Reconnaissance Investigation of Sand, Gravel, and Quarried Bedrock Resources in the Mount St. Helens 1:100,000 Quadrangle, Washington

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INTRODUCTION

Background

During its 1998 session, the Washington State Legislature, acting on a recommendation from the Governor's Land Use Study Commission, asked the Washington Department of Natural Resources (WADNR) to map gravel and bedrock resources that could be used for maintenance and construction of homes and infrastructure. The Study Commission sought this information to assess the need to protect these resources from urban sprawl and other intensive land uses. These data would, in turn, result in better long-range planning and possible legislation to aid in designating mineral resource lands under the Growth Management Act (Revised Code of Washington [RCW] 36.70A; Lingley and Jazdzewski, 1994).

Although the data are presented herein in the traditional text and map format, this report is part of a project to prepare a geographic information system (GIS) database that delineates the locations of some of the significant construction aggregate resources (sand, gravel, and bedrock) of Washington State. The digital version of this report, including ArcInfo coverages, is available through the Washington Division of Geology and Earth Resources *(see back of title page for address)*.

The Mount St. Helens 1:100,000-scale quadrangle is located in southwestern Washington (Fig. 1). Much of the quadrangle is located on the western slope of the Cascade Range and is dominated by the Mount St. Helens volcano and Tertiary volcaniclastics and volcanic flows. Natural bedrock exposures are sparse due to the dense vegetation of temperate coniferous rain forest and the thick surface cover. However, an extensive network of logging roads constructed during the past two decades provides access and many exposures in roadcuts and borrow pits, allowing for some of the detailed mapping that is reflected on Plate 1 (Evarts and others, 1987; Evarts and Ashley, 1990a,b, 1991, 1992, 1993a,b,c,d; Evarts, 2001; R. C. Evarts, USGS, written commun., 2000). The obvious straight-line boundaries between some geologic units result from incomplete unpublished 1:24,000-scale mapping in the area by Russ Evarts of the U.S. Geological Survey (USGS).

The Interstate 5 corridor is at the western edge of the quadrangle. The Columbia River and the population centers of Longview (population ~34,500) and Kelso (population ~11,960) (Dwyer and Dwyer, 2001) are in the southwest corner of the quadrangle. The total market for aggregate in the Mount St. Helens 1:100,000 quadrangle is less than one million tons per year, which is attributed mostly to use in the Longview–Kelso market and maintenance of Interstate 5.

Approximately one-half of the quadrangle is in Cowlitz County, about one-quarter in Lewis County, about one-quarter in Skamania County, and very small portions in Clark County and Oregon's Columbia County. The 2000 population of Cowlitz County was 92,948, Lewis County was 68,600, Skamania County was 9,872, and Clark County was 345,238 (Dwyer and Dwyer, 2001). Oregon's Columbia County had a 2000 population of 43,560 (U.S. Census Bureau, 2001).

Intended Audience

This inventory was created primarily for use by local government planners to help refine comprehensive plans and other zoning determinations. It will also help legislators and other policy makers assess the importance of largely nonrenewable sand,

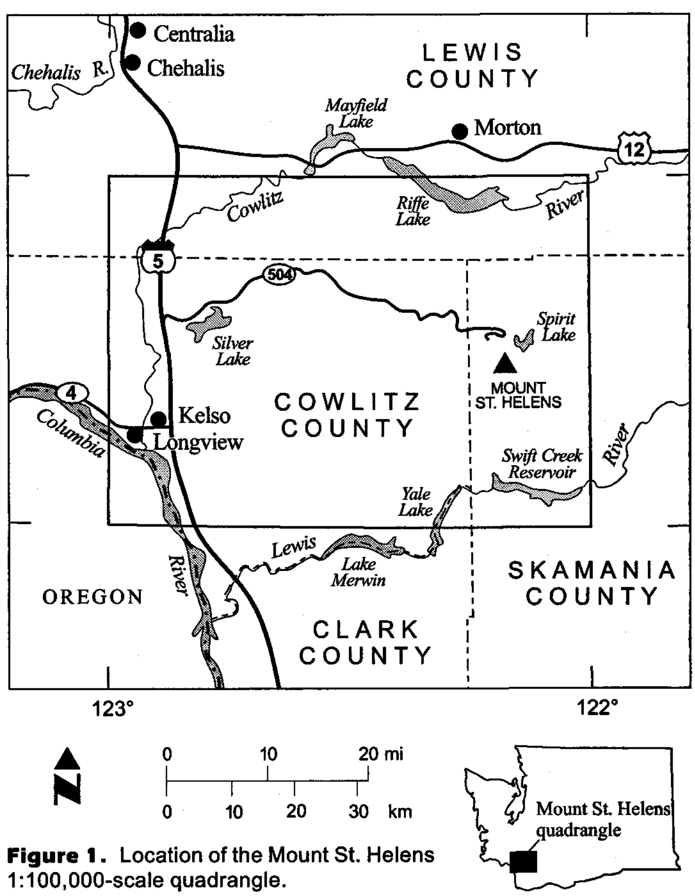

Figure 1. Location of the Mount St. Helens 1:100,000-scale quadrangle.

gravel, and quarried bedrock resources. The study should also benefit engineers, transportation departments, and industry.

Primary Products

This inventory includes the following products:

1. Databases containing the location, thickness, quality, and volume of some sand, gravel, and bedrock resources (Appendices 3–5).
2. A map showing the extent of bedrock (in pink) and gravel (in yellow) resources (Plate 1). Thickness contours (isopachs) are shown within those sand and gravel deposits for which we have sufficient data.
3. The location of active mines, borrow pits, some depleted mines, and large proposed mines (Plate 1).
4. Brief descriptions of geologic units known to contain aggregate resources (Appendix 6).
5. A description of the geology and mining history of construction aggregates in the Mount St. Helens quadrangle (see text).

A glossary of terms used in this report can be found in Appendix 1, and a complete discussion of the methods used in this study can be found in Appendix 2.

Accuracy of Estimates

We emphasize that this report almost certainly overestimates the volume of construction aggregate within the Mount St. Helens quadrangle that is available under current market conditions because of factors such as shallow bedrock under surficial gravels, diminishing rock quality with depth, unmapped areas of thick overburden, and lateral geologic variation. Furthermore, history indicates that future drilling and mining are more likely to yield disappointing results than to add significantly to hypothetical aggregate reserves. Finally, a rise in the price of construction aggregate could make some of today's subeconomic resources, such as clay-rich gravel deposits or bedrock under thick layers of overburden, commercially attractive in the future.

Threshold of Significant Resources

Because this study is designed primarily as an aid to land-use planning, we inventoried only those resources deemed as significant to the long-term economic health of the region. Therefore, we restricted our investigation to those resources that meet the following threshold criteria:

1. The thickness of the sand and gravel or bedrock deposit appears to be in excess of 25 feet (7.5 m).
2. The 'stripping ratio' (ratio of overburden to gravel or overburden to bedrock) is less than one to three (1:3).
3. The strength and durability of the rock meet the Washington State Department of Transportation (WSDOT) minimum specifications for asphalt-treated base, a rock product used to construct some lower layers of asphalt roads (Table 1).
4. The area of the deposit exposed at the surface exceeds 160 acres and measures at least 1,500 feet (450 m) across the minimum dimension of the deposit, or the reserves exceed 10 million cubic yards. However, a few exceptions are included where unusually thick deposits or resources of special local importance are present.

These threshold criteria are discussed in more detail in Appendix 2.

In some markets, a lack of quality gravel and bedrock has forced producers to mine lower-quality deposits. Homes and infrastructure constructed with weak gravel or bedrock generally have relatively short life cycles. We have not inventoried these lower-quality deposits because they do not meet the criteria of this study. However, Appendices 3 through 5 will serve as guides to the locations of some of the poorer-quality deposits as well as resources buried under thick overburden layers that may become more attractive under future market conditions.

Scope of Deposits Inventoried

In order to produce an objective analysis, we have inventoried all deposits meeting the threshold criteria, without consideration of environmental impacts or land-use conflicts that may be involved in permitting or extracting these resources. For example, the Cowlitz River flood plain has historically been a major gravel resource, and numerous permitted mines are still operating on the flood plain. However, future mining operations in flood plains will likely have more difficulty in obtaining permits because alluvial mining can adversely impact aquatic and riparian habitat (Norman and others, 1998). Nevertheless, all Cowlitz River sand and gravel deposits meeting the threshold criteria are depicted in this report. Existing mines within the Mount St. Helens National Volcanic Monument are located on Plate 1 and documented in Appendix 3; however, units with resource potential within monument boundaries are not mapped. Additionally, there are numerous landslides in the Mount St. Helens quadrangle that can affect mine development and neighboring lands. Therefore, this inventory must be used with maps of environmentally sensitive areas and land-use status in order to obtain a complete picture of available aggregate resources within the quadrangle.

GEOLOGY OF CONSTRUCTION AGGREGATES IN THE MOUNT ST. HELENS QUADRANGLE

Our discussion of the geology of the Mount St. Helens quadrangle emphasizes those units that are significant sources of aggregate. More detailed geologic descriptions of the units being mined or considered a resource can be found in Appendix 6.

Table 1. Some specifications for construction aggregate products *(after Washington State Department of Transportation, 1999)*. Los Angeles Abrasion and Percent Passing U.S. No. 200 Sieve measurements are in weight percent. Los Angeles Abrasion and Degradation specifications for coarse portland cement concrete aggregate are not rigorous because the gravel is seldom exposed on the outside of concrete structures, such as foundations or sidewalks

	Product			
Laboratory test	Asphalt-treated base	Crushed (road) surfacing, top course	Coarse aggregate for portland cement concrete	Ballast (road subgrade)
Los Angeles Abrasion	≤30%	≤35%	≤35%	≤40%
Washington Degradation	≥15	≥25	not used	≥15
Sand Equivalent	≥30%	≥35%	not used	≥30%
Percent Passing U.S. No. 200 Sieve (<0.0025 in.)	2–9%	0–7.5%	0–0.5%	0–9%

Unit abbreviations follow the Washington Division of Geology and Earth Resources method (Walsh and others, 1987).

Sand and Gravel Geology

Four types of sand and gravel deposits are present in the Mount St. Helens quadrangle:

1. Recent alluvial deposits on the flood plain of the Cowlitz River
2. Dredge spoil deposits from the 1980 eruption of Mount St. Helens
3. Pleistocene alpine glacial deposits
4. Lower Pleistocene to Lower Pliocene conglomerates of the Troutdale Formation

RECENT ALLUVIAL DEPOSITS ON THE FLOOD PLAIN OF THE COWLITZ RIVER

Alluvial gravel deposits along the Cowlitz River (unit Qa) are composed mainly of basalt and andesite clasts derived from Tertiary volcanic deposits (Livingston, 1966). Alluvial gravels in and along the Cowlitz River generally meet WSDOT specifications for asphalt-treated base (Table 1) with the exception of recent deposits from the 1980 Mount St. Helens eruption.

DREDGE SPOIL DEPOSITS FROM THE 1980 ERUPTION OF MOUNT ST. HELENS

As a result of the 1980 eruption of Mount St. Helens, volcanic mudflows (lahars) swept down the Toutle and Cowlitz Rivers and eventually to the Columbia River. The channels of these rivers were subsequently dredged and the lahar deposits piled on the adjacent flood plains. Many of these piles can be observed along Interstate 5 and the banks of the Columbia, Cowlitz, and Toutle Rivers. The dredge spoils consist of ash, pumice, sand, and gravel and generally have been placed over older flood plain sand and gravel deposits. These dredge spoils generally do not meet WSDOT specifications for asphalt-treated base (Table 1); however, they are used for fill on many construction projects in the area.

PLEISTOCENE ALPINE GLACIAL DEPOSITS

During the Pleistocene, glaciers repeatedly advanced from Mount Rainier, Mount Adams, Mount St. Helens, and adjacent alpine areas. In the Mount St. Helens quadrangle, outwash deposits (units Qao_e and Qapo) and till deposits (units $Qapt_e$ and $Qapt_h$) provide evidence of these alpine glacial events. The thickest and most extensive glacial sediments are present along the Cowlitz River in the vicinity of Toledo, where at least six distinct outwash deposits underlie loess-covered terraces. This sequence may be the best-preserved record of alpine glacial events in the Pacific Northwest (Dethier and Bethel, 1981; Phillips, 1987a). These deposits are up to 100 feet thick and are mantled with less than 1 foot (0.3 m) of loess. Although many mines have been developed in these older glacial deposits, they do not meet WSDOT specifications for asphalt-treated base (Table 1) because the gravel is weathered and coated with iron oxide (Dethier and Bethel, 1981) (Appendices 3 and 4).

LOWER PLEISTOCENE TO LOWER PLIOCENE CONGLOMERATES OF THE TROUTDALE FORMATION

The lower Pleistocene to Lower Pliocene Troutdale Formation (unit QPc_t) consists of moderately to weakly consolidated conglomerate, sandstone, and sandy siltstone. The thickness of the unit ranges from a few feet on valley walls to about 500 feet (150 m) at Kelso (Livingston, 1966). Livingston (1966) divided the Troutdale exposed near Kelso into a lower conglomeratic member and an upper sandy silt member. This division appears to be only locally relevant because descriptions of more complete Troutdale sections in the Vancouver quadrangle to the south (Trimble, 1963; Mundorff, 1964) cannot be correlated with the Kelso-area members. The Troutdale Formation is a valley-fill unit in the Mount St. Helens quadrangle and represents ancient deposits of the Columbia River system (Phillips, 1987a). Few mines produce from the Troutdale Formation although the gravel generally meets WSDOT specifications for asphalt-treated base (Table 1) when washed and screened. The few gravel mines in the Troutdale Formation in the Mount St. Helens quadrangle are depleted or nearly depleted.

The Troutdale Formation is prone to landsliding as is evidenced by the Aldercrest–Banyon slide located east of Interstate 5 in Kelso. This large slope failure (approximately 2,700 feet by 1,200 feet [825 m by 365 m]), which had destroyed over 61 residences at the time of reporting, appears to be occurring at the contact between the Troutdale and Cowlitz Formations, or possibly within interbedded silt and clay of the lower member of the Troutdale (GeoEngineers, 1998).

Bedrock Geology

Bedrock geology of the Mount St. Helens 1:100,000 quadrangle consists of volcanic, volcaniclastic, and intrusive rocks ranging in age from Quaternary to Eocene. Phillips (1987a) describes the bedrock as mostly basaltic and andesitic in composition. Detailed mapping by Evarts and others (1987), Evarts and Ashley (1990a,b, 1991, 1992, 1993a,b,c,d), Evarts (2001), and R. C. Evarts (USGS, written commun., 2000) has located many igneous flows and intrusions that would likely meet WSDOT specifications for asphalt-treated base.

Five principal types of bedrock units that are suitable for construction aggregate are present in the Mount St. Helens quadrangle:

1. Quaternary andesite and basalt flows
2. Middle Miocene Grande Ronde Basalt of the Columbia River Basalt Group
3. Miocene to Eocene andesite and basalt flows
4. Eocene basalt flows of the Grays River volcanics
5. Upper Miocene to Lower Oligocene intrusive rocks

QUATERNARY ANDESITE AND BASALT FLOWS

There are several Quaternary lava flows in the quadrangle that meet WSDOT specifications for asphalt-treated base (units Qva_1 and Qvb). These flows range in composition from andesite to basalt and are typically 50 to 100 feet (15–30 m) thick, but may be thicker locally. Jointing ranges from platy to blocky depending on silica content and individual flow characteristics. The rock is generally unweathered and unaltered. Eruptive vents for these flows are generally local or adjacent to the Mount St. Helens quadrangle.

MIDDLE MIOCENE GRANDE RONDE BASALT OF THE COLUMBIA RIVER BASALT GROUP

The Middle Miocene Grande Ronde Basalt of the Columbia River Basalt Group (unit Mv_g) erupted from vents in southeastern Washington and adjacent Idaho and Oregon. These rocks, where exposed in the Mount St. Helens quadrangle, are the remnants of a huge sheet of lava that filled channels of the ancestral Columbia River and flowed to the Pacific Ocean (Beeson and others, 1979; Wells and Niem, 1987). In the Mount St. Helens quadrangle north of the Longview–Kelso area, Grande Ronde Basalt typically consists of isolated outcrops made up of only one or two flows (Phillips, 1987a). Rock mined from the Grande Ronde Basalt flows is very high quality and meets all WSDOT specifications for asphalt-treated base. Total approximate thickness in the quadrangle may be as much as 100 feet (30 m) (R. C. Evarts, USGS, written commun., 2001) but varies locally.

MIOCENE TO EOCENE ANDESITE AND BASALT FLOWS

A thick sequence of Oligocene to Eocene andesite and basalt flows and flow breccia with thin interbeds of red-brown siltstone, sandstone, conglomerate, and tuff (unit ΦEva_g) are present throughout the quadrangle. Many lava flows meet WSDOT specifications for asphalt-treated base and have been mapped by the U.S. Geological Survey (Evarts and Ashley, 1990a,b, 1991, 1992, 1993a,b,c,d; Evarts, 2001; R. C. Evarts, USGS, written commun., 2000). Individual flows identified as potential sources of aggregate average 80 feet (25 m) thick but are locally thicker. Individual flows form cliffs and can be traced for miles. Total thickness of the unit is several thousand feet (Smith, 1993; Evarts and Swanson, 1994).

Some Oligocene to Eocene andesite flows can be traced for as much as 2.5 miles (4 km) as cliffs in the Coweeman River valley (Evarts and Ashley, 1992). They range from brownish gray to black fine-grained andesite to medium-gray to dark greenish gray fine-grained andesite (Phillips, 1987a).

One flow of note is the late Eocene andesite of Hollywood Gorge (Evarts, 2001; R. C. Evarts, USGS, written commun., 2000). It consists of dark gray to black, columnar-jointed to platy andesite near Silver Lake. It forms near-vertical cliffs up to 200 feet (60 m) high along the Hollywood Gorge of the Toutle River (sec. 16, T10N R1W). It is currently quarried by Northwest Rock, Inc., for large rock used to maintain the jetty at Westport on the Pacific coast. The andesite is interpreted as a late Eocene flow that sank into underlying sediments of the Toutle Formation and injected itself more-or-less along bedding, becoming a sill (Evarts, 2001). This caused a slower cooling rate and a joint spacing of approximately 6 feet, allowing for larger quarry rocks to be produced.

Other less-significant units are the Lower Miocene to Upper Oligocene units MΦvb, MΦva, and $M\Phi vc_2$, which consist of massive to vesicular basalt and basaltic-andesite lava flows, flow breccia, and volcaniclastic rocks. Oligocene andesite lava flows (unit Φva_1) in the Toutle Mountain Range are about 600 m thick (Roberts, 1958) and meet WSDOT specifications for asphalt-treated base.

EOCENE BASALT FLOWS OF THE GRAYS RIVER VOLCANICS

The informal term 'Grays River volcanics' (unit Evb_{gr}) is applied to Upper to Middle Eocene basalt lava flows and basaltic breccia, tuff, sandstone, and cobble to pebble conglomerate (Phillips, 1987a). Only portions of this unit meet WSDOT specifications for asphalt-treated base. Thickness of the unit varies from about 1400 feet (425 m) at Bebe Mountain (T10N R2W) to 100 feet (30 m) or less near Kelso (Phillips, 1987a). Thickness appears to increase westward toward the headwaters of Grays River west of the quadrangle, where the sequence is well-exposed in quarries and along logging roads (Walsh, 1987). Locally, flows consist entirely of scoriaceous block breccia and would not meet WSDOT specifications for asphalt-treated base. Good exposures of lava flows are present in roadcuts along State Route (S.R.) 411 south of Vader (T10N R2W), quarries on Bebe Mountain (sec. 30, T10N R2W and sec. 25, T10N R3W), and roadcuts and a very large quarry at the southeast end of the Longview bridge at S.R. 433 (secs. 17 and 18, T7N R2W) (Phillips, 1987a). The basalt flows are interbedded with sedimentary rocks of the Cowlitz Formation along the western margin of the map area. Sedimentary rocks can create significant volumes of waste material that can make the Grays River volcanics less attractive to mine.

UPPER MIOCENE TO LOWER OLIGOCENE INTRUSIVE ROCKS

Intrusive rocks are abundant in the quadrangle and include mainly Upper Miocene to Lower Oligocene dikes, sills, or plugs (units MΦian and Mid). Dikes are often steeply inclined or nearly vertical. They are basaltic andesite, basalt, or dacite and are blocky-jointed to platy and sheared. They may contain vesicles but lack flow structures or textures such as flow breccia and are commonly erosion-resistant, forming cliffs or causing waterfalls in streams. They may be locally altered to chlorite and zeolite minerals. Locally these units can provide material that meets WSDOT specifications for asphalt-treated base.

The Spirit Lake pluton is the largest intrusive complex in the Mount St. Helens quadrangle. It is part of a northeast-trending belt of large, generally intermediate-composition intrusions stretching from near the Columbia River to north of Mount Rainier. These plutons (from south to north, the Silver Star, Spirit Lake, Bumping Lake, and Tatoosh) share an Early Miocene age and shallow emplacement depths (Evarts and others, 1987). Many areas of this pluton may meet WSDOT specifications for asphalt-treated base (units Migd, Miqd, and Miqm), but there are no test data for these units, and little or no mining has occurred to date.

AGGREGATE MINING AND SIGNIFICANT DEPOSITS

Aggregate mining has occurred at more than 725 sites within the Mount St. Helens quadrangle (Appendix 3). There are approximately 13 gravel pits and 9 rock quarries currently operating in the quadrangle that have reclamation permits issued by the

Table 2. Summary of units that have sand and gravel production. Number of mines includes both permitted and unpermitted sites

Unit	No. of mines	Geologic unit symbols from Walsh and others (1987)
Recent alluvium	42	Qa
Dredge spoils	13	
Glacial deposits	34	Qao_e, Qapo
Troutdale Formation conglomerates	2	QPc_t

WADNR. The remainder of the sites are unpermitted or terminated pits and quarries intermittently operated for forest road construction and repair and are either private or government-operated. These sites include at least 30 operated by the U.S. Forest Service. Tables 2 and 3 show geologic units hosting major sand and gravel pits and bedrock quarries in the Mount St. Helens quadrangle.

Sand and Gravel Resources

The largest gravel pits with the best rock in the Mount St. Helens quadrangle are found within the flood plain of the Cowlitz River in Quaternary alluvium (unit Qa) (Table 2). Gravel mining created almost every pond on the flood plain of the Cowlitz River. Most mining occurs within about 10 miles upstream and downstream of Toledo (Plate 1). Mining is usually performed by dragline because it is effective for excavating unconsolidated and uncemented alluvial gravels below the water table. The average permitted gravel pit in the Cowlitz River flood plain is permitted to a depth of 32 feet on a 24-acre property with 2 feet of overburden (Appendix 3). The deepest gravel thickness contoured in this valley is 25 feet, with the greatest thickness identified in one water well at just over 50 feet. WSDOT test data show that all of the alluvium along the Cowlitz River is of consistently high quality. On the flood plain of the Cowlitz River, within the boundary of the gravel polygon drawn on Plate 1, there are six active permitted mines (WADNR permit nos. 11145, 11048, 12730, 12880, 11516, and 11894), six terminated permitted mines (WADNR permit nos. 11363, 11397, 11577, 11669, and 11707 and one pre-1971 gravel pit across the river from Toledo), one proposed mine (Cowlitz Ridge pit), and one borrow pit. The cumulative area covered by existing and proposed mines is at least 490 acres. The largest mine and producer to date is operated by Toledo Sand and Gravel at Toledo (215 acres). It is at least 75 percent depleted and undergoing reclamation.

Dredge spoils associated with the eruption of Mount Saint Helens in 1980 are an important resource in this quadrangle and are used for sand or fill. Of the 13 dredge spoil mines, the largest is owned by Cowlitz County under WADNR permit number 12919 (75 acres).

Alpine glacial deposits (units Qao_e and Qapo) are abundant in the quadrangle but virtually all are weathered and most are heavily coated with iron-oxide. The iron-oxide renders aggregate from 33 mines in alpine glacial deposits unusable for concrete or asphalt applications.

The two mines in the Troutdale Formation (unit QPc_t) have been depleted and the permits terminated.

Table 3. Summary of principal units that have bedrock production. Number of mines includes both permitted and unpermitted sites

Unit	No. of mines	Geologic unit symbols from Walsh and others (1987)
Quaternary basalt and andesite flows	6	Qva_1, Qvb
Grande Ronde Basalt of the Columbia River Basalt Group (Middle Miocene)	3	Mv_g
Basalt and andesite lava flows (Miocene to Eocene)	453	$ΦEva_g$, MΦva, MΦvb, $MΦvc_2$, $Φva_1$
Basalt flow of the Grays River volcanics (Eocene)	20	Evb_{gr}
Intrusive rocks (Upper Miocene to Lower Oligocene)	40	MΦian, Mid
Intrusive rocks associated with the Spirit Lake plutonic complex (Miocene)	0	Migd, Miqd, Miqm

Bedrock Resources

Bedrock quarrying occurs throughout the Mount St. Helens quadrangle but is most prevalent in the western portion owing to its proximity to major population centers (Kelso and Longview) and Interstate 5. The average commercial rock quarry in the Mount St. Helens quadrangle is permitted to a depth of 72 feet on a 39-acre property with 5 feet of overburden (Appendix 3). The bedrock that contains the most useable resources are the Miocene to Eocene basalt and andesite lava flows.

GRANDE RONDE BASALT (COLUMBIA RIVER BASALT GROUP)

In the Mount St. Helens quadrangle there are two Grande Ronde Basalt flows (unit Mv_g). Grande Ronde Basalt is exposed in three main areas of the quadrangle: (1) north of Longview–Kelso, secs. 5 and 8, T8N R2W; (2) north of Silver Lake, sec. 15, T10N R1W; and (3) southwest of Rainier, Oregon, T7N R2,3W. There is one active permitted mine (the Westside quarry, WADNR permit no. 11122) that covers 10 acres and one terminated permitted mine (WADNR permit no. 10672) that covered at least 20 acres. Strength and durability testing of Grande Ronde Basalt generally indicates high-quality rock. The entablature and colonnade zones (Fig. 2) of the basalt flows are most suitable for use as crushed aggregate, quarry stone, riprap, or decorative rock. In these zones, the rock is usually very hard and durable, has undergone little weathering, and has many fractures and joints that developed during the cooling process. The entablature zone is generally the best for making crushed aggregate because columns within this zone are commonly smaller than 1 foot in diameter and fractured. Two problems can be encountered when mining the colonnade. First, some of the columns in the colonnade zone are too large (>2 feet) to fit in a typical crusher. Second, columns with platy joints can be excessively weathered where joints are closely spaced. If vesicular top and pillow-palagonite basal zones (Fig. 2) are present within a flow, they are generally discarded during quarry operations because of weathering and high clay content. Fortunately, the vesicular tops and pillow-palagonite bases constitute at most 10 to 20 percent of each flow, vesicular tops have been eroded off some flows, and pillow-palagonite bases occur only if the lava cooled under water.

MIOCENE TO EOCENE VOLCANICS

Miocene to Eocene volcanics (basalt, andesite, and basaltic andesite; units $ΦEva_g$, MΦva, MΦvb, $MΦvc_2$, $Φva_1$) have been mined throughout the quadrangle and will be a significant source in the future. Within these geologic units there are approximately 453 mine sites (Table 3). Most of these are unpermitted sites that are used for forest road construction and maintenance purposes. In the Miocene to Eocene volcanics there are 5 active permitted mines (WADNR permit nos. 11807, 11365, 11842, 10516, and 12892) and 7 terminated permitted mines (WADNR permit no. 11734, 12103, 12201, 12608, 12109, 10994, and 11070), and the remainder are borrow pits. The combined area of active and terminated permitted mines and borrow pits is more than 600 acres. Evarts and Ashley (1990a,b, 1991, 1992, 1993a,b,c,d) and R. C. Evarts (USGS, written commun., 2001) mapped several flows that meet WSDOT specifications for asphalt-treated base.

