The Loma Prieta, California, Earthquake of October 17, 1989—Fire, Police, Transportation, and Hazardous Materials

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SOCIETAL RESPONSE
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THE LOMA PRIETA, CALIFORNIA, EARTHQUAKE OF OCTOBER 17, 1989:
SOCIETAL RESPONSE

FIRE, POLICE, TRANSPORTATION, AND HAZARDOUS MATERIALS

INTRODUCTION

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The papers in this chapter discuss some of the failures and successes that resulted from the societal response by a multitude of agencies to the Loma Prieta earthquake. Some of the lessons learned were old ones relearned. Other lessons were obvious ones which had gone unnoticed. Still, knowledge gained from past earthquakes spawned planning and mitigation efforts which proved to be successful in limiting the aftermath effects of the Loma Prieta event.

At least four major areas of response are presented in this chapter: the Oakland Police Department response to the challenge of controlled access to the Cypress freeway collapse area without inhibiting relief and recovery efforts; search and rescue of the freeway collapse and the monumental crisis management problem that accompanied it; the short- and long-term impact on transbay transportation systems to move a large work force from home to business; and the handling of hazardous material releases throughout the Bay Area.

Loma Prieta pointed out the unique problem associated with the interface of business and residential populations. Shortly after the earthquake, owing to the location of the cypress freeway collapse, business people and local residents had to be admitted to the area. Many businesses which could support the rescue and restoration efforts were located within the area of greatest damage and thus the area of controlled access by the Oakland Police Department.

Loma Prieta pointed out that effective response after such a disaster follows the implementation of specific steps: (1) Quick assessment of the needs of the scene and access control to essential personnel, (2) crisis response to specific problems, and (3) support recovery through the planned withdrawal of resources, thus opening up access to the area in a controlled manner.

Loma Prieta served as a reminder of the issues surrounding the handling of hazardous material releases and, being a midsized event, pointed out the likelihood of serious releases resulting from a great earthquake. We have learned that complete recordkeeping of the storage of hazardous materials is one of the major factors in effective management of an earthquake-induced release.

The Oakland Fire Department experienced its greatest challenge to date with the collapse of the Cypress freeway. Coordination of relief efforts, managing an unpredictable response of citizen volunteers, an effective incident command structure, and equipment logistics are a few of the areas in which significant experience which can be drawn from to prepare for a future event. Considering the magnitude of the aftermath, the freeway collapse was a firm but gentile lesson learned.

A major metropolitan area, the San Francisco Bay Area, supports a large mobile work force. The geography of the area creates interesting challenges for traffic planners on a day-to-day basis. Loma Prieta created a need to put into place quickly a transportation system which could move a sizable work force around and through disaster-impacted areas. With outage of the San Francisco Bay Bridge immediately after the earthquake, a major conduit for supporting normal operations of the Bay Area economy was eliminated for a significant period of time. Loma Prieta pointed out that even a formerly little-used transportation system could quickly fill a void by moving a work force of significant numbers on a daily basis over an extended period of time. Through the spirit of cooperation of several different public agencies to meet the demand, the necessary contractual agreements were put into place in a very short time.

THE FIRST DAY'S RESPONSE BY THE OAKLAND FIRE DEPARTMENT TO THE EARTHQUAKE—THE CYPRESS FREEWAY COLLAPSE

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ABSTRACT

Lessons learned from the earthquake became evident within hours of the initial response by the Oakland Fire Department. Coordination of relief efforts of multiple agencies and the unpredictable response from citizen volunteers soon became a major management task. The usual management plan to respond to such a challenge was quickly overcome by the extraordinary demands placed on the emergency system's Incident Command System. Managing the response effort was severely limited by inadequate emergency communication systems.

Equipment logistics proved to be a major bottleneck. Once field management of a search and rescue effort was effectively mounted, a shortage of heavy equipment for shoring the dangerously unstable Cypress Street freeway section and to extricate trapped victims was a significant impedance. Here too, the citizen volunteer played a major role by responding with whatever personal equipment could be mustered and by making use of natural materials at hand to support trained search and rescue personnel.

Though the earthquake was a natural disaster which tested the Oakland Fire Department to its limits, the lessons learned and experienced gained were invaluable for preparing a more effective response to the next one.

INTRODUCTION

The resources of the Oakland Fire Department were effectively exhausted within minutes of the earthquake. Because of the extraordinarily large volume of calls received regarding numerous major incidents, fire company availability and status was impossible to maintain. The problems were exacerbated by power outages at stations and a breakdown of the communications system. It was not possible to get a clear picture of conditions throughout the city or gather damage assessments before critical deployment decisions were made. The Oakland Police Department helicopter, which was down for repairs and service, was not available for aerial survey of damaged areas. In addition, there was a critical shortage of available command staff to manage operations during the first hour. Recalled off-duty personnel had to be assigned before many essential tasks could be accomplished.

One of the major incidents due to the earthquake was the collapse of the Cypress Street section of Interstate 880. During the first night all but one of the chief officers who managed the Cypress collapse were recalled from home. Over 100 firefighters were also recalled during the evening of October 17 to assist with the Cypress collapse and other emergency operations. The department and the city were fortunate that so many officers and firefighters could immediately return to duty.

Recall was achieved through a general broadcast on commercial radio and television stations ordering all off-duty fire and emergency personnel to return to their duty stations. There was neither time nor personnel to activate a telephone notification system. Considering that much of the telephone system was not working, the general broadcast was the best means available. Time pressures and lack of personnel also created problems in requesting mutual aid. The limited staff at the Fire Dispatch Center (FDC) and headquarters did not have sufficient time to make the required calls necessary to initiate mutual aid. The first dispatch of mutual aid was initiated by the chief of the Fremont Fire Department who on his own reacted to televised news reports about the collapse of a portion of the San Francisco Bay Bridge.

Effective coordination of units in the field, especially at the Cypress collapse, was hampered by continuing problems with communications. Part of the difficulty was due to a radio system which did not provide sufficient channel capacity to support multisite operations. Other problems were caused by the dual use of the primary dispatch and command frequency to transmit unit status changes, as well as reports on conditions from units in the field. This caused an interruption of many vital messages. Radio procedures which serve to handle routine emergency communication proved inadequate to meet the demand caused by earthquake-related operations. Cellular telephones which might have helped to relieve some of the early strain placed upon the radio system were not available until the second day of the Cypress operations.

Management and coordination of the Cypress operation were also impaired by difficulties in establishing an effective command structure to control overall operations. The Fire Department began to establish an Incident Command System (ICS) at the Cypress collapse with the arrival of the first chief officers at the scene. However, problems in communications and general unfamiliarity with the system limited the effectiveness of ICS. During the first night of operations, each agency (fire, police, paramedic, and Caltrans) was operating within its own version of ICS. Coordination of the overall response was therefore tenuous at best. Coordination was hampered by the lack of a command van or trailer to serve as a Mobile Incident Command Post. Decision making was hampered because critical planning was conducted on the hood of a car or standing on a street corner. Several hours into the Cypress operation, the Fire Department's Hazardous Material Response Van was placed in service as a mobile command post, but this proved inadequate to meet the needs of a command staff running a major rescue operation.

Rescue operations at Cypress were also hampered by a lack of specialized heavy rescue equipment and adequate portable lighting equipment. Equipment, especially shoring and lifting tools, generally were not available until late into the first night. Operating under conditions of darkness was a problem. It was not until the early morning of the 18th that portable lighting equipment was available to safely continue search and rescue operations.

Despite the problems encountered, Oakland Fire Department personnel conducted rescue and extrication operations throughout the length of the Cypress structure, which saved the lives of dozens of trapped victims. During seven hours of intensive search and rescue operations, 18 Oakland Fire companies assisted by 15 mutual aid companies and dozens of ambulance and paramedic units performed a heroic effort. These people worked under a severely damaged and unstable structure which threatened to collapse at any time. The destruction and damage was beyond comprehension. Firefighters ignored their own personal safety to rescue the many crushed and dismembered victims trapped in the wreckage.

Over 200 firefighters worked at the Cypress scene during the first night of operations. Each of these firefighters was given a Critical Incident Stress Debriefing (CISD) session before they were relieved. The sessions were conducted by trained Fire Department peer counselors at Station 1. In the 4½ years since the earthquake, not one case of stress related injury or illness has been reported.

MEDICAL RESPONSE

After the earthquake, management personnel from several area ambulance providers immediately responded with supplies and resources to the Cypress collapse. Each responded to an area which they thought was the major problem. As trained paramedics, they immediately began administering medical care, but on-scene condition reports were not relayed through Alameda County Medical Dispatchers to the Fire Dispatch Center (FDC). Though the county medical authority had declared a major medical "red alert," the Oakland Fire Department received a delayed report of conditions.

The ALCO county medical central dispatch frequency was knocked off the air soon after the earthquake. Individual ambulance providers had to rely on their own radio frequencies, public telephone, and runners.

Many victims were able to evacuate the Cypress structure with the aid of ladders and other equipment provided by the fire department or citizen volunteers; others required an average of three to four hours of extrication. Ambulance transportation was readily available where needed. Of the more than 10 agencies with paramedics and Emergency Medical Technicians (EMT) who responded to the Cypress collapse, only four reported transporting victims. These four agencies transported over 113 victims from the Cypress structure to 15 county hospitals during a period of 6 hours. Thirty five ambulances and other vehicles (including two Alameda County transit buses) were also used to transport victims.

EXTENDED OPERATIONS

By early Wednesday, October 18, primary search and rescue operations had been completed. Collapsed section had been divided into north and south divisions. Both had been searched several times and Division Supervisors were confident that all living victims had been found. Oakland and San Leandro Police dogs were used to search the structure, but they proved inadequate. After a safety survey was completed, each marked section was again searched using a search and rescue dog team from the California Rescue Dog Association (CARDA). Neither the CARDA, nor police dog teams were able to detect any additional signs of life.

Around 8:00 a.m., search operations were halted because of continuing aftershocks and concerns over the collapse of the structure. Caltrans began shoring operations, which continued around the clock for the next 48 hours. Preliminary attempts to use heavy equipment in the rescue effort had to be discontinued until adequate shoring was in place. This demonstrated the need for unified command and control of the entire Cypress operation. The Fire Department as the primary agency for search and rescue established operational priorities:

- Continue the search for live victims with established heavy rescue teams
- Prioritize search areas
- Complete body recovery operations

Three specialized multidiscipline recovery teams of approximately 25 persons each were established. Numerous "eyewitness" reports concerning survivors were investigated and proven to be false. Specialized fire and heavy rescue mutual aid units which had begun to arrive on the 18th were assigned to rescue operations or to cover vacant Oakland fire stations.

During the morning of 18th, the Incident Command Post (ICP) at West Grand and Cypress was expanded to a unified command center representing all agencies. The Department's Hazardous Materials Response Van was then used as the Fire Operations Command Post. The limitations of this soon became apparent, and other command vehicles were moved to the command site to support extended operations.

Fire Prevention personnel provided logistical support in the early phase of extended operations and were also detailed to escort government officials through damaged areas. As the scale and complexity of the operation expanded during the 18th and 19th, it became apparent that managing the incident would require greater resources than the Oakland Fire Department could provide. A State Office of Emergency Services (OES) fire coordinator arrived on the 19th to identify additional required resources.

A Management Overhead Team, composed of California Department of Forestry (CDF) Fire Officers, began arriving on the afternoon of the 19th. By the evening of Friday the 20th, this team had established an incident management system that would serve continuing Cypress operations over the next three weeks.

By Saturday October 21, (the day Buck Helm was rescued after surviving in the collapse for 86 hours) the Overhead Team consisted of 82 Emergency Management specialists providing:

- Command Post Staffing
- Operations and Planning
- Logistics and Base Support and Records Management
- Finance

At the height of the operation, over 500 incident personnel representing law enforcement (Oakland Police Department, California Highway Patrol, Sheriffs Coroner), Caltrans, California State OES, Oakland and mutual aid fire departments, county EMS and ambulance paramedics, and private contract personnel were assigned to Cypress rescue operations.

OVERVIEW OF EARTHQUAKE OPERATIONS OCTOBER 17, 1989

When the earthquake struck at 5:04 p.m., (1704 hr) Tuesday evening, most of Oakland was fairly quiet. All of the Oakland Fire Department's companies were in service at quarters, except Engine 13 which was answering an Emergency Medical Services (EMS) call. This unusual (for this time period) lack of activity was probably due to the start of the third game of the World Series.

All 23 of Oakland's Fire Stations experienced violent shaking and ground movement. None of the stations sustained major damage. But most stations experienced partial or total power outages. Along with loss of power, many stations also lost telephone and telecommunications service. The interruption of power and communication to the fire stations hampered and delayed initial earthquake response efforts.

Owing to the loss of electrical power, many companies had to manually operate station overhead doors in order to move apparatus out of the stations. This added three to five minutes to normal response times.

The Fire Dispatch Center (FDC) located at Station 1, the Department's headquarters station, also experienced violent shaking. The dispatch tape log recorded the sound of the earthquake and the nervous reaction of the emergency dispatchers working the dispatch consoles. Fortunately, the dispatch computer and radio equipment remained in operation.

Assistant Chief John Baker, the Shift Commander, was in the FDC at the time of the earthquake. As the ranking Fire Department Officer on duty, he immediately established a Headquarters Command post at FDC. The FDC was staffed by two dispatchers and one dispatch supervisor. FDC, normally staffed by nonuniform dispatchers, is headed by a Fire Captain. Chief Baker was the only officer in FDC in the first moments after the earthquake. Immediately after the quake, Chief Baker began monitoring the status of calls and dispatches, in order to make strategic decisions concerning unit assignment, recall, and mutual aid.

Earlier in the afternoon of the 17th, members of the Fire Department staff had met at Station 1 with the staff of the City's Office of Emergency Services (OES). The meeting had been scheduled to discuss plans for moving the Emergency Operations Center (EOC) to the Fire Department administrative offices. The existing EOC originally set up as a Civil Defense structure was deemed unreliable because of its proximity to the Hayward Fault. Ironically, the meeting concluded at 4:30 p.m. with a discussion of which desks would be assigned to OES personnel in the event of earthquake or similar emergency. Within an hour, most of those at the meeting would be back to establish a working EOC at the headquarters fire station. (Later when City Hall became unusable owing to earthquake damage, other city offices would be operating out of the Fire Department's administrative offices at Station 1.)

INITIAL CALLS

Immediately after the quake, the FDC dispatch consoles lit up with incoming calls. The first emergency call at 5:05 p.m. came from Oakland City Hall reporting a person trapped in a stuck elevator. According to Oakland Fire Department (OFD) dispatch rules, Truck 1 was dispatched for the elevator rescue. At the same time near the waterfront, another call reported a building collapse at 4th and Martin Luther King Jr. Way (MLK); three units responded to this incident. Chief Baker, as Battalion 2 Commander, normally would have responded to the incident, but he decided not to respond so that he could maintain Headquarters Command. He also directed FDC not to dispatch the remaining two Battalion Chiefs to incidents. (The Fire Department is organized administratively and operationally into three districts or Battalions. Two of these districts are headed by a Battalion Chief; the third is managed by the Assistant Chief.) At this point, the extent of earthquake damage was very unclear, and Chief Baker, anticipating major fires, wanted the chief officers available to respond to these expected fires.

While units were responding to 4th and MLK, another report of a building collapse in West Oakland came in. Three more units were sent to this call. By 5:06 p.m., two minutes after the quake, all fire companies in the west end of Oakland were committed. These are the same companies which would have been dispatched to Cypress Street. No calls had yet been received reporting the Cypress collapse.

The FDC was swamped by the volume of incoming calls reporting fires, natural gas leaks, building collapses, electrical lines down, and medical emergencies. There was also an overload of radio traffic from companies trying to report conditions, asking for clarification, or further assignments. Since the dispatchers were answering incoming phone calls, they were unable to quickly respond to radio reports. Many radio messages were not heard. The problem was compounded by mobile data status transmissions "covering" many of the voice transmissions. These data "bursts" are transmitted as a static squelch each time a unit activates its operating status console. Normally, a unit may change status three or four times while responding to an incident.

The first dispatch for the Cypress collapse occurred at 5:10 p.m. Engine 1 reporting nothing found at 4th & MLK. FDC informed Engine 1 that the freeway was reported down at I-880 and Cypress. Engine 2, meanwhile, was calling FDC to report they were available for assignment. The radio log between Engine 1, Engine 2, and FDC describes the first dispatches for the Cypress incident. At this point, there was still no clear indication of either the extent of the freeway collapse or the magnitude of damage.

Engine 1:	Nothing found at 4th and Martin Luther King Way, but we are going to cruise this area. Cancel the truck, you can send them maybe to those other incidents.
Dispatch:	Engine 1, 880 and Cypress the freeway is down we need you.
Engine 1:	Check, at 880 and Cypress
Engine 2 to Dispatch:	We got our apparatus doors forced open. Give us an assignment.
Dispatch:	Engine 2 standby
Dispatch to Truck 3:	You are assigned to 4th and Martin Luther King Way. Can you wait? No building found. Respond to 1600 14th Street at this time.
Dispatch to Engine 2:	Engine 2, go ahead
Engine 2:	You can give us an assignment. Do you want us to respond to 8th and Cypress?
Dispatch:	Engine 2 that is correct; we have report of the freeway collapsing at 8th and Cypress, 880.
Engine 2:	Do you want us to go up on the freeway or do you want us to stay low? Do you have any idea or just 8th and Cypress?
Dispatch:	They said, "the freeway collapsed, so it would be on the ground."

Engine 1 and Engine 2 were responding to I-880 and Cypress, but no precise location had been indicated. Originally the companies were dispatched to the vicinity of 8th and Cypress, eight blocks from the south end of collapse. At 5:11 p.m., Engine 5 was heading for the north end of the collapsed freeway near 32d and Cypress.

Engine 5, originally dispatched for a building collapse at 1600 14th Street, was delayed getting out of their station because of inoperable apparatus doors. But radio reports from the first companies on the scene at 1600 14th Street indicated that Engine 5 was not needed there. When Lieutenant Jarrett, Engine 5's officer, noticed large columns of dust and smoke from the vicinity of the Cypress freeway structure at 32d Street, he responded to that location to investigate. Upon arrival, Lt. Jarrett realized the magnitude of the problem and attempted to radio FDC to report the situation and ask for help. An excerpt from Lt. Jarrett's incident report written a few days later, describes the actions taken.

> At 1704 hr the earthquake struck. All power at quarters was lost. Engine 5 was dispatched to a building collapse in the vicinity of 16th & Cypress. The engine was backed out of quarters and as this took a few minutes, I heard the other responding companies saying they could not locate a collapse (1600 14th Street). While getting the engine outside, I could see smoke and dust in the direction of the Cypress structure. We responded to 32d & Cypress, and on arrival we found complete collapse of the 2d level onto the 1st level. We could see people running on the top of the structure and calling for help. An automobile was burning on the west side of the structure on Cypress. Engine 5 was positioned on the west side of Cypress next to the burning auto. With the aid of some civilians, one 1 1/2 inch (hose) line was pulled off and the fire extinguished while Engine 5's crew was able to climb up to the structure. We found a van with six occupants; two were injured, and four were fatalities. There were other injured lying on the ground. It was obvious that a truck company was needed as well as an ambulance. Somewhere in the initial moments, I asked for them.

FDC was not able to acknowledge Engine 5's initial radio request for assistance, owing to interference from other units trying to give radio messages. During the first half hour after the quake, most of the fire department's communication was dependent on radio, since many of the station phones had been knocked out of service. Engine 5's report from Cypress was not heard by the dispatchers above other radio transmissions.

As the first units at the Cypress scene began to arrive, many other earthquake-related responses were occurring. Two available units were quickly dispatched to elevator rescues. Two other units were sent to natural gas leaks. Another two units were dispatched to medical calls. Oakland Fire Department's Computer Aided Dispatch (CAD) System was not able to keep up with the quickly changing status of multiple responding units.

The confusion at FDC was increasing each minute as calls kept pouring in. Companies were being assigned to incidents before they were entered into the computer. In some cases, companies unable to communicate with FDC were "self dispatching" to incidents. Truck 15, returning from a call where it was not needed, stopped at 32d and Cypress and began rescue operations. In other cases, companies without power or phones were unaware that they had been assigned to incidents. Because dispatchers could not keep up with the volume of incoming calls and the rapidly changing status of units in the field, headquarters was unable to generate an accurate picture of which companies were available for assignment, or where committed companies were working.

CYPRESS COMMAND

As it became obvious that managing the increasing number of emergency operations and responses would require a headquarters staff; Chief Baker called Battalion 3, Chief Reginald Garcia, and directed him to respond to headquarters and then to the Cypress.

