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**Main Office**: Suite 965, 800 NE Oregon Street # 28, Portland 97232-2162, phone (503) 731-4100, FAX (503) 731-4066.

**Baker City Field Office**: 1831 First Street, Baker City 97814, phone (541) 523-3133, FAX (541) 523-5992.
Mark L. Ferns, Regional Geologist.

**Grants Pass Field Office**: 5375 Monument Drive, Grants Pass 97526, phone (541) 476-2496, FAX (541) 474-3158.
Thomas J. Wiley, Regional Geologist.

**Mined Land Reclamation Program**: 1536 Queen Ave. SE, Albany 97321, phone (541) 967-2039, FAX (541) 967-2075.
Gary W. Lynch, Supervisor.

**The Nature of the Northwest Information Center**: Suite 177, 800 NE Oregon Street # 5, Portland, OR 97232-2162, phone (503) 872-2750, FAX (503) 731-4066, Donald J. Haines, Manager.

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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 Beverly F. Vogt, Publications Manager, at the Portland office (address above).



## Cover photo

With this splendid view of the summit of Mount Hood, seen from the 6,600-ft level, just above Timberline Lodge, we are sending you our best wishes for a happy new year and our thanks for your being faithful readers of and contributors to *Oregon Geology*. We hope to continue our work with your attention and support. (Photo courtesy Oregon Department of Transportation)

*The publishers and editors*

## What's your earthquake IQ?

Scientists frequently warn Oregonians about seismic hazards and increasing seismic safety standards; however, the current level of awareness and preparedness does not ensure protection of lives and property from even moderate earthquake shaking. To support earthquake awareness, this quiz was modified from a quiz developed by staff member Mei Mei Wang for the November 1995 Fall Institute of the Oregon Building Officials Association.

1. What is generally considered to be a "major" earthquake?
   a. Magnitude 6.
   b. Magnitude 7.
   c. Magnitude 8.
   d. Intensity VII.
2. When will the next big earthquake be?
   a. More likely during the next full moon.
   b. No one knows. No one can reliably predict "when, where, and how big" the next earthquake will be.
   c. Sometime soon in the morning, since earthquakes generally occur in the morning.
   d. Never. Earthquakes don't occur in Oregon.
3. What should you do during an earthquake?
   a. Get frantic and scream.
   b. Duck, cover and hold on.
   c. Remain quiet and pass out.
   d. It really depends on where you are.
4. What should you do immediately after an earthquake?
   a. Go about your business and pretend it never happened.
   b. Call your family and friends and tie up the phone lines.
   c. Check for injuries, hazards (fire, gas leaks, spills, etc.), clean up, expect aftershocks, listen to radio.
   d. Anticipate tsunamis if you're on the coast.
   e. Answers c and d.
5. When did the last great subduction-zone earthquake and tsunami hit coastal Oregon?
   a. Precisely on January 26, 1700.
   b. About 300 years ago.
   c. Several thousand years ago.
   d. There hasn't been one.
6. When did the last damaging tsunami hit the Oregon coast?
   a. Precisely on January 26, 1700.
   b. About 300 years ago.
   c. March 1964.
   d. There hasn't been one.
7. Are there active faults near you?
   a. Probably yes, but their locations are not well understood.
   b. No, there are none.
   c. I don't know.
   d. There were, but they were voted out of office.
8. To protect against loss of life or damage, do the following:
   a. Vulnerability study.
   b. Risk study.
   c. Prioritize your seismic strengthening needs.
   d. Prepare emergency kit and response plan.
   e. All of the above, and follow through with necessary actions.

*(Answers on page 9)*

New areas of geothermal potential in southeastern Oregon are being explored

# Field and stable isotope indicators of geothermal resource potential, central Lake County, Oregon

*by A. Mark Jellinek, Research School of Earth Sciences, The Australian National University, Canberra; Ian P. Madin, Oregon Department of Geology and Mineral Industries; and Robert Langridge, University of Oregon*

**ABSTRACT**

The geothermal resource potential in central Lake County, Oregon, has been known for some time on the basis of active hot springs and hot wells in the Summer Lake Known Geothermal Resource Area, scattered warm springs at the north end of Summer Lake and on the east shore of Lake Abert, and a single published borehole heat-flow measurement at Paisley. We report field and stable isotopic evidence for Quaternary hot springs at the north end of Lake Abert and in the Picture Rock Pass area that indicate the presence of recently active paleogeothermal systems. At the north end of Lake Abert, tufa mounds and travertine vein fillings are possibly associated with a zone of intersecting northeast- and northwest-trending faults. The tufa mounds occur in a narrow elevation range, a feature that suggests their deposition was controlled by the Pleistocene lake level. At Picture Rock Pass, travertine and silica sinter mineralization occurs in fractures, joints, and cavities in basalt bedrock, in Pliocene or Quaternary channel gravels, and in Holocene colluvium associated with the Egli Rim escarpment and an adjacent network of closely spaced northeast- and northwest-trending faults. The $\delta^{18}O$ (SMOW) and $\delta^{13}C$ (PDB) data for samples of travertine from the study areas range from 16.1 to 17.4 per mil and –6.8 to –10.7 per mil, respectively, at Picture Rock Pass and from 24.0 to 28.9 per mil and 1.4 to 4.5 per mil, respectively, at Lake Abert. These data are similar to analogous data from geothermal areas in New Zealand, central Italy, western Germany, southwestern Colorado, and Yellowstone in Wyoming. Surface precipitation temperatures for samples of sinter and travertine from the Picture Rock Pass area are determined with equilibrium oxygen-isotopic thermometry to be 39°–70°C and 30°–49°C, respectively, and are geologically reasonable. The precipitation temperatures for samples of Picture Rock Pass sinter combined with temperature-dependent solubility curves of Rimstidt and Cole (1983) for amorphous silica and quartz indicate geothermal reservoir temperatures of 145°–205°C and suggest that the Picture Rock Pass sinter was precipitated from a hot-water system. The results of the field and stable isotopic studies indicate a significant geothermal resource potential at both sites.

## INTRODUCTION

This study is part of a program of the Oregon Department of Geology and Mineral Industries (DOGAMI) to prospect for geothermal resources in southeastern Oregon by looking for geologic evidence of late Quaternary hot spring activity. The program began in 1992 and is funded by the Bonneville Power Administration, the U.S. Department of Energy, and Portland General Electric Company.

Most of the Known Geothermal Resource Areas (KGRAs) in southeast Oregon (Alvord, Crump Geyser, Lakeview, Summer Lake, and Klamath Falls) are spatially associated with major Basin and Range faults (Oregon Department of Geology and Mineral Industries/NOAA, 1982). All of these KGRAs have natural hot springs, and the Alvord KGRA (Hemphill-Haley and others, 1989), Summer Lake KGRA (Pezzopane, 1993), and Klamath Falls KGRA (Sherrod and Pickthorn, 1992) show evidence of Holocene faulting. The program's aim is to use the association of faulting and hot springs to locate new areas of geothermal potential by locating evidence for geologically young but currently inactive hot springs associated with Neogene faulting in southeast Oregon. We report the results of preliminary field and stable isotopic studies from two sites in central Lake County, Oregon (Figure 1). The two areas, Picture Rock Pass and Sawed Horn (at the north end of Lake Abert), were selected for detailed field investigation on the basis of complex and closely spaced faulting observed with photogeologic mapping and in the field. Neither site has a known hot spring or hot well, but both sites showed evidence of late Quaternary or Holocene hot springs in the form of travertine and sinter mineralization precipitated into Miocene basalt bedrock, Pliocene or Quaternary channel gravels, and Holocene colluvium. Both sites were mapped at 1:24,000 scale, and the travertine and sinter were sampled.

Stable isotopic data are presented for samples of travertine and sinter collected from the Picture Rock Pass area and for samples of travertine collected from the Sawed Horn area. Oxygen and carbon isotopic data for the Lake Abert and Picture Rock Pass travertine are compared with similar data from travertine of central Italy, southwest Colorado, western Germany, Yellowstone National Park, and the Broadlands geothermal field in New Zealand. Additionally, surface saturation temperatures for fluids precipitating travertine and surface saturation and geothermal reservoir temperatures for fluids precipitating sinter from the Picture Rock Pass area are determined with oxygen isotope thermometry on the basis of temperature-dependent equilibrium quartz-water and calcite-water isotopic fractionations.

