Lessons Learned From the Loma Prieta Earthquake

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California's October 1989 earthquake and its effects have been thoroughly analyzed and reviewed by engineers and water utility specialists. Area utility managers interviewed by the authors believe their organizations did fairly well during and after the earthquake, but all suggested improvements that would lessen problems in a future earthquake. In this article the authors review those areas for improvement, including, among many others, internal organization, communication with other public utilities, access to supplies, emergency disinfection, construction methods, and location of distribution lines. The authors suggest that the development and regular testing of an official Emergency Response Plan is crucial if utilities are to perform effectively during the confusing and stressful circumstances of an earthquake or other disaster.

At 5:04 p.m. Pacific Standard Time Oct. 17, 1989, an earthquake measuring 7.1 on the Richter scale shook north-central California. Its epicenter was about 60 mi south of San Francisco near a mountain peak called Loma Prieta in the Santa Cruz Mountains. The earthquake was felt over a 400,000-sq-mi area for 15 seconds. Sixty-two people were killed, 3,800 were injured, and 12,000 were displaced by the Loma Prieta earthquake, which destroyed or damaged 18,000 residences and 2,600 business sites. The earthquake is estimated to have caused more than $6 billion worth of damage.

Because numerous media personnel were assembled in the San Francisco Bay area for baseball's World Series, the Loma Prieta earthquake received unprecedented media coverage. Additionally, because many engineers who specialize in the assessment of earthquake damage live in the affected area or quickly assembled there, the earthquake also received thorough analysis and review. Among those specialists were members of the American Water Works Association who focused their investigation on water utility performance. The authors were on one of several utility damage reconnaissance teams that inspected facilities and interviewed utility staff members in Oakland, San Francisco, Santa Cruz, and Hollister.

San Francisco Fire Department pumper trucks acted as makeshift booster pumps to get water to those supply areas in which numerous main breaks occurred after the earthquake Oct. 17, 1990.

This article reflects the lessons learned by water utilities immediately after the earthquake and discusses implications determined by analyses months later. The lessons to be learned from this earthquake are considered in two major categories:

- utility operations, including preparedness, response, organization, energy sources, portable equipment, communications, inventory, emergency plans, mutual aid, training, recovery planning, and vulnerability assessment; and
- engineering design and facility performance, including vulnerability assessment and design and construction of equipment and facilities to resist earthquake-induced ground motion.

The field observations and the resultant lessons learned were developed both from damage reconnaissance performed by the authors and from numerous discussions held with utility leaders since Oct. 17.

Organization

The organization and management style of a water utility significantly affect its preparedness, immediate response, and focus of attention of field personnel. All utility managers interviewed indi-

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cated that although they believe their organizations did fairly well during and after the Loma Prieta earthquake, they are working on important improvements. Organizationally, those improvements involve better definition of leadership roles, clearer statement of unit duties, improved emergency planning to cope with the complicated events of real disasters, and better preparation through "what-if" thinking and plan exercising.

Energy sources

• Water utilities should maintain close relationships with local electrical power companies to ensure that their priorities and the effect on them of potential shutdowns (as requested by state or local authorities) are understood in advance. Such shutdowns could affect a utility's headquarters, treatment plants, pumps, and other facilities. Deliberate shutdowns are often avoidable.

• Portable electrical power generators should be provided with the proper fittings and connections for each intended use. These portable generators should be periodically tested under load at each critical location where they may be used (e.g., operations centers and pumping plants).

• Permanent engine-driven electrical power generator sets should be provided at support facilities such as administrative headquarters, maintenance buildings, treatment plants, and major control centers. Petroleum fuel stations should be supplied with a permanent emergency power backup, as should laboratories, warehouses, and sump pump systems.

• Regularly scheduled periodic tests of emergency power or engine-driven systems should be conducted under load. Power units may perform well without load, but may fail when they are operated under emergency demands. These tests may be inconvenient, but they are important.

Portable equipment

Portable utility equipment needs the following attention:

• Perform scheduled preventive maintenance and test at least quarterly.

• Shelter portable light plants, chlorinators, pumps, and other equipment in earthquake-, flood- and fire-safe buildings so they will be available when needed most.

