SHORT PAPER 27

ROCK MATERIAL RESOURCES OF BENTON COUNTY, OREGON

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STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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1069 State Office Building, Portland, Oregon 97201

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In cooperation with
Benton County
Board of County Commissioners
Corvallis, Oregon
and
Oregon Land Conservation and Development Commission

Conducted in conformance with ORS 516.030

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ROCK MATERIAL RESOURCES OF BENTON COUNTY, OREGON

INTRODUCTION

Purpose

Benton County's population is expected to continue to expand in the future as a result of increased light industrial development brought about by available manpower; availability of land and electric power; and favorable aesthetic, cultural, and climatic conditions. While creating an increasing need for construction aggregate, this growth can simultaneously restrict the use of existing sources of aggregate by zoning, encroachment of incompatible development, and loss of rock material deposits when structures are built over them. With proper planning, however, 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.

The purpose of this study is to develop concise data on the rock material of Benton County in a form which can be submitted to potential users or developers of these resources and which can be used as a data base for land use ordinances in compliance with ORS 215.055. Oregon law ORS 215.055 and Land Conservation and Development Commission (LCDC) Goal 5, Topic B, formally directs the County to take the processing of mineral aggregates into consideration in the adoption of any land use ordinance. Data on the locations of sand and gravel pits, clay pits, and rock quarries; past production; the quantity and quality of material available; and the future requirements for these products are needed before land use ordinances are passed. This study, financed by the Oregon Department of Geology and Mineral Industries and Benton County through a grant from the Land Conservation and Development Commission, provides the above data along with broad parameters for secondary or tertiary land uses after mining. The data presented in this report can be used for planning and public decisions concerning land usage and also by contractors looking for rock materials for construction projects.

Study Parameters

This study is based on a rock material resources location and geology map (folded, in pocket) and a survey data table (Table 1, printed on back of folded map, in pocket). Each site has been given a number which is used throughout the report. Only sites with evidence of past mining were surveyed, even though they may not contain future reserves. A survey of all rock material reserves of Benton County is beyond the scope of this report. The geologic map, however, gives information about the amount of area underlain by each of the rock units. General conclusions about where rock material sources will be developed in future years may be drawn from this map.

A discussion concerning land use planning and reclamation processes is also included in this report. The role of the State, County, and quarry operator in these procedures is briefly discussed; information about where to seek additional reclamation assistance is given. Methods of estimating future rock material needs are presented; and estimates of future needs of Benton County and, for comparison, the Willamette Valley and all of Oregon are also included.

Appendix 1 is a glossary defining terms used in this report. This study is not directly concerned with environmental or geological hazards or with engineering geology problems. Instead, a current study (Bela, in preparation) deals with each of these problems in considerable detail.

Methods of Study

Before the physical inventorying of sites began, the files of the Department's Mined Land Reclamation Division and other State and County agencies were checked for rock material site locations. Locations of additional sites were obtained from local aggregate producers, the County, the State Highway Division, and U. S. Forest Service personnel and by inspection of aerial photographs. Other sites were located in the field during field surveying and by reconnaissance from light aircraft.

Site surveys were accomplished in the field by use of a rangefinder, a clinometer and/or a planimeter, and aerial photographs. The surveys provide data on dimensions and shape of each site, volume of material removed, and reserves remaining. The geologist determined reserves estimates, taking into consideration the depth and lateral extent of the deposit, thickness of overburden, limiting effect of ground water, property ownership, and conflicting land uses. An assumption was made that point bars normally can be cropped every 3 years.

The quality of the rock, as shown by usage from each site, was estimated by identifying geologic formation, rock type, and rock characteristics and by comparing with Oregon State Highway Division laboratory data from similar rocks found elsewhere in the County. 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 consumption of these materials. Future requirements were determined by extending least squares consumption curves.

Previous Work

A County-wide inventory or economic study of rock material resources of Benton County has not been done prior to this report. Early in 1977, the Oregon Department of Geology and Mineral Industries prepared a preliminary unpublished report which dealt with sites along the Willamette River Greenway Belt within Benton and Linn Counties. The Benton County sites have been incorporated into this report. For a geologic bibliography, "Geologic Hazards of Eastern Benton County, Oregon," by J. L. Bela (in preparation) should be consulted.

Acknowledgments

The authors are grateful for help received from many individuals. Garwood Allen of the Oregon Department of Geology and Mineral Industries conducted the field surveying of all sites. Data for the western side of the geologic map was compiled by John Beaulieu, also of the Department. Laboratory data and information about sites studied by the Oregon Highway Department were obtained from Robert Forester. James Blair, County Engineer and Roadmaster, prepared a map showing quarry sites. Bond Starker of Starker Lumber Company graciously provided access to and information about his rock resources.

Linda VanCura typed the manuscript; Lewis Nelson, of Scott Photo, Corvallis, prepared photographs; Ruth Pavlat typed camera copy; Beverly Vogt and Ainslie Bricker edited the report; and Charles Schumacher and Kath Eisele drafted the maps and figures.

GEOGRAPHY

Location, Physical Geography, Extent of Area, and Access

Benton County (see Figure 1) covers 668 sq mi. Its two distinct physiographic areas are the Willamette Valley and the Coast Range. The Willamette Valley contains about 120 sq mi of broad alluvial plains stretching westward toward the foothills of the Coast Range, which, in turn, covers about 548 sq mi of hilly to mountainous land. The highest peak in the Coast Range, Marys Peak , with an elevation of 4,087 ft, is located in the western part of the County. About 459 sq mi of the County lie in the middle Willamette River drainage basin, and 184 sq mi are included in the mid-coast drainage basin. The remaining 25 sq mi is included in the upper Willamette River basin.

Forest lands occupy about 438 sq mi of the County. About 75 percent of the land base is privately owned, with the remaining 25 percent divided as follows: Federal, 17 percent; State, 4.4 percent; and local governments, 2.6 percent.

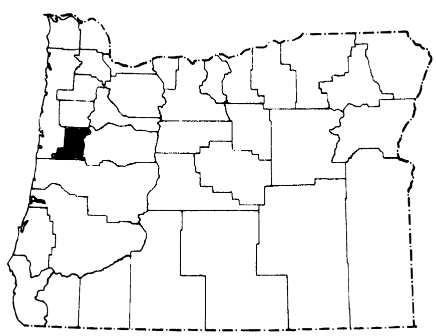

Figure 1. Index map showing location of Benton County, Oregon.

In 1972 the County had 999 mi of roadway (Ruttle, 1974). The major transportation routes are State Highway 34, which enters the County in the southwest corner and extends northeastward to Corvallis; U.S. Highway 20, which crosses the County in an east-west direction and passes through Corvallis; State Highway 99W, which enters the County near Monroe, goes north along the west side of the Willamette River through Corvallis, and leaves the County near Suver. Interstate 5, a major north-south freeway, passes 10 mi east of Corvallis, just outside the County border. The secondary system of private, County, and Federal roads provided access for this study to all parts of the County.

Socioeconomic Factors

The Benton County population has grown an average of about 2.5 percent annually since 1920. About 60 percent of the County's population is within the city limits of Corvallis, 4 percent in Philomath and Adair Village, and significant numbers just outside of the corporate limits of Albany (Linn County), Corvallis, and Philomath. Many people live in one of these counties and work in the other. Employment in higher education and supporting services account for the greatest number of persons in Benton County. The remainder are employed in timber and wood products, electronics, agriculture, and government.

Table 2. Population*						
	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
Benton County	18,629	31,570	39,165	53,776	65,600	93,600
Corvallis	8,392	16,207	20,669	35,056	40,180	-
Philomath	856	1,289	1,359	1,688	2,160	-
Monroe	311	362	374	443	485	-

* Oregon Blue Book (1977-1978)
** Center for Population Research and Census (1976)

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 include 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 characteristics of the rock material are changed.

Lands showing no evidence of past mining were not surveyed, even though they might contain future reserves. The reserve estimate given for a site may be increased through proper zoning and land acquisition by the rock material producer. The only rock materials that have been mined in Benton County are clay, sand and gravel, and quarry stone (both crushed and dimension).

Clay

Clay is a natural, earthy, fine-grained material composed of rock or mineral fragments less than 0.002 mm in size and a group of crystalline minerals known as clay minerals. Most clays exhibit plasticity when wet. Clay minerals may originate in several ways; simple weathering under generally humid conditions or by hydrothermal action will 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. Benton County clays have been used almost exclusively for common brick and tile production (see sites 86, 137, 138, and 140 in Table 1 and on the Rock Material Location and Geology Map. Since most of the clays contain a considerable quantity of iron, the fired ware is usually red to dark buff in color. No known Benton County deposits are sufficiently low in iron to produce a light-colored fired product.

Sand and Gravel

Sand and gravel are mineral commodities produced by natural erosion and abrasion of transported bedrock material. The term "sand and gravel" refers to size of the bedrock fragments, not to the mineral content or rock type. The sand and gravel deposits in Benton County are all alluvial, which means they were all deposited by streams. Such stream deposits are usually imperfectly stratified and frequently have cut-and-fill structures in which coarse sands and gravels are interspersed with lenses of fine sands or clays.

The long axes of alluvial deposits are parallel to the direction of stream flow. The beds vary greatly in thickness and are usually complex in composition. As a rule, particles are poorly sorted and usually subangular to subrounded. The size and shape of particles are direct results of joint or fracture spacing, hardness of material, and the distance they have been transported. Present-day deposits occur in the form of bars within the stream channels and as point bars along the inside banks of meanders. Previously deposited point bars occur in the Willamette River flood plain in old meander channels and beneath the flood plain, where they have been buried by up to 10 ft of sandy silt.

Quarry Stone (Dimension)

Dimension stone is quarried stone which has been specially cut or shaped for use as gravestones or in building, curbing, or other stone masonry construction. In Benton County, sandstone (see site 141, Table 1 and Rock Material Location and Geology Map) was quarried for use in the courthouse. Small amounts of basalt, gabbro, diorite, and sandstone mined for crushed and pit run have been used for dimension purposes. None of the rock types seems to be of commercial quality on which an industry could be built. Sandstones tend to crumble and gabbros to stain with weathering.

Quarry Stone (Crushed and Pit Run)

Crushed and pit run quarry stone, more than 99.9 percent of all stone produced in Benton County, is stone which has been reduced in size after mining to meet various consumer requirements. Crushed and pit run are quarried from igneous and sandstone bed rock. The igneous rock uses have ranged from riprap to road topping. The sandstone has been used mainly for embankments.

The various types of igneous rocks were tested by the Oregon State Highway Department. Table 3 shows that each rock type possesses characteristic physical properties and that, generally, fine-grained intrusive basalt is most desirable for road metal, coarse-grained intrusive (gabbro or diabase) is less desirable, and lava (Siletz River Volcanics) is least desirable. The values given are averages.

Table 3. Engineering characteristics of Benton County igneous rocks

	Specific gravity	Abrasion (% loss)	Sodium sulfate (% loss)
Intrusive fine-grained basalt	2.77	17.8	2.42
Intrusive coarse-grained gabbro or diabase	2.78	19.4	1.65
Siletz River Volcanics lava	2.70	23.8	25.9

GEOLOGIC UNITS

General

The geology shown in the Rock Material Location and Geology Map and the following brief geologic unit descriptions are patterned after Bela (in preparation). The geology given here is mainly to help provide a setting for the description of the rock material sites. If a detailed geology map is needed, Bela's work should be consulted.

Geologic units within Benton County can be classified into two broad groups, surficial and bed rock. In this report the terms "surficial" and "alluvial" are used interchangeably. In Table 1, under the heading

"Deposit Type," the terms "gravel," "surficial," and "alluvial" are also used interchangeably. The units are described from the youngest (Recent river alluvium) to the oldest (Siletz River Volcanics). Figure 2 shows the relationships between surficial and bedrock units. It also shows the complexities of the line separating Linn and Benton Counties. Two sand and gravel sites, 87 and 88, are also shown.

Surficial Geologic Units (Alluvium)

General

Benton County's proximity to the Willamette River and numerous Coast 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 and semi-consolidated deposits of gravel, sand, silt, and clay of varying extent and thickness. The origins of some of these units are complex; the units probably result from several different episodes and processes. Four surficial units have been mapped in the study area and are distinguishable by landforms, association with flood plains, thickness, and type of material.

Recent river alluvium (point bars) (Qral)

Recent alluvium consists of sediments deposited in stream channels and overflow channels on modern flood plains. Stream channel sediments are mostly gravel and sand, but sluggish streams deposit sediments ranging from sand to silt. The flood plain surficial deposits are composed mainly of sand and silt, and some clayey material may be deposited in backwater areas.

The Willamette River channel carries considerable amounts of gravel. Its stream load is derived from material eroded from rock exposures in headwaters, introduced from tributaries, and eroded from river bars and stream banks. The most recent gravel is usually deposited in point bars along the inside edge of meanders in the river. Many areas are not vegetated; others support stands of willows and cottonwoods. Areas adjacent to the Willamette River provide some of the most important sources of sand and gravel for building and construction. These areas are often abandoned major meanders, as at Fischer Island, east of Corvallis.

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 coarser grained crystalline rock. Coast Range streams that drain areas underlain primarily by sedimentary rock carry little gravel. Streams other than the Willamette River in Benton County do not have significant deposits of gravel.

Quaternary lower terraces (Qtl)

The Quaternary lower terrace unit consists of (1) low terraces just above Recent river alluvium of the Willamette River, and (2) lowlands of tributary rivers and streams, such as Marys River, Frazier Creek, and Muddy Creek. The lower terrace deposits are characterized by a low, undulating, fluvial surface resulting from flood deposits and overbank channeling. Meander scrolls, oxbow lakes, and widespread areas subject to shallow ponding are common. The first terraces above the Willamette River are only a few feet up to 8 ft or more above river level. Deposits on these terraces generally consist of 35 ft of river- and stream-deposited cobbles, gravel, and coarse sand derived from volcanic rocks, with relatively large amounts of flood deposits of silt and clay. Surficial deposits of fine sand and silt occur along Marys River and other tributary rivers and minor drainages.

Quaternary middle terraces (Qtm)

Quaternary middle terrace deposits along the Willamette River consist of unconsolidated to semi-consolidated gravel, sand, silt, and clay. In places, they are overlain by the Willamette Silt. These terraces form the main high terraces along the Willamette River and are generally 15 to 30 ft above the river level, although in some places they appear to merge gradually with lower terraces. The gravel

Figure 2. Oblique aerial view of city of Corvallis and two sand and gravel sites: site 87 in Linn County and site 88 in segment of Benton County isolated when Willamette River changed channels. Surficial and bedrock geologic units are outlined; see text for names of units.

deposits range in thickness from about 50 to more than 100 ft. For example, a thickness of up to 100 ft or more is reported near Granger, with a general thinning to 50 ft or less closer to the Willamette River. The overlying Willamette Silt constitutes a small portion of this entire unit and is included with the Quaternary middle terraces (Qtm). The silt is one of the clay sources for Benton County brick and tile manufacture.

Quaternary higher terraces (Qth)

Quaternary higher terrace deposits consist of poorly sorted, semiconsolidated gravel, sand, silt, and clay located toward the western foothills in Benton County. These terraces are generally 15 to 20 ft higher and more highly dissected by streams than are the middle terrace deposits. In places the higher terrace gravel deposits have been weathered to clay, but outlines of individual pebbles can still be easily recognized. The weathered gravel occurs mostly in the zone of aeration; but below, where the ground is constantly saturated, the gravels are sound except for a thin clay film developed at the surface of the individual gravel stones. Material from this unit has not been used for rock material in Benton County, and this unit has little potential as a future rock material resource.

Bedrock Geologic Units

General

The six bedrock units include igneous intrusives, which are the youngest; four sedimentary formations of intermediate age; and igneous extrusives, which are the oldest.

Intrusive rocks (Ti)

Intrusive rocks are bodies of once-fluid igneous rocks that penetrated other rocks underground but solidified before reaching the surface of the earth. Many intrusive rocks, consisting of fine- to medium-grained basalt and gabbro dikes, sills, and irregular shaped intrusive bodies, occur in Benton County. Dikes are tabular bodies that cut across the structure of adjacent country rocks while sills are tabular, sheetlike bodies of approximately uniform thickness, relatively thin compared to their lateral extent, emplaced parallel to the structure of the intruded rock. Age of these intrusives is not definite, but most were emplaced during late Eocene to early Oligocene.

Intrusives, generally in the form of sheetlike sills, occur in the eastern foothills of the Coast Range, in the headwaters of Bull Run Creek, at Flat Mountain, near Dawson, at Marys Peak, and west of Glenbrook.

Intrusive rocks are dark gray, fine- to coarse-grained, with porphyritic and diabasic textures. Margins of large intrusive bodies are usually basaltic with a fine-grained texture caused by rapid cooling; interiors are gabbroic and dioritic, with medium- to coarse-grained textures produced by slow cooling. Zeolite minerals are present in the fractures and interstices of the rocks; and cross-cutting dikes of whitish-colored, quartz-feldspar (aplite) micropegmatite occur rarely, primarily in the larger gabbro intrusives.

In some areas of the Coast Range, basalt dikes and sills are small, ranging in thickness from about 5 to 20 ft. The rock is dark gray to black, fine-grained to porphyritic, and generally of good quality. Mining costs are higher for these small intrusive bodies because joint spacing produces large boulders requiring secondary blasting. With better primary blasting, boulders might not be a major problem.

Larger intrusive bodies are uncommon in the Coast Range. The most common are diabase, gabbro, and granophyric gabbro sills and dikes. One of the largest is a 1,000-ft-thick sill of granophyric gabbro and diorite on Marys Peak. These dark-gray, coarse-grained rocks are composed of calcic plagioclase, augite, and accessory magnetite.

