities, and opportunities for improved coordination.

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ROLES OF AIRPORTS IN REGIONAL DISASTERS:

Lessons on Disaster Response, Short-Term Disaster Recovery, and Long-Term Economic Recovery for the San Francisco Bay Area

Prepared by Jeanne B. Perkins, Jeanne Perkins Consulting
under contract with
the Association of Bay Area Governments (ABAG)

January 13, 2015

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration, the Federal Aviation Administration, the Federal Emergency Management Agency, the State of California, Caltrans, Office of Emergency Management or Caltrans, Division of Aeronautics. This publication does not constitute a standard, specification or regulation.

Cover Photos – J. Perkins

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INTRODUCTION

The San Francisco Bay Area is subject to large disasters, including earthquakes, wildfires, and floods. However, catastrophic earthquakes are the largest threat to the region (consisting of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma counties). The Bay Area airport system includes three international airports, two commercial airports, and dozens of general aviation airports. All of these airports are key resources, as well as key transportation and logistics nodes, in emergency response and recovery. These roles continue during both immediate post-disaster recovery and long-term economic recovery of the region. However, the roles will be impacted and modified based on damage to associated surface transportation systems, utilities (telecommunications, power, fuel, water, wastewater), and support personnel, equipment and supplies. Thus, it is important that airport regulators, airports, and airport users share the same understanding of what could be asked of the aviation system to support disaster response and recovery. Some of these roles could include:

- During regional disaster response – support operations such as
  - airborne search and rescue;
  - medical evacuation;
  - moving emergency medical supplies and emergency personnel;
  - firefighting and law enforcement;
  - damage assessment and resource needs assessment, particularly related to other critical infrastructure and hazardous materials incidents;
  - media and VIP transport;
  - their impact on public safety and health due to any expansion of their normal role;
  - their impact due to any reduction in that expected role due to damage to the airport structures, runways, or infrastructure), and
  - changes in passenger and cargo operations.
- During short-term disaster recovery – such as interdependencies with infrastructure systems that have delayed airport recovery in recent disasters.
- During long-term recovery – such as the role of international, commercial and general aviation airports in the regional economy based on the changes to that role that occur due to damage (or lack of damage) to airport facilities or infrastructure.

This report describes those understandings by identifying:

1. A potential role for commercial and general aviation airports during the three disaster phases listed above, as expressed by local government organizations operating within the Bay Area, as well as disaster providers and other users of airports.
2. Actual roles of airports in several recent disasters, based on a review of the literature as well as interviews with airport operators and others involved with those airports at the time of the disasters and during long-term recovery.

3. Recommendations of actions that could be taken by airports to ensure that they can more quickly recover from an incidents, increase their value to regional response actions in future disasters using potential performance improvements, adding mechanisms to speed repair of any damage to airport facilities or to infrastructure serving those facilities, and opportunities for improved coordination with and within the regional airport system.

PART 1:

CURRENT PLANNING AND UNDERSTANDING OF THE ROLE OF INTERNATIONAL, COMMERCIAL AND GENERAL AVIATION AIRPORTS IN DISASTERS

By definition, a disaster disrupts the normal way in which business is conducted. There are, however, plans by various airports and airport users on how airports might be used after an earthquake, a wildfire, or other disaster. The current system contains formal written plans, as well as unwritten assumptions, of:

- The US Department of Homeland Security and FEMA;
- the Federal Aviation Administration (FAA);
- the three major international airports; and
- other airports (including two other Bay Area commercial airports, as well as numerous general aviation, out-of-region, and military/federal airports).

In addition, various airport users (including passenger carriers, air cargo carriers, disaster services providers, businesses or aviation enthusiasts) have their own understanding of airport recovery efforts, both before and after disasters, which could impact their disaster planning efforts. Some of these understandings may not be feasible for an airport to carry out, others may be outside that airport or airport operator's limits of authority, or are already handled by other agencies unbeknownst to those outside the emergency management community.

Finally, this section summarizes planning for disasters by these entities as of early 2013 and identifies three possible gaps in that planning:

- lack of regional examination of the role of airports in long-term regional economic recovery;
- prior lack of regional examination of the role of smaller commercial and general aviation airports; and
- lack of regional continuity in staffing of disaster and recovery planning.

FEDERAL AND AIRPORT EFFORTS

US Department of Homeland Security

The US Department of Homeland Security defines 18 areas of critical infrastructure, one of which is aviation. Homeland Security Presidential Directive 5 (HSPD-5) directs that the Secretary of Homeland Security develop and administer a consistent nationwide Incident Management system that would enable all levels of government and the private-sector to work together during domestic incidents. The National Incident Management System (NIMS) identifies the Incident Command System (ICS) as the method that will be used to manage incidents, events, emergencies and disasters.

FEMA's National Incident Management System (NIMS) guidance document notes that a designated Air Operations Branch of the Operations Section of ICS can be useful. "The Operations Section Chief may establish an Air Operations Branch and designate its director, when the complexity of air operations during response activities requires additional support and effort or when the incident requires mixing tactical and logistical utilization of helicopters and other aircraft. Aviation safety is a paramount concern in complex operations, and a designated Air Operations Branch ensures the safe and efficient use of aviation resources."[1]

Consistent with the above guidance, the Governor's Office of Emergency Services (Cal OES) is in the process of completing an Air Coordination Group (ACG) Concept of Operations (CONOP) plan. The purpose of the CONOP is to outline a general understanding of how emergency aviation will be supported by federal and State partners once Cal OES activates the ACG. The CONOP was prepared by multiple emergency aviation stakeholders who comprise the California Air Coordination Group (CACG), under guidelines established within federal Emergency Support Function and California Emergency Function 1 – Transportation (ESF/EF 1). Subsequent maturation of the ACG will continue within the framework of ESF/EF 1. [2]

Key aviation resources include airports (commercial, military, and general aviation), the air traffic control systems, aircraft and planes (including those used for commercial passengers, air cargo, and general aviation), and connections with other key aviation resources, and critical personnel, including pilots, ground support, and air traffic controllers. However, planes and people can be moved, airports are fixed assets.

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[1] See FEMA (December 2008). *National Incident Management System*, pages 101-102 at http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf for more information.

[2] Source of CONOP information: Derek Kantar, Associate Aviation Planner, Caltrans Headquarters, Division of Aeronautics, personal communication, August 2014.

FAA Emergency Preparedness Requirements

FAA requires each 14 CFR Part 139 Certified Airport to have an Airport Emergency Plan (AEP) that addresses specific types of disasters (air crash accident, bomb threat, sabotage/hijacking, natural disasters, hazardous materials, structure fires, mass casualty care, evacuation, water rescue, and power failures). Part 139 Certified Airports in the nine-county Bay Area (together with their class and Aircraft Rescue and Firefighting (ARFF) index as of May 13, 2013) include:

- SFO – San Francisco International – Hub, Class I / E
- SJC – San Jose International – Class I / C
- OAK – Oakland International – Class I / D
- STS – Charles M. Schultz / Sonoma County (in Santa Rosa) – Class I / B
- CCR – Buchannan Field (in Concord) – Class IV / A (inactive)[3]

General aviation airports owned and operated by cities, as well as private airports, are not required to prepare an AEP consistent with FAA requirements. However, they must follow the general guidelines prescribed by Homeland Security Presidential Directive 5 (HSPD-5), *Management of Domestic Incidents* and Homeland Security Presidential Directive 8 ((HSPD-8), *National Preparedness*.

Consistent with HSPD 5, FAA requires that the Airport Emergency Plans be consistent with the requirements of the Standardized Emergency Management System (SEMS) and the National Incident Management Systems (NIMS) in order for reimbursements to be received if a disaster declaration is made. These plans are implemented in concert with the National Response Plan (NRP) as warranted in individual disaster circumstances.

Specific planning sections in the FAA-mandated AEP are identified for:

a. Aircraft incidents and accidents.
b. Bomb incidents, including designated parking areas for the aircraft involved.
c. Structural fires (such as fires involving hangars, warehouses, or terminals).
d. Fires at fuel farms or fuel storage areas.
e. Natural disasters (including, as applicable, hurricanes, earthquakes, tornados, volcanoes, and floods).
f. Hazardous materials/dangerous goods incidents.
g. Sabotage, hijack incidents, and other unlawful interference with operations.
h. Failure of power for lighting of movement areas (that is, the runways, taxiways, and other areas of an airport that are used for taxiing, takeoff, and landing of aircraft, but not including loading ramps and aircraft parking areas).
i. Water rescue situations, as appropriate.

[3] For a complete list of all Part 139 Certified Airports on this FAA list, see http://www.faa.gov/airports/airport_safety/part139_cert/ to download the latest copy of the certification list.

The guidance document[4] specifies, for example, that the earthquake "section should include information about the airport as it relates to such issues as:

- **a.** The airport's susceptibility to an earthquake event, such as proximity to a fault line (reference the Hazards Analysis Program).
- **b.** The impact of such an event on the community as a whole, particularly in terms of overall impact on response and recovery resource availability, i.e. a major earthquake will impact a wide geographic area - off-airport resource accessibility may be extremely limited and should be planned for accordingly.
- **c.** The vulnerability of access roads and bridges to earthquake damage and what would be the impact if some or all of them were rendered unusable.
- **d.** Airport structures which have earthquake resistant construction.
- **e.** Airport utilities that serve key facilities and the availability of alternative sources (e.g. power - generators, communications - RACES, REACT, etc.).
- **f.** Worst case scenarios: i.e., What is the impact if an earthquake should occur during your airport's peak period? What if it occurred in the middle of the night?
- **g.** Communications capabilities that may be rendered inoperable during and after an earthquake. Systems which rely on hard wires or antenna-to-antenna for operation, such as cellular phone services and two-way radio repeaters cannot be relied upon."

"The FAA requires a full-scale airport emergency plan exercise at least every thirty-six calendar months for airports holding a Class I Airport Operating Certificate under 14 CFR part 139. This full-scale exercise requires a simulated emergency, as it would in an actual aircraft disaster, for airports holding Class I Airport Operating Certificate commensurate with the index of the airport, to ensure that all personnel having duties and responsibilities under the plan are familiar with assignments and are properly trained, and a table-top exercise or drill more frequently."

These smaller exercises are employed as part of the planning functions leading up to the full field exercise and can involve any hazard identified in the plan. However, the triennial exercise must involve an aircraft incident.

While regional response exercises are not required for earthquakes or similar natural disasters, extensive mutual aid plans are required and must be demonstrated during the exercises.

All FAA requirements for disaster planning focus on emergency preparedness and response, not on hazard mitigation or long-term recovery.

Major Airport Disaster Planning

[4] See http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/74488 for the full document.

Airport Emergency Plans (AEPs) of the major airports tend to be broad in scope. Specific Federal Air Regulation requirements ensure that airports plan for and address disaster planning in order for an airport to legally operate commercial passenger flights. Other requirements exist to address specific security measures. In AEPs, individual airports mold their plans in accordance with their experience, latest technologies, and available budget and staff. The AEPs attempt to address specific crises that are common challenges to airports.

For the most part, major airports share AEPs with each other because it is helpful for gaining insight into other airports' emergency response and their plans for managing critical incidents. These plans are also shared with local mutual aid responders that play a role in all of the Bay Area airport plans. As such, this process leads to dialogue and coordination. However, because such planning takes time, it is limited by the staff and funding available to an individual airport. As with any business, resources may be reallocated if a recession or business slowdown causes a reduction in passenger or freight volumes and revenues; safety, however, is never compromised.

For example, in the case of the AEP for SFO, the plan is posted on an internal web site for internal airport staff use. In addition, it has been burned onto a CD that has been shared with many SFO emergency planning partners. In cases involving sensitive security information, only selected portions of the document have been shared and then only in strict accordance with federal regulations. These planning partners include the passenger airlines, air cargo carriers and American Red Cross. One key aspect of this planning is the goal to maintain regular operations to the maximum extent possible. As such, SFO plans to facilitate the use of available means to assist passengers in safely reaching their ultimate destination after an emergency or disaster, including Caltrain, BART or buses. Much of this interaction would occur through use of the National Incident Command System.[5]

Major Bay Area airports typically employ tabletop exercises and drills as part of the planning functions leading up to the full field exercise.

For example, in the case of SFO, these exercises routinely involve the airport, fire, police, emergency response, the Red Cross, and, in some scenarios, the chaplaincy, FEMA, NOAA, passenger carriers, air cargo carriers, and, if available, staff of neighboring airports.[6]

Major Bay Area airports participate in regional planning through the Bay Area's Regional Airport Planning Committee (RAPC), jointly staffed by the Association of Bay Area Governments (ABAG), the Metropolitan Transportation Commission (MTC), and the Bay Conservation and Development Commission (BCDC). While airports are not required to coordinate tabletop exercises, they have done so by participating as observers/evaluators to provide input and recommendations for each other's tabletop exercises.

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[5] Source of information on SFO AEP procedures: William Wilkinson, Emergency Manager, SFO, personal communication, February 2013 (retired prior to report completion).
[6] Source: William Wilkinson, personal communication, February 2013. See reference above.

These airports work with other organizations, such as the U.S. Coast Guard, on planning for post-disaster assistance.

The Western Airports Disaster Operations Group (WESTDOG) created the *WESTDOG Mutual Aid Plan – Airports Helping Airports* in 2007 following Hurricane Katrina.[7] This document could serve as a way for airports to VOLUNTARILY assist each other following a disaster. Prof. James F. Smith of American Public University System has prepared and contributed to numerous reports and articles related to the use of mutual aid by airports. For example, the Airport Cooperative Research Program (ACRP) has published Airport-to-Airport Mutual Aid Programs.[8]

General Aviation Airport Disaster Planning

Most general aviation airport planning is not integrated regionally. Instead, they are incorporated into the emergency planning of the specific city or county that operates the airport. Requests for aid from Airport A go to through the city that operates it, then through the County Office of Emergency Services, up through (Cal OES), down through a county with Airport B that might be able to support mutual aid, to the city operating Airport B, and then to the staff of Airport B consistent with ICS protocol. However, the use of mutual aid agreements among these airports, similar to those among water and water agencies and those among transit districts, are currently being evaluated for broad use by general aviation airports that might provide a potential streamlining of this process.

Several Bay Area general aviation airports have been involved in airlift operations in past disasters 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 San Carlos, Buchanan, and Reid Hillview airports.[9]

Because general aviation airports are generally underutilized assets in the Bay Area, the California Pilots Association has urged local communities to incorporate the airport into their disaster planning programs, but few do so with the exception of those in San Mateo County. However, many general aviation airports are used as staging areas for forest firefighting.

Planned Airport and Airline Response in an Emergency

In an emergency, each airport plans to report to FAA whether it is open for operations, open with restrictions, or closed due to damage.

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[7] See http://westdogairports.com/WESTDOG-MAP.pdf.
[8] Prepared by IEM, Inc. and in association with Smith-Woolwine Associates and TransSolutions, LLC. See http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_073.pdf.
[9] Source of information in this section: Jay White, General Counsel, California Pilots Association, personal communication, 2000 and Carol Ford, Vice President, Region II, California Pilots Association, personal communication, February 2013.

Each airport strives to be self-sufficient and return to full operational status as soon as possible after an incident. For example, critical systems are on backup generators.

Each airline designates its own 'alternate' airports. Airport compatibilities, available airport services, current airline service to the alternate airports, aircraft fleet availability, availability of air crews, proximity to other airports, weather conditions, airport congestion and airline policy are some of the criteria used in selecting a safe alternate airport.

In a large-scale disaster, passenger flights would have first priority, followed by humanitarian relief operations. Commercial Service airports are concerned with assisting passengers getting to and from their flights. Therefore, during a regional disaster, they want to know when/how passengers will get to airports (including the status of the roadway network and rail transit, such as BART and SamTrans) so they can "stage" the efficient arrival/departure of aircraft on the runways.

Business cargo will have a lower priority. If necessary, cargo carriers may be directed to an airport that can accommodate the ground transportation of their freight. Airport Emergency Operations Plans typically do not specifically address the coordination of cargo movement. However, some Incident Command System (ICS) plans address this issue under the logistics section.

While airports are not currently required to have plans for long-term disaster recovery, their plans are typically based on the model of continuity of business (COB) plans and continuity of operations (COOP) plans for recovery planning. The presumption is that if their airport facilities are functional, then they will not hold back regional long-term regional economic recovery.

One of the challenges of writing a usable and effective airport 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, also known as resilience.

The FAA and Air Traffic Control Tower Operations

The Federal Aviation Administration (FAA) is in charge of Air Traffic Control, which is critical to the operation of an airport after a disaster. In past earthquakes, control towers have been subject to disproportionate damage. However, the towers for three Bay Area international

airports have been, or are being, improved. A new tower at OAK is opened in 2013 and has been designed to withstand a magnitude 7.8 earthquake. It is replacing a tower built in the late 1950s. A new tower at SFO is under construction is expected to open in August 2015. It has been designed to withstand a magnitude 8.0 earthquake and is replacing the existing tower constructed in 1983. The tower at SJC was constructed in 1990 and is not as tall as the other two (and thus less vulnerable to the type of nonstructural damage common in older control towers not specifically designed to resist this damage). However, towers at the other airports are much older. The tower at Concord-Buchanan was constructed over 50 years ago and the one at Sonoma County/Charles M. Schultz in Santa Rosa was built 40-50 years ago.

FAA has temporary aircraft control towers, but there are only three for the entire western US – located in different areas – not one currently in the Bay Area. These towers are typically brought in for fires to handle increased air traffic. They are also brought in while a tower is being remodeled, as happened recently for the Napa airport. They are mounted on 5th-wheel trailers. FAA is currently again attempting to locate one of these towers in or near the Bay Area, such as at one of the Sacramento airports.

FAA also has "suitcase towers" that can be brought in by helicopter in to a general aviation or small commercial airport. They can be put on top of shipping containers to make them taller and improve visibility. However, because of the limited height of the tower, and the size of the airport, the traffic would have to be severely limited, making them more appropriate for general aviation airports. However, even after a disaster, the Bay Area should not expect to be able to access more than one or two of these towers.

In the future, NextGen, the next generation of air traffic control technology, will improve air traffic control. However, FAA has no technology on the books at the present time, including NextGen, that would close air traffic control towers. (Such closures are not even in FAA's 20-year operations plan.) Thus, air traffic control towers will continue to be critical to airport operations.

FAA expects a catastrophic earthquake could easily limit operations at the region's airports for 3-4 months.[10]

Role of the FAA in Emergency Response

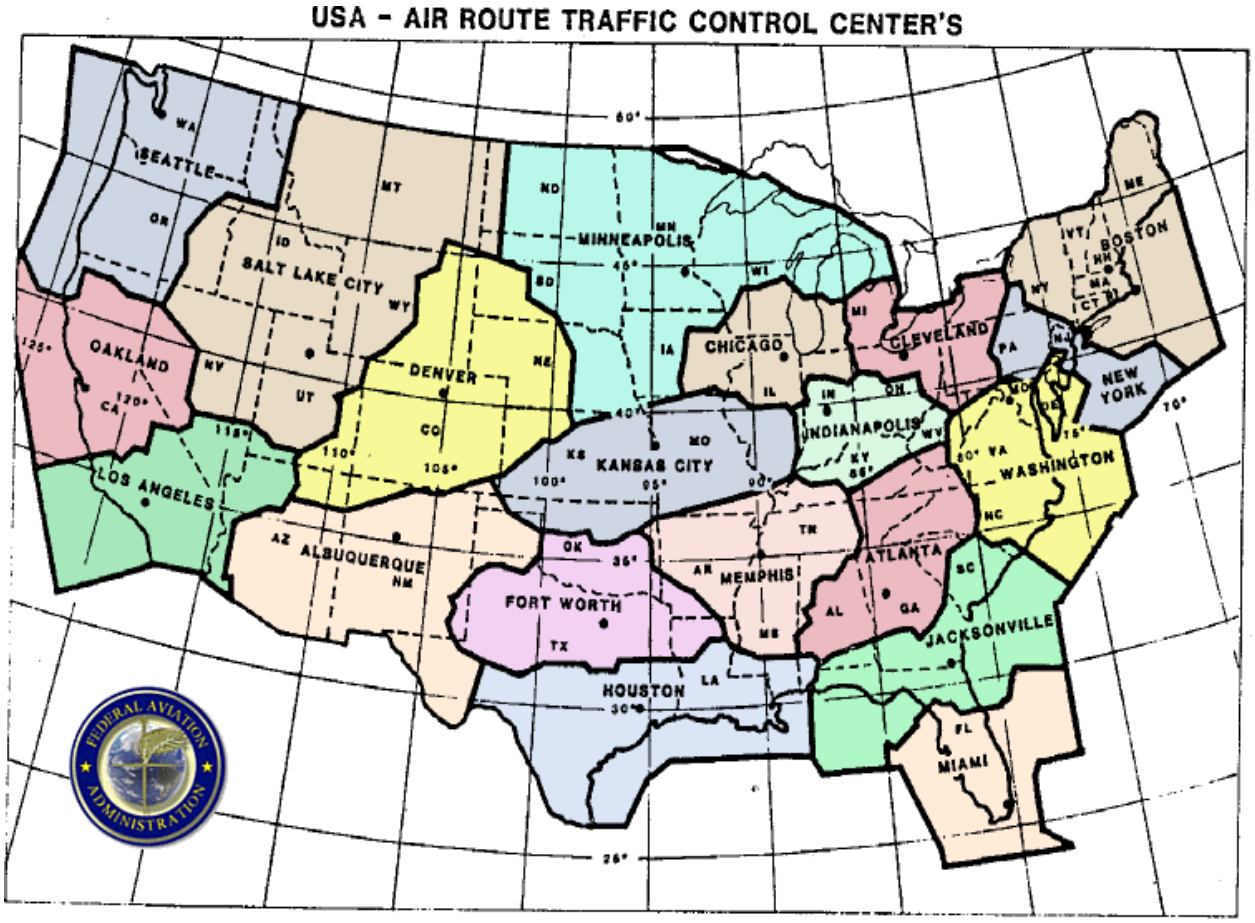
Only an FAA Air Route Traffic Control Center (ARTCC) is authorized to modify commercial aircraft routes between airports. There are two ARTCCs that control air traffic in almost all of California – the Oakland ARTCC for northern California located in Fremont (which covers a

[10] Source of information in this section: Andy Richards, FAA, District Manager, Golden Gate Air Traffic (AT) District, personal communication, March 2013.

region far larger than the Bay Area and extends to east Reno), and another for southern California (in the Los Angeles area).

Depending on aircraft size, route modifications can be out of state. An important factor for landings, more than departures, is the length of airport runways.

FAA's selection of alternative airports would be based on passenger handling, cargo-handling, ground transportation, and support for that particular type of aircraft.



An element of FAA's airspace management considerations are the needs of local emergency aviation response efforts. When wildfires broke out in the vicinity of Lee Vining Airport, the FAA helped control the airspace around the airport in conjunction with the California Department of Forestry and Fire Protection (CalFIRE). This coordinated system between the FAA and local emergency aviation operators can be both speedy and effective. After the 9/11 attacks, FAA was able to effectively close the airspace of the entire United States by coordinating Air Route Traffic Control Centers within 1 hour and 19 minutes of when Flight 11 crashed into 1 WTC at 8:26 a.m. Eastern Daylight Time and only 42 minutes after Flight 175 crashed into 2 WTC at 9:03 a.m. based on the timeline shown in the following graphic. While this system did not prevent the second attack on 2 WTC because of confusion about the meaning

of the communications with Flight 175, the safe closing of the entire US airspace was still impressive.

Nearly all international flights headed for the U.S. were redirected to Canada, while some flights from South America were diverted to Mexico.

However, during 9/11, no airports or FAA air traffic control facilities were damaged, a situation unlikely to occur in a natural disaster impacting the San Francisco Bay Area.

CLOSURE OF AIRSPACE FOLLOWING 9/11 WORLD TRADE CENTER ATTACKS

"8:40 a.m.: FAA notified NORAD's Northeast Air Defense Sector concerning the suspected hijacking of American Flight 11."

"8:43 a.m.: FAA notified NORAD's Northeast Air Defense Sector concerning the United Flight 175 suspected hijacking."

"8:46 a.m.: American Flight 11 crashed into the north tower of New York's World Trade Center."

"9:00 a.m., approx.: FAA's Boston Air Route Traffic Control Center (ARTCC) stopped all departures from airports in its jurisdiction" [*that is, New England and eastern New York State*].

"9:02 a.m.: UAL Flight 175 crashed into the World Trade Center's south tower."

"9:06 a.m.: FAA stops departures of flights bound to or through the airspace of the New York ARTCC from airports within airspace controlled by that ARTCC and its adjacent ARTCCs (Boston, Cleveland, and Washington)." [*This procedure is referred to as a First Tier Ground Stop and covers the Northeast from North Carolina north and as far west as eastern Michigan.*]

"9:08 a.m.: FAA stops departures nationwide for traffic [*flights*] going to or through the airspace of the New York ARTCC, meaning that all aircraft operating in that airspace are ordered to leave it." [*ABC later reported that the Port Authority of New York and New Jersey, the agency that runs the New York-area airports, asked the FAA for permission to close down the New York Center airspace.*]

"9:24 a.m.: FAA notified NORAD's Northeast Air Defense Sector concerning the suspected hijacking of American Flight 77. NORAD immediately ordered two F-16s to scramble from Langley Air Force Base, Va. They were airborne at 9:30 a.m. FAA established an open line to discuss AAL Flight 77 and UAL Flight 93."

"9:26 a.m.: FAA bans issued a nationwide ground stop that prevented the takeoff of all civil aircraft, regardless of destination. At 9:29 a.m., FAA issued Advisory 031 concerning the ground stop."

"9:40 a.m., approx.: American Flight 77 crashed into the Pentagon, the Defense Department's Washington headquarters."

"9:45 a.m.: In the first unplanned shut down of civil operations throughout U.S. airspace, FAA ordered all civil aircraft to land at the nearest airport as soon as possible. At the time of the order, 4,546 flights were airborne." (At 10:39 a.m., FAA followed up on this order with a Notice to Airmen closing operations at all airports; at 11:06 a.m., the agency issued Advisory 036 suspending operations in the National Airspace System.)

