ATTACHMENT H-1
ENGINEERING GEOLOGY AND SEISMIC HAZARDS SUPPLEMENT

ATTACHMENT H-1 – ENGINEERING GEOLOGY AND SEISMIC HAZARDS SUPPLEMENT TO EXHIBIT H

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1 INTRODUCTION

The intent of this report is to supplement the Exhibit H for the Application of Site Certificate (Oregon Administrative Rule (OAR) 345-021-0000) of the Energy Facility Siting Council (EFSC). The basis for this Exhibit H is Oregon Administrative Rule OAR 345-022-0020, for which EFSC requires compliance with their Application for Site Certificate. Exhibit H further delineates the specific requirements for the application and with this document, Shannon & Wilson will present information regarding geological and soil stability, as required by EFSC Exhibit H, along the proposed alignments of the Boardman to Hemingway 500kV Transmission Line. The following sections provide information as outlined in OAR 345-022-0020, which generally states that the applicant must provide evidence that they can design, engineer, and construct the proposed facility in such a way to avoid danger to human safety. Specifically, the applicant must be able to demonstrate the following, as outlined in OAR 345-022-0020:

a) *The applicant, through appropriate site-specific study, has adequately characterized the site as to Maximum Considered Earthquake Ground Motion identified at International Building Code (most recent edition) Section 1615 and maximum probable ground motion, taking into account ground failure and amplification for the site specific soil profile under the maximum credible and maximum probable seismic events; and*

b) *The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by seismic hazards affecting the site that are expected to result from maximum probable ground motion events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide liquefaction, lateral spreading, tsunami inundation, fault displacement, and subsidence;*

c) *The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggravated by, the construction and operation of the proposed facility; and*

d) *The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by the hazards identified in subsection (c).*

The following information is in accordance with OAR 345-021-0010(1)(h), and is intended to provide evidence of compliance to OAR 345-022-0020.

2 TOPOGRAPHIC AND GEOLOGIC FEATURES

OAR 345-021-0010(1)(h)(A): "A geologic report meeting the guidance in Oregon Department of Geology and Mineral Industries open file report 00-04 "Guidelines for Engineering Geologic Reports and Site-Specific Seismic Hazards Reports."

Topographic and geologic information provided in this section is based on readily available reports and maps from the Oregon Department of Geology and Mineral Industries, geographic information system (GIS)-based maps, Idaho Department of Water Resources (IDWR) GIS-based maps, and other geologic literature, including reports from the U.S. Geological Survey, as listed in the reference section of this report.

The proposed transmission alignments are located within 3 general physiographic provinces. From north to south the provinces are the Deschutes-Columbia Plateau, the Blue Mountains, and the Owyhee Plateau. The following discussion presents a brief description of the topographic characteristics of each province, major stream drainage systems (with an emphasis on those streams that will be crossed by the proposed transmission alignments), a description of the general geologic environment, and a brief description of surface soil mantling the bedrock units in each province.

Subsequent sections discuss potential geologic hazards within these geomorphic regions and the categorization of these condition/hazards for preliminary geotechnical design purposes.

2.1 Deschutes-Columbia Plateau

2.1.1 Topography

The northernmost portion of the proposed alignment is located within the Deschutes-Columbia Plateau Province. The Deschutes-Columbia Plateau is predominantly a volcanic province covering approximately 63,000 square miles in Oregon, Washington, and Idaho. The plateau is surrounded on all sides by mountains. For the purpose of this study we will describe only that portion of the province that lies in Oregon.

The Deschutes-Columbia Plateau is located in the northern portion of Oregon, and is bounded on the north by the Columbia River, on the west by the Cascade Range, on the southwest by the High Lava Plains, and on the south and east by the Blue Mountains. A portion of the IPC Proposed Route alignment, the IPC Horne Butte Alternate, and the IPC Longhorn Alternative are located within the Umatilla basin, within the western region of the Deschutes-Columbia Plateau (refer to Deschutes-Columbia Plateau Topography and Drainage, Figure 3). The province slopes gently northward toward the Columbia River with elevations up to 3,000 feet along the southern margins down to a few hundred feet along the river.

2.1.2 Drainage

Primary rivers within the project area of the province are the west-flowing Columbia River and its tributaries, the Umatilla River, and Willow Creek, both of which enter the Columbia River in Morrow County. McKay Creek and Butter Creek are major tributaries of Umatilla River. These streams have cut intricate, deep canyons across the plateau, but broad, flat plains remain between them within the Umatilla Basin. The IPC Proposed transmission alignment will cross McKay Creek, Butter Creek and several smaller tributaries of the Umatilla River.

2.1.3 Geologic Overview

The Columbia-Deschutes province was created on a grand scale. Immense outpourings of lavas during the Miocene epoch created one of the largest flood basalt provinces in the world, second only to the Deccan Plateau in India. Erupting from multiple fissures in central and northeast Oregon as well as in southeast Washington and northwest Idaho, flow after flow of basalt lava filled a gradually subsiding basin and created a featureless plateau.

Even as the lavas were still being erupted, regional stresses in the earth's crust began to warp the basalt surface into a complicated pattern of folds and faults. The Umatilla Basin is a down –warp or depression in the basalt surface. Into this depression, upper Miocene to Pliocene age sediments eroded from the geologically older Blue Mountains Province were deposited (refer to Deschutes-Columbia Plateau Geology, Figure 4). These sediments consist of partly indurated cobble gravel and tuffaceous sand and silt, which now form terraces and alluvial fan deposits that lie between the basin floor and the basalt highlands along the southern margin of the basin. In the early Pleistocene, wind-blown silt called "loess" was deposited across the basalt uplands around the margins of the Umatilla Basin.

During the Ice Ages of the late Pleistocene, numerous lakes developed behind ice dams in northern Washington and western Montana. The largest of these, Glacial Lake Missoula, occupied the Clark Fork River and much of western Montana. Glacial Lake Missoula grew steadily deeper until the ice dam failed and the lake emptied catastrophically. Once the lake had drained, the ice slowly reoccupied its position across the valley and the lake developed anew. This process of filling and emptying catastrophically was repeated numerous times. The resulting floods overpowered the landscape and scoured southeastern Washington and the Columbia River Gorge. The deluge back-flooded up stream valleys tributary to the Columbia River, including the Umatilla River. As the floodwater was temporarily impounded in the Umatilla Basin, forming a short lived lake known as Lake Condon its load of sediment was deposited across the floor of the basin. The flood sediments consist of unconsolidated silt, sand, cobble-gravel and boulders.

2.1.4 Soils

Soils data has been compiled by the National Resources Conservation Service (NRCS) in a series of county wide reports. This brief summary of soil conditions is organized similarly by county from north to south along the proposed transmission alignments. Soil data tables and strip maps of soil units within a one-half mile radius of the IPC Proposed Route and IPC Alternate alignments are provided for reference in Appendix B.

The soils in Morrow County are relatively uniform consisting of well drained fine sandy silt to silty fine sand with rare gravelly silt. A few isolated rock outcrops are present locally along Willow Creek were the soils have been eroded along stream channel. These soils are derived from late Pleistocene Lake Condon deposits that temporarily formed during catastrophic floods from Glacial Lake Missoula. The soils are generally greater than 5 feet thick and have a moderate to severe erosion potential.

A rare rock outcrop is present south of the alignment just across the county line, but similar soils continue into Umatilla County. As the alignment crosses the terraces south of the Umatilla Basin and begins to climb up the basalt highlands, the soils become gradually thinner and are replaced with similar windblown fine sandy silt to silty fine sand; erosion hazard remains moderate to severe. The soils vary from about 20 to 40 inches deep and overlie cemented alluvial terrace deposits.

Beginning about 15 miles west of the Union County line, and just after crossing Birch Creek, the alignment passes out of the Umatilla Basin and enters the Blue Mountains Province. Elevation continues to increase and the predominantly loess originated silt gradually grades to residual silty clay and clayey silt that often contain gravel- to cobble-sized rock clasts weathered from the underlying parent materials. The soils vary from a few inches to a few feet thick over the underlying materials which consist of a mixture of loess, volcanic ash, and colluvium derived from the basalt bedrock.

