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GEOLOGIC HAZARDS IN OREGON

John D. Beaulieu
Oregon Department of Geology and Mineral Industries

Introduction

The need for systematic and reliable information about geologic hazards is gaining wider recognition by county officials, planners, developers, engineers, policy formulators on the local, state, and national levels, resource specialists, and the general public. Effective use of our land resource requires both in-depth consideration of the potential uses and limitations of the land and adequate data upon which to base decisions. Providing this information to the appropriate people is one of the primary functions of resource-oriented agencies and departments within county, state, and Federal government. Providing information on geologic hazards is the specific purpose of the environmental geology program of the Oregon Department of Geology and Mineral Industries.

Major geologic hazards in Oregon include 1) mass movement (landslides), 2) wave erosion and tsunamis, 3) stream flooding, 4) earthquake potential, 5) volcanic potential, 6) slope erosion, and 7) stream erosion and deposition. Some of these hazards are more appropriately viewed as the domain of governmental agencies other than the Oregon Department of Geology and Mineral Industries. For example, the U.S. Soil Conservation Service is deeply involved in controlling stream-bank erosion and slope erosion. The Oregon Water Resources Department has the charge of coordinating flood mitigation in the state and of regulating the water resource. Statistical flood models are developed by the U. S. Soil Conservation Service, the U. S. Geological Survey, and the U. S. Army Corps of Engineers.

Mass movement, coastal erosion, earthquake potential, and volcanic hazards receive greatest attention from the Oregon Department of Geology and Mineral Industries. In addition, research efforts within the Department are aimed at the other hazards where geologic perspective offers new insights, where completeness of specific reports requires it, or where consideration must be given to the interrelationships among geologic hazards. In no case, however, does the Department duplicate the efforts of other agencies.

The Department has completed geologic hazard studies for coastal Tillamook, Clatsop, Lane, and Douglas Counties, inland Tillamook and Clatsop Counties, Lincoln County, western Coos and Linn Counties, the Tualatin Valley, the Bull Run Watershed, and various communities such as La Grande and John Day. Presently an investigation of western Curry County is in progress. The Department's ongoing investigations in the field parallel efforts by several other progressive states, including Texas, California, Illinois, and Colorado The recently completed investigation of western Coos and Douglas Counties (Bulletin 87) was adopted by the U. S. Geological Survey (the funding agency) as a model for similar studies to be sponsored in other western states.

Mass Movement

The downslope movement of rock or soil material in response to gravity is termed mass movement or landsliding. Various kinds of mass movement (slump, earthflow, debris slide, etc.) are recognized on the basis of rate of movement, water content, type of material, and type of movement. Large prehistoric landslides in the Northwest provide many of our more scenic areas and include the Bonneville slide, the Loon Lake slide (which blocked Mill Creek in the lower Umpqua drainage), the Sitkum slide, and numerous other slides throughout western and parts of eastern Oregon (Figures 1 and 2). In many areas, sliding continues to the present day. During the past year, slides having potentially disasterous consequences include the Drift Creek and Wolf Creek slides in the Coast Range and Swift Creek and Austin Creek slides in the drainage of the Clackamas River. The latter two slides have threatened water quality for half a dozen downstream communitites, including Clackamas, Estacada, and Oregon City. The coastal slides damaged acres of valuable timberland, and material eroded from one of them has threatened oyster beds in Alsea Bay.

Placing dollar figures on the losses caused by landslides over the years in Oregon is difficult, owing to the poor and scattered records and to the many intangible losses related to landslides which also must be considered. In a national study based on incomplete data, it was determined that total landslide losses for the nation as a whole have exceeded $1 billion (Table 1). California, basing estimates on more complete data and more detailed analysis, determined that for the next 25 years landslide losses to that state alone will total almost $10 billion (Figure 3).

For Oregon, rigorous analyses have not been conducted; however, consideration of a few examples provides a basis for rough estimates. For example, if present management practices in the Bull Run Watershed negate the possible need to construct a water treatment plant for Portland, savings of approximately $50 million will be realized. The Bull Run management

Table 1. Landslides of the United States – from U.S. Geological Survey. The number of slides and the damage per slide have increased, and will continue to increase, as construction and development expand into susceptible areas.

