GUIDELINES FOR UTILIZING SHAKEMAPS FOR EMERGENCY RESPONSE

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ABSTRACT

This paper describes portions of the document, *Guidelines for Using Strong-Motion Data for Postearthquake Response and Postearthquake Structural Evaluation*, currently being developed by the Applied Technology Council (ATC) for the California Division of Mines and Geology's (CDMG) Strong Motion Instrumentation Program (SMIP) 2000 Data Interpretation Project. The focus of this paper is on the use of computer-generated ground-motion maps, i.e., TriNet ShakeMaps, for emergency response applications. Two companion papers presented at the SMIP01 Seminar, by C. Rojahn et al. and by A.G. Brady and C. Rojahn, focus, respectively, on the overall description of the *Guidelines* and on the use of strong-motion data for structural evaluation. The procedures outlined in this paper are a summary of the information contained in the current draft of the document, which addresses ShakeMap applications for ten areas of emergency response. The general framework is given here, with illustration for one application – damaged buildings and safety inspections.

INTRODUCTION

The development of the document, *Guidelines for Using Strong-Motion Data for Postearthquake Response and Postearthquake Structural Evaluation*, is a 2000 California Strong-Motion Instrumentation Program (CSMIP) Data Interpretation Project in progress by the Applied Technology Council (ATC) under contract to the California Division of Mines and Geology (CDMG). The primary objective of the *Guidelines* is to improve the state of the practice and facilitate improved emergency response and structural evaluation with the utilization of near real-time computer-generated ground-motion maps and strong-motion instrument recordings. The intended audience of the document includes emergency managers, contingency planners, government officials, risk managers, and practicing engineers.

The *Guidelines* focus on two primary topics. The first concerns the use of computer-generated ground-motion maps, such as TriNet ShakeMaps, in post-earthquake response. The intended use of this part of the document is to provide guidance on the development and implementation of applications using ShakeMap for emergency response. The second topic concerns the rapid utilization of near real-time instrumental recordings from ground and structure stations, so that the data will be particularly useful for post-earthquake response and evaluation of structures.

This paper is one of three papers presented at the SMIP01 Seminar that describe the in-progress development and anticipated contents of the document, *Guidelines for Using Strong-Motion Data for Postearthquake Response and Postearthquake Structural Evaluation*, to be published as the ATC-54 Report (ATC, in preparation). The focus of this paper is on the first of the two primary topics of the *Guidelines* discussed above – the use of computer-generated ground-motion maps, such as TriNet ShakeMaps, in post-earthquake response. The companion paper, "Guidelines for Utilizing Strong-Motion Data and ShakeMap Data in Post-Earthquake Response", by C. Rojahn, C.D. Comartin, and S.A. King provides an overview of the *Guidelines*, including the purpose, scope, development process, and contents. The second primary topic of the *Guidelines* – the use of strong-motion data for structural evaluation, is covered in the companion paper, "Guidelines for Utilization of Strong-Motion Data for Evaluation of Structures", by A.G. Brady and C. Rojahn.

This paper begins with a description of computer-generated ground-motion maps, in particular the TriNet ShakeMaps. The procedures for using ShakeMaps in post-earthquake response are discussed next, including how the procedures were developed, general principles and guidelines, essential information and basic steps, and limitation on the use of ShakeMaps. The *Guidelines* address ShakeMap applications for approximately ten areas of emergency response. Due to space limitations in this paper, the application description is limited to only one area – damaged buildings and safety inspections.

The material contained in this paper forms a portion of the *Guidelines* document, which is currently under development. The information has not yet been reviewed by intended users of the *Guidelines*, the CSMIP staff, the California Seismic Safety Commission's Strong Motion Instrumentation Advisory Committee (SMIAC), the ATC-54 Project Resource and Advisory Panel, or others, and as such should be considered preliminary and subject to revision.

COMPUTER-GENERATED GROUND-MOTION MAPS

In that portion of the *Guidelines* pertaining to computer-generated ground-motion maps, the focus is on ShakeMaps, produced by the TriNet program. TriNet is a five-year collaborative effort among the California Institute of Technology (Caltech), the United States Geological Survey (USGS), and the California Division of Mines and Geology (CDMG) to create an effective real-time earthquake information system for southern California and eventually northern California. A complete description of the history, background, and products of TriNet is available on the web site **www.trinet.org**. Most of the information described in this section is based on material contained in the ShakeMap section of the TriNet web site.