(Source of Timeline: FAA report, *Chronology of the September 11 Attacks and Subsequent Events Through October 24, 2001*, undated [Referenced Chapter 1, The 9/11 Commission Report, "*We Have Some Planes*," footnote 62]. View at http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB165/faa4.pdf.

Use of Out-of-Region Airports

Major out-of-region airports include Sacramento International Airport (SMF), Mather Field (MHR), McClellan (MCC), Stockton (SCK), Monterey (MRY), and Modesto (MOD). Sacramento County handles SMF, MHR, and MCC. All are licensed by FAA for commercial flights except MCC and MHR in Sacramento County.

Sacramento International Airport (SMF) is a commercial airport with limited customs and immigration services. It serves as a primary diversion airport for the San Francisco, Oakland, and San Jose International Airports. With 2 terminals and 25 gates, it is significantly smaller than SFO (101 gates), and roughly the same size as OAK (29 gates) and SJC (28 gates). While Mather (MHR) is not certified to handle passenger aircraft, UPS operates cargo operations out of MHR. In addition, one of this airport's tenants is a National Guard helicopter unit.

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). However, in addition to the 25 gates at SMF, parking space is available on the terminal apron pads where aircraft remain overnight (RON pads) and near its cargo facilities.

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.

The Sacramento County Airport System also includes two general aviation airports – Executive Airport (SAC) and Franklin Field (F72). While these airports might be available for flights during a disaster, their capacity is also limited.

Finally, it is important to mention that the Sacramento County Airport System manages McClellan Field (MCC) even though it is not part of that System. This former Air Force airfield has space to stage aircraft that have been diverted from the Bay Area because it has ramp space. The airport is well equipped, has excellent access to I-80, a rail spur, and tends to get less valley fog than some of the other airports in that area. MCC's fixed base operator (FBO) is capable of serving a wide variety of business and general aviation aircraft types including Boeing wide body aircraft, and is operational 24 hours a day. The airport is uncontrolled, but has a closed tower. A Coast Guard unit that flies both the C-130 (4 engine turboprop cargo aircraft) and helicopters is located at MCC.[11]

[11] Source of MCC information: Colette Armao, Associate Aviation Planner, Caltrans Headquarters, Division of Aeronautics, personal communication, May 2013.

In an emergency, one priority of these out-of-region 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, in the case of an earthquake, 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 may need to request mutual aid support, 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.

It is important to understand that neither the Sacramento County Airport System (SCAS), nor any other airport, owns or operates any of the equipment needed to safely deplane passengers from any of passenger carrier aircraft, and they are therefore unable, on their own, to provide for the deplanement of passengers. In addition, airport personnel are not trained to assist in the deplanement of passengers using equipment owned or operated by air carriers or contract service providers. However, SCAS has requested that each airline, ground handler, and Fixed Base Operators (such as those offering fueling and flight instruction) provide the SCAS with a list of the equipment and resources they have for deplaning passengers. SCAS has directed the air carriers to make gates and other facilities available to an air carrier seeking to deplane at gates at the airport to the extent practicable.[12]

Use of Federal Airports for Federal Resource Flights and Staging

If federal resources are flown in to aid in disaster response and recovery, federal airports may be used to avoid disruption to commercial air traffic. They may also be used if Bay Area airport facilities or runways experience significant earthquake damage. This use could include General Aviation aircraft and helicopters.

Travis Air Force Base (SUU)

The Travis AFB priority is to support global mobility operations. However, like any airport, any aircraft declaring an in-flight emergency will normally be given permission to land.

In regards to General Aviation, Travis AFB does not have a specific, standing role in a regional disaster event outside of normal air traffic control of the airspace it manages. It is conceivable that if regional airport runway damage precluded use of larger aircraft, general aviation could be allowed to operate at Travis to support disaster recovery operations.

Since Travis AFB is a Federal installation, tasking to support sustained disaster recovery operations comes through the military chain-of-command through the Department of Defense as

[12] Source of information in this section: Sheri Thompson-Duarte, Manager, Airport Operations, Sacramento County Airport Systems, personal communication, October 2012.

requested by FEMA. This tasking would typically begin with a Governor's disaster declaration and culminate with a tasking given to the Travis Installation Commander.

The Travis Installation Commander does have some latitude to support short-term disaster recovery operations in the absence of a federal tasking to preclude loss of life or great property damage. If general aviation and helicopters needed to operate at Travis for disaster recovery operations, permission may be given, global mission permitting and on a temporary basis. The high number of large-frame aircraft that operate at Travis AFB presents obvious safety hazards to general aviation aircraft and helicopters. For operations longer than 72 hours, Travis AFB would request an "official support tasking" and that funding information be provided by FEMA.

Travis AFB is considered a FEMA Support Installation and Federal Operational Staging Area and is part of the National Disaster Medical System. After a major earthquake, Travis AFB would likely see heavy large-frame aircraft operations from numerous users. These operations depend on the post-earthquake state of the airfield and other concurrent federal taskings that may occur. The above factors could limit the use of General Aviation and helicopters at Travis AFB.

Safety and communications during general aviation and helicopter ground operations are paramount. Strict adherence to airfield diagrams, NOTAMS, tower instruction and safe operations around large fixed-wing aircraft are vital. Additionally only qualified Travis AFB personnel may provide hand signals for helicopter landing operations. The David Grant Medical Center (DGMC) at Travis AFB does have a heliport to support local medical agreements only up to a very limited bed space commitment. DGMC is not considered a medical Trauma Center.[13]

Moffett Federal Airfield (NUQ)

Moffett Federal Airfield was closed as a Naval Air Station in 1994. However, it remains a federal airfield operated by NASA Ames Research Center. Moffett Federal Airfield is limited to 25,000 operations per year per its Environmental Impact Statement. On average the airfield conducts 18,000 operations per year. Because of its capacity for additional flights, it is a logical staging area if it is useable after an earthquake or other disaster. Principal users include the 129th Rescue Wing of the California National Guard, NASA, Lockheed Martin Space Systems, the Santa Clara County Sheriff's Department STAR 1 helicopter, and some private planes. Air Force One has regularly landed at the Air Field for presidential visits.

As a federal airfield, Moffett is subject to different FAA requirements than either commercial or general aviation airports. The airport has a Mishap Plan, as required by FAA, and annual

[13] Source of information in this section: Mark Wilson, Emergency Manager, Travis AFB, personal communication, October 2012.

exercises. During 2013, the NASA Ames Emergency Operations Center (EOC) is planning to conduct a tabletop exercise focusing on airfield operations.[14]

The 129th Rescue Wing of the California National Guard is stationed at Moffett Field.[15]

In 2011, initial seed funding from the Department of Homeland Security, Santa Clara County and some anonymous donors has enabled the planning of a National Disaster Resiliency Center at the airport to include a Disaster Response and Recovery Complex, a Advanced Emergency Responder Training Institute and a Applied Research and Technology Laboratory. However, because the future of the airfield is currently uncertain, Crows Landing Airfield (a closed federal airport facility in Stanislaus County) is the current focus of implementation planning.[16]

Role of the FAA in Airport Recovery

In the event of a serious earthquake, the San Francisco Airports District Office, in conjunction with the Regional Office in Los Angeles, will conduct a survey of the airport facilities to assess damage and the need for federal funding for repairs of runways/taxiways, airport access roads, and terminal/cargo facilities. These services can be coordinated and/or provided by the FAA upon request of the airport operator should their local resources to do the same become exhausted. The public agencies that own and operate airports will be requested to submit grant applications for reconstruction projects. If the San Francisco ADO is damaged, then the responsibility for grants would transfer to the Regional Office in Los Angles. If the entire State of California is impacted, then the grants would be issued from another FAA Region or FAA headquarters in Washington, DC.

Funding priority will be given to runway/taxiway repairs and terminal areas needed to move passengers, airfreight, and the US mail.[17]

The typical mechanism for funding is the Airport Improvement Program (AIP) grant application process. The FAA provides AIP grants to owners and operators of public-use airports, and specifically those that are part of the National Plan of Integrated Airport Systems. The FAA may not provide AIP grants outside the normal capital improvement program without express Congressional authorization. In an emergency, airport sponsors typically have to address immediate repairs through on-call contractors and/or their own employees and, therefore, cannot readily comply with the federal procurement rules and other rules governing the AIP. Most commercial service airports have an emergency maintenance reserve fund as their primary source of working capital. These funds may be reimbursed by private insurance.

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[14] Source of information in this section: Lynn Bala, Emergency Preparedness Coordinator, Moffett Air Field, personal communication, October 2012.
[15] See http://www.129rqw.ang.af.mil/ for more information.
[16] Source of information in this section: Steve Jordan of Traiden Globan, personal communication, October 2012. See http://www.thendrc.org/The_NDRC/index.htm for more information.
[17] Source: J. Rodriguez, FAA, personal communication, 2000.

As such, AIP funding may only be used:

- If an AIP-eligible facility was already nearing the end of its useful life and was already identified as needing rehabilitation or replacement; and
- If there is time to properly design and procure the construction in accordance with federal statutory and regulatory requirements.

Should an airports runway be damaged by emergency aviation operations, there would be a different but compatible process between FEMA, FAA and the State, in this case California, to help the airport operator rebuild the runway.

The principal complaint on the part of grant applicants is that the AIP process is that it can be time consuming and take up to three years for funding unless waivers are given. However, the AIP process does not typically take 3 years to fund. While three years is the typical planning horizon, it is not an indication of how long it takes FAA to process an AIP grant. FAA has the ability to fund emergency (pop-up) projects each year, and if a disaster is declared then grants and funding can be issued within weeks if necessary.

CURRENT ASSUMPTIONS BY USERS

Planned Use of Airports by Air Cargo Carries

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 or other disaster could 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. Air freight business has grown in tandem with the rapid growth of e-commerce. Thus, it is that much more important for cargo carriers to be in business after a disaster than in the past.

Cargo carriers such as UPS and FedEx use the full transportation network, including airports, roads, and rail lines; however, while UPS handles more freight, FedEx has a larger air freight operation and does not rely on rail. (UPS has 230 aircraft and charters an additional 332 aircraft, while FedEx has 363 jets and 285 feeder aircraft.)

Air freight carriers use a variety of Bay Area airports, including OAK, SFO, and SJC, as well as airports in neighboring counties, such as Sacramento International Airport (SMF) (FedEx) and Sacramento County's Mather Field (MHR) (UPS), to service the Bay Area. OAK is particularly critical for FedEx, for it serves as its west coast hub, while Ontario in Southern California is the west coast hub for UPS. Most international air freight for FedEx goes directly to Memphis, rather than to OAK. United uses SFO for international air freight, however. The FedEx operation in SJC is larger than in SFO.

Peak times for UPS are 5:00 – 8:00 AM and 5:00 – 9:00 PM in these locations. However, for FedEx, the peak time for their operations at OAK is 10 PM to 3 AM. Due to the time-sensitive nature of this business, block time (that is, time from when the aircraft leaves where it is parked to the time when it arrives at its destination), taxi way delays and landing availability are critical during these times.

Many of the employees of cargo carriers work near the air facilities because it is not worth the commute time to travel from a long distance for a short work day. Hence, disruptions in surface transportation to and from these facilities are not as large a problem as for some other facilities. However, the majority of the work for off-loading of aircraft is done with specialized equipment, not manual labor.

The off-loading equipment has a much larger capacity than the smaller mobile motorized belt conveyors used for passenger baggage handling for both UPS and FedEx use large capacity cargo containers. These cargo containers are moved along the aircraft floor to the door, and then pushed onto a main deck loader – which is basically a scissor lift with a conveyor on top able to act as an elevator for the cargo containers. After they are lowered, the operator uses the loader to move the cargo containers onto a waiting tug (small tractor) that pulls four individual cargo container carts that are referred to as dollies. After one is loaded on a dolly, the tug moves forward, enabling the next cargo container to be put on its dolly. Cargo is then taken to warehouses where it is unloaded, scanned, sorted, and loaded on trucks or small turbo-prop planes. These "feeder" planes can typically hold only the equivalent of a single cargo container. This loading equipment is specialized and not available at every airport where FedEx and UPS do not have existing operations. However, "work-arounds" would be possible on a temporary basis.

In the case of UPS, smaller "feeder" turbo-prop airplanes are (operated by a subcontractor) fly to Monterey and Ukiah each morning. Items are trucked to Santa Rosa. In the evening, the UPS flight from Ukiah stops at Santa Rosa's airport on its way to OAK. The Monterey flights are simple to-from flights. In the case of FedEx, these "feeder" planes (also operated by a subcontractor) fly to Chico, Ukiah, Redding, Murray Field near Yreka, and Crescent City from SAC, and Monterey, Sonoma County, and Visalia from OAK. For both UPS and FedEx, these smaller planes, as well as the loose cargo in the larger jets, are off-loaded using a much more standard mobile motorized belt conveyor, similar to those used for passenger baggage handling, so use of alternate airports is much more feasible.

The initial concern of a cargo carrier after an earthquake or other disaster is to identify where they can and cannot operate. If an airport is shut down, the carrier also is interested in whether or not they can get to their equipment or if it needs to be moved to an alternate airport. A secondary concern is setting up an alternate service network using a combination of alternate airports (such as Mather for UPS and Sacramento International for FedEx), alternative rail yards for UPS (such as Stockton rather than Richmond), and ground transportation. While there are no formal mutual aid agreements among cargo carriers to use each others' equipment should an aircraft need to land at an airport where only a competitor has a presence, this sharing is understood to occur during an emergency.

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 and to work 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 disaster such as an earthquake. A local team of UPS Management personnel have been assembled specifically to facilitate this cooperative effort of emergency response logistics. 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.

FedEx is participating in FEMA/Northern Command's public/private partnership for disaster resilience. As part of this program, FedEx has utilized Community Emergency Response Team (CERT) trainers at some company locations to train their employees in basic disaster preparation and response. FedEx notes that the CERT program brings skill sets to their employees that are both useful for their employees at home, as well as to contribute to a culture of self-reliance and resiliency at FedEx. They have implemented the Incident Command System (ICS) concept of event management at a number of facilities in the US to manage (short term) through localized events until first responders arrive on scene. Working with some of the world's top non-governmental organizations (NGOs), including the Salvation Army, the American Red Cross, Direct Relief International, and Heart-to-Heart, they delivered the equivalent of 67 planes loaded with donated aid during 2011 alone. For its efforts, the company has received numerous awards from the American Red Cross, Direct Relief International, the Civilian Volunteer Medical Reserve Corps, the Salvation Army, and others. Following Hurricane Katrina, FedEx began working with the Salvation Army on additional projects to assist with long-term rebuilding and building resilience.

FedEx also has a "contingency go" team led by its Global Operations and Control office, dealing with teams that can be quickly dispatched to set up operations in response to disasters and to support their customers in catastrophic events as part of their business continuity process.

The FedEx corporate philosophy is to "plan for worst situation." They reach out and engage with the first responder community where appropriate. A model relationship exists between FedEx and the Tennessee Emergency Management Agency (TEMA) in a full spectrum of planning for floods to a significant earthquake in the Central United States through participation in the TEMA Transportation Control Center (part of the Tennessee State EOC). FedEx is working with other agencies and companies on the Tennessee Catastrophic Air Plan.[18]

Planned Use of Airports by 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, passenger carriers have developed guidelines for making the necessary decisions in an emergency. These guidelines have been provided to all carrier employees. Accordingly, "Southwest Airlines spends time and resources preparing for a potential disaster. Our primary goal is to protect and prepare both our Employees and Customers so that we can respond at a moment's notice."[19]

To the extent that passenger flights are diverted to other airports, these carriers may be dependent on surface roads or rail transit to allow passengers to reach their destination.

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.

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[18] Sources: Most information on UPS: George Durkee, Plant Engineering Manager, Northern California District, UPS, personal communication, October 2012. Information on UPS airplanes: http://www.ups.com/content/us/en/about/facts/worldwide.html. Information on FedEx: Dave Lusk, Senior Manager, Global Operations Control, FedEx Express, personal communication, March 2013.
Photo Sources: UPS truck and FedEx cargo contain units: J. Perkins; relief supply unloading: FedEx Thinking Outside the Box: *2012 Report on Global Programs in Disaster Readiness, Relief, and Recovery*, page 9; and FedEx planes: *FedEx Corporate Brochure*, November 2012, page 17.
[19] Source: Robert Alderete, Southwest Airlines, personal communication, February 2013.

Finally, it is important to understand that these airlines own all of the equipment the use outside of the basic terminal structure.[20]

Planned Use of Airports by Disaster Service Providers

Humanitarian Organizations and the American Red Cross

Disaster service providers such as the American Red Cross currently expect the airports and airlines to service the needs of stranded passengers and employees, particularly for the first few days.

For a major earthquake on the Hayward fault, they plan to move a substantial number of workers into the affected area for mass care, logistics, mental and physical health services and public affairs support in the first 7 – 10 days. In addition, they plan to move mass care, function and access, special medical supplies, communications equipment, computer equipment and support other supplies into the area.[21]

The Red Cross is dependent on commercial air carriers and commercial shippers for transportation of human and material resources. Major airport and road closures are also assumed. Therefore, initially, local logistics workers within the Bay Area's impacted areas will operate autonomously and support the Red Cross and other humanitarian response efforts per the plans that have been established in each County.

An initial Critical Staging Area will be established in Solano County to provide an immediate "ship to" address for critical supplies such as food, water, shelter support, and communications equipment. Solano County was selected because of its proximity to disaster workers and supplies that are close to but not inside the predicted impacted areas. Staff Reception Stations will be established in Sacramento, Modesto and Los Angeles. Available personnel from northern California will report directly to the closest mobilization center. Staff coming from outside the area and flying into Los Angeles, Sacramento or Modesto and will be processed and transported to their work locations within the impacted area when possible. If the mobilization center is not fully operational, arriving disaster workers will assist in establishing the center before being dispatched to their actual work location. A Staff Mobilization Center is planned for the Stockton area; a Staff Reception area in the vicinity of the Los Angeles area airports will also be established. Workers would be bused to Stockton if airports at Stockton and Sacramento were unavailable.

East Bay activities could be supported with a Mobilization Center in the Stockton-Tracy area because each area has port and airport facilities which could be used to move people and materials.

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[20] Photo source: J. Perkins.
[21] Source: G.L. Smith, American Red Cross – Bay Area, personal communication, October 2012.

West Bay activities could be supported by opening a logistics center at Moffett Federal Airfield. In past disasters, supplies have been brought in by air to Moffett and stored there until they can be separated and redistributed. However, this space may not be readily available (due to the uncertainty about the future of the airfield). In addition, potential problems with runways at Moffett may make use of this facility impractical.

The Red Cross continues to build relationships with the airports, developing a liaison network to support communications and coordination with the airports and; the integration of the American Red Cross and other humanitarian response agency needs into airport priorities.[22]

California Wing Civil Air Patrol (CAP)

The Civil Air Patrol (CAP) is chartered by the U.S. Congress as the official civilian auxiliary to the U.S. Air Force. While a non-profit corporation, it receives federal support. Thus, unlike the volunteer California Pilots Association or the Emergency Volunteer Air Corps (EVAC), the California Wing of the Civil Air Patrol is the only voluntary pilot organization with a direct emergency response mission. As such, their services, if needed, mean that Cal OES would contact the Air Force – and the Air Force would task the Civil Air Patrol with a specific mission. Typical missions include flying the search and rescue dogs and their handlers to disaster areas, flying blood and medical supplies, and performing photo reconnaissance. In a typical year, they fly over 4,000 hours using over 10,000 person-hours related to search and rescue alone. In another example, the photographs of the big fires in Southern California were all taken from Civil Air Patrol aircraft. In an earthquake, they would likely be tasked with taking photos of bridges and buildings to compare the pre- and post-disaster situation. In a disaster, they may also fly non-auxiliary missions, such as for the American Red Cross.

Nationally, CAP has formal agreements with many government and humanitarian relief agencies including the American Red Cross, FEMA, Federal Aviation Administration, National Transportation Safety Board and the U.S. Coast Guard. Each state has a similar organization, and the California Wing has mutual aid agreements with the organizations in adjacent states in the western U.S.

There are 28 airplanes in California and 550 nationally – all owned and maintained by the Civil Air Patrol. The 28 Cessna 182 and 206 airplanes in California are based throughout the state, including Oakland, Sonoma/Charles M. Schultz (Santa Rosa), Buchannan (Concord), and the general aviation airports of Gnoss Field (Novato), Livermore (sharing a plane with Oakland), Palo Alto, Reid-Hillview (San Jose) in the Bay Area, as well as two Cessna 182 aircraft at Sacramento Executive Airport and one in Auburn. Even if SFO or OAK has damaged runways, it is likely that the smaller planes such as they use could still land because they only need about

[22] Source: G.L. Smith, American Red Cross – Bay Area, personal communication, October 2012.

2,000 feet of runway. Finally, the airplanes can be easily flown to other airports in the region and in neighboring counties.

All of the pilots are volunteers who undergo extensive training. The national requirement is for a minimum of five trained pilots per airplane. However, the actual number far exceeds that amount.

One of the resources of the CAP is that it has its own radio network. There are 38 repeater sites in California and the CAP network has the ability to be patched into other emergency networks, including those of Cal OES and county sheriffs' offices.[23]

Volunteer Pilot Groups

The most active group of volunteer pilots in the San Francisco Bay Area is the California Pilots Association. Several of its members were extremely active in the aftermath of the Loma Prieta Earthquake, as described in the earlier section on "General Aviation Airport Disaster Planning" on page 8. In addition, it has developed a booklet, "EarthQuake Airlift: How to Do It" which includes specific checklists, directions and information related to setting up such operations after a disaster.[24] One of the advantages of organizing volunteer pilots of privately-owned small aircraft is that they can effectively utilize the numerous general aviation airports to bypass potential road closures and traffic gridlock that is likely to be present in the first few days after a disaster. In addition to transport of key supplies, particularly medical supplies and equipment, they can be used to transport critical personnel.[25] With that said, it is important to understand that following a significant event, the FAA may issue one or more Temporary Flight Restrictions (TFRs) over portions of the Bay Area. Flights within a TFR are regulated and must be coordinated with an areas Air Operations Branch Director(s), or equivalent. Aircraft operators are not authorized to 'self-deploy' or fly their own, albeit noble, response or recovery mission inside a TFR without first receiving proper authorization through the incident command structure. All flights within a TFR must be coordinated through the appropriate emergency aviation chain of command.

[23] Source: Ronald Butts, National Headquarters, Civil Air Patrol, personal communication, February 2013.

[24] The document is available on line at: http://www.dot.ca.gov/hq/planning/aeronaut/documents/EarthquakeAirliftBook.pdf.

[25] Source: Carol Ford, Vice President, California Pilots Association, personal communication, February 2013. Photo Source: J. Perkins.

The umbrella organization for many of these groups in the country is the Air Care Alliance. (See http://www.aircareall.org/.) It is a national league dedicated to promoting, supporting, and representing public benefit flying through communication and cooperation among organizations facilitating flights for health, compassion, and community service. Humanitarian missions are routinely flown following disasters. In particular, one of its members is the Emergency Volunteer Air Corps (EVAC) whose mission is to promote and coordinate effective and useful additional General Aviation volunteer participation in emergency relief efforts, especially following disasters.[26] Since 1990, EVAC has encouraged the more than sixty groups listed by the Air Care Alliance to develop emergency preparedness and response programs.

Air Care Alliance Member and other listed groups now routinely respond following disasters. For example, after Hurricane Katrina volunteer pilots from throughout the country all responded to requests of support. Most flights were into and out of the general aviation airports in the area because New Orleans major airport was impacted and the general aviation airports were closer to many of the smaller communities cut off from aid.

Even on the very afternoon of the 9/11 attacks, when all commercial and private flights were grounded, volunteer pilots began to fly approved relief missions. For example, the Oklahoma Blood Institute asked Angel Flight of Oklahoma to transport blood and test kits to New York City. The FAA contacted the North American Airspace Defense Command (NORAD) to allow this and other similar flights. Taking off on the night of September 11, Angel Flight of Oklahoma's plane was met in Louisville, KY by planes from the Volunteer Pilots Association that then took the blood to Philadelphia, then on to New York City, arriving at 6:30 AM on September 12. In the following hours and days a half dozen other volunteer groups flew 9/11 support missions delivering rescue dogs, supplies, and relief personnel — the only approved civilian aircraft permitted to fly in the Nation's airspace.

Following the earthquake in Haiti, Bahamas Habitat and other groups staged general aviation aircraft in the Dominican Republic to ferry supplies and personnel brought into that country over the mountains into Haiti, where the small planes landed on air strips and even roads to deliver supplies and relief workers to remote parts of the country. [27]

CAL FIRE – Air Program

In support of its ground forces, the CAL FIRE emergency response air program includes 23 Grumman S-2T 1,200 gallon airtankers, 11 UH-1H Super Huey helicopters, and 14 OV-

[26] See www.evac.org/ for additional information.

[27] Source: Rol Murrow, President and Founder of the Emergency Volunteer Air Corps and Chairman and Co-Founder of Air Care Alliance, personal communication, February 2013.

Photo Source: http://calfire.ca.gov/communications/downloads/fact_sheets/Aviation_TriFold_FINAL_web.pdf.

10A airtactical aircraft. CAL FIRE statewide has 13 air attack and nine helitack bases. Of these, aircraft are located in airports in Hollister and Sonoma County (Santa Rosa) that would be used in a fire disaster. The three helibases serving the Bay Area are Alma (near Lexington Reservoir), Bear Valley (south of Hollister) and Boggs Mountain (north of Sonoma). Aircraft can reach most fires within 20 minutes.

While both airtankers and helicopters are equipped to carry fire retardant or water, the helicopters can also transport firefighters, equipment and injured personnel. All CAL FIRE aircraft are strategically located throughout the state at airbases and helicopter bases. During high fire activity, CAL FIRE may move aircraft to better provide statewide air support.

