VOLUME 40, NO. 3
MARCH 1978

THE ORE BIN

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

The Ore Bin

Published Monthly
by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Head Office: 1069 State Office Bldg., Portland 97201
Telephone: [503] 229-5580

FIELD OFFICES
2033 First Street   521 N.E. "E" Street
Baker 97814   Grants Pass 97526

MINED LAND RECLAMATION DIVISION
1129 S.E. Santiam Road
Albany 97321

Subscription Rates

1 year, $3.00; 3 years, $8.00
Available back issues: $.25 at counter, $.35 mailed
Second class postage paid at Portland, Oregon

State of Oregon
Department of Geology
and Mineral Industries
1069 State Office Bldg.
Portland, Oregon 97201

The ORE BIN
Volume 40, No. 3
March 1978

SURFICIAL GEOLOGIC HAZARD CONCEPTS FOR OREGON

John D. Beaulieu
Deputy State Geologist
Oregon Department of Geology and Mineral Industries

Introduction

Geologic hazards are those geologic processes which adversely affect the activities of man and therefore pose threats to his safety, health, and welfare. Included are earthquakes, mass movement or landslides, floods, slope erosion, and stream erosion and deposition. The increased need for information on geologic hazards in Oregon is addressed by the Environmental Geology Program of the Oregon Department of Geology and Mineral Industries.

Purposes of the program are:

(1) To provide pertinent information on geologic hazards in Oregon for land use planning.
(2) To integrate information on surficial geologic processes into land management activities and policy formulation for the purpose of more effective land management.
(3) To develop new concepts and techniques in the study and portrayal of geologic processes so that data may be more effectively conveyed to the practical user.

In keeping with the third objective of the program stated above, this paper is designed to explain geologic hazard concepts that have evolved in the completion of investigations conducted by the Department to date. The selected concepts are basic to the discipline and are not products unique to this agency. Rather they are a selection and refinement of countless geologic hazard concepts developing in many disciplines and institutions throughout the State and the nation. They are adopted here owing to their unique applicability to Oregon.

Because of its varied relief, youthful topography, and highly variable bed rock, Oregon has a considerably wider array of geologic hazards than many other states have. The geologic hazards and factors producing them can be properly addressed only with a systematic and knowledgeable study of the bed rock. Accordingly, a review of the geology of an area with the emphasis on engineering properties of geologic units is an integral part of all geologic hazards investigations conducted by the Department.

Geologic Units

General

In Department reports summarizing geologic hazards investigations, discussion of geologic units is provided to (1) document and explain information on geologic maps, (2) aid in geologic hazard interpretation, and (3) systematically relate geologic units to other sections of the report.

Geologic units are distinguished primarily on the basis of rock type and, to a lesser extent, by other physical properties, distribution, topographic setting, and age. Generally, each geologic unit possesses a unique association of engineering properties that can be summarized in table form (Table 1).

Interpretation of the regional distribution of specific geologic hazards is based in part on (1) identification of the causes of the hazard, (2) relation of causes to engineering properties of rock units, and (3) delineation of the distribution of pertinent engineering properties through an understanding of the geology. Extrapolation of information from a given area to other areas follows a similar procedure.

Bedrock structure is briefly discussed in Department environmental reports to (1) document interpreted distribution of rock units, and (2) allow more accurate interpretation of hazard distribution and potential. Generally speaking, most traditional geologic mapping is aimed at interpretation of rock genesis. The manner of origin of the rock, in turn, is accurately reflected in its composition and texture and therefore in its engineering properties. Because of this coincidence, it is possible to adopt the major rock categories recognized by traditional geologic efforts as also the major engineering categories for preliminary assessments in a region.

Surficial geologic units

Surficial geologic units are unconsolidated, relatively thin stream deposits overlying bed rock. Major landforms are flood plains, terraces, and alluvial fans.

Volcanic and sedimentary geologic units

Volcanic and sedimentary geologic units include a variety of consolidated rock units that (1) underlie surficial units where they are present, (2) are to some extent folded and faulted, and (3) do not display metamorphic features. In addition, they do not include intrusive igneous rocks. These highly varied volcanic and sedimentary rocks have a wide range of engineering properties and associated hazards.

Metamorphic geologic units

Metamorphic rocks are rocks derived from preexisting rocks by temperature or pressure extremes beneath the zone of weathering. Metamorphic rocks display different mineralogic and structural characteristics than do their parent rocks and are generally very hard and jointed to give angular chips and slabs. Some metamorphic rocks are strongly foliate; that is, they possess closely spaced parallel planes of structural weakness resulting from metamorphism.