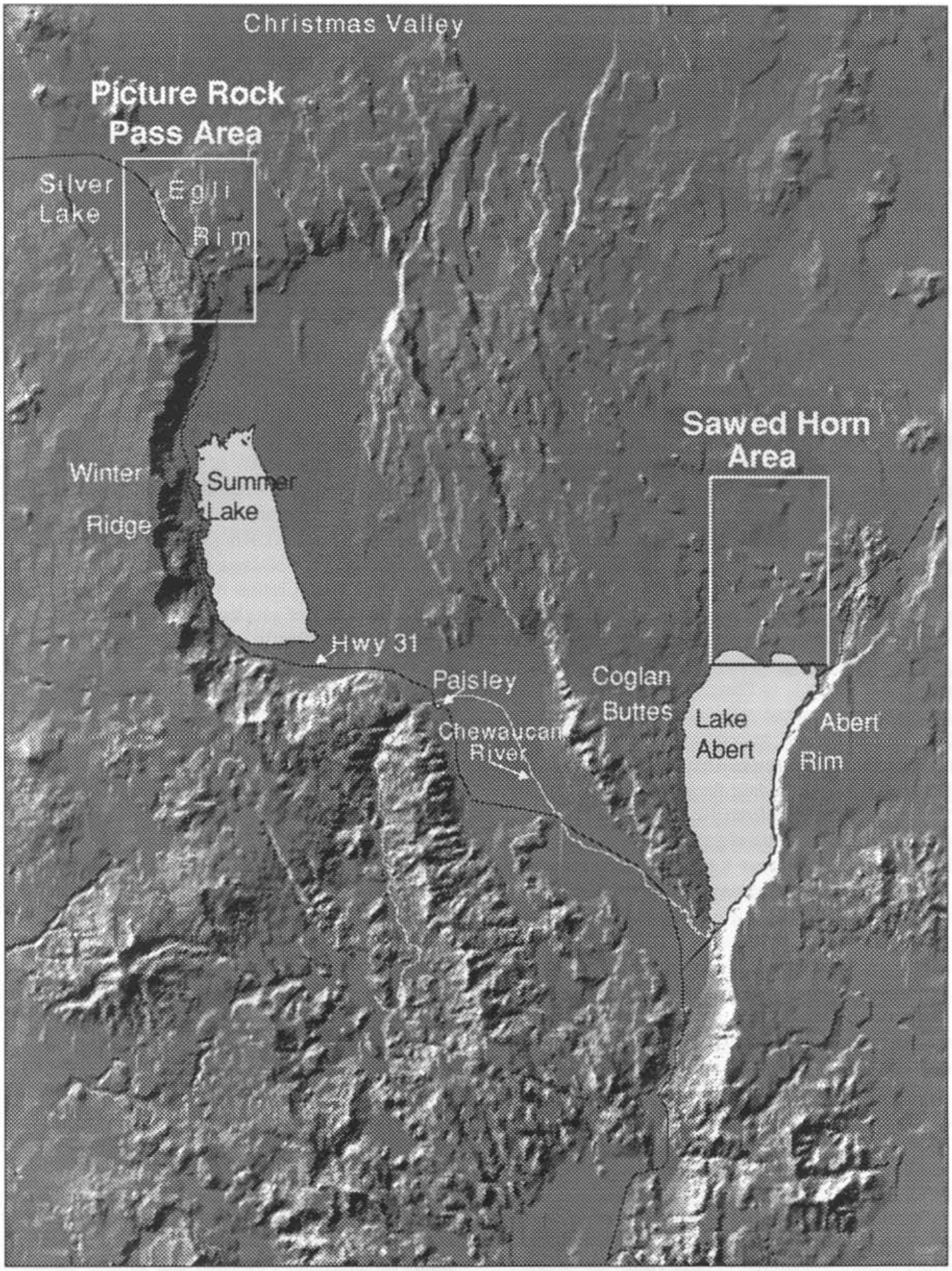


*Figure 1. Shaded-relief map of central Lake County showing study areas.*

## PICTURE ROCK PASS

The Picture Rock Pass study area is located on the Egli Rim 7½-minute quadrangle astride Highway 31 between two major Basin and Range basins, Silver Lake to the north and Summer Lake to the south (Figure 1). The bedrock is predominantly Miocene basalt (Hampton, 1964; Walker and others, 1967; Travis, 1977; Walker and McLeod, 1991). Fiebelkorn and others (1983) report a K-Ar age of 6.9 ± 0.9 Ma for basalt at Picture Rock Pass. Bedrock in the study area is cut by numerous, commonly intersecting, northeast- and northwest-trending faults (Figure 2). Paleochannels follow many of the grabens developed between the intersecting faults, and Pliocene or Quaternary cobble gravel deposits fill the channels. Where the channels are cut by intersecting faults, numerous small Pliocene or Quaternary playa lakes have formed. Quaternary lacustrine deposits fill the Silver Lake basin west of the Egli Rim, and Holocene colluvium mantles the escarpment of the Egli Rim.

Samples of sinter and travertine were collected from the cobble gravel; colluvium; and cavities, fractures, and joints in basalt flows along the Egli Rim (Figure 1). The best exposures of sinter and travertine occur in road-cuts along Highway 31 and the other unimproved roads in the area. The proximity of these exposures to regional faults and fault intersections suggests that the movement of associated geothermal fluids was strongly fault controlled.

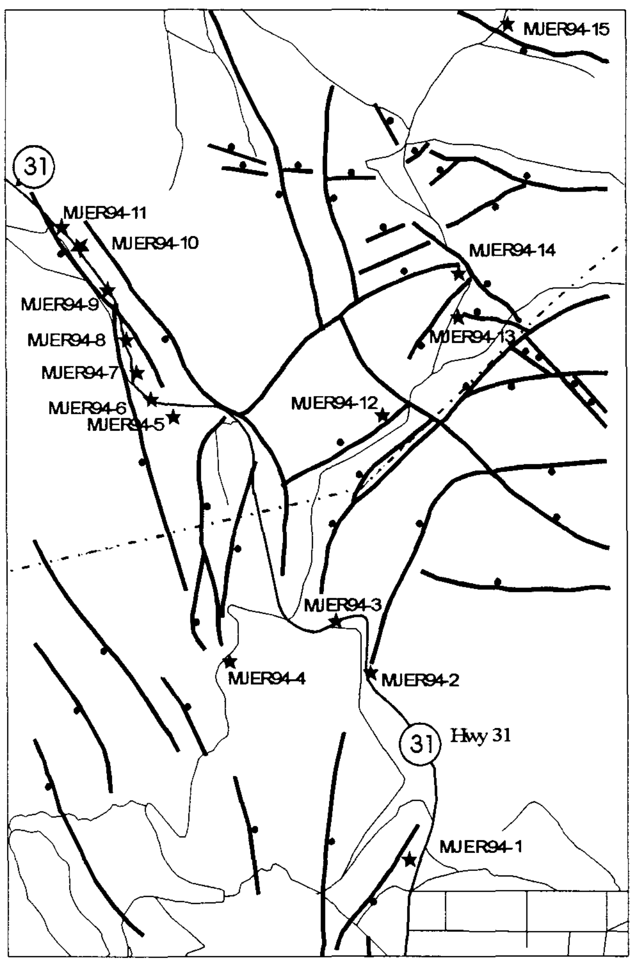


*Figure 2. Sketch map of the Picture Rock Pass area, Egli Rim quadrangle. Heavy lines are faults, with ball on downthrown side. Fine lines are unimproved roads; dot-and-dash line is a transmission line. Stars show sample locations.*

In most sampled exposures, travertine is a soft, white- to cream-colored rind on typically vitreous, honey-colored to yellow or tan, hard to friable siliceous sinter. The stratigraphic position of travertine on top of sinter indicates that the two phases were probably not syndepositional. In exposures of altered colluvium, sinter is friable, occurs as meter-scale layers or paleoterraces, and can contain internal, centimeter-scale layers that are fine grained to conglomeratic. Packages of centimeter-scale layers can include rhythmic interbeds of sinter and travertine. The pebbles constituting conglomeratic layers are generally well rounded and attributed to the host sediment. The sedimentary appearance of these exposures is similar, for example, to that described for the Beowawe, Nevada, sinter deposit (Rimstidt and Cole, 1983).

In exposures of altered and mineralized cobble gravels, boulders, and basalt flows, sinter occurs as a hard, smooth or rough glaze up to 2 cm thick that is also typically coated by rinds of travertine. Minor brecciation is common, particularly in exposures along Highway 31. Mineralized zones hosted by cobble gravel are typically massive, up to 7 m thick, and stratigraphically confined to gravel horizons of high permeability. Alteration zones in basalt flows are rectangular to prolate and up to 10 m high and can have aspect ratios of 60:1. Mineralization is typically confined to single flows within flow packages, which suggests that certain flows exhibit greater fracture permeability than others.

## SAWED HORN

Lake Abert occupies a Basin and Range graben bounded by the Abert Rim to the east and Coglan Buttes to the west (Figure 1). The Sawed Horn study area is an area of faulted bedrock at the north end of the graben and is on the Sawed Horn and Lake Abert North 7½-minute quadrangles. The bedrock consists of Miocene basalt flows overlain by the Miocene Rattlesnake Ash-flow Tuff (Walker and MacLeod, 1991). Quaternary beach, dune, and lacustrine deposits overlie the bedrock along the north shore of the lake. Numerous well-defined northwest- and northeast-trending faults cut the bedrock units (Figure 3). Several travertine mounds overlie the Quaternary deposits at an elevation of about 4,390 ft and may be associated with the projections of faults beneath the alluvium. Travertine also occurs as vein fillings in joints and fractures in the basalt bedrock.

The mounds are oblate to mushroom-shaped, 1–3 m high, and constructed of weakly bedded to massive, spongy, and exceedingly porous carbonate material or tufa (Turi, 1986). The relative proportions of calcite and aragonite are not known. Several mounds have rounded pebbles and cobbles of the host sediment entrained in their bases. Their occurrences at similar elevations suggest a rela-

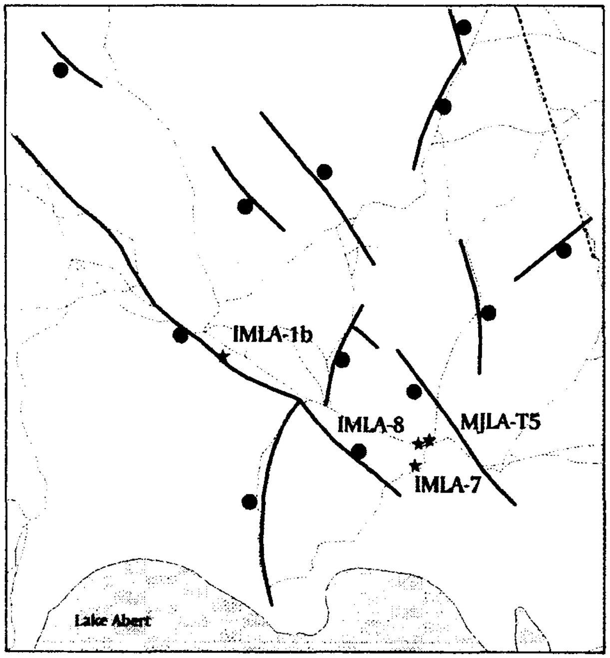


*Figure 3. Sketch map of the Lake Abert North and Sawed Horn quadrangles. Heavy lines are faults, with ball on downthrown side. Dashed lines are unimproved roads. Dot-and-dash line is a transmission line. Stars show sample locations.*

tionship to paleo-lake level. Samples were collected from tufa mounds and travertine vein fillings in the Sawed Horn area, and one tufa mound was sampled (COGBUT-1) on the shore of Lake Abert, several kilometers southwest of the study area.

## OXYGEN AND CARBON ISOTOPES AND THERMOMETRY

Samples of travertine and sinter were collected and analyzed for stable isotopic characterization and comparison with other geothermal areas around the world. Oxygen isotope data are also used with appropriate equilibrium fractionation equations to determine travertine and amorphous silica surface saturation temperatures for the geothermal fluids of Picture Rock Pass in order to evaluate fluid reservoir temperatures (Fournier and Rowe, 1966; Rimstidt and Barnes, 1980; Rimstidt and Cole, 1983). Temperatures determined in this way are generally in good agreement with measured precipitation temperatures (Clayton and others, 1968; Friedman, 1970). The methods of McCrea (1950) and Borthwick and Harmon (1982) were employed to determine $^{18}O/^{16}O$ ratios for siliceous sinter and $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios for travertine. The analyses were performed at the Stable Isotope Laboratory at Washington State University. The $^{18}O/^{16}O$ ratios are reported relative to the standard mean ocean water standard (SMOW) and the $^{13}C/^{12}C$ ratios relative to the PDB (Peedee belemnite) standard as $\delta^{18}O$ and $\delta^{13}C$ values in per mil, respectively.

The $\delta^{18}O$ and $\delta^{13}C$ data are tabulated with comparative analyses from other studies in Table 1. The $\delta^{18}O$ values are not included for all of the comparative studies because global comparison of $\delta^{18}O$ values for hydrothermal travertine and sinter is complicated by latitude-controlled variations in the $\delta^{18}O$ values for meteoric water (Taylor, 1974), from which the two phases acquire most of their oxygen. Shallow geothermal fluids are composed of nearly purely meteoric water (Truesdell and Fournier, 1976; Truesdell and others, 1977; Taylor, 1979). The $\delta^{18}O$ data for travertine of central Italy and southwest Colorado are included because they are from study areas of similar latitude to south-central Oregon. Analogous $\delta^{18}O$ values for sinter are currently unavailable.