Type slide	Major areas	No. of historical slides	Approximate frequency: Per 100 square miles	Approximate frequency: Per 40,000 square miles	Est. Prop. damage (million $ adjusted to 1971 values)	Recorded deaths
Rockslide and rockfall	White, Blue Ridge, Great Smoky, Rocky Mtns, and Appalachian Plateau	Several hundred	-	1 per 10 yrs.	30	42
Rock slump and rockfall	Widespread in central and west U.S.; prevalent in Colo. Plateau, Wyo., Mont., southern Calif., Oregon and Washington	Several thousand	Avg. 10 per year hill areas; 1 per year plateaus	100 per year hill areas; 10 per yr. plateau areas	325	188
	Appalachian Plateau	Several thousand	1 per 10 years	70 per year	350 (mainly highway & railroad damage)	20
	Calif. Coast Ranges, Northern Rockies	Several hundred	1 per 10 years	10 per year	30	-
Slump	Maine, Conn. Riv. Valley, Hudson Valley, Chicago, Red. Riv., Puget Sound, Mont. glacial lakes, Alaska	About 70	1 per 100 years	1 per year	140	103
	Long Is., Md., Va., Ala., S. Dak., Wyo., Mont., Colo.	Several hundred	1 per 50 years	1 per year	30 (mainly highways and foundations)	-
	Miss. & Mo. Valleys, eastern Wash., southern Idaho	Several hundred	1 per 10 years	1 per year	2	-
	Appalachian Piedmont	About 100	-	1 per year	Less than 1	-
Debris flow and mudflow	White, Adirondack, and Appalachian Mountains	Several hundred	1 group slides, 10+ per group per 100 yrs. in White Mtns. and North Carolina	1 group slides, 10+ per group, per 15 years	100	89

Source: Executive Office of the President, 1972

Figure 1. Massive rock failure near Lolo Pass is one of many prehistoric landslides in Oregon. Similar large slides today would have disasterous consequences in areas of inappropriate land use.

Figure 2. Slide along county road in Catching Slough Inlet, Coos County, during winter of 1974. Damage costs are difficult to determine from local and state highway maintenance records.
(Photo courtesy The World, Coos Bay)

effort is based in part on a geologic hazard investigation (Bulletin 82) conducted by this Department in 1974. The text is used on a continuing basis as a guide to land management and has been used as a basic data source in the development of a computer program aimed at properly evaluating the impacts of various types of possible land use in the watershed.

In January 1974, nine lives were lost in a single massive bedrock and soil slide (similar to that depicted in Figure 1) near Canyonville, in

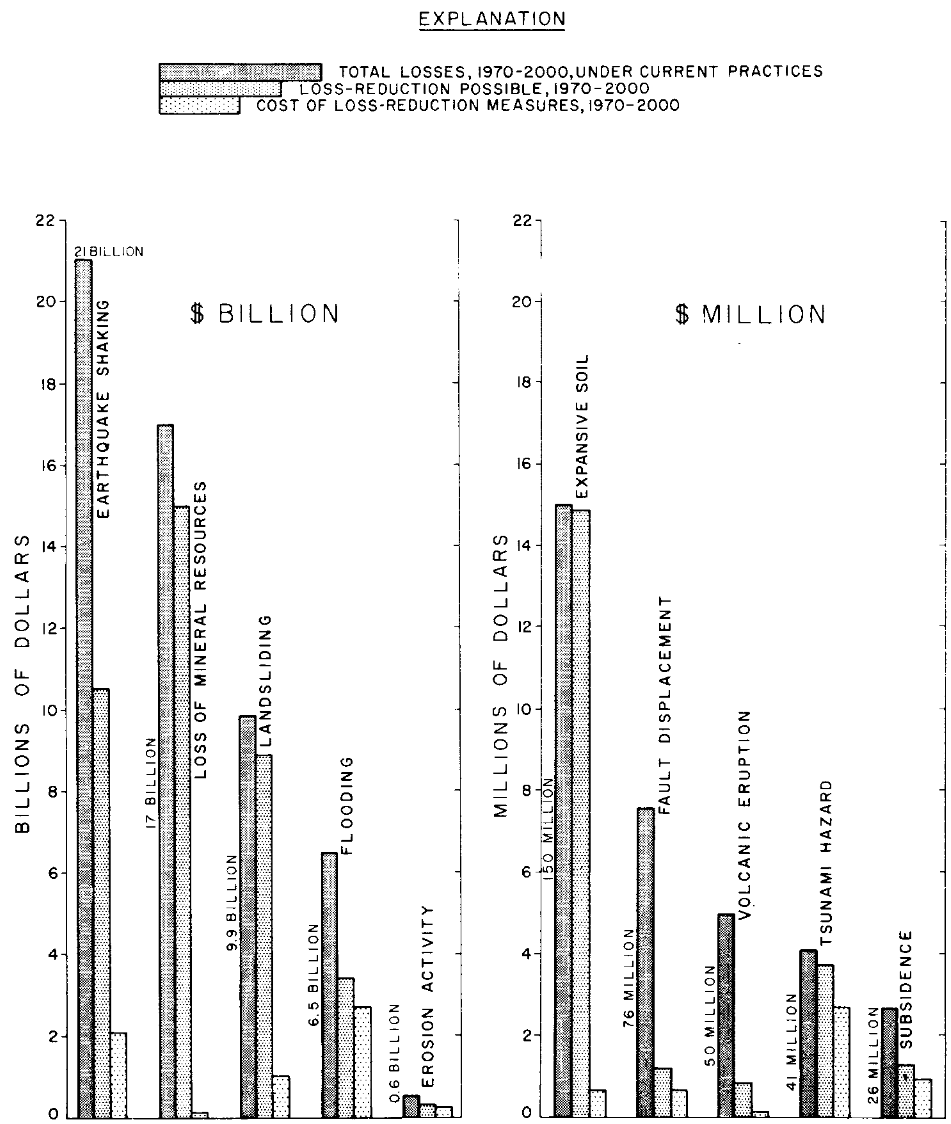

Figure 3. Estimated losses due to each of 10 geologic problems in California for the period 1970-2000. (Alfors and others, 1973)