Intrusive geologic rock units

Intrusive rocks are rocks emplaced as a unit into preexisting rocks. Subsequent erosion exposes them at the earth's surface. Most intrusive rocks are igneous and are characterized by massive textures. Intrusive

General rating

- ● Relatively high or great
- ◒ Moderate
- ○ Relatively low or small
- • Not applicable

	Physical properties										Regolith					Drainage			Local hazards									
	Hardness	Joint development	Bedding distinctness	Foundation strength	Excavation difficulty	Cut slope stability	Slope intensity	Infiltration rates	Landfill potential	Septic tank capacity of soils	Thickness on steep slopes	Thickness on gentle slopes	Clay content	Silt content	Expansion-contraction	Overland flow	Shallow subsurface flow	Deep subsurface flow	Deep bedrock slides	Earthflow and slump topography	Steep slope mass movement	Potential future mass movement	Flood prone	Slope erosion potential	Historic channel change	Stream bank erosion	Torrential flood terrain	High ground-water hazard
Surficial units																												
Volcanic units																												
Sedimentary units																												
Intrusive units																												
Metamorphic units																												

Table 1. Typical matrix of engineering properties and geologic units

rocks of nonigneous origin (e.g. serpentinite) generally possess planar fabric. The specific manner of emplacement of intrusive rocks strongly influences their engineering properties.

Bedrock structure

A final consideration in the grouping of rock types is the influence of structure (folds and faults) in the land management behavior of rock units. Thus, normally competent rocks may behave incompetently in sheared zones. Commonly an additional category of rocks (sheared rocks) must be addressed on the matrix (Table 1). Development of a grouping scheme which addresses all types of rock behavior is a useful tool in extrapolation techniques.

Geologic Hazards

General

Accomodation of orderly development while insuring public health, safety, and welfare is difficult and complex. The complexity, however, is greatly reduced where an understanding of the natural characteristics of the land, the processes that shape it, and the geologic hazards that threaten it is rationally applied in guiding growth. Surficial geologic hazards of concern to the planner include mass movement, slope erosion, stream flooding, stream erosion, and stream deposition. Each hazard is characterized by unique distribution, causes, and ranges of impacts. Recommentations for treatment or mitigation of geologic hazards should be flexible to allow for variations in physical, social, political, and economic settings.

Mass movement

General: Mass movement is the movement of rock or soil material downslope in response to gravity. Table 2 summarizes several kinds of mass movement occurring in Oregon.

Causes: Mass movement occurs on slopes where the downslope component of gravity exceeds shear resistance. In areas of sliding, potential sliding, low cutbank stability, or hazardous slopes, the activities of man should be controlled to assure that the downslope component of gravity is minimized and that shear resistance is maximized.

Downslope gravity components: Weight of the regolith (weathered rock and soil above bed rock) column is increased by the placement of fill for road construction or other purposes, saturation during winter rains, and artificial obstruction of surface and shallow subsurface runoff with improperly designed roads, poorly located dwellings, and other developments.

Models of slope failure presuppose that the weight of the regolith column is perpendicular to the earth's surface. Where nearby blasting or seismicity is a factor, a horizontal component of acceleration is introduced along with the vertical gravity component. The resulting inclined direction of acceleration has the same effect from an engineering standpoint as does steepening of the slope. Also to be considered are disaggregations and consequent loss of strength of regolith by blasting.

Shear resistance: Under saturated conditions, soil particles are buoyed, thereby reducing internal friction and shear resistance. Where soil water is increased to the point of saturation by rainfall, drainage interference, or blocking of springs, shear resistance decreases and potential for sliding increases. Under conditions of heavy rain, infiltration may exceed the rate of shallow subsurface drainage so that the liquid limit of the soil is actually exceeded (Campbell, 1975). Debris flows in colluvial (earth material transported by mass movement rather than by running water) pockets over impermeable bed rock may result.

Cohesion, the bonding attraction of soil particles, varies with soil type and water content. Silts have low cohesion when dry, moderate cohesion when wet, and no cohesion when saturated. Clay-rich soils generally accomodate large quantities of water before reaching their liquid limit. Slow moving landslides or expanding soils result.

Root support by trees is now recognized as a primary agent of stability in colluvial areas on steeply sloping terrain. Root support declines rapidly after logging, and many slides in logged areas are attributed to the loss of root support through root decay. In wooded areas it is doubtful, however, that increased soil moisture associated with logging has a measurable impact on slope stability.