During and after a disaster, CAL FIRE works closely with Cal OES. The department has mutual aid agreements with all of the counties in the state. In fact, it actually runs the fire departments in some areas of the state under contract (however none of these areas are in the Bay Area). CAL FIRE does not depend on the airports to provide logistics support or communications. CAL FIRE comes equipped with its own communications in the form of "Incident Command Trailers" that are self-sufficient complete with satellite communication systems.[28]

Planned Use of Airports by Business Users

As stated earlier when describing the role of cargo carriers, businesses have concerns about both their facilities and the items they need transported. 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 air freight. 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 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 and technology businesses in the Bay Area get supplies from all over the world, and distribute products throughout the world. Airport cargo is an integral part of this logistical system. As noted in Appendix A, almost all of the international air freight in the region is handled by SFO, not SJC or OAK. 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.[29] Back-up shipping systems

[28] Source: http://www.fire.ca.gov/fire_protection/fire_protection_air_program.php and Bill Payne, CAL FIRE Air Program, personal communication, February 2013.
[29] Source: Barry Gentry, Director of Security, Agilent Technologies, personal communication, January 2013.

include use of barges to get products 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 crisis management and business continuity 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 products being shipped. Where are the products in the distribution channel? Can the products be expected to reach the customer? What kind of shape are the products in? If a product is damaged, can it be returned to the manufacturer? Where will the products 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.

GAPS IN PLANNING

Lack of Examination of the Role of Airports in Long-Term Regional Economic Recovery

None of the existing state or federal mandated planning at commercial or general aviation airports addresses long-term planning. Long-term economic recovery is different than emergency preparedness or response. Some researchers and agencies believe that is another phase of emergency planning and begins after emergency response, led by the same group of individuals. However, a closer examination shows that this is not the case. Long-term economic recovery begins immediately after the disaster occurs with the planning needed to restore the region to a state where it can continue to have economic growth. Just as before a disaster, the people who manage the airport need to work on airport facility repair, putting their employees back to work, and serving other businesses in the region through passenger and air cargo transport. These are not the police, fire, and security personnel who have responded to the disaster, and thus there is little reason to delay such planning until search and rescue, mass care, and other immediate needs of emergency response are addressed.

While the standard belief is that the aim of recovery is to restore an affected area, together with its airports, to its pre-disaster condition, the model after a major disaster is closer to a redevelopment process where some areas may change in use, such as has occurred after Hurricane Katrina.

MTC's 2000 Regional Airport System Plan and the 2011 update discuss the role of airports on the regional economy. *This information can be used as a basis for estimating the potential impacts of major long-term airport closures on the regional economy.*

In addition, the report by the Bay Area Economic Forum, *A Baseline Economic Impact Report on Bay Area International Airports, their Relation to Jobs and Global Competitiveness, and Recommendations for Future Analysis – Phase 1*[30], details the impacts of the international airports on the Bay Area economy and can also be useful in that effort, and in promoting additional regional cooperation in long-term recovery planning for the airport system:

- *"Bay Area International Airports generated $37.7 billion in direct business revenues in fiscal year 1998-99.* Roughly two-thirds of this amount was generated by SFO, nearly a quarter by Oakland International and about an eighth by San Jose International.
- *"These revenues supported nearly half a million jobs.* Nearly 470,000 jobs were generated by airport operations, visitors to the region, and associated spending. This does not count employment at companies relying on the airports to transport their employees or ship their products.

[30] See http://www.bayareaeconomy.org/media/files/pdf/Airport.pdf.

- *"These jobs generated over $13.2 billion in personal income for residents of the Bay Area.* Of this amount, $6.3 billion was generated by personal spending in the economy.
- *"This business revenue and employment generated over $8.7 billion in federal, state, and local taxes.* Nearly $2.9 billion alone went to the state, cities, and counties for local services."

Long-term recovery also must take into account that all airports do not have the same business clients. For example, SFO carries more passengers than OAK and SJC combined, while OAK has the most cargo flights, followed by SFO and SJC, as shown in **Appendix A**.

Prior Lack of Examination of the Role of Smaller Commercial and General Aviation Airports

The two smaller commercial airports (Buchanan Field in Concord and Charles M. Schulz/Sonoma County Airport in Santa Rosa) could be particularly useful during long-term economic recovery if any of the three international airports in the region are damaged for an extended period of time. In addition, even if the three international airports are back in full service within a few days, if commuting becomes more difficult, employees end up living further from their employers for extended periods of time, or it is difficult to transport air cargo to the major international airports, smaller airports may experience expanded commercial and private use.

The Charles M. Schulz Airport in Santa Rosa currently has a commercial license and handles some smaller passenger and air cargo flights. Existing cargo operations include limited flights by FedEx and Martinaire (for UPS). The current number of passenger flights is constrained by the size of the terminal and the existing passenger and baggage screening capabilities. The existing 5,100-foot runway is being expanded to 6,000 feet. While the runway is currently weight-rated for 150,000 pounds (or a 737), it can handle an occasional 175,000 pound aircraft. For example, an empty C17 lands annually as part of its air show. The Coast Guard practices landings and take-offs with C130s using the airport. It is also designated as a site for staging for rapid deployment for the Center for Disease Control (CDC).[31]

In addition, all commercial operating certificates are up to date at Buchanan Field in Concord. Even though there is currently no commercial use at Buchanan, commercial flights could land at this airport. In an emergency, Buchannan could handle limited 737s and these aircraft could leave if not fully loaded. However, it, like Charles Schultz, operates best with smaller aircraft. The "equipment" needed for a commercial operation would not be that difficult to install at Buchanan, with the exception of passenger security screening. (Cargo screening is not as difficult.) Existing corporate hangars could be converted to commercial use if a longer use is needed. However, while some larger aircraft could land at either Charles M. Schulz or Buchanan

[31] Source: Jon Stout, Airport Manager, Charles M. Schulz/Sonoma County Airport, personal communication, October 2012.

in an emergency, the runway length at both of these smaller commercial airports would limit the size or weight of aircraft, particularly during take-off.[32]

General aviation (GA) airports have typically been left out of any discussion of regional emergency response and recovery. However, the use of these airports has been discussed by volunteer pilot organizations, firefighting organizations, and medical evacuation organizations. GA airports will be particularly critical in the movement of emergency and medical personnel, as well as in delivery of critical supplies, if they are located in an area with a disrupted surface transportation system.

Broad use of mutual aid agreements would not only speed the sharing of resources during emergency response, but could be used as a backbone for broader regional coordination of emergency response and long-term recovery planning.

Even smaller general aviation airports could have a significant role, particularly in the first few days following a disaster, in providing access to areas heavily impacted by a disaster. Plans for such use should not only examine relevant airport characteristics, but also land-side access to those facilities.[33]

Finally, as a caveat, it must be stressed that smaller commercial airports, as well as general aviation airports, have limited resources. Thus, part of any planning for these airports to have a more formal or expanded role related to disaster response and recovery needs to include thinking about innovative ways to fund and staff the creation of those plans, as well as their implementation. These airports also have limited space. Thus, if approached by a pilots association or other group to store emergency supplies, that request needs to be balanced against the space and budget constraints of the airport.

The international, commercial, and general aviation airports in the 9-county Bay Area, as well as significant airports in adjacent counties in Northern California, are listed in **Appendix B**.

Need to Appreciate that Air Cargo Carriers and Passenger Airlines Station Specialized Equipment at the International and Commercial Airports

Some disaster response planning may assume that runways and functional infrastructure are the only key items related to changing which airports can handle air cargo carriers and passenger airlines. Such plans would be deficient if they also did not include the need for alternative airports to have the capability to deplane passengers and cargo, as well as to get those people and

[32] Source: Keith Freitas, Airport Manager, Buchannan Field, personal communication, October 2012.

[33] These findings on general aviation airports are similar to those determined independently by J.F. Smith (2012). (See "The Roles of General Aviation Airports in Disaster Response" in *Journal of Homeland Security and Emergency Management*. Volume 9, Issue 2).

items to their ultimate destination. In addition, while TSA passenger and cargo screening is not essential in taking people and items off of planes, adequate TSA personnel and equipment is needed if an airport is to handle commercial cargo and passenger flights originating at an airport. Finally, additional passport control operations are needed if an airport is not currently classified as an international airport.

Lack of Continuity in Staffing of Disaster and Recovery Planning

As with any disaster operation, plans of airports and airport users and regulators, are the job of individuals. As those individuals leave or take jobs with other organizations, there are lapses in institutional memory and in long-term relationships that extend beyond the immediate individuals that each person works with. The lack of continuity of disaster and recovery planning staffing is particularly important as an issue as personnel are reduced so that a single individual is responsible for this type of planning. This problem has been particularly apparent in the preparation of this document.

The problem is exasperated because of the complexity of the airport system, particularly at the three international airports. Even cooperation among the three airports does not solve the need for coordinated business continuity planning of the air cargo carriers and passenger airlines that operate at those airports.

Need to Better Coordinate Surface Transportation with Airport Disaster Response and Recovery Planning

As described on page 4, Cal OES is in the process of completing an Air Coordination Group Concept of Operations (CONOP) plan outlining a general understanding of how emergency aviation will be supported by federal and State partners once Cal OES activates the ACG. Such a plan will better integrate airports into regional disaster response activities. This planning is critical because it will help integrate airports into the solution of how to move, people, goods and services around an area when surface transportation systems are temporarily compromised.

However, the recovery of an airport in conjunction with the local surface transportation system is more complex. If an airport is to be repaired it will require materials, equipment and labor. Normally materials, men and equipment arrive by roads, so planning for airport recovery in conjunction with the coincidental planning requirements for roadways supporting airport operations needs to occur. In addition, this planning should identify mechanisms to ensure that critical materials (such as asphalt, concrete, etc.) can be obtained to make repairs at airports (including runways, taxiways, and parking areas), as well as potential problems with transporting them to the airports. Many of these materials, as well as the equipment needed to install them, are common to both airports and roads, so there may be conflicting objectives and demands of various organizations if adequate planning does not occur.

PART 2:

ROLE OF INTERNATIONAL, COMMERCIAL AND GENERAL AVIATION AIRPORTS IN RECENT NATURAL DISASTERS

An effective way to document the role of airports in a future disaster is to examine at the role and performance of airport systems in past disasters.

A review of these case studies shows that the disasters are of three general types:

- Disasters where BOTH the airports and the surrounding community were impacted, and are recovering, often with the airports recovering first.
- Disasters where the airport remained functional and served as a lifeline during emergency response of a surrounding community, yet have suffered during the long-term regional recovery period due to lack of use.
- Disasters were the airport was closed for a relatively short period of time, but has been repaired and is recovering along with the surrounding community.

The nine disasters that were examined, and form the basis for these conclusions, include the following:

- 1989 Loma Prieta Earthquake
- 1994 Northridge Earthquake
- 2001 Seattle (Nisqually) Earthquake
- 2005 Hurricane Katrina
- 2009 Samoan Earthquake and Tsunami
- 2010 Haiti Earthquake
- 2010 Bio-Bio Chile Earthquake
- 2011 (February) New Zealand Earthquake
- 2011 Tōhoku Japan Earthquake and Tsunami

The summaries of these disasters focus on:

- What was the disaster? What happened to the region impacted by the disaster?
- What infrastructure was damaged, and to what extent?
- What damage occurred to airports?
- How did each airport work to ensure that it could again be back in service?
- Has the airport undertaken hazard mitigation efforts since that disaster?
- What was the role, if any, of airport facilities in short-term disaster response of the community and region?
- What was the impact of the disaster on the economic activity of airports?

1989 Loma Prieta Earthquake

The Loma Prieta earthquake occurred at 5:04 pm Pacific Daylight Time on October 17, 1989. With a moment magnitude of 6.9, it severely shook both the San Francisco Bay Area and the Monterey Bay Area. It lasted approximately 15 seconds. The epicenter of the earthquake was near Loma Prieta Peak in the Santa Cruz Mountains, approximately 14 km (9 miles) northeast of Santa Cruz and 96 km (60 miles) south-southeast of San Francisco. The focus was at a depth of 18 km (11 miles) and the rupture extended 35 km (22 miles) along the fault, but it did not break the surface of the Earth. Significant shaking was felt from southern Monterey County in the south to Santa Rosa in the north.

There were 63 confirmed deaths, most due to the collapse of the Cypress structure in Oakland, California. Over 3,700 people were injured.

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. Most of the damage occurred in Santa Cruz County, San Francisco, and Oakland. Loma Prieta was the first disaster in which local government building inspectors used the red-yellow-green tagging system to mark buildings for habitability. As a result of the earthquake, approximately 16,000 housing units were made uninhabitable in the 12-county San Francisco-Monterey Bay Area.[34] Direct damage to buildings and infrastructure was approximately $5.9 billion dollars.

Infrastructure Damage

The quake disrupted power throughout the heavily shaken region. However, it can be characterized as equivalent to that of a severe winter storm expected to occur annually.[35] Damage to natural gas pipelines was much more significant, causing PG&E to shut off electrical power to several neighborhoods to prevent fires. There were over 500 gas line leaks in the impacted region, as well as approximately 8.5 miles (13.6 km) of older natural gas pipelines that had to be replaced in the Marina area of San Francisco.

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[34] Source of damage to housing: Perkins, Jeanne, Chuaqui, Ben, Harrald, Joh, and Jeong, Dukhoon (1996). *Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region*. Association of Bay Area Governments: Oakland, California.

[35] Source of damage to power: Schiff, Anshel, Swan, Sam, and Matsuda, Edward (1998). "Electrical Power Systems" in *The Loma Prieta Earthquake of October 17, 1989, Performance of the Built Environment - Lifelines*. U.S. Geological Survey Professional Paper 1552-A. See http://pubs.usgs.gov/pp/pp1552/pp1552a/pp1552a.pdf.

Sources of photos in this section: OAK runway damage – Oakland Airport; OAK control tower – J. Perkins; SFO international Terminal - http://www.celebratingeqsafety.com/sfo.html (Structural Engineers Association of Northern California).

Transportation was disrupted as roads and bridges were closed due to ground failure and structural damage. In total, 142 roads and highways were closed for periods of a day to several weeks. The San Francisco-Oakland Bay Bridge, a small bridge in Watsonville, and several remote roads were the last to open. The Cypress Freeway Viaduct was torn down, rerouted, and replaced.[36]

Airport Disruption and Recovery[37]

San Francisco International Airport (SFO)

- 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. The controllers had difficulty reaching the airport because of the closure of the San Francisco-Oakland Bay Bridge, as well as general gridlock as evening commute traffic became exacerbated by traffic leaving the San Francisco Giants-Oakland A's World Series baseball game at Candlestick Park near the airport. Road closures near the airport did not occur.

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[36] Source of transportation system damage information: Perkins, Jeanne, Chuaqui, Ben, and Wyatt, Edward (1997). *Riding Out Future Quakes: Pre-Earthquake Planning for Post-Earthquake Transportation System Recovery in the San Francisco Bay Area*. Association of Bay Area Governments: Oakland, California.

[37] This description of damage to the airports is summarized from Perkins, Jeanne (2000). *Don't Wing It: Airports and Bay Area Earthquakes*. ABAG: Oakland, California. See http://quake.abag.ca.gov/wp-content/uploads/2010/10/FAApastproblem.pdf .

Oakland International Airport (OAK)

- 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.[38]

- 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.[39]

- 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.[40]

- 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.[41]

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[38] Source: Earthquake Engineering Research Institute (EERI) (1990). *Loma Prieta, California, Earthquake of October 15, 1989. Reconnaissance Report.* EERI, Oakland, California.
[39] Source: T. LaBasco, S. Kopacz, and J. Serventi, Port of Oakland, personal communications, Sept. 2000.
[40] Source: EERI (1990). See above.
[41] Source: T. LaBasco and I. Osantowski, Port of Oakland, and J. Rodriguez, FAA, personal communications, Sept. 2000).

San Jose International Airport (SJC)

- 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 [the status] of SFO and OAK. The status of the airport was then communicated to the City Emergency Response Center.[42]

- 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. No road failures at or near the airport were reported.[43]

- The airport was considered as an alternative airfield if flights needed to be diverted from San Francisco or Oakland, as is standard for this airport. Hypothetically, if numerous diversions to SJC had occurred at about the same time, there could have been delays in fueling due to limits in available fuel storage facilities and dispensing equipment; however, this was not an issue.[44]

- 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 felt that "the plan worked well, although the minimal damage did not give the plan a thorough test." [45]

Alameda Naval Air Station

- 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 tracks 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. The two runways were repaired and reopened (one in December 1989 and the second in January

[42] Source: C. Herrera, SJC, personal communication, 2000.
[43] Source: Earthquake Engineering Research Institute (EERI) (1990). *Loma Prieta, California, Earthquake of October 15, 1989. Reconnaissance Report.* EERI, Oakland, California.
[44] Source: Cary Greene, Airport Planner, SJC, personal communication, May 2013.
[45] Source: D. Chubbic, SJC, personal communication, Sept. 2000.

1990).[46] However, the facility was closed in 1995 and is now scheduled for non-airport reuse.

Airport Mitigation and Emergency Planning Activities

In the over 20 years since the Loma Prieta earthquake, the three international airports have all made significant improvements to their risk and hazard mitigation, as well as in disaster response planning. The following recent projects are significant examples.

San Francisco International Airport (SFO):[47]

- The International Terminal opened in 2000 as one of the largest buildings in the world constructed on base isolators to protect the structure from earthquake ground shaking damage.[48]

- The SFO airport completed a seismic upgrade to its upper level viaduct in 2011. It involved installing new piles, enlarging the pile caps, and reinforcing/wrapping the columns.
- Portions of Terminal 2 and Concourse D were brought up to current seismic code as part of the Terminal 2 extensive renovation project completed in 2011.
- Boarding Area E is undergoing extensive renovation in 2013 (in which it is being taken down to its steel structure and rebuilt) will be brought up to current seismic codes.
- A portion of Terminal 3 may be upgraded as re-construction opportunities present themselves during the project to expand the security checkpoint.
- The Terminal 1 Redevelopment Program will rebuild Boarding Area B, Boarding Area C and Terminal 1 to current seismic codes and standards. Enabling projects are to start in the latter half of 2013. Program is anticipated to be completed in 5 to 6 years.
- SFO's new air traffic control tower will be built to current seismic codes. The project is under construction and is to be completed by August 2015.

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[46] Source: EERI (1990). See above.

[47] Source: William Wilkinson, Emergency Manager, SFO, personal communication, February 2013 [retired prior to report finalization] and Jeff Littlefield, Deputy Airport Director, Operation and Security, SFO, personal communication, May 2013.

[48] See http://www.celebratingeqsafety.com/sfo.html and http://www.flysfo.com/web/export/sites/default/download/about/news/pressres/fact-sheet/pdf/International_Terminal_Fact_Sheet.pdf .

- SFO is conducting a Shoreline Protection Feasibility Study to assess its vulnerability to flooding, sea level rise and tsunami events. The study will provide mitigation measures and recommendations to the Airport for implementation. The Study is to be completed early 2015.

Oakland International Airport (OAK):[49]

- Modern structural design was incorporated into the new Terminal 2. Terminal 1 (constructed in 1962) is currently undergoing structural strengthening to a life-safety standard. When Terminal 2 was constructed (in 1985 and recently expanded in 2008), the levee protecting the facility from inundation by the Bay was improved in that area.

- The airport is in the design and environmental review phase of a project to improve the perimeter dike system which protects facilities at OAK's South Field, including the main air carrier runway and passenger terminals, from inundation by water from the San Francisco Bay (portions of South Field are below sea level). The improvements will strengthen the portions of the dike that are vulnerable to earthquake-induced liquefaction, and correct the areas that do not meet FEMA flood control standards. These improvements are expected to be completed in 2016.

- A new control tower has been constructed in accordance with modern engineering and construction standards. The newly constructed tower will be operational in July 2013, after which the South Tower cab and entire North Tower will be vacated.

San Jose International Airport (SJC):

- At SJC, liquefaction is a hazard related primarily to naturally occurring ancient stream channel deposits and localized fills underlying the runways. SJC has since made significant physical improvements pursuant to the City of San Jose's 1997 adoption of a new Airport Master Plan and FAA's 1999 approval of a new Airport Layout Plan.

- The short east side runway (12L-30R) was reconstructed and extended to 11,000 feet in length, providing the Airport with a second air carrier runway. The former main commercial runway (12R-30L) was also reconstructed and extended. The design of these improvements included mitigation for the underlying soil conditions.

- The passenger terminal complex has been extensively redeveloped. The 1960s-era Terminal C was demolished in 2010 and replaced by a new 600,000 square-foot Terminal B meeting

[49] Source: Hugh Johnson, Aviation Planning and Development, OAK, personal communication, February 2013 and Anne Henry, Aviation Planning and Development, OAK, personal communication, May 2013.

the latest seismic codes. The life safety systems in Terminal A were also upgraded in 2010, and the roadways providing access to and from the terminal buildings have been reconstructed. Completion of these terminal improvements also allowed the Airport to relocate all its staff back to the Airport site after several years of leasing off-airport office space.

- A new jet fuel storage facility was completed in 2009 that has ten times the storage capacity of the old facility as well as a pipeline connection that significantly reduces reliance on on-road tanker-truck deliveries.
- On the non-commercial side of the Airport, additional corporate aviation hangars and ramps have been constructed, with more expansion anticipated in the short term future.

1994 Northridge Earthquake

The Northridge earthquake occurred at 4:31 am Pacific Standard Time on January 17, 1994. With a moment magnitude of 6.7, it severely shook the entire Los Angeles County area, and was felt as far away as Las Vegas, Nevada, about 220 miles (360 km) from the epicenter. It lasted approximately 15 seconds. The epicenter of the earthquake was near the Los Angeles community of Reseda in Southern California. However, because of the initial calculation of the epicenter as being in Northridge, the media and public thought of it as the Northridge earthquake, and the name was not changed. The focus was at a depth of 17 km (10.6 mi). It ruptured the previously unknown Pico thrust fault, meaning that the land was thrust up and over another block of land. Because it was a "blind" thrust fault, it did not break the surface of the Earth.

There were 57 confirmed deaths. Over 8,700 people were injured.

Approximately 46,000 housing units were made uninhabitable, many in apartments with garages on the first floor creating a "soft" story prone to collapse.[50] Direct damage to buildings and infrastructure was approximately $20 billion dollars.

Infrastructure Damage

Transportation was disrupted as roads and bridges were closed due to ground failure and structural damage. In total, 140 roads and highways were closed. The most spectacular failures were the I-5/State Route 14 Interchange, as well as two bridges each on I-10 and Ste Rd. 118. While the number of road closures in this earthquake was approximately the same as the 142 closures in the Loma Prieta earthquake slightly over five years earlier, Caltrans and public support for speedy repair of the failures meant that the transportation system recovered more quickly.[51]

Airport Disruption and Recovery

The ABAG report *Don't Wing It: Airports and Bay Area Earthquakes*[52] notes that 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.

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[50] Source of housing losses: Perkins, Jeanne, Chuaqui, Ben, Harrald, Joh, and Jeong, Dukhoon (1996). *Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region*. Association of Bay Area Governments (ABAG). Oakland, California.

[51] Source of transportation disruptions: Perkins, Jeanne, Chuaqui, Ben, and Wyatt, Edward (1997). *Riding Out Future Quakes: Pre-Earthquake Planning for Post-Earthquake Transportation System Recovery in the San Francisco Bay Area.* Association of Bay Area Governments. ABAG. Oakland, California.

[52] Source: Perkins, Jeanne (2000). *Don't Wing It: Airports and Bay Area Earthquakes.* ABAG. Oakland, California. See http://quake.abag.ca.gov/wp-content/uploads/2010/10/FAApastproblem.pdf.

- 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.[53]

- Van Nuys Airport, the general aviation airport closest to the area of highest shaking intensity, had window glass breakage in the control tower.[54] Equipment in that tower slid up to 4 inches. Damage to FAA facilities at the airport control tower totaled about $160,000.[55]

- 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.[56]

Airport Mitigation and Emergency Planning Activities

While all three airports performed well in this disaster, emergency centers and mitigation for earthquakes and other disasters continues to occur at these airports. Recently, the following projects are significant: [57]

- LAX Airport Response Coordination Center (ARCC) – In December 2010, LAX completed the $13.9-million ARCC. The Center will streamline crisis management activities at the airport by acting as a high-tech nerve center staffed by both responding airport divisions and federal agency personnel. It houses the Incident Management Center/Department Operation Center (IMC/DOC) that is activated as a critical incident command center in a crisis. As a new facility, it complies with all current seismic and other codes for critical facilities.

- LAX-Los Angeles Fire Department (LAFD) Aircraft Rescue and Firefighting (ARFF) Station No. 80 – In November 2010, LAX completed the $13.5-million ARFF Station. The project, centrally located at LAX, doubled the size of the original facility, allowing many more firefighters, rescue vehicles and emergency-response equipment to be housed in the facility.

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[53] Source: Earthquake Engineering Research Institute (EERI) (1995). *Northridge, California, 1994 Earthquake: Reconnaissance Report.* EERI Earthquake Spectra: April 1995, Vol. 11, No. S2. Oakland, California.
[54] Source: EERI (1995). See above.
[55] Source: Schiff, Anshel J., ed. (1995). *Northridge Earthquake – Lifeline Performance and Post-Earthquake Response*. Technical Council on Lifeline Earthquake Engineering Monograph No. 8, American Society of Civil Engineers, pp. 227-235.
[56] Source: EERI (1995). See above.
[57] Source: Los Angeles World Airports (December 2012). *Los Angeles International Airport – Modernization at a Glance*. See http://www.lawa.org/uploadedFiles/LAXDev/News_for_LAXDev/LAX%20Modernization.pdf

- LAX Theme Building Renovation – In June 2010, the $12.3-million project that renovated the exterior of this iconic Theme Building (shown in photo) included a project to install a unique Tuned Mass Damper on the roof of the structure to seismically retrofit the building.[58]

[58] Photo Source: Wikipedia Commons - http://en.wikipedia.org/wiki/File:LAX_LA.jpg.

