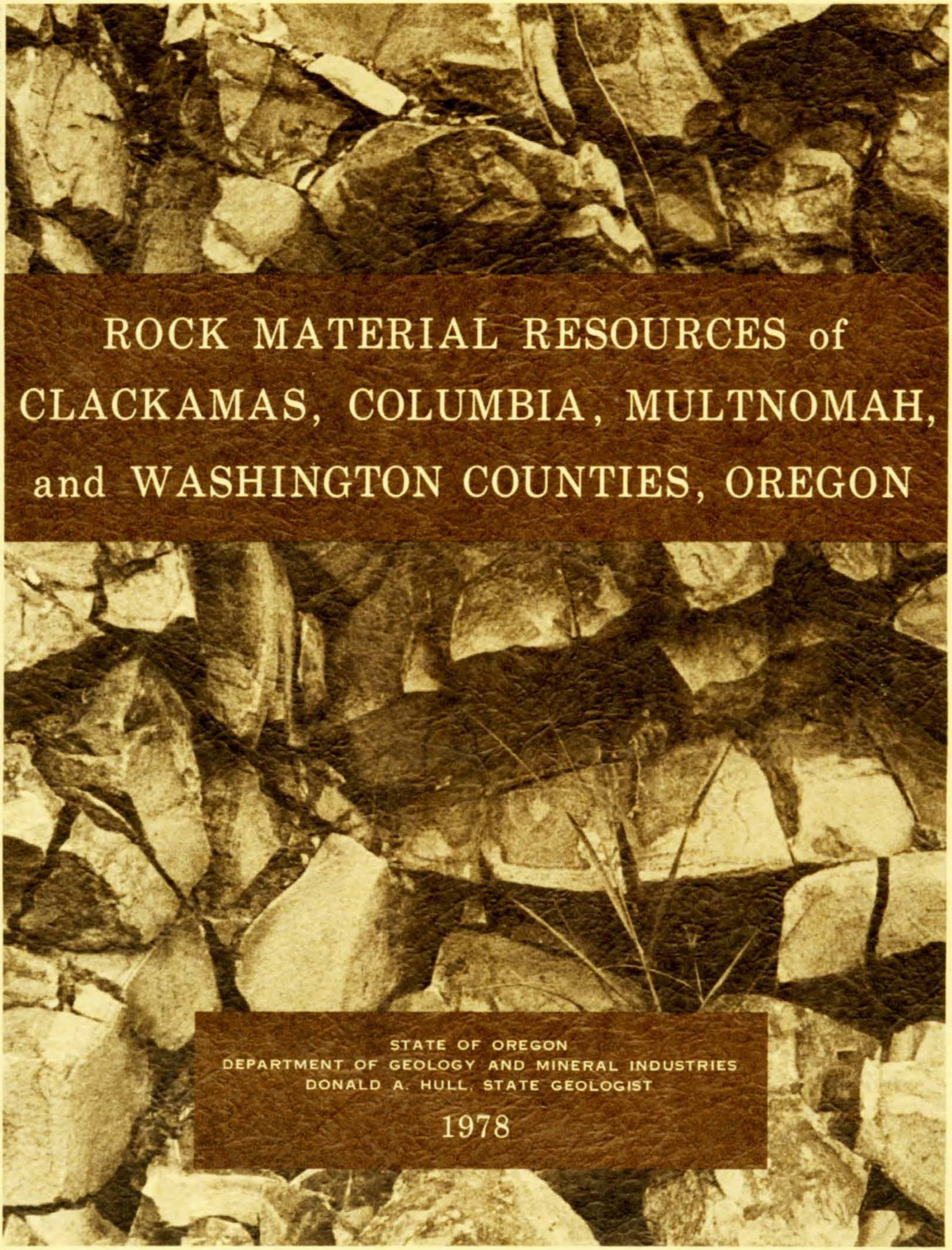
SPECIAL PAPER 3

ROCK MATERIAL RESOURCES of CLACKAMAS, COLUMBIA, MULTNOMAH, and WASHINGTON COUNTIES, OREGON



STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

1978

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ROCK MATERIAL RESOURCES of CLACKAMAS, COLUMBIA, MULTNOMAH, and WASHINGTON COUNTIES, OREGON

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In cooperation with
Board of Directors
Columbia Region Association of Governments
Portland, Oregon

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1978

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ROCK MATERIAL RESOURCES of CLACKAMAS, COLUMBIA, MULTNOMAH, and WASHINGTON COUNTIES, OREGON

SUMMARY

This study provides a strong mineral resource data base for use of the various county planning and public works departments, county and State road and highway departments, private contractors, and private citizens.

The inventory of current mineral resource availability and forecast of future rock material demands should help counties in making projections of future needs. This report also stresses the necessity of planning for secondary usage and reclamation of surface mining sites, thus eliminating adverse environmental effects often associated with surface mining.

This study presents rock material resource location maps, survey data tables, reclamation advice, and a model of future demand. General information on geography and population is given, along with specific information pertaining to types of rock materials (clay and shale, sand and gravel, and stone) that have been produced within the four-county area, major rock types (basalt and andesite), and geologic formations. Interpretive maps and tables illustrate the data and indicate anticipated demands.

The survey techniques are described, and survey results are detailed. The four counties making up the study area have 674 sites that have been mined in the past: 212 million tons of rock material were taken from these sites; and 3,000 acres, 0.1 percent of the four-county land area, were affected. Surveying shows that 514 million tons remain to be mined from the sites.

The economics of the rock material industries are described, and the base and groundwork for a consumption forecasting model are laid. The model developed here predicts that 514 million tons of rock materials will be consumed by the year 2007.

This study recommends that the land status of all active and potential mining sites, particularly those near urban areas, should be determined in terms of present use and zoning classification. All future changes in status should consider the mineral resource potential of each parcel. County zoning of land which excludes mineral resource development would have the effect of preventing any future production and would reduce the available natural resource, thus affecting resource availability projections. The counties may wish to relate land status to mineral resource potential.

Mining methods, from simple bar scalping to methods of handling cement concrete and asphalt concrete, are described and illustrated by many photographs. Mined land reclamation is discussed in general, and technical terms, specific examples, and advice are given.

The counties should encourage mined land reclamation of all surface mining sites within their boundaries. By working closely with State agencies and by reviewing all reclamation plans, the counties may also have significant input into the State program. In addition, a mined land reclamation library should be initiated and maintained by the counties.

INTRODUCTION

General

The population of the CRAG (Columbia Region Association of Governments) area counties (Clackamas, Columbia, Multnomah, and Washington Counties, Oregon; and Clark County, Washington) is expected to continue to expand. While creating an increasing need for construction aggregate, this growth can simultaneously restrict the use of existing sources because of zoning, encroachment of incompatible development, and elimination of other rock material deposits by simply building over them. With proper planning, a continued supply of these important rock material resources will be available in a manner most compatible with the environment and long-range land use plans.

Purpose

The purpose of this study is to develop concise data on the rock material resources of the Oregon CRAG counties in a form which can be used as a data base for short-range planning for rock material supplies and Land Conservation and Development Commission (LCDC) Goal 5, Program 3b, in compliance with ORS 215.055. This cooperative study by the Oregon Department of Geology and Mineral Industries, CRAG, and other local governmental units provides this data plus the broad parameters of secondary or tertiary land uses after mining and a rock material demand model with which to view long-term needs. Data from this report can be used by planners, politicians, and private citizens for planning and public decisions concerning land usage and also by contractors looking for rock materials for construction projects.

Study Parameters

ORS 215.055 states lands "that are, can, or should be utilized for sources or processing of mineral aggregate" must be taken into consideration in the adoption of land use ordinances. LCDC Goal 5, Program 3b, calls for inventories describing the location, quality, and quantity of mineral and aggregate resources. To study and identify the aggregate resources that can be mined (as required under LCDC Goal 5, Guideline A6), in-depth study of geologic units must be undertaken and a geological map prepared. To study the aggregate resources that should be mined (as required under LCDC Goal 5, Guideline B1), a cultural restraints map should be prepared to overlay the geological map. This study, however, inventories only those aggregate resources that have been in the past or are currently being mined.

This study includes a rock material demand model and material resources location maps and survey data tables for each of the Oregon CRAG counties (Plates 1, 2, 3, and 4, folded, in pocket). Sites with evidence of present or past mining were the only ones surveyed; they may or may not contain future reserves. Each site was given a number which is used throughout the report. A survey of all possible rock resources including geological and cultural restraints maps for the four-county area was beyond the scope of this report. No site surveying was performed in Clark County, Washington. This study is not directly concerned with environmental or geological hazards, engineering geology, or metallic mineral resources.

LCDC Goal 5, Program 3a, calls for an inventory of land needed or desirable for open space, and Guideline A2 states, "The maintenance and development of open spaces in urban areas should be encouraged." LCDC Goal 5, Guideline B9, states, "Areas identified as having non-renewable minerals and aggregate resources should be planned for interim, transitional and 'second use' utilization as well for the primary use."

If reclamation is built into the aggregate mining system, some of the largest areas in the urban center that have not been built upon because they are being mined for rock material could be viewed as future open spaces. A discussion concerning land use planning and reclamation processes along with examples of reclamation is included in the text, and information on where to seek reclamation assistance is presented. A glossary defining the terms used in this report appears in Appendix 1. The role of the State, county, and quarry operator in reclamation procedures and reclamation economics is discussed in Appendix 2. The method by which the area's rock material demand model was devised is given in Appendix 3.

Methods of Study

Files of the Department's Mined Land Reclamation Division and other State and county agencies were searched for rock material extraction site locations. Additional sites were identified by communication with local aggregate producers, and personnel from individual counties, State Highway Division, and U.S. Forest Service, and by inspection of aerial photographs. Other sites were located during travel while field surveying and by reconnaissance from light aircraft.

On-site surveys were accomplished by use of a rangefinder, a clinometer and/or a planimeter, and aerial photographs. The surveys provide data on dimension and shape of each site, volume of material removed, and reserves remaining. Estimates of reserves were determined by considering depth and lateral extent of deposits, the thickness of overburden, the limiting effect of ground water, property ownership, and conflicting land uses. The assumption was made that point bars in river channels normally can be cropped every 3 years.

The quality of the rock was estimated by identifying geologic formation and rock type and characteristics and by obtaining Oregon State Highway Division laboratory data.

Sand and gravel and quarry-rock production records from county, State, and Federal agencies, principally the U.S. Bureau of Mines, were compiled for the years 1940 to 1975 to determine the past rates of production, which were assumed to equal the consumption, of these materials. Future requirements were determined by extending least-squares production curves.

Acknowledgments

The authors are grateful for the help received from many individuals, private firms, and public agencies. Richard E. Freytag and David W. Wendland, field geologists, surveyed the rock material sites in Columbia County and some of those in Multnomah County. The others were surveyed by the two field-geologist authors. Herbert G. Schlicker gave advice and provided flight service for the surveying overview. David E. Brooks compiled the State Highway Division laboratory data. Normandie A. Denny, Associated General Contractors, and Art Heizenrader, Oregon Concrete Aggregate Producers Association, provided support for the project. Herbert Beals and Stanley Hirota acted as liaison between CRAG and the Oregon Department of Geology and Mineral Industries. Manuscript typist was Linda VanCura; camera copy typist was Ruth E. Pavlat. Charles Schumacher and Kath Eisele drafted the maps and figures, and Beverly Vogt and Ainslie Bricker edited the report.

Previous Work

The CRAG area rock material needs have been reported in several studies including Metropolitan Planning Commission (1964), U.S. Army Corps of Engineers (1974), and Montagne and Associates (1975). Unpublished site-specific studies by Compass Corporation (1975) and Philip Thompson and Associates (1975) are on file with the Clackamas County Planning Department. Schlicker and Deacon (1967) provide site-specific information for Washington County.

GEOGRAPHY

Location, Physical Geography, Extent of Area, and Access

As Figure 1 shows, the CRAG counties are located in northwestern Oregon and southwestern Washington and are centered around Portland, Oregon, and Vancouver, Washington. Rock material site surveys for this study were conducted in Clackamas, Columbia, Multnomah, and Washington Counties, Oregon.

The study area covers 3,742 sq mi : Clackamas County, 1,893; Columbia County, 676; Multnomah County, 457; and Washington County, 716. The region is divided into three geological and topographical provinces. They are from west to east, the Coast Range, Willamette trough, and Western-High Cascade Range. Coast Range elevations range from 20 ft above sea level along the Columbia River to 3,000 ft near the western edge of Washington County.

The Coast Range contains rugged ridges with short, steep slopes; hills and ridges with rounded tops and gentle slopes; and flat lowlands. The Willamette trough, which includes the level areas of Portland and Vancouver, is a structural depression with low, rolling hills or buttes with moderate relief separating broad, flat, generally level areas. The Western-High Cascade Range begins at the east edge of the Willamette trough and extends to the summit of the Cascades. The rugged topography of the Western Cascades is characterized by steep slopes, sharp ridge tops, and deep canyons. The High Cascades have rugged, steep topography north of Mount Hood and less rugged, rolling topography south of Mount Hood. Relief in the Western-High Cascades ranges from 200 ft near the Columbia River to 11,245 ft at the summit of Mount Hood, the highest peak in the study area.

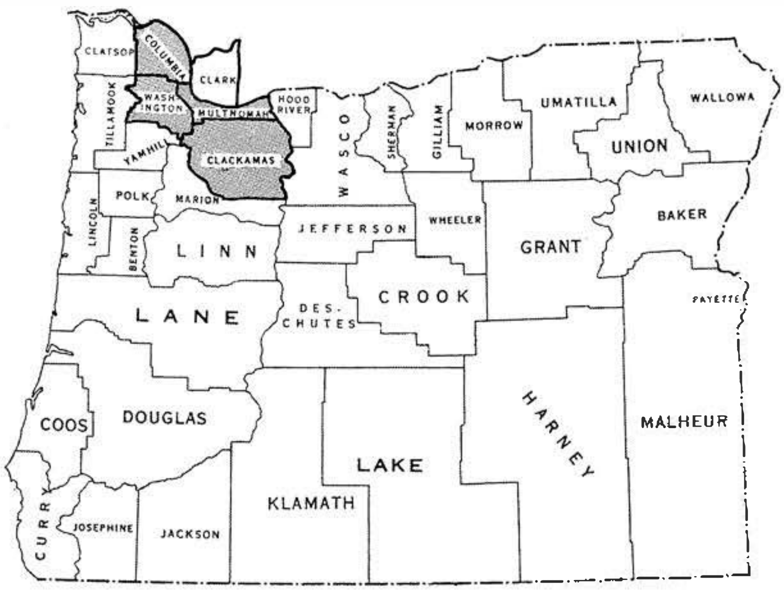

Figure 1. Index map showing CRAG counties outlined with heavy black lines. Counties studied for this report are shaded. Clark County, Washington, was not included in this study.

Transportation Net

The four Oregon CRAG counties have an excellent road and highway system. The major north-south routes are Interstate 5, U.S. 99W and 99E, and Oregon 211 and 213. Routes east-west are Interstate 80N, U.S. 30 and 26, and Oregon 8, 47, and 202. The secondary system of private, county, and Federal roads allows access to all sites mentioned in this study. Table 1 gives a breakdown of the miles of road by agency and by county.

Table 1. Miles of road by agency and by county **

Agency	County				
	Clackamas	Columbia	Multnomah	Washington	Total
Federal agency roads	1,235	13	117	14	1,379
State agency roads	258	180	255	222	915
County and public usage roads *	1,581	523	991	1,231	4,326
City streets	247	68	1,356	150	1,821
Total	3,321	784	2,719	1,617	8,441

* Roads under county jurisdiction but generally privately maintained.
** Transportation Research Institute (1970).

The Columbia and Willamette Rivers are used extensively by shallow-draft vessels, moving freight in barges and towing log rafts. The rivers are also navigated by ocean-going vessels.

Socioeconomic Setting

The CRAG area has an inner urban core, a middle suburban ring, and an outer agricultural-rural (mainly timber) ring. The urban center is growing vertically with multiple-story buildings. The suburban ring is continuing to develop vacant spaces with buildings of lower height. Between the rural and suburban areas, maximum rate of development, including single-family dwellings, is taking place. Because of Federal ownership, much of eastern Clackamas and Multnomah Counties will be maintained for timber production and other open-space usage.

The past and future growth pattern for each county is given in Table 2.

Table 2. Population statistics *

	1940	1950	1960	1970	1976	2000**
Oregon	1,089,684	1,521,341	1,768,687	2,091,385	2,341,750	3,019,900
Willamette Valley	712,175	1,015,354	1,191,278	1,475,384	1,642,600	2,118,800
CRAG						
Clackamas	57,130	86,716	113,038	166,088	205,800	364,900***
Columbia	20,971	22,967	22,379	28,790	32,400	41,000
Multnomah	355,099	471,537	522,813	556,667	553,000	648,600***
Washington	39,194	61,269	92,237	157,920	196,000	348,350***
Total	472,394	642,489	750,467	909,465	987,200	1,402,850

* Oregon Blue Book (1977-1978).
** Center for Population Research and Census (1976).
*** Columbia Region Association of Governments (1977).

ROCK MATERIAL RESOURCES

General

Rock material is any naturally formed mass of consolidated or unconsolidated mineral matter or mined products obtained from such a mass. Deposits include clay and shale, sand and gravel, and stone. Mined products may include any or all of the following material used as pit or quarry run, and/or processed by crushing, and/or screening, and/or drying. Processing does not include calcining or other treatments by which physical or chemical or both characteristics of the rock material are changed.

Lands showing no evidence of post mining were not surveyed for this study even though they might be potential sources of rock material. Furthermore, because potential in this study is based, in part, on cultural restraints, the future potential estimate given for a site might be increased through proper zoning and acquisition by the rock material producer. The only rock materials that have been mined in the four counties are clay and shale, sand and gravel, and quarry stone (both crushed and dimension).

Clay and Shale

Clay is a natural, earthy, fine-grained material composed of rock or mineral fragments less than 0.002 mm in size and containing a group of crystalline minerals known as clay minerals. Most clays exhibit plasticity when wet. Clay minerals may originate from simple weathering under generally humid conditions or from hydrothermal action which can transform surface or subsurface rocks of many types into more or less pure in situ deposits of one or more clay minerals. Transportation and deposition of exposed clay minerals will form deposits which may usually contain silt, sand, and other impurities. Shale deposits are formed by the transport of clay particles to a body of water where they settle out, forming clay beds. These beds then form compacted rock.

Oregon CRAG counties clays have in the past been almost exclusively used for common brick and tile production (see Multnomah County site 44, Figure 2, and Clackamas County sites 90 and 91). Since most of the clays contain a considerable quantity of iron, the fired ware is usually red to dark buff. No known deposits are low enough in iron to produce a light-colored fired product. An attempt was made to use one clay deposit, Clackamas County site 231, for cat litter. A drying and bagging plant was built, but it had a very short production run. The Keasey Formation shale found at Washington County sites 1 and 3 was used to produce a lightweight concrete aggregate and a pozzolan material (Figure 3). At Clackamas County site 229, carbonaceous shale is mined from underground, dried, ground, bagged, and sold as an animal feed supplement and soil conditioner.

Sand and Gravel

Sand and gravel are mineral commodities that were produced by the natural disintegration of bed rock. The term "sand and gravel" refers to size of the bedrock fragments, not to the mineral content or rock type. The deposits of sand and gravel in the Oregon CRAG counties are alluvial (river) and lacustrine (lake) deposits. Alluvial deposits are formed by stream action picking up, transporting, and depositing sand and gravel. Such deposits are usually imperfectly stratified and frequently show size gradations. Coarse sands and gravels may be interspersed with lenses of fine sands or clays. The beds vary greatly in thickness and are usually complex in composition. Particles are usually poorly sorted; they may be angular but are generally rounded because of the hardness of the material and the distance it has been transported. These deposits occur as bars within the stream channels and as point bars on the inside banks of meanders. The deposits also occur as old buried meander channels in the Willamette River flood plain and as terrace deposits along the Clackamas River.

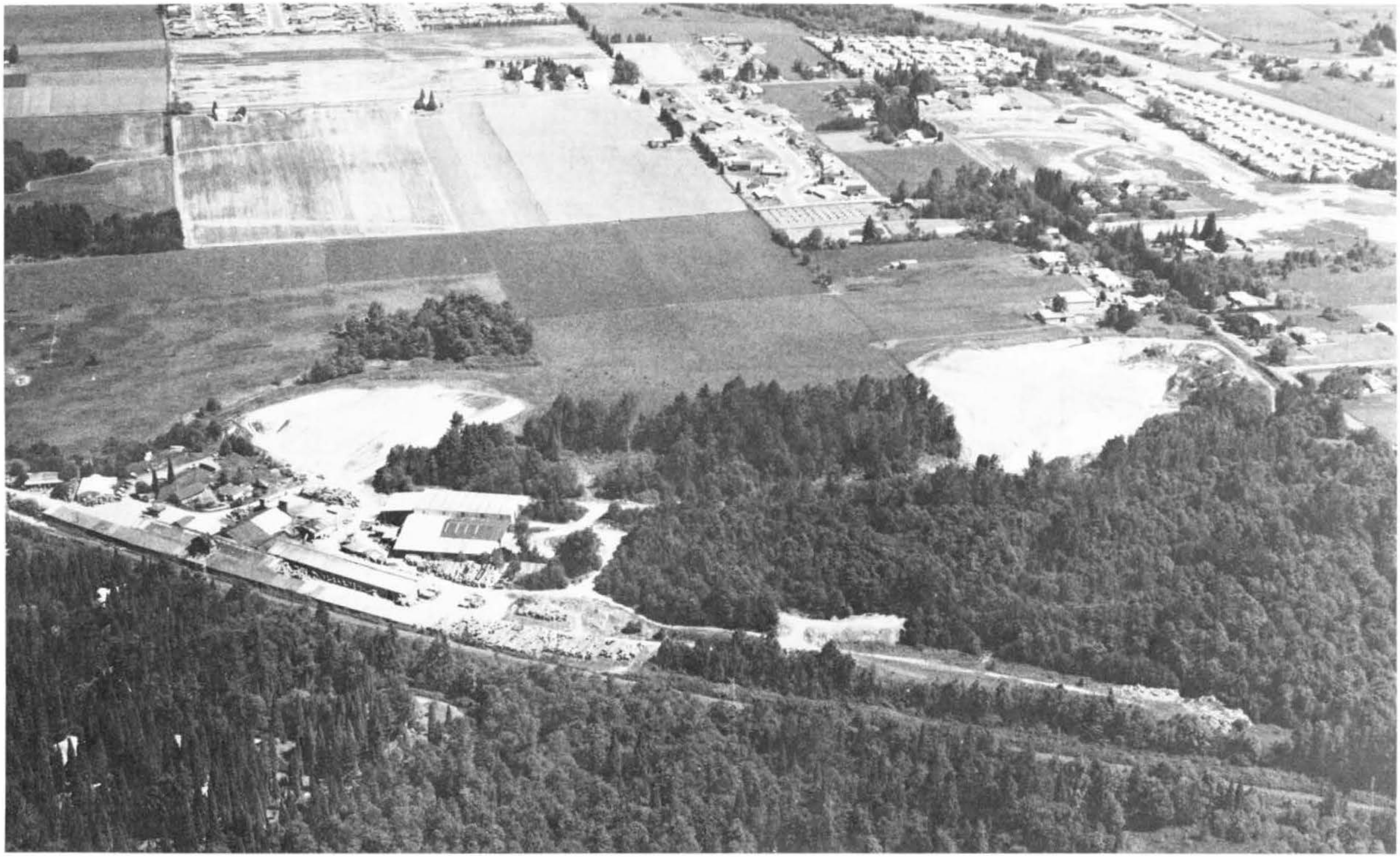

Figure 2. Oblique aerial view of Multnomah County site 44 showing Columbia Brick Works, Inc. Note that pit is being mined on slope, which allows easy reclamation.

Figure 3. Oblique aerial view of Washington County site 1, Lite Rock shale quarry. Note kiln used to bloat crushed shale to produce lightweight concrete aggregate. Plant is now being dismantled.

Lacustrine deposits usually consist of well-sorted materials, with coarse and fine particles segregated. The finer sized particles range from angular to well-rounded, while pebbles are typically well rounded and smooth. Due to a series of large late Pleistocene floods in the Portland metropolitan area, lacustrine deposits east of the Willamette River in Multnomah County have significant amounts of poorly sorted sand and gravel.

Stone (Dimension)

Dimension stone is quarried stone which has been specially cut or shaped for use as gravestones or in buildings, bridges, curbing, or other construction. In the CRAG counties, only one site, Multnomah County site 20, is listed as a dimension stone quarry. Small amounts of basalt and andesite from the quarries being mined for crushed and pit run stone have been used for dimension purposes.

Stone (Crushed and Pit Run)

Crushed and pit run quarry stone, more than 99.9 percent of all stone produced in the Oregon CRAG counties, is stone which after mining has been reduced in size to meet various consumer requirements. Most of the crushed and pit run stone has been quarried from igneous rock, mainly basalt and andesite.

GEOLOGY

General

The geological formation names that appear in Survey Data Tables 3, 4, 5, and 6 (printed on back of plates, folded, in pocket) are based on three geological reports and their geological maps. Columbia County geological formation names (Table 4, back of Plate 2) are adapted from Newton and Van Atta (1976); Washington County names (Table 6, back of Plate 4) are from Schlicker and Deacon (1967). Eastern Clackamas (Table 3, back of Plate 1, Sheets 1 and 2) and Multnomah (Table 5, back of Plate 3) Counties names are from Peck and others (1964); for western Clackamas and Multnomah Counties, Wells and Peck (1964) are used. Trimble (1963) was also consulted for parts of Multnomah and Clackamas Counties. The following brief discussion of geologic units provides a setting for the description of the rock material sites.

The geologic units within the CRAG counties can be classified into two broad groups, surficial units and bed rock. In this report, the terms "surficial" and "alluvium" are interchangeable. Under the heading "Deposit type" on the survey data tables, the term "gravel" is also used interchangeably with the terms "surficial" and "alluvium." Only units listed in the survey data tables are described in this text, starting with the youngest (river gravel) and ending with the oldest (late to middle Eocene intrusive rock).

Surficial Geologic Units (Alluvium)

General

The CRAG counties' proximity to the Columbia and Willamette Rivers and numerous Coast and Cascade Range tributary rivers and drainages, coupled with the complex history of inundation and sedimentation during Quaternary geologic time, has resulted in an abundance of surficial geologic units. These consist of unconsolidated gravel, sand, silt, and clay of varying extent and thickness. Origin of some of these units is complex and probably the result of several different episodes and processes. Surficial units in the study area are distinguishable by landform, association with flood plains, and thickness and type of material.

Development of a surficial deposit geologic map for the study area would allow definitive analysis of the distribution and variations within rock units. Interpretive data derived from such a map could serve as a basis for the determination of geologic potential for rock resources beyond the short-term predictions developed here on the basis of site inventories.

River gravel (point bars and channel gravel) - recent alluvium

Recent alluvium consists of sediments deposited in stream channels and overflow channels on modern flood plains. Stream-channel sediments of large streams are mostly gravel and sand; sluggish stream deposits range from sand to silt. Flood plain surficial deposits are composed mainly of sand and silt, with some clayey material in backwater areas.

The Willamette River carries considerable amounts of gravel. The Columbia River carries mostly sand. Stream load is derived from material eroded from rock exposures in headwaters, from tributaries, and from river bars and stream banks. The most recent gravel is usually deposited along the channel bottom and in point bars along the inside edges of meanders in the river. Many point bars are not vegetated, while others support stands of willow and cottonwood. Areas adjacent to the Willamette River and its channel provide some of the most important sources of sand and gravel for building and construction.

Recent Willamette River alluvium contains cobbles, coarse gravel, and sand and ranges from 20 to 45 ft in thickness. The rock type is mainly basalt; but considerable andesite, dacite, and rhyolite are present, with an occasional granitic textured rock.

The Clackamas River in the Cascade Range is a major gravel recharge source for the Willamette River within the CRAG area. The Sandy River carries mostly sand into the Columbia River. Coast Range streams such as the Tualatin recharge little gravel into the Willamette because the area drained is underloin primarily by sedimentary rock, which is too soft and weak to form gravel.

Quaternary terraces (unconsolidated and semiconsolidated)

Two different forms of unconsolidated terrace gravel deposits identified during the survey were alluvium (river) and lacustrine (lake). The alluvium includes low terraces adjacent to the present stream channels and filled abandoned stream channels cut in older terrace deposits. The lower terrace deposits are characterized by low, undulating, fluvial surfaces resulting from flood deposits and overbank channeling. Meander scrolls, oxbow lakes, and widespread areas subject to shallow ponding are common. Deposits extending to estimated depths of 50 to 80 ft consist of stream cobbles, gravel, coarse sand, silt, and clay. Surficial deposits of fine sand and silt occur at the junction of the Columbia and Willamette Rivers. Abandoned stream channel deposits are usually less than 30 ft thick.

The lacustrine deposits were laid down in a lake resulting from Pleistocene floods as late as 13,000 years B.P. (Before Present). Some deposits are composed almost totally of pebbles and cobbles, with a very small amount of sand. Most of the gravel is basalt, with some quartzite and granitic rock; and the deposits range from 30 to 80 ft in thickness.

Semiconsolidated deposits or beds of silt, sand, and gravel cap terraces along the Sandy, Clackamas, and other streams and form the main plain of the Willamette and Tualatin Valleys. Deposits such as those at Washington County sites 39 through 47 may be stratified and cross-bedded sand and gravel or homogeneous, light-brown, faintly stratified lacustrine silts, with interbedded sand and gravels.

Bed Rock

General

Eight bedrock units have been quarried in the study area. The youngest is the Pliocene-Recent Boring Lava-High Cascade Volcanic rock; the oldest is middle to late Eocene intrusive rock.

Boring Lava-High Cascade Lavas

These volcanic rocks are andesitic and basaltic flow rock and breccia. They are relatively undeformed and unaltered and only moderately eroded. The young High Cascade rocks make up the higher parts of the Cascade Range, including prominent volcanic cones such as Mount Hood. They also occur as intracanyon flows extending westward from the High Cascades. Boring Lava covers most of the area between the Sandy and Columbia Rivers.

Troutdale Formation

The Pliocene Troutdale Formation contains nonmarine conglomerate rocks, sandstone, and siltstone. The formation is more than 1,000 ft thick and forms bluffs along the lower Sandy and Clackamas Rivers and their tributaries. The conglomerate contains well-rounded gravel that averages 2 to 3 in. in diameter but ranges from one-half to 12 in. Composition of gravel is nearly three-fourths basalt of the Columbia River Group; the remainder is quartzite, gneiss, schist, and granitic rock.

Sardine Formation

The Sardine Formation, of middle and late Miocene age, consists mainly of andesite flow rock, breccia, and tuff. Much of the Western Cascade Range in the CRAG area is covered by this formation. In most places it is 3,000 ft thick or less; south of the area, however, it is up to 10,000 ft thick.

The flow rocks within this formation are most commonly used as rock material sources and tend to have curved, platy joints. If the jointing is close, arrowhead-shaped particles formed during crushing can damage tires, which makes this rock inappropriate for use as road topping.

Columbia River Basalt Group

The Columbia River Basalt Group, of middle Miocene age, is formed of thick to thin columnar and hackly jointed flows of hard, tough, dark-gray to black basalt and is present in each of the four counties. Individual flows can range from 10 to 100 ft in thickness. In some areas the unit top has been weathered to reddish-brown ferruginous bauxite. The maximum total thickness is about 2,500 ft along the Columbia River, thinning to about 1,500 ft along the Clackamas River. This unit provides some of the better grade rock material for construction purposes.

Little Butte Volcanic Series

The Little Butte Volcanic Series, of Oligocene to early Miocene age, consists of pyroclastic rock and flow rock. In along the Clackamas River valley, the series may be as much as 1,500 ft thick, according to Peck and others (1964). The lower port consists of flows and tuff-breccia of andesite and basaltic andesite. The upper part consists mostly of poorly exposed volcaniclastic rocks that include both massive and well-bedded, in part cross-bedded, rocks varying from fine tuff to boulder conglomerate.

Keasey Formation

The Keasey Formation, of early Oligocene to late Eocene age, consists of marine sedimentary rock. Dark greenish-gray mudstone is predominant; but the unit also contains some micaceous siltstone, sandstone, and dark micaceous shale, as well as thin limestone beds and concretionary limestone layers. Part of the formation contains enough organic material to form gas, which causes crushed rock fragments to swell when heated to the fusion point in a kiln. The bloated product is used as a lightweight aggregate. Total thickness of the formation, which crops out in the center of Columbia County and the northwest section of Washington County, is probably more than 2,000 ft.

Goble Volcanics

The Goble Volcanics, of late Eocene age, are mainly basaltic flow rock and pillow basalt of marine and subaerial origin. Locally the basalt is chloritized and cut by calcite and zeolite-filled fractures. The unit may be extensively weathered.

Nestucca Formation

The Nestucca Formation, of late Eocene age, consists of marine sedimentary rock, mostly dark-gray tuffaceous siltstone, intercalated with basaltic volcanic rocks. The volcanic rocks occur as pillow lavas, breccias, and tuffs.

Intrusive rocks

Basaltic intrusive rock, of middle Miocene and late Eocene age, crops out in Columbia County as dikes, sills, and irregularly shaped bodies. Intrusive rocks are bodies of once-fluid igneous rocks that penetrated other rocks but solidified before reaching the surface. Dikes are tabular bodies that cut across the structure of adjacent rocks or cut massive rocks, while sills are tabular bodies of approximately uniform thickness, relatively thin compared to lateral extent, emplaced parallel to bedding of the intruded rock.

SURVEY DATA TABLE AND INVENTORY MAP

General

The Oregon Department of Geology and Mineral Industries surveyed 674 rock material sites in the four Oregon CRAG counties. Plate 1, Sheets 1, 2, and 3, shows the location of rock material sites in Clackamas County. The survey data for Clackamas County is printed as Table 3 on the back of Plate 1, Sheets 1 and 2; Oregon State Highway data for Clackamas County appears as Table 9 on the back of Plate 1, Sheet 3. Columbia County rock material site locations are shown on Plate 2; survey data (Table 4) and State Highway data (Table 10) appear on the back of Plate 2. Multnomah County rock material site locations are shown on Plate 3; survey data (Table 5) and State Highway data (Table 11) appear on the back of Plate 3. Washington County rock material site locations are shown on Plate 4; survey data (Table 6) and State Highway data (Table 12) appear on the back of Plate 4.

