UTILIZATION OF RAPID POST-EARTHQUAKE DATA BY UTILITIES

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ABSTRACT

When a potentially damaging earthquake occurs, utilities (electricity, gas, water, and telecommunications) have an urgent need for information about the effects of the event so that they can make optimal decisions regarding safety and maintaining and restoring utility functionality. Modern earthquake instrumentation systems, including strong-motion recorders and regional seismic networks, can collect data and provide information products that can greatly improve this decision-making and action-taking process. Four areas of utility response to earthquakes illustrate the utilization of these data: (1) Rapidly available network and strong-motion data can provide an earthquake alert that will make utility personnel aware that an earthquake is occurring, what area of the utility's service territory is affected, and the likely extent of damaging ground motions. This alert will focus the earthquake response attention of the utility and may permit quick operational and life-safety actions. (2) Within 10 to 30 minutes after the earthquake, analysis of strong-motion data from key utility sites will provide assessments of the likelihood of damage that can be used to prioritize deployment of field personnel and guide the initial operational control and recovery plans. (3) In the same time frame, similar strong-motion-based damage assessments of transportation routes (e. g. freeways, bridges, and overpasses) along with reported damage and disruption will help the utilities plan how to get inspection and repair crews to key facilities. In addition, damage likelihood assessments of commercial, industrial, and residential buildings will indicate where utility service connections may need rapid responses to safety and secondary damage threats. (4) Within a few hours of the earthquake, pre-arranged building inspectors can use building response strong-motion measurements to help evaluate the safety of continued occupancy of structures housing critical post-earthquake response functions.

INTRODUCTION

Modern society is increasingly dependent on safe and reliable services provided by the utility industries, including electric power, natural gas, telecommunications, and water and waste-water. The utilities consist of networks of transportation conduits (primarily pipelines, conductors, and fiber-optic cables) and myriad ancillary facilities that connect the sources and destinations of utility products. Significant earthquakes in recent years have demonstrated that seismic vulnerabilities in utility networks can lead to interruptions in customer service that are dangerous to life and property, disruptive and costly to commercial enterprises, and produce long-term hardships on affected communities and people. While such long-term measures as improved seismic design practices and seismic retrofit programs can reduce the likelihood of damage, many utilities systems contain older components that are more vulnerable than their modern versions. Thus, in the coming years, utility system damage and service disruptions need to be anticipated, and utilities need to prepare for effective responses.

Accompanying the increased dependence on utility services in the Information Age have come major new developments in earthquake data acquisition, analysis and data processing, and communication of data and resultant information products (Kanamori and others, 1997). Digital strong-motion recorders, broadband seismometers and digital data loggers, high-speed and reliable telecommunications, and powerful computers and user-friendly software combine to make possible the rapid notification of earthquake occurrence and effects to emergency responders. This paper focuses on the increasingly important role that modern strong-motion data, along with other earthquake data, can play in effective and rapid earthquake response by utilities.

WHAT UTILITIES NEED

When a potentially damaging earthquake occurs, personnel in a utility who are responsible for operations, maintenance, and emergency response want to know:

- What happened: Was it an earthquake, an explosion, a plane crash? In a large utility, key personnel may be too far away from the earthquake to feel it, yet they still need to know what has happened.
- Where is the affected area: The locality affected is critical information to start the response process.
- How much damage and disruption is there: This is the most important information to utility personnel. The level of damage not only affects their response effort, but may have personal impact because of potential threats to their families and homes.

Utility personnel are practiced in gathering this emergency response information from such traditional sources as fire and police reports, field reports from utility personnel and customers, and media announcements. But the utility response can be significantly improved by additional rapidly provided data and information to speed up the decision-making processes of utilities (and other emergency responders). What is needed is to use modern scientific and engineering information based on real-time and near-real-time earthquake data to rapidly develop an accurate description of the likely state of damage of utility facilities, and other structures of interest such as transportation corridors and customer buildings. From this knowledge, utility decision-makers can take optimal action to address the damage conditions their organization is facing.

Basic earthquake data (such as recordings of strong ground shaking and of regional and broadband seismographic networks) are used to derive earthquake information such as location coordinates, focal depth, local magnitude, focal mechanism, moment tensor and moment magnitude, aftershock locations and rates, tectonic association, and others. Strong-motion data analysis adds peak acceleration, velocity, and displacement and response spectral ordinates at each instrument site; contour maps of ground motion parameters; event-specific attenuation, and others. These information products can be directly used or transformed into additional products that directly address what the earthquake did to utility facilities and other parts of the build environment. Figure 1 illustrates the relationship between earthquake data and information products and the sequence of utility responses that will be discussed in the next section.

