Evaluation of Earthquake Hazard Maps for the Portland Metropolitan Region of Oregon

FINAL PROJECT REPORT

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SUMMARY

The purpose of this study is to examine and evaluate the use, quality and accessibility of a series of earthquake hazard maps that were produced by Oregon's Department of Geology and Mineral Industries together with Metro, the regional government for the Portland metropolitan region. The mapping effort was supported with funds from the United States Geological Survey and the Federal Emergency Management Agency (FEMA). FEMA then retained Spangle Associates, a planning consulting firm, to carry out an independent evaluation focusing on how the maps are being used and problems that potential users have had with the maps.

In order to determine how the maps were being used and to gather users' opinions of the maps, Spangle Associates mailed questionnaires to 215 individuals in the region, of whom 149 responded. Respondents included emergency managers, engineers, geologists, and land use planners and other staff from public and private agencies. The project team then conducted forty-three interviews to obtain detailed descriptions of map uses and problems.

The questionnaire responses indicate that the maps are used for a number of purposes, including to design, require or check site investigations; general earthquake awareness; education and training; seismic retrofit projects; planning for development; and emergency management. Respondents also provided a number of reasons why the maps have not been used. One reason was that the small scale of the maps made them difficult to use. Other reasons were that the maps did not cover the entire geographic area of interest or that the organization lacked the resources to use the maps. The most common reason, however, was that the respondent perceived no need to use the maps.

Most respondents were pleased with the quality of the maps. The only common complaint was that the scale of the maps was too small. A couple respondents expressed concern about the accuracy of the maps, however, and others had received site-specific geologic reports that indicated that a problem shown on the maps was not actually present on the ground.

Based on the questionnaire responses and interviews, we reached a number of conclusions concerning the use of the maps in the region, including the following:

- The maps appear to have contributed to a general increase in earthquake awareness in the Portland region.
- Substantial seismic hazard mitigation efforts are underway supported with data from the maps.
- There is varied use of the maps by diverse users.

These conclusions demonstrate that the maps have been generally well received and widely used. The study concludes with a number of recommendations, which are listed below. Although these recommendations are specific to the earthquake hazard mapping program in the Metro area, the recommendations can also be used in designing similar programs for other areas.

Recommendations to Improve Map Use

- Provide information to local government planners and building officials about use of the maps.
- Consider requiring use of the maps in preparing local comprehensive plans.
- Take steps to increase use by county, regional and state agencies.
- Publicize examples of successful uses of the maps.

Recommendations to Improve Map Quality

- Include more major roads and street names.
- Show data points on individual hazard maps to indicate the locations for which ground data was collected.
- Make the map data available in GIS format, together with instructions.
- Print informative notes on the maps themselves.
- In future projects, consider using a peer review process.

Recommendations to Improve Map Accessibility

- Continue to publicize map availability.
- Publicize Metro's ability to make custom maps.
- Continue and enhance availability in GIS format, together with instructions.

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INTRODUCTION

THE MAPS

To increase the level of earthquake preparedness in the Portland area, Oregon's Department of Geology and Mineral Industries (DOGAMI) has been working with Metro, the regional government for the Portland metropolitan area, to produce earthquake hazard maps for the area. This effort was originally supported with funds from the United States Geological Survey (USGS). Subsequently, the Federal Emergency Management Agency (FEMA) provided $3.5 million to help complete the maps for the region.

This effort produced four maps for each 7.5 minute quadrangle in the region. The four maps showed the:

- relative liquefaction hazard,
- relative amplification of peak ground acceleration,
- relative slope instability hazard, and
- relative earthquake hazard.

The first three maps depict the expected distribution of specific earthquake effects. The fourth map, showing the relative earthquake hazard, is a composite of the other three maps produced using geographic information system (GIS) tools and is meant for a less technical audience than the maps of individual hazards. This composite map shows overall hazard levels without providing information about the specific hazards affecting each location. Reports that explain the methodology in detail are available from DOGAMI.

In order to apply the maps correctly, the user needs to understand several facts about the maps. One is that hazard categories on each map indicate *relative* degrees of hazard rather than *absolute* degrees of hazard. For example, while the level of damage could be expected to be higher in red zones than orange zones given comparable development patterns, the maps do not indicate either the absolute amount of hazard or the amount of damage that could be expected in either zone. In addition, because the maps were created by interpolating between known data points, the degree of hazard may vary within a zone. Some areas in the zone may have a higher hazard level than the zone as a whole, while other areas may have a lower hazard level. These issues are discussed in reports prepared for each 7.5 minute quadrangle by DOGAMI.

When the maps for the Portland quad were completed in 1993, complimentary copies were mailed to local government officials in the Metro area. Once completed, maps for other quads have been available on request. The mapping for the region was finished in 1997, and complimentary copies of a map showing the entire Metro region were mailed to all mayors, planning directors and county chairs in the Metro area in December 1997.

The maps are now available to the public in several formats. One format is a single map sheet showing the entire Metro area with the relative earthquake hazard map at the scale of 1:62,500 and the three individual hazard maps at the scale of 1:216,000. Another format available for

each of the six quadrangles at the center of the area,[1] is a single map sheet showing the relative earthquake hazard map at the scale of 1:24,000 and the three individual hazard maps at the scale of 1:55,000. In addition, Metro can produce custom maps for any portion of the region at a scale of 1:24,000 or smaller as desired.

Because the maps were created using a GIS, the map data is in digital form and can be combined with other data to produce custom maps for different purposes. For example, the relative earthquake hazard areas and floodplains can be shown on a single map to provide a combined hazard map. In another example, the City of Portland collected building data and had a map created to show the building data together with earthquake hazard zones to provide information on vulnerability.

The digital data is available from DOGAMI on CD-ROM in formats compatible with the Arc/Info, Arc/View and MapInfo GIS programs. This data is also available as part of Metro's Metro Area Disaster (MAD) GIS, which includes additional data layers and a stand-alone software program that can be used to view and query the data. MADGIS has been distributed to all emergency managers in the Metro area and may soon be available for purchase.

THIS PROJECT

FEMA is interested in evaluating the maps to determine their usefulness so that, if successful, the hazard mapping can be extended to other parts of the country. To that end, this report examines three factors: map use, map quality,[2] and map accessibility. In terms of map use, the project attempts to identify the different ways the maps are being used throughout the region. At the same time, the project considers problems people have encountered in using the maps, any map quality issues these problems raise, and what improvements could be made to the maps. The project also includes examining the process of transferring the information on the hazard maps to potential users and the ease of obtaining the information.

Spangle Associates, an urban planning and research firm, was chosen to conduct the evaluation. Prior to this project, Spangle Associates worked with Metro to develop guidelines to help local governments apply the maps in land use planning and regulation. That effort involved work with a project oversight committee—the Metro Advisory Committee for Mitigating Earthquake Damage (MACMED)—and resulted in a report entitled *Using Earthquake Hazard Maps for Land Use Planning and Building Permit Administration*, which was completed in May 1996. Simultaneously with the current project, Spangle Associates was funded by the United States Geological Survey to prepare a guidebook to demonstrate how local governments might use the maps to reduce seismic risk. This guidebook, entitled *Local Government Guide to Using Earthquake Hazard Maps to Reduce Seismic Risk*, was published in October 1998.

In the following sections, this report describes the methodology used, the results of the study, and the conclusions. Finally, a number of recommendations are provided. The

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[1] These six are the Beaverton, Linnton, Mt. Tabor, Gladstone, Lake Oswego and Portland quadrangles.
[2] The assessment of map quality is based on users' comments and evaluations of the scale, accuracy and format of the maps. We did not attempt to independently determine the scientific quality of the maps as part of this project.

recommendations are meant both to improve the use, quality and accessibility of earthquake hazard information in the region and to provide guidance on how similar projects in other parts of the country can be designed to build on the lessons learned from this evaluation.

METHODOLOGY

The project used questionnaires and follow-up telephone interviews to elicit information and opinions from a variety of individuals in the region. Questionnaires were mailed at two times in order to both gain information early in the process and allow sufficient time for potential users to receive the maps and begin using them. In particular, the second mailing was directed towards those who received maps from Metro in December 1997, which was when the maps for the entire area were released.

The basic sequence of action for the project is outlined below, together with approximate dates:

Phase One

1. Assemble mailing list for questionnaires (January 1997)
2. Design questionnaire (January 1997)
3. Mail questionnaire (February 1997)
4. Receive, track and analyze responses (March - May 1997)
5. Choose interviewees (May 1997)
6. Conduct telephone interviews (June 1997)
7. Summarize and analyze interviews (June 1997)
8. Draft interim report (July 1997)

Phase Two

1. Revise mailing list (February - March 1998)
2. Revise questionnaire (May 1998)
3. Repeat steps 3 - 7 from Phase One (June - September 1998)
4. Draft final report (October - November 1998)
5. Receive comments from readers (November - December 1998)
6. Revise report and submit final version (December 1998)

THE MAILING LIST

Because there is no record of either the total number of maps distributed or who received them, we could not draw a representative sample of all who received the maps. Therefore, we did not use statistical sampling methods. Instead, we tried to obtain data from as many potential map recipients as possible.