Distribution: Interpretation of mass movement on geologic hazards

Type		Description	Distribution
Deep bedrock slide		Downward movement of rock along a curved basal shear plane accompanied by backward rotation of the slide block. Characterized by pronounced headscarp overlooking irregular, more gently sloping terrain.	Moderately steep to steep slopes in youthful valleys of moderately large to large streams. Common in faulted terrain, jointed terrain, and areas of interbedding of distinctly differing rock types. Favored by deep percolation of ground water and undercutting.
Earthflow and slump topography		Downslope movement of regolith along numerous shear planes in manner analogous to highly viscous flow; generally accompanied by rotational failure upslope. Characterized by irregular topography, sag ponds, and irregularities of soil distribution and drainage. Commonly too small to be detected with aerial photography where bed rock is not involved.	Moderately steep to steep slopes in areas of low surface runoff and significant chemical weathering. Most common also along faults, joints, and bedrock contacts; also common in heads of gullies or in areas of natural or artificial undercutting of regolith.
Steep slope failure	Debris flow and debris avalanche	Rapid flow or sliding of regolith down steep slopes along bedrock surfaces approximately parallel to the slope. Characterized by linear deposits of unvegetated colluvium in steep drainageways.	Steep to very steep slopes where regolith overlies impermeable bed rock and where shallow subsurface flow is significant, as in steep linear drainageways. Favored by silty soils prone to liquefaction when saturated and by removal of vegetation and consequent loss of root support.
	Rockfall and rockslide	Falling and rolling rock at the base of cliffs. Characterized by unvegetated talus or scattered boulders on slopes beneath cliffs of jointed or faulted hard bed rock.	Very steep slopes with exposures of jointed or faulted bed rock, particularly breccia, agglomerate and flow interbeds; also parts of metamorphic units.

Table 2. Types of mass movement

maps produced during Department studies is based upon field reconnaissance, topographic analysis, consideration of slide mechanics, and aerial photographic analysis. More refined delineation is costlier and requires more detailed field work, larger scale photographs, and larger map scale. Locally, remote sensing, geophysics, and monitoring are sometimes appropriate in highly critical areas.

Planners are concerned with existing landslides and, in addition, with the prevention of future slides. These may be viewed in two categories. Cutbank failures result from improperly engineered cuts and generally can be avoided by adhering to the provisions of the Uniform Building Code. Critical features such as jointing, bedding, clay content, and subsurface flow, however, present special problems. The second category of future slides encompasses slides that will be initiated by natural or artificial means other than cuts including overloading, changes of drainage, and removal of vegetation. Interpretation of slide potential is based primarily on the discussion of slide causes.

The distribution of present mass movement features is easily presented on geologic hazards maps. Further mapping of areas of future mass movement can be accomplished on a regional basis using overlays of slope, critical topographic features, and rock type. More detailed maps of local extent can be generated using detailed plotting of engineering features contributing to sliding in each of the geologic rock units.

Impacts: Impacts of mass movement are variable with the type of mass movement being considered (Figures 1 and 2). Deep bedrock failures (Figure 3) are either active or inactive and have associated with them irregular ground-water and drainage conditions, highly variable foundation strengths and cutbank stabilities, and secondary slides in eroding areas.

Earthflow and slump topography are associated with poor drainage, shallow subsurface flow of ground water, and the possibility of ongoing movement which can destroy man-made structures including roads, homes, and other buildings. In addition, active earthflows leading into streams adversely impact water quality.

Debris flows (Figures 4 and 5) and debris avalanches (Figure 6) generally occur in uninhabited areas and therefore pose their greatest threats to water quality and the forestry resource. Logging roads are particularly subject to damage. Other impacts include loss of topsoil, which in extreme instances also reduces water retention capabilities of regolith. This may contribute to increased storm runoff in places.

Rockfall and rockslide are minor hazards in most areas, but they pose threats to hikers and motorists in more steeply sloping terrain. Rolling rocks in areas of high relief occasionally travel considerable distances beyond the bases of slopes from which they were derived.

Slope erosion

General: Slope erosion is the removal of soil or weathered bed rock by sheet wash (no conspicuous channels), rill erosion (numerous small rivulets), or gully erosion (larger, more permanent channels). It does not include erosion through larger channels between slopes, stream bank erosion, or mass movement, although these are sometimes grouped together in regional analyses of soil loss. Dominant factors controlling slope erosion are land use, land cover, slope, soil type, and rainfall intensity (Figure 7).

Figure 1. Coastal erosion and associated landslides such as these at Cape Blanco threaten several coastal communities (Beaulieu and Hughes, 1976). (Photo courtesy Oregon Highway Division)

Figure 2. Slide at Catching Slough inlet in Coos County during 1974 flood is typical of damage inflicted on Oregon roads by geologic hazards (Beaulieu and Hughes, 1975). (Photo courtesy The World)

Figure 3. Deep bedrock failure near Lolo Pass is similar to Canyonville slide which claimed nine lives in 1974 (Beaulieu, 1974).

