Geologic Assessment of Potential Aggregate Source Areas in Pend Oreille County, Washington

WA-RD 734.1

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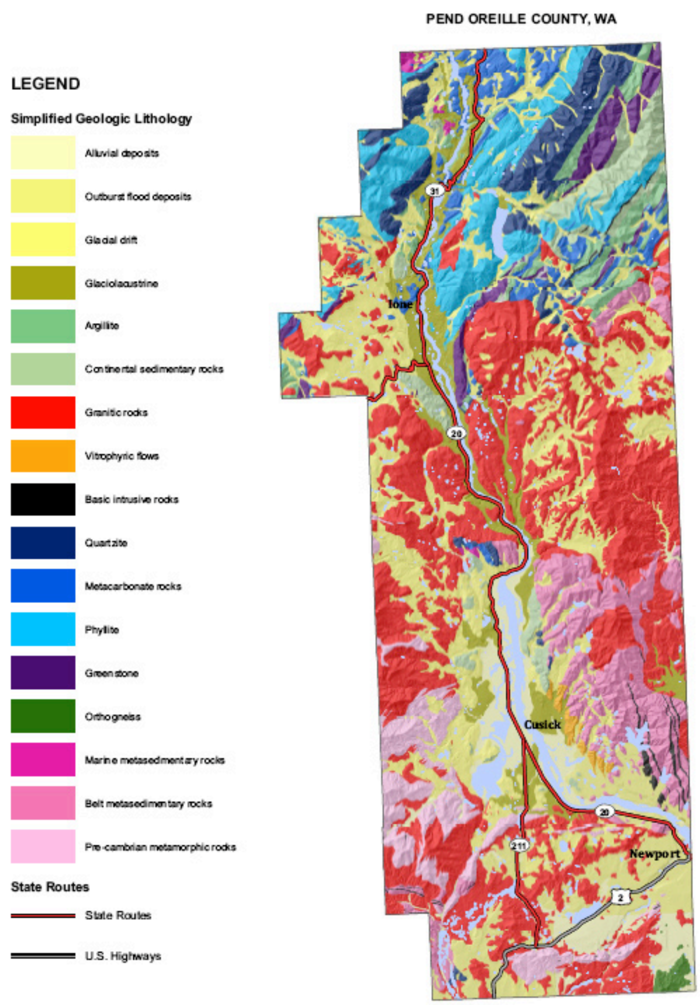
May 2009



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WSDOT Research Report

GEOTECHNICAL REPORT

Geologic Assessment of Potential Aggregate Source Areas in Pend Oreille County, Washington

MT-0019

May 2009

Washington State
Department of Transportation
Paula Hammond
Secretary of Transportation

Environmental & Engineering Programs
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16. ABSTRACT

The Pend Oreille County geologic assessment of potential aggregate source investigation was conducted in order to provide engineering geology assistance to the Region in identifying marginal aggregate material and potential new sources of high quality aggregate material in Pend Oreille County. This report provides a summary of methods employed during our investigation and identifies geologic units and specific sites that have the potential to provide high quality aggregate for the Region.

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DISCLAIMER

INTRODUCTION

The Pend Oreille County geologic assessment of potential aggregate source investigation was conducted in order to provide engineering geology assistance to the Region in identifying marginal aggregate material and potential new sources of high quality aggregate material in Pend Oreille County (Figure 1). This report provides a summary of methods employed during our investigation and identifies geologic units and specific sites that have the potential to provide high quality aggregate for the Region.

PROJECT OVERVIEW

Pend Oreille County has historically made use of aggregate sources located in the relatively young and unconsolidated deposits concentrated in the Pend Oreille River valley floor and located near the major transportation corridors. These sources have been problematic for hot-mix asphalt (HMA) aggregate due to variation of aggregate quality between pit sites and the high percentage of fine grained material (silt and clay), which cannot exceed 7% of the HMA aggregate under WSDOT standard specification 9-03.8(6).

The relatively young deposits located within the Pend Oreille River valley floor are primarily unconsolidated river-deposited (alluvial) or glacial lake-deposited (glaciolacustrine) sediments. These types of deposits are the product of sediment transport from a wide variety of source areas and the downstream accumulation of sediment in low-energy hydraulic environments, such as proglacial lakes, which favor the deposition of fine grained material. Thus, the glaciolacustrine and alluvial deposits that are typical of the Pend Oreille River valley floor are of highly variable composition and contain a high percentage of fine-grained material.

Attempting to characterize aggregate sources within the deposits located on the Pend Oreille River valley floor with laboratory tests is problematic. Each individual pit site may consist of a highly variable combination of rock types (lithologies) that may not be descriptive of the deposit as a whole. In addition, what useful aggregate does exist in these types of deposits has been largely depleted from current WSDOT sources. For these reasons, we focused this investigation on bedrock quarry sources located in the topographic highlands adjacent to the Pend Oreille River valley floor.

In order to identify new potential high quality aggregate sources, we reviewed the geologic literature and background of the region, created a simplified geologic map of Pend Oreille County (based on existing geologic mapping) which combined similar rock types into geologic units (Figure 2), and then correlated each geologic unit with laboratory test data considered pertinent to HMA aggregate acceptance (Los Angeles Abrasion at 500 revolutions and Washington Degradation Factor). HMA has the highest quality standards for construction aggregate material. If the aggregate source meets the HMA quality standards then it will also meet the quality standards for most other construction material.

The correlation of laboratory test data with geologic units was conducted after a thorough compilation and spatial analysis of historical laboratory test data from pits and quarries within Pend Oreille County and pertinent pits and quarries within Stevens County. Historical data from pits and quarries within Stevens County were included if the aggregate sources were within the same geologic units as those utilized in Pend Oreille County. We also included data from laboratory testing conducted on samples that were collected from a variety of representative geologic units within Pend Oreille County during the fall of 2007 and the summer of 2008.

The analysis of these data allowed us to broadly characterize each geologic unit. We have presented the results of this analysis in a map of Pend Oreille County which provides the location of each geologic unit as well as the potential of each geologic unit to serve as an aggregate resource (Figure 3).

In recommending specific sites for further aggregate source investigations, we considered, in general, geologic bedrock composition, proximity to existing state highways, and site suitability for development. Using these criteria, several sites were identified as potential high quality aggregate sources.

REGIONAL GEOLOGY

Pend Oreille County is located in the Eastern Okanogan Highlands physiographic province which extends from Pend Oreille County north into British Columbia, east into Idaho, and is bounded to the south by the Columbia Basin, and to the west by the Columbia River.

Pend Oreille County contains the oldest rocks in Washington State. The southern and eastern portions of the county are dominantly composed of or underlain by Precambrian (older than 540 million years) metamorphic rocks. These rocks formed from sediments which accumulated on the continental shelf of the ancient North American margin. The Precambrian rocks are overlain by a sequence of Paleozoic (540 to 250 million years ago) marine meta-sedimentary rocks. These slightly younger rocks were formed from sediments that accumulated further offshore and also from near-shore volcanic arcs. Throughout time, the Precambrian and Paleozoic rocks have been subjected to intense heat and pressure from geologic processes such as terrane accretion, burial, folding, and igneous intrusion. Resulting in these marine sedimentary and volcanic rocks becoming metamorphosed into argillite, quartzite, phyllite, greenstone, and dolostone.

From the late Paleozoic Era to the late Mesozoic Era (230 to 100 million years ago), a tectonic processes, known as *terrane accretion*, gradually added vast amounts of material onto the western margin of the North American continent. In Eastern Washington, this material included metacarbonate, metavolcanic, and marine metasedimentary rock. Although little of this material is exposed in Pend Oreille County, (much is exposed immediately west, in Stevens County), this process had a dramatic effect on the region. As material accreted onto the continent, the coast was gradually moved westward. Over many millions of years, terrane accretion gradually changed Pend Oreille County from an offshore marine environment into a mountainous continental environment.

From the middle Mesozoic Era to the middle Cenozoic Era (150 to 30 million years), the region was subjected to powerful tectonic processes causing widespread volcanism, plutonism and faulting. Regional volcanism deposited widespread volcanic flows and volcanoclastic deposits. Plutonism intruded enormous bodies of igneous rock into the crust, creating the crystalline core of the existing Selkirk Range and the related large provinces of granite, granodiorite, and quartz monzonite in the western and southern regions of Pend Oreille County. Large transform and extensional faults were formed during this time, most notably the Newport Fault. Crustal deformation along the Newport Fault formed a regional north-south trending graben that dropped the eastern portion of Pend Oreille County downward and uplifted the granitic plutons in the western portion of the county into mountainous features.

The Okanogan Highlands were periodically covered by ice during the Pleistocene Epoch (1.8 million to 10,000 years ago). The cyclic advance and retreat of the Columbia River lobe of the Cordilleran ice sheet rounded mountain peaks, carved deep meltwater channels into stream valleys and floodplains, and broadly deposited glacial sediments around Pend Oreille County. Approximately 15,000 years ago, during the most recent glacial advance, known as the Fraser glacial maximum, the ice sheet extended down the Pend Oreille River valley as far south as Newport, WA, where it terminated in a proglacial lake known as glacial Lake Clark.

During the late Pleistocene (approximately 18,000 to 10,000 years ago), glacial ice periodically dammed the Clark Fork River in Idaho. Each time this ice dam formed, an enormous amount of water was impounded upstream into a huge lake known as glacial Lake Missoula. Glacial Lake Missoula drained catastrophically across Washington State to the Pacific Ocean whenever the ice dam failed. This process was repeated many times and resulted in the erosion of the terminal moraines left by the retreating ice sheet as well as the deposition of a thick mantle of flood gravels and flood sands over proglacial lake deposits and across the southern portion of Pend Oreille County.

During the end of the Pleistocene Epoch (approximately 10,000 years ago), as the glaciers melted and the Cordilleran ice sheet retreated, a series of proglacial lakes formed along the length of the Pend Oreille River valley. Glacial gravel, sand, silt, and clay was widely deposited on the valley floor as well as the mountainous regions of the county. Much of the silt and clay deposited in Pleistocene proglacial lakes has since been overlain by more recent deposits of alluvial sand transported by the Pend Oreille River.

AGGREGATE RESOURCE INVESTIGATION

The aggregate resource investigation for this project consisted of a detailed review of the published geologic literature and geologic maps pertaining to the Pend Oreille County region, compilation of historical laboratory test data, review of USFS data, field work to collect samples and visit potential aggregate sites, laboratory testing, and analysis.

Geologic Review

Published geologic literature and geologic maps pertaining to the region were reviewed by WSDOT geotechnical specialists. Based on this review and analysis, a geologic map was created that combined rock types with similar lithologic characteristics and geologic origin into a simplified geologic units format (Figure 2).

Compilation of Historical Laboratory Test Data for Aggregate Sources

Historical laboratory test data from aggregate sources within Pend Oreille County as well as pertinent aggregate sources within Stevens County was compiled and analyzed in order to characterize each simplified geologic unit in terms of its potential as a source of construction aggregate.

Laboratory test data for aggregate sources is stored in the WSDOT Aggregate Source Approval (ASA) database. The ASA database contains historical laboratory test data that dates back to the 1930's. In most cases, the ASA database has very limited information regarding site location. Location information for each site is generally in the form of section quarter/quarter. In order to associate the historical laboratory test data with the appropriate geologic unit, it was necessary to acquire precise locations for each aggregate source. We were able to accurately locate most aggregate sources using the ASA database information, available Mylar county plan sheets, USGS 24k topographic maps, air photos, and Geographic Information Systems (GIS) software. Once the location of the aggregate source was identified, we were usually able to associate the test data with the appropriate geologic unit. In several cases, the location of the aggregate source could not be accurately identified, or the geology of the source location was questionable. In these cases, the site was identified as a candidate for groundtruthing reconnaissance-level field work.

The historical laboratory test data was then compiled into an Excel spreadsheet and sorted by the associated geologic units. Mean values and standard deviations for Specific Gravity (SPG), Los Angeles Wear at 500 revolutions (LA), Washington Degradation Factor (DEG) laboratory tests were calculated for each geologic unit. Historical laboratory test data for Pend Oreille County and Stevens County is provided in Table 1 and Table 2 in Appendix B.

Several of the geologic units of interest did not have sufficient test data to characterize their potential as an aggregate resource. In each of these geologic units, at least one site was identified for sample collection and reconnaissance-level field work. Only sites representative of the pertinent geologic unit that had the potential as a source for construction aggregate were chosen for sampling.

Review of USFS Data

Approximately 58% of Pend Oreille County is maintained by The United States Forest Service, most of which is part of the Colville National Forest. WSDOT has leased pit and quarry sites from the Colville National Forest in the past and the USFS is receptive to working out future mutually beneficial agreements.

The Colville National Forest provided access to their material source files that included field reviews, reports of specific sites, photos, GIS data and forest road numbers. The Colville National Forest material source files included limited preliminary testing data for the approximately 200 sites identified.

Specific sites in the Colville National Forest were selected for sampling and preliminary testing. Sites selected for sampling were located in geologic units that had insufficient testing data associated with them or in geologic units that had tested well in the past in Pend Oreille County or Stevens County. Sites selected for sampling were also within a reasonable haul distance from a state highway and had the potential for development as a construction aggregate source. Two site visits to Pend Oreille County were conducted to complete the required reconnaissance-level field work and sample collection.

Field Work

The field work conducted in October of 2007 focused on assessing the 12 aggregate sources currently owned or leased by WSDOT in Pend Oreille County. The majority of these aggregate sources are in unconsolidated deposits located within the Pend Oreille River valley floor. The October 2007 field work resulted in a general assessment and characterization of the valley deposits. Our assessment concluded that these deposits are of marginal quality, of variable geologic composition generally exhibiting an excessive percentage of fine-grained material, and largely depleted of useful aggregate. During this field work, additional samples were collected from potential quarry sites that were located in geologic units that had been identified at the time as lacking sufficient laboratory test data for characterization.

The field work conducted in August of 2008 focused on collecting field data required to support our spatial analysis and final characterization of the geologic units. This included groundtruthing sites with insufficient location or geologic information and collecting representative samples from potential quarry sites within geologic units that had been identified as lacking sufficient historical laboratory testing data for characterization. Eight historically tested aggregate sources were groundtruthed and representative samples were collected from fifteen potential quarry sites. The potential quarry site conditions, including haul distances and road conditions, were documented. Photographs and Global Positioning Satellite (GPS) coordinates were collected at each potential quarry site where samples were collected.

Laboratory Testing

Laboratory testing was performed on rock samples representative of geologic units within Pend Oreille County for the purpose of characterizing their potential as a source of construction aggregate. Laboratory testing included: Specific Gravity (SPG), Los Angeles Wear at 500 revolutions (LA), Washington Degradation Factor (DEG), and Absorption (ABS). Laboratory testing was performed in general accordance with appropriate ASTM laboratory testing methodology. These laboratory test results are presented in Table 3 in Appendix B.

Analysis and Classification of Geologic Units

WSDOT Standard Specification 9-03.8(1) requires aggregate materials for use in HMA to meet two laboratory test requirements: Los Angeles Wear, 500 Revolutions (LA) of 30 or less and Washington Degradation Factor (DEG) of 30 or more. These specifications were used as a baseline for determining the potential quality of each geologic unit as a source of construction aggregate.