Most of the coarser grained intrusive bodies are larger than the fine-grained dikes and sills and are commonly quarried for road metal, even though the rock is blocky and not as durable as unaltered basalt. These coarse-grained rocks are susceptible to mechanical disintegration or weathering. They may have widely spaced joints which can result in oversized material after blasting even though expertly engineered. The material is good for riprap and can be used economically by large crushing plants.

Tuffaceous sandstone (Tts)

Two small isolated outcrops of thick-bedded, greenish-gray to olive-gray, medium- to coarse-grained tuffaceous sandstone occur at Oliver and Winkle Buttes (site 135). Little is known of this unit. Individual well-indurated massive beds within the unit range in thickness from 3 to 12 ft. The formation thickness appears to be only on the order of several hundred feet.

Spencer Formation (Ts)

The Spencer Formation consists of fine- to medium-grained, arkosic, micaceous, tuffaceous sandstone and siltstone. The formation may also contain minor amounts of dark, greenish-gray, basaltic sandstone and breccia. Its composition indicates marine deposition relatively near shore and derivation in part from the underlying Flournoy Formation and Siletz River Volcanics.

The Spencer Formation occurs in the lower Coast Range foothills and in isolated erosional remnants in the western part of the Willamette Valley, both northeast and southwest of Corvallis; it is also believed to underlie most of the terrace deposits between the foothills and the Willamette River. A complete section is not present, but it is estimated that at least 4,200 ft are exposed between the base and alluvial cover.

The beds are massive to thick bedded, with a few thinner beds of sandstone and frequent partings of thin, shaly siltstone. Weathered exposures in road cuts and septic tank pits are generally pale yellowish-orange to dark yellowish-orange in color due to iron staining. The massive beds weather spheroidally and rapidly to a light to moderate yellowish-brown soil, while thinner, fine-grained beds weather to a light tan to rusty white, very similar to parts of the Flournoy. Some sections appear to be entirely altered to clay; near Monroe, at site 140, pits in the Spencer Formation have yielded clay for local clay product manufacture. At site 141, unweathered outcrops have been mined for dimension stone and for low strength crushed and broken stone.

Flournoy Formation (Tf)

The Flournoy Formation consists of sandstone, siltstone, and shale. Minor conglomeratic sandstone beds also occur. Flournoy Formation sandstone is probably the second most widespread geologic rock unit in Benton County. It occurs as steeply eastward and westward dipping beds, mainly along the eastern boundary of the Siletz River Volcanics (Tsr), where it is separated from them by the Corvallis fault. The Flournoy Formation occurs both east and west of the Siletz River Volcanics and north and west of Kings Valley, where it reportedly unconformably overlies the volcanic rocks. Although a complete section of the Flournoy is not exposed in Benton County, it is estimated to be about 3,700 ft thick.

Fresh outcrops are firmly compacted, blue gray, with conspicuous flakes of muscovite and biotite mica (up to 0.25 in long). Weathered outcrops are light tan (very pale orange) to grayish orange. The sandstone and siltstone grains are composed of angular quartz, feldspar, lithic fragments, and bent flakes of muscovite and biotite. Beds range from less than 2 to 12 ft in thickness. This unit has produced crushed and pit run stone. The material has been utilized for light-duty purposes such as fill. Used for topping, it tends to disintegrate into a muddy sand under traffic.

Kings Valley Siltstone (Tsrk)

The Kings Valley Siltstone, consisting of tuffaceous siltstone and waterlaid tuff, crops out extensively in Kings Valley, where this unit is approximately 3,000 ft thick. The lower part of the unit also contains interbedded pillows, basalt flows, tuff, and tuff breccia. There are no quarries or pits in the Kings Valley Siltstone.

Siletz River Volcanics (Tsr)

Siletz River Volcanics, the oldest rock in Benton County, covers more land surface than any other unit. It consists of vesicular to amygdaloidal, zeolitic pillow lava, basalt flows, flow breccias, coarse pyroclastics, and interbeds of thin, tuffaceous siltstone. The unit occurs at the higher elevations west and north of Corvallis and extends across Benton County northeast to southwest in a broad belt about 6 mi wide. Estimates of the minimum thickness range from 3,000 to 5,000 ft in Benton County; but elsewhere, near former centers of volcanism, the Siletz pile may be as much as 20,000 ft thick.

Siletz River Volcanic basalt is particularly well exposed at Wren (Figure 3) and at Coffin Butte (Figure 4), in quarry sites 20, 22, and 23, which supplied crushed rock for Camp Adair and State Highway 99W during World War II. Fresh rock surfaces are dark greenish-gray to black, with a general black and white mottled appearance caused by a high percentage of secondary calcite and zeolite minerals. Light rusty-brown weathered zones con be 4 to 10 ft or more thick, due to good infiltration. Much of the basalt was extruded onto a sea floor, forming elliptical bodies called "pillows." The hot rock coming into contact with water produced steam explosions which in turn caused the brecciation or fragmentation of the basalt. Individual pillows within the flows average about 3 ft in diameter; their chilled margins, originally basaltic glass, are usually altered to greenish-black clay minerals. In breccias and tuffs, original basaltic glass has been devitrified to greenish-brown, fibrous clay minerals, including montmorillonite.

Flows containing pillows and breccia fragments are commonly fine grained, vesicular, and amygdaloidal; alteration contemporaneous with marine deposition is prominent. Chlorite, clays, calcite, and zeolites are the main secondary minerals. Radiating columnar jointing occurs in individual pillows; and thin flows, intrusive dikes, and sills quite often have well-developed parallel columnar jointing.

Massive pillow lavas and breccias are relatively resistant to erosion and form topographic highs, with shallow or no soil cover; whereas interbedded siltstones and tuffs are easily eroded and weather spheroidally, leaving shells coated with iron and manganese oxides. The Siletz River Volcanics also contain unmapped intrusive rocks.

This unit is extensively quarried for crushed stone for building and road construction. Much of it can be ripped and used for rood beds without crushing.

Figure 3. Oblique aerial view of quarry site 33 at Wren. Quarry has been developed in massively jointed Siletz River Volcanics. As quarrying has gone deeper into the ridge, overburden has become greater and jointing more widely spaced, producing more massive rock fragments. This site cannot be screened from view of State Highway 20.

SURVEY DATA TABLE AND ROCK MATERIAL LOCATION AND GEOLOGY MAP

General

The Department surveyed 149 rock material sites within Benton County. Locations of sites are plotted on the Rock Material Location and Geology Map (folded, in pocket). Dots show actual site locations; circles indicate sand and gravel pits; triangles show stone quarries; and squares indicate clay pits. Three sites in Lane County and two in Linn County were also surveyed because of their proximity to Benton County.

Data for sites are shown in Table 1, printed on the back of the map (folded, in pocket). Information given in the table provides a reasonable picture of each individual mining site. Table data include site identification, location, status, size, source description, mining system, processing plant, and usage. Except for the column headed "Operator or owner," line and column entries contain dashes (-) when the data are unknown. Because maximum data are compressed into Table 1, each major column heading is discussed in the following paragraphs, in the order of appearance in the table.

Site Identification

The site numbering system for rock material begins with number 1, starting in the northwest corner of the County. The numbers follow that township to the east, move back to the west end of next township to the south, and move again to the east. The only names given in the column headed "Operator or owner" are those names located in the field; title searches were not made. Ownership of sites is as follows: Federal - 29; State - 19; County - 4; local - 3; private - 80; and unknown - 14.

Location

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

Status

The status of each site was determined. Between January and December 1977, 40 sites were active, 92 sites were inactive, and 17 were reclaimed.

Size

Table 4 summarizes the number of sites that fall within each of the five size categories and includes both past production and future potential. The table also gives total volume figures for mined material and for future potential. Cubic yards were converted to tons by a factor of 1 cu yd to 1.5 tons. In addition to the excavated acreage, acreage used for stockpiles and plant sites was measured. In Benton County, 367.5 acres have been mined and 12.4 acres used for stockpile and plant sites, a total of 0.09 percent of Benton County's land mass. On the average, 16,234 cu yds were taken from each acre mined.

Potential resources in this study are defined not strictly on the basis of quality and geologic availability but on the basis of cultural constraints to mining as well. Thus, property lines and ownership were the determining factors in developing the figures given in the tables and in arriving at the projections in the forecast section.

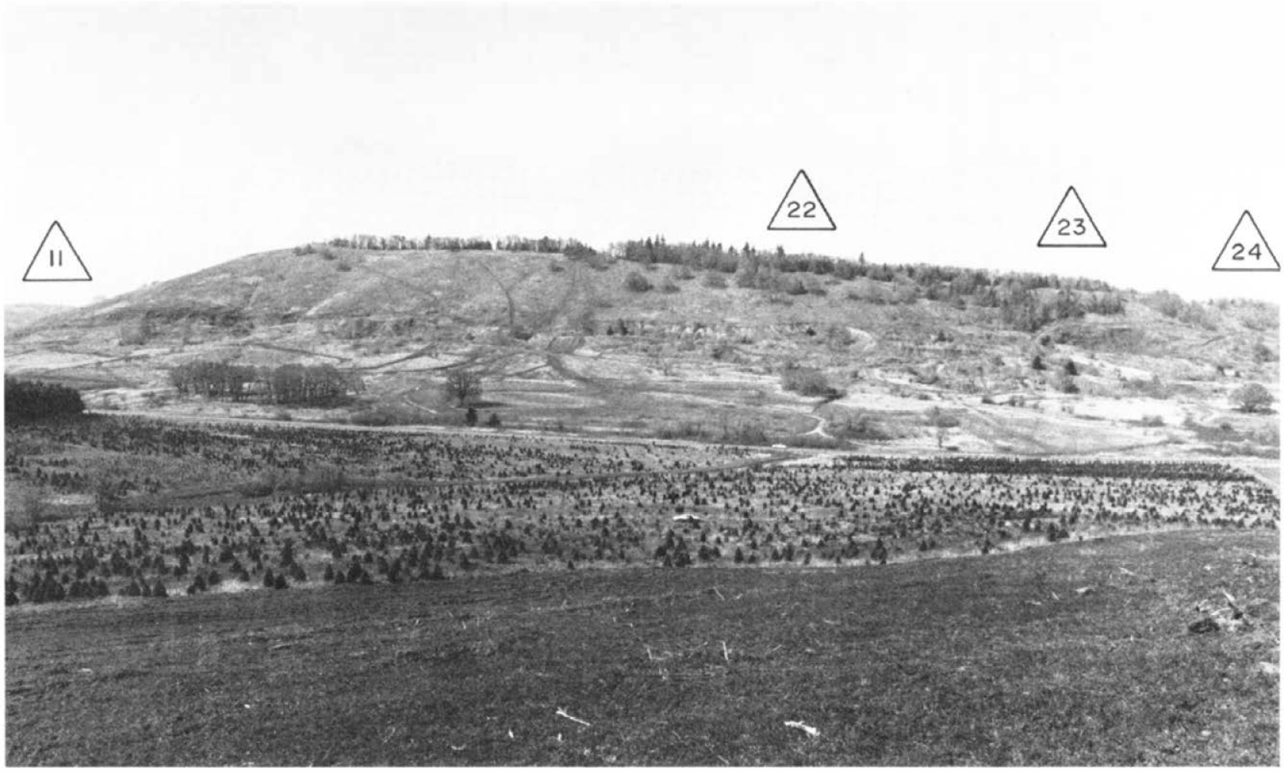

Figure 4a. Coffin Butte. Quarry sites 11, 22, 23, and 24 have been developed in Siletz River Volcanics. Although not apparent from this angle, sites 22 and 23 are filled with water. Note motorcycle trails crisscrossing ridge.

Figure 4b. Site 11, now being used for sanitary landfill.

Figure 4c. Water-filled and steep-sided quarry site 22. Note fine (1-6 inch) jointing.

Table 4. Number of sites by size		
Site size (1,000 cu yds)	Number of sites with past production	Number of sites with future potential
1 - 10	83	83*
11 - 25	22	11
26 - 50	15	19
51 - 100	14	10
101+	13	24
Total	147**	147**
Total yds	5,966,000	20,253,000
Total tons	8,949,000	30,375,500

* Includes 52 sites with no potential
** Two sites could not be surveyed

Source Description

Thirty-eight pits have been dug into alluvium and are listed under deposit type as gravel; sites 86, 136, and 137 are clay; the rest are sand and gravel. The term "various" is used to describe rock type for all sand and gravel sites. One hundred and eleven stone quarries have been developed in bed rock, one (site 140) in clay, and the remainder in igneous rock or sandstone. The geologic formation is given for each site, but it is important to note that the quality of quarry rock varies broadly with each geologic formation. The number of sites within a geologic unit does not correspond with the quality of that unit or with its land area. Table 5 shows that most sites have been developed within the Siletz River Volcanics. Although this unit is the largest, its rock is of poorer quality than the intrusive rock (see Table 3). The next largest unit, the Flournoy, has only four sites. The three geologic units containing the greatest percentages of rock material sites are indicated by color on the Rock Material Location and Geology Map.

Table 5. Number of sites by geological formation or unit		
Geological formation or unit	Number of sites	Percentage of sites
Surficial units		
Recent river alluvium (point bar) (Qral)	4	3
Quaternary lower terraces (Qtl)	32	21
Quaternary middle terraces (Qtm)	2	1
Quaternary higher terraces (Qth)	0	0
Subtotal	38	
Bedrock formations or units		
Intrusive rock (Ti)	20	13
Tuffaceous sandstone (Tts)	1	0.7
Spencer Formation (Ts)	4	3
Flournoy Formation (Tf)	4	3
Kings Valley Siltstone (Tsrk)	0	0
Siletz River Volcanics (Tsr)	80	54
Subtotal	111*	
Total	149	100*

* Includes two sites which could not be surveyed, and therefore are not assigned to a unit

Mining System

In Oregon, rock material is mined mainly by surface methods. In Table 1, information in the columns titled "Ground-breakage system," "Benching," "Highwalls," and "Jointing," refers mainly to stone quarries and is best illustrated by photographs (Figures 3,4, and 5). The table does not rate sites relative to public safety, but potential dangers to the general public are illustrated by the same photographs.

The mining procedures that were common in past years, shown by Figure 4 and site 123 in Figure 5, should not be viewed as standard practices today. Mining practices now are more consistant with those shown at site 122 (Figure 5). Quarry sites 22,23, and 24 at Coffin Butte (Figure 4a) are classified as side hill gouges. Each mine was started at the bottom of the slope, and mining continued until the highwall became too high, the overburden too deep, or the jointing spacing too massive. Each site was then abandoned, and a new site started nearby.

Another side hill gouge is shown in ground-level and aerial photographs of site 123 (Figure 5), located along a well-traveled road along the Alsea River. In the ground-level view, lack of provision for public safety is noticeable. The top of the road level highwall can be easily reached by the way of the upper bench, and a fall from the top of the highwall would probably be fatal. Loose material at the top of the quarry has not been removed, and several fracture planes slope downward into the quarry face. Large loose boulders lying on these planes could fall out at any time. Figure 4a shows a water-filled, steep-sided quarry which has motorcycle trails in and around it.

Steep-walled quarries and pits that become water filled are particularly dangerous. Sites 39 (Figure 6) and 134 (Figure 7) both illustrate these types of hazards. Access to site 39 is controlled; site 134, however, lies along a well-traveled County road, and site 22 is used as a motorcycle obstacle course.

Site 122 (Figure 5) and site 40 (Figure 6) show more of current mining practices. Mining is started at the top of the ridge, not at the bottom. Highwall heights are much lower because of multiple benches; rock fragmentation is controlled by better drilling patterns; and overburden is stockpiled for reclamation use as the resource is mined out. The final slopes have a ratio of 1.5 horizontal ft to 1 vertical ft or less.

Sand and gravel operators of pits such as sites 88 (Figure 2) and 57 (Figure 11, Reclamation and Land Planning section of this report) should consider the effects their excavations may have on erosion during flooding. Streams running through thick gravel can easily develop new channels as a result of improperly constructed berms or unprotected gravel pit excavations. Dikes, roadways, and other structures associated with rock production, when constructed in the paths of floods, can either act as dams, causing flood waters to rise higher than normal, or divert the force of the current, leading to the erosion of valuable agricultural land.

Uses

In this section of the report, rock material uses are described, starting with the use that requires the least size and strength specifications. The terms "embankment" and "fill" were used interchangeably. Materials used for embankment or fill can range in size from sand to jettystone and are used to bring roads and construction sites to grade. All that is required of the material is that it remain stable after it is placed in a low area. When rock material is needed in remote areas for construction of forest access roads or other projects, a local material of lower quality is often used in preference to a better material that has to be transported over a greater distance at higher cost. In construction of paved roads, the State or County may occasionally utilize a lower quality local rock for subbase material and a high-quality aggregate, often from a more distant source, for the top course and paving.

Normally, weathered bed rock which disintegrates into fragments, sand, or clay can be quarried with blasting. It may be suitable for embankments, or, treated, it may be usable with cement for base rock in road construction.