2.2 Blue Mountains Province

2.2.1 Topography

The proposed route continues to the southeast through the Blue Mountains physiographical province. The Blue Mountains Province is located largely in northeastern Oregon and is bounded on the east by the Snake River Canyon, on the north and west by the Columbia Plateau, and on the south by the High Lava Plains and the Owyhee Plateau Provinces. The Blue Mountains province is made up of a cluster of smaller ranges of various orientations and relief; their multiple origins are evident in the topography. The western portion of the province is part of a wide uplifted plateau, while the Wallowa Mountains on the east contain a striking array of ice-sculpted mountain peaks, deep canyons, and broad valleys. The proposed transmission line route will traverse the low hills that rise above the eastern margin of the broad Baker Valley, which lies between the Elkhorn Mountains on the west and the Wallowa Mountains on the east. The NEPA Flagstaff Alternate takes an approximately parallel track west of the proposed alignment, keeping to the high ground, but closer to the valley margin (refer to Blue Mountains Topography and Drainage, Figure 5). The two alignments merge south of the Baker Valley, split again along Alder Creek, and then rejoin east of Durkee. The IPC Proposed Route continues along Burnt River to near Huntington, then turns to the southwest, crosses Willow Creek, and then turns south. The IPC Willow Creek Alternate splits off of the proposed alignment just west of the Huntington area and takes a more southerly route across Willow Creek and then merges with the IPC Proposed Route south of the Willow Creek Valley. The IPC Proposed Route Alignment continues south, crossing Bully Creek, the Malheur River, and

Highway 20, to near the southern margin of the Blue Mountains Province where the IPC Malheur S and the IPC Double Mountain Alternates break away following more westerly routes.

Topography south of the Baker Valley consists of low, steep-sided mountains and ridges with narrow intervening valleys. Most valleys are either dry or occupied by small seasonal streams. Small springs are often present at the heads of the valleys.

2.2.2 Drainage

The Blue Mountain Range consists of several extensive watersheds, draining into rivers including the Grande Ronde, Imnaha, Wallowa, and John Day. The Grande Ronde River is the principal watershed of the Blue Mountain Range. With headwaters approximately 20 miles southwest of La Grande, Oregon, the Grande Ronde River intersects the proposed alignment approximately 7 miles northwest of La Grande. The Grande Ronde River flows along the east side of the Blue Mountains, generally trending north until it passes La Grande and begins to trend northeast, meandering through the Grande Ronde Valley. Little Catherine Creek flows in a northwesterly direction, passes along the east of Union, Oregon, and joins Grande Ronde River just east of La Grande. Continuing south and east within Blue Mountain province, the alignment crosses through the semi-arid Powder Basin. The main tributaries to the Powder Basin are the Powder River and the Burnt River. The Powder River originates in the Elkhorn Mountains and trends to the north through the city of North Powder and then east to the Snake River. The Burnt River originates in the Blue Mountains (the east slope of the uplands between the Elkhorn Mountains and the Strawberry Range) from the confluence of North Fork and South Fork of Blue River, which converge at Unity Lake. The Burnt River trends east to a confluence with the Snake River near Huntington, Oregon. The Malheur River and its tributary Willow Creek drain the southeastern portion of the Blue Mountains Province; they flow eastward to the Snake River near Ontario, Oregon.

2.2.3 Geologic Overview

The IPC Proposed Route and alternate alignments run through the central portion of the Blue Mountains Province, crossing the northern portion of the Elkhorn Mountains and then continuing south through the Baker Valley, through a portion of the Burnt River canyon, then southwest over an upland area and across the Willow Creek drainage basin, and finally southward across the Malheur Valley. This area is comprised of some of the oldest rocks in the State of Oregon. Permian, Triassic, and Jurassic rocks were scraped off of a subducting oceanic plate and accreted to the Mesozoic shoreline, which at that time was positioned near the present Idaho border with Washington and Oregon. Metamorphism, intrusion, and volcanic activity cemented these exotic blocks to North America where they became the foundation of northeast Oregon.

The proposed and IPC Alternate alignments will cross the Baker, Wallowa, and Olds Ferry Terranes. Within the Baker Terrane, the proposed alignment crosses Burnt River Schist and Elkhorn Ridge Argillite. The Wallowa Terrane portion consists of igneous rocks including the Clover Creek Greenstone. The Olds Ferry Terrane consists primarily of sedimentary rocks, including those of the Weatherby Formation and Jet Creek Formation, and some igneous rocks of the Huntington Formation. The geology of the Blue Mountains Province is shown in Figure 6.

2.2.4 Soils

Beginning about 15 miles west of the Union County line, and just after crossing Birch Creek, the alignment passes out of the Umatilla Basin and enters the Blue Mountains Province of Union County. Elevation continues to increase and the predominantly loessial silts gradually grade to residual silty clays and clayey silts that often contain gravel- to cobble-sized rock clasts weathered from the underlying parent materials. The soils vary from a few inches to a few feet thick over the underlying materials which consist of a mixture of loess, volcanic ash, and colluvium derived from the basalt bedrock.

The Proposed Alignment continues climbing southeastward, and then after crossing the Union-Baker County line descends gradually in elevation and passes through the Glass Hill area west of La Grande. The IPC Proposed Route alignment and the IPC Glass Hill Alternate both traverse areas underlain by silt soils derived from a mixture of basalt colluvium and surficial deposits of loess and volcanic ash. These soils mantle ridge crests and mountain slopes, are often stony, commonly less than five feet thick over weathered basalt bedrock and they have a severe erosion hazard.

The IPC Proposed Route Alignment continues descending gradually in elevation toward the south and southeast until, finally leaving the highlands; it enters the north portion of the Baker Valley southwest of Union, Oregon. Valley soils remain predominantly colluvial from underlying basalt parent material with admixtures of loess and volcanic ash. These soils are moderately to well drained and have a moderate to severe erosion hazard. The colluvial soils grade to gravelly to cobbly alluvial silt and sand locally near stream channels and floodplains.

After crossing the Powder River and entering Baker County, the Proposed Alignment continues southeastward and up onto the low range of hills that flank the eastern side of the Baker Valley. The IPC Proposed Route Alignment continues south past North Powder, Haines and Baker City. Just north of Highway 203, the NEPA Flagstaff Alternate breaks away on an approximately parallel track west of the Proposed Alignment, and keeping to the high ground, continues southward close to the valley margin. These two alignments merge south of the Baker Valley and north of Alder Creek. In this area the underlying parent materials begin to become more varied. In addition to basalt, bedrock units now also include granitic intrusive rock, greenstone, and argillite. Stony silt colluvial soils developed on the underlying bedrock are now mixed with loess, volcanic ash, alluvial and lacustrine sediments, and older alluvial terrace and alluvial fan deposits. These soils are generally well drained silty fine sand to fine sandy silt, often contain gravel and cobbles, and they have a moderate to severe erosion hazard. Surface soils are generally less than five feet thick over underlying consolidated parent materials.

After passing Baker City, the Proposed Alignment passes along the Alder Creek Valley, keeping to the higher hills north of the creek, and then near Durkee Valley the Proposed Alignment follows along the east side of Burnt River. Soils in this section are stony to gravelly silt and gravelly clay colluvium derived from mixed alluvial and lacustrine sedimentary rocks, basalt, greenstone, argillite, schist, and metamorphosed volcanic rocks. These soils are present on hill slopes; they are well drained, have a severe erosion hazard, and are generally less than five feet thick over the underlying consolidated parent materials.

The IPC Proposed Route Alignment continues southward through the Burnt River Canyon, and although it crosses the river three times, generally keeps to steep slopes between hill tops and ridges above the valley floor. Soils vary from fine sandy silt to very gravelly or stony sandy silt. These soils are developed from colluvium derived from schist, basalt, and some minor sedimentary rock. They are well drained, 5 to 10 feet thick over underlying consolidated rock, and have a severe erosion hazard.

Just prior to the Baker-Malheur County line, the IPC Proposed Route Alignment splits; the IPC Proposed Route Alignment takes a more westerly route while the IPC Willow Creek Alternative takes a southerly route. The alternatives rejoin south of Highway 26 and northwest of Bully Creek Reservoir in Malheur County.