Table data for each site include site identification, location, status, size, source description, mining system, processing plant, and usage. Except for the operator or owner column, line and column items are dashed (-) when data are unknown. Because a maximum of data are presented in the tables, the major column headings are discussed briefly in the following paragraphs.

Site Identification

The site numbering system for rock material starts in the northwest corner of each county. The numbers follow the township to the east, move back to the west end of the next township to the south, and continue again to the east. Sites found and surveyed after the maps had been prepared were given the nearest number with a subscript letter. Site names located in the field are listed in the "Operator or Owner" column; title searches were not made. Land ownership of the sites in the study area is as follows: Federal, 275; State, 28; county, 18; local, 6; private, 343; and unknown, 4. The ownerships within each of the counties are listed in Table 7.

Table 7. Site ownership by type and by county

	Clackamas	Columbia	Multnomah	Washington	Total
Federal	260	0	14	0	274
State	10	4	7	7	28
County	6	3	6	3	18
Local	2	0	2	2	6
Private	181	90	27	46	344
Unknown	1	2	1	0	4
Total	460	99	57	58	674

Location

Site locations are described down to the quarter section; however, the plotting on the localities map is accurate to the quarter/quarter section (40 acres).

Status

The status of each site was determined. Between January 1977 and December 1977, of the 674 sites, 185 sites were active, 408 were inactive, 46 were reclaimed, and the status of 35 is unknown.

Size

Table 8 summarizes the numbers of sites that fall within various size categories along with both past production and potential production figures. The table also shows a total volume figure for material which has been mined and for potential in both yards and tons. The term "cubic yard," as used in this report, refers to "bank yards" or "in-place yards," not "truck yards" or "crushed yards." When a cubic yard of in-place rock material ismined, it swells from 25 to 40 percent by the addition of voids to become a truck yard. When a truck yard is crushed and separated into different size fractions, it swells again, up to 100 percent, to become a crushed yard.

The cubic yard figures given as "Future potential" ore "indicated" reserves or resources (defined as reserves or resources for which tonnage and grade are completed partly from specific measurements, samples, or production data, and partly from projection for a reasonable distance on geologic evidence) reduced by conflicting cultural constraints, such as adjoining land usage, property lines, zoning, public safety, and other environmental control considerations. Other constraints may include specific actions of individual persons.

The range of specific gravities given in the four Oregon State Highway Division laboratory data tables, Tables 9, 10, 11, and 12, which are discussed in a later section, show that 1 cu yd of rock material in place weighs from 1.7 to 2.5 tons. The cubic yard foctor used is 1 cu yd to 2 tons. All tonnage statistics given in this report are short tons (2,000 lbs). At each site, acreage used for stockpiles and plant sites was measured in addition to the acreage excavated. A total of 3,003 acres hove been affected by mining in the four CRAG counties. This total is 0.1 percent of the land area. An overage of 35,000 cu yd were token from each acre affected by mining.

Source Description

Of 84 pits dug into alluvium and listed under deposit type as gravel, 3 sites were for cloy, and the rest were for sand or gravel or both. Of 574 stone quarries developed in bed rock, four were for clay and shale, one was for dimension stone, and the remainder were for crushed or pit-run stone. Of the latter, 16 were developed in talus slopes.

The two major rock types mined were basalt and andesite. A few hard sandstones, shales, and tuffs were mined, mainly for use in embankments. The geologic unit or formation for each site is given. Without o geological map with overlays, it is difficult to draw conclusions about which unit or formation has the best stone because the quality of stone can vary widely within short distances within the same unit or formation.

Mining System

In Oregon, rock material is mined by surface methods. The only exception to this is the underground operation of Mandrones Mining Company, Clackamas County site number 229, where a bed of carbonaceous shale is mined from underground.

Open-pit mining of Oregon's rock material is conducted in various ways and by various kinds of equipment under a wide range of conditions. The simplest method is the scalping of a river gravel bar with a wheeled front-end loader and a dump truck. The equipment needed for mining on underwater grovel deposit can be a drag line, os used at Multnomoh County site 36, o bucket dredge, or o suction dredge. Some grovel deposits to be mined below the water table are too well cemented for the use of o drag line.

Table 8. Number of sites by size and by county

Site size (1,000 cu yd)	Clackamas		Columbia		Multnomah		Washington		Total	
	Past production	Future potential	Past production	Future potential	Past production	Future potential	Past production	Future potential	Past production	Future potential
0 - 10	261	216	39	25	16	6	7	15	323	262
11 - 25	85	64	21	11	5	2	7	4	118	81
26 - 50	48	51	9	9	5	7	13	6	75	73
51 - 100	29	41	11	9	4	3	11	11	55	64
101+	37	66	19	45	27	25	20	22	103	158
Total number of sites	460	438*	99	99	57	43*	58	58	674	638
Total yd (1,000)	26,600	59,300	15,800	52,800	49,100	65,700	14,200	79,300	106,000	257,000
Total tons (1,000)**	53,200	118,600	31,600	105,600	98,200	131,400	28,400	158,600	212,000	514,000
Total acres affected by mining	1,138	-	433	-	637	-	795	-	3,003	-

* The difference between the total number of sites for past production and future potential is because of those sites which could not be surveyed on-site because they are located in the Bull Run Watershed.

** The factor used to convert cubic yards to tons is 1 cu yd = 2.0 tons.

Figure 4a. Oblique aerial photo of Washington County site 36, taken in 1974, showing abandoned water-filled quarry with a hazardous property line highwall. Note nearby homes. On other side of line, active quarry is being mined to same property line, leaving highwall on that side.

Figure 4b. Ground view of property line with highwalls on both sides. Note narrow ridge and coarse jointing.

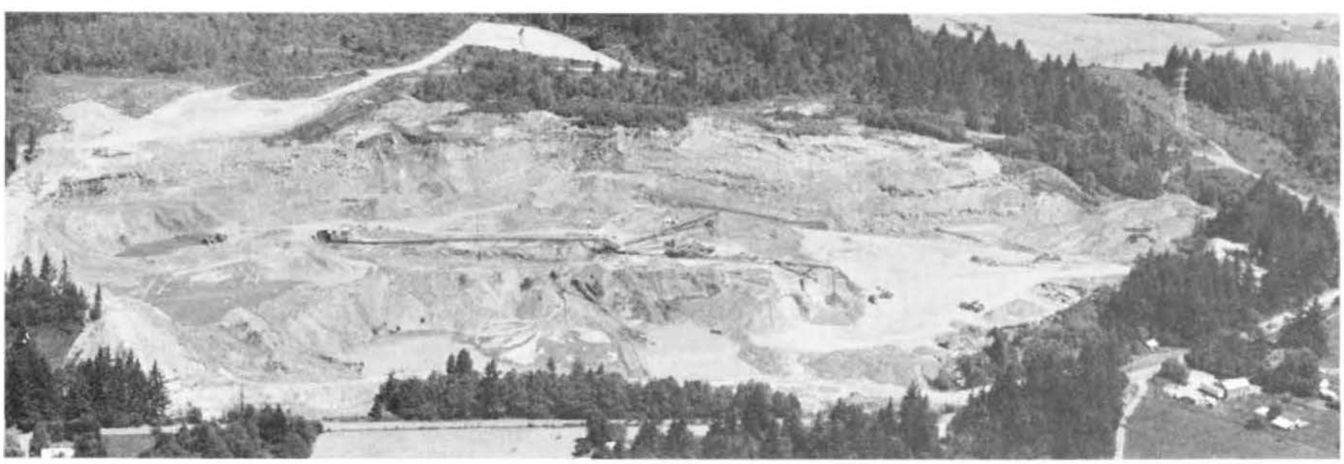

Figure 4c. Oblique aerial view of site at present, with highwalls removed and water hazard eliminated.

Figure 5a. Oblique aerial view of Washington County site 15.

Figure 5b. Ground-level view of Washington County site 15. Note ground crack in front of truck-mounted drill.

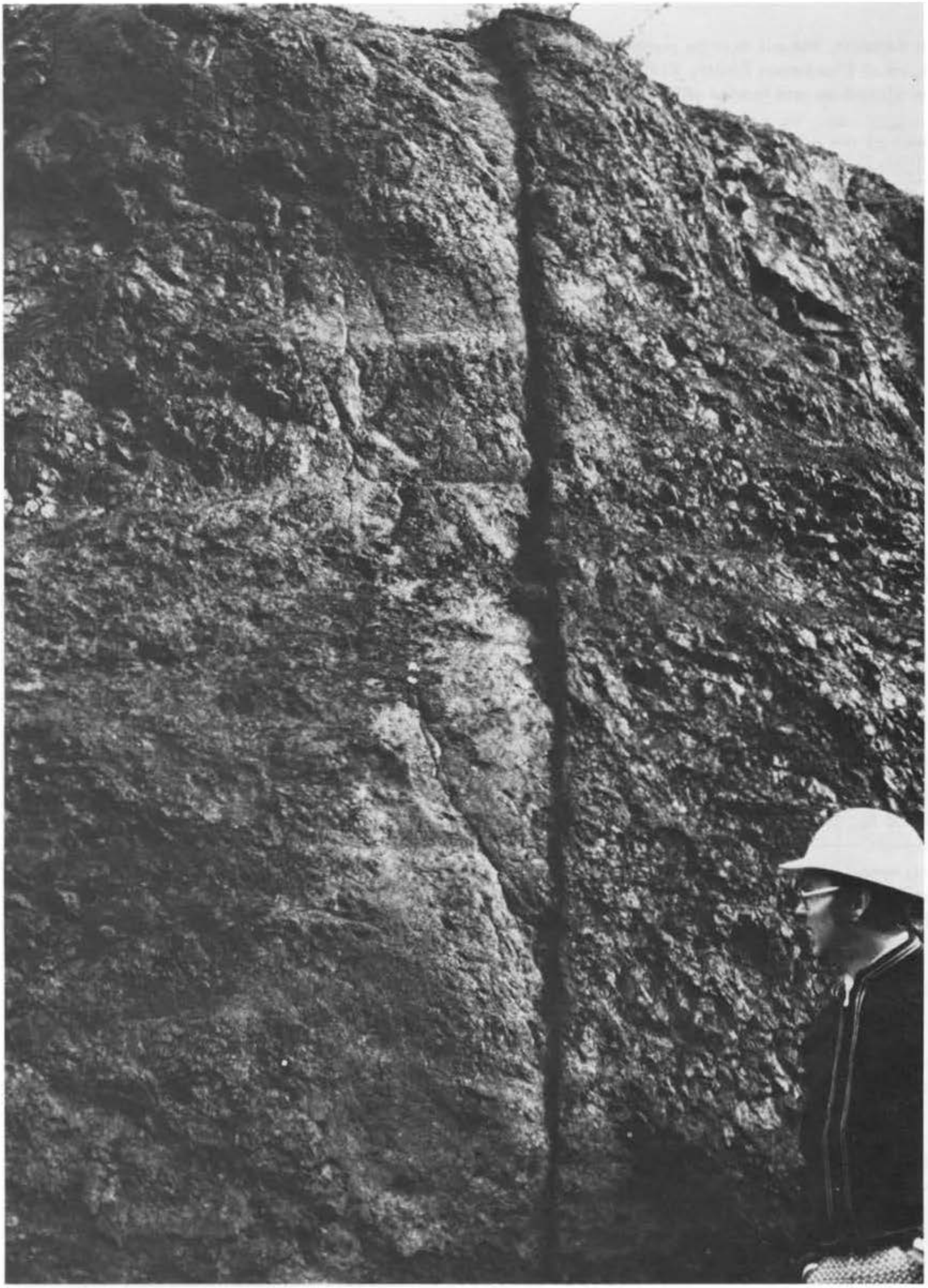

Figure 5c. Close-up ground-level view of a fracture plane along which displacement has occurred.

For these deposits, the pit must be pumped dry, and a shovel or a backhoe must be used to dig the material free, as at Clackamas County site 21; or a crawler tractor with a ripper may be used to free the material to be picked up and loaded with a wheeled front-end loader. This is done at Clackamas County site 83.

Much of the gravel pit mining equipment, such as crawler tractors, front-end loaders, shovels, truck-mounted or crawler-mounted drills, and dump trucks, can also be found in stone quarries. Stone quarries may be mined with a single bench (Figures 5 and 6), with many benches (Figures 3, 4, and 7), or on a slope (Figure 2). In many quarries, the near-surface material, which may be very soft and fractured, can be ripped, so drilling and blasting are not needed. At many sites, this soft, fractured material is too soft for any usage but embankment and subbase. Unweathered material usually requires drilling and blasting.

The amount of processing needed after mining can vary from none for pit-run pits and quarries to the huge shale kiln shown in Figure 3. Equipment needs are based on source material and market needs. County zoning restrictions are usually more severe for crushing equipment than for mining equipment. Processing equipment for a gravel pit may range from only a screen to separate the different size fractions to a full crushing, screening, and washing plant. If crushed stone is to be produced from a quarry, processing equipment starts with a crusher and usually ends with a set of screens. Stone is usually not washed.

A gravel pit can supply both cement and asphalt batch plants. Sized round gravel is preferred for cement concrete because it requires less vibrating to fill concrete forms. Some highway specifications require aggregate with 60 percent crushed fracture planes. Oversize gravel can be crushed to produce angular fragments required for use in asphalt. Stone quarries, however, produce only the angular aggregate, unsuitable for cement.

The two concretes must be handled differently. Cement concrete can be mixed no more than 45 minutes without losing strength; if aggregate and water, however, are placed in the mixer truck and cement is placed on top so that it does not get wet, it can be transported for hours. Just before or upon arrival at the construction site, the mixing is started so the concrete can be used within 45 minutes. Cement concrete is sold by the cubic yard which weighs about 4,000 lbs. One cu yd of concrete contains $1\frac{1}{4}$ to 1-1/3 cu yd crushed aggregate, about 460 lb cement, and 10-15 gal water.

Asphalt concrete can be prepared at a maximum temperature of 325°F and must be laid at a minimum temperature of 240°F. The distance asphalt concrete can be transported, therefore, is determined by how fast the load loses heat. On a hot day a load of asphalt concrete can be carried 100 mi or more; on a very cold day, the load may be taken only about 50 mi. A cubic truck yard of asphalt concrete weighs about 3,800 lb. This type of concrete is sold by the ton, which contains 1,800 lb aggregate and 120 lb liquid asphalt.

This report is not intended to be a mining system handbook; Figures 4 through 10, however, give examples of mining systems, practices, problems, and terms such as "benching," "highwalls," "jointing," and "ground breakage system" that are found heading columns in Tables 3, 4, 5, and 6.

Figures 4a, b, and c are of Washington County site 36 in basalt of the Columbia River Basalt Group. Figure 4a, taken in 1974, shows an abandoned water-filled quarry with a hazardous highwall that follows a property line. On the other side of the line, another quarry is being mined up to the line leaving, as Figure 4b shows, a very narrow vertical ridge. Through the cooperation of the two property owners, the County, and the State Department of Geology and Mineral Industries, the active quarry was allowed to take the ridge down. Figure 4c shows the present status of the site.

Figures 5 and 6 show ground control problems. Figure 5a is an oblique aerial view of Washington County site 15; Figures 5b and c are ground level views of the same site. Figure 5b shows a ground crack running in front of the truck-mounted drill. The ground in front of the drill has dropped down a few inches. Figure 5c shows a close-up of one of the fracture planes, which also shows displacement. The block of very weathered rock affected by this fracturing is 40 ft thick, 125 ft long, and 60 ft high. The quarry bench below has been backfilled with overburden to keep the block from tipping out and to allow mining of the good rock which lies behind the drill.

Figure 6a, a ground-level view of Washington County quarry site 8a, shows a much smaller block of ground tipping out. Because of the fine size, 1-in. to 6-in. jointing (Figure 6b), the quarry was operated by ripping. By this method of mining, a highwall which will stand for a period of time can be produced along a zone of weakness.

Figure 7a, an aerial view of Multnomah County quarry site 6, shows multiple bench mining of basalt of the Columbia River Basalt Group and the amount of resource remaining to be mined. Figure 7b shows the product size, ranging from crushed stone to jettystone. This site is also discussed in the mined land reclamation and economic sections of this report.

Sand and gravel operators with pits adjacent to stream channels, such as at Clackamas County gravel site 36 (Figure 8) and Multnomah County gravel site 36 (Figure 9), must consider the effects the excavation may have on erosion during flooding. Improperly constructed berms or unprotected gravel-pit excavations can easily cause streams running through thick gravel to develop new channels. Dikes, roadways, and other structures associated with the rock mining operation, when constructed in the flood path, can either dam streams, causing flood waters to rise higher than normal, or divert the force of the current, leading to accelerated stream-bank erosion.

Property line highwalls can be problems in sand pits such as in Washington County sand sites 41 and 43 (Figure 10). The only equipment needed to mine lacustrine sand is a front-end loader. Because of the ease of mining, bench heights tend to increase, creating hazards to adjoining property, the sand miner, and the public. The sand will stand nearly vertical for long periods of time but can slump without warning at any time.

Uses

Rock material uses are herein described, starting with the use that requires the least size and strength specifications. The terms "embankment" and "fill" are used interchangeably, consistent with the treatment in our various data sources. Materials for embankment or fill to bring roads and construction sites to grade can range in size from sand to jettystone. The only requirement is that the material remain stable after being placed in a low area. In construction of forest access roads or other projects in remote areas, often local material of lower quality is chosen in order to lower the transportation costs. The State or a county occasionally uses lower quality local rock for subbase and high-quality aggregate, often from another locality, for the top course and paving.

Normally, bed rock weathered into fragments, sand, or clay is suitable for embankments or, treated, it may be usable with cement for base rock in road construction.

Rock material used for subbase and base to support roads is usually smaller than 6 in. in the widest dimension. The subbase, above the embankment and below the base course, can be up to 6 in. in the widest dimension but must contain a certain percentage of fines as binder. The base course is made of specified or select graded material ranging in size from 3-1/2 in. to dust. Fines, material smaller than 1/8 in., are needed to hold coarser material in place. Fines should constitute no more than 25 percent of the material, be free draining, and remain stable when saturated. The term "fines" in soil mechanics refers to material smaller than 200 mesh size, usually detrimental to road base material.

The last layer placed on a roadbed is variously called "top course," "surfacing," "topping," or "road metal." Either sand and gravel or stone, graded to less than 1 in., with very little material smaller than 1/4 in., and mixed with a binder of fine soil to keep it from "raveling" off the surface, is used. The surfacing must be durable to withstand wear from vehicle tires. Stone for surfacing roads is usually crushed; some gravel deposits, however, can be screened to produce the correct size.

The term "aggregate" refers to uncrushed or crushed gravel, crushed stone, sand, and artificially produced inorganic material, such as smelter slag, which form the major part of portland cement or asphaltic concrete. Cement concrete is used for highways, streets, sidewalks, curbs, foundations, buildings, and bridges. Asphaltic concrete is used mainly for surfacing highways and parking lots. It lacks the structural strength of cement concrete and must rely on the road base to provide stability. Hot weather can cause an asphaltic road surface to soften. This effect is stronger in cold-rolled asphaltic concrete than in hot mix from a batch plant.

Jettystone and riprap are used to build jetties and to line stream banks, beach fronts, and highway embankments. The rock material used for riprap and jettystone should be hard, durable, angular in shape, resistant to weathering, and denser than 160 lb per cu ft. The difference between riprap and jettystone is size. Riprap weighs from 50 lb to 2,000 lb per stone; jettystone weighs from 0.25 tons to 28 tons per stone (Figure 7). Material of jettystone size is needed only where the extreme force of ocean storms must be counteracted.

Figure 6a. Ground-level view of Washington County quarry site 8a showing overhung highwall falling out to vertical fracture plane. Scale is shown by safety hat in lower left.

Figure 6b. Close-up view shows fine jointing size (1-6 in.) of basalt, which can be mined by ripping.

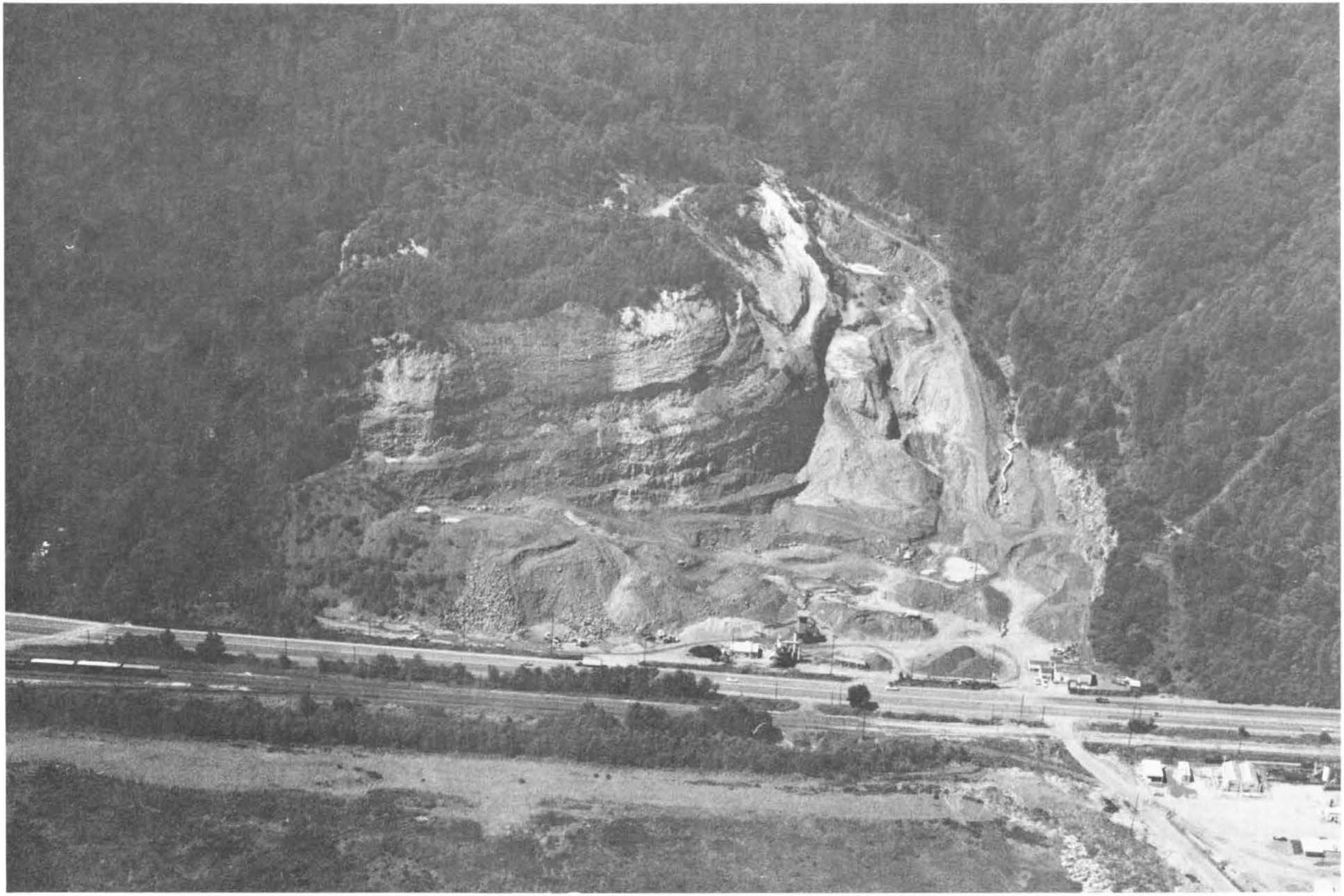

Figure 7a. Oblique aerial view of Multnomah County site 6 showing very high highwall and amount of resources remaining in quarry.

Figure 7b. Ground view of same site showing size range of product produced. Output ranges from pit run to crushed stone to jettystone.

Figure 8. Oblique aerial view of Clackamas County site 36 showing gravel pit being protected from river by dikes.

Figure 9. Oblique aerial view of Multnomah County site 36.

Figure 10. Oblique aerial view of Washington County sand sites 41 and 43 showing water and highwall ground-support hazards.

State Highway Division Laboratory Data

General

Data from all of the laboratory tests performed by the Oregon State Highway Division on materials from the four CRAG counties were made available to this study. Sites from which materials were tested are marked with asterisks in the survey data tables (printed on backs of plates, in pocket). The test data are summarized in tables also printed on the backs of plates: Table 9, Clackamas County, back of Plate 1, Sheet 3; Table 10, Columbia County, back of Plate 2; Table 11, Multnomah County, back of Plate 3; and Table 12, Washington County, back of Plate 4.

Sometimes several types of tests were performed on material from one site; in other instances only one test was done. Samples for testing were selected by various people over a long period of time, and the testing was done by various people. Data given in the tables should, therefore, be regarded only as guidelines.

Different size fractions from the same site will give different test results. Therefore, to present the best statistics for an entire deposit rather than for a particular size fraction, data ranges (the highest and lowest values) are given in the laboratory data tables. No attempt was made to determine weighted data averages for sites. If no range is recorded for material from a particular site, either all test results were the same or only one test was conducted. Table 13 gives test standards for each type of use.

Table 13. Test standards by usage

Usage	Test standards						
	Specific gravity (minimum)	Los Angeles rattler (maximum percent)	Sodium sulfate (maximum percent)	Plasticity index (nonplastic or maximum percent)	Liquid limits (nonplastic or maximum percent)	Oregon degradation: Maximum (percent)	Oregon degradation: Maximum height (in.)
Asphalt concrete aggregate							
Fine – $\frac{1}{4}$ in.		35	18	6	33	30	4
Coarse – 1 in. + $\frac{1}{4}$ in.		30	18			30	3
Cement concrete aggregate							
Fine – 3/8 in. + 100 mesh		30	10			30	3
Coarse – $2\frac{1}{4}$ in. + $\frac{1}{4}$ in.		30	12			30	3
Surface – topping		35					
Base		35		6	33	30	3
Subbase		45					
Riprap	2.5		16			35	8

For those not familiar with the tests, a brief description of each is in order.

Specific gravity

Specific gravity is an index number that is the ratio between the weight of a unit volume of a substance and the weight of an equal volume of water at the same temperature and pressure. The higher the number, the denser and, in most cases, the stronger the rock material.

Los Angeles rattler

This test indicates how material will withstand the grinding action of heavy traffic. The material to be tested is weighed, subjected to tumbling for a set time, screened, and reweighed. The statistic listed is the percentage lost during the testing.

Sodium sulfate test

The sodium sulfate test is used to determine how weather will affect rock material. The material is weighed, tested, then reweighed. Testing consists of soaking the sample in a strong brine solution at an elevated temperature for 16 to 18 hr and then drying it at an elevated temperature for 2 hr. This is repeated several times. The statistic reported is the percentage of loss.

Plasticity index and liquid limits

To test the clay content of a rock material sample, the plastic and liquid limits must be determined, from which the plasticity index is derived. The plastic limit, the lowest water content by weight percent at which the material becomes plastic, is the water-content boundary between the plastic and semisolid states. The liquid limit is the moisture content, by weight percent, at the water-content boundary between the semiliquid and the plastic states. The plasticity index is the water-content range within which a rock material is plastic. Numerically it is the liquid limit minus the plastic limit.

Oregon degradation test

The Oregon degradation test is designed to measure the quantity and quality of the material produced by attrition similar to that caused in a roadway by repeated traffic loading and unloading. The quantity is indicated by a weight percentage of fine material produced; the quality is measured by a modified sand equivalent test. The fine material is made by using air jets to rub one particle against another in water.

RECLAMATION AND LAND USE PLANNING

General

A comprehensive land use plan that attempts to accommodate surface mining must address built-in conflicts with other objectives of the plan. Residential areas must be protected from noise, dust, vibration, traffic, and unsightliness of pits and quarries, but a ready supply of mineral resources to be used for the good of each of the counties and the State of Oregon must be assured, as must a low-cost supply of rock material for construction purposes. Because of transportation costs, a mine providing material for urban construction should be in or near town. For timber harvest roads, quarries should be only a few miles apart.

Reclamation Assistance

County planners and zoning decision makers may not have a tax base which allows them to hire all the expertise needed for making technical decisions concerning the acceptability and/or feasibility of a particular reclamation plan or the integration of surface mining within a comprehensive land use plan. The Oregon Department of Geology and Mineral Industries, which regulates surface mining, is a source of such expertise.

In the past, monetary assistance has been provided to reclaim surface mines for recreation under the U.S. Department of the Interior, Bureau of Outdoor Recreation, Program of Reclamation for Recreation. The Bureau's report, "Sources of Assistance in Reclaiming Surface Mined Lands for Outdoor Recreation," lists sources of assistance for all types of recreation (U.S. Department of Interior, 1974).

The National Sand and Gravel Association has published an outstanding series of reports (Bauer, 1965, 1970; Baxter, 1969; Jensen, 1967; Johnson, 1966; National Sand and Gravel Association, 1960; and Schellie and Rogier, 1964) on all phases of reclaiming sand and gravel and rock quarries. The Mined Land Reclamation Division of the Oregon Department of Geology and Mineral Industries has a set of these reports on loan, which may be examined at the Division's Albany office.

Among uses for mined-out areas are housing, both single and high-rise; open space, such as regional parks, golf courses, and country clubs; water impoundments, such as municipal water reservoirs, water sources for fire protection, water-based parks, or sewage lagoons; commercial-industrial sites; sanitary or demolition fills; and agriculture, such as truck farms or tree farms.

Reclamation Examples and Advice

Examples of many types of mined land reclamation can be found in the four Oregon CRAG counties. Given enough time, certain rock material sites may reclaim themselves by revegetation. Figure 11 shows how, over a period of time, Washington County quarry site 36a has converted to pasture and to a small, shallow-slope water impoundment that is being used by cattle. A more dramatic, nearly completed example of reclamation appears in Figure 12, which shows how Clackamas County site 2 was converted from a worked-out pit to an industrial complex.

Most urban areas need places to store each year's mountain of garbage. In Portland, the garbage mountain appears to be about the size of the hole dug each year for rock materials. Many pits have been mined out to below the water table. If these pits could be used as sanitary fills, a major urban problem would be solved.

Figure 11. Oblique aerial view of Washington County site 36a. Nature has reclaimed site into pasture land and to a small, shallow-slope water impoundment that can be used by cattle.

Figure 12a. Oblique aerial view of Clackamas County site 2 taken just after resource was mined out.

Figure 12b. Same site being developed for industrial park. Note how highwalls have been shaped for public safety.

Figure 13a. Oblique aerial view of Multnomah County site 16 showing resource nearly depleted and demolition filling begun.

Figure 13b. Ground-level view of northwest corner of same site showing land surface regained with this type of reclamation.

In a recent paper on reclamation, Summer (1978) points out that the sides and bottoms of sand and gravel pits can be lined with a clay sealant to protect water supplies and soils from the liquid and gaseous toxic leachates of a sanitary landfill. If clays found in the four counties are not suitable for the sealant, it might be feasible to import bentonite clay, which swells up to 15 times its dry volume with the addition of water, from eastern Oregon.

Discussion of the design and engineering of a sanitary landfill is beyond the scope of this report. But we can observe that Federal, State, county, and local agencies might coordinate their efforts at a selected east Portland gravel pit to attempt development of a sanitary landfill technology appropriate for Oregon. With sound engineering and strong supervision to assure that the plans are carried out, open space that could be turned into attractive and/or productive sites could be the result. Figure 13 shows how land surface was completely regained at Multnomah County site 16.

Multnomah County site 6 (Figure 7) could be converted to an industrial or public park after it has been mined out, although this site has the highest highwall of any site in the four counties. If mining were to cease suddenly, this quarry, with its huge resource available to the Portland market, would be a hazard to the public forever.

See Appendix 2 for discussion of Oregon's formal mined land reclamation program; the roles of the State, local governments, and operators in this program; the Oregon Department of Geology and Mineral Industries Mined Land Reclamation Division procedures; and the economics of reclamation.

ECONOMICS, STATISTICS, AND FORECASTS

Economics

To many people, land is only a surface, sometimes flat, sometimes hilly, that may be low and swampy or high and dry. Land use planners talk about these surfaces in such terms as population per square mile, runoff per drainage basin, or tons of fallout per acre. To geologists, land is a three-dimensional block of the earth's crust; each block is unique in many ways, though surfaces of adjoining parcels may appear to be identical. Immediately below the surface may be a wealth of mineral resources which may be recovered if the landcover is removed. In the four Oregon CRAG counties, that wealth includes clay and shale, sand and gravel, and quarry stone.

Land is, in part, the basis for most economic activities. For example, communities rely on abundant and nearby sources of aggregate in the form of sand and gravel or crushable rock. A century ago, these materials were readily available on or near the surface in certain areas. Today these easily mined deposits are largely gone. Unfortunately, land use planning often fails to recognize that mineral wealth may lie hidden beneath the surface, and much zoning has therefore effectively prohibited the development of these resources. According to the U.S. Bureau of Mines mineral production value statistics, the total production of sand and gravel and stone in the Oregon CRAG counties from 1940 through 1975 is $281,651,000. A total of 3,003 acres have been affected by mining; for every acre mined, $93,790 of value was added to the area's economic life. This is only the value at the mine site and does not include any transportation or other construction values.

The rock material industry within the CRAG area is not operating in an open competitive market. The market has only a few rock material sellers (producers), and each of these is aware of the others' resources, output, and production costs. If one producer changes his price, the others react to that price change. The Portland market is an oligopoly, largely because it is difficult for a new firm or an established firm to bring a new mining site into the market. In recent years, zoning restrictions and local opposition have so limited the acceptance of proposed new mining sites that only two have been allowed to enter the market in or near Portland since 1972, and none have been admitted since 1974. Three rock material sites, Columbia County site 95 and Multnomah County sites 6 and 36, are the price leaders for the Portland urban area. These three control almost all of the potential for the urban center and 18 percent of the potential for the entire four-county area, which contains a total of 674 rock material sites.