It was nearly impossible to gain a clear picture of conditions around the city, especially at Cypress and I–880. Radio reports were either fragmented or too sketchy to indicate conditions. A few accurate "size-ups" were radioed by companies on the scene, but these were not heard in the confusion of other phone and radio messages. Chief Baker had called the Oakland Police Department helicopter for an aerial survey of the city, but the police helicopter was down for repairs. The loss of an "eye in the sky" proved to be a great handicap to initial Fire Department operations. During that first hour headquarters staff relied on the television monitor in FDC for local news coverage of earthquake damage. Some of the early information about the Cypress collapse came from pictures transmitted by TV news helicopters.

Since most of the reports on the Cypress collapse had come in from companies at the south end (near 18th Street), additional units responded to that location. It was still not clear that the Cypress collapse extended from 18th Street to 34th Street. Without an aerial view, the Fire Operations Center (FOC) was uncertain of the extent of the Cypress collapse. When the full extent of collapse was known, it was initially thought there might be hundreds of people trapped between the freeway decks.

Off-duty Assistant Chief Sigwart responded to the Cypress collapse, which allowed Chief Baker to manage the FDC. Once at Cypress, Chief Sigwart moved the command post to West Grand and Cypress, where the Police Department had already established their command post. The transfer of command from Battalion Chief Garcia to Assistant Chief Sigwart began the process of establishing an Incident Command System (ICS) to manage the Cypress collapse.

The extent of the collapse (1.25 miles) required dividing the rescue operation into separate actions which could be more easily managed. A South Division was established to manage rescue operations between West Grand and 17th Street. A task force consisting of two engines and a truck, supported by ambulance and paramedic units, operated on the west side of the collapse. Under the Direction of Captain Baleria, this group conducted search and rescue and several technically challenging extrications of people trapped in crushed vehicles. On the east side of this same area, two additional engines and a truck worked on the very long and difficult rescue of two young children, Julio and Cathy Berumen.

By 6:00 p.m., Cypress operations were organized into two major divisions--North commanded by Battalion Chief Navarro, and South by Battalion Chief Garcia. The ICS was maintained by Assistant Chief Sigwart from the West Grand command post.

During the next 72 hours, the Oakland Fire Department would have varying success as it employed ICS to manage the Cypress collapse. As the scale and complexity of this operation escalated, it became increasingly evident, however, that it would not be possible to manage the incident without using ICS.

DISPATCH AND COMMUNICATIONS

The Fire Dispatch Center (FDC) serves as the nerve center of the Fire Department. All calls for emergency service are handled by civilian operators that dispatch units. The dispatchers also serve as radio operators communicating with the fire units in the field. In a typical emergency, the dispatcher will receive a call, enter the information into the dispatch computer, make the dispatch, and then monitor the radio traffic from the responding units. FDC staffing consists of two dispatch operators and one supervisor. The communication section is managed by a Captain and a civilian assistant.

The Oakland Computer-Aided Dispatch (CAD) system combines a set of computers with a voice and data radio system to support fire operations in the city. It provides the means to dispatch units, track incidents, monitor unit status, and communicate with stations or companies by telephone, speaker, or radio. Emergency calls are received by Fire Dispatch from

- 911 via Police PSAP
- Police/Fire agency direct lines
- Seven digit emergency number
- Fire stations or city telephone
- PFAS direct line

When a call is received, the dispatch operator enters the incident information into the CAD system. The computer identifies the location from the geographical data base and recommends the appropriate unit response based on the type of incident. The operator may dispatch the recommended units or modify the response as necessary. The computer assigns the units to the incident, sends dispatch information to all stations, and alarm notification to responding stations. Units not in stations must be contacted by radio.

Each fire apparatus has a push-button status reporting console. It is used to report company status to the CAD computer via radio. The mobile status units interface with a status controller in the FDC. The status controller provides acknowledgment signals to reporting units and passes status changes to the central computer system. The status signal is transmitted on the same frequency as the primary dispatch and command channel. Each time a status signal is transmitted it is heard as a loud static squelch over the radio. This squelch "covers" any voice message being transmitted at that same time.

During the first hour after the earthquake each dispatcher tried to answer calls as they came in and then make the required company notification and dispatch. But within a few minutes, the dispatchers were overwhelmed by the volume of calls. As more companies were dispatched, the volume of radio traffic and data transmission status "bursts" added to the dispatch overload.

After the first 15 minutes, FDC was unable to maintain communication with the number of companies in the field. FDC personnel did not know which companies were in service and available for response, or which were out of service at an incident. Compounding the problems was the loss of telephone communications to many stations. Many companies had to rely on radio communication to verify their status and availability, further adding to radio "clutter" and confusion.

At approximately 6:00 p.m., the FDC supervisor assigned one dispatcher to handle radio traffic and the other dispatcher to work phone lines. This reduced confusion and began a smoother information flow. Near the end of the second hour emergency call volume had begun to decrease.

MUTUAL AID

During the evening of October 17, Mutual Aid Engine & Truck Companies arrived from Fire Departments throughout Alameda and Contra Costa Counties. Many of these companies were sent directly to the Cypress collapse. Others were sent for staging at Station 1. The quick response of the Mutual Aid System was invaluable in providing much needed resources necessary to conduct earthquake-related operations. Oakland was fortunate that most of the surrounding counties escaped the quake with little damage.

The manner in which the call for mutual aid was made indicates the kind of difficulties the department faced just after the quake. Within 15 minutes, over half of the department, including all of its Truck Companies, was responding to incidents. Based on the information available, the prospect of a complete depletion of fire resources seemed imminent. There was very little time to react to the changing situation or to try to equalize coverage by seeking outside assistance. There simply was not enough staff available in the FDC to initiate recall or request mutual aid.

At 1725 hr, Chief Baker received a call offering assistance from Fremont Fire Chief Dan Lydon. The following was established:

1. Oakland Fire Department had most Fire Companies committed.
2. Requests for service were escalating.
3. Preliminary information on the Cypress collapse was coming in. Ladder truck companies were needed immediately.

Chief Baker asked Fremont to notify the Contra Costa County Fire Department of Oakland's need for additional ladder trucks. South Zone Coordinator Chief Lydon placed the South Zone truck companies on yellow alert for response to Oakland. Two Fremont Chief Officers and their aides were dispatched at Chief Baker's request.

The responsibility for coordinating mutual aid in North County was passed to Fremont--the South County Zone Coordinator.

Contra Costa County sent two Mutual Aid Groups to Oakland. Battalion Chief Herman Walden led a Heavy Rescue Task Force consisting of San Ramon Truck 34 and Consolidated Truck 1. Battalion Chief Stice led a Type One Engine Strike Team composed of two Contra Costa County Engines and Engines from Moraga, Orinda, and Riverview Fire Departments.

The Heavy Rescue Task Force was assigned to rescue operations at Cypress in the North Division. Contra Costa County Engine Strike Team responded to OFD Station 1 at approximately 2000 hr. One engine was assigned to the station and the remainder of the strike team was assigned to Cypress staging and later to secondary search operations.

During the next 10 hr, other OES Region II Mutual Aid Units provided relief personnel and equipment necessary to sustain a continuous rescue effort. During the remainder of the week, Mutual Aid Units continued to work on the difficult task of search, rescue and extrication of victims.

CRITICAL INCIDENT STRESS DEBRIEFING

The Oakland Fire Department organized a Peer Counseling Program in 1988. Since early 1989, the department has used this approach to assist personnel after stressful emergency situations. The Critical Incident Stress Debriefing (CISD) peer counselors began training in February 1989 and are representative of a cross-section of OFD personnel.

The CISD team was activated following the earthquake by Lt. Donald Parker at the direction of Assistant Chief Andy Stark. The team members assembled at Fire Station 1 at approximately 11:00 p.m. the night of the earthquake. Paul Saxton, a psychologist with Life Care Systems, met with team members prior to the debriefing sessions and participated in some of the group sessions.

As fire and medical personnel were released from the Cypress collapse, they were directed to Fire Station 1 for food, rest, and CISD counseling. Oakland and Mutual Aid Firefighters as well as ambulance personnel were included in the sessions. The groups consisted of 10 to 15 persons (2-3 fire companies) and lasted 30 to 45 minutes.

The purpose of these debriefing sessions was to allow personnel to talk about the rescue experience, express their feelings, and have peer counselors outline symptoms of postincident stress. Firefighters and other rescue workers were encouraged to examine their feelings about the rescue work and were counseled on symptoms of delayed reaction stress. Peer counselors also attempted to look for initial signs of stress-related behavior and to let all personnel know the types of follow-up services that were available.

Another debriefing area was set up by the Alameda County Health Department. Services were available to all incident personnel. On October 19, a group of trained firefighter peer counselors from LA County Fire Department was assigned as a debriefing team. Their services were available to all incident personnel, but as firefighters, they were most helpful with fire and rescue personnel. Over 200 fire and rescue personnel took part in these sessions.

The success of the CISD program is evident from the absence of any reported cases of lost time stress-related sickness or injury. However some problems with the program have been identified, and other aspects of stress counseling should be considered.

Two significant groups were left out of the initial stress counseling sessions. These were the Peer Counselors themselves, and the Fire Dispatchers. Both groups reported feeling drained and exhausted from the stress induced during the height of emergency activity. Dispatch personnel were especially affected by both the increased call volume and the anxiety caused by working in a highly pressured environment. Yet, no provision was made for CISD counseling for dispatchers.

Another aspect of CISD which should be considered is the anxiety related to emergency workers' insecurity about their own families well-being. In a major earthquake, devastating effects are likely to be spread over a large area. Emergency workers responding to scenes of great damage and destruction, need to be reassured that their families are safe and taken care of. Many of the firefighters working the Cypress collapse that night expressed anxious concern for the welfare of their families. They had no way of knowing whether their homes were still intact. A plan should be in place to relay family information to the firefighters and also information about the firefighters back to families.

CITIZEN VOLUNTEERS

The success of the Cypress rescue operation was due, in large measure, to the efforts of hundreds of citizens volunteers.

These volunteers, coming from residences and business in the neighborhood, or passersby on the street and freeway, performed some of the first rescues of trapped motorists.

Using makeshift ladders, ropes, and even trees growing beside the freeway, these volunteers scrambled up onto the broken structure to render first aid and help the injured to safety. As fire and paramedic personnel arrived to take over and organize the rescue operation, volunteers continued to augment and assist the professional rescue workers.

Throughout the night, volunteers continued to pour into the rescue area. Some, having heard about the tragedy from news reports, felt compelled to offer help in some fashion. Others arrived with supplies and equipment which they thought might be needed. Contractors and construction workers volunteered their services and whatever equipment they had with them. Much of the movement of people and equipment off of and onto the Cypress was done on civilian equipment. A roofing supply yard provided an elevated roofing material conveyor which was used to carry rescue workers and their equipment up to trapped and injured people. Forklifts seemed to materialize out of nowhere to help bring down injured people.

As daylight quickly faded, Cypress Command issued a call for portable lighting equipment. Soon contractors began arriving with generators, electrical cords, and lighting units. No one asked for payment, voucher, or receipt. They brought whatever they had and offered it for use without question.

At the south end of Cypress operations, a concrete sawing expert arrived with tools and equipment to assist in the rescue of 6-year old Julio Berumen. Tow truck operators from Berry Brothers Towing also helped in this rescue effort, using inflatable air bladders to try and move part of the crushed auto pinning the boy. Down below, other citizens stockpiled air tools and hoses, compressors, wood blocks for cribbing, and anything else which might be of use.

There were many people hastily working below the damaged structure, trying to clear Cypress Street of rubble and debris. These people, working without direction, took it upon themselves to clear the street for rescue workers trying to move injured victims to safety. Brooms, shovels and bare hands were used to sweep a clear path.

Somewhere near 32d Street, Truck 1 was working with a hydraulic tool on a difficult rescue. They had placed the power unit for the tool on a ladder rung near an opening between the two collapsed freeway decks. While the crew worked inside, a volunteer stood on the ladder, outside the opening, holding the power unit in place. He remained there holding it for nearly three hours.

Jack Stein, Lieutenant at Engine 4, recounts his experience with citizens helping at Cypress:

A citizen ran up to us at that time, saying they had located a live victim trapped in a vehicle on the west side of the structure at 24th Street. We grabbed our New York Hook and hand lights and proceeded to that location. About 30 citizens were present and eager to help. They already had two forklifts in place and several people, including two CHP officers, were up on the structure.

As the upper roadway continued to settle, we realized we needed to shore the area we had to work in. Two of the citizens left and returned with a forklift load of 4x4's, which were promptly cut and sent aloft. Just prior to this, I had sent Engineer Mark Fraser to find an electrical source. He had returned with lights and cords, but no generator. A citizen had his semi-truck parked nearby and we used his on board generator for the duration. Others supplied more electrical cords and adapters. I asked for a sawzall. A man returned with his sawzall and I sent him aloft. He had volunteered to change blades, as needed.

These examples show a few of the many ways that ordinary citizens responded in extraordinary fashion to offer aid and assistance. In many cases citizen volunteers worked upon, within, and underneath the Cypress structure without thought for their own safety. Their efforts were significant and effective. Yet, as the long night wore on, it became evident that there was very little control or coordination of the volunteers. There were no centralized resources or equipment pools. People bringing equipment were directed to Cypress Command. But the command post was not set up to handle volunteer help. Later that night, a staging area was established, but it served mainly to receive Fire Department mutual aid resources.

Many of the volunteers worked at great personal risk. In some cases, the risk exceeded the needs of the situation. No one was able to monitor or supervise all of the people trying to work the incident. At each rescue undertaken that night, there were a number of people trying to offer assistance. In many cases, the firefighters could not employ this help. Though well-intentioned, these people became a hindrance. In the confusion of the night, it was impossible to identify who were the essential volunteers and who were the curious and extraneous.

SUMMARY

The Loma Prieta earthquake presented the severest test to the Oakland Fire Department's ability to manage a disaster situation up to that time. The October 1991 Oakland Hills fire was an equally challenging disaster which also tested the system to its limits. As different as these two events were as threats to life and property, the lessons both offered were quite similar. Soon into the response to both disasters, field communications proved to be woefully inadequate to meet the need. The shortage of equipment available for response quickly became a bottleneck in both disasters. Management of personnel presented a significant logistical challenge.

It is hoped that other departments can learn from these experiences of the Oakland Fire Department and use this knowledge to improve upon their ability to respond in a disaster situation.

RECOVERY IN THE MIDST OF DISASTER—MANAGING ACCESS TO THE CYPRESS FREEWAY COLLAPSE

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and
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ABSTRACT

Controlling access to emergency and disaster scenes is always difficult. Generally, emergency managers attempt to evacuate populations immediately following disasters (where this is impractical they may shield them in place), they exclude nonessential persons until the problem is reduced, and they do not readmit resident populations and restore access until the recovery phase. When the Cypress freeway section of Interstate 880 collapsed during the earthquake, the unique characteristics of the local residential and business populations challenged the scene managers to readmit persons almost immediately following the quake. The Oakland Police Department developed an access pass system which was put into place quickly and worked extremely well. It provides a model for other natural disasters and crowd control situations.

INTRODUCTION

Critical incident response is often divided into three distinct stages for analysis and instruction (Sarna, 1984). The initial phase is characterized by efforts to isolate the scene and to size up the nature and extent of the chaotic incident. Emergency responders establish perimeters to keep nonessential persons and threatened populations out of the affected area, and they begin to identify and request the resources necessary to contain the problem. The second phase encompasses the activities the public associates with crisis management. Experts do their specialized jobs to neutralize the problem: the fire is fought, the leaking gas valve is closed, or the gunman is confronted. The third phase begins the process of recovery; limited access is restored, resources begin winding down, and damage repair begins. Eventually normal services are resumed and full access to the incident scene is restored.

The importance of the first two phases is obvious. The activities associated with this period are inherently urgent. Evacuation, exclusion, isolation, treatment, and emergency response are clearly critical and mark the early stages of a disaster. In fact, it is the ability of the incident manager to prioritize efforts effectively—to expedite the truly essential and to defer other activities—that maximizes life saving efficiency in a crisis.

Following the collapse of the Cypress Street portion of Interstate 880 in Oakland during the earthquake, an interesting anomaly developed. An activity that is usually reserved for the recovery phase was undertaken in the very early stages of the incident.

Large numbers of employees, vendors, and people who lived inside the police perimeter were screened and readmitted beginning 2 days after the quake. Normally, the need for emergency access and concern for the safety of persons who live and work in the area results in their exclusion from the scene. In fact, a major challenge for managers of incidents from toxic leaks to public disorders has been the rapid evacuation and exclusion of residents and workers, followed by the need to control crowds and selectively readmit those with legitimate business in the area

(Scanlon, 1975; Coleman, 1983; U.S. Department of Justice, 1986). There are models for the controlled admission of crowds to scheduled events, but even these may break down with tragic consequences (U.S. National Bureau of Standards, 1982; Security World, 1980; New York Times, 1991, 1992). There are serious concerns about the management of crowds during disasters, and there is limited guidance for expediting civil populations back into large, spontaneous, tragic scenes.

Two significant lessons learned from the Cypress scene have relevance for critical incident planners: (1) There was an early need to restore business activity in the area immediately surrounding the collapse and (2) the means of screening, credentialing, and admitting persons based on simple forms of identification was quick and effective.

Deputy Chief Robert Nichelini, head of the Department's Bureau of Field Operations, identified the early need for access. Within 48 hours of the earthquake he recognized the disastrous potential of excluding residents, employees, and business traffic from the homes and industries that ringed the 2-mile long section of collapsed freeway.

Considerable moderate and light industry was located adjacent to, and even under, the freeway. (The Police Department's vehicle fleet was parked beneath the freeway 3 miles from the collapsed structure.) Steel and construction industries essential to recovery efforts were concentrated within blocks of the roadway. Curtailing the operations of these firms would limit access to their supplies of steel and plastic pipe, rebar, cement, structural steel, and shoring materials essential to the recovery effort.

On the second morning following the quake, Deputy Chief Nichelini directed a Patrol Division captain to establish a pass or permit point (subsequently termed the "Business Access Point") to expedite both emergency and legitimate business access to the Cypress Street perimeter and to restrict unauthorized persons from this area. He selected two police sergeants to staff the initial operation.

SELECTING A SITE FOR THE BUSINESS ACCESS POINT

East Bay Municipal Utility District (EBMUD), the local water company, had offered to provide space and some office support to the Police Department for this activity. Their administrative offices, repair shops, and corporation yards were within a mile of the collapsed freeway structure. The department tentatively accepted this site.

At 3:00 p.m. the staff began drafting application forms and access letters in preparation for their move to EBMUD. They designed a tentative record keeping system for the passes they would issue, defined the criteria for admission to the area, and made a final evaluation of the proposed site for the operation. Unfortunately, the EBMUD location lacked sufficient phone lines to support a public point of contact. (Pacific Bell was already taxed to the limit restoring subscriber service and providing additional emergency services). Other EBMUD locations had adequate phones, but would not accommodate the heavy vehicle traffic which was anticipated.

At 6:00 p.m. the Police Department opened the Business Access Point at deFremery Multicultural Arts Center, a city recreation center in a historic Victorian house surrounded by a 10-acre park. DeFremery had several features which the EBMUD location lacked and which should be considered in locating any reentry operation.

- It had sufficient phones in place to serve until additional lines could be installed. The phone numbers were already known so that they could be included on access passes and in advance media announcements.
- The parking lot and adjoining streets could accommodate business and staff vehicles. The park was bounded by a four-lane thoroughfare that would handle large trucks en route to the scene for commercial or rescue purposes.
- It was close enough to the Cypress scene that vehicles denied entry to the perimeter could divert to the access point, apply for passes, and return with minimal impact on traffic.
- The building was large enough for the staff and public.
- Because it was a city facility, it had been inspected shortly after the quake, which simplified obtaining approval for its use.
- It was within one block of a Red Cross shelter and dining facility and a county crisis counseling center. The Business Access Point staff directed victims to each of these services over the next several days. The 24-hour police presence at deFremery provided security and support to victims and the staffs at these facilities.

INITIAL OPERATIONS

The initial access permits into the Cypress Street perimeter were limited to small areas and restricted hours and were valid for less than one week. The sergeants who evaluated requests and issued these permits instructed each permit holder to return before the permit expired to obtain a renewal for a longer period. They planned to issue renewals based on the first week's traffic in the rescue area. They also cautioned permit holders that they might be contacted if traffic conditions or safety required the further restriction or withdrawal of permits.

The staff issued 2,659 permits in the first 7 days. Larger firms (those with 8 or more employees) were given a version of the access permit which authorized the bearer to enter with a photocopy of the permit together with specific indicia. The indicia varied from case to case, including a company identification badge, a pay stub, or the company truck itself. The staff evaluated requests from business tenants and residents of the area based on utility bills, rental receipts, business cards, and phone listings in a reverse directory.

To produce forms in volume, company representatives were given an original permit on Police Department stationery and were asked to photocopy and collate enough copies of the permit and attachments for each of their employees. The largest firms (more than 60 employees) sorted their forms by shift or division to simplify distribution. These firms were asked to provide an employee to help distribute materials on Monday, October 23, 1989, the day most employees were expected to return to work for the first time.