Soils data is limited in Malheur County. The IPC Proposed Route Alignment trends southwestward to the Willow Creek Valley, then turns southeastward. The only existing soil mapping on this alignment occurs in the Willow Creek Valley where the alluvial soils will support agricultural pursuits. Although soils on the upland areas north of Willow Creek have not been mapped, we can infer conditions based the underlying geologic units (refer to Appendix A). Between the Baker-Malheur County line and the Willow Creek Valley, the IPC Proposed Route Alignment crosses principally basalt rock units in the northern portion of the reach, and principally consolidated tuffaceous sedimentary rock the southern portion. From similar rock types and associated soils in Baker County, we can infer that from near the County line to near Canyon Creek, where the underlying bedrock is principally basalt, soils on the hill tops and ridge crests will consist principally of fine sandy silt to silty fine sand; hill slopes will likely be stony. These soils will most likely be from 5 to 10 feet deep over the underlying rock, well drained, and have a severe erosion hazard rating. From Canyon Creek to Willow Creek, where the underlying geology is principally sedimentary rock, fine sandy silt to silty fine sand can be anticipated. Soils will be thickest on lower slopes and across the intervening valleys, intermediate depth on hill tops and ridge crests, and thinnest on upper and middle slopes. These fine-grained soils will likely be well drained, except in the intervening valleys and in closed basins where excessive fines may be present. We would expect that soils are probably not more than 10 feet thick over consolidated materials, and the erosion hazard rating will likely be severe.

In the Willow Creek Valley soils on the IPC Proposed Route are dominated by alluvial silt and fine sand, erosion hazard is slight to moderate, and the soils are deep, i.e., exceeding at least 10 feet. These conditions most likely exist on the IPC Willow Creek Alternate alignment as well.

The Proposed Route and the IPC Willow Creek Alternate alignments merge again south of Highway 26; the IPC Proposed Route Alignment continues southward, and then between the Malheur River and Highway 20 the IPC Double Mountain Alternate, and the IPC Malheur S Alternate split off toward the west. No soils mapping is available in this area. These alignments cross a variety of geologic units including unconsolidated sediments, consolidated sedimentary rocks, and igneous rock. We infer that the soils are largely fine sandy silt, locally stony or gravelly, and that the soils are generally well drained with a moderate to severe erosion hazard rating.

Approximately 7 miles southeast of the Proposed and IPC Double Mountain Alternate, the alignments cross into the Owyhee Geomorphic Province.

2.3 Owyhee Plateau

2.3.1 Topography

The Owyhee Plateau straddles the Oregon-Idaho border at the southeastern portion of the project area and extends southward into north-central Nevada. The Owyhee Plateau is a sub-set of the much larger Basin and Range Province. The Owyhee differs from the rest of the Basin and Range in that it is a flat, deeply dissected plateau with little interior drainage, and its fault-block topography, which is a characteristic of the Basin and Range, is less pronounced. The Owyhee plateau rises from about 2,100 feet above sea level where the Malheur River enters the Snake River to about 6,500 feet at the top of Mahogany Mountain. The Owyhee, Malheur, Snake and many smaller creeks and streams have cut deeply into the plateau surface. The topography and drainage of the Owyhee Plateau is shown in Figure 7.

2.3.2 Drainage

The drainage basin of the Owyhee River encompasses the Southern portion of the route near Lake Owyhee. Due to steep gradients, the Owyhee River and its tributaries provide well-defined drainage patterns and deeply incised canyons, with intermittent small streams flowing in from the surrounding hills. The Owyhee River is a tributary to the Snake River.

2.3.3 Geologic Overview

The IPC Proposed Alignment and the IPC Double Mountain Alternate continue south and east through the Owyhee Uplands physiographic province, crossing into Idaho about 30 miles south of Ontario, Oregon. The Owyhee Plateau began with volcanic eruptions of ash and basalt lava beginning in the middle Miocene (about 15 million years ago). Much of the ash was eroded and re-deposited in stream valleys. The earlier ash and lava was covered over by additional periodic eruptions of lava, and then a period of erosion followed as regional uplift began to raise the area into low mountains. Basaltic eruptions continued, and from late Miocene and into the Pliocene epoch fault blocks developed, creating basins where ash rich sediments were deposited by streams. Alternating basalt flows, ash deposits, and stream sediments accumulated up to 2,000 feet thick (refer to Owyhee Plateau Geology, Figure 8). By the early Pliocene (about 4 to 3 million years ago), as the climate became dryer, the Owyhee River had established its present channel. As the uplift of the region continued, the streams cut even deeper into their canyons.

2.3.4 Soils

As stated earlier, soils data is limited in Malheur County. Local soils mapping is available near the IPC Proposed Route Alignment adjacent to the Owyhee River. However, the alignment crosses the river on ridges of basalt rock just upstream from the irrigated alluvial soils that have been mapped. At this river crossing we infer that the soils are thin, well drained, stony silts with a severe erosion hazard developed from colluvial materials overlying basalt lava rock.

About eight miles east of the Owyhee River crossing, the IPC Proposed Route Alignment crosses the Oregon-Idaho border. Good soils mapping is available for Owyhee County Idaho. From the state boundary soils are principally silt with some fine sand from mixed alluvial and lacustrine deposits, volcanic ash, residual and colluvial materials weathered from welded tuff, basalt, and rhyolitic lavas. These soils occur on alluvial fans, alluvial terraces valley floors, foothills, and hill slopes. They tend to be well drained with a moderate to severe erosion hazard. These soils also tend to be relatively deep, varying from about 4 to more than 15 feet thick over underlying consolidated materials.

3 PROPOSED SITE-SPECIFIC GEOTECHNICAL WORK

The following section describes proposed geotechnical exploration methods based on expected geologic conditions, and provides a generalized exploration program along the proposed alignment segments.

3.1 Geotechnical Exploration Plan

S&W and Shaw reviewed aerial photographs, topographic maps, conducted preliminary alignment reconnaissance, and studied existing geologic maps and soils maps to select boring locations along the proposed transmission line alignments. The locations of these borings, except those for the new Willow Creek Alignment, are shown in the summary table provided in Appendix C. These locations are also shown on the geologic map sheets in Appendix A. In general, a minimum of one boring will be drilled approximately every three miles, for significant proposed angle points and dead-end structures, and where additional borings are necessary to verify lithologic changes and/or geologic hazards.

The preliminary summary table provided in Appendix C presents proposed boring locations as well as information regarding access, disturbance, access distance, type of rig, type of drilling method, and anticipated subsurface conditions. All of this information will need to be verified during a field reconnaissance performed prior to drilling. Proposed borehole locations along the preferred route are identified starting at the north end of the proposed route, and continue south to the end of the proposed route, and then identified using the section identifier (i.e. BH-001-a refers to the first borehole, located within the "a" section of the preferred alignment). Alternate routes were similarly identified, starting with number BH-501-LHRN and continuing south. Proposed borehole locations are shown on the Geologic Maps, Sheets 2 through 143, in Appendix A.

The depth of each boring will generally be no more than 50 feet below the designed finish grade of the transmission line centerline. Borings may be terminated at shallower depths if the blow counts, i.e., the number of blows required to advance a split-spoon sampler 12-inches, in soil materials exceed 50 blows per foot for each consecutive sample taken in a minimum 15 foot interval. Borings may also be terminated at less than 50 feet when the boring has been advanced 10 feet into unweathered, competent rock as determined by a field geologist from examination of the recovered rock core. Depths into hard soil or competent rock will vary depending on the information needed for design.

3.1.1 Geotechnical Drilling Methods

The purpose of the geotechnical drilling will be to evaluate the foundation conditions for the proposed transmission towers and substations. Geotechnical drilling will be accomplished using a variety of drilling methods, which will vary depending on the type of soil and rock expected within the anticipated completion depth of the boring.

3.1.1.1 Hollow Stem Auger Drilling

Hollow Stem Auger (HSA) drilling consists of rotating a hollow drill stem with a continuous helical fin on the outside into the subsurface. The lead auger has a toothed bit at the bottom with a hole in the middle. During drilling, a center rod with a plug at the bottom is left inside the auger drill string to keep the center free of cuttings. The cuttings are brought to the surface on the outside of the augers by the rotation of the helical fin. For sampling, this internal rod is withdrawn, the plug is removed, and a sampler is attached.

HSA drilling does not require water or drilling mud, making it ideal for work in remote areas where available water is scarce. It is also easier to determine the depth to groundwater, if it is encountered, using HSA versus other drilling methods. Another advantage is that the hole is essentially cased during drilling, so loose or caving materials don't inhibit drilling progress or sample quality. Augers can be used as casing in combination with mud rotary drilling or rock coring to temporarily support a borehole across loose materials. The principal disadvantage of HSA drilling is the potential for soil heave into the augers and/or unreliable blow counts when sampling in soft or loose soils below the water table; under such conditions, mud rotary drilling is preferable. HSA generally cannot penetrate large cobbles or hard rock.