A measure of competition does exist among operators; it also exists between the two rock material commodities, sand and gravel and stone, with stone, on the average, 25 percent more costly to produce. Zoning trends from the recent past indicate that, in the future, competition will be lessened, which means that the price of rock materials will rise. The price rise could be very dramatic if one or more of the price leaders were out of the competition. Other factors will affect pressure for price increases. As the urban and near-urban sites are worked out and new ones are not allowed into the market, rock material must be brought from farther away. The price leaders will allow the price to rise to cover the added cost of transportation, as long as their share of the market is maintained. This means that the price leaders should make a good profit while the others will make enough to stay in business. If the price leaders are not in the market, the price will rise more than enough to cover transportation so that the next higher cost price leader may make a good profit. The suburban and rural markets outside Portland are more or less competitive than is the urban center, depending on the number and mix of operations. For example, the Beaverton-Hillsboro-Tigard market is quite competitive because it contains a great number of quarries and sand pits.

When a national heavy construction company wins a major highway contract, the effect of its operation on an urban market is usually small. Most contractors have a State-owned rock material source or can mine a new site for the life of a project. A notable exception to this occurred during the widening of I-5 at Roseburg, Douglas County, when a million tons of stone from Mount Hebo was dumped onto a local sand and gravel and stone market of about 400,000 tons per year. Local producers almost reached a point of parading with signs reading, "Contractor, go home."

A prediction of how much prices will rise in the future requires an in-depth study both of the costs of transportation by different modes and of rock material sources within and without the four-county area that could be reached by each mode and still be competitive in the Portland market. The Army Corps of Engineers is approaching this type of a study (U.S. Army Corps of Engineers, 1977) in facing a decision to enlarge the locks at the Bonneville Dam.

According to its published study (U.S. Army Corps of Engineers, 1977) and later unpublished updating work, the Corps estimates that mining and processing a ton of rock material by the year 1990 will cost from $1.65 to $2.10, loading it will cost $0.10 to $0.15, and barging it from Dundee, Yamhill County, a distance of 42 river mi, will cost $1.30. Trucking a ton from a quarry 18 mi southwest of Portland to the same point as the barge will cost $2.59 to $2.88. The total delivered cost to a central point, including 40 percent administration and profit, will be $4.27 to $4.48 for barged material and $6.27 to $6.70 for trucked material. Today's pit prices average from about $3.50 for pit run to $4.50. Transportation costs from the pit to the consumer vary with the route but average at least $2.00 per ton. Present delivered cost of a ton of sand and gravel and stone ranges from $5.50 to $6.50. The predicted delivered cost for the year 1990 is $6.27 to $8.70.

The economics for clay mining differ from those for sand and gravel and stone. Estimated production is only a few thousand tons per year, and that value does not include firing brick or tile. Over many years, the demand for brick and tile has remained steady or declined slightly. Competition from plastic drain tile producers is a major reason. The plastic pipe shortage, however, was one of the first to be caused by the energy crisis, and a segment of the market converted back to clay tile.

For many years, lightweight aggregate from Lite Rock shale quarry, Washington County site 1, competed with pumice from eastern Oregon in markets as far away as Seattle, Washington. During 1977 the mine was closed, and the equipment was sold.

Small-scale mining of the shale bed at Clackamas County site 229 continues from an underground adit. Market demands for the dried ground material for animal feed supplement and soil conditioner seem to stay constant.

Statistics

The U.S. Bureau of Mines is the source of annual mineral production statistics. The Bureau uses a mailed-out questionnaire to collect data for these statistics, which show commodity, tonnage, value, use, and type of producer for each of the various mineral resources. Although response to the questionnaire is entirely voluntary and seldom reaches 100 percent return, the Bureau obtains enough figures to be nearly in agreement with those derived from on-site surveys. Bureau statistics show that 211,441,874 tons of sand and gravel and stone were produced in the four Oregon CRAG counties from 1940 through 1976. Table 8 data, based on field survey, show that 212 million tons have been mined from these counties; however, the addition of an estimated 55.9 million tons from below the water level of the Willamette River, which cannot be surveyed (statistics from Division of State Lands), brings the total to 268 million tons. Comparison of these figures indicates that 79 percent of the four-county production was counted by the U.S. Bureau of Mines, assuming that all production took place between 1940 and 1975. Part of the uncounted production was that of the U.S. Forest Service, which reports only a total figure for its production throughout the State. (In 1976, this was 7,157,000 tons.)

Table 14 shows production statistics for the Oregon and Washington CRAG counties, the Willamette Valley, and the State of Oregon.

Forecasts

Estimates of future consumption of sand and gravel and stone must take into consideration factors that have controlled historic production. From 1940 through 1975, production is assumed to have equaled consumption. As defined by the U.S. Bureau of Mines, production is sales or shipment from a pit or quarry; therefore, production is consumption if no rock material is shipped into or out of the area. County lines, however, are not barriers to the movement of rock material. A Yamhill rock quarry supplied the riprap

Table 14. Sand and gravel and stone production statistics for CRAG counties, Willamette Valley, and State of Oregon

	CRAG									Willamette Valley	State of Oregon
	Oregon*			Washington**			Total				
Year	Sand and gravel (tons)	Stone (tons)	Total (tons)	Sand and gravel (tons)	Stone (tons)	Total (tons)	Sand and gravel (tons)	Stone (tons)	Total (tons)	Sand and gravel and stone (tons)	Sand and gravel and stone (tons)
1940	859,457	196,930	1,056,387	206,561	38,499	245,060	1,066,018	235,429	1,301,447	2,064,902	5,726,272
1941	1,355,162	325,708	1,680,870	189,847	102,634	292,481	1,545,009	428,342	1,973,351	2,490,284	6,804,785
1942	1,659,374	372,910	2,032,284	415,929	40,127	456,056	2,075,303	413,037	2,488,340	3,905,600	9,256,341
1943	1,889,848	251,267	2,141,115	403,752	16,990	420,742	2,293,600	268,257	2,561,857	3,573,875	7,598,518
1944	1,626,318	227,648	1,853,566	177,318	20,016	197,334	1,803,636	247,664	2,051,300	3,612,477	6,548,393
1945	1,363,485	265,132	1,628,617	163,936	60,119	224,055	1,527,421	325,251	1,852,672	3,741,759	6,024,464
1946	1,941,829	165,688	2,107,517	195,998	273,901	469,899	2,137,827	439,589	2,577,416	4,673,741	6,893,753
1947	1,909,684	195,903	2,105,587	188,216	326,998	515,214	2,097,900	522,901	2,620,801	4,690,188	9,022,440
1948	2,874,210	253,823	3,128,033	271,402	129,479	400,881	3,145,612	383,302	3,528,914	5,612,174	12,067,175
1949	2,673,399	384,353	3,057,752	191,171	152,475	343,646	2,864,570	536,828	3,401,398	6,075,044	11,532,171
Total	18,152,766	2,639,362	20,792,128	2,404,130	1,161,238	3,565,368	20,556,896	3,800,600	24,357,496	40,440,044	81,474,312
1950	2,873,526	374,858	3,248,384	123,990	210,761	334,751	2,997,516	585,619	3,583,135	5,422,329	12,041,740
1951	3,428,373	366,907	3,795,280	235,821	157,700	393,521	3,664,194	524,607	4,188,801	6,069,248	19,226,138
1952	6,958,099	1,462,832	8,420,931	126,394	146,226	272,620	7,084,493	1,609,058	8,693,551	12,204,984	18,470,335
1953	3,231,045	329,920	3,560,965	187,045	160,720	347,765	3,418,090	490,640	3,908,730	6,958,208	13,704,538
1954	3,721,841	288,330	4,010,171	562,628	182,127	744,755	4,284,469	470,457	4,754,926	8,299,871	19,029,592
1955	3,643,673	1,809,927	5,453,600	142,652	442,355	585,007	3,786,325	2,252,282	6,038,607	9,887,163	19,695,815
1956	4,410,939	643,685	5,054,624	202,653	168,442	371,095	4,613,592	812,127	5,425,719	9,499,369	17,735,148
1957	4,382,006	316,228	4,698,234	137,108	98,816	235,924	4,519,114	415,044	4,934,158	10,507,189	23,425,770
1958	3,571,224	1,976,173	5,547,397	118,527	209,843	328,370	3,689,751	2,186,016	5,875,767	13,255,187	25,541,043
1959	4,459,931	831,613	5,291,544	227,466	354,975	582,441	4,687,397	1,186,588	5,873,985	18,136,955	31,427,642
Total	40,680,657	8,400,473	49,081,130	2,064,284	2,131,965	4,196,249	42,744,941	10,532,438	53,277,379	100,240,503	200,297,761
1960	4,562,976	1,528,741	6,901,717	246,016	155,627	401,643	4,808,992	1,684,368	6,493,360	17,738,268	34,585,959
1961	3,348,843	1,773,116	5,121,959	375,680	434,089	809,769	3,724,523	2,207,205	5,931,728	14,421,588	29,753,606
1962	2,959,804	1,212,087	4,171,891	259,126	353,850	612,976	3,218,930	1,565,937	4,784,867	17,783,312	33,126,754
1963	3,814,258	1,685,484	5,499,742	161,613	1,061,197	1,222,810	3,976,871	2,746,681	6,722,552	15,936,558	35,407,641
1964	4,208,000	1,663,780	5,871,780	404,000	244,942	648,942	4,612,000	1,908,722	6,520,722	14,717,281	34,372,823
1965	4,290,000	1,766,747	6,056,747	1,504,000	570,202	2,074,202	5,794,000	2,336,949	8,130,949	21,413,948	43,012,392
1966	3,454,000	2,261,871	5,715,871	377,000	812,263	1,189,263	3,831,000	3,074,134	6,905,134	17,839,399	68,614,999
1967	4,727,000	2,418,295	7,145,295	254,000	450,560	704,560	4,981,000	2,868,855	7,849,855	17,208,918	32,830,522
1968	6,008,000	4,360,577	10,368,577	531,000	229,662	760,662	6,539,000	4,590,239	11,129,239	19,615,982	32,572,498
1969	5,859,000	2,535,488	8,394,488	757,000	362,681	1,119,681	6,616,000	2,898,169	9,514,169	14,691,575	27,401,811
Total	43,231,881	21,206,186	64,438,067	4,869,435	4,675,073	9,544,508	48,101,316	25,881,259	73,982,575	171,366,829	371,679,005
1970	6,709,000	2,496,793	9,205,793	705,000	537,783	1,242,783	7,414,000	3,034,576	10,448,576	15,195,239	30,971,335
1971	7,727,000	2,386,054	10,113,054	410,000	768,203	1,178,203	8,137,000	3,154,257	11,291,257	16,815,348	34,023,739
1972	9,833,853	2,912,471	12,746,324	420,000	1,091,179	1,511,179	10,253,853	4,003,650	14,257,503	19,785,885	35,404,468
1973	8,264,000	5,024,432	13,288,432	588,000	1,199,565	1,787,565	8,852,000	6,223,997	15,075,997	22,886,796	36,212,979
1974	7,560,459	3,746,589	11,307,048	310,000	817,976	1,127,976	7,870,459	4,564,565	12,435,024	22,023,531	41,910,897
1975	6,634,916	2,971,602	9,606,518	298,000	900,000***	1,198,000	6,932,916	3,871,602	10,804,518	17,318,350	37,802,162
1976	7,424,033	3,439,347	10,863,380	272,000	800,000***	1,072,000	7,696,033	4,239,347	11,935,380	18,992,584	37,903,905
Total	54,153,261	22,977,288	77,130,549	3,003,000	6,114,706	9,117,706	57,156,261	29,091,994	86,248,255	133,017,733	254,229,485
Grand total	156,218,565	55,223,309	211,441,874	12,340,849	14,082,982	26,423,831	168,559,414	69,306,291	237,865,705	445,065,109	907,680,563

* Clackamas, Columbia, Multnomah, and Washington Counties.
** Clark County.
*** Estimated by authors.

used to build Scoggins Dam in Washington County. Sand and gravel from Multnomah County was barged to Clatsop County to be used in concrete for the Astoria Bridge. Therefore, in a single county, a smaller local political unit, or a political unit that overlaps two counties, production may not equal consumption. One local unit's consumption may be supplied totally from outside the unit; another unit may be a large net exporter of rock material. However, production statistics for larger political units or areas as the State, the Willamette Valley, or the four-county area can be used as consumption indexes for the years 1940 through 1975 because exports and imports for these units are nearly in balance.

It is beyond the scope of this report to determine the consumption needs of small political units such as cities. Furthermore, because time is used as an independent variable for projecting consumption, this study is not meant to be a definitive treatment of rock material demand for either the State, the Willamette Valley, or the four-county area. The method used in this study does produce a reasonable estimate of future consumption for these units, but an in-depth examination of rock material demand requires an higher level of economic analysis.

To show past production trends for the Oregon CRAG counties and to make it possible to compare their annual productions to those of the Willamette Valley and the State of Oregon, tonnages from Table 15 are plotted against time, using several different types of least-squares correlations. These models for past production and future consumption are presented in Appendix 3, along with a discussion of basic statistical concepts of forecasting time trends. In this appendix, Table 15, Figure 14, and all steps taken to arrive at the models used for the forecasts presented in this section are discussed at length; and Table 16 and Figures 17, 18, and 19 present data for and projections of all models.

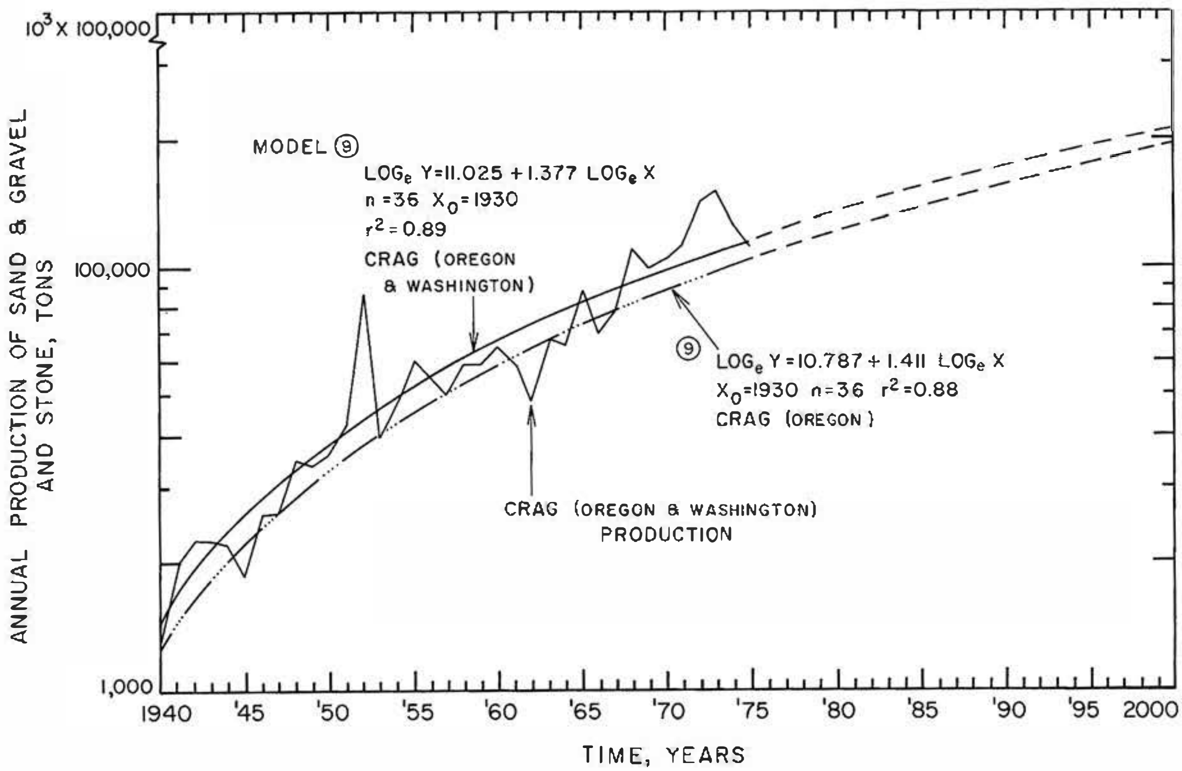

Figure 14. Annual production of sand and gravel and stone v. time.

The authors believe that the projections presented in Table 15 for the State, Willamette Valley, and CRAG counties are the most reasonable, based on past trends for the State obtained with power-curve fit. Table 15 summarizes projected annual consumption tonnages and per capita production for the year 2000 for the selected models. The production tonnages and per capita production data for 1976 are also given.

Table 15. Present production and predicted future consumption of sand and gravel and stone

	1976		2000	
Model number	Production (tons)	Per capita production (tons)	Projected consumption (tons)	Per capita consumption (tons)
State of Oregon				
6	37,903,905	16	88,900,000	26
Willamette Valley				
7	18,991,621	12	46,900,000	22
CRAG (Oregon and Washington)				
8	11,935,380	--	21,300,000	--
CRAG (Oregon)				
9	10,863,380	11	19,400,000	15

For the year 2000, 19.4 million tons of rock material will be needed in the Oregon CRAG counties. This represents a per capita consumption of 15 tons which is less than that figure for the entire State for 1976.

If the 1976 production is divided into the total future potential indicated in Table 8, the four-county resources, in a no-growth situation, could last 47 years. But, if economic and population growth occur as predicted by model 9 (Appendix 3), the resources would instead be gone in 31 years, by the year 2007. This does not mean that the four counties will be out of rock materials by the year 2007; it means that new sites and/or imports will be needed in both the immediate and distant future. It could also mean that today's producing sites should conceivably be protected from closure until the resource is depleted. The trend for the future is for rock material to increase in price. If producing sites are closed prematurely and new ones are not allowed to open, the price rise will be greatly magnified. Production most likely will not equal consumption between 1977 and 2000. The import-export balance should tip toward imports.

Any new sites should be planned in terms of market needs and secondary land uses. Data from the survey data tables indicate that some sites will be depleted faster than others. Planners should take into account the life expectancy of individual sites.

Two sites are of particular importance to the Portland market: Multnomah County sites 6, Rivergate Rock, and 36, Ross Island. These contain 7 percent of the future supply of rock material for the four counties and 56 percent of Multnomah County's supply. Presently these two are price leaders. If one or both were to be taken out of the market, the cost of aggregate would rise because of higher transportation costs and less competition.

All the modeling and projecting for this study utilizes annually combined sand and gravel and stone figures. To separate the projection for the year 2000 into each component and to determine if one commodity is replacing the other, three least-square models, the same types used to estimate production, are used. The sand and gravel tonnage figure for each of the 36 years is divided by the sand and gravel and stone tonnage figure for the same year, and the figures are plotted against time (Figure 15). All three mathematical models developed for this study show that sand and gravel production is becoming a smaller portion of the total production.

Figure 15 shows that the downward trend holds true not only for the State of Oregon but also for the Willamette Valley and for the four Oregon CRAG counties. The r^2 values are low; however, they are high enough to pass the Student T test at the 95-percent level (Appendix 3). By the year 2000, sand and gravel should account for only 55 to 65 percent of the total rock material annual production of the four counties if these trends continue. The nature and source of imported rock material could modify or even reverse this trend.

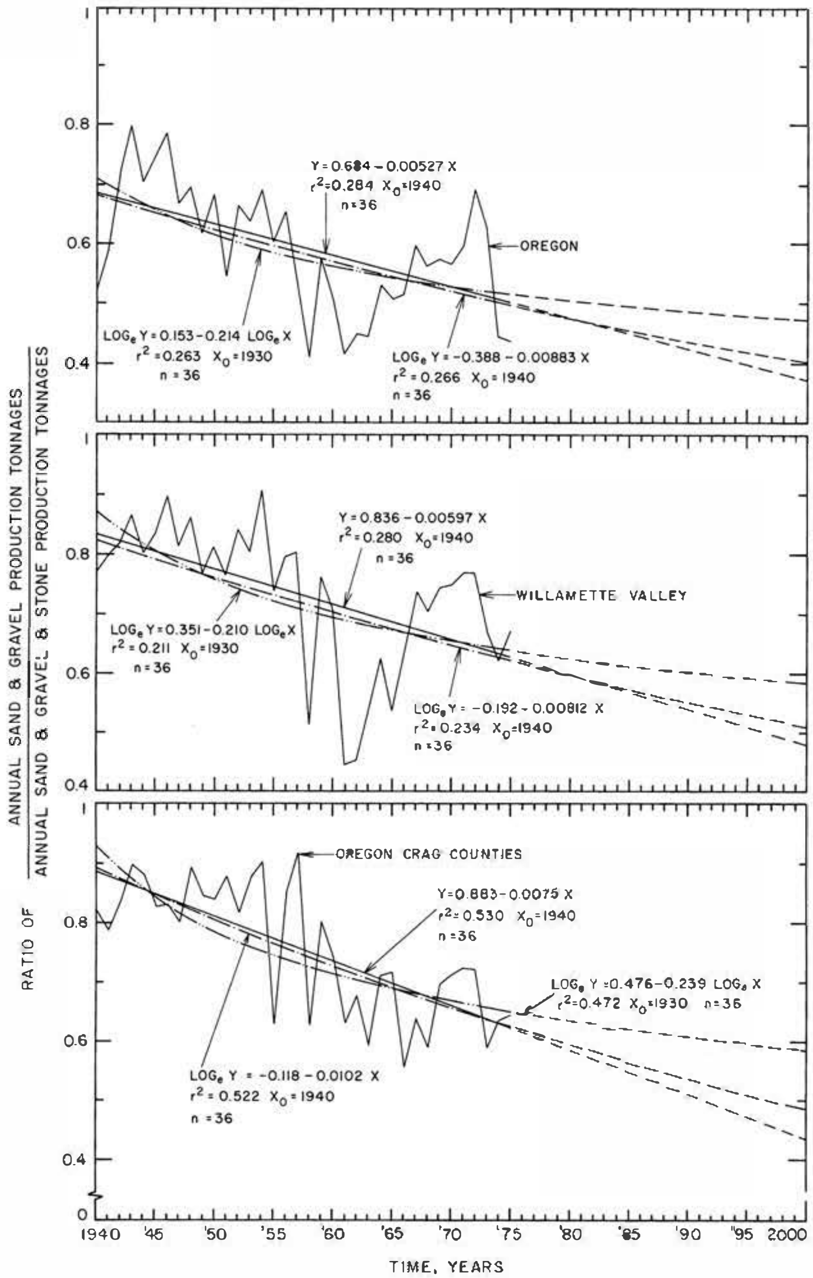

Figure 15. Oregon, Willamette Valley, and CRAG production tonnage ratios of sand and gravel to sand and gravel and stone v. time.

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APPENDIXES

APPENDIX A. GLOSSARY

aggregate - crushed or uncrushed gravel, crushed stone, sand, or artifically produced inorganic material used to form the major part of portland cement concrete or asphaltic concrete.

alluvium - earth, sand, gravel, or other rock materials transported and laid down by flowing water.

aplite - a light-colored igneous rock characterized by a fine-grained "sugary" texture. Generally free from dark minerals.

bar - ridge-like accumulation of sand, gravel, or other alluvial material formed in a stream where a decrease in velocity causes deposition.

basalt - igneous rock of volcanic character, composed chiefly of pyroxene and plagioclase feldspar; usually fine grained and black.

base rock or base course - layer of specified or select graded material of planned thickness constructed on the subgrade or subbase of a road. Size is usually 3½ inch minus for base course; can be larger for subgrade or subbase.

bed rock - any more or less solid, undisturbed rock in place at the surface of the earth. May be exposed or may be hidden beneath unconsolidated surficial material.

crushed gravel - oversize water-rounded stones from a gravel pit that have been crushed and screened to certain maximum and minimum dimensions. Individual fragments have at least one broken face.

crushed stone - quarry rock (bed rock) which has been crushed and screened to specific dimensions.

diabasic - rock with lath-shaped crystals of plagioclase lying in all directions among the dark, irregular, augite grains.

diced rock - closely jointed and/or naturally fractured rock outcrop; can usually be excavated from a quarry with little or no blasting.

diorite - granitoid rock composed essentially of hornblende and plagioclase feldspar; usually coarse grained and light colored.

flood plain - strip of relatively smooth land adjacent to a river channel; generally covered with water when river overflows its banks during floods.

gabbro - igneous rock of granitoid texture consisting of plagioclase and pyroxene.

granitic (granitoid) - term used describing the textures of those igneous rocks which are composed entirely of recognizable minerals of approximately the same size. The most familiar rock with this texture is granite.

gravel - small stones and pebbles worn by action of air and water; larger than sand and smaller than cobbles; the size of material that passes a 3-inch sieve and is retained on a 3/8-inch sieve. Cobble gravel may have sizes up to 10 inches.

gravel bed - deposit of stream-transported stones and sand. These water-worn and round to subrounded stones represent prehistoric stream deposits.

gravel pit - excavation in an alluvial area from which sand and gravel have been or are being mined.

interstices - opening or space between one thing and another; spaces between crystals in igneous rocks or between sand and rock fragments in sedimentary rocks.

joint - surface of actual or potential fracture or parting within a rock; surface is usually planar and often occurs with parallel joints to form part of a joint set.

materials source - gravel pit or rock quarry.

meander - one of a series of somewhat regular, sharp, freely developing, and sinuous curves, bends, loops, turns, or windings in the course of a stream.

outcrop - that part of a rock formation or stratigraphic unit that is exposed at the surface of the ground or would be exposed if surficial materials were removed.

pit or quarry run - raw rock material taken from a pit or quarry; not crushed, screened, or dried.

point bar - one of a series of low, arcuate ridges of sand and grovel developed on the inside of a growing meander.

porphyritic - texture of igneous rock containing both large- and small-sized crystals.

quarry - bedrock outcrop or talus area from which rock material is being dug or mined.

road metal - gravel or stone suitable for surfacing roods.

rock material - any natural occurrence of consolidated or unconsolidated mineral matter and products dug or mined from that occurrence. Includes cloy, shale, pumicite (volcanic ash), volcanic cinders, scoria, sand and grovel, and stone. Also includes the above material mined as pit or quarry run that has been crushed, screened, or dried. Does not include material calcined or otherwise processed to alter physical characteristics.

sand - any hard, granular rock material resulting from the natural disintegration of bed rock; finer in size than grovel and coarser than dust; the size of material that posses a 3/8-inch sieve but is retained on a 200-mesh sieve.

sand and grovel deposit - on alluvial deposit composed of a mixture of sand, gravel, cobbles, and boulders.

stone - individual blocks, mosses, fragments, or crushed sizes of material token from bed rock in a quarry or natural outcrop.

stratified - rocks that were originally deposited in horizontal beds or strata.

talus - loose, unsorted, and incoherent rock fragments and cliff debris transported downslope chiefly by gravity.

zeolite - secondary mineral found in cavities, on joint planes, and in cracks in basaltic rock.

APPENDIX B. MINED LAND RECLAMATION

Mined Land Reclamation Law

In passing the Mined Land Reclamation Law (ORS 517.750-517.990), the 1971 Oregon Legislative Assembly found that

"(a) The extraction of minerals by surface mining operation is a basic and essential activity making an important contribution to the economic well-being of the State and nation.

"(b) Proper reclamation of surface-mined lands is necessary to prevent undesirable land and water conditions that would be detrimental to the general welfare, health, safety and property rights of the citizens of this State."

The Assembly therefore declared that the purpose of the Mined Land Reclamation Law was

"(1) To provide that the usefulness, productivity and scenic values of all lands and water resources affected by surface mining operations within this state shall receive the greatest practical degree of protection and reclamation necessary for their intended subsequent use; and

"(2) To provide for cooperation between private and governmental entities in carrying out the purposes of ORS 517.750 to 517.900 and subsection (4) of 517.990."

Role of the Division, the Counties, and the Operator

The State Department of Geology and Mineral Industries has been charged by law to carry out the purposes of the Mined Land Reclamation Law. To discharge its duty under that law, a Division of Mined Land Reclamation was established in Albany, Oregon. The Division procedures were designed to allow as much input into the reclamation plan as possible, to minimize conflict with other land uses, and to insure performance of the planned reclamation. The procedural steps are, briefly, as follows:

(1) A potential mining operator files an application, a reclamation plan (the Division's Reclamation Plan Guideline may be used), and the appropriate permit fee with the Division of Mined Land Reclamation.

(2) The application and plan are copied and submitted for review to 11 State agencies and to the appropriate county. If the operation is to be on Federal land, copies are also sent to the appropriate Federal land manager. The County planners have the opportunity and duty to provide input to an operator's reclamation plan during the review cycle.

(3) Review comments are collected and evaluated by Division specialists.

(4) An on-site inspection is arranged with the operator and a Division specialist. If the review of the reclamation plan has produced some conflict or concerns, representatives of the reviewing agencies may be requested to meet on-site to resolve differences.

(5) On-site inspection determines feasibility of the reclamation plan, resolves conflicts, and determines the amount of bond that needs to be posted by the operator.

(6) The operator accepts the modified reclamation plan and posts the bond.

(7) The Oregon Department of Geology and Mineral Industries issues an operating permit that may or may not have conditions attached to it.

Each county, through its zoning laws, is involved with needs addressed by the Mined Land Reclamation Law. Within their respective roles, the county and/or the State Department of Geology and Mineral Industries may modify or veto a reclamation plan submitted by a mining operator. The two roles are complementary: the Oregon Department of Geology and Mineral Industries has expertise in mining geology, mining techniques, and reclamation processes; the county officials have the best knowledge of local needs and set guidelines that include projections for secondary and tertiary uses. For example: a gravel resource might be kept in an open-space use, such as farming, even if it were circled with urban development. Then, after the area is mined, the secondary use might be as a site for demolition fill; the tertiary use could be as a residential development or a community park.

The operator-landowner's role supplements that of the two agencies. The operator can gain by carrying out the purposes of the Mined Land Reclamation Law. Reclamation is a planning process that allows the operator-landowner to maximize his total profits by continuing utilization of mined-out land.

Reclamation Economics

What is the value of reclamation? A paper by Dunn (1970) addresses this question. By taking the land purchase price and comparing estimates of the value of the land if it is reclaimed and if it is not reclaimed after the resource is mined out, a figure is obtained that shows how much can be spent each year for reclamation, with the owner still receiving a profit on those expenditures if the land is finally sold.

Although Dunn's paper is based on a general assumption which may or may not apply to the CRAG area, the practice of comparing land values with and without reclamation is important to establish within the mining community. A study by Mason and Gray (1977) shows that, with reclamation, the land value of a Marion County mining site increased 135 percent from the time mining started until reclamation was completed, about 3 years later.

According to Dunn, in terms of noninflated dollars, the value of mined-out land with reclamation is five times that of unreclaimed land. Assuming that a rock material site has reserves for 20 years, that the land value with reclamation would be $50,000 and without reclamation would be $10,000, the value of reclamation can be estimated as $40,000. At first it might appear that the maximum justifiable annual expenditure for reclamation would be $2,000 ($40,000 divided by 20 years). That $2,000, however, must be discounted first for 20 years, then for 19, then for 18, etc., to arrive at the real maximum allowable figure. Using a discount figure of 10 percent per year, a curve such as the break-even upper curve in Figure 16, which shows that $270 could be spent the first year, can be drawn. If a 25 percent annual profit is also discounted for reclamation, the lower curve, representing a reasonable annual expenditure for reclamation, can be drawn. These curves indicate an estimated 25 percent profit, or $10,000, at the end of 20 years.

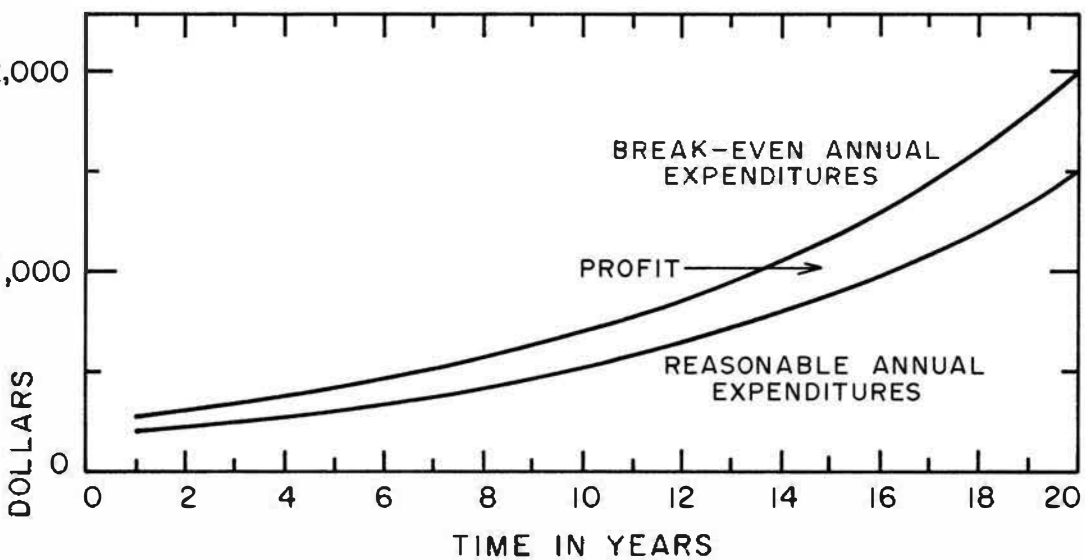


Figure 16. Discounted reclamation costs.

APPENDIX C. FORECAST MODELING

Any economic projection rests on the basic assumption that some identifiable relation exists between the past and the future. The methods used in this particular study are identification of past linear trends and projection of them into the future through the use of least-squares correlations between time and annual production of sand and gravel and stone. To build a projection model using time, population, road construction, county budgets, timber production, and other demand components of rock material consumption is beyond the intent of this report.

Several types of least squares were tried at the State level; the best fit (highest $\underline{r}^2$ value) obtained was then used for the Willamette Valley and for the CRAG counties.

The first step in building the forecasting model was to establish a historical data series. In this case, annual production tonnages for sand and gravel and stone from 1940 to 1975 were available, and production was assumed to equal consumption. The historic time series was plotted on semilog graph paper (Figure 17) to show whether production has been increasing rapidly, increasing slowly, fluctuating, remaining level, or declining over the historic period.

The next step was to choose the length of the data base. The exponential curve type of least square (general formula of $\mathrm{Log}_e\ \underline{Y} = \underline{a} + \underline{b}\ \underline{x}$) produced a straight line on semilog paper; therefore, this type was used to determine the length of the data base to be used in Figure 17. $\underline{Y}$ is the dependent variable (production tonnages), $\underline{a}$ is the constant where the curve crosses the $\underline{x}$ axis, $\underline{b}$ is the slope of curve, and $\underline{x}$ is the independent variable (time). The $\underline{n}$ shown with the formula in Figures 14, 15, 17, 18, and 19 is the number of years used in the least-square correlation. The $\underline{x}_o$ is the starting year for least-square correlation.