TriNet ShakeMaps are a representation of the ground shaking produced by an earthquake, an example of which is shown in Figure 1. They are generated automatically following moderate and large earthquakes. These are preliminary ground shaking maps, normally posted within several minutes of the earthquake origin time. They show the distribution of peak ground acceleration and velocity, spectral acceleration at three periods, and an instrumentally-derived, estimated Modified Mercalli Intensity. The Instrumental Intensity map is based on a combined regression of recorded peak acceleration and velocity amplitudes. In order to stabilize contouring and minimize the misrepresentation of the ground motion pattern due to data gaps, the data are augmented with predicted values in areas without recorded data. Given the epicenter and magnitude, peak motion amplitudes in sparse regions are estimated from attenuation curves. As the real-time TriNet station density increases, the reliance on predicted values will decrease.

In addition to producing near real-time ground shaking maps, the TriNet ShakeMap program also produces earthquake scenario ground shaking maps. The earthquake scenarios describe the expected ground motions and effects of specific hypothetical large earthquakes. The maps are used in planning and coordinating emergency response by utilities, emergency responders, and other agencies. The scenario earthquakes provide a more realistic example for training exercises and loss estimation studies, and can be generated for any hypothetical or historic earthquake. The steps involve assuming a particular fault or fault segment will (or did) rupture over a certain length, estimating the likely magnitude of the earthquake, and estimating the ground shaking at all locations in the chosen area around the fault. The ground motions are estimated using an empirical attenuation relationship, which is a predictive relationship that allows the estimation of the peak ground motions at a given distance and for an assumed magnitude.

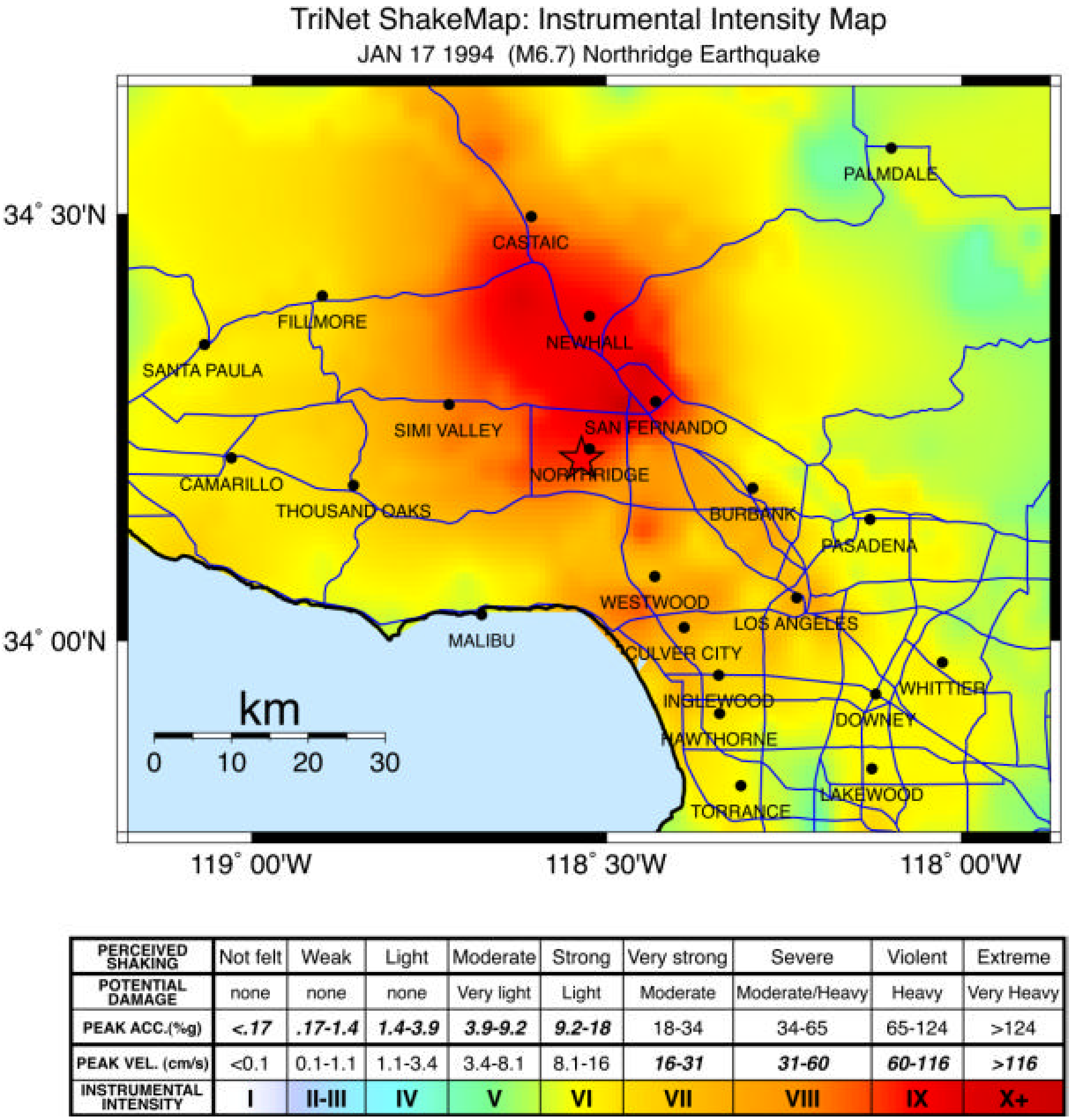
The web address for the TriNet ShakeMaps is **www.trinet.org/shake/**. Users of the *Guidelines* are encouraged to visit this site often, not only for the near real time ground shaking maps, but also for the new or improved products that are periodically added to the web site.