The first task was to develop a list of potential map users. Metro provided addresses of local and state government officials and staff, non-profit organizations and people who had attended Metro workshops. DOGAMI added more names and addresses, forming a list of potential users who were considered likely to have purchased or received maps. These potential users received questionnaires in 1997. The 1998 mailing was intended primarily for those who received complimentary copies of the regional map from Metro in December 1997. At the same time,

however, the questionnaire was also mailed to other potential users identified in the intervening months and those who had received the questionnaire in 1997 but had not responded.

To check the distribution of the questionnaire mailings and responses, all individuals were classified according to their profession and type of organization. Categories of profession include emergency manager, engineer, geologist, planner, building official, fire/police, other local staff, elected officials and other. Professions categorized under "other" include attorney, professor, health care professional, and communications representative. Organization types represented include consultants, utilities, local governments, other government agencies, and other. "Other" types of organizations include law offices, environmental groups, universities, health care organizations, and non-profits such as the American Red Cross. The distribution of mailed and returned questionnaires is provided in Table 1.

THE QUESTIONNAIRE

Questionnaires from both 1997 and 1998 covered topics such as:

- how the maps were obtained,
- whether or not the maps were used and why or why not,
- how the maps were used, if they were,
- whether the scale, technical information and accuracy of the maps were sufficient, and
- what modifications would improve the maps.

The questionnaires are substantially the same for the two years, although the format and a few questions were modified in 1998 based on the 1997 results. Copies of the questionnaires can be found in Appendix A of this report.

While the questionnaire remained essentially the same in both years, the survey technique used did change. In 1997, questionnaires were mailed once in February and follow-up postcards were sent to non-respondents a few weeks later. To improve the response rate in 1998, a technique involving four mailings was used. [3] Advance letters introducing and explaining the project were mailed, followed by the questionnaires and cover letters approximately a week later. A week after that, reminder postcards were sent to each questionnaire recipient, and two weeks later a final mailing with another copy of the questionnaire and a cover letter was mailed to everyone who had not yet responded. Copies of all of the letters and postcards used can be found in Appendix B.

In 1997, 104 people received the questionnaire and 40 responded (38%), while in 1998, 163 people received the questionnaire and 98 responded (60%). Altogether, 215 people received the questionnaire and 138 responded (64%).[4] In addition to people on the mailing list, the

[3] This four-part mailing technique is taken from *How to Conduct Your Own Survey* by Salant and Dillman, John Wiley & Sons, Inc., 1994. The 1998 mailing that used this technique did have a higher response rate (60% as opposed to 38% in 1997).

[4] Because questionnaires were mailed to some people in both 1997 and 1998, the total number of recipients is less than the sum of the number of recipients in 1997 and the number of recipients on 1998.

questionnaire was also distributed to attendees of two workshops in the area. One was a joint meeting of the American Society of Civil Engineers and the Association of Engineering Geologists on February 20, 1997. The second was a Natural Hazard Mitigation Workshop hosted by Metro and held on March 13-14, 1997. Eleven questionnaires were received from participants at of these workshops, so that a total of 149 people were heard from. Respondents included emergency managers, engineers, geologists, and land use planners from consulting companies, utilities, and all but one of the local jurisdictions in the Metro area, as shown in Table 1.

Table 1: Distribution of Questionnaire Recipients and Respondents

	Recipients	Respondents	Percent Responded	Workshops	TOTAL
Agency Type					
Local Govt.	151	102	68%	0	102
Other Govt.	19	13	68%	2	15
Consultant	18	7	39%	8	15
Utility	10	6	60%	0	6
Other	17	10	59%	1	11
TOTALS	215	138	64%	11	149
Position/Profession					
Planner	40	25	63%	1	26
Building Official	18	16	89%	0	16
Engineer	32	26	81%	2	28
Geologist	9	3	33%	6	9
Fire/Police	14	12	86%	0	12
Emergency Mgt.	19	13	68%	1	14
Other Local Govt.	18	18	100%	0	18
Elected Official	38	12	32%	0	12
Other	27	13	48%	1	14
TOTALS	215	138	64%	11	149

Table 1 shows that most of the people who received and returned questionnaires worked for a local government agency. The distribution was more even in terms of the type of profession for both recipients and respondents, with over 30 people in each of the categories of planning, engineering, and elected official receiving questionnaires. Table 1 is important because it tells us who is represented by the results of this project.

Because the mailing lists provided by Metro and DOGAMI included primarily people in the public sector, we made additional efforts to reach potential private sector users with the help of members of HAZTAC (the Natural Hazards Technical Advisory Committee for the Metro Region). One member volunteered to mail cover letters and a shortened form of the questionnaire to approximately 30 insurers who may have seen or used the maps. Another member placed a notice and very short form in a newsletter that is sent to general contractors in the Metro area. Copies of these notices are in Appendix C. No responses were received from either of these efforts.

THE TELEPHONE INTERVIEWS

Telephone interviews provided an opportunity to explore some of the uses and problems mentioned on the questionnaires in more depth. Interviewees were chosen from each profession and agency type. We made an effort to follow up on all reports of significant applications, particularly those in which the maps were used in a program or effort to mitigate hazards. Several respondents who wrote that they did not use the maps were also interviewed.

In some cases, an interviewee suggested speaking with another person for more information, and a follow-up interview was then conducted. A total of 43 people were interviewed, with 23 interviews conducted the first year and 20 interviews the second. In 1997, we interviewed 16 respondents who had used the maps and 4 who had not. Three additional interviews were conducted to follow up on suggestions made by other interviewees. The telephone interviews were conducted over a period of two weeks in June 1997. In 1998, we spoke with 16 respondents who had used the maps and 2 who had not, with 2 follow up interviews. These interviews were conducted during three weeks in September and October 1998. The overall breakdown of telephone interviewees by profession and agency type is given in Table 2 below.

Table 2: Distribution of Telephone Interviewees

	Questionnaire Respondents	Telephone Interviewees	Percentage Interviewed	Follow-up Interviewees
Agency Type				
Local Govt.	102	23	23%	4
Other Govt.	15	4	27%	1
Consultant	15	6	40%	0
Utility	6	2	33%	0
Other	11	3	27%	0
TOTALS	149	38	26%	5
Position/Profession				
Planner	26	6	23%	3
Building Official	16	4	25%	1
Engineer	28	10	36%	0
Geologist	9	3	33%	0
Fire/Police	12	1	8%	0
Emergency Mgt.	14	6	43%	1
Other Local Govt.	18	2	11%	0
Elected Official	12	2	17%	0
Other	14	4	29%	0
TOTALS	149	38	26%	5

The telephone interviews focused on how the interviewees had used the maps together with any problems encountered and suggestions for modification. Each interview provided more detail about responses on the questionnaire, along with other information volunteered by the interviewees. Most interviews lasted for approximately fifteen minutes. Summaries of the interviews were then written and analyzed together with comments from the survey.

RESULTS

This section covers the results from the questionnaires and telephone interviews, starting with uses of the maps followed by reasons why the maps were not used. Next, differences between users and non-users are discussed. The last two subsections are about map quality issues and map accessibility.

USES OF THE MAPS

The map uses described in the questionnaires and telephone interviews were divided into six general categories, as shown in Table 3. The most common use of the maps is in designing, requiring, or checking site specific seismic investigations. Other uses include increasing general earthquake awareness, education and training, designing seismic retrofit programs, planning for development, and emergency management. These categories are described below together with specific examples of how the maps have been used. In the last section, map usage in the Metro area is evaluated and compared with uses that were anticipated by both Metro and DOGAMI.

Table 3: Distribution of Map Uses[5]

	Use for Site Investigations	Gen'l EQ Awareness	Education & Training	Seismic Retrofit	Planning for Development	Emergency Management
Agency Type						
Local Govt.	6	9	5	5	7	5
Other Govt.	2	2	3	0	0	1
Consultant	11	0	0	1	1	0
Utility	0	1	1	2	0	0
Other	3	4	1	1	0	1
TOTALS	22	16	10	9	8	7
Position/Profession						
Planner	0	3	0	1	2	0
Building Official	2	0	0	0	2	0
Engineer	8	1	2	4	1	1
Geologist	6	0	0	0	0	0
Fire/Police	1	1	0	0	1	1
Emergency Mgt.	2	2	7	2	0	3
Other Local Govt.	0	3	0	1	1	0
Elected Official	0	1	0	0	1	2
Other	3	5	1	1	0	0
TOTALS	22	16	10	9	8	7

[5] Several respondents use the maps for more than one of these purposes, and therefore the numbers shown in Table 3 are greater than the numbers of actual map users.