The size of rock material used for subbase and base is normally less than 6 in. in the widest dimension. This material supports the road. The base course is a layer of specified or select graded material of planned

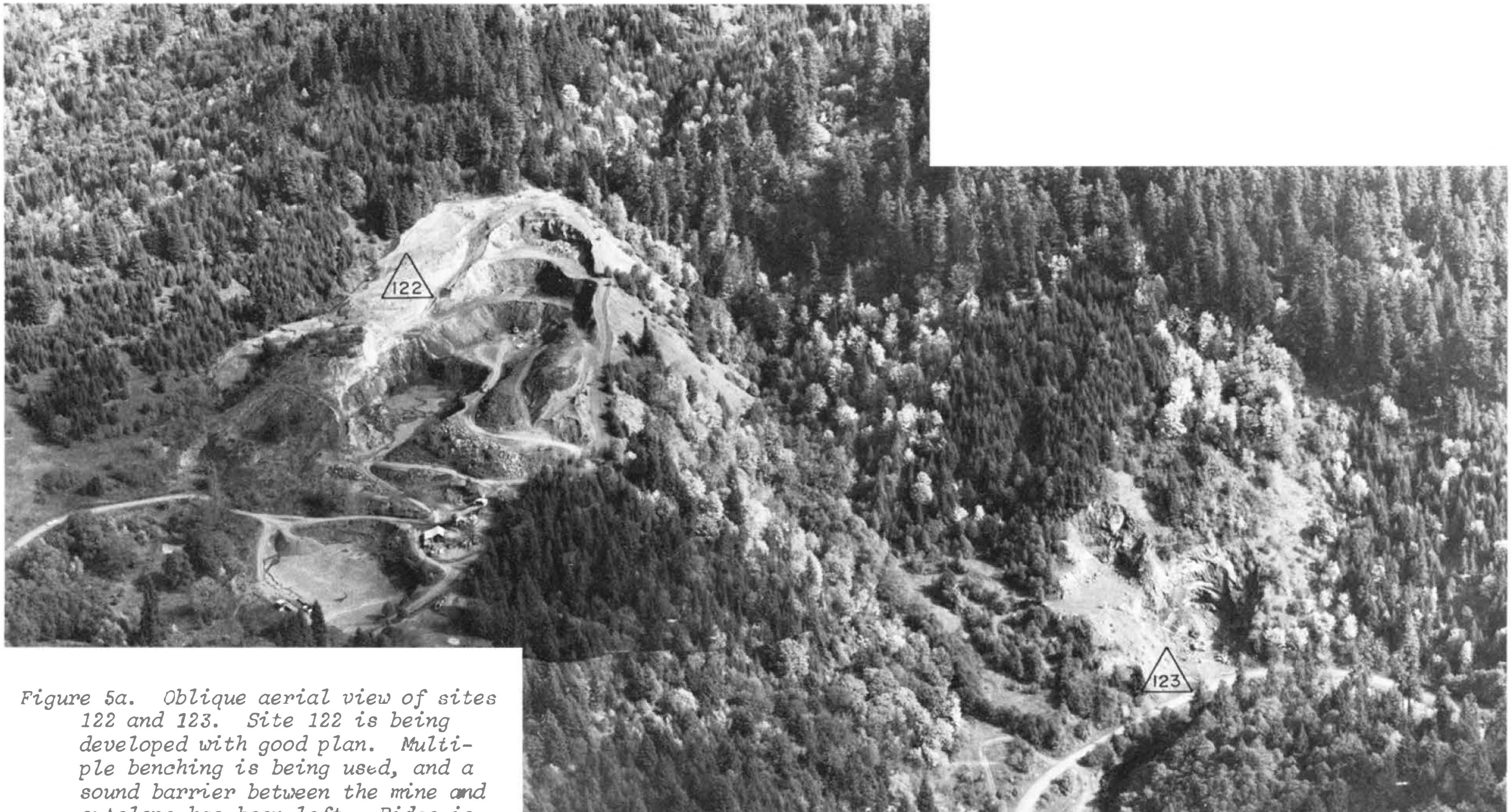

Figure 5a. Oblique aerial view of sites 122 and 123. Site 122 is being developed with good plan. Multiple benching is being used, and a sound barrier between the mine and outslope has been left. Ridge is being mined from the top down, making reclamation easier when the resource is all mined out. Site 123, in contrast, is a side hill gouge with uncontrolled access and numerous other hazards.

Figure 5b. Site 123. Note man in foreground for scale. Hazards include highwall heights, large loose boulders on sloping fracture planes, and loose overburden at top of quarry.

thickness constructed on the subgrade or subbase of a roadbed. The subbase is below the base course and above the embankment. Material placed in the subgrade or subbase can range up to 6 in. in the widest dimension but must also contain a certain percentage of fines to act as binder. Material placed in the base course ranges in size from less than $3\frac{1}{2}$ in. down to dust. Fines (material smaller than 1/8 in) are needed to hold coarser material in place but should be free draining, stable when saturated, and constitute up to only 25 percent of the total material. The term "fines" in soil mechanics refers to material smaller than No. 200 mesh size. These fines are usually detrimental to road base material.

Small-sized material of less than 1 in. is used as what is variously called "top course," "surfacing," "topping," or "road metal" and is the last layer placed on a roadbed. This rock material should be durable because the aggregate road surface is subject to wear from vehicle tires. The rock material can be either sand and gravel or stone and must be graded to less than 1 in. with very little material smaller than a quarter of an inch. Fine soil is usually mixed with the rock for binder to keep it from "raveling" off the road surface. Stone to be used for surfacing roads should normally be crushed; some gravel deposits, however, can be screened to give the correct size for road surfacing.

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 partland 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 does not have 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 with cold-rolled asphaltic concrete than with hot mix from a batch plant.

Jettystone and riprap are rock materials used to build jetties and to line stream banks, beach fronts, and highway embankments. The rock materials used for riprap and jettystone should be hard, durable, angular in shape, resistant to weathering, and denser than 160 lbs per cu ft. The difference between riprap and jettystone is size. The size range of riprap is from 50 lbs to 2,000 lbs for each stone. The size range of jettystone is from 0.25 tons to 28 tons for each stone (see Figure 5). Material of jettystone size is needed only where the extreme force of ocean storms must be counteracted.

Figure 6. Oblique aerial view of sites 39 and 40. Site 39 is hazardous because it has steep walls and is water filled. Site 40 demonstrates current mining practices: top of ridge instead of bottom of slope is being mined; other benches are started as needed to keep highwalls at workable heights. Access to both sites is controlled, and neither can be seen from any public road.

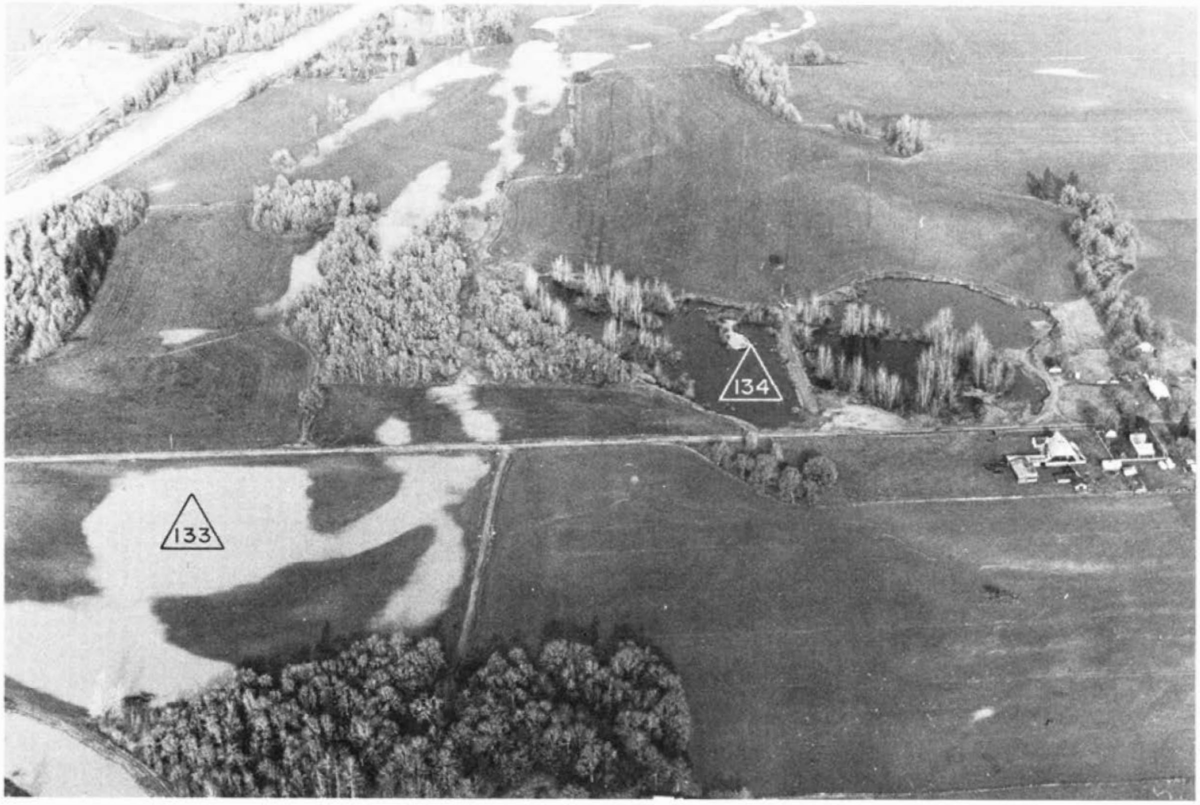

Figure 7a. Oblique aerial view of sites 133 and 134. Site 133 is gravel pit reclaimed as farmland. Water-flooded area is only remaining evidence of pit.

Figure 7b. Site 134, showing hazardous steep-sided water-filled gravel pit.

State Highway Division Laboratory Data

General

All of the laboratory test data performed by the Oregon State Highway Division on materials from Benton County were made available to this study. Sites from which materials were tested are marked with asterisks in Table 1. Test data are summarized in Table 6 (back of Rock Material Location and Geology Map, folded, in pocket). Sometimes several types of tests were performed on material from one site; other times only one test was done. Samples for testing were selected by various persons over a long period of time, and the testing was also done by various people. Data given in Table 6 should therefore be regarded only as a guide and not as final authority.

Different size fractions from the same site will give different test results. Therefore, to present the best statistics for the entire deposit instead of just for a particular size fraction, data ranges (the highest and lowest values) were given in Table 6. No attempt was made to determine weighted data averages for sites. If no range is indicated for material from a particular site, either all test results were the same or only one test was conducted. Table 7 gives test standards for each type of use.

Table 7. Test standards by usage

Usage	Test standards						
						Oregon degradation	
	Specific gravity (minimum)	Los Angeles rattler (maximum percent)	Sodium sulfate (maximum percent)	Plasticity index (nonplastic or maximum percent)	Liquid limits (nonplastic or maximum percent)	Maximum (percent)	Maximum height (inches)
Asphalt concrete aggregate							
Fine - ¼ in.		35	18	6	33	30	4
Coarse - 1 in.+ ¼ in.		30	18			30	3
Cement concrete aggregate							
Fine - 3/8 in.+ 100 mesh		30	10			30	3
Coarse - 2¼ in.+ ¼ in.		30	12			30	3
Surface - topping		35					
Base		35		6	33	30	3
Subbase		45					
Riprap	2.5		16			35	8

The test data table will probably be used by contractors and others who know and understand the testing. 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 tells 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 then reweighed. The statistic listed is the percentage lost during the testing.

Sodium sulfate test

The sodium sulfate test is used to see how weather will affect rock material. Again the material is weighed, tested, then reweighed. The statistic reported is the percent of loss. Testing consists of soaking the sample in a strong brine solution at an elevated temperature for 16 to 18 hours and then drying it at an elevated temperature for 2 hours. The sample is soaked and dried for several cycles.

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 then determined. The plastic limit is the lowest water content, by weight percent, at which the rock material becomes plastic. It 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 of a rock material. The plasticity index is the water-content range at 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 percentage, by weight, 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

When the Benton County planners or the land use decision makers try to accommodate surface mining into a comprehensive land use plan, they must address built-in conflicts with other objectives of the plan. On one hand, they must protect residential areas from noise, dust, vibration, traffic, and unsightliness of pits and quarries; on the other hand, they must insure the availability of mineral resources to be used for the good of Benton County and the State of Oregon. They must insure 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.

The 1971 Oregon Legislative Assembly passed the Mined Land Reclamation Law, which addresses the following concerns:

(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 the Mined Land Reclamation Law.

Role of the Division, the County, 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 with the Division of Mined Land Reclamation an application, a reclamation plan (the Division's Reclamation Guideline printed as Appendix 2 may be used), and the appropriate permit fee.

(2) The application and plan are copied and submitted for review to 11 State agencies and to Benton 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 into 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.

Benton County, through its zoning laws, also is involved with needs addressed by the Mined Land Reclamation Law; and its role is no less important than that of the State Department of Geology and Mineral Industries. Within their respective roles, both agencies 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 has the best knowledge of local needs. It should not be the function of the County Planning Department to prepare a reclamation plan for a particular mining site, but the County may set guidelines that have secondary and tertiary uses in mind. 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 for a demolition fill; the tertiary use could be a residential development or a community park.

The operator-landowner's role should not be that of an adversary of the two agencies. The operator has as much at stake in carrying out the purposes of the Mined Land Reclamation Law as any agency. Reclamation is a planning process that allows the operator-landowner to maximize his total profits by continued utilization of mined-out land.

Reclamation Assistance

Benton County planners and zoning decision makers probably do not have a tax base which allows them to hire all the expertise needed for making rational decisions concerning either 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 expertise which can be called upon both formally and informally. A copy of the Division of Mined Land Reclamation's "Reclamation Plan Guideline" is included in this study as Appendix 2. This guideline was prepared as a checklist for the Division specialists and can be used by the operator in preparing a standard reclamation plan. The questions indicate what the Division looks for in a reclamation plan.

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 Shellie and Rogier, 1964) on all phases of reclaiming sand and gravel and rock quarries. The Reclamation Division has a set of these reports on loan, which may be examined at the Division's Albany office.

A major means that Benton County could use to aid the surface mining planning process would be to establish a reclamation library. The main value of the library's availability at the County level would be that the operator, the planner, and the public could study what has been and what could be done to plan for secondary and tertiary uses of mined-out areas. A partial list of uses for mined-out areas could include housing, both single family 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

Benton County has many examples of acceptable and unacceptable mined land reclamation. Examples of unacceptable reclamation have already been discussed in other sections of this report. Any reclamation for sites such as site 33 (Figure 3), sites 22, 23, and 24 (Figure 4); and site 123 (Figure 5) would be prohibited because of cost.

Figure 8 shows two quarries mined without reclamation consideration that are now being used beneficially. The rise in land values within and near urban areas provided the incentive to use formerly abandoned site 26, North Albany, and site 52, Corvallis. As the aerial and ground level views show, these sites have been reclaimed into very pleasant back yards.

Many pits and quarries, if given enough time, will reclaim themselves to the point of being hidden by trees and other vegetation. Such natural reclamation has taken place in site 45 (Figure 9).

The planning for reclamation should be done before a pit or quarry is opened; as much as possible, reclamation should be an ongoing process that begins long before the resource is mined out. For water-based recreation sites, certain factors should be kept under consideration. All slopes from water level to 10 ft below water level should be 3 to 1, meaning that for every 3 ft of horizontal distance, the vertical drop is 1 ft. In addition, most gravel deposits have an unsalable portion that is screened out. If this material is just dumped back into the pit, the water depth is decreased. Instead, it would be better to use this material to build dry land areas for parking, camping, and other human activities. Figure 2 shows the importance of keeping the river from eroding into the pit.

In a recent paper on reclamation, Summer (1978) points out that the sides and bottoms of sand and gravel pits could be lined with a clay sealant in a way that would protect water supplies and soils from liquid and gaseous toxic leachates. If a clay sealant could be used at some otherwise unfavorable site, the site might be converted into a sanitary landfill. Bentonite, which swells up to 15 times its dry volume with the addition of water, would make such a sealant. If local Benton County clay is not suitable, it might be practical to import bentonite from Crook County. After the pits were filled, the land could be used again for farming.

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 values of the land reclaimed and unreclaimed, a figure can be obtained that can be used to show how much can be spent each year for reclamation, with the owner still receiving a profit on the expenditure if the land is later sold.

According to Dunn, in terms of noninflated dollars, reclaimed mined-out land is worth five times as much as unreclaimed land. Assuming that a rock material site had reserves for 20 years, that the land value with reclamation would be $50,000, and that without reclamation it would be $10,000, the

Figure 8a. Oblique aerial view of site 26. Urban development and corresponding rise in land values mandate that old quarries such as this one and site 52 be put to beneficial uses. These two sites are now pleasant back yards.

Figure 8b. Ground view of same location, now a home site.

Figure 8c. Oblique aerial view of site 52.

Figure 8d. Ground view of site 52.

Figure 9. Oblique aerial view of site 45, quarry that, through time, has naturally reclaimed itself with vegetation cover. Original quarry is now hard to see.

value of reclamation can be estimated to be $40,000. If this figure is divided by 20, the first approximation of maximum annual justifiable expenditure on reclamation is $2,000. This $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 10, 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 also be drawn. These curves (Figure 10) indicate an estimated 25 percent profit, or $10,000, at the end of 20 years.

ECONOMICS, STATISTICS, AND FORECASTS

Economics

To many people, land is only a surface, sometimes flat, sometimes hilly. It may be low and swampy or high and dry. Land use planners talk about these surfaces in terms such as population per square mile, runoff per drainage basin, or tons of fallout per acre. Geologists view land as a three-dimensional block of the earth's crust. Each block is unique in many ways, though surficially it may appear to be identical to adjoining parcels. What lies immediately below the surface may be a wealth of mineral resources which may be set free if the surface land cover is removed. In Benton County, that wealth includes clay, sand and gravel, and quarry stone.