Four models were developed: model 1 covers the total time from 1940 through 1975; for model 2, the time span is shortened by 10 years to 1950 through 1975; model 3 is shortened by another 10 years to 1960 through 1975; and model 4 is shortened by an additional 10 years to 1970 through 1975. The range of $\underline{r}^2$ values is from 0.01 for model 3 to 0.83 for model 1; perfect correlation between time and production is 1.0, and no correlation is 0.0.

Each trend was projected to the year 2000. Figure 17 shows how the length of the data base determines the projection for the year 2000. The range of projections using different data base lengths was from 40 to 240 million tons per year. The model that gave the highest $\underline{r}^2$ value (0.83) was model 1, which used the total length of the time series; therefore, the longest data base was used in the next step.

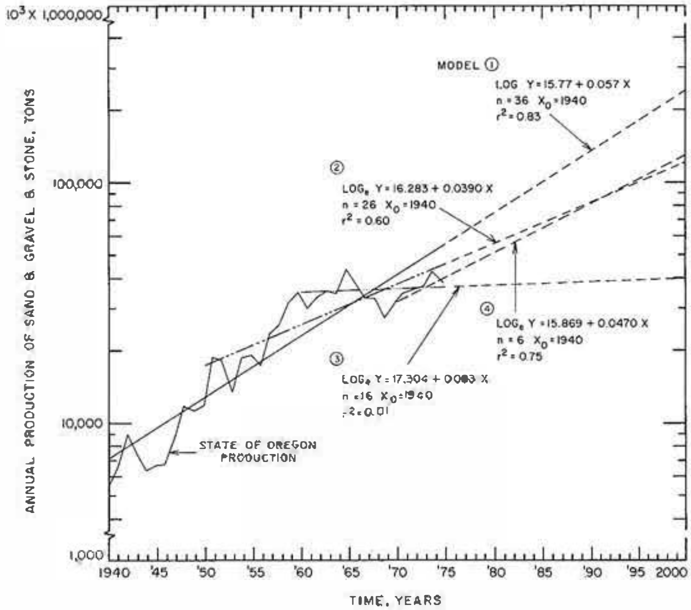
Model 1 and the historic series were replotted (Figure 18). Arithmetical least-square type (model 5), with the general formula of $\underline{Y} = \underline{a} + \underline{b}\ \underline{x}$, was tried. It has an $\underline{r}^2$ value of 0.73. The power-curve least-square type (model 6) with the general formula $\mathrm{Log}_e\ \underline{Y} = \underline{a} + \mathrm{Log}_e\ \underline{x}$ was tried. It has an $\underline{r}^2$ value of 0.88; therefore, this model was used to project the State's future consumption. This least-square type was also used to make projections for the State's smaller political units. Model 6 and the State historic series were then replotted (Figure 19), along with a similar series for the Willamette Valley, for the Oregon and Washington CRAG counties, and for the Oregon CRAG counties. Power-curve types of least square were run for the Willamette Valley (model 7), for CRAG (Oregon and Washington) (model 8), and CRAG (Oregon) (model 9).

The $\underline{r}^2$ values for each of the nine models shown on Figures 14, 17, 18, and 19 were tested by the Student T test. Only the $\underline{r}^2$ value for model 3 was too low to be significant. The Student T test has the form:

$$|t| = \left| \frac{r}{\sqrt{1-r^2}} \right| \sqrt{n-2} \geq t_{\alpha/2}\ ;\ n-2$$

Past trend projections obtained with power-curve fit marked with asterisks in Table 17 for the State, Willamette Valley, and CRAG counties are the most reasonable and were used for Table 16, which summarizes projected annual consumption tonnages and per capita consumption for the year 2000 for each of the models found in Figures 14, 18, and 19. The production tonnages and per capita production for 1976 are also given.

Figure 17. Oregon production tonnages of sand and gravel and stone v. time. Four exponential least-square curve fits with different data base lengths are also plotted with trend lines extending to the year 2000.



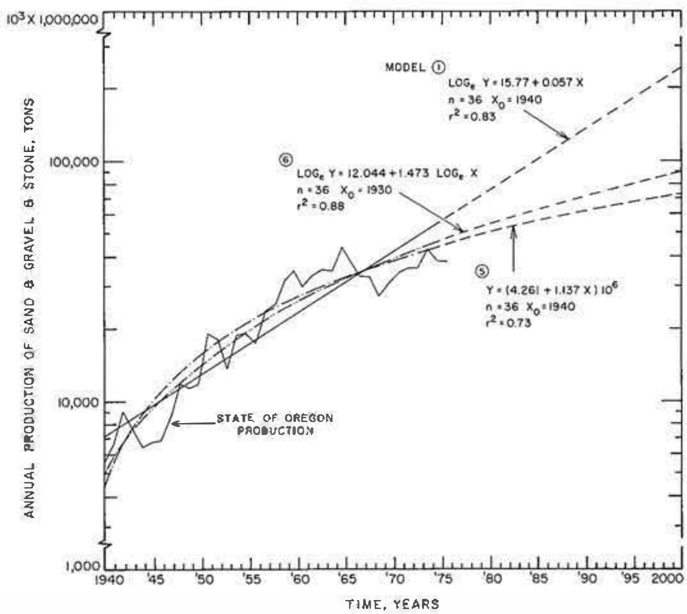


Figure 18. Production tonnages v. time with different tyes of least-square curve fits and their trend lines extended to the year 2000.

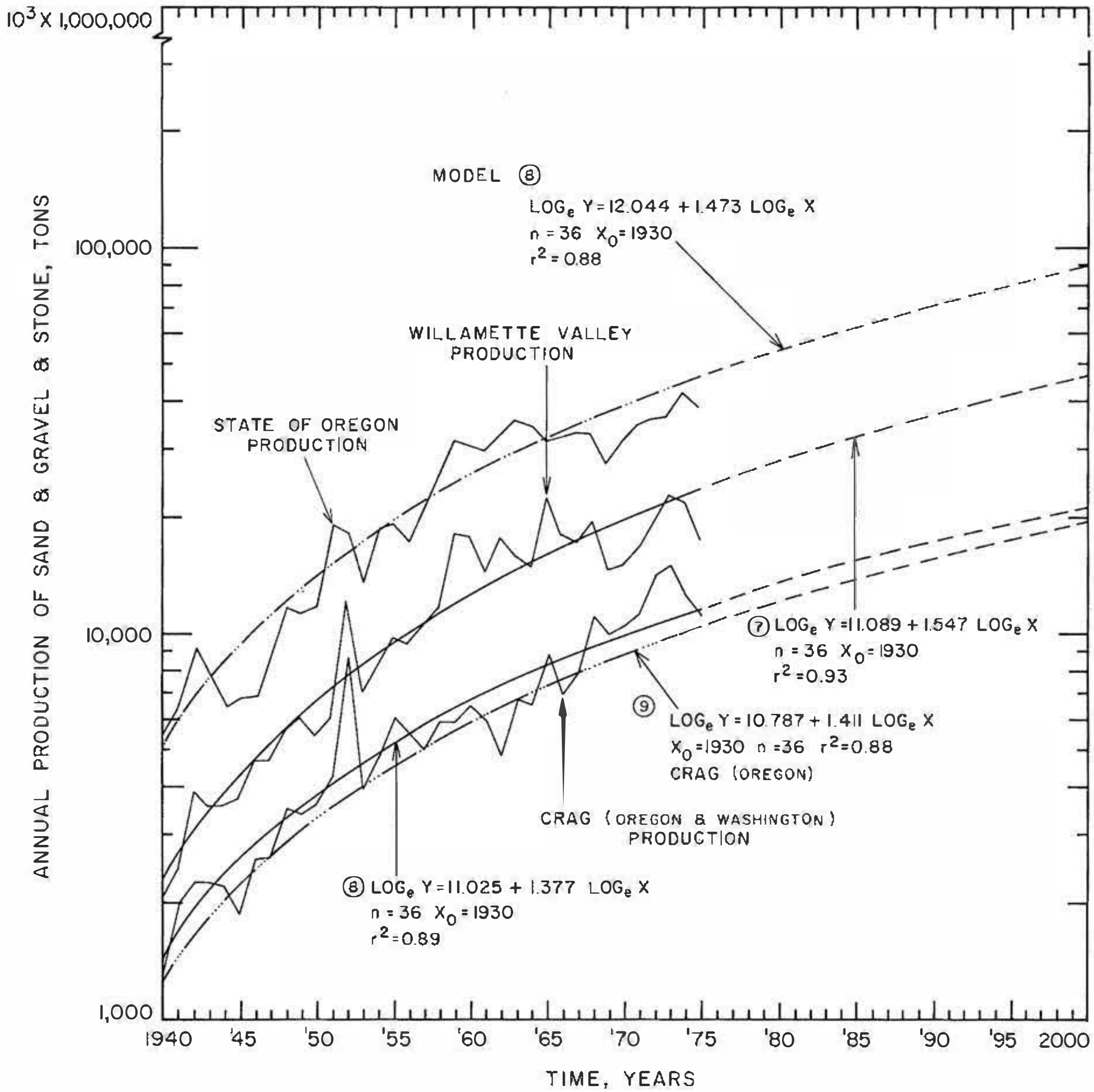


Figure 19. Oregon, Willamette Valley, and Oregon and Washington CRAG counties sand and gravel and stone production tonnages v. time with least-square curve fits.

The per capita statistics are given, not as part of any of the projecting models, but as a tool for comparing today's production with tomorrow's consumption, using the population census statistics and population projections shown in Table 2. The population projection was independent of any work within this study. Model 6 shows a per capita consumption of 26 tons for the State, which gives the appearance of being very high, if the State's projection in Table 2 is correct. However, if more people move to Oregon than has been projected, we will have a lower per capita consumption figure than the 26 tons.

Model 9 shows that by the year 2000, the projected per capita consumption for the CRAG area will be 14 tons, which is less than the present per capita consumption of 16 tons for the State as a whole. The closeness between the two consumption figures indicates the reasonableness of the CRAG projections.

Table 16. Present production and predicted consumption of sand and gravel and stone for all models

Year		1976		2000	
Models*	r^2	Production (tons)	Per capita production (tons)	Projected consumption (tons)	Per capita consumption (tons)***
State of Oregon					
3	0.01	37,903,905	16	40,100,000	12
5	0.73	37,903,905	16	72,500,000	21
**6	0.88	37,903,905	16	88,900,000	26
2	0.60	37,903,905	16	122,000,000	36
4	0.75	37,903,905	16	131,000,000	39
1	0.83	37,903,905	16	240,000,000	71
Willamette Valley					
**7	0.93	18,991,621	12	46,900,000	22
CRAG (Oregon and Washington)					
**8	0.89	11,935,380	-	21,300,000	-
CRAG (Oregon)					
**9	0.88	10,863,380	11	19,400,000	14

* In order of increasing projected consumption.
** Highest r^2 and therefore most reasonable model.
*** See last paragraph, Appendix 3.

TABLE 3 CLACKAMAS COUNTY ROCK MATERIAL SURVEY DATA

Site number	Operator or owner	Commodity	Domain	1/4 section	Section	Township	Range	Status	Past production (1,000 cu yds)	Acres excavated	Acres (plant and stockpile)	Future potential (1,000 cu yds)	Deposit type	Rock type	Geologic formation or unit	Number of benches	High wall (yds)	Jointing	Breaking ground	Processing plant	Usage	Remarks
1	Blacktop Paving Co.	g	P	NE	30	1S	2E	a	75	3	1	300	G	Various	Terrace gravel	2	20	-	r	-	e,b,s,t,c	
2	Crosswhite Enterprises	g	P	NW	29	1S	2E	i	1,800	28	-	0	G	Various	Terrace gravel	1	20	-	r	-	e,b,s,t	Site abandoned
3	Portland Road and Driveway	g	P	SE	29	1S	2E	a	2,300	33	4.3	100	G	Various	Terrace gravel	2	15	-	r	c,s,o	e,b,s,t	Pit being filled with sanitary landfill
4	Jim Hartman	g	P	NE	29	1S	2E	a	60	10	-	60	G	Various	Terrace gravel	1	7	-	r	-	e,b,s,t	Site being reclaimed as industrial area as soon as area is mined
4a	Unknown	s	P	SE	27	1S	5E	i	25	0.6	-	50	B	Andesite	Boring Lava	1	17	F	r,e	-	e,s,b,t	
5	U.S. Forest Service	s	F	NW	30	1S	6E	-	2	1.5	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
6	U.S. Forest Service	s	F	NE	29	1S	6E	-	3	0.4	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
7	U.S. Forest Service	s	F	SE	28	1S	6E	-	2	0.6	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
8	U.S. Forest Service	s	F	NE	27	1S	6E	-	10	1.2	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
9	U.S. Forest Service	s	F	NE	31	1S	6E	-	2	0.3	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
10	U.S. Forest Service	s	F	SE	34	1S	6E	-	3	0.3	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
11	U.S. Forest Service	s	F	SE	29	1S	8E	-	6	0.8	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
12	U.S. Forest Service	s	F	NE	31	1S	8E	-	3	0.4	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
13	U.S. Forest Service	s	F	SE	33	1S	8E	-	2	1	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
14	Waluga Park	s	P	NE	7	2S	1E	i	17	1	-	10	B	Basalt	Boring Lava	1	5	B	e	-	e,s,b	Surrounded by houses and city park
15	Grimm Fuel Co.	s	P	SW	10	2S	1E	r	50	1.5	-	0	B	Basalt	Columbia River Basalt Group	1	13	C	e	-	e,b,s,t	Now occupied by bark dust plant
16	Allen B. Pynn	s	P	NW	35	2S	1E	a	230	14	-	500	B	Basalt	Columbia River Basalt Group	1	17	F-C	r	-	e,s,b	
*17	Rock Creek Sand and Gravel	g	P	SE	12	2S	2E	a	825	58	8.3	100	G	Various	Terrace gravel	1	15	-	r	c,s	e,b,s,t	
18	Void																					
19	Seventh Day Adventist	s	P	SE	17	2S	2E	a	100	30	-	645	B	Basalt	Columbia River Basalt Group	3	10	B-M	e	-	e,b,s,t,j	
20	Void																					
*21	Northwest Sand and Gravel, Inc.	g	P	NW	15	2S	2E	a	560	40	5	2,000	G	Various	Terrace gravel	2	50	-	r	c,s	e,b,s,t,c	
22	Arrowhead Timber	g	P	NE	13	2S	2E	a	400	10	-	350	G	Various	Terrace gravel	-	3	-	r	-	e,s,b,t,c	Past production was gravel from south of highway. Future mining would be from north of highway and would be basalt from Boring Lava
23	Void																					
24	Edward M. Johnson	g	P	SW	21	2S	2E	a	14	0.2	-	28	G	Various	Terrace gravel	1	17	-	r	-	e,b,s,t	
25	Nature Conservatory	s	P	SW	30	2S	2E	i	30	1	-	0	B	Basalt	Columbia River Basalt Group	1	12	B-M	e	-	e,b,r	Camassia Natural Area
*26	Willamette Sand and Gravel	g	P	NW	29	2S	2E	a	1,260	45	8	0	G	Various	River gravel	1	7	-	r	c	b,s,c,t	Concrete, asphalt plants
27	Oregon City	s	L	SE	31	2S	2E	i	100	1	-	75	B	Basalt	Columbia River Basalt Group	1	23	M	e	-	r,j	
28	Jack Parker	g	P	NE	33	2S	2E	i	31	6	-	150	B	Sandstone	Troutdale	1	9	F	r	-	-	
29	Wes King	g	P	SE	8	2S	3E	i	40	2	1	275	G	Various	Terrace gravel	1	8	-	r	-	e,s,b,t	
*30	MCS, Inc.	g	P	SW	10	2S	3E	i	150	3	-	0	G	Various	River gravel	1	1	-	r	c,s	b,s	Site shut down by DEQ
*31	Clackamas County	s	C	SE	17	2S	3E	i	65	3	-	190	B	Basalt	Boring Lava	1	35	B-M	e	-	b,s,r	
32	G. Althauser	g	P	SE	15	2S	3E	a	50	2	-	600	G	Various	Terrace gravel	1	8	-	r	c,s	b,s	
33	L. Bell	g	P	SE	14	2S	3E	i	4	0.2	-	10	G	Various	Terrace gravel	1	8	-	r	-	e	
34	R and R Excavations	g	P	NW	13	2S	3E	i	3	0.1	-	20	G	Various	Terrace gravel	1	12	-	r	-	b,s,t	
*35	Clackamas County	g	C	NW	23	2S	3E	a	500	19	4	70	G	Various	Terrace gravel	2	10	-	r	c	b,s,t	
36	River Island Sand and Gravel	g	P	SE	23	2S	3E	a	750	45	15	1,000	G	Various	River gravel	1	6	-	r	c	e,s,b,t	
*37	Barton Sand and Gravel	g	P	NW	19	2S	4E	a	75	2	5	150	G	Various	Terrace gravel	1	30	-	r	-	e,s,b,t	
*37a	Oregon State Hwy. Div.	g	S	SE	7	2S	5E	i	40	2.7	-	0	G	Various	Terrace gravel	1	3	-	r	-	e,s,b,t	
38	U.S. Forest Service	s	F	NE	11	2S	6E	-	1	0.1	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
39	U.S. Forest Service	s	F	SW	12	2S	6E	-	15	2.9	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
40	U.S. Forest Service	s	F	SE	12	2S	6E	-	4	0.6	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
41	U.S. Forest Service	s	F	NE	14	2S	6E	-	3	0.5	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
42	Unknown	s	-	SW	24	2S	6E	i	9	0.2	-	90	B	Basalt	Sardine	1	23	F-C	e	-	e,b,s,t	
43	Clackamas County	s	C	SW	24	2S	6E	a	285	2.5	-	1,500	B	Basalt	Sardine	3	47	F-B	e	-	e,b,s,r,j	
44	Hood-Land Sand and Gravel	g	P	SW	24	2S	6E	a	40	5	-	20	G	Various	River gravel	1	3	-	r	-	e,s,b,t	
45	Saxton	s	P	NE	24	2S	6E	a	60	1.5	1	2,000	B	Basalt	Sardine	2	12	F-C	e	-	e,s,s,t	
*46	Oregon State Hwy. Div.	s	S	SE	25	2S	6E	a	900	2	6.5	4,000	B	Basalt	Sardine	2	70	F-C	e	-	e,b,s,r	
47	U.S. Forest Service	s	F	SW	5	2S	7E	-	2	0.7	-	-	B	No on-site survey; data taken from aerial photos								
48	U.S. Forest Service	s	F	NW	3	2S	7E	-	2	1	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
49	U.S. Forest Service	s	F	NW	3	2S	7E	-	1	0.2	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
50	U.S. Forest Service	s	F	NE	3	2S	7E	-	1	0.1	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
51	U.S. Forest Service	s	F	SE	3	2S	7E	-	1	0.4	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
52	U.S. Forest Service	s	F	NE	7	2S	7E	-	9	1	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
53	U.S. Forest Service	s	F	SW	9	2S	7E	-	2	0.8	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissance August 1977								
54	U.S. Forest Service	s	F	NE	17	2S	7E	-	5	1.6	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
55	U.S. Forest Service	s	F	NW	5	2S	7E	-	3	1	-	-	B	No on-site survey; site checked by aerial reconnaissance August 1977								
56	U.S. Forest Service	s	F	NW	9	2S	8E	i	60	1.5	-	100	B	Andesite	Sardine	7	30	F	r	-	r,s,b	
57	U.S. Forest Service	s	F	SE	17	2S	8E	i	1	0.1	-	0	B	Basalt	Boring Lava	2	15	-	-	-	-	
58	U.S. Forest Service	s	F	NE	16	2S	8E	i	4	0.2	-	2	B	Diorite	Intrusive rock	1	10	C-M	e	-	e,r,s,b	
59	Wilsonville Concrete Products	g	P	SW	23	3S	1W	a	2,500	5	15	2,500	G	Various	River gravel	1	-	-	r	c,s	s,r,e	
60	City of Wilsonville	g	L	SE	33	3S	1W	i	280	7	-	0	G	Various	Lacustrine gravel	1	10	-	r	-	e,b,s	Sewage treatment plant site
61	N. Calvin	g	P	SE	36	3S	1W	a	30	2.5	-	70	G	Sand	Lacustrine sand	1	7	-	r	-	e	Sand and topsoil
*62	Tigard Sand and Gravel	s	P	SE	6	3S	1E	a	290	10	30	250	B	Basalt	Columbia River Basalt Group	2	25	C	e	-	e,b,s,r	
63	Growth Resources	s	P	NE	3	3S	1E	a	40	2	-	50	G	Sand	Lacustrine sand	1	6	-	r	-	e	Sand and topsoil
64	J.P. Vlahos	s	P	SE	15	3S	1E	a	30	2.5	-	30	B	Basalt	Columbia River Basalt Group	1	5	B	e	-	e,s,b,r	
65	Unknown	g	P	SW	30	3S	1E	a	5	0.5	-	15	G	Sand	Lacustrine sand	1	10	-	r	-	e	Sand and topsoil
*66	Oregon State Hwy. Div.	g	S	NE	32	3S	1E	i	10	0.5	-	1	G	Various	Terrace gravel	1	2	-	r	-	e,b,s	
*67	E. Fischer	s	P	NE	4	3S	3E	i	61	1	-	970	B	Basalt	Boring Lava	1	20	C-B	e	-	b,s,r,e,t	
68	Coffall Brothers	s	P	NE	8	3S	3E	a	50	2.8	-	500	B	Basalt	Boring Lava	2	3	C	e	-	b,s,r,e	
69	McGee	g	P	NE	9	3S	3E	i	125	2	2	100	G	Various	Terrace gravel	1	37	-	r	-	e,s,b,t	
*70	Eagle Creek Sand and Gravel Co.	g	P	NE	6	3S	4E	a	500	18	12	500	G	Various	Terrace gravel	1	26	-	r	-	e,s,b,t	
71	Oregon State Hwy. Div.	g	S	NW	5	3S	4E	a	220	5	8	650	G	Various	Terrace gravel	1	10	-	r	-	b,s,t	
*72	Estacada Rock Prod.	g	P	NE	19	3S	4E	a	375	14	3	5,100	G	Various	Terrace gravel	1	9	-	r	c,s,o	e,b,s,t	Concrete plant
*72a	Oregon State Hwy. Div.	g	S	SE	17	3S	4E	i	30	1.5	0.5	50	G	Various	Terrace gravel	-	-	-	r	-	e,b,s,t	
73	Unknown	s	P	SW	34	3S	4E	i	60	0.3	-	600	B	Basalt	Columbia River Basalt Group	1	47	C-M	e	-	e,b,s,t	
74	U.S. Forest Service	s	F	SW	31	3S	6E	i	20	0.6	1.9	40	B	Andesite	Sardine	1	6	F-M	e	-	e,s,r,b,r	
*75	U.S. Forest Service	s	F	SW	16	3S	8E	i	50	0.9	4	150	B	Andesite	Sardine	2	25	C-M	e	-	e,r,s,b	
75a	U.S. Forest Service	s	F	NE	18	3S	8E	i	150	3.2	-	500	B	Andesite	Boring Lava	2	22	F-B	e	-	e,s,b,t	
76	U.S. Forest Service	g	F	NE	15	3S	8E	i	7	0.3	-	5	G	Various	River gravel	1	12	F	r	-	e	
77	U.S. Forest Service	s	F	SE	29	3S	8E	i	15	0.1	-	0	T	Andesite	Sardine	1	14	C	r	-	r,s,b	
78	U.S. Forest Service	s	F	NW	34	3S	8E	i	1	0.1	-	100	T	Andesite	Sardine	1	25	F	r	-	r,s,b	
79	U.S. Forest Service	s	F	SE	36	3S	8½E	i	2	0.1	-	0	B	Andesite	Sardine	1	11	F-B	r	-	r,s,b	
80	U.S. Forest Service	s	F	NW	17	3S	9E	i	25	0.3	-	50	B	Andesite	Sardine	1	18	B-M	r,e	-	e,r,s,b	
81	Oregon State Hwy. Div.	g	S	SW	12	4S	1W	i	4	0.1	-	5	G	Various	Lacustrine gravel	1	7	-	r	-	e	
82	Unknown	g	P	NE	6	4S	1E	i	1	0.3	-	2	G	Various	Terrace gravel	1	2	-	r	-	e,s,r	
83	Hiway Concrete	g	P	SW	5	4S	1E	a	1,700	40	3.5	1,000	G	Various	Terrace gravel	1	10	-	r	c,s	b,s,t	
84	J and W Sand and Gravel Products	g	P	SE	5	4S	1E	a	30	0.5	0.5	770	G	Various	River gravel	1	2	-	r	-	b,s,t	
*85	Hiway Concrete	g	P	SE	5	4S	1E	a	3	0.1	-	4,800	G	Various	Terrace gravel	1	-	-	r	-	b,s,t	
86	Unknown	g	P	NE	14	4S	1E	i	35	4	-	150	G	Various	Terrace gravel	1	2	-	r	-	e,s	
87	Forman Brothers	s	P	NW	7	4S	2E	a	10	2	-	200	B	Basalt	Boring Lava	1	3	-	r	-	e,s,b	
88	Don Belding	g	P	NE	19	4S	2E	a	13	1	-	15	G	Various	Terrace gravel	1	3	-	r	-	e,s	
*89	Molalla Sand and Gravel	g	P	NE	19	4S	2E	a	280	20	40	600	G	Various	Terrace gravel	1	2	-	r	c,s,o	e,b,s,t	Concrete plant
90	Needy Brick and Tile	c	P	NW	28	4S	2E	a	30	5	2	60	G	Clay	Lacustrine	1	2	-	r	r,e	o	Brick and tile plant
91	Molalla Clay Products	c	P	SW	32	4S	2E	a	45	2.7	2	10	G	Clay	Lacustrine	1	2	-	r	c,o	o	Drain tile plant
92	Clackamas County	s	C	SW	1	4S	4E	i	200	5	-	200	B	Andesite	Sardine	1	20	-	e	-	e,s,b	
93	Clackamas County	s	C	NW	28	4S	4E	i	30	0.4	-	100	B	Andesite	Sardine	1	19	C-B	e	-	e,s,b	
94	Publishers Paper	s	P	SE	33	4S	4E	i	6	0.3	-	5	B	Tuff	Sardine	1	12	F	r	-	e,s,b	
95	Publishers Paper	s	P	SE	1	4S	5E	i	50	3.4	1.6	100	B	Andesite	Sardine	2	10	F-M	r,e	-	e,r,s,b,e	
96	Publishers Paper	s	P	SE	8	4S	5E	i	11	0.5	-	35	B	Andesite	Sardine	2	8	F-M	r	-	r,s,b	
97	Publishers Paper	s	P	NW	9	4S	5E	i	2	0.1	-	5	B	Ande	Sardine	1	8	F-M	r	-	e,r,s,b	
98	Publishers Paper	s	P	NE	15	4S	5E	i	9	0.3	-	0	B	Basalt	Sardine	1	12	F-C	r	-	e,r,s,b	
99	U.S. Forest Service	s	F	SE	22	4S	5E	i	4	0.2	-	15	B	Andesite	High Cascade Volcanics	1	17	C-M	e	-	e,r,s,b	
100	U.S. Forest Service	s	F	SE	23	4S	5E	i	1	0.4	-	0	B	Andesite	Sardine	1	6	F	r	-	r,s,b	
101	Publishers Paper	s	P	NW	30	4S	5E	a	30	2.5	1	100	B	Andesite	Sardine	2	10	F-C	e,r	-	e,s,b,t	
102	U.S. Forest Service	s	F	SW	28	4S	5E	a	110	0.3	0.3	60	B	Basalt	Columbia River Basalt Group	5	120	F-C	e	-	e,s,b,t	
103	U.S. Forest Service	s	F	SE	27	4S	5E	i	90	0.5	-	900	B	Basalt	Columbia River Basalt Group	1	22	F-C	e	-	b,s,e,t	
104	U.S. Forest Service	s	F	SW	13	4S	6E	i	1	0.1	-	5	B	Andesite	Sardine	1	7	C-M	e,r	-	e,r,s,b	
105	U.S. Forest Service	s	F	SE	19	4S	6E	i	10	0.8	-	10	B	Basalt	Sardine	2	5	F-C	r	-	r,s,b	
106	U.S. Forest Service	s	F	NW	22	4S	6E	i	3	0.2	-	5	B	Andesite	Sardine	1	9	C-M	e	-	e,r,s,b	
107	U.S. Forest Service	s	F	SE	31	4S	6E	i	42	1	-	40	B	Andesite	Sardine	1	30	F-C	r	-	r,s,b	
108	U.S. Forest Service	s	F	NE	36	4S	8E	i	12	1.1	0.5	10	B	Andesite	Sardine	3	9	F-M	r,e	-	e,r,s,b,r,j	
109	U.S. Forest Service	s	F	SE	2	4S	8½E	i	140	3.7	3.8	450	B	Andesite	Sardine	12	25	F-M	r	-	e,r,s,b	
*110	U.S. Forest Service	s	F	NW	1	4S	8½E	i	10	0.7	-	30	B	Andesite	Sardine	3	14	F-C	r	-	r,s,b	
111	U.S. Forest Service	s	F	SW	11	4S	8½E	i	3	0.2	-	0	B	Andesite	Sardine	1	12	F-C	r	-	r,s,b	
112	Unknown	s	P	NW	35	5S	1E	i	15	1	-	20	B	Basalt	Little Butte Volcanics	1	7	C	e	-	c,b,s	
113	John Coerling	s	P	SW	35	5S	1E	i	40	1.5	-	100	B	Basalt	Little Butte Volcanics	1	10	C	e	-	e,b,s	
*114	W. Deardorf	s	P	NE	11	5S	2E	a	300	22	-	2,000	B	Andesite	Sardine	1	30	C-M	e	-	e,b,s,r,t	
115	Clackamas County	s	C	NE	24	5S	2E	i	200	4	1	400	B	Andesite	Sardine	4	23	B-M	e	c,s	e,b,s,t	
116	Coffall Brothers	s	P	SW	29	5S	2E	a	50	10	2	150	B	Andesite	Sardine	1	5	C	e	-	e,b,s,t	
117	Bernrath Quarry	s	P	SW	32	5S	2E	a	70	1.5	-	15	B	Basalt	Columbia River Basalt Group	2	25	B-M	e	-	e,b,s,t	
*118	Jorgenson Construction	s	P	SW	32	5S	2E	a	300	5	1	250	B	Basalt	Columbia River Basalt Group	2	10	C	e	-	e,b,s,t	
119	Crown Zellerbach	s	P	NW	33	5S	2E	a	500	3.5	-	950	B	Andesite	Little Butte Volcanics	2	37	C-M	e	-	e,b,s,t	
120	W. Deardorf	s	P	NW	17	5S	3E	i	3	4	-	135	B	Andesite	Sardine	2	13	F	r,e	-	e,s,b	
121	Crown Zellerbach	s	P	NW	30	5S	3E	i	55	1.7	-	50	B	Andesite	Sardine	2	22	F-M	e	-	r,s,b	
122	Crown Zellerbach	s	P	NW	29	5S	3E	i	14	0.6	-	10	B	Andesite	Sardine	1	12	F	r	-	r,s,b	
123	Crown Zellerbach	s	P	NE	25	5S	3E	a	20	1.5	-	35	B	Andesite	Sardine	1	30	F-C	e,r	-	e,s,b,t	
124	Crown Zellerbach	s	P	NE	33	5S	3E	i	9	0.3	-	20	B	Andesite	Sardine	2	12	F-M	r,e	-	r,s,b,t	
125	Crown Zellerbach	s	P	NE	34	5S	3E	i	2	0.1	-	0	B	Andesite	Sardine	1	13	F	r	-	r,s,b	
126	Crown Zellerbach	s	P	NW	35	5S	3E	i	8	1	-	10	B	Andesite	Sardine	1	6	B-M	r	-	e,b,s	
127	Crown Zellerbach	s	P	NW	36	5S	3E	i	55	2	-	100	B	Andesite	Sardine	1	13	B	r	-	e,b,s,t	
128	Publishers Paper	s	P	NW	6	5S	4E	i	15	0.1	-	0	B	Tuff	Sardine	1	6	F	r	-	s,b	
129	Crown Zellerbach	s	P	SW	6	5S	4E	i	2	0.2	-	1	B	Andesite	Sardine	1	3	F-C	r	-	t,s,b	
130	Publishers Paper	s	P	SE	6	5S	4E	i	11	0.3	-	20	B	Andesite	Sardine	2	12	F-C	r	-	t,s,b	
131	Publishers Paper	s	P	SW	5	5S	4E	i	22	1	-	20	B	Andesite	Sardine	1	9	C-M	r,e	-	t,s,b,e	
132	U.S. Bureau of Land Management	s	F	SE	5	5S	4E	i	2	0.1	-	5	B	Andesite	Sardine	0	0	C-M	r	-	t,s,b,e	
133	U.S. Bureau of Land Management	s	F	NE	3	5S	4E	i	7	0.1	-	3	B	Andesite	Sardine	1	4	F-B	r	-	t,b,s	
134	Publishers Paper	s	P	NW	2	5S	4E	i	7	0.3	-	30	B	Andesite	Sardine	3	5	F-C	r	-	t,s,b	
135	U.S. Bureau of Land Management	s	F	SE	9	5S	4E	i	4	0.1	-	5	B	Andesite, weathered	Sardine	1	24	B-M	r	-	b,s	
136	U.S. Forest Service	s	F	SW	11	5S	4E	i	10	0.4	-	3	B	Andesite	Sardine	2	10	C-B	r	-	e,t,s,b,r	
137	U.S. Forest Service	s	F	NE	11	5S	4E	i	24	0.6	-	48	B	Andesite	Sardine	3	16	F	r	-	t,s,b	
138	U.S. Forest Service	s	F	NE	11	5S	4E	i	92	0.2	-	0	B	Andesite	Sardine	3	18	F	r	-	t,s,b	
139	U.S. Bureau of Land Management	s	F	NE	12	5S	4E	i	40	0.8	-	50	B	Andesite	Sardine	2	22	C-B	r	-	e,b,s,t	
140	U.S. Bureau of Land Management	s	F	NE	12	5S	4E	i	6	0.2	-	0	B	Andesite	Sardine	1	10	F-B	e	-	e,t,s,b,r	
141	Publishers Paper	s	P	SE	18	5S	4E	i	1	0.1	-	1	B	Andesite	Sardine	1	3	F-B	r	-	t,s,b	
142	Publishers Paper	s	P	SE	18	5S	4E	i	5	0.4	-	10	B	Andesite	Sardine	1	4	F-M	r,e	-	t,s,b,e	
143	U.S. Bureau of Land Management	s	P	NW	17	5S	4E	i	1	0.1	-	5	B	Andesite	Sardine	1	4	F-B	r	-	t,s,b,e	
144	U.S. Forest Service	s	F	NE	15	5S	4E	i	15	0.4	-	0	B	Andesite	Sardine	2	17	F	r	-	s,b	
145	U.S. Bureau of Land Management	s	F	SW	14	5S	4E	i	16	0.4	-	30	B	Andesite	Sardine	1	19	C-M	r	-	e,b,s	
146	U.S. Bureau of Land Management	s	F	NE	14	5S	4E	a	110	4.2	-	31	B	Andesite	Sardine	2	3	C-B	e	-	e,b,s,t	
147	Crown Zellerbach	s	P	SW	20	5S	4E	i	2	0.1	-	5	B	Andesite	Sardine	1	12	F-C	r,e	-	t,s,b	
148	Crown Zellerbach	s	P	SE	20	5S	4E	i	15	0.6	-	30	B	Andesite	Sardine	2	32	F-C	e	-	t,s,b	
149	U.S. Bureau of Land Management	s	F	NW	21	5S	4E	i	1	0.1	-	1	B	Andesite	Sardine	1	7	F-M	r	-	t,s,b	
150	U.S. Forest Service	s	F	NW	23	5S	4E	i	23	0.5	-	9	B	Andesite	Sardine	1	40	F-C	e,r	-	e,t,s,b,r	
151	U.S. Bureau of Land Management	s	P	NW	24	5S	4E	i	1	0.4	-	2	B	Andesite	Sardine	1	10	F	r	-	s,b,t	
152	U.S. Bureau of Land Management	s	P	NW	24	5S	4E	i	6	0.2	-	12	B	Andesite	Sardine	1	12	F-C	r	-	e,s,b,t	
153	U.S. Bureau of Land Management	s	F	SE	24	5S	4E	i	3	0.2	-	5	B	Andesite	Sardine	1	0	C-B	e	-	e,t,s,b,r	
154	U.S. Bureau of Land Management	s	F	NE	24	5S	4E	i	6	0.4	-	20	B	Andesite	Sardine	2	9	F-C	e	-	e,t,s,b	
155	Crown Zellerbach	s	P	NW	28	5S	4E	i	10	0.5	-	10	B	Andesite	Sardine	1	34	F-M	r	-	t,s,b	
156	Crown Zellerbach	s	P	SE	27	5S	4E	i	31	0.9	-	93	B	Andesite	Sardine	3	11	C-B	e	-	e,t,s,b,r	
157	Crown Zellerbach	s	P	NW	26	5S	4E	i	45	1.6	-	47	B	Andesite	Sardine	4	24	F-C	r	-	t,s,b	
158	U.S. Forest Service	s	F	SW	25	5S	4E	i	6	0.4	-	60	B	Andesite	Sardine	3	16	F	r	-	t,s,b	
159	U.S. Forest Service	s	F	SW	25	5S	4E	i	6	0.3	-	0	B	Andesite	Sardine	1	7	F-C	r	-	t,s,b	
160	U.S. Forest Service	s	F	NW	25	5S	4E	r	10	0.3	-	0	B	Andesite	Sardine	1	15	C-B	r	-	e,s,b	
161	U.S. Forest Service	s	F	NE	25	5S	4E	i	30	2	1	300	B	Andesite	Sardine	1	9	F-M	r,e	-	e,t,s,b,r,j	
162	Crown Zellerbach	s	P	NE	31	5S	4E	i	3	0.2	-	5	B	Andesite	Sardine	2	22	F	r	-	t,s,b	
163	Crown Zellerbach	s	P	SW	32	5S	4E	i	10	0.3	-	10	B	Andesite	Sardine	2	24	F-M	r,e	-	t,s,b,e,r	
164	Crown Zellerbach	s	P	NE	32	5S	4E	i	17	1.4	0.2	20	B	Andesite	Sardine	1	8	F-B	r,e	-	t,s,b,e	
165	Crown Zellerbach	s	P	SW	33	5S	4E	i	2	0.1	-	0	B	Andesite	Sardine	1	27	C-B	r,e	-	t,s,b	
166	U.S. Forest Service	s	F	SE	3	5S	5E	r	25	0.6	-	250	B	Andesite	Sardine	1	10	F	r	-	e,b,s,t	
167	U.S. Forest Service	s	F	SW	1	5S	5E	i	120	2	0.2	250	B	Basalt	Columbia River Basalt Group	5	58	F-M	r,e	-	e,t,s,b,r,j	
168	U.S. Forest Service	s	F	SW	8	5S	5E	i	16	1	-	100	B	Andesite	Sardine	1	3	C	r	-	e,b,s,t	
169	U.S. Forest Service	s	F	NE	12	5S	5E	i	5	0.5	-	5	B	Andesite	Sardine	2	5	B-M	r	-	e,b,s,t,r	
170	U.S. Forest Service	s	F	NE	18	5S	5E	a	65	1.5	-	50	B	Andesite	Sardine	1	17	C-B	r	-	e,b,s,t	
171	U.S. Forest Service	s	F	SW	15	5S	5E	a	35	0.5	-	300	B	Andesite	Sardine	1	17	C	r	-	e,b,s,t	
172	U.S. Forest Service	s	F	SE	15	5S	5E	a	30	1	-	300	B	Andesite	Sardine	2	15	F	r	-	e,b,s,t	
173	U.S. Forest Service	s	F	SE	14	5S	5E	a	5	0.5	0.5	15	T	Basalt	Columbia River Basalt Group	1	10	C	r	-	e,b,s,t	
174	U.S. Forest Service	s	F	NW	13	5S	5E	a	3	0.1	-	25	B	Basalt	Columbia River Basalt Group	1	8	F	r	-	e,b,s,t	
175	U.S. Forest Service	s	F	SE	21	5S	5E	i	2	0.1	-	150	B	Andesite	Sardine	1	13	C-M	r	-	e,b,s,t,r	
176	U.S. Forest Service	s	F	NW	23	5S	5E	r	80	0.1	-	25	B	Basalt	Columbia River Basalt Group	1	17	B-M	e,r	-	s,b,r	
177	U.S. Forest Service	s	F	NW	30	5S	5E	i	12	0.5	-	25	B	Andesite	Sardine	4	16	C-M	e	-	e,t,s,b,j,r	
178	U.S. Forest Service	s	F	NE	28	5S	5E	i	2	0.1	-	1	B	Andesite	Sardine	2	18	C-B	r	-	e,b,s,t	
179	U.S. Forest Service	s	F	NW	28	5S	5E	a	61	1.3	-	60	B	Andesite	Sardine	2	22	C	r	-	e,b,s,t	
180	U.S. Forest Service	s	F	SE	27	5S	5E	i	12	0.2	-	4	B	Andesite	Sardine	1	35	C-M	r,e	-	e,t,s,b,r	
181	U.S. Forest Service	s	F	NW	26	5S	5E	i	4	0.1	-	8	B	Basalt	Columbia River Basalt Group	2	24	C-M	r	-	e,s,b,r	
182	U.S. Forest Service	s	F	NW	25	5S	5E	a	20	1.5	-	30	B	Basalt	Columbia River Basalt Group	1	8	C	r	-	e,b,s,t	
183	U.S. Forest Service	s	F	NW	25	5S	5E	i	6	0.2	-	0	B	Basalt	Sardine	1	10	C	r	-	e,b,s,t	
184	U.S. Forest Service	s	F	NE	25	5S	5E	a	70	1	0.2	300	B	Andesite	Sardine	1	15	F	r	-	e,b,s,t	
185	U.S. Forest Service	s	F	SE	34	5S	5E	r	2	0.2	-	0	B	Andesite	Sardine	1	3	F-C	r	-	t,s,b	
186	U.S. Forest Service	s	F	SE	35	5S	5E	a	40	0.3	-	40	B	Basalt	Sardine	1	37	F-B	r,e	-	e,b,s,t,r	
187	U.S. Forest Service	s	F	SE	35	5S	5E	i	16	0.5	-	20	B	Basalt	Sardine	1	23	F	r,e	-	e,b,s,t	
*188	U.S. Forest Service	s	F	SE	6	5S	6E	a	270	1	-	2,000	B	Basalt	Columbia River Basalt Group	1	60	F-B	e	-	b,s,e,t,r	
189	U.S. Forest Service	s	F	NW	7	5S	6E	a	5	0.1	-	15	B	Andesite	Sardine	1	10	F	r	-	e,b,s,t	
190	U.S. Forest Service	s	F	SW	7	5S	6E	a	12	0.5	0.2	2	B	Andesite	Sardine	1	10	F	r	-	e,b,s,t	
191	U.S. Forest Service	s	F	NE	19	5S	6E	a	85	1	-	80	B	Andesite	Sardine	1	17	F	r	-	e,b,s,t	
192	U.S. Forest Service	s	F	NE	19	5S	5E	a	30	1	-	100	B	Andesite	Sardine	1	13	F-B	r	-	e,b,s,r,t	
193	U.S. Forest Service	s	F	NE	27	5S	6E	i	40	0.5	-	30	B	Andesite	Sardine	2	23	C-B	r	-	e,b,t	
194	U.S. Forest Service	s	F	NW	33	5S	6E	a	40	0.3	-	120	B	Basalt	Columbia River Basalt Group	1	15	F	r	-	e,b,s,t	
195	U.S. Forest Service	s	F	NW	36	5S	6E	a	300	1.5	-	1,500	B	Basalt	Boring Lava	7	51	F-B	e	-	b,s,e,t	
196	U.S. Forest Service	s	F	NE	1	5S	7E	i	13	1.7	-	25	B	Andesite	High Cascade Volcanics	2	20	F-M	e	-	e,t,s,b	
197	U.S. Forest Service	s	F	NE	11	5S	7E	i	11	3.1	-	30	T	Andesite	High Cascade Volcanics	7	12	F-B	r	-	e,t,s,b,r	
198	U.S. Forest Service	s	F	SE	16	5S	7E	a	3	3	-	10	B	Andesite	High Cascade Volcanics	2	10	F-C	e	-	t,s,b	
199	U.S. Forest Service	s	F	SE	15	5S	7E	i	8	5	-	20	T	Andesite	High Cascade Volcanics	8	16	F-B	r	-	e,t,s,b	
200	U.S. Forest Service	s	F	NE	21	5S	7E	i	2	1.2	-	5	T	Andesite	High Cascade Volcanics	1	5	F-M	r	-	e,t,s,b	
201	U.S. Forest Service	s	F	SE	22	5S	7E	i	4	0.2	-	10	T	Andesite	High Cascade Volcanics	1	15	F-M	r	-	e,t,s,b	
202	U.S. Forest Service	s	F	NE	24	5S	7E	i	2	0.2	-	0	B	Andesite	High Cascade Volcanics	1	4	F-C	r	-	t,s,b	
203	U.S. Forest Service	s	F	NW	28	5S	7E	i	13	2.7	-	5	B	Andesite	High Cascade Volcanics	3	1	B-M	e,r	-	r,j	
204	U.S. Forest Service	s	F	SW	25	5S	7E	a	16	3	1	100	B	Andesite	High Cascade Volcanics	2	15	F	r	-	t,s,b	
205	U.S. Forest Service	s	F	SE	31	5S	7E	a	53	0.5	-	600	B	Basalt	Boring Lava	1	40	F	e	-	b,s,e,t	
206	U.S. Forest Service	s	F	SW	32	5S	7E	i	17	0.5	-	25	B	Andesite	Sardine	1	15	F-M	e	-	b,s,e,t	
207	U.S. Forest Service	s	F	SE	35	5S	7E	i	3	0.1	0.2	3	B	Andesite	High Cascade Volcanics	1	3	F	e	-	t,s,b	
208	U.S. Forest Service	s	F	SW	36	5S	7E	i	3	0.3	-	5	B	Andesite	High Cascade Volcanics	2	10	F-C	r	-	e,t,s,b	
209	U.S. Forest Service	s	F	SW	36	5S	7E	i	1	0.1	-	0	B	Andesite	High Cascade Volcanics	1	3	B-M	e	-	e,t,s,b,r	
210	U.S. Forest Service	s	F	NE	7	5S	8E	i	15	1.6	1	45	B	Basalt	High Cascade Volcanics	6	16	F-C	e	-	e,t,s,b	
211	U.S. Forest Service	s	F	SW	17	5S	8E	i	8	0.3	-	5	B	Andesite	High Cascade Volcanics	1	10	F	r	-	t,s,b	
212	U.S. Forest Service	s	F	SW	16	5S	5E	i	12	0.3	-	3	B	Andesite	High Cascade Volcanics	2	27	F	r,e	-	t,s,b	
213	U.S. Forest Service	s	F	NW	21	5S	8E	i	1	0.1	-	0	B	Andesite	High Cascade Volcanics	3	10	F-C	r	-	t,s,b	
214	U.S. Forest Service	s	F	SW	28	5S	8E	i	7	0.3	-	10	B	Andesite	High Cascade Volcanics	2	30	F	r	-	t,s,b	
215	U.S. Forest Service	s	F	SW	31	5S	8E	i	2	0.2	-	4	B	Andesite	High Cascade Volcanics	1	15	F-C	e	-	e,t,s,b	
216	U.S. Forest Service	s	F	SE	31	5S	8E	i	2	0.2	-	2	B	Andesite	High Cascade Volcanics	2	10	F-B	r	-	e,t,s,b	
217	U.S. Forest Service	s	F	NW	32	5S	8E	i	18	1.1	-	10	B	Andesite	High Cascade Volcanics	3	15	F-C	r	-	t,s,b	
218	U.S. Forest Service	s	F	SW	32	5S	6E	i	2	0.4	-	1	B	Andesite	High Cascade Volcanics	2	4	F-C	r,e	-	t,s,b	
219	U.S. Forest Service	s	F	SE	32	5S	8E	i	15	2	-	15	B	Andesite	High Cascade Volcanics	3	9	F	r	-	t,s,b	
220	U.S. Forest Service	s	F	SW	32	5S	8E	i	12	0.3	-	10	B	Andesite	High Cascade Volcanics	2	35	F	e,r	-	t,s,b	
221	U.S. Forest Service	s	F	SW	33	5S	8E	i	5	0.1	-	5	B	Andesite	High Cascade Volcanics	1	30	F	e,r	-	t,s,b	
222	U.S. Forest Service	s	F	SW	35	5S	8½E	r	45	2.5	-	50	B	Andesite	High Cascade Volcanics	2	30	C-M	r,e	-	t,s,b,e	
223	Floyd Grohn Construction Company	s	P	SW	9	6S	1E	i	35	2	-	50	B	Basalt	Little Butte Volcanics	1	5	M	r	-	r	
224	Robert Qualey	s	P	SW	24	6S	1E	a	15	3	-	150	B	Basalt	Columbia River Basalt Group	1	17	F-B	e	-	e,b,s,r	
225	Unknown	s	P	NW	5	6S	2E	i	3	0.3	-	5	B	Basalt	Columbia River Basalt Group	2	3	B-M	e	-	e,b,s,r	
226	Unknown	s	P	NW	5	6S	2E	i	4	0.3	-	20	B	Basalt	Columbia River Basalt Group	1	5	C	r	-	e,b,s	
227	Yoder Quarry Rock Products	s	P	NW	2	6S	2E	a	70	3	0.5	75	B	Andesite	Sardine	3	10	C-M	e	-	e,b,s,t,r	
228	Unknown	s	P	SE	8	6S	2E	i	1	0.1	-	5	B	Basalt	Little Butte Volcanics	2	3	C	e	-	e,b,s,t	
229	Mandrones Mining Co.	o	P	NW	15	6S	2E	a	0	0.1	1	0	B	Carbonaceous shale	Little Butte Volcanics	-	-	-	-	c,s,w	o	Madrona mine. Carbonaceous shale high in humic acid is mined from underground, dried, bagged, and sold as feed supplement and soil additive
230	Unknown	s	P	SE	15	6S	2E	i	2	0.1	-	2	B	Andesite	Sardine	1	5	C	r	-	c,b,s	
231	Peter Blythe	o	P	NW	14	6S	2E	a	40	5	2.2	100	B	Clay	Sardine	1	1	-	r	c,o	o	Clay used for kitty litter
232	Crown Zellerbach	s	P	NW	6	6S	3E	i	75	2	-	500	B	Andesite	Little Butte Volcanics	3	38	C-M	e	-	e,b,s,t,r	
233	Crown Zellerbach	s	P	SE	1	6S	3E	i	5	0.2	-	10	B	Andesite	Sardine	1	13	F-C	e	-	t,s,b	
234	Crown Zellerbach	s	P	SE	8	6S	3E	i	11	0.5	-	25	B	Andesite	Little Butte Volcanics	2	3	F-M	r	-	t,s,b,e	
235	Crown Zellerbach	s	P	SE	8	6S	3E	i	26	0.7	-	25	B	Andesite	Little Butte Volcanics	2	22	F-B	r	-	t,s,b	
236	Crown Zellerbach	s	P	SW	10	6S	3E	i	2	0.8	-	15	B	Andesite	Sardine	1	2	F-C	r	-	t,s,b	
237	Crown Zellerbach	s	P	NW	12	6S	3E	i	8	0.3	-	10	B	Andesite	Sardine	1	14	F-C	r,e	-	t,s,b	