3.1.1.2 Mud Rotary Drilling

Mud-rotary borings are typically advanced using a smooth-walled hollow drill stem and a tri-cone bit, through which a bentonite drilling mud is pumped. The drill mud serves to cool the bit, keep the borehole open, and flush the cuttings to the surface. Returning drill mud is typically passed through a screen and into a tub over the borehole. The screen collects the cuttings and the tub collects the mud for recirculation back into the hole. If a borehole cannot be kept open using mud alone, casing such as hollow stem auger may be set to facilitate advancement of the hole. Mud rotary drilling requires a water source or a supply vehicle which may have difficulty accessing some boring locations. Also, due to the presence of drilling fluid, groundwater levels may be difficult to discern during drilling.

3.1.1.3 HQ Coring

HQ Coring is typically used to advance through and sample rock. This can be done using a conventional coring system, where an HQ core barrel with a diamond impregnated bit is attached to a string of smaller drilling rod, or using a wireline system, where an HQ casing is advanced behind a diamond impregnated bit and an inner barrel is inserted and retracted between runs using a winch and a wireline with an overshot. The inner barrel latches into the lead HQ casing, and is released when the wireline is applied. Clean water or water mixed with polymer is used to lubricate the casing, cool the bit, and flush fine cuttings from the hole.

3.1.2 Types of Drill Rigs

The drilling techniques described above can be performed using rigs mounted on road-legal trucks, tracked vehicles, or mobile platforms. Truck-mounted drilling rigs will be used at all locations not inhibited by access restrictions. The other drilling rigs are proposed for areas where the truck mounted drilling rigs cannot be used due to steep terrain and/or difficult access. Other vehicles and equipment may also be mobilized to each boring location and may include: a water truck or support vehicle, an air compressor, geologist’s pickup truck or utility vehicle, and possibly another support pickup truck. In some very limited areas a dozer or grading equipment may be required to assist with access to the boring location.

3.1.2.1 Truck-Mounted Drilling Rigs

Truck-mounted drilling rigs are proposed for the majority of the borings. These rigs are road-legal, heavy trucks that require access to be relatively flat (5 percent grade or less), and will travel on existing roadways and two track trails as close as possible to boring locations then overland on firm ground. The truck rigs are typically 30 feet long, 8.5 feet wide, 12 feet high with mast down, and 34 feet high with the mast up, and have a gross vehicle weight of approximately 30,000 lbs with 30 to 50 psi ground pressure.

3.1.2.2 Track-Mounted Drilling Rigs

Track-mounted drilling rigs are another alternative drill rig type for borings where there are softer ground conditions and up to 20-percent grade. These rigs are approximately 8,000 lbs with rubber tracks, resulting in approximately 10 psi ground pressure, the lowest available ground disturbance mobile rig for softer ground. Tracked rigs are typically 22 ft long, 6 feet wide, 22 feet high with mast up, and travel on low-boy trailers using existing roadways and two-track trails to get as close as possible to the boring location, then overland to boring location.

3.1.2.3 Platform Drilling Rigs

Platform drilling rigs will be utilized to access areas where the above mobile drilling rigs cannot access. These rigs will be transported to the boring location by helicopter in eight to ten pieces; and assembled on site. Platform rigs are approximately 6,500 lbs assembled, up to 32 ft high with mast up with base dimensions of 8.5 feet by 6 feet and 5-foot-long stabilizer legs extending out from all sides of the base. The use of platform rigs will require a staging area near existing roadways to load equipment to the helicopter.

3.1.3 Sampling Methods

During drilling operations, samples will generally be taken at 2.5 to 5 foot depth intervals. Most soil sampling will be performed using split spoon samplers. Thin-walled tubes may be used to sample fine-grained or cohesive soils. HQ core will generally be used to advance through and sample rock. These sampling methods are described further in the following subsections.

3.1.3.1 Split-Spoon Sampling

Disturbed samples in borings are typically collected using a standard 2-inch outside diameter (O.D.) split spoon sampler in conjunction with Standard Penetration Testing. In a Standard Penetration Test (SPT), ASTM D1586, the sampler is driven 18 inches into the soil using a 140-pound hammer dropped 30 inches. The number of blows required to drive the sampler the last 12 inches is defined as the standard penetration resistance, or N-value. The SPT N-value provides a measure of in-situ relative density of granular soils (sand and gravel), and the consistency of fine-grained or cohesive soils (silt and clay). All disturbed samples are visually described in the field, sealed to retain moisture, and returned to the laboratory for additional examination and testing. In some cases, it may be necessary to use a larger sampler, such as a 3.25-inch O.D. Dames & Moore sampler, to collect a representative quantity of soil that contains coarse gravels.

3.1.3.2 Thin-walled Tubes

Relatively undisturbed samples of fine-grained and/or cohesive soils encountered in the borings may be obtained by pushing a 3-inch outside diameter thin-walled tube sampler (also known as Shelby tube sampler, ASTM D1587) a distance of approximately 2 feet into the bottom of the borehole using a hydraulic ram. After a thin-walled sample is recovered from the boring, it is sealed at both ends to prevent moisture loss and carefully transported back to the laboratory. Care is taken to keep the sample upright and to avoid dropping, jarring, or rough handling.

3.1.3.3 Coring

HQ coring is typically used to advance through and sample rock. Core runs are typically 5 feet long. Core samples are photographed in a split tube immediately after it is extracted from the core barrel. The core is evaluated in the field to determine the percentage of recover as well as the Rock Quality Designation (RQD), defined as the sum of the length of core pieces 4 inches and above divided by the total length of the drilled core run. The degree of weathering, soundness, joints and structural discontinuities, and other rock characteristics are documented on the boring logs. Rock core samples which are sensitive to moisture loss may be individually wrapped in the field with cellophane. All core is stored in a wax or plastic corrugated box labeled with the boring number and depth intervals.

3.1.4 Boring Logs

A geologist will be present during all drilling activities. The geologist will determine the location of the borehole, collect samples, and maintain a log of the materials encountered. The log will include sample locations and types, sample descriptions, and notes regarding drilling methods, drill action, fluid loss, problems encountered during drilling, and the depth to groundwater (if observed). The boring logs will present interpretation of soil and rock materials encountered at each boring and the approximate depths where the material changes characteristics.

3.1.5 Geophysical Surveys

In addition to geotechnical drilling, non-invasive geophysical surveys may be conducted at substation expansion areas and remote areas that cannot be accessed by the previously described drilling equipment. Geophysical survey techniques may include resistivity testing for grounding design or seismic refraction for subsurface density estimation.

4 SEISMIC HAZARDS

<u>OAR 345-021-0010(1)(h)(F) – Evaluation of Seismic Hazards and Earthquake Effects</u>
An assessment of seismic hazards. For the purposes of this assessment, the maximum probable earthquake (MPE) is the maximum earthquake that could occur under the known tectonic framework with a 10 percent probability of being exceeded during a 50 year design

life. If seismic sources are not mapped sufficiently to identify the ground motions above, the applicant shall provide a probabilistic seismic hazard analysis to identify the peak ground accelerations expected at the site for a 500 year return period and a 5000 year return period. In the assessment, the applicant shall include: (i)Identification of the Maximum Considered Earthquake(MConE) Ground Motion as shown for the site under the 2009 International Building Code; (ii) Identification and characterization of all earthquake sources capable of generating median peak ground accelerations greater than 0.05 g on rock at the site. For each earthquake source, the applicant shall assess the magnitude and minimum epicenter distance of the maximum credible earthquake (MCE); (iii) A description of any recorded earthquakes within 50 miles of the site and of recorded earthquakes greater than 50miles from the site that caused ground shaking at the site more intense than the Modified Mercalli III intensity. The applicant shall include the date of occurrence and a description of the earthquake that includes its magnitude and highest intensity and its epicenter location or region of highest intensity; (iv) Assessment of the median ground response spectrum from the MCE and the MPE and identification of the spectral accelerations greater than the design spectrum provided in the 2010 Oregon Structural Specialty Code. The applicant shall include a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic or subsurface conditions that could result in expected ground motions greater than those characteristic of the MConE Ground Motion; (v) An assessment of seismic hazards expected to result from reasonably probable seismic events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence.