Land is in part the basis for 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

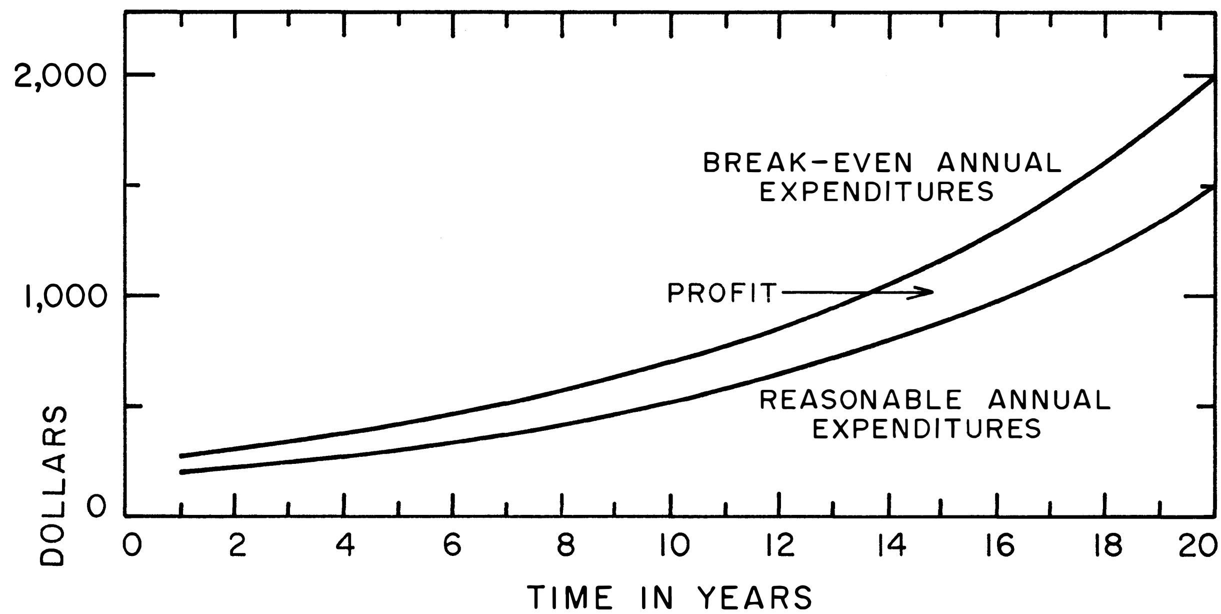

Figure 10. Discounted reclamation costs.

were readily available in certain areas on or near the surface. Today these easily mined deposits are largely gone, and only the buried reserves are left. Unfortunately, land use planning often fails to recognize that mineral wealth may lie hidden beneath the surface, and much zoning has effectively prohibited the development of these resources.

According to the U.S. Bureau of Mines mineral production value statistics, Benton County sand and gravel and stone production from 1940 through 1975 totals $13,530,000. Based on the figures in Table 1, a total of 367.5 acres have been mined in Benton County, which means that for every acre mined, $36,816 of value was added to Benton County economic life. This value is only the mine plant value and does not include any transportation or other construction values. According to Mason (1973), if the rock product is used in a concrete structure, its worth is approximately 100 times greater than the original pit price. The Bureau's value figure also does not include any value for the use of the road or structure built of the rock materials. Rock used for timber-haul roads to keep trucks from sinking into the mud has a much greater value to the trucker than is reported by the Bureau.

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

After the sand and gravel or other mineral has been extracted, the mined area may serve a variety of useful purposes, if properly handled. Such pits may become solid waste landfill sites, "instant basements," or recreational sites with ready-made lakes. If used for solid waste landfill, the surface acreage will again be available to the planner for a variety of other commercial uses.

We are running out of natural resources, and future needs must be considered in current land use planning. We must start thinking of an acre as being more than just 43,560 sq ft of surface.

Statistics

The U.S. Bureau of Mines is the source of annual mineral statistics. These statistics are gathered by commodity, tonnage, value, use, and type of producer. Data is collected by a mailed-out voluntary canvass. The Bureau tries for a 100 percent canvass return but seldom reaches that goal. In Benton County, past production figures from the Bureau's canvass and those determined by on-site surveying are in agreement, except for production from site 57. This site (Wildish-Corvallis Sand and Gravel Company) is in Linn County, but the U.S. Bureau of Mines included the production in Benton County figures because it is on the west side of the river. The Willamette River, in most other locations, forms the boundary between Linn County and Benton Counties. At site 57, however, the river has fairly recently changed channels.

The Bureau shows that 11,288,083 tons of sand and gravel and stone were produced in Benton County from 1940 through 1975. Table 4 data, based on field survey, shows that 8,949,000 tons have been mined from Benton County; however, if the past production from site 57, which is actually located in Linn County (Table 1), is added, the total becomes 11,949,000 tons. The total should also be higher from production below the water level of the Willamette River. This production cannot be surveyed. This analysis shows that 94 percent of Benton County production was counted by the U.S. Bureau of Mines, assuming that all production took place between 1940 and 1975. Benton County, Willamette Valley, and State production statistics are given in Table 8.

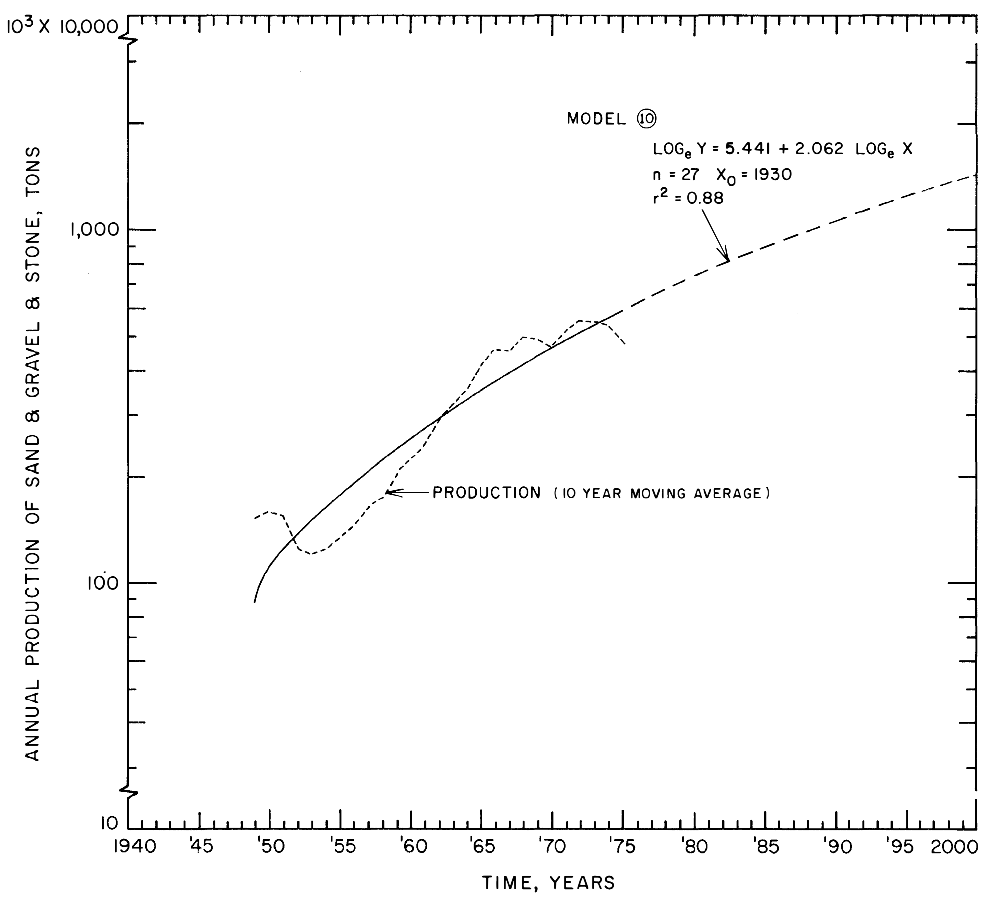

Figure 11. Benton County sand and gravel and stone production tonnages (10-year moving average) v. time with least square correlation (model 10) trend line extending to year 2000.

Table 8. Sand and gravel and stone production statistics for Benton County, Willamette Valley, and the State

Year	Benton County (tons) Sand and gravel	Stone	Total	Willamette Valley (tons) Sand and gravel and stone	State (tons) Sand and gravel and stone
1940	58,719	-	58,719	2,064,902	5,726,272
1941	80,611	-	80,611	2,490,284	6,804,785
1942	323,323	-	323,323	3,905,600	9,256,341
1943	125,739	28,600	154,339	3,573,875	7,598,518
1944	140,972	15,400	156,372	3,612,477	6,548,393
1945	135,639	25,000	160,639	3,741,759	6,024,464
1946	171,930	51,750	223,680	4,673,741	6,893,753
1947	104,276	32,770	137,046	4,690,188	9,022,440
1948	101,650	-	101,650	5,612,174	12,067,175
1949	115,617	-	115,617	6,075,044	11,532,171
Total	1,358,476	153,520	1,511,996	40,440,044	81,474,312
1950	139,369	-	139,369	5,422,329	12,041,740
1951	38,640	-	38,640	6,069,248	19,226,138
1952	37,925	-	37,925	12,204,984	18,470,335
1953	31,050	67,500	98,550	6,958,208	13,704,538
1954	123,718	65,000	188,718	8,299,871	19,029,592
1955	235,581	26,943	262,524	9,887,163	19,695,815
1956	254,742	92,971	347,713	9,499,369	17,735,148
1957	286,128	40,950	327,078	10,507,189	23,425,770
1958	155,985	37,218	193,203	13,255,187	25,541,043
1959	291,085	119,546	410,631	18,136,955	31,427,642
Total	1,594,223	450,128	2,044,351	100,240,503	200,297,761
1960	321,593	18,172	339,765	17,738,268	34,585,959
1961	154,095	85,505	239,600	14,421,588	29,753,606
1962	378,938	90,124	469,062	17,783,312	33,126,754
1963	355,230	72,651	427,881	15,936,558	35,407,641
1964	405,000	101,651	506,651	14,717,281	34,372,823
1965	701,000	190,317	891,317	21,413,948	43,012,392
1966	609,000	211,384	820,384	17,839,399	68,614,999
1967	235,000	11,066	246,066	17,208,918	32,830,522
1968	492,000	137,700	629,700	19,615,982	32,572,498
1969	297,000	80,396	377,396	14,691,575	27,401,811
Total	3,948,856	998,966	4,947,822	171,366,829	371,679,005
1970	*	*	498,180	15,195,239	30,971,335
1971	*	*	293,085	16,815,348	34,023,739
1972	*	*	835,141	19,785,885	35,404,468
1973	*	*	407,115	22,886,796	36,212,979
1974	*	*	378,790	22,023,531	41,910,897
1975	*	*	371,603	17,318,350	37,802,162
Total	2,123,809	660,105	2,783,914	114,025,149	216,325,580
Grand total	9,025,364	2,262,719	11,288,083	426,072,525	869,776,658

* Concealed to avoid disclosing individual company confidential data

Forecasts

Estimates of future production of sand and gravel and stone must take into consideration past factors that have controlled historic production. To show past production trends for Benton County and to make it possible to compare annual productions of Benton County, the Willamette Valley, and the State of Oregon, tonnages from Table 8 were plotted against time, using several different types of least square correlations. These models for future production and consumption are presented in Appendix 3. All steps taken to arrive at the model used for the forecast presented in this section are discussed at length in Appendix 3 and shown in Table 10 and Figures 13, 14, 15, and 16 (also found in Appendix 3).

The authors felt that the projections presented in Table 9 for the State, Willamette Valley, and Benton County are the most reasonable, based on past trends for the State obtained with power curve fit. Table 9 summarizes projected annual production tonnages and per capita production for the year 2000 for the preferred models. The same data for 1976 are also given. To arrive at the per capita consumption, the highest projection was used from the Statistical Data Base (1973). The authors believe that the high projection model 10 (annual production of 1,468,339 tons for the year 2000) is best for Benton County. For this model, per capita consumption is still less, by far, than the per capita figure for the entire State for 1976. If the production for 1976 is divided into the total future potential indicated in Table 4, Benton County's resources, under a no-growth situation, could last 80 years. If economic and population growth, however, occur as predicted by model 10 (see Appendix 3), the resources will instead be gone in 26 years (by the year 2004). This does not mean that Benton County will be out of rock material by the year 2004. It means, instead, that new sites will be needed in both the immediate and distant future. These new sites should be planned in terms of market needs and secondary land uses. Data from Table 1 indicate that some sites will be used up faster than others. Planners should take into account the life expectancy of individual sites.

Table 9. Present and predicted production

	1976		2000	
Model number*	Production (tons)	Per capita consumption (tons)	Estimated production (tons)	Per capita consumption (tons)
6 (State of Oregon)	37,903,905	16	88,852,000	26
7 (Willamette Valley)	18,991,621	12	46,907,000	22
10 (Benton County)	538,142	8	1,468,339	16

* See Appendix 3

All the modeling and projecting was performed by using the annually combined sand and gravel and stone figure. To separate the projection for the year 2000 into each component and to determine whether one of the commodities is replacing the other, the three least squares models, the same types used to estimate production, were used. The sand and gravel tonnage figure for each of the 36 years was divided by the sand and gravel and stone tonnage figure for the same year. The figures were plotted against time (Figure 12). All three models for Benton County show that sand and gravel production is becoming a smaller portion of the total production. Figure 12 also shows a downward trend for the Willamette Valley and for the State. The r^2 values are low; however, they are high enough to pass the Student T test at the 95 percent level (see Appendix 3). By the year 2000, sand and gravel should account for only 55 to 65 percent of Benton County's total rock material annual production.

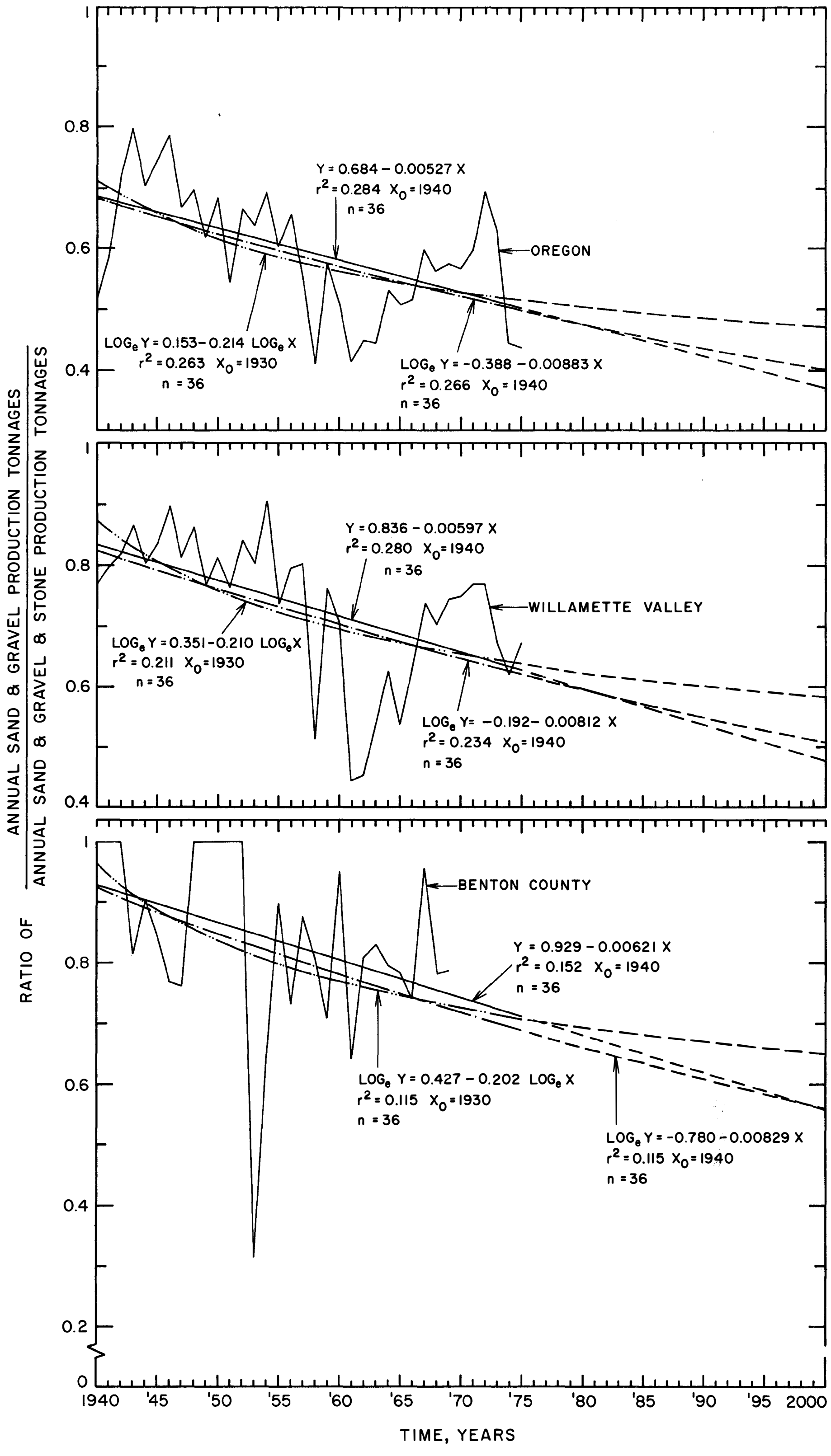

Figure 12. Oregon, Willamette Valley, and Benton County production tonnage ratios of sand and gravel to sand and gravel and stone v. time. To avoid disclosure of individual company confidential data, Benton County data for last 6 years is not plotted.