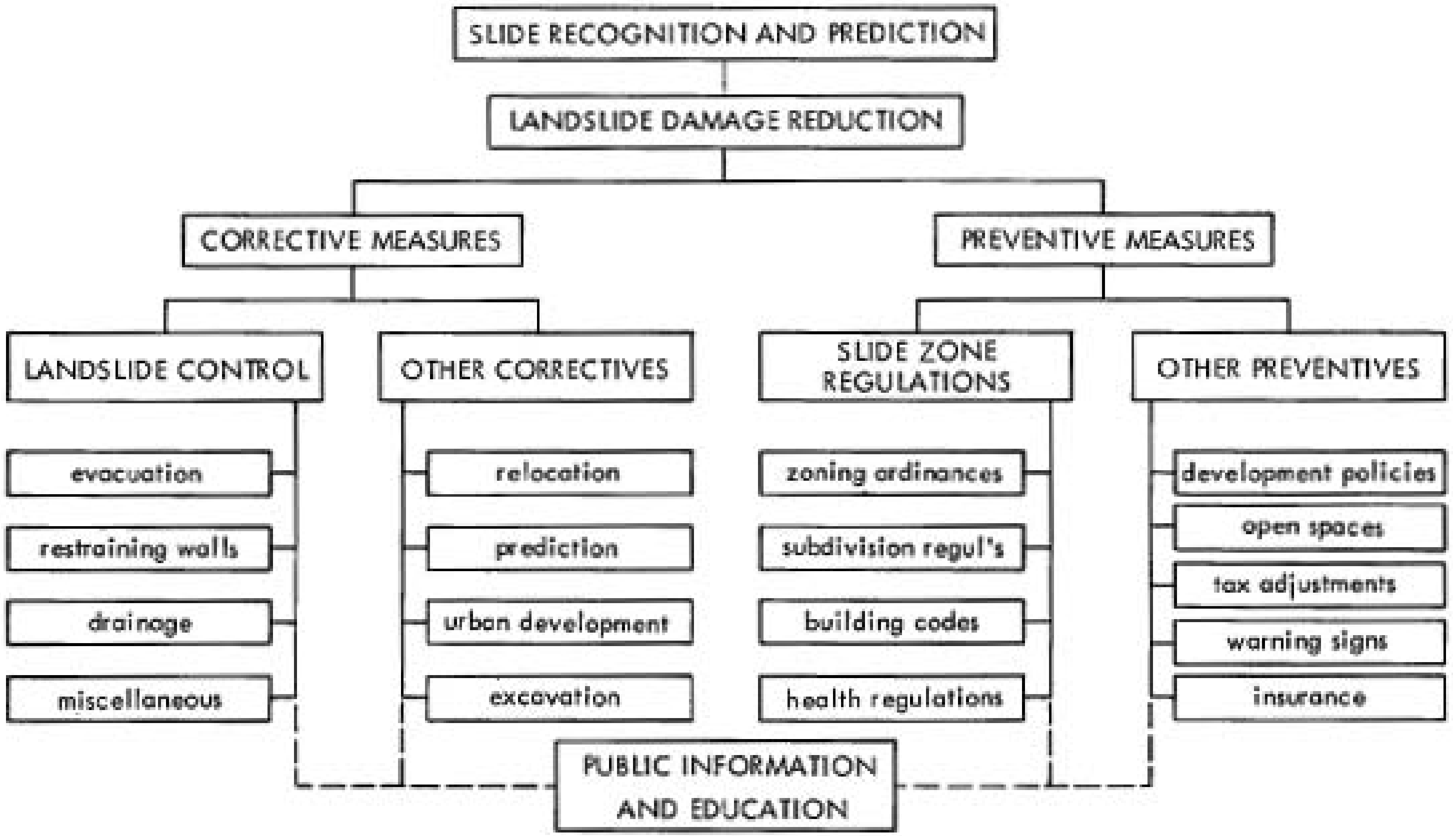

Figure 4. Slide mitigation.

Figure 5. Rate of coastal retreat at Merchants Beach, Coos County, may average as much as several inches per year.

Figure 6. Storm waves at Cape Arago illustrate the tremendous erosive power of the ocean. Elevation of terraces is about 50 feet above sea level. (Photo courtesy The World, Coos Bay)

Douglas County. In the 1950's over 50 homes were partially or completely destroyed by landslides in Astoria (Dole, 1954), and damage continues to the present day. Portland has a long history of continuing and sporadic landslide damage. Although very few of these or similar incidents in Oregon were incorporated into the national estimates provided in Table 1, the national estimates do provide us with a minimum approximation of landslide damage for the nation as a whole.