Figure 4. Debris flows emanating from steep terrain destroyed part of Union Pacific railway near Mapleton in winter of 1964-1965 (Schlicker and Deacon, 1974). (Photo courtesy ***Siuslaw News****)*

Figure 5. Debris flows in Portland are typically small but historically numerous and troublesome (Oregon Department of Geology and Mineral Industries, 1970).

Figure 6. Debris avalanches such as this one in steep terrain along the South Fork of the Coquille River commonly expose bed rock (Beaulieu and Hughes, 1975).

Figure 7. Areas such as this in western Curry County when exposed by mass movement are commonly sites of severe slope erosion (Beaulieu and Hughes, 1976).

Soil erosion is extremely sensitive to slope gradient and moderately sensitive to slope length. The slope intensity factor is greatest in mountainous areas and along steep valley sides. It is least in flat bottomlands.

Soil erodibility varies greatly with land use and soil cover. Where sediment yield rates have been measured, they provide a good general guide to slope erosion but should not be confused with actual soil loss (Wischmeier, 1976). Sediment yield studies do not measure footslope deposition and other local forms of deposition which capture much of the eroded material before it ever reaches the streams being monitored. Actual soil loss is always greater than measured sediment yield.

In California, Knott (1973) demonstrates that the conversion of woodland to intensive agriculture and construction increases sediment yields by 65 to 85 times. Yorke and Davis (1971) record a 90-fold increase in sedimentation during conversion of pastureland to townhouses in a small watershed in Maryland. In the H.J. Andrews Experimental Forest, uncontrolled clear cut logging increased rates of sedimentation 67 times; and Anderson (1971) reports similar results in a similar study in California. Langbein and Schumm (1958) determine that for areas of greater than 40 inches annual effective precipitation, the sediment yield rate under natural vegetation is approximately 200 cubic meters per kilometer per year (about 1,500 tons per square mile). For areas having lower rainfall, the sediment yield is greater because of the decrease in protective cover offered by natural vegetation. These figures apply to land in the natural state; erosion in agricultural or construction areas is much higher.

Soil erosion is also a function of permeability, structure, grain size, and organic content of the soil. For example, soils composed primarily of silt and fine-grained sand are easily eroded. On steeper slopes, very shallow depths to bed rock increase soil erosion because of decreased infiltration and increased runoff.

Methods of study: Many of the diverse factors controlling soil erosion are brought together in the Universal Soil Loss Equation developed by the U.S. Department of Agriculture (1972):

$$A = RKLSCP$$

A refers to annual soil loss in tons per acre, R is the rainfall intensity factor, K is a measure of soil erodibility, LS is a slope intensity factor which considers slope gradient and slope length, C is the land cover and land use factor, and P is a factor of conservation practices. Until very recently, empirical data used in deriving the equation were based entirely on studies of flat to gently sloping agricultural land. Land use figures are now extended to consider nonagricultural uses.

Figures for steeper slopes are extrapolated beyond the range of empirical data and are used only for speculative estimates. In practice, mass movement processes are a greater concern on more steeply sloping terrain. The Universal Soil Loss Equation, however, is appropriate for estimating soil losses for particular parcels of land and gives good results within broad limits for gently sloping terrain (Williams and Berndt, 1972).

Additional techniques for estimating slope erosion potential on a more regional basis are also available. In a manner similar to the analysis of mass movement in Table 2, a series of pertinent overlays can be developed for a region and a series of erosion potential provinces can be defined. These can then be related to existing erosion data and monitor information to produce relative measures of erosion or actual semiquantitative estimates of erosion. Identification of erosion potential provinces also allows the projection of erosion data from one locality to other areas of similar nature. The erosion province method of analysis is appropriate for regional assessments of erosion potential and sedimentation potential in gently to moderately sloping terrain.

Impacts: Severe slope erosion removes valuable topsoil and may form gullies, damage landscapes, and hinder revegetation. Where allowed to continue to extreme conditions, it may also result in more rapid storm runoff.

Soil material carried to streams may adversely impact stream biology and cause greater flooding by raising the stream beds. Although increased turbidity is also an adverse impact of slope erosion, it is largely the result of mass movement and stream bank erosion.

Flooding

Causes: Flooding is caused by large increases in discharge or by natural or man-caused modifications of the channel. The Manning Equation of stream discharge provides a systematic basis for reviewing the causes of stream flooding and for qualitatively predicting impacts of various possible channel modifications:

$$Q = \frac{1.486}{n} AR^{2/3}S^{1/2}$$

Q is discharge (cfs), n is channel roughness, A is cross-sectional area of the channel, R is hydraulic radius (A divided by the wetted perimeter), and S is slope (gradient) of the stream. Flooding is caused by increasing Q or by holding Q constant and modifying factors on the right side of the equation to generate compensating increases in depth.