• Disperse stored portable equipment if the utility's operations area requires access via tunnels, bridges, or slide-prone routes. Preplan alternate access routes.

• Be sure personnel know how to operate portable equipment and know the equipment's limits.

Communications and public information

The following factors were determined to be necessary to ensure adequate response by the utility in the areas of communications and public information:

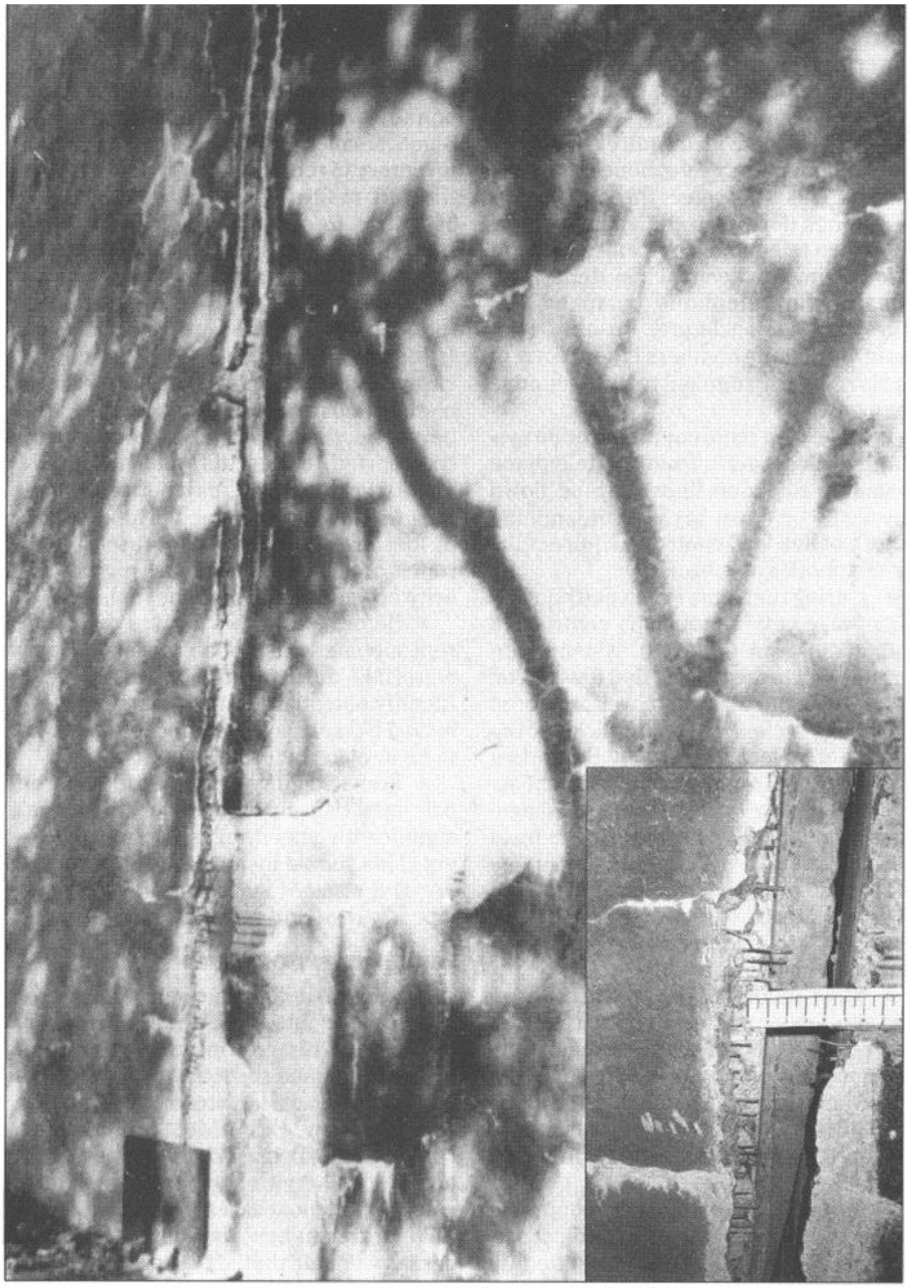
• In the calm atmosphere of predisaster operations, create fill-in-the-blank media release forms with advice from the local media. It is also helpful to acquaint media personnel ahead of time with the format of your utility's emergency information statements.