Other procedures streamlined the operation. For instance, unscheduled deliveries to businesses within the perimeter were admitted without passes if they could show proof of their destination and a valid pickup or delivery. The officers maintaining the perimeter used bills of lading, invoices, addressed packages, and dispatch slips to verify the legitimacy of business in the perimeter. They advised the Business Access Point staff by police radio when they made these common sense exceptions.

CITY OF OAKLAND

POLICE ADMINISTRATION BUILDING • 455 - 7th STREET • OAKLAND, CALIFORNIA 94607-3985

Police Department

Telephone Device for the Deaf 273-3227

AUTHORIZED ACCESS

The person listed below is authorized to enter the Cypress Street Emergency Area for dates and times indicated.

NAME:

DATE: 27 Oct 89 to 30 Nov 89

TIME:________________to__________________.

LOCATION:___________________________.

___________________________.

This permits access to the specified location only. Please use the most direct safe route.

Follow all police and emergency workers directions.

Valid photo identification must be presented with this permission.

FOR:
George T. Hart
Chief of Police

Phone: (415) 832-0360

RECORD KEEPING

The Business Access Point lacked the staff and equipment to automate their records. The sergeants who established the operation requested and screened citizen volunteers who had called the community volunteer hotline and who came to the center offering to help. They selected a local businessman and service club member who provided a copy machine, a personal computer, and a network of other professionals. This volunteer used his computer to develop a database (Application Database) of businesses and persons who had been issued access passes. He printed daily alphabetical listings by name and by street address showing the employees' or visitors' names, phone numbers, and the contact persons for each pass. The Oakland Police, California Highway Patrol, and the California State Department of Transportation (CalTrans) used these lists to verify passes and to contact the owners of business where hazardous conditions were reported.

The pass application form included questions about lost time and hazardous materials stored at the business. Information from the application forms was used to evacuate occupants and businesses from locations where hazardous conditions developed. For example, some of the buildings close to the freeway structure were inspected soon after the quake and reoccupied. Subsequent analysis suggested that these areas were too close to the structure itself and that it might be destabilized by rescue efforts. The Business Access Point staff used the Application Database to print lists of contact persons and their phone numbers by street address to evacuate the endangered buildings. The application also attempted to capture some measure of the economic impact of the quake. For months after the quake, firms with work interruption and lost revenue insurance contacted the department for verification of their down time and lost production.

The Business Access Point first operated from 6:00 a.m. to 6:00 p.m. for 7 days a week. Within 2 days it was open round the clock and operated the public "Earthquake Hotline." It was staffed by two sergeants 24 hours a day with an additional two officers, one police trainee, and community volunteers during business hours. Within 2 weeks of the earthquake the Business Access Point began reducing its hours of operation and its staff. After 6:00 p.m. the hotline phone numbers were placed on call forwarding to the Police Department's main Patrol Desk. The Desk Officer was provided the resource lists and a limited number of one-day passes for late night arrivals.

CHARACTERISTICS OF AN ADEQUATE LOCATION FOR AN ACCESS CONTROL SITE

1. *Proximity to the disaster scene.*—Vehicles that attempt to enter the scene will be referred to the access point. They should not have to drive far, minimizing the impact on congested streets.

2. *Situated on or near major arterials.*—The access point should be on or near the main supply route to the incident scene.

3. *Adequate turn around and parking space.*—The location must accommodate trucks and heavy equipment and provide adequate parking for staff and clients. Parking signs, cones, and barricades will help channel traffic.

4. *Well known and easily recognizable.*—The access point must be announced early in the operation. If it is an established landmark (like a park or school) it will appear on area maps, and emergency crews, volunteers, and citizens will be able to give adequate directions.

5. *Sufficient size and facilities.*—It should include rest rooms, a dining area, secure rooms for computers and supplies, and staff break areas. It must have adequate space to permit applicants to wait protected form the weather. Separate rooms for interviews or to mediate disputes are helpful. Non-public space may also be used to temporarily house detainees. The public areas must provide wall space or bulletin boards for maps and information. Parks, recreation centers, and elementary schools have art supplies for improvising maps and signs. They also have varying amounts of duplicating and word processing equipment.

6. *Phones.*—Phone companies can supply banks of portable pay phones to almost any location within hours. They can also upgrade service by delivering additional lines, commercial phone equipment, and voicemail. However, the existence of working phone numbers permits the immediate announcement of these numbers in news broadcasts and their inclusion in printed forms. Additional lines can be configured to serve the existing numbers.

ACCESS DOCUMENTS

1. *The access pass.*—A form letter on distinctive stationery is quick to produce and is not easily duplicated. Official stationery (for example, police chief, city manager, or

OAKLAND POLICE DEPARTMENT

CYPRESS STREET EMERGENCY AREA

Application for Access

Firm Name: ______________________________

Location: ______________________________

Authorized Representative: ______________________________
(Last Name) (First Name)

Telephone numbers - Business:

Home:

Nature of Business: ______________________________

Normal Days and Hours of Operation: ______________________________

Total Number of Employees: ________ Days Lost to Quake: ________

Potentially hazardous materials located at the business:

____

____

____

Perishable materials on site:

____

____

Employees Authorized Access:

______________ ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

mayor) is available in quantity and limited to official sources. Personal authorizing signatures make forging passes difficult. The bearer of the pass is required to present photo identification and supporting documents unique to his business or reason for entry.

2. *Keep records.*—Business representatives who apply for employee access must name their employees and provide evidence of employment. The access point can confirm all valid passes by name, and businesses are discouraged from authorizing non- employees access.

CONCLUSION

The Oakland community's response to the Loma Prieta earthquake centered on the failure of several miles of Interstate 880 known as the Cypress freeway. The management of this disaster reinforces several lessons common to natural disasters and other events.

There is no substitute for anticipating and planning for the hazards which your community is likely to face, and for studying the national experience with how disasters strike and how communities respond to them.

Emergency managers must remain flexible. Emergencies are not created equal. The unique local circumstances of a disaster may require you to adapt the standard approaches to your population and event. In this case, actions that are usually taken in the later stages of an incident were required very early on.

Some solutions cause problems of their own. The police perimeter which was established to simplify emergency access and to ensure the safety of employees and residents had two unintended consequences. As soon as the perimeter was in place, it began "downtime" for the businesses which it isolated, adding business losses to the expenses from quake damage. More seriously, the evacuation and exclusion of employees restricted the flow of essential materials and supplies from these sites closest to the disaster scene.

Oakland's process for evaluating individuals' requests for access and for credentialing them worked very well. It was put in place rapidly and used simple controls. It used commonly available materials and volunteer help. It tailored its staff and services to the need. And it kept simple records and a log of its major activities for future operations. *Postscript*: On October 20, 1991, the Oakland-Berkeley Hills suffered a major fire which required the evacuation of more than 5,000 families from their homes. The day following the fire the Oakland Police Department assigned a police sergeant and three officers to prepare a fire access point modeled after the Business Access Point at the Cypress perimeter. Within 4 hours this team had selected a school building, assembled maps, drafted passes, and obtained computers to operate an access site. The access point was not required for the Hillfire perimeter, but a lesson learned from Loma Prieta was exercised, and it continued to work well.

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BAY AREA EMERGENCY FERRY SERVICE— TRANSPORTATION RELIEF AFTER THE EARTHQUAKE

By Richard M. Fahey and George E. Gray,
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ABSTRACT

The earthquake's most noticeable impact on the San Francisco Bay Area's transportation system, from a commuter's standpoint, was the temporary loss of the use of the San Francisco-Oakland Bay Bridge (SFOBB). An emergency ferry service was developed immediately to provide transportation between San Francisco (in the West Bay) and Oakland, Alameda, Richmond, and Berkeley (in the East Bay), all under one contract with the Red & White Fleet (owned by Crowley Maritime). This service lasted from October 23, 1989 through March 23, 1990. The California Department of Transportation (Caltrans) also chartered three Washington State ferries to supplement the preexisting Vallejo-to-San Francisco service from October 30 to January 9. Red & White also operated this service as sub-charterer of the Washington vessels.

Some of the problems that arose in operating the ferry service were the constant need to revise the different service contracts and ferry schedules, especially early on, as well as the uncertainty of reimbursement by the Federal Emergency Management Agency. Overall, however, the program was successful in providing an alternative commute mode for transbay travelers while the SFOBB was inoperative, and even after it was repaired. Evolving from the emergency service was the one year Oakland/Alameda to San Francisco ferry service pilot program as well as the development of a long-range plan for permanent Bay Area ferry service.

This report will discuss the problems and successes of the emergency ferry service from start up activities, through operations, to its present status. The main items of focus will include ridership trends, operation costs and reimbursement, public sentiment, and legislation relating to the service.

BAY AREA FERRY SERVICE BACKGROUND (PRE-EARTHQUAKE)

On the morning of the day the earthquake struck, the commute around the Bay Area was typical. Those who live in the East Bay and work in or near San Francisco were commuting by one of the two available transbay modes: riding transit (the Bay Area Rapid Transit (BART) or the Alameda-Contra Costa Transit (AC Transit)) or driving across one of three bridges linking the East Bay and the West Bay, mainly the San Francisco-Oakland Bay Bridge (SFOBB). Although there was no direct commuter ferry service connecting the East Bay to the West Bay at this time, there was ferry service serving various North Bay communities. Specifically, Golden Gate Transit ran daily commuter ferries from Larkspur and from Sausalito to San Francisco. Similarly, the Red and White Fleet operated ferry service from Vallejo and Tiburon to San Francisco.

Very few if any of that morning's commuters were more concerned with how they would get home that night rather than who would win that evening's scheduled third game of the World Series between transbay rivals the San Francisco Giants and the Oakland A's. That all changed shortly after the earthquake struck at 5:04 p.m.

EMERGENCY FERRY SERVICE IN AFTERMATH OF EARTHQUAKE

EARTHQUAKE DAMAGE PROMPTING FERRY SERVICE

Damage from the earthquake was extensive throughout and even outside the Bay Area. Within the Bay Area, however, the transportation system sustained some of the most comprehensive damage. Most significantly, a section of the Bay Bridge had collapsed rendering it unusable for some 31 days. The SFOBB, which connects Oakland to San Francisco, was the main travel artery between the East and West Bay, handling an average of 243,000 vehicle trips per day (Metropolitan Transportation Commission, unpub. data). All Bay Bridge commuters were forced to find another route.

Another significant transportation problem created by the earthquake was the collapse of a 1-mile section of the I-880 Freeway, which was the main connector for people traveling from Oakland and areas south of Oakland to the Bay Bridge. This closure would force drivers to use either the already overcrowded I-580 connector, or BART's Fremont line.

Other earthquake-related damage hampering East Bay-West Bay travel were the closures of many of the San Francisco freeways. The closures of I-480 (the Embarcadero freeway), I-280 from 101 to 6th St., the Fell St. on-ramp, and the 8th St. and 5th St. on-ramps to I-80 east all made travel within San Francisco very difficult. Even after the Bay Bridge did reopen, most of these freeways and on-ramps have remained closed, which continues to have an adverse effect on transbay travel.

EMERGENCY FERRY SERVICE

START-UP ACTIVITIES

On a typical day before the earthquake, the average number of peak-period (5:00-10:00 a.m.) westbound vehicle trips across the SFOBB was about 42,000 (Metropolitan Transportation Commission, unpub. data). The vehicle-occupancy rate of westbound morning peak-period SFOBB commuters is about 1.42 (Metropolitan Transportation Commission/Caltrans, unpub. data). Thus about 59,640 San Francisco-bound commuters had to find alternative means of crossing the bay for the next 31 days. Unfortunately, what was left of the Bay Area's transportation system was ill-equipped to handle this extra load. It was decided that the best way to get commuters across the bay, and at the same time get them out of their automobiles, was to provide transbay ferry service until most of the damaged roadways could be repaired. Successful commuter and recreational ferry systems were already operating on the bay, and in recent years, there had been serious discussions among transportation officials about providing East Bay-West Bay commuter ferry service on a permanent basis.

On Thursday, October 19, a meeting with all the major transit service providers and select public officials was held to discuss special emergency services. Each transit agency reported on the status of their operations and its ability to provide services. It was here that emergency ferry service between San Francisco and the East Bay was developed. Specifically, ferries would be run between the Ferry Building in San Francisco and four points in the East Bay: (1) Jack London Square in Oakland, (2) Todd Shipyards in Alameda, (3) the Container Terminal in Richmond, and (4) the Berkeley Marina in Berkeley. Also, plans were made to supplement the existing runs between Vallejo and San Francisco. Most of the East Bay transit services modified their schedules to accommodate the new, temporary ferry terminals, and adjust to the SFOBB closure (fig. 1).

In order to provide this additional service, more ferryboats would be needed. Therefore, Crowley Maritime (which owns and operates the Red and White Fleet) arranged to have four of its Catalina ferries from Southern California brought north to the Bay Area. Also, arrangements were made with the State of Washington's Department of Transportation to send down three of their vessels from Puget Sound, which were not being used at the time. The Washington ferries would primarily be used to supplement the Vallejo ferry service.

CONTRACTS AND AGREEMENTS

Once the basic ferry service was formulated, contracts and agreements between the California Department of Transportation (Caltrans) and the ferry operators had to be drawn up. This took place over the weekend of October 21 in order to get the service up and running by Monday, the 23. Three different agreements were drawn up to provide emergency ferry service. One agreement, entitled "RM-25," between Caltrans and Harbor Carriers required the Red and White Fleet (a subsidiary of Harbor Carriers) to provide ferry service between San Francisco and Richmond, Alameda, Oakland, and Berkeley. A second agreement executed between Caltrans and Harbor Carriers, "RM-26," was developed to supplement the already existing service between Vallejo and San Francisco with three extra vessels. However, Harbor Carriers did not own enough ferry boats to both supplement the Vallejo service and operate the East Bay service. Therefore, a third Agreement, "the Bare-Boat Charter Agreement," between Caltrans and the State of Washington Department of Transportation-Marine Division, was executed. The Bare-Boat agreement named Caltrans Charterer of three Washington State vessels which were brought down to the Bay Area. Caltrans named Harbor Carriers as sub-charterer to operate these ferries as part of the provisions in RM-26.

ROUTES AND SCHEDULES

On Monday, October 23, less than one week after the earthquake, the emergency ferry service began operating using an aggressive schedule. The Oakland to San Francisco ferry left Oakland every 20 to 30 minutes beginning from 6:00 a.m. to midnight. The ferries returned on the same schedule. This made up 90 trips back and forth each day.

The Alameda ferry operated 12 runs per day on an hourly schedule only during the morning and evening peak periods. The Richmond ferry ran under an almost identical schedule also with 12 trips each day. The Vallejo ferry operated on a similar schedule with 10 runs per day, and the Berkeley ferry made 19 trips each way, running hourly during peak periods and every 2 hours off peak.

The Golden Gate Ferry Service catering to the North Bay also added extra runs to its already existing Larkspur/Sausalito to San Francisco ferry service. Throughout the entire 5 months of emergency ferry service operation, the schedule changed 17 times. The majority of changes, however, were minor; usually a slight time change in one of the routes for various reasons. These changes will be discussed later in the report.

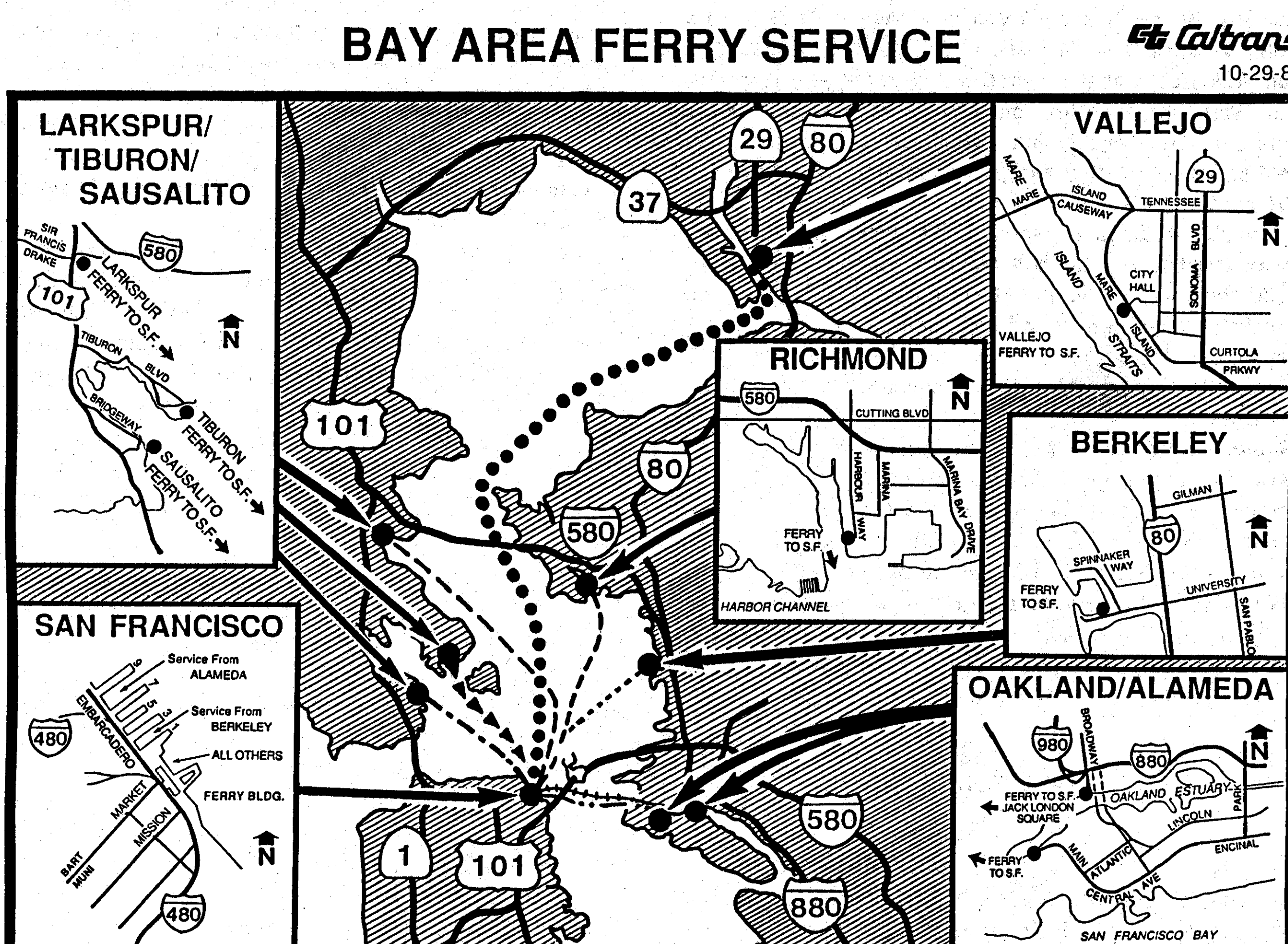


Figure 1.—Ferry service in San Francisco Bay Area following the earthquake.

OPERATIONS HISTORY: OCTOBER 23, 1989 TO MARCH 23, 1990

RIDERSHIP

PRE-QUAKE FERRY RIDERSHIP

Of the emergency ferry routes established, only the Vallejo-to-San Francisco service existed prior to the earthquake. The Red & White Fleet carried an average of 440 passengers per day between the two cities. Half of these daily passengers rode the ferries during peak periods. In the aftermath of the earthquake, this service was supplemented through the use of the Washington Sate ferries.

POST-QUAKE FERRY RIDERSHIP

While the daily ridership of the four East Bay ferries (Oakland, Alameda, Richmond and Berkeley) varied greatly in total numbers, each system followed the same basic ridership pattern throughout the 5-month emergency program. Service initiation on October 23, 1989, resulted in average daily ridership increasing dramatically through mid-November, when the ridership figures peaked out and began to drop off. The reopening of the SFOBB on November 18 contributed to the steady decline in ferry patronage through December 22. On December 23, major service cuts were initiated, which eliminated most weekend and midday ferry runs in order to utilize the emergency funding in a cost-effective manner. This produced a sharp reduction in daily ridership levels, although it did not noticeably effect peak-period ridership. From this point, the average daily ridership figures began to level off until mid-January, after which they remained fairly constant through the end of service on March 23, 1990 (fig. 2*A*-*F*).

The Vallejo service showed similar ridership trends at first. As soon as the supplemental service started, the daily ridership increased sharply from the pre-earthquake levels of 440 riders per day. It also peaked out in mid-November and began to drop off after the reopening of the SFOBB. However, ridership figures leveled off more quickly and averaged around 700 people per day through mid-December. From this point, the passenger count began to drop off slightly each week through the end of State service on January 9, 1990; this drop was probably due to the continuing uncertainty as to whether this service would be extended or canceled. The Vallejo data in figure 2*F* show the average daily ridership through March 23. Note that even though the ferry service there returned to pre-quake conditions after January 9, the ridership remained above its pre-quake average of 440 passengers per day.