PROCEDURE FOR USING COMPUTER-GENERATED GROUND-MOTION MAPS IN POST-EARTHQUAKE RESPONSE

As discussed above, the *Guidelines* address the development and implementation of applications using ShakeMap for post-earthquake response, Specifically, the applications focus on the following emergency response topics:

- extent of damaged buildings and planning related safety evaluation inspections
- condition of hospitals and other emergency response structures
- impact on utility systems and transportation networks
- extent of liquefaction, landslide, and inundation
- casualties and associated need for victim extraction from damaged structures
- extent of debris from collapsed structures
- sheltering needs
- extent of possible hazardous materials release
- preliminary economic loss estimates
- management of insurance claims

With respect to these applications, the *Guidelines* are intended to help users evaluate existing practices and policies, plan for future improvements, coordinate mutual aid, allocate resources, and design and budget for mitigation and planning exercises and programs.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1 *TriNet ShakeMap for the 1994 Northridge, California earthquake (image provided by David Wald, U.S. Geological Survey).*

Background

The *Guidelines* were developed through a multi-step approach, which is described in more detail in Appendix A of the document and in the companion paper by C. Rojahn, C.D. Comartin, and S.A. King presented at this seminar. The guidance provided on how to develop capabilities for using computer-generated ground-motion maps in post-earthquake response is the result of many months of effort by the project team members. They first identified and described the state-of-the-art in available data resources, building and lifeline inventory data, geographic information system (GIS) hazard maps, and loss estimation tools. Next, for each of the ten emergency response topics listed above, they defined the state-of-the practice at the state, regional, and local levels. Based on this information, primarily gathered through interviews with key individuals, an assessment was made of the existing capabilities in emergency response planning, i.e., how the identified available data resources are currently being used and how they might be utilized more effectively.

In the *Guidelines,* the procedures for using computer-generated ground-motion maps in post-earthquake response are described for each of the ten emergency response topics. This information is prefaced by a section that outlines the general framework for use of near real-time data, covering material that is common to the ten areas of emergency response. The general framework includes the essential information and basic steps, as well as the limitations to the ShakeMap applications, and is summarized below.

General Principles and Guidelines

There are several basic concepts related to the use of strong ground motion maps and data for post-earthquake response. The focus here is on emergency response – the decisions that are made immediately after an earthquake has occurred. Time and effective communication are critical, as the needs for quick and reliable decisions and information dissemination are typically the most important issues facing emergency managers. Given an earthquake occurrence, questions such as the following need to be immediately addressed:

- What has happened and where?
- How bad is it?
- How can I allocate my resources most effectively?

As discussed briefly in this paper and more thoroughly in the *Guidelines*, the use of near real-time ground-motion maps can provide information that helps answer these questions.

Essential Information

Near real-time ground-motion maps (i.e., TriNet ShakeMaps) provide excellent information on the distribution of shaking in the region affected by the earthquake. Post-earthquake response decisions can be made based only on the ground shaking information, however; these decisions require various levels of inference and are not making the most effective use of the ground shaking data. Combining the ground shaking information with other types of data for the region will allow for more reliable and meaningful emergency response decisions.

The basic information that is essential for making quick and reliable post-earthquake response decisions includes:

- Ground Shaking Data – information about the distribution of ground shaking in the region
- Facility Inventory Data – information about structures in the region
- Demographic Data – information about people who live or work in the region
- Vulnerability Data – information about how structures and people are typically affected by various levels of ground shaking

The most efficient procedure for storing, combining, and displaying these various types of data is through the use of a geographic information system (GIS). A GIS is similar to a regular database management system, except that in addition to dealing with tables of data, it has the added capability of storing and processing data on maps. Information on individual maps can be overlaid (or combined to form new maps) to show relationships and help with decision making, especially those that involve locations in a region.