* State Highway Division laboratory data

(continued)

TABLE 4.
COLUMBIA COUNTY ROCK MATERIAL SURVEY DATA

IDENTIFICATION				LOCATION				STATUS	SIZE				SOURCE DESCRIPTION			MINING SYSTEM AND USES						REMARKS
Site number	Operator or owner	Commodity: s-stone, g-sand and gravel, o-other	Domain: L-local, P-private, C-County, S-State, F-Federal	1/4 section	Section	Township	Range	a-active, i-inactive, r-reclaimed, p-prospect	Past production (1,000 cu yds)	Acres excavated	Acres [illegible]	Future potential (1,000 cu yds)	Deposit type: B-bed rock, T-talus, G-gravel	Rock type	Geological formation or unit	Number of benches	High wall (ft)	Jointing: F-fine (1"-6"), C-coarse (6"-12"), B-blocky (12"-18"), M-massive (18"+)	Breaking ground: r-rippable, e-explosive	Processing plant: c-crusher, s-screen washing, o-other	Usage: e-embankment, t-topping, s-subbase, b-base, r-riprap, j-jettystone, a-asphalt, c-concrete, o-other	
1	Unknown	s	-	SW	24	8N	4W	i	13	0.3	-	700	B,T	Basalt	Columbia River Basalt Group	1	25	F-M	r,e	-	e,t,s,b,r,j,a,c	
2	T. Johnson	g	P	SE	34	8N	4W	i	18	2	-	60	G	Various	Terrace gravels	1	9	F-C	r	-	b,s	Site is now junkyard
3	Unknown	s	-	NE	19	8N	3W	a	7	0.3	-	1	B	Basalt	Columbia River Basalt Group	1	10	F	e	c	e,s,b,t	No reclamation; site against property line
4	E. Johnson	s	P	SE	1	7N	5W	i	3	0.13	-	10	B	Basalt	Columbia River Basalt group	1	5	B-M	e	-	r,j	
5	Kynsi-Lammi	s	P	NW	10	7N	5W	a	300	3	1	1,000	B	Basalt	Intrusive	2	17	F-C	r,e	c	e,s,t	Appears to be vertical dike
* 6	W. Everson	s	P	SE	9	7N	5W	a	35	0.5	-	150	B	Basalt	Columbia River Basalt Group	1	25	C	r	-	e,b,s,t	
7	Crown Zellerbach	s	P	NE	16	7N	5W	a	15	0.5	-	50	B	Basalt	Columbia River Basalt Group	1	12	C	r	-	e,b,s,t	Some altered zones; most of the rock is sound
8	Longview Fiber	s	P	SE	27	7N	5W	a	130	2.5	-	400	B	Basalt	Columbia River Basalt Group	3	20	C	e	-	e,b,s,t	
9	Longview Fiber	s	P	SE	32	7N	5W	i	40	2.5	-	150	B	Basalt	Columbia River Basalt Group	1	37	C	e	-	e,b,s	
10	Longview Fiber	s	P	NE	33	7N	5W	a	130	7	-	250	B	Basalt	Columbia River Basalt Group	1	7	F-C	r	-	e,b,t	
11	W. Everson	s	P	NW	35	7N	5W	a	25	2.5	2.5	90	B	Basalt	Columbia River Basalt Group	2	4	C	e	c	e,b,s,t	
12	W. Everson	s	P	NE	35	7N	5W	a	150	1.5	0.5	200	B	Basalt	Columbia River Basalt Group	1	33	C	e	c	e,b,s,t	
13	W. Everson	s	P	NE	35	7N	5W	i	130	1	-	0	B	Basalt	Columbia River Basalt Group	1	67	C	e	-	e,b,s,t	Abandoned
14	W. Everson	s	P	SE	35	7N	5W	i	15	0.5	-	30	B	Basalt	Columbia River Basalt Group	2	13	C	r	-	e	Abandoned; very poor rock; badly altered
15	Columbia County	s	C	SW	2	7N	4W	i	40	0.5	-	120	B	Basalt	Columbia River Basalt Group	1	30	F	r	-	e,b,s	
16	A. Bergmon	g	P	NE	7	7N	4W	i	7	0.2	-	50	G	Various	Terrace gravels	1	5	-	r	-	b,s,t	
17	R. Olson	s	P	NE	8	7N	4W	a	60	1.5	1	120	B	Basalt	Columbia River Basalt Group	1	17	F	r,e	s	e,b,s	
18	Unknown	s	P	NE	10	7N	4W	a	11	0.5	-	110	B	Basalt	Columbia River Basalt Group	1	17	F	r	-	e,b,s	
19	P. Zimmerly	s	P	SE	11	7N	4W	a	110	1.5	3	2,000	B	Basalt	Columbia River Basalt Group	1	48	F-B	r	-	e,b,s,t	
20	Longview Fiber	s	P	SE	20	7N	4W	a	11	1.5	-	25	B	Basalt	Columbia River Basalt Group	1	2	F	r	-	e,b,s	
21	Crown Zellerbach	s	P	SE	23	7N	4W	i	15	1	-	100	B	Basalt	Columbia River Basalt Group	1	25	F-C	e	-	e,b,s,t	
22	Crown Zellerbach	s	P	SE	23	7N	4W	i	10	0.5	-	100	B	Basalt	Columbia River Basalt Group	1	25	F-C	e	-	e,b,s,s	
23	Longview Fiber	s	P	NW	31	7N	4W	a	0.3	0.1	-	5	B	Basalt	Columbia River Basalt Group	1	3	F	r	-	b,s	
24	Longview Fiber	s	P	SE	32	7N	4W	a	8	0.5	-	20	B	Basalt	Columbia River Basalt Group	1	5	F	r	-	b,t	
25	Longview Fiber	s	P	NW	33	7N	4W	a	4	1	-	10	B	Basalt	Columbia River Basalt Group	1	4	F	r	-	e,b,s	
26	Unknown	s	P	NE	3	7N	3W	i	7	0.3	-	100	B	Basalt	Columbia River Basalt Group	1	12	F	r	-	b,s,e	
* 27	Oregon State Hwy. Div.	s	S	SW	8	7N	3W	a	150	2	4	450	B	Basalt	Columbia River Basalt Group	3	13	F-M	r-e	-	e,b,s,t,r	
28	E. Musgrove	s	P	SE	8	7N	3W	a	13	1	-	56	B	Basalt	Columbia River Basalt Group	1	3	F	r	-	e,b,t	
29	F. Sutter	s	P	SE	18	7N	3W	a	60	2.5	5	200	B	Basalt	Columbia River Basalt Group	1	20	F-C	e	-	e,b,t,t	
30	Crown Zellerbach	s	P	SW	30	7N	3W	a	20	2	-	140	B	Basalt	Columbia River Basalt Group	1	4	F	r	-	e,b,t	
31	Bernards Excavating	s	P	NE	34	7N	3W	a	4	1	-	10	B	Basalt	Columbia River Basalt Group	1	2	F-C	e	-	e,b,t	Site bounded by county road and property line and split by another road; 5 ft of solid rock exposed below pyroclastics
32	Longview Fiber	s	P	SE	34	7N	3W	a	200	2	-	1,500	B	Basalt	Columbia River Basalt Group	1	22	C	e	-	e,b,s,t	50 ft of solid rock capped by pillow lavas
* 33	Columbia West Materials and Construction Co.	s	P	NW	17	7N	2W	a	2,000	10	3	700	B	Basalt	Columbia River Basalt Group	3	78	F-M	r-e	c,s	e,b,s,t,r,j	
34	Peterson	s	P	NW	19	7N	2W	a	1.3	0.1	-	12	B	Basalt	Columbia River Basalt Group	1	-	F	e	-	b,s,e	
35	Columbia West Materials and Construction Co.	s	P	NE	19	7N	2W	a	22	0.5	-	22	B	Basalt	Columbia River Basalt Group	1	-	F	e	-	b,s,e,t	
36	Pete Matioco	s	P	NE	19	7N	2W	a	15	0.5	-	150	B	Basalt	Columbia River Basalt Group	1	-	F	e	-	b,s,e,t	
37	C. Zimmerman	s	P	NW	31	7N	2W	a	0.1	0.1	-	0.5	B	Basalt	Columbia River Basalt Group	1	2	F	r	-	b,s	
38	Just-A-Mere Farm, Inc.	s	P	NW	31	7N	2W	i	3	0.2	-	1,000	B	Basalt	Columbia River Basalt Group	1	5	F-C	r	-	b,s,e	Pods of pillow rock
39	Just-A-Mere Farm, Inc.	s	P	NE	31	7N	2W	a	4	0.2	-	1,000	B	Basalt	Columbia River Basalt Group	1	5	F-C	r	-	b,s,e	
40	Longview Fiber	s	P	NE	6	7N	4W	a	2.2	0.2	-	10	B	Conglomerate and basalt	Columbia River Basalt Group	1	5	F	r	-	b,s	Very vesicular and brecciated rock below conglomerate
41	Evanson and others	s	P	NW	5	6N	4W	a	20	6	-	45	B	Basalt	Columbia River Basalt Group	1	4	F	r-e	-	e,b,t,t	
42	Evanson and others	s	P	NE	9	7N	4W	a	12	1	-	40	B	Basalt	Columbia River Basalt Group	1	4	F	r-e	-	b,s,e	
43	Longview Fiber	s	P	SE	25	6N	4W	a	0	1	-	15	B	Basalt	Columbia River Basalt Group	1	0	F	r	-	b,s,t	
44	Longview Fiber	s	P	SE	36	6N	4W	a	8.4	0.5	-	2,000	B	Basalt	Columbia River Basalt Group	2	5	F	r	-	e,b,t	
45	I. Jones	s	P	SE	15	6N	3W	i	10	0.4	-	5	B	Basalt	Goble Volcanics	1	6	F	r	-	t,b,s	
46	Publishers Paper	s	P	SE	15	6N	3W	a	30	3	-	1,000	B	Basalt	Columbia River Basalt Group	2	14	F	r	-	b,s	Lenses of pillow basalt, badly weathered, with some fresh rock
47	Longview Fiber	s	P	NE	34	6N	3W	a	1	0.1	-	5	B	Basalt	Columbia River Basalt Group	1	3	F	r	-	e,b,s	
48	Longview Fiber	s	P	NW	35	6N	3W	a	1.5	0.1	-	15	B	Basalt	Columbia River Basalt Group	1	2	F	r	-	e,b,t	
49	Longview Fiber	s	P	SW	36	6N	3W	a	60	2.5	-	180	B	Basalt	Columbia River Basalt Group	1	9	F	r-e	-	e,b,t	10-ft thick layer of pillow basalt
* 50	Babler Brothers	s	P	NE	11	6N	2W	i	60	1.5	4	1,000	B	Basalt	Goble Volcanics	1	22	F-M	e	-	t,b,s,e	Stockpile area is active
51	Pete Matioco	s	P	SW	12	6N	2W	a	327	5	4	1,700	B	Basalt	Columbia River Basalt Group	2	21	F-M	e	c	e,t,b,s,j,a,r	Some rock goes to Cowlitz County, Wash.; asphalt plan to be installed
* 52	McAree	s	P	NE	13	6N	2W	i	123	5	-	200	B	Basalt	Goble Volcanics	2	13	C-M	e	-	t,b,s,e,r	
53	Longview Fiber	s	P	SW	36	6N	2W	i	15	0.3	-	15	B	Andesite	Goble Volcanics	1	12	F	r	-	s	Very poor, weathered, and brecciated rock
54	Tide Creek Rock	s	P	NE	36	6N	2W	a	260	5	2	2,000	B	Andesite	Goble Volcanics	1	7	F	r	-	b,s	
* 55	Crown Zellerbach	s	P	NW	24	5N	4W	i	20	0.5	-	20	B	Basalt	Columbia River Basalt Group	1	7	F	r	-	e,b	
* 56	Crown Zellerbach	s	P	SW	5	5N	3W	a	1,480	13	-	5,000	B	Basalt	Columbia River Basalt Group	3	75	F	r	-	e,t,s,b	
57	Longview Fiber	s	P	NW	7	5N	3W	a	135	1.5	0.5	1,000	B	Basalt	Columbia River Basalt Group	1	37	F	r	-	e,s,s,b	
58	Oregon State Hwy. Div.	s	S	NE	16	5N	3W	i	0.5	0.1	-	2	B	Basalt	Columbia River Basalt Group	1	3	F	r	-	e,s,b	
59	Oregon State Hwy. Div.	s	S	NE	21	5N	3W	i	12	0.5	-	500	B	Basalt	Columbia River Basalt Group	1	5	F	r	-	e,s,b	
60	Crown Zellerbach	s	P	NW	27	5N	3W	i	2	0.1	-	10	B	Basalt	Columbia River Basalt Group	1	7	F-C	r	-	e,b,s	Abandoned
61	Crown Zellerbach	s	P	NE	25	5N	3W	i	5	0.1	-	15	B	Basalt	Columbia River Basalt Group	1	8	F	r	-	e,b	Very poor, highly brecciated rock
62	Longview Fiber	s	P	NE	18	5N	2W	a	0.7	0.2	-	1	B	Basalt	Columbia River Basalt Group	1	3	F	r	-	e,b	
63	Longview Fiber	s	P	NE	15	5N	2W	a	34	0.7	-	70	B	Basalt	Columbia River Basalt Group	1	22	F	r	-	e,s,b,t	
64	Boise Cascade	s	P	SE	32	5N	2W	i	1	0.1	-	5	B	Basalt	Columbia River Basalt Group	1	5	F	r	-	e,t,s,b	
* 65	Oregon State Hwy. Div.	g	S	SW	8	5N	1W	i	175	6	-	110	B	Basalt	Columbia River Basalt Group	1	8	F	r	-	b,s,t	
66	Longview Fiber	s	P	NW	18	5N	1W	a	3	1.8	-	2,900	B	Basalt	Columbia River Basalt Group	-	-	C-B	e	-	e,b,s,t	Overburden has been removed, exposing bed rock
67	Longview Fiber	s	P	NW	18	5N	1W	i	5	0.3	-	1,000	B	Basalt	Columbia River Basalt Group	1	9	F	r	-	s	Very poor rock
* 68	Dwight Irby	s	P	SW	32	5N	1W	a	63	1	-	190	B	Basalt	Columbia River Basalt Group	1	20	F	e	-	b,s,t	
69	Watters Concrete Products	s	P	SW	33	5N	1W	i	10	0.4	-	0	B	Basalt	Columbia River Basalt Group	1	7	F-C	e	-	s,b,s,e,r	Rock must be shot; residential growth encroaching upon site
70	Columbia County	s	C	NE	33	5N	1W	i	100	2	-	25	B	Basalt	Columbia River Basalt Group	1	13	F-C	e	-	b,s,t	
* 71	Watters Concrete Products	s	P	NE	33	5N	1W	a	450	6.3	4	500	B	Basalt	Columbia River Basalt Group	1	17	F-C	e	c,s	r,b,s,t,c	
72	Columbia County	s	C	SE	33	5N	1W	i	80	2	-	0	B	Basalt	Columbia River Basalt Group	1	8	F	r	-	b,s,t	
73	Rush Realty Co.	s	P	SW	6	4N	5W	i	45	0.4	-	130	B	Basalt	Goble Volcanics	1	-	F-C	e	-	b,s,e	
74	Stimson Timber Co.	s	P	SW	5	4N	5W	i	8	0.4	-	16	B	Basalt	Goble Volcanics	1	-	C-M	e	-	b,s,e,t	
75	Longview Fiber	s	P	SW	8	4N	5W	i	2.5	0.2	-	200	B	Basalt	Goble Volcanics	1	12	C-B	e	-	e,b	Poor rock; soft and badly weathered
76	Longview Fiber	s	P	NE	18	4N	5W	a	1.5	0.1	-	0	B	Basalt	Goble Volcanics	1	11	C	r	-	e,b,s	Only pyroclastics exposed
77	Longview Fiber	s	P	SW	15	4N	5W	a	22	0.8	0.4	1,100	B	Basalt	Goble Volcanics	1	22	C-M	e	-	e,b,s,t	20 ft of pyroclastic overburden at this site; rock quality variable
78	Longview Fiber	s	P	NW	22	4N	5W	i	2	0.1	-	2	B	Basalt	Goble Volcanics	1	5	C-M	r	-	e,b,s	Poor rock and thick overburden; site abandoned
79	Longview Fiber	s	P	NE	22	4N	5W	i	15	0.3	-	200	B	Basalt	Goble Volcanics	1	-	F-C	e	-	b,s,a,t,r	
80	Longview Fiber	s	P	NW	28	4N	5W	a	3	0.3	-	10	B	Basalt	Intrusive	1	10	C-B	e	-	e,b,s	Fairly high overburden ratio
81	Crown Zellerbach	s	P	NE	24	4N	4W	i	13	0.4	-	30	B	Basalt	Columbia River Basalt Group	1	7	F	r	-	e,b	
82	Crown Zellerbach	s	P	NE	24	4N	4W	i	1	0.1	-	10	B	Basalt	Columbia River Basalt Group	1	5	F	r	-	e,b	Brecciated rock lies above Oligocene marine sediment contact; very poor rock
83	Crown Zellerbach	s	P	SW	24	4N	4W	a	10	2	2	30	B	Basalt	Columbia River Basalt Group	1	12	F-C	r	-	e,b	Very vesicular and friable rock
84	Crown Zellerbach	s	P	NE	25	4N	4W	i	8	0.3	-	2	B	Basalt	Columbia River Basalt Group	1	8	F	r	-	e,s,b	
* 85	G. Hawkins	s	P	SW	4	4N	3W	i	75	3	-	100	B	Basalt	Columbia River Basalt Group	1	8	C-B	r	-	e,b,r	
86	Crown Zellerbach	s	P	NW	22	4N	3W	i	40	1	-	80	B	Basalt	Columbia River Basalt Group	1	50	F-C	r	-	e,t,s,b	Site located on unstable hillslope; subject to slumping
87	Deane S. Chappell Rock and Construction	s	P	NW	21	4N	2W	a	68	2.3	-	4,600	B	Basalt	Columbia River Basalt Group	2	40	F-B	r	-	e,s,b,r	Quarrying in two locations on this site
88	Neuman	s	P	NE	28	4N	2W	a	20	1	-	40	B	Basalt	Columbia River Basalt Group	1	20	F-M	r	-	e,t,s,b	
89	Crown Zellerbach	s	P	NE	28	4N	2W	i	4	0.3	-	4	B	Basalt	Columbia River Basalt Group	1	3	F-B	r	-	e,s,b	
90	C.H. May	s	P	SE	27	4N	2W	a	31	1	-	30	B	Basalt	Columbia River Basalt Group	1	33	F-C	r	-	e,t,b	
91	L. Eklund	s	P	NE	34	4N	2W	a	2	1	-	200	B	Basalt	Columbia River Basalt Group	1	20	F	r	-	e,t,s,b	
92	D.F. Salzman	s	P	NE	34	4N	2W	i	8	0.3	-	20	B	Basalt	Columbia River Basalt Group	1	17	F	r	-	e,s,b	
93	C. Aniker	s	P	SW	35	4N	2W	a	36	0.5	-	150	B	Basalt	Columbia River Basalt Group	1	33	F	r	-	e,t,b	
94	Corth	s	P	SW	35	4N	2W	i	1	0.1	-	5	B	Basalt	Columbia River Basalt Group	1	20	F	r	-	e,s	
* 95	Pacific Building Material [illegible]	g	P	NW	32	4N	1W	a	6,300	157	40	10,000	G	Various	Terrace gravels	1	12	F	r	c	e,t,s,b,c,a	Most material removed was shipped by barge to Portland, Oreg.; 85% of estimated future potential lies below water table
96	Les Brady	s	P	NE	2	3N	2W	a	85	0.75	-	1,000	B	Basalt	Columbia River Basalt Group	2	20	F	r	-	e,s,b	
* 97	Scappoose Sand and Gravel	g	P	SW	1	3N	2W	a	50	1,500	-	2,000	G	Various	Terrace gravels	1	12	F	r	c	e,t,s,b,c	Unused portion of pit being used for log storage
98	Unknown	g	P	NE	12	3N	2W	i	80	4	-	0	G	Various	Terrace gravels	1	5	F	r	-	e,t,s,b	
99	Warren Sand and Gravel Co.	g	P	NW	6	3N	1W	a	150	3	2	2,200	G	Various	Terrace gravels	1	10	F	r	-	e,t,s,b,c	Most reserves are below water level; present lateral expansion is at maximum

* State Highway Division laboratory data

TABLE 10.
OREGON STATE HIGHWAY DIVISION LABORATORY DATA FOR COLUMBIA COUNTY

Number	Specific gravity	Los Angeles rattler (% loss)	Sodium sulfate (% loss)	Natural fines		Manufactured fines		Degraded material		Oregon degradation	
				Plasticity index(%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Plasticity index(%)	Liquid limit (%)	Pass No. 20 (%)	Height (inches)
6	2.54-2.71	16.4	0.1- 7.3	-	-	NP	NP	-	-	12.6-19.7	0.2- 0.8
27	2.47-2.86	17.1-18.6	-	NP*	NP-35	-	-	-	-	10.0-16.8	0.3- 1.1
33	2.21-2.99	17.1	0.7-36.2	12	39	-	-	-	-	19.2-19.4	2.3- 6.9
50	2.80	16.3	-	-	-	-	-	NP	23	-	-
52	2.58-2.76	17.0-27.2	1.3- 6.3	-	-	-	-	NP-3	24-41	-	-
55	2.79	16.3	2.2	NP	28	-	-	-	-	7.8	-
56	2.12-2.88	16.8-25.6	-	1-7	27-35	-	-	-	-	16.4-26.6	0.7-10.2
65	2.78	16.3	-	NP	22	-	-	-	-	-	-
68	2.82	16.3	-	NP	16	-	-	-	-	16.6	0.6
71	2.29-2.90	12.8	-	NP	NP	-	-	-	-	11.0-12.4	0.3
85	2.00-2.83	17.9-47.9	-	20	51	-	-	-	-	17.6-62.8	0.6-15.0

* NP = nonplastic

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

TABLE 5.

