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REMEMBER:

APRIL IS EARTHQUAKE AND TSUNAMI PREPAREDNESS MONTH!

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, letters, notices, and meeting announcements should be sent to Klaus Neuendorf, Editor, at the Portland office (address above).

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Cover photo

Enerfin Resources Company plugged four depleted natural gas wells during 1997 at the Mist Gas Field in Columbia County. One of them was the Columbia County well 32-32 shown here during operation.

Summary report on oil and gas exploration and development in Oregon in 1997 begins on next page.

April is Earthquake and Tsunami Preparedness Month

Each year the Governor proclaims April as Earthquake and Tsunami Preparedness Month. This helps focus awareness and efforts to get Oregonians ready for an earthquake.

We now know that our state has experienced earthquakes with magnitudes between eight and nine. The source of these deadly events is the Cascadia subduction zone located offshore, off Oregon and Washington. It was the process of subduction that produced the magnitude 9.2 earthquake of 1964 in Alaska, killing 122 people in that sparsely populated state. The same earthquake triggered a tsunami that caused damage along the Oregon coast and the deaths of several people at Beverly Beach.

Oregon also experiences smaller earthquakes, such as the ones in 1993, centered near Mount Angel and Klamath Falls. However, consider this: The amount of destructive energy released is 30 times higher for each next-higher number on the Richter scale. The Mount Angel quake was of magnitude 5.6; a magnitude 9 Cascadia earthquake would be over 25,000 times more powerful than that relatively small event!

Although the thought of such a killer quake can be terrifying, there are things we can do to protect ourselves. The most important thing we can do to save lives is to upgrade our buildings to withstand a serious earthquake. Make sure your house is bolted to its foundation and your water heater is strapped to a wall.. Stay away from unreinforced masonry and brick buildings if you feel a ground tremor.

In what condition are your local schools? The Riverdale School District in Portland just completed rebuilding a gym that will now protect its students, rather than endanger them, in the event of a strong earthquake.

Oregon Emergency Management, the Oregon Department of Geology and Mineral Industries, the Red Cross, the Salvation Army, and the Bank of America are supporting the organization of a statewide earthquake drill for Oregon schoolchildren. The drill will be held the morning of April 30, to coincide with a similar effort in the State of Washington.

Earthquakes are the main triggers of tsunamis. Signs explaining tsunami hazards are being erected along Oregon beaches. Tsunami warning systems and evacuation routes are being developed in many coastal communities. Both residents and visitors should note this tsunami information and take a moment to figure out how they would react if they felt an earthquake.

These steps may seem small in relation to the incredible power of earthquakes, but every small piece of information and preparation will increase your chances of making it safely through the next natural disaster. □

Oil and gas exploration and development in Oregon, 1997

by Dan E. Wermiel, Petroleum Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

There was an increase in oil and gas leasing activity during 1997 compared to 1996. The increase was primarily due to two oil and gas lease sales held by Columbia County during the year, at which approximately 10,405 acres were acquired by four companies. The acreage leased was located within or in proximity to the Mist Gas Field. Four U.S. Bureau of Land Management (BLM) lease sales were held during the year, and no offers were received. A total of 39,131 federal acres were under lease at year's end, and filed applications are pending on 4,943 federal acres. The State of Oregon conducted no lease sales during the year. There were 12 State of Oregon tracts under lease at year's end, comprising 941 acres.

Northwest Natural Gas Company (Northwest Natural) continued underground natural gas injection and withdrawal operations at the Flora and Bruer Pools at the Mist underground natural gas storage project. Operations began for development of additional underground natural gas storage at the Calvin Creek underground natural gas storage project located approximately 3 mi to the south at Mist Gas Field. This included drilling of service wells and installation of pipelines and other infrastructure development.

Northwest Natural drilled four service wells at Calvin Creek. Drilling was under way at a fifth service well at year's end. These wells will be used for injection-withdrawal and monitoring of natural gas stored in depleted reservoirs of former gas producers at Mist Gas Field. Enerfin Resources plugged four former gas producers at Mist Gas Field and worked over two wells to enhance gas production during the year.

At Mist Gas Field, 19 wells were productive during 1997. A total of 1.4 billion cubic feet of gas (Bcf) was produced, less than the 1.7 Bcf produced during 1996. The total value for the gas was about $2.6 million, which is less than the $3.4 million for 1996.

DOGAMI revised administrative rules during the year related to oil and gas drilling bond requirements. Bonding was revised to more closely reflect actual costs to plug and abandon wells and reclaim drill sites.

LEASING ACTIVITY

After several years of low activity, oil and gas leasing increased during 1997 primarily due to two oil and gas lease sales held by Columbia County, where approximately 10,405 acres were acquired. The leases were offered through an oral auction bidding system, and the majority of the acreage was acquired by Enerfin Resources, Houston, Texas, and Eldorado Exploration, Lakewood, Colorado. In addition, Northwest Natural Gas Company (Northwest Natural), Portland, Oregon, and Northwest Fuels, Lake Oswego, Oregon, also acquired acreage from Columbia County during the year. The leases were all located within or in proximity to the Mist Gas Field, Columbia County, Oregon. The majority of the acreage was leased at a minimum bid of $1.00 per acre, and the highest bid of $13.00 per acre was received for a 120.0-acre parcel located in sec. 31, T. 6 N., R. 5 W. within the Mist Gas Field.

The U.S. Bureau of Land Management (BLM) held four lease sales during 1997, at which no bids were received for any leases on federal lands. A total of 39,131 federal acres was under lease at year's end in Oregon. Pending applications have been filed on an additional 4,943 acres located primarily in eastern Oregon. Total rental income to the BLM was $55,544.50 for 1997.

The State of Oregon held no lease sales during 1997, and no new leases were issued. At year's end, 12 State of Oregon tracts were under lease, comprising 941 acres, which is the same as during 1996. Total rental income to the State of Oregon was $941 during 1997.

DRILLING

Four underground natural gas storage service wells were drilled by Northwest Natural during 1997, and drilling at a fifth well was under way at year's end. The wells are part of the development of the Calvin Creek underground natural gas storage project at the Mist Gas Field. This project is adding additional underground natural gas storage capacity by converting depleted, formerly producing reservoirs into use for underground storage. The wells will be used for injection-withdrawal and monitoring of natural gas in the storage reservoirs. The injection-withdrawal wells drilled and completed were the IW 23a–22–65, located in sec. 22, T. 6. N., R. 5 W., drilled to a total depth of 2,298 ft, and the IW 32H–22–65, located in sec. 22, T. 6 N., R. 5 W., drilled to a measured depth of 2,600 ft. The latter was the first successful horizontal well drilled and completed in Oregon. The purpose of the horizontal drilling of this well was to avoid unfavorable topography and to expose a greater amount of the storage zone to the wellbore to maximize gas injection and withdrawal efficiency. A third injection-withdrawal well, the IW 22H–22–65, located in sec. 22, T. 6 N., R. 5 W., was horizontally drilled to a measured depth of 1,825 ft. The well was lost due to mechanical problems that occurred during the cementing of the intermediate casing string and was plugged and abandoned. A replacement well, the

Above and on facing page: Installation of natural gas pipelines was part of the Northwest Natural development of the Calvin Creek gas storage project at Mist Gas field. While the pipes were being assembled, they were temporarily suspended above Highway 202 near Mist, Oregon, before they were permanently buried deep underground—and under the highway.

IW 22dH–22–65, was being drilled at year's end. One monitoring well was drilled by Northwest Natural, the OM 12–22–65, located in sec. 22, T. 6 N., R. 5 W. It was drilled initially to a total depth of 2,350 ft, when the drillstring became stuck. It was then sidetracked to a final total depth of 2,337 ft.

Enerfin Resources plugged and abandoned four depleted former producers at Mist Gas Field during 1997. These are the JH 31–20–54, located in sec. 20, T. 5 N., R. 4 W.; the CC 22B–19–65, located in sec. 19, T. 6 N., R 5 W.; the CC 32–32, located in sec. 32, T. 6 N., R. 5 W.; and the CFI 34–1–55, located in sec. 1, T. 5 N., R. 5 W. In addition, Enerfin Resources did workovers at two wells during 1997 to increase production capabilities. These wells were the CFI 31–16–54, located in sec. 16, T. 5 N., R. 4 W., and the CER 13–1–55, located in sec. 1, T. 5 N., R. 5 W., both of which were returned to gas production at years end.

During 1997, DOGAMI issued six permits to drill. One permit was canceled during the year. Permit activity is listed in Table 1.

PRODUCTION

The Mist Gas Field was operated by Enerfin Resources and Northwest Natural during 1997. During the year, 19 natural gas wells were productive at Mist Gas Field, 15 operated by Enerfin Resources and 4 by Northwest Natural. This is slightly less than the 21 wells which were productive at Mist Gas Field during 1996. Gas production for the year totaled 1.4 billion cubic feet (Bcf) of gas, which is lower than the production during 1996, when the Mist Gas Field produced 1.7 Bcf of gas. Most of the decrease in gas production during 1997 can be attributed to the normal decline in the production from existing wells and to the fact that no new wells were brought into production during the year.

The gas price during 1997 remained constant all year at about 21 cents per therm, which is about the same as the 20 cents per therm during 1996. The total value of the gas produced at Mist Gas Field was about $2.6 million, a decline from the $3.4 million during 1996, when there was a greater quantity of gas production. Cumulatively, the Mist Gas Field has produced about 62 Bcf of gas with a total value of about $119 million since it was discovered in 1979.

GAS STORAGE

The Mist gas storage project, operated by Northwest Natural, remained fully operational during 1996. The gas storage project has nine injection-withdrawal service wells, five in the Bruer Pool and four in the Flora

(Continued on page 30)

(Continued from page 28)
Pool, and 13 monitoring service wells. The two pools have a combined storage capacity of 10 Bcf of gas. This allows for the cycling of about 6 Bcf of gas in the reservoirs at pressures between approximately 400 and 1,000 psi and will provide for a maximum peak day delivery capability of 100 million cubic feet (MMcf) of gas per day. During 1997, about 6.6 Bcf of gas was injected and 5.0 Bcf of gas was withdrawn at the Mist gas storage project.

During 1997, Northwest Natural began development of the Calvin Creek natural gas storage project which is located about 3 mi south of the Mist Gas Field storage project. The Calvin Creek storage project will increase maximum peak day delivery capability for the combined total Mist underground gas storage to 145 MMcf of gas from the current maximum of 100 MMcf of gas. Activities currently under way for the expansion include the development of a new storage reservoir with high-capacity injection-withdrawal wells, the installation of new gathering pipelines, and the upgrading of processing and compression equipment at the Miller compression station. These activities will continue during 1998.