• During the disaster, use the preplanned forms to let customers know, through the media, that their water utility is on top of the problems. Provide early damage reports and frequent updates.

• Install additional "hotline" telephones before the need for them arises so that customer inquiries during an emergency will not jam the communication lines into the emergency operation center (EOC). These units must be separate from telephone equipment used in normal operations, but they may be in or near the same locations.

• Preplan employee communications for early notice of (1) how the utility is doing; (2) what employees should do; (3) what transportation options exist; and (4) other employee and family instructions and information. Taped messages are useful and should be updated.

• A separate radio frequency dedicated to emergency water operations is preferred to sharing a frequency with fire, police, medical, and other commu-



A wire-wound posttensioned concrete tank, constructed in 1964 by alternate pours of the vertical panels, in the La Purissima Water District emptied because of the collapse of its column-supported roof slab and the opening of one of the vertical panel joints (inset) after the earthquake.

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nity disaster functions. A base station, alternate base station, and emergency power supply, as well as compatible mobile and personal radios, should be part of this system.

• Provide "line load control" for continuity of emergency telephone communications. This will protect the water utility telephones (for vital facilities and personnel) when telephone companies perform a "load dump" to keep their systems functional. Your telephone company will know this nomenclature. Ensure that a list of vital phone numbers is kept current and is regularly supplied to the telephone company.

• Develop a radio communication system that is separate from the telephone system. Telephone lines may be down physically or down because of jamming or lack of line load control. Acquire cellular telephones as a backup.

• During the Loma Prieta earthquake, microwave radio supervisory control and data acquisition (SCADA) systems performed well to the degree that towers and transceiver antennas were well anchored and were backed up with quick-startup emergency electrical power. Be certain that personnel are trained to reorient antennas on towers or poles if misalignment occurs. Plan a backup for the main station. Train operations center personnel to recognize the symptoms of failure of various parts of the distribution system. This will ensure rapid resolution of system problems.

• Most utilities discovered that they had too few portable radio transceivers and quickly bought more. Smaller utilities bought radios from retail suppliers.

• Many utilities found that they had inadequate stocks of batteries necessary for battery-operated communication equipment.

• Provide a means for radio communication with police, fire, and medical services in communities served by the utility. Frequency scanner receivers can provide such emergency contact at an economical price. Testing these systems is vital to ensure smooth communications during a disaster.

• Make prior arrangements with the local office of Radio Amateur Civil Emergency Services for amateur radio operators to report to the water utility during emergencies.

• Utilities that suffer significant earthquake damage should expect visiting inspection teams from all over the world. Organizational outlines, maps, system data sheets, and other informational handouts should be available for these visitors. These teams are composed of technical personnel who can provide valuable information to the utility.

Inventory

The Loma Prieta earthquake emphasized the following important lessons related to the adequacy of supplies and ease of access to them:

• Maintain an adequate inventory of repair materials to meet the needs of reasonable disaster damage scenarios. Some smaller utilities had virtually no inventory of repair clamps and fittings for the full range of pipe sizes damaged. They had to order the needed material from suppliers and hope that another utility would provide aid in the meantime.

• Maintain a full range of petroleum fuels in on-site storage or in drums (within local fire department limits). In case of loss of normal electrical power, a method and necessary equipment should be provided so that fuel can be loaded, transported, connected, and delivered. Tank truck supplies may not reach the area for as long as a week. The delivery of fuel may be delayed because access routes are blocked or because higher-priority organizations need the fuel.

• Before a disaster, discuss with current suppliers the probable availability of materials during a major emergency. Identify potential additional suppliers. Informal bid and payment procedures need to be in place before disasters occur.

• Prepackaging and prelocation of repair materials in difficult locations can significantly speed up repair and recovery. This should include the proper number and sizes of such vital materials as pipes, valves, and repair clamps.