Assuming that Oregon losses to the year 2000 will be 10 percent of those for California (proportional to population), we can anticipate a total of $1 billion of losses or an average of $40 million per year, if no mitigative measures are followed. Assuming that Oregon losses will be only 1 percent of those of California (an assumption that is clearly too low) still leads to the conclusion that annual losses will average $4 million per year.

Regardless of specific figures, it is obvious that the impact of landslides will continue to inflict substantial losses on Oregonians in future years. With mitigative measures, however, losses can be reduced to a fraction of what they would be otherwise (Figure 2). In addition, potential savings are cumulative over the years. Mitigative measures for landslides (Figure 4) vary with the location and the nature of the slide. For example, in Astoria an excellent relocation program is in effect. Elsewhere, retaining walls, drainage control, and other engineering techniques might be more appropriate. Alternatively, these measures would possibly be more appropriate in Astoria if more were known about the specific nature and distribution of slide-prone areas.

The most critical factor in slide mitigation shown in Figure 4 is the identification and prediction of slide potential. Without basic information of this kind, appropriate techniques and policies cannot be selected and implemented. How, for example, is a governmental body to provide for open-space use or tax adjustments in slide-prone areas if adequate information on slide-prone areas and mechanisms is not available? One of the primary aims of the geologic hazards effort at the Oregon Department of Geology and Mineral Industries is to provide this much needed information to the appropriate personnel and agencies.

Wave Erosion and Tsunamis

June 22, 1912 was opening day for the community of Bayocean on the prominent spit at the mouth of Tillamook Bay. Buildings included a post office, a large enclosed swimming pool, a three-story hotel, a bowling alley, and 59 homes and summer cottages. Investments totaled well over a million dollars (1912). Erosion was first noticed in the 1920's, and in 1939 the first breach of the spit occurred. With final breaching in 1952, the community was totally destroyed. Today at low tide many of the original lots are as much as a quarter of a mile out to sea.

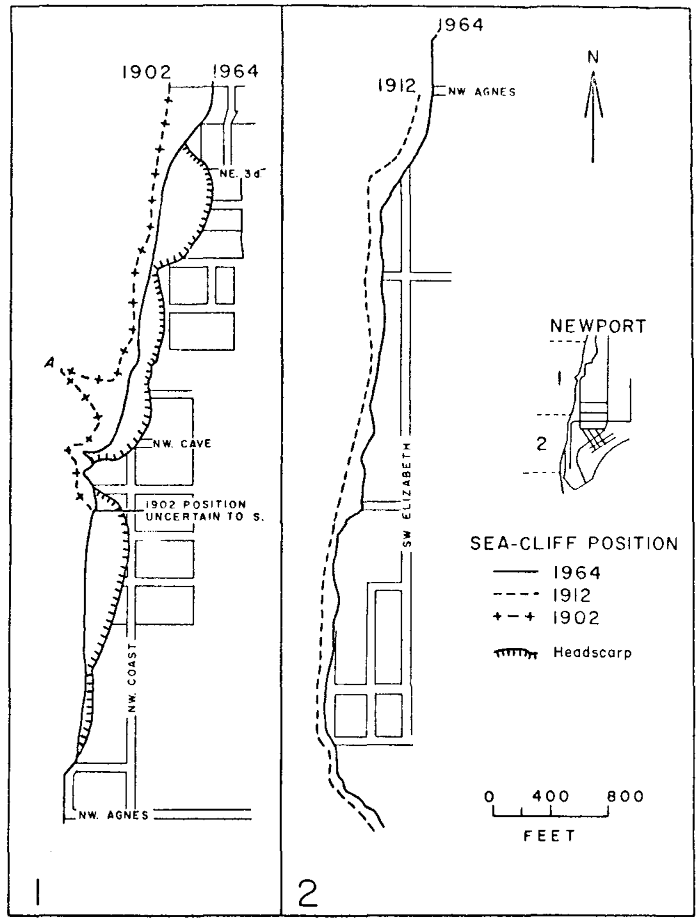

Figure 7. Coastal retreat at Newport showing areas where landslides in coastal material extend inland for hundreds of feet. (North and Byrne, 1965).

Wave erosion continues to be a threat to other spit areas along the Oregon Coast. In addition, bedrock headlands and sea cliffs are retreating in places, with average annual rates of several inches or even several feet per year in critical areas (Figures 5, 6, and 7).