4.1 Earthquake Ground Motions

The MPE is the largest earthquake predicted under the known tectonic framework within a 500 year recurrence period (RP) while the MCE is the largest earthquake that an active or potentially active fault is capable of generating. For the purposes of this preliminary evaluation the seismic sources are not mapped sufficiently to perform deterministic evaluations of ground motions along a several hundred mile long power line alignment. The location, length and age of last offset for credible fault ruptures are not sufficiently documented in to determine magnitude and minimum epicentral distance. Therefore based on the OAR criteria above, probabilistic peak ground acceleration (PGA) for a 500- and 5,000-year return period have been evaluated. The probabilistic evaluation method considers multiple specific sources and regional seismicity to predict the probability of an earthquake of a given magnitude occurring anywhere along the alignment within a given return period, which in the case of the OAR is a 500, 2,500, or 5,000 year return period.

For the B2H project, seismic hazards will be evaluated according to the most recent version of the International Building Code (IBC). Peak ground acceleration (PGA), short- and long-period (0.2 and 1.0 second) spectral accelerations will be provided. The OAR specifies use of IBC 2009 for design, however we assume the most recent version of IBC will be used at that time, most likely IBC 2012. In accordance with IBC 2012, ground motions are provided for preliminary design only, project specific design will determine site specific ground motions. Probabilistic ground motions in this evaluation were obtained from the USGS Seismic Hazards Maps (USGS, 2008).

As required in the OAR above, the PGA that corresponds to a 500-year mean return period is shown in Figure D-1 in Appendix D which provides mapped contours of the 500-year PGA along the entire alignment.

Digital data required to prepare 5,000-year return period PGA contour maps along the entire alignment is not available from the USGS. Therefore, the 5,000-year return period PGA has been estimated at representative points along the alignment as shown in Table 1.

The 2012 International Building Code (IBC) provides MConE ground motions that correspond to a 2 percent probability of exceedance in 50 years, or a 2,500 return period. The PGA, short- and long-period (0.2 and 1.0 second) spectral acceleration is shown on Figures D-2 through D-4 in Appendix D.

The ground motions shown on Figures D-1 through D-4 and on Table 1 correspond to a Site Class B/C (soft rock) soil profile. Section F(iv) of the OAR requires "assessment of the median ground response spectrum" and "a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic of subsurface conditions that could result in expected ground motions greater than those characteristic of the MConE." To develop ground motions that correspond to other Site Class types, Site Coefficients that consider site soil type and level of ground shaking are required. The Site Class definitions and Site Coefficients can be obtained from ASCE 7-10. Subsurface explorations along the alignment have not been performed. Therefore, site specific design criteria for structures will be developed upon completion of the subsurface exploration program.

4.2 Seismic Sources

Evaluation of source specific probabilistic ground motions along the 300 mile alignment has been provided herein using USGS 2008 PGA and spectral accelerations. Site class determinations and specific hazard evaluations for each tower will be determined in future design studies. The magnitude and minimum epicentral distance of the MCE is not evaluated as part of this preliminary study. Specific faults in close proximity to the alignment will be further evaluated during final design.

Potential seismic hazards along the proposed and alternate alignments can result from any of three seismic sources: interplate, intraplate, and crustal events. Interplate sources are those which occur between two plate boundaries. The major interplate source for the alignment is the subduction zone megathrust, which represents the boundary of the Juan De Fuca Plate and the overriding North American Plate along the Oregon coast, generating uplift forming the Cascade Range and the Cascade Volcanic Arc. Although extremely large earthquakes are anticipated, the substantial distance from the alignment would attenuate ground shaking causing this source not to represent the most significant earthquake hazard.

Intraplate sources are those which occur in the interior of a tectonic plate. An example of an intraplate earthquake in the Pacific Northwest was the 2001 Nisqually earthquake. Although relatively common in Washington State, significant intraplate earthquakes have not been experienced in Oregon. Quaternary Faults

We have evaluated shallow crustal earthquakes that might occur within approximately 10 miles of the earth's surface, along relatively shallow crustal faults. Because of their proximity, crustal faults represent the most significant seismic hazard to the proposed transmission alignment. In accordance with section F(ii) known significant faults near the proposed alignments associated with crustal earthquakes are outlined in the following paragraphs.

We show known Quaternary faults within a 50-mile-radius of the proposed project alignments on Figure D-5, Appendix D. For the purpose of this report, we have identified mapped crustal faults within 5-miles of the alignment based on USGS 2008 mapping. The original mapped faults and folds were digitized and are shown on the geologic maps in the attached Appendix A. Slip rates for these faults have all been estimated at less than 0.008 in/year (0.2 mm/year) in the USGS fault database. These values reflect a low rate based on lack of identified measureable offsets. Descriptions of these faults are provided in the following sections.

Quaternary faults mapped in Oregon and Idaho have been subdivided by approximate age and include the categories of:

- Quaternary – less than 2,000,000 years old
- Mid- to Late-Quaternary – less than 750,000 years old
- Late Quaternary – less than 130,000 years old
- Latest Quaternary – less than 15,000 years old
- Historic – less than 150 years old

The faults are shown on the attached geologic maps (Appendix A) as dashed lines for concealed or inferred faults, solid lines for confirmed faults, or heavy lines for significant faults. Evidence of latest Quaternary faults should be studied on aerial photographs and checked in the field. Faults outlined in the following paragraphs are the "significant faults"

(M>6.0) mapped within a 5-mile distance of the proposed alignment. In the following sections, the significant faults have a numerical identifier, e.g., 845, that corresponds with the fault ID provided by the USGS fault database (USGS, 2010), as shown in Appendix D, Figure D-5. Additionally, these significant faults have been summarized in Appendix D, Table C-1.

4.2.1 Hite Fault System (845)

The Hite Fault System is a north-east trending system that runs parallel and to the west of the Blue Mountains. Total length of the Hite Fault System is 87 miles with an average dip direction of N20°E. The Hite Fault System is divided into four sections; however, only two of the sections are significant to the proposed transmission alignment (within 5 miles of proposed centerline): the Thorn Hollow section (845c) and the Agency section (845d).

4.2.1.1 The Thorne Hollow Section

The Thorne Hollow section consists of 27 miles of fault forming a complex zone of linear streams, saddles, and notches in ridges within the Columbia River Basalt Group, as well as shallow linear depressions south of the Umatilla River. Movement is suggested to have occurred in the Quaternary period within the southern portion of the section, and middle to late Quaternary movement within the northern portion of the section. Faults located within the Thorn Hollow section has been described as normal, left-lateral, and right-lateral strike-slip, with an average strike direction of N10°E and a dip of 80° - 90° NW. Total displacements in the Miocene CRB's may be on the order of 175-260 feet long.

4.2.1.2 The Agency Section

The Agency section consists of 17 miles of faults creating offsets within the Columbia River Basalt Group. Movement is suggested to have occurred in the Quaternary period in CRB rocks. Sense of slip on faults located within the Agency section has been described as normal, left-lateral, and right-lateral strike-slip, with an average strike direction of N6°E.

4.2.2 West Grande Ronde Valley Fault Zone (802)

The West Grande Ronde Valley Fault Zone is a north-west trending system forming the western margin which confines the Grande Ronde Valley. Total length of the fault zone is 30 miles. Faults located within the fault zone have been described as normal or high angle, with an average strike of N19°W. This fault zone is divided into three sections, the Mt. Emily section (802a), the La Grande section (802b), and the Craig Mountain section (802c). Each of the sections are part of a large graben system formed in Miocene and Pliocene volcanic rocks overlying thick Neogene and Quaternary alluvial sediments, forming steep echelon range fronts containing tonal contrasts, linear depressions, springs and scarps. Fault systems within this zone offset Neogene rocks of the CRB and Powder River Volcanic field and Quaternary surficial deposits.

4.2.2.1 The Mt. Emily Section

The Mt. Emily section consists of 18 miles of fault, forming steep range front from Thimbleberry Mountain to the mouth of the Grande Ronde River Canyon. Recent detailed mapping suggests latest Quaternary displacement on the southern half of the section. Faults located within the Mt. Emily section have an average strike direction of N2°W and an estimated dip of 60° - 70°. Vertical offsets of the Miocene CRB is estimated to be around 3280 feet.