OTHER ACTIVITIES

During 1997, DOGAMI revised the Oregon administrative rules for oil and gas drilling bonds in Oregon. The intent was to provide protection to Oregon while not creating a disincentive for oil and gas operations in the state. Discussions to develop options for action by the DOGAMI Governing Board included the affected industry and interest groups. The final revisions that were adopted include changes to bonding requirements that reflect more closely the actual costs of plugging and drill-site reclamation. The new individual well bonding amounts for each well drilled, redrilled, deepened, or reworked are $10,000 for each well drilled to a depth less than 2,000 ft; $15,000 for each well drilled to a depth of 2,000–5,000 ft; and $25,000 for each well drilled to a depth greater than 5,000 ft. In multi-well operations, a blanket bond in the minimum of $100,000 may be filed in lieu of individual well bonds. In addition, the revisions allow DOGAMI to require that a bond be posted for any well that is idle or suspended for a period of one year or more or a gas producer that does not generate annual revenue greater than the individual bonding amount. Wells that are on production and generating annual revenue greater than that of the individual well bond may be granted an exclusion by DOGAMI. Contact DOGAMI for details.

A DOGAMI oil and gas internet homepage was constructed during 1997. The webpage address is http://sarvis.dogami.state.or.us/oil/homepage.htm. Included on this homepage are Mist Gas Field production data, oil and gas statutes and administrative rules, drilling permit application forms and other forms, a publication list, and other information.

Table 1. *Oil and gas permit activity in Oregon, 1996*

Permit number	Operator, well, API number	Location	Permit activity (TD=total depth)
339	Enerfin Resources Co. CC 32-32 36-009-00180	NE¼ sec. 32 T. 6 N., R. 5 W. Columbia County	Abandoned; TD 2,711 ft.
398	Enerfin Resources Co. CFI 34-1-55 36-009-00232	SE¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Abandoned; TD 1,370 ft.
481	Enerfin Resources Co. CC 22B-19-65 36-009-00306	NW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Abandoned; TD 2,940 ft.
500	Enerfin Resources Co. CC 22-26-65 36-009-00320	NW¼ sec. 26 T. 6 N., R. 5 W. Columbia County	Canceled.
501	Enerfin Resources Co. JH 31-20-54 36-009-00321	NE¼ sec. 20 T. 5 N., R. 4 W. Columbia County	Abandoned; TD 2,436 ft.
503	Northwest Natural Gas IW 22H-22-65 36-009-00323	SW ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; abandoned; TD 1,825 ft.
504	Northwest Natural Gas IW 23a-22-65 36-009-00324	SW ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; service well; TD 2,298 ft.
505	Northwest Natural Gas IW 32H-22-65 36-009-00325	NE ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; service well; TD=2,600 ft.
506	Northwest Natural Gas OM 12-22-65 36-009-00326	NW ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; service well; TD 2,337 ft.
507	Northwest Natural Gas OM 32-22-65 36-009-00327	NE ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Permit issued; proposed TD 2,250 ft.
508	Northwest Natural Gas IW 22dH-22-65 36-009-00328	SW ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Permit issued; drilling; proposed TD 2,800 ft.

The Northwest Energy Association remained active during 1997 with over 100 members. At its regular monthly meetings, speakers gave talks that were generally related to energy matters in the Pacific Northwest. The 1997 fall symposium was held in Troutdale, Oregon, and plans are being developed for the 1998 fall symposium. For more information, contact the NWEA, P.O. Box 6679, Portland, OR 97228.

A map of the Mist Gas Field is available from DOGAMI: Open File Report O–98–1 contains well locations and status, total depth, date drilled, and other information, including locations of the Mist and Calvin Creek underground natural gas storage projects through the end of 1997. Contact The Nature of the Northwest Information Center (503-872–2750) for a complete publication list including the Oil and Gas Investigations Series. □

Seismic hazard mapping in Eugene-Springfield, Oregon

by Yumei Wang [1], David K. Keefer [2], and Zhenming Wang [1]

This paper was presented at the Seventh U.S.–Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems, held November 4–7, 1997, in Seattle, Washington, and will be published in the Proceedings of that workshop by the National Institute of Standards and Technology, edited by Donald B. Ballantyne, EQE International, Seattle, Washington. We are publishing it here, with minor editorial changes, by permission of the authors. *—ed.*

ABSTRACT

The Oregon Department of Geology and Mineral Industries (DOGAMI) and the U.S. Geological Survey (USGS) are developing earthquake hazard maps for the Eugene-Springfield area in Lane County, Oregon. The method for producing the map is derived from state-of-practice dynamic analyses for ground-response, slope-stability, and liquefaction analyses; empirical correlations of slope stability with engineering properties of materials; and manipulation of data on local topography, engineering geology, and hydrology, using geographic information system (GIS) tools. Specific types of data used to produce the map include (1) distribution of geologic units, (2) engineering properties of materials in each geologic unit, (3) slope inclinations, (4) regional hydrology, (5) distribution of existing landslide deposits, (6) distribution of artificial slope alterations, and (7) ground motions from design scenario earthquakes (M 6.5 shallow crustal and M 8.3 subduction zone event).

Seismically induced ground deformation is evaluated as follows: Slopes steeper than 25° are analyzed using empirical criteria that relate slope stability to degree of weathering, strength of cementation, spacing and openness of rock fractures, and hydrologic conditions. Slopes between 5° and 25°, which in the project area are commonly mantled with aprons of heterogeneous colluvium, are evaluated with a dynamic slope-stability analysis that uses slope inclinations, engineering geologic characteristics of geologic units, and shaking parameters from design earthquakes as inputs. Slopes gentler than 5° are analyzed for liquefaction and resultant lateral spreading. Results of these analyses are then combined to produce a ground deformation map with five slope instability categories (very high, high, medium, low, and nil potential for slope failure). Site periods and maximum spectral ratio are also shown on the ground deformation hazards map. Site effects of local geology on ground shaking are evaluated using the program SHAKE91. Site periods and maximum amplification of spectral accelerations are determined and used to produce a ground response map.

The 1:24,000-scale maps resulting from this study are intended for use by local communities for regional planning and mitigation purposes. Techniques developed in this study are intended to be applicable to regional-scale mapping in other areas with a wide variety of topographic, geologic, and hydrologic characteristics.

INTRODUCTION AND PURPOSE

Many types of earthquake hazards can be evaluated and mitigated to an acceptable level of risk in advance of future damaging earthquakes. Ground failures from slope instability can be a significant threat, especially in urban areas with concentrated development on unstable slopes. Amplified ground shaking can be destructive, intensifying and prolonging ground shaking. Many recent earthquakes have caused significant loss of life and property damage from earthquake-induced landslides and amplified ground shaking.

This paper presents a preliminary method for producing an earthquake hazard map showing (1) dynamic (i.e., earthquake-induced) slope stability for slopes that range from steep to gentle, and (2) dynamic ground response. Dynamic slope stability is evaluated for a wide spectrum of landslide failure types. Steep slopes (>25°) are most susceptible to rockfalls and other fast-moving landslides; moderate slopes (5°–25°) are susceptible to deep-seated rotational and translational block slides; and even gentle slopes (<5°) may be susceptible to liquefaction-induced lateral spreading. Ground response results show site periods and maximum spectral ratio (earthquake-related engineering properties of a site). Site periods and maximum spectral ratios are shown as 0.1-second and 1.0-contour intervals, respectively.

The method described here for producing a hazard map is derived from dynamic ground-response, slope-stability, and liquefaction analyses; empirical correlations of slope stability with engineering properties of materials; and manipulation of data on local topography, engineering geology, and hydrology, using geographic information system (GIS) tools. The final map will be produced at a scale of 1:24,000 and with 30-ft-grid digital elevation model (DEM) data and will provide information for regional planning, design, and mitigation. The map should serve as a useful tool in

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reducing hazards through effective land-use and emergency planning, regional vulnerability studies, identification of areas that would benefit from site-specific studies, and organization of mitigation efforts.

The project area encompasses three 7½-minute quadrangles (Eugene West, Eugene East, and Springfield) and totals about 200 mi^2 (Figure 1). The project area is rectangular, includes the Metro Plan boundary, and extends beyond the three quadrangles. This project involves working closely with an advisory task force composed of local community members. It also includes establishing a temporary local seismograph network to monitor local and distant earthquakes to gain a better understanding of local sources and ground response, and performing an evaluation of structural seismic vulnerability on a limited number of selected buildings.

BACKGROUND

From beginnings in the 1840s, the population of the Eugene-Springfield metropolitan area is now approaching 200,000 and continues to increase. The population within the Metro Plan boundary (Figure 1), an area slightly larger than both the city and urban growth areas, is projected to increase by approximately 57 percent between 1990 and 2020 (Meacham, 1990).

Building expansion continues to penetrate the hillslope and urban development areas, which tend to be difficult areas for building. Due to the nature of the geology, topography, and climate, certain areas are prone to ground failure and amplified ground shaking, which threaten both existing and new developments.

Geographic setting

The project area is located in the southern reach of the upper Willamette basin near the confluence of the Coast and Middle Fork Willamette Rivers and the McKenzie River. It includes hills bounding the valley, with the Cascades on the east flank and the Coast Range on the west and south. The climate is moderate in temperature, and the average annual precipitation is 40 in. Generally, the elevation of central Eugene and Springfield is about 400 ft.