Use for Site Investigations

This category includes use by public agencies as a guide to determine when geological or soils investigations may be necessary prior to the issuance of development approvals and to check the scope of soils and geological investigations. In addition, consulting geologists and engineers use the maps to design investigations for a particular site. While the maps are generally not appropriate for site-specific use, two agencies have been able to use the maps in this way without misusing the information. Examples of these uses are described below.

Examples of Use by Public Agencies

- The Oregon Water Resources Department uses the map in initial studies for proposed dam sites to help determine the kinds of investigations needed to adequately explore subsurface conditions. In addition, the department has used the maps to review the safety of existing dams.
- The City of Forest Grove has begun to require reports for all projects of any significance, including subdivisions, commercial buildings and industrial buildings, regardless of their hazard zone. This requirement is stricter than the state building code that mandates geotechnical reports for essential structures and structures with special occupancies, such as schools and hospitals. The city adopted the requirement because the maps show widespread hazardous conditions and because previously conducted soils and geotechnical reports confirm the presence of hazards.
- The Portland Bureau of Buildings uses the individual hazard maps to be sure that hazards shown on the maps are appropriately addressed in soils and geotechnical reports submitted with building permit applications.
- In an interesting example, the City of West Linn used the maps when a new middle school was proposed in an area with high liquefaction potential. A soils report was submitted that concluded the site was fine. The building official noted that liquefaction was not discussed as a hazard in the report and called DOGAMI for guidance. He was told that if the blow counts listed in the soils report fell within a certain range, liquefaction was a probable hazard and he might require a pile foundation. Since the blow counts were in the liquefaction range, he informed the school district that a pile foundation would be necessary. The school district, faced with the geologic issues and the extra cost of foundation work as well as growing neighborhood opposition to the project, chose another site for the new middle school. This “heads-up” use of the map by the building official also illustrates the need for adequate local government review of soils and geotechnical reports submitted with development applications.
- The City of Lake Oswego relies primarily on soils maps from the Soil Conservation Service and an old map of landslide hazards to trigger requirements for soils or geotechnical reports. Now the city also uses the earthquake hazard maps as a double check, and copies of parts of the maps are included in staff reports if relevant. For all projects, geotechnical and soils reports are reviewed by a Development Review Commission that by ordinance includes an engineer with soils experience. This is key since the staff who review the reports do not have geotechnical training. An engineer

with the city observes that practice has changed in the last five years, and now most applications are submitted with geotechnical reports whether or not the city requires it. The quality of the reports has also improved and most refer to the DOGAMI maps.

- The American Red Cross used the liquefaction map in lieu of site specific investigations to select emergency shelter sites that are not in liquefaction areas. Since the Red Cross could not afford to conduct site investigations of all the many potential shelter locations, the map allowed them to make a reasonable first cut and concentrate on sites that are less likely to have potential seismic hazard problems.
- In order to identify sites for future facilities, the Portland Bureau of Water Works commissioned a study that examined a number of factors, including earthquake hazards. This study used the data on which the maps were based rather than the maps themselves to assess hazard levels.

Examples of Use by Consultants

- A geologist at David J. Newton Associates uses the individual hazard maps when preparing proposals, planning investigations, analyzing hazards and writing geotechnical reports. He found the Portland quad numerical data on lateral spreading to be particularly useful.
- Maps provide preliminary, very basic information for a consulting engineer who uses them to check if his "calculation results are in the right range." He also finds them "pretty on the wall."
- A consulting structural engineer uses the maps to help determine the extent of soils investigations needed for building sites. For example, he might require borings in an area shown as hazardous.
- A consulting geologist frequently uses the data from the technical report accompanying the maps, such as shear wave velocity and borehole data.

General Earthquake Awareness

Respondents of all professions mentioned using the maps to increase their understanding of the nature and extent of earthquake hazards in the Metro area. In addition, a number of respondents posted the maps in public locations or otherwise made them available to the public. Several interviewees from local government agencies, insurance companies and geotechnical firms stated that they believe the level of public awareness of earthquake hazards has increased since the release of the maps. The examples described below provide some information on ways that the maps have been used to increase general earthquake awareness.

Examples

- The Bonneville Power Administration displays the maps in its lobby, where people look at the map and try to find their own neighborhoods. Staff thinks that many of its 2,000 Portland area employees have been encouraged to prepare their homes as a result.
- An attorney reports giving copies of the maps to clients before they buy properties, so they can consider potential seismic hazards in making their decisions.

- The City of Tualatin uses the maps at the building counter to address questions about earthquake hazards in different parts of the city.
- Similarly, the City of Gresham posted the maps near the building division reception area and reports that there has been interest in the maps.

Education and Training

Most of the respondents who use the maps for education and training are emergency managers who work for public agencies. These respondents write that they use the maps for general public education and education of groups such as teachers and hospital staff. In addition, the maps are also used to develop training exercises for employees and others who will have special duties in the event of an earthquake. Examples of these types of uses are provided below.

Examples

- Tualatin Valley Fire and Rescue uses the map for public education. "When we do our dog and pony show, we put the map up in the booth. It's the #1 attraction that draws people in. The map really helps—it's a tool to get people to prepare a bit more."
- The Washington County Emergency Manager uses the maps in training elementary school teachers and staffs, hospital staffs, and others who could have special responsibilities in the event of an earthquake. The agency finds the maps "great attention getters, very educational and captivating. An excellent tool."
- Portland Bureau of Maintenance has a program to train neighborhood emergency teams. It uses the maps to demonstrate that earthquakes are a regional problem and to identify areas with high risk that do not have teams so that employees can be assigned to those locations.
- The Bonneville Power Administration is the major supplier of electric power in the northwest in the event of a disaster. The agency develops and tests its emergency management plan once a year, and uses the maps to write scenarios for earthquake exercises, specifically to estimate the impact on facilities and transmission lines for the recovery portion of the exercise.
- The American Red Cross has also used the maps to develop training exercises for its employees.

Seismic Retrofit Projects

One of the ways that the maps are used for concrete, on-the-ground actions is in seismic retrofit projects. The maps have been used to determine areas in which retrofit may be needed and also to set priorities for retrofit. The City of Portland in particular has used the maps in this way to examine much of the public infrastructure of the city, as shown in the examples below.

Examples

- The City of Portland hired CH2M Hill to recommend priorities for seismic retrofit of 160 highway bridges—any span more than 20 feet long on a locally maintained road.

The consultant used the hazard categories on maps as a factor in scoring systems to rate the vulnerability of the bridges to earthquake damage. The high priority bridges are both vulnerable to damage and critical to the functioning of the transportation system. So far, two bridges have been retrofit—one as part of a general repair project and the other as a retrofit project without other work. Several more projects are designed and ready to go pending the availability of funding.

- Portland Public Schools used the maps in a system to set priorities in a long-term seismic strengthening program. The program has $40 million from a bond passed by voters in November 1995 to finance the first phase in a program expected to cost $200 to $250 million. The district considered the zone on the relative earthquake hazard map for each school as well as factors such as the construction type and the number of students in determining which schools to strengthen first. Buildings of unreinforced masonry construction in hazard zones A and B are the focus of the first phase.
- The Portland Bureau of Water Works commissioned a study to identify sites for future facilities and for seismic retrofit of existing facilities. The study used the data collected for the earthquake hazard maps rather than the maps themselves and resulted in recommendations for both new facilities and priorities for seismic strengthening.
- The City of Portland has also used the maps in assessing the vulnerability of its sewer system to disruption in the event of an earthquake and in establishing priorities for the retrofit of fire stations.
- Portland requires a preliminary hazard assessment of older buildings when owners apply for a use or occupancy change, rehabilitation, remodeling, or other act requiring a building permit. A consultant who conducts these assessments uses the map to alert owners to potential site problems in addition to work needed to meet code.
- The Portland Office of Emergency Management used the maps while examining the locations of hazardous materials facilities. When a number of facilities were found to be located in an area with a potentially high relative liquefaction hazard along the Columbia River, the office began to work with the facilities to reduce the hazard. As a result, a chlorine manufacturing plant has spent $100 million to upgrade its equipment and has reduced the amount of chlorine held on-site by placing it directly into railroad cars and shipping it off-site rather than storing it in holding tanks.
- The Bonneville Power Administration used the maps to identify places where transmission lines and substations are in vulnerable areas in order to help establish priorities for its seismic hardening program for Portland area substations. At least three substations near Portland are scheduled for retrofit beginning in 1999 and lasting between 5 and 10 years.
- The Oregon Water Resources Department uses the maps in initial studies to help determine the kinds of investigations needed to prepare plans for new dams. Earthquake hazards do not affect the location of dams, but do affect the design and cost. The agency also uses the maps to review plans to enlarge reservoirs and review the safety of existing dams.