MULTNOMAH COUNTY ROCK MATERIAL SURVEY DATA

IDENTIFICATION				LOCATION				STATUS	SIZE				SOURCE DESCRIPTION			MINING SYSTEM AND USES						REMARKS
Site number	Operator or owner	Commodity: s-stone, g-sand and gravel, o-other	Domain: L-local, P-private, C-County, S-State, F-Federal	1/4 section	Section	Township	Range	a-active, i-inactive, r-reclaimed, p-prospect	Past production (1,000 cu yds)	Acres excavated	Acres (plant and stockpile)	Future potential (1,000 cu yds)	Deposit type: B-bed rock, T-talus, G-gravel	Rock type	Geological formation or unit	Number of benches	High wall (yds)	Jointing: F-fine (1"-6"), C-coarse (6"-12"), B-blocky (12"-18"), M-massive (18"+)	Breaking ground: r-rippable, e-explosive	Processing plant: c-crusher, s-screen washing, o-other	Usage: e-embankments, t-topping, s-subbase, b-base, r-riprap, j-jettystone, a-asphalt, c-concrete, o-other	
1	Unknown	s	S	SE	36	3N	2W	i	20	0.8	-	26	B	Basalt	Columbia River Bosolt Group	2	12	C-B	e	-	e,b,s, r,t	
* 2	Oregon State Hwy. Div.	s	S	SE	36	2N	2W	a	250	3.5	-	30	B	Basalt	Columbia River Basalt Group	1	26	F-B	r	-	e,b,s	
3	Hidden Valley	s	P	NE	29	2N	1W	r	500	2.5	-	-	B	Basalt	Columbia River Basalt Group	1	27	F-C	r,e	-	e,b, s,t	Landfill
* 4	Angel Brothers, Inc.	s	P	NW	28	2N	1W	a	250	1.5	0.5	7,000	B	Basalt	Columbia River Basalt Group	2	67	F-C	r,e	c,s	e,b,s,t	
* 4a	Oregan State Hwy. Div.	s	S	NE	3	2N	7E	i	225	5.1	2.3	2,000	B	Basalt	Columbia River Basalt Group	1	108	F-C	r	-	e,b,s,t	
5	Multnomah County	s	C	NW	5	1N	1W	a	340	3.5	-	300	B	Basalt	Columbia River Bosalt Group	1	22	F-B	e	c,s	e,b,s, t,r	
* 6	Rivergate Rack Prod.	s	P	NW	13	1N	1W	a	3,250	26	8	16,000	B	Basalt	Columbia River Basalt Group	3	113	C-M	e	c,s, o	e,b,s, t,r	Asphalt plant
7	City of Portland	s	L	SE	24	1N	1W	i	23	0.4	-	230	B	Basalt	Columbia River Basalt Group	1	27	F	e	-	e,b,s	
8	Unknown	g	P	NE	32	1N	1E	i	10	0.3	-	10	B	Conglomerate	Troutdale	1	20	-	r	-	e	
9	City of Portland	s	L	SE	32	1N	1E	i	90	0.6	-	0	B	Basalt	Columbia River Basalt Group	1	47	F-B	e	-	e,b,s, r,t	
10	Unknown	s	P	SW	33	1N	1E	i	150	1	-	50	B	Basalt	Columbia River Basalt Group	4	40	F-C	e	-	e,b	
* 11	Parter W. Yett Co.	g	P	SW	17	1N	2E	a	1,520	18	7	300	G	Various	Terrace grovel	2	23	-	r	c,s, o	e,s,b,t, c	Reserves ore under plant area; material under water not included in reserves; asphalt plant
* 12	Porter W. Yett Co.	g	P	SW	17	1N	2E	i	720	10	-	280	G	Vorious	Terrace grovel	2	26	-	r	-	e,s,b,t	
* 13	Kibby estate	g	P	SE	17	1N	2E	i	1,150	15	-	260	G	Various	Terrace grovel	2	18	-	r	-	e,s,b, t,c	Site contains fine sand to jettystone
14	Portland Sand and Grovel Co.	g	P	NE	20	1N	2E	a	1,500	16	-	500	G	Various	Terrace gravel	1	26	-	r	-	e,s,b, t	
15	Woybo, Inc.	g	P	NE	20	1N	2E	a	1,800	23	-	550	G	Various	Terroce grovel	2	26	-	r	c,s	e,s,b, t	
* 16	Lavelle and Yett	g	P	NW	28	1N	2E	r	1,750	20	-	0	G	Various	Terrace gravel	1	30	-	r	-	e,s,b, t,c	Landfill fills former Rose City Sond and Grovel pit; company is using 5 acres for concrete batch plant and stockpile; Columbia County is source of concrete aggregate
17	Unknawn	s	S	NE	21	1N	2E	i	125	0.7	-	60	B	Basalt	Boring Lova	2	37	C-M	e	-	e,b,s,r	Long abandoned
18	Lewis Celoria	g	P	SW	24	1N	2E	a	30	10	-	30	G	Sandy loom	Terroce sand	1	3	-	r	-	o	Being mined for topsoil; mined land is reshaped and returned ta forming within ane year of mining
19	Unknown	s	C	SE	28	1N	2E	i	380	3	-	350	B	Basalt	Boring Lava	1	103	C-M	e	-	e,b,s,r	
20	Unknown	s	C	SE	28	1N	2E	i	70	0.7	-	50	B	Basalt	Boring Lava	1	32	C-M	e	-	e,b,s,r,o	Used for dimension stone on Rocky Butte, Stork Street, etc.; closed 20 years
* 21	Columbia Sand and Gravel Co.	g	P	SW	26	1N	2E	a	1,120	8	3	400	G	Various	Terroce grovel	2	40	-	r	s,o	e,s,b,t,c	Concrete plant
22	Bob Kingsbury	g	P	SW	30	1N	3E	a	30	6	-	5	G	Sondy loom	Terrace sand	1	3	-	r	-	a	Being mined for topsoil; site appears to hove been left in shape for building construction
23	Troutdale Sand and Gravel Co.	g	P	SE	25	1N	3E	a	43	3	-	15	G	Various	River grovel	1	5	-	r	-	e,s,b,t,c	
* 24	Rogers Const.Co.	g	P	SW	33	1N	3E	i	1,500	30	10	500	G	Various	Terroce grovel	1	10	-	r	-	e,s,b,t,c	
25	Loren Obrist	g	P	NW	36	1N	3E	a	300	4	-	30	G	Sand	Terrace sand	1	20	-	r	-	e,s	
26	Don Obrist	g	P	SW	36	1N	3E	a	1,200	17	-	500	G	Sand	Terroce sand	1	22	-	r	-	e,s	
27	C.T. Howell	s	P	NW	31	1N	4E	a	100	5	-	150	T	Basalt	Boring Lava	1	15	-	r	-	e,s,b	
28	Hershel McGriff	s	P	NW	22	1N	5E	i	50	3	-	100	B	Basalt	Columbia River Basalt Group	1	7	F-C	r	-	e,s,b	
* 29	Oregon State Hwy. Div.	s	S	SW	14	1N	5E	i	500	7	-	3	B	Basalt	Columbia River Basalt Group	1	15	F	r	-	e,b,s,t	
30	Raymond Smith	s	P	NE	27	1N	5E	i	75	2	-	25	B	Basalt	Boring Lava	1	10	C	e	-	e,s,b	
31	Unknown	s	S	SE	7	1N	5E	i	50	1.6	-	200	T	Basalt	Columbia River Basalt Group	1	5	F-C	r	-	e,b,s,r	
* 32	Oregon Stote Hwy. Div.	s	S	NW	1	1N	6E	i	0	0	-	5,000	T	Basalt	Columbia River Basalt Group	0	0	F-C	r	-	e,b,s, c,o	Located to neorest ¼ section
33	U.S. Forest Service	s	F	SW	33	1N	6E	r	2	1.2	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnoissance August 1977								
34	U.S. Forest Service	s	F	SE	24	1N	6E	-	5	1.0	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial recarnoissonce August 1977								
35	U.S. Forest Service	s	F	-	20	1N	7E	-	3	1.0	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnaissonce August 1977								
* 36	Ross Island Sond and Grovel Co.	g	P	NE	15	1S	1E	a	15,000	135	55	21,000	G	Various	River gravel	1	33	-	r	c,s	e,s,b,t, c,a	Reserves will come from removal of Ross Island; logoon area now exhausted; mining is by flooting dredge; concrete plont
* 37	Portlond Sand and Grovel Co.	g	P	SW	3	1S	2E	a	4,400	27	2	1,000	G	Various	Terrace gravel	3	47	-	r	c,s	e,s,b,t, c,a	Fill and concrete
* 38	Oregon Asphol-tic Paving Co.	g	P	NE	1	1S	2E	a	1,200	12	-	250	G	Vorious	Terrace grovel	1	20	-	r	-	e,s,b,t, c,o	
39	Unknown	s	P	SW	13	1S	2E	i	15	0.3	-	50	B	Basalt	Boring Lava	1	23	B	e	-	e,b	Badly weathered
40	Unknown	g	P	SE	13	1S	2E	r	15	2.5	-	80	G	Various	Terrace grovel	1	3	-	r	-	e,b,s	Boneyord for construction company; reserve estimate based on 20 ft depth
*40a	Dan Obrist	s	P	NE	24	2S	1E	a	6	0.7	-	2,500	B	Andesite	Boring Lovo	2	3	C-M	e	-	e,b,s,t	
*41	Multnomoh County	g	C	SW	5	1S	3E	a	1,800	40	3	230	G	Various	Terrace gravel	3	5	-	r	c,s	e,s,b,t, c,o	
*42	Rogers Const. Co.	g	C	SE	5	1S	3E	a	4,000	20	4	4,000	G	Various	Terrace grovel	1	40	-	r	c,s	e,s,b,t, c,a	
*43	Gresham Sand and Grovel Co.	g	C	SE	5	1S	3E	a	3,300	26	5	1,200	G	Various	Terrace grovel	1	30	-	r	c,s	e,s,b,t, c,o	
44	Columbia Brick Works, Inc.	a	P	SW	14	1S	3E	a	150	6	3.6	400	B	Cloy	Terrace silt	0	0	-	r	c,o	a	Kiln used to burn cloy into brick
45	U. S. Forest Service	s	F	SE	24	1S	5E	-	2	0.3	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnoissonce August 1977								
46	U. S. Forest Service	s	F	SW	1	1S	6E	-	3	0.5	-	-	B	No on-site survey; Bull Run Reserve; data token from aerial photos								
47	U. S. Forest Service	s	F	SE	10	1S	6E	-	17	3.4	-	-	B	No on-site survey; Bull Run Reserve; data token from aerial photos								
48	U. S. Forest Service	s	F	NE	10	1S	6E	-	6	1.3	-	-	B	No on-site survey; Bull Run Reserve; dota token from aerial photos								
49	U. S. Forest Service	s	F	SW	11	1S	6E	-	2	0.2	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
50	U. S. Forest Service	s	F	NW	21	1S	6E	-	8	1.3	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
51	U. S. Forest Service	s	F	-	3	1S	7E	-	5	4.0	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnoissonce August 1977								
52	U. S. Forest Service	s	F	SW	22	1S	7E	-	1	0.1	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
53	U. S. Forest Service	s	F	NW	24	1S	7E	-	3	0.2	-	-	B	No on-site survey; Bull Run Reserve; site checked by aerial reconnoissonce August 1977								
54	U. S. Forest Service	s	F	SE	19	1S	8E	-	2	0.7	-	-	B	No on-site survey; Bull Run Reserve; data taken from aerial photos								
55	U. S. Forest Service	s	F	SW	20	1S	8E	-	1	0.3	-	-	B	No on-site survey; Bull Run Reserve; data token from aerial photos								

* Stote Highway Division laboratory data

TABLE 11.

OREGON STATE HIGHWAY DIVISION LABORATORY DATA FOR MULTNOMAH COUNTY

Number	Specific gravity	Los Angeles rattler (% loss)	Sodium sulfate (% loss)	Natural fines		Manufactured fines		Degraded material		Oregon degradation	
				Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Pass No. 20 (%)	Height (inches)
2	2.74-2.91	16.3-34.5	2.7 -13.4	NP* - 8	NP-40	-	-	2-3	25-27	11.0-48.7	0.3-10.6
4	-	-	-	-	-	-	-	-	-	21.1	1.4
4a	2.85-2.88	15.1	-	NP - 2	19-31	-	-	NP	24	20.3-22.0	0.7- 1.3
6	2.35-2.91	15.7-21.9	1.6 -37.0	NP -12	NP-46	NP	29	-	-	14.2-20.5	0.3- 7.4
7a	2.74	19.0	6.9	-	-	-	-	-	-	25.5	4.5
11,12,13	2.51-2.85	11.8-17.31	0.2 -20.9	NP - 6	NP-29	-	-	-	-	13.7-21.8	0.3- 3.6
16	-	-	-	-	-	-	-	-	-	19.0	0.9
21	2.40-2.85	8.1	0.8 -25.1	-	-	-	-	-	-	10.8-17.4	0.4- 2.6
24	2.78-2.82	16.3-19.0	-	NP	20-23	-	-	-	-	21.2	1.7
29	2.67-2.74	19.0-40.9	-	NP -12	23-40	-	-	-	-	-	-
32	2.68-2.85	22.14	0.5 - 1.0	-	-	-	-	-	-	16.3	0.4
36	2.44-2.78	11.7-15.0	0.4 -19.5	NP	NP-22	-	-	-	-	13.6-21.5	0.5- 0.9
37	-	-	-	-	-	-	-	-	-	19.6	0.8
38	2.21-2.84	14.7-20.9	0.1 -23.0	NP - 9	8-34	NP-4	NP-26	-	-	14.4-24.6	0.4- 1.4
41	2.73-2.80	20.0-23.6	-	NP - 2	20-29	-	-	-	-	-	-
42	2.19-2.84	15.5-23.3	1.34-41.8	NP -20	NP-45	NP-8	25-30	-	-	16.3-26.8	0.6- 3.1
43	-	-	-	-	-	-	-	-	-	25.4	0.9

* NP = nonplastic

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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

TABLE 6.

WASHINGTON COUNTY ROCK MATERIAL SURVEY DATA

IDENTIFICATION				LOCATION				STATUS	SIZE				SOURCE DESCRIPTION			MINING SYSTEM AND USES						REMARKS
Site number	Operator or owner	Commodity: s-stone, g-sand and gravel, o-other	Domain: L-local, P-private, C-County, S-State, F-Federal	1/4 section	Section	Township	Range	a- active, i-inactive, r-reclaimed, p-prospect	Past production (1,000 cu yds)	Acres excavated	Acres (plant and stockpile)	Future potential (1,000 cu yds)	Deposit type: B-bed rock, T-talus, G-gravel	Rock type	Geological formation or unit	Number of benches	High wall (yds)	Jointing: F-fine (1"-6"), C-coarse (6"-12"), B-blocky (12"-18"), M-massive (18"+)	Breaking ground: r-rippable, e-explosive	Processing plant: c-crusher, s-screen washing, o-other	Usage: e-embankments, s-topping, s-subbase, b-base, r-riprap, j-jettystone, a-asphalt, c-concrete, o-other	
1	Lite Rock Co.	o	P	NE	23	3N	5W	a	450	62	6	2,000	B	Siltstone	Keasey	5	20	F	r	c,s, o	c,o	Shale from this pit was crushed, screened, and kilned, causing the shale to bloat. Bloated material was used as a lightweight aggregate
* 1a	Oregon State Hwy. Div.	s	S	NW	6	3N	5W	i	200	2.5	0.5	2,000	B	Basalt	Nestucca	1	55	F-M	e	-	e,s, b,t	
* 2	Oregon State Hwy. Div.	s	S	SE	25	3N	5W	i	36	0.5	-	10	B	Shale	Keasey	1	52	F	r	-	e	
3	Cloverleaf Mines Ltd.	o	P	NW	8	3N	4W	i	85	2	-	30	B	Siltstone	Keasey	2	50	F	r	-	o	Post production from this shale pit was bloated and used as a lightweight aggregate
4	Publishers Paper Co.	s	P	NE	13	3N	3W	i	75	1	-	75	B	Basalt, shale	Keasey	3	20	F-C	r	-	e,s, b,t	
5	Crown Zellerbach	s	P	NW	23	3N	4W	i	20	0.3	-	50	B	Shale	Keasey	3	16	F-C	r	-	b,t	
* 6	D. Ellis	s	P	NW	29	3N	4W	i	38	0.5	-	5	B	Siltstone	Keasey	1	16	F	r	-	e	
* 6a	Unknown	s	P	NW	35	3N	4W	i	50	0.7	0.9	700	B	Basalt	Columbia River Basalt Group	1	25	F	r,e	-	e,s, b,t	
* 7	Oregon State Hwy. Div.	s	S	NW	33	3N	3W	i	35	1	-	20	B	Basalt	Keasey	2	30	F	r	-	e	
8	Oregon State Hwy. Div.	s	S	NE	20	2N	5W	i	20	0.5	-	5	B	Basalt	Nestucca	1	16	B	r,e	-	e,b, s,t	
* 8a	State of Oregon	s	S	SE	13	2N	5W	i	9	0.2	-	100	B	Basalt	Columbia River Basalt Group	1	13	F	r	-	e,s, b,t	
* 9	Peters Gravel Pit	g	P	SE	36	2N	5W	i	85	5	-	0	G	Various	Terrace gravel	0	0	-	r	-	b,t	Pit filled with water
*10	Banks Rock Products	s	P	NE	28	2N	4W	a	200	5	0.5	35,000	B	Basalt	Columbia River Basalt Group	4	22	C	r,e	c,s	s,b,t	
11	Unknown	g	P	NW	33	2N	2W	i	15	5	-	0	G	Sand	Terrace sand	3	2	-	r	-	e	Pit being used as trash dump
*12	Washington County	s	C	NE	33	2N	2W	i	450	6.5	-	150	B	Basalt	Columbia River Basalt Group	1	46	B-M	e	-	s,b, t,e	
13	City of Forest Grove	s	L	NE	14	1N	5W	i	18	0.4	-	30	B	Siliceous shale	Nestucca	3	10	F	r	-	e,s, b,t	
14	City of Forest Grove	s	L	NE	22	1N	5W	i	4	0.2	-	20	B	Siliceous mudstone	Nestucca	2	3	F-C	r	-	e,s, b,t	
*15	Karban Construction	s	P	NW	16	1N	4W	i	150	3	-	100	B	Basalt	Columbia River Basalt Group	1	48	F	r	-	e,s, b,t	
16	Gales Creek Sandand Gravel	g	P	NW	17	1N	4W	r	200	20	-	110	G	Various	River gravel	0	0	-	r	-	e,s, b,t	Pit refilled with river gravel and overgrown with trees
*17	Melvin Howell	g	P	SW	17	1N	4W	i	400	40	-	200	G	Various	Terrace gravel	0	0	-	r	-	e,s, b,t	
18	Karban Construction	s	P	SW	21	1N	4W	i	31	5	-	2,700	B	Basalt	Nestucca	3	22	B	e,r	-	e,s, b,t,r	
19	David Otto	s	P	NW	33	1N	4W	a	55	2	-	150	B	Basalt, shale	Nestucca	4	32	F-C	r,e	c	e,s,b,t	
*20	Washington County	s	C	NE	12	1N	2W	r	10	1	-	10	B	Basalt, weathered	Columbia River Basalt Group	1	13	C	r	-	e,t,b, s,r	Pit has 1 ft of standing water and is overgrown with trees
21	Stimson Lumber Co.	s	P	SW	8	1N	5W	a	21	0.5	-	40	B	Basalt, weathered	Nestucca	2	6	F	r	-	e,s, b,t	
22	Unknown	s	P	NE	36	1S	5W	r	4	0.2	-	0	B	Basalt	Columbia River Basalt Group	1	7	C	e,r	-	e,s, b,t	
23	Vanaken Crushed Rock	s	P	NE	9	1S	4W	a	500	25	5	120	B	Basalt	Nestucca	4	52	F-C	e,r	-	e,s, b,t	
24	Voondering Crushed Rock	s	P	NW	9	1S	4W	a	40	10	0.2	200	B	Basalt	Nestucca	4	18	C-B	r,e	c	e,s, b,t	
25	Oregon State Hwy. Div.	s	S	NW	27	1S	4W	i	50	2	-	35	B	Tuff, silty sandstone	Keasey (?) Nestucca (?)	2	27	C-M	r,e	-	s,b,r, e,j	
26	Oregon State Hwy. Div.	g	S	NW	7	1S	3W	r	100	20.5	-	0	G	Various	Terrace gravel	0	0	-	r	-	e	Site reclaimed
27	Willamette Industries	s	P	SE	20	1S	3W	i	200	2.5	-	100	B	Basalt	Columbia River Basalt Group	3	29	F-C	r,e	-	e,s, b,t	
*28	John Mathews	s	P	NE	30	1S	2W	r	7	1	-	0	B	Basalt, weathered	Columbia River Basalt Group	1	10	F	r	-	e	Pit partially filled
29	Vandecoevering	s	P	NW	29	1S	2W	i	40	1	-	0	B	Tuff	Columbia River Basalt Group	1	10	F	r	-	e	
*30	Quality Rock Plant #1	s	P	NW	26	1S	2W	a	520	14	5.5	700	B	Basalt	Columbia River Basalt Group	3	26	M	e,r	c	e,r,s, b,t	
*31	Baker Rock Crushing	s	P	NW	26	1S	2W	a	1,000	14	8	400	B	Basalt	Columbia River Basalt Group	4	33	F-M	e,r	c,s	e,r,s, b,t	
*32	Cobb Rock	s	P	SE	26	1S	2W	a	1,500	106	5	10,000	B	Basalt	Columbia River Basalt Group	4	13	F-M	e,r	c,s	e,s, b,t	
*33	Progress Quarries	s	P	NE	29	1S	1W	i	1,250	12	-	100	B	Basalt, weathered	Columbia River Basalt Group	5	23	C	e,r	-	e,s, b,t	Pit partially filled with water and partially reclaimed with demolition material. Part of the area is being used for storage of bark chips
*34	Vanaken Crushed Rock	s	P	NE	11	2S	3W	r	22	1.5	-	0	B	Basalt	Columbia River Basalt Group	1	14	M	e,r	-	e,s, b,t	Pit is in stream bed
35	Dayton Sand and Gravel	s	P	SW	8	2S	3W	i	50	3	0.2	400	B	Basalt	Columbia River Basalt Group	4	26	C	r	-	e,s, b,t	
*36	Progress Quarries	s	P	NE	5	2S	1W	a	1,200	21	12	800	B	Basalt	Columbia River Basalt Group	5	26	C	r,e	c,s	e,s, b,t	
*36a	Unknown	s	P	NW	2	2S	2W	r	10	0.6	-	400	B	Basalt	Columbia River Basalt Group	1	4	F-B	e	-	e,s, b,t	
37	Unknown	s	P	SE	9	2S	1W	r	17	0.5	-	0	B	Basalt, weathered	Columbia River Basalt Group	1	18	C	r	-	e,s, b,t	Pit being filled with demolition material
38	Washington County	g	C	NE	13	2S	1W	a	750	70	3	200	G	Various	Lacustrine gravel	3	15	-	r	c,s	e,s, b,t	
39	Steinban	g	P	SE	19	2S	1W	i	55	4	-	50	B	Sand	Lacustrine sand	1	13	-	r	-	e	
40	Albertson	g	P	NW	21	2S	1W	r	5	0.5	-	2	G	Sand	Lacustrine sand	1	1	-	r	-	e	
41	Thompson Sand	g	P	NE	21	2S	1W	i	300	25	-	100	G	Sand	Lacustrine sand	2	7	-	r	-	e	
42	Doles Sand and Gravel	g	P	NE	21	2S	1W	r	30	2	-	0	G	Sand	Lacustrine sand	1	7	-	r	-	e	Pit being reclaimed for industrial site
43	Brineger-Barstad	g	P	NE	21	2S	1W	i	350	11	-	100	G	Sand	Lacustrine sand	1	7	-	r	-	e	
44	Southwest Ready Mix	g	P	SW	21	2S	1W	r	30	2	-	0	G	Sand	Lacustrine sand	1	2	-	r	-	e	Pit being reclaimed
45	George Albertson	g	P	NE	21	2S	1W	a	900	45	-	350	G	Sand	Lacustrine sand	1	7	-	r	-	e	
46	John D. Hagg	g	P	SE	21	2S	1W	i	30	2.7	-	20	G	Sand	Lacustrine sand	2	1	-	r	-	e	
47	Unknown	g	P	SE	21	2S	1W	r	80	4.2	-	20	G	Sand	Lacustrine sand	1	7	-	r	-	e	Pit being filled with demolition material
*48	Tigard Sand and Gravel	s	P	SW	34	2S	1W	a	2,000	140	6	20,000	B	Basalt	Columbia River Basalt Group	5	16	F-M	e,r	r,e	e,s,b, t,r,a	
49	Baker Rock Crushing	s	P	NW	35	2S	1W	i	75	3	-	100	B	Basalt	Columbia River Basalt Group	2	10	F-C	r	-	e,s, b,t	
50	Eaton Sand and Gravel	s	P	NE	33	2S	1W	i	40	3	-	100	B	Basalt	Columbia River Basalt Group	1	6	C-M	e,r	-	e,s, b,t	
*51	J.C. Compton Co.	s	P	NW	33	2S	1W	i	65	8	-	150	B	Basalt	Columbia River Basalt Group	1	3	F-M	e,r	-	e,s, b,t	
*52	Eaton Sand and Gravel	s	P	SE	33	2S	1W	a	55	4.7	3.1	100	B	Basalt	Columbia River Basalt Group	3	9	M-C	e,r	c	r,e,s, b,t	
53	Stearns Rock	s	P	NW	3	3S	1W	a	130	9	1.8	1,000	B	Basalt	Columbia River Basalt Group	2	12	F-M	e,r	-	r,e,s, b,t	
54	Dales Sand and Gravel	s	P	NW	3	3S	1W	a	100	3	0.3	300	B	Basalt	Columbia River Basalt Group	4	70	F-M	e,r	c	r,e,s, b,t	

* State Highway Division laboratory data

TABLE 12.