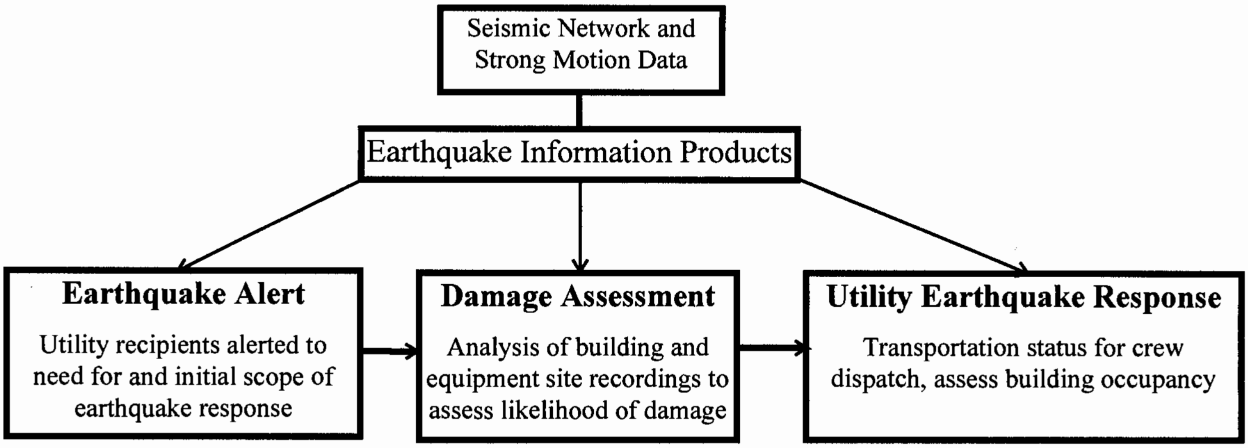


Figure 1. Rapid earthquake data used in earthquake response sequence by utility decision-makers.