Natural flooding is caused by heavy orographic rainfall, rapid snowmelt, low infiltration rates, steep slopes, and steep gradients. Most floods on local streams crest shortly after peak precipitation; floods on larger streams show greater delay. An additional potential cause of flooding is the impoundment and sudden release of waters behind landslide dams.

Land use can influence local flooding by altering surface water residence times and infiltration rates. Urbanization greatly increases peak flow and total runoff (Seaburn, 1969; Knott, 1973). In logging areas, road construction decreases regional infiltration and intercepts shallow subsurface flow to produce increases in peak flow (Harr and others, 1975). A variety of modeling procedures are available for predicting runoff in areas of changing land use and should be incorporated into storm sewer design.

The impact of logging on stream flooding varies with type of tree, soil, and climate but appears to be minimal in most instances. In the Alsea drainage (Harris, 1977) and the H.J. Andrews Experimental Forest (Rothacher, 1970), no increase in peak flows with logging is noted. Changes in channel geometry and the manner of flood water conveyance through lowlands outside logged watersheds has been little investigated.

A beneficial impact of logging in many areas is increased summer streamflow when the need is greatest. Removal of conifers under ideal conditions of soil thickness and climate reduced summer evapotranspiration by approximately 18 inches in the H.J. Andrews Experimental Forest (Rothacher, 1970). As a result, summer streamflow after logging increased 30 percent (Moore, 1966). In regions of drier climate, thinner soils, and less uniform original conifer cover, the beneficial impact is less dramatic. In the Ochoco Mountains, for example, evapotranspiration was reduced by 2 inches and resulted in slightly increased stream flow (Berndt and Swank, 1970).

If discharge Q is held constant, flooding may be caused by modifications of the cross-sectional area A or slope S. Thus, artificial fill, other artificial obstructions (roads, bridges, structures), gravel and silt deposits, and natural channel obstructions such as log jams may contribute to flood potential. The Flood Insurance Act of 1968, administered by the U.S. Department of Housing and Urban Development, and Goal 7 of the Land Conservation and Development Commission regulate obstructions in the floodway. Placing of fill in channels is regulated by the U.S. Army Corps of Engineers and the Division of State Lands.

Slope S is influenced by aggradation and channel modifications. If slope is decreased, cross-sectional area (and therefore, depth) must be increased accordingly to accommodate a given discharge.

Impacts of channel modifications for the purposes of flood control, aggregate removal, or erosion control depend on the specific conditions at a given site. Thus, channel restrictions in some parts of a stream may aggravate flooding whereas constrictions elsewhere may have no significant impact on flooding. Likewise, channel modifications may be justified to minimize flooding or stream bank erosion elsewhere.

Stream erosion and deposition

General: Much planning and designing of channel modifications emphasize the water aspects of the total stream system. Equally important, but often neglected, are sediment load and a variety of transient stream parameters including width, depth, channel roughness, and channel layout. Changes in any one of these leads to changes in one or more of the others.

Larger particles in stream beds, including boulders, pebbles, and coarse sand grains that are moved by rolling, sliding, and bouncing, constitute the bed load. The capacity of a stream to transport bed load is determined by channel geometry, volume of discharge, and velocity. Smaller particles, including fine sand, silt, and clay, generally are transported in suspension. The volume of suspended load is controlled primarily by runoff and slope erosion. This aspect of sediment transport is particularly significant in terms of water quality management. Medium-grained sand can be carried in suspension under extreme conditions of velocity and turbulence.

Torrential flood channels: Torrential flood channels are most prevalent in mountainous terrain, where slopes are characteristically steep and infiltration rates are low. Areas of recent torrential flooding are easily recognized on the basis of scoured, unvegetated creek bottoms and coarse, poorly sorted stream bed deposits. Where vegetation has reclaimed the channel, recognition is based upon indirect features including steep side slopes, steep gradients, impermeable bed rock, narrow stream channels, and the absence of a flood plain. Torrential flood channels pass downstream into topographically more mature channels with flood plains.

Because torrential flood channels are generally cut in bed rock, they are unable to adjust to rapid changes in discharge by channel modification. Instead, depth and velocity increase sharply during times of high flow. Consequently, torrential floods are highly erosive and commonly destroy artificial obstructions in the channel such as bridge abutments and road fill. Where torrential flood channels spill into flat terrain, rubble and debris fans may quickly bury roads or clog culverts (Figure 8).

Concentrations of suspended sediment during torrential floods are commonly high. Under extreme conditions of slope erosion and rainfall, torrential stream channels may transport flowing mud and debris rather than water (Beverage and Culbertson, 1964).