OREGON STATE HIGHWAY DIVISION LABORATORY DATA FOR WASHINGTON COUNTY

Number	Specific gravity	Los Angeles rattler (% loss)	Sodium sulfate (% loss)	Natural fines		Manufactured fines		Degraded material		Oregon degradation	
				Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Pass No. 20 (%)	Height (inches)
1a	2.51-2.85	14.5-38.1	3.9	4-5	25-27	-	-	-	-	9.6-37.9	1.5-14.1
2	2.86-2.91	27.2-49.0	16.6	-	-	NP	28	-	-	28.1-52.6	7.7-13.1
6	2.88	20.0	1.5	-	-	-	-	-	-	25.2	6.0
6a	2.80-2.88	14.5-15.1	0.2- 0.5	-	-	NP	NP	NP	24	15.4	0.8
7	2.84-2.94	14.5-17.4	-	NP*	21-26	-	-	-	-	11.9-25.3	0.4- 1.3
8a	2.81-2.88	11.8-19.0	0.2-11.5	-	-	-	-	-	-	13.9-33.7	0.8-14.3
9	2.85	-	-	NP-3	20-26	10	36	-	-	-	-
10	2.58-2.86	7.3-20.66	-	-	-	-	-	4	33	11.7-25.1	0.2- 1.3
12	2.85	19.0	-	-	-	-	-	NP	23	-	-
15	-	15.5	-	-	-	-	-	-	-	16.8	1.4
17	2.84-2.89	22.7-23.6	-	NP-3	22-31	-	-	-	-	-	-
20	2.76-2.88	25.4-26.3	7.9	-	-	-	-	NP	25	18.6	1.8
28	2.66-2.80	30.9-48.1	10.7	NP-4	28-34	-	-	3	28	-	-
30,31,32	2.14-2.93	16.4-33.0	0.6-28.9	NP-5	NP-43	NP	22	-	-	14.5-28.2	0.8- 9.1
33	2.71-2.89	14.5-18.1	0.2	NP-4	24-30	-	-	-	-	13.7-26.2	0.5- 4.0
34	2.64	25.4	-	NP	24	-	-	-	-	-	-
36	2.13-2.82	15.7-34.5	8.5-55.0	NP-10	23-43	NP-4	27-41	-	-	15.2-24.6	0.7- 7.7
36a	2.76-2.79	25.4-27.2	2.3	NP	23	-	-	NP	23	20.4	2.1
48	2.22-2.95	22.8-34.6	0.6-49.4	NP-5	NP-32	-	-	-	-	17.4-26.3	0.5- 5.9
51	2.41-2.94	20.3-22.8	1.1-14.3	NP	25-29	-	-	-	-	0.9- 1.1	15.4-23.5
52	2.79	24.5	-	-	-	-	-	NP	25	-	-

* NP = nonplastic

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

TABLE 9

OREGON STATE HIGHWAY DIVISION LABORATORY DATA FOR CLACKAMAS COUNTY

Number	Specific gravity	Los Angeles rattler (% loss)	Sodium sulfate (% loss)	Natural fines		Manufactured fines		Degraded material		Oregon degradation	
				Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Plasticity index (%)	Liquid limit (%)	Pass No. 20 (%)	Height (inches)
17	2.78	15.0-21.3	2.6- 9.4	NP*	NP-20	-	-	-	-	13.6-23.6	0.4- 1.9
21	-	-	-	-	-	-	-	-	-	16.7	0.7
26	2.74-2.89	12.7-18.6	0.1	NP-4	18-24	-	-	-	-	15.9-26.7	0.4- 2.7
30	-	15.3	-	NP	NP	-	-	-	-	-	-
31	2.59-2.84	20.5-28.4	0- 0.2	-	-	-	-	-	-	17.3-17.7	0.4- 0.5
37	2.42-2.74	-	1.5-20.8	NP	NP	-	-	-	-	15.5-25.9	0.5- 7.5
37a	2.68	30.9-49.0	-	-	-	-	-	NP	22-24	-	-
46	2.47-2.93	13.9-25.9	1.5- 9.0	NP	NP-25	-	-	-	-	14.9-21.5	0.3- 1.2
62	2.69-2.89	17.3-35.4	1.7- 2.3	NP-6	22-32	-	-	-	-	19.1-23.9	0.7- 2.8
66	2.79	21.8	-	NP	22	-	-	-	-	21.9	1.6
67	2.74	17.5	-	-	-	-	-	-	-	-	-
70	-	-	-	NP	NP	-	-	-	-	-	-
72	2.60-2.80	15.3-18.1	5.43	NP	22-26	-	-	-	-	18.5-18.9	0.7- 1.0
72a	2.55-2.81	14.8-32.7	1.7	NP-11	NP-48	-	-	-	-	21.2-24.9	1.2- 2.6
75	2.74-2.78	8.2	2.9	NP	18-26	-	-	-	-	10.0	0.4
85	2.55-2.63	13.9-20.5	2.3-15.8	NP	NP	-	-	-	-	15.7-21.0	0.7-15.7
89	2.79	16.9-24.0	1.9-12.0	NP	NP-19	-	-	-	-	11.1-21.9	0.6- 2.3
110	2.79-2.84	22.7-28.3	0.5- 5.0	NP	NP-25	-	-	-	-	9.1-20.6	0.3- 0.5
114	-	21.0-32.6	-	NP	NP-21	-	-	-	-	15.4-23.3	1.0- 2.1
118	-	18.9-21.6	-	3	26	-	-	-	-	16.8-26.8	3.5- 5.8
188	2.86	16.3	-	-	-	-	-	-	-	18.35	0.3

* NP = nonplastic

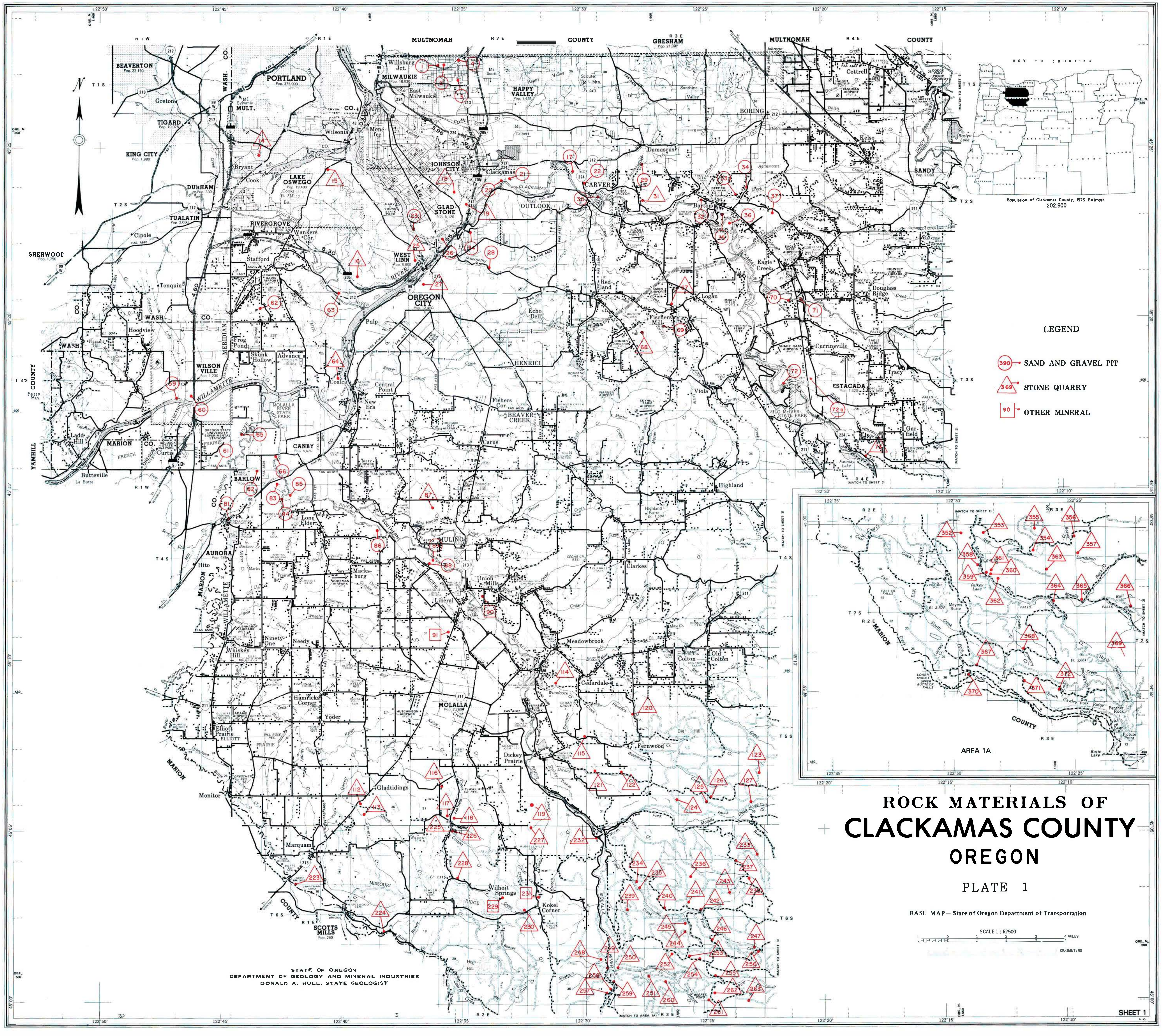
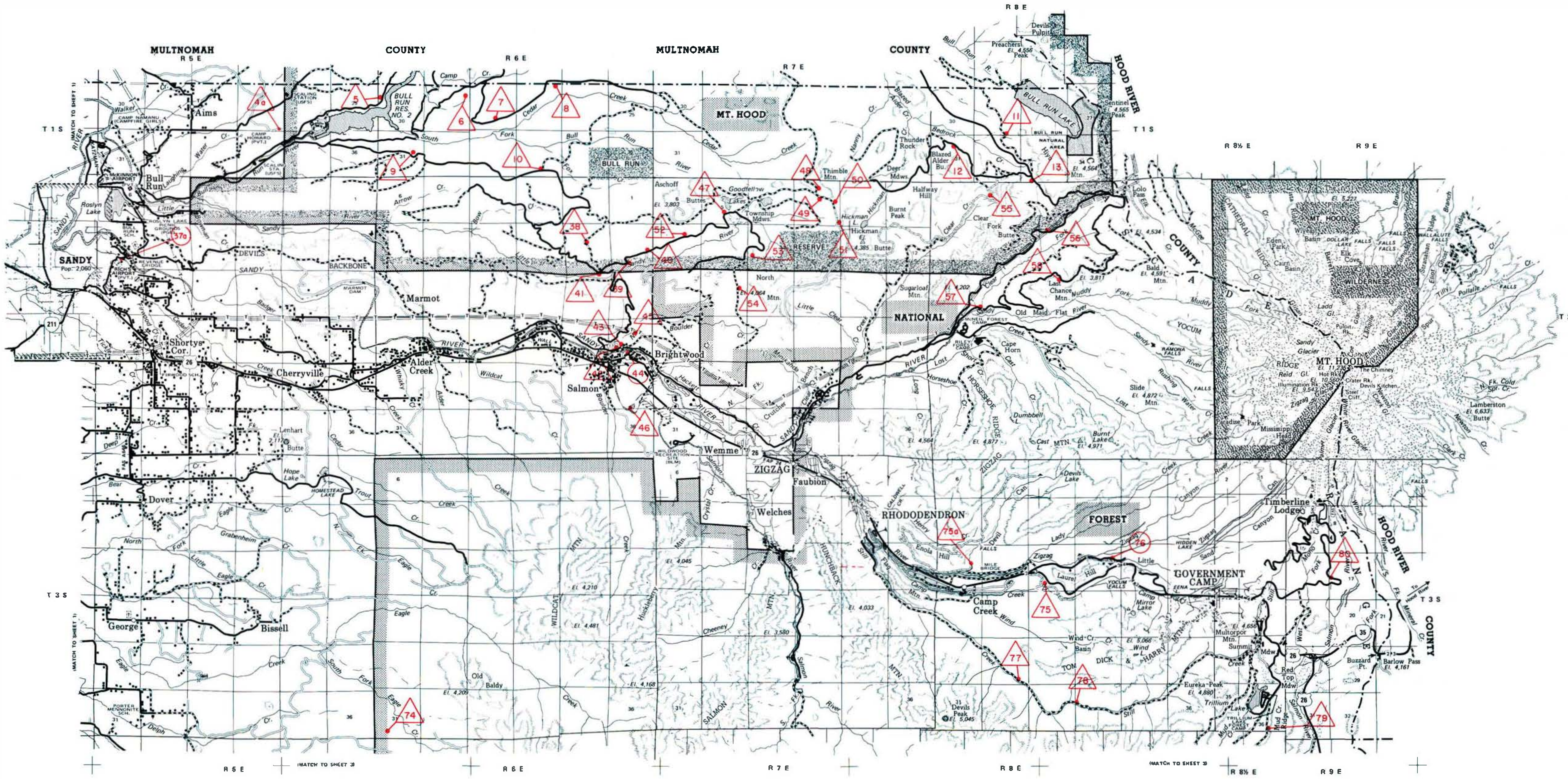

ROCK MATERIALS OF
CLACKAMAS COUNTY
OREGON
PLATE 1
BASE MAP— State of Oregon Department of Transportation
SCALE 1 : 62500
LEGEND
SAND AND GRAVEL PIT
STONE QUARRY
OTHER MINERAL
KEY TO COUNTIES
Population of Clackamas County, 1975 Estimate 202,900
AREA 1A
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST
SHEET 1

PLATE 1



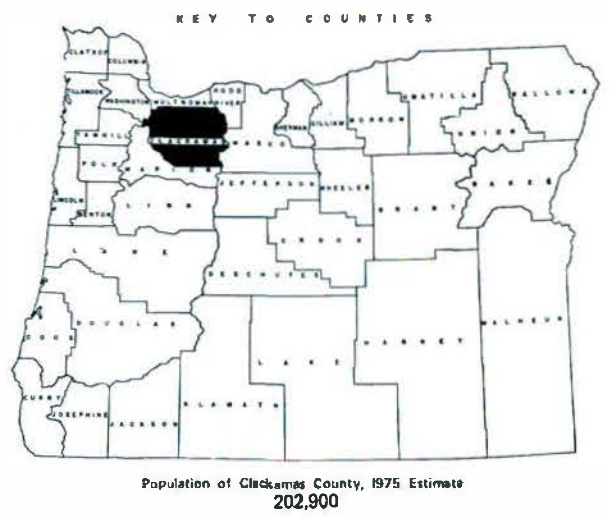
ROCK MATERIALS OF CLACKAMAS COUNTY

LEGEND

76 SAND AND GRAVEL PIT

75 STONE QUARRY

90 OTHER MINERAL



Population of Clackamas County, 1975 Estimate 202,900

STATE OF OREGON
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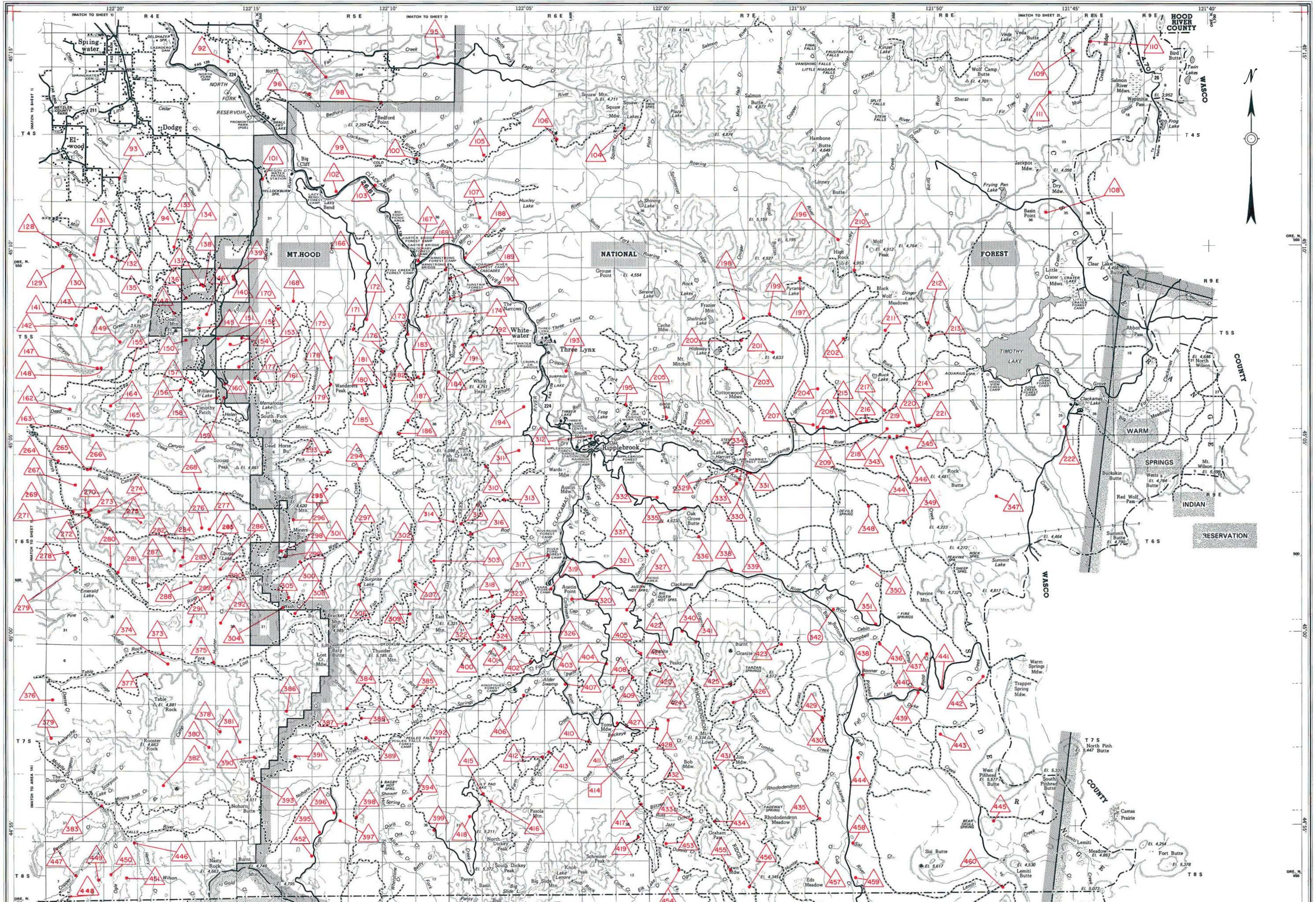
DONALD A. HULL, STATE GEOLOGIST

SCALE 1 : 62500

BASE MAP – State of Oregon Department of Transportation

SHEET 2



ROCK MATERIALS OF
CLACKAMAS COUNTY
OREGON

PLATE 1

BASE MAP – State of Oregon Department of Transportation

SCALE 1 : 62500

Polyconic Projection
Plane Coordinate on Lambert Projection

LEGEND

317 SAND AND GRAVEL PIT

317 STONE QUARRY

17 OTHER MINERAL

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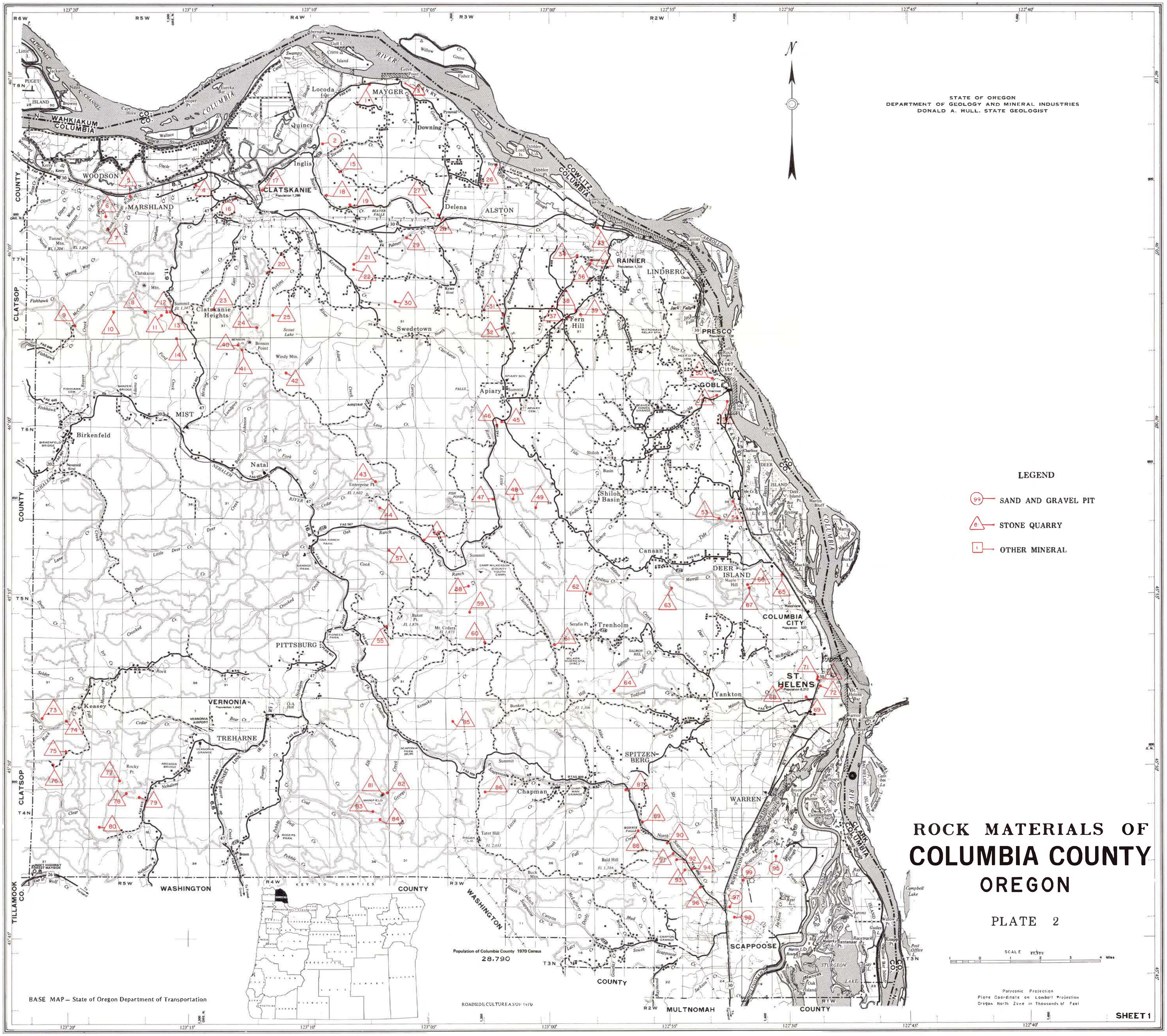
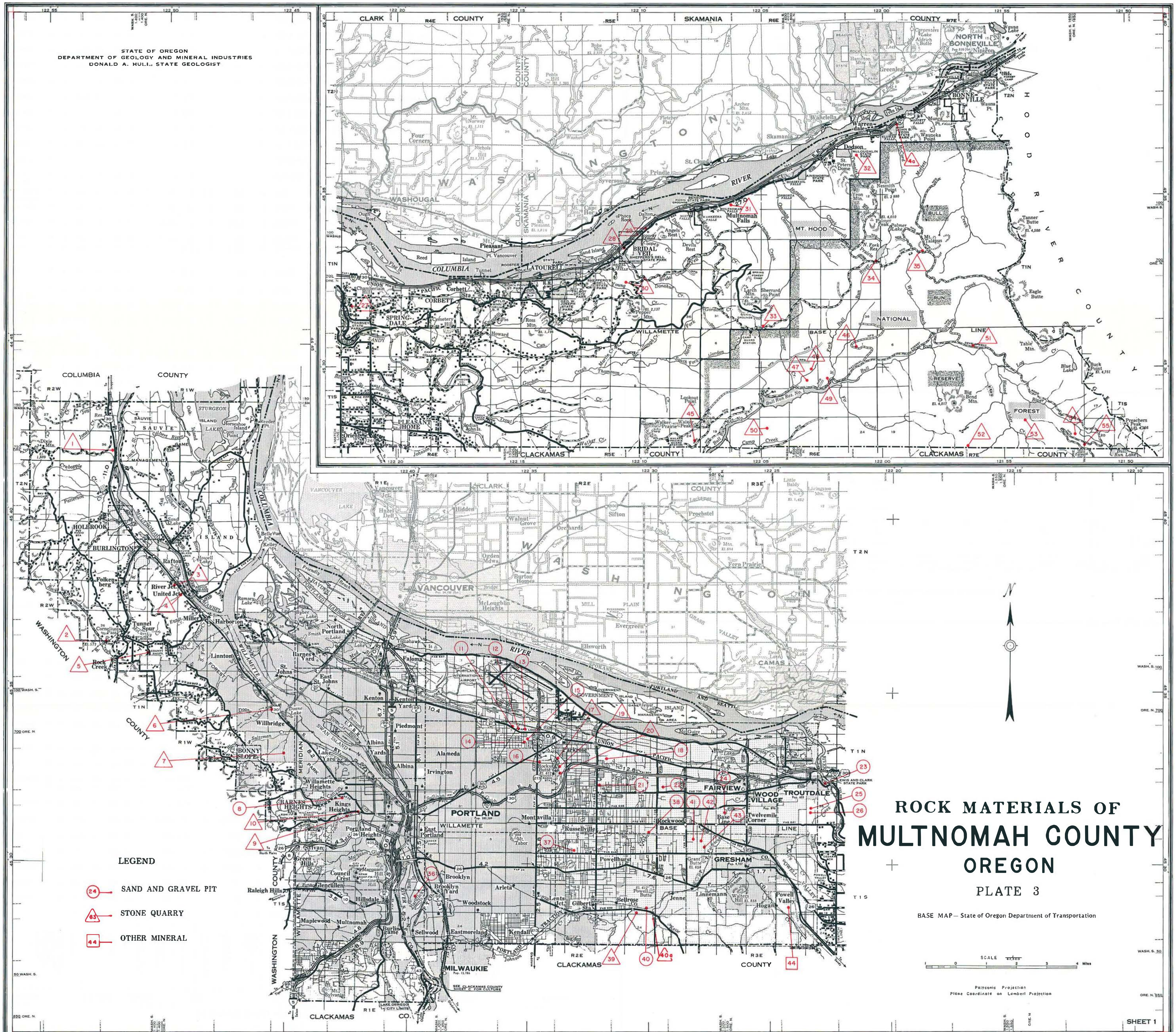
SHEET 3


STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST
LEGEND
SAND AND GRAVEL PIT
STONE QUARRY
OTHER MINERAL
ROCK MATERIALS OF
COLUMBIA COUNTY
OREGON
PLATE 2
Population of Columbia County 1970 Census
28,790
BASE MAP— State of Oregon Department of Transportation
KEY TO COUNTIES
SHEET 1


STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST
ROCK MATERIALS OF
MULTNOMAH COUNTY
OREGON
PLATE 3
BASE MAP— State of Oregon Department of Transportation
LEGEND
SAND AND GRAVEL PIT
STONE QUARRY
OTHER MINERAL
SHEET 1
PORTLAND
GRESHAM
TROUTDALE
FAIRVIEW
VANCOUVER
MILWAUKIE
COLUMBIA RIVER
WASHINGTON
CLACKAMAS COUNTY
HOOD RIVER COUNTY
SKAMANIA COUNTY
CLARK COUNTY
COLUMBIA COUNTY
WASHINGTON COUNTY

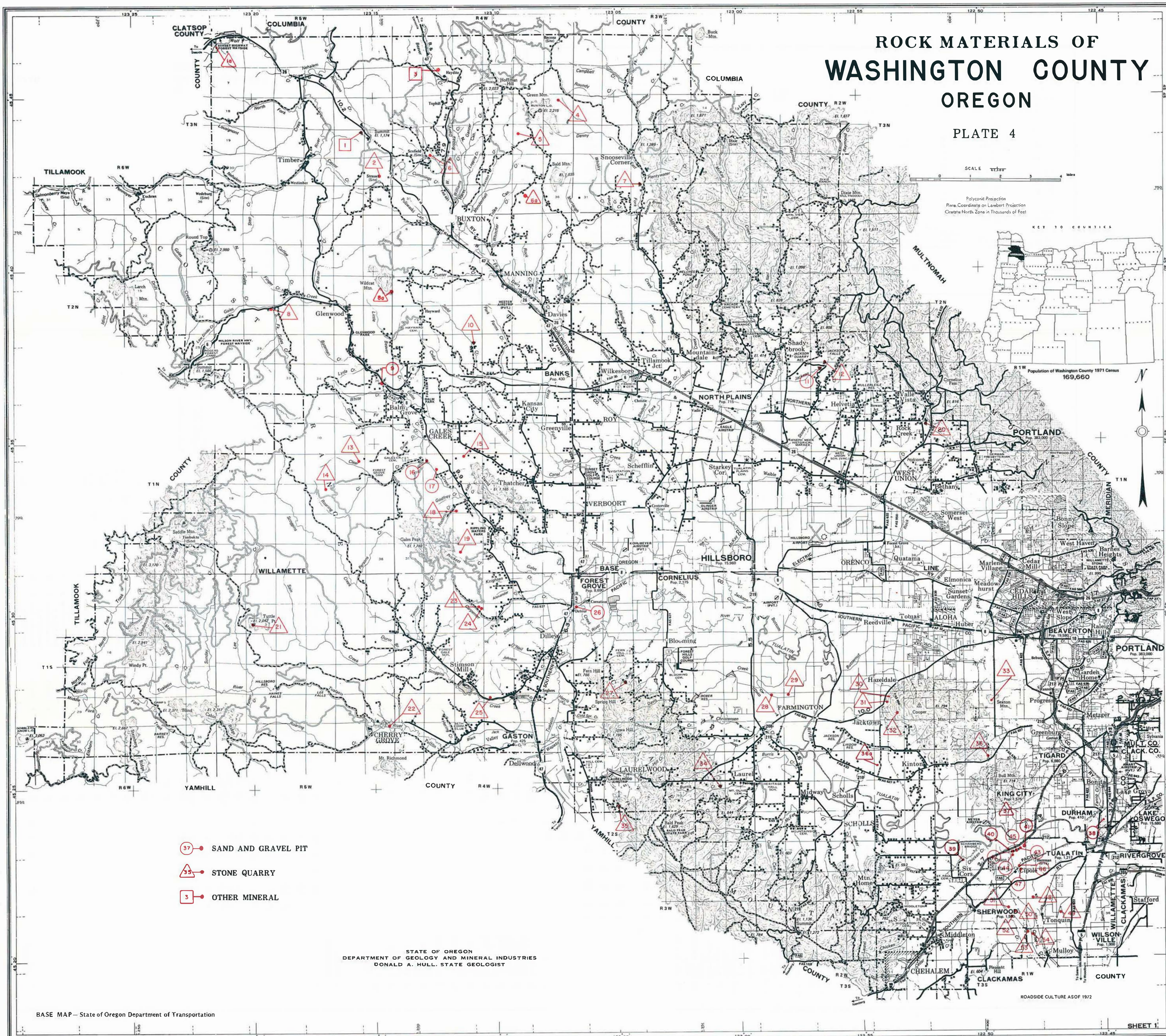

ROCK MATERIALS OF
WASHINGTON COUNTY
OREGON
PLATE 4
Polyconic Projection
KEY TO COUNTIES
Population of Washington County 1971 Census
169,660
SAND AND GRAVEL PIT
STONE QUARRY
OTHER MINERAL
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST
BASE MAP— State of Oregon Department of Transportation
ROADSIDE CULTURE AS OF 1972
SHEET 1

TABLE 3 CLACKAMAS COUNTY ROCK MATERIAL SURVEY DATA

(CONTINUED)