A GIS with complete databases for a region is the ideal, but not often the reality, of those involved with post-earthquake response. The time and financial resources involved with setting up the system with required maps and data can be quite substantial, even for a small region. The procedures described in the *Guidelines* assume the most basic level of user in terms of experience and know-how, but not in terms of access to computer and data resources, as well as GIS or relational database management software. The purpose of the *Guidelines* is to outline the procedures for the most effective use of strong-motion data and maps, which in almost all cases involves combining the strong-motion maps and data with other types of data for the region.

Basic Steps

The basic steps for effectively using computer-generated ground-motion maps in post-earthquake response are outlined in this section. They are general, as the more specific information is described in the sections of the *Guidelines* that deal with the individual emergency response topics. Ideally, some of these steps would be done before an earthquake occurs, or the entire process could be done as a training/planning exercise. The steps include:

1. Download the relevant ShakeMaps that illustrate the distribution of ground shaking parameters in the region.

2. Assemble the relevant inventory data, such as building portfolio information, Census data, street maps, and utility system maps, that can be overlaid or combined with the ShakeMaps to identify areas or facilities subjected to high levels of shaking.

3. Estimate damage or loss to regions or facilities based on the combination of ground shaking levels and inventory information. Some users will rely on a specific loss estimation methodology or software for this step. The three most commonly used ones,

HAZUS (NIBS, 1999), ATC-13 (ATC, 1985), and EPEDAT (Eguchi, et al, 1997), are described in Appendix B of the *Guidelines*.

4. Combine or overlay additional inventory data, such as emergency vehicle locations, shelters, and hospitals, as needed to provide information for decision making.

Limitations

There are several general limitations that should be kept in mind when using the computer-generated ground-motion maps for post-earthquake response. The most important issues include the following; more specific ones are discussed in the sections of the *Guidelines* that deal with the individual emergency response topics:

- ShakeMaps are generated automatically after moderate and large earthquakes and are not initially checked by humans. They are based on recorded data and augmented with predicted values in areas without a sufficient number of recording instruments. It is possible that the distribution of shaking will be biased towards a high anomalous recording, such as the Tarzana record in the 1994 Northridge earthquake.

- Following an earthquake, users need to be able to rapidly update data and mapped information based on reports from the field and revised ShakeMaps.

- Inventory data needs to be kept up to date in terms of accuracy and completeness, especially with respect to locations and facility information.

APPLICATION TO DAMAGED BUILDINGS AND SAFETY INSPECTIONS

For each of the ten areas of emergency response listed previously, the *Guidelines* describe the procedures for effectively utilizing ShakeMaps for post-earthquake response by discussing the typical users and needs, the potential data resources, and the potential models or data analysis procedures. Examples, real or hypothetical, are included to illustrate the concepts. The remainder of this paper summarizes the information contained in the *Guidelines* for one of the ten areas of emergency response – damaged buildings and safety inspections.

Typical users and needs

Near real-time ground-motion data will be most useful in aiding engineers or officials in local jurisdictions with prioritizing building inspections within the first day or two following an event. In this application, the focus is on the use of ShakeMaps for help with making quick and reliable decisions, typically for a large group of buildings or for all buildings within a specific region. More advanced structural modeling for individual buildings using recorded instrumental data is covered in other sections of the *Guidelines*.

Following a moderate to large earthquake, a building owner or manager is under pressure from the occupants to have a trained professional inspect the building and determine whether or not it is safe to occupy. Owners and managers of multiple buildings, as well as the consulting engineers they hire for building investigation services, typically need some sort of priority ranking to effectively deal with occupancy decisions within a reasonable amount of time. Computer-generated ground-motion maps, such as ShakeMap, can be used to quickly determine the level of ground shaking experienced at each building and, when combined with structural and occupancy information, help illustrate which buildings should be inspected first.

An owner or manger of a single building is not likely to be interested in the ground shaking at the site, as this person will probably either call an engineer immediately after the event based on its magnitude and location or later after receiving reports of damage from the building occupants. Similarly, an owner or manager of several buildings clustered in a small region would assume that the ground motion is constant throughout the region, and would likely rely on an inspection priority scheme that relates only to building type and/or occupancy.