CONCLUSIONS AND RECOMMENDATIONS

This study provides a strong mineral resource data base and a geologic map for use of the 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 demands help to focus the County's 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.

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 County may wish to relate land status to mineral resource potential.

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

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APPENDIXES

APPENDIX 1. 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 $3\frac{1}{2}$ 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 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 gravel 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 roads.

rock material - any natural occurrence of consolidated or unconsolidated mineral matter and products dug or mined from that occurrence. Includes clay, shale, pumicite (volcanic ash), volcanic cinders, scoria, sand and gravel, 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 gravel and coarser than dust; the size of material that passes a 3/8-inch sieve but is retained on a 200-mesh sieve.

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

stone - individual blocks, masses, fragments, or crushed sizes of material taken 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 2. RECLAMATION PLAN GUIDELINE

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
MINED LAND RECLAMATION DIVISION

RECLAMATION PLAN GUIDELINE

A. NAME, ADDRESS AND TELEPHONE NUMBER OF THE OPERATOR OR HIS AGENT:

B. NAME AND ADDRESS OF LANDOWNER:

C. LIST OF KNOWN MATERIALS FOR WHICH THE OPERATION IS TO BE CONDUCTED:

1. PROPOSED STARTING DATE:
2. PROPOSED ENDING DATE (IF KNOWN):

D. OPERATIONAL PLAN:

1. METHOD TO BE EMPLOYED:

   a. SINGLE BENCH   c. DREDGE

   b. MULTIPLE BENCH   d. OTHER ____________

2. TYPES OF EQUIPMENT TO BE USED:

3. DISPOSITION OF OVERBURDEN:

E. WHAT WILL BE THE PLANNED SUBSEQUENT "BENEFICIAL USE" OF THE PERMIT AREA? THIS CAN INCLUDE, BUT IS NOT LIMITED TO, CONSTRUCTION SITE, SANITARY LAND FILL, PARK, WATER IMPOUNDMENT, AGRICULTURAL USE (BE SPECIFIC, EXAMPLE: GRAZING LAND, CROP TO BE PLANTED, ETC.), FOREST LAND.

SMLR-16 072776

F.1. (a) Reclamation will begin ________ days following completion of mining.
(b) Reclamation will be concurrent with mining. ______ yes ______no

F. 2. PROVISION FOR RECLAIMING MINED LANDS ON A CONTINUING BASIS WHERE FEASIBLE.

G. RECLAMATION PROCEDURES

1. WHAT WILL YOU DO TO INSURE GROUND STABILITY?

2. PROVISION FOR REVEGETATION. (Minimal survival rate is 75% uniformly distributed.)

(a) HOW WILL YOU SAVE AND STORE TOPSOIL?

(b) WHAT MEASURES WILL YOU TAKE TO PREVENT EITHER WIND OR WATER EROSION OF TOPSOIL DURING STORAGE?

(c) WHAT WILL BE THE AVERAGE DEPTH OF TOPSOIL REPLACED ON THE AREA TO BE RECLAIMED.

(d) HOW WILL YOU PREPARE SEED BED PRIOR TO PLANTING?

(e) WHAT TYPES AND AMOUNTS OF GRASS SEED WILL YOU USE PER ACRE AND HOW WILL THIS BE PLANTED?

(f) WHAT TYPES AND AMOUNTS OF FERTILIZER, MULCH, AND LIME WILL YOU USE?

(g) WHAT TYPES AND AMOUNTS OF SEEDLINGS AND SHRUBS WILL YOU PLANT?

(h) WHEN WILL SEEDING AND PLANTING TAKE PLACE? (SEASON OF YEAR)

H. WATER AND DRAINAGE

(a) WHAT PROVISION WILL YOU TAKE TO INSURE PROPER DRAINAGE?

(b) WHAT PROVISION HAS BEEN TAKEN FOR SILT CONTROL?

(c) IF WATER IMPOUNDMENT IS TO BE LEFT, SEE PAGE 6.

I. VISUAL SCREENING

(a) WILL YOU EMPLOY VISUAL SCREENING? (IF NO, EXPLAIN)

(b) WHAT TYPES AND AMOUNTS OF PLANTS WILL YOU USE?

(c) WHAT WILL BE THE SPACING BETWEEN PLANTS?

J. PROVISION FOR REMOVING STRUCTURES, EQUIPMENT, AND REFUSE FROM THE PERMIT AREA IN ACCORDANCE WITH THE RECLAMATION PLAN.

K. MAP OF AERIAL PHOTO REQUIREMENTS

(a) WILL AREA PHOTO BE SUBMITTED? YES ______ NO _______
SCALE______

(b) MAP(S) REQUIREMENTS. THE MAP SHOULD SHOW, BUT IS NOT LIMITED TO:

(1) SCALE: (1" = 400' to 600')

(2) NORTH SHALL BE INDICATED

(3) QUARTER SECTION, SECTION, TOWNSHIP AND RANGE

(4) DISTANCE AND DIRECTION TO NEAREST MUNICIPALITY

(5) LOCATIONS AND NAMES OF ALL STREAMS, ROADS, RAILROADS, UTILITIES

(6) LOCATION AND NAMES OF ADJACENT LANDOWNERS

(7) ALL OCCUPIED HOUSES WITHIN 500 FEET

(8) LOCATION OF ALL PROPOSED ACCESS ROADS

(9) LOCATION OF PLANT, OFFICE AND MAINTENANCE FACILITIES

(10) SHOW BOUNDARIES OF AREA TO BE PERMITTED

(11) TYPICAL CROSS-SECTION OF PRESENT GROUND LINE AND PROJECTED GROUND LINE AFTER RECLAMATION

(12) CONTOUR INTERVAL, DATE OF MAP PREPARATION, NAME OF PERSON PREPARING MAP.

(13) AREA FOR TOPSOIL STORAGE, WASTE DISPOSAL

(14) A SEPARATE MAP SHOWING GENERAL LOCATION OF THE OPERATING AREA (NOT LARGER THAN $8\frac{1}{2}$" x 11")

(c) A REVISED MAP MAY BE REQUIRED ANNUALLY

L. IF APPLICABLE, WHAT PROVISIONS HAVE BEEN MADE FOR STREAM CHANNEL, BANK STABILIZATION AND REHABILITATION?

M. EVIDENCE, IN WRITTEN FORM, STATING THAT ALL OWNERS OF A LEGAL, EQUITABLE, FIDUCIARY OR POSSESSORY INTEREST IN THE LAND CONCUR WITH THE PROPOSED SUBSEQUENT USE FOR ANY MINING OPERATION COMMENCING SUBSEQUENT TO JULY 1, 1972.

N. OTHER PERMITS IF APPLICABLE:

DIVISION OF STATE LANDS	NO.________	DATE ________
DEPARTMENT OF ENVIRONMENTAL QUALITY	NO.________	DATE ________
COUNTY USE PERMIT	NO.________	DATE ________
OTHER (IDENTIFY)	________	

O. OTHER COMMENTS:

____
(SIGNATURE OF APPLICANT)

TITLE __________ DATE ________

WATER IMPOUNDMENTS

(1) HOW LARGE WILL THE SURFACE AREA BE, IN ACRES? ____________________

(2) WHAT PROVISIONS HAVE BEEN MADE FOR PUBLIC SAFETY?

(3) WHAT PROVISIONS HAVE YOU MADE TO PREVENT WATER STAGNATION?

(4) WHAT IS THE WATER SOURCE FOR THE IMPOUNDMENT?

(5) WILL THERE BE PUBLIC ACCESS FOR FISHING?

INSTRUCTIONS FOR CROSS-SECTION

1. THE TWO EXAMPLES SHOWN ARE "TYPICAL" CROSS-SECTIONS OF A WATER IMPOUNDMENT LEFT AFTER EXCAVATION IS COMPLETE.

2. IF ONE OF THE PLANS SHOWN IS TO BE USED, PLEASE INDICATE WHICH ONE AND PROVIDE THE FOLLOWING INFORMATION ON THE PLAN SELECTED. YOU DO NOT HAVE TO RE-DRAW THE CROSS-SECTION.

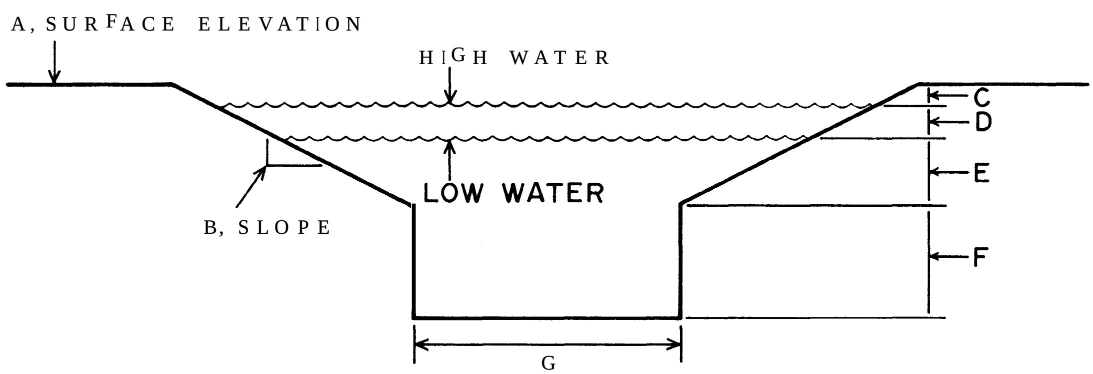
   A. SURFACE ELEVATION TO THE NEAREST 5 FEET.

   B. SLOPE OF THE BANK (MAXIMUM IS 2:1 OR 27°).

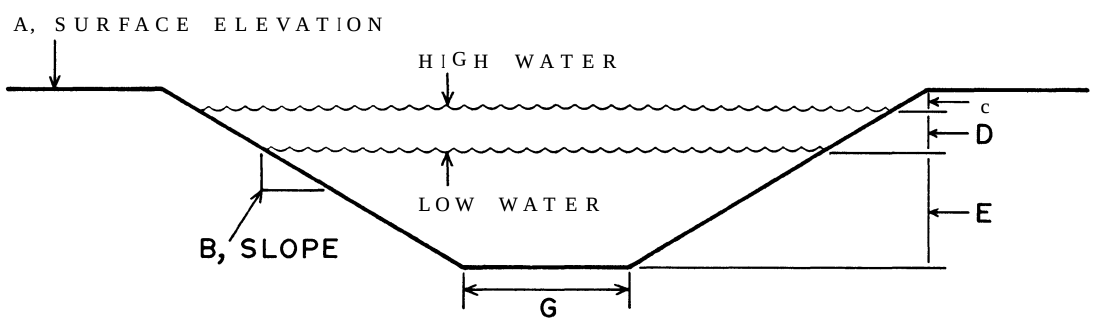
   C - G. THE DIMENSIONS IN FEET.

Typical Cross - Section(s) of Water Impound

TYPE I



TYPE II



APPENDIX 3. FORECAST MODELING

Any economic projection, long-range or short-range, County or Statewide, rests on the basic assumption that some identifiable relation exists between the past and the future. The methods used in this study were identification of past linear trends and projection of them into the future through the use of least squares correlations. The correlation which gave the highest r^2 value was the one that was used. Several different type of least squares were tried at the State level; the best fit (the highest r^2 value) that was obtained was then used for the Willamette Valley and for the County.

The first step in building a 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. The historic time series was plotted on semilog graph paper (Figure 13) to show whether it has been increasing rapidly, increasing slowly, fluctuating up and down, 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 $\text{Log}_e\, Y = a + b\,x$) produced a straight line on semilog paper; therefore, this type was used to determine the length of the data base to be used (Figure 11). Y is the dependent variable (production tonnages), a is the constant where the curve crosses the x axis, b is the slope of the curve, and x is the independent variable (time). Four models were developed: model 1 covers the total length of time from 1940 to 1975; for model 2, the length of time is shortened by 10 years; model 3 is shortened by another 10 years; and model 4 is shortened by an additional 10 years. The range r^2 values (goodness of fit) was from 0.01 for model 3 to 0.83 for model 1. A perfect correlation between time and production is 1.0; no correlation is 0.0.

Each trend was projected to the year 2000. It is easy to see from Figure 13 that the length of the data base determined 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 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 14). Arithmetical least square type (model 5), with the general formula of $Y = a + b\,y$, was tried. It has an r^2 value of 0.73. The power curve least square type (model 6) with the general formula $\text{Log}_e\, Y = a + b\, \text{Log}_e\, x$ was tried. It gave an r^2 value of 0.88; therefore, this model was used to project future production for the State. This least square type was also used to project for the State's smaller political units. Model 6 and the State historic series were then replotted (Figure 15) along with a similar series for the Willamette Valley and for Benton County. Power curve types of least square were run for the Willamette Valley (model 7), and for Benton County (model 8). A very high r^2 value was obtained for the Valley, but for Benton County it was only 0.47. This low figure means that over half of the variation in the data cannot be accounted for by the model. The reason for the large swing in production is the smallness of Benton County's production. To minimize the effect of these oscillations, a moving average can be used.

A 5-year moving average (model 9) was plotted (Figure 16). The first point plotted (1944) was an average of productions of 1940, 1941, 1942, 1943, and 1944. The next point plotted (1945) was an average of production of years 1941, 1942, 1943, 1944, and 1945. The least square power fit (model 9) had an r^2 value of 0.66. A 10-year moving average was also plotted. The data were transformed the same way they were for the 5-year moving average, by averaging production figures for 10 years instead of 5 years. The least square power curve fit model 10 has an r^2 value of 0.88, which is high enough to have a good projection for the year 2000.

The r^2 values for each of the 10 models shown on Figures 11, 13, 14, 15, and 16 were tested by the Student T test. Only the r^2 value for model 3 was too low to be significant. The Student T test has the form of

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

The authors felt that the projections marked with asterisks in Table 10 for the State, Willamette Valley, and Benton County are the most reasonable, based on past trends for the State obtained with power curve fit. Table 10 summarizes projected annual production tonnages and per capita production for the year 2000 for each of the models found in Figures 13, 14, 15, and 16. The same data for 1976 are also given. To arrive at the per capita consumption figure, the highest projection was used from the Statistical Data Base (1973). The authors believe that model 10, which predicts an annual production of 1,468,339 tons for the year 2000, is best for Benton County.

Table 10. Present and predicted production for all models

		1976		2000	
*Models	r^2	Production (tons)	Per capita consumption (tons)	Estimated production (tons)	Per capita consumption (tons)
State of Oregon					
3	0.01	37,903,905	16	40,070,000	12
5	0.73	37,903,905	16	72,487,000	21
**6	0.88	37,903,905	16	88,852,000	26
2	0.60	37,903,905	16	122,020,000	36
4	0.75	37,903,905	16	130,700,000	39
1	0.83	37,903,905	16	240,400,000	71
Willamette Valley					
**7	0.93	18,991,621	12	46,907,000	22
Benton County					
8	0.47	538,142	8	875,057	9
9	0.66	538,142	8	1,051,597	11
**10	0.88	538,142	8	1,468,339	16

* In order of increasing growth
** Authors' preferred model

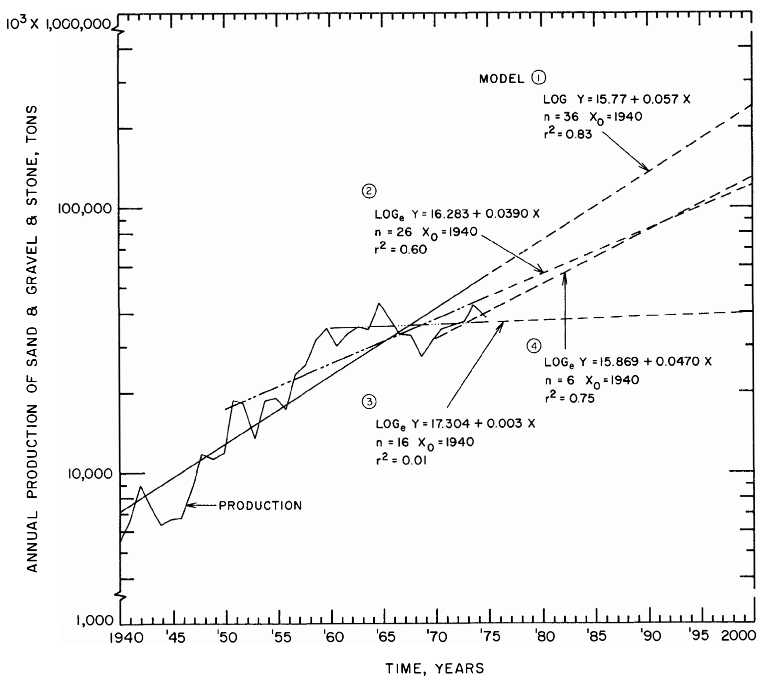


Figure 13. Oregon production tonnages of sand and gravel and stone v. time. Four exponential least square curve fits with different data base lengths are also plotted with trend lines extending to the year 2000.