2001 SEATTLE (NISQUALLY) EARTHQUAKE

The Nisqually earthquake occurred at 10:54 am Pacific Standard Time on February 28, 2001. With a moment magnitude of 6.8, it was one of the largest *recorded* earthquakes in Washington State history. It lasted approximately 45 seconds. The epicenter of the earthquake was Anderson Island, about 17 km (11 mi) northeast of the State Capitol of Olympia and in the lowlands of southern Puget Sound. It was named the Nisqually Earthquake because the epicenter lies under the Nisqually River Delta. The focus was at a depth of 52 km (32 mi). Shaking was felt from Scio, Oregon in the south, north to Vancouver, British Columbia, Canada, and 175 mi (282 km) east to Pasco, Washington. There were also reports that it was felt as far away as Sandpoint, Idaho and Spokane, Washington. In total, the earthquake was felt over an area of 350,000 square km, or approximately 135,000 square miles.[59]

Although there were no reports of deaths directly from the earthquake, there was one death from a heart attack at the time of the earthquake and approximately 400 people sustained injuries.[60]

Several buildings were closed temporarily pending structural inspections, including all state offices in Olympia, schools in the impacted area, and the facilities at Boeing's factory in the Seattle area. Almost 300 buildings were declared uninhabitable (red-tagged or yellow-tagged) due to the earthquake. Most of the damage to buildings occurred in areas of highest shaking or in unreinforced concrete or masonry buildings in the First Hill, Pioneer Square, and Sodo (South of Downtown) neighborhoods of Seattle. Buildings in the Sodo area were also damaged by liquefaction-induced ground failure. In addition, a buttress under the dome of the capitol building in Olympia was damaged. Previous mitigation was credited with preventing further damage.[61]

Infrastructure Damage

The quake disrupted power in downtown Seattle.

Transportation was disrupted as bridges were closed for inspection. In downtown Olympia, the Fourth Avenue Bridge was heavily damaged, but was decaying and scheduled for replacement even before the earthquake occurred. The Fourth Avenue on-ramp to I-90 was found to be heavily damaged due to concrete spalling from the bearing seat of an expansion joint. It has since been demolished and replaced. The Alaskan Way Viaduct and its seawall along the Seattle waterfront were damaged and closed for emergency repairs. The decision has since been made to replace the viaduct. The Holgate Street Overpass over I-5 sustained shear failure of its columns. The Spokane Street overcross of SR-99 sustained damage to the superstructure.[62]

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[59] Source: Dewey, James W., Hopper, Margaret G., Wald, David J., Quitoriano, Vincent, and Adams, Elisabeth R. (2002). *Intensity Distribution and Isoseismal Maps for the Nisqually, Washington, Earthquake of 28 February 2001*. U.S. Geological Survey. See http://pubs.usgs.gov/of/2002/ofr-02-0346/OFR-02-0346.pdf.
[60] Source: Dewey and others (2002). See reference above.
[61] Source: Source: Dewey and others (2002). See reference above.
[62] Dewey and others (2002). See reference above.

Airport Disruption and Recovery

Air traffic into the Puget Sound region was disrupted due to damage to SeaTac Airport and Boeing Field.

The USGS report on the earthquake[63] notes that the most extensive damage was nonstructural, rather than structural, damage. For example, the North Satellite Terminal was closed for a day due to water damage from broken fire sprinklers. Terminal C lost ceiling tiles and light fixtures fell. Most significantly, the "steel framework supporting the windows and roof of the SeaTac control tower failed resulting in an estimated $2 million in damage."

The report continues by quoting a worker on the ramp at the airport: "I was stationary in a minivan when I noticed a rolling motion. I initially thought someone was jumping on the tow hitch. I realized it was a quake when I saw the twin turboprop aircraft directly in front of me bouncing from side to side. I could feel and see the ground welling up and down underneath my feet. The poles for the flood lights above the passenger terminal were swaying back and forth rapidly. The air traffic control tower 200 feet to my right was swaying back and forth, as well. Just then, the windows of the control tower blew out and shattered. I saw the aircraft in the air abort their approach and enter into a holding pattern."

One of the controllers stayed in the damaged tower for a few minutes to allow aircraft on final approach to land. Then a few aircraft were diverted until an FAA portable temporary control tower was

[63] Source: Dewey, James W., Hopper, Margaret G., Wald, David J., Quitoriano, Vincent, and Adams, Elisabeth R. (2002). *Intensity Distribution and Isoseismal Maps for the Nisqually, Washington, Earthquake of 28 February 2001*. U.S. Geological Survey. See http://pubs.usgs.gov/of/2002/ofr-02-0346/OFR-02-0346.pdf.

Photo sources for this section: Damaged tower – your.kingcounty.gov ; temporary and new tower – Port of Seattle at http://www.portseattle100.org/properties/control-tower.

operational (about 30 minutes later). The FAA temporary towers are mounted on trucks, allowing them to be moved to where they are needed. It was set up and operated from the west side of the airport starting less than an hour after the earthquake. FAA has a supply of these portable control towers.[64]

The temporary tower was later moved to Viewpoint Park and placed on two shipping containers for added height.

The air traffic control tower at SeaTac Airport that was heavily damaged during the earthquake has since been replaced with a more earthquake-resistant tower. While installation of the new tower was planned, it was not built until after the earthquake and the damage from the earthquake served to speed-up the project. Construction of the new tower was funded, in large part, with FAA Airport Improvement Program grants.[65]

None of the damage to roads and highways impacted access to the SeaTac airport because of the availability of alternate routes. In addition, the only disruptions to water supply were a few water pipeline breaks that were easily identified and repaired within an hour.[66]

Other Airports in the Seattle Area

The following description of damage to Boeing Field appeared in the SCAA News[67]:

> King County Airport (Boeing Field) suffered severe damage to its two runways, both built on old fill (in the flood plain of the Duwamish [River]). Large cracks opened in the concrete, and fountains of watery sand spouted through them. Freight operations were halted, and the Boeing Company had several new aircraft stranded on the ground. Small-plane operations were restored on Feb. 28th, and on March 13

[64] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[65] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[66] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[67] Source: Seattle Council on Airport Affairs (Spring 2001). "The Rattle in Seattle Paralyzes Airports." In *SCAA News*. Vol. 3, No. 2. See http://www.scn.org/scaa/newsletters/2001spring/page1.html and http://www.scn.org/scaa/newsletters/2001spring/page4.html.

temporary repairs to the main runway were completed, so that the airport was again open to all traffic.

Extensive liquefaction also occurred in the industrial area to the north of Boeing Field.

The U.S. Military's Ft. Lewis and McChord Air Force Base was damaged in the quake, but it appears that the damage was largely to a steam plant, not to its aviation facility. Paine Field had no reported damage.

On-Going Emergency Planning and Hazard Mitigation Activities

Unlike with most airports, the SeaTac Airport Emergency Plan (AEP) is available online,[68] enabling anyone with access to the internet to examine that plan. (Due to security concerns, a small section of this plan dealing with terrorist event response is in a separate plan not available on line.)

The AEP discusses the role of each of the airport departments in future disasters, including the fire, emergency medical and police departments, airport operations, maintenance, communications center, the incident commander, and the emergency operations center. In addition, the AEP reviews coordination with FAA tower staff, airlines, and mutual aid agencies.

The SeaTac AEP also has specific chapters addressing various specific types of disasters, including severe storms, earthquakes and volcanic eruptions. The situational assumptions for these disasters provide airport staff with an idea of what makes these disasters different from a "normal" emergency. The following bullet points are extracted from that AEP:

- "It is understood that pre-established mutual aid assistance of all types may or may not be available.
- It is assumed that coming to or leaving the airport may be difficult or impossible for some period of time.
- It is assumed that restoration of the aircraft movement area will be critical as area wide relief efforts may be centered around air transport."

The concept of operations of that plan notes that: "Following an earthquake or other significant natural disaster, the initial strategic objectives will be as follows:

- Rescue and medical aid for all victims
- Provide safe shelter and comfort to all affected
- Inspect and minimize further damage to facilities
- Restore utilities and transportation infrastructure

[68] See Port of Seattle (2011). *Airport Emergency Plan*. See http://www.portseattle.org/Employee-Services/Documents/AEP_2011_Updates.pdf. Hazard-specific planning is on pages 106-125.

- Restore Airport Operations-Airfield/Terminal and Airport Operations-Landside operations as quickly as possible
- Coordinate with local, state and federal agencies for response and recovery initiatives."

In addition to the departments listed in the generic emergency section of this document, the natural hazards section adds checklists for the airport environmental department, chaplaincy and the King County coroner, and the American Red Cross.

As SeaTac worked to develop this plan, emergency managers worked with the Red Cross, businesses, private ambulance companies, 17 hospitals, 48 fire departments, 7 police departments, airlines (both passenger and cargo) and other vendors at the airport. They have also offered to come to each of these other groups and give them training sessions on the plan. They have an inventory of their own equipment, and those of the passenger airlines and air freight carries, in a FEMA inventory model database called "Kind and Type."[69]

Similar to the Ports of Oakland and San Francisco, the Port of Seattle operates both the Seattle waterfront and the SeaTac airport. The Port and SeaTac take continuity of operations seriously. They are prepared to do whatever it takes to maintain operations. For example, they have created specialized positions in the Emergency Coordination Center that are unique – one for Continuity of Operations (COOP) and a second for Recovery of Operations. They also treat each of their work groups as individual businesses and they EACH have their own COOP plans. They find this key to their response. They also train their people on the importance of maintaining an operational status.[70]

SeaTac has shared its experiences with the WESTDOG (Western Airports Disaster Operations Group) community and is part of that voluntary mutual aid agreement. SeaTac also actively coordinates disaster planning with the Spokane airport and has local relationships with the other general aviation and military airports in their more immediate area.[71]

Hazard mitigation also continues to be a priority at the SeaTac airport. A third runway has been constructed since the earthquake. The airport continues to mitigate seismic deficiencies in its terminals. While some mitigation would have happened regardless of the earthquake, that disaster served to focus the priority of hazard mitigation in the community and likely streamlined the process for prioritizing funding and constructing these improvements for both the airport and FAA.[72]

[69] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[70] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[71] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.
[72] Source: Ron Harmon, Emergency Manager, SeaTac, personal communication, February 2013.

2005 Hurricane Katrina

On August 29, 2005 Hurricane Katrina struck the Gulf Coast area as a Category 3 hurricane with a storm surge equivalent to a Category 5 hurricane. The disaster, partly natural and partly human-induced, resulted in hundreds of deaths along the Gulf Coast, displaced 1.7 million people, and resulted in more than $150 billion in losses – making it the worst disaster in U.S. history.

The Hurricane track veered to the east to the Mississippi coast as it approached New Orleans, and observers relaxed, believing that the City had escaped damage. What was not immediately realized was that the storm surge and resulting winds across Lake Pontchartrain on the north side of the City had undercut and then collapsed a levee on a canal leading to the lake, allowing lake water to flow into a portion of the City. Subsequently, levees of the incomplete Corps Flood Protection System failed catastrophically in many places across the City, flooding approximately 80% of the City to a depth of up to 20 feet.

Based on the 2000 census, the City of New Orleans had a population of 484,674, but it had declined to about 455,000 by 2005. Approximately 50% of its 215,091 housing units were flooded with more than 4 feet of water. Yet parts of the City on high ground near the Mississippi River were spared, including the historic French Quarter.

The State of Louisiana Department of Health and Hospitals documented 971 deaths in the State, as well as 15 deaths of Katrina evacuees in other states.[73] While the mandatory evacuation order resulted in saving thousands of lives, the number of deaths was still the deadliest hurricane to hit the Gulf Coast since 1928. Many were poor, and since the disaster occurred near the end of the month, they had no money for gas or bus fare. Others were not evacuated because they were ill and fragile, and the concern was that they could not survive being moved. The media coverage of the Superdome and Convention Center provided an overriding impression of emergency response failure.

The impacts of Katrina to the Gulf Coast of Mississippi were different, for the storm concentrated its impacts on commercial and industrial areas, rather than just housing. For example, all of the Biloxi casinos were impacted. Two of them have no plans to re-open.

Katrina's storm surge had a large impact on the housing in Biloxi, as well. For example, the City of Biloxi had a population of 50,644 and 22,155 housing units at the time of the 2000 census. Many of those in the City did not comply with the mandatory evacuation order, in spite of the Mayor's plea to evacuate, explaining, on television, that the storm would be worse than Camille.

[73] Source: Brunkard, Joan, Narmulanda, Gonza, Ratard, Raoult (August 28, 2008). "Hurricane Katrina Deaths, Louisiana, 2005" in *Disaster Medicine and Public Health Preparedness*, a journal published by the American Medical Association (AMA). See http://new.dhh.louisiana.gov/assets/docs/katrina/deceasedreports/KatrinaDeaths_082008.pdf.

As a result, over 50 people died. The death toll would have been worse if the storm had made landfall at night, rather than during the day when stranded people could be located and rescued.[74]

Both the areas adjacent to the Gulf, as well as those near the Back Bay, were impacted. A RAND Corporation report[75] estimates that, in all, 55% of the housing units were damaged, with 29% suffering "severe" damage from the storm surge, high winds, flooding, and rain.

Infrastructure Damage

The infrastructure systems of the City of New Orleans collapsed. In particular, over 30% of customers in the City were still without power 26 days later when Hurricane Rita struck, causing additional damage. Many local roads were flooded and blocked by debris. The I-10 bridge over Lake Pontchartrain was closed and heavily damaged.

In Southern Mississippi, extensive damage to Highway 90, the main road along the Gulf Coast, delayed recovery. In particular, the Hwy. 90 bridge across Biloxi Back Bay leading to Ocean Springs did not re-open until early 2008. Impacts to City of Biloxi facilities were significant, with the City losing 17 of its facilities.

Louis Armstrong New Orleans International Airport Damage and Recovery

Prior to Hurricane Katrina, Louis Armstrong New Orleans International Airport (MSY) was a publicly owned airport. It had an Airport Emergency Plan approved by FAA. However, that plan focused on terrorism. It also had mutual aid pacts with neighboring jurisdictions, but they focused on aviation accidents. There was no plan for a disaster that shut down not only New Orleans, but these neighboring jurisdictions. In addition, the airport did not have an on-going relationship with either regional or state emergency management agencies or personnel.[76]

The New Orleans Airport was closed before the storm but reported no flooding in airplane movement areas or inside of the terminal building. By August 30 (the

[74] For more information on the difference impacts in four different communities, see Perkins, Jeanne (2008). *Recovery After Hurricane Katrina: Tales of Four Cities*. Association of Bay Area Governments (ABAG). See http://quake.abag.ca.gov/wp-content/uploads/2010/10/PR-Recovery-Katrina.pdf.

[75] Source: McCarthy, Kevin, Peterson, D.J., Sastry, Narayan, and Polard, Michael (2006). *Technical Report: Hurricane Katrina*. RAND Corporation Gulf States Policy Institute, Santa Monica, California.

[76] See James Smith (October, 2008). "Maintaining Airport Continuity of Business and Operations During Disaster Response: The Role of Command and Control Relationships with Emergency Management Agencies" in *Journal of Business Continuity & Emergency Planning.*

Photo source: http://www.katrinadestruction.com/images/d/15315-2/new+orleans+airport

day after the storm), it was reopened to military, humanitarian and rescue operations, even though there was some damage to building and hangars, particularly roof damage.

Airport terminals also served as a staging area for evacuees, including those needing medical assistance. During the week following the hurricane, the terminal served as a staging area for 27,000 patients. Of these, 3,000 were evacuated by air, representing the largest air evacuation of its type in history.[77] Use of the terminals for this purpose showed how desperate the situation had become, as reported by Kerry Sanders for NBC News[78]. James Smith notes[79]:

> Numerous responders descended on the airport as the most intact, largest, most secure space in the region: eight mobile hospitals; medical evacuation (medevac) contractors; medical triage; refugee evacuation center; urban search and rescue (USAR) helicopter operations; logistics support; operating bases; and agency offices. There was no command and coordination. FEMA tried to impose order by importing an expert incident command system (ICS) team from the U.S. Forest Service in California, but they were unable to deal with turf battles and egos, particularly among the medical units. Airports in a five-state region were wholly or partially overwhelmed by incoming logistics that piled up. … The New Orleans airport became the main communications hub for the region. Initially the airport operated from one EOC located within the terminal facility. Shortly thereafter, a Joint Operations Center (JOC) was established to coordinate the MSY, local, state and federal efforts.

Full opening of the airport was staged. Commercial cargo flights resumed on September 10, and commercial passenger service resumed on September 13.

James Smith notes[80]:

> The combination of damage to the facility from the storm and the response with the economic consequences of decreased air traffic was deadly to MSY in terms of resources for implementing improvements, and U.S. federal grant guidelines did not help improve the facility or preparedness against the next storm.

Due to the disruption of the airport, business at the Baton Rouge Metropolitan Airport experienced record levels of use. In particular, according to an article in USA Today (Feb. 15, 2006), both FedEx and DHS started new operations in Baton Rouge due to the disruption. "FedEx has resumed its operations at the New Orleans airport, but … the shipping company is

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[77] Source: Sanford, C., Jui, J., Miller, H.C., Jobe, K.A. (April 26, 2007). "Medical treatment at Louis Armstrong New Orleans International Airport after hurricane Katrina: the experience of disaster medical assistance teams WA-1 and OR-2" in *Travel Medicine and Infectious Disease*. 2007 Jul;5(4):230-5. Epub 2007 Apr 26. See http://www.ncbi.nlm.nih.gov/pubmed/17574144.

[78] Source: Sanders, Kerry (September 2, 2005). "*Horrible Scenes at New Orleans Airport*" *in Katrina: The Long Road Back*. NBC News. See http://www.msnbc.msn.com/id/9175928/ns/us_news-katrina_the_long_road_back/t/horrible-scenes-new-orleans-airport/.

[79] Source: Smith, James (2008). See reference on previous page.

[80] Source: Smith, James (2008). See reference on previous page.

planning to stay in Baton Rouge. … The Federal Aviation Administration had already allocated $2.1 million to build a new cargo facility at Metro Airport, but recently agreed to expand the grant to $4.8 million."[81]

The airport and others in New Orleans instituted campaigns to bring business back to New Orleans. In general, the airport business is recovering as New Orleans recovers.

Gulfport/Biloxi International Airport

The Gulfport/Biloxi International Airport was closed for repairs following severe damage by Hurricane Katrina on August 29, 2005. On September 8, 2005, the airport reopened for Northwestern Airlines commercial flights to Memphis and other airlines quickly followed suit. By February 1, 2006, Gulfport-Biloxi International Airport was back to 100% of pre-Katrina seats.

The airport received a $44 million federal FAA grant to repair hurricane damage. The project was completed in 2007. In a press conference announcing the grant, then Transportation Secretary Norman Mineta announced, ""This grant won't just repair, rebuild and revitalize this airport, it will also bring new passengers, new business, and new energy to this storied region," said Mineta. "This grant will lay the foundation for the Gulfport/Biloxi International Airport of tomorrow, and what an airport it will be." The funding was used to help build new air cargo and general aviation facilities, provide for the main terminal's ongoing renovation, and build a new control tower that was relocated on the west side of the airport and nearly twice as high.

Stennis International Airport

Stennis International Airport in Bay St. Louis, Mississippi was key to the response efforts in Southern Mississippi. According to General Aviation News[82]:

> Immediately following Hurricane Katrina, Airport Manager Bill Cotter and his son cleared debris from operational and safety areas and repaired runway edge lights to allow resumption of night operations. The airport borrowed airport rescue and fire fighting vehicles, and two days after the hurricane, relief flights began.
>
> The airport provided bivouac areas for soldiers and airmen providing security and relief services. This enabled military and civilian aircraft operating out of Stennis to support massive relief efforts in southwest Mississippi and New Orleans.
>
> The airport staff coordinated space for parking and unloading military and civilian cargo aircraft delivering relief supplies. At the height of post-Katrina operations, 1,500 tons of supplies were delivered daily to the airport.

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[81] Source: USA Today (February 15, 2006). "Airport's business jumps after Hurricane Katrina" in *USA Today*. See http://usatoday30.usatoday.com/travel/flights/2006-02-15-baton-rouge-airport_x.htm.

[82] Source: General Aviation News (2006). "Stennis Airport Honored for post-Katrina Efforts" in *General Aviation News*. See http://www.generalaviationnews.com/2006/03/02/stennis-airport-honored-for-post-katrina-efforts/.

"Stennis Airport acted quickly to restore service so critical relief flights could operate quickly and safely out of the airport," said Rusty Chapman, manager, airports division, FAA Southern region. "The airport staff's actions are a testament to their dedication and professionalism."

Use and Recovery of General Aviation Airports

An extensive report was prepared by DMJM Harris and DMJM Aviation for the Southeast Louisiana Regional Planning Commission on the impact of the airport on general aviation airports in the impacted region.[83] The researchers surveyed all of the general aviation airports in the area and developed several key findings and recommendations summarized below. The full 240-page report summarizes the damage at several of these airports in an appendix. Key excerpts include:

- Some areas of southern Louisiana are more populated with more economic activity, while others are shrinking. According to the report, "If nothing else was learned by businesses in particular from the experiences of Katrina and Rita it was the absolute necessity of having a "Plan B" to ensure business continuity in the wake of a major disaster. …To a large extent, these decisions are being fueled by the state's most critical issue: casualty insurance."

- New Orleans Lakefront Airport suffered the most physical damage from Hurricane Katrina. Impediments to the airports recovery (in addition to physical damage) include:
    - the inoperability of the Air Traffic Control Tower (which finally fully re-opened in early 2008);
    - the price of fuel at the airport because of only one facility;
    - and the uncertain and erratic nature of the ownership of the facility (which delayed FAA AIP funding for improvements, but not repairs to damage).

- "Many of the inland airports are seeing an increase in hangar demand, much of which is due to tenants relocating from other damaged airports, or from a general increase in activity. For example, some airport tenants from Lakefront moved to Hammond and to St. John airports. St Tammany reports a 40% increase in requests for hangar space and an increase in fuel sales. Slidell, Baton Rouge, Louisiana Regional, and New Orleans International all report that daily general aviation activity has increased because of users relocating to their facilities. Houma-Terrebonne has seen a sharp increase in the amount of helicopter activity from Petroleum Helicopters Incorporated (PHI). They relocated their operations from Boothville, LA where their facilities were completed destroyed."
- "There is a need to expand infrastructure, and most airports have Capital Improvement Plans (CIPs) that identify their needs. These CIPs include adding FBOs, construction of

[83] Source: DMJM Harris and DMJM Aviation (2008). *Impact of Hurricane Katrina on General Aviation in Southeast Louisiana*. Regional Planning Commission: Jefferson, Orleans, Plaquemines, St. Bernard, St. Tammany. See http://www.norpc.org/assets/pdf-documents/Katrina_Impact_on_Aviation_2008.pdf.

new airfield pavement, airfield pavement rehabilitation, and more hangar space (some to replace hangars damaged by Katrina, but mostly to accommodate growth). In some cases, because of the role some airports played in the hurricane recovery efforts, they see a need to strengthen runway pavement to accommodate larger aircraft, especially military aircraft, which supported the recovery efforts. *Unfortunately, runway strengthening to accommodate military aircraft is not eligible for AIP funding, but alternate methods of obtaining such funding, such as through the U.S. Department of Homeland Security, should be investigated [emphasis added]*."

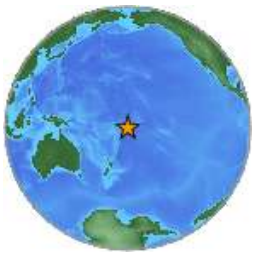
- "Several airports reported plans to acquire more land for expansion, with the main desire being to lengthen the primary runways. In two cases, flood control infrastructure is seen as limiting the ability of the airports to expand."

2009 Samoa Earthquake and Tsunami

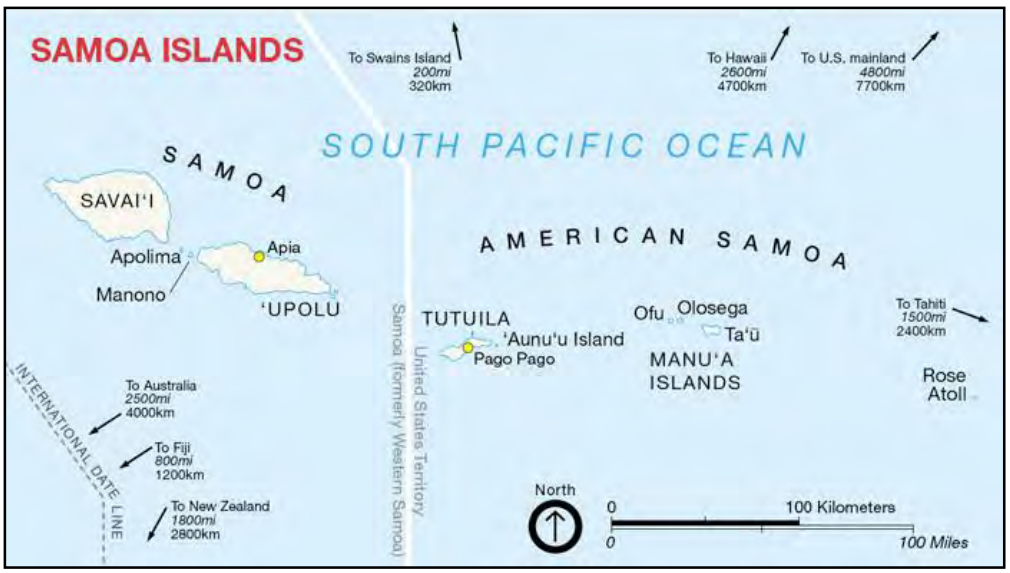
The 2009 Samoa earthquake occurred at 6:48 am (local time) on September 29, 2009. With a moment magnitude of 8.1, it was the largest recorded earthquake of 2009. The epicenter was under the ocean 190 km (120 miles) south of Apia, Samoa, and 185 km (115 miles) northeast of Hihifo, Tonga. The focus of the quake was a depth of 18 km (11.2 miles).[84]

In addition to damage from the shaking, this submarine earthquake generated a tsunami that caused significant damage in American Samoa (a territory of the United States), Samoa, and Tonga. The tsunami had wave heights (peak-to-trough) of 314 cm at Pago Pago, American Samoa and 140 cm at Apia, Samoa.[85]

Deaths attributed to the earthquake and tsunami included at least 149 people in Samoa, 34 people in American Samoa and nine people on Niuatoputapu, Tonga.[86]



[84] Source: USGS website at http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/us2009mdbi.php
[85] Source: USGS website. See above.
[86] Source: USGS website. See above.