COST/SUBSIDY ANALYSIS

Even though some of the Federal reimbursement funding for the ferry service at the time this report was written was still in doubt, the majority of the costs involved in setting up and operating the emergency service have been identified. The total cost involved in operating the emergency ferry service from October 23, 1989, through March 23, 1990, was $6,450,578. These costs are detailed in table 1.

The following section compares the operating costs of the emergency ferry service with the ridership figures at varying times during the 5-month operation. Table 2 shows the cost per passenger for both the Vallejo service and the East Bay service during the three different phases of the East Bay contract (discussed in more detail in the next section). The four East Bay routes are grouped into one category because Caltrans' contract with Crowley Maritime specified compensation for all four services in one fixed amount, rather than a separate cost for each service. The slightly higher cost per rider for the Vallejo service is most likely the result of higher operating costs due to the longer trip lengths than those from the East Bay. The one-way trip length from Vallejo to San Francisco is 26.4 miles, whereas the average East Bay trip was 8 miles long.

The last column in table 2 (subsidy/rider) is simply the difference between the operating cost of the service and the revenue credited to Caltrans, divided by the number of riders for that period. As expected, the cost per passenger increased as the ridership decreased throughout the service. In fact, near the end of the service period when the East Bay ridership was averaging about 1,000 people per day and Caltrans was paying Red & White $26,000 a day to operate, the cost per passenger was therefore $26.00, a primary reason for terminating the service.

The total cost per passenger associated with the entire emergency ferry service operations includes all costs, including additional costs that were not included in contracts with the ferry operators such as operations plus dredging, ferry charter, ticket collection, and so forth. This indicates that the total cost per passenger was $11.79, or $9.85 per rider with State revenue subtracted from the cost.

CONTRACT AMENDMENTS

FERRY SERVICE AGREEMENT RM-25

The following section discusses the different amendments to the three basic ferry contracts (RM-25, RM-26/sub-charter, and The Bare-Boat Charter Agreement) that occurred during the service period. As was mentioned earlier, the original service agreement (RM-25) between

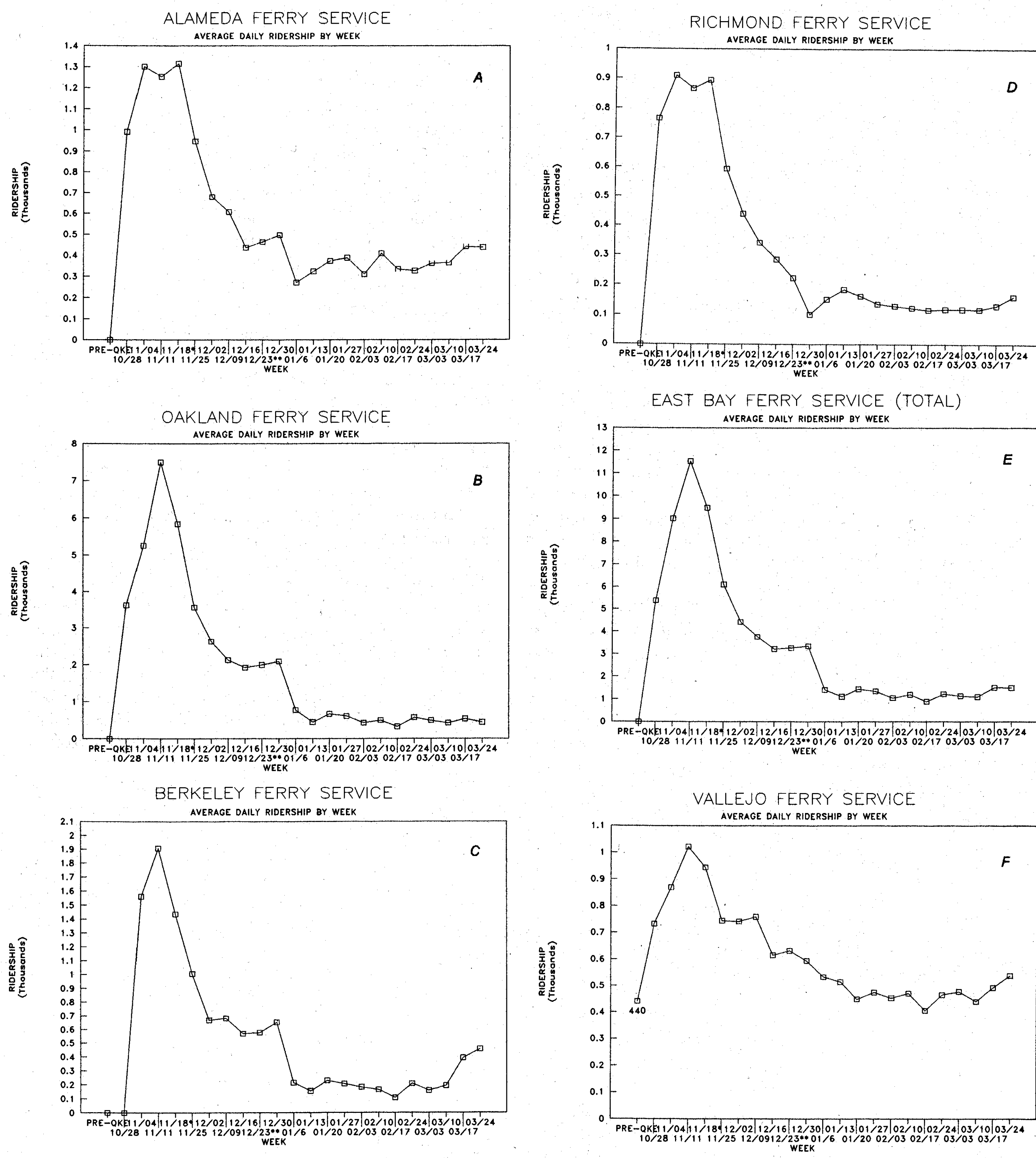


Figure 2.—Ridership on San Francisco Bay emergency ferry service following the earthquake.

Table 1.—*Cost of operating emergency ferry service*

Item	Cost
Ferry Boat Facility Investigation by Army Corps of Engineers	$ 100,000
Ferry Boat Facility Dredging by Army Corps of Engineers	$ 325,000
Labor Cost of Ticket Vendors	$ 222,082
Consultant Services	$ 15,324
Parking lot & access road construction, and signage	$ 145,946
Auditor Contract	$ 2,787
Accounting services; ticket counting	$ 11,436
Ticket printing	$ 15,441
Caltrans Staff (10/26/89-1/25/90)	$ 20,300
Washington ferry boat charter, insurance, expenses, & repairs	$ 384,718.11
Total Operating Cost of East Bay Ferry Service	$4,466,555.50
Total Operating Cost of Vallejo Ferry Service	$ 740,988.75
Total Emergency Ferry Service Costs	$6,450,578.36

Table 2.—*Cost-per-passenger analysis of emergency ferry service*

Contract period	Service	Operating costs	Riders	Cost/ rider	Caltrans revenue	Subsidy/ rider
10/23-11/17	East Bay	$1,239,556	234,341	$5.29	$651,735	$2.51
10/30-11/19	Vallejo	201,982	20,046	10.08	102,643	4.96
11/18-12/22	East Bay	1,615,000	144,265	11.19	133,920	10.27
11/20-12/24	Vallejo	371,402	23,340	15.91	126,993	10.47
12/23-3/23	East Bay	1,612,000	116,548	13.83	0	13.83
12/25-1/9	Vallejo	167,605	8,707	19.25	41,272	14.51
Total	East Bay	4,466,556	495,154	9.02	785,655	7.43
	Vallejo	740,989	52,093	14.22	270,908	9.02
Non-contract additional costs		1,243,033				
Grand total		$6,450,578	547,247	$11.79	$1,056,563	$9.85

Caltrans and Harbor Carriers, executed October 22, 1989, required Harbor Carriers to provide ferry service between San Francisco and three East Bay points: Richmond, Alameda, Oakland, and Berkeley. As compensation, Caltrans was to transmit all the revenue from $5.00 round-trip ticket sales to Harbor Carriers plus $4.50 for each return trip ticket collected. No contract termination date was identified, but instead a 2-day cancellation notice by either party was required to terminate the agreement.

About a month later, Restatement and Amendment #1 modified the compensation clause so that Caltrans would reimburse Harbor Carriers $4.75 for each one-way ticket sold. The price per round-trip ticket was set at $5.00, with Caltrans to receive 100 percent of the revenue from ticket sales. Under this formula Caltrans was providing a $4.50 per passenger subsidy for each round-trip ticket sold. This payment schedule was only effective from October 23 through November 17. The revised contract also added a new compensation clause effective November 18 so that Caltrans would pay Harbor Carriers $47,500 per day of operation plus 60 percent of the revenue collected from ticket sales. It stated that the total payments from Caltrans to Harbor Carriers was not to exceed $2,765,000.

Also, under this restated contract, the agreement was to terminate on December 1, 1989, the date that the Federal Highway Administration (FHWA) agreed to extend reimbursement for the emergency ferry service. With the passage of Senate Bill #SB36X(89), which redirected $2,000,000 in Transit Capital Improvement funds to Caltrans to sustain the emergency ferry service, and the mounting public pressure to continue the program, the service was extended three different times during December (with Letters of Agreement).

By this time, Caltrans was also in contact with the Federal Emergency Management Agency (FEMA) requesting FEMA participation in reimbursement for ferry service costs. With the seemingly relative abundance in funding sources, and the outside pressure to continue the ferry service, a second amendment to the contract (San Francisco Bay Purchase of Ferry Service Agreement RM-25, Amendment 2) was executed, which extended the ferry service through March 23, 1990, and increased the limit that Caltrans could pay Harbor Carriers to $4,000,000. The compensation clause was also changed again to produce a simpler payment scheme. Under this amendment, effective December 22, Caltrans was to pay Harbor Carriers $26,000 per day to operate the East Bay ferry service. Also taking effect were major schedule changes (discussed in the next section), which eliminated most of the weekend and off-peak trips in order to stretch the subsidy as far as possible for peak-period users.

SERVICE AGREEMENT AND BAREBOAT SUB-CHARTER RM-26

The other two contracts, the Bare-Boat Charter and RM-26 Sub-charter, were interrelated. As was mentioned earlier, the RM-26 Sub-charter agreement between Caltrans and Crowley Maritime named Red & White Fleet as Sub-charterer of the Washington State vessels, along with other provisions to supplement the Vallejo ferry service. Although this contract was never amended throughout the service period, it did contain some gray areas open to interpretation, which required certain negotiating between the two parties afterwards.

First, the original compensation provision stated that Caltrans would reimburse Harbor Carriers its total costs plus an additional 10 percent of such costs, and that the two parties would meet, sometime after the first week of service, to agree on a cost plus fixed fee compensation amount. Months after the State's involvement in the Vallejo service had ended and after continued negotiations the following provision was agreed upon: "For the first week of service, Caltrans shall reimburse Harbor Carriers for the actual costs of conducting the Vallejo ferry service plus a fixed fee of $5,323.95," which was 10 percent of the first week's operating costs. The Agreement also obligates Caltrans to pay a $6,191-per-week fixed fee for the remainder of the service period.

Another item in the sub-charter section of the original contract needing revision was the insurance clause. The original insurance clause required Caltrans to add Harbor Carriers as additional assured to the hull and machinery insurance maintained by Caltrans and by Washington, when, in actuality, Harbor Carriers maintained their own insurance covering the Washington State vessels.

Finally, there was a question as to which party was responsible for specific repairs to the Washington State ferries. Even though the Red & White Fleet operated the vessels during the service period, Caltrans was ultimately responsible for the vessels. The contract language did not clarify matters either. It stated that "Harbor Carriers shall only be responsible (i) for ordinary maintenance and (ii) for repairing any damage Harbor Carriers may cause due to (their) failure to comply with Section VI of the Bareboat charter." Section VI requires the charterer not to operate the vessels at more than 25 knots and not more than 16 hours per day. Although Harbor Carriers appeared to stay within these boundaries while operating the Washington ferries, there was some minor damage to the boats, as well as some missing items.

The logical solution was to have Caltrans pay only for damages obtained during the trips between Seattle and San Francisco, while Crowley Maritime should be responsible for repair costs resulting from their operation. Unfortunately, the damages were not easily distinguishable because there was no on-hire survey done in Seattle, and only a quick one was done in San Francisco due to time constraints and the urgency of beginning emergency service. Therefore, the various repair costs are currently being negotiated between the two parties, and the contract language regarding repairs will not be amended at this point.

BARE-BOAT CHARTER AGREEMENT

The Bare-Boat Charter Agreement between Caltrans and the State of Washington, as mentioned earlier, allowed Caltrans to use three Washington State ferries (which were sub-chartered to Crowley Maritime as described above) at a rental rate of $18,300 per month, plus an additional charge of $2.00 per operating-hour per engine. The original agreement was to expire on December 1, 1989. Caltrans was also responsible for the costs involved in transporting the vessels from Seattle to San Francisco and back again, including the off-hire survey/inspection and repairs. The agreement also required Caltrans to provide insurance for the ferries from the time they left Seattle until the time they were returned.

On November 27th, Supplement No.1 to the Bare-Boat Charter was executed for two main reasons: (1) the Urban Mass Transportation Administration (UMTA) requested the Charter agreement include a federal interest clause as a condition of approval, and (2) Harbor Carriers requested a restatement (Bare-Boat Charter Agreement Supplement No.1) of the hull and machinery insurance coverage in a format acceptable to their underwriters. Also, this Supplement clarified that Caltrans would be responsible for the costs relating to travel and redelivery of the vessels. On December 1, 1989, an extension agreement (Bare-Boat Charter Agreement Supplement No. 2) was signed to continue operating the service under the original charter agreement on a day-to-day basis. This was necessary because it was still unclear at this point as to how long the ferry service would continue.

Table 3 summarizes the contract amendment and supplement information for the three main emergency ferry service contracts.

SCHEDULES

Between the beginning of the emergency ferry service on October 23, 1989, and the last day, March 23, 1990, there had been 17 different schedules. Most of the schedule changes were minor, such as a slight time change to one of the five routes. Also, most of the schedule refinements took place within the first month or two of service. Other reasons or events prompting schedule changes included pier availability, citizen group requests, transit connections, and reductions in service to maximize the subsidy. Although these schedule changes did not have a noticeable impact on ridership, the early, continuous changes drew criticism from the public in that the fluctuations and uncertainty may have scared off potential riders. At the same time, however, the schedule changes may have helped attract new riders who could not use the service under the previous schedules.

As ridership declined, certain ferry runs within various routes were eliminated in an effort to keep the service cost-effective. By mid-December, about 75 percent of the riders were using the service during peak hours. It was determined that by eliminating the weekend and off-peak runs, the State could save about $175,000 per week in operating costs and therefore stretch the subsidy through mid-March. The most significant schedule change occurred on December 22, when most of the remaining mid-day and weekend runs were eliminated. The last schedule change occurred on February 17, 1990, and was used throughout the remainder of the service. Table 4 shows both the first schedule (full service) and the last (reduced service) for comparison.

REIMBURSEMENT/FUNDING

As was mentioned at the beginning of the report, emergency relief funding to operate the ferry service while the SFOBB was being repaired was secured from the Federal Highway Administration (FHWA). Eventually, Caltrans received a funding extension from the FHWA through December 1, 1989. By this time, it was estimated Caltrans had spent $1,635,997 in operating the emergency service, which was reimbursed by the FHWA. Also by this time, an extra $2,000,000 had become available to extend ferry operations with the passage of Senate Bill #SBX36(89).

During this time, Caltrans had been submitting Damage Survey Reports (DSRs) to the Federal Emergency Management Agency (FEMA) as part of the process to receive reimbursement for the costs of all repairs and services made necessary by the earthquake. All requests for Federal aid were made through the State Office of Emergency Services (OES), which would request FEMA participation based on Caltrans' requests. It was originally understood that FEMA would reimburse Caltrans from the time FHWA funding stopped (12/1/89) through a period when traffic patterns on and around the SFOBB returned to normal. It was difficult to predict when this might happen, but by cutting out most midday and weekend ferry runs, and eliminating the Vallejo subsidized service (1/9/90), it was determined that the East Bay service could be maintained through mid-March of 1990 by utilizing the available funding.

Unfortunately, Caltrans did not learn until January 9, 1990, that FEMA had planned to terminate financial assistance on December 31, 1989. In spite of this, Caltrans decided to stick to their original plan of operating the service through March by utilizing SBX36(89) funds and, at the same time, appeal FEMA's December 31, 1989, cut-off date. In mid-April (3 weeks after ferry service termination) Caltrans learned that FEMA had rejected the appeal, prompting a second level appeal to be submitted. Two weeks later it was learned that FEMA had decided not to participate in any ferry service related funding at all. This instigated a meeting between Caltrans, FEMA, and OES to resolve matters. FEMA officials indicated they would consider reimbursement for the service for as long as ridership warranted running such service. Caltrans submitted a supplement to the second appeal, which specifically pointed out that FEMA should provide financial aid for the ferry service at least through February 9, the approximate date that SFOBB traffic volumes had begun to return to normal levels (B. Crockett, unpub. data).

Outstanding service costs to Caltrans during this period totaled $2,910,555. With Caltrans providing a 25 percent

Table 3.—*Contract amendment summary for emergency ferry service*

Original Contract	1st Amend/ Supplement	2nd Amend/ Supplement	3rd Amend/ Supplement
RM-25			
(10/23-11/17) $4.75/ticket Revenue - CT	(11/18-12/22) $47,500/day Revenue Split: 60%-HC:40%-CT	(12/26-3/23) $26,000/day Revenue - HC	(2/23/90) $4,852,635 pay cap
RM-26			
(10/30-1/9) Cost plus 10% fixed fee.	(Unsigned) 1st week's costs + 10%. Op. Costs + $6,191/week. Modified insurance clause.		
BAREBOAT			
(10/30-12/1) Charter three WA ferries.	(11/27/89) Federal clause. Insurance modify. Redelivery costs.	(12/1/89) Charter extension: day by day agreement.	

(CT = Caltrans, HC = Harbor Carriers)

Table 4.—*Emergency ferry service schedule 1 and schedule 17*

SCHEDULE 1	SCHEDULE 17
From Oakland to S.F. Ferry Building (40 minutes)	
-Leave at 6 a.m. & every 20-30 min. thereafter until midnight.	-Leave at 6 a.m. & every hour therafter until 10:00 p.m.
-Ferries return on same schedule .	-Ferries return on same schedule.
From Alameda to S.F. Ferry Building (35 minutes)	
-Leave 6,7,8,9 a.m. and 5,6 p.m.	-Leave hourly from 6:15-10:15 a.m. & every hour until 4:45 p.m., then hourly until 8:15 p.m.
-Return 7,8 a.m. and 4,5,6,7 p.m.	-Return on similar schedule.
From Richmond to S.F. Pier 9 (45 minutes)	
-Leave 6,7,8,9 a.m./5:30,6:30 p.m.	-Leave 6,7,8 a.m. / 5:25 p.m.
-Return 7,8 a.m./4:30,5:30,6:30,7:30	-Return 6:50 a.m./4:30,5:30,6:30 p.m.
From Berkeley to S.F. Pier 3 (40 minutes (Beginning 10/30/89))	
-Leave at 6:00 a.m. and every hour (two hours, mid-day) until 8:00 p.m.	-Leave at 6:00 a.m. & every other hour until 8:30 p.m.
-Return at 7:00 a.m. and every hour (two hours, midday) until 7:00 p.m.	-Return on similar schedule.
From Vallejo to S.F. Ferry Building (60 minutes)	
- Ferries leave 6:00 and 6:30 a.m.	-Subsidized service ended 1/9/90.
- Return at 5:15,6:15,and 7:40 p.m.	

FEMA match [using SBX36(89) funds], the total amount Caltrans requested from FEMA was $2,182,916. Figure 3 shows the entire financial spreadsheet, including costs and funding sources for the emergency ferry service.