Emergency response plan

In general, utility emergency response plans were not well documented or tested. For this reason, utilities are encouraged to take the following steps:

• Develop or update an emergency response plan (ERP). Most utilities contacted in the Loma Prieta damage area admitted to serious shortcomings in this category. In most cases in which reasonable performance was reported, successes were attributed to the isolated existence of specific procedures or to intelligent response by employees in the absence of a plan or procedure. (A plan describes the coordination of the response of all units of an organization; a procedure describes functional details and usually applies to a specific unit of the organization.)

• Coordinate the water utility ERP with the plans of other agencies with whom the utility will cooperate during the disaster.

• Create an incident-logging procedure to record reports of and responses to events. Include descriptions, times, names of reporters, and actions taken. This procedure will provide a good working mechanism to handle first reports and to set priorities.

• Provide guidelines for water quality sampling, alternative laboratory testing, notification of the public, reports to health agencies, and related actions.

• However, remember that microbiological sampling is not a substitute for disinfection. The ERP should ensure that a sufficient inventory of disinfectant supplies will be available, even if vehicular access is limited. The ERP should include the training of personnel in the application of the disinfectant.

• Health departments may be available for counsel, but utility operators must evaluate information and decide on a course of action to ensure maintenance of water quality. A plan of action for potential problems should be determined before the disaster, and the plan should be tested periodically.

• Conduct periodic tests of the ERP to acquaint employees with disaster conditions as close to reality as possible. During the test exercises, it is vitally important to practice communications with agencies that may assist you in a mutual aid relationship.

• Submit your utility's ERP to the state office of emergency services and arrange for formal recognition of the participation of the utility under the state master mutual aid agreement.

• Participate in the utilities division activities of the state office of emergency services. If such a division does not exist, be instrumental in its creation.

• Include in the ERP a procedure for the operation of the water treatment facility when its various parts are inoperable because of earthquake damage. This should include details of how a plant might be bypassed. Discuss this procedure with public health officials.

• Create identification cards for utility personnel and provide copies of valid cards to local police agencies. This will improve checkpoint passage during emergencies.

Mutual aid planning

• Improve mutual aid planning. Be sure formal agreements exist with other agencies.

• Inform utility personnel of mutual aid plans, procedures, and the utility's expectations.

• Participate in regional interagency meetings and test exercises to identify problems and improve performance.

• Be ready to answer requests for aid by nearby military facilities or other federal or state organizations. During the Loma Prieta earthquake, such organizations were unprepared to quickly handle the number of pipe breaks encountered.

• Obtain prior authorization from fire department officials to use fire engines as booster pumping equipment. This will require cooperation between the water utility and the fire department for the provision of between-zone hydrants and portable hydrant assemblages. Both organizations may need to share the cost of procuring these portable assemblies, which are made up of pipe crosses, regu-