All available LA and DEG laboratory test data for bedrock aggregate sources in Pend Oreille County and pertinent sources within Stevens County were associated with the appropriate geologic unit. These data were then compiled and analyzed. An average test value and a standard deviation for both LA and DEG laboratory tests were calculated for each geologic unit. The material was then classified as low, marginal, or high quality using the following criteria.

Low Quality Aggregate:

Materials are classified as 'low quality' if **any** of the following are true:

- The aggregate from the geologic unit has an average LA value of more than 30
- The aggregate from the geologic unit has an average DEG value of less than 30

Marginal Quality Aggregate:

Materials are classified as 'marginal quality' if **all** of the following are true:

- The aggregate from the geologic unit has an average LA value of 30 or less
- The aggregate from the geologic unit has an average DEG value of 30 or more
- The average LA value plus one standard deviation is over 30 **or** the average DEG value minus one standard deviation is less than 30

High Quality Aggregate:

Materials are classified as 'high quality' if **all** of the following are true:

- The aggregate from the geologic unit has an average LA value of 30 or less
- The aggregate from the geologic unit has an average DEG value of 30 or more
- The average LA value plus one standard deviation is 30 or less
- The average DEG value minus one standard deviation is 30 or more

This classification criterion was used to characterize each geologic unit within Pend Oreille County as a potential as a source of construction aggregate. The classification calculations are summarized in Table 4 in Appendix B. The results are summarized in the following table.

GEOLOGIC UNIT	QUALITY
Continental sedimentary rocks	Low
Granitic rocks	Low
Phyllite	Low
Vitrophyric flows	Low
Argillite	Marginal
Belt metasedimentary rocks	Marginal
Marine metasedimentary rocks	Marginal
Metacarbonate rocks	Marginal
Basic intrusive rocks	High
Greenstone	High
Pre-Cambrian metamorphic rocks	High
Quartzite	High

Spatial Analysis

The quality classification was applied to each geologic map unit to produce a geologic map of potential aggregate quality for Pend Oreille County (Figure 3). The unconsolidated deposits located within the Pend Oreille River valley floor were classified as 'low quality' in this map.

RECOMMENDATIONS

The relatively young deposits located within the Pend Oreille River valley floor are primarily unconsolidated alluvial or glaciolacustrine sediments. Our 2007 field review and assessment of these deposits concluded that these aggregate materials are of low to marginal quality and of variable geologic composition which generally exhibit an excessive percentage of fine-grained material. Furthermore, the WSDOT-owned pit sites located in these deposits are largely depleted of useful aggregate. For these reasons, we focused this investigation on bedrock quarry sources located in the topographic highlands adjacent to the Pend Oreille River valley floor.

There are four bedrock geologic units within Pend Oreille County that have been identified as potential high quality aggregate resources. All four of these bedrock units consist of high-density fine-grained material with *massive* texture (meaning that there is little to no observable internal rock fabric such as layering, foliation, etc. visible in the bedrock). The quality of a bedrock material does not appear to be controlled by composition or mineralogy, except for those cases when density, grain size, or texture would be affected. Bedrock materials that perform poorly as aggregates typically exhibit unusually low density, large grain size, or strong textural internal rock fabric, such as layering and foliation.

Descriptions of the four high-quality bedrock types are provided below.

<u>Greenstone:</u>

Greenstone is a low-grade metamorphic rock that is formed from the heating and pressurizing of basalt. The largest outcrop of greenstone in the county is east of the Pend Oreille River and south of Sullivan Lake. Greenstone can also be found sporadically in smaller outcrops in the northwestern portion of the county. It is a dark, fine-grained, and dense metamorphic rock that is named for several of the minerals in the rock which are green in color. The rock is typically a dark grey-green color on fresh surfaces and a rusty reddish brown color on weathered surfaces. Most greenstone has a *massive* texture, meaning that there is little to no layering, foliation, or other visible internal rock fabric. Some greenstone may exhibit a weakly foliated texture, appearing to have thin and wavy layering. Some greenstone contains a small amount of light gray minerals which appear as wispy streaks and flecks that are oriented roughly parallel to any existing foliation (layering). Photographs and mapped locations of greenstone are provided in Figure 4.

<u>Quartzite:</u>

Quartzite is a metamorphic rock that is formed from the heating and pressurizing of quartz-rich sedimentary rocks, usually sandstone. There is a large amount of quartzite in the northern portion of the county. It can also be found in the southwest corner and center of the county in smaller outcrops. This material is known for its extreme hardness and durability. It is fine-grained and light yellow in color. Most quartzite has a *massive* texture, meaning that there is little to no layering, foliation, or other visible internal rock fabric. However, some quartzite may exhibit a weakly foliated texture, indicated by very thin parallel layers of darker brown minerals within the larger mass of the light yellow rock. Photographs and mapped locations of quartzite are provided in Figure 5.

Precambrian metamorphic rocks:

The term 'Precambrian metamorphic rocks' is used in this report to refer to metamorphic rocks that are Precambrian in age (older than 540 million years), but are not included in the geologic formation known as the 'Belt Supergroup'. Material from the Belt Supergroup was assessed as a separate geologic unit (Belt metasedimentary rocks), and was found to be of marginal quality. Precambrian metamorphic rocks are widespread throughout the southeastern portion of Pend Oreille County. This geologic unit may vary in composition and quality from one location to another. However, samples from this unit have consistently tested well in laboratory tests. Precambrian metamorphic rocks are typically greenish-gray or yellowish-brown to reddish-brown in color. Most of the material observed in this unit is fine-grained. These rocks are weakly foliated to massive and typically break along flat surfaces, creating angular cobbles. Photographs and mapped locations of Precambrian metamorphic rocks are provided in Figure 6.

Basic intrusive rocks:

Basic intrusive rocks include several different types of igneous rock including diorite and gabbro. These rocks are of middle Proterozoic age (1.8 to 1.0 billion years old) and are exclusively located in the southeast portion of the county, north of the Pend Oreille River and near the Idaho state border. The term '*basic*' indicates that the rock has relatively low silica content. Basic rocks are generally very dense and dark in color. The term '*intrusiv*e' indicates that the rocks were intruded, while in a semi-liquid state, into fractures and other zones of weaknesses within existing bedrock, where it cooled and crystallized into a solid material. Intrusive rocks generally exhibit a *massive* texture, meaning that there is little to no layering, foliation, or other visible internal rock fabric and that mineral assemblages are evenly distributed and randomly oriented. Photographs and mapped locations of basic intrusive rocks are provided in Figure 7.

Site Specific Recommendations:

Several potential aggregate source sites have been identified in Pend Oreille County (Figure 8). These sites were evaluated for potential based on three criteria: aggregate rock quality, proximity to state routes, and site suitability (defined below). Five of the potential sites are in the WSDOT ASA database and are named with their county and pit/quarry designation (i.e. PO128). The remaining four were given names that reflect the USFS or county road that they are located near (i.e. 1359).

In Appendix A, a figure is presented for each potential site (Figures 9 – 16). The figures provide site location information as well as site photographs.

Sites selected for quarry development should be further evaluated with a detailed site-specific material source investigation in accordance with Chapter 21 of the WSDOT Geotechnical Design Manual.

Aggregate Rock Quality

Geologic units are characterized as 'high quality', 'marginal quality', or 'low quality' depending on statistically averaged laboratory test data and variability. Seven of the eight sites identified in this report are in geologic units characterized as 'high quality'. The eighth site is in a 'marginal quality' geologic unit, but is highlighted for consideration due to its very close proximity to SR 31 and excellent suitability for development.

Proximity to State Routes

Sites were prioritized by proximity to state routes. We limited the investigation of potential aggregate sites to within twelve miles of state routes. All of the sites recommended below are within 6.5 miles of state routes. Four of the sites mentioned below are located directly on a state route.

Site Suitability

Sites were prioritized based on their suitability for quarry development. For each site visited during reconnaissance field work, we considered several factors, including: the functionality and length of the road connecting the potential aggregate resource to the nearest state route, prior development of the site as an aggregate source or quarry, and land ownership, including potential partnerships with the USFS.

Site PO128

This site is located on Sullivan Lake Road approximately 6.5 miles east of SR 31 (Figure 9). Sullivan Lake Road intersects with SR 31 at two locations, near MP 3 and near MP 16. PO128 is approximately 6.5 miles from SR 31 MP 3 and approximately 11.5 miles from SR 31 MP 16.

This site is an active quarry operated by the USFS. The approximately 3.5 acre quarry site is located at the base of an arcuate greenstone talus slope overlying greenstone bedrock. The talus ranges in size from several inches to approximately 1-foot in dimension. Material has been stockpiled on the quarry floor at the base of the slope. The floor of the quarry is easily accessed by an approximately 500 foot-long unpaved access road off of Sullivan Lake Road. The access road is secured with a USFS gate.

Site 1359-alt

This site is located on USFS land, approximately 2.6 miles south on USFS Road 1359, which intersects SR 20 in the vicinity of MP 388 (Figure 10). USFS Road 1359 is in good condition and consists of generally flat topography.

This is an undeveloped site that has not been utilized as an aggregate source in the past. The site consists of an approximately 100 foot-high flat-topped hill that is composed of greenstone. Greenstone was observed in outcrop at the top of the hill and locally exposed in outcrop on the flanks of the hill. This site would require the construction of approximately 400 feet of access road to connect the greenstone resource to USFS Road 1359.

Site 1304

This site is located on USFS land, approximately 5.5 miles from SR 31 in the vicinity of the town of Ione (Figure 11). It is accessed by USFS Road 1304, which is in good condition, but climbs approximately 1250 feet over 4.25 miles.

This is an undeveloped site that has not been used as an aggregate resource in the past. The site consists of a large hillside composed of greenstone with localized granitic intrusions. USFS

Road 1304 approaches the site from the southeast and curves around the west slope of the hill, potentially allowing the site to be developed from multiple directions. The hill is approximately 500 feet in height above USFS Road 1304 and rises in a series of benches that are 15 to 20 feet in height.

Site PO28

This site is located on the west side of SR 211, adjacent to a private driveway in the vicinity of MP 10.41 (Figure 12). The site consists of an outcrop of heterogeneous Precambrian metamorphic rock that is approximately 50 feet high and 300 feet long.

Historical records indicate that this site was used as an aggregate resource for a nearby surfacing project in 1935.

Site PO12

This WSDOT-owned site is located approximately 0.75 miles down a private driveway off of SR 20 in the vicinity of MP 407.5 (Figure 13). An easement agreement from 1936 grants WSDOT access to the site. The road is secured by a gate near SR 20. The flat, narrow, and brush-covered road would require minor improvements in order to utilize the site as a material source.

This site consists of a talus slope that is approximately 100 feet in height. The talus blocks range in size from approximately one to twelve inches in dimension, with the larger blocks located near the base of the slope. The material consists of Precambrian metamorphic rocks of various high-quality aggregate lithologies. This site may have been used as a source of materials in the 1930s.

Site PO21-alt

This site is located on the east side of SR 2 in the vicinity of MP 318.45 (Figure 14). It consists of an outcrop of Precambrian metamorphic rock that is approximately 50 feet high and 500 feet long.

This is an undeveloped site that has not been used as an aggregate resource in the past. However, material from a nearby outcrop (PO21) in the same geologic unit was used for a roadway surfacing project in 1930.

Site LECL

This site is located in a through-cut on Bead Lake Road, approximately 3.2 miles west of the Idaho border, and north of the Pend Oreille River (Figure 15). The site is reached by traveling east on SR 20 out of Newport, WA into Idaho and then, after crossing over the Pend Oreille River, back into Washington for approximately 5 miles on LeClerc Road.

This is an undeveloped site that has not been used as an aggregate resource in the past. It consists of a through-cut in basic intrusive rock. The north side of the through-cut consists of an approximately 35 foot tall outcrop. An approximately 80-foot high outcrop of basic intrusive rock lies several hundred feet north of the through-cut on the far side of a small flat field.

Site PO74

This is a WSDOT owned pit site located on the west side of SR 31 in the vicinity of MP 6.77 (Figure 16). The site is accessed by a short unpaved access road that is in good condition. The intersection of SR 31 and the access road has very limited sight distance.

This is a WSDOT pit site consisting of three broad terraces covering approximately 10 acres vegetated with brush and grass. Several bedrock outcrops of dolomite rock were observed at this site. This dolomite rock is also exposed to the south of the access road along the road cut on the west side of SR 31.

Although the dolomite rock at this site is characterized as a marginal quality aggregate resource, the proximity to SR 31 and the suitability of the site is excellent. Additional sampling and testing is warranted at this site.

CONCLUSION

This study has shown that there is a significant amount of potentially high-quality aggregate resource in Pend Oreille County. The potentially high-quality aggregate material is generally characterized as dense, fine-grained, and massive rock belonging to one of the following four geologic units: greenstone, quartzite, Precambrian metamorphic rock, and basic intrusive rock. The majority of this resource is located in the highland areas adjacent to the Pend Oreille River valley floor.

We associated all available and pertinent laboratory test data with the appropriate geologic units in order to characterize the potential of each geologic unit in Pend Oreille County as a source of construction aggregate. Specific potential quarry sites were recommended on a basis of geologic potential, as well as proximity to state routes and site suitability.

Site-specific geotechnical investigations, potentially including site-specific geologic mapping, subsurface field exploration, and laboratory testing, are recommended to assist in the future exploration and development of aggregate sources.

INTENDED REPORT USE AND LIMITATIONS

This report has been prepared to assist the Washington State Department of Transportation in the assessment of potential sources of construction aggregate in Pend Oreille County. It should not be used, in part or in whole for other purposes without contacting the E&EP Geotechnical Division for a review of the applicability of such reuse.

Site exploration and testing describes conditions only at the sites of geologic investigation where samples are collected. The characteristics of identified subsurface materials may vary considerably from that indicated by the laboratory test data.