To date, Caltrans has not received a response from FEMA either accepting or rejecting the second appeal. Therefore, table 5 shows the breakdown of the two possible reimbursement scenarios: (1) FEMA provides financial aid through February 9, 1990, and (2) FEMA provides no aid for ferry service. The first scenario would leave Caltrans with a balance of $518,362 in SBX36(89) funds, which would be returned to the State Legislature, whereas the second leaves Caltrans with a deficit of $1,664,553. The Caltrans cost figure of $5,947,632 refers to the total

Item	Days	(1) R&W Contract Payments	(2) Total Costs	(3) FHWA	(4) FEMA	(5) Caltrans	(6) Army CORPS	(7) SBX36 Funding	(8) MTC/ Vallejo	(9) Revenue Kept by R&W	(10) Rev. Credited to Caltrans	(11) Total Revenue
COEngr – Investigat'n			$100,000				$100,000					
COEngr – Dredging			$325,000				$325,000					
Toll Collectors			$222,082			$222,082						
Consultants			$15,324	$15,324								
Parking/Access/Signs			$145,946	$145,946								
Auditor Contract			$2,787	$2,787								
Accounting/Tickets Counting			$11,436		$11,436							
Ticket Printing			$15,441	$7,000	$8,441							
Caltrans Staff 10/26–1/25			$20,300		$20,300							
Operating Costs–Wash DOT:												
Insurance			$73,981	$73,981								
Monthly Fees ($18,300/mo)			$62,220	$19,520								
Engine Hours ($2/op–hr/eng.)			$18,608	$3,960								
Expenses (Labor,Travel,etc.)			$142,555	$129,000								
Off Hire/Drydocking/Props.			$18,869	$60,000								
Repairs (R&W Responsible)			$68,486									
Sub–Sub–Total			$384,718	$286,461	$98,258							
Operating Costs–E Bay	Days											
(1) 10/23–11/05	14	$596,330	$596,330							$0	$313,195	$313,195
11/6–11/17	12	$643,226	$643,226	$487,815						$0	$338,540	$338,540
(2) 11/18–12/1	13	$558,922	$617,500	$590,500						$87,867	$58,578	$146,445
12/2–12/15	14	$610,976	$665,000							$81,036	$54,024	$135,060
12/16–12/22	7	$311,182	$332,500							$31,977	$21,318	$53,295
(3) 12/26–3/23/90	62	$1,612,000	$1,612,000							$558,000	$0	$558,000
Sub–Sub–Total	122	$4,332,636	$4,466,556	$1,078,315	$2,500,321 (thru 2/9/90)			$753,999		$758,880	$785,655	$1,544,535
Op.Costs+Fixed Fee – Vallejo (4) 10/30–1/9	70	$371,962	$740,989	$100,164	$271,799				$98,118	$270,908	$270,908	$270,908
Sub–total		$4,704,598	$6,450,578	$1,635,997	$2,910,555	$222,082	$425,000	$753,999	$98,118	$1,029,788	$1,056,564	$1,815,444
FEMA 25% MATCH FROM SB 36X					$727,639			$727,639				
Total		$4,704,598	$6,450,578	$1,635,997	$2,182,916	$222,082	$425,000	$1,481,638	$98,118	$1,029,788	$1,056,564	$1,815,444
$ 2 mil balance								$518,362				

Notes:

East–Bay

(1) 10/23–11/17:Payments to R&W = # of tickets sold x $4.75
CT keeps 100% of Revenue.
(Revenue = $651,795.32)

(2) 11/18–12/22:Payments to R&W = $47,500/day + 60% Revenue.
CT keeps 40% of Revenue.
(Revenue = $334,800)

(3) 12/26–3/23:Payments to R&W = $26,000/day + 100% Revenue.
(Reduced Service – No Weekend)
* (Revenue Estimation :
= 1800RT/Day * $5 * #Days)

Vallejo

(4) 10/30–1/9:Payments to R&W =Op.Costs+Fixed Fee($6191/wk).
Weekend Service throughout.

Assumes: FHWA reim: 10/30–12/1
FEMA reim: 10/30–2/09

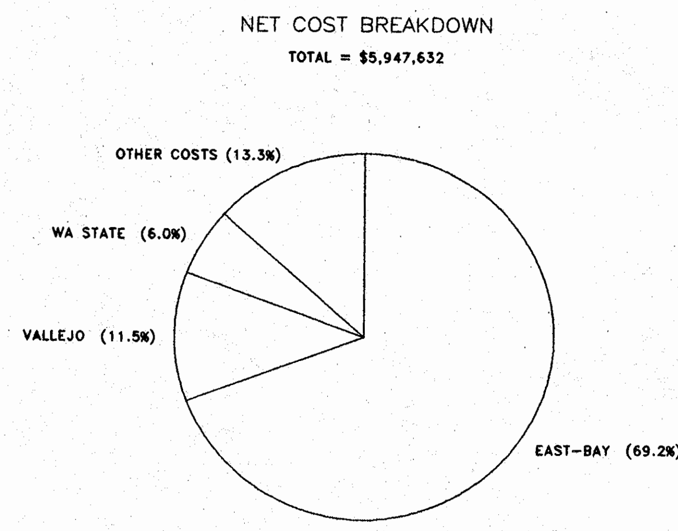
Total Payments to R & W = Sum of Columns (1)&(9):

$4,704,598
$1,029,788
$5,734,386

Figure 3.—Emergency ferry service reimbursement and expenditure report.

Table 5.—*Reimbursement sources for operation of emergency ferry service*

SOURCE	With FEMA aid	Without FEMA aid
FEMA	$2,182,916	$ 0
FHWA	$1,635,997	$1,635,997
CALTRANS	$ 222,082	$ 222,082
ARMY CORPS	$ 425,000	$ 425,000
25% FEMA MATCH	$ 727,639	
SBX36 FUNDS	$ 753,998	$2,000,000
TOTAL REIMB.:	$5,947,632	$4,283,079
CALTRANS COSTS:	$5,947,632	$5,947,632
SURPLUS SBX36:	$ 518,362	$ 0
DEFICIT:	$ 0	$1,664,553



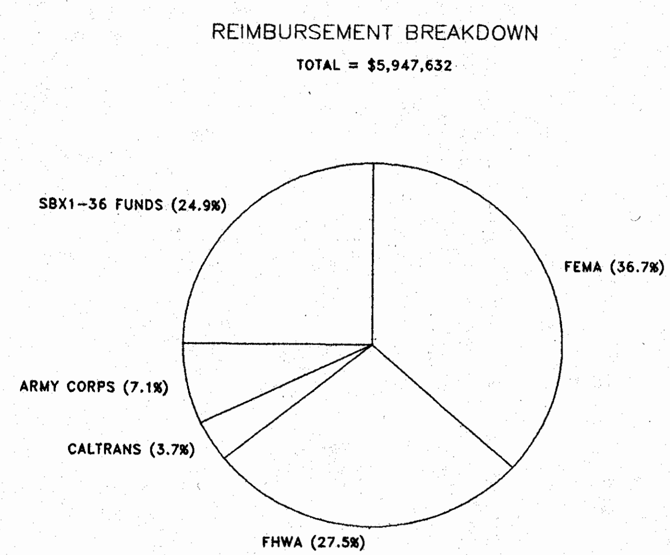


Figure 4.—Net cost breakdown and reimbursement breakdown.

net costs, derived from all costs less revenue and other credits.

Figure 4 shows a proportional breakdown of the net costs and reimbursement sources involved. The 3.7 percent contributed by Caltrans under the Reimbursement Breakdown chart reflects the labor costs of the toll collectors who sold and collected ferry tickets while the SFOBB was inoperative. The 7.1 percent reimbursed by the Army Corps of Engineers was for its postquake port investigations and Berkeley channel dredging related to the ferry service.

PUBLIC SENTIMENT

Although ferry ridership began to subside after the SFOBB reopened, the amount of public support for the ferries, and for continued ferry service did just the opposite. The more the State threatened to eliminate the ferry service due to decreasing ridership, the more letters that were received by Caltrans and the legislators from angry support groups and individuals. For example, Caltrans received many letters from commuters riding the Vallejo ferries when they learned that Caltrans planned to terminate the supplemental service. One ferry support group, "The Berkeley Ferry Committee," submitted a letter with over 2,300 signatures, and approximately 150 separate letters, to the Caltrans District Director requesting that the State keep the Berkeley ferry service operating on a permanent, subsidized basis. Similarly, many East Bay politicians were the recipients of letters from their constituents who wanted to see the Oakland and Alameda ferries kept running on a permanent basis.

As it turned out, perhaps partly due to public pressure, the Oakland and Alameda ferry service was continued, after State involvement ceased, by the City of Alameda and the Port of Oakland as a one year demonstration project. Some of the different ferry support groups which were formed included the following: The Berkeley Ferry Committee, The Richmond Ferry Run, The North Bay Water Commuters out of Vallejo, The Tiburon Commuters from Marin County, and The Bay Organization for Aquatic Transit (BOAT). The latter was originally formed to support the Oakland and Alameda ferry runs, but eventually reorganized to include representatives of all the other support groups to create an alliance to help facilitate the development of a Bay Area ferry system. These groups were all successful in recruiting volunteers, distributing schedules and informational newsletters, and keeping local politicians informed of their concerns.

LEGISLATION

Many measures were passed during the 5-month period that affected the emergency ferry service, most of which were authored by Senator Quentin Kopp (San Francisco), or Senator Keene (Vallejo). Most of the State bills passed during this time provided funds or authorization for earthquake damage relief of all types, not strictly ferry service activities. The following section, however, describes how the different measures related specifically to the ferry service.

Immediately after the earthquake, the Governor declared a state of emergency. This allowed for quick implementation of the emergency ferry service. Many of the approvals and regulations that would normally apply to ferry operation on the bay were now superseded under the state of emergency. This situation enabled dredging, parking lot construction and service contract negotiations.

A few weeks later, on November 2, Senator Keene introduced Senate Bill #SBX37, which required the Metropolitan Transportation Commission (MTC) to develop a permanent ferry plan for the San Francisco Bay and the City of Vallejo to determine the feasibility of acquiring ferries on a permanent basis. Two days later, Senator Kopp introduced Senate Bill #SBX36 (adopted 11/7/89) which, among other things, transferred $2,000,000 from Transit Capital Improvement funds to Caltrans to sustain emergency ferry services. It also reallocated $1,500,000 from the same funding source to MTC for allocation to transit operators for continuation of their emergency bus and rail services.

Senate Bill #SBX39 by Senator Kopp, introduced on January 23, required MTC to develop objective criteria (including ridership per run, fare-box recovery ratio, and local financial support) to determine which ferry runs were the most cost-effective so that the limited funding could be utilized efficiently. Although this bill was not adopted until July 7, 1990, these criteria (among others) were being used all along by the State in an effort to stretch the limited funding by eliminating the least cost-effective runs, such as the midday and weekend service.

Senate Bill #SBX2169, adopted at the beginning of 1990, authorized MTC to develop and adopt a long-range plan for implementing high-speed water transit on the San Francisco Bay. By this point, the emergency service was winding down, so this bill was introduced to help develop a more permanent transbay ferry service.

Finally, Proposition 116 on the California ballot was passed by voters in the June election. Although this proposition had no effect on the emergency ferry service, it will provide $30,000,000 for water-borne ferry systems through bonds. Specifically, it provides $10,000,000 to the City of Vallejo for capital improvements to the Vallejo ferry service. It also allocates $20,000,000 to local agencies through competitive (statewide) grants for construction, improvements, acquisition, and other capital expenditures for ferry service.

OVERVIEW

Although problems were encountered throughout its operation, the emergency ferry service successfully transported thousands of people across the San Francisco Bay on a daily basis.

Two obvious problems encountered during the 5-month period of emergency service were (1) the constant contract revisions required and (2) the continually changing ferry schedules. Considering the circumstances however, these were minor complications. The original contracts were developed and executed quickly in order to implement service as soon as possible. Most of the eventual factors which necessitated contract revisions, such as additional funding sources, ridership levels, insurance needs, public pressure, and so forth, could not have been foreseen when the contracts were first developed. In hindsight, the contract with the fewest problems was the simplest: RM-25 amendment #2, which required Caltrans to pay a fixed, daily fee of $26,000 for the East Bay ferry service. This, of course, was developed after the funding sources had been identified and the operation duration specified.

Another problem, which still exists, is the indecision by FEMA as to whether they will reimburse Caltrans for some or any of the costs in operating the ferry service. It is not known if this dilemma could have been avoided.

On the positive side, there was tremendous and unprecedented cooperation between the local transit operators; Federal, State, and local officials; local politicians; and the private sector in developing and operating an alternative public transportation system on such short notice. Also on the plus side, the emergency ferry service carried over 547,000 passengers over the 5-month period and averaged over 4,200-person-trips per day. Another benefit to emerge from this situation was the long-range plan to provide transbay ferry service, which MTC is now developing. Finally, one of the most important secondary developments is that the City of Alameda, the Port of Oakland, and MTC are now jointly subsidizing a 1-year trial ferry service program between Oakland, Alameda, and San Francisco, which is simply a continuation of the emergency ferry service. If successful, it will become permanent.

HAZARDOUS MATERIALS PROBLEMS DUE TO THE EARTHQUAKE

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Association of Bay Area Governments, Oakland, Calif.

CONTENTS

ABSTRACT

The problems with hazardous materials associated with the Loma Prieta earthquake, as with other recent earthquakes in California and other industrialized areas, have resulted from a number of different types of nonstructural, rather than structural, failures:

(1) Dislodging of asbestos or encapsulated asbestos
(2) Underground pipeline breaks due insufficient flexibility to withstand soil movement
(3) Above-ground pipeline breaks due to breaks in short connector pipes due to differential movement between pipes, tanks and buildings; impact from other structures or equipment; or damage from failing pipe supports
(4) Cylindrical storage tank failures due to "pitting" corrosion, "elephant's foot" buckling, or sloshing of contents
(5) Toppling of elevated tanks
(6) Shifting and overturning of horizontal tanks
(7) Sloshing of liquids from open tanks or secondary containment
(8) Falling shelving or inadequate lips/restraints on shelves, particularly in hospital, school or private company laboratories, in liquor, drug or grocery stores, or in warehouses
(9) Industrial equipment sliding, swinging, overturning, or failing internally
(10) Breakdown in utilities, including communications, water, and power.

Clean-up of most incidents was handled by in-house personnel.

The survey effort for collecting data on the extent of these problems in the Loma Prieta earthquake extended from Santa Cruz County through all affected counties in northern California. Leads on hazardous materials releases were obtained from a variety of sources; among them the California Department of Health Services, the Environmental Protection Agency—Region IX, county health departments, local fire departments, hospitals, and schools. All companies were surveyed individually to clarify or correct initial reports.

Documented hazardous materials releases due to this earthquake total 495, excluding innumerable leaks in Pacific Gas and Electric Company's natural gas distribution system.

This study indicated certain areas which should be singled out for future hazard reduction efforts, and more effective cleanup preparation and response.

The specific measures for minimizing potential problems are often nonstructural and include the following:

(1) Using an adequate factor of safety when designing tanks and pipeline supports
(2) Designing pipelines so that they can withstand differential movement
(3) Accounting for sloshing when designing open-topped tanks and secondary containment

(4) Using appropriate restraints for cylinders
(5) Bracing and anchoring shelving systems, equipment or raised floors
(6) Incorporating adequate lips or other restraints on shelves
(7) Applying redundancy to utility systems

Other potential mitigation strategies relate more to controlling the risk (through removal of the material, inventory control, or secondary containment) or improving emergency response.

BACKGROUND

During 1988 and 1989, the Association of Bay Area Governments (ABAG) compiled a database of known hazardous materials releases in approximately 30 recent earthquakes. Because of the availability of supplemental funding from the National Science Foundation, ABAG was able to gather more complete information on the Loma Prieta earthquake than on other earthquakes listed.

In performing the original NSF-funded study, ABAG determined that, although some information is available on hazardous materials problems in prior earthquakes, no studies had attempted to systematically compile data on problems of this nature. The project was an interdisciplinary analysis, as neither professionals in earthquake planning nor in hazardous spill prevention and response normally consider the effects of problems in the other field.

ABAG designed a flexible, accessible database to store this information, and documented releases from those earthquakes. The database contains 17 pieces of information for each event: the name and the location of the earthquake, the date and the time of the earthquake, the magnitude of the earthquake, the company where the release occurred, the street address of the company, the city and the county in which the release occurred, the type of problem, the material released, the quantity released, the units defining the quantity of materials, the comments on details of the release, whether the release was contained, the companies involved in the clean-up of the release, and the source of the information. After creating the database, we slowly added data on individual incidents.

Thus, ABAG was in an excellent position to collect extensive data on the Loma Prieta event in a timely manner.

DATA COLLECTION

The collection of data on hazardous material releases in the Loma Prieta event was confined primarily to the southern six counties of the Bay Area and the four counties to the south and east. These 10 counties are listed below:

(1) Santa Cruz
(2) Monterey
(3) San Benito
(4) Santa Clara
(5) San Mateo
(6) San Francisco
(7) Alameda
(8) Contra Costa
(9) San Joaquin
(10) Marin

The data were compiled using references from a number of different sources. Books, magazine and journal articles, and written records from public agencies were examined. However, conversations with representatives from firms or organizations with first-hand knowledge of these releases were the most valuable when documenting the problems. ABAG staff contacted regulatory agencies, local government departments, businesses, and clean-up companies. These sources are listed below:

(1) 12 local cleanup companies
(2) U.S. Coast Guard
(3) U.S. Environmental Protection Agency
(4) California Office of Emergency Services
(5) California Highway Patrol
(6) Regional Water Quality Control Boards (San Francisco and Monterey Bay Areas)
(7) Air Quality Management Districts (San Francisco and Monterey Bay Areas)
(8) 10 county Offices of Emergency Services
(9) 10 county Environmental Health Departments
(10) All Fire Departments with hazardous materials teams
(11) 4 selected business groups
(12) All hospitals in the 10 counties
(13) All universities and colleges in the 10 counties
(14) All public high schools in the 10 counties

Each of these organizations was contacted to determine whether it had any knowledge of specific hazardous materials events which occurred due to the earthquake. The most useful sources on this list were the U.S. Environmental Protection Agency, the California Office of Emergency Services, and the local fire and health departments. Most of the companies which experienced releases were also called to confirm reports received from the organizations listed above, and these interviews were very valuable. Data compiled indicated releases occurred in 41 different cities within the 10 affected counties.

Problems in hospitals, public high schools, and both public and private colleges and universities are represented more completely than other facilities because all of these facilities were contacted. Dozens of additional spills occurred in laboratories and plating shops. If these spills were cleaned up by in-house "hazmat" response teams or by the researchers themselves and if they were not reported, they do not appear in this database. All information presented in this database is as accurate as the sources allowed at the time of compilation.

Information was obtained in a variety of forms, making it difficult to compare directly the sizes of various spills. For example, five basic categories of units were given by the sources, including liquid, volumetric, and mass measures, and as well as location and spill types. Several unit measurements were given in each of these categories.

TYPES OF PROBLEMS

ASBESTOS

Asbestos contamination is a poorly publicized form of hazardous materials release which can result in very expensive clean-up costs and unplanned temporary loss of use of buildings that can last for months.

The most common causes of contamination are the asbestos in ceiling tiles or sprayed-on insulation shaking loose and falling with the suspended ceiling. The other major cause of asbestos contamination is the rubbing loose of insulation on pipes due to contact with the pipe supports, other pipes, or a building structural member.

Asbestos may need to be cleaned up prior to building demolition, delaying and complicating that problem.

PIPELINES

Because of their widespread distribution, natural gas leaks are the most common releases during earthquakes and are responsible for most of the resulting explosions and fires. This type of damage demonstrates the vulnerability of all underground pipelines. They can be broken by soil movement, particularly if there is some pre-existing deterioration in the lines. Such movement can be caused by liquefaction, landsliding, lateral spreading, and other forms of ground failure. Recent underground storage tank regulations tend to promote the identification and containment of leaks in pipelines associated with underground tanks.

Above-ground piping is especially vulnerable to breakage from differential movement between pipes, tanks, and buildings. Typically, the sliding of an unanchored tank or piece of equipment ruptures short spans of connection pipe. Pipelines which cross building expansion joints, or where pipes intersect at right angles, also may be subject to failure. Another damage-prone area is at threaded, rather than welded, joints, probably because the threading process leaves grooved areas of thinner material. Ground failure can trigger damage to tank foundations and pipeline supports. Damage can also occur from falling pipe supports and impact from other equipment or structures. Even if the pipeline itself contains water, rather than hazardous materials, the loss of that water can impede firefighting capability.

Several large releases did occur from pipes, the most difficult of which to clean up was in a cold-storage food processor. In this case, a carbon-steel line was sheared, causing several thousand pounds of anhydrous ammonia to spill. This liquid rapidly transformed into the gaseous state and required a controlled, water-diluted release to the atmosphere over a period of several days to allow use of the facility again.

Several petroleum above-ground tanks suffered loss of product through breaking of connecting piping. Most contents were contained within diked areas.

Performance data from the Loma Prieta and other recent California earthquakes emphasize, however, that well-designed process pipelines can perform well in an earthquake. In those earthquakes, the damage to pipelines was usually limited to sections that were corroded or anchored at two locations experiencing large relative displacement.

TANKS

CYLINDRICAL TANKS

Large cylindrical storage tanks are vulnerable to several types of failure. "Elephant's foot" buckling failure at the base of tanks is caused by horizontal forces and often results in the loss of contents. Such failures are not limited to petroleum tanks but can occur in tanks containing everything from water to wine. The sloshing of contents can cause tank roofs to collapse or failure of the upper portions of tank walls. Sliding is common for unanchored tanks during earthquakes. If there is enough flexibility in the connecting pipelines, such movement can occur without any loss of contents. Storage tanks at industrial facilities did not leak in spite of sliding 4 inches in the Loma Prieta earthquake. Since there was not a spill, the owner has requested that the site remain unnamed. Such movement can easily lead to a loss of contents if "pitting" corrosion has occurred at the base of a tank. Even anchored tanks can move. Tanks also can settle into gravel pads, pointing to a need for concrete foundation pads. Tank walls can be damaged due to inadequate detailing at connections with external pipes, valves, and ladders. Leaks can also occur due to the failure of internal baffles.