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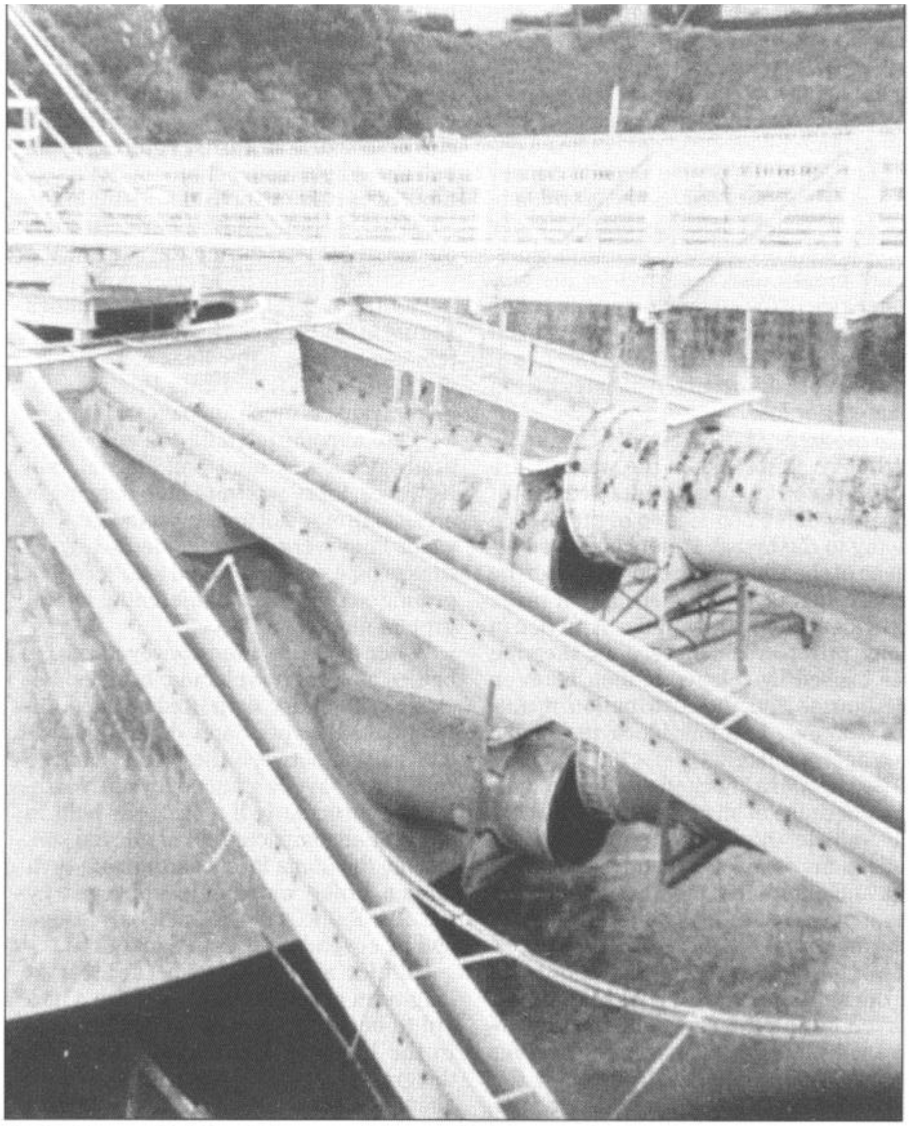

At the Rinconada Water Treatment Plant, which is located about 6 miles from the epicenter of the Loma Prieta quake, pretreatment equipment was badly damaged as a result of wave action and the lack of lateral support at the top of the equipment.

lators, valves, and large-diameter fire hoses (up to 5 in. in diameter for larger cities). Water utilities should obtain the necessary adapters for the various fire hose diameters and thread types.

• Maintain close personal relationships with leaders of nearby utilities to ensure cooperation under highly stressful conditions. Predisaster discussions regarding potential emergency situations and how the agencies will resolve them can prevent serious misunderstanding during emergencies.

Training

• Acquaint all employees with the ERP to ensure that everyone understands the plan's goals and will work harmoniously to carry them out.

• Conduct training in all of the planned emergency actions, and cross-train employees to permit the coverage of essential jobs in an emergency. Training should include regular retraining of current employees, new-employee training, ERP exercises, and problem-solving sessions.

• Train employees in emergency communication procedures. Include not only radio and telephone communications within the utility but also communications with the public via telephone and the mass media.

• Thoroughly inspect facilities immediately following earthquakes. In Santa Cruz, 1,100 gal of zinc orthophosphate used to control pH was missing. The material was discovered in the plant's treated-water channel and removed. Close inspection prevented a problem. A check valve with a failed exterior spring caused the spill.

• "Boil order" planning is important so that, when called upon, the utility is prepared for action. Issue a boil order if any of the following occur: pressure is reduced in water mains (this will create a vacuum), water main breaks are too numerous to repair quickly, sewers have overflowed to the level of the manhole covers, or indications of broken sewers exist. Tell customers to bring water to a rolling boil. Water is drinkable when it cools. If heat is unavailable, water should be filtered through gauze or clean cloth. Add one teaspoon of bleach per gallon of filtered water. Let the bleach–water mixture stand for 15 min, after which it is drinkable.

• Review "Coliform Rapid Detection Bacteriological Methods," section 9211 of *Standard Methods*.[1] Seven-hour tests may be applicable.

• Train personnel to respond only to water utility leaders, not to other supervisors of public employees who may tell them what their priorities should be. Conduct predisaster discussions with police and fire leaders to encourage chain-of-command communications. This will avoid conflicts in the field during emergencies. As a corollary, field forces need to keep their own supervisors well informed, especially with respect to valve closures. This will ensure that EOC information is accurate and that supervisory decisions are correct.