TERTIARY INTRUSIVE ROCKS

Tertiary intrusive rocks (Upper Miocene to Lower Oligocene; units MΦian and Mid) in the quadrangle have been mined mostly for the construction of logging roads. Many of these forestry borrow pits are owned by Weyerhaeuser, WADNR, or the U.S. Forest Service because they are the major landowners in this quadrangle. Tertiary intrusive units generally meet WSDOT specifications for asphalt-treated base.

VOLUME OF AGGREGATE

Volumes of currently available aggregate have been estimated based on a compilation of currently permitted properties (Appendix 3; Tables 2 and 3). Reserve estimates for permitted properties are largely based on values listed on permit application forms (SM-2 and SM-8a) filed with the WADNR, augmented with information from field investigations and personal communication with operators. These reserve estimates have been modified based on volumetric calculations and the estimated degree of depletion of the properties as of February 2001. Reserves in tons are obtained by multiplying cubic yards by the conversion factor 1.6 tons per cubic yard for sand and gravel and 2.4 tons per cubic yard for basalt and andesite bedrock units.

Percent depletion was estimated either visually during field investigations or by multiplying the annual production rate by the number of years of production. In many cases the amount of depletion was discussed with the operator. Those mines with 100 percent depletion have terminated status or are nearing termination.

As part of this investigation, we present estimates of the amount of gravel and bedrock reserves within currently permitted properties and estimate production rates for each product. Bedrock units are not contoured due to a lack of subsurface data. It is important to remember that the potential reserves are substantially less than the total volume of these units because land-use and environmental considerations have not been factored into our calculations.

Currently permitted gravel pits have about 4.1 million tons (2.6 million cubic yards) of resource in reserve. The production rate for these pits is about 0.15 million tons (0.09 million cubic yards) per year. Based on these figures, these sand and gravel pits will be depleted in approximately 27 years. Currently permitted bedrock quarries have about 72 million tons (30 million cubic yards) of resource in reserve. The production rate for these quarries is 0.75 million tons (0.31 million cubic yards) per year. Based on these figures, these bedrock quarries will all be depleted in approximately 96 years.

The potential bedrock resources (shown in pink on Plate 1) are much larger than the potential gravel resources (in yellow) because of their areal extent and thickness. For practical purposes the volume of available bedrock can be considered infinite.

SUMMARY

The Mount St. Helens 1:100,000-scale quadrangle contains one high-quality gravel deposit and many bedrock units meeting WSDOT specifications for asphalt-treated base. All significant gravel deposits are alluvial gravels found along the Cowlitz River. The most important bedrock units are the Miocene to Eocene andesite and basalt flows and the Grande Ronde Basalt flows of the Columbia River Basalt Group.

Strength and durability testing of the alluvium indicates that is a high-quality source for crushed aggregate and sand and gravel. The largest gravel pits are nearly depleted unless additional acreage is permitted. Toledo Sand and Gravel is reclaiming parts of the largest mine. One new gravel pit is proposed adjacent to the Cowlitz River downstream of Toledo.

The Mount St. Helens quadrangle has an abundance of bedrock that makes excellent crushed aggregate (Plate 1). Hard and durable bedrock resources are present in the Oligocene to Eocene andesites and basalts and the Grande Ronde Basalt flows. While the Grand Ronde Basalt flows have not been used

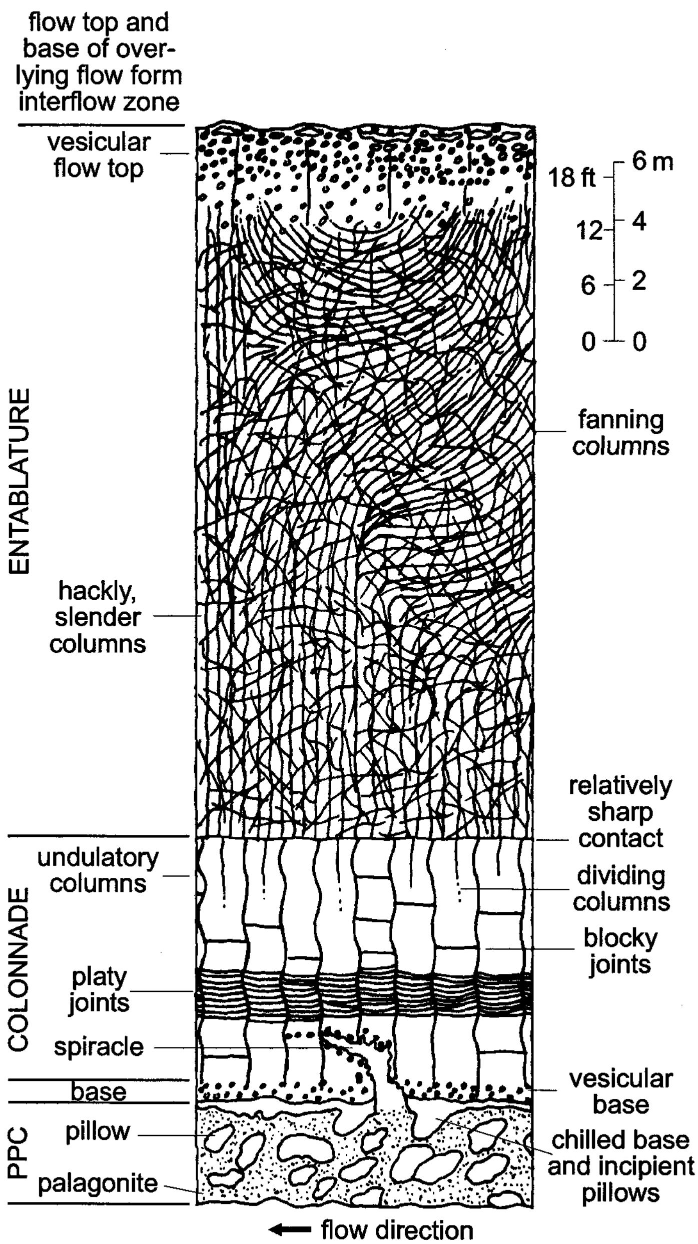

Figure 2. Cross section of a typical flow in the Columbia River Basalt Group showing, in idealized form, jointing patterns and other structures. PPC, pillow-palagonite (hyaloclastite) complex, which is present at the base of flows that entered water. *(Modified from Swanson, 1967, and Swanson and Wright, 1978.)*

extensively for quarried bedrock, field inspections and WSDOT data suggest that the rock is very fresh and hard and contains high-quality bedrock. Entablatures within the Grande Ronde Basalt flows tend to be highly sought after for mining because smaller (up to 1 foot) fragments are produced after blasting. Mining Grande Ronde Basalt flows might be limited by the thickness of the vesicular top and pillow-palagonite base for each individual flow, thickness of interflow sedimentary deposits, weathering around platy joints, or columns in the colonnade zone that are too large for a typical crusher.

The total market for aggregate in the Mount St. Helens 1:100,000-scale quadrangle is less than one million tons per year, which is used mostly in the Longview–Kelso market and for maintenance of Interstate 5. Permitted gravel pits have about 4.1 million tons (2.6 million cubic yards) of resource in reserve and produce about 0.15 million tons (0.09 million cubic yards) per year. Based on this calculation, these sand and gravel pits will be depleted in approximately 27 years. Permitted bedrock quarries have about 72 million tons (30 million cubic yards) of resource in reserve and produce 0.75 million tons (0.31 million cubic yards) per year. Based on these figures, these bedrock quarries will be depleted in approximately 96 years. However, for all practical purposes the volume of available bedrock in the Mount St. Helens 1:100,000-scale quadrangle can be considered almost unlimited.

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Appendix 1. Glossary of mining-related terms

The terms defined below are modified from Jackson (1997), American Geological Institute (1997), and Washington State Department of Transportation (1999).

Aggregate, construction aggregate – A mixture of sand and gravel or sand and crushed rock used in portland cement concrete, asphaltic concrete, mortar, plaster, or graded fill. Gravel and crushed stone that are in grain-to-grain contact in the aggregate are strong enough to support the weight of roads, buildings, or other infrastructure. The sand keeps the coarse aggregate in grain-to-grain contact by limiting the ability of the larger particles to shift laterally.

Alluvium – Unconsolidated boulders, cobbles, pebbles, sand, silt, and (or) clay deposited relatively recently from a stream or river and sorted by the current velocity.

Andesite – A dark-colored volcanic rock with a silica content of about 60%. It is the second most abundant volcanic rock, intermediate in composition between basalt and rhyolite. When it is porphyritic, it contains phenocrysts of plagioclase and one or more mafic minerals, commonly biotite, hornblende, or pyroxene. The fine-grained groundmass consists of mineralogy similar to the phenocrysts, with the inclusion of quartz. This rock is usually deposited as lava flows or shallowly intruded sills.

Asphalt – Heavy oil (tar) produced from oil wells that is used to make asphalt roads.

Asphaltic concrete – Concrete made of asphalt and crushed aggregate.

Asphalt-treated base – A specific construction aggregate used to prepare the base of an asphaltic concrete road.

Basalt – A black volcanic rock that is finely crystalline. Basalt is the most common rock in the earth's crust and forms the floor of almost all of the oceans. In Washington, basalt covers the entire Columbia Basin and much of the Cascade Range and high Olympic Mountains. Basalt that erupted on land (for example, the Columbia River Basalt Group) is hard and makes excellent crushed aggregate, whereas basalt that erupted on the sea floor is commonly weak (for example, much of the Crescent Formation basalts).

Batching, batch plant – A concrete manufacturing process or plant that mixes aggregate and portland cement or aggregate and asphaltic cement to manufacture concrete. Basically, a batch plant functions like a gigantic eggbeater and bowl.

Blend(ing) sand – Sand that is combined with coarse aggregate in order to achieve the appropriate grading for an end product. The sand must be clean and hard with a Sand Equivalent of at least 27.

Boulder – A rock fragment larger than 10 inches (256 mm) in diameter that has been somewhat rounded by abrasion in the course of transport.

Cement – (1) baked limestone dust and water that glues aggregate particles together to form concrete; (2) minerals, usually precipitated from hydrothermal fluids, that naturally glue the grains of a rock together creating a hard sediment or harder rock.

Clast – A rock fragment of any size, initially broken off bedrock by the force of water freezing in cracks or by impact from another rock. Clasts become smaller as they roll off a hillside and (or) down a stream.

Clay – Sediment composed of particles that are plastic, consolidated when dry, and are smaller than 0.000079 inch (0.002 mm) in diameter. Clay will not support weight (it behaves as a paste) because it is composed primarily of platy clay minerals. Clay is unsuitable for use in construction aggregates, and even small amounts must be washed off coarser aggregate.

Coarse aggregate – Gravel or crushed stone that is larger than ¼ inch (4.76 mm) in diameter. All clasts in coarse aggregate are larger than pea gravel (pebbles, cobbles, and boulders).

Cobble – A rock fragment larger than a pebble, but smaller than a boulder, having a diameter in the range of 2½ to 10 inches (64–256 mm) that has been somewhat rounded by abrasion in the course of transport.

Construction aggregate – *see Aggregate*

Cross-bed – A bed inclined at an angle to the main plane of stratification. Usually indicates deposition in a delta.

Crushed stone – Bedrock, cobbles, or boulders that have been crushed with a mechanical crusher to gravel-size rock fragments with at least three freshly broken faces. Crushed stone makes an excellent base course for road construction because the rock fragments tend to form an interlocking matrix. It is the only material suitable for asphaltic concrete because asphalt sticks only to freshly broken surfaces.

Degradation Test – A laboratory test designed to test the durability of rock under wet conditions. The degradation number indicates the percentage of rock remaining intact after tumbling with steel balls in a wet chamber. Large numbers indicate favorable rock.

Dike – A tabular intrusive rock that cuts across the bedding or foliation of the country rock.

Fine aggregate – Sand and gravel or crushed stone that will pass through a ¼-inch (4.76 mm) sieve, but will be trapped in a 200 mesh (ultrafine) sieve.

Granite – A light gray or pink, coarsely crystalline (typically ⅛-inch crystals) intrusive igneous rock composed of the hard minerals quartz and feldspar with minor amounts of black mica and black iron-magnesium-rich minerals. Granite and closely related rocks can make excellent construction aggregate.

Gravel – An unconsolidated natural accumulation of typically rounded rock fragments resulting from erosion and consisting predominantly of particles larger than sand, such as boulders, cobbles, and pebbles, in any combination.

Intrusive rock – Igneous rock that was emplaced below the earth's surface as a magma that cooled very slowly to form a coarsely crystalline rock.

Kame – A hummock, terrace, or short ridge composed of stratified sand and gravel deposited at the margin of a glacier as a delta or fan. In Washington, the term is generally applied to landforms created by deposition in the low area between the margin of a glacial ice sheet and the confining hills. After the ice has melted away, a high-quality sand and gravel deposit frequently remains.

Limestone – A rock composed of the mineral calcite. Normally, these are rocks deposited in the ocean from materials that are by-products or remnants of shells. Limestone is an important source of construction aggregate in much of the nation.

Loess – Silt and fine sand that is produced by the erosion of glacial outwash and transported by wind.

Los Angeles Abrasion Test – A laboratory test to assess the strength of aggregate under dry conditions. A 100-pound sample is placed in a tumbler resembling a washing machine with a tungsten carbide ball weighing about five pounds. The tumbler is revolved 500 times and then the sample is passed through a U.S. Standard No. 4 sieve. The larger the percent of the sample that passes through the sieve, the weaker the sample. The Los Angeles Abrasion number indicates the percent of the sample that has passed through the sieve.

Outwash – Sand, gravel, and coarser round rock deposited from streams and rivers issuing from alpine or continental (ice-age) glaciers. Proximal outwash was deposited relatively close to the snout of a glacier and is poorly sorted and has a large fraction of cobbles and boulders. Distal outwash was deposited miles from the edge of the glacier and is relatively well sorted and dominated by sand.

Overburden – The material that overlies an aggregate or mineral resource and must be removed before mining the underlying material.

Pebble – A stone, usually rounded by water transport, 1/6 to 2½ inches (4–64 mm) in diameter—the size of a small pea to that of a tennis ball.

Pebble imbrication – A sedimentary fabric characterized by disk-shaped or elongate pebbles dipping in a preferred direction at an angle to the bedding. It is commonly displayed by pebbles on a stream bed, where flowing water tips the pebbles so that their flat surfaces dip upstream.

Pit – This term is restricted herein to sand and gravel mines, regardless of size. A borrow pit is a small (<3 acre) mine that periodically produces unprocessed gravel and other sediment, generally for use as fill.

Pit run – Unprocessed material taken directly from the undisturbed geologic formation.

Plug – A vertical, pipe-like body of magma that represents the conduit to a former volcanic vent.

Portland cement – Cement made by heating limestone to about 2,700°F (calcining) to form lime. This lime is mixed with small amounts of water and dries to a hard adhesive that can glue aggregate together to form portland cement concrete. Portland cement by itself does not have great compressive strength, and it is costly because of the heat used in its manufacture. For these reasons, aggregate is added to form concrete. The gravel in portland cement concrete has great compressive strength and adds inexpensive filler to the mix.

Quarry – Used exclusively herein for mines that produce aggregate by blasting bedrock.

Round rock, round rock aggregate – Coarse aggregate that has been rounded by the process of stream or glacial transport. It generally has greater value than crushed aggregate because it is less expensive to mine, easy to mix in batch plants, and easy to finish to a smooth surface with trowels or other tools when used in concrete. Asphalt does not adhere effectively to round rock aggregate.

Sand Equivalent Test – A laboratory test that measures the cleanness of a sample in terms of the relative proportion of fine-grained dust or clay. High numbers indicate less dust and (or) clay, whereas low numbers indicate greater plasticity. Favorable samples have values greater than 30.

Sill – A tabular intrusion that parallels the bedding or foliation of the sedimentary or metamorphic country rock and is substantially wider than it is thick. Sills form within a few miles of the Earth's surface.

Silt – Sediment composed of particles that are unconsolidated or poorly consolidated when dry and will pass a U.S. Standard No. 200 sieve (0.0025 in. or 0.074 mm) but are larger than clay (0.000079 in. or 0.002 mm). Silt has little or no cohesive strength because it contains a small proportion of clay minerals. Abundant silt can render a gravel deposit unsuitable for use in construction aggregates.

Specific gravity – The specific gravity of a sample is the weight of the substance relative to the weight of an equal volume of water. The specific gravities of water, weak aggregate, granite, limestone, and basalt are 1.0, 1.95, 2.65, 2.72, and 3.2 grams per cubic centimeter, respectively.

Stabilometer R Value Test – A laboratory test that measures horizontal deformation when a vertical weight is applied. High numbers indicate stronger materials. Favorable samples have values greater than 70.

Till – Very poorly sorted clay, silt, sand, gravel, cobbles, and boulders deposited directly from glacial ice in the form of a moraine or a compact blanket of sediment under the ice. Generally, till is unsuitable for construction aggregate.

Appendix 2. Methods

INVENTORY PHILOSOPHY

Two end-member philosophies for resource inventory have been employed in Washington: (1) strictly factual reporting showing only those sand, gravel, and bedrock resources that have been proven to exist because they are part of active mines, and (2) a speculative approach that reports all of the potential aggregate deposits that might exist, as determined from surficial geologic or soils mapping. Both approaches have shortcomings. The first philosophy results in underestimation of available aggregate in any given area by ignoring high-quality deposits that have not been mined. The second philosophy results in overestimation of the resource because this method cannot adequately account for the heterogeneous nature of aggregate-bearing geologic units. In this study, we attempt to achieve a balance between these two philosophies using a method developed by William S. Lingley, Jr. (Loen and others, 2001) that includes the geologic and engineering criteria described below.

The accuracy of any assessment of undiscovered gravel or bedrock resources, whether performed as a proprietary exploration project or as a governmental or academic research study, is largely controlled by the quantity and quality of available subsurface data. As a general rule, subsurface information is not readily available for undeveloped deposits. Consequently, mineral economists categorize resources based on degree of certainty that any given deposit actually exists, mainly as determined from subsurface and other data.

The most commonly used categories are identified and undiscovered reserves, which are further subdivided as shown on Table 4. In order to demonstrate that an identified (or commercially viable) resource exists, the geology of the deposit must be very well known and (or) the deposit must have been defined by closely spaced exploratory drilling. Such costly work is beyond the scope of this study. Conversely, studies that rely solely on surficial information in order to delineate speculative undiscovered reserves are of little value to industry and have led to poor land-use decisions.

In this study, we mapped hypothetical (and some speculative) undiscovered reserves throughout the state as defined in Table 4 and shown on Plate 1. The most widely available source of subsurface geological data for mapping hypothetical reserves is water-well logs, but the accuracy of information on these logs is generally very poor or even misleading. To reduce the inherent uncertainty introduced by use of these logs, we depict hypothetical reserves only where the average of data from several water wells, together with other information such as landform analysis (geomorphology), geotechnical bores, outcrop descriptions, hydrologic data, and mine data allow reasonable extrapolation of surficial data into the subsurface. These hypothetical reserves are shown on Plate 1 with isopachs (thickness contours) for the gravel deposits. Elsewhere, speculative undiscovered reserves are mapped, but only where several data sets strongly suggest the presence of a deposit meeting the threshold criteria. These speculative reserves are shown on Plate 1 as simple polygons showing the extent of high-quality sand, gravel, or bedrock at the surface.

DEFINITION OF SIGNIFICANT RESOURCES

This study is limited to assessing significant aggregate resources. Significant aggregate resources are defined herein as those hard and durable sand and gravel or bedrock deposits that are likely to yield at least 10 million cubic yards of recoverable aggregate. Ten million cubic yards is the approximate volume necessary to maintain existing infrastructure in a 100,000-person market during the 20-year period mandated by the Growth Management Act, calculated as follows. Lingley and Manson (1992) estimated that the total annual per capita demand for sand, gravel, and crushed rock products in Washington is approximately 12 cubic yards. An informal rule of thumb used in industry and government is that about half of the demand for construction aggregates in any market will be used to repave roads, rebuild bridges, and remodel existing buildings, and half is used for new construction. Therefore, a hypothetical maintenance level of production for a 100,000-person market can be approximated as follows:

100,000 persons x *12 cubic yards/year* x *20 years* x *50%*
= *~10 million cubic yards*

Keep in mind that local governments are required to designate at least double this volume for every 100,000 people in order to comply with the Growth Management Act in accounting for new construction as well as maintenance (Lingley and Jazdzewski, 1994).

THRESHOLD CRITERIA USED IN PREPARING THIS INVENTORY

Inherent weaknesses in many common lithologies in the earth's crust, such as claystone or layered sedimentary and metamorphic rocks, coupled with unfavorable alteration and weathering processes render much of the outcropping bedrock and gravel unsuitable for construction aggregates. Furthermore, extraction or development costs may exceed expected return under current

Table 4. Classification of gravel and bedrock resources *(modified from U.S. Geological Survey, 1976)*

IDENTIFIED RESERVES			UNDISCOVERED RESERVES	
Measured	**Indicated**	**Inferred**	**Hypothetical**	**Speculative**
Deposit whose engineering properties, reserves in tons or cubic yards, and grain sizes are measured with a margin of error <20% (that is, a mine or a well-drilled prospect)	Deposit whose measurements, together with reasonable geologic projections, can be used to compute reserves in tons or cubic yards	Reasonable extension of indicated or measured deposit (generally <0.50 miles); thickness contours can be drawn with confidence	Undiscovered resources that may reasonably be expected to exist; applicable where landforms, water wells, proximal mines, or geophysical data justify such extension	Unexplored surficial deposit with no subsurface data
Active mine	Densely drilled deposit	Deposit with good subsurface control	Possible deposit defined only by poor subsurface control	Possible deposit; surficial data only

market conditions. In order to reduce the probability of including weak or insignificant resources, we have developed the following threshold criteria to determine which resources should be included in our inventory.

THICKNESS—Only those deposits that are known or likely to exceed 25 feet (~7.5 m) in the thickest portions are depicted. Thin gravel deposits rarely contain significant reserves. For example, a 20-foot-thick deposit covering 20 acres would yield only about 500,000 cubic yards of sand and gravel, and the value of the gravel might not exceed proceeds from selling the land in its undisturbed state for its real estate value. Moreover, current mining technology does not allow efficient excavation of thin veneers of sediment or bedrock. Thin deposits must spread over a large area in order to contain a significant volume of gravel, but relatively inexpensive excavating equipment (that is, front-end wheel loaders) cannot be used to carry pit run long distances within the mine. Finally, thinner deposits require greater surface disturbance per unit of aggregate produced, and damage to the plant/soil ecosystem increases in proportion to the surface area of mining. Therefore, permitting costs per unit of resource generally increase as a function of decreasing thickness.

SURFACE AREA AND DIMENSIONS OF THE DEPOSIT—Gravel deposits are seldom more than 100 feet thick and, consequently, the deposit must cover a large area to contain significant volumes of construction aggregate. The smallest geologic polygons inventoried as significant gravel resources cover at least 0.25 square mile (160 acres). The volume of a 50-foot-thick gravel unit of this size would be about 10 million cubic yards. Additionally, we map only those deposits that have minimum widths of 1,500 feet (450 m). As noted above, deposits with long, narrow map patterns are generally inefficient to operate. Although environmental issues are not considered herein, long narrow deposits are generally associated with rivers or streams where mining cannot take place owing to environmental considerations.

The surface area of each deposit was initially estimated using a 1:100,000-scale geologic map compiled by the Washington Division of Geology and Earth Resources (Phillips, 1987a) and other geologic maps (Evarts and Ashley, 1990a,b, 1991, 1992, 1993a,b,c,d; Evarts, 2001; R. C. Evarts, USGS, written commun., 2000). The resulting polygons were modified where the portion of the deposit meeting the threshold criteria is less extensive than the mapped surface area of the deposit. Most of the geologic polygons depicted on this compilation contain existing mines or engineering tests of outcrops that prove at least some of the rock or sediment meets the threshold criteria. This approach, taken to expedite the inventory process, probably results in omission of a few significant resources.

OVERBURDEN—Only those deposits that have stripping ratios (ratios of overburden to gravel or overburden to rock) of less than 1 to 3 are included in this inventory. Overburden can cost from $0.35 to more than $1.50 per ton to remove. Typically, miners try to achieve a net profit of $1.00 per ton, so the overburden volume must be much less than the volume of underlying aggregate if the mine is to be commercially viable. The stripping ratio can be larger where supply restrictions, favorable topography, or other considerations allow the overburden to be removed profitably. The largest stripping ratio for a profitable mine in Washington was 1 to 2, or 0.50.

The practice of topsoil sales and (or) synthesis is one method of profitably disposing of thicker organic or clay-rich overburden, but as a general rule, most overburden must be saved for reclamation (Norman and others, 1998; Norman and Lingley, 1992). Historically, few gravel deposits with more than 10 feet (3 m) of overburden have been mined.

STRENGTH AND DURABILITY—In order to perform adequately as construction aggregate, gravel or bedrock must have high compressive strength and resist degradation when wet. Without these characteristics, the aggregate cannot support the weight of roads or buildings. Much of the vertical compressive strength, or load-bearing capacity, comes from grain-to-grain contact among individual pebbles that are effectively stacked up and prevented from shifting by cement and fine aggregate. Stronger aggregate commands a higher price, but weak rock is of no use. Minimum specifications for strength and durability of various rock products are published by the Washington State Department of Transportation in the Standard Specifications for Road, Bridge, and Municipal Construction, 2000 (Washington State Department of Transportation, 1999), a key industry reference book that is updated periodically. Specifications for gravel and bedrock are determined with laboratory tests, including Los Angeles Abrasion, Degradation, Sand Equivalent, Specific Gravity, and Stabilometer tests (Appendix 1). Table 1 identifies some specifications for certain uses of aggregate.

For this study, we inventory gravel and bedrock that meet WSDOT specifications for asphalt-treated base (Table 1). Asphalt-treated base is a compacted layer of aggregate treated with asphalt for stability and weatherproofing and placed directly on bulldozed earth or rock of the subgrade. Minimum acceptable test results are: Los Angeles Abrasion ≤30%, Degradation ≥15, Sand Equivalent ≥30%, specific gravity >1.95 grams per cubic centimeter, and weight percent passing a U.S. Standard No. 200 sieve <9%. If most of the deposit appears to meet these specifications (Appendices 3 and 4), we depict the entire deposit as meeting the strength and durability threshold criteria (Plate 1).

OTHER CONSIDERATIONS—Typically, sand and gravel deposits should have a sand-to-gravel ratio of 40:60 and be free of weak or deleterious materials such as foliated metamorphic rock, poorly indurated clasts, clay, iron oxides, sulfides, glassy volcanic rock, and organic matter (Kroft, 1972; Washington State Department of Transportation, 1999).

SOURCES OF DATA

The locations of most mines in Washington are given in Lingley and Manson (1992) and McKay and others (2001). Data for existing and terminated mines are archived in Washington Department of Natural Resources permit files, Washington State Department of Transportation pit site files, and U.S. Forest Service mine files. The thicknesses of mined units, for example, are taken from Washington Department of Natural Resources Form SM-2 or from other permit-related documentation such as Environmental Impact Statements. The surface extent of geologic units are depicted on a Washington Division of Geology and Earth Resources 1:100,000-scale geologic map (Phillips, 1987a) and other geologic maps (Evarts and Ashley, 1990a,b, 1991, 1992, 1993a,b,c,d; Evarts, 2001; R. C. Evarts, USGS, written commun., 2000). Hydrology studies are particularly useful in assessing the stratigraphy of gravel deposits. Such reports are included in various types of environmental documentation, wellhead protection studies, and water resource reports. Logs of geotechnical bores (for example, bores for foundation engineering studies) are frequently useful. Water-well logs and some logs of geotechnical borings are archived by the Washington Department of Ecology and the Washington State Department of Transportation, respectively.

Appendix 3. Mine database

This database contains information about most small active and terminated borrow pits or quarries and large active, terminated, and proposed mines in the area inventoried in the Mount St. Helens 1:100,000 quadrangle. All of the borrow pits, quarries, and mines in this database are plotted on Plate 1. The information contained herein is available digitally as part of the geographic information system (GIS) files for the Mount St. Helens quadrangle. The columns that are not self-explanatory are defined as follows:

WADNR unique number – The Washington Department of Natural Resources (WADNR) unique number used by the geographic information system (GIS) to relate a feature on Plate 1 to a row in the database. The first four digits of the number identify the 7.5-minute quadrangle map in which the mine is located. The last four digits are a unique number in each 7.5-minute quadrangle.