Source of Maps: U.S. Geological Survey

Infrastructure Damage

The earthquake caused significant damage to American Samoa's electrical system. The main (diesel-fired) generator in Satala was damaged, which caused a loss of all power to several villages for over a month while the American Samoa Power Authority (ASPA) worked to restore power.

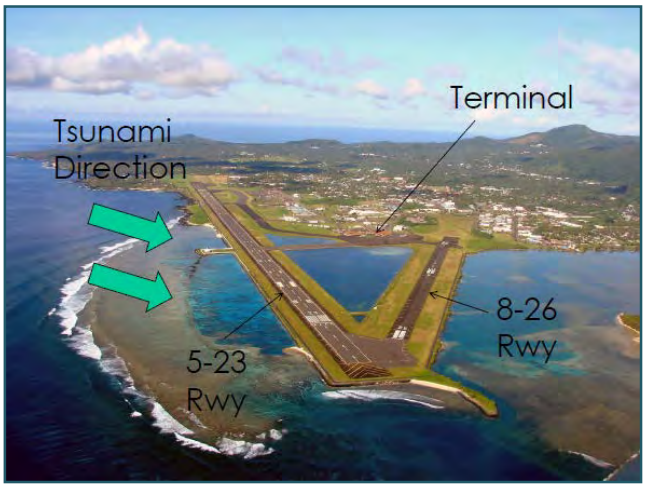
The water system was also damaged, particularly in eastern American Samoa, due to broken water lines. The water division of the American Samoa Power Authority determined that it needed to bring water in tanker trucks to affected villages.

The water supply, electricity, and communications were reestablished to the point where emergency crews had needed infrastructure support within a few days of the disaster. Full repair and replacement of damaged facilities took considerably longer.[87]

Pago-Pago Airport Disruption and Role in Emergency Response

[87] See Earthquake Engineering Research Institute (EERI) (January 2010). *Learning from Earthquakes – Samoa Earthquake and Tsunami of September 29, 2009.* EERI Special Earthquake Report. See http://eeri.org/site/images/eeri_newsletter/2010_pdf/Samoa-Rpt.pdf for additional information.

The Pago Pago International Airport at Pago Pago on American Samoa (PPG) is located approximately 7 miles southwest of the central business district of Pago Pago in the village of Tafuna. It was first constructed as a naval airfield in 1941/1942, and converted to partial commercial use in 1946. Its primary runway is a 10,000-foot long asphalt runway. From the mid-1970s to the mid-1980s, it was heavily used by 10 passenger airlines. However, a combination of larger airplanes able to fly directly from North America to Australia and New Zealand, and increased business to an enlarged airport in Samoa (with a population that is 3½ times as large as American Samoa), flights dropped significantly, and now only Hawaiian Air flies to Pago Pago. Similarly, the number of air cargo carriers has dropped from four to one – Asia Pacific. However, the airport remains a frequent stopover for U.S. military aircraft.



The main 5-23 runway acted as a seawall protecting the most populated low-lying coastal area of Nuuuli Village.

As a result of the tsunami, the security fence around the Pago Pago International Airport at Pago Pago in American Samoa was severely damaged. The fence was temporarily secured before airport operations could resume. While the airport's main runway pavement was not damaged, significant debris was brought in by the tsunami waves, including rocks, rubbish and sand. Crews began to clear the runways of debris at 11:30 a.m. the morning of the disaster and some generators were installed for lighting. The airport was opened at 7:00 p.m. the evening of the tsunami – about 12 hours after the disaster. [88]

Aircraft carrying relief supplies were able to land on the island within 24 hours of the tsunami.[89]

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[88] Source of information on airport impacts: personal communication, Chris Soti, Airport Engineer, Department of Port Administration, American Samoa Pago Pago International Airport, January 2013.
Photo sources: Peter Lefiti, DPA, Assistant Director, Airports (from the report referenced above) and Ted Le'iato, Power Generation Manager, American Samoa Power Authority.

[89] Federal Department of the Interior (October 13, 2009). *American Samoa Earthquake and Tsunami Damage: Federal Response Activities, DOI Personnel & Facilities Update*. See http://www.doi.gov/emergency/factsheets/upload/10-13-09-DOI-American-Samoa-roundup-fq.pdf.

During the relief operations, not enough hardstand area (or paved area for parking heavy vehicles) was available for the many cargo planes arriving at the same time. Other secondary runway and taxiways were closed for these many aircraft. In addition, fuel for the aircraft was a constant need. Thus, larger capacity fuel tanks at the airport would have been useful to handle this emergency.[90]

This airport proved critical in the recovery of the remainder of the island's infrastructure. For example, power generators were flown into American Samoa on C-17s. The Antonov An-225, the world's largest and heaviest aircraft, also landed at the airport on October 13th and 18th 2009, delivering emergency generators and transformers.[91] The U.S. Coast Guard, the Department of Defense and Hawaiian Airlines all provided relief flights to the island.

Pago-Pago Airport Mitigation and Disaster Response Planning Activities

Prior to the earthquake and tsunami, the FAA had awarded an Airport Improvement Program (AIP) grant to American Samoa for a total of approximately $15 million to develop a training facility for airport firefighters and the territory's first emergency responders. In addition, in August of 2009, Pago Pago International airport began a $2.4 million departure terminal remodeling and modernization with $1.5 million in funding from the American Recovery and Reinvestment Act of 2009 and $900,000 of Passenger Facility Charges (PFC) and AIP grant funds. Both efforts were completed and dedicated on September 3, 2010.[92] While these projects were all completed after the disaster, they were all funded prior to that disaster and thus were not part of any disaster recovery process.

[90] Source: personal communication, Chris Soti, Airport Engineer
[91] Source: Air and Space.com. See http://www.air-and-space.com/Antonov%20An-225%20Mriya.htm.
[92] FAA website and personal communication with Gordon Wong, FAA Honolulu Airports District Office, January 2013, and *Samoa News Community Briefs* (September 9, 2010). See http://ip-208-109-238-104.ip.secureserver.net/viewstory.php?storyid=18666&edition=1284022800.

On the other hand, following the disaster, FEMA awarded over $100 million to various programs to aid in disaster recovery. Of particular significance was funding to improve airport security and to purchase equipment for the American Samoa Department of Homeland Security's Emergency Operation Center.[93]

The disaster did not have any effect on the renewable energy efforts as at the time of the American Samoa Power Authority (ASPA), as all the island's power was generated from diesel generators. However, ASPA now has 2 PV farms at the airport totaling 1.75MW, and another 500+kW of roof-mounted PV's in place funded by the American Recovery and Reinvestment Act (ARRA). The PV farms which were installed after the tsunami in April 2012 above the inundation area of the tsunami.[94]

The Pago Pago International Airport also would like to solve some of the identified problems during the relief operation. The two largest problems were the congestion on the ground with 8-to-10 aircraft and the inadequate fueling capability. Thus, the airport has identified a need to rehabilitate apron pavement. Additional fuel pits need to be added to the apron area and aviation fuel farm capacity needs to be increased. Designs for these improvements are in place and await funding. Approximately $55 million is needed to implement the plans.[95]

Other Airport Disruption and Recovery

The runway at Faleolo International Airport on Upolu in Samoa was confirmed safe by early afternoon the day following the quake (September 30, 2009).

The Niuatoputapu Airport in Tonga was closed for a limited period due to tsunami damage from mud and debris on the runway. In this case, relief supplies were delivered to Tonga by ship rather than aircraft.

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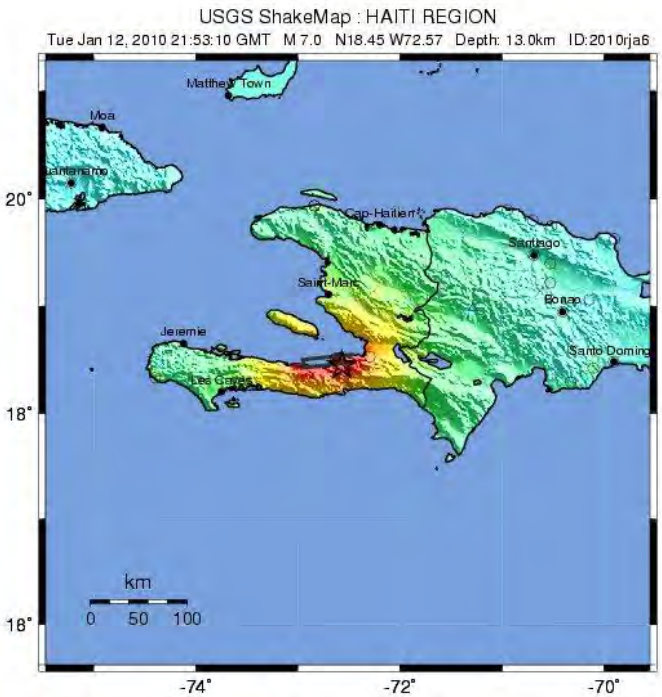
[93] Source: Federal Emergency Management Agency (FEMA) (September 27, 2012). Press Release. See http://www.fema.gov/news-release/2012/09/27/fema-invests-100-million-post-tsunami-disaster-relief-emergency-preparedness.

[94] Source: personal communications with Ted Le'iato, Power Generation Manager, ASPA, January 2013.

[95] Source: Lefiti, Peter (2010). "Tsunami Report: Department of Port Administration, American Samoa Pago Pago International Airport" Presentation at *2010 Western-Pacific Region Airports Conference*, June 2 -4, 2010. See http://www.faa.gov/airports/western_pacific/airports_news_events/2010_conference/media/safety/asgtsunami.pdf.

2010 Haiti Earthquake



The Haiti earthquake occurred at 4:53 pm Eastern Standard Time on January 12, 2010. With a moment magnitude of 7.0, it severely shook the entire country of Haiti. Shaking was felt in the Bahamas, Cuba, and as far away as southern Florida. The epicenter of the earthquake was 15 miles WSW the capital of Port-au-Prince. The focus was at a depth of 13 km (8.1 mi). It occurred on the Enriquillo fault in the boundary region between the North American and Pacific plates.

Haitian official government estimates note over 220,000 people were killed, and over 300,000 injured. The estimates of total damage from the earthquake total $7.8 billion, more than 120% of Haiti's 2009 Gross Domestic Product. Approximately 1.3 million people were displaced.[96] Over 105,000 homes were destroyed and more than 208,000 homes were damaged.[97] Damage was heaviest in the Port-au-Prince metropolitan area and in much of southern Haiti. Recovery is being led by non-governmental aid organizations because Haiti is one of the poorest countries in the world.

Infrastructure Damage

According to researchers with the Earthquake Engineering Research Institute (EERI), the public water system experienced only minor damage to most facilities and pipelines, enabling water service to be restored in less than a week. According to this report, the Centrale Autonome Metropolitaine d'Eau Potable (CAMEP) reported eight to ten pipeline breaks in their 70 km of pipe. This is a very low break rate, considering the extent of other types of damage. More significantly, however, because five Port-au-Prince water system employees lost their lives in the earthquake, and now serve less than 50% of their former paying customers, they have inadequate revenue to cover payroll. In addition, because 1.3 million people were displaced, the water system was not serving that displaced population.[98]

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[96] Source: USGS website at http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/us2010rja6.php.

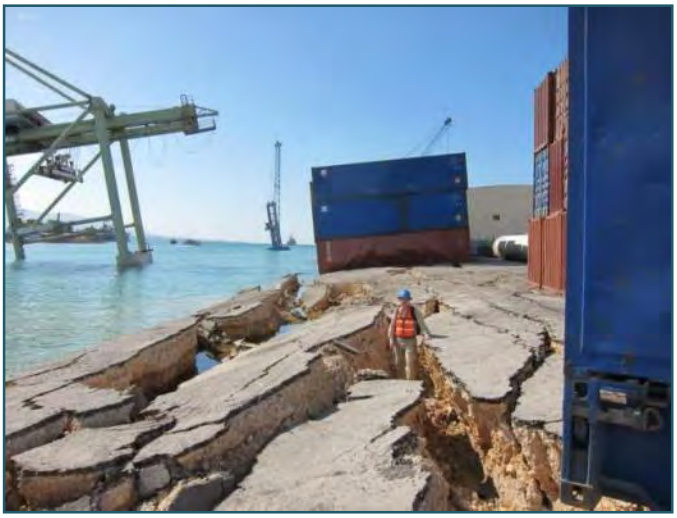
[97] Source: Earthquake Engineering Research Institute (EERI) (May 2010). *Learning from Earthquakes: The Mw 7.0 Haiti Earthquake of January 12, 2010 – Report #2.* EERI Special Earthquake Report. See http://www.eeri.org/site/images/eeri_newsletter/2010_pdf/Haiti_Rpt_2.pdf.

[98] Source: EERI (May 2010). See above reference.

Wastewater treatment was problematic or non-existent prior to the earthquake, and thus was not significantly impacted.

Before the earthquake only 10% or so of the population had electricity. Thus, even before the earthquake, anyone or any facility with any means had a back-up generator, including the international airport.[99]

The largest infrastructure problem impacting airport operations was the complete closure of the port, leaving the airport as the best means of getting supplies and relief workers into and out of the country. According to the USGS report on the earthquake, "The collapse of the North Wharf appears to have been caused by liquefaction-induced lateral spreading. The westernmost 120 meters (400 ft) of the South Pier collapsed, and approximately 85 percent of the vertical and batter piles supporting the remaining section were moderately damaged or broken. The remaining section of pier was shut down to vehicle traffic following additional damage that occurred during an aftershock. The collapse of a pile-supported pier at the Varreux Terminal resulted in the deaths of about 30 people working on the pier at the time of the earthquake."[100]



Airport Disruption and Recovery

Haiti has one major international airport in Port-au-Prince. Before the earthquake, this airport handled over 90% of the air traffic into the country, which amounted to approximately 35 flights a day.

Major shear cracks were obvious throughout the passenger terminals, so they were immediately closed. The terminals were not useable for 6-12 months. In addition, the control tower was heavily damaged and put out of service.[101] Access to the airport was difficult even before the earthquake because of the standard congestion in that part of Haiti. This problem was made worse because streets were blocked due to collapsed and damaged buildings. As a result, traffic

[99] Source: Reginald DesRoches, Professor of Civil and Environmental Engineering, Georgia Institute of Technology, personal communication, January 2013.
[100] Source of this information, as well as of photo: Eberland, Marc O., Baldridge, Steven, Marshall, Justin, Mooney, Walter, and Glenn J. Rix (2010). *The Mw 7.0 Haiti Earthquake of January 12, 2010: USGS/EERI Advance Reconnaissance Team Report.* U.S. Geological Survey Open-File Report 2010-1048, 58 pp. See http://pubs.usgs.gov/of/2010/1048/.
[101] Source: Reginald DesRoches (2013). See reference above.

into and out of the airport was re-routed to a new entrance for pick-up and delivery of passengers. Getting to the previous entrance was also not as important because the passenger terminals were not safe. The new route configuration seemed to have been created by the government as the best option for airport access.[102]

The Commander of Joint Special Operations Air Component-Haiti, Col. Albert M. "Buck" Elton II, noted that he led a force of 220 airmen executing air traffic control, airfield security, rescue, critical care evacuation, special operations surgical teams, aerial port duties, humanitarian airdrop surveys, planning, and landing zone (LZ) control, rotary wing ops command and control, communications specialists and logistics. His recollections, excerpted below, are perceptive.[103]

> *For the first week, we were virtually the only people in country who had communications, food/water, transportation, tents and security. We completely ran the international airport with a small force normally organized, trained and equipped to command and control special operations air. But we became the focal point for the evacuation of 12,000 American citizens, the primary casualty evacuation center coordinating hundreds of evac flights, our surgeons performed 14 major operations in their field hospital, mostly amputations of crushed limbs, our security held back rioting crowds and fence jumpers for the first several days, our pararescue jumpers saved 13 lives conducting confined space rescue missions with Fairfax Country Urban Rescue, the best in the world. Our security teams flew aid in to crowded landing zones and secured the LZ to distribute aid. Our Special Tactics Combat Controllers controlled an international airport 24/7 from a card table in the grass next to the runway for 12 days without a single incident, controlled almost 1700 fixed wing flights and 800 rotary wing flights from the infield with tactical radios until we handed the job back to Air Force air traffic controllers in their portable FAA tower (with air conditioning) on 25 Jan. We coordinated and planned 3 airdrop missions from C-17 aircraft. Our Joint Special Operations Forces distributed 43,800 hand cranked radios to allow disaster survivors to receive news and information regarding international relief efforts and public safety messages. And we provided internet and phone service to virtually every arriving unit and aid organization that showed up here without a plan.*
>
> *We took some heat at the airfield early on for the large number of diverts international flights were executing. Most aircraft were arriving without enough fuel to hold for a few hours, some with only a few minutes to hold before diverting for more fuel. We had 40-50 diverts a day for the first few days because there were no flow control measures to meter the number of aircraft that wanted to land here. The runway only has a single taxiway to the ramp and it is located at midfield. This makes it a single aircraft operation for takeoff, landing and taxi because all arriving and departing aircraft must use the runway to back taxi. The max aircraft on the ground is 12, but we only had enough material handling*

[102] Source: Reginald DesRoches (2013). See reference above.
[103] Excerpted from: Elton, Col. Albert M. "Buck" II (2009). "Haiti: Boots on the Ground Perspective" in *Small Wars Journal*. See smallwarsjournal.com.

equipment to offload 3 at a time. The first night we hotwired a 6K forklift and provided the only means to offload military aircraft, until we flew down our own 10K forklift from Hurlburt. We had to hand off load a Chinese A330 because we didn't have the proper equipment. It took over 8 hours and they blocked half of the ramp because their pilots wouldn't taxi where we directed them to park. We pushed small civilian aircraft out of the way, threatened international aircraft with fines and threatened to tow aircraft into the grass unless they complied with our instructions. We were landing over 250 aircraft per day without phones, computers, or electricity and people were complaining about the log jam at the airport.

One of the prime complaints was from the Geneva-based aid group *Medecins Sans Frontiers /Doctors Without Borders*. A representative of that organization noted on January 18, 2010: "There is little sign of significant aid distribution." … The "major difficulty," the representative continued, was the bottleneck at the airport. A flight carrying its own inflatable hospital was denied landing clearance and was being trucked overland from Santo Domingo, almost 200 miles away in the Dominican Republic, delaying its arrival by 24 hours.[104] A World Food Program official noted that the Americans' priorities were out of sync, allowing too many US military flights and too few aid deliveries.[105]

Any initial problems with NGOs in the early days after the disaster were exasperated by the government in Haiti when they continued to charge tariffs on all equipment and most supplies, even if the supplies were donated. The Haitian government said that it could not tell the difference between "relief" equipment and equipment brought in by companies doing "work" for which they were being paid. Thus, the government charged everyone tariffs.[106]

Relief organizations came under attack for the slow response to the disaster, but cited various issues that made this disaster particularly difficult, including its size, lack of disaster coordination, strained and collapsed infrastructure, medical challenges in an area with extensive poverty even before this disaster, large numbers of homeless and displaced people, and inadequate or non-existent communications.

The issue of disaster coordination is particularly applicable to any discussion of long-term recovery and the airport. According to *Wired Magazine*, "Each big agency has its own style and priorities, and each sets up its own supply chain of planes, ships and trucks. They compete with one another for resources, duplicate one another's efforts and generally get in one another's way. The result is wasted effort at best and total chaos at worst."[107] According to *InsideDisaster.com*,

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[104] Source: The Telegraph (January 18, 2010). "Haiti earthquake: confusion at airport hampers aid effort" in *The Telegraph*. See http://www.telegraph.co.uk/news/worldnews/centralamericaandthecaribbean/haiti/7016051/Haiti-earthquake-confusion-at-airport-hampers-aid-effort.html.
[105] Source: The Telegraph (January 18, 2010). See above reference.
[106] Source: Reginald DesRoches (2012). See above reference.
[107] Source: Vince Beiser (May 28, 2000). "Organizing Armageddon: Behind the Haiti Rescue" in *Wired Magazine*. See http://www.wired.co.uk/magazine/archive/2010/06/features/organising-armageddon-behind-the-haiti-rescue/page/4.

"Over 900 NGOs responded to the Haiti earthquake… . , The job of coordinating the response in Haiti fell to two major groups: the United Nations, which created the humanitarian 'Cluster System' for this purpose, and the U.S. military, which became a de facto coordinator through its control of the airport. The two failed to work together, leading to what one NGO termed 'a situation of utter chaos.'"[108]

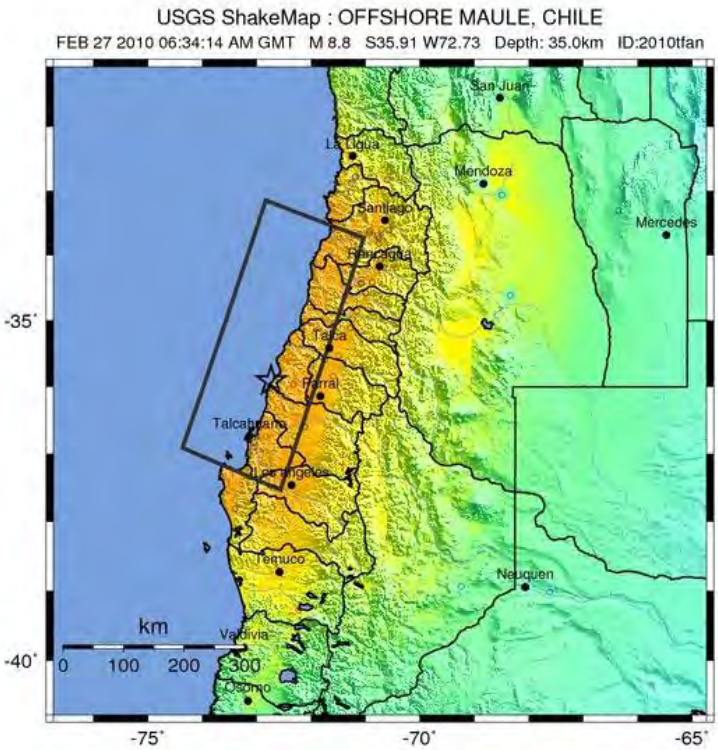
The airport was particularly critical for short-term and long-term recovery in the initial weeks following the earthquake because the port was closed due to damage and collapse. As soon as the port reopened for delivery of relief supplies, and later to commercial traffic approximately 2-3 months after the disaster, freight was diverted to the port and the airport could concentrate on passenger traffic. As of January 2013, a few tourists had even returned.[109]

Service at the airport has continued to improve, but, as of January 2013, nothing has been done to mitigate problems at the airport in future earthquakes, in part because of the slow decision making on the part of the Haitian government bureaucracy. However, there are now plans to rebuild the existing airport, as well as to build another airport outside of the city.[110]

[108] Source: InsideDisaster.com (undated, downloaded on January 28, 2013). *The Haiti Earthquake – Response – Relief Challenges.* See http://insidedisaster.com/haiti/response/relief-challenges.
[109] Source: Reginald DesRoches (2013). See reference above.
[110] Source: Reginald DesRoches (2013). See reference above.

2010 Maule, Chile Earthquake

The Maule (or Bio-Bio) Chile earthquake occurred at 3:34 am Newfoundland (local) Time on Saturday February 27, 2010. With a moment magnitude of 8.8, it was the sixth largest earthquake ever recorded. (A magnitude 9.5 earthquake in Chile on May 22, 1960 was the largest earthquake ever recorded.)[111] Shaking of over .05g lasted approximately 120 seconds. The epicenter of the earthquake was offshore of Bio-Bio Chile, about 335 km (210 mi) northeast of the national capital of Santiago. USGS named it the Bio-Bio Earthquake because the epicenter lies just offshore of Bio-Bio. The focus was at a depth of 35 km (21.7 mi). Twelve million people, or ¾ of the population of the country, were in areas that felt strong shaking.[112]



As of July 2010 (5 months after the earthquake), 521 fatalities have been confirmed, with 56 people still missing and presumed dead in the tsunami.[113]

Based on the July 2010 ARC/USGS report, the economic losses totaled $30 billion USD or 17% of the GDP of the country.[114] The earthquake and tsunami destroyed over 81,000 housing units and another 109,000 suffered major damage.[115] In addition, the Earthquake Engineering Research Institute (EERI) noted that "According to unconfirmed estimates, 50 multi-story reinforced concrete buildings were severely damaged, and four collapsed partially or totally."[116]

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[111] See USGS Website at http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php.
[112] Source: American Red Cross Multidisciplinary Team (July 2010). *Report on the 2010 Chilean Earthquake and Tsunami Response.* U.S. Geological Survey Open-File Report 2011-1053 Verions 1.1. See http://pubs.usgs.gov/of/2011/1053/.
[113] Source: American Red Cross/USGS (July 2010). See reference above.
[114] Source: American Red Cross/USGS (July 2010). See reference above.
[115] Housing losses based on a Ministry of Housing and Urban Development, 2010 report cited by the Earthquake Engineering Research Institute (EERI) report (June 2010). *Learning from Earthquakes: The Mw 8.8 Chile Earthquake of February 27, 2010.* EERI Special Earthquake Report. See http://www.eeri.org/site/images/eeri_newsletter/2010_pdf/Chile10_insert.pdf.
[116] Source: EERI (June 2010). See reference above.

Infrastructure Damage

ARC/USGS[117] noted that fires following the earthquake were minimal in part because of the shutdown of the national electrical grid early in the shaking. However, EERI[118] noted:

> The earthquake was followed by a blackout that affected most of the population, with power outages affecting selected regions for days. … The transmission network performed reasonably well and was ready to provide power 24 hours after the main shock. … Lower voltage subtransmission systems near the coast, where there were higher levels of ground shaking, were damaged sporadically. The low-voltage distribution system was also affected by collapsed buildings and damaged poles. Two weeks after the earthquake, the distribution system service was restored.

The ground transportation system was disrupted by ground failure, particularly liquefaction near the coast, structural failures, and tsunami damage. Based on the EERI report, "Of the nearly 12,000 highway bridges in Chile, approximately 200 were damaged. About 20 of these bridges had collapsed spans."[119] Damage was caused by liquefaction-induced ground failure as well as structural failure. Localized road damage due to ground failures closed Route 160 in both directions near Lota along the coast and closed Route 5 (the main north-south route) in several locations. Damage due to the tsunami occurred to highways and railroads between Concepción and Constitución.