Planning for Development

The maps are used in planning for development as environmental data in the preparation of comprehensive plans, hazard mitigation plans and environmental impact statements. In addition, the maps are also used to review construction plans, especially in concert with requirements for site-specific investigations. As the examples below illustrate, the maps are used in planning for development despite the fact that many local planners and building officials had difficulty seeing how the maps could be used given the small scale of the maps.

Examples

- Metro uses the maps in a variety of ways, including planning regional emergency management transportation routes and facilities planning, especially for hazardous waste sites. In addition, Metro is encouraging towns to use the relative earthquake hazard map in designating urban reserve areas, which are areas that will eventually be brought inside the urban growth boundary. Metro also incorporated the maps into the Natural Hazards chapter of its Regional Framework Plan adopted by the Council in December 1997. The plan includes the statement that Metro "will consider the relative earthquake hazard maps for a variety of planning purposes . . . [and that local] governments should be encouraged to apply information contained in the relative earthquake hazard maps in developed and undeveloped areas." (p.143)
- Oregon City used the maps in drafting its own hazard mitigation plan that has been developed with help from Metro. The plan was adopted in November 1998 and may either become part of the general plan or kept as a separate document. The draft plan contains 20 action items, including developing post-disaster building inspection procedures, conducting risk assessments of priority facilities, and revising the comprehensive plan and development ordinances.
- A community planner with the Portland Fire Department works with neighborhoods that are updating plans affecting their communities. She uses the maps to educate people about public safety concerns associated with land uses in particular areas.
- The Tualatin Building Department uses the information in reviewing construction plans submitted for building permits. The plans examiner asks for information on the hazard zones and categories on the application cover sheet. He also asks the geotechnical engineer to write a letter confirming that the final project design is in accord with recommendations in soils reports done for the project.
- A consultant with CH2M Hill uses the maps in writing federal EISs. She also uses the maps to assess whether extra testing for liquefaction or another hazard will be needed when designing the scope of work for proposals.

Emergency Management

Emergency managers use the maps for a variety of uses, including the seismic retrofit, education and training uses described above. Additional uses by emergency managers include anticipating areas of vulnerability, planning for post-earthquake response, and producing models of potential damage and loss. These are described in the examples below.

Examples

- The Army Corps of Engineers uses the maps to anticipate where to deploy people after an earthquake to help clear debris and open roads and bridges.
- Similarly, Metro is using the maps to identify areas that should be the top priorities for post-earthquake damage surveys and clean up efforts.
- The Washington County Emergency Manager used maps to identify hazards when drafting the emergency operations plan.
- Portland University, working with Metro, used the individual hazard maps in a study to inventory buildings in Portland and assess their vulnerability to earthquake damage.
- The Portland Office of Emergency Management used the individual hazard maps in a loss estimation study (the NIBS pilot study). The staff drew roads on the maps and were "staggered" by the results. They will be meeting with public utility groups and local building departments to coordinate mitigation efforts. They also will be working to harden facilities shown on the maps to be in high hazard areas.
- A particularly interesting use of the map data has been their incorporation into the HAZUS program for the Portland area. HAZUS is a GIS program that uses earthquake hazard information and building inventory data to generate estimates of damage and loss as the result of specified earthquakes. While the Relative Earthquake Hazard Map was not directly used in HAZUS, information from the individual slope and liquefaction hazard maps were used, and other information collected as part of the process of developing the maps was also used. Several respondents wrote that the HAZUS results would be more useful to them than the hazard maps alone.

Comparison with Anticipated Uses

Both Metro and DOGAMI have produced documents that discuss anticipated uses for the maps. The first of these was a report issued jointly by DOGAMI and Metro in January 1993 with the release of the maps for the Portland 7.5 minute quadrangle. In May 1996, the Metro Advisory Committee for Mitigating Earthquake Damage adopted a report prepared by Spangle Associates entitled *Using Earthquake Hazard Maps for Land Use Planning and Building Permit Administration*, and in October 1997, DOGAMI drafted a document called *Applications of Earthquake Ground Response Maps*. The uses discussed for the maps in these three documents are listed in Table 4, which also shows which uses were found in this study.

Examples of many anticipated uses were found in this study, indicating that the maps are being used in a wide variety of ways. Many of the anticipated uses that were not found are either uses that would be expected to occur over a longer time frame, such as comprehensive planning, redevelopment planning, zoning, and public facility planning, and/or uses which are more complex or indirect, such as influencing insurance rates and pre-engineering design. Also, while this study attempted to obtain a comprehensive list of map uses, the fact that a use was not found does not mean that the use does not exist.

Table 4: Comparison of Anticipated and Actual Uses of the Maps

Anticipated Use	From Joint Report	From Metro Report	From DOGAMI Report	Example of Use Found
Uses by Metro				
2040 Plan		X		X
Establishment of urban growth boundaries	X	X		X
Parks and greenspace planning		X		
Public facility plans		X		
Transportation planning		X		X
Solid waste management plans		X		X
Natural hazard mitigation programs		X		X
Uses by Local Governments				
Comprehensive plans		X		
Redevelopment plans	X	X		
Subdivision reviews		X		
Zoning		X		
Infrastructure plans		X		X
Siting of new public facilities		X		X
Public facility plans		X		
Mitigation programs, including retrofit	X	X	X	X
Grading permits		X		
Requirements for geotechnical reports	X	X	X	X
Uses by Emergency Managers				
Generate earthquake scenarios for drills			X	X
General public education			X	X
Develop emergency response plans	X	X		X
Locate emergency response facilities			X	X
Generate earthquake damage estimates			X	X
Locating evacuation routes			X	X
Uses by Others				
Hazard zoning for insurance rating			X	
Evaluation of potential expansion sites			X	
Designing site-specific studies			X	X
Pre-engineering design			X	
Planning lifeline routes			X	X

REASONS MAPS HAVE NOT BEEN USED

Respondents provided a number of reasons why the maps have not been used, as shown in Table 5.[6] Of those with maps who did not use them, the most common reason given was that the respondent did not perceive a need for the map relative to his or her responsibilities. This was the reason given most often by local planners and building officials. Others stated that the small

[6] We found in the telephone interviews that some of those who classified themselves as non-users may use the maps to increase their general earthquake awareness. However, in order to ensure consistency in reporting, we have always categorized respondents according to their self-reported use (or non-use) of the maps as indicated on the questionnaires.

scale of the maps precluded their use. These respondents generally indicated that they wanted to use the maps to obtain site-specific information. Additional reasons given for non-use were that the maps did not cover the entire geographic area of interest and that the organization lacked the resources to use the maps. These reasons are discussed in more detail below.

No Need for the Maps

Building officials and planners who explained why they did not use the maps gave this explanation most often. Several building officials stated that their job was to enforce the state building code and that they would not have a reason to use the maps unless the code required them to do so. One wrote that the maps are not necessary since structural work is done to code and geotechnical reports address seismic issues.

A planner wrote that his town has no need of the maps since the town he works in is largely built out, while another stated that the maps had little use for implementing the zoning code. A third said that the maps are not necessary because the jurisdiction has no code provisions to address earthquake hazards other than the building code.

Others who felt that they had no need of the maps included an insurance provider who wrote that his company already knew the areas of concern and an engineer who said that his jurisdiction had its own landslide potential and weak soils maps. These two non-users, however, viewed the maps very positively and felt that the maps could be a useful product for others.

Small Scale of the Maps

Scale was the second most common reason given for not using the maps. Several planners, a building official, an engineer and a geologist cited this as their reason. Most of these respondents went on to write that the maps were not used because they were not appropriate for site-specific applications, such as development review. Those concerned about misuse of the maps should be reassured that most respondents appeared to realize that the maps could not be simply enlarged for site-specific use.