WADNR data type code – The code number that indicates the type and size of the mine, as follows: 15 = small borrow pit or quarry (point); 16 = small terminated/depleted borrow pit or quarry (point); 18 = large active mine (polygon); 21 = large terminated/depleted mine (polygon); 22 = large proposed mine (polygon).

WADNR permit number – The five-digit number on Washington Department of Natural Resources Form SM-2, *Application for Surface Mining Reclamation Permit* (for a permitted mine).

WSDOT site number – The number assigned by the Washington State Department of Transportation (WSDOT) that links results of strength and durability testing to a particular mine. The number consists of a letter that identifies the county the site is in, followed by a sequentially assigned number.

¼ ¼ section, ¼ section, Section, Township, Range, Meridian – Legal description of the mine with reference to the Government Land Office grid. Townships and ranges are shown on Plate 1.

Product – The material being mined: rock, sand, or gravel.

Rock type – The type of rock that is being quarried at the site, if the mine is a quarry.

Geologic unit – The short label that identifies a particular unit on a geologic map. This field indicates the unit in which the mine is located as identified in Phillips (1987a), using the updated geologic unit labels consistent with Walsh and others (1987). Most units are described in Appendix 6.

Qualifier – Indicates either that the thickness shown in the adjacent column is exact because the mine penetrates all the way through the resource (blank) or that the actual resource thickness is greater than the thickness reported because the bottom of the resource was not identified (>).

Resource thickness (feet) – The thickness, in feet, of the sand, gravel, or bedrock that is being mined.

Million cubic yards – The estimated volume (in millions of cubic yards) of aggregate resource present within the permitted boundary of a mine as of May 2000.

Million tons – The reserve weight calculation based on reserve volume estimates. Conversion factors are 1.6 tons per cubic yard for sand and gravel, 2.4 tons per cubic yard for basalt and gabbro, and 2.2 tons per cubic yard for siliceous igneous rocks.

Acres – Typically the number of acres permitted on Washington Department of Natural Resources Form SM-2, *Application for Surface Mining Reclamation Permit*. For unpermitted mines, indicates the estimated area of the mine. Includes not only areas of aggregate extraction, but also all operations associated with the mine (stockpiling, crushing, screening, scales, etc.).

Percent depletion – The percentage by which the resource within the mine boundary has been depleted by mining, determined by communication with the mine operators or by field investigations.

Overburden thickness (feet) – The thickness, in feet, of soil, clay, or non-commercial aggregate that must be removed in order to reach the aggregate resource.

Stripping ratio – The overburden thickness divided by the resource thickness. A value of less than 0.33 (ratio of less than 1:3) is preferred.

Los Angeles Abrasion, Degradation, Specific Gravity, Sand Equivalent, and Stabilometer R Value tests – Results of laboratory tests, conducted mainly by the WSDOT, that reflect the quality of the deposit. See the glossary (Appendix 1) for explanation of tests.

Percent >2½ inches, Percent ¼–2½ inches, Percent <¼ inch, Percent <U.S. No. 200 sieve – Results of laboratory grain-size analysis of samples. Values are given in weight percent. The first three fields divide the whole sample, and the fourth field refers to the amount of silt and clay in the entire sample.

IDENTIFIER						LOCATION							RESERVES									QUALITY											
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
24190010	15					SE	SW	1	6	1	E	Cowlitz	rock		ΦEva_g																	
24190009	15					NW	NE	2	6	1	E	Cowlitz	rock		ΦEva_g																	
24190007	15					SW	SW	3	6	1	E	Cowlitz	rock		ΦEva_g																	
24190008	15					NE	SW	3	6	1	E	Cowlitz	rock		ΦEva_g																	
24190006	15					SE	SE	4	6	1	E	Cowlitz	rock		ΦEva_g																	
24180007	16	11627			J. L. Ledgett	NW	NW	5	6	1	W	Cowlitz	gravel		Qa		20			3		3	0.15									
24180010	16	10893			Leonard Ledgett	NE	NW	5	6	1	W	Cowlitz	gravel		Qa		20			10		3	0.15									
24190004	15					NE	NE	5	6	1	E	Cowlitz	rock		ΦEva_g																	
24190005	15					SE	NE	5	6	1	E	Cowlitz	rock		ΦEva_g																	
24180004	16	11421			Columbia West Materials	NE	SE	6	6	1	W	Cowlitz	gravel		QPc_t		60	0.2		30		2	0.03									
24180005	16	11660			First Federal Savings and Loan	NE	SE	6	6	1	W	Cowlitz	gravel		Qa		60		0.2	5.75		2	0.03									
24190003	15					SW	SW	6	6	1	E	Cowlitz	rock		ΦEva_g																	
24190001	15					NW	SE	12	6	1	W	Cowlitz	rock		ΦEva_g																	
24200001	15					NE	NE	12	6	1	E	Cowlitz	rock		ΦEva_g																	
24190002	15					NE	SE	15	6	1	E	Cowlitz	rock		ΦEva_g																	
24180006	16	11529	N-132		Monte Kress Trucking	NE	NE	6	6	1	W	Cowlitz	rock		QPc_t		60	0.5		3		4	0.07	22.6	27	2.76	5					
24200009	15					NE	SW	2	6	2	E	Cowlitz	rock		ΦEva_g																	
24200008	15					SW	SE	4	6	2	E	Cowlitz	rock		ΦEva_g																	
24200005	15					SW	NE	6	6	2	E	Cowlitz	rock		ΦEva_g																	
24200006	15					SW	NE	6	6	2	E	Cowlitz	rock		ΦEva_g																	
24200007	15					SE	NE	6	6	2	E	Cowlitz	rock		ΦEva_g																	
24200002	15					NE	NW	7	6	2	E	Cowlitz	rock		ΦEva_g																	
24200003	15					SE	NW	7	6	2	E	Cowlitz	rock		ΦEva_g																	
24200004	15					NE	SW	7	6	2	E	Cowlitz	rock		ΦEva_g																	
24210008	15					NE	NW	1	6	3	E	Cowlitz	rock		ΦEva_g																	
24220001	15					NW	NE	1	6	3	E	Cowlitz	rock		ΦEva_g																	
24220002	15					NE	SE	1	6	3	E	Cowlitz	rock		ΦEva_g																	
24210006	15					SW	NW	2	6	3	E	Cowlitz	rock		ΦEva_g																	
24210007	15					SE	NW	2	6	3	E	Cowlitz	rock		ΦEva_g																	
24210002	15					SE	SW	7	6	3	E	Cowlitz	rock		ΦEva_g																	
24210003	15					NW	NE	9	6	3	E	Cowlitz	rock		ΦEva_g																	
24210004	15					NW	NW	11	6	3	E	Cowlitz	rock		ΦEva_g																	
24210001	15					NW	NW	15	6	3	E	Cowlitz	rock		ΦEva_g																	
24220004	15					SE	SE	2	6	4	E	Clark	rock		Φva_1																	
24220003	15					NW	SE	4	6	4	E	Cowlitz	gravel		Qvl																	
24230002	15					SE	NW	1	6	5	E	Skamania	rock		$M\Phi vc_2$																	
24230001	15					NE	NW	2	6	5	E	Skamania	rock		$M\Phi vc_2$																	

IDENTIFIER						LOCATION							RESERVES										QUALITY									
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
24240002	15					SW	NW	2	6	6	E	Skamania	rock		$M\Phi va$																	
24240001	15					SE	SE	10	6	6	E	Skamania	rock		Qva_1																	
24190026	15					SW	SE	3	7	1	E	Cowlitz	rock		ΦEva_g																	
24190025	15					NE	SE	5	7	1	E	Cowlitz	rock		ΦEva_g																	
24180024	18	11807	N-154	Carrolls pit	J. L. Storedahl & Sons	S	NW	6	7	1	W	Cowlitz	rock		ΦEva_g/Qls		100	0.5		91.73		2.5		16	64	2.76	62					10.4
24190024	15					NW	SW	6	7	1	E	Cowlitz	rock		ΦEva_g																	
24190020	15					SW	NW	8	7	1	E	Cowlitz	rock		ΦEva_g																	
24190021	15					SE	SW	8	7	1	E	Cowlitz	rock		ΦEva_g																	
24190022	15					SE	SE	8	7	1	E	Cowlitz	rock		ΦEva_g																	
24190023	15					SE	SW	11	7	1	E	Cowlitz	rock		ΦEva_g																	
24190019	15					SW	SW	13	7	1	E	Cowlitz	rock		ΦEva_g																	
24180022	15					NE	SW	20	7	1	W	Cowlitz	rock		ΦEva_g																	
24190018	15					NE	SW	23	7	1	E	Cowlitz	rock		ΦEva_g																	
24187010	21	10629			General Construction	E	E	24	7	1	W	Cowlitz	sand		Qa		20			145		0	0.00									
24190017	15					NW	SW	25	7	1	E	Cowlitz	rock		ΦEva_g																	
24200014	15					NE	SE	25	7	1	E	Cowlitz	rock		ΦEva_g																	
24200015	15					NE	SE	25	7	1	E	Cowlitz	rock		ΦEva_g																	
24190015	15					NE	SW	26	7	1	E	Cowlitz	rock		ΦEva_g																	
24190016	15					SE	SE	26	7	1	E	Cowlitz	rock		ΦEva_g																	
24190014	15					NW	NW	28	7	1	E	Cowlitz	rock		ΦEva_g																	
24190013	15					NE	NE	29	7	1	E	Cowlitz	rock		ΦEva_g																	
24180011	21	11437	N-147		Longview Rock Products, Inc.	NW	SE	31	7	1	W	Cowlitz	sand		Qa		10		0.1	20		1	0.10				50	63				39
24180013	21	11734			Weyerhaeuser	NW	NE	31	7	1	W	Cowlitz	rock		ΦEva_g		100			23		4	0.04									
24180014	16	12591			Lloyd A. Nelson	SW	SE	31	7	1	W	Cowlitz	gravel		Qa		20			10.5		6	0.30									
24180016	15		N-90			NW	SW	31	7	1	W	Cowlitz	gravel		Qa			0.2									83	70	0	0	100	5
24180039	21					NE	SE	31	7	1	W	Cowlitz	gravel		Qa																	
24180018	18	11365	N-157		Roland Brusco Jr.	E	NW	32	7	1	W	Cowlitz	rock		ΦEva_g		50			100		6	0.12	17.3	56	2.7						
24180037	21					NW	SW	32	7	1	W	Cowlitz	gravel		Qa																	
24190011	15					NE	SE	33	7	1	E	Cowlitz	rock		ΦEva_g																	
24190012	15					SE	NW	34	7	1	E	Cowlitz	rock		ΦEva_g																	
24180020	15		N-78		Davis	SW	SE	35	7	1	W	Cowlitz	rock		ΦEva_g			0.005						16	57	2.76						16
24210041	15					SE	NE	2	7	2	E	Cowlitz	rock		ΦEva_g																	
24200031	15					SE	NE	4	7	2	E	Cowlitz	rock		ΦEva_g																	
24200030	15					NE	SE	6	7	2	E	Cowlitz	rock		ΦEva_g																	
24170007	21	10717	N-118				NE	11	7	2	W	Cowlitz	dredge spoils		Qa		20			20		0	0.00			2.49	96	69				0
24200026	15					NE	NW	11	7	2	E	Cowlitz	rock		ΦEva_g																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
24200027	15					SE	NE	11	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24180038	21					SW	SE	12	7	2	W	Cowlitz	rock		ΦEvc$_g$																	
24200028	15					SW	SW	12	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200029	15					NE	NW	12	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24177010	21	10629			General Construction	SE	SW	13	7	2	W	Cowlitz	sand		Qa		20			145		0	0.00									
24200025	15					SE	SW	13	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24170006	18	12906			Wasser & Winters Co., Inc.	NE	NE	14	7	2	W	Cowlitz	sand		Qa	>	46	1.5		51.3			0.00									
24200019	15					NW	SE	21	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200020	15					NE	NE	21	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200021	15					SE	NE	21	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200022	15					SE	NE	22	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200023	15					NE	SE	22	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200024	15					SE	NW	24	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200018	15					NW	SW	26	7	2	E	Cowlitz	gravel		Qvl																	
24200016	15					NW	SW	29	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200017	15					NE	SW	29	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200010	15					NW	NW	33	7	2	E	Cowlitz	gravel		Qvl																	
24200011	15					NE	SW	34	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200012	15					NE	SW	34	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24200013	15					SE	SE	34	7	2	E	Cowlitz	rock		ΦEva$_g$																	
24210051	15					SW	SE	3	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210049	15					SE	SW	4	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210050	15					SE	NE	4	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210048	15					SE	NE	6	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210042	15					NW	NW	8	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210043	15					NE	NW	8	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210044	15					SE	SW	8	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210045	15					NW	SE	8	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210046	15					NW	SE	8	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210047	15					SW	NE	11	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210038	15					SW	SW	13	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210039	15					SW	SW	13	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210040	15					NE	SW	13	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210037	15					SW	NW	15	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210036	15					NW	NW	16	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210033	15					NE	NW	17	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210034	15					NE	NW	17	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210035	15					SW	SE	17	7	3	E	Cowlitz	rock		ΦEva$_g$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
24210030	15					NW	NW	18	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210031	15					NE	SW	18	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210032	15					NE	SE	18	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210024	15					NE	NW	19	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210025	15					SW	NW	20	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210026	15					NE	SW	20	7	3	E	Cowlitz	gravel		Qvc																	
24210027	15					SE	NW	23	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210028	15					SE	NE	23	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210023	15					SE	SE	24	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210029	15					NW	NW	24	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210022	15					NW	SE	25	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210020	15					SE	NW	28	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210021	15					NE	SE	28	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210019	15					SW	SW	30	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210010	15					NW	NE	31	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210011	15					NW	SE	32	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210012	15					SW	NW	33	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210013	15					SW	SW	33	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210014	15					NW	SW	33	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210015	15					NE	SW	33	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210016	15					NW	SW	35	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210017	15					SW	NW	35	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210009	15					NE	SE	36	7	3	E	Cowlitz	rock		ΦEva$_g$																	
24210018	15					NW	SW	36	7	3	E	Cowlitz	rock		ΦEva$_g$																	
23220003	15			Lost	U.S. Forest Svc., Gifford Pinchot National Forest	NE	NE	2	7	4	E	Cowlitz	gravel		Qapt$_h$																	
24220022	15			Cougar pit	U.S. Forest Svc., Gifford Pinchot National Forest	NE	SE	2	7	4	E	Cowlitz	rock		Φva$_1$?																	
24220021	15					SE	SE	3	7	4	E	Cowlitz	rock		Φva$_1$?																	
24220020	15					SW	NE	5	7	4	E	Cowlitz	gravel		Qvl																	
24220019	15					SW	NE	6	7	4	E	Cowlitz	gravel		Qvl																	
24220017	15					SW	NW	10	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220018	15					NW	NW	11	7	4	E	Cowlitz	rock		Φva$_1$?																	
24220016	15					NW	NE	15	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220013	15					NW	NW	17	7	4	E	Cowlitz	rock		Qvb																	
24220014	15					SE	NW	17	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220010	15					NE	NW	18	7	4	E	Cowlitz	rock		ΦEva$_g$																	
24220011	15					NW	NE	18	7	4	E	Cowlitz	rock		Φvc$_1$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
24220012	15					NE	SE	18	7	4	E	Cowlitz	rock		Qvb																	
24220007	15					NW	NW	20	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220008	15					SW	NW	20	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220009	15					SE	NE	21	7	4	E	Cowlitz	rock		Φvc$_1$																	
24220006	16	10904	N-127		International Paper Co.	NW	SW	27	7	4	E	Cowlitz	rock		Mid		105	0.03		1.5		1.5	0.01	29.1	40	2.49						
24220005	15					NW	NE	30	7	4	E	Cowlitz	rock		ΦEva$_g$																	
24230009	15			Marble Mountain quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NE	SW	2	7	5	E	Skamania	rock		MΦvc$_2$?																	
24230008	16			Gobbler's Knob	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SE	6	7	5	E	Skamania	rock		Φva$_1$?																	
24230007	15					NE	NW	8	7	5	E	Skamania	rock		Φva$_1$?																	
24230005	15			Quarter Corner	U.S. Forest Svc., Gifford Pinchot National Forest	SW	SE	14	7	5	E	Skamania	rock		Qva$_1$																	
24230006	15					SE	SE	14	7	5	E	Skamania	rock		Qva$_1$																	
24230004	16			Diamond Creek	U.S. Forest Svc., Gifford Pinchot National Forest	SW	SW	23	7	5	E	Skamania	rock		Qva$_1$																	
24230003	15					NW	NW	28	7	5	E	Skamania	gravel		Qvl																	
23240001	16			Gully Whopper quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NE	NW	2	7	6	E	Skamania	rock		MΦvc$_2$																	
24240011	15					NE	NW	8	7	6	E	Skamania	rock		ΦEvc$_g$																	
24240012	15			Section 8 quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NW	NE	8	7	6	E	Skamania	rock		ΦEvc$_g$																	
24240010	16			Cedar Flats	U.S. Forest Svc., Gifford Pinchot National Forest	SW	NE	14	7	6	E	Skamania	gravel		Qvl																	
24240008	15					NE	NE	16	7	6	E	Skamania	gravel		Qvl																	
24240007	15					SW	NE	17	7	6	E	Skamania	rock		MΦva?																	
24240004	15					SE	NW	20	7	6	E	Skamania	rock		MΦva?																	
24240005	15					SW	SE	23	7	6	E	Skamania	gravel		Qvl																	
24240006	15			Pine pit	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SW	24	7	6	E	Skamania	gravel		Qvl																	
24240003	15			Ranger Station quarry	U.S. Forest Svc., Gifford Pinchot National Forest	SW	SW	26	7	6	E	Skamania	gravel		Qvl																	
23200008	15					NW	SE	2	8	1	E	Cowlitz	rock		ΦEva$_g$																	

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23180003	21	12103	N-156		Ostrander Rock & Construction Co., Inc	SW	NW	7	8	1	W	Cowlitz	rock	sand-stone, basalt	ΦEvc_g		100	0.5		5		0.5	0.01	23.9	28	2.51	61					15.9
23190015	15					SW	NW	8	8	1	E	Cowlitz	rock		ΦEvc_g																	
23190016	15					NE	SW	9	8	1	E	Cowlitz	rock		ΦEvc_g																	
23190014	15					SE	SE	13	8	1	E	Cowlitz	rock		ΦEva_g																	
23190013	15					SW	SE	17	8	1	E	Cowlitz	rock		ΦEvc_g																	
23190010	15					SW	NW	19	8	1	E	Cowlitz	rock		ΦEva_g																	
23190011	15					SE	NE	20	8	1	E	Cowlitz	rock		ΦEva_g																	
23190012	15					NW	NE	21	8	1	E	Cowlitz	rock		$M\Phi vb$																	
23190004	15					NW	SE	25	8	1	E	Cowlitz	rock		ΦEva_g																	
23190005	15					SW	SE	25	8	1	E	Cowlitz	rock		ΦEva_g																	
23190009	15					NE	SW	27	8	1	E	Cowlitz	rock		ΦEva_g																	
23190008	15					SW	NE	28	8	1	E	Cowlitz	rock		ΦEva_g																	
23190007	15					NW	SW	29	8	1	E	Cowlitz	rock		ΦEva_g																	
23180002	18	11842	N-189		Zimmerly Rock Products	NW	NW	30	8	1	W	Cowlitz	rock		ΦEva_g		50			20		10	0.20	26	36	2.5						
23190006	15					NE	NW	30	8	1	E	Cowlitz	rock		ΦEva_g																	
23180008	15		N-24		Coweeman Crushing Co.		E	31	8	1	W	Cowlitz	gravel		Qa		80			5		2	0.03						2	84	14	2.6
23180001	18	10516	N-89	Coweeman quarry	DeRosier Trucking	SE	SW	32	8	1	W	Cowlitz	rock		ΦEva_g		500			70.56		10	0.02	19.4	66	2.69	55					16
23190001	15					SE	NW	32	8	1	E	Cowlitz	rock		ΦEva_g																	
23190002	15					SW	SW	33	8	1	E	Cowlitz	rock		ΦEva_g																	
23190003	15					NE	NW	33	8	1	E	Cowlitz	rock		ΦEva_g																	
23170048	18	11333			Fiorito Brothers	NW	SW	2	8	2	W	Cowlitz	gravel		Qa	>	40			12		0	0.00									
23170046	18	11706	N-87		Richard A. DeRosier	SE	SE	3	8	2	W	Cowlitz	gravel		Qa		30			14		0	0.00				36	62				32
23170050	18	11307	N-166		Homer L. Vance and Dick DeRosier	SE	NE	3	8	2	W	Cowlitz	gravel		Qa	>	24			12		1.5	0.06				90					1.8
23170052	18	12477			Richard A. DeRosier	NE	NE	3	8	2	W	Cowlitz	gravel		Qa	>	55			6		0	0.00									
23170038	18	11122	N-167		Jonathan E. Nichols	W	SE	4	8	2	W	Cowlitz	rock	basalt	Mv_g		50	0.15		10		1.5	0.03	19.7	88	2.79						
23170037	16	10672	N-110		Rex Gardner	SW	SE	6	8	2	W	Cowlitz	rock		Mv_g		40			10		5	0.13	27.6		2.74						
23170041	16	12337			Ronald J. Brown, Jr.	NE	SW	11	8	2	W	Cowlitz	dredge spoils		Qa	>	14	0.15		7.5		14	1.00									
23170034	18	12515			Ostrander Rock & Construction Co., Inc.	SW	NW	14	8	2	W	Cowlitz	dredge spoils		Qa		20			14		0	0.00									
23170035	16	12425		Johnson pit	J. L. Stordahl	NW	NW	14	8	2	W	Cowlitz	dredge spoils		Qa		12	0.1		15												
23170036	15					NE	NW	14	8	2	W	Cowlitz	gravel		Qa																	

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23200007	15					SW	NW	15	8	2	E	Cowlitz	rock		ΦEva_g																	
23170023	18	12220			Hilding C. Gerlund	NW	SE	22	8	2	W	Cowlitz	dredge spoils		Evb_{gr}		15			20		0	0.00									
23170028	21	11315	N-120		Peter Kiewit Sons', Inc.	SE	SE	23	8	2	W	Cowlitz	gravel		QRc_t	>	80	0.4		22		3	0.04				51	74	0	76	24	10
23200006	15					NE	SW	27	8	2	E	Cowlitz	rock		ΦEva_g																	
23170017	16	10641			Leffert Construction	SE	NE	29	8	2	W	Cowlitz	gravel		Qa?					1												
23200005	15					NE	NE	29	8	2	E	Cowlitz	gravel		Qa																	
23200001	15					NE	SE	33	8	2	E	Cowlitz	rock		ΦEva_g																	
23200002	15					SW	SE	35	8	2	E	Cowlitz	rock		ΦEva_g																	
23200003	15					NE	NW	35	8	2	E	Cowlitz	rock		ΦEva_g																	
23200004	15					SE	NE	35	8	2	E	Cowlitz	rock		ΦEva_g																	
23210034	15					NW	NW	1	8	3	E	Cowlitz	rock		Φva_1																	
23210035	15					NW	SE	1	8	3	E	Cowlitz	rock		Φva_1																	
23210033	15					SE	NE	2	8	3	E	Cowlitz	rock		Φva_1																	
23210031	15						SE	3	8	3	E	Cowlitz	rock		Φva_1																	
23210032	15					SE	NE	3	8	3	E	Cowlitz	rock		Φva_1																	
23210028	15					NW	SE	4	8	3	E	Cowlitz	rock		ΦEva_g																	
23210029	15					NE	SE	4	8	3	E	Cowlitz	rock		ΦEva_g																	
23210030	15					NE	SE	4	8	3	E	Cowlitz	rock		ΦEva_g																	
23210024	15					SE	NW	5	8	3	E	Cowlitz	rock		ΦEva_g																	
23210025	15					NE	NW	5	8	3	E	Cowlitz	rock		ΦEva_g																	
23210026	15					SE	NW	5	8	3	E	Cowlitz	rock		ΦEva_g																	
23210027	15					SE	SW	5	8	3	E	Cowlitz	rock		ΦEva_g																	
23210020	15					SE	SE	8	8	3	E	Cowlitz	rock		ΦEva_g																	
23210021	15					SE	NW	9	8	3	E	Cowlitz	rock		ΦEva_g																	
23210022	15					NE	NE	9	8	3	E	Cowlitz	rock		ΦEva_g																	
23210023	15					SE	SW	11	8	3	E	Cowlitz	rock		Φva_1																	
23210014	15					SE	SE	14	8	3	E	Cowlitz	rock		Φva_1																	
23210015	15					SE	SE	14	8	3	E	Cowlitz	rock		Φva_1																	
23210019	15					NE	NW	14	8	3	E	Cowlitz	rock		Φva_1																	
23210013	15					SW	SE	15	8	3	E	Cowlitz	rock		ΦEva_g																	
23210018	15					NE	NW	15	8	3	E	Cowlitz	gravel		$Qapt_e$																	
23210017	15					NW	NW	16	8	3	E	Cowlitz	rock		ΦEva_g																	
23210012	15					SE	SE	17	8	3	E	Cowlitz	rock		ΦEva_g																	
23210016	15					SE	NE	17	8	3	E	Cowlitz	rock		ΦEva_g																	
23210009	15					SE	SE	19	8	3	E	Cowlitz	rock		ΦEva_g																	
23210010	15					NE	NE	23	8	3	E	Cowlitz	rock		Φva_1																	
23210011	15					NW	NW	24	8	3	E	Cowlitz	rock		Φva_1																	

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23170013	16	10666	N-113		Columbia West Materials	NE	NE	25	8	3	W	Cowlitz	rock		Evb_{gr}/Qls		20			10		14	0.70	11.9		2.84						8
23210008	15					NW	SE	25	8	3	E	Cowlitz	rock		Φvc_1																	
23210006	15					SE	SW	26	8	3	E	Cowlitz	rock		ΦEva_g																	
23210007	15					NE	SW	26	8	3	E	Cowlitz	rock		ΦEva_g																	
23210005	15					NW	NW	28	8	3	E	Cowlitz	rock		ΦEva_g																	
23210004	15					NE	NW	29	8	3	E	Cowlitz	rock		ΦEva_g																	
23210002	15					NW	SW	30	8	3	E	Cowlitz	rock		ΦEva_g																	
23210003	15					NE	SE	30	8	3	E	Cowlitz	rock		ΦEva_g																	
23210001	15					NE	SW	36	8	3	E	Cowlitz	rock		ΦEva_g																	
23220016	15					SW	NW	5	8	4	E	Cowlitz	rock		Φva_1																	
23220011	15					SE	SE	8	8	4	E	Cowlitz	rock		Φva_1																	
23220012	15					SE	SW	9	8	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220009	15					SE	SE	14	8	4	E	Cowlitz	rock		$M\Phi vc_2$?																	
23220015	16			Hemlock Pass	U.S. Forest Svc., Gifford Pinchot National Forest	NW	NW	14	8	4	E	Cowlitz	rock		$M\Phi vc_2$?																	
23220014	15					NE	NE	15	8	4	E	Cowlitz	rock		$M\Phi vc_2$?																	
23220013	15					NW	NE	16	8	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220006	15			Fossil	U.S. Forest Svc., Gifford Pinchot National Forest	NE	NE	20	8	4	E	Cowlitz	rock		Φva_1																	
23220007	16			Woolly Rock	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SW	21	8	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220008	15			Goat Mountain	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SW	22	8	4	E	Cowlitz	rock		Qida																	
23220010	16			N-847	U.S. Forest Svc., Gifford Pinchot National Forest	NE	NW	24	8	4	E	Cowlitz	rock		$M\Phi vc_2$?																	
23220005	15			Goat Marsh	U.S. Forest Svc., Gifford Pinchot National Forest	NW	NE	26	8	4	E	Cowlitz	rock		$M\Phi vc_2$?																	
23220004	15			N831-C	U.S. Forest Svc., Gifford Pinchot National Forest	SW	NW	28	8	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220001	16			Cinder Cone quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NE	SE	32	8	4	E	Cowlitz	rock		Qida																	
23220002	15			Kalama	U.S. Forest Svc., Gifford Pinchot National Forest	SE	NW	33	8	4	E	Cowlitz	gravel		Qvl																	