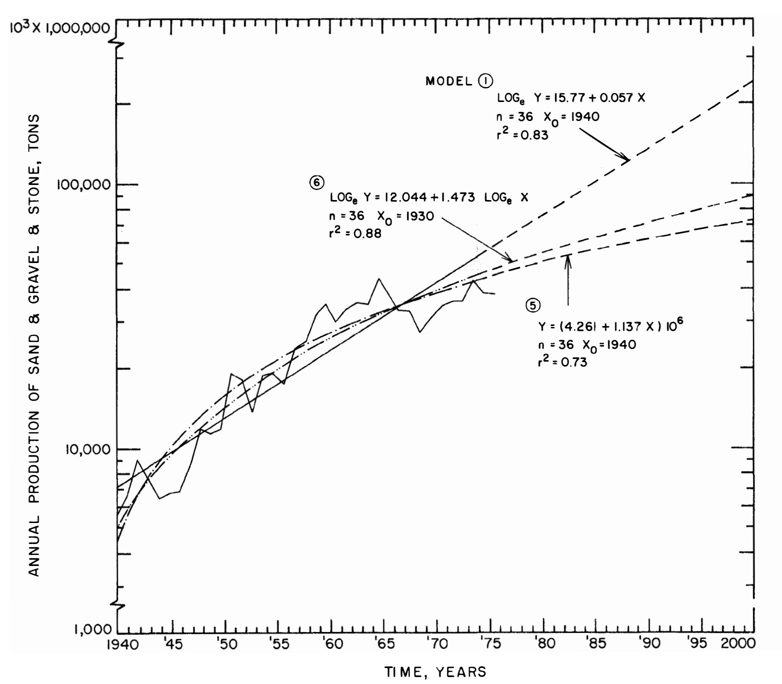


Figure 14. Production tonnages v. time with different types of least square curve fits and their trend lines extended to the year 2000.

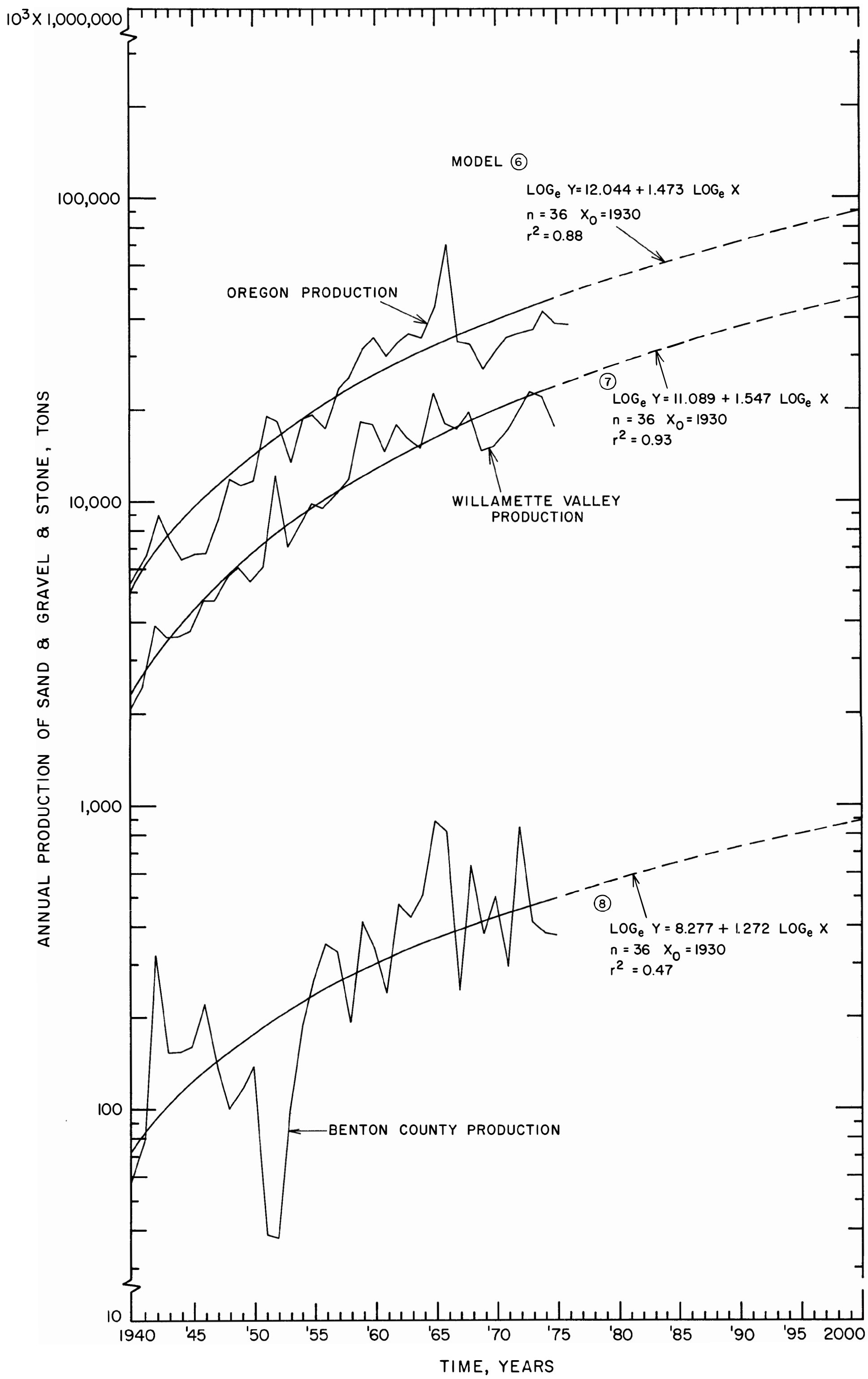


Figure 15. Oregon, Willamette Valley, and Benton County sand and gravel and stone production tonnages v. time with least square curve fits.

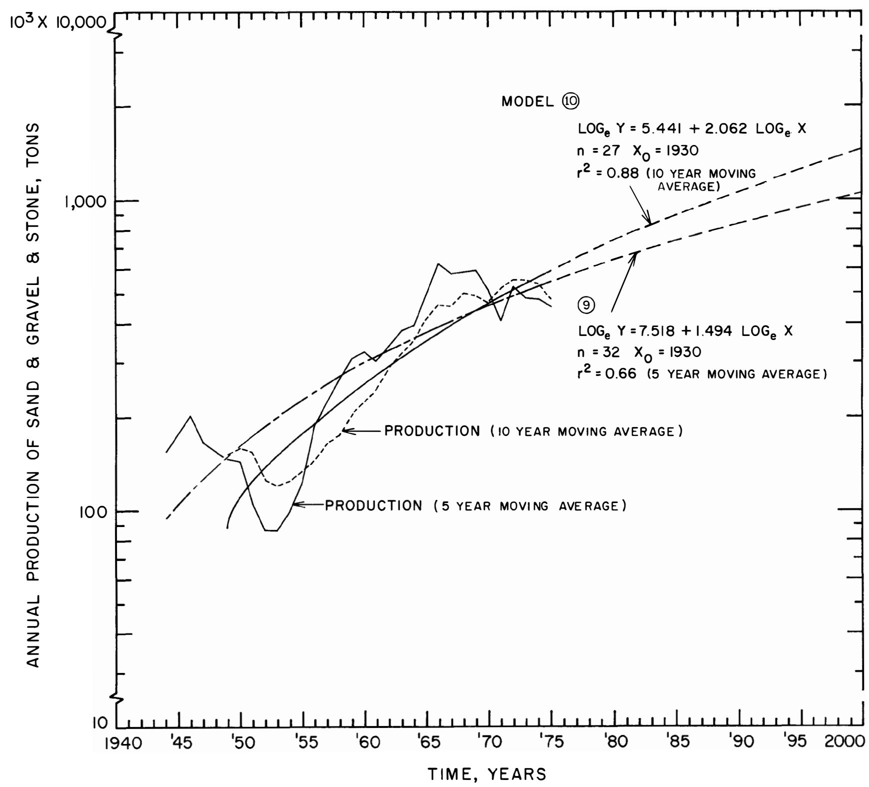


Figure 16. Benton County sand and gravel and stone production tonnages (5- and 10-year moving averages) v. time. Power least square curve fits and their trend lines extending to year 2000 are also plotted.

PLATE I

ROCK MATERIAL LOCATION AND GEOLOGY MAP OF BENTON COUNTY, OREGON

HERBERT G. SCHLICKER - PROJECT DIRECTOR

1978

LEGEND

(40) SAND AND GRAVEL PIT

(40) STONE QUARRY

(40) OTHER MINERAL (CLAY PIT)

IDENTIFICATION NUMBER FOR SURVEY AND LABORATORY DATA ON REVERSE SIDE OF MAP (TABLES 1 AND 6)

Tsr Tsr-p — GEOLOGICAL UNIT CONTAINING 54% OF ROCK MATERIAL SITES

Qtl — GEOLOGICAL UNIT CONTAINING 21% OF ROCK MATERIAL SITES

Ti — GEOLOGICAL UNIT CONTAINING 13% OF ROCK MATERIAL SITES

CREDITS

MINERAL LOCALITIES SURVEY — Garwood Allen, Richard E. Freytag, David W. Wendland

EXPLANATION

(Boundaries are approximate; statements are general; specific evaluations require on-site investigation)

SURFICIAL GEOLOGIC UNITS

Stream and terrace deposits

Qral Recent river alluvium: *Unconsolidated cobbles, coarse gravel, sand, and some silt within active channels of Willamette River; 20-45 ft thick; equivalent to part of Qal of Allison (1953), part of Qal of Vokes and others (1954), part of Horseshoe surface of Balster and Parsons (1968), part of Qyal of Frank (1974), part of Qal of Beaulieu (1974); characterized by low relief, point-bar deposits, and secondary active channels locally.*

Qtl Quaternary lower terrace deposits: *Semiconsolidated cobbles, gravel, sand, silt, clay, and organic matter of variable thickness on lowland terraces above Qral (approx. 35 ft thick) and along usually entrenched tributary rivers and streams, as Marys River (10-100 ft thick); surficial material generally 10-30 ft light-brown silty clay and fine sand; equivalent to part of Qal of Allison (1953), part of Qal of Vokes and others (1954), Ingram surface of Balster and Parsons (1968), and part of Qyal and Qoal of Frank (1974); characterized by low, undulating, fluvial surface with meander scrolls and oxbow lakes.*

Qtm Quaternary middle terrace deposits: *Semiconsolidated gravel, sand, silt, and clay forming terraces of major extent along Willamette River; surficial material generally 10-30 ft light-brown silty clay and fine sand; equivalent to part of Qws of Allison (1953); part of Qal of Vokes and others (1954); Winkle, Calapooyia, and Senecal surfaces of Balster and Parsons (1968); part of Qoal of Frank (1974). Very flat terraces well above Qtl along Willamette River; approximately 50-100 ft thick; 100 or more near Granger, thinning to 50 ft or less near Willamette River.*

Qth Quaternary higher terrace deposits: *Semiconsolidated gravel, sand, silt, and clay of variable thickness (10-200 ft) on higher terraces near foothills; surficial material generally 10-30 ft light-brown silty clay and fine sand at Corvallis-Philomath; equivalent to part of Qdg of Vokes and others (1954), part of Quad and Dolph surfaces of Balster and Parsons (1968), part of Qt of Frank (1974); generally higher and more dissected by streams than Qtm; transitional with pediments and thinner near bedrock foothills (several tens of ft or less); 100 ft at OSU, 170-200 ft at and south of Philomath.*

GEOLOGIC SYMBOLS

Definite contact

Approximate contact

Normal fault (ball and bar on downthrown side)

Approximate fault

Concealed fault

BEDROCK GEOLOGIC UNITS

Sedimentary rocks

Tts Early Oligocene sandstone: *Equivalent to Tts (tuffaceous sandstone) of Vokes and others (1954); greenish-gray, medium- to course-grained, tuffaceous sandstone containing fossils and occurring in isolated outcrops in southeast part of county; beds 3-12 ft thick; weathers to yellowish gray; not well known.*

Ts Late Eocene sandstone: *Equivalent to Ts (Spencer) of Turner (1938); massive to thin-bedded, indurated, fine- to medium-grained, micaceous, arkosic, and tuffaceous sandstone; sandstones similar to sandy beds within Flournoy Formation; also indurated dark-green to gray basaltic sandstone (east of Dawson, northeast of Lewisburg, and in Albany quad), spheroidally weathering to medium yellowish-brown soil; thin-bedded, medium-gray siltstones forming topographic valleys near Monroe; carbonaceous and bony coal at Spring Hill near Albany and locally; concretions locally; underlies many terrace deposits.*

Tf Middle Eocene sandstone: *Equivalent to Tf (Flournoy) of Baldwin (1975), and Tyee (Tt) of Vokes and others (1949); bluish-gray, firmly compacted, graded sandstone and dark-gray siltstone; 3-12 ft beds medium-grained, micaceous, arkosic sandstones and mudstones; weathers to light tan; dark yellowish-brown silty clay loam soils, often well-drained; often deeply weathered and easily excavated; conglomeratic sandstone beds containing basalt pebbles on west flank northeast-trending hill north of Lewisburg and locally on west side of Witham Hill in Corvallis; interfingering to north with marine siltstone in Albany quad; sandstones predominate in Monroe quad and toward lower part of section.*

Tsrk Kings Valley siltstone: *Equivalent to Tsrk (Kings Valley siltstone member of Siletz River Volcanics) of Vokes and others (1954), named for extensive outcrops in Kings Valley, where 3,000 ft thick; generally well-bedded, dark brownish-gray, tuffaceous siltstone and waterlaid tuff; lower part near Wren a dark-gray, shaly, tuffaceous siltstone, weathering spheroidally to talus of grayish-orange to light-brown chips (interbedded pillows, basalt flows, tuff, and minor flow breccia also more common); upper part near Hoskins is thin-bedded, fine-grained, tuffaceous siltstone interbedded with occasional light yellowish-grayish-white tuff, weathering to light-brown soil.*

Ts-p / Tf-p Sandstone pediments: *Gently inclined, planar erosion surfaces cut into bed rock and generally veneered with thin deposits of unconsolidated material in transport, including gravel, sand, silt, and clay.*

Volcanic rocks

Tsr Eocene volcanic rock: *Equivalent to Tsr (Siletz River Volcanics) of Vokes and others (1954) and Snavely and Baldwin (1948); 3,000-9,000 ft of marine-deposited dark greenish-gray to black, vesicular to amygdaloidal pillow lavas and basalt flows, with minor interbedded and overlying tuffaceous claystone, siltstone, and basaltic sandstone; flow breccia and coarse pyroclastics rare; often 20-50 ft deep-weathered zones light rusty-brown in soft sediments and breccia, 4-10 ft zones more common in pillows and flows; pillows north of Philomath and along Greasy Creek.*

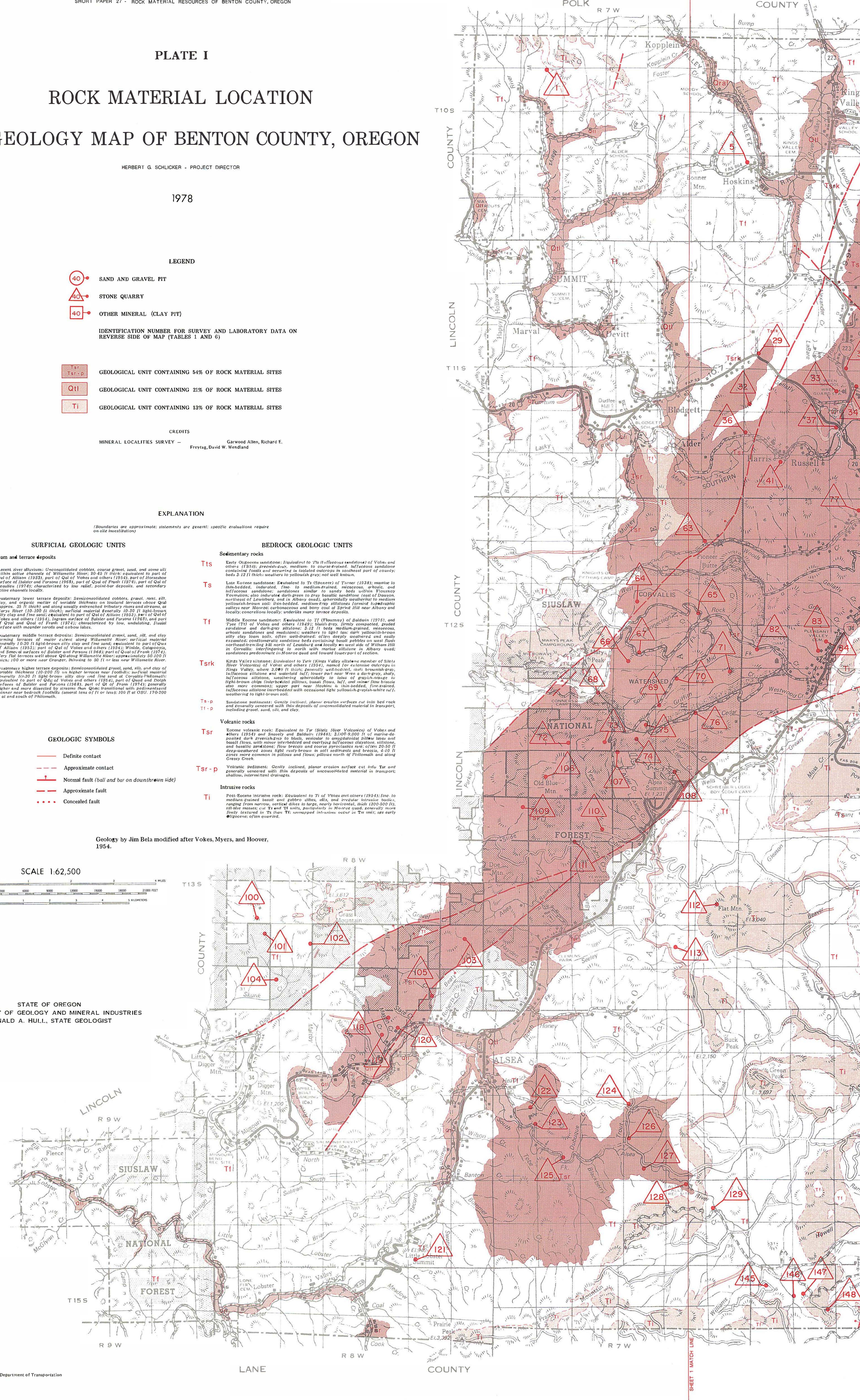
Tsr-p Volcanic pediment: *Gently inclined, planar erosion surface cut into Tsr and generally veneered with thin deposits of unconsolidated material in transport; shallow, intermittent drainages.*

Intrusive rocks

Ti Post-Eocene intrusive rock: *Equivalent to Ti of Vokes and others (1954); fine- to medium-grained basalt and gabbro dikes, sills, and irregular intrusive bodies, ranging from narrow, vertical dikes to large, nearly horizontal, thick (300-500 ft), sill-like masses; cut Ts and Tf units, particularly in Monroe quad, generally more finely textured in Ts than Tf; unmapped intrusives occur in Tsr unit; age early Oligocene; often quarried.*

Geology by Jim Bela modified after Vokes, Myers, and Hoover, 1954.