4.2.2.2 The La Grande Section

The La Grande section consists of 9 miles of fault, forming steep range front from the mouth of the Grande Ronde River Canyon (north) to the mouth of Ladd Canyon (south). La Grande consists of two primary fault strands, one adjacent to La Grande and one parallel to Foothill Road. The La Grande strand is identified as small fault scarps on late Quaternary alluvial deposits in the mouths of canyons and larger scarps in older landslide debris near the southern end of the strand, forming a steep linear range front. The Foothill strand is identified by topographic benches, linear benches, springs and vegetation along the range. Offsets of alluvial deposits and landslide displacements near the southern end of the La Grande strand are estimated to be late Quaternary. Latest Quaternary displacement has been inferred by the presence of scarps on the La Grande section. Faults located within the La Grande section have an average strike of N30°W and an estimated dip of 60° - 70°E. Displacement along the Miocene CRB and Powder River volcanic field is estimated to be around 1400 – 2300 feet.

4.2.2.3 The Craig Mountain Section

The Craig Mountain section consists of 6 miles of fault, forming steep range front along the East flank of Craig Mountain. Craig Mountain is identified by linear fronts and numerous springs, with hot springs located at the northern end of the section. Latest Quaternary displacement has not been identified at this time; however, multiple landslide complexes located along the mountain front may be covering evidence of young faulting. Faults in the Craig Mountain section have an average strike of N49°W and an estimated dip of 60° - 70°E. Vertical offsets of the Miocene CRB is estimated to be around 2400 feet southeast of Hot Lake hot springs.

4.2.3 South Grande Ronde Valley Faults (709)

The South Grande Ronde Valley Fault Zone is a north-west trending system forming north-west fault blocks on the Miocene volcanic rocks. Total length of the fault zone is 14 miles. Faults located within the fault zone have been described as normal or high angle, with an average strike of N39°W. Faults within this system offset Miocene volcanic rocks with escarpments up to 650 feet high, with possible Quaternary alluvial deposits against bedrock. The most recent movement is suggested to be middle and late Quaternary. Total displacements of 295 – 1510 feet have been described in the High Valley, Catherine Creek, and Pyle Canyon faults.

4.2.4 Unnamed East Baker Valley Faults (712)

The Unnamed East Baker Valley Fault Zone is a north-west trending system forming the eastern margin of Baker Valley. Total length of the fault zone is 17 miles. Faults located within the fault zone have been described as normal, with an average strike of N40°W. This fault zone consists of several faults which juxtapose Miocene volcanic rocks, Mesozoic and Paleozoic igneous and metamorphic rocks against Quaternary alluvial deposits, forming escarpments less than 325 feet high. Late Quaternary displacement has been suggested on a small section of one of the faults, while Quaternary displacement has been described along the length of the faults.

4.2.5 West Baker Valley Fault (804)

The West Baker Valley Fault is a north-west trending, down-to-the-northeast system forming a large, steep range along the western margin of Baker Valley. The fault is identified by linear range fronts, faceted spurs, benches, springs, tonal and vegetation lineaments, scarps observed in late Quaternary alluvial-fan deposits, and the exposed Mesozoic and Paleozoic igneous and metamorphic rocks of the Elkhorn Ridge. Total length of the fault zone is 20 miles. Faults located within the fault zone have been described as normal with an average strike of N54°W and a dip of 40° - 70° NE. The fault is buried by fan deposits, making it difficult to determine the age of surface faults. However, these middle to late Holocene deposits, along with large scarps in Quaternary deposits, indicate late Quaternary surface-faulting and recurrent displacement.

4.2.6 Juniper Mountain Fault (805)

The Juniper Mountain Fault is an east-west trending, down-to-the-north fault along the northern flank of Juniper Mountain. The fault is identified by prominent fault scarps across alluvial fans, short discontinuous scarps, and tonal lineaments. Total length of the fault zone is 10 miles. Faults located within the fault zone have been described as normal with an average strike of N81°W and a dip of 60° - 70° NE. Short scarps observed in Pleistocene to possibly Holocene deposits along with large scarps in older deposits indicate recurrent late Quaternary displacement.

4.2.7 Cottonwood Mountain Fault (806)

The Cottonwood Mountain Fault is a north-west trending system located along the eastern margin of Cottonwood Mountain. The fault is identified by prominent fault scarps in the alluvial fans east of Cottonwood Mountain and offsets in the Miocene and Pliocene ash-flow tuffs and tuffaceous lacustrine deposits. Scarps are middle to late Quaternary. Larger scarps in older Quaternary alluvial fan deposits indicate recurrent Quaternary activity, at a recurrence rate of about 3,750 – 25,000 years. Total length of the Cottonwood Mountain Fault is 26 miles. Faults located within the fault zone have been described as normal with an average strike of N33°W and an estimated dip of 40° - 70° NE.

4.2.8 Faults near Owyhee Dam (808)

The faults near Owyhee Dam are generally north-trending system faults forming narrow basins and ranges between the Blue Mountains, the Basin and Range, and the Snake River. The fault is identified by vegetation lineaments, scarps, and springs in Miocene sedimentary and volcanic rocks. Fault activity has been mapped as active in the Quaternary, with some debate over evidence of mid to late Quaternary activity. Total length of these faults is 23 miles. Faults located within the fault zone have been described as normal with an average strike of N13°W and an estimated dip of 60° - 70° E, W.

4.2.9 Owyhee Mountain Faults (636)

The Owyhee Mountain Faults are northwest-trending faults forming a border between the Owyhee Mountains and the Snake River Plain. The faults offset volcanic rocks of late Tertiary age, with the possibility of Quaternary activity. The majority of surficial faults are of Quaternary age, with the faults of the Halfway Gulch and Water Tank faults showing evidence of latest Quaternary activity. Total length of these faults is 128 miles. Faults located within the fault zone have been described as normal with an average strike of N50°W and an estimated dip of 65° - 70° NE.

4.3 Historical Earthquakes

In accordance with section F(iii) Shannon & Wilson reviewed historical earthquake data for recorded earthquakes from the USGS Earthquake Search Data Base (USGS, 2009b, 2011), the National Geophysical Data Center (NGDC, 1985), and the Pacific Northwest Seismic Network (PNSN, 2008). Recorded earthquakes, having magnitudes of 2 or greater, within a 50-mile radius of the proposed alignments are shown in Appendix D, Figure D-6.

The NGDC reports 169 intensity records from earthquakes known to have caused Modified Mercalli Intensity (MMI) III or greater within 50 miles of the alignment. Intensity records were obtained from the NGDC. MMI intensities within the 50-mile corridor ranged from III to VII. Abbreviated descriptions of the MMI values reported for the site are as follows (USGS, 2009):

- III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

- IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
- V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
- VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
- VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

4.4 Seismic Hazards from Probable Seismic Events

In section F(v) seismic hazards from a probable seismic event include ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence. Ground shaking will be evaluated during final design once subsurface explorations are performed and soil site classes can be determined. Ground failure including landslide, lateral spreading, liquefaction, and surface rupture or settlement will be evaluated using site specific bedrock ground accelerations and subsurface conditions defined through planned geotechnical investiagetions. Areas where mapped faults cross the alignment will be evaluated for fault rupture during final design and may result in a slight shifts of a tower location. Tsunami or seiche hazards are not an issue along any of the proposed alignment alternatives.

5 NON SEISMIC HAZARDS

OAR 345-021-0010(h)(G): "An assessment of soil-related hazards such as landslides, flooding and erosion which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility."

Eight categories of potential geologic hazards were identified by this desktop study:

- Landslides
- Rockfall, Talus and Debris Flow
- Soil Creep
- Erosion
- Alluvial Fan
- Groundwater
- Soil Resistivity
- Corrosion Potential

Descriptions of the potential hazard and the proposed hazard evaluation methods are discussed below.   Future geologic reconnaissance and geotechnical investigations are planned to address these hazards on a site specific basis.

5.1 Landslides

Landslides are mass movements with a distinct zone of weakness separating the slide material from the more stable underlying material, either by translational movement of the landslide mass along a roughly planar surface or rotational movement in which the zone of weakness is curved concavely upward. Landslides are typically identified by the presence of scarps at the top, steep areas at the toe, hummocky topography, and chaotic bedding attitudes.