Table 5: Distribution of Reasons for Not Using the Maps

	Don't Have Maps	No Need for Maps	Map Scale Too Small	Incomplete Geographic Coverage	Lack Resources	Other	No Reason Provided
Agency Type							
Local Govt.	39	13	5	3	3	3	5
Other Govt.	5	1	1	1	0	2	1
Consultant	2	0	1	0	0	0	0
Utility	1	0	0	0	0	1	1
Other	1	2	0	0	0	0	0
TOTALS	48	16	7	4	3	6	7
Position/Profession							
Planner	8	6	4	0	0	1	2
Building Official	7	4	1	0	0	0	0
Engineer	8	2	1	0	0	2	1
Geologist	0	1	1	1	0	0	0
Fire/Police	10	0	0	0	0	1	0
Emergency Mgt.	1	0	0	0	1	0	1
Other Local Govt.	5	0	0	3	2	1	2
Elected Official	5	2	0	0	0	1	1
Other	4	1	0	0	0	0	0
TOTALS	48	16	7	4	3	5	7

Lack of Geographic Coverage

Four respondents mentioned that the maps did not cover their geographic area of interest. Two of these apparently had early versions of the maps that did not include the entire Metro area. As the completed maps have since been released, information is now available for those respondents. The other two respondents were from a county with jurisdiction outside the Metro boundary and from an office of the U.S. Forest Service whose area includes more of the lower and middle Willamette Valley.

Lack Resources

Three respondents wrote that they had not used the maps because of a lack of resources. All of these respondents worked for local government agencies. One stated that he had no staff, while the other two cited a lack of staff time.

Other

Several other reasons for not using the maps were provided. Two respondents said that they were concerned about the accuracy of the maps. Another respondent wrote that his utility company has not used the maps because they need a digital version of the maps in order to overlay utility locations, while a planner mentioned that his city is split between two of the USGS quadrangles, making the maps difficult to use.

MAP USERS AND NON-USERS

Understanding who is and who is not using the maps is also important. While the information collected in this study is not necessarily representative, certain trends do appear. To learn more about the significance of these trends, we aggregated the data in this table and ran Chi square tests.[7] A Chi square test is one way of assessing whether the differences observed between several groups are significant or only due to chance. In this case, we have used the Chi square test to compare the frequency of use and non-use by different agency types and by different profession types. The trends and the results of the Chi square tests are discussed below.

Table 6: Distribution of Map Users

	Total Who Had Maps	Total Who Used Maps	Percent of Those Who Had Maps Who Used Them
Agency Type			
Local Govt.	63	33	52%
Other Govt.	10	7	70%
Consultant	13	12	92%
Utility	5	3	60%
Other	10	8	80%
TOTALS	101	63	62%
Position/Profession			
Planner	18	7	39%
Building Official	9	4	44%
Engineer	20	15	75%
Geologist	9	6	67%
Fire/Police	2	2	100%
Emergency Mgt.	13	12	92%
Other Local Govt.	13	5	38%
Elected Official	7	3	43%
Other	10	9	90%
TOTALS	101	63	62%

Who is Using the Maps?

Table 6 shows the distribution of map users by agency and profession type. In terms of agency type, nearly all consultants who responded to the questionnaire both had and used the maps. Also, a significantly higher proportion of non-governmental agencies than governmental agencies used the maps, suggesting that respondents from consulting firms, utilities and other types of agencies may be more likely to use the maps. The Chi square test showed the difference between governmental and non-governmental agencies to be significant at the .01 level.

Over half of the respondents in the following professional categories who had maps were using them: engineers, geologists, fire/police, emergency managers, and other. Of these, the

[7] In order to have sufficient observations in each category for the Chi square test to be valid, the agency types were aggregated into government agencies and non-government agencies. Similarly, the following professions were combined: building official and engineer; fire, police, and emergency management; other local staff and elected officials.

proportion of fire, police and emergency managers using the maps was significantly higher than other professions. The Chi square test showed this difference to be significant at the .01 level. These results suggest that fire, police and emergency managers may be more likely to use the maps. This makes sense because fire and police often have emergency management responsibilities, and Metro has been making a special effort to help emergency managers use the maps. For example, free copies of the Metro Area Disaster (MAD) GIS have been distributed to all emergency managers in the Metro area but not to other potential users.

Who is Not Using the Maps?

Table 7 shows the distribution of map non-users by agency and profession type. Non-users fit into one of two main categories: those who had the maps and those who did not have the maps. The largest group of non-users are those who did not have copies of the maps. These non-users comprised 32% of the respondents and were primarily from local government fire, police, planning or building departments.

While over 50% of respondents from all agency types who had the maps were using them, a significantly smaller proportion of respondents from government agencies used the maps. This difference is significant at the .05 level, according to the Chi square test, and probably can be attributed to the large number of respondents from local government agencies who felt there was no need to use the maps or that the maps were at too small a scale to be useful.

A look at the professions of respondents who did not use the maps shows that less than half of the planners, building officials, other local staff, and elected officials with maps were using them. The Chi square test found that a significantly smaller proportion of planners who responded used the maps (significant at the .01 level), likely due to the problems reported by planners in using maps at small scales.

Table 7: Distribution of Map Non-Users

	Total Who Had Maps	Total Non-Users of Those Who Had Maps	% Who Had Maps Who Did Not Use Them	Total Who Did Not Have Maps
Agency Type				
Local Govt.	63	30	48%	39
Other Govt.	10	3	30%	5
Consultant	13	1	1%	2
Utility	5	2	40%	1
Other	10	2	20%	1
TOTALS	101	38	38%	48
Position/Profession				
Planner	18	11	61%	8
Building Official	9	5	56%	7
Engineer	20	5	25%	8
Geologist	9	3	33%	0
Fire/Police	2	0	0%	10
Emergency Mgt.	13	1	1%	1
Other Local Govt.	13	8	62%	5
Elected Official	7	4	57%	5
Other	10	1	10%	4
TOTALS	101	38	38%	48

Other Users and Non-Users

This study found little evidence of map usage by groups such as insurers, bankers, realtors and contractors, although there are indications that a couple of these groups may have used these maps on occasion. For example, a former state employee thought that a bank had considered the maps after a merger as one factor in deciding which branches to keep open and which to close, although this could not be confirmed. Also, a group of realtors who saw the maps became interested in the issue and began lobbying for a disclosure law. Such a law will be before the state legislature in the next session.

MAP QUALITY

The most common complaint about map quality concerns the scale of the maps. Many respondents wrote that they would like the maps at a larger scale, although a few questioned whether this would be worth the expense. Local government planners were particularly likely to mention the scale of the maps as an issue. In contrast, none of the emergency managers, fire or police officers who responded commented on the scale of the maps.

A few respondents mentioned other map accuracy issues. Two wrote about a lack of peer review that undermined their confidence in the maps. A couple also stated they were concerned because some site-specific studies in areas shown on the map as hazardous revealed no hazards, while another mentioned finding hazards in areas that were not shown as hazardous. These respondents felt that the difference between these results called the accuracy and reliability of the maps into question. Several respondents said that showing the data points on which the maps are

based on the maps themselves would help to both demonstrate the level of detail for which the maps are meant to be used and increase their understanding of the maps.

A number of respondents mentioned two other map quality issues. Several said that the maps would be more helpful if they showed more of the major roads, and one felt that the roads should be darker so that they would be easier to see from a distance. The second issue that was mentioned was problems with areas of interest located along map boundaries. These respondents had problems either with piecing different quadrangles together or with data that did not cover their entire area of interest.

MAP ACCESSIBILITY

The most common way that respondents had heard about and received copies of the maps was through Metro's direct mailings. Metro mailed complimentary copies of the maps of the Portland quad to local government officials when those maps were first completed in 1993. In 1997, when the mapping was finished for the entire Metro region, complimentary copies of the map of the region were mailed to all mayors, planning directors and county chairpersons in the Metro area. Several people also mentioned the maps' availability at the Nature of the Northwest store run by the state.

Respondents also heard about the maps at meetings and workshops and in the newspapers, and many seemed to hear about the maps by word of mouth or through personal connections. Several know people at either Metro or DOGAMI who told them about the maps. Others had served on MACMED, or knew someone who had.

None of the respondents mentioned any difficulty obtaining the maps, indicating that the system works for those who know about the maps and wish to purchase copies. However, many respondents did not know about the availability of either the 7.5 minute quadrangle maps or the custom maps that Metro could produce. In some cases, obtaining these products could have allowed non-users to become map users.

Several respondents mentioned that they had been unable to obtain the map data in GIS format and stated that providing the data digitally would be very helpful. These respondents wrote that they wished to overlay the maps with other data, such as utility lines, or to produce maps focusing on their geographic area of interest. This problem may have been solved with the release of the map data on CD-ROM from DOGAMI in September 1998. [8]

[8] The CD is available for $25.00 and includes the digital map data in four different file formats: MapInfo(r) .tab and .mif/.mid; ARC/INFO(r) .shp and .e00.

CONCLUSIONS

Analysis of the questionnaire results leads to the conclusions listed here. These are discussed in more detail below.