Long-term recovery planning

It is not sufficient to plan only for the immediate response to earthquakes and other disasters. Long-term recovery actions must also be considered. Recovery planning must take into account broader issues including options to repair, such as abandonment or replacement at another location; redundancy of pipelines and other facilities; relocation away from newly observed fault areas; rate structure change reflecting cost of mitigation programs; personnel training and procedures for recovery; review and update of communications systems and of standard designs that are no longer appropriate; and shared use with other agencies (e.g., emergency equipment and laboratory facilities).

In addition, the procedure for the collection of utility revenues during the recovery period should be identified. This should include turn-off and turn-on procedures for emergency periods, especially with respect to nonpayment. Record keeping during emergencies is crucial to the recovery of insurance-covered costs or state or federal emergency funds. These records should include

• first survey and quick estimate of damage to assist the state's governor in determining whether a state of emergency should be declared,

• a mechanism to distinguish between costs for system improvement and for disaster mitigation, and

• detailed description of limits of work, materials ordered (including pickup tags, trucking records, and so on). State and federal audits may not occur for three or more years. For larger

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utilities, it is probably not worth the overhead costs to try to recover costs below $3,000 per damage site.

Vulnerability assessment and mitigation of hazards

Each utility should develop a program to assess and mitigate its vulnerability to earthquake damage. This program should consist of the following steps:

- Conduct a vulnerability assessment of the utility's entire system to identify potential earthquake-induced hazards. These hazards could be grouped in one of three categories: structural, operational, or geotechnical. For example, facilities and piping systems in areas of alluvial soil or uncompacted fill are highly vulnerable to earthquake damage. This would include old shorelines (San Francisco Marina area), old river beds, and filled ponds.
- After the field assessment, itemize the utility's vulnerable elements. These could include items in the distribution system (such as valves, pumps, or lengths of piping), items in treatment plants (such as pumps, cylinders, electrical equipment, or computers), and major items such as tanks, reservoirs, and entire buildings.
- List the vulnerable elements in the order of their importance to operation of the utility. In some cases, a conscious decision may be made to accept the existing risk without mitigation. These items should be specifically identified in writing.
- On the basis of the list, plan to mitigate or eliminate the hazard to these elements, and place the plan into action.

Examples of water lines vulnerable to earthquake damage. ***Types of pipe in water distribution systems.*** The Loma Prieta earthquake demonstrated the superior performance of asbestos–cement (AC) and polyvinyl chloride (PVC) pipe over cast-iron pipe. Although it is recognized that installation of AC pipe has ceased in the United States because of potential health risks associated with its use, the following observations are reported to alleviate concerns about the performance during an earthquake of existing systems composed of this material.

For example, in the rural town of Hollister, the water utility was significantly damaged. (Hollister is located about 85 mi southeast of San Francisco and about 40 mi east of the epicenter. The San Andreas Fault is about 10 mi west of the town and the Calaveras Fault traverses the town.) The water mains in the area of the branches of the Calaveras Fault were mostly pre-1950 vintage, containing 4-in. and 6-in. cast-iron mains with lead-caulked bell-and-spigot connections. At the fault crossings, no special precautions such as flexible couplings had been taken. This was the area where significant damage occurred. In an area near the Calaveras Fault branches, the distribution mains were 6-in. and 8-in. AC pipe in 13-ft sections with rubber-ring collar connections. The average cover was 3 ft. The AC water lines had cast-iron gate valves, and the service connections were either 0.75-in. PVC pipe or 1-in. copper tubing. There was only one case of damage to AC water lines. However, 11 water main breaks occurred to cast-iron pipes. Many breaks also occurred on the customer side of the connection to the public system because of differential ground settlement in the alluvial soil. Only two of the main breaks occurred on lines 2 in. in diameter or less.