Local emergency response managers and building officials would use near real-time ground-motion maps to help prioritize the inspection of public and essential services buildings, as well as allocate staff or consultants for responding to citizen requests for assistance with building safety issues. In addition, this information could be used to notify residents or businesses about the potential loss of city services in specific areas, assign police and fire response to neighborhoods most likely to be damaged, establish the most critical locations to set up emergency shelters, and several other uses as described in the sections of the *Guidelines* focusing on these other applications.

Potential data resources

In order to effectively use computer-generated ground-shaking maps for prioritizing building inspections and determining regions of most severe damage, building information needs to be stored electronically and geographically referenced. Most building owners or managers have electronic databases of their facilities; however, few have this information in a geographic information system (GIS). As described previously, one of the basic analysis steps involves being able to overlay a map of facilities on the map of ground shaking distribution in the region. Converting existing electronic or paper building inventory databases to GIS format is not as difficult or time consuming as it would seem, given the user-friendly and reasonably-priced GIS software that is now available. In addition, the ability to store and manipulate building inventory data in a GIS has many benefits beyond responding to an earthquake.

Overlaying a map of buildings on a map of ground shaking distribution in the region will identify which buildings were subjected to the various levels of ground shaking. To make the most effective use of the GIS data and capabilities, the building data should include structural information, attributes that are often not part of typical building inventories. The exact structural information to be collected and stored depends on the resources available for database development (some information may require a structural engineer), as well as how the data are going to be used in the future, for post-earthquake response and other building management decisions. A relatively complete record in a building inventory database would include the following information:

- Location: address, ZIP code, Census tract, longitude and latitude
- Size: square footage, height, number of stories
- Construction data: year built, lateral load system, gravity load system,
- Occupancy data: use type, daytime occupancy, nighttime occupancy
- Other: existing condition, retrofits, irregularities, importance factor

The information listed above is sufficient in most cases to make first order estimates of earthquake damage and loss to buildings when combined with a map of ground shaking distribution. More detailed information on building attributes, such as that collected during rapid visual screening using ATC-21 procedures (ATC, 1988), results from detailed building evaluations using FEMA 310 (ASCE, 1998) or push-over analysis investigations to develop capacity curves, would provide an improved capability for estimating building vulnerability. Most building owners and managers are not likely to make the investment required to hire structural engineers to develop these data, as the cost versus the perceived benefit in automatically generating more detailed damage estimates for post-earthquake inspection is not readily apparent. They do, however, see the benefit in having engineers write reports on the structural quality of select critical buildings, and for the engineers to be available after an earthquake to use these reports in their damage assessment.

For regional use of computer-generated ground-shaking maps, building information is typically stored by summary statistics for the area. For example, Census tract or ZIP code maps can have the number or square footage of each building type as an attribute in the GIS database. The information is typically not very detailed because it is aggregated by geographic region and any building-specific information will be lost in the aggregation. Additionally, the use of the data for first-order prioritization of damaged areas, does not warrant more detailed building-specific information. Regional databases of building inventory can be found in existing loss estimation software or can be developed using techniques described in the loss estimation methodology reports. Information on loss estimation methods and software is described in Appendix B of the *Guidelines*.

Potential models or data analysis procedures

Building owners and managers typically rank life safety as the top priority and business operation as the next most important for prioritizing post-earthquake building inspections. In order to use near real-time ground motion information they must develop at least four important pieces of information before the earthquake occurs. These are similar to the four basic steps outlined previously, and include:

- A database of their facilities with information on occupancy and the importance to overall business operations.
- A list of engineers who are contracted to provide post-earthquake inspections. In lieu of this, companies will rely on building officials from the local jurisdiction to make inspections.
- A software program (typically a GIS) that can be used to access and store the near real-time ground motion maps and combine them with the facility database.

- Models that: (1) relate the level of ground shaking to damage and loss of function for each building (such as those found in the loss estimation methods described in Appendix B of the *Guidelines*), and (2) assign an inspection priority to each building (this is user-dependent). The level of sophistication of the models depends on the financial resources of the building owner or manager, the in-house technical capabilities, the level of detail in the facility databases, and the desired results. These models can include:
    1. Simple visual inspection of map overlays to make qualitative decisions
    2. Programs within the software that will do the analyses automatically
    3. Programs external to the software, run as a post-processor on the output of the map overlays

The information described above also applies to regional use by local emergency response managers and building officials. The main differences are in the facility databases as discussed above. In this case, the building information is stored in an aggregated format. Local officials are likely to be estimating building damage in conjunction with other effects of the earthquake, such as casualties, need for shelter, and preliminary economic loss – many of which are conditional on building damage. Although several of them still rely on manual methods as discussed in the *Guidelines*, the most efficient methods for making first-order estimates of emergency response needs in a region require the investment to develop accurate regional databases of facility information, and to acquire and learn an automated GIS-based loss estimation methodology.