Closely associated with wave erosion in the minds of the public is the hazard of tsunami (tidal wave) caused by violent subsea volcanic eruptions or severe earthquakes. The tsunami of 1964 caused $700,000 damage along the Oregon Coast (Figures 8 and 9) and resulted in the loss of four lives. Were it not for exceptional luck with regard to the arrival time of the tsunami, losses could have been far greater. If, for example, the tsunami had occurred at low tide during the clamming season, literally hundreds of lives could have been threatened or lost. Instead, the series of

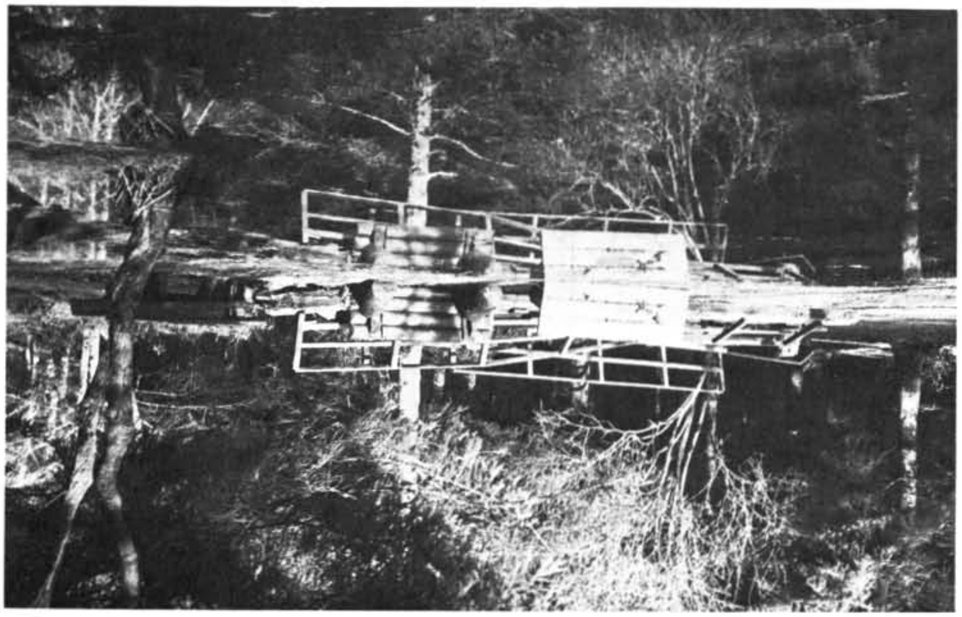

Figure 8. Damage to the picnic grounds at Sunset Beach by the 1964 tsunami provides a hint of potential injuries if such a wave were to occur during heavy daytime use. (Photo courtesy The World, Coos Bay)

Figure 9. Boat washed ashore at Charleston by the tsunami of 1964. At Seaside, at least one house was knocked off its foundation. (Photo courtesy The World, Coos Bay)

Figure 10. During the erosion of parts of Salishan Spit in the winter of 1973, riprap was placed around several houses to avert certain destruction. Sand spits are very sensitive to cyclic climatic activity and consequent changes in beach-zone sand budget.

Figure 11. Undercutting of coastal terraces in Newport has triggered large areas of landsliding. Investigations of coastal mass movement in this area by the Oregon Department of Geology and Mineral Industries dates back to the early 1940's.

waves occurred at night during the high spring tides, when beach and lowland use was at a minimum, and many persons barely recall the incident.

Storm surge is the rise of the sea as it is pushed on land by high winds and low barometric pressures. Storm surge has inflicted considerable damage on coastal developments of Oregon over the years. In 1967, Cannon Beach sustained $125,000 damages to 3 motels and 10 stores and was declared a disaster area by Governor Tom McCall. On January 3, 1939, sandspits all along the Oregon Coast were breached at numerous localities and surf-swept logs damaged dozens of houses. South of Bayview (Tillamook County), 300 feet of Southern Pacific Railway track was carried inland over Highway 101 by storm waves during that storm. Sunset Bay, noted for its quiet atmosphere and scenic value, is forgotten as the site of the ill-fated Sunset Inn development, which was destroyed by storm surges in January, 1939. Today, developments are contemplated by some parties for similar low-lying cove beaches along the southern Oregon Coast.

Total damage due to wave erosion and coastal flooding is difficult to estimate, but surely it exceeds millions of dollars. Examples of Bayocean and Salishan (Figure 10) come to mind. Other damages include the loss of several city blocks at Cape Meares and Newport (Figure 11). Road damages from Silver Point (Clatsop County) southward to the California line undoubtedly have drained millions of dollars from the economy of the state over the years. Damages inflicted by the storms of mid-February, 1976, exceeded $100,000 in Lincoln County alone. The damage will continue to grow rapidly if information of coastal hazards is not fully developed and utilized.

Coastal hazard mitigation includes the location of structures at safe distances from the shoreline (proper setback) and also close control of various coastal activities, such as removal of sand from the beaches, construction of jetties, and dredging, that could accelerate erosion or deposition in unfavorable areas. Processes involved in coastal hazards are generally complex, and the impacts of specific activities enumerated above vary with the nature of the project and the natural setting. Arbitrary rules of thumb for the management of the coastal zone are not appropriate, and the development of adequate information on the processes acting in the coastal zone is absolutely essential.