Conclusions Concerning Map Use

- The maps appear to have contributed to a general increase in earthquake awareness in the Portland region.
- Substantial seismic hazard mitigation efforts are underway supported with data from the maps.
- There is varied use of the maps by diverse users.
- There is very little misuse of the maps.
- Most respondents who had problems using the maps are local planners and building officials who feel that the maps need to be at a tax-lot level to be useful.
- While emergency managers have found the relative earthquake hazard map quite useful, many other users have found more use for the individual hazard maps.
- In addition to the maps themselves, the raw data used to produce the maps has also found several uses.

Conclusions Concerning Map Quality

- The vast majority of respondents were pleased with the quality of the maps.
- Map quality could be improved with a few straightforward changes.

Conclusions Concerning Map Accessibility

- Obtaining the maps was not difficult for those who were aware of their availability and interested in getting copies.
- Providing the maps in a GIS format has the potential to help people make better use of the data.

CONCLUSIONS CONCERNING MAP USE

Increased Awareness of Earthquake Hazards

The maps appear to have contributed to a general increase in earthquake awareness in the Portland region. Interviewees from local government agencies, insurance companies and geotechnical firms mentioned that they believe the level of public awareness of earthquake hazards has grown since the release of the maps. All reported an increase in inquiries related to seismic hazards. One local building official also noted that a number of developers were now providing geotechnical reports for proposed projects even when the reports were not required.

Seismic Hazard Mitigation Efforts Underway

Substantial seismic hazard mitigation efforts are underway supported with data from the maps, as described in the results section above. In some cases, including projects involving Portland sewers, bridges and schools, the maps were used to set priorities for retrofit. The maps have also been used to review the safety of existing facilities such as dams and hazardous materials facilities, sometimes leading to retrofit projects.

Varied Use by Diverse Users

Emergency management was one of the main uses for which the maps were intended, and the maps have been well received for that purpose. As mentioned previously, a higher proportion of emergency managers, fire and police officers used the maps, and none mentioned any problems with the scale or accuracy of the maps. These groups have used the maps for a wide variety of uses, including education and training, siting emergency response facilities, selecting emergency routes, and encouraging retrofit.

Use by these groups should continue to increase as other related materials become available. For example, the Metro Area Disaster (MAD) GIS has been distributed to all emergency managers in the area, and Metro is currently working to both improve the program and educate emergency managers about possible uses of the information. At the same time, DOGAMI has been using information related to the maps to develop HAZUS simulations of specified potential earthquakes. The results of these simulations will provide more detailed estimates of the levels of damage that could be sustained and where these losses may be concentrated, information that will be extremely useful to emergency managers.

At the regional level, Metro has used the maps for a number of planning purposes, including facilities planning, hazard mitigation planning, emergency response planning, and urban growth planning. The scale of the maps is appropriate for planning recommendations by a regional agency since the recommendations often affect broad areas rather than individual parcels.

Some local planners and building officials discovered ways to use the maps despite the difficulties many encountered (see below). These staff members have used the maps to require and check the content of geologic reports, as part of a process to choose future locations for public facilities, and for hazard mitigation planning.

Geotechnical firms and consulting structural engineers have also used the maps. These consultants generally use the maps in determining the extent and type of site-specific hazard investigations that are needed for a particular project.

Little Misuse of Maps

When the maps were developed, one of the concerns was that people would use the maps improperly by enlarging them and using them instead of site-specific studies. Another concern was that users would incorrectly assume uniformity of data-- that areas in Zone A are all equally dangerous while areas in Zone D are all equally safe. This study did not find any of these improper uses. In fact, many respondents seemed to understand the purpose of the maps and the reasons why they could not be used for site-specific hazard determinations. However, a couple

respondents mentioned the possibility of enlarging the maps and overlaying them with parcel data at some point in the future. On the whole, though, the maps are being used appropriately.

Most Problems for Planners and Building Officials

Many local planners and building officials had difficulties determining how the maps could be used given their small scale. These groups usually work with maps at a tax-lot level, and often wrote that the maps had no utility if they could not be used to determine conditions on specific parcels. Additionally, a couple of respondents wrote that they did not understand how they were meant to use the maps. This is possibly due to both the small scale of the map and the fact that most planners and building officials have never seen or worked with maps of this type before.

Usefulness of Relative Earthquake Hazard Map and Individual Hazard Maps

In general, emergency managers thought the relative earthquake hazard map very useful because it provided them with overall estimates of relative earthquake hazards. In contrast, geotechnical engineers and building officials in particular found more use for the individual hazard maps. This group preferred the individual hazard maps because they provided more information about the types of seismic hazards that might be expected in a given area.

Uses of Raw Data

While the maps themselves have been used in a variety of ways, the raw data on which the maps were based has also been useful. For example, geologists have used the data as a starting point in their investigations; a consultant to the Portland Bureau of Water Works used the data in a facilities location study; and DOGAMI used the data in developing a HAZUS program for the Portland area.

CONCLUSIONS CONCERNING MAP QUALITY

Majority of Users Pleased with Map Quality

Most users had no complaints about the quality of the maps, and several were extremely impressed by the maps. One user, for example, wrote that “It’s a great map and . . . a great tool for public education!” Some non-users also had positive reactions to the maps.

As mentioned previously, the only widespread negative comment was that the maps are at too small a scale. A few respondents also mentioned concerns such as differences between the maps and the results of site-specific investigations, the lack of peer review, difficulty in interpreting the data, and the need for the maps to show more of the road system.

Minor Changes Could Improve Map Quality

Although few users raised issues with the quality of the maps, some of the changes suggested by those who did are fairly minor and could be implemented when the maps are reprinted. For example, the road system shown on the maps could include more major arterials and could label roads more frequently. Data points could be displayed on the individual hazard maps, and

informative notes could be added to the maps. These recommended changes are discussed in more detail in the recommendations section below.

CONCLUSIONS CONCERNING MAP ACCESSIBILITY

Obtaining the Maps was Not Difficult

On the whole, the responses to the questionnaires indicate that obtaining the maps was not difficult for those who were aware of their availability and interested in getting copies. Complimentary copies of the maps were sent to a number of people in the region, and the maps have also been readily available at the Nature of the Northwest store.

The number of respondents who did not have copies of the map (48 out of 149, or 32%), however, shows that distribution of the maps is not as good as it might be. A significant number of people who could reasonably be expected to use the maps do not have copies of them. Because obtaining the maps is fairly straightforward, the lack of maps is likely due to either a lack of awareness of the maps' availability or a lack of interest in using the maps.

Usefulness of Data in GIS Format

Many respondents expressed interest in obtaining the data in a GIS format. This would allow them to layer the earthquake hazard data with other mapped data to produce maps that address a particular concern. An example of this type of map is the one that Metro produced for the Portland public schools showing the location of each school in addition to the relative earthquake hazard zones. Providing the maps in a GIS format also allows jurisdictions to produce maps centered on their particular locations at any scale down to 1:24,000, which is especially useful for towns located in more than one quadrangle.

RECOMMENDATIONS

The comments on the returned questionnaires and from people interviewed included a number of suggestions for improvement. In this section, we present the most feasible of these recommendations. Our own suggestions, which are based on issues that came to light through the information collection and analysis processes, are also included.

Although the recommendations are specific to the earthquake hazard mapping program in the Metro area, the recommendations are also meant to be used in designing similar programs for other areas. In the discussion below, the recommendations are divided into three sections, each of which addresses one of the three factors that this project focused on: map use, map quality, and map accessibility.

RECOMMENDATIONS TO IMPROVE MAP USE

Provide information to local government planners and building officials about use of the maps.

Planners and building officials from local governments frequently wrote either that they did not have any use for a map of such a small scale, or that they did not know how to make use of the maps. It would be very helpful for these staff members to hear how maps of this type and scale can be used, together with examples of ways others have used the maps. In addition, there appear to be a number of potential map uses that no one has yet implemented, as shown in Table 4. Providing information about possible ways to utilize the maps could thus both encourage non-users to use the maps and help map users to expand and improve their usage.

A publication funded by the U.S. Geological Survey should be helpful for this purpose. This publication, entitled *Local Government Guide to Using Earthquake Hazard Maps to Reduce Seismic Risk*, provides a comprehensive look at the many uses that local governments can make of the earthquake hazard maps. Examples are included throughout the guidebook to demonstrate specific uses. The guidebook was presented at the Regional Natural Hazard Mitigation Plan Workshop on October 30, 1998 and is now available from Metro.

Consider requiring use of the maps in preparing local comprehensive plans.

One of the ways that the earthquake hazard map information has not yet been used is in the preparation of local comprehensive plans. Yet the state could easily require consideration of the maps as part of the planning process in areas for which the maps are available. This is possible because the State of Oregon requires local jurisdictions to submit their comprehensive plans to the Department of Land Conservation and Development (DLCD) for periodic review every 4-10 years to ensure compliance with statewide planning goals. The maps could be used to meet the requirements for several of the goals, including Goal 7, which is “to protect life and property from natural disasters and hazards.” To that end, DOGAMI and Metro could open discussions with the DLCD about the possibility of requiring use of the maps.