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23230001	16			Ash Ash	U.S. Forest Svc., Gifford Pinchot National Forest	SE	NW	32	8	5	E	Skamania	gravel		Qvl																	
23230002	15			Ridge quarry	U.S. Forest Svc., Gifford Pinchot National Forest	SW	NE	34	8	5	E	Skamania	rock		Mid																	
23240008	16			Skyline pit	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SW	2	8	6	E	Skamania	rock		Mva_s																	
23240006	15			Dike quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NW	NW	3	8	6	E	Skamania	rock		Mva_s																	
23240007	16			Lookout quarry	U.S. Forest Svc., Gifford Pinchot National Forest	SW	SW	3	8	6	E	Skamania	rock		Mva_s																	
23240005	16			806-4A quarry	U.S. Forest Svc., Gifford Pinchot National Forest	SW	NE	4	8	6	E	Skamania	rock		$MΦvt_3$																	
23240004	15					NW	NW	24	8	6	E	Skamania	rock		$MΦvt_3$																	
23240002	15			Mudflow Borrow	U.S. Forest Svc., Gifford Pinchot National Forest	NW	NW	31	8	6	E	Skamania	gravel		Qvl																	
22190012	15					SW	SE	2	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190013	15					SE	SE	2	9	1	E	Cowlitz	gravel		Qvl																	
22190014	15					E	NE	2	9	1	E	Cowlitz	gravel		Qvl																	
22190011	15					NW	SE	4	9	1	E	Cowlitz	rock		Mc_w																	
22190006	15					NW	NW	7	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190007	15					SE	NW	7	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190008	15					SE	NW	8	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190009	15					NW	NE	9	9	1	E	Cowlitz	rock		Mc_w																	
22190010	15					NE	NE	11	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22180004	15					SE	NE	15	9	1	W	Cowlitz	rock		$ΦEvc_g$																	
22190003	15					SE	SE	15	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190005	15					SW	SW	15	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190004	15					SE	NE	16	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22190002	15					SW	SW	17	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22180002	15					SW	NE	18	9	1	W	Cowlitz	rock		$ΦEvc_g$																	
22180003	15					NW	SE	18	9	1	W	Cowlitz	rock		$ΦEvc_g$																	
23190022	15					NE	SE	19	9	1	E	Cowlitz	rock		$ΦEva_g$																	
22180001	15					NW	NE	22	9	1	W	Cowlitz	rock		$ΦEvc_g$																	
22190001	15					SW	NW	22	9	1	E	Cowlitz	rock		$ΦEva_g$																	
23190023	15					SW	NE	22	9	1	E	Cowlitz	rock		$ΦEva_g$																	
23190024	15					NW	SE	22	9	1	E	Cowlitz	rock		$ΦEva_g$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY											
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
23190025	15					NW	SW	23	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
23190021	15					NW	NE	26	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
23190020	15					SW	SE	27	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
23190018	15					SE	SW	28	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
23190017	15					SW	SE	29	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
23190019	15					NW	NE	34	9	1	E	Cowlitz	rock		ΦEva$_{g}$																	
22200009	15					SE	NW	1	9	2	E	Cowlitz	rock		Φva$_{1}$																	
22170021	21	11090	N-141		Peter Kiewit Co.	W	SW	2	9	2	W	Cowlitz	gravel		Qa		30	0.2	0.2	10		5	0.17	41.4	78	2.53	79	68				3
22170084	21					NW	SW	2	9	2	W	Cowlitz	gravel		Qapt$_{e}$																	
22170011	15					NE	SW	3	9	2	W	Cowlitz	gravel		Qa																	
22170013	21	11342	N-146		Gordon Ball Inc.	SE	NW	3	9	2	W	Cowlitz	gravel		Qa		34		0.55	10		1.5	0.04				80					4
22170014	18	12205			Carl A. Lang	NE	SE	3	9	2	W	Cowlitz	dredge spoils		Qa		18			20		1.5	0.08									
22170015	16	11213	N-31		Peter Kiewit Co.	SE	SE	3	9	2	W	Cowlitz	gravel		Qa		30	0.03	0.7	30		5	0.17	54	69	2.56	86	64	15	52	33	4.6
22200005	15					W	SW	7	9	2	E	Cowlitz	rock		Φva$_{1}$																	
22200006	15					SE	SE	9	9	2	E	Cowlitz	rock		Φvc$_{1}$																	
22200007	15					NE	SW	11	9	2	E	Cowlitz	rock		Φva$_{1}$																	
22200008	15					NW	SE	11	9	2	E	Cowlitz	rock		Φva$_{1}$																	
22180005	16	12194			Lyle Dahlman	SE	SE	12	9	2	W	Cowlitz	rock		ΦEvc$_{g}$		100			5		8	0.08									
22170008	16	12133	N-158		CMS Rock Quarries	SW	SW	13	9	2	W	Cowlitz	rock		ΦEvc$_{g}$		125			8.4		2	0.02	23	56	2.71						
22170009	16	12299			Gilnett Construction Co.	SW	SW	13	9	2	W	Cowlitz	rock		Evb$_{gr}$		125			4		2	0.02									
22170010	16	12113	N-159		M. A. Segale	NE	SW	13	9	2	W	Cowlitz	rock		ΦEvc$_{g}$		100	0.15		2.3		1	0.01	49.7	4	2.23						
22210003	15					SE	SE	13	9	2	E	Cowlitz	rock		Φva$_{1}$																	
22170002	16	11693	N-51		Westside Construction	SE	NW	15	9	2	W	Cowlitz	gravel		Qa		20	1.5		5		3	0.15							11	53	5
22170003	16	12468			Cowlitz County	SE	NW	15	9	2	W	Cowlitz	dredge spoils		Qa			0.025		1		0										
22170004	16	10735	N-3	Whittle Lake	Cowlitz County	NE	NW	15	9	2	W	Cowlitz	gravel		Qa		40			16		1	0.03	46.9	74	2.52	89	77	8	60	32	4
22170005	21	11220			Howard Carson	SW	NE	15	9	2	W	Cowlitz	gravel		Qa		12	0.5		24		0	0.00									
22170006	16	12457			City of Castle Rock	NW	NE	15	9	2	W	Cowlitz	dredge spoils		Qa	>	20		0.06	1		0	0.00									
22200004	15					SW	NE	18	9	2	E	Cowlitz	rock		Φvc$_{1}$																	
22200001	15					NW	NW	19	9	2	E	Cowlitz	rock		ΦEva$_{g}$																	
22200002	15					NW	NE	21	9	2	E	Cowlitz	rock		Φvc$_{1}$																	
22200003	15		N-164		Weyerhaeuser	SW	NW	22	9	2	E	Cowlitz	rock		ΦEva$_{g}$									55.2	79	2.45	70					13.7
23170069	16	12204			Jesse Amos	S	SW	23	9	2	W	Cowlitz	dredge spoils		Qa		21	0.067		7		0	0.00									
23170067	16	11284	N-101		Peter Kiewit Co.	NW	SW	25	9	2	W	Cowlitz	rock		Evb$_{gr}$		50	0.1		5.5		3	0.06		46	2.62						
23170068	16	12099			Richard DeRosier	NW	SE	25	9	2	W	Cowlitz	rock		Evb$_{gr}$		40			5		6	0.15									

IDENTIFIER						LOCATION							RESERVES										QUALITY									
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
23170096	21					E	NW	26	9	2	W	Cowlitz	gravel		Qa																	
23200015	15					NW	SW	26	9	2	E	Cowlitz	rock		ΦEva_g																	
23170061	16	12174			Capital Development Co.	SW	NW	29	9	2	W	Cowlitz	rock		Evb_{gr}?		100	0.5		5		4	0.04									
23200009	15					NW	NW	31	9	2	E	Cowlitz	rock		ΦEva_g																	
23170056	16	12144			SWR Rock Products	NW	SE	32	9	2	W	Cowlitz	rock		Evb_{gr}		160	0.5		4		8	0.05									
23200010	15					SE	NW	34	9	2	E	Cowlitz	rock		ΦEva_g																	
23200011	15					SW	NW	35	9	2	E	Cowlitz	rock		ΦEva_g																	
23200012	15					SE	NE	35	9	2	E	Cowlitz	rock		ΦEva_g																	
23200013	15					SW	SW	36	9	2	E	Cowlitz	rock		ΦEva_g																	
23200014	15					SW	NE	36	9	2	E	Cowlitz	rock		ΦEva_g																	
22220009	15					SW	NE	1	9	3	E	Cowlitz	rock		Φvc_1																	
22210030	15					SW	NW	4	9	3	E	Cowlitz	rock		Φvc_1																	
22210031	15					SE	SE	4	9	3	E	Cowlitz	rock		Φvc_1																	
22210029	15					NE	NE	5	9	3	E	Cowlitz	rock		Φvc_1																	
22210028	15					SW	SW	6	9	3	E	Cowlitz	rock		Φva_1																	
22210016	15					NW	SE	7	9	3	E	Cowlitz	rock		Φva_1																	
22210017	15					SW	SW	8	9	3	E	Cowlitz	gravel		$Qapt_e$																	
22210018	15					W	NW	8	9	3	E	Cowlitz	gravel		$Qapt_e$																	
22210019	15					NW	SE	8	9	3	E	Cowlitz	gravel		$Qapt_e$																	
22210020	15					NW	NE	9	9	3	E	Cowlitz	rock		Φvc_1																	
22210021	15					NW	NE	9	9	3	E	Cowlitz	rock		Φvc_1																	
22210022	15					SE	NE	9	9	3	E	Cowlitz	rock		Φvc_1																	
22210023	15					NE	NE	9	9	3	E	Cowlitz	rock		Φvc_1																	
22210024	15					NE	SW	10	9	3	E	Cowlitz	rock		Φvc_1																	
22210025	15					NW	SW	11	9	3	E	Cowlitz	rock		MΦian																	
22210026	15					NW	NW	11	9	3	E	Cowlitz	rock		Φvc_1																	
22210027	15					NE	NW	11	9	3	E	Cowlitz	rock		Φvc_1																	
22210014	15					SW	SW	13	9	3	E	Cowlitz	rock		Φva_1																	
22210015	15					NE	NW	13	9	3	E	Cowlitz	rock		Φva_1																	
22220001	15					NW	SE	13	9	3	E	Cowlitz	rock		Φva_1																	
22220002	15					NW	SE	13	9	3	E	Cowlitz	rock		Φva_1																	
22210013	15					NW	SE	14	9	3	E	Cowlitz	rock		Φva_1																	
22210010	15					SW	NE	15	9	3	E	Cowlitz	rock		Φva_1																	
22210011	15					NW	NE	15	9	3	E	Cowlitz	rock		Φva_1																	
22210012	15					SE	SE	15	9	3	E	Cowlitz	rock		Φva_1																	
22210007	15					NE	SW	16	9	3	E	Cowlitz	rock		Φva_1																	
22210008	15					E	NE	16	9	3	E	Cowlitz	rock		Φva_1																	
22210009	15					NE	SE	16	9	3	E	Cowlitz	rock		Φva_1																	

IDENTIFIER						LOCATION							RESERVES										QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
22210004	15					SW	NW	18	9	3	E	Cowlitz	rock		Φva_1																	
22210005	15					SW	NW	18	9	3	E	Cowlitz	rock		Φva_1																	
22210006	15					SE	NW	18	9	3	E	Cowlitz	rock		Φva_1																	
22210001	15					SE	NE	19	9	3	E	Cowlitz	rock		Φva_1																	
23210050	15					SE	SW	19	9	3	E	Cowlitz	rock		Φvc_1																	
23210051	15					SW	NE	20	9	3	E	Cowlitz	rock		Φva_1																	
23210052	15					NW	SE	20	9	3	E	Cowlitz	rock		Φva_1																	
23210053	15					SE	SE	21	9	3	E	Cowlitz	rock		Φva_1																	
23210054	15					NE	SE	21	9	3	E	Cowlitz	rock		Φva_1																	
22210002	15					NE	NW	22	9	3	E	Cowlitz	rock		Φva_1																	
23210055	15					NE	SW	23	9	3	E	Cowlitz	rock		Φva_1																	
23210056	15					SE	SE	23	9	3	E	Cowlitz	rock		$M\Phi vt_3$																	
23210045	15					NW	NE	25	9	3	E	Cowlitz	rock		ΦEva_g																	
23210046	15					NE	NE	25	9	3	E	Cowlitz	rock		ΦEva_g																	
23210049	15					NE	NE	27	9	3	E	Cowlitz	rock		Φvc_1																	
23210048	15					NW	NE	28	9	3	E	Cowlitz	rock		Φvc_1																	
23210047	15					SW	SE	30	9	3	E	Cowlitz	rock		ΦEva_g																	
23210036	15					NW	SE	31	9	3	E	Cowlitz	rock		ΦEva_g																	
23210037	15					SW	NE	31	9	3	E	Cowlitz	rock		ΦEva_g																	
23210038	15					NW	SE	31	9	3	E	Cowlitz	rock		ΦEva_g																	
23210039	15					NW	NE	31	9	3	E	Cowlitz	rock		ΦEva_g																	
23210040	15					NW	NW	32	9	3	E	Cowlitz	rock		ΦEva_g																	
23210041	15					SW	NW	35	9	3	E	Cowlitz	rock		Φva_1																	
23210042	15					SW	SW	35	9	3	E	Cowlitz	rock		Φva_1																	
23210043	15					SW	NE	35	9	3	E	Cowlitz	rock		Φva_1																	
22230001	16					NW	SE	1	9	4	E	Cowlitz	rock		MΦvb																	
22220010	15					NW	SW	6	9	4	E	Cowlitz	rock		Evb_{gr}																	
22220006	15					SE	SE	9	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
22220007	15					NW	NW	15	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
22220005	15					SW	NW	17	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
22220003	15					SW	NE	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
22220004	15					NE	NE	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220024	15					SW	SW	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220025	15					SE	NW	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220026	15					SW	SE	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220027	15					SW	NE	19	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220028	15					NW	SW	21	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
22220008	15					NW	NW	22	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	
23220021	15					NE	NW	29	9	4	E	Cowlitz	rock		$M\Phi vt_3$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
23220022	15					SW	SE	29	9	4	E	Cowlitz	rock		MΦvt$_3$																	
23220023	15					NE	NE	29	9	4	E	Cowlitz	rock		MΦvt$_3$																	
23220017	15					SW	NW	31	9	4	E	Cowlitz	gravel		Qvc																	
23220018	15					NW	SW	31	9	4	E	Cowlitz	rock		Φva$_1$																	
23220019	15					NE	SW	33	9	4	E	Cowlitz	rock		MΦvt$_3$																	
23220020	15					NW	NE	33	9	4	E	Cowlitz	rock		MΦvt$_3$																	
22230003	16					SW	NW	5	9	5	E	Skamania	rock		MΦvc$_2$																	
22230004	16					NE	NW	5	9	5	E	Skamania	rock		MΦvc$_2$																	
22230005	16					NE	NW	5	9	5	E	Skamania	rock		MΦvb																	
22230002	16					SE	NE	6	9	5	E	Skamania	rock		MΦvc$_2$																	
22240001	16			Independence West quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NW	SE	7	9	6	E	Skamania	rock		MΦva																	
22240003	16			Curtis Lake quarry	U.S. Forest Svc., Gifford Pinchot National Forest	SW	NE	10	9	6	E	Skamania	rock		MΦva																	
22240002	15			Way quarry	U.S. Forest Svc., Gifford Pinchot National Forest	NE	NW	16	9	6	E	Skamania	rock		MΦvc$_2$																	
21190001	15					N	NW	2	10	1	E	Cowlitz	rock		ΦEva$_g$																	
21190002	15		N-161			NW	NE	2	10	1	E	Cowlitz	rock		ΦEva$_g$									26.4	24							
22190027	15		N-23		Taylor	SW	SE	10	10	1	E	Cowlitz	gravel		Qvl									20.4			64				100	12
22180019	15		N-181		Weyerhaeuser	SE	NW	11	10	1	W	Cowlitz	gravel		Qvl			0.1									81					5.3
22190026	16	11823			Weyerhaeuser	SE	SE	11	10	1	E	Cowlitz	rock		Φvc$_1$		40		0.075	6.4		5	0.13									
22190028	15		N-48		Rex Gardner	SW	NW	12	10	1	E	Cowlitz	gravel		Qvl									33	6	2.51			19	46	35	
22200033	16	11631		Cook pit	Weyerhaeuser	SW	NE	12	10	1	E	Cowlitz	gravel	pumice	Mc$_w$		45	0.035		5		1	0.02									
22190025	16	12201	N-94			NW	NE	14	10	1	E	Cowlitz	rock		ΦEva$_g$		8	0		6		0	0.00	21.8		2.68						
22190024	21	11100	N-179		Weyerhaeuser	SE	NW	15	10	1	E	Cowlitz	gravel		Qvl		30	0.15		10		0	0.00	62	78	2.5	81					5.3
22180021	22	12959		Phipps quarry	Northwest Rock, Inc.	NE	SE	17	10	1	W	Cowlitz	rock	andesite	ΦEva$_g$		130	8	17	178	5	20	0.15									
22190023	15					NE	NE	18	10	1	E	Cowlitz	rock		ΦEn$_t$																	
22180013	15					NW	NE	19	10	1	W	Cowlitz	rock		ΦEn$_t$																	
22190019	16	12237	N-163		M. A. Segale	NW	NE	19	10	1	E	Cowlitz	rock		Qls		40		0.016	1.5		2	0.05	25	79	2.65						
22180014	15					NW	NW	20	10	1	W	Cowlitz	rock		ΦEn$_t$																	
22180015	15					SW	SE	20	10	1	W	Cowlitz	gravel		Qa																	
22180016	15					SE	SE	20	10	1	W	Cowlitz	rock		ΦEn$_t$																	
22180017	15					SE	SE	20	10	1	W	Cowlitz	rock		ΦEn$_t$																	
22180018	15					SE	SW	20	10	1	W	Cowlitz	rock		ΦEn$_t$																	
22190020	21	12219			WSDOT	NW	NE	20	10	1	E	Cowlitz	dredge spoils		ΦEva$_g$			0.985		13		0		49	2.72							
22190021	16	10826	N-139		Rex Gardner	NE	SE	22	10	1	E	Cowlitz	rock		Φva$_1$		50			10		5	0.10	17	61	2.7						

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22190022	15					NW	SW	24	10	1	E	Cowlitz	rock		Φva_1																	
22190018	15					NE	NE	26	10	1	E	Cowlitz	rock		Φva_1																	
22180009	15					SW	SW	28	10	1	W	Cowlitz	rock		ΦEva_g																	
22180008	15					SE	SE	29	10	1	W	Cowlitz	rock		ΦEva_g																	
22190017	16	10755			G. D. Dennis	NW	NE	30	10	1	E	Cowlitz	gravel		Qvl		55			2.5		2.5	0.05									
22190015	15					N	NE	34	10	1	E	Cowlitz	rock		Φva_1																	
22190016	15					NW	NE	35	10	1	E	Cowlitz	rock		Φva_1																	
22180007	16	10106			Silver Lake Flood District	SE	NW	36	10	1	W	Cowlitz	gravel		Qvl		25			5		1	0.04									
22200039	16	12608	N-183			SE	SE	3	10	2	E	Cowlitz	rock		ΦEva_g		100	0.117		2		10	0.10	21.3	53	2.69						
21200001	15					SE	NW	6	10	2	E	Cowlitz	rock		ΦEva_g																	
22200034	15					SE	SW	8	10	2	E	Cowlitz	rock		Φva_1																	
22200035	16	11844	N-19			SW	NE	8	10	2	E	Cowlitz	rock		Φva_1		60	0.02		1		6	0.10									
22200036	16	12241	N-47		M. A. Segale	W	NE	8	10	2	E	Cowlitz	rock		Φva_1		60		0.076	2		10	0.17	31.1	1	2.52						
22200037	21	12240	N-20			NW	NE	8	10	2	E	Cowlitz	dredge spoils		Qvl				0.097	13		0		23.6								
22200038	15					NW	NE	9	10	2	E	Cowlitz	gravel		Qvl																	
22200040	15					SW	SE	11	10	2	E	Cowlitz	rock		ΦEva_g																	
22200032	15					NE	NW	15	10	2	E	Cowlitz	rock		Φvc_1																	
22170037	15					SE	NW	16	10	2	W	Cowlitz	rock		Evb_{gr}																	
22170044	15					SW	SW	16	10	2	W	Cowlitz	rock		Evb_{gr}																	
22170045	16	10915			Nick Askins	NE	SW	16	10	2	W	Cowlitz	rock		Evb_{gr}		6			10		3	0.50									
22170047	16	12119	N-160		Segale	NW	NE	16	10	2	W	Cowlitz	rock		Evb_{gr}		110	0.4		9		1	0.01	17	80	2.91						
22170048	15	12741			Craig Opsahl	NW	NE	16	10	2	W	Cowlitz	rock	basalt	Evb_{gr}	>	130	1		6.9			0.00									
22170090	18	12933	N-92	Barnes Drive quarry	Harold Sorensen Trucking, Inc.		NE	16	10	2	W	Cowlitz	rock	basalt	Evb_{gr}		100	1.6	3.8	30.6	5	10	0.10	17	53	2.79						
22170052	21	12211	N-11		M. A. Segale	SE	SE	16	10	2	W	Cowlitz	rock		Evb_{gr}		125			25		2	0.02	18.8	56	2.81						
22200030	15					NW	NW	18	10	2	E	Cowlitz	rock		Φva_1																	
22200031	15					SW	SE	18	10	2	E	Cowlitz	rock		Φva_1																	
22200019	15					NW	NE	19	10	2	E	Cowlitz	rock		Φva_1																	
22170038	15					NW	NE	20	10	2	W	Cowlitz	rock		Evb_{gr}																	
22200020	15					SE	SW	20	10	2	E	Cowlitz	rock		Φva_1																	
22200021	15					NW	NW	21	10	2	E	Cowlitz	rock		Φva_1																	
22170042	16	10787	N-142		Cowlitz County	NE	SW	22	10	2	W	Cowlitz	rock		Evb_{gr}		100	0.015		15		3	0.03	22.9	24	2.79						
22200022	15					NE	SE	22	10	2	E	Cowlitz	gravel		Qvl																	
22170036	18	12919			Cowlitz County Public Works	SE	SW	23	10	2	W	Cowlitz	sand		Qvl	>	87			75												
22180010	15					SW	NE	24	10	2	W	Cowlitz	rock		Mc_w																	
22180011	15					NE	SE	24	10	2	W	Cowlitz	rock		ΦEvc_g																	
22180012	15					SE	SE	24	10	2	W	Cowlitz	rock		ΦEvc_g																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	*Stripping ratio*	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
22210051	15					NW	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210052	15					NW	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210053	15					SE	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210054	15					NW	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210055	15					NE	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210056	15					SE	NE	24	10	2	E	Cowlitz	rock		Φva_1																	
22210037	16	11091		Camp Baker Rock pit	Weyerhaeuser	NW	NE	25	10	2	E	Cowlitz	rock		Φvc_1		100	0.303		4		1	0.01									
22210038	16	12621	N-8			NE	NE	25	10	2	E	Cowlitz	rock		Φvc_1		70	0.024		7.7		10	0.14									
22170030	15	12093			Glen A. Paget	N	NE	28	10	2	W	Cowlitz	rock		Evb_{gr}		10			4		0.5	0.05									
22200017	15					SW	SW	28	10	2	E	Cowlitz	rock		Φva_1																	
22200018	15					SE	NE	28	10	2	E	Cowlitz	rock		Φva_1																	
22170028	15					NW	NW	30	10	2	W	Cowlitz	rock		Evb_{gr}																	
22170029	15					NW	NE	30	10	2	W	Cowlitz	rock		Evb_{gr}																	
22200013	15					SE	SW	30	10	2	E	Cowlitz	rock		Φva_1																	
22200014	15					SE	SW	30	10	2	E	Cowlitz	rock		Φva_1																	
22200015	15					SW	SE	30	10	2	E	Cowlitz	rock		Φva_1																	
22200016	15					S	NE	30	10	2	E	Cowlitz	rock		Φva_1																	
22200010	15					NW	SE	31	10	2	E	Cowlitz	rock		Φva_1																	
22200011	15					W	NW	33	10	2	E	Cowlitz	rock		Φva_1																	
22170025	15					NE	SW	34	10	2	W	Cowlitz	gravel		Qa																	
22200012	15					SW	SE	34	10	2	E	Cowlitz	rock		Φva_1																	
22180006	16	12109	N-21		M. A. Segale	SE	SE	36	10	2	W	Cowlitz	rock		ΦEvc_g		40			2		2	0.05	23.2	20	2.56						
21220001	15					SW	NE	1	10	3	E	Cowlitz	gravel		$Qapt_h$																	
22210074	15					SE	SW	1	10	3	E	Cowlitz	rock		Φvc_1																	
22210067	15					SW	NE	9	10	3	E	Cowlitz	rock		ΦEva_g																	
22210068	15					NW	SW	10	10	3	E	Cowlitz	rock		ΦEva_g																	
22210069	15					NW	NE	10	10	3	E	Cowlitz	rock		ΦEva_g																	
22210070	15					NE	SW	11	10	3	E	Cowlitz	rock		Φvc_1																	
22210071	15					SE	SW	11	10	3	E	Cowlitz	rock		Φvc_1																	
22210072	15					SW	NE	11	10	3	E	Cowlitz	rock		Φvc_1																	
22210073	15					NE	NW	12	10	3	E	Cowlitz	rock		Φvc_1																	
22220054	15					SE	NW	12	10	3	E	Cowlitz	rock		Φvc_1																	
22220055	15					NW	SE	12	10	3	E	Cowlitz	rock		Φvc_1																	
22220056	15					SW	SE	12	10	3	E	Cowlitz	rock		Φvc_1																	
22220057	15					SE	SE	12	10	3	E	Cowlitz	rock		Φvc_1																	
22220053	15					SW	SW	13	10	3	E	Cowlitz	gravel		$Qapt_h$																	
22210062	15					SW	NE	15	10	3	E	Cowlitz	rock		Φvc_1																	
22210063	15					NW	NE	15	10	3	E	Cowlitz	rock		Φvc_1																	
22210064	15					SW	NE	15	10	3	E	Cowlitz	rock		Φvc_1																	

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22210065	15					SE	SE	15	10	3	E	Cowlitz	rock		MΦian																	
22210066	15					SE	SE	15	10	3	E	Cowlitz	rock		MΦian																	
22210039	15					SE	SW	19	10	3	E	Cowlitz	rock		Φva_1																	
22210040	15					NE	SW	19	10	3	E	Cowlitz	rock		Φva_1																	
22210041	15					NW	SE	19	10	3	E	Cowlitz	rock		Φvc_1																	
22210057	15					NE	SW	19	10	3	E	Cowlitz	rock		Φva_1																	
22210058	15					NE	SW	19	10	3	E	Cowlitz	rock		Φva_1																	
22210059	15					NE	SE	22	10	3	E	Cowlitz	rock		Φvc_1																	
22210060	15					SW	NE	23	10	3	E	Cowlitz	rock		MΦian																	
22210061	15					NE	NE	23	10	3	E	Cowlitz	rock		MΦian																	
22210047	15					SE	SW	25	10	3	E	Cowlitz	rock		MΦian																	
22210048	15					NE	SW	25	10	3	E	Cowlitz	rock		MΦian																	
22210049	15					NW	NW	25	10	3	E	Cowlitz	rock		Φvc_1																	
22210050	15					NE	NW	25	10	3	E	Cowlitz	rock		Φvc_1																	
22220019	15					SW	SE	25	10	3	E	Cowlitz	rock		Φvc_1																	
22220020	15					SE	SE	25	10	3	E	Cowlitz	rock		Φvc_1																	
22210045	15					SE	SW	26	10	3	E	Cowlitz	rock		MΦian																	
22210046	15					SW	NE	26	10	3	E	Cowlitz	rock		MΦian																	
22210044	15					SW	SE	27	10	3	E	Cowlitz	rock		MΦian																	
22210043	16	12609	N-173		WSDOT	SW	NW	29	10	3	E	Cowlitz	rock	andesite	MΦian		80	0.048		1.85		10	0.13	17	26	2.74						
22210042	15					SE	NE	30	10	3	E	Cowlitz	rock		MΦian																	
22210032	15					NW	SW	32	10	3	E	Cowlitz	rock		Φvc_1																	
22210033	15					SW	SE	32	10	3	E	Cowlitz	rock		Φvc_1																	
22210034	15					SE	SE	32	10	3	E	Cowlitz	rock		Φvc_1																	
22210035	15					NE	NE	35	10	3	E	Cowlitz	rock		MΦian																	
22210036	15					NW	NW	36	10	3	E	Cowlitz	rock		MΦian																	
21220005	15					SE	NW	2	10	4	E	Cowlitz	rock		ΦEva_g																	
21220004	15					NE	NW	3	10	4	E	Cowlitz	rock		ΦEva_g																	
22220065	15					SE	SE	4	10	4	E	Cowlitz	rock		Φvc_1																	
21220003	15					SW	NE	5	10	4	E	Cowlitz	gravel		$Qapt_h$																	
21220002	15					SW	NW	6	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220058	15					SW	SW	7	10	4	E	Cowlitz	rock		MΦian																	
22220059	15					NE	NW	7	10	4	E	Cowlitz	rock		MΦian																	
22220060	15					NE	NW	7	10	4	E	Cowlitz	rock		MΦian																	
22220061	15					SW	NE	7	10	4	E	Cowlitz	rock		MΦian																	
22220062	15					NE	SW	8	10	4	E	Cowlitz	rock		Φvd_1																	
22220063	15					SE	NW	8	10	4	E	Cowlitz	rock		Φvd_1																	
22220064	15					SE	NW	9	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220066	15					NE	NE	9	10	4	E	Cowlitz	rock		Φvc_1																	