The largest tank spill in this earthquake occurred when 1.7 million pounds of caustic sodium silicate escaped from a ruptured tank, 40 percent of which entered a storm drain and disrupted sewer plant operations downstream. A portion of this was not treated and flowed into San Francisco Bay. Even taking a tank out of service may not render it harmless! In Hollister, an empty silo fell on an adjacent building, causing extensive damage. Elevated tanks can topple if inadequately supported. Elevated tanks typically perform worse in earthquakes than ground-mounted structures.

SLOSHING

Another type of tank "failure" is not a structural failure of the tank, but a problem with open-top tank design. Earthquakes can cause sloshing of various liquids, such as plating solutions, and lead to mixing of incompatible chemicals and materials on the building floor. Such mixing can generate toxic gases. If the secondary containment trenches are shallow, continued sloshing can result in a loss of containment and material escaping to the storm drain or sanitary sewer. Although rarely documented in past earthquakes, ABAG staff documented sloshing problems in at least 40 locations from the Loma Prieta earthquake.

PRESSURE VESSELS AND CYLINDERS

Pressure vessels can shift and bounce on their supports. They can even roll over if inadequately anchored. This occurred at several locations in the Santa Cruz Mountains as a result of the Loma Prieta earthquake.

Because they are so tall relative to their diameter, 150-pound gas cylinders are prone to falling over in earthquakes. Therefore, many companies routinely chain their cylinders. This requires people to chain them, which sometimes does not happen. In addition, the restraint must be adequate. C-clamps routinely come loose in earthquakes. Flimsy chains can break, and chains anchored into gypsum board pull out. Cylinders can slip out from under single chains.

VALVES

A valve may also be the location for a material leak, although problems with valves are rare. Each incidence has its own unique circumstances. For example, after the earthquake, when power was restored hours after it had failed at a plating facility, production pumps began pumping a caustic solution into a holding tank. A float valve, which had unknowingly jammed during the earthquake, prevented the pumps from shutting down and the tank overflowed (company staff, oral commun., 1989). At another site, a small leak of ammonia occurred at a cold storage facility in Watsonville when the packing on a valve failed (Watsonville Fire Dept. and company staff, oral communs., 1990).

SHELVING

One of the biggest problems for laboratories (at schools, hospitals, and private companies) results from the falling and breaking containers of chemicals (many of which are incompatible). In addition, shelves holding chemical bottles can collapse or bow, causing the chemical bottles to fall to the ground. This problem emphasizes that shelves need to be anchored and braced.

"Biological" spills occurred in at least one hospital's specimen library in the Whittier earthquake of 1987. The worker who went to clean up the mess was overcome by the formaldehyde fumes and passed out in an adjacent hall (hospital safety manager, oral commun., 1989). A spill of similar size and materials occurred at a Bay Area hospital during the Loma Prieta earthquake. These clean-up workers were not affected by the formaldehyde because they were using proper equipment (hospital environmental safety staff, oral commun., 1989).

Problems of falling containers and shelves are not limited to laboratories. Falling containers in retail stores and warehouses also create problems. At a retail store in Mountain View, containers containing malathion and chlorine fell and mixed, resulting in the evacuation of the building (store staff, oral commun., 1990). Even homes contain liquor bottles and cleaning materials. A garage often contains petroleum products, pesticides and other hazardous materials. Pool chemicals are also common. These chemicals often spill and mix during earthquakes.

In the container category, the largest incident was caused by a set of tall racks containing a large inventory of cans of paint which toppled over in a warehouse, spilling 100,000 gallons of paint—primarily latex, but some enamel. A portion of this spill also entered the bay.

Existing "solutions" are often inadequate. Chemicals in small (approx. 1 liter) bottles have fallen off shelves with 1 to 1 1/2 inch high lips. Cabinet doors routinely open because of the lack of positive latches, allowing the contents to fall to the floor.

EQUIPMENT

Equipment can slide, causing damage to attached pipelines. Broken gas lines can ignite and cause fires. If ceiling-mounted equipment is not adequately braced, it can swing and break attached piping. An evaporator at a freezing facility had such a bracing deficiency, causing a release of several thousand pounds of ammonia in the Loma Prieta earthquake (Watsonville Fire Dept. and company personnel, oral communs., 1990).

There is a common myth that something can be "too heavy" to move. Unanchored biological safety hoods slid and refrigerators containing hazardous chemicals fell over.

Even anchored equipment is vulnerable to damage. A screw on a Nuclear Magnetic Resonance Imager (NMR) unthreaded in the Loma Prieta earthquake, allowing the NMR to become misaligned (company personnel, oral commun., 1989). Anchors can also break. Even if the anchor holds, this is no guarantee that the equipment internals will not shake apart.

Sometimes the building contents can be so large and massive that it, rather than the direct shaking, can lead to structural failure. Following the Loma Prieta earthquake, ABAG staff observed severe damage (even partial collapse) to tilt-up and light metal warehouses in Hollister caused by overturning pallets of cans containing tomato products. Interestingly, ABAG staff observed that the tilt-up buildings were being repaired while the light metal building was being torn down during a return visit in March 1990. Luckily, tomato sauce is not hazardous!

STRUCTURAL AND OTHER INDIRECT PROBLEMS

Although nonstructural failures are the most common causes of hazardous materials releases, other problems, including structural failures, severe ground failures, and indirect or "domino" effects can lead to releases. In one storeroom, a structural beam collapsed on a 55- gallon drum of liquid pesticides. The material leaked to surrounding soil, causing a large clean-up problem.

UTILITIES

Although utility malfunctions were not the primary cause of hazardous materials releases during the Loma Prieta earthquake, they exacerbated problems with control and clean-up operations.

Water supply may be disrupted for both process and fire fighting applications. Excessive water, such as from broken sprinkler lines, can also lead to problems with pyrophoric chemicals and computer-driven process control systems.

Power may be disrupted for several days, rather than just a few hours. Battery back-ups designed to provide power for a few minutes to a few hours may not be adequate or advisable. For example, because of the fear of ignition of natural gas, PG&E did not restore electrical power in some areas for several days following the Loma Prieta earthquake.

Telephone communications may be disrupted because of overuse or equipment failures (particularly with internal PBX systems). If repeaters on walkie-talkie or radio systems are not on back-up power, these systems can be crippled, as occurred at one Bay Area hospital in the Loma Prieta earthquake (environmental safety staff at hospital, oral commun., 1989). Back-up power for communications can also be inadequate. The battery back-up for the telephone equipment at San Francisco's City Hall lasted about 10 hours, but the electrical service from PG&E was not restored for several days (Frank Lew, San Francisco Bureau of Building Inspection, oral commun., 1990).

EMERGENCY RESPONSE

Several actors related to nonstructural deficiencies can contribute to emergency staff being less available than planned. Fallen lights and equipment overturn and block corridors. Offices in shambles also disrupt building evacuation. Transferring emergency responders to emergency locations becomes difficult. The emergency response staff can even be injured in the original shaking.

Manual alarms or emergency shut-off systems may not be triggered because the person responsible for pushing the buttons is under a desk. This scenario actually happened to one company in the Loma Prieta earthquake; that company is now installing shut-off devices triggered by shaking (company staff, oral commun., 1989).

Finally, emergency response facilities themselves may be damaged. In the Loma Prieta earthquake, the San Mateo County Emergency Operations Center had to be evacuated and moved upstairs in the County Administration Building for about an hour due to a leaking natural gas line. One of two sprinkler line breaks threatened essential communications equipment (Kent Paxton, San Mateo County Office of Emergency Services, oral commun., 1990).

FREQUENCY OF PROBLEMS

Known hazardous material releases occurring as a result of the Loma Prieta earthquake are documented in 184 records representing 495 actual releases. A total of 155 unique companies are listed.

Although many types of releases occurred in this earthquake, they can be classified by 11 fundamental types: laboratory spills; asbestos releases; tank, pipe, container, and valve breakage; cylinder and equipment failure; sloshing problems; transportation accidents; and indirect releases which occurred due to a "domino" effect. Table 1, below, presents data for each of these problem types.

As is evident from table 1, the most frequent type of hazardous spill occurred in laboratories. This category includes spills from shelves, countertops, cabinets, and bench-top apparatuses. It cannot be expected that for all earthquakes occurring in urbanized areas that laboratory spills would always be most frequent; because stricter seismic codes are in force in California than in many other areas of the world, other types of problems may be more likely to occur elsewhere. In the Bay Area, however, this result is predictable.

Surprisingly, the second most frequent type of observed problem was with asbestos. Surviving asbestos stock in older buildings is often overlooked as an earthquake hazard, and structural shaking can—and did—loosen this material.

Other problems which occurred somewhat frequently were due to failures of three types of objects generally containing liquids (tanks, containers, and pipes). In 40 documented cases, open-topped tanks allowed sloshing to take place.

The remaining five problem types accounted for less than 4 percent of the spills Few difficulties occurred because of equipment failures, and most of those were from electrical devices spilling mineral oil. Also surprising, given the extensive criticism of existing written guidelines for securing these items and the call for more stringent requirements, was the small number of problems that were seen with cylinders. Only two of the four reported leaks from cylinders resulted in confirmed hazardous material releases. Problems with valves were also unusual.

By examining these problems more closely, we see that certain types of releases were of concern—not due to frequency, but due to magnitude; we defined large releases as at least 100 gallons, 100 pounds, or 100 cubic yards. The percentages of these large releases are given in table 2.

Although the number of equipment failures was small, all but three of them resulted in a large release. One-third of the releases caused by sloshing were large.

MATERIALS

As expected, a wide range of hazardous materials was released as a result of this earthquake. They included fuel and petroleum products, asbestos, plating solutions, fertilizers and pesticides, acids, paints, ammonia, alkaline materials, formaldehyde, and chlorine. In several instances, however, the chemicals spilled were not identified and, therefore, were not classifiable.

CONTAINMENT

Approximately two-thirds of the available data indicates whether or not a hazardous materials release was contained. Of this information, about 57 percent of the releases were fully contained. Thus 43 percent, or 3 releases out of 7, resulted in some material reaching the local environment. Approximately 16 percent of the releases were partially contained, while 27 percent were not contained. All of these known uncontained releases involved fluids (liquids or gases) that had five general destinations (table 3).

The most common destination for these uncontained releases was the atmosphere. All of the liquids which escaped this way were either compressed and entered the gaseous state upon release or were volatile and simply vaporized over time. Flammable fluids or their combustion products, also escaped to the atmosphere by fire. Other common destinations were surface waters (via drains) and soil.

In one location, a tank containing 35,000 gallons of an unidentified acid shifted, rupturing a pipe connection and spilling both the tank's entire contents and an additional 15,000 gallons from the pipe. Although secondary containment was in place, it was inadequate, and an unknown quantity of acid reached San Francisco Bay. Similarly, another inadequate secondary containment system allowed

Table 1.—*Types of problems in verified hazardous materials releases occurring from the earthquake*

Problem	Number of occurrences	Percentage of known events
Laboratory	226	45.6
Asbestos	81	16.4
Tank	49	9.9
Container	44	8.9
Sloshing	40	8.1
Pipe (not including numerous leaks in Pacific Gas and Electric Company's natural gas distribution system)	36	7.3
Equipment	8	1.6
Cylinder	4	0.8
Valve	3	0.6
Indirect	3	0.6
Transportation	1	0.2
	495	100.0

Table 2.—*Percentages of total occurrences of large hazardous materials releases for selected problems from the earthquake*

["Large" defined as greater than 100 gallons, pounds, or cubic yards]

Type of problem	Number of large occurrences	Percentage of this problem
Equipment	5	63
Sloshing	14	35
Tank	11	22
Container	6	14
Pipe	5	13

Table 3.—*Destination of uncontained fluid releases from the earthquake*

Destination	Liquid	Gas
Atmosphere	10	11
Drain	16	0
Soil	7	0
Fire	3	0

approximately 200 gallons of a 5,500-gallon sloshing incident at a plating shop to flow to surface waters.

CLEANUP

For those releases which were contained, four principal methods were used to clean up the spills: in-house personnel, local health departments, local fire departments, and private contractors (table 4).

Most cleanup was done in-house by untrained staff or trained response teams, often in conjunction with outside help. Both health departments and fire departments from local governments were called in, and in many cases other private contractors were used. In some locations, local agencies (health and fire) were overwhelmed, creating the need for private cleanup contractors.

CONCLUSIONS

In looking at the available information on hazardous material incidents related to earthquakes, several key messages appear.

1. A moderate-sized earthquake (such as the Coalinga (1983), Livermore (1980), or Whittier (1987) earthquakes) can create serious hazardous material releases. Bigger earthquakes (such as the Loma Prieta earthquake) cause more numerous and widespread releases.

2. When working with hazardous materials in earthquake-prone areas, system design should be performed by trained and experienced professionals. When adequate earthquake protection measures are used, facilities perform well during moderate and destructive earthquakes. Based on experiences from the Loma Prieta earthquake, laboratory spills, asbestos releases, spills in plating shops, and gasoline/petroleum product leaks are specific cases for which the most concern and attention should be paid. Certainly, difficulties with hazardous material releases from earthquakes could be reduced with improvements in these systems.

3. Some existing "solutions" may not be adequate restraints in violent ground shaking. Examples include single chains on gas cylinders and 1 to 1$^1/_2$ inch shelf lips. Some existing design standards ignore seismic considerations or provide inadequate or incomplete criteria on how seismic design considerations should be considered. It is the responsibility of professionals who live and work in earthquake-prone areas to help minimize or eliminate possible hazardous materials problems from future earthquakes.

4. Additional hazards may be caused or exacerbated by lack of power (such as with tanks requiring refrigeration or pumping), water, or communications.

5. Only through keeping more comprehensive and specific records of nonstructural problems in past earthquakes can we design better solutions to future earthquakes.

Table 4.—*Frequency of response for cleanup organizations after the earthquake*

[Frequency percentages sum to more than 100 percent because, for many of the cases, more than one cleanup organization was used]

Cleanup organization	Frequency of response
In-house personnel	70.4
Local health departments	24.6
Local fire departments	11.2
Private contractor	19.6
Unknown	30.2

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APPENDIX 1: ABAG DATABASE OF HAZARDOUS MATERIALS PROBLEMS FROM THE LOMA PRIETA EARTHQUAKE

As discussed earlier, ABAG has developed a standard database file which can be used with dBASE, Foxbase, Foxpro, or Clipper. The database contains 184 records related to 495 hazardous materials incidents from the Loma Prieta earthquake. Each record contains 17 fields, each described below. The 9 fields marked with an asterisk (*) are printed in the following table. Only those records pertaining to the Loma Prieta earthquake are included.

NAMEOFEQ:	Names the earthquake which caused the release described.
LOCATION:	Identifies the general area where the earthquake occurred.
DATEOFEQ:	Specifies the date on which the earthquake occurred.
TIMEOFEQ:	Specifies the time at which the earthquake occurred.
MAGNITUDE:	Lists the accepted Richter-scale size of the earthquake.
*COMPANY:	Identifies the company which experienced the release, when possible. If no specific company name, listing is indented 2 spaces.
ADDRESS:	Gives the street address of the company involved, when possible.
*CITY:	Gives the city in which the company is located, when possible.
*COUNTY:	Gives the county in which the company is located, when possible.
*PROBLEM:	Specifies the type of problem which occurred. There are 13 categories:
ASBESTOS:	Indicates an asbestos release of some kind.
CONTAINER:	Indicates a container break and release of some contents.
CYLINDER:	Indicated a specific container with the potential of a gas release.
EQUIPMENT:	Indicates an equipment failure resulting in a release.
INDIRECT:	Indicates a release occurred due to a secondary cause.
LABORATORY:	Indicated a spill of laboratory chemicals of some kind.
PIPE:	Indicates a leak in a pipeline, main, tube, or hose.
SLOSHING:	Indicates a liquid spill over the edge of a tank or vat.
STRUCTURE:	Indicates a structural problem resulted in the release.
TANK:	Indicates a collapse, rupture, leak, or failure of a storage tank.
TRANSPORTATION:	Indicates a hazardous material problem in a transportation network.
TSUNAMI:	Indicates an earthquake-generated wave damaging facilities containing hazardous materials.
VALVE:	Indicates a release from valve failure in a mechanical system.
*MATERIAL:	Lists the type of material released in the event.
*QUANTITY:	Gives the amount of the material released, if known ("unk" = unknown).
*UNITS:	Gives the units of measure for the material released, if known ("unk" = unknown).
COMMENTS:	Further describes details of the release.
*CONTAINED:	Tells how much of the release was contained ("unk" = unknown).
CLEANUP:	Lists known companies which assisted in the clean-up.
*SOURCE:	Lists the sources from which this information was culled. Complete source citations are provided in the "Earthquake Reference List" on the ABAG diskette (Perkins, et al., 1990b). Common abbreviations are "CA OES" for California Office of Emergency Services, "FD" for Fire Department, "EPA" for U.S. Environmental Protection Agency, "PG&E" for Pacific Gas and Electric Company, and "SFRWQCB" for San Francisco Regional Water Quality Control Board.

APPENDIX 2: KNOWN HAZARDOUS MATERIALS RELEASES DUE TO THE LOMA PRIETA EARTHQUAKE

[Note: many small lab & plating spills not included]