SCALE 1:62,500



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

BASE MAP — State of Oregon Department of Transportation


SHORT PAPER 27 - ROCK MATERIAL RESOURCES OF BENTON COUNTY, OREGON
PLATE I
ROCK MATERIAL LOCATION AND GEOLOGY MAP OF BENTON COUNTY, OREGON
HERBERT G. SCHLICKER - PROJECT DIRECTOR
1978
LEGEND
40 SAND AND GRAVEL PIT
40 STONE QUARRY
40 OTHER MINERAL (CLAY PIT)
IDENTIFICATION NUMBER FOR SURVEY AND LABORATORY DATA ON REVERSE SIDE OF SHEET 2
Tsr Tsr-p GEOLOGICAL UNIT CONTAINING 54% OF ROCK MATERIAL SITES
Qtl GEOLOGICAL UNIT CONTAINING 21% OF ROCK MATERIAL SITES
Ti GEOLOGICAL UNIT CONTAINING 13% OF ROCK MATERIAL SITES
CREDITS
MINERAL LOCALITIES SURVEY — Garwood Allen, Richard E. Freytag, David W. Wendland
GEOLOGIC SYMBOLS
Definite contact
Approximate contact
Strike and dip of bed
Normal fault (ball and bar on downthrown side)
Approximate fault
Concealed fault
Geology by Jim Bela modified after Vokes, Myers, and Hoover. 1954.
SCALE 1:62,500
LOCATION MAP
BASE MAP — State of Oregon Department of Transportation
SHEET 1
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST
Prepared and Published by the Cartographic Section of the Department of Geology and Mineral Industries

TABLE 1. BENTON 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	Oregon State Hwy. Div.	s	S	NE	17	10S	7W	a	16	0.4	-	20	B	Gabbro	Intrusive	1	37	M	e	-	t,s,b,e,r	
2	Unknown	s	P	SW	15	10S	6W	i	2	0.1	-	0	B	Basalt	Siletz River Volcanics	1	5	B	e	-	t,s,b,r	Site surrounded by rural homes
3	La Ro Lumber Co.	s	P	SE	15	10S	6W	i	4	0.3	-	10	B	Basalt	Siletz River Volcanics	1	4	F	r	-	s,b	
*4	Tri-County	s	P	SE	22	10S	6W	i	90	1.3	-	100	B	Basalt	Siletz River Volcanics	1	35	F-M	e	-	s,b	
5	Clemons	s	P	NW	30	10S	6W	i	3	0.2	-	0	B	Sandstone, siltstone, interbedded mudstone	Flournoy	2	10	F-M	e	-	r,e	Overgrown by alder
6	Oregon State Hwy. Div.	s	S	SW	26	10S	6W	i	20	0.4	-	50	B	Basalt	Siletz River Volcanics	1	25	F	r,e	-	s,b	
7	Evans Products	s	P	SW	26	10S	6W	a	1	0.1	-	50	B	Basalt	Siletz River Volcanics	3	11	F	r	-	a	Weathered basalt with clay used to dam water pond
8	Publishers Paper	s	P	NE	36	10S	6W	i	6	0.1	-	30	B	Basalt	Siletz River Volcanics	2	26	F	r,e	-	s,b	
9	Publishers Paper	s	P	NE	36	10S	6W	i	2	0.1	-	10	B	Basalt	Siletz River Volcanics	1	13	F	r	-	s,b	
10	Oregon State University	s	P	NE	07	10S	5W	a	25	0.4	-	30	B	Basalt	Siletz River Volcanics	3	10	C	e	-	t,s,b	
11	Corvallis Disposal Co.	s	P	SE	13	10S	5W	i	35	0.5	-	500	B	Basalt	Siletz River Volcanics	1	32	F-M	e	-	t,s,b,r	Tri-County sanitary landfill
12	Oregon State University	s	S	SW	21	10S	5W	i	4	0.1	-	15	B	Basalt	Siletz River Volcanics	1	19	C	e	-	s,b	
13	Oregon State University	s	S	SE	22	10S	5W	i	3	0.2	-	0	B	Basalt	Siletz River Volcanics	1	9	F	e,r	-	s,b	Water hole for fire fighting
14	Oregon State University	s	S	SW	23	10S	5W	i	8	0.5	0.2	0	B	Basalt	Siletz River Volcanics	2	7	M	e	-	s,b	Water hole for fire fighting
15	Starker Forests	s	P	SW	28	10S	5W	i	3	0.2	-	10	B	Basalt	Siletz River Volcanics	2	4	F	r	-	s,b	
16	Unknown	s	-	NW	31	10S	5W	i	2	0.1	-	0	B	Basalt, weathered	Siletz River Volcanics	1	11	F	r	-	s,b	Overgrown with alder and brush
17	Dean Bauman	s	P	SE	32	10S	5W	i	2	0.1	-	0	B	Basalt, weathered	Siletz River Volcanics	1	9	F	r	-	s,b	Used as landing; rock may have been used to build pond across road
18	Starker Forests	s	P	NW	33	10S	5W	a	3	0.2	-	20	B	Basalt	Siletz River	1	8	M	e	-	s,b	
19	Starker Forests	s	P	NW	34	10S	5W	i	3	0.2	-	15	B	Basalt	Siletz River Volcanics	1	9	M	e	-	s,b	
20	D. Vanderpool	g	P	SE	10	10S	4W	i	120	6.0	-	150	G	Various	Lower terrace deposits	1	20	-	-	-	b,s,t	
21	D. Vanderpool	g	P	SW	11	10S	4W	i	105	7.5	-	1,000	G	Various	Lower terrace deposits	1	15	-	-	-	b,s,t	
*22	Oregon State Hwy. Div.	s	S	NW	18	10S	4W	i	45	0.6	-	500	B	Basalt	Siletz River Volcanics	1	33	F	e	-	s,b	
*23	Oregon State Hwy. Div.	s	S	NW	18	10S	4W	i	75	3.5	-	0	B	Basalt, weathered	Siletz River Volcanics	1	10	F	e	-	s,b	Consists of 2 pits, now lakes, 2-3 yds deep
*24	Oregon State Hwy. Div.	s	S	NW	18	10S	4W	i	55	0.8	-	500	B	Basalt	Siletz River Volcanics	1	34	F-C	e	-	s,b	Consists of 2 pits: One covers 0.4 acres with 25,000 cu yds past production; the other covers 0.4 acres with 30,000 cu yds past production
25	Unknown	g	P	SE	14	10S	4W	i	5	0.7	-	400	G	Various	Lower terrace deposits	1	20	-	-	-	b,s,t	Closed at least 15 years; 12 ft of gravel
26	Unknown	s	P	SE	36	10S	4W	r	8	0.4	-	0	B	Sandstone	Spencer	1	10	M	e	-	o	Naturally reclaimed; overgrown with berry bushes and grass; residential area
27	Albany Rock Products	s	P	SE	30	10S	3W	a	300	12.5	-	1,000	G	Various	Lower terrace deposits	1	25	-	-	-	b,s,t	Fifteen feet of gravel; being expanded
28	Unknown	s	-	NE	11	11S	6W	i	2	0.1	-	0	B	Basalt, weathered	Siletz River Volcanics	2	7	C	e,r	-	s,b	
*29	Oregon State Hwy. Div.	s	S	SW	18	11S	6W	i	3	0.2	-	0	B	Basalt	Siletz River Volcanics	2	4	M	e	-	r,j	Covered by fir trees and berry bushes
*30	Oregon State Hwy. Div.	s	S	SW	16	11S	6W	i	30	1.7	-	5	B	Basalt	Siletz River Volcanics	1	20	F	e	-	t,s,b	Mined up to property fence line; power poles would need to be moved for advancing face
31	Unknown	s	P	NW	14	11S	6W	i	4	0.2	-	0	B	Basalt	Siletz River Volcanics	1	5	M	e	-	s,b,r	Site located adjacent to farm buildings
32	Starker Forests	s	P	SW	19	11S	6W	a	55	3.2	-	150	B	Basalt	Siletz River Volcanics	2	19	M	e	c	t,s,b,e,r	
*33	L. and T. Crushing	s	P	NW	21	11S	6W	i	110	2.0	-	150	B	Basalt gabbro	Siletz River Volcanics	2	40	F-M	e	-	s,b,e,r	
34	Unknown	s	-	NE	21	11S	6W	i	1	0.1	-	0	B	Basalt	Siletz River Volcanics	1	3	M	e	-	r	
35	Corvallis Elks Lodge #1413	s	P	SE	22	11S	6W	i	3	0.6	-	0	B	Basalt	Siletz River Volcanics	1	3	M	e	-	r	
36	Benton County	s	C	SW	30	11S	6W	i	6	0.1	-	0	B	Basalt	Siletz River Volcanics	1	20	B	e	-	s,b	Appears to be road cut; may have been quarry during early road construction of County Rd. #16520
37	Unknown	s	P	NW	28	11S	6W	i	2	0.2	-	0	B	Basalt	Siletz River Volcanics	1	13	F	e	-	s,b,r	Highwall is adjacent to U.S. Highway 20, preventing further expansion
*38	L. and T. Crushing	s	P	SW	27	11S	6W	a	2	0.1	-	10	B	Basalt	Siletz River Volcanics	1	8	C-B	e	-	t,s,b,e,r	
39	Unknown	s	P	SW	27	11S	6W	r	60	1.3	-	0	B	Basalt	Siletz River Volcanics	1	15	C-B	e	-	t,s,b,e,r	Private recreation site with picnic tables, lake, trap range
*40	L. and T. Crushing	s	S	SW	27	11S	6W	a	120	2.9	0.6	300	B	Basalt	Siletz River Volcanics	2	22	C-B	e	c	t,s,b,e,r,j	
41	Unknown	s	P	NE	31	11S	6W	i	1	0.1	-	3	B	Basalt	Siletz River Volcanics	2	7	F	e,r	-	s,b	Water in pit
42	Oregon State University	s	S	SW	06	11S	5W	a	5	0.4	0.5	5	B	Basalt, weathered	Siletz River Volcanics	1	3	C	r	-	b	
43	Oregon State University	s	S	NW	06	11S	5W	i	3	0.1	-	10	B	Basalt	Siletz River Volcanics	2	17	M	e	-	t,s,b,r	Pit used as dump for burned logs
44	Oregon State University	s	S	SW	03	11S	5W	a	30	0.5	1.0	30	B	Basalt	Siletz River Volcanics	1	34	F	e,r	c,s	t,s,b	
*45	H. and L. Teigen	s	P	NE	11	11S	5W	i	20	0.6	-	0	B	Basalt	Siletz River Volcanics	1	16	M	e	-	s,b,r,j	In residential district
46	Oregon State University	s	S	NW	07	11S	5W	a	5	0.1	-	50	B	Basalt, weathered	Siletz River Volcanics	1	16	C	e	-	s,b	
47	Oregon State University	s	S	NW	07	11S	5W	i	10	0.6	-	0	B	Basalt, laterite	Siletz River Volcanics	1	9	F	r	-	o	Naturally reclaimed borrow pit
48	Oregon State University	s	S	SE	07	11S	5W	a	2	0.2	-	5	B	Basalt, weathered	Siletz River Volcanics	1	3	F	r	-	s,b	
49	Unknown	s	P	SE	21	11S	5W	a	1	0.1	-	0	B	Basalt, weathered	Siletz River Volcanics	1	2	F	r	-	o	Used as borrow pit
50	Unknown	s	P	SE	21	11S	5W	i	1	0.1	-	0	B	Basalt	Siletz River Volcanics	1	2	M	e	-	s,b,r	Filled with riprap; part of Timberhill residential area
51	Unknown	s	P	SE	22	11S	5W	i	1	0.1	-	0	B	Diorite	Intrusive	1	2	C	e	-	s,b	Naturally reclaimed; part of Timberhill residential area
52	N. Thiel	s	P	SE	28	11S	5W	r	6	0.2	-	0	B	Diorite, gabbro	Intrusive	2	7	M	e	-	t,s,b,r	Residential area
53	Unknown	s	P	SW	27	11S	5W	r	1	0.1	-	0	B	Diorite	Intrusive	-	-	-	-	-	-	
54	Unknown	s	P	SE	06	11S	4W	i	1	0.1	-	0	B	Sandstone	Spencer	1	-	-	-	-	-	
55	Unknown	g	P	SE	08	11S	4W	i	37	2.5	-	1,800	G	Various	Lower terrace deposits	1	10	-	-	-	b,s,t	Abandoned
56	Unknown	g	P	NE	09	11S	4W	i	24	3.0	-	2,600	G	Various	Lower terrace deposits	1	5	-	-	-	b,s,t	
*57	Wildish-Corvallis Sand and Gravel Co.	g	P	NE	17	11S	4W	a	2,000	58	20	9,600	G	Various	Lower terrace deposits	1	10	-	-	-	t,s,b,o	Figures obtained from Mined Land Reclamation Plan which shows 58 acres mined out, 272 left to mine, and gravel is 22 ft thick. Pit is in Linn County
58	Unknown	g	-	SE	19	11S	4W	i	15	3.1	-	5	G	Various	Lower terrace deposits	1	3	-	r	-	o	Overgrown with cottonwood and alder
*59	Oregon State Hwy. Div.	g	S	SW	20	11S	4W	i	57	4.4	-	20	G	Various	Lower terrace deposits	1	7	-	-	-	s,b,t	
60	Unknown	g	P	SE	20	11S	4W	i	110	8.5	-	60	G	Various	Point bar	1	8	-	-	-	s,b,t	
61	Builders Supply Co.	g	P	NW	28	11S	4W	i	120	8.8	-	100	G	Various	Lower terrace deposits	1	9	-	-	-	s,b,t	
62	Unknown	g	P	SW	28	11S	4W	i	100	19.3	-	75	G	Various	Lower terrace deposits	1	9	-	-	-	s,b,t	
*63	Starker Forests	s	P	NW	12	12S	7W	a	6	0.4	-	10	B	Basalt	Siletz River Volcanics	1	13	M	e	-	s,b,e,r,t	
64	City of Corvallis	s	L	NE	15	12S	7W	i	1	0.1	-	1	B	Basalt	Siletz River Volcanics	2	4	C	r,e	-	t,s,b,e	
*65	City of Corvallis	s	L	SW	13	12S	7W	i	8	0.2	-	50	B	Basalt	Siletz River Volcanics	1	23	F-M	e	-	t,s,b,e,r	
66	U.S. Forest Service	s	F	SW	22	12S	7W	i	16	0.3	-	50	B	Basalt	Siletz River Volcanics	2	34	F	e	-	t,s,b,e	
67	U.S. Forest Service	s	F	SE	22	12S	7W	i	1	0.1	-	0	B	Basalt	Siletz River Volcanics	1	5	F	r	-	s,b	
68	U.S. Forest Service	s	F	SE	28	12S	7W	r	10	0.4	-	0	B	Basalt	Siletz River Volcanics	0	0	-	-	-	-	Now a landing built up with sedimentary fill material
69	Unknown	s	-	SW	26	12S	7W	i	3	0.2	-	10	B	Basalt	Siletz River Volcanics	2	2	F	r	-	s,b	
70	U.S. Forest Service	s	F	NE	26	12S	7W	i	1	0.1	-	5	B	Basalt	Siletz River Volcanics	1	4	F	r	-	s,b	
71	U.S. Forest Service	s	F	NE	25	12S	7W	i	5	0.2	-	20	B	Basalt	Siletz River Volcanics	1	16	F	r	-	s,b	
72	U.S. Bureau of Land Management	s	F	SE	32	12S	7W	i	3	0.2	-	5	B	Basalt	Siletz River Volcanics	1	15	F	r	-	s,b	
*73	U.S. Bureau of Land Management	s	F	SE	33	12S	7W	r	35	1.2	-	100	B	Basalt	Siletz River Volcanics	2	19	C	e	-	s,b,e	
74	U.S. Forest Service	s	F	SE	34	12S	7W	i	12	0.3	-	0	B	Basalt	Siletz River Volcanics	2	24	F	r	-	s,b	Microwave relay station just above quarry face
75	U.S. Forest Service	s	F	NE	34	12S	7W	i	2	0.1	-	20	B	Basalt	Siletz River Volcanics	1	19	F	e	-	s,b	
76	U.S. Forest Service	s	F	NE	35	12S	7W	i	2	0.1	-	20	B	Basalt	Siletz River Volcanics	1	14	M	e	-	s,b	
*77	Starker Forests	s	P	NE	04	12S	6W	i	25	1.0	-	50	B	Gabbro	Intrusive	3	14	M	e	-	s,b,e,r,t	
78	Philomath Shake Mill	s	P	SE	03	12S	6W	i	7	0.3	-	0	B	Basalt	Siletz River Volcanics	1	17	F	r	-	s,b	Reclaimed as building site for mill
79	George Neuman	g	P	NE	10	12S	6W	a	3	0.2	-	200	G	Various	Lower terrace deposits	1	3	F	r	-	o	
80	George Neuman	s	P	SE	14	12S	6W	a	30	2.0	-	200	B	Diorite	Intrusive	1	14	M	e	-	t,s,b,e,r	
81	George Neuman	s	P	NW	15	12S	6W	a	25	0.9	-	150	B	Diorite	Intrusive	2	15	M	e	c	t,s,b,e,r	
*82	City of Corvallis	s	L	SW	19	12S	6W	i	4	0.1	-	0	B	Basalt	Siletz River Volcanics	1	36	C	e	-	t,s,b,e,r	
83	Unknown	s	P	SE	20	12S	6W	r	2	0.2	-	0	B	Basalt	Siletz River Volcanics	1	4	F	e	-	s,b	Naturally reclaimed by brush and trees
84	Starker Forests	s	P	NE	20	12S	6W	a	16	0.3	0.7	30	B	Basalt	Siletz River Volcanics	1	12	F-M	e	-	s,b	
85	Mid Valley Gravel	s	P	SE	06	12S	5W	a	50	1.5	-	50	B	Basalt	Siletz River Volcanics	1	14	F-C	e	c	s,b	Expect 2-4 yrs. additional life
86	Corvallis Brick and Tile Works	o	P	SE	02	12S	5W	a	15	1.2	-	100	G	Clay	Lower terrace deposits	1	4	F	r	c,o	o	
*87	Builders Supply Co.	g	P	NW	01	12S	5W	i	203	10.6	-	0	G	Alluvium	Lower terrace deposits	1	20	-	-	-	b,s,t,o	Bounded by property line and slough; office in Benton County; pit in Linn County
*88	Builders Supply Co.	g	P	NE	01	12S	5W	a	2,000	104	-	2,000	G	Various	Lower terrace deposits	1	35	-	-	c,s,o	b,s,t,o	
89	Rex Clemens	s	P	NE	07	12S	5W	i	3	0.1	-	0	B	Basalt	Siletz River Volcanics	1	10	F-C	r	-	s,b	
90	Rex Clemens	s	P	NE	07	12S	5W	i	20	0.8	-	0	B	Basalt	Siletz River Volcanics	1	8	F-C	e	-	s,b	Pit filled with water
91	Builders Supply Co.	g	P	SE	12	12S	5W	i	60	8	-	400	G	Various	Point bar	-	-	-	-	-	b,s,t	
92	Builders Supply Co.	g	P	SE	12	12S	5W	a	53	5.5	-	2,000	G	Various	Lower terrace deposits	1	6	-	-	-	s,b,t	
*93	Endicott Farms	g	P	NW	13	12S	5W	a	200	44	-	2,500	G	Various	Point bar	1	10	-	-	-	s,b,t	
94	C.E. Jones-Green and White River Rock	g	P	SW	26	12S	5W	a	230	7	-	250	G	Various	Lower terrace deposits	1	6	F	r	c,s	t,o	
95	C.E. Jones-Green and White River Rock	g	P	SW	25	12S	5W	i	80	4.1	-	0	G	Various	Lower terrace deposits	1	5	F	r	-	t,o	Consists of 2 lakes
96	Benton County	g	C	SW	25	12S	5W	a	10	0.8	-	2	G	Various	Lower terrace deposits	1	4	F	r	-	t,o	Water in pit
97	C.E. Jones-Green and White River Rock	g	P	NE	35	12S	5W	i	74	12	-	0	G	Various	Lower terrace deposits	1	4	F	r	-	t,o	Filled with demolition trash and water
98	Benton County	g	C	SE	35	12S	5W	i	100	7	-	100	G	Various	Lower terrace deposits	1	4	F	r	-	t,o	Overgrown with trees and shrubs; only access through private property
99	C.E. Jones-Green and White River Rock	g	P	NW	36	12S	5W	i	26	1.3	-	10	G	Various	Lower terrace deposits	1	4	F	r	-	t,o	Water in pit
100	U.S. Bureau of Land Management	s	F	SE	19	13S	8W	a	15	0.5	-	40	B	Sandstone and gabbro	Intrusive	2	10	F	r	-	s,b	
101	U.S. Bureau of Land Management	s	F	NE	30	13S	8W	a	6	0.3	-	20	B	Gabbro	Intrusive	3	20	F	r	-	s,b	
102	U.S. Bureau of Land Management	s	F	NE	29	13S	8W	i	13	0.3	-	0	B	Sandstone	Flournoy	2	18	C	r	-	s,b,o	Used as water hole
103	U.S. Bureau of Land Management	s	F	NE	25	13S	8W	i	1	0.1	-	1	B	Gabbro	Intrusive	2	9	F	r	-	s,b	
104	U.S. Bureau of Land Management	s	F	NW	32	13S	8W	i	13	1.1	-	20	B	Sandstone and gabbro	Flournoy	5	8	F	r	-	s,b	
105	U.S. Bureau of Land Management	s	F	SE	35	13S	8W	i	4	0.2	-	10	B	Mudstone	Flournoy, intrusive	1	14	F	r	-	o	Gabbro directly beneath quarry floor; small intrusive may have been mined but mudstone predominates now
106	U.S. Bureau of Land Management	s	F	SW	05	13S	7W	a	1	0.2	-	5	B	Basalt	Siletz River Volcanics	2	4	F	r,e	-	s,b	