Geologic setting

The Willamette Valley geomorphic province is a broad lowland separating the Oregon Coast Range from the Cascade Range. This terrain is part of the forearc basin associated with the Cascadia subduction zone and consists of interfingering, gently dipping Tertiary rocks ranging from Eocene to Miocene in age,

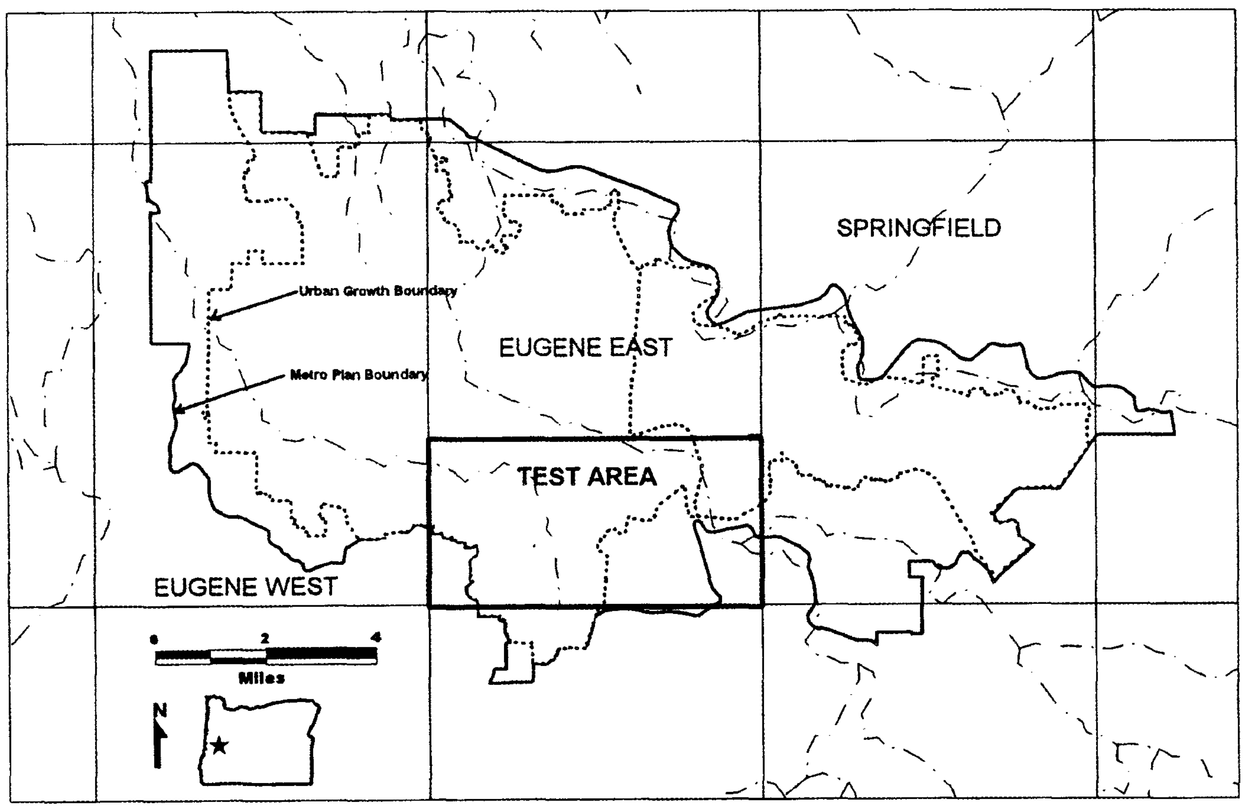

Figure 1. Location map showing test area for pilot project and its location with respect to urban growth and Metro Plan boundaries of the Eugene-Springfield area as well as main topographic quadrangles. Dash-dot lines mark major drainages.

including volcanic flows and intrusions, tuffaceous sediments, and sedimentary rocks (Walker and Duncan, 1989). In the Willamette Valley, bedrock units are overlain by Quaternary-age alluvium and thus are not well understood in detail. The smooth alluvial plain of the Willamette Valley is interrupted by occasional flood and stream channels. Table 1 describes the geologic units found, and Figure 2 shows their distribution, in the test area that is discussed later under "Slope Analyses."

Seismic setting

The physiographic setting of the Pacific Northwest results from its plate tectonic setting. From northern California to British Columbia, oceanic plates, including the Juan de Fuca plate, are being subducted beneath the North American plate along the Cascadia subduction zone. Earthquakes can occur within the subducting Juan de Fuca plate (oceanic intraplate earthquakes), within the overriding North American plate (crustal earthquakes), or along the interface between the two

Table 1. *Geologic units in the Eugene-Springfield metropolitan area. Modified from Walker and Duncan (1989).*

Symbol	Age	Description
Qal	Holocene	**Alluvium**—Clay, silt, sand, and gravel in river and stream channels
Qoal	Holocene/Pleistocene	**Older alluvium**—Poorly consolidated clay, silt, sand, and gravel marginal to active stream channels and filling lowland plains of Willamette River Basin and tributary drainages
Tub	Miocene	**Basalt and basaltic andesite flows and flow breccias**—Grades laterally into palagonitic tuff and breccia and into clastic sedimentary rocks
Ti	Oligocene	**Mafic intrusions**—Sheets, sills, and dikes of massive granophyric ferrogabbro; some bodies strongly differentiated and include pegmatitic gabbro, ferrogranophyre, and granophyre
Tf	Oligocene/Eocene	**Fisher Formation, undivided**—Predominantly continental volcaniclastic rocks, including andesitic lapilli tuff, breccia, water-laid and air-fall silicic ash, and interbedded basaltic flows
Te	Oligocene/Eocene	**Eugene Formation**—Thin- to moderately thick-bedded, coarse- to fine-grained arkosic, micaceous, and, locally, palagonitic sandstone and siltstone, locally highly pumiceous, assigned to the upper Eocene to middle Oligocene, marine Eugene Formation
Tfb	Eocene	**Basaltic flows**—Flows, some of which may be invasive into the undivided Fisher Formation (unit Tf), and undivided and questionable sills that may intrude the undivided Fisher Formation

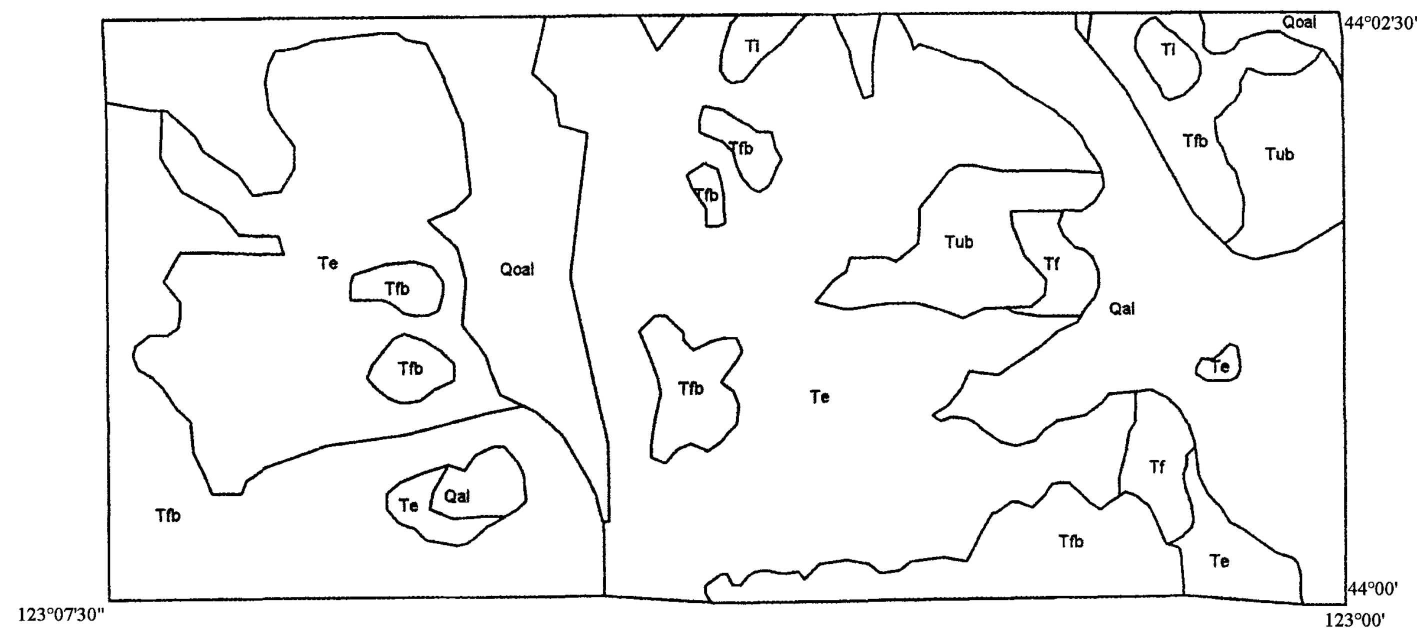

Figure 2. Simplified geologic map of test area, modified from Walker and Duncan (1989). Coordinates approximate. Geologic unit symbols keyed to Table 1 above.

plates (subduction zone earthquakes). All three possible earthquake types (subduction, oceanic intraplate, and crustal) can severely impact the project area, and each was considered as part of this study.

Although no damaging earthquakes have occurred during historic times, small local earthquakes have been recorded. A recent study that focused on evaluating ground response in Eugene and Springfield (R. Weldon and S. Perry-Huston, University of Oregon Geological Sciences Department, unpublished data) included the recording of several very small local earthquakes. In January 1996, a cluster of small earthquakes occurred about 15 mi east of Eugene. Later, in May 1996, a small earthquake occurred about 3 mi north-northwest of downtown Eugene. These earthquakes have not been identified with any specific fault structure (S. Perry-Huston, oral communication, 1997) but indicate zones of potential threat to local communities. The project area is located about 60 mi east of the Cascadia subduction zone, where several large-magnitude subduction zone earthquakes are thought to have occurred in the past few thousand years (Atwater, 1996). A strong local crustal earthquake or great subduction zone earthquake would likely produce strong ground shaking for all geologic units in the project area. Bedrock ground motions incorporated in the study were developed by Geomatrix Consultants, Inc. (1995).

DATA COLLECTION

The method used to evaluate earthquake-induced ground failure and local ground response requires information on the geologic units (their distribution and engineering characteristics), slope angles, hydrology, and the occurrence of existing landslides and large artificial slope alterations. The distribution of geologic units was determined from published geologic maps (Walker and Duncan, 1989; Vokes and others, 1951) and from additional mapping carried out as part of the study. The engineering properties of materials in each geologic unit were determined from field mapping, laboratory testing of selected materials, in situ tests, and engineering judgment. Field work included the mapping of over 200 outcrops considered to be reasonably representative of the geologic units. In situ tests included downhole shear wave velocity profiling, surface refraction profiling, and standard penetration testing. Slope inclinations were determined using geographic information system (GIS) tools and digital elevation models (DEMs) with a grid spacing of 30 ft. Regional hydrology was determined from borehole and well data, mapping of springs and seeps, and also hydrologic modeling conducted by the local water departments. Existing landslide deposits were mapped as part of the study. Input on active landslides was provided by local consultants and public works department staff. Lastly, artificial slope alterations, such as large road and railroad cuts were identified. The method does not specifically address slope aspect, vegetation, and human effects (such as logging and grading practices).

SLOPE ANALYSES

Preliminary analyses were conducted in a test area that covers about 20 mi^2 of the project area (Figure 1). Slopes in the test area are divided into four groups: (A) existing landslides; (B) steep slopes, greater than 25°; (C) moderate slopes, ranging from 5° to 25°; and (D) gentle slopes, less than 5° (Figure 3). It was assumed that groups (B), (C), and (D) have fundamentally different modes of dynamic failure. Consequently, different analytical techniques were applied to these groups as shown in Figure 4.