Example

In the following example, a city and two building owners within the city cooperate to develop a post-earthquake response and recovery program. For this example, a city in southern California and two hypothetical companies (ABC, a high-technology company, and XYZ, a chain of grocery stores) are used. After an earthquake, the city's primary responsibility is to inspect its residential housing stock and the facilities it owns. A secondary but important goal is to make sure that businesses are adequately inspected. The purpose of both of these goals is two-fold: first, to insure that dangerous buildings are declared unsafe (red-tagged), and second, to allow safe buildings to be reoccupied.

ABC company has ten facilities in the area, located at four campuses. The campuses are primarily: manufacturing, research and development (R&D), office, and warehousing. A basic seismic study of the buildings has been done by the company's structural engineering consultant, and the estimated performance of each in a given Modified Mercalli Intensity (MMI) event is as shown in Table 1. The company has decided that a more detailed assessment of shaking intensity is not warranted for an initial response. They have prioritized the value of their buildings in the order shown in Table 1, and have decided that if the intensity at any facility exceeds the life safety threshold, that facility is inspected first. If more than one facility exceeds the life safety threshold, they are inspected in order of the number of occupants. Buildings in areas not exceeding the life safety threshold are inspected in the order shown in Table 1.

An earthquake strikes southern California with an intensity distribution as shown in Figure 2. (Note that this map is one of the ShakeMap Earthquake Planning Scenarios taken from the

ShakeMap web site **www.trinet.org/shake**/.) Based on this intensity map and the location of the four campuses as shown, a simple GIS-based algorithm is developed to prioritize the inspections as: E, F, G, A, C, B, D, H, I, J. ABC uses this information to send its inspecting engineers to the building sites to make an ATC-20 (ATC, 1995) detailed evaluation, suitable for posting the buildings as red-tagged (unsafe), yellow-tagged (restricted use), or green-tagged (inspected).

Table 1 Estimated Seismic Performance of Buildings in Example

		Performance Threshold at MMI:	
Campus	**Building**	**Functionality**	**Life Safety**
Manufacturing	A	VI	VIII
	B	VII	IX
R&D	C	V	VII
	D	VI	VIII
Office	E	VII	IX
	F	VII	IX
	G	V	VII
Warehousing	H	VII	IX
	I	VII	IX
	J	VI	VIII

A week following the initial posting, ABC’s engineers determine that buildings C, D and F are susceptible to structural damage that was not evident from an initial walkthrough of the building. ABC’s engineers use pushover curves (estimates of the capacity of each building) developed prior to the earthquake with the response spectra obtained from ground motions recorded at nearby free field instruments. They are then able to determine if and where damage may be concentrated and respond accordingly.

XYZ company is unable to contract with structural engineers because of the lack of financial resources. The company has ten structures spread throughout the area and will rely on city inspectors to evaluate the facilities. The company develops a cooperative relationship with the city as follows: XYZ supplies the city with a list of its buildings, photographs, a brief description of the number of stories, year of construction, and material type, and any structural drawings it may have, reduced to 11x17 format.

The city creates a GIS map of the residential and public facilities with an intensity-based inspection prioritization similar to ABC company’s. It then runs several scenario earthquakes through a model that creates estimated intensity contours. Based on these scenarios, the city determines its immediate inspection needs for the housing and public building stock. It estimates how long these inspections will take, and places XYZ company on a waiting list for inspection after the initial inspections are completed. The city then gives XYZ company an estimate of how long it will take to have its buildings inspected after each scenario. Because the city has basic information on the buildings, provided by XYZ, it is theoretically able to make inspections of XYZ’s buildings more quickly and accurately. The city also determines for each scenario, which of XYZ's buildings are likely to fall outside the contours of shaking intensity that would cause moderate to severe damage.

An earthquake occurs and the near real-time map of ground shaking intensity generated from free field instrumentation is incorporated into the city's GIS software as shown in Figure 3. The city notifies XYZ company that it will take approximately 96 hours for inspectors to get to XYZ's buildings, but it also tells them that four of their ten buildings are not within the high intensity ground shaking zone, and unless hazardous damage is clearly evident the buildings can be occupied.