Stream Flooding

Flooding occurs when rising water in streams and rivers spills over the established channels into the surrounding lowlands (Figure 12). In Oregon, flood mapping is conducted by the counties, the U. S. Army Corps of Engineers, the U. S. Soil Conservation Service, and the U. S. Geological Survey. The Oregon Water Resources Department offers state-coordinated relief. The numerous causes of flooding generally include

Figure 12. Extensive flooding of the Coquille valley two miles north of Coquille during the 1964 flood. In addition to water damage, flooding causes severe problems associated with erosion and deposition. (Photo courtesy The World, Coos Bay)

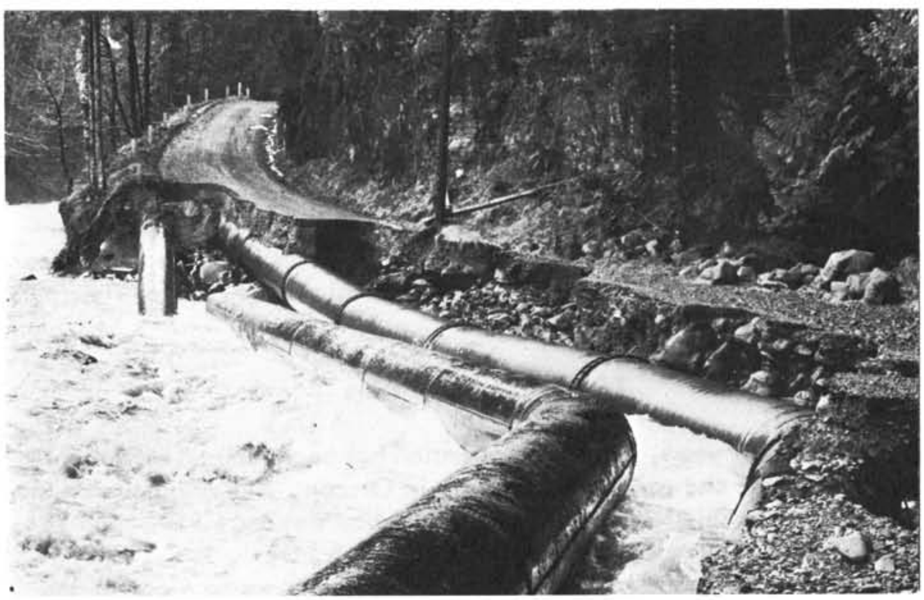

Figure 13. Stream-bank erosion on December 22, 1964 destroyed one conduit and threatened two others leading from Bull Run to Portland. Small-scale hazard damage concentrated in critical areas can result in catastrophe.

high rainfall, rapidly melting snow, and impermeable bedrock. Commonly activities of man can aggravate flooding. Examples include channel modifications and improper flood-plain development. In instances where stream hydraulics (Figure 13) and other geologic processes are involved, the Oregon Department of Geology and Mineral Industries has meaningful information to offer.

In the Bull Run Watershed in 1972, water cascading down the North Fork of the Bull Run River undercut an ancient landslide to deliver tons of colloidal red clay into the supply of drinking water for Portland. An investigation was initiated which included input from this Department to determine the cause of the flood and the distribution of the red clay material in the watershed. As is often true with geologic hazards, total isolation of one hazard from others is not possible. The flooding was caused by the sudden release of water from an ice dam upstream, and the colloidal red clay entered the water from an ancient landslide area along the channel.

Average losses to flooding in Oregon totaled $16 million in 1965 and will total $36 million annually by the year 2000 (Oregon State Water Resources Board, 1972).

Assistance in developing flood-plain management plans is provided by the Oregon Water Resources Department. The U. S. Soil Conservation Service administers the Watershed Protection and Flood Protection Act of 1954 and provides technical assistance for channel protection and other flood-related projects. The Flood Insurance Act of 1968 is administered by the U. S. Department of Housing and Urban Development with the assistance of the Oregon Water Resources Department and provides flood insurance to individuals and businesses in regulated developments.

The function of the geologic hazards program at the Oregon Department of Geology and Mineral Industries is to supplement the work conducted by other agencies by 1) providing uniform mapping, 2) developing field-oriented flood data where more sophisticated data has not been developed, 3) providing a mechanism for formally recording flood histories for given areas, and 4) providing a broad geologic framework for viewing all the aspects of flooding.