RAPID DATA UTILIZATION BY UTILITIES

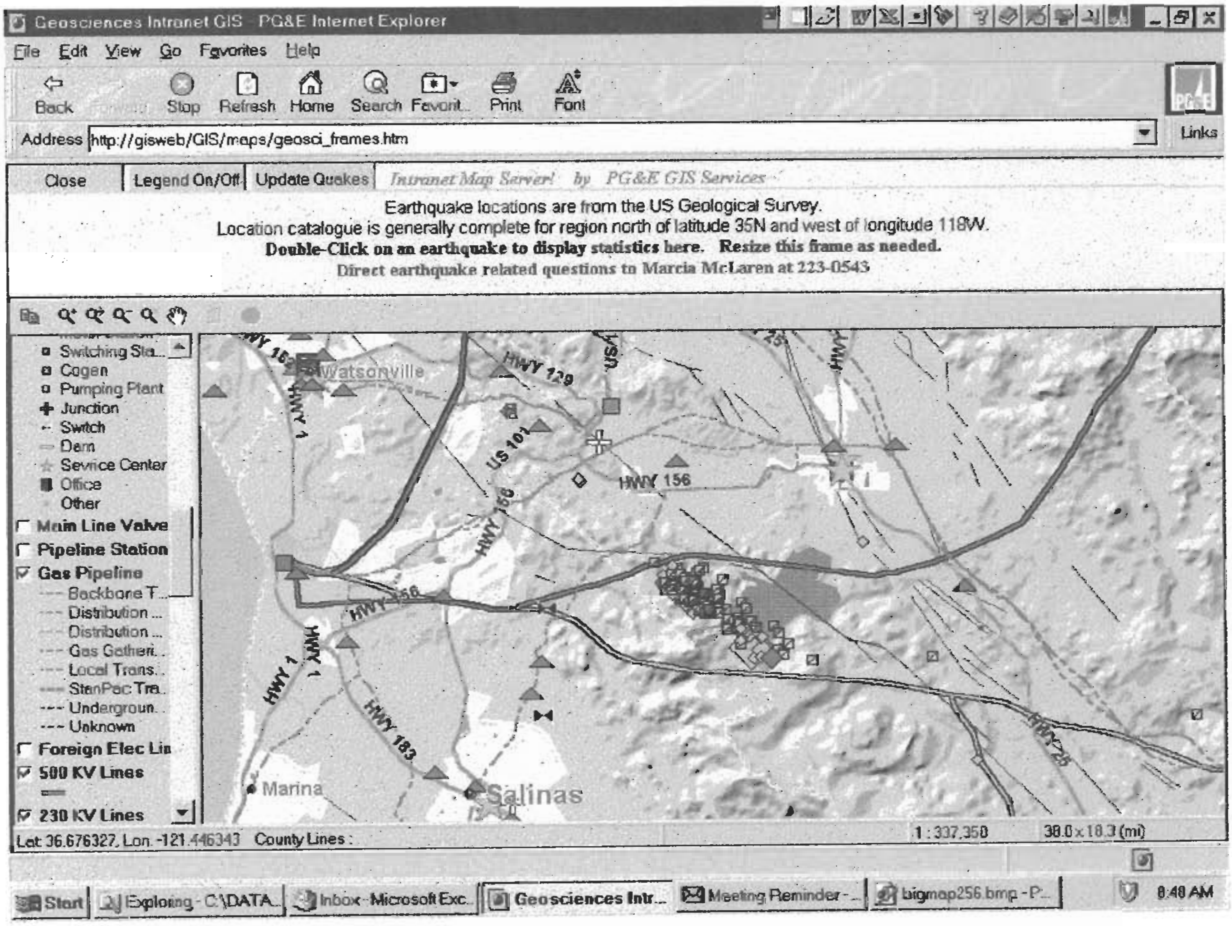
Earthquake Alert

In a modern-instrumented urban region, as the Los Angeles basin or the San Francisco Bay Area are becoming, an alert that an earthquake is occurring and information about its location (geographic coordinates) and size (magnitude) can be provided to utility recipients in a minute or two. This notification has immediate value to the recipients:

- Utility personnel know that an earthquake has just happened, rather than some other kind of disruptive or damaging event.
- The region affected by the earthquake is known. Current systems incorporate paged or e-mailed notification information into utility computers or GIS map servers, and distribute the combined earthquake and facilities location information within the utility via its intranet. This provides a vivid picture of where the earthquake occurred with respect to utility facilities. Figure 2 shows an example of a recent earthquake

near San Juan Bautista east of Monterey Bay plotted on a map along with locations of gas and electric power facilities, faults, and highways.

- From the earthquake location and magnitude, computations using attenuation relations can give an initial map of the areal distribution and severity of ground shaking. The utility personnel can gain a graphic understanding of the extent of the region affected by the earthquake.



Earthquake locations are from the US Geological Survey.
Location catalogue is generally complete for region north of latitude 35N and west of longitude 118W.
Double-Click on an earthquake to display statistics here. Resize this frame as needed.
Direct earthquake related questions to Marcia McLaren at 223-0543

Address http://gisweb/GIS/maps/geosci_frames.htm

Lat 36.676327, Lon -121.446343

Figure 2. Map of August 12, 1998, M5.4 earthquake near San Juan Bautista plotted on map of PG&E gas and electric facilities. Light lines are faults (note that the earthquake sequence is systematically located about 2 miles southwest of the San Andreas fault zone due to local seismic velocity effects; the earthquakes actually occurred along the San Andreas zone).

The initial rapid notification information serves to immediately initiate the utility organization's response to the consequences of the event. The CUBE and USGS/UC Berkeley notification systems are excellent examples of providing increasingly rapid information.

Because the utility response is people- and decision-intensive, the faster they know the area within which a serious event has taken place, the more accurate their response can be.

It is desirable from the utility perspective to have faster initial information made available on earthquake location and size, instead of delaying while getting highly accurate values. A quick location that is accurate within 5 miles is close enough for the initial utility response to begin. It is particularly important to quickly distinguish between earthquakes with significant damage potential (M6½+) and those that may be locally damaging but that are not large enough to affect a widespread area (M5½ to 6½). It would be useful to develop a fast, approximate measure of earthquake size, even if the size were described by words (e.g. "moderate, big, very big") or magnitude ranges (e.g. M5±, M6±, or M5½ to M6½).

If the earthquake alert is prepared and distributed sufficiently quickly, it becomes an early warning of strong earthquake shaking for locations relatively far from large earthquakes. Possible benefits of such early warnings are enabling employees to get out of potentially dangerous working situations, or alerting remote backup operational facilities to take over for possibly threatened primary facilities. However, utilities need to practice receiving earthquake alerts, and to gain experience and confidence in using such information before the implementation of substantial early warning actions will be acceptable. Utility operators are reluctant to take significant preemptive operational actions that result in customer services being interrupted. There are likely to be major liability issues if electric power is cut off in a region that is threatened by strong shaking, for example. In general, any responsive actions taken as a result of receipt of an earthquake early warning will need to be preceded by extensive training and practice by employees, and the benefits of such actions will need to be clearly established.