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Appendix A

Report Figures

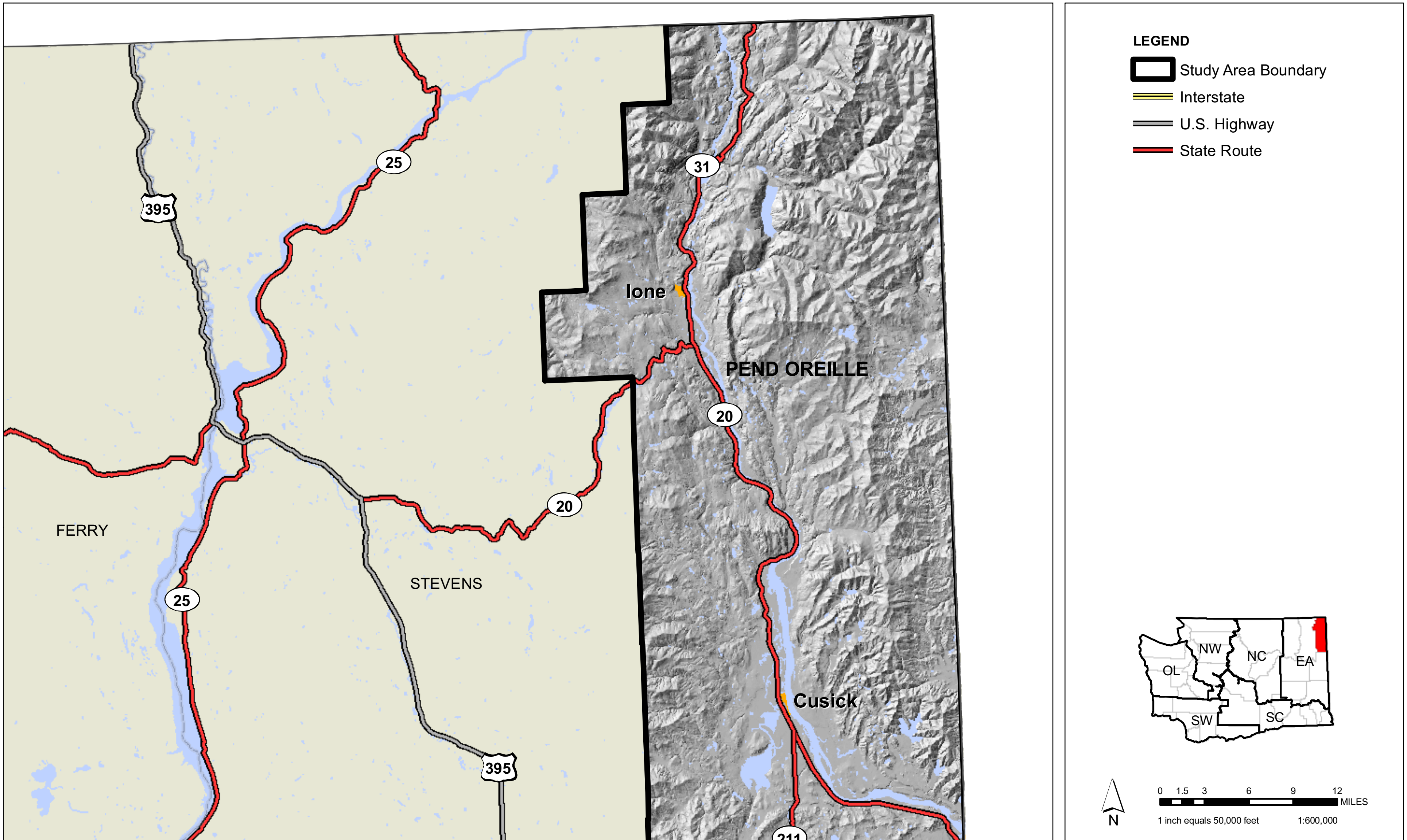


FIGURE 1: SITE VICINITY

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander DATE March 30, 2009

File Location: M:\GEOGIS\Projects\SR-000\Pits & Quarries\P&Q_PendOreille\Projects\ArcGIS\Update_01122009

PEND OREILLE COUNTY, WA

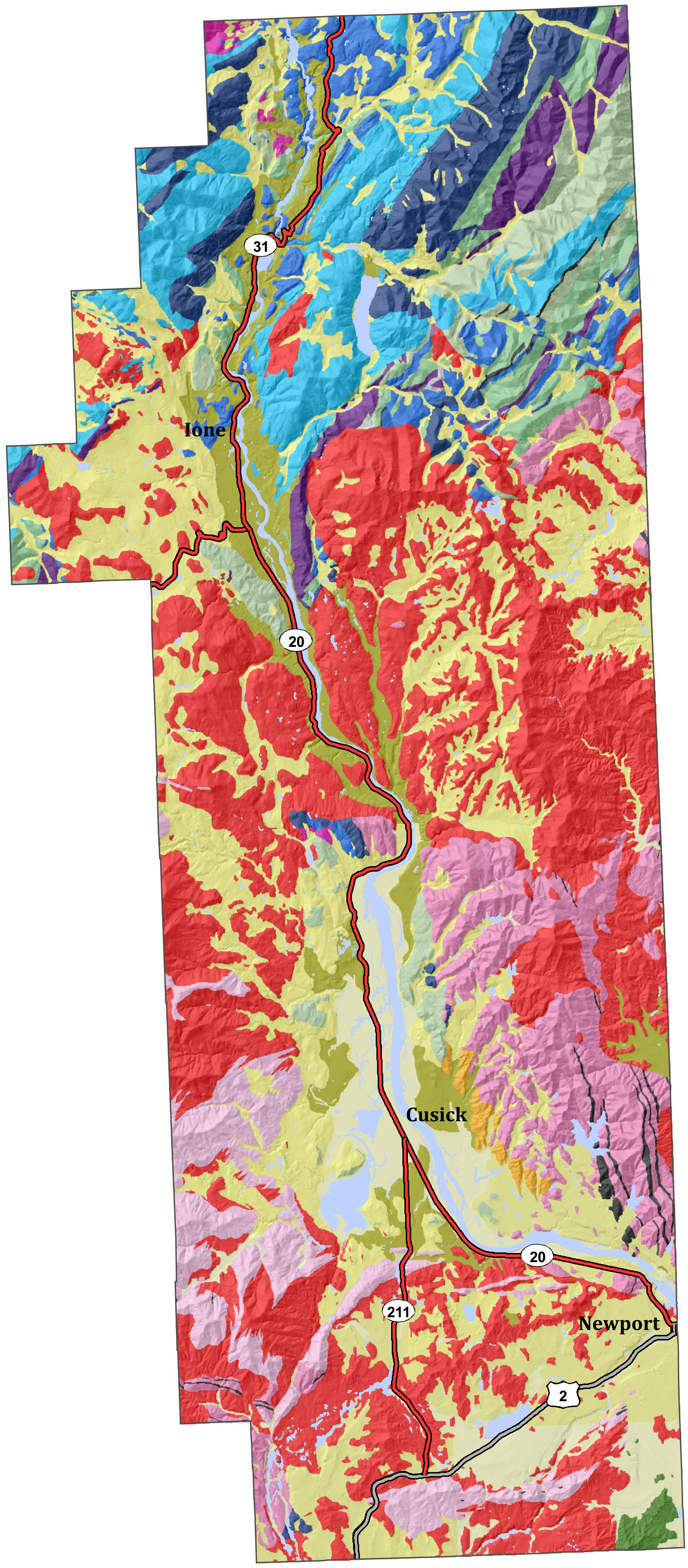
LEGEND

Simplified Geologic Lithology

- Alluvial deposits
- Outburst flood deposits
- Glacial drift
- Glaciolacustrine
- Argillite
- Continental sedimentary rocks
- Granitic rocks
- Vitrophyric flows
- Basic intrusive rocks
- Quartzite
- Metacarbonate rocks
- Phyllite
- Greenstone
- Orthogneiss
- Marine metasedimentary rocks
- Belt metasedimentary rocks
- Pre-cambrian metamorphic rocks

State Routes

- State Routes
- U.S. Highways



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REFERENCES

Open File Report 2005-3 Digital 1:100,000-scale Geology of Washington State version 1.0 by Washington Division of Geology and Earth Resources Staff, December 2005.

*** Simplified geology was derived from 1:100K geology data. WSDOT geologists determined units based upon dominant lithology and aggregrated polygons to simplify existing 1:100K data.

MILES

0 1.5 3 6 9 12

1:360,000

1 inch equals 30,000 feet

FIGURE 2:
SIMPLIFIED GEOLOGIC MAP

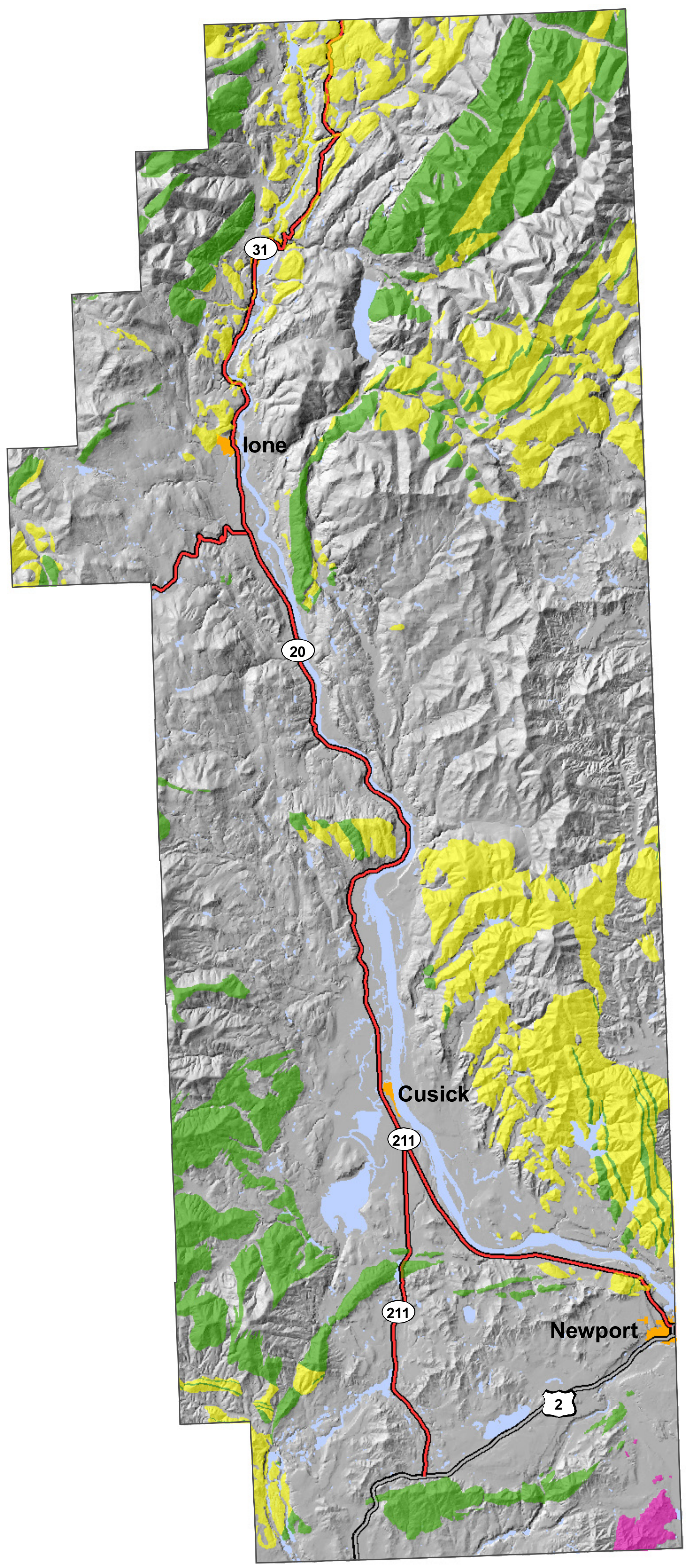
Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** May 12, 2009

File Location: M:\GEOGIS\Projects\SR-000\Pits & Quarries\P&Q_PendOreille\Projects\ArcGIS\Update_01122009

PEND OREILLE COUNTY, WA



LEGEND

Aggregate Quality by Geologic Unit

- High Quality
- Marginal Quality
- Low Quality
- Insufficient Data
- City Limits
- State Route
- U.S. Highway

N

MILES

0 1.5 3 6 9 12

1:360,000
1 inch equals 30,000 feet

FIGURE 3: AGGREGATE QUALITY BY GEOLOGIC UNIT

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** May 12, 2009

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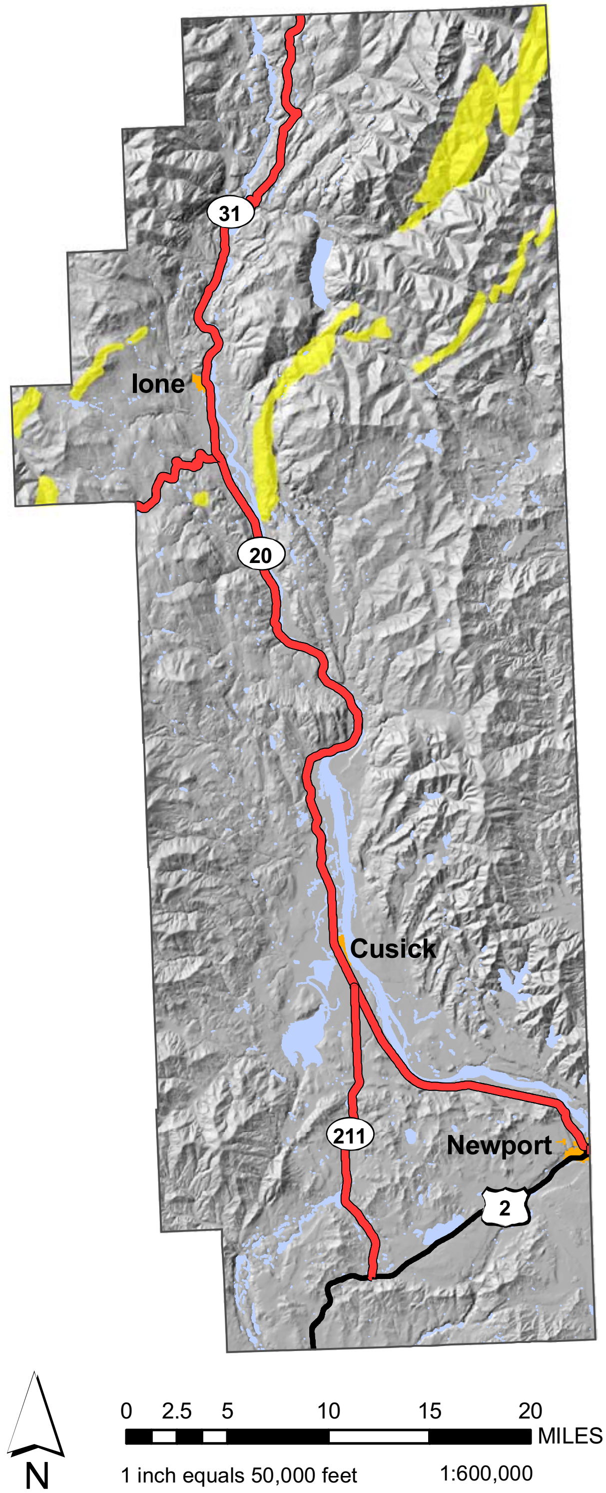
LEGEND

Greenstone



Greenstone is a low-grade metamorphic rock that is formed from by heating and pressurizing basalt. The largest outcrop of greenstone in the county is east of the Pend Oreille River and south of Sullivan Lake. Greenstone can also be found sporadically in smaller outcrops in the northwestern portion of the county. It is a dark, fine-grained, and dense metamorphic rock that is named for several of the minerals in the rock which are green in color. The rock is typically a dark grey-green color on fresh surfaces and a rusty reddish brown color on weathered surfaces. Most greenstone has a massive texture, meaning that there is little to no layering, structure, or other visible fabric in the rock. Some greenstone may exhibit a weakly foliated texture, appearing to have thin and wavy layering. Some greenstone contains a small amount of light gray minerals which appear as wispy streaks and flecks that are oriented roughly parallel to any existing foliation (layering).