A landslide hazard assessment was conducted to support the development of the Application of Site Certificate. The landslide assessment was completed by:

- Review of the landslides within in a 1-mile radius of the alignment that were identified in the 2008 Statewide Landslide Information Database for Oregon (SLIDO-1) compiled by Oregon Department of Geology and Mineral Industries (DOGAMI).
- Compiling and geo-referencing in GIS all available existing geologic maps along the alignment to confirm the most accurate location of each mapped landslide along the route, and to check that each mapped landslide was included in SLIDO-1 (2008) and the 2011 SLIDO release 2 (SLIDO-2) (Burns, et. al, 2011).
- Site reconnaissance of landslide locations conducted on October 26-28 and November 15-18, 2011. The second site visit was ended on November 18, 2011, due to access limitations resulting from snowfall and winter conditions.
- Aerial Photography review of 1:24,000 scale aerial photographs provided by 3Di, and the ESRI Microsoft Virtual Earth layer in GIS, and review of 1:24,000 USGS topographic quadrangles.
- Review of the Digital Terrain Model (DTM) data provided by 3Di along a 1-mile-wide alignment corridor.
- Review of DOGAMI Lidar Data Viewer (Lidar data was only available for portions of the Kamelse, Hilgard, and Meacham Lake quadrangles).

Appendix E provides summary information and site maps of each landslide that was identified along the IPC Proposed Route alignment and certain landslides within the 1-mile-wide alignment corridor that could potential effect the stability of tower locations. Also included are descriptions of additional mapped landslides and potential landslides not included SLIDO-1 or SLIDO-2 that were discovered during the course of this assessment. Additionally, mapped and potential landslide locations are also shown as hatched areas on the attached geologic maps in Appendix A.

Where landslides lie downslope of the proposed transmission line routes, the field investigation will include field reconnaissance by the senior geotechnical engineer and/or engineering geologist. Where landslides are observed, Shannon & Wilson’s geotechnical team will evaluate the mechanics of why the landslide occurred, and how stable these areas are expected to be in the future. For example, some landslide areas may have filled in a ravine, rendering further movement unlikely because the mass could not reasonably force upslope ground movement on the opposite side of the ravine. On the other hand, some landslide areas may be the result of recent sliding along a weak layer of soil or rock. Undercutting by erosion may cause additional mass sliding in the future and, therefore, may indicate against siting towers in these areas. Seismic triggering of slope failures may pose additional hazard, particularly for granular deposits in areas of historic slope failures. If tower sites must be located near or within currently mapped landslides, additional investigation/exploration will be required, and provisions made to avoid aggravating slide hazards in the geotechnical report.

5.2 Debris Flow and Talus

A debris flow is a form of mass movement that can contain a combination of loose soil and rock. Debris flows are typically caused by intense surface-water flow eroding the surface and mobilizing loose soil or rock on steep slopes. Debris-flow source areas are often identified by the presence of debris fans at the mouths of gullies. This includes gravity slide breccias (huge landslides of mixed lithologies), volcanic and sedimentary rock masses that have slid down slope, chiefly on softer underlying rocks and other mass movement deposits, including talus, at the base of steep slopes.

Talus is a form of debris flow consisting of broken, angular rock fragments accumulated at the base of crags, mountain cliffs, or valley shoulders. The SLIDO GIS format was used to overly areas where talus occurs along the alignment. These areas are shown as brown hatch patterns in the Geologic Maps, Appendix A.

Where these areas extend below the proposed transmission line routes, the field investigation will include field reconnaissance by the senior geotechnical engineer and/or engineering geologist. Where talus or other debris flows are observed, Shannon & Wilson’s geotechnical team will evaluate the mechanics of why the debris flow occurred, and how stable these areas are expected to be in the future. Intense surface-water flow, such that caused by heavy precipitation or snow melt, may cause additional debris flow in the future and, therefore, may indicate against siting towers in these areas. If tower sites must be located near or within currently mapped talus, additional investigation/exploration will be required, and provisions to minimize exacerbation of the debris flow will be included in the geotechnical report.

5.3 Soil Creep

Soil creep is a slow, down slope movement of soil under the influence of gravity. Movement is caused by increase in shear stress that is too small to produce shear failure. Typical causes of soil creep are seasonal fluctuations in water levels and temperature. As a slope that is experiencing creep increases, the shear stresses increase and could eventually cause slope failure. Soil creep can be identified by curved tree trunks, bent fences, tilted poles, small soil ripples or ridges, and the presence of colluvium.

5.4 Erosion Potential

Erosion of surface soils is influenced by factors such as rainfall, soil type, slopes and land use. The erosion factor (K) represents susceptibility of soils to erosion and the amount and rate of runoff. It is primarily a function of soil texture, organic matter, structure and permeability. The K factor is one of the six factors used to compute sheet and rill erosion from rainfall and the associated runoff for a landscape profile.

K values along the alignment were determined by reviewing surface soil data collected from the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). The National Soil Information System (NASIS) GIS-based information system provided soil maps for the proposed alignments and were used to determine the near surface soils which may be encountered in the top 60 to 80 inches of the existing ground surface, and if shallow rock can be expected within this depth. Major units of surficial soils have been grouped into map units, which are a combination of General Soil Units (GSU's) identified within the individual counties. These map units are based on information provided in the Soil Survey of each individual county.

Surface soil data was collected from the Erosion factors along the project alignment range from 0.12 to 0.55. Soils with K factors in the 0.45 – 0.65 range are expected to have high erosion potential. Soils that may be encountered along the proposed alignment that are anticipated to have high erosion potential are outlined in the following table. Values were compiled from information provided in the SSURGO database. Erosion potential is shown as a red overlay in the Soil Maps, Appendix B.

5.5 Alluvial Fan

Alluvial fans are the accumulation of sediment that fans out from the downstream end of a natural drainage basin such as a canyon depression between mountain ridges. Alluvial fans may be considered geologic hazards if they continue to have active eroded soil and rock slurry, displaced vegetation, and water flow (collectively referred to herein as debris flow) across the alluvial fan after a rain or snowmelt event. The SLIDO GIS format was used to overly areas where talus occurs along the alignment. These areas are shown as hatch patterns in Appendix A.

5.6 Groundwater

Groundwater can have dramatic implications on design, construction, and long-term performance. Groundwater must be considered in areas with development on steep terrain where slope stability may be a hazard or is loose alluvial deposits where liquefaction may occur. The study of groundwater is essential for determining the best construction means and methods. In all of these situations, groundwater flow and fluid pressure can create serious geotechnical problems.

During drilling, the depth to groundwater and occurrence of perched groundwater will be documented. While the boring is being completed, the Shannon & Wilson geologist will attempt to estimate groundwater levels.

5.7 Expansive Soils

Swelling clays can do extensive damage to lightly loaded structures such as transmission line towers. Expansive soils owe their characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely, as they dry they shrink, leaving large voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with smectite clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Over time, the shrinking and swelling cycles can cause loss of foundation support.

Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50 percent and plasticity index over 30; usually have high inherent swelling capacity. The levels of expansion in the soils are very site-specific and will be identified during the geotechnical investigation.

5.8 Soil Resistivity

Ground resistivity surveys measure the capacity of the ground to pass an electrical current. This property is useful for designing a grounding system for a transmission tower or substation. Grounding systems provide a safe connection between an electrical circuit and the ground. They are used for the dissipation of electrical faults, grounding lightning strikes, and maintaining the correct operation of electrical equipment. It can also be used as an indicator to measure the corrosion susceptibility of buried ferrous materials.

5.9 Corrosion Potential

There are several variables that have an influence on the corrosion rates in soils. Shannon & Wilson will perform laboratory testing to capture these rates and develop recommendations regarding general soil corrosion potential and suggest concrete types to use for the project.

- pH - Soils usually have a pH range of 5 to 8. In this range, pH is generally not considered to be the dominant variable affecting corrosion rates. More acidic soils obviously represent a serious corrosion risk to common construction materials such as steel, cast iron and zinc coatings. Soil acidity is produced by mineral leaching, decomposition of acidic plants (for example, coniferous tree needles), industrial wastes, acid rain, and certain forms of micro-biological activity. Alkaline soils tend to have high sodium, potassium, magnesium and calcium contents. The latter two elements tend to form calcareous deposits on buried structures with protective properties against corrosion. The pH level can affect the solubility of corrosion products and also the nature of microbiological activity.
- Resistivity (See Above) - Resistivity has historically been used as a broad indicator of soil corrosivity. Soil resistivity generally decreases with increasing water content and the concentration of ionic species. Soil resistivity is by no means the only parameter affecting the risk of corrosion damage.
- Chloride level - Chloride ions are generally harmful, as they participate directly in anodic dissolution reactions of metals and their presence tends to decrease the soil resistivity. The chloride ion concentration in the corrosive aqueous soil electrolyte will vary, as soil conditions alternate between wet and dry.
- Sulfate level - Compared to the corrosive effect of chloride ion levels, sulfates are generally considered to be more benign in their corrosive action towards metallic materials. However, concrete may be attacked as a result of high sulfate levels. The presence of sulfates does pose a major risk for metallic materials in the sense that sulfates can be converted to highly corrosive sulfides by anaerobic sulfate reducing bacteria.