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22220067	15					NW	NW	10	10	4	E	Cowlitz	rock		Φvc_1																	
22220068	15					SE	NE	10	10	4	E	Cowlitz	rock		Φva_1																	
22220069	15					SW	NW	11	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220070	15					NE	SW	11	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220071	15					NE	SW	11	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220072	15					NW	SE	11	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220042	15					SE	SE	13	10	4	E	Cowlitz	rock		Φvc_1																	
22230008	16					SE	NE	13	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220051	15					NW	SW	14	10	4	E	Cowlitz	rock		Φva_1																	
22220052	21	12742	N-188		Washington Construction Co.	N	SW	14	10	4	E	Cowlitz	rock		Φva_1		150	0.4		5		10	0.07	15	55	2.68						
22220046	15					SE	NW	15	10	4	E	Cowlitz	rock		Φva_1																	
22220047	15					NW	SE	15	10	4	E	Cowlitz	rock		$M\Phi ian$																	
22220048	15					NE	NE	15	10	4	E	Cowlitz	rock		Φva_1																	
22220049	15					SE	NE	15	10	4	E	Cowlitz	rock		Φva_1																	
22220050	15					NE	SE	15	10	4	E	Cowlitz	rock		Φva_1																	
22220045	15					NE	SW	16	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220044	15					NE	NW	17	10	4	E	Cowlitz	rock		Φvc_1																	
22220043	15					SW	NE	18	10	4	E	Cowlitz	rock		$M\Phi ian$																	
22220031	15					SW	SE	19	10	4	E	Cowlitz	rock		Φvc_1																	
22220032	15					NE	SE	19	10	4	E	Cowlitz	rock		Φvc_1																	
22220033	15					SE	SE	19	10	4	E	Cowlitz	rock		$M\Phi ian$																	
22220034	15					NW	NE	19	10	4	E	Cowlitz	rock		Φvc_1																	
22220035	15					NW	NW	20	10	4	E	Cowlitz	rock		Φvc_1																	
22220036	15					NE	NW	21	10	4	E	Cowlitz	rock		Φvd_1																	
22220037	15		N-175			SE	SW	22	10	4	E	Cowlitz	rock	tuff	Φva_1									20.3	7	2.58						
22220038	15					SE	NW	22	10	4	E	Cowlitz	rock		Φva_1																	
22220039	15					NW	SE	22	10	4	E	Cowlitz	rock		Φva_1																	
22220040	15					NW	SE	23	10	4	E	Cowlitz	rock		$M\Phi vc_2$																	
22220041	15					SE	NW	24	10	4	E	Cowlitz	rock		$M\Phi vc_2$																	
22220030	15					NW	NE	28	10	4	E	Cowlitz	rock		$M\Phi ian$																	
22220021	15					NW	SE	30	10	4	E	Cowlitz	rock		Φvc_1																	
22220013	15					NE	NE	31	10	4	E	Cowlitz	rock		$M\Phi vc_2$																	
22220012	15					NW	SW	32	10	4	E	Cowlitz	rock		$M\Phi ian$																	
22220014	21	12606	N-182		Weyerhaeuser	N	NW	32	10	4	E	Cowlitz	rock		Φvc_1		150	2		17.1		7	0.05	17	81	2.7						
22220015	15					NE	NW	33	10	4	E	Cowlitz	rock		Φvc_1																	
22220016	15		N-184			NE	SE	33	10	4	E	Cowlitz	rock	andesite	$Qapt_h$									17.7	46	2.66						
22220011	15					SE	SW	35	10	4	E	Cowlitz	rock		$M\Phi vc_2$																	
22220017	15					SE	NE	35	10	4	E	Cowlitz	gravel		$Qapt_h$																	
22220018	15					SE	NE	35	10	4	E	Cowlitz	gravel		$Qapt_h$																	

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21230002	15					NW	NW	5	10	5	E	Skamania	rock		MΦvb																	
21230003	15					NE	SW	5	10	5	E	Skamania	rock		MΦvc$_2$																	
21230001	15					NE	NW	6	10	5	E	Skamania	rock		MΦvb																	
22230007	16					NW	NW	19	10	5	E	Skamania	rock		MΦvc$_2$																	
22230006	16					SE	NW	30	10	5	E	Skamania	rock		MΦvb																	
22240005	15					NW	NE	23	10	6	E	Skamania	rock		Qls																	
22240004	15					SW	NE	26	10	6	E	Skamania	rock		MΦvd$_3$																	
21180053	16	11669			Jack Keller	SE	SW	3	11	1	W	Lewis	gravel		Qa		30	1		12		2.5	0.08									
21180054	21	11363	L-202		WSDOT	SE	SE	3	11	1	W	Lewis	gravel		Qa		25		1	37		3	0.12	16	69	2.66	88		7	29	64	2
21180042	18	11516	L-148, L-233	Thompson Gravel pit	Robert J. Thompson	E	NE	9	11	1	W	Lewis	gravel		Qa		20			5		1.5	0.08	9	76	2.68	86		3	69	28	2
21180129	18	11894	L-233	Riverside pit	Robert J. Thompson	NW	NW	10	11	1	W	Lewis	gravel		Qa	>	30			30				9	76	2.68	86		3	69	28	2
21190010	15		L-260		Hugh Kalich	SW	SW	11	11	1	E	Lewis	rock		ΦEva$_g$									20	12	2.63						
21180130	15			Satcher pit	Knab Construction	E	SE	14	11	1	W	Lewis	gravel		Qapo																	
21190009	18	12892	L-259	Cedar Creek quarry	Harold Sorensen Trucking, Inc.	NW	NW	14	11	1	E	Lewis	rock		ΦEva$_g$		140	1	2.4	30.7	20	20	0.14	17.9	22	2.68						
21180033	18	11327			Lewis County Road Department	SW	NW	16	11	1	W	Lewis	gravel		Qao$_e$		20			20		3	0.15									
21180028	21					SW	SW	17	11	1	W	Lewis	gravel		Qa																	
21180032	18	11048	L-119	Toledo Sand and Gravel	Nick Askins	NE	NW	17	11	1	W	Lewis	gravel		Qa		25	0.16		90		2	0.08	17.1	63	2.63	80	65	0	67	33	3.1
21180017	18	12880	L-149	Bar O Ranch	Kathy Oberg	SE	NE	19	11	1	W	Lewis	gravel		Qa	>	30	0.3		27.4				12.4		2.65	92	79	33	50	17	1
21190007	15					SE	SW	21	11	1	E	Lewis	rock		Mc$_w$																	
21190004	15		L-264	Bones pit	Weyerhaeuser	SE	SW	28	11	1	E	Lewis	gravel		Qa									20.9	17							
21190005	15					NW	NE	28	11	1	E	Lewis	rock		ΦEva$_g$																	
21190006	15					SE	NE	28	11	1	E	Lewis	rock		ΦEn$_t$																	
21190003	15					SE	NW	35	11	1	E	Lewis	rock		ΦEva$_g$																	
21200013	15					SW	SE	2	11	2	E	Lewis	rock		ΦEvc$_g$																	
21200012	15					SW	SE	3	11	2	E	Lewis	rock		ΦEvc$_g$																	
21200011	15					NE	SE	6	11	2	E	Lewis	rock		Mc$_w$																	
21200010	15					SE	NE	7	11	2	E	Lewis	rock		ΦEvc$_g$																	
21170034	16	11418	L-224		WSDOT	NE	NW	12	11	2	W	Lewis	gravel		Qapo		40	0.144		12.5		2	0.05		6		2	32	8	40	52	24
21180301	22			Cowlitz Ridge pit	Wallace Sand and Gravel			13	11	2	W	Lewis	gravel		Qa		27	5.3	8.5	181.6	0	3	0.11									
21200009	15					NW	SW	13	11	2	E	Lewis	rock		ΦEva$_g$																	
21200008	15					SW	SW	15	11	2	E	Lewis	rock		ΦEvc$_g$																	
21200007	15					SE	NE	16	11	2	E	Lewis	rock		ΦEvc$_g$																	
21200006	15					SW	SE	17	11	2	E	Lewis	rock		ΦEva$_g$																	
21200005	15					SE	NW	20	11	2	E	Lewis	rock		ΦEva$_g$																	

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21170029	21	11577	L-237		S. D. Spencer and Sons	NE	SE	23	11	2	W	Lewis	gravel		Qa		16	0.3		35		2.5	0.16	20.6	41	2.63	91		0	80	20	1
21170030	16	11397	L-203, L-139		Peter Kiewit Co.	SW	NW	24	11	2	W	Lewis	gravel		Qa		15	0.225	0.5	27		5	0.33	13	46	2.66	72	78	33	43	24	5
21170014	18	11145	L-137		Wallace Brothers Construction, Inc.	SW	SW	27	11	2	W	Lewis	gravel		Qa		20	0.03		20		1	0.05	14.8	61	2.62	67	76	24	54	22	
21170016	16	11707			R. E. Enbody	NE	SE	27	11	2	W	Lewis	gravel		Qa		20			2		2.5	0.13									
21170017	18	12730	L-143		Donna Wallace	SE	SE	27	11	2	W	Lewis	gravel		Qa	>	50	0.111		20		12	0.24	10.2		2.66	4	83	73	23		
21200004	15					SE	NE	29	11	2	E	Lewis	rock		ΦEva$_g$																	
21200003	15					SW	NW	30	11	2	E	Lewis	rock		ΦEva$_g$																	
21200002	15					SE	SE	31	11	2	E	Lewis	rock		ΦEva$_g$																	
21170008	18	12715			Donna Wallace	SE	NW	35	11	2	W	Lewis	rock		ΦEvc$_g$	>	100			18		5	0.05									
21170012	16	10994	L-229	Farmer Brown pit	Weyerhaeuser	NE	NE	35	11	2	W	Lewis	rock		ΦEvc$_g$		20			40		1	0.05	21	49	2.62		48			100	
21220048	15					SE	SE	1	11	3	E	Lewis	gravel		Qapt$_h$																	
21210004	15					SW	SW	2	11	3	E	Lewis	rock		ΦEva$_g$																	
21210006	15					NE	SW	2	11	3	E	Lewis	rock		MΦian																	
21210007	15					NW	NE	2	11	3	E	Lewis	rock		MΦian																	
21210008	15					NW	NW	2	11	3	E	Lewis	rock		Φvc$_1$																	
21210001	15					NE	NE	3	11	3	E	Lewis	rock		ΦEva$_g$																	
21210002	15					SE	NE	3	11	3	E	Lewis	rock		ΦEva$_g$																	
21210003	15					NE	SW	3	11	3	E	Lewis	rock		ΦEva$_g$																	
21210005	15					NE	NE	3	11	3	E	Lewis	rock		ΦEva$_g$																	
21210022	15					SE	SW	14	11	3	E	Lewis	rock		ΦEva$_g$																	
21210021	15					SW	NW	23	11	3	E	Lewis	rock		ΦEva$_g$																	
21220032	15					SE	SE	24	11	3	E	Lewis	rock		ΦEva$_g$																	
21210016	15					SE	SE	25	11	3	E	Lewis	rock		ΦEva$_g$																	
21210019	15					SW	NW	25	11	3	E	Lewis	rock		Φvd$_1$																	
21210020	15					SE	SW	25	11	3	E	Lewis	rock		Φvd$_1$																	
21210018	15					SW	SE	26	11	3	E	Lewis	rock		ΦEva$_g$																	
21210017	15					NW	SW	30	11	3	E	Lewis	rock		ΦEva$_g$																	
21210009	15					NE	NW	35	11	3	E	Lewis	rock		ΦEva$_g$																	
21210010	15					SE	SE	35	11	3	E	Lewis	rock		MΦian																	
21210011	15					SW	SW	36	11	3	E	Lewis	rock		MΦian																	
21210012	15					SW	NW	36	11	3	E	Lewis	rock		MΦian																	
21210013	15					NW	SW	36	11	3	E	Lewis	rock		MΦian																	
21210014	15					NW	SW	36	11	3	E	Lewis	rock		MΦian																	
21210015	15					SE	SW	36	11	3	E	Lewis	rock		MΦian																	
21210024	15					SW	SE	36	11	3	E	Lewis	rock		Φvc$_1$																	
21220006	15					SW	SE	36	11	3	E	Lewis	rock		Φvc$_1$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
21220007	15					SW	SE	36	11	3	E	Lewis	rock		Φvc$_1$																	
21220049	15					NE	NW	5	11	4	E	Lewis	rock		ΦEva$_g$																	
21220047	15					N	NE	8	11	4	E	Lewis	rock		ΦEva$_g$																	
21230006	15					SE	SE	13	11	4	E	Lewis	rock		MΦvb																	
21220046	15					NW	NE	14	11	4	E	Lewis	rock		ΦEva$_g$																	
21220044	15					NW	NW	17	11	4	E	Lewis	rock		ΦEva$_g$																	
21220045	15					SW	SE	17	11	4	E	Lewis	rock		ΦEva$_g$																	
21220042	15					SE	SW	18	11	4	E	Lewis	rock		ΦEva$_g$																	
21220043	15					SE	SW	18	11	4	E	Lewis	rock		ΦEva$_g$																	
21220033	15					SW	SW	19	11	4	E	Lewis	rock		ΦEva$_g$																	
21220034	15					SE	NW	20	11	4	E	Lewis	rock		Φvc$_1$																	
21220035	15					SE	NW	20	11	4	E	Lewis	rock		Φvc$_1$																	
21220036	15					NW	SW	21	11	4	E	Lewis	rock		ΦEva$_g$																	
21220037	15					NW	NE	21	11	4	E	Lewis	rock		ΦEva$_g$																	
21220038	15					NW	SE	21	11	4	E	Lewis	rock		ΦEva$_g$																	
21220039	15					NW	SE	22	11	4	E	Lewis	rock		ΦEva$_g$																	
21220040	15					SE	SE	22	11	4	E	Lewis	rock		ΦEva$_g$																	
21220041	15					NE	SW	23	11	4	E	Lewis	rock		ΦEva$_g$																	
21220030	15					NE	SW	25	11	4	E	Lewis	gravel		Qapt$_h$																	
21220031	15					NE	SW	25	11	4	E	Lewis	gravel		Qapt$_h$																	
21220018	15					SW	SW	26	11	4	E	Lewis	rock		ΦEva$_g$																	
21220028	15					NE	SW	26	11	4	E	Lewis	rock		MΦian																	
21220029	15					NE	SE	26	11	4	E	Lewis	rock		MΦvc$_2$																	
21220026	15					SE	NW	27	11	4	E	Lewis	rock		ΦEva$_g$																	
21220027	15					NE	SW	27	11	4	E	Lewis	rock		ΦEva$_g$																	
21220025	15					SW	NE	28	11	4	E	Lewis	rock		ΦEva$_g$																	
21220022	15					SW	NW	29	11	4	E	Lewis	rock		Φvc$_1$																	
21220023	15					NW	SW	29	11	4	E	Lewis	rock		Φvc$_1$																	
21220024	15					NE	SE	29	11	4	E	Lewis	rock		MΦian																	
21220019	15					NE	NW	30	11	4	E	Lewis	rock		Φvd$_1$																	
21220020	15					NW	NE	30	11	4	E	Lewis	rock		Φvc$_1$																	
21220021	15					SE	SE	30	11	4	E	Lewis	rock		Φvc$_1$																	
21220008	15					SE	NW	31	11	4	E	Lewis	rock		Φvc$_1$																	
21220009	15					SE	SE	31	11	4	E	Lewis	rock		Φvc$_1$																	
21220010	15					NE	SE	31	11	4	E	Lewis	rock		Φvc$_1$																	
21220011	15					NE	NE	31	11	4	E	Lewis	rock		Φvc$_1$																	
21220012	15					NE	SE	32	11	4	E	Lewis	rock		ΦEva$_g$																	
21220013	15					SW	NE	33	11	4	E	Lewis	rock		ΦEva$_g$																	
21220014	15					NE	NE	33	11	4	E	Lewis	rock		ΦEva$_g$																	

IDENTIFIER						LOCATION							RESERVES									QUALITY										
WADNR unique number	WADNR data type code	WADNR permit number	WSDOT site number	Mine name	Operator or permit holder	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	Resource thickness (feet)	Million cubic yards	Million tons	Acres	Percent depletion	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent < U.S. No. 200 sieve
21220015	15					SW	NW	34	11	4	E	Lewis	rock		ΦEva_g																	
21220016	15					NE	NW	34	11	4	E	Lewis	rock		ΦEva_g																	
21220017	15					NE	SW	34	11	4	E	Lewis	gravel		$Qapt_h$																	
21220052	15					SE	SE	35	11	4	E	Lewis	gravel		$Qapt_h$																	
21230008	15					NW	NE	7	11	5	E	Lewis	rock		$M\Phi vc_2$																	
21230009	15					NW	NW	8	11	5	E	Lewis	rock		$M\Phi vc_2$																	
21230010	15					SW	NW	11	11	5	E	Lewis	rock		$M\Phi vb$																	
21230007	15					SE	NW	17	11	5	E	Lewis	gravel		$Qapt_h$																	
21230005	15					NE	NW	29	11	5	E	Lewis	gravel		$Qapt_h$																	
21230004	15					NE	SW	30	11	5	E	Lewis	gravel		$Qapt_h$																	
21240003	15					SE	SW	2	11	6	E	Lewis	rock		$M\Phi vb$																	
21240004	15					SE	SE	2	11	6	E	Lewis	rock		$M\Phi vb$																	
21240001	15					NW	SW	8	11	6	E	Lewis	rock		$M\Phi vc_2$																	
21240002	15					SE	SW	11	11	6	E	Lewis	rock		Mid																	
21190035	15					SW	NE	29	12	1	E	Lewis	gravel		Qao_e																	
21190036	18	11173	L-116		Lewis County Public Works	NW	SE	29	12	1	E	Lewis	gravel		Qao_e		35			15.5		1.5	0.04	12.3					35	46	19	16
21190029	15					SE	SE	32	12	1	E	Lewis	gravel		Qao_e																	
21190030	15					SE	SE	32	12	1	E	Lewis	gravel		Qao_e																	
21190050	15			Brinson pit	George Gill Construction	SE	SW	32	12	1	E	Lewis	gravel		Qa		20															
21190031	15					NW	SW	33	12	1	E	Lewis	gravel		Qao_e																	
21190032	15					NE	SW	33	12	1	E	Lewis	gravel		Qao_e																	
21170035	15					SW	SE	31	12	2	W	Lewis	rock		Evb_{gr}																	
21170036	15					SW	SE	31	12	2	W	Lewis	rock		Evb_{gr}																	
21200014	16	11070			Weyerhaeuser	NE	NE	32	12	2	E	Lewis	rock		ΦEvc_g		24	0.015		4.5		0	0.00									
21210023	15					SW	SW	36	12	3	E	Lewis	gravel		$Qapt_h$																	
21220051	15					NW	SE	26	12	4	E	Lewis	rock		ΦEva_g																	
21220050	15					SE	NE	27	12	4	E	Lewis	rock		ΦEva_g																	
21230011	15					NW	NE	36	12	4	E	Lewis	rock		ΦEva_g																	
21230013	15					SW	NE	29	12	5	E	Lewis	rock		Evb_{gr}																	
21230012	15					NW	SW	30	12	5	E	Lewis	rock		ΦEvc_g																	
21240005	18	12763	L-286	Falls Creek pit	Menaska	SW	SW	28	12	6	E	Lewis	gravel		$Qapt_e$	>	50	0.96		20				19	72	2.66						

Appendix 4. Outcrop database

This database contains information about outcrops on which strength and durability testing was performed, but mining did not take place, as well as other outcrops identified by the authors. These locations are plotted on Plate 1. The information contained herein is available digitally as part of the geographic information system (GIS) files for the Mount St. Helens 1:100,000 quadrangle. The columns that are not self-explanatory are defined as follows:

WADNR unique number – The Washington Department of Natural Resources (WADNR) unique number used by the geographic information system (GIS) to relate a feature on Plate 1 to a row in the database. The first four digits of the number identify the 7.5-minute quadrangle map in which the outcrop is located. The last four digits are a unique number on each 7.5-minute quadrangle.

WADNR data type code – The code number that indicates the type of investigation, as follows: 13 = strength and durability outcrop test location (point).

WSDOT site number – The number assigned by the Washington State Department of Transportation (WSDOT) that links results of strength and durability testing to a particular outcrop. The number consists of a letter that identifies the county the site is in, followed by a sequentially assigned number.

¼ ¼ section, ¼ section, Section, Township, Range, Meridian – Legal description of the outcrop with reference to the Government Land Office grid. Townships and ranges are shown on Plate 1.

Product – The material of interest at the location: rock, sand, or gravel.

Rock type – The type of rock at the location, if the outcrop is a bedrock unit.

Geologic unit – The short label that identifies a particular unit on a geologic map. This field indicates the unit in which the outcrop is located as identified in Phillips (1987a), using the updated geologic unit labels consistent with Walsh and others (1987). Most units are described in Appendix 6.

Qualifier – Applies only to the deepest resource thickness reported (see following columns) and indicates either that the thickness is exact because the whole section could be measured (blank) or that the actual resource thickness is greater than the thickness reported because the bottom of the resource was not identified (>).

1st resource thickness (feet), 1st interbed thickness (feet), 2nd resource thickness (feet) – These fields refer to the bedding identified in the outcrop by the authors, starting at the top. 'Resource thickness' refers to the thickness of a likely aggregate resource, whereas 'interbeds' are non-commercial materials such as silt and clay.

Dip, Strike – Indicate orientation of sedimentary bedding in a bedrock resource; if horizontal or no data, fields are blank.

Induration – The relative quality of a rock as determined in the field with a one-pound ball peen hammer. Estimates range from rebound (highest quality) through fracture, pit, and dent (lowest quality).

Overburden thickness (feet) – Thickness, in feet, of soil, clay, or non-commercial aggregate that must be removed in order to reach the aggregate resource.

Stripping ratio – The overburden thickness divided by the resource thickness. A value of less than 0.33 (ratio of less than 1:3) is preferred.

Los Angeles Abrasion, Degradation, Specific Gravity, Sand Equivalent, and Stabilometer R Value tests – Results of laboratory tests, conducted mainly by the WSDOT, that reflect the quality of the deposit. See the glossary (Appendix 1) for explanation of tests.

Lab (L) or visual (V) – This code indicates whether grain-size analysis is from a laboratory test (L) or estimated visually in the field (V).

Percent >2½ inches, Percent ¼–2½ inches, Percent <¼ inch, Percent <U.S. No. 200 sieve – Results of laboratory grain-size analysis of samples. Values are given in weight percent. The first three fields divide the whole sample, and the fourth field refers to the amount of silt and clay in the entire sample.