The $\delta^{18}O$ data for Picture Rock Pass sinter vary from 17.5 to 21.5 per mil. The $\delta^{18}O$ and $\delta^{13}C$ data for travertine range from 16.1 to 17.7 per mil and –6.8 to –10.7 per mil, respectively. The $\delta^{18}O$ values are similar to those reported by Chafetz and others (1991) for travertine deposited from a warm spring in southwest Colorado and are substantially lighter than values given by Turi (1986) for travertine of central Italy. The $\delta^{13}C$ values are analogous to data of Savelli and Wedepohl (1969) for travertine of the Westerhof, Göttingen, and Iburg areas of western Germany and to data of Blattner (1975) for travertine of the Broadlands geothermal field, New Zealand. The $\delta^{18}O$ values for samples of Lake Abert tufa mounds vary from 24.0 to 28.9 per mil and are similar to values recorded by Turi (1986) for travertine of central Italy. The $\delta^{13}C$ data range from 1.4 to 4.5 per mil and are analogous to data reported by Friedman (1970) for samples of travertine from New Highland Terrace, Mammoth Hot Springs, Yellowstone National Park, and also similar to data of Turi (1986). These $\delta^{18}O$ and $\delta^{13}C$ values are considerably heavier than those of Picture Rock Pass samples.

Precipitation temperatures are determined for sinter and travertine samples from Picture Rock Pass with the assumption that the geothermal fluids and precipitates were in stable isotopic equilibrium at the time of their deposition (Bottinga and Javoy, 1973; O'Neil, 1986; Clayton and others, 1989). We evaluated the equilibrium fractionation temperatures for sinter using the quartz-water fractionation equation of Sharp and Kirschner (1994):

$$\delta^{18}O_{qtz} - \delta^{18}O_{H2O} = 3.65(10^6/T^2) - 2.9 = 1000 \ln\alpha,$$

where $T$ is absolute temperature and $\alpha$ is the fractionation factor. We determined similar temperatures for travertine by combining the quartz-calcite and quartz-water fractionation equations of Clayton and others (1989) and Sharp and Kirschner (1994) into a calcite-water fractionation equation:

$$\delta^{18}O_{Cc} - \delta^{18}O_{H2O} = 3.27(10^6/T^2) - 2.95 = 1000 \ln\alpha.$$

We calculated the $\delta^{18}O_{H2O}$ values for meteoric water of south-central Oregon, which are taken to be equivalent to geothermal fluid values, using the meteoric water line and

Table 1. *Stable isotope data from this and comparative studies along with calculated precipitation temperatures of samples of travertine and sinter from Picture Rock Pass. Values in per mil*

| | | Sample number | $\delta^{18}O$ | $\delta^{13}C$ | Tp (−112.5)* | Tp (−13.75)* | Tp (−15)* |
|---|---|---|---|---|---|---|---|
| **Picture Rock Pass** | | | | | | | |
| | **Sinter** | MJER 94–2 | 17.5 | — | 60.0 | 53.8 | 48.0 |
| | | MJER 94–3 | 21.5 | — | 41.4 | 36.2 | 31.3 |
| | | MJER 94–8 | 18.7 | — | 54.0 | 48.1 | 42.6 |
| | | MJER 94–4 | 21.5 | — | 41.3 | 36.1 | 31.1 |
| | | MJER 94–10 | 19.7 | — | 49.1 | 43.5 | 38.2 |
| | | MJER 94–12 | 15.8 | — | 68.9 | 62.3 | 56.0 |
| | **Travertine** | MJER 94–9 | 17.3 | −8.4 | 42.6 | 36.7 | 31.2 |
| | | MJER 94–11 | 17.7 | −7.7 | 40.9 | 35.1 | 29.7 |
| | | MJER 94–1 | 16.8 | −10.7 | 45.2 | 39.3 | 33.6 |
| | | MJER 94–7 | 16.1 | −6.8 | 48.9 | 42.7 | 36.9 |
| | | MJER 94–5 | 17.0 | −8.8 | 44.4 | 38.4 | 32.8 |
| | | MJER 94–13 | 17.4 | −6.8 | 42.5 | 36.6 | 31.2 |
| **Sawed Horn** | | | | | | | |
| | **Travertine** | IMLA–7 | 24.9 | 1.8 | — | — | — |
| | | COGBUT–1 | 24.0 | 1.4 | — | — | — |
| | | IMLA–8 | 24.8 | 1.3 | — | — | — |
| | | IMLA–1b | 28.9 | 4.5 | — | — | — |
| | | MJLA–5 | 24.8 | 1.5 | — | — | — |
| **Comparative studies** | | | | | | | |
| | | Chafetz and others (1991) | 16.74 to 16.95 | −2.89 to −2.70 | 33.21 | — | — |
| | | Blattner (1975) | — | −5.4 to −10.2 | — | — | — |
| | | Friedman (1970) | — | 1.7 to 4.3 | 73 to 30.5 | — | — |
| | | Turi (1986) | 16 to 26 | −4 to 8 | — | — | — |
| | | Savelli and Wedepohl (1969) | — | −10 to −7 | — | — | — |

* Tp (x) is the calculated precipitation temperature in degrees Celsius for the phase in equilibrium with meteoric water that has a $\delta^{18}O$ value of x.

δD values reported by Taylor (1974) for meteoric surface waters of south-central Oregon and northern Nevada. The $\delta^{18}O_{H2O}$ values used in this study are −13.8 ± 1.3 per mil and assume negligible $^{18}O$-shifting to higher values as a result of the interaction of hot geothermal waters with their host rocks.

Calculated surface saturation temperatures for fluids precipitating samples of Picture Rock Pass sinter and travertine are tabulated in Table 1. The $\delta^{18}O$ values for samples of Lake Abert tufa were too heavy to allow geologically reasonable temperatures to be calculated with equilibrium isotope thermometry—a feature that may reflect significant evaporation occurring as the tufa was precipitated. For Picture Rock Pass samples, the ranges of precipitation temperatures predicted are 30°–49°C for travertine and 31°–70°C for sinter and are geologically reasonable. Travertine and sinter are typically deposited by waters cooling through 75°–25°C and 100°–50°C, respectively (Friedman, 1970; Rimstidt and Cole, 1983). The consistent stratigraphic position of travertine on top of sinter in outcrops of altered alluvium, colluvium, and basalt suggests that the precipitation of these two phases was sequential and may, in part, reflect changes in the thermal histories of the geothermal fluids. Temperatures predicted for two travertine/sinter sample pairs, ER94–1/ER94–2 and ER94–9/ER94–10, suggest that the precipitation of travertine after sinter correlates with cooling of the geothermal fluids. Finally, assuming that the surface fluids were saturated in amorphous silica, the reservoir fluid equilibrated with quartz, and there was no subsurface boiling, one can use Figure 1 of Rimstidt and Cole (1983) to evaluate reservoir fluid temperatures on the basis of the different temperature-dependent solubilities of amorphous silica and quartz (see also Truesdell and Fournier, 1976; Rimstidt and Barnes, 1980). Sinter precipitated from fluids saturated in amorphous silica at 30°–50°C indicates geothermal reservoir temperatures of 145°–205°C.

## CONCLUSION

The results of the preliminary stable isotope study support three conclusions. The first is that $\delta^{18}O$ and $\delta^{13}C$ data for samples of travertine from Picture Rock Pass and Lake Abert tufa mounds are similar to analogous data for travertine from other geothermal areas around the world. Second, precipitation temperatures for sinter and travertine determined with oxygen isotope thermometry of 31°–70°C and 30°–49°C, respectively, are geologically reasonable. Last, precipitation temperatures for sinter combined with the temperature-dependent solubility curves of Rimstidt and Cole (1983) for amorphous silica and quartz indicate geothermal reservoir temperatures of 145°–205°C. This assessment assumes that the surface fluids were saturated with respect to amorphous silica, that the reservoir fluid equilibrated with quartz, and that there was no subsurface boiling.

These results also suggest that hot springs systems were active at the north end of Lake Abert during the late Quaternary and at Picture Rock Pass during the late Quaternary and Holocene. The combination of geologically recent hot spring activity and extensive faulting in both of these areas indicates that they have significant geothermal resource potential. Further work, including local heat flow measurements, is warranted to better evaluate the resource potential of both areas.


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*(Continued from page 2)*

## Earthquake IQ test answers

1. **Question:** What is generally considered to be a "major" earthquake?

   **Answer:** b — Magnitude (M) 7. However, smaller magnitude earthquakes can be very damaging. Remember, the M 5.6 earthquake on March 1993 at Scotts Mills ("Spring Break Quake") caused minor damage (about $30 million). The *intensity* scale (expressed in Roman numerals) describes the effects people experienced ("felt effects") from an earthquake and can be associated with damage levels.

2. **Question:** When will the next big earthquake be?

   **Answer:** b — No one knows. No one can reliably predict "when, where, and how big" the next earthquake will be.

3. **Question:** What do you do *during* an earthquake?

   **Answer:** d — It really depends on where you are. (1) If you are indoors, ***duck*** or drop down to the floor. Take ***cover*** under a sturdy desk, table, or other furniture. ***Hold*** on to it and be prepared to move with it. Hold the position until the ground stops shaking and it is safe to move. Stay clear of windows, fireplaces, wood stoves, and heavy furniture or appliances. Stay inside. Outside, you may be injured by falling glass or building parts. If you are in a crowded area, take cover and stay where you are. Stay calm and encourage others to do likewise. (2) If you are outside, get into the open, away from buildings, power lines, and trees. (3) If you are driving, stop if it is safe, but stay inside your car. Stay away from bridges, overpasses, and tunnels. Move your car as far out of the normal traffic pattern as possible. Avoid stopping under trees, light posts, power lines, or signs if possible. (4) If you are in a mountainous area, or near unstable slopes or cliffs, be alert for falling rock and other debris that could be loosened by the earthquake.

4. **Question:** What do you do immediately *after* an earthquake?

   **Answer:** e — Both c and d. Check for injuries, hazards (fire, gas leaks, spills, etc.), clean up, expect aftershocks, listen to radio. Anticipate tsunamis if you're on the coast and quickly go inland or uphill. Also, remember that there very well may be strong aftershocks, that is, additional earthquakes.

5. **Question:** When did the last great subduction-zone earthquake and tsunami hit coastal Oregon?