Rapid Damage Likelihood Assessment for Facilities

As noted previously, the information that utility personnel want to have immediately after an earthquake is the state of damage of utility equipment (substations, pump facilities, etc.) and of office buildings and buildings housing repair equipment and spare parts. Since many facilities and buildings are not routinely occupied, particularly at night or on weekends, on-site personnel may not be available to conduct immediate inspections. If personnel are on-site, they may be initially occupied with injuries or other immediate safety matters. Strong-motion instruments located at the facilities and buildings provide a means to perform a remote damage likelihood assessment. Using a free-field recording taken at the facility, the ground motion can be compared with previously determined fragility curves for the equipment and structures at a site. The comparison would take about 15 minutes after the earthquake begins, allowing time for data transmission from 10 or so key sites in the affected region. The fragility curves indicate probability of damage as a function of ground motion parameter for specified damage states (e.g., porcelain break for a transformer, limited entry for a building). Figure 3 illustrates this comparison for a high-voltage transformer shaken at 0.5g. While this is presently an approximate procedure due to the uncertainties in available fragility curves, it is a useful first assessment of what the damage is at a utility site, prior to conducting field inspections, which may occur several hours later.

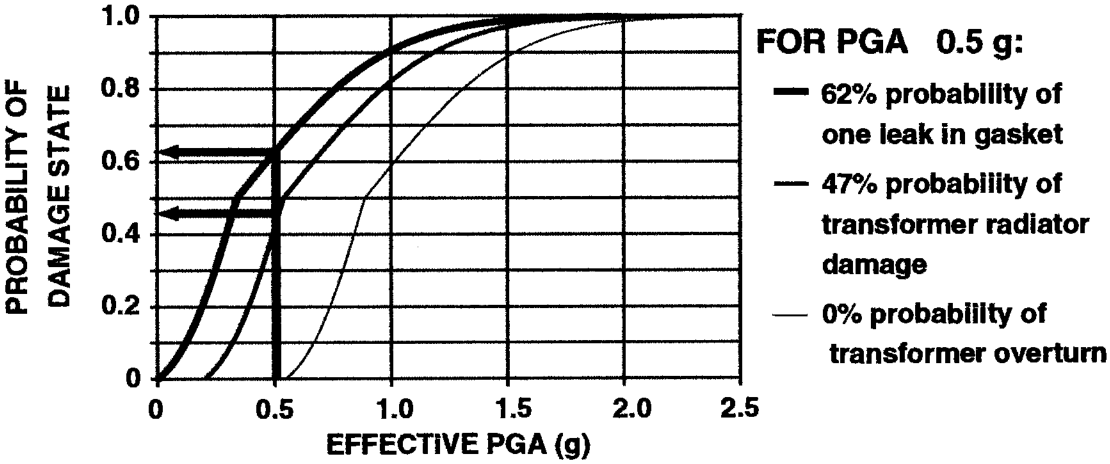


Figure 3. Illustrative fragility curves for three damage states of a 500 kV transformer. The effective PGA value includes the effects of magnitude and site period.

Detailed contoured ground shaking maps can be constructed that include strong-motion data provided by many public and private sources, including utilities. For utility sites that do not have strong-motion instruments, ground motion estimates can be obtained from these maps. These estimates can them be used in fragility comparisons to assess likely damage. This approach depends upon having maps with sufficient input ground-motion observations to provide a reasonably accurate estimate of site ground shaking.

Installation of strong-motion instruments at utility facilities provides a valuable additional benefit in that ground-motion data from earthquakes can be used to refine the fragility functions for the equipment and buildings exposed to strong shaking from future earthquakes. Along with the site ground-motion recording, it is critical to accurately compile characteristics of the facility or equipment damage that occurs along with the lack of damage.

Damage Likelihood Assessment of Transportation System and Customer Building Classes

The response of a utility to a damaging earthquake is also dependent upon the utility having information about the status of other parts of the built environment. Of particular importance is the operational status of the freeways, roads, and streets in the earthquake-affected area immediately after the event. Emergency access is needed to shut off downed power lines, or shut in leaking gas lines or water mains. The California Department of Transportation has instrumented a number of bridges and overpasses; as for utility facilities, rapid analysis of these data can result in remote assessments of the likely damage to the structures and the prudence of continuing to use them or not. When combined with on-site reports of damage, useful early information about traffic access can be provided to utilities.