FIGURE 4: GREENSTONE

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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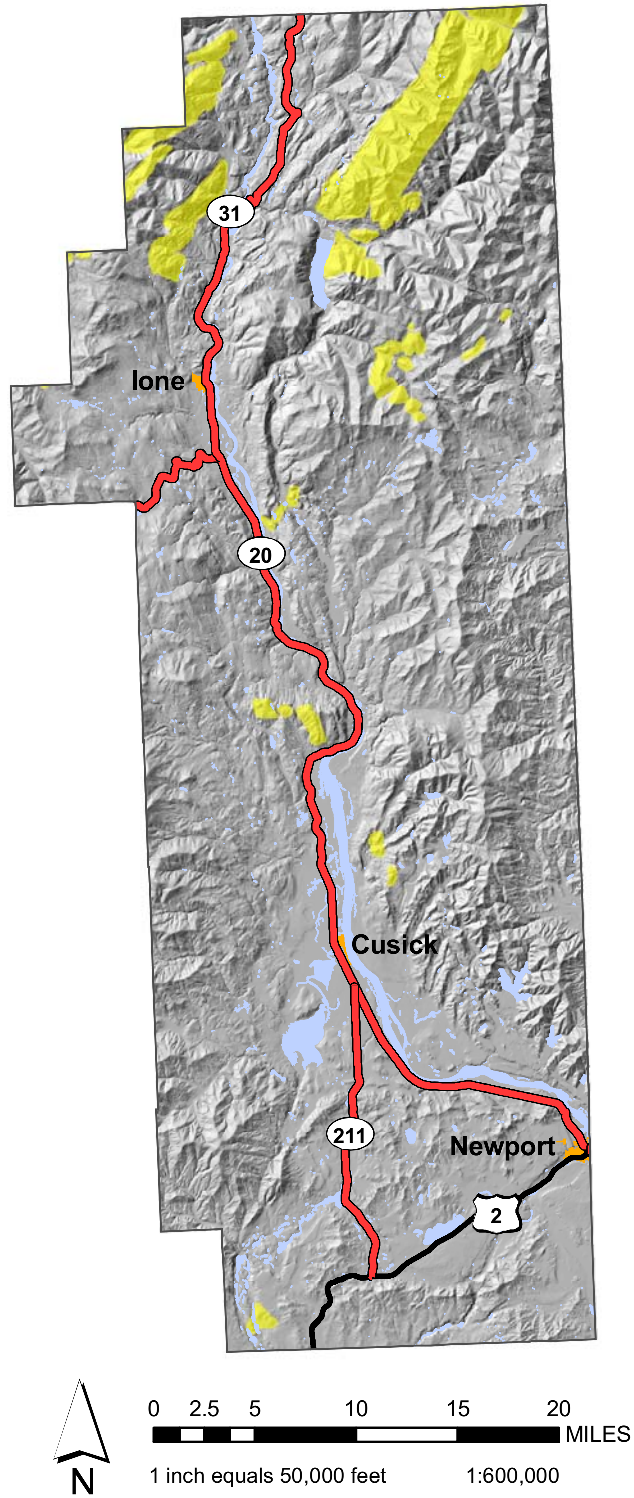

LEGEND

Quartzite

Quartzite is a metamorphic rock that is formed from the heating and pressurizing of quartz-rich sedimentary rocks, usually sandstone. There is a large amount of quartzite in the northern portion of the county. It can also be found in the southwest corner and center of the county in smaller outcrops. This material is known for its extreme hardness and durability. It is fine-grained and light yellow in color. Most quartzite has a massive texture, meaning that there is little to no layering, structure, or other visible fabric in the rock. However, some quartzite may exhibit a weakly foliated texture, indicated by very thin parallel layers of darker brown minerals within the larger mass the light yellow rock.

FIGURE 5: QUARTZITE

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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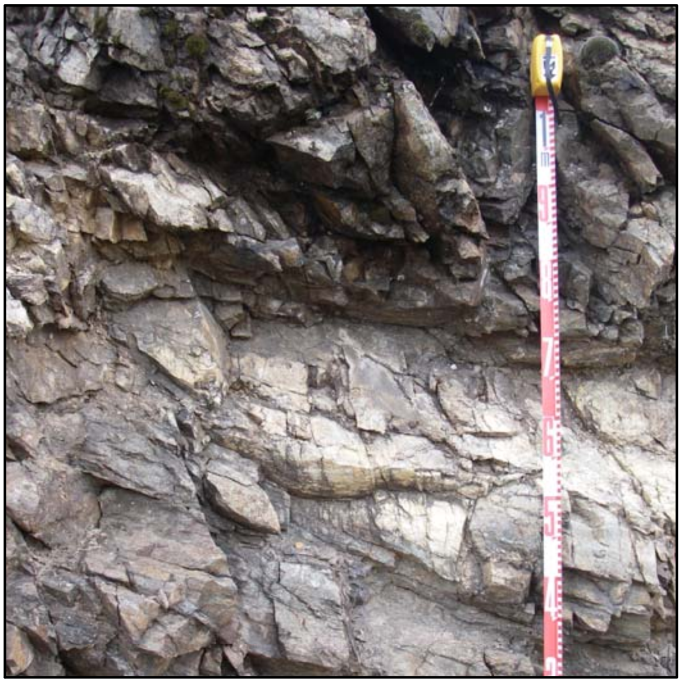
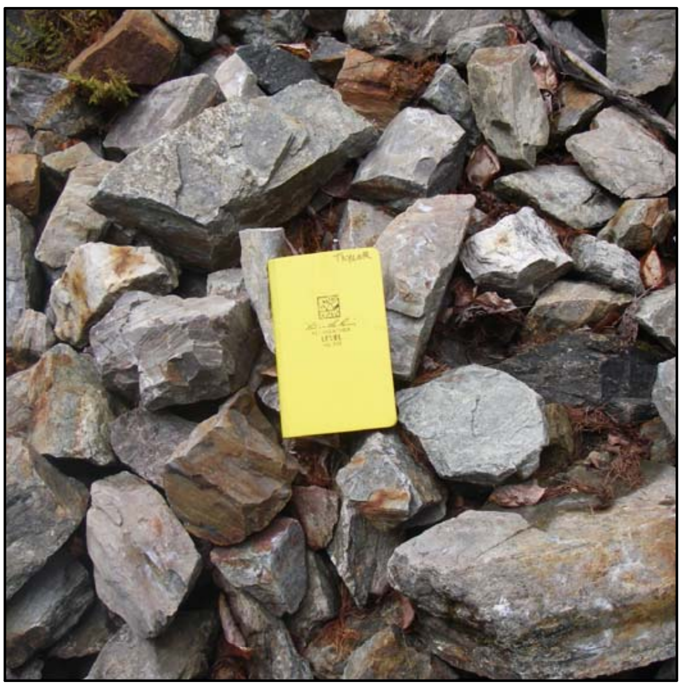
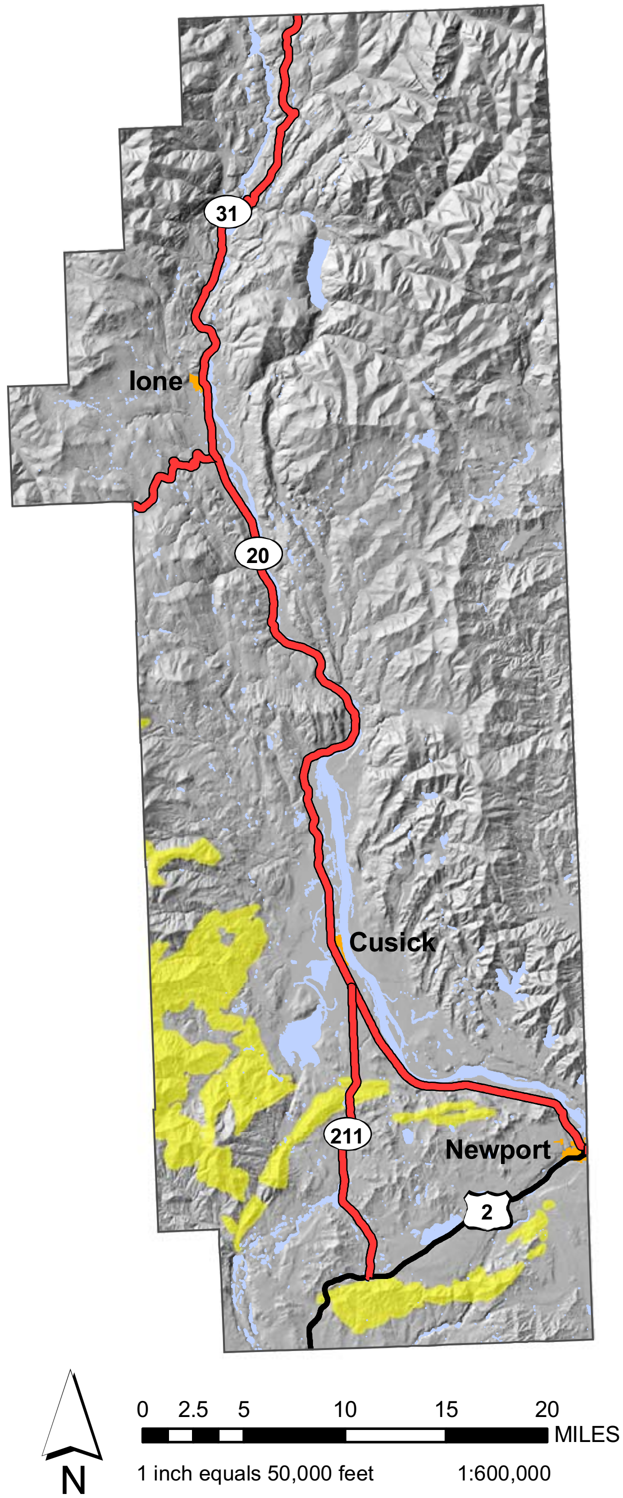




PEND OREILLE COUNTY, WA



LEGEND

Pre-cambrian Metamorphic Rocks

The term 'Precambrian metamorphic rocks' is used in this study to refer to metamorphic rocks that are of Precambrian age (older than 540 million years), but are not included in the Belt Supergroup. Precambrian metamorphic rocks are widespread throughout the southeastern portion of Pend Oreille County. This geologic unit may vary in composition and quality from one location to another. However, samples from this unit have consistently performed well in aggregate laboratory tests. Precambrian metamorphic rocks are typically greenish-gray or yellowish-brown to reddish-brown in color. Most of the material observed in this unit is fine-grained. These rocks are weakly foliated to massive and typically break along flat surfaces, creating angular cobbles.

FIGURE 6: PRE-CAMBRIAN METAMORPHIC ROCKS

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** January 11, 2009

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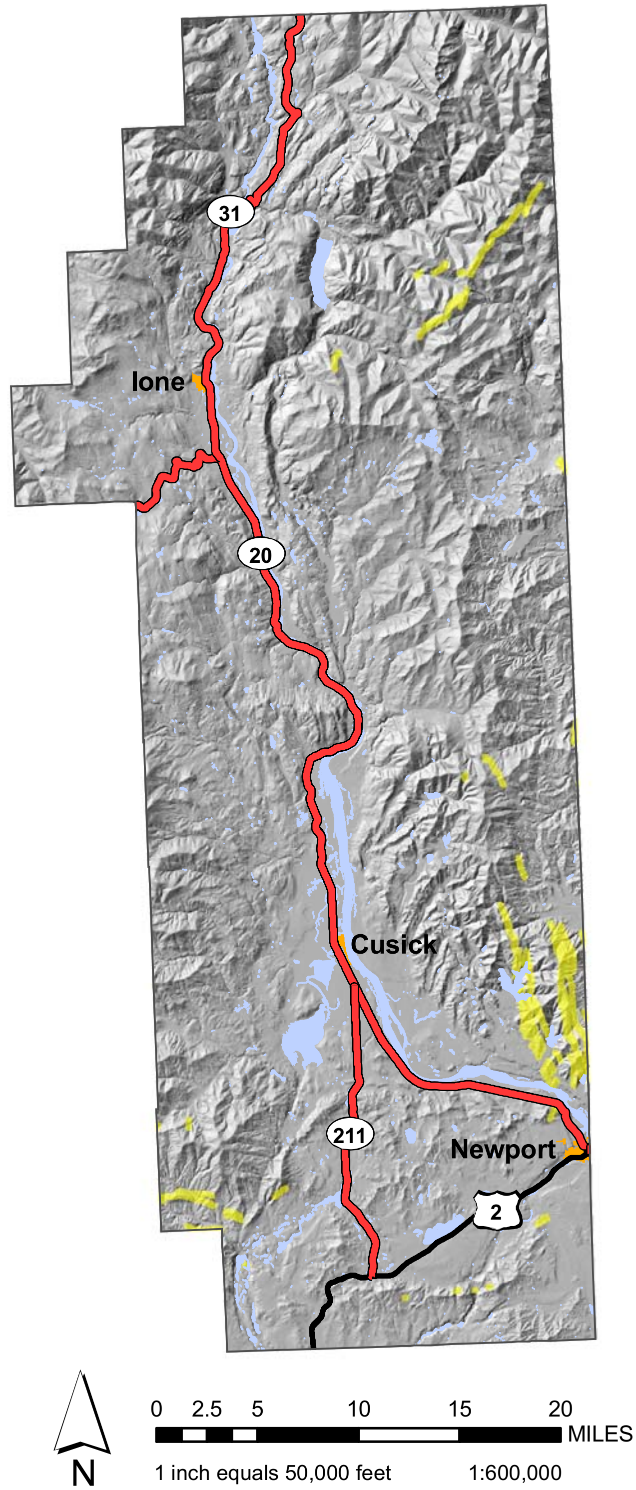

LEGEND

Basic Intrusive Rocks

Basic intrusive rocks include several different types of igneous rock including diorite and gabbro. These rocks are of middle Proterozoic age (1.8 to 1.0 billion years old) and are exclusively located in the southeast portion of the county, north of the Pend Oreille River and near the Idaho border. The term 'basic' indicates that the rock has relatively low silica content. Basic rocks are generally very dense and dark in color. The term 'intrusive' indicates that the rock was pushed, while in a semi-liquid state, into fractures and weaknesses in previously existing rock, where it crystallized into a solid material. Intrusive rocks generally exhibit a massive texture, meaning that there is little to no layering, structure, or other visible fabric in the rock and that mineral assemblages are evenly distributed and randomly oriented.