In the area of the cast-iron mains, some of the private breaks in the water distribution system occurred because of shearing of the connection of the service tubing to the house. Others occurred because of shearing of the connection of the service tubing to the distribution main. As evidenced by the significant motion in many private residences, this shearing was caused by relative motion between the houses and the distribution mains. For example, in a four-block residential area approximately 1,700 × 700 ft, at least 10 houses were knocked off their foundations because of shear failure of the cripple wall. In the same area, there were indications of pavement and curb separation and differential motion and sidewalk seam openings of 1 to 4 in. These curb, pavement, and house motions are indicative of the significant ground motion and of the settlement of alluvial soil that occurred during the earthquake. This motion and settlement caused the numerous water service connection breaks.

Where the distribution system consisted of rubber-gasketed AC pipe and PVC pipe, there was only one pipe break. That break was in a 0.75-in. PVC service connection to a house; the break occurred on the customer side of the connection. It was a pull-out break caused by the relative motion between the house and the distribution main.

The scarcity of breaks in these AC and PVC piping systems can be attributed to their inherent flexibility. In both systems the typical pipe length (13 ft) increases flexibility of the system; and the joints of both systems are more flexible than the lead-caulked joints of cast-iron pipe segments. (In AC pipe, joints typically contain rubber gaskets. In PVC pipe, the articulated joint allows for some pipe motion without breakage.)

The superior performance of AC pipe was also demonstrated in areas farther from the epicenter. In Oakland's East Bay Municipal Utility District (EBMUD), the total number of breaks in the water distribution system exceeded 120. Only one occurred in AC pipe; the remaining breaks were in cast-iron lines. Many of the cast-iron breaks were caused by compression, as was indicated by jammed bells. There were also numerous shear and bending failures. Several breaks in a 20-in.-diameter line in Oakland caused a rapid loss of water level in the EBMUD Central Reservoir. These breaks occurred because of thrust failures in the bell-and-spigot connections of 18-ft sections of cast-iron pipe laid in 1916. In the EBMUD system, the superior performance of AC pipe during the earthquake was attributable to its greater flexibility.

Location of water lines. Utilities should identify places in distribution systems where the water lines are vulnerable to damage. The Loma Prieta earthquake caused much damage to lines in areas of uncompacted fill soil and in naturally occurring sand and alluvial soil. However, there was very little damage in areas of firmer soil or compacted fill. The water lines were damaged because long runs of pipe were subjected to differential ground settlement or differential lateral ground motion.

Water lines are often conveyed across bodies of water by vehicular bridges. Because bridges are supported by piles, differential settlement and differential lateral motion between the bridge and the roadway may be caused by an earthquake, particularly if a bridge is built in areas of uncompacted fill or alluvial soil. During the Loma Prieta earthquake such motion broke water lines conveyed by the San Francisco–Oakland Bay Bridge and by several bridges in Santa Cruz.

Utilities also need to be aware that long-term ground creep may pose a hazard to buildings, equipment, and piping. In the Hayward Fault area of Oakland, the ground creeps continually at a rate of about 1/16 in. per year, causing vertical pipe to become inclined from its original position and gradual movement of the supports for the suction and discharge piping of pumps.

Design and construction of equipment and facilities

Structural facilities. Utilities should assess the vulnerability of pipelines in masonry buildings. A significant break occurred in a private water line in the city of Hollister as a direct result of structural failure of a masonry building. This occurred when the building housing the International Order of Odd Fellows collapsed into the adjacent state office building, severing a 4-in.-diameter fire sprinkler connector. The buildings were in downtown Hollister on the East Branch of the Calaveras Fault.

Both structures were unreinforced masonry buildings. The state office building had a double brick wall; the bricks were interlocked at every tenth row. The Odd Fellows building was constructed with the wood floor beams embedded into the masonry wall. During ground motion, the wood floor of the Odd Fellows building pulled out of the masonry wall. Without

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the lateral support of the floor, the masonry wall collapsed, causing the parapet to fall about 30 ft through the roof of the state office building. Because the fire sprinkler line was severed upstream of a detector, no alarm was activated. The severing of the fire sprinkler line caused significant water damage in the state office building.

A two-story reinforced masonry building about two blocks from the Odd Fellows building, also on the East Branch of the Calaveras Fault, suffered only superficial cracks in the facade, interior walls, and ceilings. That building, built in the early 1930s, was constructed with 18-in.-thick walls and a wooden frame.