Lowland flood channels: Gentler gradients, broader valleys, and the greater capacity to modify channel geometry in response to rapidly fluctuating discharge are characteristics which distinguish flood plain stream channels from torrential flood channels (Figure 9). Short-term variations in depth and velocity are less extreme in these channels, but long-term changes in width, depth, and layout are more variable in response to slope, discharge, and bed load. Stream meandering (flow along a curved sinuous channel) and stream braiding (flow along several channels) in flood plains are subjects of considerable research but still are incompletely understood.

Erosion in flood plains is restricted primarily to channels, outer bends of meanders, and cutoff channels that develop during times of flooding. Stream deposition includes not only the deposition of silt and clay from relatively slow moving overbank flood waters but also the formation of bars in channels, on the inner bends of meanders, and behind obstruc-

Figure 8. Torrential flood channels are characterized by channel scour in high gradient segments and rapid deposition at foot of mountainous areas in western Curry County (Beaulieu and Hughes, 1976).

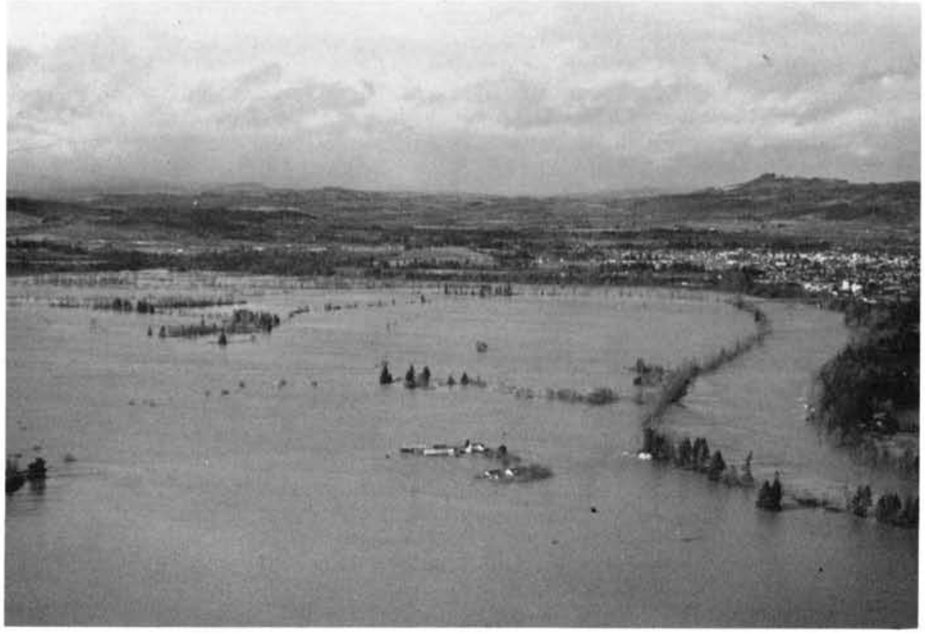

Figure 9. Lowland flooding of Willamette River is typical of floods that inflict $20 million losses annually in Oregon (Oregon Department of Geology and Mineral Industries, 1970).

tions such as snags. Stream erosion and deposition operate in harmony to modify the stream channel. Sediment supplied by stream bank erosion is deposited as bars farther downstream. Bars, in turn, redirect streamflow against river banks downstream to cause additional stream bank erosion.

Conclusion

Regional investigations of surficial geologic hazards have been conducted by the Department in Tillamook, Clatsop, Lincoln, Coos, Douglas, Curry, Jackson, Hood River, Wasco, Sherman, Linn, Marion, and Washington Counties. Selection of concepts used in the successive investigations has been a balanced consideration of (1) the need for technical accuracy, (2) the need of information useful for a wide variety of persons, and (3) the fundamental place of geology in the geologic hazards of Oregon. In future projects the Department will continue to draw upon the experience of others and produce documents useful to a wide spectrum of persons and agencies in need of geologic hazard information.

References

(Bibliographies of publications related to environmental geology will be found in Department Bulletins 79, 81, 82, 84, 85, 87, 90, 91, 93, and 94. Complete titles of these bulletins are listed on the inside back cover of this Ore Bin, and the bulletins are available at the Department's Portland, Grants Pass, and Baker offices.)

Anderson, H.W., 1971, Relative contributions of sediment from source areas, and transport processes, *in* Forest land uses and stream environment, proceedings of symposium, Oct. 19-21, 1970: Oregon State Univ., p. 55-63.

Beaulieu, J.D., 1974, Geologic hazards of the Bull Run Watershed, Multnomah and Clackamas Counties, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull 82, 77 p.

Beaulieu, J.D., and Hughes, P.W., 1975, Environmental geology of western Coos and Douglas Counties, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 87, 148 p.