Site number	Operator or owner	Commodity: s-stone, g-sand and gravel, o-other	Domain: L-Local, P-Private, C-County, S-State, F-Federal	1/4 section	Section	Township	Range	Status: a-active, i-inactive, r-reclaimed, p-prospect	Past production (1,000 cu yds)	Acres excavated	Acres (plant and stockpile)	Future potential (1,000 cu yds)	Deposit type: B-bed rock, T-talus, G-gravel	Rock type	Geological formation or unit	Number of benches	High wall (yds)	Jointing: F-fine (1"-6"), C-coarse (6"-12"), B-blocky (12"-18"), M-massive (18"+)	Breaking ground: r-rippable, e-explosive	Processing plant: c-crusher, s-screen washing, o-other	Usage	Remarks
238	Crown Zellerbach	s	P	SW	12	6S	3E	i	2	0.1	-	5	B	Andesite porphyry	Sardine	1	8	F	r	-	t,s,b	
239	Crown Zellerbach	s	P	SW	17	6S	3E	i	35	1.5	-	20	B	Andesite	Little Butte Volcanics	4	3	F-C	r	-	t,s,b	
240	Crown Zellerbach	s	P	SE	16	6S	3E	r	1	0.1	-	0	B	Andesite	Sardine	1	3	F-C	r	-	s,b	
241	Crown Zellerbach	s	P	NW	15	6S	3E	i	5	0.1	-	10	B	Andesite	Sardine	2	13	F-M	r	-	t,s,b	
242	Crown Zellerbach	s	P	SE	15	6S	3E	i	110	4	-	50	B	Andesite	Sardine	4	22	F-B	r	-	t,s,b	
243	Crown Zellerbach	s	P	NE	14	6S	4E	i	1	0.1	-	0	B	Andesite	Sardine	1	9	F	r	-	t,s,b	
244	Crown Zellerbach	s	P	NW	22	6S	3E	i	5	0.2	-	5	B	Andesite	Sardine	1	4	F-C	r	-	t,s,b	
245	Crown Zellerbach	s	P	NW	22	6S	3E	i	7	0.1	-	3	B	Andesite	Sardine	1	14	F	r	-	s,b,t	
246	Crown Zellerbach	s	P	SW	23	6S	3E	i	4	0.1	-	3	B	Andesite	Sardine	1	13	M	r,e	-	t,s,b,e	
247	Crown Zellerbach	s	P	SE	24	6S	3E	i	1	0.1	-	0	B	Andesite	Sardine	1	4	F-M	r	-	s,b,t	
248	Crown Zellerbach	s	P	NW	30	6S	3E	i	10	0.5	-	5	B	Basalt	Columbia River Basalt Group	2	17	C	r	-	e,b,s	
249	Crown Zellerbach	s	P	SE	30	6S	3E	i	30	0.5	-	60	B	Basalt	Columbia River Basalt Group	1	18	C	e	-	e,b,s,t	
250	Crown Zellerbach	s	P	SW	29	6S	3E	i	16	0.5	-	20	B	Basalt	Columbia River Basalt Group	1	12	C	r	-	e,b,s,t	
251	Crown Zellerbach	s	P	SW	28	6S	3E	i	13	0.4	-	30	B	Andesite	Sardine	3	24	F-B	r	-	t,s,b,r	
252	Crown Zellerbach	s	P	NE	28	6S	3E	a	3	0.5	-	15	B	Andesite	Sardine	1	7	F-C	r,e	-	e,s,b,t	
253	Crown Zellerbach	s	P	NW	27	6S	3E	i	15	0.5	-	10	B	Andesite	Sardine	1	7	F-B	r	-	t,s,b	
254	Crown Zellerbach	s	P	NE	27	6S	3E	i	6	0.2	-	2	B	Andesite	Sardine	1	11	C-M	r	-	t,s,b	
255	Crown Zellerbach	s	P	SW	26	6S	3E	i	15	0.3	-	10	B	Andesite	Sardine	2	20	F-M	r	-	t,s,b,e	
256	Crown Zellerbach	s	P	NE	25	6S	3E	i	2	0.2	-	3	B	Andesite	Sardine	0	0	C-M	r,e	-	t,s,b,e	
257	Crown Zellerbach	s	P	NE	31	6S	3E	i	20	0.5	-	40	B	Basalt	Columbia River Basalt Group	1	10	B	e	-	e,b,s,t	
258	Crown Zellerbach	s	P	NE	31	6S	3E	a	35	0.5	-	500	B	Basalt	Columbia River Basalt Group	1	37	C-B	r	-	e,b,s,t	
259	Crown Zellerbach	s	P	NE	31	6S	3E	i	50	1	-	50	B	Andesite	Little Butte Volcanics	1	30	C	r	-	e,b,s	
260	Crown Zellerbach	s	P	NE	33	6S	3E	i	9	0.6	-	10	B	Andesite	Sardine	3	14	F	r	-	s,b	
261	Crown Zellerbach	s	P	SW	35	6S	3E	i	4	0.2	-	5	B	Andesite weathered	Sardine	1	9	F-M	r	-	t,s,b,e	
262	Crown Zellerbach	s	P	SW	35	6S	3E	i	4	0.3	-	5	B	Andesite	Sardine	2	5	F-C	r	-	t,s,b	
263	Crown Zellerbach	s	P	SW	36	6S	3E	i	2	0.1	-	2	B	Andesite	Sardine	1	6	F-B	r	-	t,s,b	
264	Crown Zellerbach	s	P	SW	6	6S	4E	i	15	0.1	-	2	B	Andesite	Sardine	1	30	C-B	r	-	e,b,s,t	
265	Crown Zellerbach	s	P	SW	5	6S	4E	i	60	0.6	-	200	B	Andesite	Sardine	1	26	C-B	r	-	e,b,s,t	
266	Crown Zellerbach	s	P	SW	5	6S	4E	i	5	0.1	-	100	B	Andesite	Sardine	1	20	C-M	r	-	e,b,s, t,r	
267	Crown Zellerbach	s	P	NE	7	6S	4E	i	12	0.2	-	50	B	Andesite	Sardine	1	34	F-C	e	-	t,s,b	
268	U.S. Bureau of Land Management	s	F	NE	11	6S	4E	i	11	0.3	-	10	B	Andesite	Sardine	1	13	C-M	r	-	e,b,s, t,r	
269	Crown Zellerbach	s	P	NE	18	6S	4E	i	12	0.2	-	20	B	Andesite	Sardine	2	26	F-C	e	-	t,s,b	
270	Crown Zellerbach	s	P	NW	17	6S	4E	i	2	0.1	-	0	B	Andesite	Sardine	1	17	F	r	-	s,b	
271	Crown Zellerbach	s	P	NW	17	6S	4E	i	7	0.2	-	20	B	Andesite	Sardine	2	22	F	e	-	t,s,b	
272	Crown Zellerbach	s	P	NW	17	6S	4E	i	14	0.2	-	30	B	Andesite	Sardine	1	46	M	e	-	t,s,b,e	
273	Crown Zellerbach	s	P	NW	17	6S	4E	i	3	0.2	-	0	B	Ash flow	Sardine	1	15	F	r	-	s,b	
274	Crown Zellerbach	s	P	NE	17	6S	4E	i	15	0.5	-	150	B	Andesite	Sardine	1	7	B	r	-	e,b,s,t	
275	Crown Zellerbach	s	P	NE	16	6S	4E	i	3	0.1	-	2	B	Andesite	Sardine	1	5	F	r	-	t,s,b	
276	Crown Zellerbach	s	P	SE	14	6S	4E	i	20	1	-	20	B	Andesite	Sardine	4	14	F-C	r	-	t,s,b	
277	Crown Zellerbach	s	P	SE	14	6S	4E	i	2	0.1	-	10	B	Andesite	Sardine	1	11	C-M	e	-	t,s,b,e	
278	Crown Zellerbach	s	P	NE	19	6S	4E	i	4	0.1	-	0	B	Andesite, weathered	Sardine	2	14	F	r	-	s,b	
279	Crown Zellerbach	s	P	SE	19	6S	4E	i	8	0.2	-	30	B	Andesite	Sardine	5	28	F-C	r,e	-	t,s,b,e	
280	Crown Zellerbach	s	P	SE	20	6S	4E	i	5	0.1	-	20	B	Andesite	Sardine	1	24	F-C	e	-	t,s,b	
281	Crown Zellerbach	s	P	SW	21	6S	4E	i	8	0.1	-	20	B	Andesite	Sardine	1	25	F-C	e	-	t,s,b	
282	Crown Zellerbach	s	P	NE	22	6S	4E	i	10	0.5	-	15	B	Andesite, weathered	Sardine	2	6	F	r	-	s,b	
283	Crown Zellerbach	s	P	SE	22	6S	4E	i	12	0.3	-	20	B	Andesite	Sardine	2	12	F	r	-	t,s,b	
284	Crown Zellerbach	s	P	NW	23	6S	4E	i	3	0.2	-	1	B	Andesite	Sardine	1	11	F	r	-	t,s,b	
285	Crown Zellerbach	s	P	NE	23	6S	4E	i	5	0.1	-	10	B	Andesite	Sardine	1	14	F-M	e	-	t,s,b	
286	Crown Zellerbach	s	P	SW	24	6S	4E	i	3	0.5	-	0	B	Andesite	Sardine	1	10	C-M	r	-	t,s,b	
287	Crown Zellerbach	s	P	NW	27	6S	4E	i	3	0.1	-	10	B	Andesite porphyry	Sardine	1	17	C	e	-	t,s,b	
288	Weyerhaeuser	s	P	NW	26	6S	4E	i	2	0.2	-	0	B	Andesite	Sardine	1	10	F-M	e	-	t,s,b	
289	Crown Zellerbach	s	P	SE	26	6S	4E	i	10	0.5	-	25	B	Andesite	Sardine	3	17	C-M	e	-	t,s,b	
290	Crown Zellerbach	s	P	NW	25	6S	4E	i	8	0.7	-	10	B	Andesite	Sardine	2	5	F	r	-	t,s,b	
291	Crown Zellerbach	s	P	NW	35	6S	4E	i	3	0.3	-	1	B	Andesite	Sardine	1	9	F	r	-	s,b	
292	Crown Zellerbach	s	P	NW	36	6S	4E	a	10	0.7	-	20	B	Basalt, weathered	Sardine	1	8	F-C	r,e	-	e,s,b	
293	U.S. Forest Service	s	F	NE	4	6S	5E	i	8	0.2	-	8	B	Andesite	Sardine	3	6	C-M	r,e	-	t,s,b	
294	U.S. Forest Service	s	F	SW	3	6S	5E	i	8	0.2	-	15	B	Andesite	Sardine	1	14	F-M	r,e	-	e,t,s,b	
295	U.S. Forest Service	s	F	NW	9	6S	5E	i	9	0.2	-	20	B	Andesite	Sardine	2	13	C	r	-	t,s,b	
296	U.S. Forest Service	s	F	NW	17	6S	5E	i	10	0.5	-	20	B	Andesite	Sardine	1	8	F-M	r,e	-	e,t,s,b	
297	U.S. Forest Service	s	F	SW	15	6S	5E	i	2	0.1	-	6	B	Andesite	Sardine	1	0	F-B	r	-	e,t,s,b	
298	U.S. Forest Service	s	F	NW	20	6S	5E	i	15	0.6	-	30	B	Andesite	Sardine	2	17	F-B	r,e	-	e,t,s,b	
299	U.S. Forest Service	s	F	NW	20	6S	5E	i	10	0.2	-	20	B	Andesite	Sardine	1	26	F-B	r	-	e,t,s,b	
300	U.S. Forest Service	s	F	SE	20	6S	5E	i	3	0.2	-	15	B	Andesite	Sardine	1	0	C-M	e	-	t,s,b,e	
301	U.S. Forest Service	s	F	NW	22	6S	5E	i	2	0.1	-	4	B	Andesitic tuff	Sardine	2	6	F-C	r	-	t,s,b,e	
302	U.S. Forest Service	s	F	SE	23	6S	5E	i	8	0.2	-	2	T	Andesite	Sardine	1	34	F-B	r,e	-	t,s,b	
303	U.S. Forest Service	s	F	SE	24	6S	5E	i	15	0.7	0.6	5	B	Basalt	Sardine	1	28	C-B	r,e	-	t,s,b	
304	U.S. Forest Service	s	F	SW	29	6S	5E	i	4	0.2	-	12	B	Andesite	Sardine	1	5	F-M	r,e	-	e,t,s, b,r	
305	U.S. Forest Service	s	F	NW	29	6S	5E	i	3	0.3	-	3	B	Andesite	Sardine	2	26	F-B	r,e	-	e,t,s,b	
306	U.S. Forest Service	s	F	NW	27	6S	5E	i	5	0.1	-	1	T	Andesite	Sardine	1	16	C-M	r	-	e,s,b,t	
307	U.S. Forest Service	s	F	NW	25	6S	5E	i	45	2.5	0.5	150	B	Basalt	Sardine	3	8	F-B	r,e	-	t,s,b,e	
308	U.S. Forest Service	s	F	NE	32	6S	5E	i	3	0.1	-	2	B	Andesite	Sardine	1	0	F-C	r	-	t,s,b	
309	U.S. Forest Service	s	F	NE	35	6S	5E	i	15	0.6	-	6	B	Andesite, weathered	Sardine	2	20	F-B	r	-	e,s,b	
310	U.S. Forest Service	s	F	SW	5	6S	6E	i	8	0.6	-	15	B	Andesite	Sardine	1	21	C-B	r	-	t,s,b	
311	U.S. Forest Service	s	F	NW	4	6S	6E	a	75	1.5	1	140	B	Basalt	Columbia River Basalt Group	1	23	F	r,e	-	e,b,s,t	
312	U.S. Forest Service	s	F	NW	2	6S	6E	i	27	1.5	-	300	B	Andesite	Sardine	2	25	F	r	-	t,s,b	
313	U.S. Forest Service	s	F	SE	8	6S	6E	r	5	0.2	-	0	B	Tuff	Little Butte Volcanics	1	7	F-B	r	-	t,s,b	
314	U.S. Forest Service	s	F	NW	18	6S	6E	i	4	0.2	-	5	B	Andesite	Sardine	1	6	C-B	r	-	t,s,b,e	
315	U.S. Forest Service	s	F	NW	18	6S	6E	a	27	0.3	-	55	B	Basalt	Sardine	1	15	F	r	-	e,b,s,t	
316	U.S. Forest Service	s	F	SE	18	6S	6E	r	2	0.1	-	0	B	Tuff	Sardine	1	3	F	r	-	t,s,b	
317	U.S. Forest Service	s	F	NW	22	6S	6E	i	6	0.2	-	50	B	Rhyodacite	Little Butte Volcanics	3	18	C-B	e	-	e,t,s,b	
318	U.S. Forest Service	s	F	SW	29	6S	6E	i	7	0.2	-	10	B	Andesite	Sardine	1	18	C-M	r	-	t,s,b,e	
319	U.S. Forest Service	s	F	SW	27	6S	6E	a	25	2.5	0.5	15	B	Andesite	Little Butte Volcanics	2	117	B-M	e	-	e,b,s,t, r,a	
320	U.S. Forest Service	s	F	SE	27	6S	6E	a	200	3	2.5	1,000	B	Andesite	Little Butte Volcanics	2	77	C-M	e	-	e,b,s, t,r	
321	U.S. Forest Service	s	F	NW	26	6S	6E	i	1	0.1	-	2	B	Andesite	High Cascade Volcanics	1	6	F	r	-	t,s	
322	U.S. Forest Service	s	F	SW	32	6S	6E	i	7	0.3	-	2	B	Andesite	Sardine	1	25	C-B	r	-	t,s,b,e	
323	U.S. Forest Service	s	F	NW	32	6S	6E	i	5	0.1	-	5	B	Andesite	Sardine	1	15	F-C	r	-	t,s,b	
324	U.S. Forest Service	s	F	NW	32	6S	6E	i	12	0.7	-	10	B	Andesite	Sardine	2	11	F-M	r,e	-	t,s,b, e,r	
325	U.S. Forest Service	s	F	NW	32	6S	6E	i	1	0.1	-	0	B	Andesite	Sardine	1	7	F-C	r	-	t,s,b	
326	U.S. Forest Service	s	F	SW	33	6S	6E	r	20	0.6	-	0	B	Andesite	Little Butte Volcanics	1	26	F-C	r	-	t,s,b	
327	U.S. Forest Service	s	F	NW	36	6S	6E	i	15	1.5	-	25	B	Andesite	Little Butte Volcanics	1	5	C	r	-	e,b,s	
328	Void																					
329	U.S. Forest Service	s	F	SE	4	6S	7E	i	50	2.5	-	100	B	Andesite	High Cascade Volcanics	1	43	F-M	e	-	e,t,s, b,r	
330	U.S. Forest Service	s	F	SW	3	6S	7E	i	12	0.3	-	10	T	Andesite	High Cascade Volcanics	1	40	F	r	-	t,s,b	Combination slide area and quarry
331	U.S. Forest Service	s	F	SW	3	6S	7E	i	1	0.1	-	20	T	Andesite	High Cascade Volcanics	1	3	F-C	r	-	e,t,s,b	
332	U.S. Forest Service	s	F	SW	7	6S	7E	i	7	0.8	-	5	B	Basalt	High Cascade Volcanics	2	11	F	r	-	t,s,b	
333	U.S. Forest Service	s	F	NE	9	6S	7E	i	23	0.5	-	100	B	Andesite	High Cascade Volcanics	1	15	C-M	r	-	e,b,s, t,r	
334	U.S. Forest Service	s	F	NE	9	6S	7E	a	75	0.5	-	200	B	Andesite	High Cascade Volcanics	3	37	C-M	e	-	e,b,s, t,r	
335	U.S. Forest Service	s	F	NW	17	6S	7E	i	2	0.1	-	5	B	Andesite	High Cascade Volcanics	1	11	F-C	e	-	e,t,s,b	
336	U.S. Forest Service	s	F	SE	17	6S	7E	i	1	0.2	-	0	B	Andesite	High Cascade Volcanics	3	3	F-B	r	-	e,t,s,b	
337	U.S. Forest Service	s	F	NW	19	6S	7E	i	9	0.8	-	20	B	Andesite	High Cascade Volcanics	3	9	F-C	e	-	t,s,b	
338	U.S. Forest Service	s	F	SE	21	6S	7E	i	7	1.8	-	10	B	Andesite	High Cascade Volcanics	5	34	C-B	e,r	-	e,s,t,b	
339	U.S. Forest Service	s	F	NW	22	6S	7E	i	4	0.3	-	0	B	Andesite	High Cascade Volcanics	2	13	F	r	-	t,s	
340	U.S. Forest Service	s	F	SW	32	6S	7E	i	1	0.3	-	10	B	Andesite	High Cascade Volcanics	1	20	F-C	e	-	t,s,b	
341	U.S. Forest Service	s	F	SE	32	6S	7E	i	1	0.2	-	10	B	Andesite	High Cascade Volcanics	1	12	F	r	-	t,s,b	
342	U.S. Forest Service	g	F	NE	36	6S	7E	r	8	1	-	0	G	Various	River gravel	1	3	F	r	-	t,b	
343	U.S. Forest Service	s	F	NW	5	6S	8E	i	3	0.2	-	5	B	Andesite	High Cascade Volcanics	1	29	F-B	e	-	e,t,s,b	
344	U.S. Forest Service	s	F	SW	5	6S	8E	i	10	0.4	-	10	B	Andesite	High Cascade Volcanics	1	10	F-C	r	-	t,s,b	
345	U.S. Forest Service	s	F	NW	5	6S	8E	i	2	0.1	-	3	T	Andesite	High Cascade Volcanics	1	32	F	r	-	t,s,b	
346	U.S. Forest Service	s	F	NE	5	6S	8E	i	20	0.5	-	30	B	Andesite	High Cascade Volcanics	2	14	F-M	r	-	t,s,b,e	
347	U.S. Forest Service	s	F	SW	11	6S	8E	i	85	5.5	0.2	150	B	Andesite	High Cascade Volcanics	1	24	F-M	r,e	-	t,s,b, e,j	
348	U.S. Forest Service	s	F	NE	18	6S	8E	i	2	0.3	-	0	B	Andesite	High Cascade Volcanics	2	3	C-M	r	-	e,t,s,b	
349	U.S. Forest Service	s	F	NE	17	6S	8E	r	3	0.2	-	0	B	Andesite	High Cascade Volcanics	1	0	F-C	e	-	t,s,b	
350	U.S.Forest Service	s	F	SE	19	6S	8E	a	40	2.3	1.2	300	B	Andesite	High Cascade Volcanics	1	11	F-C	e	-	t,s,b	
351	U.S. Forest Service	s	F	SE	31	6S	8E	i	3	0.1	-	10	B	Andesite	High Cascade Volcanics	1	14	B-M	e	-	e,t,s,b	
352	Crown Zellerbach	s	P	NW	6	7S	3E	a	0	0	-	100	B	Basalt	Columbia River Basalt Group	-	-	F-B	e	-	r,e,s,b	
353	U.S. Bureau of Land Management	s	F	NE	6	7S	3E	i	20	1.4	-	60	B	Basalt	Columbia River Basalt Group	2	15	F	r	-	t,s,b	
354	U.S. Bureau of Land Management	s	F	SE	4	7S	3E	i	3	0.2	-	5	B	Andesite	Sardine	2	4	F-C	r	-	t,s,b	
355	Crown Zellerbach	s	P	NE	4	7S	3E	i	5	0.4	-	2	B	Andesite	Sardine	2	4	F-C	r	-	t,s,b	
356	U.S. Bureau of Land Management	s	F	NE	3	7S	3E	i	2	0.5	-	2	B	Andesite	Sardine	1	7	F-M	r	-	t,s,b, e,r	
357	U.S. Bureau of Land Management	s	F	SW	2	7S	3E	i	3	0.5	-	5	B	Andesite	Sardine	1	0	F	r	-	t,s,b	
358	Crown Zellerbach	s	P	NE	7	7S	3E	a	50	1	-	30	B	Basalt	Columbia River Basalt Group	3	15	C-B	e	-	e,b,s,t	
359	Crown Zellerbach	s	P	SW	8	7S	3E	i	20	2	-	10	B	Basalt	Columbia River Basalt Group	1	13	B	r	-	e,b,s,t	
360	Crown Zellerbach	s	P	SW	8	7S	3E	i	1	0.2	-	2	B	Basalt	Columbia River Basalt Group	2	5	C	r	-	e,b,s,t	
361	Crown Zellerbach	s	P	SW	8	7S	3E	i	6	0.2	-	100	B	Basalt	Columbia River Basalt Group	1	12	F-C	e	-	e,b,s,t	
362	Crown Zellerbach	s	P	SW	8	7S	3E	i	30	0.3	-	300	B	Andesite	Little Butte Volcanics	1	27	B-M	e	-	e,b,s, r,r	
363	Crown Zellerbach	s	P	SW	10	7S	3E	i	10	0.4	-	50	B	Andesite	Sardine	4	12	F-C	r	-	t,s,b	
364	Crown Zellerbach	s	P	SW	15	7S	3E	a	2	0.1	-	15	B	Andesite	Little Butte Volcanics	1	18	F-B	r	-	e,b	
365	Crown Zellerbach	s	P	SW	14	7S	3E	i	10	0.3	-	30	B	Andesite	Little Butte Volcanics	1	15	F-B	r	-	t,s,b	
366	U.S. Bureau of Land Management	s	F	SE	13	7S	3E	i	10	0.2	-	30	B	Basalt	Sardine	2	25	F	r	-	t,s,b	
367	State of Oregon	s	S	SE	30	7S	3E	i	17	1	0.3	10	B	Andesite	Sardine	1	14	F	r	-	t,s,b	
368	Publishers Paper	s	P	NW	28	7S	3E	i	20	0.4	-	40	B	Andesite porphyry	Sardine	4	32	F-C	e	-	t,s,b	
369	U.S.Bureau of Land Management	s	F	SW	25	7S	3E	i	25	2	-	25	B	Andesite	Sardine	2	12	F-C	e	-	e,s,b,t	
370	State of Oregon	s	S	NW	31	7S	3E	i	3	0.2	-	1	B	Andesite	Sardine	1	7	F	r	-	t,s,b	
371	State of Oregon	s	S	NW	33	7S	3E	i	1	0.1	-	2	B	Andesite	Sardine	2	3	F	r	-	t,s,b	
372	State of Oregon	s	S	SW	34	7S	3E	i	1	0.1	-	1	B	Andesite	Sardine	1	7	F	r	-	t,s,b	
373	Crown Zellerbach	s	P	NW	3	7S	4E	i	9	0.1	-	20	B	Andesite	Sardine	1	42	M	e	-	t,s,b,r	
374	Crown Zellerbach	s	P	SE	3	7S	4E	a	10	2	-	20	B	Andesite, weathered	Sardine	1	11	F-C	e	-	e,s,b	
375	Crown Zellerbach	s	P	SE	2	7S	4E	i	8	0.1	-	20	B	Andesite, weathered	Sardine	1	29	B-M	e	-	s,b,r	
376	U.S. Bureau of Land Management	s	F	SW	7	7S	4E	i	20	1.2	-	100	T	Andesite	Sardine	1	6	F	r	-	t,s,b	
377	U.S. Bureau of Land Management	s	F	NE	9	7S	4E	i	5	0.2	-	20	B	Basalt	Sardine	2	17	C	r	-	t,s,b	
378	Crown Zellerbach	s	P	SW	13	7S	4E	a	5	0.1	-	10	B	Andesite, weathered	Sardine	1	7	C	e	-	e,s,b,t	
379	U.S. Bureau of Land Management	s	F	NW	19	7S	4E	i	7	0.2	-	5	B	Andesite	Sardine	1	21	F	r	-	t,s,b	
380	Crown Zellerbach	s	P	NE	23	7S	4E	a	10	1.5	-	20	B	Andesite, weathered	Sardine	1	8	F-C	e	-	e,s,b,t	
381	Crown Zellerbach	s	P	NE	24	7S	4E	i	3	0.2	-	30	B	Andesite	Sardine	1	30	F	e	-	t,s,b	
382	Unknown	s	P	NW	27	7S	4E	i	15	0.3	-	30	B	Andesite	Sardine	2	30	F	r	-	t,s,b	
383	Crown Zellerbach	s	P	NE	32	7S	4E	i	24	0.4	-	75	B	Andesite	Sardine	2	34	F	r,e	-	t,s,b	
384	U.S. Forest Service	s	F	SW	10	7S	5E	i	19	0.8	-	15	B	Andesite	Sardine	3	42	F	r	-	t,s,b	
385	U.S. Forest Service	s	F	SW	12	7S	5E	a	200	3	-	2,000	B	Andesite	Sardine	2	20	F-C	e	-	b,s,e	
386	U.S. Bureau of Land Management	s	F	NW	17	7S	5E	i	110	1.4	-	200	B	Andesite	Sardine	3	30	C-B	r	-	t,s,b,r	
387	U.S. Forest Service	s	F	SW	15	7S	5E	i	4	0.2	-	5	B	Andesite	Sardine	1	7	F-C	r	-	t,s,b	
388	U.S. Forest Service	s	F	NE	15	7S	5E	i	8	1	-	15	B	Andesite	Sardine	4	14	F-B	r	-	t,s,b	
389	U.S. Forest Service	s	F	SE	15	7S	5E	a	13	0.5	-	100	B	Andesite	Sardine	1	5	C	e	-	e,b,s,t	
390	U.S. Bureau of Land Management	s	F	NW	19	7S	5E	i	3	0.2	-	0	B	Andesite	Sardine	1	18	F	r	-	t,s,b	
391	U.S. Forest Service	s	F	NW	20	7S	5E	i	1	0.1	-	0	B	Andesite	Sardine	2	11	F	r	-	t,s,b	
392	U.S. Forest Service	s	F	SW	24	7S	5E	i	4	0.2	-	65	B	Andesite	Sardine	1	12	F	r	-	b,s,e	
393	U.S. Bureau of Land Management	s	F	NW	30	7S	5E	i	9	0.2	-	50	B	Andesite	Sardine	3	50	F	r	-	t,s,b	
394	U.S. Forest Service	s	F	SE	26	7S	5E	i	3	0.1	-	5	B	Andesite	Sardine	1	11	F-C	r	-	t,s,b	
395	U.S.Forest Service	s	F	SW	33	7S	5E	i	2	0.2	-	0	B	Basalt	Sardine	1	2	C-M	r	-	t,s,b	
396	U.S. Forest Service	s	F	NE	33	7S	5E	i	3	0.2	-	0	B	Basalt	Sardine	2	5	C-M	r,e	-	e,t,s,b	
397	U.S. Forest Service	s	F	NE	33	7S	5E	i	26	0.5	-	75	B	Basalt	Sardine	2	19	C-M	e,r	-	e,t,s,b	
398	U.S. Forest Service	s	F	NW	34	7S	5E	i	11	0.4	-	5	B	Andesite	Sardine	4	19	F-M	r	-	e,t,s,b	
399	U.S. Forest Service	s	F	SE	36	7S	5E	i	8	0.2	-	5	B	Basalt	Sardine	1	12	F-B	r	-	t,s,b	
400	U.S. Forest Service	s	F	NW	5	7S	6E	i	20	0.5	-	20	B	Andesite	Sardine	1	17	F-C	r	-	t,s,b,e	
401	U.S. Forest Service	s	F	NE	5	7S	6E	i	1	0.1	-	0	B	Andesite	Sardine	1	0	F-M	r,e	-	t,s,b,e	
402	U.S. Forest Service	s	F	SE	4	7S	6E	i	1	0.2	-	0	B	Basalt	Little Butte Volcanics	1	8	C-M	r	-	e,t,s,b	
403	U.S. Forest Service	s	F	NW	3	7S	6E	i	7	0.3	-	0	B	Basalt	Columbia River Basalt Group	1	14	F-M	r,e	-	e,t,s,b	
404	U.S. Forest Service	s	F	SE	2	7S	6E	i	5	0.2	-	0	B	Basalt	High Cascade Volcanics	1	17	F-C	r	-	t,s,b	
405	U.S. Forest Service	s	F	NE	1	7S	6E	i	2	0.1	-	0	B	Andesite	Sardine	1	5	F	r	-	t,s,b	
406	U.S. Forest Service	s	F	SW	9	7S	6E	i	6	0.2	-	100	B	Andesite	Sardine	1	11	F-C	e	-	b,s,e	
407	U.S. Forest Service	s	F	NE	10	7S	6E	i	3	0.2	-	0	B	Dacite	Little Butte Volcanics	1	0	F-M	r,e	-	r,t,s,b,r, e,j	
408	U.S. Forest Service	s	F	NW	12	7S	6E	i	2	0.3	-	4	B	Andesite	Sardine	2	6	C-B	r	-	t,s,b,e	
409	U.S. Forest Service	s	F	NE	12	7S	6E	i	3	0.1	-	10	B	Andesite	Sardine	1	15	F	r	-	t,s,b	
410	U.S. Forest Service	s	F	SW	14	7S	6E	i	3	0.3	-	5	B	Tuff	Sardine	1	3	C-M	r,e	-	t,s,b,e, r,j	
411	U.S. Forest Service	s	F	NW	13	7S	6E	i	16	0.3	-	0	B	Andesite	Sardine	1	19	F-C	r	-	t,s,b	
412	U.S. Forest Service	s	F	NE	21	7S	6E	i	1	0.1	-	0	B	Tuff	Sardine	1	0	F-C	r	-	t,s,b	
413	U.S. Forest Service	s	F	NW	22	7S	6E	i	6	0.1	-	0	B	Andesite	Sardine	1	20	F-C	r	-	t,s,b	
414	U.S. Forest Service	g	F	NE	24	7S	6E	i	1	0.2	-	0	B	Sand	High Cascade Volcanics	1	0	F	r	-	e	
415	U.S. Forest Service	s	F	NW	29	7S	6E	i	80	1	0.2	100	B	Andesite	Sardine	5	19	F-M	r,e	-	t,s,b,e	
416	U.S. Forest Service	s	F	SW	29	7S	6E	i	4	0.2	-	3	B	Andesite	Sardine	2	6	F-C	r	-	t,s,b	
417	U.S. Forest Service	s	F	SE	25	7S	6E	i	13	0.2	-	0	B	Basalt	High Cascade Volcanics	1	23	F-M	r	-	e,t,s,b	
418	U.S. Forest Service	s	F	NE	31	7S	6E	i	2	0.1	-	1	B	Andesite	Sardine	1	7	F-C	r	-	t,s,b	
419	U.S. Forest Service	s	F	SE	36	7S	6E	i	2	0.6	-	3	B	Tuff	High Cascade Volcanics	1	5	F-M	r	-	t,s,b	
420	U.S. Forest Service	s	F	SW	6	7S	7E	i	3	0.2	-	15	B	Andesite	High Cascade Volcanics	1	5	F	r	-	t,s	
421	U.S. Forest Service	s	F	SW	6	7S	7E	i	5	0.2	-	15	B	Andesite	High Cascade Volcanics	1	11	F	r	-	t,s,b	
422	U.S. Forest Service	s	F	NE	6	7S	7E	i	1	0.1	-	1	B	Andesite	High Cascade Volcanics	1	14	F-C	e	-	t,s,b	
423	U.S. Forest Service	s	F	NW	7	7S	7E	i	4	0.2	-	0	B	Andesite	High Cascade Volcanics	2	4	F-B	r	-	t,s,b	
424	U.S. Forest Service	s	F	NW	8	7S	7E	i	7	0.4	-	15	B	Andesite	High Cascade Volcanics	1	5	F-C	r	-	t,s,b	
425	U.S. Forest Service	s	F	NE	9	7S	7E	i	2	0.2	-	0	B	Andesite	High Cascade Volcanics	1	18	M	e	-	t,s,b, r,e	
426	U.S. Forest Service	s	F	SE	9	7S	7E	i	15	0.6	0.1	10	B	Andesite	High Cascade Volcanics	1	13	F-M	e	-	e,t,s, b,j	
427	U.S. Forest Service	s	F	SW	18	7S	7E	i	3	0.1	-	0	B	Andesite	High Cascade Volcanics	1	19	F-M	e	-	t,s,b,e	
428	U.S. Forest Service	s	F	NW	18	7S	7E	i	8	0.6	-	10	B	Andesite	High Cascade Volcanics	1	12	F-M	e	-	e,t,s,b	
429	U.S. Forest Service	s	F	NW	13	7S	7E	i	5	0.2	-	20	B	Andesite	High Cascade Volcanics	1	13	F-M	e	-	e,t,s,b	
430	U.S. Forest Service	s	F	NW	13	7S	7E	i	5	0.1	-	1	B	Andesite	High Cascade Volcanics	1	17	F-M	r	-	t,s,b	
431	U.S. Forest Service	s	F	SW	21	7S	7E	i	1	0.1	-	5	B	Andesite	High Cascade Volcanics	3	3	C-B	r,e	-	e,s,t,b	
432	U.S. Forest Service	s	F	NW	29	7S	7E	i	4	1	-	5	B	Andesite	High Cascade Volcanics	1	7	F-B	r	-	t,s,b	
433	U.S. Forest Service	s	F	NW	32	7S	7E	a	2	1	-	5	B	Andesite	High Cascade Volcanics	1	5	F	r	-	t,s,b	
434	U.S. Forest Service	s	F	NW	32	7S	7E	i	4	0.2	-	10	B	Andesite	High Cascade Volcanics	1	11	F-B	r	-	t,s,b,e	
435	U.S. Forest Service	s	F	NW	36	7S	8E	i	15	0.6	-	10	B	Andesite	High Cascade Volcanics	1	19	F-C	r,e	-	t,s,b	
436	U.S. Forest Service	s	F	NW	2	7S	8E	i	3	0.2	-	2	B	Andesite	High Cascade Volcanics	1	3	C-M	r	-	t,s,b,e	
437	U.S. Forest Service	s	F	NW	4	7S	8E	i	3	0.3	-	2	B	Andesite	High Cascade Volcanics	1	6	C-M	r	-	t,b,e,r	
438	U.S. Forest Service	g	F	NE	7	7S	8E	i	2	0.1	-	0	G	Various	River gravel	1	6	-	-	-	e,t,b,r	
439	U.S. Forest Service	s	F	NW	9	7S	8E	i	5	0.3	-	10	B	Andesite	High Cascade Volcanics	1	9	C-M	r	-	t,s,b,e	
440	U.S. Forest Service	s	F	NW	9	7S	8E	i	2	0.3	-	0	B	Andesite	High Cascade Volcanics	1	0	F-C	r	-	t,s,b	
441	U.S. Forest Service	s	F	NE	9	7S	8E	i	2	0.3	-	5	B	Andesite	High Cascade Volcanics	1	0	C-M	r	-	t,s,b,e	
442	U.S. Forest Service	s	F	NW	11	7S	8E	i	7	0.6	-	30	B	Andesite	High Cascade Volcanics	2	17	C-M	r,e	-	t,s,b,e	
443	U.S. Forest Service	s	F	SE	16	7S	8E	i	2	0.2	-	5	B	Andesite	High Cascade Volcanics	1	0	C-M	r	-	t,b,e	
444	U.S. Forest Service	s	F	NW	19	7S	8E	i	20	2	-	60	B	Andesite	High Cascade Volcanics	1	13	F	e	-	e,t,b	
445	U.S. Forest Service	s	F	NW	35	7S	8E	i	3	1	-	0	B	Andesite	High Cascade Volcanics	1	2	C-M	r	-	e,t,s,b	
446	Crown Zellerbach	s	P	NE	4	8S	4E	i	4	0.1	-	10	B	Andesite	Sardine	1	17	M	e	-	t,s,b,r	
447	Crown Zellerbach	s	P	NW	8	8S	4E	a	3	0.8	-	10	B	Andesite	Sardine	1	7	F-C	e,r	-	t,s,b	
448	Crown Zellerbach	s	P	SW	8	8S	4E	a	2	1	-	40	B	Andesite	Sardine	1	6	F-C	e,r	-	e,s,b	
449	Crown Zellerbach	s	P	NW	8	8S	4E	a	3	0.5	-	5	B	Andesite	Sardine	1	5	F-C	e,r	-	e,s,b	
450	Crown Zellerbach	s	P	NW	9	8S	4E	a	1	0.5	-	5	B	Andesite	Sardine	1	3	F-C	r	-	e,s,b	
451	Crown Zellerbach	s	P	NW	9	8S	4E	a	1	0.5	-	5	B	Andesite	Sardine	1	4	F-C	r	-	e,s,b	
452	U.S. Forest Service	s	F	SE	5	8S	5E	a	15	1	0.1	30	B	Andesite	Sardine	1	22	F-M	e	-	t,s,b, e,r,j	
453	U.S. Forest Service	s	F	NE	6	8S	7E	i	4	0.2	-	10	B	Tuff	High Cascade Volcanics	2	6	F-M	r	-	t,s,b,e	
454	U.S. Forest Service	s	F	NE	7	8S	7E	i	1	0.1	-	0	B	Basalt	High Cascade Volcanics	2	6	F-M	r	-	t,s,b	
455	U.S. Forest Service	s	F	NE	9	8S	7E	i	10	0.6	-	30	B	Andesite	High Cascade Volcanics	2	14	F	r	-	t,s,b	
456	U.S. Forest Service	s	F	NW	10	8S	7E	i	5	0.4	-	10	B	Andesite	High Cascade Volcanics	1	4	F	r	-	t,s,b	
457	U.S. Forest Service	s	F	NW	12	8S	7E	i	20	1.3	-	40	B	Andesite	High Cascade Volcanics	2	17	F-M	r	-	t,s,b	
458	U.S. Forest Service	s	F	NW	6	8S	8E	i	3	0.3	-	2	B	Basalt	High Cascade Volcanics	1	4	C-M	e,r	-	e,t,s,b	
459	U.S. Forest Service	s	F	SW	7	8S	8E	i	16	5	0.7	20	B	Basalt	High Cascade Volcanics	7	1	C-M	r,e	-	e,t,s,b	
460	U.S. Forest Service	s	F	SE	11	8S	8E	i	12	0.8	-	4	B	Andesite	High Cascade Volcanics	5	14	C-M	r	-	e,t,s,b,r	

* State Highway Division laboratory data

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