Company	City	County	Problem	Material	Quantity	Units	Containment	Source
14 additional lab spills	various	various	LABORATORY	various chemicals	14	labs	unknown	clean-up companies
16 various companies	various	various	ASBESTOS	asbestos	30	bldgs	unknown	clean-up companies
ARCO--11 gasoline stations	various	various	TANK	gasoline	0	unk	unknown	CA OES
Kaiser Hospitals	various	various	LABORATORY	misc. lab chemicals	0	unk	unknown	conversation w/Kaiser staff
PG&E	various	various	PIPE	natural gas	0	unk	no	conversation w/PG&E
Chipman Middle School	Alameda	Alameda	ASBESTOS	asbestos	1	bldg	unknown	Alameda Unified School District
APOC Corporation	Berkeley	Alameda	CONTAINER	liquid asphalt tar	1000	gal	all	EPA\ CA OES\ Berkeley FD (Falstead)
Davlin Coatings	Berkeley	Alameda	CONTAINER	solvents	20	gal	all	EPA\ CA OES\ Berkeley FD (Falstead)
Davlin Coatings	Berkeley	Alameda	SLOSHING	mineral spirits	80	gal	all	EPA\ CA OES\ Berkeley FD (Falstead)
ECI Systems	Berkeley	Alameda	SLOSHING	plating solution	70	gal	all	EPA\ CA OES\ Berkeley FD (Falstead)
Hawkins & Hawkins	Berkeley	Alameda	INDIRECT	solvent	0	unk	unknown	clean-up company/Berkeley Fire Dept
Hustead's Garage	Berkeley	Alameda	CONTAINER	solvent	0	unk	no	conv. w/Berkeley F.D. (Falstead)
Pacific Coast Chemical	Berkeley	Alameda	CONTAINER	titanium dioxide/paint	0	unk	all	EPA\ CA OES\ Berkeley FD (Falstead)
Philadelphia Quartz (PQ)	Berkeley	Alameda	TANK	sodium silicate (caustic)	1700000	lb	some	CA OES \ Berkeley F.D. (Falstead)
Varif lo Corp.	Berkeley	Alameda	SLOSHING	plating solution	1000	gal	most	EPA\ CA OES\ Berkeley FD (Falstead)
Western Roto Engravers	Berkeley	Alameda	SLOSHING	sulphuric acid	15	gal	all	EPA\ CA OES\ Berkeley FD (Falstead)
Global Plating	Fremont	Alameda	SLOSHING	various plating chemicals	2000	gal	all	EPA \ CA OES
Electro Plating Service	Hayward	Alameda	SLOSHING	plating solution	200	gal	all	CA OES
National Sanitary Supply	Hayward	Alameda	CONTAINER	muriatic acid (35%)	250	liter	all	conv. w/Hayward F.D. (S. Fales)
east of 5625 Brisa Ave.	Livermore	Alameda	CONTAINER	various paints	5	gal	unknown	EPA \ Livermore F.D.
880 freeway	Oakland	Alameda	TRANSPORTATION	diesel/oil/gasoline	5	fires	no	Cal Trans
recycling center	Oakland	Alameda	CONTAINER	miscellaneous chemicals	5	oz	all	conv. w/Howell @ Ala Co Envr Health
Alameda Co. Environ. Health	Oakland	Alameda	LABORATORY	acid	1	quart	all	conv. w/Howell @ Ala. Co Env Health
Highland General Hospital	Oakland	Alameda	LABORATORY	benzene, hexanes	2	pints	all	Chang @ Alameda Co. Env. Health Lab
private residences	various	Contra Costa	CONTAINER	pool chemicals	0	unk	unknown	conv. w/ContraCosta Co. Health Dept
Castrol, Inc.	Richmond	Contra Costa	TANK	lube oil additive	3	gal	all	EPA \ CA OES \ Richmond Fire Dept.
Richmond Treatment Plant	Richmond	Contra Costa	TANK	digester gas	0	unk	unknown	SFRWQCB
Texaco Terminal	Richmond	Contra Costa	PIPE	diesel fuel	0	unk	all	Erickson \ Richmond Fire Dept.
Unitank Terminal	Richmond	Contra Costa	TANK	coconut oil	4000	lb	some	EPA \ CA OES \ SFRWQCB\ Richmond FD
Unocal Terminal	Richmond	Contra Costa	TANK	gasoline (3) lube oil (1)	400000	gal	most	CA OES \ SFRWQCB \ Richmond FD
Unocal Terminal	Richmond	Contra Costa	PIPE	gasoline, lube oil	500	gal	most	CA OES \ SFRWQCB \ Richmond FD
Golden Gate Ferry Terminal	Larkspur	Marin	PIPE	diesel fuel	300	gal	unknown	EPA
Specification Chromium Corp.	San Rafael	Marin	SLOSHING	zinc plating solution	50	gal	all	CA OES
W. Granger, Inc.	San Rafael	Marin	CONTAINER	enamel paint	20	gal	unknown	EPA
Western Plating & Polishing	San Rafael	Marin	SLOSHING	plating solutions	370	gal	all	CA OES
Fort Hunter-Leggett	SW-King City	Monterey	TANK	petroleum products	0	unk	unknown	Jennings @ Monterey Co. Health Dept
Beacon Station	Castroville	Monterey	TANK	petroleum products	200	gal	no	Jennings @ Monterey Co. Health Dept
winery	Gonzales	Monterey	TANK	wine	20000	gal	unknown	EQE--10/89
Hyatt Regency	Monterey	Monterey	CONTAINER	ammonia, cleaning agents	0	unk	most	Monterey Co. Health & Fire Depts.
PG&E Moss Landing PowerPlant	Moss Landing	Monterey	PIPE	natural gas	0	unk	unknown	Benuska (ed.), EQ Spectra, May 1990
PG&E Moss Landing substation	Moss Landing	Monterey	EQUIPMENT	mineral oil	200	gal	all	EPA \ CA OES \ PG&E
Unikool Cooling Plant	Pajaro	Monterey	PIPE	ammonia	1000	gal	no	CA OES \ Monterey Co. Public Health
Av Gas	Hollister	San Benito	PIPE	aviation fuel	0	unk	unknown	Hollister Fire Dept.
BP station	Hollister	San Benito	PIPE	petroleum products	0	unk	unknown	Hollister Fire Dept.
Baroness Beauty Supply	Hollister	San Benito	CONTAINER	peroxide, ammonia	4	gal	unknown	Hollister Fire Dept.
Benuellos Exxon Station	Hollister	San Benito	PIPE	petroleum products	0	unk	unknown	Hollister Fire Dept.
Hazel Hawkins Hospital	Hollister	San Benito	CONTAINER	formaldehyde	1	gal	all	Hazel Hawkins Hosp. \ Hollister FD
McAbee Trucking	Hollister	San Benito	TANK	fertilizer rinsate	4000	gal	unknown	conv. w/Monterey RWQCB (Jones)
Mini-Mart	Hollister	San Benito	PIPE	petroleum products	0	unk	unknown	Hollister Fire Dept.
R.L. Ahlport Beacon Station	Hollister	San Benito	PIPE	petroleum products	0	unk	all	Hollister Fire Dept.
Ranch Milk	Hollister	San Benito	PIPE	petroleum products	0	unk	unknown	Hollister Fire Dept.
San Benito Plating	Hollister	San Benito	TANK	chromic solution	1300	gal	unknown	Hollister Fire Dept.
residences	San Francisco	San Francisco	ASBESTOS	asbestos	2	bldgs	unknown	SF County Environmental Health
unknown	San Francisco	San Francisco	PIPE	contaminated soil	0	unk	unknown	clean-up company
Academy of Sciences	San Francisco	San Francisco	ASBESTOS	asbestos	1	bldg	unknown	SF County Environmental Health
Asian Art Museum	San Francisco	San Francisco	ASBESTOS	asbestos	1	bldg	unknown	SF County Environmental Health
Balboa High School	San Francisco	San Francisco	CONTAINER	formaldehyde	0	unk	all	CA OES\ S.F.Fire+Health+School Dist
Balboa High School	San Francisco	San Francisco	LABORATORY	misc. lab chemicals	0	unk	all	CA OES\ S.F.Fire+Health+School Dist
Cal Trans	San Francisco	San Francisco	CONTAINER	MEK/peroxide	0	unk	no	CA OES\ S.F.FD, Miranda @ Cal Trans
California Meat Co.	San Francisco	San Francisco	PIPE	ammonia	0	unk	unknown	S.F. Fire Dept \ S.F. Health Dept.
Ferry Building	San Francisco	San Francisco	ASBESTOS	asbestos	1	bldg	unknown	SF County Environmental Health
Goodman Lumber	San Francisco	San Francisco	PIPE	propane	0	unk	all	conversation w/Grey @ SF Fire Dept.
John O'Connell High School	San Francisco	San Francisco	CONTAINER	oil-based paint	5	gal	all	CA OES\ S.F. Fire Dept\ S.F. Health
John O'Connell High School	San Francisco	San Francisco	LABORATORY	misc. lab chemicals	0	unk	all	S.F. Health Dept\ S.F. School Dist.
John O'Connell High School	San Francisco	San Francisco	CONTAINER	mercury	5	oz	all	S.F. Health Dept\ S.F. School Dist.
Laguna Honda Hospital	San Francisco	San Francisco	ASBESTOS	asbestos	1	bldgs	unknown	SF County Environmental Health
Lowell High School	San Francisco	San Francisco	LABORATORY	misc. lab chemicals	0	unk	unknown	S.F. Fire+Health Depts +School Dist
Pay 'N' Pack	San Francisco	San Francisco	CONTAINER	pesticides	0	unk	unknown	S.F. Fire Dept\ S.F. Health Dept
Presidio	San Francisco	San Francisco	LABORATORY	mercury	10	lb	all	Erickson
SF Unified School District	San Francisco	San Francisco	ASBESTOS	asbestos	5	bldgs	unknown	M. Sheykhzadeh at SF Unified S.D.
San Francisco City Hall	San Francisco	San Francisco	ASBESTOS	asbestos	1	bldg	unknown	SF County Environmental Health
San Francisco State Univ.	San Francisco	San Francisco	ASBESTOS	asbestos	2	bldgs	all	SF State EH&S
San Francisco State Univ.	San Francisco	San Francisco	CONTAINER	vanillin	1	pint	unknown	SF State EH&S
University of California Med	San Francisco	San Francisco	LABORATORY	various + lab specimens	30	labs	all	conversation w/UCSF
Newark Sierra Paperboard	Stockton	San Joaquin	SLOSHING	oil	5	bbl	all	EPA \ conv. w/Mike Rogey @ Newark
S.F. International Airport	unincorp.	San Mateo	TANK	fuel	0	unk	unknown	EQE report on the Loma Prieta quake
S.F. International Airport	unincorp.	San Mateo	PIPE	chlorine	0	unk	unknown	SFRWQCB
S.F. International Airport	unincorp.	San Mateo	ASBESTOS	asbestos	1	bldg	all	SF County Environmental Health
Stanford Linear Accelerator	Menlo Park	San Mateo	SLOSHING	alkaline +cyanide +acids	500	gal	most	SFRWQCB \ SLAC (Jensen)
Builders Emporium	Redwood City	San Mateo	CONTAINER	paint,acid,flam.liq.,pest	28	gal	all	clean-up company (Scott Soden) 7/91
Leslie Salt	Redwood City	San Mateo	PIPE	concentrated brine	0	unk	no	SFRWQCB
Home Depot	San Carlos	San Mateo	CONTAINER	paint	319	gal	all	clean-up company (Scott Soden) 7/91
Kelly-Moore Paint Co.	San Carlos	San Mateo	CONTAINER	latex paint (some enamel)	100000	gal	most	EPA \ CA OES \ SFRWQCB
PG&E San Mateo substation	San Mateo	San Mateo	EQUIPMENT	mineral oil	500	gal	all	PG&E \ Earthquake Spectra, 5/90
DJ Simpson Co.	South S.F.	San Mateo	CONTAINER	lacquer	500	gal	all	EPA \ CA OES
Pri-Nova Co.	South S.F.	San Mateo	LABORATORY	muriatic acid	1	gal	all	CA OES
San Bruno Treatment Plant	South S.F.	San Mateo	PIPE	chlorine	0	unk	unknown	SFRWQCB
Westmont High School	Campbell	Santa Clara	CONTAINER	formaldehyde	2	qts	all	Westmont High School
PG&E Metcalf substation	Coyote	Santa Clara	EQUIPMENT	mineral oil	800	gal	all	EPA \ CA OES \ PG&E
private residences	Cupertino	Santa Clara	CONTAINER	pesticides	0	unk	unknown	conv. w/Central Fire District
private residences	Los Gatos	Santa Clara	CONTAINER	pesticides	0	unk	unknown	conv. w/Central Fire District
Becton-Dickinson	Los Gatos	Santa Clara	SLOSHING	copper sulfate solution	200	gal	all	conv. w/Central Fire District
T.C. English Middle School	Los Gatos	Santa Clara	LABORATORY	lab chemicals	0	unk	all	Santa Cruz Co. EH&S, Dist. office
private residences	Morgan Hill	Santa Clara	CONTAINER	pesticides	0	unk	unknown	conv. w/Morgan Hill Fire Dept.

APPENDIX 2: KNOWN HAZARDOUS MATERIALS RELEASES DUE TO THE EARTHQUAKE—Continued

Company	City	County	Problem	Material	Quantity	Units	Containment	Source
plating shops	Mountain View	Santa Clara	SLOSHING	plating chemicals	6	shops	all	Mtn. View Fire Dept. (Leinweber)
GTE	Mountain View	Santa Clara	SLOSHING	plating solutions	150	gal	most	SFRWQCB \ Mtn. View Fire Dept \ GTE
Target dept store	Mountain View	Santa Clara	CONTAINER	chlorine & malathion	11	gal	all	EPA \ Mtn. View Fire Dept. \ Target
Alza Pharmaceuticals	Palo Alto	Santa Clara	LABORATORY	solvent acids & bases	2	labs	all	SFRWQCB \ conv. w/Alza
Ford Aerospace	Palo Alto	Santa Clara	SLOSHING	plating baths	225	gal	no	SFRWQCB \ Healy @ Ford Aerospace
Hewlett-Packard	Palo Alto	Santa Clara	VALVE	caustic water (10-30%)	200	gal	no	SFRWQCB \ H-P
Hewlett-Packard	Palo Alto	Santa Clara	SLOSHING	various caustics & acids	0	unk	all	SFRWQCB \ H-P
Hewlett-Packard	Palo Alto	Santa Clara	PIPE	copper chloride/acid	10	gal	no	EPA \ CA OES \ H-P
Specific Plating	Palo Alto	Santa Clara	SLOSHING	plating solutions	500	gal	all	CA OES
Stanford University	Palo Alto	Santa Clara	LABORATORY	lab chemicals and buffers	109	labs	all	conv. w/Stanford EH&S
Stanford University Hospital	Palo Alto	Santa Clara	LABORATORY	formalin (10%)	10	pints	all	Stanford EH&S \ Stanford Hospital
Syntex Corp.	Palo Alto	Santa Clara	ASBESTOS	asbestos	0	unk	all	conv. w/J. Haag @ Syntex
Syntex Corp.	Palo Alto	Santa Clara	LABORATORY	flamm./corr./rad./biohaz.	25	labs	all	conv. w/J. Haag @ Syntex
Veteran's Admin. Med. Center	Palo Alto	Santa Clara	CONTAINER	formaldeyde	0	unk	unknown	S. Bailey & J. DeNiro @ Med Center
Veteran's Admin. Med. Center	Palo Alto	Santa Clara	LABORATORY	lab chemicals	0	unk	unknown	J. DeNiro @ Med Center
plating shops	San Jose	Santa Clara	SLOSHING	plating chemicals	6	shops	all	San Jose Fire Dept. (J. Carter)
Good Samaritan Hospital	San Jose	Santa Clara	CONTAINER	formaldehyde	1	pint	unknown	Good Samaritan engineering dept.
Home Club	San Jose	Santa Clara	CONTAINER	paints, pest., pool chem.	565	gal	all	clean-up company (Scott Soden) 7/91
Home Club	San Jose	Santa Clara	CONTAINER	paints, pest., pool acid	76	gal	all	clean-up company (Scott Soden) 7/91
Mirassou Vineyards	San Jose	Santa Clara	TANK	wine	3500	gal	unknown	conversation w/Keller @ Mirassou
O'Connor Hospital	San Jose	Santa Clara	CONTAINER	formalin	1	gal	all	O'Connor Hospital Engineering Dept.
San Jose State University	San Jose	Santa Clara	LABORATORY	miscellaneous chemicals	7	labs	some	Staley @ San Jose State Univ.
San Jose State University	San Jose	Santa Clara	ASBESTOS	asbestos	21	rooms	unknown	Steley @ San Jose State Univ.
San Jose State University	San Jose	Santa Clara	PIPE	unknown	3	leaks	unknown	Steley @ San Jose State Univ.
San Jose-Santa Clara WPCP	San Jose	Santa Clara	EQUIPMENT	methane gas	0	unk	unknown	SFRWQCB report--11/3/89
Santa Clara Co. coroner	San Jose	Santa Clara	LABORATORY	formaldehyde	0	unk	all	Santa Clara Co. OES
Santa Fe-Pacific Pipeline	San Jose	Santa Clara	SLOSHING	petroleum	100	gal	all	CA OES
Willow Glen High School	San Jose	Santa Clara	CONTAINER	hydrochloric acid	1	qt	all	Santa Clara School District
San Martin Winery	San Martin	Santa Clara	TANK	wine	0	unk	unknown	EQE--10/89
A-1 Plating	Santa Clara	Santa Clara	SLOSHING	hydrochloric acid (10%)	500	gal	most	EPA \ CA OES
AMEX Plating, Inc.	Santa Clara	Santa Clara	SLOSHING	sulfuric acid (16%)	20	gal	all	CA OES
Airco	Santa Clara	Santa Clara	CYLINDER	unknown	0	unk	no	conv. w/Santa Clara F.D. (Parker)
Devco Metal Finishing	Santa Clara	Santa Clara	SLOSHING	acidic solution (12% max)	207	gal	most	EPA \ CA OES
Haro Enterprises	Santa Clara	Santa Clara	SLOSHING	plating solution	600	gal	most	CA OES
K-Mart	Santa Clara	Santa Clara	CONTAINER	janitorial chemicals	0	unk	all	conv. w/Santa Clara F.D. (Parker)
Linde Gas	Santa Clara	Santa Clara	CYLINDER	silane	0	unk	no	conv. w/Santa Clara F.D. (Parker)
National Semiconductor	Santa Clara	Santa Clara	PIPE	aqueous solution, pH 2	50000	gal	some	SFRWQCB \ Santa Clara F.D. (Parker)
Swift Metal Corp.	Santa Clara	Santa Clara	SLOSHING	various plating chemicals	70	gal	all	EPA \ CA OES
Valley Plating	Santa Clara	Santa Clara	SLOSHING	nickel plating solution	30	gal	all	EPA \ CA OES
Varian Associates	Santa Clara	Santa Clara	SLOSHING	chromic acid	5	gal	most	EPA \ CA OES
apartment complex	Sunnyvale	Santa Clara	EQUIPMENT	natural gas	0	unk	no	conv. w/Sunnyvale F.D. (Williams)
American Hoecht	Sunnyvale	Santa Clara	TANK	phosphene gas	0	unk	no	EPA\ CA OES\Sunnyvale Public Safety
Hewlett-Packard	Sunnyvale	Santa Clara	SLOSHING	various plating chemicals	10	gal	all	EPA \ CA OES \ H-P
Home Depot	Sunnyvale	Santa Clara	CONTAINER	paint	350	gal	all	clean-up company (Scott Soden) 7/91
Kentucky Fried Chicken	Sunnyvale	Santa Clara	EQUIPMENT	natural gas	0	unk	no	conv. w/Sunnyvale F.D. (Williams)
Lockheed Miss. & Space B-102	Sunnyvale	Santa Clara	EQUIPMENT	photographic solution	36	gal	half	Lockheed
Lockheed Miss. & Space B-103	Sunnyvale	Santa Clara	SLOSHING	chromic (plating) sol'n	15	gal	all	EPA \ CA OES \ Lockheed
Lockheed Miss. & Space B-182	Sunnyvale	Santa Clara	SLOSHING	plating solution	5500	gal	most	Lockheed
U.S. Navy	Sunnyvale	Santa Clara	ASBESTOS	asbestos	0	unk	unknown	conv. w/Sunnyvale F.D. (Williams)
Verbatim	Sunnyvale	Santa Clara	EQUIPMENT	natural gas	0	unk	no	SFRWQCB
private residences	various	Santa Cruz	TANK	propane	30	tanks	no	CA Dept. of Forestry\Salsipuedes FD
private residences	various	Santa Cruz	PIPE	natural gas	4	fires	no	conv. w/Calif. Division of Forestry
Aptos High School	Aptos	Santa Cruz	ASBESTOS	asbestos	0	unk	unknown	Pajaro Valley School District
Vessey Drug Store	Aptos	Santa Cruz	CONTAINER	malathion	4	pints	all	Santa Cruz Co. EH&S, Robt. Vessey
Scarborough Lumber	Boulder Creek	Santa Cruz	CONTAINER	paint and paint products	0	unk	unknown	Santa Cruz Co. EH & S
West Coast Beauty Supply	Capitola	Santa Cruz	CONTAINER	beauty supply chemicals	4	oz	all	Santa Cruz Co. EH&S, conv. w/Murphy
unknown clinic	Santa Cruz	Santa Cruz	LABORATORY?	phenol	0	unk	unknown	Santa Cruz Co. EH & S
Cabrillo College	Santa Cruz	Santa Cruz	LABORATORY	lab chemicals	0	unk	unknown	Cabrillo College, Santa Cruz EH&S
Cabrillo College	Santa Cruz	Santa Cruz	ASBESTOS	asbestos	10	bldgs	unknown	Cabrillo College
Santa Cruz High School	Santa Cruz	Santa Cruz	ASBESTOS	asbestos	1	bldg	unknown	Santa Cruz Unified School District
Santa Cruz Metro Transit Dis	Santa Cruz	Santa Cruz	TANK	diesel fuel	1500	yd3	no	Santa Cruz Co. EH&S, S.C. Metro TD
University of California	Santa Cruz	Santa Cruz	LABORATORY	various	23	labs	most	UCSC Env. Health & Safety.
Scarborough Lumber	Scotts Valley	Santa Cruz	CONTAINER	paint and paint products	0	unk	all	Santa Cruz Co. EH&S, Matt @ store
fruit ranch (Nikano's?)	Watsonville	Santa Cruz	INDIRECT	pesticides	55	gal	all	Salsipuedes Fire Dept.
irrig./fertilization stn.	Watsonville	Santa Cruz	PIPE	liquid fertilizer	0	unk	unknown	EQE--10/89
private residence	Watsonville	Santa Cruz	CYLINDER	oxygen	0	unk	some	Watsonville Fire Dept.
Apple Growers Ice & Storage	Watsonville	Santa Cruz	PIPE	ammonia	0	unk	no	Green Giant \ Watsonville Fire Dept
Buak Fruit Co.	Watsonville	Santa Cruz	PIPE	ammonia	0	unk	no	Salsipuedes Fire Dept.
Burchell pumping station	Watsonville	Santa Cruz	CYLINDER	chlorine	150	lb	no	CA OES\ Watsonv. FD\ C.Wales @plant
Del Mar Cold Storage	Watsonville	Santa Cruz	VALVE	ammonia	0	unk	no	Watsonville FD \ W. Jordan @ co.
Driscoll Strawberry Assoc.	Watsonville	Santa Cruz	PIPE	ammonia	0	unk	no	Salsipuedes Fire Dept.
El Camino Crop Supply Inc.	Watsonville	Santa Cruz	CONTAINER	liquid pesticide	2	oz	all	Watsonville FD \ conv. w/plant mgr.
Hansen Bottling	Watsonville	Santa Cruz	PIPE	ammonia	0	unk	no	Watsonville Fire Dept.
Horsnyder Pharmacy	Watsonville	Santa Cruz	CONTAINER	various	0	unk	all	Watsonville Fire Dept.
Johnson Drug Co.	Watsonville	Santa Cruz	CONTAINER	pharmaceuticals	0	unk	unknown	Watsonville FD \ conv. w/drug co.
Ketema-Pacific Extrusion Div	Watsonville	Santa Cruz	SLOSHING	sulfuric acid & caustic	0	unk	all	Watsonville FD \ K.Bryan @ Ketema
Mobil service station	Watsonville	Santa Cruz	PIPE	gasoline	0	unk	no	Watsonville Fire Dept.
Moyer Products Inc.	Watsonville	Santa Cruz	CONTAINER	pesticides	5	gal	all	Watsonville FD \ conv. w/Emil @ co.
NorCal-Crosetti Frozen Foods	Watsonville	Santa Cruz	VALVE	ammonia	0	unk	no	Watsonville Fire Dept.\ conv. w/Co.
Pillsbury-Green Giant Co.	Watsonville	Santa Cruz	PIPE	anhydrous ammonia	5000	lb	no	CA OES \ Watsonville Fire Dept.
Puregro	Watsonville	Santa Cruz	TANK	fertilizers & pesticides	200	lb	unknown	Watson. FD \Mont. RWQCB \Salsip. FD
S. Martinelli & Co.	Watsonville	Santa Cruz	INDIRECT	fuel	5	gal	no	Watsonville FD \ L.Haskins @ co.
Santa Cruz Metro Transit Dis	Watsonville	Santa Cruz	TANK	diesel fuel	15000	yd3	no	Santa Cruz Co. EH&S, S.C. Metro TD
Value Drug Mart	Watsonville	Santa Cruz	CONTAINER	malathion (5% solution)	1	pint	all	CA OES\ Watsonv. FD\ D.Bell @ store
Watsonville Commun. Hospital	Watsonville	Santa Cruz	LABORATORY	various lab chemicals	0	unk	all	conv. w/G.Mills @ W. Comm. Hospital
Watsonville Commun. Hospital	Watsonville	Santa Cruz	PIPE	natural gas	0	unk	no	conv. w/G.Mills @ W. Comm. Hospital
Watsonville Commun. Hospital	Watsonville	Santa Cruz	SLOSHING	radiolog. process fluid	0	unk	all	conv. w/G.Mills @ W. Comm. Hospital
Watsonville Commun. Hospital	Watsonville	Santa Cruz	TANK	oxygen	0	unk	no	conv. w/G.Mills @ W. Comm. Hospital
Watsonville High School	Watsonville	Santa Cruz	LABORATORY	chemicals	0	unk	all	Watsonville Fire Dept.
Well-Pict Inc.	Watsonville	Santa Cruz	PIPE	ammonia	0	unk	no	Watsonville Fire Dept.