   **Answer:** a and b — On January 26, A.D. 1700, **and** about 300 years ago. Scientists have found many lines of evidence for a great (i.e., magnitude 8 and higher) earthquake event about 300 years ago. Evidence includes land subsidence, land uplift, tsunami deposits, liquefaction features, and turbidites, as well as cultural evidence from coastal Native Americans. Studies by a Japanese scientist of the historic record of tsunamis experienced in Japan suggest that a Cascadia event occurred specifically on January 26, 1700. The M 7 Cape Mendocino ("Petrolia") earthquake of April 1992 occurred on the northern Californian coastline about 50 km south of Eureka and was likely a subduction zone earthquake.

6. **Question:** When did the last damaging tsunami hit the Oregon coast?

   **Answer:** c — March 1964. The M 9.2 Prince William Sound Alaska ("Good Friday") earthquake on this date generated a tsunami that hit coastal Oregon (and California). There were several fatalities at Beverly Beach, Oregon, and in Crescent City, California. Low-lying coastal areas that suffered damage due to flooding included Seaside, which suffered the most damage to structures; Newport's Yaquina harbor; and Cannon Beach, which had a bridge collapse.

7. **Question:** Are there active faults near you?

   **Answer:** a — Probably yes, but their locations are not well understood. Earth scientists (seismologists and geologists) have identified **some** faults in Oregon, but certainly not **all** of them. Furthermore, faults that have been identified may or may not be *active*, that is, capable of generating earthquakes. A 1995 report titled "Seismic Design Mapping, State of Oregon," and prepared for the Oregon Department of Transportation includes the most comprehensive *active* fault map for the state. Copies are available in the libraries of the DOGAMI offices in Portland, Baker City, and Grants Pass.

8. **Question:** To protect against loss of life, property, and injury, do the following:

   **Answer:** e — All of the above (vulnerability study, risk study, prioritizing your seismic strengthening needs, and preparing emergency kit and response plan) **and follow through with necessary actions.** □

# The development of the Portland, Oregon, Building Code—50 years of evolution, 1945–1995. A comparison of seismic events and structural aspects

*by R. Evan Kennedy, Consulting Engineer, Kennedy Associates, Inc., 2309 SW First Avenue, Portland, Oregon 97201*

**ABSTRACT**

Revision to building codes has not always been an action resulting from specific steps taken by specific identities. The growth of a code has often been a very vague process. One factor that could affect a structural design code evolution is the seismic environment in which the code operates. It therefore is of interest to see if the occurrence of seismic events in the geographic area serviced by the Portland Building Code seems to have had an effect on the structural requirements of the code for designing a structure in that area. The tabulation herein shows very little connection between seismic occurrences and code changes from 1940 to 1990. Subsequent changes were made by an entity created to examine the seismicity of Oregon, which reversed a previous disinterest to a highly sensitive interest. Code changes as revealed by the records in the Portland Archives then began to respond to seismic events.

## INTRODUCTION

The City of Portland emerged from the days of World War II with a code that had been written during the Depression as a job maker. It specified in detail the materials that could be used in construction in Portland and how they were to be used. The Code did not pretend to address any loading condition that could come from an earthquake. It did address wind, with numbers provided for the pounds per square foot of vertical surface that were to be applied in the design, but no other horizontal loading was mentioned.

Structural engineering as an identified engineering discipline was greatly augmented by the Long Beach, California, earthquake of 1933. That event, causing much loss of life and property, was a surprise to southern California and caused the passage of a state law requiring public buildings to be designed by a structural engineer. It also started the study in California of the effects of earthquakes on buildings.

In 1948, the American Telephone and Telegraph Company (AT&T) was planning to build a central switching building in Portland. AT&T wanted that building to be solid and to survive major events. They became interested in its exposure to earthquakes and thus were responsive to the insistence of a consulting structural engineer named Guy Taylor, who had been preaching about the susceptibility of Oregon to earthquakes ever since his return from service in the Army. His firm, Moffatt, Nichol, and Taylor, now Moffatt, Nichol, and Bonney, was retained to furnish the structural design of this switching building with Pietro Belluschi as the architect. Since I had extensive experience in aircraft design and responding to loads from any direction, he assigned to me the task of designing that building.

In that process I became convinced that Portland should in fact address the probability of having an earthquake and began to talk to the city commissioners about that. There had been for very many years a structural engineer named Miles Cooper who had been, until Taylor came on the scene, virtually the only structural engineer in the state and who had been kept overwhelmingly busy just designing things to take their vertical loads and thus had never thought much about earthquakes. But Guy Taylor and I kept working on the city commissioners to convince them that earthquakes could happen in Portland.

In 1949, we started the Structural Engineers Association of Oregon. The organization had an exceedingly small membership at the beginning, but we were attuned to the activities of the Structural Engineers Associations of both northern and southern California, where seismic design was extremely high on the agenda. We attended their conventions and listened to their theories. We advised the local City Council on the expectations that many engineers were beginning to accept: that we were likely to have earthquakes and needed to be current on designing for them—as was being pursued in California. The Public Works Commissioner then was Bill Bowes. We started talking to him about adopting a code that included earthquake loading. The idea of a performance code was a real problem with Bill. In fact, we had two problems with him: In his view, (1) the old specification code was an Oregon product and thus was just right for Portland, and (2) only California and Washington had earthquakes.

The business community, fearing higher construction costs, was glad to agree with Bowes wholeheartedly.

We were suggesting the adoption of the Uniform Building Code (UBC) by the City of Portland. Bill was sure that no one outside Oregon was qualified to write a proper code for Portland, much less for Oregon. So we did not get far very fast. The earthquake in the Olympia, Washington, area in 1949 that also shook Portland fairly firmly had a slight effect on Bill's thinking. Finally in 1955, after a good shake on December 15, 1953, the City Council became convinced that an improvement was overdue and decided to adopt at least parts of the UBC. But when it came to earthquake loading, the City adopted the code in such a way as to put Portland in a Zone 1 location, even though the UBC suggested it be in Zone 2.

Table 1. *Correlation of Portland, Oregon, building code revisions with seismic events felt in Portland 1940–1995. Comparison of city ordinance and state actions and intent with seismic events magnitude 4.0 or greater. Earthquake data from Bott and Wong (1993). Portland ordinances in City of Portland Archives*

| | City and state actions | | | Seismic design requirements | | Seismic events | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Ordinance** | **Adopted** | **Provisions** | **Portland** | **UBC[1]** | **Date** | **Magnitude** | **Location** |
| 1995 | 168627 | 03/22/95 | Delays retrofitting existing buildings until 1997 | Zone 3 | Zone 3 | — | — | — |
| 1994 | — | — | — | Zone 3 | Zone 3[1] | — | — | — |
| 1993 | (State) | 01/01/93 | OSSPAC[2] adopts Zone 3 for western Oregon | Zone 3 | Zone 2B | 09/20/93 | 6.0 | Klamath Falls |
| | | | | | | 03/25/93 | 5.6 | Scotts Mills |
| 1992 | 166111 | 12/23/92 | State 1993 Structural Code adopted with UBC 1990 edition | Zone 2B | Zone 2B | — | — | — |
| 1991 | — | — | — | Zone 2B | Zone 2B[1] | — | — | — |
| 1990 | 162695 | 01/18/90 | State 1990 Structural Code adopted with UBC 1988 edition | Zone 2B | Zone 2B | — | — | — |
| 1989 | — | — | — | — | — | — | — | — |
| 1988 | — | — | — | Zone 2 | Zone 2B[1] | — | — | — |
| 1987 | — | — | — | — | — | — | — | — |
| 1986 | (State) | 07/01/86 | State adopts 1985 UBC edition | Zone 2 | Zone 2 | — | — | — |
| 1985 | — | — | — | Zone 2 | Zone 2[1] | — | — | — |
| 1984 | — | — | — | — | — | — | — | — |
| 1983 | 155104 | 09/15/83 | Replaces City Title 24 regulations with new version. Adopts State Code of 1983 | Zone 2 | Zone 2 | — | — | — |
| | (State) | 08/01/83 | State adopts 1982 UBC edition | Zone 2 | Zone 2 | | | |
| 1982 | — | — | — | Zone 2 | Zone 2[1] | — | — | — |
| 1981 | — | — | — | — | — | 02/13/81 | 5.5 | Mt.St. Helens |
| 1980 | (State) | 07/01/80 | State adopts 1979 UBC edition | Zone 2 | Zone 2 | — | — | — |
| 1979 | — | — | — | Zone 2 | Zone 2[1] | — | — | — |
| 1978 | (State) | 03/01/78 | State adopts 1976 UBC edition | Zone 2 | Zone 2 | — | — | — |
| 1977 | — | — | — | — | — | — | — | — |
| 1976 | — | — | — | Zone 2 | Zone 2[1] | — | — | — |
| 1975 | — | — | — | — | — | — | — | — |
| 1974 | (State) | 07/01/74 | State adopts 1973 UBC. Cities' acceptance made mandatory | Zone 2 | Zone 2 | — | — | — |
| 1973 | — | — | — | Zone 2 | Zone 2[1] | — | — | — |
| 1972 | 134654 | 05/26/72 | Replaces Title 24 City Code. Adopts UBC 1970 edition | Zone 2 | Zone 2 | — | — | — |
| 1971 | — | — | — | — | — | — | — | — |
| 1970 | 130672 | 03/20/70 | An ordinance enacting the "Code of the City of Portland, Oregon" on the regulations and prohibitions relating to public space, health, safety, or public welfare | Zone 1 | Zone 2[1] | — | — | — |
| 1969 | — | — | — | — | — | — | — | — |
| 1968 | — | — | — | — | — | — | — | — |
| 1967 | — | — | — | Zone 1 | Zone 2[1] | — | — | — |
| 1966 | — | — | — | — | — | — | — | — |
| 1965 | — | — | — | — | — | — | — | — |
| 1964 | — | — | — | Zone 1 | Zone 2[1] | — | — | — |
| 1963 | — | — | — | — | — | 12/27/63 | 4.5 | Banks |
| 1962 | — | — | — | — | — | 11/05/62 | 5.5 | Scappoose |
| 1961 | — | — | — | Zone 1 | Zone 2[1] | 11/06/61 | 5.0 | Portland |
| | | | | | | 09/17/61 | 5.0 | Cougar |
| | | | | | | 09/15/61 | 4.5 | Cougar |
| | | | | | | 08/18/61 | 4.5 | Mill City |
| 1960 | — | — | — | — | — | — | — | — |
| 1959 | — | — | — | — | — | — | — | — |
| 1958 | — | — | — | Zone 1 | Zone 2[1] | — | — | — |
| 1957 | — | — | — | — | — | 11/16/57 | 4.5 | Tillamook |
| 1956 | 103415 | 01/07/56 | Replaces Building Code of Ordinance 77435. First to incorporate "Earthquake Regulations" per UBC of 1955. Restricts to Zone 1 loading | Zone 1 | — | — | — | — |
| 1955 | — | — | — | — | Zone 2[1] | — | — | — |
| 1954 | — | — | — | — | — | — | — | — |
| 1953 | — | — | — | — | — | 12/15/53 | 4.5 | Portland |
| 1952 | — | — | — | — | Zone 2[1] | — | — | — |
| 1951 | — | — | — | — | — | — | — | — |
| 1950 | — | — | — | — | — | — | — | — |
| 1949 | — | — | — | — | Zone 2[1] | 04/13/49 | 7.1 | Olympia |
| 1948 | — | — | — | — | — | — | — | — |
| 1947 | — | — | — | — | — | — | — | — |
| 1946 | — | — | — | — | Zone 1[1] | — | — | — |
| 1945 | — | — | — | — | — | — | — | — |
| 1944 | — | — | — | — | — | — | — | — |
| 1943 | — | — | — | — | — | — | — | — |
| 1942 | 77435 | May 1942 | Specification Code written by Bureau of Municipal Research and Service, University of Oregon/League of Oregon Cities. Funded by Works Progress Administration | None | — | — | — | — |
| 1941 | — | — | — | — | — | 12/29/41 | 4.5 | Portland |
| 1940 | — | — | — | — | — | — | — | — |

[1] UBC = Uniform Building Code, which is reissued every three years.
[2] OSSPAC = Oregon Seismic Safety Policy Advisory Commission.