IDENTIFIER				LOCATION							MATERIAL							QUALITY														
WADNR unique number	WADNR data type code	WSDOT site number	Site name/ description	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	1st resource thickness (feet)	1st interbed thickness (feet)	2nd resource thickness (feet)	Dip	Strike	Induration	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Lab (L) or visual (V)	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent <U.S. No. 200 sieve
24180028	13	N-61		NW	NE	6	6	1	W	Cowlitz	gravel		Qa										37.2		2.48			L	7	49	44	1
24180035	13	N-67		NE	SE	6	6	1	W	Cowlitz	gravel		QRc_t										21.8	26	2.61	39	67	L	15	62	23	7
24180026	13	N-93		SE	SE	7	6	1	W	Cowlitz	rock	basalt	ΦEva_g										10.7									
24180027	13	N-72		NW	NW	17	6	1	W	Cowlitz	rock	basalt	ΦEva_g										14.6									
24180034	13	N-124		SE	NW	18	7	1	W	Cowlitz	rock	basalt	ΦEva_g										12.2	61	2.78							
24180036	13	N-80		SW	SW	30	7	1	W	Cowlitz	rock	basalt	ΦEva_g																			
24180029	13	N-79		SE	SW	31	7	1	W	Cowlitz	rock		ΦEva_g										37.1					L				12
24180030	13	N-133		SE	NE	31	7	1	W	Cowlitz	gravel		Qa											62	2.58	90	62	L	0	2	98	2
24180031	13	N-69		SE	SW	32	7	1	W	Cowlitz	gravel		Qa										44		2.54	89	72	L	0	40	60	2
24180032	13	N-81		NW	SE	34	7	1	W	Cowlitz	gravel		Qa															L	17	59	24	4
24180033	13	N-100		SW	NE	35	7	1	W	Cowlitz	rock		ΦEva_g										15.6	69	2.69							
23170095	13	N-168		NW	NW	3	7	2	W	Cowlitz	dredge spoils		Qa													91		L				1
24170014	13	N-105		NW	NE	8	7	2	W	Cowlitz	gravel		Qa										21	50	2.72							
24170013	13	N-143			NE	9	7	2	W	Cowlitz	dredge spoils		Qa													92		L				2
24180025	13	N-171		NW	SE	36	7	2	W	Cowlitz	gravel		Qa																			
24240009	13		U.S. Forest Svc. proposed quarry	NE	NE	15	7	6	E	Skamania	rock	basalt	$M\Phi vc_2$																			
23180009	13	N-153				30	8	1	W	Cowlitz	rock		ΦEvc_g										19.4	74	2.58							
23180007	13	N-73			NW	31	8	1	W	Cowlitz	gravel		Qa													62	83	L	0	62	38	5
23180006	13	N-75		W	SW	32	8	1	W	Cowlitz	gravel		Qa										17	64	2.69		77					
23180005	13	N-107			NE	34	8	1	W	Cowlitz	rock	basalt	ΦEvc_g										15.1		2.77							
23180004	13	N-104		SW	SW	35	8	1	W	Cowlitz	rock	basalt	ΦEvc_g										19.6		2.72							
23170086	13	N-144		NW	NE	2	8	2	W	Cowlitz	rock	basalt	Evb_{gr}											67	2.71							
23170091	13	N-25		SE	NE	2	8	2	W	Cowlitz	gravel		Qt															L				11
23170084	13	N-109		SW	NW	9	8	2	W	Cowlitz	rock	basalt	Mv_g										23.3		2.76							
23170083	13	N-83		NE	NW	10	8	2	W	Cowlitz	gravel		Qt															L	6	71	23	5
23170085	13	N-2	Ostrander Bar	SE	NW	11	8	2	W	Cowlitz	gravel		Qa																			
23180010	13	N-155			S	12	8	2	W	Cowlitz	rock		Evb_{gr}										17.5	47	2.59							
23170082	13	N-1		NW	SE	15	8	2	W	Cowlitz	gravel		Qa															L	98	12	0	0.05
23170078	13	N-18			SW	20	8	2	W	Cowlitz	gravel		Qa																			
23170079	13	N-5		SE	SE	20	8	2	W	Cowlitz	gravel		Qa															L	19	56	25	2.5
23170080	13	N-106			SE	20	8	2	W	Cowlitz	rock		Mv_g										18.4		2.72	41	78					
23170081	13	N-14			NW	27	8	2	W	Cowlitz	gravel		Evb_{gr}																			
23170074	13	N-95		NE	SW	31	8	2	W	Cowlitz	gravel		Qa													91	70	L	0	0	100	1
23170076	13	N-4		SW	SW	31	8	2	W	Cowlitz	gravel		Qa															L	100		61	0.7
23170094	13	N-108		SW	SW	36	8	2	W	Cowlitz	gravel		QRc_t										15.9		2.62		66	L	10	61	29	7
23170077	13	N-82			SE	25	8	3	W	Cowlitz	rock		Evb_{gr}										11.2									

IDENTIFIER				LOCATION							MATERIAL							QUALITY														
WADNR unique number	WADNR data type code	WSDOT site number	Site name/ description	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	1st resource thickness (feet)	1st interbed thickness (feet)	2nd resource thickness (feet)	Dip	Strike	Induration	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Lab (L) or visual (V)	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent <U.S. No. 200 sieve
23170075	13	N-55		NE	SE	36	8	3	W	Cowlitz	dredge spoils		Qa													97		L				0.4
23240003	13		U.S. Forest Service Muddy Pine pit	NW	SW	35	8	6	E	Skamania	rock	basalt	$M\Phi vc_2$										23.2									
22170082	13	N-77		NE	SW	2	9	2	W	Cowlitz	gravel		Qvl										47.1					L	29	54	17	4
22170080	13	N-99			S	14	9	2	W	Cowlitz	gravel		Qa										56.8		2.48	83	74	L	0	30	70	1
22170081	13	N-7		NE	NE	15	9	2	W	Cowlitz	gravel		Qa												2.56			L	15	40	45	2
23170093	13	N-112		SW	NE	23	9	2	W	Cowlitz	gravel		Qvl										56		2.46	66	77	L	7	65	28	8
23170090	13	N-88		E	SW	25	9	2	W	Cowlitz	gravel		Qt																			
23170088	13	N-85		NW	NW	26	9	2	W	Cowlitz	gravel		Qa										57.6					L	5	64	31	0.8
23170089	13	N-26		NE	SE	26	9	2	W	Cowlitz	rock	basalt	Evb_{gr}										16.1	50	29							
23170092	13	N-6		NE	NE	26	9	2	W	Cowlitz	gravel		Qa															L		100		0.1
23170087	13	N-76		NE	SE	34	9	2	W	Cowlitz	gravel		Qa										57.7		2.47	91	76	L	3	61	36	2
22210076	13	N-149		NE	SW	1	9	3	E	Cowlitz	rock	basalt	Φvc_1											13	2.63							
22190035	13	N-54		SE	SE	9	10	1	E	Cowlitz	gravel		Qvl													81	74	L	0	50	50	11
22190034	13	N-22		SE	SW	10	10	1	E	Cowlitz	gravel		Qvl															L	11	61	28	15.2
22190030	13	N-37		NE	SE	11	10	1	E	Cowlitz	rock		ΦEva_g										20									
22190031	13	N-38		SE	NE	11	10	1	E	Cowlitz	rock	basalt	ΦEva_g										19									
22190029	13	N-165		NE	SW	12	10	1	E	Cowlitz	rock	basalt	Qls										25.3	24	2.68							
22190032	13	N-170		NW	NW	14	10	1	E	Cowlitz	gravel		Qvl													79	58	L				6
22190036	13	N-169		NW	SE	17	10	1	E	Cowlitz	gravel		Qvl														60					
22190038	13	N-162		NE	NE	19	10	1	E	Cowlitz	rock		ΦEva_g											88	2.69							
22190037	13	N-130		NW	NW	20	10	1	E	Cowlitz	rock	gabbro	ΦEva_g										18.7	35	2.72							
22190039	13	N-190		NW	SE	29	10	1	E	Cowlitz	rock		Mc_w										25	79	2.68							
22190040	13	N-180		W	NE	30	10	1	E	Cowlitz	rock		Mc_w										17.5	45	2.68							
22180020	13	N-172		NW	NW	31	10	1	W	Cowlitz	gravel		Qa										16.5	12		96		L				3.2
22170089	13	N-13		SE	SE	4	10	2	W	Cowlitz	gravel		Qa															L	98			0.1
22170088	13	N-66		NW	NE	9	10	2	W	Cowlitz	gravel		Qa														67					
22170087	13	N-12		NE	NE	16	10	2	W	Cowlitz	rock	basalt	Evb_{gr}																			
22170086	13	N-10		NE	SW	22	10	2	W	Cowlitz	rock	basalt	Qvl																			
22200044	13	N-177		NW	SE	23	10	2	E	Cowlitz	gravel		Qvl										65.4	85	2.51	90	71	L				2.7
22170085	13	N-9		SE	SE	27	10	2	W	Cowlitz	gravel		Qvl															L	16	57	27	
22170083	13	N-86		SE	SW	34	10	2	W	Cowlitz	gravel		Qa										57.1					L	28	44	28	3
22170090	13	N-131		SE	NE	13	10	3	W	Cowlitz	gravel		Evb_{gr}										24.7	40	2.78	62		L				9
22210075	13	N-174		SE	NW	21	10	3	E	Cowlitz	gravel		$Qapt_h$										22.1	3	2.64	31		L				20.3
22220074	13	N-186		NE	NE	27	10	4	E	Cowlitz	rock		$Qapt_h$										22	6	2.55							
22220073	13	N-185		NW	NE	32	10	4	E	Cowlitz	rock	basalt	Φvc_1										29	4	2.4							
21190049	13	L-169		N	NE	1	11	1	W	Lewis	gravel		Qa										13.8		2.68		72					
21180122	13	L-117		SW	SW	2	11	1	W	Lewis	gravel		Qa															L	16	42	26	3

IDENTIFIER				LOCATION							MATERIAL							QUALITY														
WADNR unique number	WADNR data type code	WSDOT site number	Site name/ description	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	1st resource thickness (feet)	1st interbed thickness (feet)	2nd resource thickness (feet)	Dip	Strike	Induration	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Lab (L) or visual (V)	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent <U.S. No. 200 sieve
21180117	13	L-94		SE	SE	7	11	1	W	Lewis	gravel		Qapo															L	9	75	16	14
21180188	13	L-157		NE	SW	8	11	1	W	Lewis	gravel		Qapo										12.4		2.67		80	L	8	72	20	
21180121	13	L-128		N	NE	11	11	1	W	Lewis	gravel		Qa																			
21180123	13	L-121		NE	NW	12	11	1	W	Lewis	gravel		Qapo										17.4					L	19	52	29	22
21180118	13	L-120		NW	SE	17	11	1	W	Lewis	gravel		Qa													55		L	17	47	36	20
21180119	13	L-232		SW	SW	17	11	1	W	Lewis	gravel		Qa													64	73	L	11	88	1	5
21180124	13	L-138		SE	NW	17	11	1	W	Lewis	gravel		Qa												2.6	85	75	L	2	64	34	4
21180125	13	L-84		NW	SE	17	11	1	W	Lewis	gravel		Qa										2.92					L	31	44	25	14
21180126	13	L-2	Cowlitz River	NE	SW	17	11	1	W	Lewis	gravel		Qa										12.1	61	2.67			L				9
21180115	13	L-122		SW	SE	18	11	1	W	Lewis	sand		Qa															L				25
21180116	13	L-95		SE	NE	18	11	1	W	Lewis	gravel		Qao_e															L	12	66	12	3.4
21180120	13	L-3			NE	19	11	1	W	Lewis	gravel		Qa																			
21180127	13	L-293	Aruba Rock, Hampton	SE	NE	19	11	1	W	Lewis	gravel		Qa										15	71	2.68							
21190048	13	L-253		SE	SW	29	11	1	E	Lewis	rock		Mc_w											2	2.33							
21170056	13	L-140		NE	NW	13	11	2	W	Lewis	gravel		Qls										13		2.62	89	79	L	24	50	26	3
21170057	13	L-140B		NE	SW	13	11	2	W	Lewis	gravel		Qa										8.8		2.69	81		L	14	70	16	4
21180113	13	L-140A		NW	SE	13	11	2	W	Lewis	gravel		Qa										12.8		2.64	80		L	13	69	18	6
21180114	13	L-150	Miller Bar	S	SE	13	11	2	W	Lewis	gravel		Qa										13		2.69	93	80	L	14	49	37	1
21170054	13	L-141		SW	SW	24	11	2	W	Lewis	gravel		Qa										15.2	58	2.67	58	71	L	3	70	27	19
21170052	13	L-143			NW	26	11	2	W	Lewis	gravel		Qa										10.2		2.63		83					
21170053	13	L-234		NE	NE	26	11	2	W	Lewis	gravel		Qa										18.4			56	79	L	7	90	3	10
21170049	13	L-245		NE	SW	27	11	2	W	Lewis	gravel		Qa														74	L	6	62	32	
21170050	13	L-127		SW	SE	27	11	2	W	Lewis	gravel		Qa										12.8			65		L	13	70	17	11
21170051	13	L-144		SW	NW	35	11	2	W	Lewis	gravel		Qapo										8		2.67	28	77	L	30	49	21	10
21170058	13	L-220		SW	NE	35	11	2	W	Lewis	rock	basalt	Qapo										25.5	36	2.61							
21220054	13	L-99		NW	NW	1	11	4	E	Lewis	gravel		Qa										17.9					L	10	64	26	1.4
21230018	13	L-109		NE	NE	1	11	4	E	Lewis	gravel		Qa															L	17	63	20	2
21230017	13	L-170		NW	NW	6	11	5	E	Lewis	gravel		Qa										17.1		2.64	91	75	L	24	51	25	3
21190047	13	L-147		S	S	29	12	1	E	Lewis	gravel		Qa										12.4		2.67		79	L	26	56	18	3
21180128	13	L-225		NE	SW	30	12	1	W	Lewis	gravel		Qapo													1	19	L	0	11	89	74
21190046	13	L-168	Excelsior Bar	S	NW	31	12	1	E	Lewis	gravel		Qa										12.9		2.71	85	75	L	14	58	28	1
21190045	13	L-118		SE	SE	36	12	1	W	Lewis	gravel		Qao_e										14.8		2.67		71	L	23	50	27	2
21200015	13	L-35		NE	SW	28	12	2	E	Lewis	gravel		Qapo										21					L	34	45	21	11
21230015	13	L-45		E	SW	31	12	2	E	Lewis	gravel		Qa															L	33	67	0	1
21220053	13	L-17		SE	SW	35	12	4	E	Lewis	gravel		Qa										15.4					L	51	32	17	4
21230014	13	L-19		SE	SE	29	12	5	E	Lewis	gravel		Qa										14.2		2.7	70	73	L	18	45	37	6
21230019	13	L-222		NW	SE	29	12	5	E	Lewis	rock		Φvc_1										26.5	62	2.49							
21230022	13	L-204			SE	29	12	5	E	Lewis	rock	basalt	Φvc_1										19.4	56	2.54							
21230020	13	L-98		W	SE	31	12	5	E	Lewis	gravel		Qa										14.7					L	19	43	24	2

IDENTIFIER				LOCATION							MATERIAL							QUALITY														
WADNR unique number	WADNR data type code	WSDOT site number	Site name/ description	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Product	Rock type	Geologic unit	Qualifier	1st resource thickness (feet)	1st interbed thickness (feet)	2nd resource thickness (feet)	Dip	Strike	Induration	Overburden thickness (feet)	Stripping ratio	Los Angeles Abrasion	Degradation	Specific Gravity	Sand Equivalent	Stabilometer R Value	Lab (L) or visual (V)	Percent >2½ inches	Percent ¼–2½ inches	Percent <¼ inch	Percent <U.S. No. 200 sieve
21230016	13	L-46			W	32	12	5	E	Lewis	gravel		Qa										14.8		2.67	62	71	L	15	51	34	12.6
21230021	13	L-85		NW	NW	33	12	5	E	Lewis	gravel		Qa										15.5					L	34	53	19	5.9
21240006	13	L-243		NE	NW	33	12	6	E	Lewis	gravel		$Qapt_e$													77		L	5	58	37	1

Appendix 5. Well database

This database contains information about all water wells and geotechnical bores that are plotted on Plate 1. The information contained herein is available digitally as part of the geographic information system (GIS) files for the Mount St. Helens 1:100,000 quadrangle. The columns that are not self-explanatory are defined as follows:

WADNR unique number – The Washington Department of Natural Resources (WADNR) unique number is used by the geographic information system (GIS) to relate a feature on Plate 1 to a row in the database. The first four digits of the number identify the 7.5-minute quadrangle map in which the well is located. The last four digits are a unique number on each 7.5-minute quadrangle.

WADNR data type code – The code number that indicates the type of drill hole, as follows: 11 = water well (point); 12 = geotechnical or other bore (point).

WADOE well number – One of a variety of numbers found on the Washington Department of Ecology (WADOE) water-well report forms. The possible types include start card, application, or permit numbers.

Data verified? – Relates to the quality of data. 'Y' indicates that the drill log is from a geotechnical bore or has been verified by a consulting firm; otherwise, the field is blank.

Well location – Gives the street address of the well or the nearest geographical feature. Washington State Department of Transportation bores are referenced to the bridge, intersection, or street location where the bore is drilled.

¼ ¼ section, ¼ section, Section, Township, Range, Meridian – Legal description of the well with reference to the Government Land Office grid. Townships and ranges are shown on Plate 1.

Geologic unit – The short label that identifies a particular unit on a geologic map. This field indicates the unit in which the well is located on the surface as identified in Phillips (1987a), using the updated geologic unit labels consistent with Walsh and others (1987). Most units are described in Appendix 6.

Qualifier – Applies only to the deepest gravel thickness reported (see following columns) and indicates that either the thickness is exact because the whole layer is penetrated by the well (blank) or that the actual gravel thickness is greater than the thickness reported because the bottom of the gravel was not identified in the well log (>).

Overburden thickness (feet) – The thickness, in feet, of soil, clay, or non-commercial aggregate that must be removed in order to reach the aggregate resource.

1st gravel thickness (feet), 1st interbed thickness (feet), 2nd gravel thickness (feet), 2nd interbed thickness (feet), 3rd gravel thickness (feet) – These fields refer to the interpretation of the well log by the authors, starting at the ground surface. 'Gravel thickness' refers to the thickness of a likely aggregate resource, whereas 'interbeds' are non-commercial materials such as silt and clay.

Depth to water-bearing zone (feet) – Gives depth, in feet, to top of the first water-bearing unit encountered during drilling.

Bedrock penetrated? – This column contains either a Y (yes), N (no), or blank (unknown) indicating whether or not the well was drilled to the depth of bedrock.

Reference – The source of data for the well log, if other than the Washington Department of Ecology water-well log archives.

IDENTIFIER						LOCATION									WELL LOG										
WADNR unique number	WADNR data type code	WADOE well number	Data verified?	Well name	Original well owner	Well location	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Geologic unit	Qualifier	Overburden thickness (feet)	1st gravel thickness (feet)	1st interbed thickness (feet)	2nd gravel thickness (feet)	2nd interbed thickness (feet)	3rd gravel thickness (feet)	Depth to water-bearing zone (feet)	Well total depth (feet)	Bedrock penetrated?	Reference
24180008	11				Peterson	611 Modrow Rd	NW	NW	5	6	1	W	Cowlitz	Qa		12	8						314	Y	
24180009	11	W070794		ACD801	Ruckel	125 Spencer Cr Rd	NE	NW	5	6	1	W	Cowlitz	Qa		31							106	N	
24180003	11				Peavey Co. Inc.	2211 N 111 St	SW	NW	6	6	1	W	Cowlitz	Qa									319	Y	
24180001	12	7431	Y	Piezo 5	Kalama Chemicals	1296 3rd St	NW	NW	7	6	1	W	Cowlitz	Qa		0	11						37	N	
24180002	12	47992	Y	T-103	Kalama Chemicals		SE	NW	7	6	1	W	Cowlitz	Qa			0						20	N	
24180012	11	W105483			Montana Reach, Inc.	5100 Old Pacific Hwy	NE	NW	31	7	1	W	Cowlitz	ΦEva_g			0						483	Y	
24180015	11	18564			Manville	123 Kalama River Rd	SE	SE	31	7	1	W	Cowlitz	Qa	>	2	6	83	24			91	115	N	
24180017	11				Thompson	465 Kalama River Rd	NE	SW	32	7	1	W	Cowlitz	Qa	>	0	28	7	15	39	5	89	95	N	
24180019	11				Piper	725 Kalama River Rd	SW	NE	32	7	1	W	Cowlitz	Qa		8	12						143	Y	
23170002	11	69949			Rusk	1921 Grade St	NE	NW	2	7	2	W	Cowlitz	Qa			0						181	Y	
23170003	11				Rhinehart	1919 Grade St	NE	NE	2	7	2	W	Cowlitz	Qa			0						185	Y	
24170012	12	R04670	Y	SW 1	Safway Steel	2409 Talley Way	SE	SE	2	7	2	W	Cowlitz	Qa			0						4	N	
24170011	11				Sewage Pump station	2260′ S, 1480′ W of NE corner of section	SE	NE	3	7	2	W	Cowlitz	Qa			0					70	101	N	
24170009	12	16594	Y	MW #3	Bearings Inc.	1320 Industrial Way	SW	SW	4	7	2	W	Cowlitz	Qa			0					9	18	N	
24170010	12	A16475	Y		VCI Kelso Tower	620 California Way	NW	SE	4	7	2	W	Cowlitz	Qa			0					10	45	N	
24170001	12		Y	HC 101	Weyerhaeuser		SE	NW	8	7	2	W	Cowlitz	Qa			0						14	Y	
24170002	11				Chevron USA, Inc.	S69°W ~400′ from NE corner of section	NE	NE	8	7	2	W	Cowlitz	Qa			0					10	14	N	
24170003	12	12950	Y	PW 4-3	International Paper	10 International Way	NW	SW	9	7	2	W	Cowlitz	Qa			0						43	N	
24170004	11				*Long-Bell Lumber*		NE	SW	9	7	2	W	Cowlitz	Qa		74	29	71	35			178	215	N	
24170005	12	20299	Y	B-4	Cowlitz Co. Landfill		SE	NW	11	7	2	W	Cowlitz	Qa			0						96	N	
24170008	11				Burlington Northern		NW	NE	13	7	2	W	Cowlitz	Qa			0						297	Y	
24180023	11				North	113.5 Norwood Dr	SE	NE	13	7	2	W	Cowlitz	Qa			0						365	Y	
24180021	12		Y	ABN 728/MW-1	Burlington Northern Railroad	4 mi S of Kelso on I-5	NE	NE	24	7	2	W	Cowlitz	Qa			0						15	N	
23170047	11			#5	Cowlitz PUD #1	400′ E, 600′ N of SW corner of section	SW	SW	2	8	2	W	Cowlitz	Qa		65	9						96	N	
23170049	11			#4	Cowlitz PUD #1	1300′ E, 700′ N of SW corner of section	SE	SW	2	8	2	W	Cowlitz	Qa		20	22	17	21	8	6		118	N	
23170053	11				Sawyer	192 Cole Rd	SE	NE	2	8	2	W	Cowlitz	Evb_{gr}			0						305	Y	
23170054	11			#6	Cowlitz PUD #1	600′ N, 200′ W of SE corner of section	SE	SE	2	8	2	W	Cowlitz	Evb_{gr}	>	15	60	35	23	7	45		203	N	
23170039	11	92195		ACR-026	Greear	401 King Rd	SE	SW	3	8	2	W	Cowlitz	Evb_{gr}			0						125	Y	
23170051	11	35575			Kiser	West Side Hwy	NW	NE	3	8	2	W	Cowlitz	Qa			0						305	Y	
23170033	11	W044010			Strange	46 W Stock Rd	NW	NE	11	8	2	W	Cowlitz	Evb_{gr}		114	6						240	Y	
23170040	11				Young	1906 West Side Hwy	SW	NW	11	8	2	W	Cowlitz	Qa			0					21	34	N	
23170042	11			Well #9	Cowlitz PUD #1		NE	SW	11	8	2	W	Cowlitz	Qa		10	31	23	7	4	3		93	Y	
23170043	11				Ostrander Water Co.	145 Collins Dr	NW	SE	11	8	2	W	Cowlitz	Qa			0						165	Y	
23170044	11				*Cowlitz PUD*		NE	SE	11	8	2	W	Cowlitz	Evb_{gr}			0						252	Y	
23170032	11	68875			Ford	200 Holcomb Acres Rd	SW	SW	14	8	2	W	Cowlitz	Evb_{gr}			0						425	Y	

IDENTIFIER						LOCATION									WELL LOG										
WADNR unique number	WADNR data type code	WADOE well number	Data verified?	Well name	Original well owner	Well location	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Geologic unit	Qualifier	Overburden thickness (feet)	1st gravel thickness (feet)	1st interbed thickness (feet)	2nd gravel thickness (feet)	2nd interbed thickness (feet)	3rd gravel thickness (feet)	Depth to water-bearing zone (feet)	Well total depth (feet)	Bedrock penetrated?	Reference
23170045	11	68780			Hallett	620 Holcomb Acres Rd	SE	SE	14	8	2	W	Cowlitz	Qa		60	7						402	Y	
23170022	12	R28271	Y		BP Station, Minit Shop	3808 Ocean Beach Hwy	SE	SW	19	8	2	W	Cowlitz	Qa			0						15	N	
23170024	12	R039105	Y	B-1 & 2	Nevada Bridge	Nevada Br Dr	SE	NW	22	8	2	W	Cowlitz	Qa			0						65	Y	
23170025	12	R03923	Y	AEM 058-060	N. Kelso Drainage	2400 N Pacific Ave	NE	NE	22	8	2	W	Cowlitz	Qa			0						40	N	
23170026	11				King	512 Williams - Finney Rd	SE	NE	23	8	2	W	Cowlitz	QRc_t		83	51						160	N	
23170027	11	18533			Goodman	1920 Mt Brynion Rd	SE	SE	23	8	2	W	Cowlitz	QRc_t	>	98	30	29	12			157	169	N	
23170029	11				Effray	527 Holcomb Acres Rd	NE	NE	23	8	2	W	Cowlitz	Evb_{gr}			0						280	Y	
23170019	12	A16482	Y	Geot. Hole	Three Rivers Tower	250 Kelso Dr	SE	SW	27	8	2	W	Cowlitz	Qa			0						36	N	
23170020	11	W066591		#1	Cowlitz County	312 S First St	SW	SE	27	8	2	W	Cowlitz	Qa		41	11						77	N	
23170021	11	R16560			Chevron USA, Inc.	400 Allen St	SE	SE	27	8	2	W	Cowlitz	Qa			0						25	N	
23170018	12				Shell Oil		NE	SW	28	8	2	W	Cowlitz	Qa			0						15	N	
23170016	11	W051923			Palazzo	16 Larry Ln	SW	NW	29	8	2	W	Cowlitz	Qa			0						38		
23170014	12	R05252	Y	ABV 166	Longview	2160 & 2192 38th Ave	NE	NW	30	8	2	W	Cowlitz	Qa			0						20	N	
23170015	12	A16486	Y		Columbia Valley Garden	SE corner of Olive Way & 34th Ave	SE	NW	30	8	2	W	Cowlitz	Qa			0						42	N	
23170005	11				Weyerhaeuser Company		NW	SW	31	8	2	W	Cowlitz	Qa		176	26					176	202	N	
23170006	11				Weyerhaeuser Company		SE	SW	31	8	2	W	Cowlitz	Qa	>	186	15					186	201	N	
23170007	11				Weyerhaeuser Company		N	S	31	8	2	W	Cowlitz	Qa	>	213	15					213	233	N	
23170008	12	216288		MW-1	Gulf		SW	NE	33	8	2	W	Cowlitz	Qa	>	0	16						16	N	
23170009	12	16596		MW #1	Astro Site	1459 Hudson St	NE	NE	33	8	2	W	Cowlitz	Qa			0						25	N	
23170010	12				Interstate Packers		NE	SW	34	8	2	W	Cowlitz	Qa	>	0	40						40	N	
23170011	11				American Cyanamid	2000′ E, 600′ N of SW corner of section	SE	SW	34	8	2	W	Cowlitz	Qa		29	13						111	N	
23170030	11				Keizer	250 N 50th	SW	NE	13	8	3	W	Cowlitz	Qa			0						290	Y	
23170031	11	W055147		AAH930	Burr	1307 Stella Rd	NW	NE	13	8	3	W	Cowlitz	Evb_{gr}			0						101	Y	
23170012	11				Bechtel Corp.		SW	SE	25	8	3	W	Cowlitz	Qa	>	304	35					304	339	N	
23170004	11				Reynolds Metals Co.		SE	NE	36	8	3	W	Cowlitz	Qa	>	197	64					224	261	N	
22170020	11				McDermott		NW	SW	2	9	2	W	Cowlitz	Qa	>	3	56					56	59	N	
22170023	11				Rein	7566 Old Pacific Hwy	NW	NW	2	9	2	W	Cowlitz	Evb_{gr}			0						267	Y	
22170012	11	W29012			Polacek	5490 West Side Hwy	SE	NW	3	9	2	W	Cowlitz	Qa		0	27	12	27				80	N	
22170016	11				Miller	5390 West Side Hwy	SE	SE	3	9	2	W	Cowlitz	Qa	>	1	49					46	50	N	
22170022	11	18538			Seventh Day Adventist	7531 Old Pacific Hwy N	SE	NE	3	9	2	W	Cowlitz	Qa	>	132	20						152	N	
22170062	11				Wend	265 Quick Rd	SW	SW	3	9	2	W	Cowlitz	Qa	>	11	32					27	43	N	
22170063	11	W096824			Bowen	134 Gausman Rd	SW	SW	3	9	2	W	Cowlitz	Qa	>	2	58					43	60	N	
22170064	11	67960			Althof	192 Chapman Rd	NE	NW	3	9	2	W	Cowlitz	Qa	>	8	69						77	N	
22170065	11	18532			Bartolus	5408 Westside Hwy	SE	SW	3	9	2	W	Cowlitz	Qa		1	35					24	41	N	
22170017	11	207784			Quaife	313 Cemetary Rd	SE	SE	10	9	2	W	Cowlitz	Qa			0						265	Y	
22170057	11				MSH Motorcycle Club		SE	SW	10	9	2	W	Cowlitz	Qa		31	17					31	52	N	
22170066	11	5571			Cunningham		NW	NW	10	9	2	W	Cowlitz	Qa	>	12	35					30	47	N	
22170067	11				Framin	203 Mosier Rd	SE	NW	10	9	2	W	Cowlitz	Qa	>	1	66						67	N	