Take steps to increase use by county, regional and state agencies.

Because the scale of the maps fits them best for use at regional and county levels, agencies that commonly work at this level should be especially encouraged to use the maps. Such agencies include Metro itself, the three counties, and various departments of the State of Oregon. To encourage their usage of the maps, these agencies should be educated about the availability of the maps and how use of the maps could help in accomplishing their missions.

Publicize examples of successful uses of the maps.

One of the most powerful ways to encourage use of a relatively new product such as the earthquake hazard maps is by providing examples of successful usage. These can show potential users how other, similar organizations have used for the maps and demonstrate the types of use for which the maps were intended. A number of examples are provided in *Local Government Guide to Using Earthquake Hazard Maps to Reduce Seismic Risk*. Examples from the *Guide*, as well as examples mentioned in this report, could be featured in Metro and DOGAMI publications, professional newsletters, and other publications received by potential users. In addition, a simple web page could be produced that highlights examples of map usage in the region.

RECOMMENDATIONS TO IMPROVE MAP QUALITY

Include more major roads and street names.

Several respondents wrote that including more major roads would improve the maps and make them easier to use. The roads serve as the main references on the maps, allowing users to determine the approximate locations of areas of interest more easily. A related suggestion was to include more street names. Many of the roads shown on the maps are not labeled, which again makes the maps more difficult to use.

Show data points on individual hazard maps to indicate the locations for which ground data was collected.

Including the data points on the three individual hazard maps would be helpful for several reasons. It would demonstrate that much of the information on the maps has been extrapolated, thus illustrating the reliability of the maps. Adding the data points would help all users to understand why site-specific investigations may produce results different from the information shown on the maps. For geotechnical engineers and geologists, adding data points would make the maps more useful by showing the locations for which detailed information is available.

Print informative notes on the maps themselves.

Although reports discussing the mapping technique and uses of the maps are supplied with all quad-scale maps, the questionnaire responses indicate that many potential users post the maps on the wall and file the report for later reference. Most had never read the reports, and some were unaware of the reports' existence. Also, reports are not included with the regional map. For

these reasons, a few general notes that are printed directly on the map sheet could greatly help to improve users' understanding of and use of the maps.

One note could explain the mapping technique in general terms and provide a phone number at DOGAMI so that interested people could call to obtain more information. This would provide an information source for staff members who do not know about the written reports, either because of staff turnover or because the reports have been lost. Another note could state that the earthquake hazard maps are available as GIS files at the Nature of the Northwest store. A third note could add that Metro can produce custom maps showing specific areas of interest and other data layers for interested parties, and provide a phone number at Metro for more information. These notes would inform people of the availability of additional resources for using the maps.

In future projects, consider using a peer review process.

If similar projects are undertaken in other parts of the country, integrating peer review of the maps into the projects should be considered. This may both improve map accuracy and allay fears of some potential map users about the accuracy of the maps. In the Metro area, a team assembled at the beginning of the project worked out the mapping methodology, and because that methodology was followed for each of the maps, peer review was not seen as an essential part of the process. However, several respondents mentioned the lack of peer review as a factor that undermined their confidence in the maps.

RECOMMENDATIONS TO IMPROVE MAP ACCESSIBILITY

Continue to publicize map availability.

Responses to the questionnaires indicate that the maps are easy to obtain if a potential user knows about them and wants to get copies. However, despite the amount of publicity to date, several respondents stated that they did not know what the maps were or where they were available. As a result, efforts to inform potential users about the maps need to continue. These efforts should discuss the availability and uses of the individual hazard maps as well as the relative earthquake hazard maps, since some respondents indicated that the individual hazard maps were actually more useful. Information should also be provided about the different scales at which the maps are available, as well as the availability of the map data in GIS format.

Publicize Metro's ability to make custom maps.

The fact that Metro can produce custom maps of an area showing the earthquake hazard map layers as well as information from a number of other data layers is not widely known. Respondents mentioned their need for maps including areas from several quadrangles, and for maps including additional information such as flood plains or school locations, but were unaware that Metro could make maps such as these for them. This ability may be especially useful to towns and organizations that do not have GISs of their own, and could encourage use of the maps by certain potential users. The price of a custom map varies depending on the amount and

complexity of information to be shown on the map and the size and scale of the map, and can range upward from $75.00.

Continue and enhance availability in GIS format, together with instructions.

In order for potential users to get the most use out of the maps, the data needs to be available in GIS format that can be easily integrated with other existing GIS data. A number of respondents wrote that they would like the data in GIS format so that they could either overlay it with other data in their systems or print maps focusing on their particular area of interest. In September 1998, the earthquake hazards data became available in GIS format from DOGAMI. Metro is working towards a release of their Metro Area Disaster (MAD) GIS in early 1999, which would include the hazards data as well as other data along with a specially designed program for viewing and analyzing the data.

Providing the earthquake hazards data in this format will make it easier for users to misuse the data by overlaying them with parcel boundaries and printing maps at larger scales than the data can accurately support. However, not providing the data in GIS format penalizes those who would use it correctly. The possibility of misuse is a reason to educate users about appropriate and inappropriate uses of the data, not a reason to prevent the release of the data to all potential users. Therefore, the GIS versions of the earthquake hazard maps should continue to be made available, together with information on ways to use the data correctly. To this end, a short booklet could be included in the CD case with examples and suggestions, as well as references to sources of further information.

ADDENDUM: EARTHQUAKE MITIGATION AND RECOVERY EXERCISE

After the evaluation was completed and the final report written, some funds remained in the contract with Spangle Associates. Those funds were used to facilitate an earthquake mitigation and recovery exercise in Oregon City on April 30, 1999. The purpose was to assess the usefulness of the maps in this tabletop training exercise and include the results of the assessment in an addendum to this final project report.

EARTHQUAKE MITIGATION AND RECOVERY EXERCISE

In the early 1990s, Spangle Associates developed, under a National Science Foundation grant (BCS-9025125), a training exercise for local government officials in long-term recovery and reconstruction after earthquakes. FEMA adopted the exercise as part of its training program and commissioned us, along with The Mitigation Assistance Corporation, to help prepare similar exercises for recovery after floods and hurricanes. The exercise manuals and accompanying slides are available from the FEMA web site and on a CD-Rom available from FEMA's Emergency Management Institute. These "tabletop" training exercises are the first to treat long-term recovery tasks. They have proven especially useful to help local staff members understand the transition from emergency response to recovery activities and the options for reducing potential damage before the disaster. Discussion of mitigation possibilities is incorporated into each task.

The exercises are designed for the high-level staff of a single local jurisdiction. Participants typically include the city manager, financial officer, emergency manager, planning director, public works director, building official, and others such as housing, parks and recreation, transportation, community development and redevelopment specialists. They spend an entire day going through a series of tasks starting with creating a damage scenario for their city and ending with outlining a hazard mitigation plan. The tasks are:

A. Damage Scenario
B. Emergency Shelter
C. Closure and Relocation
D. Damage Assessment
E. Geologic Evaluation
F. Demolition
G. Temporary Business Sites
H. Temporary Housing
I. Permit Processing
J. Reconstruction Planning
K. Timing and Recap
L. Reducing Risks

Each task is introduced with a slide presentation giving background and examples of how communities have handled the task after an earthquake. Players sit around a table with a large-scale base map of their community. As they work the tasks, information is added to the base map and a series of one-page handouts. At the end of the day they leave with a list of things the community could do now to reduce damage in earthquakes and to make the process of recovery and rebuilding easier.

The exercise is unusual in that the participants—not earthquake experts—create the scenario using the best available information about earthquake hazards coupled with their detailed knowledge of the city. This feature of the exercise is often an eye-opener to the participants and usually results in a realistic and credible assessment of the jurisdiction's vulnerabilities.

USE OF EARTHQUAKE HAZARD MAPS IN EXERCISE

We believed the DOGAMI earthquake hazard maps could be used effectively in creating the scenario, locating sites for emergency shelters, determining policies for repairs and rebuilding in geologically hazardous areas, deciding what buildings to demolish, selecting temporary sites for businesses and residences, developing a reconstruction plan for the city, and outlining plans to reduce risk. We thought if the maps were useful in the training exercise, they would also be useful in planning for long term recovery and reconstruction as well as actually carrying out these tasks after an earthquake.