Communication systems were also disrupted for the first week following the earthquake. As noted by EERI[120]:

> Santiago's 131 emergency call center (analogous to 911 in the U.S.), located in the uppermost level of the Posta Central building, suffered severe nonstructural damage and could not operate following the earthquake. … Both landline and wireless services were bedeviled by commercial power outages, equipment failures, building failures, and loss of reserve power in most distributed network facilities (base stations, small remote switches, and digital loop carrier [DLC] remote terminals). Only critical offices have backup power generators, with the majority of cell sites and remote offices relying on battery reserve power; by about 6:30 a.m., most cell sites and remote sites ran out of power. Damage to roads and bridges made access to these sites difficult; additionally, many utilities that relied on wireless service found it difficult to dispatch maintenance

[117] Source: American Red Cross/USGS (July 2010). See reference above.
[118] Source: EERI (June 2010). See reference above.
[119] Source: EERI (June 2010). See reference above.
[120] Source: EERI (June 2010). See reference above.

Photo sources: Eduardo Miranda, Gilberto Mosqueda, and Gokhan Pekcan presentation for EERI, October/November, 2011.

crews in order to restore service. Both landline and wireless services were restored within seven days of the quake.

Airport Disruption and Recovery

Two airports in Chile were significantly impacted by the earthquake. In both cases, relatively new buildings built to modern codes were damaged and closed not due to structural damage, but due to nonstructural damage.

The Santiago Airport (SCL) is the largest airport in Chile. Prior to the disaster, the annual passenger traffic was approximately 10 million, divided between international and domestic passengers. This passenger level is approximately the same as OAK in the Bay Area, but with a much heavier level of international traffic. Prior to the earthquake, the airport was handling an average of 323 flights per day, compared to almost 600 flights into OAK, in part due to the larger number of cargo flights into OAK.

SCL has two adjacent terminals. The international terminal building was built in 1994 – only 6 years prior to the earthquake and compliant with modern building codes roughly equivalent to those in the United States. Thus, the extensive nonstructural damage is particularly significant, and extensively studied, as depicted in the following paragraphs excerpted from two separate studies:

> Nonstructural damage included damage to more than 80% of the ceilings throughout the airport, breakage of fire sprinkler pipe with extensive water damage, collapse of hot water piping, partition damage, extensive damage to retail space, damage to light fixtures, collapse of most suspended air handling units, damage to cable trays, damage

to air conditioning ducts, damage to hydraulic elevators, glazing damage, etc.[121]

In addition, it was reported that four or more HVAC units anchored from the concrete slab above fell through the suspended ceiling, including one at the third level. Reportedly, similar units fell at the second level and had already been removed. The units were supported by rods on spring hangers. Multiple pipe hangers failed and, in some cases, it seemed that the impacted pipes caused the sprinkler pipes to deform as shown while most other sprinkler heads remained vertical. The sprinkler heads appeared damaged around areas where the ceiling was damaged. The exterior and interior elevators were inoperable with housing damage observed in the exterior and derailing in the interior with deformations evident in one of the rails. The counterweights were clamped and remained in place. … Walkways from elevated road to terminal were damaged and were being removed at time of observation. Impact damage was evident between the concrete walkway on corrugated steel and the concrete elevated road.[122]

Insured losses due to direct losses attributable to physical damage at the airport have been estimated at US$40 million … . The cost of the earthquake to LAN, the national airline in Chile, was approximately $25 million in lost passenger traffic alone (LAN 2010). The airport was closed from the time of the earthquake to 3 March 2010 when it resumed partial operations by using large tents installed near the runway. International flights partially resumed on 6 March 2010.[123]

[121] Source: Miranda, Eduardo, Mosqueda, Gilberto, Retamales, Rodrigo, and Pekcan, Gokhan (June 2012). "Performance of Nonstructural Compoents during the 27 February 2010 Chile Earthquake" *in 2010 Maule, Chile*. EERI Spectra Special Issue.

[122] Source: Mosqueda, Gilberto (March 8, 2010). "Santiago Chile International Airport" *in Preliminary Damage Reports from the Chile Earthquake: February 27, 2010*. Multidisciplinary Center for Earthquake Engineering Research (MCEER). See http://mceer.buffalo.edu/research/reconnaissance/Chile2-27-10/Santiago_Airport/default.asp

[123] Source: Miranda and others (June 2012). See reference above.

> [While international flights resumed on 6 March, …] the actual international terminal remained closed. Arriving passengers collected their checked-in baggage plane-side and proceeded through two temporary large tents housing immigration and customs services.[124]

The passenger traffic at SCL airport in Santiago has recovered in the months and years following the earthquake, and actually increased over time, as shown by this graph produced by the airport.[125]

In December 2012, the air passenger traffic totaled 1,255,062, which included 591,787 international passengers and 663,275 domestic passengers.

The International Airport in Concepción is the second largest airport in Chile. The terminal building at this airport was also relatively new, having been constructed in 2001 to modern building code standards. Again, while the terminal itself was relatively undamaged, it, too, suffered extensive nonstructural damage. Together, the Santiago and Concepción airports handle over two thirds of the air traffic in Chile.

> The main nonstructural damage in the airport consisted of water damage caused by damage to fire sprinkler heads. Approximately 130 mm of water accumulated throughout the terminal. Damage to fire sprinklers occurred in the main terminal, as well as in the gates area. The hydraulic elevators, glazing, and ceiling were also damaged by the shaking.[126]

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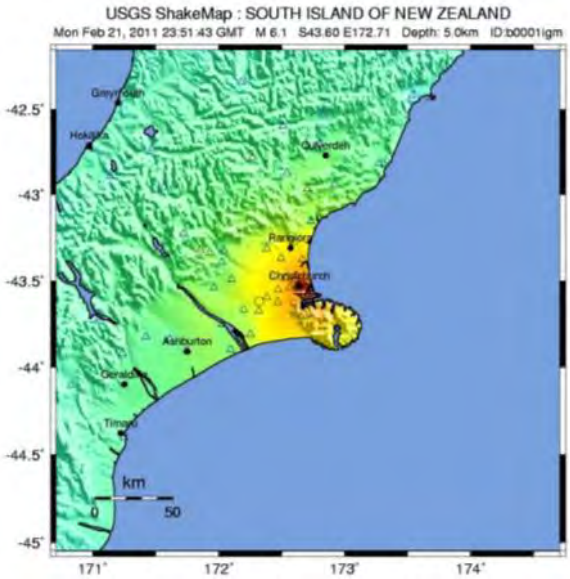
[124] Source: Mosqueda, Gilberto (2010). See reference above.
[125] Source: Aeropuerto de Santiago(December 2012). *Passenger Traffic Statistics*. See http://www.aeropuertosantiago.cl/estad-sticas-tr-fico-de-pasajeros/estadisticas-de-trafico-de-pasajeros.html.
[126] Source: Miranda and others (June 2012). See reference above.

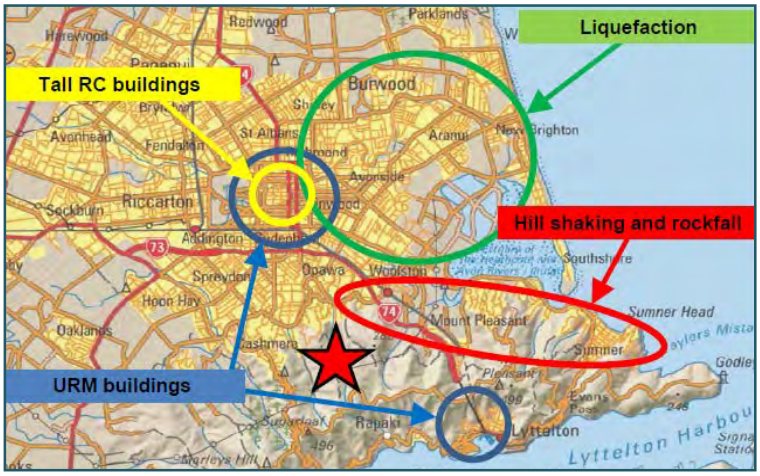
2011 (FEBRUARY) NEW ZEALAND EARTHQUAKE



The Christchurch New Zealand earthquake occurred at 12:51 pm on Tuesday February 22, 2011 (local time). With a moment magnitude of 6.1, it was technically an aftershock of the M 7.0 September 2010 Darfield, New Zealand earthquake.[127]

The epicenter was located only 6 km (3 miles) southeast of Christchurch, New Zealand, near Christchurch's port of Lyttleton, while the earlier "main" shock epicenter was 45 km (30 miles) west of Christchurch. The earthquake focus was at a depth of 5.9 km (3.7 miles).[128]

Located on the central east coast of New Zealand's South Island and with a population of 375,000, Christchurch is New Zealand's second most populous city and the largest city on the South Island.



The February 2011 aftershock caused significantly more damage than the September 2010 event due to its closer location to the Central Business District (CBD) of Christchurch. Over 100,000 buildings were destroyed or damaged in the Christchurch-Lyttleton area. Extensive landslides and liquefaction occurred in that area. Shaking was felt in much of the South Island and as far as Invercargill (at the southern end of the South Island) and Palmerston North (in the central southern area of the North Island).[129]

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[127] Source: USGS summary report on the Christchurch earthquake on the USGS website at http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usb0001igm/

[128] Source: USGS summary report. See reference above.

[129] Source: USGS summary report. See reference above.

Source of map showing damage: Kam, Weng Yuan, and Pampanin, Stefano (2011). *General Building Performance in the Christchurch CBD: a contextural report prepared for the New Zealand Department of Building and Housing*: University of Canterbury, 62 pp. See http://www.dbh.govt.nz/UserFiles/File/Reports/quake-contextual-report-canterbury-uni.pdf.

In addition, unlike the earlier earthquake which struck at night (at 4:36 am on Saturday September 4th local time), the February 2011 earthquake struck in the middle of the day when the CBD was highly populated. A total of 185 people were killed (including 115 people in the Canterbury Television building) and 1,500 suffered significant injuries.[130]

Extensive foundation damage due to liquefaction occurred to both residential and commercial buildings in the city. According to the Earthquake Engineering Research Institute (EERI) report on the earthquake, "Two reinforced concrete [RC] office buildings and one parking garage collapsed, as did hundreds of unreinforced masonry buildings [URM], including a number of heritage structures. Many other buildings in the CBD were severely damaged, and some required demolition, which necessitated careful controlled access to the CBD in the weeks following the earthquake."[131]

Over 1,100 buildings had been demolished or partially demolished by February 8, 2013, based on data from the Canterbury Earthquake Recovery Authority (CERA).[132] Hundreds of additional buildings may be demolished. Recovery and rebuilding have been slowed by the abnormally large number of aftershocks. As of March 2013 access to portions of the CBD remains limited, particularly to car traffic.

Unlike in the United States, many losses were covered by insurance. The New Zealand government's Earthquake Commission (EQC) is responsible for damage to residential property up to $100,000 plus goods & services tax (GST) for buildings and $20,000 + GST for contents. Private insurers are responsible for damage exceeding this amount, as well as any damage to businesses.

Total insured losses were estimated at $30 billion US$ by the New Zealand Treasury, an amount equal to approximately 15% of the GNP of New Zealand (as opposed to the March 2011 Japan earthquake with direct damage of approximately 3-5% of Japan's GNP). These losses are separate from the estimated $4 billion in insured losses from the September 2010 earthquake, as well as insured losses of $1.8 billion from the December 2011 aftershock. Because of the magnitude of the losses, much of the insured losses will be covered by reinsurance. As a result,

[130] Source: USGS summary report. See reference above.
[131] Source: Earthquake Engineering Research Institute (EERI) (May 2011). *Learning from Earthquakes - The M 6.3 Christchurch, New Zealand, Earthquake of February 22, 2011*. EERI Special Earthquake Report. See http://www.eeri.org/site/images/eeri_newsletter/2011_pdf/EERI_NewZealand_EQRpt_web.pdf.
[132] See http://cera.govt.nz/demolitions/list for the most recent information in this continuing effort.

not only are insurance rates in New Zealand being changed, but also the loss modeling of the world-wide reinsurance industry is being examined.[133]

Infrastructure Damage

Damage to lifelines, including water, wastewater, power, and transportation systems, was largely due to extensive liquefaction.

Christchurch City Council identified more than 50,000 individual road surface "defects" following the earthquake, as compared to 1,200 defects following the September 2010 earthquake.[134] A "defect" included anything from a bump in the road to more major damage.

The EERI report on the earthquake[135] noted:

> Differential settlement and lateral spreading disrupted both potable water pipelines (mostly asbestos cement and PVC) and wastewater pipelines (mostly gasketed concrete and PVC). There are likely thousands of breaks and lesser flaws in these networks, and the total number of required repairs is still unknown. Buoyancy of concrete vaults at potable water and wastewater pump stations, compounded by liquefaction-induced settlement, caused pipes to break at connections with the vaults. Approximately 1m of settlement at the Bexley Pump Station ruptured the well, which flooded the surrounding neighborhood [with wastewater] at [a rate of] 140m^3/hr. Massive amounts of silt and sand from liquefaction washed into the Bexley sewage treatment plant, damaging the primary settling tanks and overloading the system. Liquefaction also caused differential settlement of the clarifiers, thereby seriously impairing secondary treatment capabilities.
>
> The water distribution network in Lyttelton and Harwood had been replaced with high-density polyethylene (HDPE) pipelines after the September earthquake, and there was not a single instance of damage in that system, although Lyttelton had some of the strongest ground motion recorded in the earthquake, and massive liquefaction was observed in Harwood, including lateral spreading and settlements of 1-2m.
>
> Moreover, there was no damage in the medium-density polyethylene (MDPE) gas distribution system, even though the MDPE pipelines were located in areas subjected to liquefaction during both earthquakes.
>
> The electric power administration buildings were badly damaged. All major 66 kV underground cables supplying the Dallington and Brighton areas of eastern Christchurch

[133] Source: Insurance Council of New Zealand (2012). *Insurance Council Annual Review*: ICNZ, 24 pp. See http://www.icnz.org.nz/downloads/icnz-annual-review-2012.pdf

[134] For the source of this, and the most current, information, see Christchurch City Council. *Road Status*. See http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/roads.aspx#jumplink3

[135] Source: EERI (May 2011). See reference above.

failed. Over 50% of all 66 kV cables at multiple locations were damaged by liquefaction-induced ground movement.

More recent reviews of water and wastewater pipeline damage note that 77 miles (124 km) of water mains were damaged and 186 miles (300 km) of sewer pipes were damaged.[136] Because of the number of aftershocks, some pipeline leaks have been repaired more than once. As of March 2013, many streets were still torn up as water, sewer, and storm water pipelines were being repaired or replaced. Permanent street repairs are not planned until these underground networks are repaired.

Airport Disruption and Recovery

The Christchurch International Airport, Ltd. (CIAL), New Zealand's second largest airport, is located 7 miles (12 km) northwest of the CBD.[137] It is a government organization that is expected to be a profit-generating operation. CIAL is owned 25% by the New Zealand government and 75% by the Christchurch local council. Profits go back to these two owners in a 25/75 split.

CIAL was largely undamaged in the earthquake. While some reports noted damage to the control tower, the tower had no structural damage. However, communications to the tower were interrupted for a limited period. Damage to the terminal was limited to a few ceiling tiles being dislodged, one water sprinkler broken, some minor cracking of the façade and internal walls and a couple of broken windows. While CIAL has earthquake insurance, damage did not meet the minimum deductible, and thus costs of all repairs were borne by the airport itself.

The airport had clean water, some of the best in the Christchurch area. No sewer lines were broken and the sewer system was completely functional. The airport has its own power, and it was functional. Following the earthquake, fuel lines and tanks were examined and found to have no damage. Finally, there was no damage to facilities owned by the airlines or associated vendor operators.

Flights were diverted to several other commercial airports in New Zealand, and other flights that had not yet departed were cancelled. Following the damage assessment conducted by airport personnel and structural engineers on contract to the airport, the airport began accepting medical

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[136] Source: Insurance Council of New Zealand (2012). See reference above.

[137] Source of the information in this, and the following, sections: personal communication, Andy Lester, Chief Operating Officer, Christchurch International Airport Ltd. (CIAL) (March 2013), supplemented with CIAL website data on cargo and passenger levels at http://www.christchurchairport.co.nz/en/about-us/corporate-information/facts-and-figures/.

Photo source: J. Perkins, March 2013.

and military flights 1½-2 hours after the earthquake. Limited commercial service resumed the following morning. At that time, the commercial airlines made the decision to bring in larger aircraft to handle larger numbers of passengers.

The airport was critical during the response and recovery phase of this disaster. In the days following the earthquake, the airport handled more military flights and chartered commercial aircraft carrying portable toilets, personnel and equipment from Australia, China, England, Israel, Japan, Mexico, Singapore, Taiwan, Thailand, UK, USA and other countries. There were many medevac flights using over 20 helicopters. Air New Zealand operated extra flights to/from Auckland and Wellington to move people and supplies in and out of Christchurch.

Because of damage to other parts of the area's transportation network, many people decided to walk to the airport. Buses picked up people walking and took them to the airport, and casual carpooling occurred, particularly by people with campervans. The airport was inundated by people – both approximately 1,000 passengers and approximately 1,000 others with no place to stay who were seeking transportation off of the South Island. For example, as a result of the earthquake, the city lost three-quarters of its hotel rooms, reducing the rooms from 3,710 before the September quake to 825 following the February quake. Airport staff helped organize the humanitarian effort to distribute food and blankets to these people.

Since the earthquake, cargo levels have not changed significantly, although there has been some increase because of the rebuilding. (The 12-month period ending in January of 2013 showed international cargo was up by 6% over the 12-month period ending in January 2011 and 5% over the 12-month period ending in January 2012.)

CIAL has experienced a 10% reduction in passengers since the earthquakes. CIAL was down by ½ million passengers, first due to the earthquakes, and then due to the lack of hotel space. In May 2012 carrier Air Asia X stopped service to Christchurch. In March 2013, passenger traffic remains less than its pre-earthquakes level.

Airport Emergency Planning, Response, Mitigation and Recovery Lessons

CIAL is committed to the "Rs" of Reduction, Readiness, Response, Recovery, and Review – with Review being the critical one. After each event, CIAL reviews what happened and how it can do a better job the next time. These reviews are viewed as a learning opportunity, not a blame game.

As in the United States, airports in New Zealand are required to prepare airport emergency plans. Prior to the September 2010 earthquake, the CIAL plan for earthquake emergencies was just one paragraph – await for direction from government civil defense officials. But after the September earthquake, the airport was never given direction by civil defense and left to respond and recover on its own. The Airport understood its key role in the emergency and did not wait for others to take action. In New Zealand law the airport has a regulatory requirement as a Lifeline Utility to get up and operational as soon as possible, and this they did. Prior to that

earthquake, CIAL staff had assumed that airport had more of a logistics and facilitation role – but now they realize that they have a leadership role in the recovery of the region.

CIAL has also made extensive changes in the way in which it responds to an earthquake. After the September 2010 earthquake, CIAL evacuated the terminal and closed the runway. Because it occurred at 4:36 am, it was dark. At first light, staff inspected the runway. The structural and civil engineers on retainer examined the buildings. The airport was reopened after approximately 5 hours.

Staff now realizes that "the dirty little secret of earthquakes that no one talks about is the aftershocks." They had to re-inspect the runways and the buildings after each significant one. That is when they decided that they had to establish a mechanism to decide which aftershocks were large enough to require re-inspection – and which were not. They learned that magnitude was not useful in determining response because it depends on how far away you are from the epicenter, the depth of the earthquakes and other factors. Then they investigated using modified Mercalli intensity (MMI), but that was not effective because they concluded that "one person's MMI vi is another's MMI ix." They quickly decided after an early aftershock that intensity was too subjective and they wanted a concrete number about the severity of shaking at the airport itself. Therefore, they decided to install an accelerometer. They have concluded that this has been one of the best investments the airport has ever made. The specificity of the readings, the history built up with regard to ground acceleration after the numerous aftershocks, and the trust the entire airport team have in the acceleration data has been invaluable. It measures both ground acceleration and duration and then emails immediately those key people that will determine the response necessary.

CIAL has now established a 3-tiered category of response: – C – felt, not concerned – B – big enough to require checking the terminal and runways, but not stop flights or close the terminals – A – evacuate the terminal and close the runways. The accelerometer has established a scale with a hard data point; this sets a minimum category. Then, based on the assessment of staff of the consequences of the shaking within the terminal, control tower and other locations, they can increase the response category, such as from a B to an A, but can never decrease it. Based on the response category, each of CIAL's business units has a prescribed process and actions. Thus, after the first earthquake in September 2010, it took CIAL 5 hours to return to operation, while after the one in February 2011, it took the airport only 1½-2 hours to return to operation.

CIAL has been impressed with the accelerometers. The airport originally purchased one that was tied to the A-B-C response system, but staff has since added another 12 around the facility to direct structural engineers to different floors or areas with abnormal readings. (The structural engineers are on call; they are private consultants, not members of the city staff.)

Due to a full scale exercise in 2010 (before the September 2010 earthquake), CIAL staff learned that cell phones were not that resilient, so they formulated processes and invested in radio

communications with the entire airport stakeholders as well as satellite phones for key airport company executives. In the September 2010 earthquake, it turned out that the cell phones did not work, and there was a heavy reliance on the radios they had purchased. In the February 2011 earthquake, cell phones lost some coverage but were so heavily overloaded that they could not be relied upon. The airport also added satellite phones to its communications system. (The CEO got his satellite phone the day before the September earthquake; it had paid for itself by the next day!)

Another change following the September 2010 event was that the Civil Aviation Authority (CAA), New Zealand's equivalent of the FAA, now routinely turns over control of Control Zone airspace to the airport. CIAL knew how many planes they could handle before CAA and we were in a better position to decide what flights should be able to land – and when. In February 2011, after 1½-2 hours of being closed, medical and military flights got the first priority to land, with limited commercial service resuming the following morning.

Mutual aid agreements were in place prior to the September 2010 earthquake. Following that earthquake, CIAL brought in electricians from other airports, largely to assist in the repair of nonstructural damage and fittings. However, in February, staff determined that they were better off not using these staff from other airports in the short term. It takes time or people to manage outsiders; even if they were familiar with airports, they were not familiar with CIAL. Thus, CIAL staff determined that they could best handle the repairs themselves.

In the 1930s, the airport had a choice of location. It chose the site northwest of the CBD because it was predominantly cheaper farmland, and thus not selecting the New Brighton area on the water (which was a more typical type of site to be chosen at the time). The airport staff believes they were lucky to have been at their current location because if they had been in New Brighton, the airport might still be closed due to liquefaction damage exacerbated by repeated aftershocks. In addition, CIAL has an asphalt, not a concrete, runway. If they had a concrete one, staff believes it would not have been as forgiving to the type of ground shifting and buckling which they have experienced.

CIAL structures were all constructed based on the council building code at the time each part was built. At the time of the earthquakes, the terminal was being replaced with a larger $230 million (NZ$) building that effectively surrounded the existing terminal. The same building is used for international, domestic, and general aviation flights. No changes in design were made as a result of the earthquakes. In addition, no changes have been made, or have been recommended, to the water lines, sewer lines, fuel lines or fuel storage capacity as a result of the earthquakes.

In terms of economic recovery to the airport revenues, CIAL staff would advise other airports to expect a minimum of 2-3 years for recovery from an earthquake. Unlike a forest fire, earthquakes have no immediate warning. Fires also have no aftershocks, which impact morale – and tourism. Media "hype" and perception further impact morale and particularly tourism.

2011 Tōhoku Japan Earthquake and Tsunami

The Tōhoku Japan earthquake occurred at 2:46 pm (local time) on Friday March 11, 2011. With a moment magnitude of 9.0, it was the most powerful earthquake known to have ever hit Japan and the fourth most powerful earthquake ever recorded.[138] The epicenter approximately 70 km (43 mi) east of the Oshika Peninsula of Tōhoku, 129 km (80 miles) east of Sendai, Honshu, and 373 km (231 miles) northeast of Tokyo. The depth of the quake was 30 km (18.6 miles). [139]

In addition to damage from the shaking, this submarine earthquake generated a tsunami with waves that reached heights of 40.5 meters (133 feet).

The USGS description for the earthquake[140] cites a 12 March 2012 Japanese National Police Agency report confirming 15,867 deaths, 6,109 injured, and 2,909 people missing across twenty prefectures, as well as 129,225 buildings totally collapsed, with a further 254,204 buildings "half collapsed" and another 691,766 buildings partially damaged.

The World Bank report on the disaster[141] estimated losses at $122 to $235 billion (compared to $6 billion for the 1989 Loma Prieta earthquake). Risk Management Solutions (RMS) noted that its "estimate of USD$200 to 300 billion was issued on March 14, 2011, and ten days later on March 24, 2011, the Japanese government issued a total economic loss estimate of JPY16 to 25 trillion (USD$197 to 308 billion)." The RMS report estimates insured losses from the earthquake alone at US$18 to $26 billion.[142] The Bank of Japan offered ¥15 trillion (US$183 billion) to the banking system on 14 March in an effort to normalize market conditions.

General Infrastructure Damage

Around 4.4 million households in northeastern Japan were left without electricity and 1.5 million without water.

USGS notes transportation damage of 2,126 roads, 56 bridges and 26 railways destroyed or damaged by the earthquake and tsunami along the entire east coast of Honshu from Chiba to Aomori.

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[138] Source: USGS website at http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php.
[139] Source: USGS website at http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xgp/
[140] Source: USGS website. See reference above.
[141] Source: World Bank (March 2011). "The Recent Earthquake and Tsunami in Japan: Implications for East Asia." See http://siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/550192-1300567391916/EAP_Update_March2011_japan.pdf.
[142] Source: Risk Management Solutions (RMS) (April 2011). *Estimating Insured Losses from the 2011 Tohoku, Japan Earthquake and Tsunami*. See https://support.rms.com/Publications/2011TohokuReport_041111.pdf.

Sendai Airport Disruption and Recovery

At 15:55 JST, about one hour after the earthquake, a tsunami ripped over Sendai Airport, close to the center of the devastation. The spectacle was caught on film by a China Central Television (CCTV) camera, was posted online, and has become one of the most well-known images of the event.[143] At the time, roughly 1,300 people were inside the airport, including 600 people who worked at the airport. Damage appeared devastating.