It is also valuable information for the initial utility response effort to have a preliminary picture of the localities in the earthquake-affected area where there are concentrations of building damage. These are places where there is likely to be extensive damage to customer utility connections, threatening life and property, and requiring immediate utility attention.

Post-Earthquake Building Inspection for Occupancy

Utilities, medical providers, and other organizations with critical post-earthquake emergency response functions have recognized that certain occupied buildings or buildings containing vital information or equipment may be closed by authorized building inspectors, or may be evacuated by frightened employees, some of who have critical post-earthquake response roles. To address this problem, some organizations have established Post-Earthquake Inspection Programs to facilitate the access to and use of essential buildings. Qualified engineers are contracted by the owner and pre-assigned to automatically inspect key facilities given certain earthquake location and magnitude criteria. They will have the benefit of pre-earthquake evaluations and post-earthquake inspection manuals, and will be able to tag the facilities regarding occupancy (red/yellow/green) under authorization from the local jurisdiction.

To assist the inspecting engineers, certain buildings can be instrumented to provide time history and response spectral data on the actual behavior of the building. The engineer can thus assess the potential for concealed structural damage that may make the building too dangerous for further occupancy, or that may be sufficiently minor to permit necessary emergency access or even full normal occupancy. The data will be available in the same time frame that the inspector arrives at the facility, within an hour after the earthquake.

ADDITIONAL COMMENTS

False Alarms

The providers of rapid earthquake information are sincerely concerned about the occurrence of false alarms—issuing an announcement of a large earthquake that has not occurred—or failing to report the occurrence of a large event. For the foreseeable future, utilities will most likely rely on their practical experience with their own status and information notification systems, and expect occasional problems and errors coming from the earthquake notifiers . It is simply not prudent for a utility to initiate aggressive or expensive initial response efforts on the basis of an earthquake alert that is not consistent with or verified by other available information. It is incumbent on the organizations issuing rapid notifications to have in place reasonable systems to detect false alarms and to rapidly correct them.

The problem of not issuing an accurate rapid report for a major damaging event that actually occurs has been the case for the 1989, 1992, and 1994 events in California. Recognizing this unfortunate history, the various seismological organizations have taken extensive efforts to build “earthquake-proof” systems. While these efforts are commendable, it is still possible for failures to occur. As the current notification systems continue to be installed and operated, additional opportunities to improve their reliability will no doubt be found and instituted. It should be the responsibility of the utilities and other recipients of rapid earthquake information to continue to use the notifications to gain experience in how to best apply them, and to let reliance on notifications grow with that experience.

Rapid Earthquake Information as a Service

Rapid earthquake information capabilities have been largely developed in the research seismology community. For some years, these capabilities have been provided to a limited number of recipients on a somewhat experimental basis. These arrangements have been helpful in learning how to improve essentially all aspects of the notification systems. With the development of the FEMA-supported TriNet project in Southern California, it is time to begin to view the provision of rapid earthquake information, from initial alerts, to shake maps and site-specific ground motions, to final archived data sets, as a public service, not an add-on to a research program. Instituting this distinction will clarify many of the uncertainties that currently exist in defining the responsibilities of the issuers and the recipients of information, in determining the sources of financial support for the service versus related research, and other issues. Shifting to a service-oriented perspective should result in a more professional and customer-oriented relationship between issuers and recipients. Federal/state agency partnerships with research/educational organizations appears to be developing into a good model for establishing an "earthquake service" that draws on the best of both academic and agency capabilities.

Utility Responsibilities

Users of earthquake information must take responsibility for effectively understanding and applying the data and information they receive. This includes training and exercises in simulating the use of the rapid notification and damage likelihood assessments. The more frequent occurrence of small events help keep both the notification providers and notification users practiced.

CONCLUSIONS

Utilities and the communities they serve are at the dawn of a new era in earthquake response, as they begin to use the earthquake information products from modern seismic instrumentation. Through the application of such key technologies as digital strong-motion instruments, alternative reliable telecommunication pathways, powerful computers and software, and digital maps for displaying earthquake information, utility personnel will receive faster and more accurate information on earthquake occurrence and damage to be used for improved utility decision-making. This new capability is consistent with the increasing societal value placed on utility safety and reliability.

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