SELECTION OF OREGON CITY AS EXERCISE SITE

Oregon City was selected after discussions with Metro staff because the city staff and political leaders are aware of earthquake hazards and the needs for hazard mitigation. The city had recently completed a local hazard mitigation plan as a pilot project that is part of a regional effort to prepare a regional hazard mitigation plan. In addition, key members of the city staff attended a week-long training course in disaster recovery at FEMA's Emergency Management Institute (EMI) in Emmitsburg, Maryland. The Earthquake Mitigation and Recovery Exercise seemed like an ideal follow-up to these efforts since it covers subjects not included in the EMI program and could serve as a test of the plan. The hazard mitigation planning process in Oregon City, led by the city's fire department, established working relationships between the emergency responders and other city departments that would be involved in long-term recovery and reconstruction. The exercise could reinforce these relationships.

EXERCISE IN OREGON CITY

The exercise was conducted in Oregon City on April 30, 1999 at the Environmental Learning Center at Clackamas Community College.

Players were:

- Ken Dawson, Captain, Oregon City Fire Department
- Carol Poulton, Administrative Secretary, Oregon City Fire Department
- Clark Poulton, Deputy Chief, Oregon City Fire Department
- Bob Cullison, Engineer, Oregon City Engineering Department

- Bryan Cosgrove, Director, Oregon City Department of Community Development
- Rick McClung, Director, Oregon City Department of Public Works
- Joe McKinney, Oregon City Department of Public Works
- Barry Rotrock, Superintendent, Oregon City School District
- Barb Streeter, Director, Oregon City Community Activities
- Shirley Nixon, Oregon City Courts
- Jessica Schriever, GIS Coordinator, Oregon City

Observers were:
- Jim Davis, Chief, Oregon City Fire Department
- Rocky Smith, Sergeant, Oregon City Police Department
- Gordon Huiras, Oregon City Police Department
- Lynda Orzen, Oregon City Neighborhood Emergency Response Team Representative
- Dave Adelhart, Chairman, Oregon City Community Involvement Council
- Casey Marley, Emergency Manager, Clackamas County
- Mike McGuire, Growth Management, Metro

Most of the players had attended the training in Emmitsburg and were familiar with the city's emergency response plans and FEMA's recovery programs and procedures.

RESULTS OF THE EXERCISE

Participants stated that the material covered in the exercise was not covered in the Emmitsburg program. They seem to feel the exercise raised issues and concerns the city had not yet addressed in either emergency management planning or hazard mitigation planning. Participants left the exercise with a list of concerns and actions to pursue in the months ahead.

The list was compiled from recommendations made at the end of each task. The list included the following items:

- Avoid building any more unreinforced masonry buildings.
- Review land uses designated for hazardous areas.
- Check agreements with Red Cross re emergency shelter sites.
- Develop a plan to house people after shelters close.
- Have list of historic buildings available at time of damage assessment.
- Obtain a supply of placards for posting buildings.
- Prearrange for structural engineering services.
- Train staff in damage assessment procedures—learn relevant rules and regulations
- Prepare ordinances that can be adopted after an earthquake to require geologic studies of areas with ground failure.
- Plan ahead for debris disposal, considering recycling possibilities.
- Plan to relocate students from damaged schools.

- Work out agreement with Clackamas Community College for temporary business sites.
- Work with Downtown Business Association to help businesses prepare for an earthquake.
- Adopt code pertaining to retrofit of unreinforced masonry buildings.
- Check on HUD housing programs that might be used to help replace damaged housing.
- Have ordinance in place to streamline permit processing after an earthquake.
- Allow some permits to be issued in the field.
- Realize the rebuilding can be an opportunity as well as a problem.
- Have zoning regulations in place or "in the drawer" to guide rebuilding.

In reviewing this list, the group agreed that two types of action were high priority. The first action was to prepare or revise ordinances and the second was to work out mutual aid agreements. Ordinances needed include:

- Organization and authority for reconstruction planning and decision making
- Streamlined permit processing
- Code standards for repair and retrofit
- Rezoning for areas likely to be damaged that might be rebuilt differently than before
- URM retrofit procedures and standards

Responsibility for preparing the ordinances was assigned to the Community Development and Public Works departments with funds needed for legal review. The group estimated they could be completed by 2002.

Mutual aid agreements or mechanisms for interagency coordination need to be reviewed or established with:

- Red Cross and school district re emergency shelters
- Downtown Business Association re business preparedness and relocation
- Department of Housing and Urban Development re housing vouchers and other programs
- Metro re debris removal plans
- Structural engineering associations and consultants re assistance with damage assessments
- FEMA re procedures and requirements

The exercise reinforced the need for many of the actions in the hazard mitigation plan and participants felt that the results could be used to refine certain parts of the plan. Some noted that the plan should include a section on organization and planning for long-term recovery and reconstruction.

The damage scenario showed heavy losses in areas also subject to flooding and rain-generated slope failures. The exercise helped to stimulate thinking about what should happen in these areas with multiple hazards after a disaster. These concerns may be addressed in the city's revision of its comprehensive plan now underway.

USE OF THE EARTHQUAKE HAZARD MAPS

A paper copy of the Relative Earthquake Hazard Map for Oregon City was available at the exercise and a Fire Department staff person brought a laptop computer to the exercise containing a GIS with all the earthquake hazard maps, a building inventory, and parcel data. The map and the GIS were used by the participants in developing the earthquake scenario and referred to for several of the other tasks. Players were able to ask questions and the computer provided answers quickly enough to be useful. For example, the GIS data base told them how many unreinforced masonry buildings were in the city and where they were located. The number in the data base was less than they thought and they stayed with their own estimate, apparently assuming their estimate was more accurate than the data base number.

The paper maps were referred to in doing the scenario, locating shelters, temporary housing and temporary businesses and discussing reconstruction planning. The maps helped drive home the point that the potential for earthquake damage is not uniform. Some areas are clearly more vulnerable to damage than others simply because of ground conditions. The group recognized that these areas, particularly the ones that also have flood and landslide hazards, needed special consideration in comprehensive planning and in planning for reconstruction after an earthquake (or other disaster).

CONCLUSIONS

1. The earthquake hazard maps are useful for mitigation and recovery exercises and, by extension, in mitigation and recovery planning.

2. Paper maps had more credibility than map information in the GIS program, probably because they are more familiar. GIS would be a valuable tool after a real earthquake, and its value would be greatest if potential users know and trust the information in it and know how to use it. People trust the information sources they use under normal circumstances. This means that those who will need information from GIS after a disaster should have a voice in determining the information that goes into the GIS and be trained to use it ahead of time.

3. Because the map data are digitized, they can be updated after an earthquake to incorporate actual ground motion, ground failures and other earthquake effects. Such an update, done as quickly as possible after the event, would be a very powerful tool in planning for reconstruction and mitigation actions to be undertaken as part of long-term recovery.

ACKNOWLEDGMENTS

Many people contributed to this project, especially the 149 individuals from the Metro area who took the time to fill out and return a questionnaire they received in the mail. Forty-three people then generously gave more of their time and provided additional information in telephone interviews. The voices of the respondents and interviewees provide the basis for this report, and we have tried to remain faithful to their statements while categorizing, counting, and otherwise interpreting their remarks.

Throughout the project, the staff at Metro has been a source of help and information. A few people deserve special mention. Gerry Uba, the Natural Hazard Mitigation Program Coordinator, provided assistance by contributing to the mailing list, coordinating the logistics and acting as the contact person for the survey in Oregon. Mike McGuire provided a copy of MADGIS and then answered questions about the program. Mike Burton, the Executive Officer of Metro, contributed his name and a sore hand from signing cover letters that accompanied the questionnaires.

Similarly, staff at the Oregon Department of Geology and Mineral Industries (DOGAMI) have provided information and advice throughout the duration of the project. John Beaulieu, Deputy State Geologist, supplied names for the mailing list and many useful suggestions. Mei Mei Wang answered questions on several occasions about map uses and HAZUS simulations.

Jim Davis, Ken Dawson, and Carol Poulton of the Oregon City Fire Department helped arrange for the Earthquake Mitigation and Recovery Exercise conducted in Oregon City by Martha Tyler on April 30, 1999.

Arthur Zeizel of the FEMA office of Natural and Technological Hazards in Washington, D.C., provided comments that helped make this a more useful study.

At Spangle Associates, Associate Planner Karen Kristiansson did most of the research for the project and authored the interim and final reports. Principal Planner Martha Tyler prepared the work program, drafted the original questionnaire, conducted half of the telephone interviews and reviewed the interim and final reports. President George Mader helped develop the first mailing list and reviewed the interim and final reports. Office Manager Joette Farrand and Administrative Secretary Irmgard Ibara assembled the mailing list from bits and pieces and helped with the mailings.

APPENDIX A

Questionnaires from the 1997 and 1998 Mailings

APPENDIX B

Letters and Postcards from the 1997 and 1998 Mailings

APPENDIX C

Materials from Additional Efforts to Gather Information