FIGURE 7: BASIC INTRUSIVE ROCKS

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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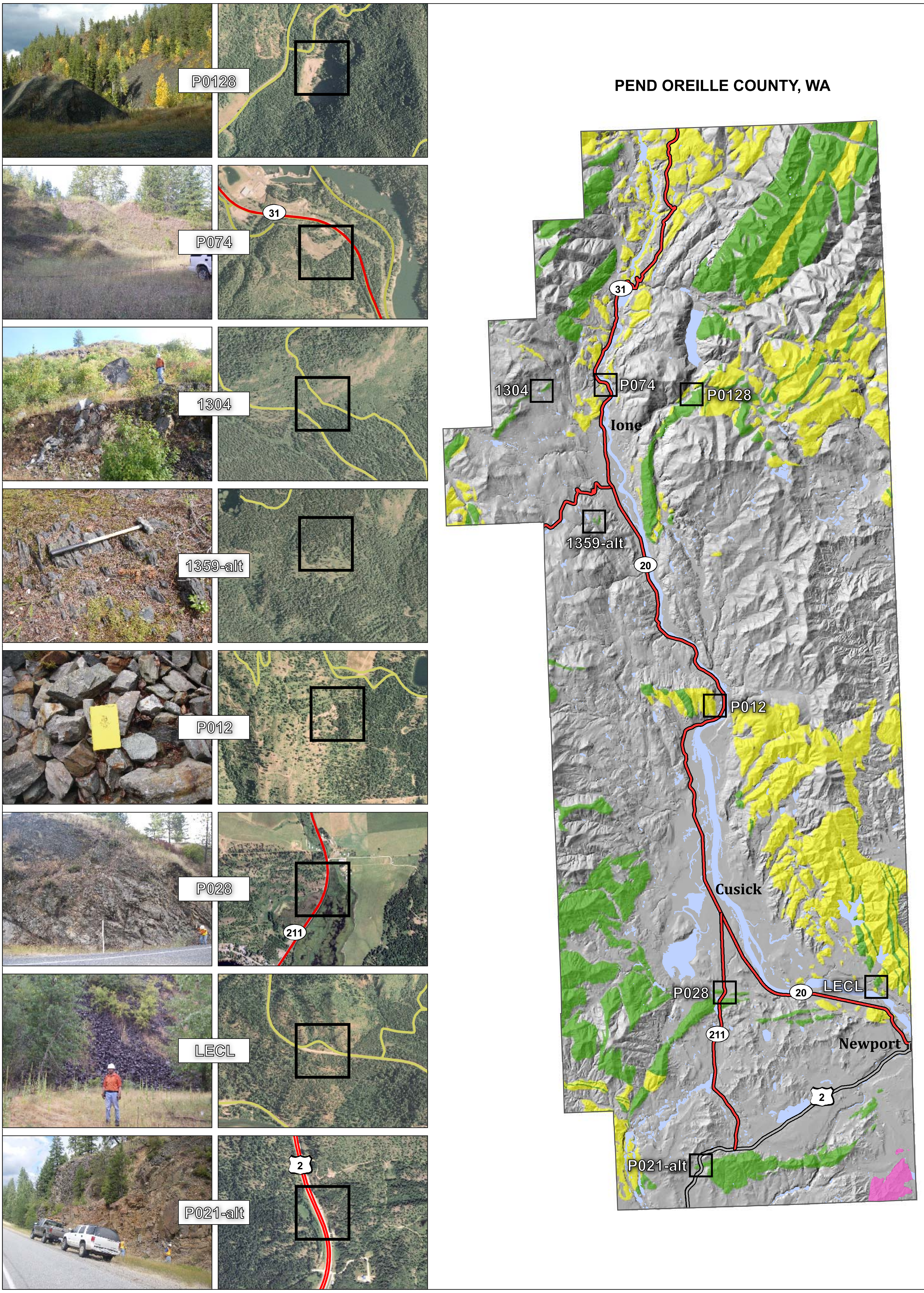

LEGEND

Aggregate Quality by Geologic Unit

- High Quality
- Marginal Quality
- Low Quality
- Insufficient Data

- State Route
- U.S. Highway

N

MILES

0 1.5 3 6 9 12

1:360,000

1 inch equals 30,000 feet

FIGURE 8: SITE SPECIFIC RECOMMENDATIONS BY GEOLOGIC UNIT

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** May 12, 2009

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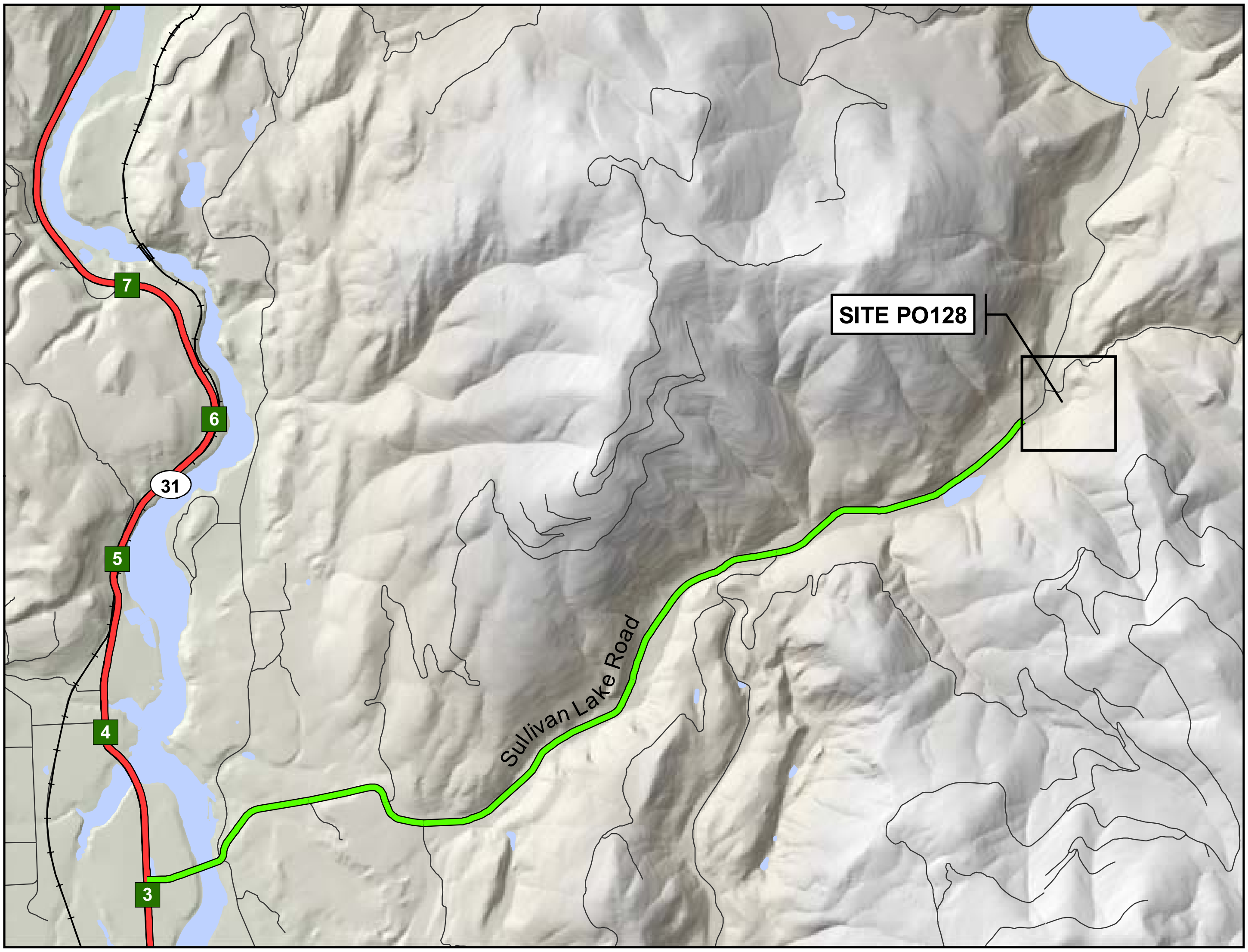

LEGEND

- Access Route
- State Routes
- U.S. Highways
- Milepost Markers
- Railroads
- Local Transportation Routes

N

0 1,500 3,000 6,000 9,000 FEET

1 inch equals 5,000 feet 1:60,000

FIGURE 9: SITE PO128

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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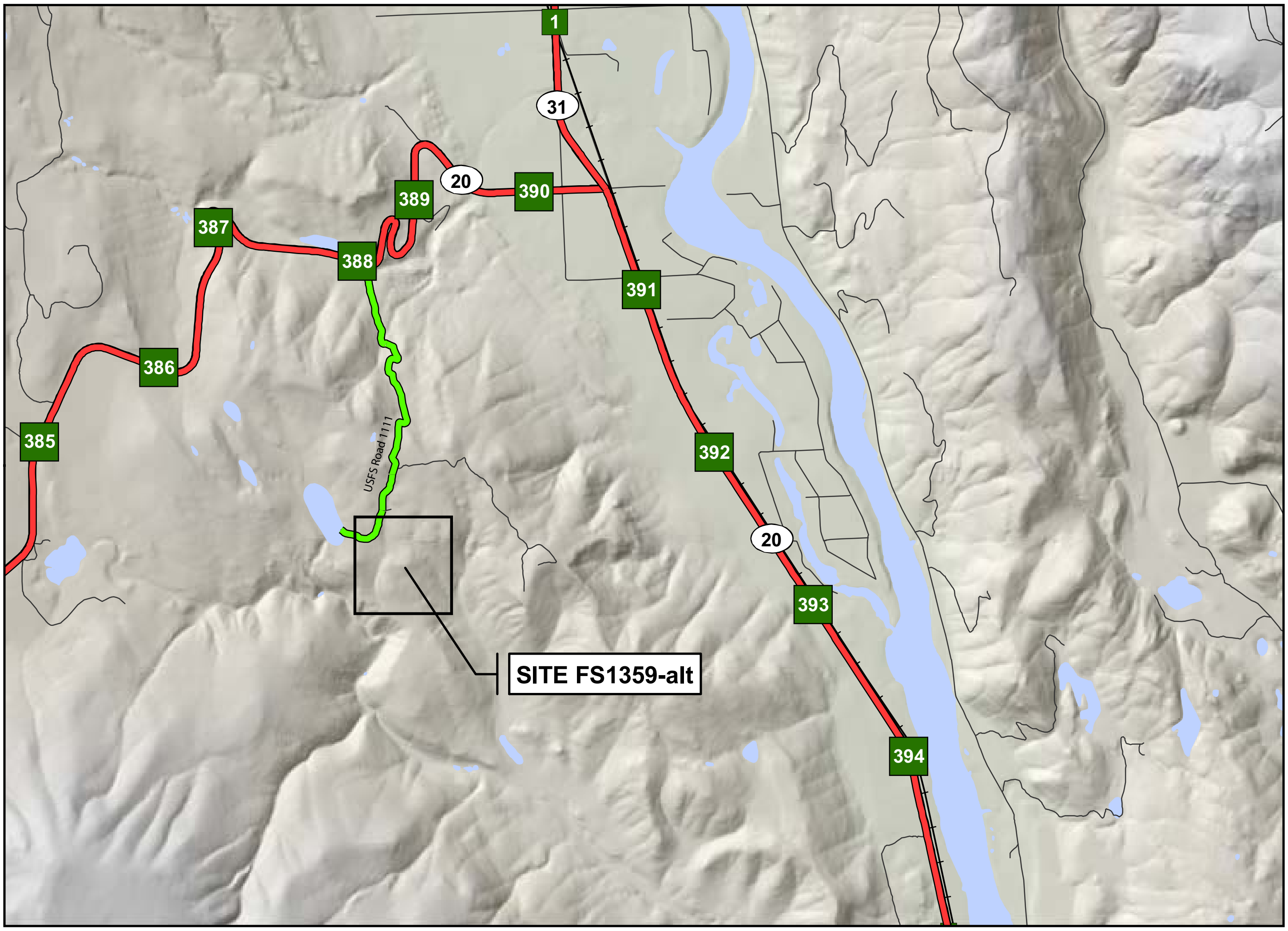

LEGEND

- Access Route
- State Routes
- U.S. Highways
- Milepost Markers
- Railroads
- Local Transportation Routes

N

0 2,250 4,500 9,000 FEET

1 inch equals 5,000 feet 1:60,000

FIGURE 10: SITE FS1359-alt

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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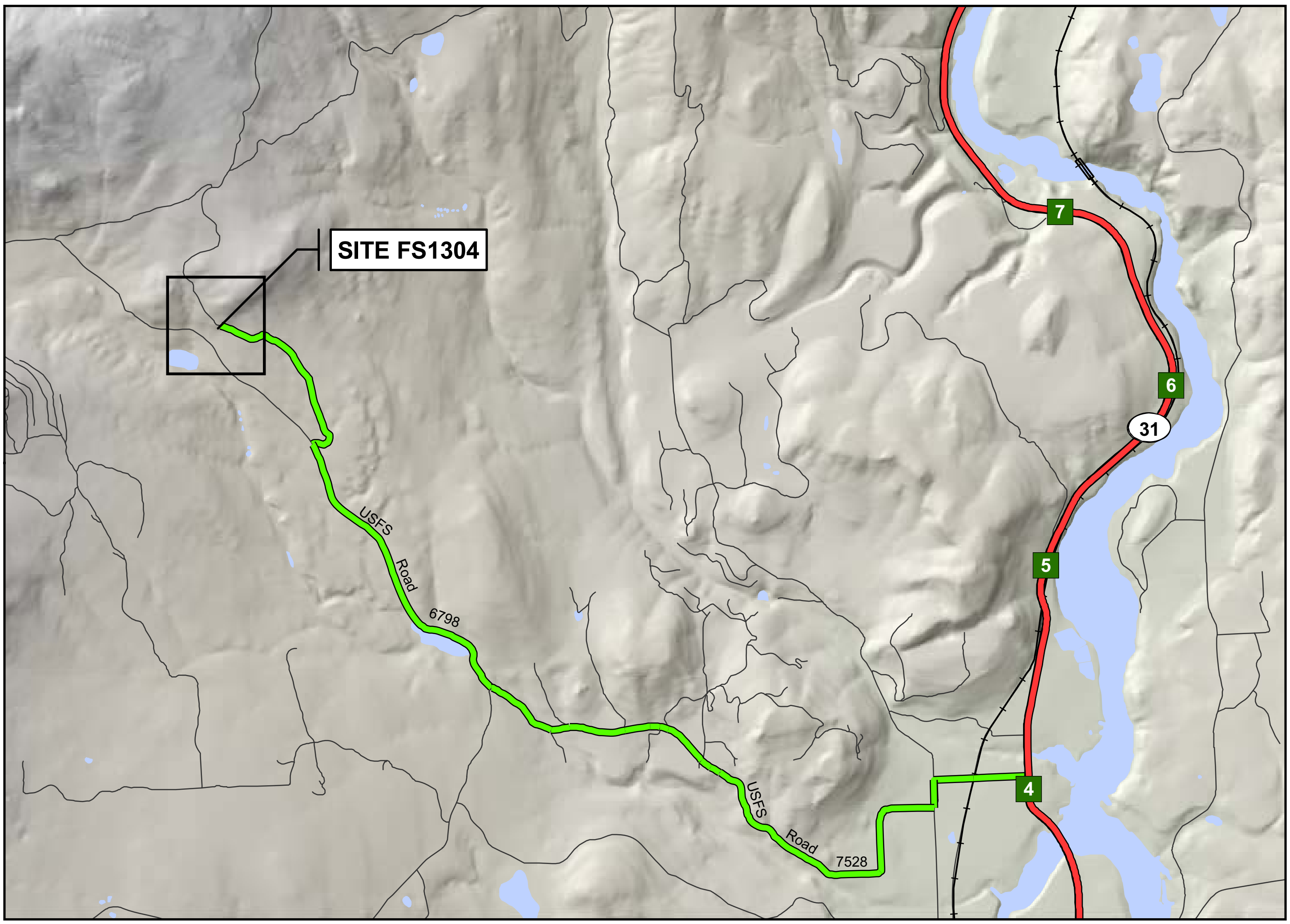

LEGEND

- Access Route
- Milepost Markers
- State Routes
- Railroads
- U.S. Highways
- Local Transportation Routes