(A) Existing landslides

The movement characteristics of existing landslides are highly variable and range from actively moving to stable. To understand the nature of each existing landslide would require numerous site-specific evaluations. In the absence of this landslide information, it was assumed that the slip planes are at reduced shear strengths of unknown values, and that existing landslide masses are inherently unstable under earthquake loading. Thus, existing landslides were assigned to the very high susceptibility rating. No analytical techniques were applied.

(B) Steep slopes

Bedrock slopes greater than 25° are particularly susceptible to slope failures (Keefer, 1993). Consequently, slopes greater than 25° were assigned to Group B, steep slopes. Engineering properties of geologic units, including degree of weathering, strength of cementation, spacing and openness of rock fractures, and hydrologic conditions, were mapped in outcrops. Each outcrop was assigned to a mapped geologic unit. Then, each geologic unit was evaluated for susceptibility to slope failure, using a decision tree outlined in Keefer (1993) and shown in Figure 5.

For each geologic unit, the average value from the rating category was analyzed, using empirical criteria that relate slope instability to area (Keefer, 1993). Keefer (1993) related engineering properties observable in outcrop to landslide concentrations, expressed as number of landslides per square kilometer (LS/km^2) ($1\ km^2 \approx 0.4\ mi^2$). For the geologic units within the test area, each outcrop was rated according to Figure 5. Then, the results were averaged for each geologic unit, using the following landslide concentration relationship:

$$LS/km^2 = (32)(\%\ \text{extremely high}) + (8)(\%\ \text{very high}) + (2)(\%\ \text{high}) + (0.125)(\%\ \text{low}),$$

where the multipliers (32, 8, 2, and 0.125) are taken from landslide concentrations used to assign ratings in Keefer (1993). Landslide concentration results are shown in Table 2, column 3. Then, each geologic unit was assigned a new susceptibility rating compatible with the DOGAMI earthquake hazard rating system of high, medium, or low on the basis of calculated landslides per square kilometer value as follows:

$$\text{high} > 2\ \text{LS/km}^2 > \text{medium} > 1\ \text{LS/km}^2 > \text{low}.$$

Table 2. *Landslide concentration and ratings for geologic units. Geology after Walker and Duncan (1989)*

Geologic unit		Lithology	LS/km²	DOGAMI rating
Tfb	Basalt flows	Basalt	10.82	High
Te	Eugene Formation	Sandstone	5.34	High
Tf	Fisher Formation	Volcaniclastics	2.73	High
Tub	Basalt flow breccias	Breccias	1.83	Medium
Ti	Mafic intrusions	Gabbro	1.30	Medium

The resulting dynamic landslide susceptibilities for each geologic unit are shown in Table 2, column 4.

The following illustrates how the susceptibility was determined for a specific geologic unit, unit Tub, which consists predominantly of basalt and basaltic andesite flows and flow breccias: A total of 34 outcrops was mapped and evaluated in accordance with Keefer's (1993) method. Of this total, 31 outcrops, or 91 percent, were assigned a susceptibility rating of high, and 3 outcrops, or 9 percent, were assigned a rating of low. Landslide concentration was determined as follows:

$$2 \times 0.91 + 0.125 \times 0.09 = 1.83$$

and produced a result of 1.83 landslides per square kilometer. This value falls into the medium susceptibility rating.

(C) Moderate slopes

Slopes ranging from 5° to 25° were assigned to Group C, moderate slopes. For moderate slopes, we assumed that coherent, relatively deep-seated translational and rotational slides are the most common modes of failure (Keefer, 1984). Moderate slopes in the project area are commonly mantled with aprons of heterogeneous colluvium. Our method for rating these slopes is based on the dynamic slope stability analysis of Newmark (1965), as verified and extended to regional-scale use by Wilson and Keefer (1983, 1985), Wieczorek and others (1985), Jibson (1993, 1996), and Jibson and Keefer (1993).

The selected earthquake input parameters included two controlling events: A magnitude 8.5 subduction zone earthquake at a 100-km (~60-mi) distance from

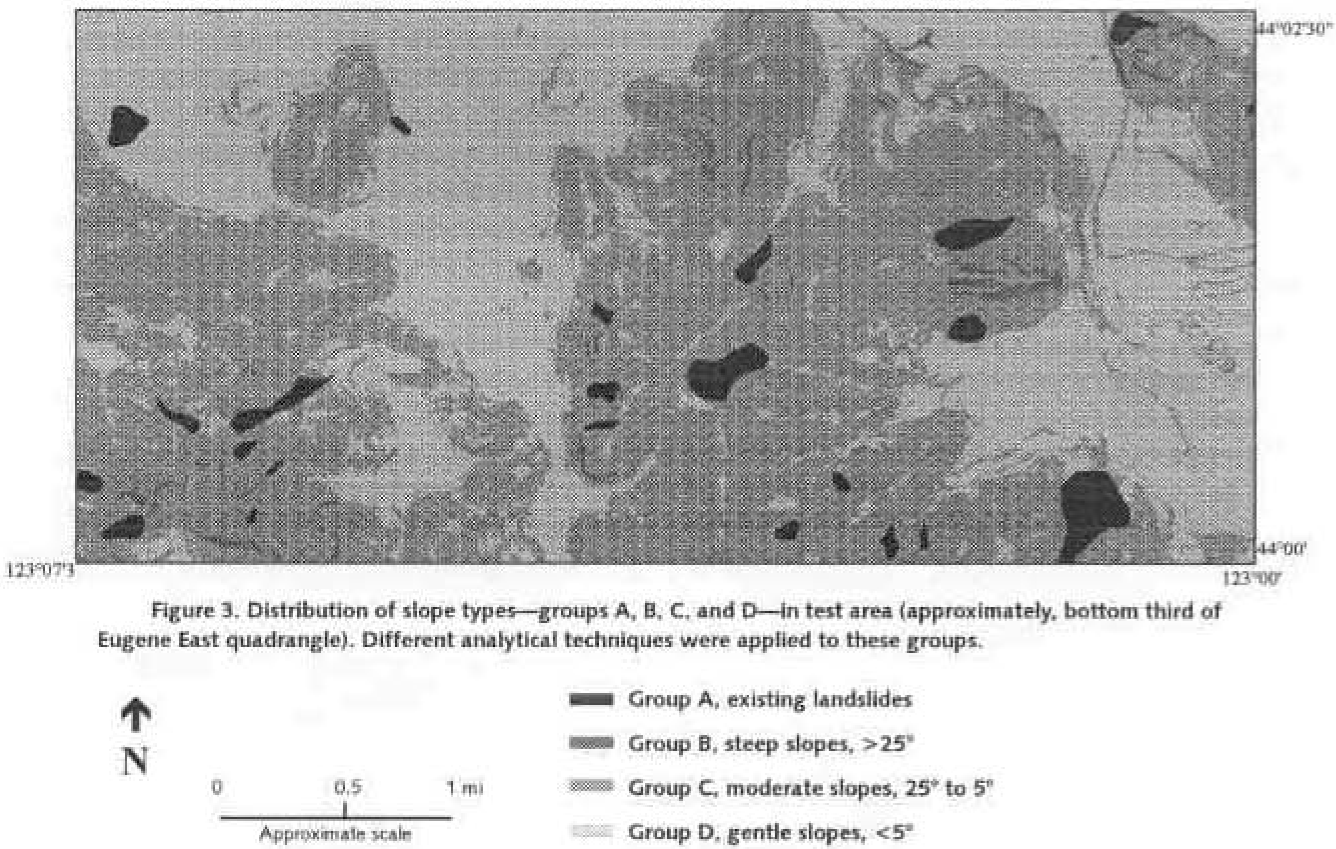

Figure 3. Distribution of slope types—groups A, B, C, and D—in test area (approximately, bottom third of Eugene East quadrangle). Different analytical techniques were applied to these groups.

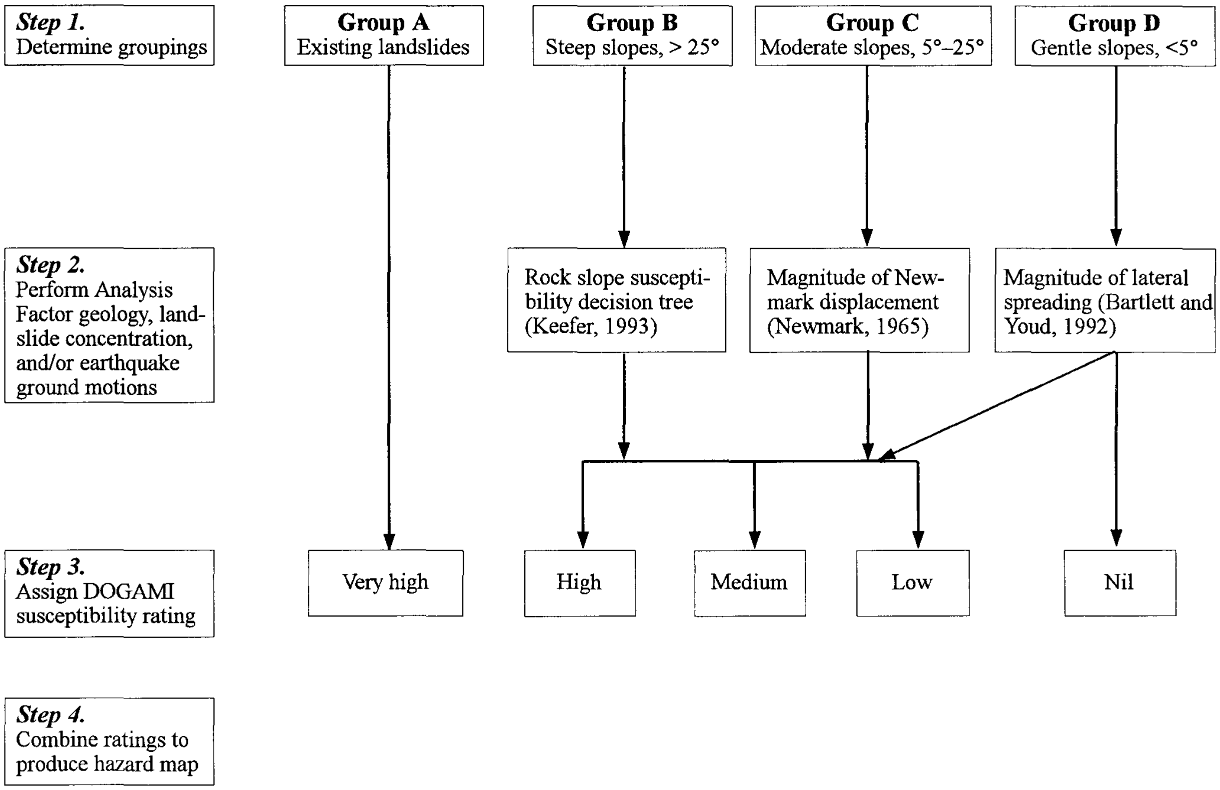

Figure 4. Method of slope ratings flow chart.