It is also worthwhile to note the good seismic performance of the EBMUD administrative headquarters building in Oakland about 85 mi north of Hollister. This two-story building, about two blocks from the collapsed section of the Highway I-880 Cypress Street viaduct, suffered no significant damage because its concrete frame had been retrofitted for seismic resistance in 1972. The retrofit included improving shear wall resistance by replacing large windows with reinforced concrete closures, greatly reducing window dimension. Retrofit to the roof included slab extension and improvement of the ties between the roof and the support columns.

To summarize, reinforced masonry buildings and concrete buildings with shear walls are less vulnerable to damage by earthquakes than unreinforced masonry buildings; and masonry buildings constructed with wood (or steel) frames and buildings constructed with concrete frames and shear walls are not vulnerable to collapse caused by pullout of the floors from the walls.

Utilities should be aware that equipment in customers' homes, such as meters, is also vulnerable to earthquake damage. Typical residential structures are susceptible to ground motion–induced shear failure of the cripple wall, which occurs when there are too few shear connectors (nails, studs, sheets of plywood) between the foundation sill and the first floor.

Utilities should assess their warehouses and storage buildings for vulnerability to earthquake damage. The contents of the warehouses should be restrained so that they will not fall off shelves or topple over. In the Hollister area, two tiltup concrete warehouses and one metal frame warehouse were badly damaged when their contents (canned tomatoes) toppled and knocked down major parts of the north walls.

In one tiltup warehouse investigated by the authors, no. 10 cans of tomatoes had been stacked nine cans high on pallets stacked four deep. The stacks, about 22 ft tall, had not been provided with lateral restraint. The overall dimension of the structure was about 282 × 142 ft. Its 30-ft-high walls were constructed of 5.75-in.-thick two-way reinforced concrete slabs. In addition to the lack of lateral restraint of its contents, insufficient connections between the wall slabs and the columns made the warehouse vulnerable to earthquake damage. At some failed wall–column joints there was no evidence of any connections; at others, connections were made with #4 bars spaced 1–2 ft apart but not hooked into the column. These wall–column connections could not withstand the lateral load imposed by the northward motion of the tomato cans, and apparently that is why the north wall failed. No other walls showed any sign of distress.

Equipment anchorage. Utilities should ensure that all equipment is positively anchored. Anchor clips provide a more secure restraint than friction clips do. Seismic restraint straps can be used to anchor the underside of temporary office trailers to the ground. Additionally, electrical and communications conduit should have enough slack so that it is not stretched or broken as a result of differential lateral motion between the conduit support and the panel.

During any disaster, communications within the utility are vitally important. Consequently, utilities should ensure that communications equipment is properly anchored to lessen its vulnerability to damage.

Tanks. An earthquake's ground motion causes significant water motion. (During the Loma Prieta earthquake, the water motion in a Hollister pool was so severe that swimmers were swept out of the pool.) Earthquake-induced ground and water motion caused significant damage to a concrete tank in the La Purissima Water District. The wire-wound post-tensioned concrete tank was built in 1964 by alternate pours of the vertical panels. The earthquake caused the collapse of the column-supported roof slab and the rupture of a panel joint that appeared to have had a corrosion problem in the post-tensioning wires. The entire 1.1 mil gal of water in the tank were lost.

Wave action also significantly damaged the pretreatment equipment at the Rinconada Water Treatment Plant near Los Gatos, about 6 mi from the epicenter. To prevent this type of damage, support such equipment at the top.

Because tanks are susceptible to significant water motion, the flexibility of the water line connections to the tank is vitally important. Flexible connections should be provided that allow relative motions of at least 6 in. (vertically and in both horizontal directions) between the tank and the water lines.

Summary

The material covered in this article only scratches the surface of the subject of earthquake preparedness and hazard mitigation for water utilities. The response of water utilities to the demands of the Loma Prieta Earthquake and their openness in discussing the lessons they learned is commendable. Their sharing of experiences will help other utilities throughout the world make better preparations for earthquakes and perform better when earthquakes occur.

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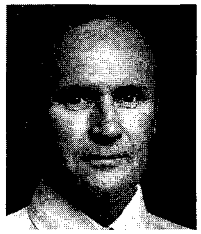

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