N

0 1,500 3,000 6,000 9,000 FEET

1 inch equals 4,000 feet 1:48,000

FIGURE 11: SITE FS1304

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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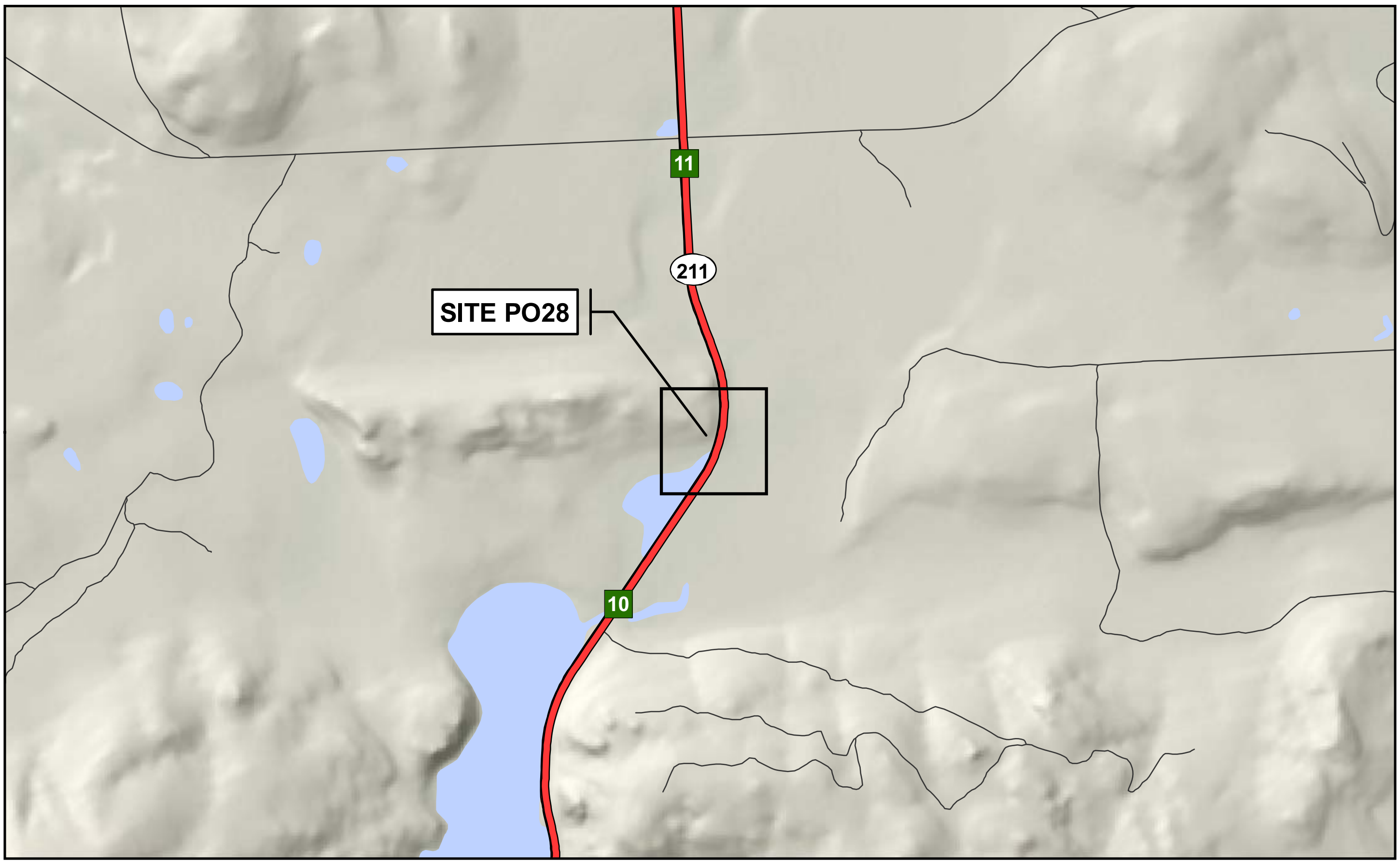

LEGEND

State Routes
Milepost Markers
U.S. Highways
Railroads
Local Transportation Routes

N

0 500 1,000 2,000 3,000 4,000
FEET

1 inch equals 2,000 feet 1:24,000

FIGURE 12: SITE PO28

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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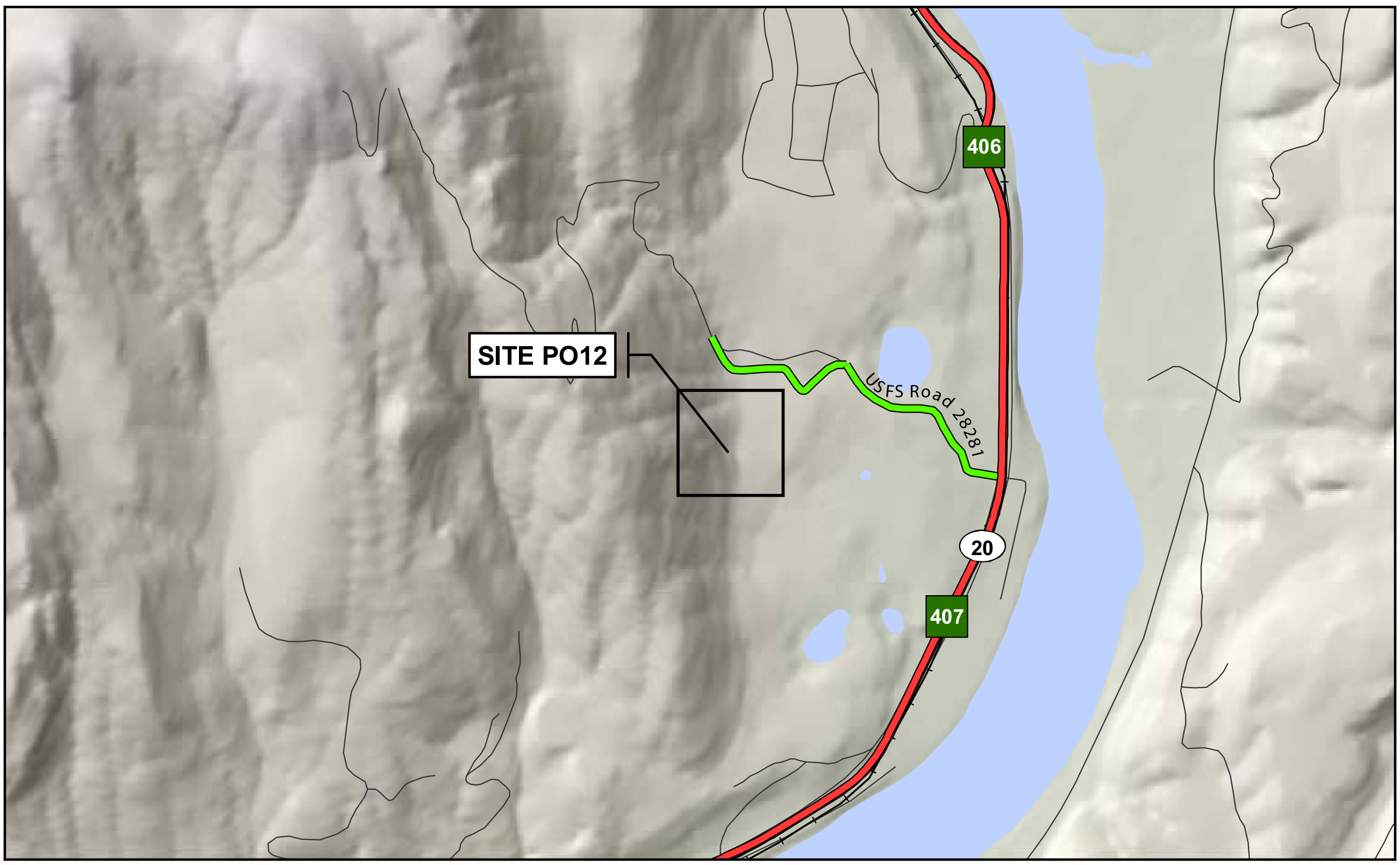

LEGEND

Access Route
Milepost Markers
State Routes
Railroads
U.S. Highways
Local Transportation Routes

N

0 500 1,000 2,000 3,000 4,000 FEET

1 inch equals 2,000 feet 1:24,000

FIGURE 13: SITE PO12

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

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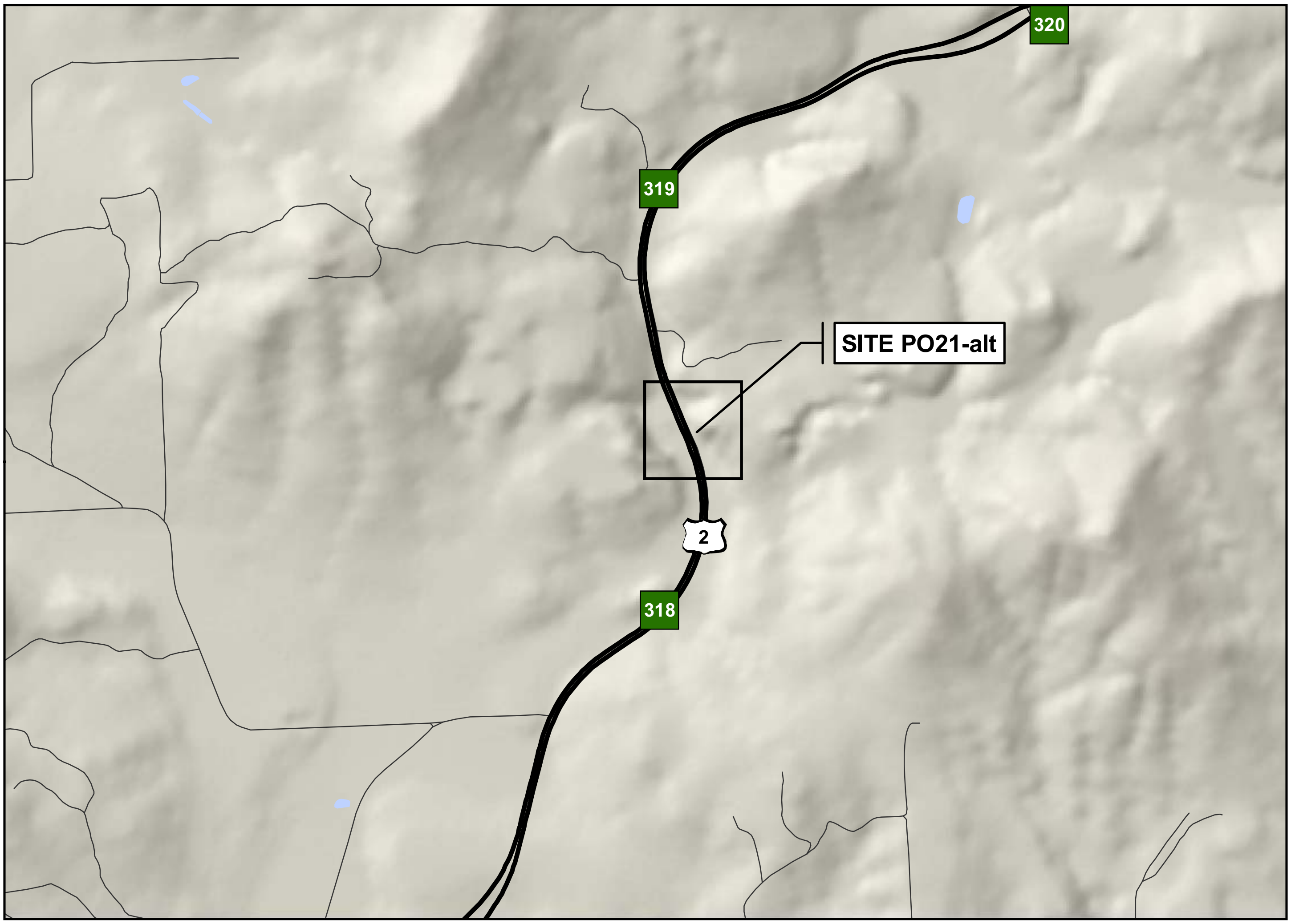

LEGEND

State Routes
Local Transportation Routes
U.S. Highways
Railroads
Milepost Markers

N

0 500 1,000 2,000 3,000 4,000 FEET

1 inch equals 2,000 feet 1:24,000

FIGURE 14: SITE PO21-alt

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander DATE January 11, 2009

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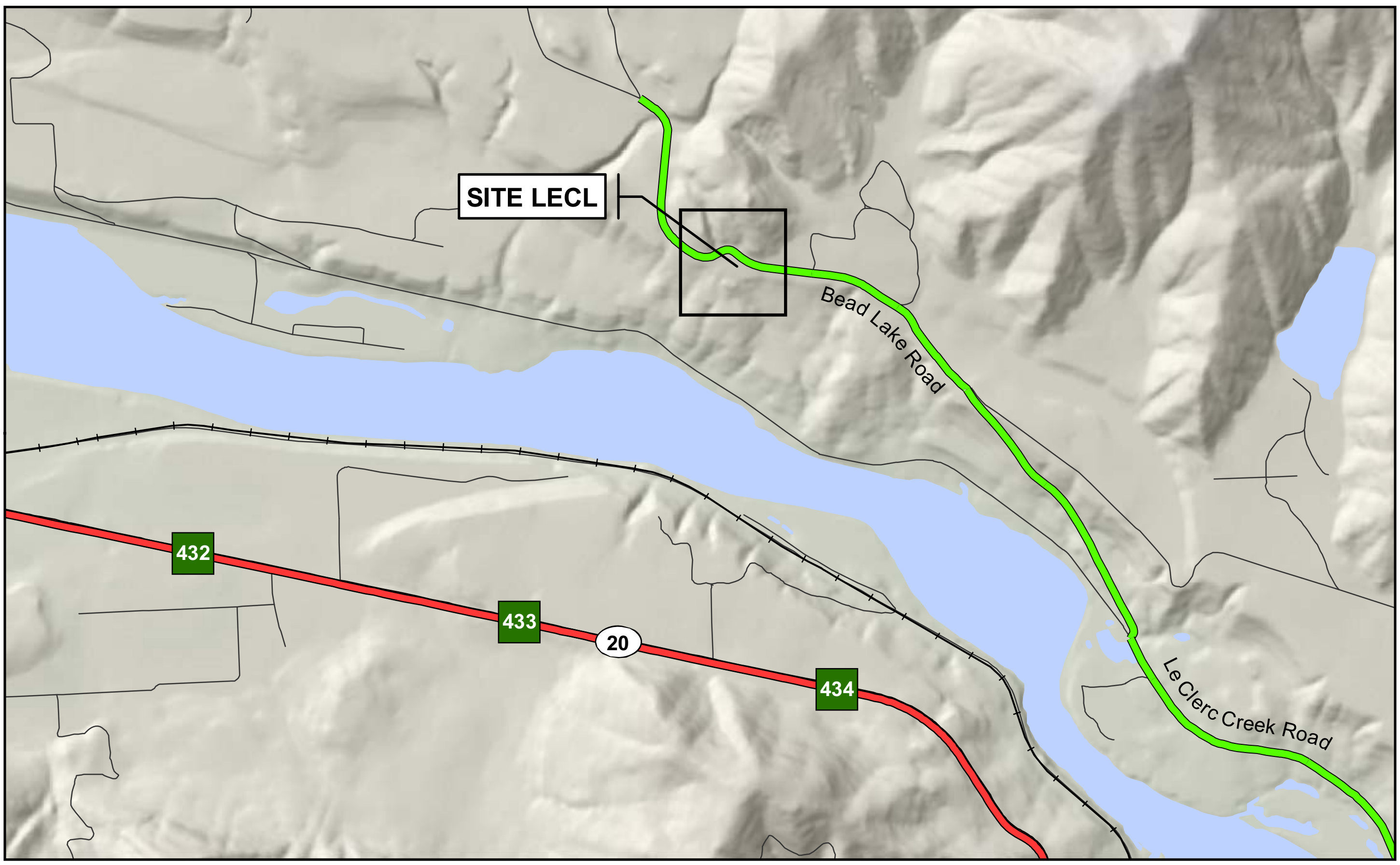