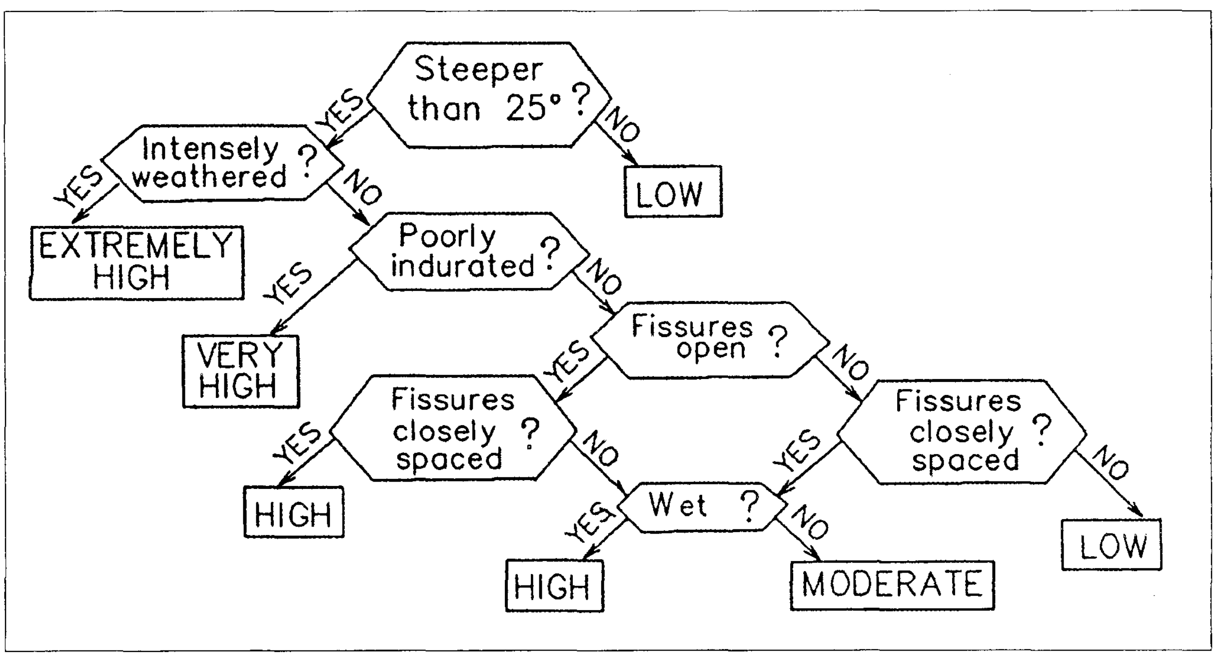

Figure 5. Decision tree for susceptibility of rock slopes to earthquake-induced landslides (from Keefer, 1993). For the test area, all slopes were assumed to be wet.

the earthquake source and a magnitude 6.5 event at 10-km (~6-mi) distance. Arias Intensity (I_a) values were determined based on magnitude and distance from the source according to the equation developed by Wilson and Keefer (1985):

$$\log (I_a) = \mathbf{M} - 2 \log R - 4.1,$$

where I_a is in meters per second, **M** is moment magnitude, and R is earthquake source distance in kilometers. Next, assuming an infinite slope failure, an equation by Newmark (1965),

$$a_c = (FS - 1)\, g \sin \alpha,$$

was used to calculate the critical acceleration (a_c). Here, a_c is the acceleration required to overcome frictional resistance and initiate sliding in terms of g, the acceleration due to Earth's gravity; FS is the static factor of safety; and α is the angle from the horizontal by which the center of the mass of the potential landslide block first moves. The Newmark displacement (D_N, in cm) was then determined from the relationship (Jibson, 1993; Jibson and Keefer, 1993):

$$\log (D_N) = 1.460 \log I_a - 6.642\, a_c + 1.546.$$

Finally, each slope was assigned a DOGAMI susceptibility rating based on the calculated displacement D_N:

high > 100 cm > medium > 10 cm > low,

as shown in Figure 4.

(D) Gentle slopes

Slopes less than 5° were assigned to Group D, gentle slopes. For these, we calculated lateral-spreading (i.e., slope-instability) susceptibility for Quaternary-aged geologic units that are prone to liquefaction failure. Gentle slopes underlain by pre-Quaternary geologic units were assumed to be stable and were automatically given a susceptibility rating of nil. Areas of Quaternary-aged units were separated in order of depositional age, with artificial fill and the youngest deposits generally being the most vulnerable to slope movement. The selected earthquakes include a **M** 6.5 event at a 10-km distance and a **M** 8.5 subduction zone earthquake at a 100-km (~60-mi) distance and were adopted from an Oregon Department of Transportation study (Geomatrix Consultants, Inc., 1995).

To evaluate for lateral-spreading susceptibility, we first estimated the site effects of local geology on ground shaking by using SHAKE91, a commercially available program for analyzing one-dimensional site-response of vertically propagating (normally incident) shear waves at a level site (Idriss and Sun, 1992). Peak rock accelerations on the synthetic acceleration time history were scaled to 0.34 g and used as input parameters in SHAKE91. The peak surface accelerations determined from SHAKE91 analysis were used as input accelerations in the liquefaction analyses.

Next, initial liquefaction was analyzed by two methods: The first, by Robertson and Fear (1996), is an improvement of the method developed by Seed and others (1984) and is based on standard penetration test (SPT) measurements. The second, by Andrus and Stokoe (1996), is based on shear wave velocity measurements. Both methods were used to maximize the available in situ data in the project area and account for the uncertainties associated with evaluating the predominantly gravelly soils.

For soils that are prone to liquefaction, lateral spreading was estimated using Barlett and Youd (1992). According to Barlett and Youd (1992), lateral spreading due to liquefaction satisfies:

$$\log (D_H) = -15.787 + 1.178\,\mathbf{M} - 0.927 \log R - 0.013\,R + 0.429 \log S + 0.348 \log T_{15} + 4.527 \log (100 - F_{15}) - 0.922\,D50_{15},$$

where D_H is lateral spreading in meters; **M** is moment magnitude; R is horizontal distance to the nearest seismic energy source, in kilometers; S is ground slope, in percent; T_{15} is the cumulative thickness, in meters, of saturated cohesionless soils with $(N_1)_{60}$ value ≤15; F_{15} is the average fines content, in percent; $D50_{15}$ is mean grain size.

To illustrate this method, we used drill hole data from Test Site ES-2, which is located in the Eugene West quadrangle (Figure 1). SHAKE91 was run, and a peak surface acceleration of 0.40 g was achieved. Liquefaction was analyzed using methods of Robertson and Fear (1996) and Andrus and Stokoe (1996). Next, for soils that liquefy, lateral spreading was calculated, using Bartlett and Youd (1992). We assumed: **M** = 8.5, R = 100 (km), $D50_{15}$ = 1.0 (mm), F_{15} = 5 percent, T_{15} = 5 m, and S ranging from 1° to 5°. Results, shown in Table 3, indicate that for this liquefiable deposit, steeper slopes have greater lateral spreading displacements (0.56 m) than gentler slopes (0.28 m). According to the method shown in Figure 4, the DOGAMI susceptibility rating based on the calculated displacement D_H,

high > 100 cm > medium > 10 cm > low — or nil,

places all of these slopes in the medium susceptibility category.

Table 3. *Lateral spreading displacements (D_H) for test site ES-2. After Bartlett and Youd (1992)*

Slope (S, in degrees)	Displacement (D_H, in meters)
1	0.28
2	0.38
3	0.45
4	0.51
5	0.56

Slope susceptibility ratings

Applying susceptibility ratings within each of the four groups (A—existing landslides, B—steep slopes, C—moderate slopes, and D—gentle slopes) requires professional judgment. The last step involves bringing the independent analytical results from each group together to produce a coherent, uniform, relative hazard susceptibility map. Results from each group fall within one of five susceptibility ratings for dynamic slope instability: very high, high, medium, low, and nil (Figure 4).

DYNAMIC GROUND RESPONSE ANALYSES

For the local geologic conditions in valley areas with about 10 ft or more of soil deposits (Figure 6), site period and maximum spectral ratio were evaluated. Site effects on ground shaking were determined using SHAKE91. Design earthquakes for M 6.5 crustal and M 8.3 subduction zone events were modeled, assuming epicentral distances of 10 km and 100 km, respectively.

Preliminary results of site period, which was determined for 26 site-specific soil locations, were contoured at 0.1-second intervals (Figure 7). At these locations, amplification curves and Fourier response spectra were plotted to determine maximum spectral ratios, that is, maximum amplification of spectral accelerations. Figure 8 illustrates the process of determining maximum spectral ratios, including the input parameters (initial damping, density, shear wave velocity), input and output acceleration time histories, and spectral response showing the maximum spectral ratios. Figure 9 shows preliminary results of maximum spectral amplification contours. These amplification factors can be correlated with site period (shown in Figure 7) to indicate areas of potential soil-structure resonance that can cause structural damage. Higher damage also occurs in areas with prolonged strong shaking, which can be generally related to areas with longer site periods.

DISCUSSION

The method described in this paper is still under development, and preliminary results using this method are scheduled to undergo additional review during 1998. The tentative final product is one 1:24,000-scale colored map showing ground failure hazards, site period, and maximum spectral ratios. These data were selected by community representatives with the assistance of DOGAMI and USGS staff for the purpose of predicting high-damage areas for a wide range of users.

Additional research is needed to improve the accuracy of predicting dynamic ground response on a regional basis. To calibrate the reliability of this method, more post-earthquake field calibrations must be performed. Special attention should be given to determining dynamic slope-stability hazards for moderate slopes.

ACKNOWLEDGMENTS

We owe special thanks to Stephen E. Dickenson of the Oregon State University Civil Engineering Department and Robert E. Kayen of the U.S. Geological Survey for their helpful reviews. We also thank Gerald Black for technical advice, Donald Hull and John Beaulieu for supporting this study, Klaus Neuendorf for editorial assistance, Tom Wiley and Robert Murray for geologic assistance, and Neva Beck for assisting in the preparation of this paper.