(CONTINUED)

(CONTINUED)

TABLE 1. BENTON 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	
*107	U.S. Bureau of Land Management	s	F	NW	03	13S	7W	i	5	0.3	-	10	B	Basalt	Siletz River Volcanics	2	4	F	e	-	s,b	
108	U.S. Forest Service	s	F	NW	02	13S	7W	r	6	0.2	-	0	B	Basalt, weathered	Siletz River Volcanics	1	14	F	r	-	o	
109	U.S. Bureau of Land Management	s	F	NE	07	13S	7W	i	2	0.2	-	3	B	Basalt	Siletz River Volcanics	2	9	F	r	-	s,b	
110	U.S. Bureau of Land Management	s	F	SE	09	13S	7W	i	1	0.1	-	1	B	Basalt, weathered	Siletz River Volcanics	1	11	F	r	-	s,b	Naturally reclaimed borrow pit
111	U.S. Bureau of Land Management	s	F	NW	16	13S	7W	i	2	0.1	-	10	B	Basalt	Siletz River Volcanics	1	21	F	r	-	s,b	
112	Starker Forests	s	P	--	24	13S	7W	a	No on-site survey; site checked by aerial reconnaissance; located to nearest section													
113	Starker Forests	s	P	--	26	13S	7W	i	No on-site survey; site checked by aerial reconnaissance; located to nearest section													
114	Unknown	g	P	SE	01	13S	5W	r	4	1.1	-	0	G	Various	Lower terrace deposits	1	2	F	r	-	o	
115	Unknown	g	P	SW	12	13S	5W	i	7	0.4	-	0	G	Various	Lower terrace deposits	1	4	F	r	-	o	
116	U.S. Fish and Wildlife Service	s	F	SW	32	13S	5W	i	15	0.3	0.2	0	B	Gabbro	Intrusive	6	23	M	e	-	r	Closed to mining
117	U.S. Fish and Wildlife Service	s	F	NE	32	13S	5W	a	15	2.2	-	0	B	Gabbro	Intrusive	2	14	M	e	-	r	Closed to mining
118	Unknown	s	P	NE	03	14S	8W	i	2	0.1	-	10	B	Basalt	Siletz River Volcanics	1	20	M	e	-	s,b,r	3 contiguous quarries
119	Unknown	s	-	SW	03	14S	8W	i	3	0.1	-	10	B	Sandstone, mudstone	Siletz River Volcanics	3	14	M	r,e	-	s,b,r	
120	Unknown	s	-	NE	03	14S	8W	i	6	0.2	-	0	B	Basalt	Siletz River Volcanics	1	36	M	e	o	r	Houses too close for renewed operation
121	Starker Forests	s	P	SW	35	14S	8W	i	2	0.1	-	5	B	Basalt	Intrusive	1	4	C	r	-	s,b	Naturally reclaimed borrow pit
122	Alsea Lumber Co.	s	P	NE	18	14S	7W	a	120	4.6	4.5	200	B	Basalt	Siletz River Volcanics	4	26	M	e	c	t,s,b,r,e	
*123	Oregon State Hwy. Div.	s	S	SE	18	14S	7W	i	45	0.5	-	100	B	Basalt	Siletz River Volcanics	2	52	M	e	-	s,b,e,r	
124	I.P. Miller	s	P	NW	15	14S	7W	r	10	0.3	-	0	B	Basalt, weathered	Siletz River Volcanics	1	13	F	e,r	-	s,b	Pit filled with slash and water
125	Hull-Oaks	s	P	NE	20	14S	7W	i	12	0.7	-	10	B	Basalt	Siletz River Volcanics	4	8	M	e	-	s,b,e	
126	Hull-Oaks	s	P	NW	22	14S	7W	a	8	0.1	-	10	B	Basalt	Siletz River Volcanics	3	12	B	e	-	s,b	
127	Unknown	s	-	SW	22	14S	7W	i	3	0.1	-	50	B	Basalt	Siletz River Volcanics	1	20	M	e	-	t,s,b,r	Highwall is cutbank to road running through quarry
128	Unknown	s	-	NW	26	14S	7W	r	4	0.1	-	0	B	Basalt	Siletz River Volcanics	2	22	F	r	-	t,s,b	Natural reclamation; alder covers quarry; located at busy intersection
129	U.S. Bureau of Land Management	s	F	SW	25	14S	7W	r	15	1.1	0.2	15	B	Gabbro, weathered	Intrusive	2	7	F	r	-	s,b	
130	Unknown	g	-	SE	03	14S	5W	i	15	0.7	-	0	G	Various	Lower terrace deposits	1	5	F	r	-	o	Surrounded by homes
131	Unknown	g	P	SW	02	14S	5W	i	10	0.6	-	0	G	Various	Lower terrace deposits	1	4	F	r	-	o	Pit filled with water
132	Unknown	g	P	SE	02	14S	5W	i	3	2.9	-	400	G	Various	Lower terrace deposits	1	3	-	-	-	-	Abandoned; pit totally overgrown with shrubs and cottonwoods; gravel does not show
133	Unknown	g	P	NE	21	14S	5W	r	5	3	-	0	G	Various	Lower terrace deposits	-	-	-	-	-	-	
134	Benton County	g	C	NW	22	14S	5W	a	110	6.3	-	100	G	Various	Lower terrace deposits	1	4	F	r	-	o	Two pits under water
135	Unknown	o	P	NE	22	14S	5W	i	1	0.1	-	0	B	Sandstone	Tuffaceous sandstone	1	11	M	e	-	o	Naturally reclaimed by brush and maple; may have been used for dimension stone
136	Melvin Becker	g	P	SW	23	14S	5W	a	55	3.5	-	50	G	Various	Lower terrace deposits	1	4	F	r	o	o	Operator has reached water table in east end of pit
137	Unknown	o	P	SE	28	14S	5W	a	13	0.7	-	0	G	Clay	Middle terrace deposits	1	4	F	r	-	o	Old log pond
138	Monroe Clay Products	o	P	NE	28	14S	5W	a	120	8.8	2	100	G	Clay	Middle terrace deposits	1	3	-	r	o	o	
139	Unknown	g	P	NW	26	14S	5W	a	5	0.3	-	50	G	Various	Lower terrace deposits	1	5	F	r	-	o	East end of pit used as water pumping station for agricultural use
140	Monroe Clay Products	o	P	NE	32	14S	5W	a	40	2.2	-	50	B	Clay	Spencer	4	6	-	r	o	o	
141	Unknown	o	P	NW	33	14S	5W	r	2	0.1	-	0	B	Sandstone	Spencer	1	5	M	e	-	-	Surrounded by homes; dimension stone used in Corvallis for parts of Benton County courthouse
142	Unknown	g	-	NW	34	14S	5W	r	10	0.5	-	0	G	Various	Lower terrace deposits	1	2	F	r	-	o	Present landfill for city of Monroe
143	Unknown	g	-	SE	35	14S	5W	r	10	0.6	-	0	G	Various	Lower terrace deposits	1	5	F	r	-	o	Naturally reclaimed; pit shown west of Schultz Rd. on 7½' Monroe quad no longer exists; pit shown east of road on 15' Monroe quad exists
144	Unknown	g	P	NW	18	14S	4W	i	80	16.5	-	520	G	Various	Point bar	1	0	-	-	-	b,s,t	Inactive; assumed one removal for past production
145	U.S. Bureau of Land Management	s	F	NW	06	15S	6W	i	30	1.0	-	50	B	Basalt, weathered	Intrusive	1	23	F	r	-	s,b	
146	U.S. Bureau of Land Management	s	F	SW	05	15S	6W	a	35	2.0	2.4	200	B	Basalt	Intrusive	4	46	C	e	-	t,s,b,r	3 major benches; numerous smaller ones are too narrow to prevent rock falls from reaching pit floor
147	U.S. Bureau of Land Management	s	F	SW	05	15S	6W	a	1	0.1	-	10	B	Basalt	Intrusive	2	2	F	r	-	s,b	
148	U.S. Bureau of Land Management	s	F	NE	08	15S	6W	i	30	0.5	-	30	B	Basalt, weathered	Intrusive	1	14	F	r	-	s,b	Used mainly as borrow pit
149	Unknown	s	-	NE	09	15S	6W	i	3	0.3	0.1	40	B	Basalt	Intrusive	1	4	F	r	-	s,b	
150	Unknown	s	P	NW	03	15S	5W	r	15	0.7	-	0	B	Laterite, decomposed basalt	Intrusive	1	4	F	r	-	o	Farm buildings on private land occupy borrow pit; located adjacent to abandoned railroad cut
151	Unknown	g	-	SE	01	15S	5W	i	2	0.2	-	2	G	Various	Lower terrace deposits	1	3	F	r	-	o	Pit on south side of Noraton Rd. is reclaimed; pit 151 is being reclaimed naturally
152	J.W. Pickett	s	P	NW	08	15S	5W	i	17	0.3	-	0	B	Basalt	Intrusive	1	22	B	e	-	t,s,b	Benton County operates quarry; mined up to fence line; pit is 50 yds south of radar dome; quarry in Lane County
153	J.W. Pickett	s	P	NW	08	15S	5W	i	1	0.1	-	0	B	Basalt	Intrusive	1	9	B	e	-	t,s,b	Quarry in Lane County
154	J.W. Pickett	s	P	NE	08	15S	5W	i	35	0.8	0.2	0	B	Basalt	Intrusive	2	12	M	e	-	t,s,b	Benton County operates quarry; mined up to fence line; pit is 125 yds east of radar dome; quarry in Lane County

* Oregon State Highway Division laboratory data

** See text (p.11) for discussion of size and potential

TABLE 6.

OREGON STATE HIGHWAY DIVISION LABORATORY DATA

Number	Specific gravity	Los Angeles rattler (% loss)	Sodium sulfate (% loss)	Natural fines: Plasticity index (%)	Natural fines: Liquid limit (%)	Manufactured fines: Plasticity index (%)	Manufactured fines: Liquid limit (%)	Degraded material: Plasticity index (%)	Degraded material: Liquid limit (%)	Oregon degradation: Pass No. 20 (%)	Oregon degradation: Height (inches)
4	2.74-2.97	13.6-21.8	1.4- 4.1	---	-----	0-2	21-26	5-9	27	24	5.7
22,23,24	2.75-2.91	14.5-19.0	1.4-16.0	0	29	0	29	---	-----	-----	---
29	2.76-2.82	13.6-17.2	1.8- 2.9	---	-----	---	-----	4	28	-----	---
30	2.80	18.0	----	---	-----	0	24	0	24	-----	---
33	2.70	21.0	22.8	3	36	---	-----	---	-----	22.9	4.5
38	2.79	30.9	22.3	---	-----	---	-----	---	-----	-----	---
40	2.79	16.1	9.0	0	32	---	-----	---	-----	17.5	1.3
45	2.61	28.1	----	---	-----	---	-----	---	-----	-----	---
57	2.69	18.1	----	0	21	---	-----	---	-----	-----	---
59	2.64-2.71	18.1-20.0	----	0-2	19-26	---	-----	---	-----	-----	---
63	2.93	23.6-28.1	2.3- 2.8	---	-----	---	-----	0	23-26	-----	---
65	2.76	20.0	----	---	-----	---	-----	11	3	-----	---
73	2.91-2.94	17.2-24.5	9.5- 9.9	0	28	---	-----	---	-----	30.4-33.2	2.9-8.1
77	2.84	23.6	19	---	-----	---	-----	0	24	-----	---
82	2.63	26.3	----	---	-----	---	-----	2	20	-----	---
87,88	2.63-2.76	15.2-19.3	3.61	---	-----	---	-----	---	-----	13.3-18.5	0.8-1.4
93	2.63	----	10.0	---	-----	---	-----	---	-----	-----	---
107	2.89	18.1	----	0	40	---	-----	---	-----	37.92	10.1
123	2.80-2.86	14.5-17.2	----	0-2	21-24	---	-----	---	-----	-----	---

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