There was no state building code at that time. Outside a city limit, anything could be built with anything to any criteria, if any. So there was considerable concern expressed in the rural areas about the thought of requiring a building to be made expensive to build by requiring earthquake considerations in its design. So the Portland adoption was not a welcome development in the State of Oregon. The majority of the people did not consider Oregon to be subject to earthquakes—California, yes, and maybe Washington, but not Oregon.

Structural designing is taken very seriously by structural engineers. During the 1950s, many of us designed to Zone 2 loading. Even so, very often wind was the major factor, not the light requirement of Zone 2. One thing we did not fully appreciate was the relation between the characteristics of the site and those of the building. We had not thought much about the site—it was just there.

The Oak Street Building of AT&T had been designed with the steel frame taking all the horizontal forces, then the outer concrete shear wall being nearly equal in strength to provide redundancy. In that process was used a method called Moment Distribution that determines the moments and shears acting on the steel frame. This was a method of calculating the moments created in a steel frame with continuous joints and had been developed by Hardy Cross at Yale. Using that moment distribution method was a tedious procedure, requiring calculating moments reflected back and forth, up and down, until the refinement of accuracy presumed to be required by the analyst was reached. So it was a slow process, increasing design costs.

The role of the structural engineer was undergoing a strain in this evolution of the criteria accepted as that which was necessary and proper for use to both safeguard the life and property of the public and do so at minimum cost to that public. That dichotomy still exists. The professional engineer is committed to obtaining a product safe for the public to use—and yet to achieving this at minimum cost to the using public. It is easy to establish high requirements and design to them, but if during the life of a structure this structure is never subjected to conditions that justify those requirements, the cost of providing for them may be considered as a loss or, at a minimum, as the cost of insurance. So the profession has debated and continues to debate how much is enough but not more than needed.

This burden is now being shared with the seismologists. Society is now looking to them for guidance on the probable size of the next earthquake as well as its possible imminence. Both have major impacts on the investment that society decides to make in the environment it builds. The seismologist has joined the meteorologist as a major influence on the structural design of our built environment.

## DISCUSSION OF TABLE 1

Table 1 lists all the Portland ordinances adopted by the City Council that affected the structural designing of buildings from 1940 to 1995. It also lists code-related activities that occurred in that time. Such activities were the issuance of a new Uniform Building Code, the adoption of a new city ordinance, or an action of the State of Oregon. Also shown are the dates and magnitudes of earthquakes felt in Portland to the extent that they were deemed to have had a magnitude of 4 or greater.

The table reads chronologically from the bottom up. Each activity is shown with its date. If there was no activity, no information on that year is supplied.

The first code in the State of Oregon that required structures to be designed to resist earthquake forces did so gingerly. The Portland Code 103415, adopted January 7, 1956, incorporated that requirement as an appendix and provided that Portland designs should utilize earthquake Zone 1 forces, even though the UBC of 1955 that was being adopted showed Portland in a Zone 2 location. Portland Code 103415 called for the application of a horizontal loading at each floor, influenced by the number of stories above that floor. The total weight is made up of all the dead load tributary to the point under consideration. It called for foundation ties but did not address the geological characteristics of the site. Stresses were allowed to exceed the allowable working stresses by 33.3 percent. Overturning moment was not to exceed two thirds of the moment of stability. The Force Formula was a simple one of $F = CW$, with $C$ coming from a table wherein the Zone was recognized and $W$ being the contributing weight.

The zone recommended by the UBC for Portland and western Oregon had been Zone 2 since the UBC edition of 1949, which moved Portland from Zone 1 to Zone 2. The reluctance by Portland to accept the Zone 2 designation was primarily a political decision.

The 1961 UBC edition formula for calculating the horizontal force became $V = ZKCW$, with $Z$ coming from the table as before but with $K$ from a new table reflecting the type of framing system and $C$ being a numerical coefficient for base shear calculated to recognize the period of the structure. This lateral force $V$ was distributed over the height of the building by an equation that reflected the mass of the building at the point of application of the force. The structural frame for buildings 13 stories high or higher had to be a moment-resisting ductile space frame capable of resisting not less than 25 percent of the required seismic load for the structure as a whole.

The overturning moment was more fully addressed than previously by the utilization of three formulas that recognized the possible differences in resistance to overturning among various elements of the building—as well as the period of the structure. Story drift was mentioned, but no limitations were established. Reference was made to "accepted engineering practice." Stresses from a combination of vertical and lateral loads could be increased.

Thus this code reflected considerable thought on the structural analysis aspects of an earthquake but did not consider the characteristics of the site that would affect the structure. It was not adopted by the City of Portland.

The 1964 UBC edition was structurally substantially the same as the 1961 edition. The earthquakes of 1961 had not had an opportunity to have an influence on the code.

The 1967 UBC edition required a more careful analysis of the *W* factor (total dead load). It distributed the total lateral load over the height of the structure by a new formula for *V*. It was still interested in the period of the building. The overturning moment analysis was unchanged. There was no reference to site geology.

The 1970 UBC edition was substantially the same as the 1967 code in reference to earthquake designing. It showed Portland as being in Zone 2, with a revised area of southern and western Oregon placed in Zone 1.

On March 20, 1970, City Ordinance 130672 enacted the "Code of the City of Portland, Oregon," revising the makeup of the city codifying and retaining the established structural requirements, which still put the city in Zone 1, while the UBC had it in Zone 2 at that time (1970 edition).

On May 26, 1972, Portland Ordinance 134654 substituted a new Title 24 code for the existing one. It specifically adopted the UBC 1970 edition, moving Portland from Zone 1 to Zone 2 for the first time. Thus, ten years after the last Oregon earthquake—Banks (magnitude 4.5), on 12/27/63—Portland moved up a space from the minimum zone level.

The 1973 UBC edition simplified the determination of the weight *W* but did not change the basic lateral load formula which still reflected the period of the structure. Overturning moment was addressed in Section 2314; and for specific limits, reference was made to Section 2308. Still no comment was made about site relevance. On July 1, 1974, the State of Oregon adopted the 1973 edition of the UBC with its designation of Zone 2 for Portland.

The 1976 UBC edition added to the earthquake design a requirement to consider the "Occupancy Importance Factor" as taken from a table. This factor varied from 1.5 for "Essential Facilities," to 1.25 for buildings of primary assembly for more than 330, to 1.0 for all others. Provisions for consideration of the site characteristics were added to the basic lateral forces formula. The formula $V = ZIKCSW$ thus included the *I* (Importance) and the *S* (Site-structure resonance) in its makeup. The *S* factor reflected *T* the period of the site, which could be determined by geotechnical data or was to be taken as 1.5, if not otherwise established. The minimum *T* as established could be 0.3 seconds, or up to 2.5 seconds. Provisions for ductile design and distribution of lateral loads were more fully addressed.

On March 1, 1978, the State of Oregon adopted the 1976 edition of the UBC—with Portland in Zone 2.

The 1979 UBC edition made structural refinements in some of the equations and addressed the use of concrete shear wall design. It also addressed what had become known as "Exterior Elements" at considerable length. Portland was still in Zone 2, with a Zone 1 area inserted across central and southern Oregon.

On July 1, 1979, the State of Oregon adopted the 1979 edition of the UBC with Portland in Zone 2.

The 1982 UBC edition made no change in the basic lateral force formula as established. It did make some refinements in the loading of bracing members. Portland was unchanged in Zone 2.

On August 1, 1983, the State of Oregon adopted the 1982 edition of the UBC.

On September 9, 1983, with Ordinance 155104, the City of Portland replaced its Title 24 regulations with a revised Title 24, and adopted the Oregon State Building Code of 1983, thus adopting the 1982 UBC edition.

The 1985 UBC edition added a new provision relating to the *S* factor in the horizontal force formula. The factor varied according to the makeup of the site, varying from rock to stiff clay to soft clay. The factor varied from a minimum of 1.0 on rock to 1.5 on soft clay. In sites of unknown characteristics, factor 1.5 was to be used. Refinements were made in structural requirements, but the Zone identities were not changed.

On July 7, 1986, the State of Oregon adopted the 1985 edition of the UBC.

The 1988 UBC edition made major changes. It required that consideration be given in the structural design to zoning, site characteristics, occupancy, configuration, structural system, and height. It introduced a factor *R*, which reflected the type of structural system being used, into the lateral force equation. It mandated that design use the dynamic lateral force procedures for structures 240 ft or more in height, for those having certain vertical irregularities, and, with some exceptions, for any structure over five stories or 65 ft in height in Zones 3 and 4 that did not have the same structural system throughout their height. The code addressed both static and dynamic structural design and their relationships to the site. The soil coefficient *S* varied from 1.0 for rock to 2.0 for a 40-ft depth of clay.

This edition put all of Oregon in a new Zone 2B and added a set of curves to guide the selection of the effect of site on structures of various periods.

On January 18, 1990, the City of Portland, with Ordinance 162695, adopted the State of Oregon Structural Code of 1990 with its 1988 UBC edition, putting Portland in Seismic Zone 2B.

The 1991 UBC edition made extensive revisions to many aspects of structural design but did not revise the basic approach to site characteristics and their possible effects on the structure. The factor *S* was still obtained from a table.

On December 23, 1992, the City of Portland, with Ordinance 166111, adopted the State of Oregon Structural Code of 1993 with its 1990 UBC edition, continuing Portland in Seismic Zone 2B.

On January 1, 1993, the Oregon Seismic Safety Policy Advisory Commission adopted Seismic Zone 3 for western Oregon. This was the result of long analysis and debate among Oregon structural engineers and state geophysicists.