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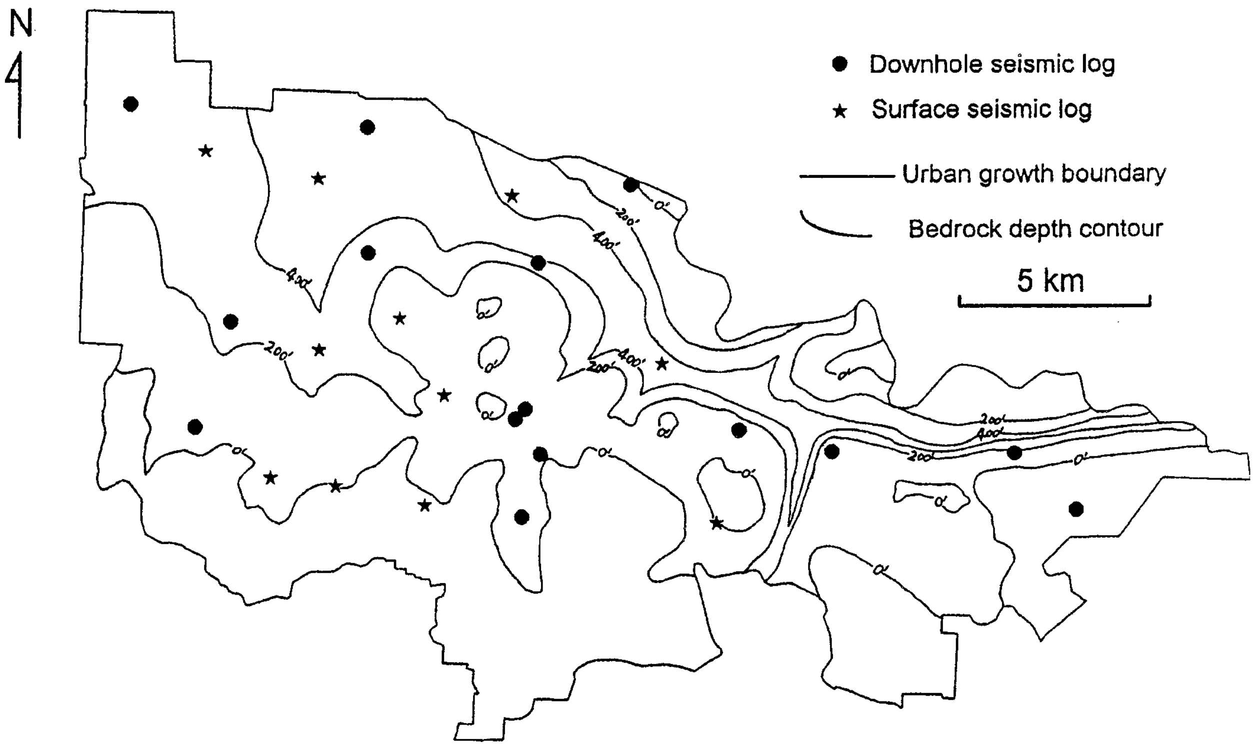

Figure 6. Location of seismic log and generalized depth to bedrock contours in the Eugene-Springfield urban growth boundary. Contours in 200-ft intervals.

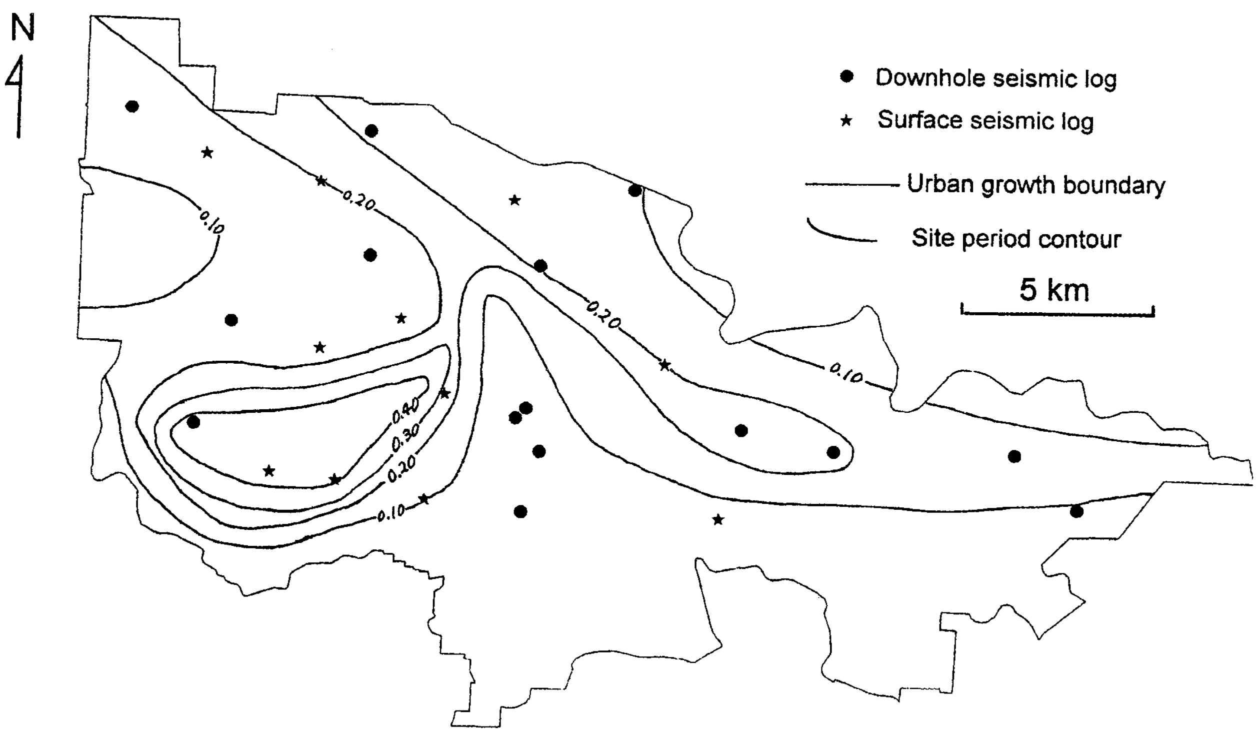

Figure 7. Site period, preliminary results. Contours in 0.1-second intervals.

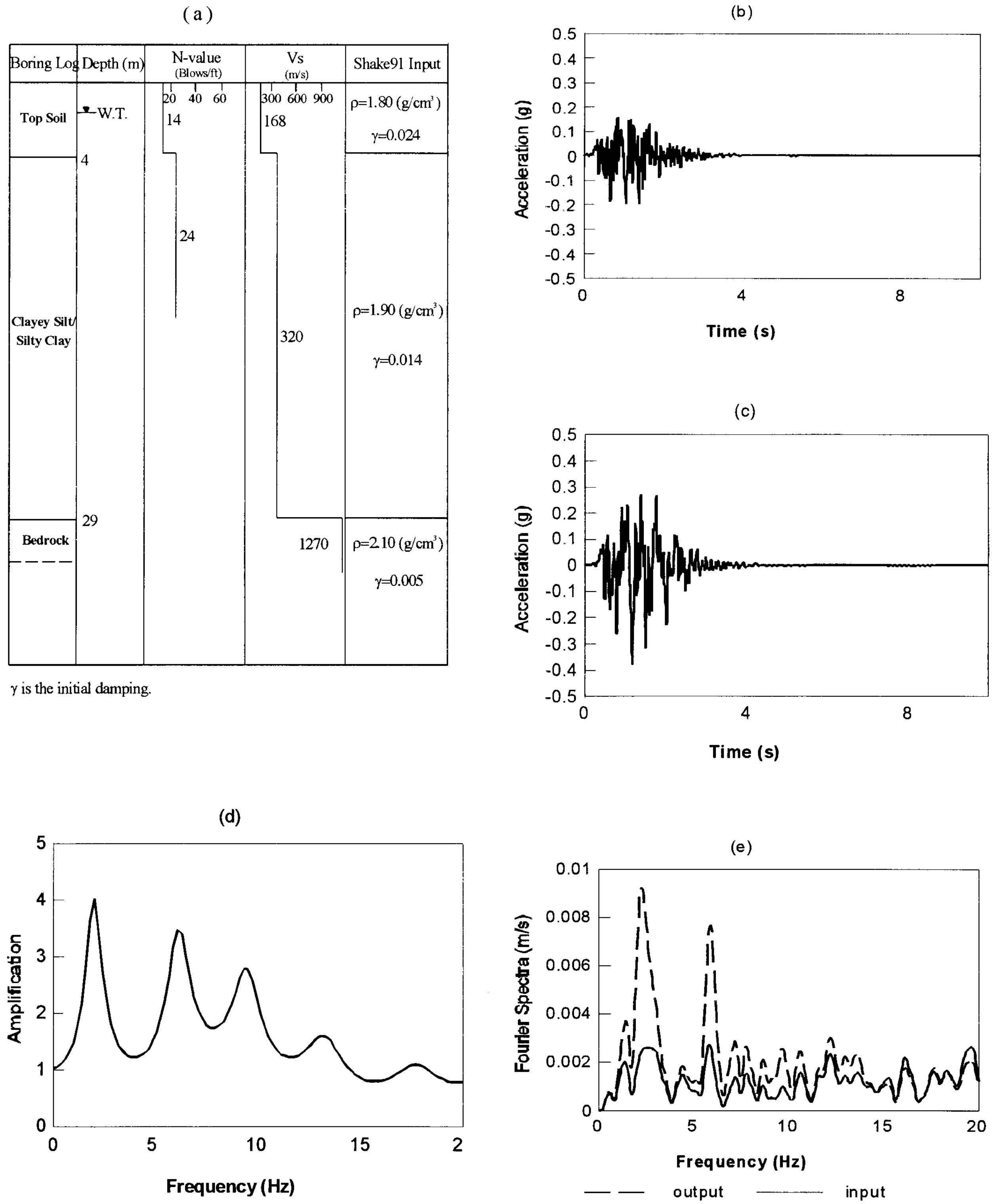

Figure 8. Soil column and SHAKE91 modeling at Site ES-2. (a) soil column and SHAKE91 input parameters; (b) input ground motion (M 6.5 crustal earthquake) at bedrock; (c) output ground motion on free surface; (d) amplification curve; (e) input and output Fourier spectra.