LEGEND

- State Routes
- U.S. Highways
- Milepost Markers
- Railroads
- Local Transportation Routes

N

0 750 1,500 3,000 4,500 6,000 FEET

1 inch equals 3,000 feet 1:36,000

FIGURE 15: SITE LECL

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** January 11, 2009

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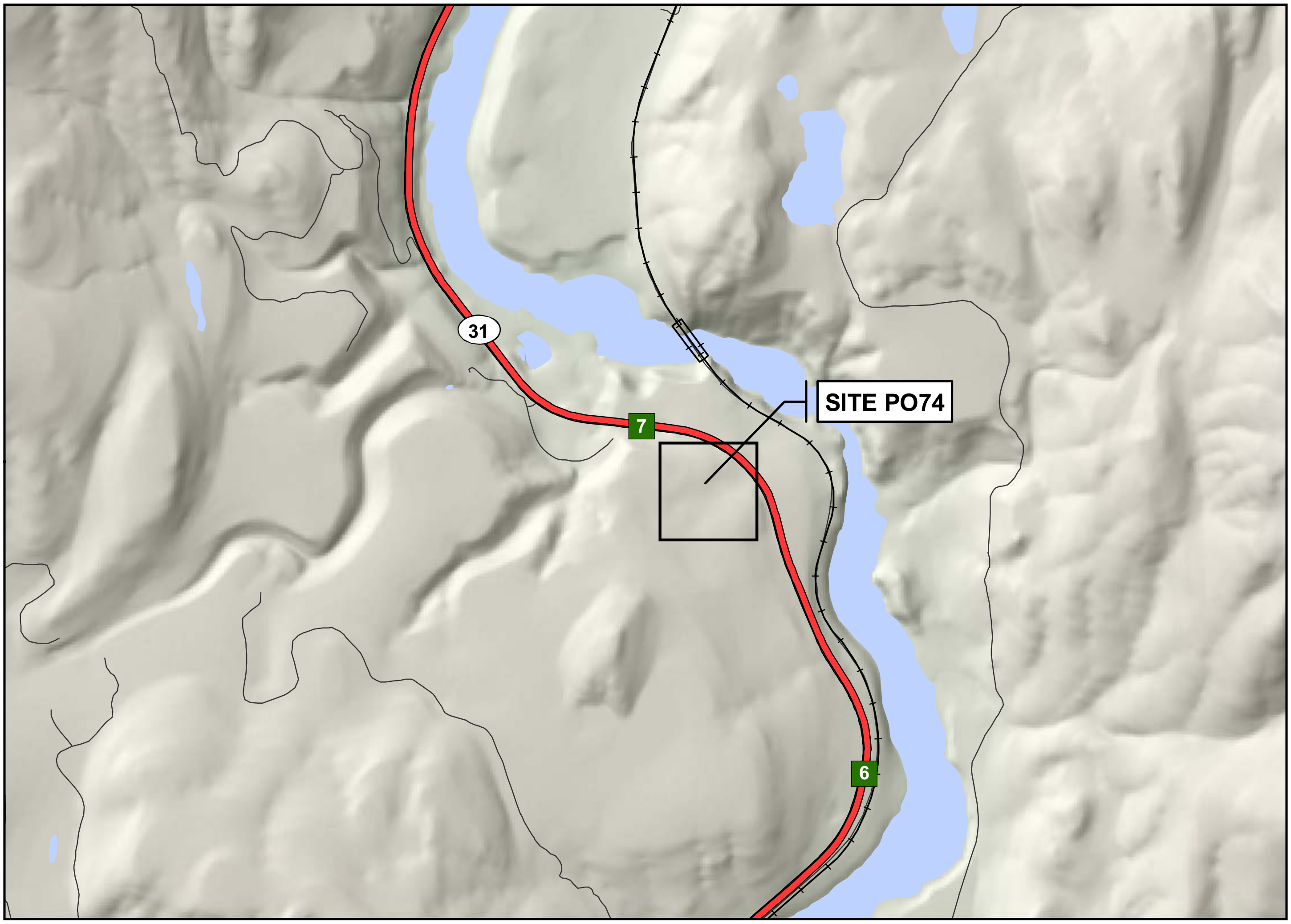

LEGEND

State Routes — Local Transportation Routes

U.S. Highways — Railroads

Milepost Markers

N

0 500 1,000 2,000 3,000 4,000 FEET

1 inch equals 2,000 feet 1:24,000

FIGURE 16: SITE PO74

Pits & Quarries
Pend Oreille County

Washington State Department of Transportation
GEOTECHNICAL DIVISION

PREPARED BY Andy Bohlander **DATE** January 11, 2009

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Appendix B

Laboratory Testing

Table 1: Summary of Historical Laboratory Test Data (Pend Oreille County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
PO2		28.7		6/8/1944	Glaciolacustrine
PO3	2.67			5/1/1950	Glaciolacustrine
PO6	2.65	27.2		8/18/1942	Glaciolacustrine
PO9	2.71	20.7	60	12/24/1958	Glaciolacustrine
PO10	2.68	22.4	64	9/11/1984	Glaciolacustrine
PO12	2.75	16.1	78	2/1/1961	Belt metasedimentary rocks
	2.75	17	71	10/7/2008	Belt metasedimentary rocks
PO17	2.66	19.02	53	8/28/1967	Outburst flood deposits
PO18	2.68	21	35	10/12/1989	Outburst flood deposits
PO32	2.69	25.2		8/27/1951	Glaciolacustrine
PO33		22.1		4/25/1951	Outburst flood deposits
PO34		31		6/12/1945	Granitic rocks
PO35		27.2		6/12/1945	Outburst flood deposits
PO36		26.1		12/4/1937	Glaciolacustrine
PO37		25.5		9/8/1942	Glaciolacustrine
PO38		32.4		8/6/1938	Glaciolacustrine
PO39		32.3		8/6/1938	Alluvial deposits
PO40	2.7	25	40	8/9/1999	Metacarbonate rocks
PO41	2.68	20.2	54	6/13/1980	Glaciolacustrine
PO42		24.8		9/22/1942	Glaciolacustrine
PO43		22.7		6/8/1944	Glaciolacustrine
PO44		43.3		7/7/1944	Glaciolacustrine
PO45		29.3		7/7/1944	Glacial drift
PO46		21.7		3/19/1951	Alluvial deposits
PO50	2.64	26.5	54	12/3/1964	Outburst flood deposits
PO51		30		6/12/1945	Outburst flood deposits
PO53		25.6		5/16/1945	Alluvial deposits
PO54		22.9		6/20/1945	Metacarbonate rocks
PO55		20		5/13/1947	Granitic rocks
PO56	2.73	28.1	63	6/30/1977	Glacial drift
PO62		22.2		10/6/1948	Glacial drift
PO63	2.69	17.4	39	3/30/1998	Glacial drift
	2.7	21		6/22/2005	Glacial drift
PO64		38.8		4/12/1951	Glacial drift
PO65	2.66	43.5		7/9/1951	Glacial drift
PO66	2.68	23.7	15	11/4/1976	Glaciolacustrine
	2.68	23	87	8/25/1993	Glaciolacustrine
	2.69	22	48	5/18/2005	Glaciolacustrine
PO67	2.74	31.6	48	5/22/1969	Glacial drift
PO69	2.71	32.5		7/23/1951	Glaciolacustrine
PO70	2.78	25		6/10/1953	Glacial drift
PO71	2.66	24.6		1/7/1954	Outburst flood deposits
PO73	2.8	30.6	35	6/30/1977	Glaciolacustrine
PO74	2.7	18.9	62	3/23/1966	Metacarbonate rocks
	2.8	23	45	10/7/2008	Metacarbonate rocks
PO75	2.62	36.8	66	6/27/1955	Glacial drift
PO77	2.69	26.1		8/5/1955	Glaciolacustrine
PO78			59	4/19/1963	Outburst flood deposits
PO80	2.63	39.1		3/13/1959	Glacial drift

Table 1: Summary of Historical Laboratory Test Data (Pend Oreille County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
PO83	2.81	25.8	83	7/6/1959	Metacarbonate rocks
PO87	2.68	18	44	5/18/2005	Glaciolacustrine
PO91	2.63	22.1	75	11/10/1961	Metacarbonate rocks
PO92	2.78	21.6	31	7/5/1977	Glaciolacustrine
PO94	2.97	11.2	77	8/9/1963	Glaciolacustrine
PO98		15.8	48	6/3/1966	Outburst flood deposits
PO100	2.49	27.2	14	10/7/1966	Glacial drift
PO101	2.68	24.3	29	5/10/1967	Alluvial deposits
PO102	2.64	26.8	55	5/10/1967	Alluvial deposits
PO103	2.65	29	58	11/13/1967	Glaciolacustrine
PO104	2.63	25.3	46	5/22/1969	Alluvial deposits
PO106	2.93	28.8		6/19/1978	Metacarbonate rocks
	2.8	27	80	8/25/1999	Metacarbonate rocks
	2.87	25	78	8/16/2000	Metacarbonate rocks
PO111	2.68		59	4/3/1975	Glacial drift
PO112	2.69	26	31	5/15/2003	Glaciolacustrine
PO113	2.69	22.5	37	1/30/1976	Metacarbonate rocks
PO114	2.72	25.8	9	6/24/1977	Glaciolacustrine
PO117	2.65	32.5	39	5/5/1978	Glaciolacustrine
PO119	2.61			3/17/1998	Outburst flood deposits
PO121	2.71		26	11/20/1984	Metacarbonate rocks
PO122	2.63	16	55	2/19/1998	Outburst flood deposits
	2.66			7/2/2007	Outburst flood deposits
PO128	2.86	16	52	12/16/1992	Greenstone
	2.93	17	59	10/7/2008	Greenstone
PO129	2.77	24	77	5/16/1997	Outburst flood deposits
PO130	2.72	25	36	5/8/2002	Metacarbonate rocks
PO131	2.81	39	72	7/22/2002	Metacarbonate rocks
	2.83	40	89	12/12/2005	Metacarbonate rocks
PO132	2.77	25	42	12/24/2002	Metacarbonate rocks
PO133	2.82	19	29	6/25/2003	Continental sedimentary rocks
PO134	2.66	24	67	6/17/2003	Outburst flood deposits
PO135	2.75	24	18	12/9/2003	Marine metasedimentary rocks
PO136	2.76	30	54	4/29/2004	Glaciolacustrine
PO137	2.66	32	59	9/21/2005	Outburst flood deposits
PO138	2.68	36	3	12/11/2005	Glaciolacustrine
	2.7	28	41	12/12/2005	Glaciolacustrine
PO139	2.67	17	38	11/17/2005	Glacial drift

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W2		12.2		3/1/1946	Glacial drift
W7	2.653	26	89	6/9/1993	Alluvial deposits
	2.67	28	71	8/4/2003	Alluvial deposits
W8		23.1	67	5/1/1978	Glacial drift
		24		9/4/1991	Glacial drift
W15	2.64	21.3	57	4/1/1978	Glaciolacustrine
W19	2.64	25	65	7/12/1994	Outburst flood deposits
W24	2.82	18	79	5/1/1980	Glacial drift
W30		25.4		12/1/1938	Alluvial deposits
W33		19.5		12/1/1938	Glaciolacustrine
W34	2.84	39.6	37	4/1/1984	Metacarbonate rocks
W38		13.2		7/1/1947	Marine metasedimentary rocks
W40	2.64	18.7	77	3/1/1961	Glacial drift
W44		23		5/1/1940	Marine metasedimentary rocks
W45	2.76	24	70	1/1/1980	Glacial drift
W48	2.72	19.9	77	1/1/1978	Alluvial deposits
W50	2.68	17.9	77	9/1/1977	Glaciolacustrine
W51	2.65			4/1/1933	Glaciolacustrine
W56				9/1/1937	Glacial drift
W59	2.645	22.8	58	8/1/1984	Glacial drift
	2.68	21	83	7/11/2002	Glacial drift
W61	2.66	21.8	65	11/1/1977	Glacial drift
W62	2.62	19.7	36	3/1/1981	Alluvial deposits
W63	2.675	18	71	6/16/1995	Glacial drift
	2.75	24	79	4/7/2005	Glacial drift
W67		26.4		12/1/1938	Glacial drift
W68	2.65	20	46	12/16/1993	Outburst flood deposits
W69		22.1		12/1/1938	Alluvial deposits
W70	2.64	26.1	88	5/1/1983	Alluvial deposits
W71		24.3		12/1/1938	Alluvial deposits
W72		19.7		11/1/1938	Quartzite
W73		24		11/1/1938	Glacial drift
W74		22.6		11/1/1938	Glacial drift
W75		15.9		11/1/1938	Glaciolacustrine
W77		33.3		5/1/1937	Marine metasedimentary rocks
W78		20		6/1/1948	Continental sedimentary rocks
W79		16.2		4/1/1939	Vitrophyric flows
W80	2.71	17.8	28	4/1/1982	Glacial drift
W84		34.5		4/1/1939	Glacial drift
W85		18		4/1/1939	Glacial drift
W86		20.4		6/1/1948	Marine metasedimentary rocks
W88	2.65	21.4	71	12/1/1973	Glaciolacustrine
W89		19		7/1/1939	Glaciolacustrine
W90		23.8		7/1/1939	Alluvial deposits
W94		15.7		3/1/1940	Marine metasedimentary rocks
W96		22.1		10/1/1939	Argillite
W98		21		2/1/1940	Glacial drift
W99	2.64			5/1/1949	Glacial drift
	2.66	22.6	72	8/1/1984	Glacial drift