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22170068	11				Huff			NW	10	9	2	W	Cowlitz	Qa	>	10	19						33	N	
22170069	11				Lewellen		NW	NW	10	9	2	W	Cowlitz	Qa	>	12	12						32	N	
22170070	11				Lewellen		N	N	10	9	2	W	Cowlitz	Qa	>	12	39						51	N	
22170071	11			Well #1	Lewellen		NE	NW	10	9	2	W	Cowlitz	Qa	>	12	12						40	N	
22170072	11				Terry	201 Mosier Rd	NW	SE	10	9	2	W	Cowlitz	Qa	>	1	32					20	33	N	
22170073	11				Umiker		NE	SW	10	9	2	W	Cowlitz	Qa		12	54						60	N	
22170018	11			CR80-2	Castle Rock	375′ E, 1000′ S of NW corner of section	NW	NW	11	9	2	W	Cowlitz	Qa		71	18					90	120	N	
22170019	11			CR80-5	City of Castle Rock	1850′ S, 1330′ E of NW corner of section	SE	NW	11	9	2	W	Cowlitz	Qvl		72	26					96	115	Y	
22170007	11				Slack	Cook Perry Rd	SE	SW	14	9	2	W	Cowlitz	Qa	>	0	40					30	40	N	
22170058	12	85433	Y	B-2		Huntington Br	SE	SE	14	9	2	W	Cowlitz	Qa	>	15	74						89	N	
22170059	11			1	Cochran	121 Bond Dr	SE	NE	14	9	2	W	Cowlitz	Qa		40	116					148	172	N	
22170060	11			2	Hornstra	256 Larson Ln	SE	SE	14	9	2	W	Cowlitz	Qa	>	15	27						42	N	
22170061	11				Lieurance	570 Bond Dr	NE	NE	14	9	2	W	Cowlitz	Qa		65	95					160	229	Y	
22170001	11	W070759		#1	Lane	195 Cook Perry Rd	SW	NE	23	9	2	W	Cowlitz	Qa	>	2	36						38	N	
22170077	11				Larsen	256 Huntington Rd	NW	NE	23	9	2	W	Cowlitz	Qa	>	20	21					30	41	N	
22170078	11				Larsen		NW	NE	23	9	2	W	Cowlitz	Qa	>	3	38						41	N	
22170079	11				Baker		NE	NW	23	9	2	W	Cowlitz	Qa	>	15	15						30	N	
23170070	11				Bayes	5414 Pleasant Hill Rd	SE	SE	23	9	2	W	Cowlitz	Qa	>	88	2					88	90	N	
23170063	11				Franz	West Side Hwy	SW	SW	26	9	2	W	Cowlitz	Qa	>	12	28						58	N	
23170064	11	W096529		#3	Eagle Ridge homes	Lot #18 171 Horseshoe Bend E	NE	SW	26	9	2	W	Cowlitz	Qa	>	24	15	3	37				79	N	
23170065	11	W25760			Snodgrass	3504 West Side Hwy	NW	NW	26	9	2	W	Cowlitz	Qa		22	12						120	Y	
23170066	11			#2	McBride	100′ S, 20′ W of NE corner of section	NE	NE	26	9	2	W	Cowlitz	Qa		39	34						86	Y	
23170072	11	W096516			Powell	223 Horseshoe Bend Estates Rd	N	SW	26	9	2	W	Cowlitz	Qa		0	71						142	N	
23170073	11	W090673			Balderree	134 Horseshoe Bend Estates Rd	NW	SE	26	9	2	W	Cowlitz	Qa	>	0	12	20	22			33	55	N	
23170062	11				Daniels	3222 West Side Hwy	NE	SE	27	9	2	W	Cowlitz	Qa	>	40	5						45	N	
23170071	11				Dudonsky		SW	SE	27	9	2	W	Cowlitz	Qa	>	3	40					20	42	N	
23170055	11				Latham	3428 Columbia Hts Rd	SW	SW	32	9	2	W	Cowlitz	Evb_{gr}			0						415	Y	
23170057	11				Baker	955 Hazel Dell Rd	SW	SW	33	9	2	W	Cowlitz	Evb_{gr}			0						120	Y	
23170058	11				Beasley	2914 West Side Hwy	NE	SE	34	9	2	W	Cowlitz	Qa	>	3	132						135	N	
23170059	11			#2	Cowlitz County PUD #1	700′ W, 700′ N of SE corner of section	SE	SE	34	9	2	W	Cowlitz	Qa		5	35	23	3			27	70	N	
23170060	11			#3	Cowlitz County PUD #1	1300′ N, 500′ E of SW corner of section	SW	SW	35	9	2	W	Cowlitz	Qa		10	27	7	9			44	110	N	
21170003	11	201807			Potter	Hill Cr Rd	NE	NW	2	10	2	W	Cowlitz	Evb_{gr}			0						115	Y	
21170001	11	W065552		#3	Wallace	424 Imboden Rd	NW	SW	3	10	2	W	Cowlitz	Qa	>	19	10	1	11			30	41	N	

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22170056	11	W061372			Kalich	344 Imboden Rd	SW	SW	3	10	2	W	Cowlitz	Qvl		28	7						360	Y	
21170002	11	W061352			Winters		NE	NE	4	10	2	W	Cowlitz	Qa		2	46						60	N	
22170055	11				Partridge	Imboden Rd	SE	SE	4	10	2	W	Cowlitz	Qa			0						267	Y	
22170076	11				Raymond	8421 West Side Hwy	SW	SE	4	10	2	W	Cowlitz	Qa		33	14						82	Y	
22170053	11	13742			Acker	405 Olequa Heights Rd	NE	SW	9	10	2	W	Cowlitz	Evb_{gr}			0						383	Y	
22170054	11	75360			Wiest	704 Olequa Heights Rd	NW	NW	9	10	2	W	Cowlitz	Evb_{gr}			0						160	Y	
22170046	11	96754			Jensen	Olequa Heights Rd	SE	NW	16	10	2	W	Cowlitz	Qa			0						170	Y	
22170050	11				Phillips	9755 Barnes Dr	NE	NE	16	10	2	W	Cowlitz	Evb_{gr}			0						111	Y	
22170051	11	W096510		#2	Nation	9531 Barnes Dr	NE	SE	16	10	2	W	Cowlitz	Evb_{gr}			0						362	Y	
22170039	11	68823		#2	Strickland	6971 West Side Hwy	NE	NW	21	10	2	W	Cowlitz	Qa			0						262	Y	
22170041	11				Watkins	9207 Barnes Dr	SW	NW	22	10	2	W	Cowlitz	Qvl	>	55	31					75	86	N	
22170043	11	W064975			Arata	270 Rimrock Dr	SW	SE	22	10	2	W	Cowlitz	Qapo			0						290	Y	
22170075	11	18554			Dec	314 Dwight Rd	SE	SW	22	10	2	W	Cowlitz	Qa		0	23						48	N	
22170031	11				Keatly	Chapman Rd	SW	SW	27	10	2	W	Cowlitz	Evb_{gr}			0						182	Y	
22170032	11				Reebs	210 Dwight Rd	NE	NW	27	10	2	W	Cowlitz	Qa		0	36	21	4	21	24	85	114	N	
22170033	11	21737			Langdon	8808 Barnes Dr	NE	NE	27	10	2	W	Cowlitz	Qa		43	10					43	160	Y	
22170034	11	67962		#2	Eagle Ridge Development	250 Burma Rd	SE	NE	27	10	2	W	Cowlitz	Qa	>	52	22	2	16			76	92	N	
22170035	11				Peabody	8401 Old Pacific Hwy	NE	SE	27	10	2	W	Cowlitz	Qa		0	13						71	Y	
22170024	11				Gordon	911 Chapman Rd	NW	NW	34	10	2	W	Cowlitz	Evb_{gr}			0						367	Y	
22170026	11				Jacques	225 Chapman Rd	SE	SW	34	10	2	W	Cowlitz	Qa		39	74						127	Y	
22170027	11	W066753			Cherrington	Old Pacific Hwy N	NE	SE	34	10	2	W	Cowlitz	Qa			0						220	Y	
22170074	11				Paxton	212 Chapman Rd	SE	SW	34	10	2	W	Cowlitz	Qa	>	5	95						100	N	
21190011	11				Messmore		NE	SE	1	11	1	W	Lewis	Qa		2	16						120	Y	
21180055	11	38818			Brimm	461 Howe Rd	SW	NE	2	11	1	W	Lewis	Qao_e		0	16						140	Y	
21180056	11	W41069			Marston	518 Howe Rd		NE	2	11	1	W	Lewis	Qao_e			0						143	Y	
21180052	11	W096756			Hockett	299 Buckley Rd		NW	3	11	1	W	Lewis	Qapo		4	2	14	36	2	3	54	78	N	
21180094	11				Jackson	499G Collins Rd	SW	SW	3	11	1	W	Lewis	Qa	>	0	28						28	N	
21180050	11				Chestnut	145 Poitsche Rd	SW	SW	4	11	1	W	Lewis	Qapo	>	7	35	2	4			44	48	N	
21180051	11				Dugan		SE	NW	4	11	1	W	Lewis	Qapo	>	14	70					62	84	N	
21190018	11				Raupp		NW	NW	4	11	1	E	Lewis	Qapo		66	15						108	N	
21190019	11	W092979		#2	Stanton	840 Evans Rd	NE	NW	4	11	1	E	Lewis	Qapo	>	3	30	15	32			71	80	N	
21180048	11	34776			McGraw	5411 Jackson Hwy	NW	SE	5	11	1	W	Lewis	Qapo	>	8	68					62	76	N	
21180049	11				Lemmons	1400′ N, 600′ S of SE corner of section	NE	SE	5	11	1	W	Lewis	Qapo		17	80					55	140	N	
21190015	11	W076185			Alvis	540 Evans Rd	NW	SW	5	11	1	E	Lewis	Qa	>	15	4						19	N	
21190016	11	84097			Bailey	124 Hinkley Rd	SW	NW	5	11	1	E	Lewis	Qa		2	20						75	Y	
21190017	11	11216			Brinson	197 Grimes Rd	NW	NW	5	11	1	E	Lewis	Qa			0						60	N	
21190042	11	25698			Hart	638 Evans Rd	SE	NW	5	11	1	E	Lewis	Qa	>	3	27					24	30	N	
21190012	11	201737			Freeman	Greenwater Ln	NW	NW	6	11	1	E	Lewis	Qa	>	0	30						30	N	

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21190013	11	W07514			Clark	Green Acre Dr	SE	NW	6	11	1	E	Lewis	Qa		6	15						28	N	
21190014	11	W061485			Johnson	Evans and Grimes Rd	NE	SE	6	11	1	E	Lewis	Qa			0						21	N	
21190039	11	W061493			Kruger	253 Greenwater Dr	NW	SE	6	11	1	E	Lewis	Qa		2	33						37	N	
21190040	11	W096788			Brown	Greenwater Ln Lot 7	NW	NW	6	11	1	E	Lewis	Qa		2	30					20	40	N	
21190041	11	201738			Wolslegel	Greenwater Ln Lot 8	NW	NW	6	11	1	E	Lewis	Qa		0	24						25	N	
21180040	11				Sessions		NW	NW	8	11	1	W	Lewis	Qapo		16	29						104	Y	
21180041	11				McTimmons	5585 Jackson Hwy			8	11	1	W	Lewis	Qapo		12	35						52	N	
21180095	11	44291			Bowen	370 Collins Rd	SW	SW	9	11	1	W	Lewis	Qa	>	9	14					17	23	N	
21180096	11	211740			Briton	460 Collins Rd	NW	SE	9	11	1	W	Lewis	Qa	>	8	24					28	32	N	
21180097	11	W044290			Duckworth	432 Collins Rd	NW	SE	9	11	1	W	Lewis	Qa	>	8	28					24	36	N	
21180098	11				Craig	389 Collins Rd			9	11	1	W	Lewis	Qa	>	15	19					31	39	N	
21180099	11	6784			Fancher	447 Collins Rd	NW	SE	9	11	1	W	Lewis	Qa	>	8	21					26	29	N	
21180100	11				Jackson	461 Collins Rd	SE	NE	9	11	1	W	Lewis	Qa	>	7	21					23	26	N	
21180101	11	W091945			Jackson	Collins Rd	NE	SE	9	11	1	W	Lewis	Qa		18	10						31	N	
21180102	11				Jacobson	433 Collins Rd	NW	SE	9	11	1	W	Lewis	Qa	>	13	23					33	36	N	
21180103	11				Jackson	361 Collins Rd	NE	SE	9	11	1	W	Lewis	Qa	>	10	30						40	N	
21180043	11				Speer	500 A Collins Rd	SW	NW	10	11	1	W	Lewis	Qao$_e$		0	33						33	N	
21180044	11	W100381			Hoettzel	402 Eden Rd	NE	SW	10	11	1	W	Lewis	Qapo		3	17						73	N	
21180045	11				Industrial Forestry Association		NW	NE	10	11	1	W	Lewis	Qapo		12	16					21	31	N	
21180105	11	W096827			Koth	536 Eadon Rd	NE	SE	10	11	1	W	Lewis	Qa		2	52						101	N	
21180106	11	66303			Dias		NE	NW	10	11	1	W	Lewis	Qa	>	90	5						95	N	
21180046	11				Kirkendoll		SW	SE	11	11	1	W	Lewis	Qapo	>	12	97					76	109	N	
21180047	11	25703			Miffelin	140 Kirkendall Rd	SW	NE	11	11	1	W	Lewis	Qapo		10	24					18	34	N	
21180104	11				Kabler	Eadon Rd	NE	NE	11	11	1	W	Lewis	Qa		1	46					44	47	N	
21180035	11				Hammon	Cooper Rd	SW	SW	15	11	1	W	Lewis	Qapo	>	9	39					40	48	N	
21180037	11	65014			King		SW	NW	15	11	1	W	Lewis	Qapo		15	43					32	58	N	
21180038	11				Bartley	336 Eadon Rd	NW	NW	15	11	1	W	Lewis	Qapo		8	17						80	N	
21180039	11				Whatley		SE	NE	15	11	1	W	Lewis	Qapo	>	8	60					38	68	N	
21180034	11				House	940 Hwy 505	NW	SW	16	11	1	W	Lewis	Qapo		6	45					44	60	N	
21180036	11			#1	Young	286 Eadon Rd	NE	NE	16	11	1	W	Lewis	Qapo	>	6	19					22	25	N	
21180027	11	W11673			Lewis County Parks	Hwy 505	SW	SW	17	11	1	W	Lewis	Qa		9	15						90	N	
21180030	11				Toledo Shake Co., Inc.		SE	NW	17	11	1	W	Lewis	Qa		0	39					23	42	N	
21180031	11				Buswell		NW	SE	17	11	1	W	Lewis	Qao$_e$	>	6	32	13	3			51	54	N	
21180109	11				Willow Drive Nursery	154 Branch Rd	NE	NE	17	11	1	W	Lewis	Qa		7	18					20	32	N	
21180110	12	66934	Y			Cowlitz River Br	SW	NW	17	11	1	W	Lewis	Qa		0	40						75	Y	
21180111	11				White		SE	NW	17	11	1	W	Lewis	Qa	>	7	23					23	30	N	
21180112	11				Willow Grove Nursery	154 Branch Rd		NE	17	11	1	W	Lewis	Qa		7	33					23	45	N	
21180026	11				Miller		NE	SW	18	11	1	W	Lewis	Qa		14	28						47	N	
21180107	11				Davis		NW	SE	18	11	1	W	Lewis	Qa	>	10	14						24	N	

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21180108	11	17220	Y	SB-1	Toledo School District		NW	SE	18	11	1	W	Lewis	Qa			0						19	N	
21190008	11				Haines	202 Schmidt Rd	SW	SW	18	11	1	E	Lewis	Qapo			0					72	106	N	
21180013	11				Oberg	507 Jackson Hwy	NW	SE	19	11	1	W	Lewis	Qapo	>	12	55					61	67	N	
21180014	11	W059535			Rose		SE	SE	19	11	1	W	Lewis	Qapo	>	15	54					63	69	N	
21180015	11	41080			Meyers	181 Lone Yew Rd	SW	SW	20	11	1	W	Lewis	Qapo	>	23	47					44	70	N	
21180016	11				Kliner	117 Lone Yew Rd	NW	SW	20	11	1	W	Lewis	Qapo		18	49					65	68	N	
21180019	11				Sharp		SE	NW	20	11	1	W	Lewis	Qapo	>	12	45					51	57	N	
21180020	11				Washington Mutual Bank	Tooley Rd	SW	SE	21	11	1	W	Lewis	Qapo		10	41						181	N	
21180021	11				Rice		NE	NE	21	11	1	W	Lewis	Qapo	>	5	26	9	12			40	52	N	
21180022	11				Lutz	588 Salmon Cr Rd	NE	SE	21	11	1	W	Lewis	Qapo		8	45					42	55	N	
21180024	11				Coverdell		SE	SE	21	11	1	W	Lewis	Qapo		5	39					41	80	N	
21180023	11	W41076		93-1	Evers	Salmon Cr Rd	NW	SW	22	11	1	W	Lewis	Qapo	>	4	56					38	60	N	
21180025	11	W043937			Meister	651 Salmon Cr Rd	SW	SW	22	11	1	W	Lewis	Qapo		0	25						100	Y	
21180009	11				Clark		NE	SW	28	11	1	W	Lewis	Qapo		0	2						219	N	
21180010	11				Beebe	15619 NE Caples Rd	NW	NE	28	11	1	W	Lewis	Qapo		8	34						55	N	
21180008	11	W055833			Busley	228 Blake Rd	SW	NE	29	11	1	W	Lewis	Qapo		13	35						59	Y	
21180018	11				Killian	Blake Rd	NW	NE	29	11	1	W	Lewis	Qapo	>	9	51						60	N	
21180004	11				Humbert		NW	NW	30	11	1	W	Lewis	Qapo	>	25	6	9	5			40	45	N	
21180005	11	W056202			Tech	Smokey Valley Rd	SE	SE	30	11	1	W	Lewis	Qapo	>	20	20						40	N	
21180006	11	12845			Shannon	288 Lone Yew Rd	NE	SE	30	11	1	W	Lewis	Qapo		15	32					47	51	N	
21180007	11	W051596			Hagquist	Smokey Valley Rd	NE	NW	32	11	1	W	Lewis	Qapo			0						318	Y	
21170037	11	W119716			Baydo	Inman Rd	SE	SW	13	11	2	W	Lewis	Qa	>	17	14					17	31	N	
21170033	11				Zion		NE	NE	15	11	2	W	Lewis	Qapo	>	10	36					28	46	N	
21170021	11				Lair	970 S Military Rd	NE	NW	21	11	2	W	Lewis	Qapo		20	113					126	140	N	
21170022	11				Sardo	1046 S Military Rd	SE	NW	21	11	2	W	Lewis	Qapo	>	26	2	22	12	13	29	60	104	N	
21170023	11				Leak	S Military Rd	NE	NE	21	11	2	W	Lewis	Qapo		40	33						85	N	
21170024	11				Watson	219 Telegraph Rd	SW	SE	22	11	2	W	Lewis	Evb_{gr}		0	16						215	Y	
21170025	11				Clark		SW	SE	23	11	2	W	Lewis	Qapo		5	12						148	Y	
21170026	11				Kolehmainen		SW	NE	23	11	2	W	Lewis	Qapo		16	14						34	N	
21170027	11	W043946			Proto's Inc.	271 Cowlitz Ridge Rd	NE	NE	23	11	2	W	Lewis	Qapo		21	5					23	40	N	
21170028	12	72039	Y		B. P. Toledo	101 Mulford Rd	SE	SE	23	11	2	W	Lewis	Qa	>	0	6	8	6				20	N	
21170042	11				Clark		SW	SE	23	11	2	W	Lewis	Qa		5	12						148	Y	
21170043	11				Clark		SW	SE	23	11	2	W	Lewis	Qa		11	14					19	30	N	
21170031	11	69995			Johnson	132 Mulford Rd	SW	NW	24	11	2	W	Lewis	Qa		0	15						100	N	
21170032	11				Sealey	180 Herriford Rd	SE	SW	24	11	2	W	Lewis	Qa		0	16						97	Y	
21170038	11	W067149			Crites	Lot 4 Shoreline Dr	NE	NW	24	11	2	W	Lewis	Qa		11	28						39	N	
21170039	11				Washington		SW	SW	24	11	2	W	Lewis	Qa		15	15					15	30	N	
21170040	11	5568			White	123 Mulford Rd	SW	SW	24	11	2	W	Lewis	Qa		0	22					18	26	N	
21170041	11	W061370			Wright	Lot 2 Sunshine Shores		SW	24	11	2	W	Lewis	Qa	>	12	28					17	40	N	

IDENTIFIER						LOCATION									WELL LOG									
WADNR unique number	WADNR data type code	WADOE well number	Data verified?	Well name	Original well owner	Well location	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Geologic unit	Qualifier	Overburden thickness (feet)	1st gravel thickness (feet)	1st interbed thickness (feet)	2nd gravel thickness (feet)	2nd interbed thickness (feet)	3rd gravel thickness (feet)	Depth to water-bearing zone (feet)	Well total depth (feet)	Bedrock penetrated?	Reference
21180011	11				Cowlitz Shores Campground		SW	NE	24	11	2	W	Lewis	Qa	>	0	41					25	41	N	
21180012	11				Wright	127 Shoreline Dr	NE	SE	24	11	2	W	Lewis	Qa	>	2	31					16	33	N	
21180092	11	W124459			Adolf	263 Shoreline Dr	NE	NE	24	11	2	W	Lewis	Qa	>	8	20					25	28	N	
21180093	11	W117095			Smith	Herriford Rd	NW	NE	24	11	2	W	Lewis	Qa		5	30						80	Y	
21170019	11	29660			Brunner	Jackson Hwy S	NW	SW	25	11	2	W	Lewis	Qapo	>	22	35					52	57	N	
21170020	11	12854			Mathis	708 Jackson Hwy	NE	NW	25	11	2	W	Lewis	Qapo		12	6						300	Y	
21180002	11	12833			Allen	Smokey Valley Rd	SW	SE	25	11	2	W	Lewis	Qapo			0						142	Y	
21170018	11	W045856			McNew	538 Hwy 506	NE	NW	26	11	2	W	Lewis	Qa		2	24						113	N	
21170044	11	30523			Owens	550 Mandy Rd	SE	NW	26	11	2	W	Lewis	Qa		16	8					18	30	Y	
21170045	11	201835			Butcher	545 Hwy 506	W	NW	26	11	2	W	Lewis	Qa		0	12						145	Y	
21170046	11				Cowlitz Basin Oil Co. Inc.		S	N	26	11	2	W	Lewis	Qa		7	59						467	Y	
21170047	11				Lund		NE	NW	26	11	2	W	Lewis	Qa	>	3	8	14	5				30	N	
21170048	11				Phillips	534 Hwy 506	NE	NW	26	11	2	W	Lewis	Qa		0	20						75	Y	
21170015	11				Elkinton	532 Mandy Rd	SE	SW	27	11	2	W	Lewis	Qa		16	10						58	Y	
21170013	11			Well #2	Chesterfield/Hoss Inc.		SE	SW	28	11	2	W	Lewis	Qapo			0						200	Y	
21170300	11				Daily		NW	SE	33	11	2	W	Lewis	Qapo	>	48	16					58	64	N	
21170004	11				Sheperdson	316 Rogers Rd	SE	NW	34	11	2	W	Lewis	Qapo		7	24						70	N	
21170005	11	203940			Wallace	Barnes Dr	SE	SE	34	11	2	W	Lewis	Qapo		28	20					38	140	Y	
21170006	11				Wallace	Jackson Hwy S	NE	SW	35	11	2	W	Lewis	Qa		23	62					75	150	N	
21170007	11	W066746		96-1	Estes	183 Foster Cr Rd	SW	NW	35	11	2	W	Lewis	Qapo	>	25	33						58	N	
21170009	11	41078			Lyons	241 Foster Rd	NW	NW	35	11	2	W	Lewis	Qapo		20	33					48	60	N	
21180003	11				Calvin		NE	NE	36	11	2	W	Lewis	Qapo		10	30						65	Y	
23170001	11				Calvin		NW	NE	36	11	2	W	Lewis	Qa	>	20	27					22	47	N	
21180088	11	W066762			Davidson	162 Boone Rd	SW	NW	26	12	1	W	Lewis	Qapo	>	13	45					42	58	N	
21180089	11				Andrews	642 Tucker Rd	SE	NE	26	12	1	W	Lewis	Qapo	>	16	34						50	N	
21180090	11				Fish	Tucker Rd	NW	SE	26	12	1	W	Lewis	Qapo		15	1	4	28	28	6	66	84	Y	
21180091	11				Tobias	693 Tucker Rd	SE	SE	26	12	1	W	Lewis	Qapo	>	16	42					51	58	N	
21180085	11				Secrest		SW	NE	27	12	1	W	Lewis	Qapo	>	18	26						44	N	
21180086	11				Sharp		SW	SE	27	12	1	W	Lewis	Qapo	>	19	26					42	45	N	
21180087	11				Sharr	904 Tucker Rd	SE	SE	27	12	1	W	Lewis	Qapo	>	12	40					48	60	N	
21190038	11				Toney	1247 Evans Rd	SW	SW	27	12	1	E	Lewis	Qao$_e$		8	82						220	Y	
21180081	11				Delaney	Tucker Rd	SW	SW	28	12	1	W	Lewis	Qapo	>	17	25					38	42	N	
21180082	11				Hastings		SE	SW	28	12	1	W	Lewis	Qapo	>	22	12					32	34	N	
21180083	11				Andreessen	132 Gray Rd	NW	SE	28	12	1	W	Lewis	Qapo	>	10	30					29	40	N	
21180084	11				Herd	208 Gray Rd	NE	SE	28	12	1	W	Lewis	Qapo	>	13	28						41	N	
21190037	11				Amrine	263 Drews Prairie Rd	SW	NW	28	12	1	E	Lewis	Qapo		12	20						150	Y	
21180080	11	W092989			Carolan	Henriot & Frost	SW	SW	30	12	1	W	Lewis	Qapo			0						126	N	
21190033	11	W064891			Hamilton	229 Howe Rd	SE	SW	30	12	1	E	Lewis	Qapo	>	2	22	8	5	88	1	125	126	N	

IDENTIFIER						LOCATION									WELL LOG										
WADNR unique number	WADNR data type code	WADOE well number	Data verified?	Well name	Original well owner	Well location	¼ ¼ section	¼ section	Section	Township (N)	Range	Meridian	County	Geologic unit	Qualifier	Overburden thickness (feet)	1st gravel thickness (feet)	1st interbed thickness (feet)	2nd gravel thickness (feet)	2nd interbed thickness (feet)	3rd gravel thickness (feet)	Depth to water-bearing zone (feet)	Well total depth (feet)	Bedrock penetrated?	Reference
21190034	11	55839			Kahler	1152 Spencer Rd	SW	SE	30	12	1	E	Lewis	Qa		10	21						44	Y	
21180059	11	W059343			Keys		NW	NW	31	12	1	W	Lewis	Qapo	>	49	1					49	50	N	
21180060	11				Miller		NE	SW	31	12	1	W	Lewis	Qapo	>	8	17	10	5			35	40	N	
21180061	11	202603			Turner	189 Ivy Dale Ln	NE	SE	31	12	1	W	Lewis	Qapo			0						101	Y	
21190022	11	W058479			Lincoln	Hinckley Rd	NW	SW	31	12	1	E	Lewis	Qa	>	2	17	36	3			55	58	N	
21190023	11	29686			Bryan	Blue Cr Development	NE	SW	31	12	1	E	Lewis	Qa		2	24						240	Y	
21190024	11	19282			Beaman	150 Mallard Ln	SE	NE	31	12	1	E	Lewis	Qa		8	12						35	N	
21190043	12	R036808	Y	MW-1,2,3,4		Cowlitz Trout Hatchery	NE	NE	31	12	1	E	Lewis	Qa	>	0	15						15	N	
21190044	11	W096113			Pond	185 Deer Park Ln	NE	SE	31	12	1	E	Lewis	Qa	>	1	31						32	N	
21180062	11				Schoonover		SE	NW	32	12	1	W	Lewis	Qapo	>	12	45					47	51	N	
21180063	11				Salzsieder		NW	SE	32	12	1	W	Lewis	Qapo		2	66					35	77	N	
21180064	11				Wild	Sareault Rd	SE	SE	32	12	1	W	Lewis	Qapo	>	25	18					41	43	N	
21190025	11	W071638			Novak	Grimes Rd	NW	NW	32	12	1	E	Lewis	Qa		0	9						40	N	
21190026	11				Mingle		SE	NW	32	12	1	E	Lewis	Qao_e		1	23						270	N	
21190027	11				Brenner		NW	NE	32	12	1	E	Lewis	Qao_e		10	8						205	N	
21190028	11	W064882			Serl	115 Cougar Ln	SW	NE	32	12	1	E	Lewis	Qao_e	>	4	14	49	1			67	68	N	
21180065	11				Schone		NE	NW	33	12	1	W	Lewis	Qapo	>	6	44						50	N	
21180066	11				Cowlitz Prairie Grange	Jackson Hwy	NW	SE	33	12	1	W	Lewis	Qapo	>	25	17	24	4			66	70	N	
21180067	11	W068195			Pratt	1177 Tucker Rd	SW	NE	33	12	1	W	Lewis	Qapo	>	12	43					35	65	N	
21180070	11				Secrest		NE	NE	33	12	1	W	Lewis	Qapo	>	6	55					56	61	N	
21180068	11				Fase	1132 Tucker Rd	NW	NW	34	12	1	W	Lewis	Qapo	>	5	54					45	59	N	
21180069	11	15783			Lauderbrock Farms	1066 Tucker Rd	NW	SW	34	12	1	W	Lewis	Qapo	>	25	33					52	58	N	
21180071	11	W068181			Webster	389 Spencer Rd	NE	SW	34	12	1	W	Lewis	Qapo	>	13	62					60	75	N	
21180072	11				Bell	855 Spencer Rd	SE	SE	34	12	1	W	Lewis	Qapo	>	16	58					63	75	N	
21180073	11				Glerum		NW	NE	34	12	1	W	Lewis	Qapo		12	66					40	83	N	
21180074	11				Pitzer	School Ln	NW	NW	35	12	1	W	Lewis	Qapo	>	14	46					58	60	N	
21180075	11	W096720			Goodwin	Spencer Rd	NW	SE	35	12	1	W	Lewis	Qapo		20	60					56	83	Y	
21180077	11	W060733			Merly	714 Spencer Rd	SE	NE	35	12	1	W	Lewis	Qapo	>	26	54						80	N	
21180078	11	W104463		#1	Askin	757 Spencer Rd	NE	NE	35	12	1	W	Lewis	Qapo		6	35						55	N	
21180076	11				Isolei		SE	SW	36	12	1	W	Lewis	Qao_e		2	21						82	N	
21180079	11	W35837			Beaufait	Spencer Rd	SE	NW	36	12	1	W	Lewis	Qapo	>	1	79					32	80	N	
21190020	11	66822			Meyers	165-13 Howe Rd E	NW	SE	36	12	1	W	Lewis	Qao_e		2	20						120	N	
21190021	11				Harley	229 Howe Rd E	SE	SE	36	12	1	W	Lewis	Qao_e		0	37					28	52	N	
21180057	11	21735			Deep Forest Nursery	1298 Winlock-Toledo Rd	SW	SE	36	12	2	W	Lewis	Qapo		8	57					48	80	N	
21180058	11				Hopper	Henriot Rd	SE	NE	36	12	2	W	Lewis	Qapo	>	47	3	14	3	14	4	64	85	N	

Appendix 6. Geologic description of significant and (or) historically mined units

This appendix includes unit descriptions for most geologic units in the Mount St. Helens 1:100,000-scale quadrangle that have been mined for construction aggregates regardless of quality and (or) have potential to produce gravel or bedrock meeting the threshold criteria of this study. These descriptions are intended for geologists and engineers and contain a number of terms that are not included in the glossary (Appendix 1). Unit abbreviations follow the Washington Division of Geology and Earth Resources method (Walsh and others, 1987). Descriptions for all units except dredge spoil deposits are compiled from Phillips (1987a), with the following exceptions: the description for Grande Ronde Basalt (unit M̶v$_g$) was compiled from Phillips (1987a) and Evarts (2001); the description of the dacite of the Kalama dome (unit Qida) is from Evarts and Ashley (1990b).