Tectonic Hazards

In recent years, increasing attention has been focused on the potential for volcanic and earthquake activity in Oregon. Active volcanism in the Northwest in historic times is documented by Folsom (1970), and renewed volcanism is indeed a possibility. The U.S. Geological Survey is monitoring several northwestern United States volcanoes on a continuing basis, using newly developed remote sensing techniques. Rosenfeld and Schlicker (1976) describe renewed fumarolic activity on Mount Baker in Washington and remind us that activity on Mount Hood may have occurred as late as 1820. Crandell and others (1975) predict a possible eruption on Mount St. Helens by the year 2000. Renewed volcanic activity of a violent nature can constitute significant threats to the health, safety, and welfare of Oregonians. Hammond (1973) has prepared a realistic scenario of many of the impacts to be expected from an eruption of Mount Hood. Of most significance are possible ash falls in the Bull Run Watershed, which would seriously degrade Portland's water supply and perhaps would render the water unfit for consumption.

Although Oregon is characterized by only minor to moderate earthquake potential as compared to neighboring areas in California and Washington, the hazard warrants close study, especially in urban areas. The Portland earthquake of 1962 damaged numerous chimneys and inflicted severe damage on the Veterans Hospital, rotating a chimney 20° on its axis. Earthquakes of the magnitude of the 1962 quake are on the lower end of the range of quakes which can cause temporary liquefaction of saturated and well-sorted sand. Ground response under buildings on steep slopes and on the saturated flood plains designated for future industrial growth are of prime consideration in planning efforts. Evidence continues to grow for the presence of an active earthquake fault beneath the city of Portland (Balsillie and Benson, 1971).

Conclusions

Average annual losses caused by geologic hazards in Oregon are difficult to determine, owing to incomplete and scattered data. Preliminary considerations, however, indicate that losses to landslides may total between $4 million and $40 million per year. As many as nine persons have been killed by one landslide in Oregon in recent years. Losses through coastal retreat have totaled millions of dollars as large parts of major communities have been destroyed. Tsunami damage totals approximately $1 million and would probably be far greater were it not for the fortunate timing of the 1964 tsunami. Flood losses will average $36 million per year by the year 2000. Because this hazard is so large and complex, it is dealt with by several state and Federal agencies. Volcanic and earthquake hazards constitute long-range threats, with the potential for catastrophic consequences. Specific identifications of these hazards and long-range mitigative efforts can reduce the risk considerably.

It is the aim of a good hazards investigation to regard not only the historic distribution of hazards but also the causes and the distribution of hazardous antecedent conditions. The net result is the generation of information that is more than purely a descriptive account of past events, but which is also a predictive tool for evaluating the impacts of contemplated changes in land use. In this way, the information becomes a powerful land-management tool (Figure 14).

Figure 14. Marsh growth at mouth of Kentuck Slough (Coos Bay) has accelerated in recent years, possibly owing to construction of a nearby tidal gate. If presently available information on the geologic hazards of the area had existed at time of decision to build, this adverse impact could have been considered.

Effective mitigation and planning can only proceed on a firm foundation of accurate hazards analysis and mapping. The aim of the geologic hazards program at the Oregon Department of Geology and Mineral Industries is to provide objective and accurate data, free of personal value judgments. The purpose is to provide government with an array of appropriate uses for land in hazardous areas, based on adequate information and on unbiased investigation.

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SOUTHWESTERN BLUE MOUNTAINS MAPPED

"Reconnaissance geologic map of the John Day Formation in the southwestern part of the Blue Mountains and adjacent areas, north-central Oregon," by Paul T. Robinson, is a multicolored map published by the U.S. Geological Survey as Miscellaneous Investigations Map I-872. The map has a scale of 1:125,000 (1 inch equals about 2 miles). It consists of one sheet 44"x33" which includes descriptions of 38 map units, cross sections, correlation chart, index map of previous mapping, and list of references.

The area covered by the map is irregular in outline, extending roughly from Spray on the east to Madras on the west, and from West Branch of Bridge Creek on the south to the high plateau north of Shaniko.

In general, the map shows Clarno and John Day Formations widely exposed in a large northeast-trending anticline and in lesser folds and flanked by Columbia River Basalt. The Dalles Formation is exposed at the west end of the area, and small outcrops of pre-Tertiary rocks occur within the anticline on either side of the axis.

Map I-872 is for sale by U.S. Geological Survey, Denver, Colo. 80225. Price is $1.00.

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NORTHEAST OREGON STREAM SEDIMENTS TESTED FOR METALS

The Oregon Department of Geology and Mineral Industries has completed its current program, begun in 1971, of collecting and analyzing stream sediments from northeastern Oregon, a region known for its early-day gold production. A total of 1,005 samples were collected from drainages of the Snake, Powder, and Burnt Rivers in Baker, Malheur, and Wallowa Counties and were analyzed for copper, lead, zinc, and nickel. The bulk of the analyses were prepared in the Department's Portland laboratory.

Analytical data and locations of samples have been tabulated and the sample sites plotted on topographic maps. At present the information is available for inspection on open file at the Department's Portland office; copies will be obtainable at cost of reproduction from both the Portland and Baker offices.

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KLEPPE OUTLINES FEDERAL MINERALS POLICY

Secretary of the Interior Thomas S. Kleppe, speaking before the American Mining Congress on January 20, declared he will establish a clear policy for mineral production from Federal lands, and that policy will include a production requirement for coal leases or the lease will be terminated.