Yet just over a month after the event, on April 13, 2011, the airport reopened to limited commercial service with flights by All Nippon and Japan Airlines. This dramatic turn-around occurred due clean-up by the Japanese Self-Defense Forces and the U.S. Air Force. According to *Bloomberg News*,[144] these forces cleared "uprooted trees, houses and about 5,000 vehicles thrown about by rushing water." In a phone interview with *Bloomberg News*, U.S. Air Force Colonel Robert Toth said, 'Nothing compares to the scale and absolute destruction of what went on up there,' The *Bloomberg News* article explains the timeline and mechanics of the event and clean-up:

> *Toth, whose unit specializes in restoring aviation facilities in war zones and disaster areas, was on the first U.S. military plane to land in the area after the natural disaster.*
>
> *The start of commercial flights at the airport, the largest on the tsunami-hit Tohoku coast, may bolster reconstruction efforts following the magnitude-9 earthquake that left about 27,500 people dead or missing and crippled a nuclear-power plant. All Nippon Airways Co. and Japan Airlines Co. will fly to the airport three times a day each.*
>
> *"I didn't think we would be able to restart operations so soon," Shinichiro Ito, All Nippon's chief executive officer, said at today's reopening ceremony. "The airport was a mountain of debris."*
>
> *… [One of the passengers trapped in the airport said that he had] spent the next two days in the airport, sleeping under packing materials on a sofa to keep warm as aftershocks rattled the building. He eventually left after a civilian rescue operation arrived with a bus to ferry passengers to the railroad station.*

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[143] To view this video, see http://www.bbc.co.uk/news/world-asia-pacific-12714713.

[144] Source: McCombs, Dave, and Matsuda, Kiyotaka (April 13, 2011). "Tsunami-Hit Sendai Airport Opens as U.S. Helps Clear Trees, 5,000 Vehicles." *Bloomberg News*. See http://www.bloomberg.com/news/2011-03-11/tokyo-narita-airport-cancels-all-flights-today-after-quake.html.

Full restoration of the facility will take at least a year after today's partial reopening, Sendai Airport President Katsuhiko Ito said [in April 2011]… .

Parts of the terminal building, hangars and other facilities were still caked in mud as crews continued removing vehicles and debris.

The U.S. Air Force began helping Japan's Self-Defense Forces with the cleanup five days after the quake struck, Toth said. Members of the U.S. Navy, Army and Marines also were involved, he said.

Toth and a team of about a dozen airmen flew to a Self- Defense Force airfield about a 90-minute drive from Sendai. A convoy of Humvees then ferried them to the devastated airport.

Within hours of their arrival, Japanese and U.S. personnel had cleared a 5,000-foot (1,500-meter) strip of asphalt, Toth said. That allowed a Lockheed Martin Corp. (LMT) C-130 military freighter, fitted with avionics designed for landing without ground control in war zones, to touch down the same day, bringing in fuel and further equipment.

Japanese personnel and workers used forklifts and cranes to load smashed cars and other heavy debris onto trucks. They then used street-sweepers, earth-moving vehicles and construction equipment to clean smaller pieces and mud off the tarmac, Toth said.

"The reopening at Sendai is way ahead of what anybody would have thought when we started," he said. "Most of the praise goes out to the Japanese workers."

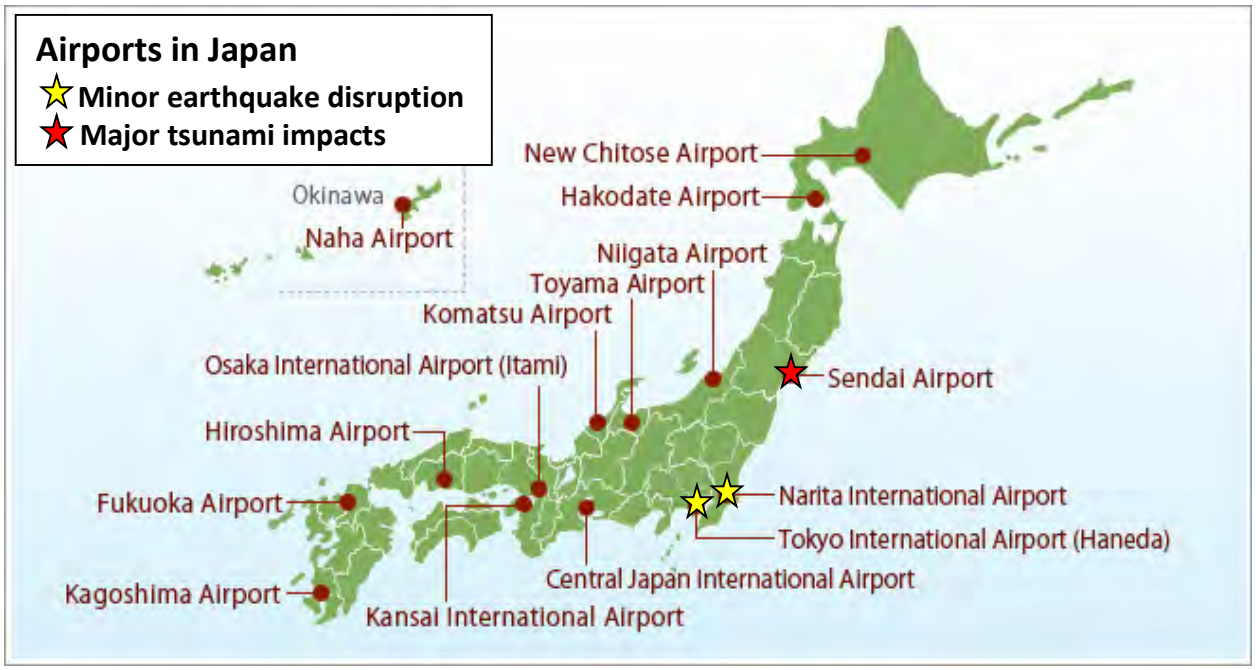
More C-130 flights followed as work on clearing the rest of the runway continued. That [clearing] was completed by March 21, allowing larger Boeing Co. (BA) C-17 planes to bring in power shovels and vehicles to help clear debris, as well as food, water and fuel for distribution to evacuation centers, Toth said.

"Cleanup operations went into high gear on the 21st," Toth said. "That's also when we brought in bathrooms, showers, sleeping quarters and large vehicles."

The Air Force handled more than 250 aircraft at the airport, including ones flown by the Marines, Army, Navy and Royal Australian Air Force. The aircraft delivered more than 2.31 million pounds of food, water and aid, and more than 15,000 gallons of fuel, Toth said.

Once larger planes began landing, work moved on to restoring the airport's air-traffic control functions and replacing lights, sensors and other gear smashed by the tsunami. By March 22, the perimeter fence was being rebuilt and Self- Defense Forces were restoring communications with the tower, said Toth, who recently flew to the airfield.

"Hearing the Japanese controller back on the radio from the control tower as we were coming in to land was a wonderful feeling," he said.



According to the December 11, 2012 issue of *The Daily Yomiuri*[145], "Regular domestic flights resumed in July [2011]… and regular international service restarted that September. The number of domestic and international flights are back to pre-disaster levels, but the number of passengers is down by about half." *Thus, the operations of this airport became impacted not by the damage to the airport itself, but likely due to the general economic activity in the Sendai area.*

According to Dr. Goh Moh Heng in a blog posting on September 9, 2012,[146] "The President of Sendai Airport in his briefing noted that any airport operation is always vulnerable to unforeseen or unplanned events such as the Tsunami and earthquake. The impact of unexpected and disruptive events (such as the "3/11″) is seen as something outside management control. Fortunately, the airports in Japan have already explored how working in a collaborative way with the other airport users can be beneficial in re-establishing an early recovery, and build on simple set of key protocols and plans that can unlock the route to operational recovery. … [The] Sendai Airport management … had protected the airport operational teams from media and public distraction, so that they could focus on the restoration of the airport and its services."

Dr. Heng continues by providing various recommendations based on his experience as a business recovery specialist in the Asia-Pacific region:

Map modified from http://www.yadyad.com/en/travelinfo/air-tyuubu by adding impact information

[145] Source: *The Daily Yomiuri* (December 11, 2012). "Kansai Airport operator may manage Sendai." *The Daily Yomiuri*. See http://www.yomiuri.co.jp/dy/national/T121210003551.htm.

[146] Source: Heng, Goh Moh (September 6, 2011). "Stop 5: Sendai Airports # Disaster Affected Regions" on *Business Continuity Planning Community: Official Blog for Dr. Goh Moh Heng*. See http://www.goh-moh-heng.com/2011/09/06/stop-5-sendai-airport-disaster-affected-regions/.

Railway Access Lines:

Because the tsunami and earthquake damaged the railway facilities, as well as its command and communication systems, the airport line was suspended. The airport Business Recovery Plan called for using shuttle bus services to run from the airport station to the nearest operational station.

It was critical to have the both the commercial train station and the rapid transit station next to the airport operation. This interdependency was critical to the transportation of both people and emergency supplies into the area. Thus, in a time of limited resources, the prioritization of the repair and operation of these lines is essential.

Passenger and Freight Terminals:

The clean-up and repair of the 1st and 2nd floors was critical to reopening the airport to passenger travel.

Dr. Heng noted[147] that, "As for freight operations, the key was to re-open the bonded warehouses and the interim resumption of truck services from Sendai to Narita. The leveraging of another international airport as a recovery strategy is crucial as Sendai is a key port to export some of Japan's major brands and products."

Other Airport Disruption and Recovery

Both the Tokyo's Narita International Airport (the largest international airport in the country) and Tokyo International Airport in Haneda suspended flights after the shaking to allow for examination of the facilities. After only minor damage was identified, these two airports reopened within 24 hours. Yet the relatively short closure of these two airports caused a major disruption of passenger flights, including the diversion of at least eleven flights to Yokota Air Base.[148] One of the lessons from this experience was the importance of rapid inspection of critical facilities to allow facilities that have had only minor damage to reopen.

According to *Bloomberg News*,[149] approximately 13,000 passengers were stranded at Narita Airport when flights were stopped into and out of the airport. Japan Airlines and All Nippon Airways told *Bloomberg News* that over 290 flights were cancelled, impacting more than 60,000 passengers. Flights by Cathay Pacific Airways, China Southern Airlines, British Airways and Qantas Airways were also cancelled and diverted.

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[147] Source: Heng, Goh Moh (September 2011). See reference above.

[148] For a first-person account of a passenger stranded at Tokyo's Narita Airport while waiting for the airport to reopen, in spite of the slight damage, see http://quake.abag.ca.gov/wp-content/documents/Japan-Earthquake-Airport-Report.pdf.

[149] Source: McCombs, Dave, and Matsuda, Kiyotaka (April 13, 2011). See reference above.

Summary of Findings from Review of Recent Disasters

Airport Emergency Plans and Planning Can Comply with FAA Requirements – and Still Have Gaps

Most of the effort associated with existing Airport Emergency Plans is related to airline crashes and security lapses, rather than natural disasters. When natural disasters are addressed, the focus is on the direct impact of the disaster on the airport facility, rather than addressing the indirect impact of the disaster on the airport in terms of airport access and airport customers. For example, one of the principal impacts of the Christchurch disaster on the airport was the convergence of hundreds of people into the facility who had been staying in Christchurch hotels that no longer were habitable, while existing Airport Emergency Plans may assume that passengers will leave the airport to reach their destination. The role of the airport can also change if the adjacent port is destroyed or severely damaged.

Cell Phone and Land-Line Communications Are Likely to Be Disrupted as Airports Struggle to Re-Open

While telephone communications are more robust than other utility infrastructure, communications can still be disrupted for several days. In addition, cell phones have now replaced radios at many airports. Cell towers can be damaged and overloaded, making communication both within airports and to outside lines more subject to disruption.

Airport Staff Will Be Stressed and Additional Equipment May Be Needed

Airport staff will be required to help inspect and repair the airport facility at the same time they, or their families, may be the victim of the same disasters. The staff may be dealing with inadequate inventory of spare parts and emergency equipment, such as emergency generators to power emergency lighting, items that may be easier to obtain from another airport than through standard procurement procedures.

Flights Into and Out of Airports Will Increase and Change in Response to the Disaster – and During Long-Term Recovery

Once airport facilities are inspected and flights are resumed, the types and number of aircraft will change from those prior to the disaster. Likely, aircraft will be larger. Cargo flights will increase as emergency supplies are flown into the impacted area. Then cargo flights will likely continue to be higher than pre-disaster as the impacted area is rebuilt. On the other hand, numbers of passenger flights will likely be fewer than before the disaster as tourism is reduced. Parking for additional aircraft will likely be needed, fuel supplies may be taxed, and airport staff will likely be stressed.

Priorities of Airport Users and Government Agencies Can Be in Conflict, Particularly If the Disaster Involves Large Numbers of Casualties

Military, air cargo, passenger airlines, and chartered flights (largely of humanitarian organizations) have traditionally all been accommodated following most disasters, such as following Loma Prieta, Northridge, and Christchurch. However, if the disaster involves mass casualties, such as Hurricane Katrina and the Haiti Earthquake, conflicts among users have appeared.

Airport Facility Inspections Can Delay Airport Operations – Even If No Damage Has Occurred

After any disaster, airport personnel need to inspect the airport runways, lighting, terminals, and critical facilities. In the larger airports, airports may have contracts with structural or other engineers to inspect the terminals, and even the fuel-handling facilities. If the disaster has occurred at night, such inspections may need to occur during daylight hours. Other delays may occur if transportation damage slows the travel of contractors to the airport. Finally, earthquakes may have numerous significant aftershocks, resulting in repeated inspections just as the airport is needed during emergency response.

Airport Runways, Terminals and Associated Facilities Have All Been Affected by Recent Disasters

Earthquakes have caused runways to buckle and crack, and hurricanes and tsunamis have left debris on runways. Terminals have been damaged and destroyed in past earthquakes and due to wind damage in hurricanes. Fuel lines, tanks and lighting have been damaged, sometimes beyond repair.

Airport Control Towers Are Subject to Damage and Controllers Have Had Problems Gaining Access to Airports in Disaster Areas

In both the Loma Prieta and Northridge earthquakes, aircraft control towers were damaged. In the case of the Seattle earthquake, that damage was significant and a portable control tower was used. Control towers at OAK and SFO are being replaced and the tower at SJC was replaced in 1990. (The current control tower status is described in Part One.) In addition, gridlock on surface transportation networks caused delays in FAA personnel reaching the towers following the Loma Prieta earthquake. Following the Haiti earthquake, damage to local roads caused the previous entrance to the airport to be moved, and the U.S. military ended up flying in and establishing the air traffic control system.

Airport Terminals Can Become De Facto Shelters

As airport terminals are designed to higher structural standards than the surrounding community, they may become de facto shelter locations. As noted earlier, one of the principal impacts of the

Christchurch disaster on the airport was the convergence of hundreds of people into the facility who had been staying in Christchurch hotels that no longer were habitable. Following Hurricane Katrina, people staged for medical and other evacuations at the New Orleans airport made it, in effect, a shelter.

Airport Revenues Can Decrease Significantly Just as Repairs Are Required

Most airports in the United States, including all of the international and commercial airports, as well as the major general aviation airports, are owned and operated by cities and counties. They are run as separate departments and expected to operate as a revenue generating operation. As passenger levels drop, revenues will drop. Cargo revenues may also drop, however, typically not to as great an extent. In some cases, these revenues may actually increase if repairs can be made quickly. However, revenues, even to an undamaged airport, can be reduced for years after a disaster. Traditionally, cities and counties lose significant revenues as the result of disasters since damage to property results in significantly lower property taxes and business taxes drop. Thus, these local governments will not be in a position to assist airports with their revenue needs.

PART 3:

RECOMMENDATIONS FOR CHANGE

The following recommendations should be viewed as ideas for actions to be taken by the international, commercial, and general aviation airports in the region and adjacent areas to ensure that these facilities are available and effectively used after disasters. They include:

1. Ways to improve the speed at which airports can resume operation
2. Ways to more effectively use airports during emergency response
3. Ways to improve the contribution of airports to long-term regional recovery

Bay Area and other airports, particularly the international airports, are likely already doing many of these activities. This list is not intended to imply that important planning is not already occurring. Instead, it is intended to serve as an overview of the key activities important for airports as we jointly prepare for disasters. As part of this review process, individual airports may want to identify a priority for each recommendation as it relates to that particular facility, as well as to identify activities that have already been undertaken, or that may be inappropriate for a facility.

ALL Airports – Importance of Support from Elected Officials and Regional Organizations

- All Bay Area airports are generally considered key resources under the broad context of the Critical Infrastructure Key Resources (CIKR) Support Annex, as coordinated through the U.S. Department of Homeland Security. These airport are also transportation and logistics nodes in emergency response and continue through the long-term physical and economic recovery of the region. These roles should be formally recognized by regional groups of elected officials, such as ABAG and MTC, as well as the Regional Airport Planning Committee (RAPC) operated by ABAG, MTC, and BCDC. Resolutions passed by these groups of elected officials, as well as by individual cities and counties, would be invaluable for top-down support of emergency preparedness, as well as response and recovery planning by the airports themselves. The following recommendations for Bay Area airport owners might then be taken more seriously by the individual airport management and would likely lead to improved coordination among the airports and between airports and the emergency managers of the cities and counties where they are located.

International and Commercial Airport Emergency Plans and Planning

- Elements within Bay Area commercial and international Airport Emergency Plans may be beneficial to share among Bay Area airports to the extent they do not compromise sensitive information as communicated through the U.S. Department of Homeland

Security. The intent is to gain insight into opportunities to expand airport emergency response and recovery plans at other airports in the area.

- Elements within Bay Area commercial and international Airport Emergency Plans may also have an opportunity to share lessons learned among related agencies, such as the American Red Cross, or other agencies with which the airport has mutual aid agreements. Other regional or local emergency departments of adjacent cities and counties, as well as transit districts, may benefit from an exchange of emergency planning activities.

- ~~Some suggest that these Airport Emergency Plans are best utilized if openly shared on the internet to promote transparency and provide opportunities for the public and companies to contribute to the improvement of the plan.~~ [Note: there are Homeland Security issues here that the authors are probably not aware of. Internet posting of this type of info has to be deleted as any kind of an action item.]

- Bay Area Airport Emergency Plans could have additional value if they had a specific section on earthquakes. This may assume that even if the airport is physically unaffected by the disaster, the role of the airport will have likely changed, including increased military and chartered or contract aircraft use. Hundreds of international visitors staying in the region attempting to get the first available flight out of the region will add additional pressure on airport operators and within the emergency TFR airspace. For example, if hotel space is reduced in the Bay Area due to extensive damage (as in Christchurch), hundreds of additional people will show up at airports attempting to leave the area.

- Bay Area commercial and international airports should employ more frequent training, drills and exercises as part of the planning functions leading up to full field exercises with transit districts, water, wastewater, and power utilities, the American Red Cross, the U.S. Coast Guard, and other related organizations.

- While Bay Area commercial and international airports are not required to coordinate exercises, they are encouraged to do so by participating as observers and evaluators to provide feedback on appropriate exercises within the region.

General Aviation Airport Emergency Planning

- While Bay Area general aviation airports are not required to prepare an FAA-certified Airport Emergency Plans, they would benefit from examining those prepared by the five international and commercial airports in the region. As an option, a template for a general aviation airport AEP might be a useful product.

- GA airports should participate in City/County training and exercises to enhance their understanding of what would be expected of them following a disaster and to test their emergency plans on a regular basis.

- General aviation airports (as well as smaller commercial airports) have limited resources. Thus, part of any planning for these airports to have a more formal or expanded role related to disaster response and recovery needs to include thinking about innovative ways to fund and staff the creation of those plans, as well as their implementation. These airports also have limited space. Thus, if approached by a pilots association or other group to store emergency supplies, that request needs to be balanced against the space and budget constraints of the airport.

ALL Airports – Importance of Redundant Communications

- All Bay Area airports should have redundant communications systems that supplement cell phones with radios for on-site communication.
- All Bay Area airports should have redundant communications systems that supplement land lines with satellite phones for communication with outside organizations.
- Emergency communications systems should be tested monthly.

ALL Airports – Mutual Aid and Mutual Aid Agreements

- The Western Airports Disaster Operations Group (WESTDOG) created the WESTDOG Mutual Aid Plan – Airports Helping Airports – in 2007 following Hurricane Katrina.[150] This document should serve as a way for Bay Area commercial and international airports work to assist each other following a disaster, and to obtain aid from other airports in the western U.S. These agreements are extremely valuable because:
  1) Airport personnel from another airport will be familiar with working with complex regulations, passenger airlines, and air cargo carriers.
  2) Airports use some equipment that is extremely specialized and more easily, and quickly, obtained from another airport than from an independent vendor.
  3) Any staff members assisting another airport after a disaster gain invaluable experience that can assist them in a future disaster impacting the airport where they work.

  One key to support by airport management is that the impacted airport management continues to maintain control. In addition, requests for mutual aid, and decisions to respond to requests for mutual aid, are completely voluntary and under the control of airport operating authority.

- While the WESTDOG agreement is a model mutual aid agreement among airports, general aviation airports can also be served through master mutual aid agreements among the cities and counties that ultimately operate these facilities. Knowledge of the location and availability of key equipment, including emergency generators and forklifts or other equipment to unload planes, is particularly important. General aviation airports, due to their small staff, are particularly vulnerable to staffing shortages if any personnel have family emergencies requiring their attention. Increased traffic or different traffic at these smaller airports may mean that additional, or more specialized, personnel are needed. Finally, improved communications among airports will likely be useful, perhaps with additional radios supplied by emergency managers of the city or county operating the airport.

[150] See http://westdogairports.com/WESTDOG-MAP.pdf for additional information.

- Bay Area general aviation airports have few redundant resources. If a group such as the Water-Wastewater Agency Response Network (WARN) were set up, this group could obtain communications and emergency equipment to be integrated into the larger emergency response and recovery network of local governments. Grant funding for the establishment of such a group and to obtain needed equipment should be sought.
- All airports should understand some of the potential problems with mutual aid so that they do not use it as a substitute for appropriate emergency planning. For example, if an airport requests electricians from another airport to assist in the repair of nonstructural damage and fittings, it takes time or people to manage outsiders; even if they are familiar with airports, they are not familiar with the airport where they are sent. In another example, an emergency generator for lighting may be delivered which has not been properly maintained and thus is of limited use.
- In advance of the response to a mutual aid request, both requesting, and responding, airports should put the following in writing:
    - description or map of airport operating environment (length/layout of runways and facilities; limitations or uniqueness of a particular airport layout);
    - roles that are particularly amenable to mutual aid with minimal training;
    - record-keeping systems for expenditures so that financial claims for reimbursement are clear;
    - cost of materials, equipment, and staff to be deployed;
    - reimbursement procedures;
    - security access procedures; and
    - financial sufficiency of aid teams (including travel expenses).

International and Commercial Airports – Equipment and Resources Inventories

- Some airports do not own or operate equipment to deplane passengers from any of passenger carrier aircraft, and are therefore unable, on their own, to provide for the deplanement of passengers. In addition, some airport personnel may not be trained to assist in the deplanement of passengers using equipment owned or operated by air carriers or contract service providers. If an aircraft operated by an airline that does not normally land at a particular airport needs to rely on airlines currently operating at that airport to deplane passengers. If no commercial airlines currently operate at an airport, little or no equipment may be present. Thus:
    1) These airports should request that each airline, ground handler, and Fixed Base Operator (such as those offering fueling and flight instruction) provide the airports with a list of the equipment and resources they have for deplaning passengers so that airports can work with re-routed airlines to deplane passengers.
    2) These airports should also direct the air carriers to make gates and other facilities available to an air carrier seeking to deplane at gates at the airport to the extent practicable.

- Air cargo carriers utilize specialized equipment to load and unload the large jets that they use for much of their cargo. This equipment is only located in airports where they have existing operations, although temporary "work-arounds" could be used on an emergency basis. Thus, it is particularly important that existing commercial and international airports with air cargo operators share their emergency response and recovery plans and work together to develop improved plans.

ALL Airports – Aviation Fueling

- Coordinate, communicate and maintain an inventory of any limitations in available aviation fuel to support disaster response aircraft, as well as returning to normal operations to the appropriate regional Air Operations Branch or equivalent. Such limitations may be due to increased demand and exacerbated by broken underground pipelines carrying fuel lines, as well as damage to fuel storage facilities.
- Limitations may require the establishment and maintenance of designated airports for refueling, as needed and on a temporary basis, to supplement airports that may have sustained damage to facilities and/or fuel servicing capabilities, or that have had unexpected increases in fuel requests.
- Pre-planning and mitigation include strengthening pipelines and tanks, as well as identifying back-up sources of fuel and alternative mechanisms to obtain fuel.

ALL Airports – Speed Up Operability Inspections

- Bay Area commercial and international airports have staff trained to examine runways and runway lighting so these inspections happen quickly and seamlessly. However, many rely on others to inspect terminals and other airport structures and fuel facilities. These airports should have on-site staff trained, access to city or county public works personnel, or consultants on retainer to evaluate these facilities quickly.
- Bay Area commercial and international airports should plan for numerous aftershocks following a major earthquake, some of which may be nearly as large as the initial event. Thus, they need to establish a mechanism to decide which aftershocks are large enough to require re-inspection – and which are not. Magnitude will likely not be useful in determining response because it depends on how far away the airport is from the epicenter, the depth of the earthquakes and other factors. Even modified Mercalli intensity (MMI) may not be effective because one person's MMI vi may be another's MMI ix. Therefore, these airports have two options:
  1) Purchase and install appropriate instrumentation to measure shaking forces exerted at the facility site. A suite of instrumentation would measure ground motions as well as the performance of key structural elements, as is currently done through the California Geological Survey (CGS) California Strong Motion Instrumentations

Program (CSMIP) (http://consrv.ca.gov/cgs/smip/Pages/Index.aspx). The data is used to alert key responders.