The current 1994 UBC edition contains a major revision of the design requirements for seismic resistance of buildings. It extensively addresses dynamic as well as static design and relates the structures to the geology. It does not address the identification of the characteristics of sites in the retrofitting of structures less than five stories high. It puts all of western Oregon in Zone 3, along with western Washington and portions of northern California. It puts eastern Oregon in Zone 2B.

## CONCLUSION

Thus it is seen that seismic events seem to have had little effect on the determination of seismic structural design of buildings until after the 1991 UBC edition. Portland had ten very quiet years to contemplate its seismic exposure after the Banks event (M 4.5) on December 27, 1963. Subsequent events in California and elsewhere (especially the 1989 Loma Prieta earthquake and its well-publicized effects on the San Francisco area), however, caused the Oregon Seismic Safety Policy Advisory Commission to take a hard look at the potential in Oregon for a major seismic event. With input from geologists of the Oregon Department of Geology and Mineral Industries, the Structural Engineers Association of Oregon, and others, this led to the adoption of Zone 3 as the design loading for all of western Oregon. In response to the adoption by Oregon, the UBC promptly did likewise.

Careful examination of failures of structures in earthquakes in the last ten years or so has revealed a potentially close relationship between the seismic characteristics of the site and the seismic performance of the structure on it. The UBC has increasingly recognized that potential tie. Whether that recognition is sufficiently close now is a matter that deserves much more attention.

## ACKNOWLEDGMENTS

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Current practice in seismic design of structures owes a great deal to the obsessed devotion to that matter among many pioneer engineers and geologists. The Earthquake Engineering Research Institute with its worldwide membership has been at the cutting edge of the development of the seismic design technology. Early members like George W. Housner, John Blume, and John Rinne provided imaginative and innovative thinking on a problem that had been recognized for several years but was not appreciated as something that could be conveniently addressed. They and many others were instantly aware that it was a problem that had solutions, and they devoted their professional skills to fully understand the phenomena involved and to provide for their effects.

Response observed after recent earthquakes indicates that considerable progress has been made, but perfection may not yet have been reached. As yet, the vast field of retrofitting is far from being adequately addressed. An economical and effective way to obtain safety for historic or cherished structures at the site on which they happen to be located still deserves much attention.

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# EERI offers new slide set: Expected seismic performance of buildings

The Ad Hoc Committee on Seismic Performance of the Earthquake Engineering Research Institute (EERI) has created a slide set to complement the highly popular booklet, *Expected Seismic Performance of Buildings*, which it published in 1994. The booklet and slide set were developed to help building owners, code administrators, and others involved in building maintenance understand how seismic design provisions and quality of construction affect earthquake performance. They describe damage to buildings that may be expected from earthquakes of various magnitudes. The focus is on new buildings in Seismic Zone 4 designed under the 1991 UBC (Uniform Building Code) and on older unreinforced masonry (URM) buildings rehabilitated under the 1991 UCBC (Uniform Code for Building Conservation).

Both booklet and slide set are intended for a nontechnical audience. They can be used by building officials, engineers, and others involved in seismic design, codes, and construction techniques as an easy way to answer questions with the help of a slide presentation. They also provide an excellent educational tool to explain the goals and limitations of seismic provisions in building codes and to dispel some myths that lead to false expectations about building performance.

The new set, *Expected Seismic Performance of Buildings*, consists of 40 slides (including a printed copy of each slide for better reference) and is offered in a package with the 20-page booklet of 1994 for $70 ($60 EERI members). The booklet alone is available for $4. California orders must include 8.25 percent sales tax; orders from outside the U.S. must add 10 percent for shipping.

Orders should be directed to the EERI office at 499 14th Street, Suite 320, Oakland, CA 94612-1934, phone (510 451-0905, FAX (510) 451-5411.

# Evaluating the effectiveness of DOGAMI's Mined Land Reclamation Program

*by Deborah Gellar, Urban and Regional Planning Program, Michigan State University, East Lansing, Michigan 48824*


## ABSTRACT

Since 1972, the Mined Land Reclamation (MLR) Program of the Oregon Department of Geology and Mineral Industries (DOGAMI) has been responsible for directing reclamation at mine sites across Oregon. In that time, over 3,000 acres have been reclaimed under DOGAMI's MLR program. What happens to former mine sites after they have met reclamation requirements and have been released from the program? Has reclamation had long-term impact on the overall condition of the sites? What second uses are being supported by these lands? To begin addressing these questions, the MLR Program conducted a field study in 1995 to determine the condition of former mine sites. Field data were collected at 47 former mine sites across Oregon. The landform, vegetation, land use, and other primary site characteristics indicate that the reclamation process has had lasting, beneficial effects on site conditions. This strongly suggests that the MLR program has been effective over an extended period.


## INTRODUCTION

Mining is an active industry in Oregon, with the extraction of industrial minerals (e.g., diatomite, limestone, pumice, bentonite, silica), metals (e.g., gold, silver, nickel), and aggregate (e.g., sand, gravel, rock) occurring throughout the state. In particular, the demand for aggregate products continues to rise along with population and urban growth.

Historically, the consequence of mining operations over time has resulted in short-term impacts on natural resources and permanent changes to natural landforms. The state of Oregon has risen to the challenge of responsibly regulating the mineral industry. Comprehensive state requirements regulate the operation and reclamation of active mines. In 1971, legislation was passed which required that operators reclaim surface mine areas to support a second beneficial land use after mine closure. The Oregon Department of Geology and Mineral Industries (DOGAMI) began implementation of the Mined Land Reclamation (MLR) program in 1972. The Oregon Mined Land Reclamation Act exempted lands disturbed prior to July 1, 1972, from the reclamation requirements. However, any acreage mined after 1972 that exceeds minimum production and acreage requirements is subject to state reclamation requirements.

Applications for a mine operating permit must include a reclamation plan. Therefore, the preferred reclamation methods and goals are determined prior to beginning or expanding mining operations. A post-mining land use must be designated during the application process and must be supported by the reclamation plan. Standard information required in the reclamation plan includes designation of second land use, creation of stable landforms, restoration of drainage(s), and identification of specific measures to protect surface-

*Healthy stream that was reestablished after mining.*

and ground-water quality, sloping and grading, and vegetation establishment. After a site has been reshaped, and revegetation has been successfully established, the site is evaluated by DOGAMI for release from the program.

DOGAMI's six-year plan, *Mission, Goals, and Activities 1991-1997*, states as part of the Department's "vision" that "regulatory programs will ensure that mineral resource extraction is conducted as an interim use of lands that are returned to subsequent beneficial long-term uses." More than 500 surface mine sites in Oregon have been closed since the MLR program began in 1972. Since then, 3,160 acres have been successfully reclaimed and released from the program. Until this project, no comprehensive study had been done to evaluate the condition of these lands years after they were released from the MLR program.

This paper summarizes a 1995 study to evaluate the effectiveness of the MLR program. The study asks the following questions: Is the goal of providing long-term beneficial land use being met? What post-mining uses are these lands supporting? Have the required reclamation practices been effective over a long period of time? Have former mine sites continued their development towards healthy, self-sustaining environments?

## SITE SELECTION

The primary goal of the study was to document former mine site conditions and to evaluate the MLR program. This task was addressed through field studies of 47 former mine sites (Table 1). DOGAMI's computer database was used to select sites meeting three basic criteria for the study: (1) Sites were subject to state reclamation requirements. (2) Sites have met all reclamation requirements. (3) Sites have been closed for at least five years (i.e., closed prior to 1990). Selections were further winnowed as sites were sorted by location and mineral commodity to ensure reasonable representation of mine types and geographic coverage.

The selected post-mined sites form a representative sample of lands that have been accepted as reclaimed by DOGAMI. In order to determine the effectiveness of the reclamation program, MLR-managed sites were also compared to sites not subject to reclamation. Ten mine sites exempt from DOGAMI reclamation requirements (pre-law sites[1]) were also included in the study.

Field studies were performed at 17 reclaimed sites in high-precipitation regions, at 20 reclaimed sites in low-precipitation regions, and at ten pre-law sites at scattered locations in Oregon. The commodities represented include rock, sand, gravel, clay, gold, topsoil, shale[2], picture rock, and cinder. Sites were surveyed in remote, rural areas as well as in densely populated, urban regions.

[1] Term for mine sites that are exempt from state reclamation requirements because they began operation prior to 1972 and have not expanded beyond the 1972 perimeter.

[2] In Oregon miner's terminology, shale is almost any fine-grained material that can be mined with a front-end loader and can be used without further processing for such applications as surfacing driveways.

Table 1. *Site Summary*

| Site | County | Commodity | Years closed | Precipitation type |
|---|---|---|---|---|
| 0001 | Clatsop | Gravel | 9 | High |
| 0002 | Deschutes | Gravel | Inactive | Low |
| 0003 | Douglas | Gold | 9 | High |
| 0004 | Douglas | Gold | 10 | High |
| 0005 | Douglas | Gold | 9 | High |
| 0006 | Gilliam | Basalt | 7 | Low |
| 0007 | Gilliam | Basalt | Inactive | Low (pre-law site) |
| 0008 | Grant | Gold | 10 | Low |
| 0009 | Grant | Gravel | 13 | Low |
| 0010 | Harney | Cinder | 10 | Low (pre-law site) |
| 0011 | Harney | Basalt | 10 | Low |
| 0012 | Harney | Gravel | 7 | Low |
| 0013 | Hood River | Basalt | 12 | Low |
| 0014 | Jackson | Shale | 13 | Low |
| 0015 | Jackson | Shale | 13 | Low |
| 0016 | Lane | Basalt | 8 | High |
| 0017 | Lane | Basalt | 8 | High |
| 0018 | Lane | Basalt | 2 | High |
| 0019 | Lane | Gravel | 13 | High |
| 0020 | Lincoln | Clay | 17 | High |
| 0021 | Linn | Rock | Inactive | High (pre-law site) |
| 0022 | Linn | Rock | Inactive | High (pre-law site) |
| 0023 | Linn | Gravel | 11 | High |
| 0024 | Linn | Gravel | 10 | High |
| 0025 | Linn | Basalt | >20 | High (pre-law site) |
| 0026 | Malheur | Gravel | 7 | Low |
| 0027 | Malheur | Picture rock | 5 | Low |
| 0028 | Malheur | Gravel | 9 | Low |
| 0029 | Malheur | Gold | 6 | Low |
| 0030 | Malheur | Gold | 9 | Low |
| 0031 | Malheur | Gold | 9 | Low |
| 0032 | Marion | Topsoil | 13 | High |
| 0033 | Morrow | Gravel | Inactive | Low |
| 0034 | Multnomah | Gravel | 5 | High |
| 0035 | Sherman | Rock | 14 | Low |
| 0036 | Tillamook | Basalt | 11 | High |
| 0037 | Umatilla | Rock | Inactive | Low (pre-law site) |
| 0038 | Umatilla | Rock | Inactive | Low (pre-law site) |
| 0039 | WalLowa | Gravel | 8 | Low |
| 0040 | Wasco | Rock | >20 | Low (pre-law site) |
| 0041 | Wasco | Basalt | 5 | Low (pre-law site) |
| 0042 | Wasco | Gravel | 8 | Low (pre-law site) |
| 0043 | Washington | Basalt | 8 | High |
| 0044 | Washington | Gravel | Inactive | High |
| 0045 | Wheeler | Gold | 12 | Low |
| 0046 | Wheeler | Gold | 13 | Low |
| 0047 | Yamhill | Rock | 10 | High |

## FIELD STUDIES

The state of Oregon has diverse environmental regimes, including mountain ranges, large valleys and basins, coastal regions, and desert. For simplicity in this study, however, the state has been divided into two regions on the basis of annual precipitation rates. Low-precipitation regions are those areas with total annual precipitation of < 40 in./year, which generally describes regions east of the Cascades. There, most sites have a precipitation of < 20 in./year. High-precipitation regions are typically those west of the Cascades, where the much wetter climate is characterized by annual precipitation rates of 40–100 in./year.