Kleppe told the audience that Interior intends "to set new standards which would require diligent development--or relinquishment--of new or existing Federal coal leases. We are in the business of seeing that the Federal resources are produced for the nation's benefit."

The Secretary predicted new battles over surface-mining legislation in Congress and said the issue must be settled before major increases in mining can occur. He went on to say, "However, in the absence of legislation, it is the Interior Department's intention to establish firm coal strip-mining regulations for the Federal lands."

Another element of new minerals policy stressed by Kleppe was a new definition of "valuable deposits that must be demonstrated in order to obtain noncompetitive Federal leases, instead of showing the presence of minable minerals. He proposed a definition which would require a showing that a "prudent person" would be economically justified in mining the minerals and would be likely to succeed.

With respect to withdrawals, Kleppe announced the formation of a Task Force on Mineral Withdrawals to determine the extent of restrictions on mineral development as a result of Federal withdrawals. He specifically cited the Bennethum-Lee article, "Is Our Account Overdrawn?" [See summary of the report in the October 1975 issue of The ORE BIN.]

Kleppe stressed that the "government must clarify its policies before the mining industry can effectively undertake its critical mission to increase America's mineral production."

(Amer. Mining Cong. News Bull., no. 76-2, 1976)

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INTERIOR REPORT ON ENERGY NEEDED IN MINERAL PRODUCTION

The Department of the Interior has placed on open file two reports containing detailed estimates of the energy needed to extract 14 "high priority" and 37 "intermediate priority" metals and nonmetallic minerals and to convert them to primary products. The reports were prepared as part of a project to ascertain energy used to make mineral products and to pinpoint areas with potential for energy savings.

"High priority" commodities include aluminum, cement, copper, iron and steel, lead and zinc; the "intermediate priority" commodities include asbestos, boron, clays, gypsum, manganese, molybdenum, nickel, sand and gravel, uranium, and titanium.

Copies of the reports can be purchased from National Technical Information Service, Springfield, VA 22151, at following prices:

Phase 4 - High priority commodities (PB 245 759/AS) $7 on paper, $2.25 on microfiche; Phase 5 - Intermediate priority commodities (PB 246 357/AS) $8 on paper, $2.25 on microfiche. Show title and "PB" number.

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DEPARTMENT'S GEOTHERMAL STUDIES DATA ON OPEN FILE

Listed below are the unpublished open-file reports on the Department's geothermal investigations between 1971 and the present. Most of these reports have already been announced in previous issues of The ORE BIN; they are briefly reviewed here for the convenience of those interested. Copies reproduced from originals are available at prices indicated.

1. "Central Western and High Cascades geological reconnaissance and heat-flow hole location recommendations," N. V. Peterson and Walter Youngquist. 41 p., illus. Unnumbered open-file report, Nov. 1, 1975. $4.00.

   Discusses geology of region extending from Breitenbush Hot Springs to the Oakridge area, with special reference to locations recommended for drilling to obtain heat-flow data.

2. "Geothermal gradient data released March 1975," R.G. Bowen, project supervisor. 133 p. Open-file report O-75-3. $10.00.

   Presents temperature gradients on computer read-out sheets for 75 deep pre-drilled bore holes in Oregon, measured by the Department between 1971 and 1973.

3. "Geothermal gradient data, Vale area, Malheur County, Oregon," D. A. Hull, supervisor. 18 p. Open-file report O-75-4. $2.00.

   Continuation of Department's temperature-gradient measurements; provides detailed temperature logs of five holes in the Vale area.

4. "Geothermal studies and exploration in Oregon," R.G. Bowen, D.D. Blackwell, and D.A. Hull. 65 p. Open-file report O-75-7. $2.00.

   Summarizes geothermal data gathered by Department between 1972 and 1975 under a U. S. Bureau of Mines contract. Identifies anomalously high heat-flow areas.

5. "An estimate of southest Oregon's geothermal potential," Deborah Miles Fisher. 9 p. Open-file report O-75-8. $1.00.

   Mathematical adaptation of methods used by oil companies for calculating petroleum reserves to estimating geothermal potential in an untested area of Oregon compared to estimates from The Geysers, Calif.

6. "Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly, Lake County, Oregon," D. A. Hull, with appendix: "Report of a reconnaissance dipole-dipole resistivity survey in the Glass Buttes area, Lake County," prepared by Phoenix Geophysics, Inc. 26 p., 6 plates. Open-file report O-76-1 $8.00

7. "Geothermal gradient data, Brothers Fault Zone, central Oregon," D. A. Hull, R.G. Bowen, D.D. Blackwell, and N.V. Peterson. 24 p. Open-file report O-76-2. $2.00.

   Presents temperature logs and graphs of data collected in 1975 during Department's continuing geothermal resources study of the Brothers Fault Zone under a U.S. Geological Survey grant.

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BULLETINS

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57.	Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
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