2) Use the USGS ShakeCast system, and, if necessary, augment the statewide California Integrated Seismic Network (CISN) with seismic instruments purchased by the airport to provide site specific ground shaking measurements. Since ShakeCast is currently used by Caltrans for assessment of highways and bridges, use of ShakeCast would provide an opportunity to coordinate airport and Caltrans response planning. Additional information on ShakeCast is included in **Appendix C**.

- Once the acceleration data is obtained, airports should tie response plans to that data. For example, the Christchurch, New Zealand International Airport has now established a 3-tiered category of response: – C – felt, not concerned – B – big enough to require checking the terminal and runways, but not stop flights or close the terminals – A – evacuate the terminal and close the runways. The accelerometer has established a scale with a hard data point; this sets a minimum category. Then, based on the assessment of staff of the consequences of the shaking within the terminal, control tower and other locations, they can increase the response category, such as from a B to an A, but can never decrease it. Based on the response category, each of the airport's business units has a prescribed process and actions.

ALL Airports – Long-Term Financial Recovery Planning

- Bay Area airports are owned and operated by cities and counties as independent entities that are typically not dependent on general fund tax dollars, but are still under the umbrella of these local governments. A disaster will impact the economy of the community where the airport is located – increasing the number of construction-related jobs as repairs to the buildings damaged by the disaster are made, while decreasing the number of jobs in businesses damaged by the disaster. To the extent that the revenues of the airport are dependent on the damaged businesses, and not on construction workers or their suppliers, those revenues will decrease, sometimes dramatically, and result in stresses on airport operations. (While cargo may increase, passenger levels will likely decrease significantly.) As with the remainder of city and county services that are impacted by reduced post-disaster revenues, airports need to have adequate financial reserves to weather these reductions and contingency plans for obtaining additional revenues, if needed.

General Aviation Airports – Coordination with Volunteer Pilot Groups (California Pilots Association, EVAC, and California Wing of the Civil Air Patrol)

- Several groups have developed programs for volunteer pilots to help deliver supplies and personnel to areas isolated due to damaged transportation systems. General aviation airports should recognize these groups and work with the emergency managers of their cities or counties to allow other government workers to handle the ground logistics of

managing the people, equipment, and supplies that will need to be transported. As always, any activity using the resources of volunteer aviation must be properly vetted through the emergency aviation chain of command before they can commence aviation activities.

ALL Airports – Post-Disaster Review

- Bay Area airports should meet with their own staff, as well as with airport vendors, cargo and passenger airlines, and other airports, to determine which measures were effective, as well as to identify planning gaps, following emergencies and disasters. Documenting and sharing this information is one of the most effective means of ensuring that future mitigation, preparedness, response, repair, and long-term recovery plans are improved.

APPENDIX A:

INTERNATIONAL AIRPORTS IN THE BAY AREA – PASSENGERS, CARGO, AND FLIGHTS

As shown in the following three tables, SFO has traditionally had, and continues to handle, the majority of passengers, while OAK handles the majority of cargo. Data for 2011 and 2012 (the most recent information) and 2007 (pre-recession when flights peaked) are provided.

Passenger Operations

Table 1 shows the share of Bay Area air passengers using each of the three international airports. SFO handled the most passengers annually, and that share increased slightly from 70% to 71% between 2011 and 2012. SFO was followed (as a distant second) by OAK at 16% for both years and SJC at 14% in 2011, dropping to 13% in 2012. The dominance of SFO in international flights is even more marked, for it handled 96% of the international passengers in 2011, with that share increasing to 97% in 2012.

TABLE 1: Air Passengers[151]

	OAK	SFO	SJC	Total
2012				
Domestic	9,885,679	34,776,416	8,124,270	52,786,365
Domestic %	19%	66%	15%	
International	155,185	9,546,145	171,904	9,873,234
International %	2%	97%	2%	
Total	10,040,864	44,322,561	8,296,174	62,659,599
Total %	16%	71%	13%	
2011				
Domestic	9,074,541	31,787,331	8,187,813	49,049,685
Domestic %	19%	65%	17%	
International	192,029	9,013,021	169,571	9,374,621
International %	2%	96%	2%	
Total	9,266,570	40,800,352	8,357,384	58,424,306
Total %	16%	70%	14%	
2007				
Domestic	14,455,632	26,354,276	10,505,188	51,315,096
Domestic %	28%	51%	20%	
International	160,962	8,962,965	153,201	9,277,128
International %	2%	97%	2%	
Total	14,616,594	35,317,241	10,658,389	60,592,224
Total %	24%	58.3%	18%	

[151] Source: Regional Airport Planning Committee (April 2013). *Regional Aviation Activity Tracking Report: 2013 Edition*.

- The airlines operating the largest number of passenger flights at SFO are United, Alaska, American, and Virgin America.
- At OAK, the top five airlines in terms of market share for 2011 are Southwest Airlines (75.35%), JetBlue Airways (6.45%), Alaska Airlines (4.94%), US Airways (2.84%) and Hawaiian Airlines (2.41%).

Air Cargo Operations

As shown in Table 2 for 2011 and 2012, OAK handled 54% of the Bay Area air cargo tonnage of the three large airports, followed by SFO at 41% for 2012 (and 42% for 2011) and SJC at 4%.

TABLE 2: Air Cargo (tons)[152]

	OAK	SFO	SJC	Total
2012				
Freight	542,662	371,868	41,247	955,777
Freight %	57%	39%	4%	
Mail	7,923	47,877	570	56,370
Mail %	14%	85%	1%	
Total	550,585	419,745	41,817	1,012,147
Total %	54%	41%	4%	
	OAK	**SFO**	**SJC**	**Total**
2011				
Freight	540,051	375,694	43,318	959,063
Freight %	56%	39%	5%	
Mail	10,517	45,481	772	56,770
Mail %	19%	80%	1%	
Total	550,568	421,175	44,040	1,015,783
Total %	54%	42%	4%	
2007				
Freight	706,700	555,549	89,849	1,352,098
Freight %	52%	41%	7%	
Mail	7,165	65,085	1,577	73,827
Mail %	10%	88%	2%	
Total	713,865	620,634	91,426	1,425,925
Total %	50%	43.5%	6%	

- At OAK, the principal air cargo carriers are Federal Express (FedEx) and United Parcel Service (UPS). The ultimate destinations of the cargo are principally domestic.[153]
- On the other hand, in 2009, SFO was the carrier of 94% of the international air cargo market. The $53 billion of international air freight imports and exports moving through SFO was 7% of the entire international market in 2009. Unlike at OAK, over 60% of the

[152] Source: Regional Airport Planning Committee (April 2013). See previous reference.
[153] Source: Caltrans (July 2012). *Caltrans Freight Planning Fact Sheet: Oakland International Airport*. See http://www.dot.ca.gov/hq/tpp/offices/ogm/air_cargo/Oakland_Airport_Fact_Sheet_073112.pdf.

air cargo at SFO is carried on passenger aircraft, not air freight aircraft, with the largest carrier being United Airlines.[154]

- At SJC, cargo operations are handled by FedEx (58%) and UPS (42%).[155]

These carriers also use airports in neighboring counties, such as Sacramento International Airport (SMF) (FedEx) and Sacramento County's Mather Field (MHR) (UPS), to service the Bay Area. Transport of air freight into trucks to reach its ultimate destination is typical. However, some carriers do use satellite airports. UPS uses both Santa Rosa (Charles M. Schultz/Sonoma County) and Monterey as satellite airports, flying smaller aircraft into these airports. In the case of FedEx, feeder planes fly to Chico, Ukiah, Redding, Murray Field near Yreka, and Crescent City from SAC, and Monterey, Sonoma County, and Visalia from OAK. OAK is particularly critical for FedEx, for it serves as its west coast hub, while Ontario in Southern California is the west coast hub for UPS. (Most international air freight for FedEx goes directly to Memphis, rather than to OAK.) United uses SFO for international air freight, however. The FedEx operation in SJC is larger than in SFO. For more information on UPS and FedEx, see pages 17-20 of this report.

Total Aircraft Operations

As shown in Table 3 for 2011 and 2012, SFO handled 55% of the Bay Area annual aircraft operations of the three large airports in 2011, with that share increasing slightly to 56% in 2012. SFO was followed (as a distant second) by OAK at 29% for 2011, dropping to 28% in 2012, and SJC at 16% for both years.

TABLE 3: Annual Aircraft Operations[156]

2012	OAK	SFO	SJC	Total
Air Carrier	91,271	314,025	70,562	475,858
Air Carrier %	19%	66%	15%	
Air Taxi	19,819	88,987	15,752	124,558
Air Taxi %	16%	71%	13%	
Air Cargo	21,376	6,274	1,540	29,190
Air Cargo %	73%	21%	5%	
GA & Military	78,184	15,280	31,575	125,039
GA & Military %	63%	12%	25%	
Total	210,650	424,566	119,429	754,645
Total %	28%	56%	16%	

[154] Source: Caltrans (July 2012). *Caltrans Freight Planning Fact Sheet: San Francisco International Airport*. See http://www.dot.ca.gov/hq/tpp/offices/ogm/air_cargo/San_Francisco_Airport_Fact_Sheet_072512.pdf.
[155] Source: Caltrans (July 2012). *Caltrans Freight Planning Fact Sheet: Norman Y. Mineta San Jose International Airport*, July 2012. See http://www.dot.ca.gov/hq/tpp/offices/ogm/air_cargo/San_Jose_Fact_Sheet_072612.pdf.
[156] Source: Regional Airport Planning Committee (April 2013). See previous reference.

TABLE 3: Annual Aircraft Operations (continued)

	OAK	SFO	SJC	Total
2011				
Air Carrier	86,052	290,849	73,094	449,995
Air Carrier %	19%	65%	16%	
Air Taxi	22,980	90,582	15,592	129,154
Air Taxi %	18%	70%	12%	
Air Cargo	22,945	6,782	1,932	31,659
Air Cargo %	72%	21%	6%	
GA & Military	83,896	15,351	30,348	129,595
GA & Military %	65%	12%	23%	
Total	215,873	403,564	120,966	740,403
Total %	29%	55%	16%	
2007				
Air Carrier	141,735	254,995	97,702	494,432
Air Carrier %	29%	52%	20%	
Air Taxi	31,024	95,582	30,452	157,058
Air Taxi %	20%	61%	19%	
Air Cargo	32,174	7,140	3,242	42,556
Air Cargo %	76%	17%	8%	
GA & Military	141,417	21,783	55,801	219,001
GA & Military %	65%	10%	25%	
Total	346,350	379,500	187,197	913,047
Total %	38%	42%	21%	

APPENDIX B:

AIRPORT AND RUNWAY INFORMATION CATEGORIZED BY CAPACITY

The following table lists the various runways in the San Francisco Bay Area and adjacent areas in Northern California. Rather than listing the airports alphabetically by county, they are subdivided into runways of various length and weight capacity categories. As with any categorization scheme, the cut-offs for various categories are arbitrary.

APPENDIX B - TABLE 1: Airport and Runway Information Categorized by Capacity

(based on FAA data effective January 10, 2013)

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	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Oakland	Oakland Intl Arprt, South Field	OAK	Public	11/29	10,001	150	Asphalt	MALSR / ALSF2	200,000	200,000	400,000	900,000
Monterey	Monterey	Monterey Peninsula Airport	MRY	Public	10R/28L	7,616	150	Asphalt	MALSR	100,000	160,000	300,000	
Sacramento	Sacramento	Sacramento International Airport	SMF	Public	16L/34R	8,605	150	Concrete	MALSR	100,000	209,000	407,000	850,000
Sacramento	Sacramento	Sacramento International Airport	SMF	Public	16R/34L	8,598	150	Asphalt	ALSF2	100,000	209,000	407,000	850,000
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	04R/22L	11,301	150	Asphalt or Concrete	MALSR	160,000	280,000	500,000	
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	01R/19L	8,646	200	Asphalt	MALSR	60,000	195,000	325,000	710,000
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	10L/28R	11,870	200	Asphalt	ALSF2	60,000	200,000	355,000	710,000
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	10R/28L	11,381	200	Asphalt	SSALR	60,000	200,000	355,000	710,000
Santa Clara	San Jose	San Jose International Airport	SJC	Public	12R/30L	11,000	150	Concrete	MALSR	220,000	250,000	605,000	875,000
Santa Clara	San Jose	San Jose International Airport	SJC	Public	12L/30R	11,000	150	Concrete	High Int	220,000	250,000	605,000	
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	Federal	14L/32R	9,197	200	Concrete	ALSF1	64,000	144,000	253,000	528,000
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	Federal	14R/32L	8,122	200	Concrete	High Int	82,000	239,000	300,000	814,000
Solano	Fairfield	Travis Air Force Base	SUU	Military	03L/21R	11,001	150	Porous European Mix (PEM)	High Int	155,000	260,000	470,000	720,000
Solano	Fairfield	Travis Air Force Base	SUU	Military	03R/21L	10,992	150	Concrete	ALSF2	155,000	260,000	470,000	720,000

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	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport	HWD	Public	10R/28L	5,694	150	Asphalt	Medium Int	30,000	75,000		
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	09L/27R	5,458	150	Asphalt	High Int	75,000	115,000	180,000	
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	09R/27L	6,213	150	Asphalt	High Int	75,000	200,000	400,000	800,000
Napa	Napa	Napa County Airport	APC	Public	18R/36L	5,930	150	Concrete	MALS	30,000	50,000	120,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	02/20	5,503	150	Asphalt	MALSR	60,000	130,000	210,000	
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	04L/22R	6,038	150	Asphalt	Medium Int	90,000	105,000	190,000	
San Benito	Hollister	Hollister Municipal Airport	3O7	Public	13/31	6,350	100	Asphalt		30,000	45,000		
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	11L/29R	10,650	150	Asphalt	MALSR	40,000	150,000	360,000	650,000
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	01L/19R	7,500	200	Asphalt	High Int	60,000	170,000	270,000	710,000
Stanislaus	Modesto	Modesto Cty-CO-Harry Sham Fld Arprt	MOD	Public	10L/28R	5,904	150	Asphalt	MALSR	60,000	200,000	350,000	
Yolo	Davis	Yolo CO - Davis/Wdlnd/Winters Arprt	2Q3	Public	16/34	6,000	100	Asphalt		30,000	36,000		

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	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Livermore	Livermore Municipal Airport	LVK	Public	07L/25R	5,253	100	Asphalt	MALSR	45,000	60,000		
Contra Costa	Byron	Byron Airport	C83	Public	12/30	4,500	100	Asphalt		29,500			
Contra Costa	Concord	Buchanan Field [1]	CCR	Public	01L/19R	5,001	150	Asphalt	MALS	60,000	90,000	140,000	
Contra Costa	Concord	Buchanan Field [1]	CCR	Public	14L/32R	4,602	150	Asphalt		60,000	90,000	140,000	
Merced	Los Banos	Los Banos Municipal Airport	LSN	Public	14/32	3,801	75	Asphalt	Medium Int	23,000			
Mendocino	Ukiah	Ukiah Municipal Airport	UKI	Public	15/33	4,423	150	Asphalt		28,000			
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	08/26	6,004	150	Asphalt		25,000	32,000	62,000	
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	13/31	4,825	150	Asphalt	MALSR	65,000	100,000	170,000	
Napa	Napa	Napa County Airport	APC	Public	06/24	5,007	150	Concrete		30,000	50,000	120,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	12/30	3,837	100	Asphalt	Medium Int	30,000	43,000	67,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	16/34	3,505	150	Asphalt		60,000	85,000	90,000	
San Joaquin	Lodi	Kingdon Airpark Airport	O20	Public	12/30	3,705	60	Asphalt		30,000			
San Joaquin	Tracy	Tracy Municipal Airport	TCY	Public	08/26	4,005	100	Asphalt	Medium Int	50,000	70,000	120,000	
San Joaquin	Tracy	Tracy Municipal Airport	TCY	Public	12/30	4,001	100	Asphalt	Medium Int	50,000	70,000	120,000	
San Mateo	Half Moon Bay	Half Moon Bay Airport	HAF	Public	12/30	5,000	150	Asphalt / Concrete	Medium Int	30,000	200,000	360,000	
Santa Clara	San Jose	San Jose International Airport	SJC	Public	11/29	4,599	100	Asphalt		60,000			
Santa Cruz	Watsonville	Watsonville Municipal Airport	WVI	Public	02/20	4,488	150	Asphalt	Medium Int	81,000	96,000	167,000	
Santa Cruz	Watsonville	Watsonville Municipal Airport	WVI	Public	08/26	4,012	100	Asphalt		45,000	65,000		
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	07/25	4,201	75	Asphalt		30,000			
Solano	Vacaville	Nut Tree - Solano County Airport	VCB	Public	02/20	4,700	75	Asphalt		30,000			
Sonoma	Santa Rosa	Sonoma County Airport [1]	STS	Public	01/19	5,020	100	Asphalt		60,000	95,000	150,000	
Sonoma	Santa Rosa	Sonoma County Airport [1]	STS	Public	14/32	5,121	150	Asphalt		60,000	95,000	150,000	
Stanislaus	Modesto	Modesto Cty-C/O-Harry Sham Fld Arpt	MOD	Public	10R/28L	3,464	100	Asphalt	Medium Int	30,000			

[1] Charles M. Schulz / Sonoma County Airport has an on-going project to increase the runway lengths from approximately 5,100 feet to 6,000 feet. After this occurs, the airport will be able to accommodate larger aircraft.

Runway Able to Accommodate Small Aircraft

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport	HWD	Public	10L/28R	3,107	75	Asphalt	Medium Int	13,000			
Alameda	Livermore	Livermore Municipal Airport	LVK	Public	07R/25L	2,699	75	Asphalt		12,500			
Alameda	Livermore	Meadowlark Field Airport	23Q	Private	07/25	1,848	25	Asphalt	Medium Int				
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	15/33	3,376	75	Asphalt	Medium Int	12,500			
Colusa	Colusa	Colusa County Airport	O08	Public	13/31	3,035	60	Asphalt		10,000			
Contra Costa	Brentwood	Funny Farm Airport (Brentwood Arprt)	4CA2	Private	17/35	1,880	20	Asphalt					
Contra Costa	Byron	Byron Airport	C83	Public	5/23	3,000	75	Asphalt	Medium Int	29,500			
Contra Costa	Concord	Buchanan Field	CCR	Public	01R/19L	2,770	75	Asphalt		17,000			
Contra Costa	Concord	Buchanan Field	CCR	Public	14R/32L	2,799	75	Asphalt		12,500			

Runway Able to Accommodate Small Aircraft (continued)

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Marin	Novato	Marin County Airport (Gnoss Field)	DVO	Public	13/31	3,300	75	Asphalt	Medium Int	26,000			
Marin	San Rafael	San Rafael (Smith Ranch Airport)	CA35	Private	04/22	2,140	30	Asphalt		7,000			
Mendocino	Gualala	Ocean Ridge Airport	Q69	Public	13/31	2,500	50	Asphalt		8,000			
Merced	Gustine	Gustine Airport	3O1	Public	18/36	3,207	60	Asphalt		12,000			
Monterey	Monterey	Monterey Peninsula Airport	MRY	Public	10L/28R	3,513	60	Asphalt		12,500			
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	14/32	1,900	50	Asphalt		30,000	45,000	75,000	
Napa	Angwin	Angwin-Parrett Field Airport	2O3	Public	16/34	3,217	50	Asphalt					
Napa	Napa	Moskowite Airport	41Q	Private	03/21	2,217	80	Dirt					
Napa	Napa	Napa County Airport	APC	Public	18L/36R	2,510	75	Asphalt		12,500			
Napa	Pope Valley	Mysterious Valley Airport	0CL	Private	14/32	3,500	30	Gravel		N/A			
Napa	Pope Valley	Pope Valley Airport	05CL	Private	10/28	3,700	60	Asphalt		6,000			
Sacramento	Sacramento	Natomas Field Airport	Q96	Public	16/34	2,692	30	Asphalt		12,000			
San Benito	Hollister	Frazier Lake Airpark Airport	1C9	Public	05/23	2,500	100	Turf		6,700			
San Benito	Hollister	Hollister Municipal Airport	3O7	Public	06/24	3,150	100	Asphalt		30,000	45,000		
San Joaquin	Lodi	Lodi Airport	1O3	Public	08/26	3,735	42	Asphalt		30,000			
San Joaquin	Lodi	Lodi Airport	1O3	Public	12/30	2,073	26	Asphalt		30,000			
San Joaquin	Lodi	Lodi Airpark Airport	Q80	Public	07/25	1,875	22	Asphalt					
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	11R/29L	4,448	75	Asphalt		12,500			
San Joaquin	Tracy	New Jerusalem Airport	1Q4	Public	12/30	3,530	60	Asphalt		12,500			
San Mateo	San Carlos	San Carlos Airport	SQL	Public	12/30	2,600	75	Asphalt	Medium Int	12,500			
Santa Clara	Palo Alto	Palo Alto Airport	PAO	Public	31/13	2,443	66	Asphalt	MRL	12,500			
Santa Clara	San Jose	Reid-Hillview Airport	RHV	Public	31R/13L	3,101	75	Asphalt	MIRL,REIL	17,000			
Santa Clara	San Jose	Reid-Hillview Airport	RHV	Public	31L/13R	3,099	75	Asphalt		17,000			
Santa Clara	San Martin	San Martin Airport	E16	Public	32/14	3,100	75	Asphalt	MIRL	12,500			
Solano	Cordelia	Garibaldi Brothers Airport	6Q2	Private	06/24	2,006	50	Grass					
Solano	Dixon	Maine Prairie Airport	Q33	Private	16/34	1,953	50	Gravel					
Solano	Fairfield	Travis AFB Aero Club	8Q0	Military	04/22	2,006	40	Asphalt					
Solano	Fairfield	Travis AFB Aero Club	8Q0	Military	16/34	1,795	40	Grass					
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	15/33	2,217	60	Asphalt	Medium Int	12,500			
Solano	Vacaville	Blake Sky Park Airport	CA57	Private	17/35	1,600	75	Turf					
Sonoma	Cloverdale	Cloverdale Municipal Airport	O60	Public	14/32	3,147	60	Asphalt		12,000			
Sonoma	Healdsburg	Healdsburg Municipal Airport	O31	Public	13/31	2,707	60	Asphalt		12,500			
Sonoma	Petaluma	Petaluma Municipal Arprt (Skyranch)	O69	Public	11/29	3,601	75	Asphalt	Medium Int	12,500			
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	Private	E/W	2,500	70	Dirt					
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	Private	N/S	1,500	80	Dirt					
Sonoma	Sonoma	Sonoma Skypark	0Q9	Public	08/26	2,480	40	Asphalt		8,000			
Sonoma	Schellville	Sonoma Valley Airport	0Q3	Public	07/25	2,700	45	Asphalt		12,500			
Sonoma	Schellville	Sonoma Valley Airport	0Q3	Public	17/35	1,500	50	Asphalt		12,500			
Sonoma	The Sea Ranch	The Sea Ranch Airport	CA51	Private	12/30	2,600	40	Asphalt		12,500			
Yolo	Davis	University Airport	EDU	Public	17/35	3,176	50	Asphalt	NSTD MIRL	12,500			

Seaplane Base

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Merced	Los Banos	San Luis Reservoir Seaplane Base	0O0	Public	ALL/WAY	15,840	4,000	Water					
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	13/31	7,000	2,000	Water					
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	14/32	13,000	2,000	Water					
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	15/33	10,500	1,500	Water					
San Benito	Hollister	Frazier Lake Airpark Airport	1C9	Public	05W/23W	3,000	60	Water					
San Joaquin	Stockton	Lost Isle Seaplane Base	Q87	Public	NW/SE	4,000	300	Water					

Helipads

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Runway Width (ft)	Surface	Lighting	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport [2]	HWD	Public	Helipad	110	110	Asphalt	Medium Int				
Napa	Rutherford	River Mdw Frm Hlprt/Inglenook Rnch	7CA9	Private	Helipad H1	65	65	Concrete					
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	Helipad 1	30	30	Asphalt					
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	Helipad 2	100	100	Asphalt					
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	Helipad H1	70	70	Concrete	ODALS	45,000	55,000	N/A	N/A
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	Helipad H1	180	180	Concrete	Perimeter				

[2] Hayward Executive Airport helipad has three parking spots.

[3] Sonoma County Airport helipad has parking for four helicopters.

USGS ShakeCast Instrumentation Near Bay Area Airports

The following list provides information on the closest CISN[157] instrument for selected Bay Area airports. Accelerograms located at an airport are preferable to stations located off-site; however, nearby instruments are often useful. Instruments purchased by airports can be integrated into the CISN system through the NetQuake program and used in ShakeCast.

International Airports:

San Francisco - SFO
- CGS Station 58662 San Francisco Airport - North Access Rd
- CGS Station 58223 San Francisco Airport – Engineering Services

San Jose - SJC
- CGS Station 57333 San Jose - County Building Grounds

Oakland - OAK
- USGS Station 1858 Oakland - Oakland FS 27 (P06)
- NCSN Station C044 Maitland Dr, Alameda

Other Commercial, Federal, and Military Airports:

Charles M Schultz/Sonoma County - STS
- NCSN Station N005 Pan Abode Ct, Santa Rosa

Concord/Buchannan - CCR
- CGS Station 58467 Concord - I680 & Galaxy

Moffett Federal Field – NUQ
- USGS Station 1695 Sunnyvale; Salsman Residence

Travis Air Force Base - SUU
- USGS Station 1769 Fairfield; Travis AFB

Selected General Aviation Airports:

Byron - C83
- NCSN Station CBS Cerro Bola Mex

Half Moon Bay - HAF
- NCSN Station J009 Orval Av Moss Beach CA

Hayward - HWD
- CGS Station 58407 Hayward - Hesperian & Golf Course Rd

Livermore - LVK
- CGS Station 57449 Livermore - Airport Fire Station

Napa - APC
- Nothing within 4 km

Nut Tree - VCB
- CGS Station 67520 Vacaville - Nut Tree & Ulatis
- CGS Station 67210 Vacaville - I80 & Meridian Rd

Rio Vista - 088
- Nothing within 4 km

San Carlos - SQL
- USGS Station 1002 Redwood City; APEEL No. 2
- CGS Station 58374 Belmont - Quarry Rd (APEEL 3)

[157] For additional information on the ShakeCast instrument locations, see http://www.strongmotioncenter.org/LoaderNC.html.