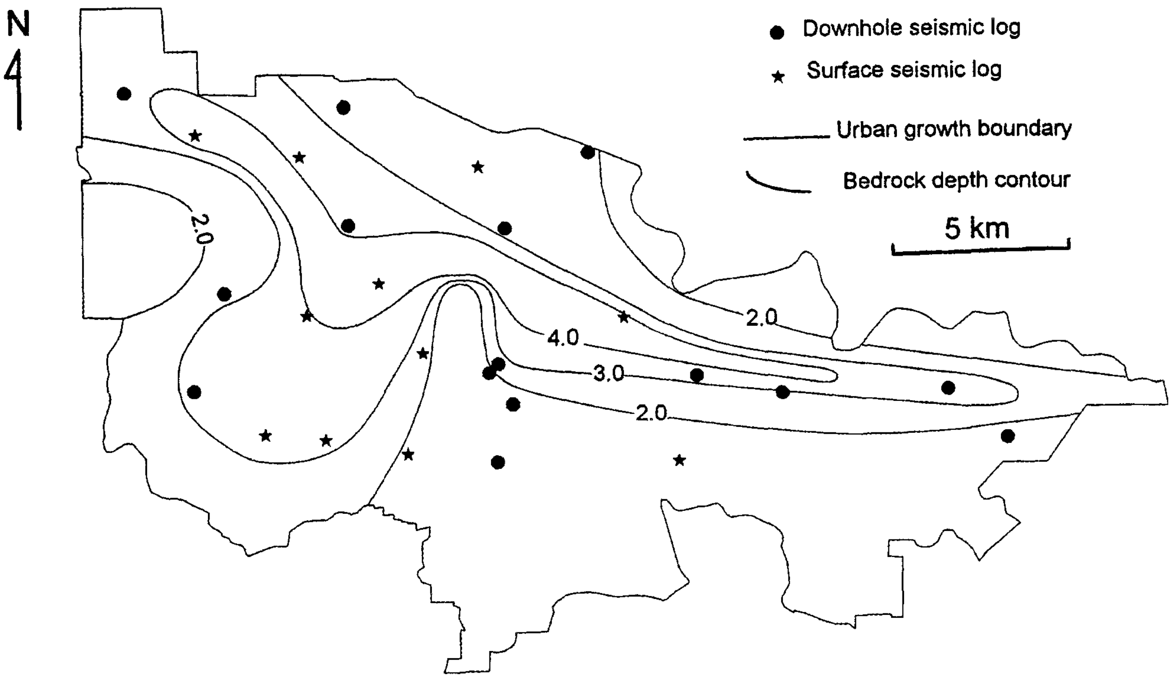

Figure 9. Spectral amplification, preliminary results. Contours in 1.0 intervals.

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Papers on applied geology now available as a book

An important and voluminous treatment of geologic applications in Oregon has been published in conjunction with the 40th annual meeting of the Association of Engineering Geologists held in Portland last fall:

Environmental, Groundwater, and Engineering Geology: Applications from Oregon, edited by Scott Burns of Portland State University, is a 689-page, hardbound volume now available from the Nature of the Northwest Information Center. See listing on p. 48. □

Measuring earthquakes in Oregon

By Yumei Wang, Zhenming Wang, and Gerald L. Black, Oregon Department of Geology and Mineral Industries

How do we know when earthquakes occur? Sometimes, earthquakes are felt by people. Sometimes, they are recorded by seismic instruments. In some cases where there are no people and the seismic instrument coverage is poor, earthquakes are not detected at all. A primary goal of earthquake monitoring with specialized instruments is to detect and locate earthquakes and to obtain a better understanding of potential earthquake sources. Instruments measure data that help scientists understand the likely sizes, locations, frequency of occurence, and types of earthquakes and their effects. In the Pacific Northwest, modern seismic instruments have been recording since about 1950 (Shedlock and Weaver, 1991).

The three main types of seismic instruments are strong-motion instruments, short-period instruments, and broadband instruments. These instruments record ground motions for various levels of shaking (i.e., amplitudes) and frequencies. To explain frequencies in terms of sound: A high pitch is characterized by high frequencies, and a low pitch by low frequencies. In general, strong-motion instruments measure strong levels of shaking over a wide range of frequencies (i.e., a wide bandwidth). In contrast, short-period and broadband instruments measure low levels of shaking; at high levels of shaking, the ground motions are "clipped" or "saturated" and are not recorded. Broadband instruments can measure a wide range of frequencies, whereas short-period instruments measure only high frequencies. Oftentimes, at important locations, both broadband and strong-motion instruments are installed so that a full range of amplitudes and frequencies is recorded.

Other important features of seismic instruments include the type of data-recording system and communication linkage. The age and available resources often dictate the data functionality and accessibility. For example, many older instruments record in analog form on photographic film and usually require on-site visits to download data. Newer instruments record data in a digital format. Recorded data may be designed to be accessed via modem (i.e., phoning the site to retrieve data) or even automatically telemetered back to a central network in real time.

The Pacific Northwest Seismic Network (Network) covers a large part of the Pacific Northwest. The Network is operated through the University of Washington (UW) and the U.S. Geological Survey (USGS) at UW in Seattle, Washington. DOGAMI coordinates with Network staff and helps facilitate the development of the Network. The Network maintains an array of strong-motion, short-period, and broadband instruments. These instruments have communication links that include (a) real-time, (b) dial-up, and (c) on-site downloading. The Network archives the data collected, performs routine processing, and provides information to researchers and the public, including DOGAMI.

The latest technological trend involves "real-time warning systems." It is possible to provide real-time information on earthquakes, provided that adequate instruments and communication links are in place. This new technology can determine the magnitude and location of the earthquake while it is in progress. The goal is to relay information to nearby communities before the onset of damaging shaking. Early warning information has a number of applications. One example is to stop trains so that derailment and loss of shipment does not occur. Several real-time systems are currently operational in the United States. The most advanced system, called California Institute of Technology/U.S. Geological Survey Broadcasting Earthquakes (CUBE), is located in southern California.

The Network is developing a real-time monitoring network, called Rapid Alert of Cascadia Earthquakes (RACE). Ground motions from earthquakes are automatically telemetered to central recording facilities in Seattle. A detection algorithm is immediately applied to these data, and the earthquakes are analyzed by a computerized system that determines earthquake arrival times and epicentral locations. For earthquakes larger than magnitude 2.9, magnitude and location information is quickly disseminated via commercial pager to RACE test sites. DOGAMI, which was the first test site for RACE, is helping the Network by testing an off-site prototype.

Over the next few years, the USGS plans to add several instruments along the coast. The purpose is twofold: (1) to detect Cascadia subduction zone earthquakes that can produce near-field tsunamis, that is, big waves that are generated from nearby offshore earthquakes, and (2) to minimize false alarms of tsunamis, that is, to distinguish inland earthquakes that cannot initiate tsunamis from subduction zone earthquakes that can. The sites will include both strong-motion and broadband instruments. A long-term goal is to develop a real-time, near-field tsunami warning system. This system will warn the citizens in tsunami prone (low-lying coastal) areas to evacuate.

The remaining discussion focuses on DOGAMI's involvement with seismic instruments in Oregon.

DOGAMI's instrumentation program focuses on three fundamental areas:

1 To improve the regional seismic network.
2 To evaluate ground response in the greater Portland area.
3 To satisfy regulations stipulated by Oregon Building Code statutes.

IMPROVE REGIONAL SEISMIC NETWORK

The current instrument density in Oregon is low and needs improvement. DOGAMI's recent survey of all known strong-motion instruments is shown in Figure 1. Public sector owners include the Oregon Department of Transportation Bridge Section, the U.S. Army Corps of Engineers, the U.S. Geological Survey, the Oregon State System of Higher Education, and several local governments. There is only one private-sector owner, who has several instruments at the Trojan power plant in Columbia County.

Strong-motion accelerographs are deployed primarily to record ground motion accelerations generated by earthquakes that might have significant impacts on engineered structures. The primary uses are to provide data for seismological and geotechnical modeling studies and for the design and analysis of engineered structures (e.g., bridges and buildings). Most current systems are designed to trigger the recording mechanism only during substantial shaking (Shaking greater than 0.01 *g* can be felt.) A low level of shaking, for example from traffic vibrations, is ignored.

DOGAMI supports the expansion of the Network to better serve the citizens of Oregon. Oregon's population is concentrated in the greater Portland area and the Willamette Valley. DOGAMI's current records indicate approximately nine strong-motion instruments in this area, of which three belong to the USGS. Instrument density is sparser outside this populated corridor.

DOGAMI has recently proposed to expand the Network in the Portland metropolitan area and the Willamette Valley. We have recommended that 50 free-field strong-motion instruments be added to improve the regional geographic coverage for earthquake monitoring. This would allow scientists to better characterize earthquake seismicity and ground response in developed areas and may lower the current detection threshold for very small earthquakes.

EVALUATING GROUND RESPONSE IN PORTLAND

Currently, DOGAMI and the University of Oregon Department of Geological Sciences (UO) are deploying a temporary seismic network in the greater Portland area. The purpose is to measure and analyze actual earthquake ground response and to evaluate the ground motion amplification portion of the 1997 DOGAMI/Metro relative earthquake hazard map (Mabey and others, 1997). To collect ground motion data, a total of approximately 12 sites will be occupied for six- to eight-week periods over a one-year time span. DOGAMI is responsible for the site selection, which is based on geologic conditions. UO deploys the portable broadband instruments and performs data analyses. This effort is funded by the U.S. Federal Emergency Management Agency (FEMA) and is scheduled to be completed in late 1998.

OREGON BUILDING CODE STATUTES AND RULES

In the 1994 Uniform Building Code, Chapter 16 (Structural Forces), Division II, the sections 1646–1649 (Earthquake Recording Instrumentation) describe the

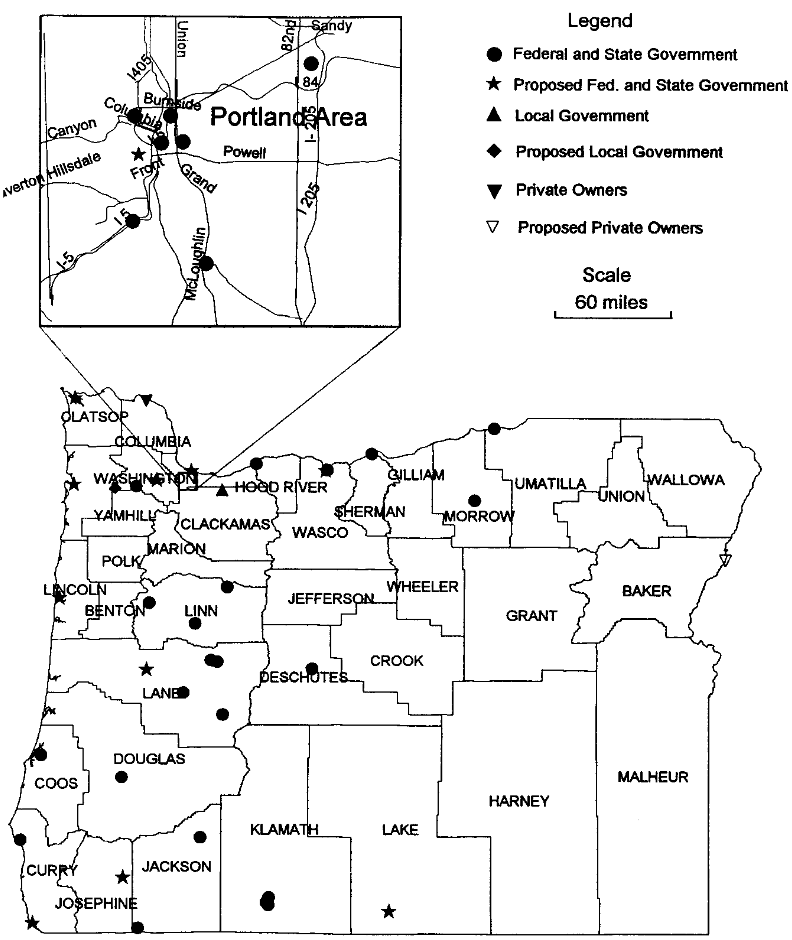

Figure 1. Strong-motion accelerograph stations in Oregon.

requirements of seismic instrumentation for certain newly constructed buildings. The owner/developer of these buildings is required to install seismic monitoring equipment and monitor and maintain the equipment once installation is complete. The purpose of instrumenting buildings is to understand and improve the dynamic response of buildings during earthquakes. Alternately, the owner/developer may be allowed to provide DOGAMI with funds equivalent to the cost of instrumenting the building. DOGAMI will use these funds to acquire and install strong-motion instruments. Sites selection will be focused on such sites that will increase our understanding of structural and regional ground motion response during earthquakes.