The data collected during the field studies describe the primary site characteristics. These are separated into five categories:

1. The **landform characteristics** describe erosional features such as gullies, slumps, and slides, and identify any overburden piles and whether they were sloped and vegetated. A determination was made whether the final landforms conflict with or support the current land use and whether they blend in with the surrounding topography.

*Pond in high-precipitation area.*

2. Successfully reclaimed lands must support a second beneficial **land use**. Information was gathered to record the type of current use and then compared to the land use proposed in the reclamation plan.

3. Dominant plant and tree species were identified, as well as percentage of ground cover and general species diversity. The **vegetation** identified at the time of closure was compared to that currently supported on site. Volunteer species were identified and their abundance noted, including annual and noxious weeds. Any appearance of overgrazing was also noted.

4. Sites were evaluated for their use as **wildlife habitat**, regardless of the designated end use. Basic indicators included estimates of percent of cover, diversity of vegetation, and visual observations of animals, tracks, scat, game trails, bedding areas, and burrows. These gave a general impression of the usage or potential usage as wildlife habitat.

5. Any **wetlands** created or left were described by size, type of vegetation, and general vigor. **Streams** were examined for stable and vegetated banks. **Ponds** were often created by gravel mining or other excavations below water table, and these were described on the basis of their shape, size, bank stability, and vegetation.

In addition to the preceding list, photographs were taken during the field surveys to document current site conditions. A comparison of historical photographic records with current photos allowed visual evaluation of program effectiveness over an extended period.

## RESULTS

### Landform characteristics

The landforms observed at reclaimed mine sites were generally in excellent condition. Soils and slopes were consistently stable, and erosion was not an issue. No safety hazards were noted from unstable or oversteepened areas. One feature occasionally observed was the presence of unvegetated rock piles. This prevented the site from blending in well with the surrounding areas and was aesthetically detrimental. This is not necessarily a reflection on reclamation regulations, as DOGAMI policy permits leaving stockpiles for landowner use after mine closure. Further, no regulations address aesthetics (except in designated "Scenic Areas").

Sloping is critical as a reclamation procedure for safety, topographic continuity, erosion control, and vegetative success. An overly steep highwall/slope may not support vegetation, whether volunteer, planted, or seeded, and is more likely to erode or be unstable. The few small bare areas observed during the study were either rock piles with no cover of topsoil, steep slopes, or highwalls. The lack of vegetation in these cases seemed to be a function of poor landform characteristics rather than failure of revegetation efforts.

Most sites did blend in well with surrounding topography. The regulations regarding final angle of slopes are 3:1 (horizontal to vertical ratio) below water, 2:1 for above-water slopes of fill material, and 1.5:1 for above-water slopes cut into the pre-mine topography. These standard requirements serve to accomplish safety, erosion control, and establishment of vegetation. They have been applied effectively and have resulted in the maintenance of high-quality landforms over time.

### Land use

Statutes require that the post-mining (second) land use be declared in the reclamation plan. The planned reclamation techniques must provide the appropriate resources to support the declared land use. Second land uses also must be physically supported by the underlying landform, type and amount of soil resources, vegetation, and appropriate water bodies.

Second uses may be determined by the value of the land for post-mining development. Land in urban areas has relatively high property value, and study sites in these settings tended to have high-intensity second uses. Reclamation of post-mined land in urban regions can be highly profitable, and this is a strong incentive for operators to reclaim the land for industrial sites, residential developments, or parklands. For those sites that were high in human traffic, negative impacts on natural resources included compacted soils, littering, and trampled vegetation. Therefore, some second uses can have a negative impact on the condition of the land if they are not designed to accommodate high-intensity uses.


*Heavily used fishing pond in Lane County.*

The sites in rural and remote areas were supporting low-impact land uses. In high-precipitation areas, land uses were often fields and ponds, which also functioned as wildlife habitat. Sites in the low-precipitation areas frequently were reclaimed to rangeland. This is due to the fact that eastern Oregon sites are predominantly located on Bureau of Land Management (BLM) land, where policy generally requires the land to be returned to pre-mine use. At most of these sites, reclamation to grazing conditions was successfully accomplished.

The proposed end use must be clearly stated within the reclamation plan, and this use must have landowner concurrence. The plan is circulated to the appropriate local land use agency for comment. The accepted post-mining land uses can then be used as a goal that will be achieved through supportive reclamation practices. This administrative procedure appears to be successful, as former mining sites consistently support viable second uses, which are sustained by the underlying landforms and vegetation.

### Vegetation

In general, post-mining vegetation was well established in all regions. A high percentage of ground cover and good species diversity existed on most sites. The reclamation plantings and seedings did remain healthy at most sites, but with varying degrees of assimilation into much larger, more diverse vegetative communities.

In high-precipitation regions, fast-growing species are selected to assure immediate erosion control through ground cover. The long-term persistence of these species was less important, because growing conditions also favor rapid volunteer growth. The survival rate and percent cover of vegetation is naturally greater in the high-precipitation regions because of the available moisture, topsoil, and adjacent seed sources.

In low-precipitation regions, the seeding mixes are more critical, because survival rates are lower due to the limited moisture and to the poor quality of topsoil. Survival of the planted species may be low due to overgrazing, and therefore volunteer species may come from less diverse, and sometimes less desirable, vegetative communities. This can include noxious weeds, which create undesirable ecosystems that out-compete native vegetative species. Better grazing practices and fencing to exclude cattle can give vegetation time to achieve proper root development and develop into self-perpetuating ecosystems.

Even in cases where percent of ground cover was low, reclaimed low-precipitation sites still fit in well with the surrounding plant communities, in part due to volunteer species. One possible exception is proliferation of aggressive vegetation (e.g., annual/noxious weeds), which induce adjacent native plant communities to encroach. Again, it is critical to determine the appropriate seed mix for each site in low-precipitation regions. The type of vegetation desired should support the second land use and take advantage of proper planting times and ground preparation techniques.

State reclamation requirements include successful revegetation of the site. In low-precipitation regions, delayed germination can result in a longer monitoring period (1–3 years) after seeding has been initiated. While this period appears to be an adequate time frame for establishing vegetative cover, no set standard for vegetative species mix exists.

DOGAMI, working with the BLM and other appropriate natural-resource agencies, recommends specific seed mixes to mine operators. The agencies also provide information about techniques to increase the survival rate of seedings, including tilling, mulching, and use of topsoils. This no doubt contributes towards higher survival rates on low-precipitation lands.

**Wildlife habitat**

More than 50 percent of the sites were clearly functioning as viable wildlife habitats, and another 25 percent had significant potential (or less obvious usage by wildlife). Wildlife habitat was created in a variety of environments across the state and was not region-specific. Poor landform or aesthetic characteristics may not negatively affect wildlife usage. Many sites with rock piles and highwalls were inhabited by wildlife. A wide diversity of animal species was directly observed, from song and game birds to antelope and deer. Sites with water bodies supported the most vigorous wildlife habitats. Vegetative diversity is also important, and the presence of a wide variety of species usually increased the quality of the habitat.

Many sites did not have wildlife habitat as their designated end use but were functioning as such. Those sites that were not supporting wildlife were in urban areas or areas with high human usage. In eastern Oregon, overgrazing of reclaimed sites was observed to negatively impact both vegetation and soil stability. Cattle will eat selectively, thus affecting the vegetative composition and reducing preferred food for grazing wildlife.

The creation of wildlife habitat is specifically supported by regulations only when this is the second land use designated in the reclamation plan. Otherwise, while DOGAMI encourages seed mixes that foster wildlife habitat, such a requirement is not part of the regulatory framework. Most of the reclaimed and pre-law sites are supporting wildlife habitats, in addition to the primary proposed end use. This suggests that regulatory initiatives are not required to promote post-mining wildlife habitat. While these successes are not a direct function of regulatory requirements, DOGAMI's practice of encouraging diverse seed mixes and variety in landform has resulted in post-mining sites that support a second land use as well as wildlife populations.

*Wetlands that were specifically designed to attract wildlife.*

**Water/wetlands issues**

All streams and ponds at the observed sites were well established. Banks were consistently well sloped, stable, and revegetated, and no sedimentation problems existed. Wetlands were created as a fringe effect around ponds created by the mining operations. Ponds are commonly created at former sand and gravel pits, and these consistently had stable, well-vegetated banks. The water bodies supported fish populations and aquatic vegetation and appeared to be healthy environments. Ponds are more common in the regions of abundant precipitation. However, several ponds in low-precipitation areas were of exceptional quality. Reclamation requirements that direct the reestablishment of streams and drainages, including bank restoration, appear to be very effective. Banks were well vegetated and fit in with surrounding environments. The ecosystem established was vigorous and contributed diversity to the surrounding environments.

## INCIDENTAL OBSERVATIONS

All surveyed sites had been closed for at least five years. Greater age did not seem to be an important factor in establishment and thickness of vegetation. For vegetation to establish itself and diversify, five years appears to be an adequate period. The four remaining primary site characteristics showed no obvious correlation to age.

The type of commodity mined generally did not have a noticeable effect on the quality of long-term reclamation. The possible exception to this statement may come from rock quarries. Quarries may experience lower percentages of vegetative cover (due to rocky substrates and highwalls) and may be more difficult to blend with surrounding topography. Otherwise, there was no obvious pattern of commodity type affecting overall quality of reclamation.

There were some relative differences in quality between low- and high-precipitation sites. Low-precipitation sites supported lower percentages of vegetative cover than high-precipitation sites. Yet revegetation was considered successful, because low-precipitation regions are characteristically sparsely vegetated. These lands also are impacted by grazing pressure, which prevents plant establishment and increases erosion. A visual impression of lower quality exists due to exposure of bare soil, but often the mine sites blend in well with surrounding topography and vegetation. Therefore they are, for all functional and legal purposes, well-reclaimed sites.