SEDIMENTARY DEPOSITS

Nonglacial Deposits

Qa **Alluvium (Holocene to upper Pleistocene?)**—Sand, silt, and gravel forming bars or islands within rivers and low, undissected terraces along flood plains of rivers and major creeks. Along the Columbia River, consists mostly of sand and silt; along the Cowlitz River, dominantly sand and basaltic gravel (Livingston, 1966). Along Cedar and Salmon Creeks, alluvium is composed of bars of reworked landslide debris from the Tertiary Wilkes, Toutle, or Cowlitz Formations (Roberts, 1958). Gravel- and sand-sized alluvium along the Toutle River consists mostly of reworked lahar deposits from the 1980 eruption of Mount St. Helens and contains abundant pumice. Thickness of alluvial deposits is highly variable but is commonly 1.5–15 m.

Qt **Terraced deposits (Holocene? to Pleistocene)**—In the Kelso and Castle Rock areas, light-colored silt containing late Pleistocene vertebrate (mammoth) fossils (Roberts, 1958; Livingston, 1966); forms dissected terrace about 12–24 m high; possibly correlative with Hayden Creek–age outwash deposits (unit Qapo) in the upper Cowlitz River drainage (Livingston, 1966), but more likely consists of late Pleistocene slackwater deposits from outburst floods of Glacial Lake Missoula.

Qls **Landslide deposits (Holocene to Pleistocene)**—Heterogeneous mixtures of basalt and andesite blocks with weakly consolidated sand, silt, and clay; typically form hummocky, poorly drained earthflows or slides into river drainages; most landslides in the map area result from the failure of incompetent sedimentary rocks (Cowlitz, Toutle, or Troutdale Formations) underlying resistant volcanic rocks (Grays River volcanics, Goble Volcanics, Grande Ronde Basalt, or unnamed Oligocene flows) (Livingston, 1966; Roberts, 1958).

QP̶c$_t$ **Troutdale Formation (lower Pleistocene to Lower Pliocene)**—Moderately to weakly consolidated conglomerate, sandstone, and sandy siltstone; conglomerate crossbedded and channeled, with well-rounded, dominantly basaltic pebbles and cobbles, distinctive light orange quartzite cobbles and pebbles forming 5–15% of all clasts, and rare schist and granite clasts; lenticular, cross-bedded, coarse-grained sandstone beds are intercalated with conglomerate; sand grains consist of angular quartz, feldspar, rock fragments, and mica; siltstone is light gray, very weakly consolidated, and mineralogically similar to the sandstone except that more clay is present; degree of cementation and consolidation is variable.

Mc$_w$ **Wilkes Formation (Upper to Middle Miocene)**—Semiconsolidated, rust-colored to greenish-gray tuffaceous siltstone and sandstone, with interbedded conglomerate, claystone, and minor fibrous lignite.

Dredge Spoil Deposits

Unconsolidated deposits dredged from the Toutle, Cowlitz, and Columbia Rivers. Consist of pumice, ash, sand, and gravel derived from the 1980 Mount St. Helens eruption.

Glacial Deposits

Qao$_e$ **Alpine glacial outwash, younger than Evans Creek Stade (Holocene to upper Pleistocene?)**—Sand and gravel deposits along the Cowlitz River near Toledo; thickness unknown, mantled with less than 0.3 m of fine sand and silt (loess) and oxidized to a depth of about 0.5 m (Dethier and Bethel, 1981).

Qapt$_e$ **Evans Creek till (upper Pleistocene)**—Till and outwash deposits confined to north-facing cirques or cirque-headed valleys at elevations above about 750 m in the highlands north, west, and southwest of Mount St. Helens; correlated by Hammond (1985) and Evarts and Ashley (1984) with Evans Creek Drift.

Qapo **Outwash (upper Pleistocene)**—Includes Evans Creek outwash, pre-Evans Creek–post-Hayden Creek outwash, and Hayden Creek outwash. Evans Creek outwash gravel deposits along the Cowlitz River are generally 3–8 m thick and mantled with 0.3–2.0 m of fine sand and silt (loess); deposits oxidized to a depth of about 1 m (Dethier and Bethel, 1981). Pre-Evans Creek–post-Hayden Creek outwash gravel deposits are generally 3–5 m thick and mantled with about 0.5–1.5 m of silt and fine sand (loess); deposits form isolated terrace remnants near Toledo; oxidation extends to a depth of about 1.0–1.5 m (Dethier and Bethel, 1981). Hayden Creek outwash gravel deposits along the Cowlitz River are generally 5–16 m thick and mantled with about 0.5–2.0 m of fine sand and silt (loess); oxidation extends to a depth of about 1.5 m (Dethier and Bethel, 1981).

Qapt$_h$ **Hayden Creek till (upper Pleistocene)**—In the upper Cowlitz River valley, till covered with 1.5–3.0 m of weathered silt (loess) and thin sand and gravel deposits

(Dethier and Bethel, 1981); in the Elk Rock area, silt-rich bouldery till covered with 1–9 m of yellow-brown, massive reworked volcanic ash and, locally, colluvium; interbedded with thinly laminated glacial-lacustrine sediments and deltaic outwash gravels at Hoffstadt Creek (T3E R10N); locally distinguished with difficulty from high-elevation lahar deposits; characterized by striated and faceted clasts and by clasts of granitic composition derived from the Spirit Lake pluton; basaltic to andesitic cobbles from till have weathering rinds of 0–2 mm.

VOLCANIC DEPOSITS

Qvl **Lahar deposits (Holocene)**—In North and South Fork Toutle Rivers, 2–9 m of clast-supported sandy gravel sharply overlain by 2 m to <20 cm of matrix-supported, unstratified mixtures of gravel and sand; along the center of channels, overlain by thin (<0.5 m) stratified and cross-bedded sands with gravel lenses (Gilkey, 1983).

Qvc **Lahar and pyroclastic flow deposits, undivided (Holocene to Pleistocene)**—Unconsolidated lahar and pyroclastic flow deposits characterized by gray, pink, and red hornblende-hypersthene dacite and andesite clasts (Hopson, 1980) and absence or near-absence of mafic lithic clasts; consists entirely of lahar deposits in the Toutle–Cowlitz and lower Kalama River systems; elsewhere contains mixed pyroclastic flow, lahar, glacial, and alluvial deposits; includes the Pine Creek volcanic assemblage of Crandell and Mullineaux (1973) and the Swift Creek volcanic assemblage of Hyde (1975).

Qva_1 **Andesite flows (upper Pleistocene)**—Gray fine-grained to very fine-grained hornblende andesite; erupted from vent on south side of Marble Mountain in the NW¼ sec. 13, T7N R5E; forms block lava flows, 10–15 m thick with top and bottom breccia zones; platy jointed; maximum thickness about 40–60 m (Hammond, 1980). Also includes the andesite flows of Timbered Peak (upper Pleistocene?)—medium gray, porphyritic augite-olivine basaltic andesite; form thick (~31 m) intracanyon flows; massive, with smooth glaciated surface.

Qvb **Basalt flows, unnamed (Pleistocene?)**—Poorly known, dark to medium gray basalt or basaltic-andesite lava flows in highlands south of Swift Reservoir and east of Merrill Lake (sec. 18, T7N R4E); recognized by geomorphic character and fresh, unaltered appearance of generally dense, very fine-grained basalt or basaltic andesite; age uncertain but most flows appear to have been glaciated.

Mv_g **Grande Ronde Basalt of the Columbia River Basalt Group (Middle Miocene)**—Light to dark-gray to black, dense, hackly-fractured to blocky- or columnar-jointed, vesicular to microvesicular, aphyric to microphyric basaltic andesite (Evarts, 2001). Commonly deeply weathered and laterized; in the Kelso area and southwest of Rainier, Oregon, forms reddish ferruginous bauxite deposits averaging about 4 m thick (Livingston, 1966).

The Grand Ronde Basalt was erupted from vents in southeastern Washington, Idaho and Oregon. The rocks exposed in the Mount St. Helens quadrangle are the eastern edge of a huge sheet of flows that filled channels of the ancestral Columbia River, reached the Pacific Ocean, and invaded soft marine sediments of Miocene to Middle Eocene age (Beeson and others, 1979). North of the Longview–Kelso area, Grande Ronde Basalt typically consists of isolated outcrops made up of only one or two flows.

Mva_s **Andesite of Smith Creek Butte (Lower Miocene?)**—Pyroxene andesite and olivine-pyroxene andesite lava flows (Hopson, 1980); possibly equivalent to Lower Miocene units—for instance, andesite of Council Bluff or andesite of Three Corner Rock, found east of the map area in the Mount Adams and Vancouver quadrangles (Korosec, 1987; Phillips, 1987b).

$M\Phi vc_2$ **Volcaniclastic rocks (Lower Miocene to Upper Oligocene)**—Subaerial pyroclastic and sedimentary rocks including andesitic to dacitic, typically lithic-rich, ash-flow and air-fall tuff, tuff breccia, volcanic siltstone, sandstone, conglomerate, minor coal beds, and many poorly sorted volcanic breccia beds of uncertain origin; dominantly pumiceous pyroclastic rocks in eastern portion of outcrop area where closely associated with thick accumulations of dacite; volcanic glass altered to smectite, quartz, feldspar, and zeolites (Evarts and Ashley, 1984).

MΦvb **Basalt flows (Lower Miocene to Upper Oligocene)**—Black to dark gray-green, aphyric to sparsely porphyritic, massive to vesicular basalt and basaltic-andesite lava flows and flow breccia; locally includes interbedded mafic tuff, lahar, and minor sedimentary rocks; porphyritic flows contain phenocrysts of plagioclase, olivine, and augite in intergranular to intersertal groundmass of plagioclase, clinopyroxene, magnetite, and rare brown to green glass; slightly to completely altered to zeolite or prehnite-pumpellyite facies assemblages; within contact aureole of Spirit Lake pluton, recrystallized to fine-grained hornblende- and pyroxene-hornfels facies assemblages (Evarts and Ashley, 1984).

MΦva **Basaltic-andesite and andesite flows (Lower Miocene to Upper Oligocene)**—Porphyritic pyroxene andesite and basaltic-andesite flows and flow breccia, locally includes minor basalt and dacite flows, breccia, and interbedded volcaniclastic rocks; typically consists of plagioclase, augite, and hypersthene phenocrysts in pilotaxitic groundmass of plagioclase, pyroxene, magnetite, quartz, and interstitial glass (usually altered to fine-grained smectite); includes hypabyssal sills or dikes in areas where contacts could not be observed (Evarts and Ashley, 1984).

$M\Phi vt_3$ **Tuff (Lower Miocene to Upper Oligocene)**—Tuff-breccia and lapilli-tuff with angular volcanic-lithic fragments in matrix of pumice lapilli and ash; pumice-lapilli tuff in beds several centimeters to tens of meters thick; typically lithic-rich with eutaxitic foliation; includes air-fall tuff, nonwelded to poorly welded ash-flow tuff, reworked pyroclastic material, and pumiceous mudflow deposits; quartz-phyric tuff not present; massive poorly sorted tuff-breccia and lapilli-tuff several hundred meters thick northeast of the Spirit Lake pluton may represent caldera-fill deposits (Evarts and others, 1987).

Φvd_1 **Dacite flows, plugs or lava domes (Lower Miocene to Upper Oligocene)**—White to light greenish gray, sparsely phyric, commonly flow-banded dacite flows, flow breccia, or hypabyssal, chaotically jointed plugs or lava domes; typically contains less than 10% plagioclase and 5% pyroxene phenocrysts in a groundmass of devitrified glass that now consists of fine-grained granular to spherulitic quartz and feldspar; contains rare hornblende; quartz and biotite not present; secondary alteration more common than in interbedded, more mafic volcanic rocks; commonly contains alteration resulting from supergene oxidation of minor but widespread pyrite (Evarts and Ashley, 1984).

Φva_1 **Andesite lava flows (Lower Oligocene)**—Porphyritic two pyroxene andesite, clinopyroxene basaltic andesite, and associated flow breccia forming two major flow complexes at the Toutle Mountain Range (T9N R2E) and near Big Bull Mountain (T8N R3,4E).

At the Toutle Mountain Range, the unit consists of platy, light- to medium-gray, porphyritic andesite with abundant medium-grained hypersthene, plagioclase, and clinopyroxene phenocrysts; ground-mass is hypocrystalline with trachytic, intersertal texture composed of dark brown glass, tabular plagioclase, and equant clinopyroxene; about 600 m thick (Roberts, 1958)

Φvc_1 **Volcaniclastic sedimentary and volcanic rocks (Lower Oligocene)**—Diverse lithologies including dark green-gray boulder conglomerate and breccia, and light-colored pumiceous lapilli tuff and tuffaceous sediments; major accumulations include the beds of Fossil Creek (T8N R3,4E) consisting of about 120 m of well-bedded pumice-vitric-crystal tuff of andesitic to dacitic composition.

ΦEva_g **Basaltic andesite flows (Lower Oligocene to Upper Eocene)**—Porphyritic pyroxene basaltic andesite lava flows and flow breccia with thin interbeds of red-brown siltstone, sandstone, conglomerate, and tuff; also contains lesser olivine basalt, pyroxene andesite, and platy to irregularly jointed dacite; flows are typically thin (1–4 m) but can be 60 m thick (R. C. Evarts, USGS, written commun., 2001) with wavy top and bottom contacts; thin (5–50 cm) siltstone or sandstone layers often separate flows; dense flow centers typically blocky-jointed to platy; well-developed columnar-jointing or colonnade-entablature sets rare; locally scoriaceous flow breccia forms bulk of unit, enveloping small, lenticular dense flow-centers in block rubble; vugs and fractures contain characteristic assemblage of calcite and complex suite of zeolite minerals (Tschernich, 1986); unit thickness is several thousand meters (Smith, 1993; Evarts and Swanson, 1994).

ΦEvc_g **Volcaniclastic sedimentary and volcanic rock member of the Goble Volcanics (Lower Oligocene to Upper Eocene)**—Light-colored volcanic-lithic sandstone, siltstone, and conglomerate, lapilli and ash tuff, breccia, and minor coal and carbonaceous shale; locally contains interbedded lava flows similar to unit ΦEva_g; thin-bedded to massive with coarser-grained strata commonly cross-bedded; tuff commonly normally graded; upon weathering, unit produces characteristic brilliant red, sticky, clay-rich soils; thickness variable; at least 180 m thick in the vicinity of Mount Brynion (T8N R1W), about 50 m thick north of Castle Rock in (secs. 11 and 12, T10N R2W) (Roberts, 1958, p. 20).

ΦEn_t **Toutle Formation (Lower Oligocene to Upper Eocene)**—Poorly sorted basaltic to andesitic conglomerate and sandstone with interbedded tuffaceous siltstone, high-alumina clay, lignite, pumiceous lapilli tuff, and locally basalt or basaltic andesite lava flows; volcanic-lithic sandstone is olive-gray and composed of basalt, andesite, red scoria, pumice, plagioclase, magnetite, and small amounts of quartz, biotite, augite, and hornblende; tuffaceous siltstone usually carbonaceous; about 173 m (570 ft) thick (Roberts, 1958, p. 24-31).

Evb_{gr} **Grays River volcanics (Upper to Middle Eocene)**—Porphyritic and aphyric, dark gray to black, high-TiO_2 olivine-augite basalt lava flows and flow breccia, basaltic tuff, hyaloclastic breccia, basaltic sandstone, and cobble to pebble basaltic conglomerate; interbedded with light-colored quartzo-feldspathic sedimentary rocks of the Cowlitz Formation along the western margin of the map area.

Lava flows typically consist of 5 to 15 m of dense, blocky- to columnar-jointed, massive flow-centers, with 1 to 2 m of basal or flow-top scoriaceous breccia; locally flows consist entirely of scoriaceous block breccia; flow tops and bases are hummocky, often oxidized and rust-colored, and are commonly intercalated with massive feldspathic sandstone or sandy siltstone, coal, or basaltic volcaniclastic sedimentary rocks.

INTRUSIVE ROCKS

Qida **Dacite of the Kalama dome (Holocene or Pleistocene)**—Light-gray to pink porphyritic to seriate hypersthene-hornblende dacite forming the Kalama dome (informal name for a small dome along Kalama River 4.2 km southwest of Goat Mountain); dome carapace consists of large angular dacite blocks as much as 2 m across; phenocrysts include conspicuous slender prisms of shiny black hornblende (4–5%; as long as 1 cm); age of emplacement unknown but apparently postdates Fraser Glaciation and is petrographically and chemically similar to dacites erupted from Mount St. Helens (Evarts and Ashley, 1990b).

Migd **Granodiorite (Lower Miocene)**—In the Spirit Lake area, consists of a complex of dikes and irregularly shaped intrusions of fine-grained porphyritic to seriate pyroxene-quartz diorite, together with numerous screens of thoroughly recrystallized (hornfelsed) country rock; extensive to complete deuteric alteration characteristic (Evarts and others, 1987).

Elsewhere in the map area, consists of small, poorly known dikes, sills, and irregular shaped intrusive bodies with fine- to medium-grained phaneritic texture or porphyritic texture with phaneritic groundmass and granodioritic to quartz dioritic mineralogy.

Miqd **Quartz diorite of the Spirit Lake pluton (Lower Miocene)**—Dark to light gray to pale pink-gray, medium- to coarse-grained quartz diorite, quartz monzodiorite, granodiorite, and quartz monzodiorite; consists of numerous small, irregular bodies with complex, commonly gradational contacts. Most lithologies moderately to extensively deuterically altered; coarse-grained hypidiomorphic granular textures predominate in southwest portion of unit and porphyritic textures elsewhere (Evarts and others, 1987).

Miqm **Quartz monzonite of the Spirit Lake pluton (Lower Miocene)**—Light gray to pale pinkish gray, fine- to medium-grained, generally sparsely porphyritic pyroxene-hornblende-quartz monzonite, granite, and aplite.

Mid **Intrusive diorite dike, sill, or plug (Lower Miocene)**—Consists of poorly known small dikes, sills, or irregular plugs; fine- to medium-grained phaneritic texture or porphyritic texture with fine-grained groundmass; contains dioritic to gabbroic mineralogy (plagioclase, pyroxene, and magnetite).

MΦian **Intrusive andesite dikes, sills, or plugs (Upper Miocene to Lower Oligocene)**—Dark gray to black, porphyritic to aphyric pyroxene basaltic andesite or basalt with lesser pyroxene andesite and hornblende andesite; typically blocky-jointed to platy; often sheared; may contain vesicles but lack flow structures such as flow breccia; commonly resistant, forms cliffs or waterfalls in streams; locally altered to chlorite and zeolite minerals. Small, poorly known hypabyssal intrusions very numerous in eastern one-third of map area; distinguished with difficulty from lava flows of similar composition unless contacts observed; easiest to observe cutting volcaniclastic or tuff units.

Washington Division of Geology and Earth Resources
Ron Teissere, State Geologist
Information Circular 95
October 2001

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

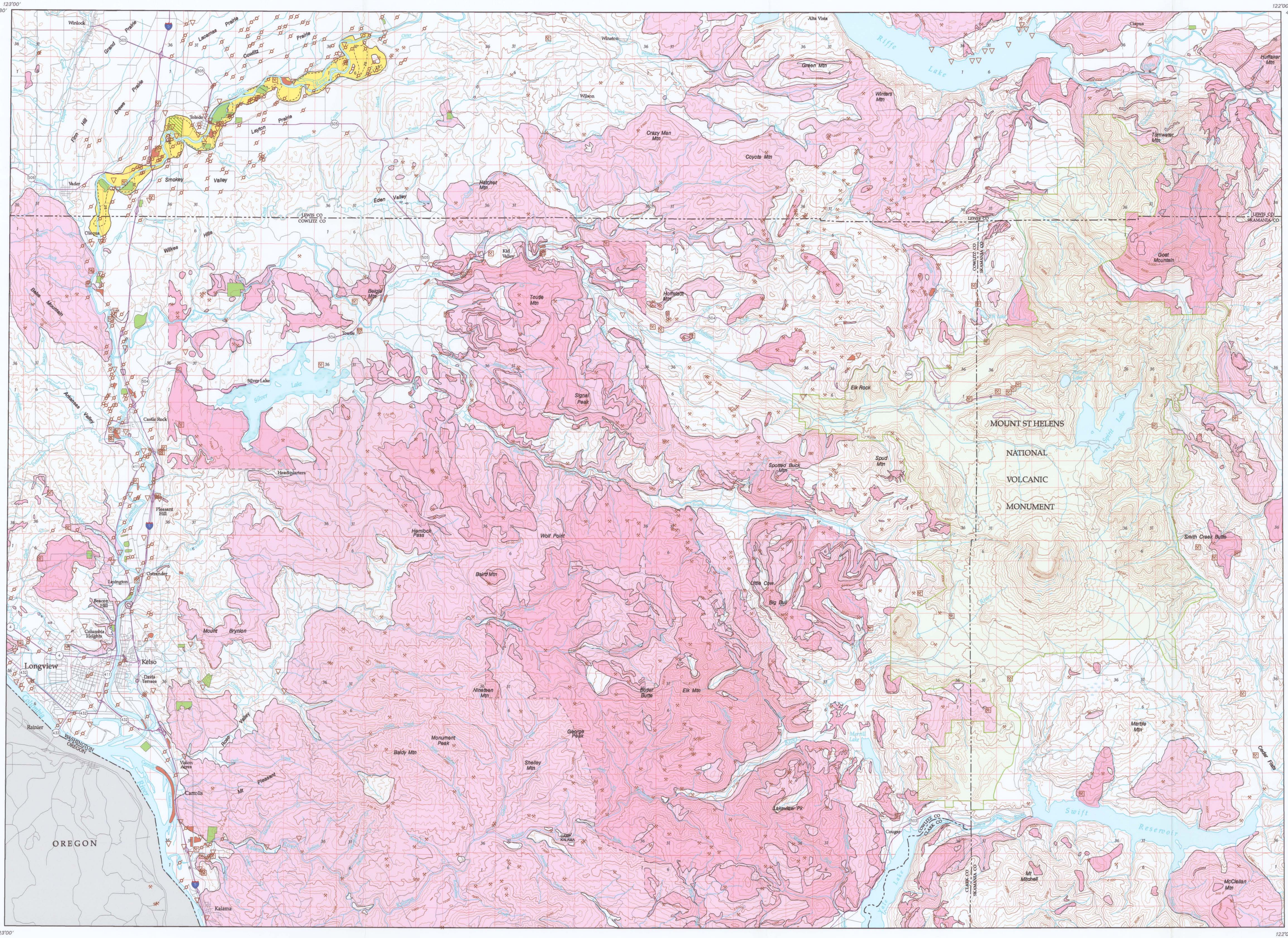

PLATE 1

RECONNAISSANCE INVESTIGATION OF SAND, GRAVEL, AND QUARRIED BEDROCK RESOURCES IN THE MOUNT ST. HELENS 1:100,000 QUADRANGLE, WASHINGTON

David K. Norman, Andrew B. Dunn, and Cathrine Kenner

with digital cartography by
Phung Ho and Charles G. Caruthers

EXPLANATION

- Location of water well used in this study for subsurface information
- Location of geotechnical or other borehole used in this study
- Sampling site for laboratory test of strength and durability of gravel or rock. (Does not include analyses from most mines. These are described in Appendix 4)
- Small gravel pit, borrow pit, or quarry. Most of these mines are used for forest road maintenance or construction and/or do not significantly influence the market at this time
- Depleted or abandoned small gravel pit, borrow pit, or quarry. Includes mines with terminated state reclamation permits, reclaimed sites, and mines that cannot be operated owing to changes in land use (for example, if the site has been flooded by a reservoir)
- Large active mine. Includes intermittently operated sites and a few sites that may have been abandoned, but not reported as such
- Large depleted or abandoned mine
- Large proposed mine
- Potential extent of 'hypothetical undiscovered' sand and gravel reserves, most of which meet threshold criteria for strength, durability, thickness, areal extent, and clast-size distribution, and are not buried under thick layers of overburden. (See text for further explanation)
- Potential extent of "speculative undiscovered" bedrock reserves, most of which meet threshold criteria for strength, durability, thickness, and areal extent, and are not buried under thick layers of overburden. (See text for further explanation)
- Potential extent of "speculative undiscovered" bedrock reserves that locally meet the threshold criteria, but are composed mostly of weak lithologies that are unsuitable for construction aggregate
- Contour showing possible thickness of some hypothetical gravel deposits meeting the threshold criteria
- Scratch boundary

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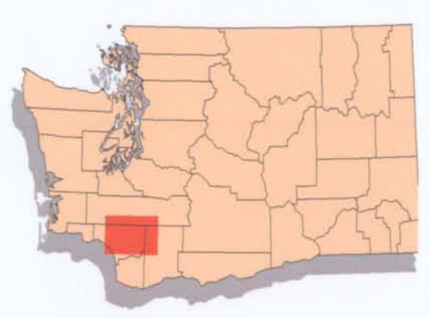

0 1 2 3 4 5
MILES

Scale 1:100,000

TOPOGRAPHIC CONTOUR INTERVAL 200 FEET

Lambert Conformal Conic Projection
1927 North American Datum
Washington State Plane Coordinate System, South Zone
Other base map information from the Washington Department of Natural Resources, Geographic Information System Database - 2000
Washington Division of Geology and Earth Resources

Map production date: 02 Nov 2001