__________, 1976, Land use geology of western Curry County, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 90, 148 p.

Berndt, H.W., and Swank, G.W., 1970, Forest land use and streamflow in central Oregon: Portland, Oreg., Pacific Northwest Forest and Range Exp. Stn., U.S. Dept. Agr. Forest Service Research Paper PNW-93, 15 p.

Beverage, J.P., and Culbertson, J.K., 1964, Hyperconcentrations of suspended sediments: Jour. Hydraulics Div., Am. Soc. Civil Eng., v. 90, no. HY6, Proc. Paper 4136, p. 117-128.

Campbell, R.H., 1975, Soil slips, debris flows, and rainstorms in the Santa Monica Mountains and vicinity, southern California: U.S. Geol. Survey Prof. Paper 851, 51 p.

Harr, R.D., Harper, W.C., and Krygier, J.T., 1975, Changes in stream hydrographs after road building and clear cutting in the Oregon Coast Range: Water Resources Research, v. II, no. 3, p. 436-444.

Harris, D.D., 1977, Hydrologic changes after logging in two small Oregon watersheds: U.S. Geol. Survey Water-Supply Paper 2037, 31 p.

Knott, J.M., 1973, Effects of urbanization on sedimentation and flood flows in Colma Creek Basin, California: U.S. Geol. Survey open-file report, 54 p.

Langbein, W.B., and Schumm, S.A., 1958, Yield of sediment in relation to mean annual precipitation: Am. Geophys. Union Trans., v. 39, no. 6, p. 1076-1084.

Moore, S.T., 1966, Management of a municipal watershed, *in* Practical aspects of watershed management: Am. Foresters and Oregon State Univ. School of Forestry Symposium, p. 61-68.

Oregon Department of Geology and Mineral Industries, 1970, Seventeenth biennial report of the State of Oregon Department of Geology and Mineral Industries: Oregon Dept. Geol. and Mineral Indus. Bull. 68, 45 p.

Rothacher, Jack, 1970, Increases of water yield following clear-cut logging in the Pacific Northwest: Water Resources Research, v. 6, no. 2, p. 653-668.

Schlicker, H.G., and Deacon, R.J., 1974, Environmental geology of coastal Lane County, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 85, 116 p.

Seaburn, G.E., 1969, Effects of urban development on direct runoff to east Meadow Brook, Nassau County, Long Island, New York: U.S. Geol. Survey Prof. Paper 627-B, 14 p.

U.S. Department of Agriculture, 1972, Procedure for computing sheet and rill erosion on project areas: U.S. Soil Conservation Service Tech. Release 51, 14 p.

Williams, J.R., and Berndt, H.D., 1972, Sediment yield computed with Universal Equation: Jour. Hydraulics Div., Am. Soc. Civil Eng. Proc. Paper 9426, v. 98, no. HY12, p. 2087-2098.

Wischmeier, W.H., 1976, Use and misuse of the Universal Soil Loss Equation: Jour. Soil and Water Conserv., v. 31, no. 1, p. 5-9.

Yorke, T.H., and Davis, W.J., 1971, Effects of urbanization on sediment transport in Bel Pre Basin, Maryland, *in* Geological research 1971: U.S. Geol. Survey Prof. Paper 750-B, p. 218-224.

* * * * *

CORRECTION

In the article "Oil and Gas Exploration in 1977" (ORE BIN, January 1978) page 19, paragraph two, line 11, which reads "60 MCF/D (1,000 cu ft/day)", should instead read "60 MCF/D (60,000 cu ft/day)".

* * * * *

ENGINEERING GEOLOGY SYMPOSIUM TO BE HELD AT PSU

A symposium "The Practice of Engineering Geology in Oregon - Techniques and Legalities" will be held March 18, Earth Science Department, Cramer Hall, Portland State University, Portland. The symposium, sponsored by the Oregon section of the Association of Engineering Geologists and co-sponsored by the Oregon Department of Geology and Mineral Industries and Portland State University, will focus on current techniques and practices of engineering geology in Oregon, the position of engineering geology within the framework of land use planning requirements, and registration of geologists and engineering geologists.

Cost of registration is $26 and includes registration, luncheon, and symposium papers in published form. Student registration is $10 (not including luncheon). Preregistration prior to March 11, 1978, is $22. For more information or preregistration contact Rick Kent, AEG, 19443 Wilderness Drive, West Linn, Oregon 97068.

AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. A complete list of Department publications, including out-of-print, mailed on request.)