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W99		23	80	12/1/2004	Glacial drift
W100		28.1		4/1/1940	Glacial drift
W101		19.5		5/1/1940	Glaciolacustrine
W102		23.8		5/1/1940	Glacial drift
W103		19.7		5/1/1940	Glacial drift
W104		18.7		5/1/1940	Glacial drift
W105		14.6		5/1/1940	Glaciolacustrine
W106		28.3		7/1/1940	Alluvial deposits
W108	2.68			10/1/1940	Glacial drift
W109		18.3		5/1/1941	Glacial drift
W113		22		7/1/1941	Alluvial deposits
W115		19.8		7/1/1942	Alluvial deposits
W117		18		1/1/1942	Glacial drift
W118		17.6		9/1/1941	Glacial drift
W120		16.6		1/1/1942	Glacial drift
W121		14.8		3/1/1942	Quartzite
W122		33.2		4/1/1942	Alluvial deposits
W123	2.66	31	25	2/11/1993	Alluvial deposits
W125		21.8		1/1/1946	Glacial drift
W126	2.65	18	83	8/13/1992	Alluvial deposits
W127		21		4/1/1945	Glacial drift
W128		31.9		6/1/1945	Glacial drift
W130	2.89	29.1		3/1/1946	Metacarbonate rocks
W133		22.5		8/1/1946	Metacarbonate rocks
W134		18		10/1/1946	Alluvial deposits
W135		13.8		9/1/1946	Alluvial deposits
W136		23.4		10/1/1946	Alluvial deposits
W137		16.4		6/1/1948	Glacial drift
W138	2.83	31.6		4/1/1971	Metacarbonate rocks
W139		17.7		1/1/1949	Alluvial deposits
W140		20.3		1/1/1949	Alluvial deposits
W141	2.63			5/1/1949	Glacial drift
W142		17.9		5/1/1949	Glacial drift
W143	2.72	25.2	52	6/1/1977	Glacial drift
W144	2.84	14.7	79	5/1/1960	Glacial drift
W145		16.6		3/1/1950	Glacial drift
W146		31.6		3/1/1950	Glacial drift
W147		28.6		3/1/1950	Glacial drift
W148		16.2		3/1/1950	Glacial drift
W149		20.8		3/1/1950	Glacial drift
W150	2.65	15.2		6/1/1958	Glacial drift
W151		39.4		12/1/1950	Metacarbonate rocks
W152	2.65	25	81	5/17/1993	Alluvial deposits
W153		27.6		5/1/1951	Alluvial deposits
W154		25.3		5/1/1951	Alluvial deposits
W155		20.4		6/1/1951	Glaciolacustrine
W156	2.61	51.8	30	12/1/1981	Alluvial deposits
W157	2.67	18.3	74	6/1/1983	Metacarbonate rocks
	2.7	17	82	4/29/2004	Metacarbonate rocks

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W157	2.78	31	56	4/30/2004	Metacarbonate rocks
W158	2.9	21.7		7/1/1951	Glacial drift
W159	2.63	22.3	75	6/1/1959	Alluvial deposits
W164	2.66	21.3		8/1/1954	Alluvial deposits
W165	2.61	25.9		8/1/1954	Glacial drift
W166	2.8	20.2		12/1/1954	Glacial drift
W167	2.72	19.2		12/1/1954	Alluvial deposits
W168	2.62	50.4		12/1/1954	Glacial drift
W169	2.64	23		12/1/1954	Alluvial deposits
W170	2.68	21.4	74	6/1/1981	Glacial drift
W171	2.58	19.6		1/1/1955	Continental sedimentary rocks
W172	2.66	15.6		1/1/1955	Glacial drift
W173	2.78	24		1/1/1955	Glacial drift
W174	2.64	18.4		7/1/1955	Glacial drift
W175	2.65	15.5		7/1/1955	Glacial drift
W177	2.61	25.4		1/1/1956	Glacial drift
W178	2.69	20.7	77	5/1/1983	Alluvial deposits
W179	2.6	32.6	4	2/1/1987	Alluvial deposits
W180	2.59	23	70	9/1/1992	Alluvial deposits
W181	2.73	17.5	60	4/1/1978	Glaciolacustrine
W182	2.62	27		1/1/1957	Alluvial deposits
W183	2.78	26.1		1/1/1957	Phyllite
W184	2.7	22.7		1/1/1957	Glacial drift
W185	2.59	35.7		1/1/1957	Granitic rocks
W187	2.59	46.4		1/1/1958	Belt metasedimentary rocks
W188	2.64	18.3		1/1/1958	Glacial drift
W189	2.57	20.7		1/1/1958	Glacial drift
W190	2.65	20.3	59	4/1/1958	Glacial drift
W191	2.65	26.2		5/1/1958	Glacial drift
W192	2.66	20.4	58	3/1/1982	Alluvial deposits
W194	2.83	22	61	12/14/1993	Glacial drift
W196	2.83	23.7		5/1/1959	Metacarbonate rocks
W197	2.71	28.8		5/1/1959	Argillite
W198	2.64	22		5/1/1959	Glaciolacustrine
W199	2.69	17		5/1/1959	Glaciolacustrine
W200	2.71	18.3		5/1/1959	Alluvial deposits
W201	2.65	24.1		5/1/1959	Alluvial deposits
W202	2.66	16		5/1/1959	Alluvial deposits
W203	2.75	19.6		5/1/1959	Metacarbonate rocks
W204	2.7	24.4		5/1/1959	Glacial drift
W205	2.65	18.7	59	7/1/1966	Alluvial deposits
W206	2.7	20.6	51	6/1/1959	Glacial drift
W207	2.72	18		5/1/1960	Alluvial deposits
W208	2.7	20.7		6/1/1960	Glacial drift
W212	2.68	36.5	25	2/1/1962	Glacial drift
W213	2.7	23.7	40	5/1/1962	Glacial drift
W214	2.68	22.6	56	5/1/1962	Glacial drift
W215	2.72	27.8	42	4/1/1984	Glacial drift
W217	2.66	16.4	69	4/1/1963	Glacial drift

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W218	2.76	24.3	74	8/1/1986	Glacial drift
W219	2.7	16.1	69	1/1/1964	Glacial drift
W221	2.68	35	33	12/5/1991	Metacarbonate rocks
W223	2.67	50	74	3/1/1965	Granitic rocks
W225	2.7	32.2	28	5/1/1965	Glacial drift
W228	2.62	46.5	60	6/1/1966	Alluvial deposits
W229	2.97	14.9	77	4/1/1973	Quartzite
W230	2.65	20.4	75	10/1/1967	Quartzite
W231	2.68	23.4	15	8/1/1968	Glacial drift
W232	3.05	10.8	75	11/1/1968	Greenstone
W234	2.59	29.8	84	4/1/1971	Argillite
W235	2.74	22.3	48	4/1/1971	Metacarbonate rocks
W236	2.73	25.2	32	4/1/1971	Quartzite
W237	2.69	25.4	30	4/1/1971	Metacarbonate rocks
W238	2.69	30.5	21	4/1/1971	Metacarbonate rocks
W239	2.7	31	25	4/1/1971	Alluvial deposits
W240	2.85	20.1	29	4/1/1971	Marine metasedimentary rocks
W241	2.67	14.9	77	4/1/1971	Outburst flood deposits
W242	2.7	39.1		6/1/1971	Marine metasedimentary rocks
W243	2.67	25.8	21	11/1/1972	Glacial drift
W244	2.7	25.4	10	11/1/1972	Glacial drift
W245	2.59	28.4	34	11/1/1972	Glacial drift
W246	2.66	29.1	78	11/1/1972	Quartzite
W247	2.59	22.5	58	11/1/1972	Glacial drift
W248	2.61	29.6	17	11/1/1972	Alluvial deposits
W250	2.7	23.3	77	9/1/1973	Glacial drift
W251	2.91	16.5	40	4/1/1974	Alluvial deposits
W252	2.64	23	95	4/17/1996	Greenstone
W253			75	4/1/1975	Outburst flood deposits
W254	2.68	21.5	59	12/1/1975	Greenstone
W256	2.67	35	15	8/1/1976	Belt metasedimentary rocks
W257	2.7	37.1	17	11/1/1976	Glaciolacustrine
W258	2.58	23.8	60	2/1/1977	Glacial drift
W259	2.69	29.3	55	3/1/1977	Glaciolacustrine
W260	2.64	34	17	3/1/1977	Quartzite
W261	2.69	20.1	63	6/1/1977	Alluvial deposits
W262		22.4	44	7/1/1977	Glacial drift
W263		22	37	7/1/1977	Alluvial deposits
W264	2.62	47.1	71	9/1/1977	Granitic rocks
W265	2.65	26.6	41	2/1/1979	Marine metasedimentary rocks
W266		25	44	11/1/1977	Marine metasedimentary rocks
W267	2.65	22.3	48	10/1/1977	Alluvial deposits
W268	2.819	29	92	9/1/1989	Alluvial deposits
W268	2.82	27	92	5/16/2001	Alluvial deposits
W272	2.78	19.1	63	6/1/1980	Glacial drift
W273	2.61	24	27	7/27/1994	Glacial drift
	2.62	23	63	7/2/1998	Glacial drift
	2.639	23	95	5/28/2002	Glacial drift
	2.723	25	28	4/7/2003	Glacial drift

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W273	2.675	19	62	4/6/2005	Glacial drift
W275	2.68	33.5	51	12/1/1983	Alluvial deposits
W276	2.71	20.1	90	8/1/1983	Granitic rocks
W277	2.72	26.4	32	1/1/1984	Glacial drift
W278	2.67	28.7	59	1/1/1984	Alluvial deposits
W279	2.67	28.3	43	1/1/1984	Glacial drift
W280	2.65	28.1	55	3/1/1984	Glacial drift
		28		9/26/2001	Glacial drift
	2.649	26	59	3/18/2003	Glacial drift
		30		11/3/2006	Glacial drift
W281	2.66	23	54	4/1/1984	Pre-cambrian metamorphic rocks
	2.692	22	66	6/14/1999	Pre-cambrian metamorphic rocks
W282	2.65	30.2	17	3/1/1984	Glacial drift
W283	2.58	27.2	18	2/1/1987	Outburst flood deposits
W284	2.64	22.7	22	2/1/1987	Belt metasedimentary rocks
W285	2.68	22.9	29	9/1/1987	Glacial drift
	2.68	17	54	6/15/1998	Glacial drift
W286	2.63	25.6	78	9/1/1987	Alluvial deposits
W287		21		10/1/1987	Alluvial deposits
W288	2.84	28	96	7/12/1993	Metacarbonate rocks
W289	2.7	35.7		5/1/1988	Glacial drift
W290	2.63	26	61	4/19/1995	Outburst flood deposits
W292	2.69	16	77	3/31/1994	Glacial drift
W293	2.63	21	71	4/28/1994	Alluvial deposits
W294	2.64	19	84	12/19/1994	Glacial drift
	2.677	22	69	7/21/2005	Glacial drift
W295	2.65	22	62	5/26/1995	Metacarbonate rocks
W296	2.66	55	55	5/24/1995	Glacial drift
W297	2.66	26	69	5/25/1995	Glacial drift
W298	2.97	18	55	2/28/1996	Greenstone
	3.034	15	79	6/11/2002	Greenstone
W299	2.66	21	65	1/19/1996	Glacial drift
W300	2.65	28	76	6/12/1996	Glacial drift
W301	2.96	13	57	10/23/1996	Greenstone
W302	2.56	21	22	5/23/1997	Glacial drift
W303	2.81	26	37	6/4/1998	Alluvial deposits
W304	2.652	17	89	8/9/1999	Glacial drift
	2.777	17	70	7/11/2002	Glacial drift
W305	2.634	24	76	4/7/2000	Glacial drift
W306	2.755	17	29	4/27/2000	Argillite
W307	2.624	25	86	8/3/2000	Quartzite
W308	2.621	29	80	8/4/2000	Quartzite
W309	2.768	20	84	10/19/2000	Metacarbonate rocks
W310	2.835	14	12	4/17/2001	Glacial drift
	2.812	15	23	4/24/2002	Glacial drift
W311	2.671	20	72	6/21/2001	Glacial drift
W312	2.642	20	93	5/2/2002	Alluvial deposits
W313	2.605	25	59	6/14/2002	Continental sedimentary rocks
W314	2.624	33	10	2/4/2003	Metacarbonate rocks

Table 2: Summary of Historical Laboratory Test Data (Stevens County)

Pit ID	SPG	LA	DEG	Test Date	Geologic Unit
W314	2.671	19	61	3/29/2005	Metacarbonate rocks
	2.73	29	10	3/30/2005	Metacarbonate rocks
	2.797	30	19	8/15/2005	Metacarbonate rocks
W315	2.876	16	54	5/29/2003	Argillite
W316	2.641	34	91	10/16/2003	Pre-cambrian metamorphic rocks
W317	2.736	20	3	10/5/2004	Glacial drift
W318	2.763	20	25	9/1/2004	Glacial drift

Table 3: Laboratory Testing Results from Samples Collected During 2008 Field Work

Sample ID	Local Name	SPG	LA	DEG	Absorption	Geologic Unit
LECL		2.94	18	83	0.48	Basic intrusive rocks
33	Tacoma Creek	2.63	34	74	0.65	Granitic rocks
1296	Ruby Quarry	2.57	66	61	1.45	Granitic rocks
1362	Blueslide White Granite	2.61	44	70	1.05	Granitic rocks
97-ALT		2.69	45	46	1.03	Granitic rocks
1304	Jim Creek	3.00	22	82	0.68	Greenstone
1359-ALT	Little Browns Lake Quarry (nearby)	3.01	24	78	0.77	Greenstone
PO128		2.97	17	69	0.49	Greenstone
1337	Lead Hill Mine	2.85	29	90	0.36	Metacarbonate rocks
PO74	Exposure Creek	2.80	23	45	0.82	Metacarbonate rocks
83-ALT	DC2 (nearby)	2.66	42	10	1.84	Phyllite
FLOW		2.69	20	44	0.98	Pre-cambrian metamorphic rocks
PO12	Jared	2.75	17	71	0.68	Pre-cambrian metamorphic rocks
PO21-ALT		2.70	14	62	0.63	Pre-cambrian metamorphic rocks
PO28		2.64	22	60	0.72	Pre-cambrian metamorphic rocks
PO99		2.71	22	11	1.34	Pre-cambrian metamorphic rocks
1240-ALT	Totem (nearby)	2.58	27	83	0.53	Quartzite

Table 4: Summary of Bedrock Aggregate Laboratory Testing Grouped by Geologic Unit

Quality	Geologic Unit	Absorption	SPG-AVE	LA-AVE	LA-STD	LA + 1 STD	DEG-AVE	DEG-STD	DEG - 1 STD	Pass-Ave	Pass +/- 1 STD	NOTES
Low Quality	Continental sedimentary rocks		2.58	31	8	39	46	27	19	No Pass	No Pass	Fails LA and Highly Variable DEG
	Granitic rocks	1.05	2.70	48	16	64	68	7	62	No Pass	No Pass	Fails LA
	Phyllite	1.84	2.72	34	11	45	10	0	10	No Pass	No Pass	Fails LA and DEG
	Vitrophyric flows			16	0	16		0	0	No Pass	No Pass	No DEG data
Marginal Quality	Argillite		2.65	27	4	31	84	0	84	Pass	No Pass	Marginal LA
	Belt metasedimentary rocks	1.01	2.67	29	12	41	31	30	1	Pass	No Pass	Marginal LA and Highly Variable DEG
	Marine metasedimentary rocks		2.73	23	10	33	38	8	30	Pass	No Pass	Marginal LA and DEG
	Metacarbonate rocks	0.45	2.76	27	6	32	55	24	31	Pass	No Pass	Marginal LA and DEG
High Quality	Basic intrusive rocks	0.48	2.92	18	0	18	83	0	83	Pass	Pass	
	Greenstone	0.66	2.88	20	4	24	71	15	56	Pass	Pass	
	Pre-cambrian metamorphic rocks	0.78	2.68	20	4	24	57	8	48	Pass	Pass	
	Quartzite	0.53	2.71	23	7	30	60	28	32	Pass	Pass	