Mine sites operated under the MLR program are reclaimed better than the pre-law sites. Field study results clearly showed that the pre-law sites consistently had the poorest landforms. However, these lands were often functioning as viable wildlife habitats, which may develop despite landform. Pre-law sites were usually supporting some type of second land use, although in several cases the end use could not be determined. Water quality characteristics scored well on both types of sites. At pre-law sites, vegetation often had a lower percentage of cover and tended to provide less even ground cover. This was most prevalent in low-precipitation regions. In the high-precipitation regions, sites without reclamation seeding/planting were colonized through volunteer species. The most common negative characteristic for both types of sites was the presence of bare rock piles. Most of the problems associated with pre-law sites could have been addressed in a cost- and labor-effective manner, had reclamation occurred at or before the time of closure.

*Low-precipitation site that blends well with surroundings.*

The overall conclusion from comparing reclaimed sites to pre-law sites is that MLR regulations do have a positive and lasting affect on the quality of primary site characteristics. It is also noteworthy that unlike the pre-law sites, almost all of the sites accountable to the MLR program were indistinguishable from the surrounding area as former mines.

While most of the reclaimed sites were not identifiable as extractive sites, the pre-law sites were obviously former mine sites and were aesthetically unappealing. This suggests that by meeting state reclamation requirements, aesthetics are indirectly affected in an advantageous manner. Therefore, it appears unnecessary to specifically regulate aesthetics.

Some of the reclamation activities were voluntarily in excess of the regulatory requirements. In these cases, the landowners or operators often had taken active roles in the reclamation process and produced reclaimed sites with greatly enhanced aesthetic characteristics. Several sites in the study were nominated for reclamation awards in past years because of the excellent work done by landowners and operators.

## CONCLUSIONS

The purpose of the reclamation regulations is "to provide that the usefulness, productivity, and scenic values of all lands and water resources affected by surface mining . . . receive the greatest practical degree of protection and reclamation necessary for their intended subsequent use" (Oregon Mined Land Reclamation Act, Division 30, 1994). Under these regulations, reclamation is defined as any procedure that minimizes the disturbance from surface mining and rehabilitates surface resources adversely affected by mining. Specifically, this includes the use of land-shaping and soil-stabilizing procedures, establishment of vegetative cover, and protection of surface and subsurface water resources, as well as any other measures supporting the second beneficial use of post-mining lands.

The data collected from this study of 47 mine sites strongly suggest that the goal of returning mined lands to subsequent beneficial long-term uses is being met by the MLR program. This means that mineral extraction is, in effect, an interim land use in the life of the site. Regulations applied through the MLR program appear to have a lasting affect on the shape and quality of the land. These reclaimed lands are supporting second beneficial land uses and have continued their development, since their release from the program, as healthy, self-sustaining environments.

The existence of a reclamation plan prior to the mining process has been a positive influence on reclamation success in Oregon. Following an approved reclamation plan makes the requirements readily apparent to operator and regulator, gives guidelines for procedures ranging from vegetation and topsoil stripping to regrading and revegetating, and provides clear goals for the reclamation process.

Successful reclamation is contingent upon site inspection by DOGAMI and the determination that the approved reclamation objective was met. Since each reclamation plan is site specific, final reclamation conditions vary from site to site. In addition, multiple opportunities exist in the Oregon Mined Land Reclamation Act to allow DOGAMI the discretion to permit alternative, site-specific reclamation practices. This allows opportunities for implementing creative reclamation techniques and unique second land uses when they are well supported by a reclamation plan. Mine

*Pre-law site with poor quality of landforms and aesthetics.*

sites once permitted by DOGAMI are now functioning as raptor habitat, recreational parks, industrial or office parks, fishing facilities, wildlife habitat, and a variety of other second land uses.

**Summary points**

- DOGAMI's MLR goal, to reclaim mined lands to support long-term, beneficial second land uses, is being met.
- MLR regulations have positive, long-term impacts on the shape and quality of former mine sites.
- Nearly all of the sites from the MLR program are indistinguishable from their surroundings as former mines.
- Former mine sites are consistently supporting second uses that are viable because they are supported by the underlying landforms and vegetation.
- Landforms at reclaimed mine sites are generally in excellent condition.
- Post-mining vegetation at reclaimed sites is diverse and well established in both high- and low-precipitation regions.
- Five years is an adequate period for vegetation to become established and diversify.
- More than 75 percent of the reclaimed and pre-law sites are clearly functioning as viable wildlife habitats or have significant potential in that respect.
- Reclamation requirements directing the reestablishment of streams, ponds, and drainages is highly effective.
- Land values tend to drive reclamation in urban areas.
- Mine sites operated under the MLR program are better reclaimed than the pre-law sites.

## FURTHER STUDIES

The objective of this preliminary field study has been to document the general condition of a representative selection of former mine sites from across Oregon. The results of the study reflect positively on both the regulatory agency and the mining industry. In addition to the program evaluation process, this preliminary field study may be used as a reference in future studies where vegetation transects, habitat diversity, and plant community changes are studied in more detail. As an extension of this study, field data are being analyzed as part of a master's thesis in Mined Land Reclamation at Michigan State University. Some of the preliminary objectives include the use of principal component analyses to identify and relate critical site characteristics and the generation of equations to predict wildlife habitat and vegetative compositions.


## ACKNOWLEDGMENTS

This work was done as part of an internship with DOGAMI-MLR in Albany, Oregon. The internship was made possible by Gary Lynch, MLR Supervisor, and done under the direction of Allen Throop. The entire MLR staff was supportive of the effort. □


# Geology Board plans final adoption of tsunami rules at January meeting

The Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI) met December 11 at the Hatfield Marine Science Center in Newport to receive public comment on proposed rules to implement Senate Bill 379. The bill was passed by the last Oregon Legislature and is designed to protect public safety on the Oregon coast by placing restrictions on construction of certain types of emergency and special occupancy structures within the tsunami inundation zone. The Board anticipates final adoption of the rules at its next meeting, which is scheduled for January 22, 1996, in Grants Pass.

The Governing Board is in the process of making long-term plans for DOGAMI programs and welcomes public participation in this process. At the January meeting in Grants Pass, time will be set aside for suggestions from the public as to the role they think DOGAMI should play in the future. People who are unable to attend the meeting but would like to submit written suggestions should send them to Angie Karel, DOGAMI, 800 NE Oregon St. #28, Portland, OR 97232-2162, phone 503-731-4100, FAX 503-731-4066. The following Board meeting is scheduled for April in Bend. □

## DOGAMI PUBLICATIONS

**Released November 15, 1995:**

***Relative Earthquake Hazard Maps of the Siletz Bay Area, Coastal Lincoln County, Oregon***, by Yumei Wang and George R. Priest. Geological Map Series map GMS–93, 4 maps on 3 sheets, 13 p. text, $20.

The four-map set covers a coastal strip of the Lincoln City-Siletz Bay area, from D River in the north to Gleneden Beach in the south. Three earthquake hazards related to site geology (liquefaction, amplification, and landsliding) were evaluated individually and presented on separate maps. The three were then combined to develop the *Relative Earthquake Hazard Map* (map 4).

The four maps are printed on orthophoto base maps. The liquefaction and amplification maps are at the scale of 1:24,000, the landslide and relative earthquake hazard maps at 1:12,000. Colors depict the three to four different zones of hazard levels. The accompanying 13-page text is written for nontechnical as well as technical readers. An appendix contains two site-specific seismic hazard evaluations.

**Released December 11, 1995:**

***Reconnaissance Geologic Map of the Dora and Sitkum Quadrangles, Coos County, Oregon***, by Thomas J. Wiley. Geological Map Series map GMS–98, 1 map, 5 p. text, $6.

The Dora and Sitkum quadrangles cover an area in the east-central part of Coos County around and north of the two towns of the same names along the East Fork Coquille River. The maps represent the final two of a block of maps for eight quadrangles in the southern Coast Range for which geologic maps have been produced by DOGAMI, including also the Camas Valley, Kenyon Mountain, Mount Gurney, Remote, Reston, and Tenmile quadrangles.

The new, two-color geologic map and accompanying cross section were produced at a scale of 1:24,000. A five-page text discussing rock units, structural geology, geologic history, and mineral resources accompanies the map sheet.

Mapping of these quadrangles in the southern Coast Range represents part of DOGAMI's study of the geology of the Tyee sedimentary basin. The study is supported by a consortium of nine corporations and agencies from private industry and federal, state, and county government and by the National Geologic Mapping Program (STATEMAP) administered by the U.S. Geological Survey.

**Released December 29, 1995:**

***Geology and Mineral Resources Map of the Lakecreek Quadrangle, Jackson County, Oregon***, by Frank R. Hladky. Geological Map Series map GMS–88, 1 map, 9 p. text, $8.

The publication continues the series of geologic maps planned to aid regional planning in the Medford-Ashland area, which is experiencing rapid population growth. The area of the Lakecreek quadrangle lies on the western margin of the Cascade Range and roughly 15 miles northeast of Medford.

The full-color geologic map is at a scale of 1:24,000 and is accompanied by two geologic cross sections. Innovative mapping techniques allowed detailed mapping of the many lava flows that built up this part of the Western Cascades. A separate sheet contains tabulated analytical data from rock samples collected in the quadrangle. The nine-page text that accompanies the map contains rock-unit explanations and discussions of geologic structure, geologic history, and ground-water and mineral resources.

***Geologic Map of the Coos Bay Quadrangle, Coos County, Oregon***, by Gerald L. Black and Ian P. Madin. Geological Map Series map GMS–97, 1 map, 6 p. text, $8.

The area of the Coos Bay 7½-minute quadrangle includes most of the city of Coos Bay at its northern edge and the Isthmus and Catching Sloughs. Directly adjacent to the west lies the Charleston quadrangle, for which a geologic map was published recently as DOGAMI map GMS–94.

The full-color geologic map is at a scale of 1:24,000 and is accompanied by three geologic cross sections. A six-page text contains rock-unit explanations and discussions of geologic structure, geologic history, resources, and hazards.

***Landslide Loss Reduction: A Guide for State and Local Government Planning***, by Robert L. Wold, Jr., Colorado Division of Disaster Emergency Services, and Candace L. Jochim, Colorado Geological Survey. DOGAMI Open-File Report O–95–8, 50 p., $8.

This report was designed to be used as a guide for state and local governments. It has been distributed to all states through the support of the Federal Emergency Management Agency (FEMA). In nine well-illustrated chapters, it describes landslide losses and the benefits of mitigation; causes and types of landslides; hazard identification, assessment, and mapping; transferring and encouraging the use of information; landslide loss reduction techniques; and plan preparation and necessary steps in implementing such a plan.

The 50-page report was published originally by the Colorado Geological Survey for FEMA to provide stimulation and assistance to government agencies, private interests, and citizens throughout the nation to reduce the landslide threat. The preparation of the report was guided by an advisory committee that included Oregon's Deputy State Geologist John D. Beaulieu.

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