The use of recorded ground motion in the above example is threefold. First, on a near real time basis, the general distribution of intensity is used to make a rapid prioritization of inspection needs, both for the city and for ABC company. Near real time information would not typically be used in this case to make a determination or estimation of specific building damage. Second, more detailed ground motion information that would not have to be assembled in real time would be used in the days following the event, to help engineers analyze building damage. Third, companies are able to get estimates quickly after an event of when their buildings will be inspected, and whether or not certain buildings outside the zones of high shaking can be reoccupied immediately.

SUMMARY

This paper describes one of the key topics of the document, *Guidelines for Using Strong-Motion Data for Postearthquake Response and Postearthquake Structural Evaluation*, currently being developed by ATC for CDMG as one of the 2000 CSMIP Data Interpretation Projects. It concerns the development and implementation of applications using computer-generated ground-motion maps, such as TriNet ShakeMaps, for post-earthquake response. The *Guidelines* address ShakeMap applications for approximately ten areas of emergency response. In this paper, the focus is on the general framework, including essential information, basic steps, and limitations. Due to space limitations, the application description is limited to only one of the ten emergency response topics – damaged buildings and safety inspections.

It should be emphasized again that the material in this paper forms a portion of the draft *Guidelines* document, and should be considered preliminary until the final document is released.