EARTHQUAKES AND HAZARDOUS MATERIALS—A STATE EMERGENCY MANAGEMENT PERSPECTIVE FOCUSING ON THE EARTHQUAKE

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CONTENTS

ABSTRACT

Hazardous material emergencies, more than most other hazards, require a multidisciplinary and multijurisdictional response. Combined, hazardous material incidents stemming from an earthquake can create impacts beyond the sum of the individual events. This paper explores several aspects of hazardous material emergency management as it relates to seismic activity, focusing primarily, but not exclusively, on the Loma Prieta earthquake.

INTRODUCTION

The dramatic increase in use of hazardous materials in this century has created a potential impact from earthquakes of exposure to released chemicals. One need only look back to the Loma Prieta and Whittier (1987) earthquakes to gain an understanding of the potential associated with hazardous material emergencies during a catastrophic earthquake. During the Whittier earthquake a large chlorine gas leak occurred; fortunately meteorological conditions were such that the potentially deadly gas cloud dissipated rather than affected surrounding populations. According to a study conducted by the U.S. Environmental Protection Agency there were over 125 hazardous material incidents related to the Loma Prieta event. These releases included: solvents sloshing out of open vessels to laboratory chemicals falling off of shelves at a University of California campus, to thousands of gallons of latex paint that found their way into San Francisco Bay, and beauty supply chemicals hampering the demolition of an unsafe building.

This author has concluded that hazardous material releases, although significant, were not disastrous for the following reasons:

- Loma Prieta was a major earthquake, not a catastrophic earthquake.
- Most of the impacts were to residential areas and not industrial facilities.
- Many of the mitigation measures implemented by handlers of hazardous materials were effective.
- There were most likely many incidents that were not reported.

THREAT SCENARIO

Hazardous material emergencies due to earthquakes can conceivably occur any place or time in California and will threaten the public health and safety and the environment. It is most likely that significant hazardous material incidents will occur in large population centers where hazardous materials are present in business and transportation. Other, more remote areas with lower populations but less available resources are also vulnerable. These include the Humboldt Bay area with its concentration of chlorine at pulp mills and the Long Valley caldera with its numerous military facilities. Small spills in nonindustrial (residential and rural/agricultural) locations may also result. Examples include a 10,000 pound ammonia spill at a packing plant in Watsonville during the Loma Prieta event that took several days and over a million gallons of water to mitigate; the release of pesticides, solvents, fuels, and other materials from individual residences; spills of pesticides at farms and agricultural supply facilities; and the release of cyanides and heavy metals at mining facilities.

The California transportation system including the roads, rails, and sea lanes is especially vulnerable to seismic activity. While bridges are designed and are being retrofitted to withstand earthquake shaking, other aspects of the transportation system are expected to cause hazardous material emergencies. These include accidents involving trucks transporting hazardous materials during the shaking and train derailments due to damage to tracks. Seiches and possibly tsunamis can impact ships near shore, within harbors, and along the inland cargo routes.

All of these scenarios require emergency planners to expect that a catastrophic earthquake may create a significant number of large and small hazardous material incidents that will result in the overwhelming of any one jurisdiction's ability to respond, abate, and mitigate their impact.

PLANNING

Planning for hazardous material release due to earthquakes in California is often addressed separately and lacks coordination. Figure 1 identifies many of the plans that may be encountered.

Locally each level in the planning diagram should be fully coordinated with those within their grouping and above and below. Unfortunately, this is not always the case. One technique to avoid the conflict inherent in multiagency coordination is to combine planning for the identified hazards that may be encountered within a particular area (jurisdiction or facility). In Federal parlance this is known as "all-hazard planning," while the state of California refers to this method of emergency planning as "multihazard functional planning."

IMPACTS

INFRASTRUCTURE

During an earthquake many basic services generally provided by government and utilities will likely be interrupted due to hazardous material releases. These include:

•*Transportation system.*—Roads, airports, port facilities and rail lines may be impacted. Even if the facilities or corridor are intact, incidents not related to the transportation mode may render that mode unusable. For example, a major highway and rail line run parallel in an area that is impacted by an earthquake are spared from major damage. However, a hazardous material release from a fixed facility upwind that wafts over the transportation corridor makes the highway and rail line unavailable for evacuation or transporting resources.

•*Energy.*—Liquid and compressed gas fuel tanks and lines are susceptible to explosion at the time of an earthquake and afterwards, including when gas is turned back on if pilot lights and appliances are damaged. Electrical generating plants which use fuels such as oil, natural gas, and nuclear fuels are susceptible to catastrophic releases. (Nuclear power plants are theoretically engineered to withstand anticipated tremors.) Petroleum fuels pipelines carry product over long distances and are vulnerable to failure. According to the State and Federal Hazard Mitigation Survey Team Report for the Loma Prieta earthquake, about 840,000 gallons of petroleum products were lost from their vessels at the Unocal Corporation's facility in Richmond, Calif. The material was contained in a berm and largely recovered. Foam was used to prevent ignition. The destruction of refineries and electrical systems could affect areas far outside the impacted area due to dependence on pipelines of refined product and an integrated energy grid. A large number of the phone calls reported to the Santa Cruz County 911 consisted of reports of gas leaks from residences.

•*Freshwater and wastewater facilities.*—Almost all water treatment facilities have considerable amounts of chlorine and other hazardous materials on site that could be released during an earthquake. These water treatment plants are often near residential and industrial areas. During the Loma Prieta event, 150 lb of in-service bottles containing compressed, liquefied chlorine at two city well sites in Watsonville leaked because they were attached to the building by a chain at the top one-third of the tank. These bottles sheared off the lines at the metering valves during the earthquake when the unsecured bottom portion of the tanks moved. Further, hazardous materials may infiltrate into freshwater sources and distribution lines. For example, the failure of an underground storage tank can lead to the intrusion of flammable liquids into sewer systems which can cause explosions far from the source of the release.

Wastewater facilities rely on microbial action to digest wastes. Infiltration due to the breakdown of industrial pretreatment and other sources could cause a sewage plant to cease functioning. Without wastewater capabilities and supplies of freshwater most residential areas are uninhabitable.

Failure of freshwater delivery systems will make unavailable large quantities of water for fire suppression and other hazardous material response techniques.

SPECIAL POPULATIONS

Special populations are those who are not able or permitted to act independently. Generally facilities that hold special populations are schools, hospitals, prisons, skilled nursing facilities, and so forth. These are difficult to evacuate and present other problems. For example, while many hospitals are able to isolate their ventilation systems from external plumes, hospitals and academic institutions often

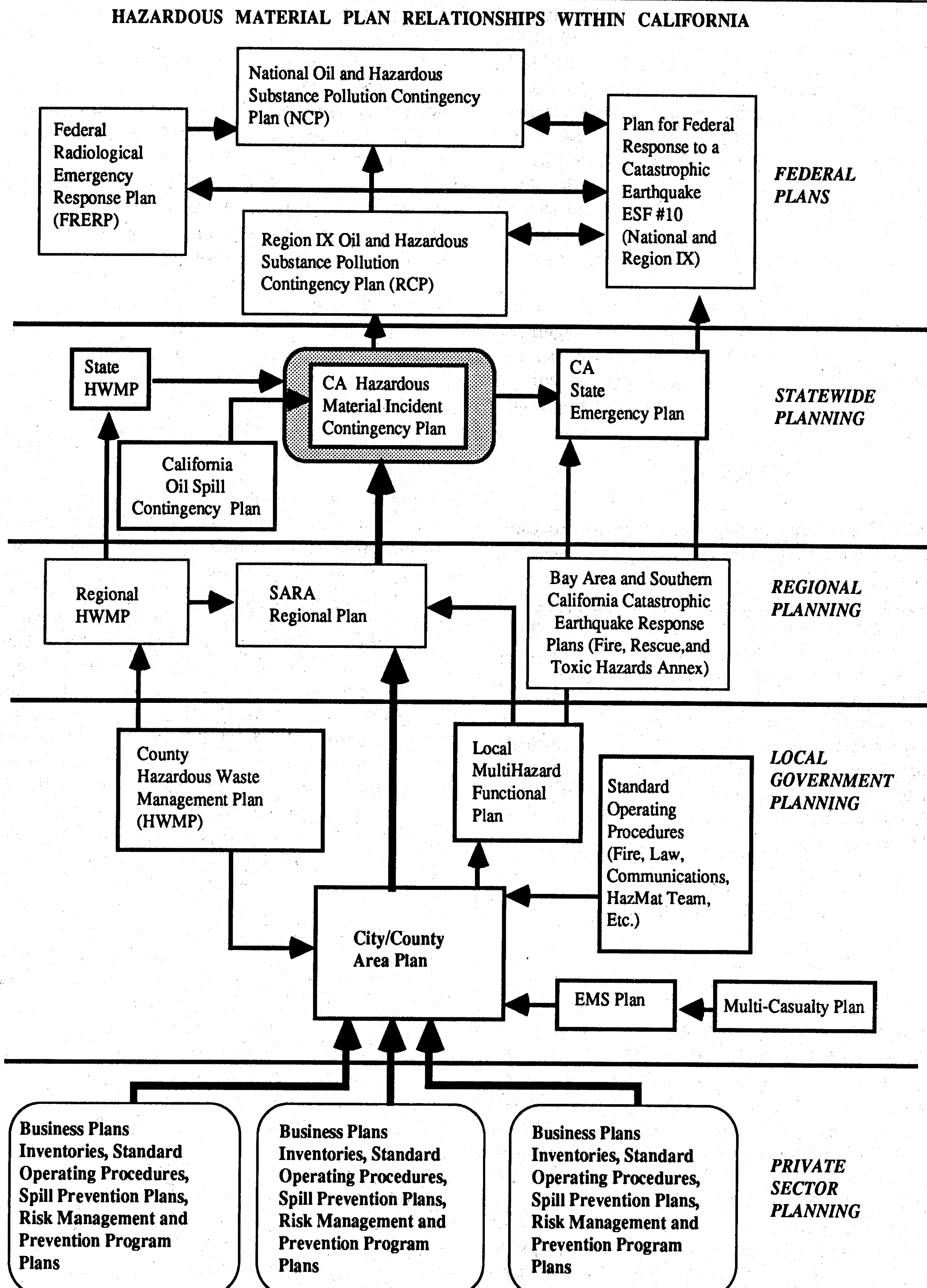

Figure 1.—Hazardous material planning relationships in California.

have large amounts of hazardous materials on site (in laboratories) which may be spread internally if spilled. If exposed patients are brought from a prehospital setting to an emergency room without adequate decontamination, the chemical may also be spread throughout the facility. During the Loma Prieta earthquake, numerous secondary schools and university laboratories experienced chemicals falling off shelves. Similarly hospitals experienced chemical releases following the earthquake, and one hospital found that its liquid oxygen tank outside the facility was structurally compromised.

RESPONSE

RESPONSE MECHANISMS

Good pre-incident planning requires the assumption that hazardous materials incidents in the area impacted by a catastrophic earthquake will quickly exceed local response capabilities. Nondedicated teams may be responding to nonhazardous material incidents (for example, extrications, structure fires) if those are the first emergencies reported. Communications systems may not be operable to receive or dispatch emergency responders. During the Loma Prieta earthquake, Watsonville's emergency communications were disrupted and the Fire Department had to set up makeshift communications capabilities with two communications vehicles in the Fire Department's parking lot for 2 hours before normal service could be restored. San Francisco experienced interruption of telephone service on the first day of the earthquake, which prevented the San Francisco Health Department from deploying. Transportation system elements may be compromised, as indicated at the Cypress Freeway and Highways 1 and 17 after the earthquake. Crews dispatched to incidents will likely have minimal backup or relief when response agencies are fully committed.

The collapse of the Cypress Freeway (an overpass near the Oakland Bay Bridge) was a major nonhazardous material incident which required a massive and protracted response. A major hazardous material incident in a similar setting, either from a fixed facility or transportation accident, would also require extended operational and logistical support during an earthquake. Further, if one of the vehicles involved in the failure of the roadway contained a hazardous material, the rescue efforts would have been delayed and made more complicated. As local resources become fully committed, some hazardous material releases may have no one to abate or mitigate the incident.

A catastrophic earthquake will require the mobilization of all of the capabilities within the state to adequately manage the multiple incidents, many of them long term. As currently envisioned in local multihazard functional plans, the Southern California Earthquake Response Plan (San Francisco Earthquake Research Project, 1990) the California Emergency Plan (published by the California Office of Emergency Services), and the Federal Response Plan, the response begins locally in the cities and counties. When resources are used up locally, requests are made by the operational areas (counties) to the OES mutual aid region. It is important that, except in limited cases, operational areas do not attempt to acquire the resources independently to avoid problems in resource management. At the regional level resources are acquired, as available, within the region. When regional capabilities are exceeded, the regional emergency operations center will contact the State Operations Center to meet outstanding current and anticipated needs. The State Operations Center will then attempt to fulfill the requirements statewide or pass the request up to the Federal level, if necessary.

The statewide hazardous material response is addressed in the Southern California Earthquake Response Plan in the Fire, Rescue and Toxics Section. The U.S. Environmental Protection Agency (EPA) is the primary agency for the Federal counterpart in the Federal Response Plan, Emergency Support Function #10 (Hazardous Material).

The State and Federal activities are designed to be colocated at the State Operations Center in order to facilitate coordination. The California Office of Emergency Services Hazardous Material Division and the U.S. EPA along with the other State and Federal agencies with hazardous material responsibilities will coordinate the disaster intelligence gathering and analysis, operations, and logistics support for hazardous material incidents during an earthquake with the other functions for the overall response.

As in other hazards (for example, wildland fires) logistical support is best carried out using the Incident Command System (ICS) or the Multi-agency Coordination System (MACS). (The Incident Command System was developed following a massive wildland fire in Southern California in 1970. What followed was a Federal, State and local project to develop a common organizational structure, terminology, communications, and span of control. ICS has been refined over the years to become the preferred management tool for management of all emergencies. Federal [29 CFR 1910.120] and state [5192 California Code of Regulations] regulations for Hazardous Waste Operations and Emergency Response require the use of an ICS at a hazardous material incident.) When resources are requested they should be by type and function so that they can be acquired and distributed appropriately. Examples include 100 pairs of butyl rubber gloves, a team capable of performing hot tapping of 10,000 lb of liquid propane with the necessary equipment, and a fully equipped hazardous material emergency response team trained to the specialist level. The use of a common organizational structure and a common terminology is key to this process. The definition of terms for hazardous material emergency response has been developed and distributed by the Equipment and Training Subcommittee of the California Chemical Emergency Planning and Response Commission (which serves as the State Emergency Response Commission, pursuant to the Superfund Amendments and Reauthorization Act of 1986, Title III).

Therefore, it is important that resources are requested with a clear and concise description so that the logistics function can meet the need from as many sources as possible. At the Emergency Operations Centers and State Operations Center request orders will be consolidated. For example, the 100 butyl rubber gloves requested from one site may be consolidated with an order for 50 Viton gloves that would be procured from a glove distributor.

Those resources that have been activated from outside the impacted area would come to a mobilization center at the periphery of the region in need of the resources. The resources would then be dispatched to staging areas close or adjacent to the actual incident site.

Some incidents will not be responded to for extended periods of time. With minimal resources available, an emergency management decision may be to evacuate the area and let the incident stabilize by itself. This would require a prioritization of which incidents present the greatest threat to the public health and safety and the environment and whether sufficient resources are accessible to be effective. A release of material that requires special equipment that is not available to emergency responders may be isolated and resources applied elsewhere. A release of an extremely hazardous substance in a remote area that would require a long term and personnel intensive response is also a candidate for self-stabilization. Emergency managers should prepare for developing decisionmaking processes for multiple incidents occurring simultaneously and exercise those scenarios.

MUTUAL AID AND FUNDING

Unlike fire, law, and public works emergencies, for which agencies use mutual aid on a regular basis and have the ability to reciprocate, mutual aid for hazardous material emergency response is often not mutual. Since hazardous material emergency response is expensive and labor intensive, many jurisdictions do not have an adequate capability to respond to incidents during nondisaster times. To address the problems of cost recovery, liability, and local coverage, many agencies have developed methods of sharing costs such as Joint Powers Agreements or have refused to respond out of their political boundaries. It is expected that during a catastrophic earthquake the economic and political constraints of nondisaster modes will fall apart, at least during the initial response period. Mutual aid will be covered under the Master Mutual Aid Agreement signed by all California cities and counties in the 1950s. (The Master Mutual Aid Agreement has been amended over the past 40 years but does not specifically address hazardous material mutual aid issues.) Further, cost recovery and the traditional funds used by responders may be augmented by other funding sources, such as the Robert Stafford Amendments to Public Law 93-288, and special appropriations made available after major events.

MITIGATION

As in all forms of emergency management, the most effective methodology of minimizing the impacts of hazardous materials incidents during an earthquake is preventing the release from occurring. Simple and inexpensive actions can be effective in preventing hazardous material emergencies. Examples include securing vessels in place and not relying on their weight to hold them in place, installing flexible piping where they make connections, separating incompatibles that may commingle, and installing automatic cutoff systems. Northern California is known for its fine wines and the area impacted by the Loma Prieta earthquake has many large and small wineries. As with other temblors in the region, a number wineries received substantial damage. Shifting of large tanks filled with product and welding failure were recorded, including the loss of about 20,000 gallons of wine. Buckling, "elephant footing" (a bulging at the base of vessels containing liquids caused by earthquakes), and piping failure are typical of all industries that contain liquids, including hazardous materials, in bulk. Damaged structures during the Loma Prieta earthquake highlighted that many of the unreinforced masonry buildings contained asbestos. This caused a hazard for demolition workers and created a waste management problem.

The best overall techniques involve eliminating and minimizing the use of hazardous materials at any one site. These are all important during any period, but the results may mean the difference between minor impacts and major damage that could result in death, human health consequences, or extensive environmental cleanup. For both business and government, mitigation is the most cost effective approach.

CONCLUSION

A catastrophic earthquake will be the ultimate peacetime test of California's ability to function. Even without the chemicals that have become so ubiquitous in our daily lives, the impacts associated with a catastrophic event will test the mettle of all segments of society. The addition of hazardous material emergencies will have far reaching impacts on the capability to respond and recover from a significant seismic event. By recognizing the hazards and addressing them forthrightly, our ability to prevent and respond will lessen but not eliminate the impacts of hazardous materials release from earthquakes.

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