DOGAMI is adding two new free-field strong-motion instrument sites in 1998 with the fund moneys. The sites will be located in the greater Portland metropolitan area and integrated into the Network. DOGAMI has identified several possible sites. Characteristics influencing site selection include geologic conditions, security, electrical and communication access, and local background "noise" due to culturally induced vibrations (e.g., traffic).

The Department is also pursuing a cooperative project with USGS staff associated with the Network. DOGAMI has selected the potential sites, and the USGS would evaluate the suitability of these sites with respect to background noise. In addition, DOGAMI would like the USGS to perform initial tests of the newly purchased instruments, install and maintain the instruments, and help collect, analyze, and disseminate data.

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DOGAMI PUBLICATIONS

Released February 12, 1998

Best Management Practices for Reclaiming Surface Mines in Washington and Oregon, revised edition, December 1997, by David K. Norman, Peter J. Wampler, Allen H. Throop. E. Frank Schnitzer, and Jaretta M. Roloff. Open-File Report O–96–02 rev., approx. 130 p., $8.

The manual describes reclamation and mining practices for landowners, land-use planners, and mine operators in Oregon and Washington. The revision incorporates comments from the mining industry as well as other reviewers of the initial 1996 release. In addition, several new diagrams and innovative best management practices have been added.

Best Management Practices was produced cooperatively by members of the Washington Department of Natural Resources, Division of Geology and Earth Resources, and the DOGAMI Mined Land Reclamation Program. The project was supported in part by the U.S. Environmental Protection Agency and conducted under the Tri-State Agreement for Mining between Idaho, Oregon, and Washington.

The approximately 130-page, extensively illustrated manual provides information about managing a surface mine from start-up to final reclamation, incorporating water and erosion control during operation and reclamation, soil salvage and replacement, land shaping, and revegetation. The authors urge miners to use this manual as a resource in developing an environmentally and financially sound mine.

The Capes Landslide, Tillamook County, Oregon, by George R. Priest. Open-File Report O-98-02, 10 p., $5.

The report concerns the current landslide threat to The Capes development near Netarts on the coast of Tillamook County. It contains a preliminary assessment of the geologic conditions and discusses some possible options for mitigating this hazard.

It was prepared by Dr. Priest as a memorandum to the Director of the Oregon Emergency Management Division of the Oregon State Police Department. The report includes two draft illustrations showing the location of the landslide and a cross section.

Released February 12, 1998

Tsunami Hazard Map of the Yaquina Bay Area, Lincoln County, Oregon, by George R. Priest, Edward Myers, António M. Baptista, Robert A. Kamphaus, Curt D. Peterson, and Mark E. Darienzo. Interpretive Map Series IMS–2, two-color, scale 1:12,000 (aerial-photo base map), $6.

The new map is intended primarily for evacuation planning for the event of a tsunami but could also be adopted as a basis for planning and decisions in the areas of building code, construction, or insurance ratings.

The map was produced by Dr. George R. Priest in cooperation with scientists from the Oregon Graduate Institute of Science and Technology, the Center for

(Continued on page 46)

LETTERS

Geology along U.S. Highways 197 and 97 between The Dalles and Sunriver, by Gary Smith, v. 60, no. 1 (January/February 1998), p. 3–17:

I reckon it is correct to say that "dozens" of cinder cones dot the flanks of Newberry volcano. However, we feel that *several hundred* or *over three hundred* sounds considerably more impressive. A minor point, I admit, but we are all slaves to our pet volcanoes, and we are fortunate to have several on the Deschutes that are worth arm-waving about. Unlike those flashy, unstable volcanic showoffs to the north and south of us, "our" volcanoes presently keep to themselves (and in doing so take us out of the running for large appropriations from Congress).

—Sherri L. Lee,
Newberry National Volcanic Monument,
Bend

***GeoDestinies*, by Walter L. Youngquist** (Book review by R.M. Whelan), v. 60, no. 1 (January/February 1998), p. 22:

As Mr. Whelan says, *GeoDestinies* discredits the widely-held belief that "Science will think of something." Population growth on this planet is increasing almost exponentially, especially in the so-called "developing countries," and although technological discoveries have been able to provide the food and energy needed to maintain a reasonably comfortable living for most people, this situation cannot continue forever.

Mr. Whelan asserts that the price of most mineral products has declined over the years and implies that this trend will continue into the foreseeable future. As much as we may wish otherwise, there are *finite amounts* of minerals, including fossil fuels, on this earth, and a point will be reached sometime during the next century when technology simply will not be able to keep up with the increased demand. As a result, commodity prices will rise.

GeoDestinies is a carefully documented report covering a wide range of topics that describe be the ever-growing importance of minerals in both national and international affairs. The two chapters on alternative energy sources are especially worth of study and should be required reading for everyone who feels that such "new technologies" as solar power, wind power, fusion, and hydrogen fuel cells will produce all our energy needs in the 21st century.

I am particularly disturbed by Mr. Whelan's comment that the author's "personal background" as a petroleum geologist with more than 50 years' experience does not allow him to give a completely objective view of the subject. I would argue that, on the contrary, what we need at the policy-making level in this country are people like Dr. Youngquist who are especially knowledgeable in the fields of mineral exploration and development because of the very nature of their expertise.

—R.E. Corcoran,
Mineral Investigations and Land Appraisals,
Portland

It is fashionable to speak of resource-dependent communities, by which we mean those that are immediately dependent upon exploitation of natural resources. Dr. Youngquist's book shows that this concept is flawed: *every* community is resource dependent. Everyone daily exploits energy, food, and materials from the Earth.

Working from the perspective of an experienced petroleum geologist, Dr. Youngquist has given his audiences a lively, readable, realistic, extraordinarily broad survey of global resources. He brings together multiple aspects of human use, abuse, and depletion of resources and explains interconnections among resources, geopolitics, and society. The effect is incisive.

The book is usefully arranged as twenty-nine chapters that range through introductory historical essays on civilizations and peoples to discussions of the geologically fortunate, resource-rich nations and the unfortunate ones; the enormous importance of petroleum and its coming exhaustion; the importance of the mostly hidden depletion of soil and groundwater; alternative sources of energy and their prospects and the energy and resources of the oceans; and on to summary chapters on policy, politics, society, "sustainable" society, and the future. There are ample subheadings and a good index The book is an essential reference for our future. I know of no other quite like it.

—Laurence R. Kittleman,
Geologist, Eugene

GeoDestinies comes at the reader like a steamroller with facts, data, logic, and a lot of old-fashioned horse sense to examine the relationship of mineral resources to the destinies of host nations. Youngquist does not pretend the relationship is absolute, but he makes a good case with example after example of nations that have emerged to prominence and power when the mineral resources they controlled became appropriate to the technology of the day—and then faded when those mineral resources became depleted. With no mineral resource is this more clearly demonstrated than with petroleum.

Youngquist, a veteran of *The Oil Patch*, speaks with authority of the most critical mineral resource of our day. It is clearly appropriate to call this *The Petroleum Interval*, in contrast to the Iron Age or the Bronze Age, in that this interval began about a hundred years ago and won't last more than another hundred. There's a good reason: We're clearly running out of the stuff. He explains in some detail why there's no more to be found.

The book treats with the oil-generated affluence of the nations of the Persian Gulf and with our own affluence; but however fascinating it gets, there is the feeling that there is the *Skull Looking In at the Banquet*: About the year 2007, this planet's ability to produce oil will have peaked and begun a nosedive that will not be reversed. At the same time there will be an increasingly sophisticated demand for greater production by a population that is growing at an exponential rate.

Youngquist meets head-on the inevitable suggestion that the depletion of resources, be they petroleum or groundwater or copper, be resolved by exploiting ever lower grade deposits. This proposed solution withers rather readily when confronted with the mathematical proof that such exploitation rapidly creates a negative return. You put more into the ground than you get out.

It's not a pretty picture, and you might not read this thing just for he fun of it, but you can't put it down, either. It makes too much sense, scary sense.

Robert G. Russell,
Metals exploration geologist (ret.),
Coeur d'Alene, Idaho

(Continued from page 44)
Tsunami Inundation Mapping Effort of the National Oceanic and Atmospheric Administration (NOAA) at Newport, Oregon, and the Department of Geology at Portland State University.

The tsunami hazard map shows a black-and-white air-photo image of the coastal zone, approximately from Northwest 15th Street in the north to Henderson Creek and the south end of King Slough in the south with elevation contours superimposed. The scale of 1:12,000 (1 inch = 1,000 feet) allows identification of streets and medium-sized structures. Three different types of red lines mark expected tsunami runup elevations that serve to separate risk zones: high runup, moderately high runup, and moderately low runup. The map also identifies drill sites where cores revealed buried soils and, in some cases, tsunami sand layers from prehistoric events.

Detailed discussion of the map and its use, the methods used, and the geologic evidence of prehistoric earthquakes and tsunamis on the coast is provided in a separate publication, entitled Cascadia Subduction Zone Tsunamis: Hazard Mapping at Yaquina Bay, Oregon. Final Technical Report to the National Earthquake Hazard Reduction Program, and released in December 1997 as DOGAMI Open-File Report O–97–34 (price $10).

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