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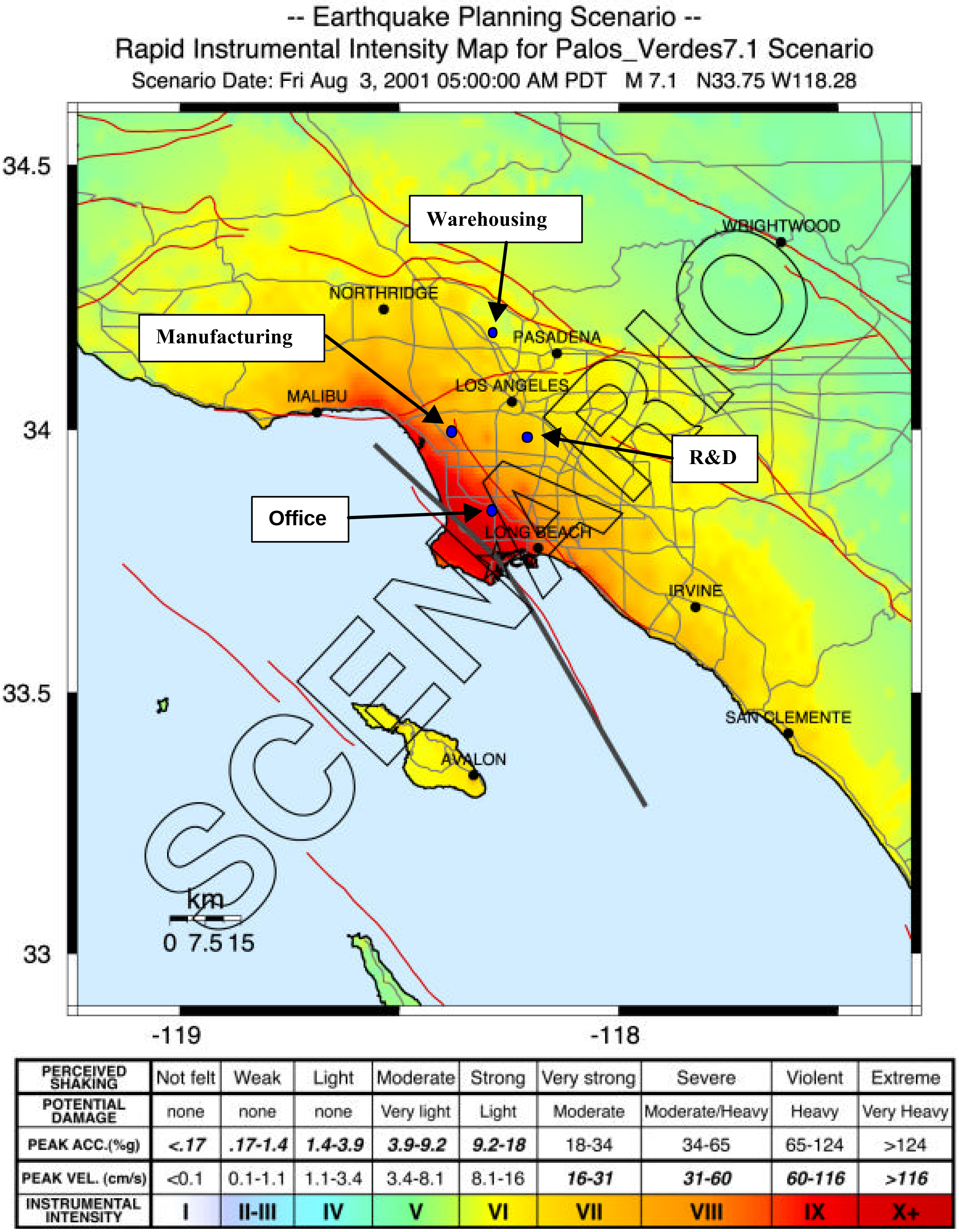
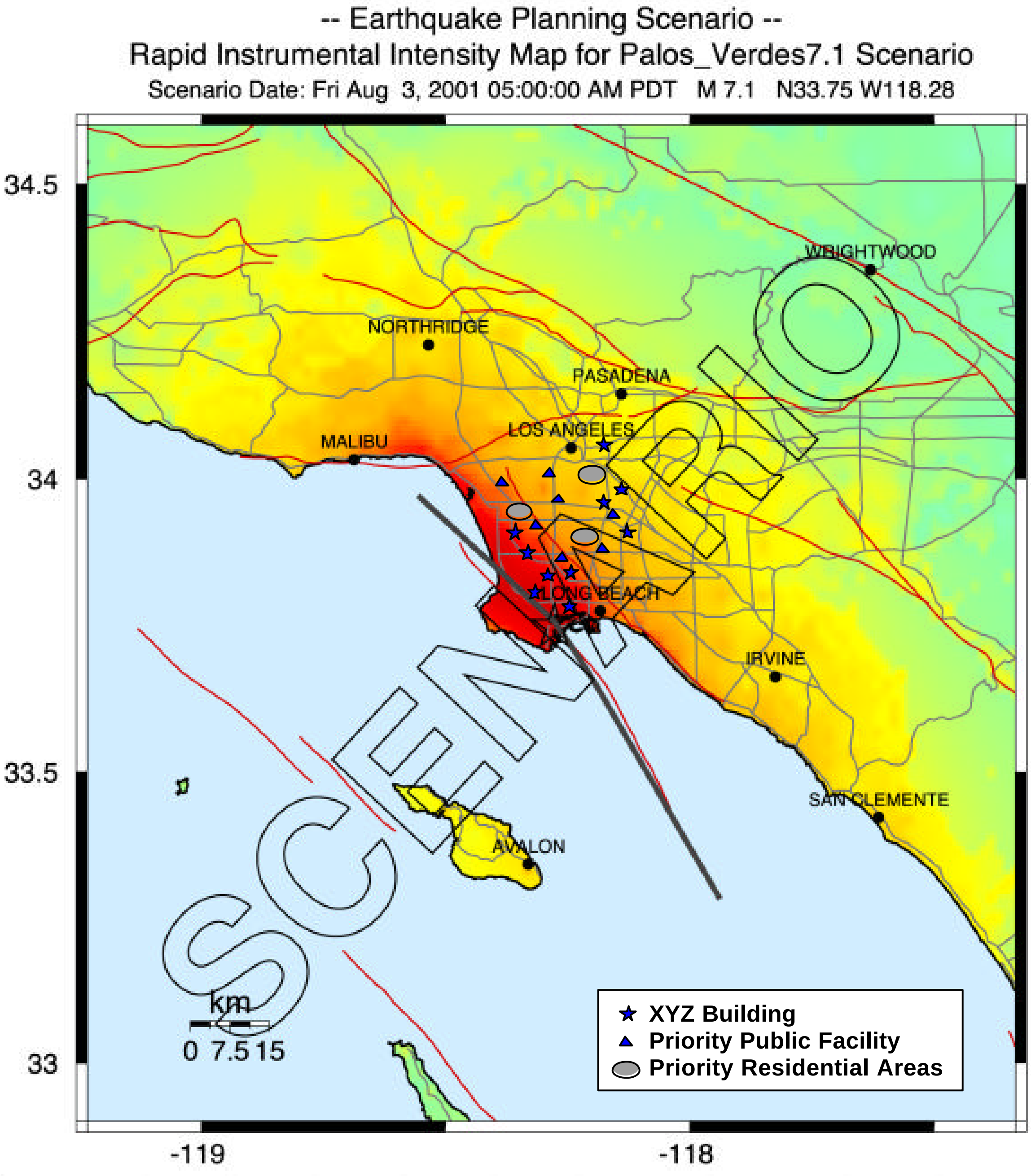


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 2 *Distribution of ground shaking intensity with location of example ABC Company buildings.*



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 3 Distribution of ground shaking intensity with location of example XYZ Company buildings.

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ACKNOWLEDGEMENTS

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