BULLETINS	Price
26. Soil: Its origin, destruction, and preservation, 1944: Twenhofel	$ .45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v.2	1.25
39. Geol. and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliog. (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere	2.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
53. Bibliog. (3rd suppl.)geology and mineral sources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	8.00
62. Andesite Conference guidebook, 1968: Dole	3.50
63. Sixteenth biennial report of the Department, 1966-1968	1.00
64. Mineral and water resources of Oregon, 1969: USGS with Department	3.00
65. Proceedings of Andesite Conference, 1969: [copies]	10.00
67. Bibliog. (4th suppl.) geology and mineral resources of Oregon, 1970: Roberts	3.00
68. Seventeenth biennial report of the Department, 1968-1970	1.00
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1971: Oles and Enlows	3.00
75. Geology and mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00
78. Bibliog. (5th suppl.) geology and mineral resources of Oregon, 1973: Roberts	3.00
79. Environmental geology inland Tillamook and Clatsop Counties, 1973: Beaulieu	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82. Geol. hazards of Bull Run Watershed, Mult., Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00
89. Geology and mineral resources of Deschutes County, 1976	6.50
90. Land use geology of western Curry County, 1976: Beaulieu	9.00
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00
92. Fossils in Oregon (reprinted from the ORE BIN), 1977	4.00
93. Geology, mineral resources, and rock material of Curry County, Oregon	in press
94. Land use geology of central Jackson County, Oregon, 1977	9.00

GEOLOGIC MAPS	
Geologic map of Galice quadrangle, Oregon, 1953	1.50
Geologic map of Albany quadrangle, Oregon, 1953	1.00
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50
Geologic map of Bend quadrangle and portion of High Cascade Mtns., 1957	1.50
Geologic map of Oregon west of 121st meridian, 1961	2.25
Geologic map of Oregon east of 121st meridian, 1977	3.75
Geologic map of Oregon (9 x 12 inches), 1969	.25
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00
GMS-4: Oregon gravity maps, onshore and offshore, 1967 [folded]	3.00
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00
GMS-6: Prelim. report on geology of part of Snake River Canyon, 1974	6.50
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00

The ORE BIN
1069 State Office Bldg., Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

The Ore Bin

Available Publications (continued)

THE ORE BIN

		Price
Issued monthly - Subscription	[Annual]	$ 3.00
	[3-year]	8.00
Single copies of current or back issues	[Over the counter]	.25
	[Mailed]	.35

OIL AND GAS INVESTIGATIONS

1.	Petroleum geology, western Snake River basin, 1963: Newton and Corcoran	3.50
2.	Subsurface geology, lower Columbia and Willamette basins, 1969: Newton	3.50
3.	Prelim. identifications of foraminifera, General Petroleum Long Bell #1 well	2.00
4.	Prelim. identifications of foraminifera, E.M. Warren Coos Co. 1-7 well, 1973	2.00
5.	Prospects for natural gas prod. or underground storage of pipeline gas	5.00

SHORT PAPERS

18.	Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75
19.	Brick and tile industry in Oregon, 1949: Allen and Mason	.20
21.	Lightweight aggregate industry in Oregon, 1951: Mason	.25
24.	The Almeda mine, Josephine County, Oregon, 1967: Libbey	3.00
25.	Petrography, type Rattlesnake Fm., central Oregon, 1976: Enlows	2.00

MISCELLANEOUS PAPERS

1.	A description of some Oregon rocks and minerals, 1950: Dole	1.00
2.	Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973):	1.00
4.	Laws relating to oil, gas, & geothermal exploration & development in Oregon	
	Part 1. Oil and natural gas rules and regulations, 1977	1.00
	Part 2. Geothermal resources rules and regulations, 1977	1.00
5.	Oregon's gold placers (reprints), 1954	.50
6.	Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00
7.	Bibliography of theses on Oregon geology, 1959: Schlicker	.50
	Supplement, 1959-1965: Roberts	.50
8.	Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00
11.	Collection of articles on meteorites, 1968 (reprints from The ORE BIN)	1.50
12.	Index to published geologic mapping in Oregon, 1968: Corcoran	.50
13.	Index to The ORE BIN, 1950-1974	1.50
14.	Thermal springs and wells, 1970: Bowen and Peterson (with 1975 suppl.)	1.50
15.	Quicksilver deposits in Oregon, 1971: Brooks	1.50
16.	Mosaic of Oregon from ERTS-1 imagery, 1973	2.50
18.	Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00
19.	Geothermal exploration studies in Oregon - 1976, 1977	3.00

MISCELLANEOUS PUBLICATIONS

Oregon base map (22 x 30 inches)	.50
Landforms of Oregon (17 x 12 inches)	.25
Mining claims (State laws governing quartz and placer claims)	.50
Geological highway map, Pacific NW region, Oregon-Washington (pub. by AAPG)	3.00
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975 (including papers on gold deposits, exploration, history, and production)	5.00

Colored postcard, GEOLOGY OF OREGON . . . 10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00