Corrosive soils can damage subsurface utilities and structures. Preliminary indications of soil corrosivity to concrete and steel were analyzed using SSURGO GIS Data. Susceptibility of concrete to corrosion when in contact with the onsite surficial soils is expected to be low, with a few instances where moderate susceptibility is anticipated. Susceptibility of uncoated steel to corrosion when in contact with the soils is expected to be moderate to high along the alignment. Corrosion testing will be conducted during the Geotechnical Investigation on each soil type and generally throughout the corridor to evaluate soil impacts on concrete and steel.

6 GEOLOGIC HAZARD RECONNAISSANCE

Since the work by Shaw Environmental & Infrastructure, Inc., presented in their report dated January 19, 2012 was completed, two new alignments and 17 changes were added to the project. Shannon & Wilson, Inc. reviewed the changes and new alignments and identified areas that stretched far enough from the original work that additional field reconnaissance was warranted. Shannon & Wilson Engineering Geologists performed a geologic hazard reconnaissance of accessible areas of the IPC Glass Hill Alternate and the NEPA Flagstaff Alternate, the IPC Willow Creek Alignment, and the Owyhee River crossing on the IPC Malheur S Alternate between July 30, 2012, and August 2, 2012. In many areas, our reconnaissance of the alignment was limited by denied access to private property. The following sections summarize our geologic hazard reconnaissance.

6.1 IPC Glass Hill Alternate

The area covered in our reconnaissance is shown in Appendix A, Pages 115 and 116. The dominant geologic unit as mapped by Ferns and others (2003) and the Oregon Geologic Data Compilation (2009), is Grande Ronde Basalt, which is a member of the Columbia River Basalt Group. Due to restricted access to private property, direct observations of the alignment were limited. We did, however, reconnoiter the general landscape characteristics where the alignment crosses Ladd Creek Road as well as those visible from Mill Canyon Road.

The DOGAMI SLIDO 2 is a compilation of landslides in Oregon that have been identified on published maps. The SLIDO database does not contain any landslides within the area of our reconnaissance that could impact the proposed change to the IPC Glass Hill Alternate Alignment. However, Ferns and others (2003) mapped several landslides within the Grande Ronde Basalt around La Grande. The types of landslides most likely to occur in this terrain are rock slides or rock falls. These generally create debris fields comprised mainly of angular rock fragments. In our opinion, such debris fields, if present at or near the alignment, pose relatively low risks to tower foundations. We recommend, however, that landslide hazards be investigated further at specific tower locations once access to private property is granted.

The United States Geological Survey maintains a Quaternary Fault and Fold Database of the United States. Within the database, the USGS defines four categories of faults (Class A through Class D). Only Class A and B faults have demonstrated evidence of movement during the Quaternary Period, within the last 1.8 million years. According to the USGS Fault and Fold Database, there are no Class A or B faults adjacent to or crossing the Glass Hill IPC Alternate within the area of our reconnaissance. Ferns and others (2003) as well as the Oregon Geologic Data Compilation (2009) show older faults in the vicinity, but their potential for activity is relatively low.

6.2 NEPA Flagstaff Alternate

The proposed NEPA Flagstaff Alternate alignment, near Baker City, is approximately 14 miles long as shown in Appendix A, Pages 117 through 120. Northeast of Baker City, the first 4 miles of the alignment run generally north-south along the eastern margin of the Baker Valley, about 3 miles east of I-84, north of Highway 86. The dominant geologic units encountered by the alignment in this area, according to the Oregon Geologic Data Compilation (2009), are Quaternary Alluvium and Miocene Olivine Basalt. The alignment then begins to rise into the mountains as it crosses south over Highway 86. There, the alignment encounters the Basalt of Powder River, other Tertiary Basalt, Upper Jurassic to

Lower Cretaceous Plutons, and a Pre-Upper Triassic Intrusive Complex. South of Highway 86, around Flagstaff-27, the geology changes to Miocene Olivine Basalt with lesser amounts of Tertiary Tuffaceous Sedimentary Rocks and Miocene Sedimentary and Volcanic Rocks. The alignment change then turns east-southeast about 1900 feet north of I-84 and nearly parallels the interstate for the last 3 miles. This 3-mile stretch is mapped as Tertiary Tuffaceous Sedimentary Rocks.

The SLIDO database does not contain landslides mapped in areas that could impact the proposed NEPA Flagstaff Alternate Alignment. Access to all property around the NEPA Flagstaff change alignment was denied at the time of the reconnaissance, so visual observations of the alignment were made from public roadways, including Schetky Road, Medical Springs Highway, Sunny Slope Road, Highway 86, and Sunset Lane. From our limited vantage points, we did not observe features indicative of landslide hazards. We recommend further geologic hazard reconnaissance be performed once access to the properties is obtained, but at this time it is our opinion that the risks posed by landslide hazard along the NEPA Flagstaff Alternate Alignment are low.

According to the USGS Fault and Fold Database, there are two Class A faults that intersect the alignment. These include the Unnamed East Baker Valley faults, which run along the alignment from about Flagstaff-1 to Flagstaff-16 (Personius, 2002). Another fault of the same group intersects the alignment near Flagstaff-26. Traces of the West Baker Valley faults cross the alignment near Flagstaff-32, Flagstaff-41, and Flagstaff-45 (Personius, 2002). These and some other older faults are mapped in Brooks and others (1976). The areas where the Unnamed East Baker Valley faults parallel the alignment are an area where fault rupture could potentially impact a number of towers and fault rupture should be considered in this area. An alignment which traverses the faults perpendicularly or obliquely would be preferable.

6.3 IPC Willow Creek Alternate

The IPC Willow Creek Alternate is a new alignment alternative that stretches approximately 24.6 miles from Huntington south to within four miles of the Bully Creek Reservoir, shown in Appendix A, Pages 121 through 129. Mapping by Brooks (1979) and the Oregon Geologic Data Compilation (2009) shows the dominant geology along the alignment to be Miocene Basalt and Andesite, Miocene to Pliocene Tuffaceous Sedimentary Rocks, and Quaternary Alluvium. We were able to observe most tower locations from Malheur Line Lane, Benson Creek Road, North Lockett Road, Lockett Road, Lower Mud Springs Road, 13th Avenue West (near Jamieson), various unnamed roads, and excursions from the above roads on foot. Due to denied access to private property, we were unable to observe the locations of towers north of Willow Creek-5 or south of Willow Creek-101.

The SLIDO database shows a mapped landslide area northwest of the alignment between Willow Creek-31 and Willow Creek-35. It is discussed as feature BrooHC1979a_3461 in the Landslide Assessment, Appendix D. During our reconnaissance, we observed two other areas, not mapped as landslides in SLIDO or geologic maps, which had characteristics indicative of possible landsliding. These are discussed as features PLS-012 and PLS-013 in Appendix D. In short, we observed all three of these areas in the field and do not think that they present risks to the IPC Willow Creek Alternate Alignment. Slope stability hazards are low throughout most of the alignment. However, steep slopes in the Tuffaceous Sedimentary Rocks, and soils derived thereof, appear very prone to erosion. We recommend that tower locations be set back a minimum of 75 feet from any steep breaks in slope. Examples of tower locations that should have increased setbacks include Willow Creek-52 and Willow Creek-65. Also, the relative strength of weathered Tuffaceous Sedimentary Rocks appears to be very low. Weathering products of this unit are typically fine-grained and become very soft when exposed to water.

According to the USGS Fault and Fold Database, there is one Class A fault that intersects the alignment. Traces of the Cottonwood Mountain fault are mapped within 1 mile of the alignment between Willow Creek-76 and Willow Creek-85, and cross the alignment obliquely between Willow Creek-109 and Willow Creek-111 (Personius, 2002). The Oregon Geologic Data Compilation (2009) shows an older fault crossing the alignment near Willow Creek-37, but its potential for activity is relatively low.

6.4 IPC Malheur S Alternate

The IPC Malheur South Alternate Alignment, north of Lake Owyhee, is approximately 0.9 miles long as shown in Appendix A, Sheet 143 through 145. This section of the alignment includes the alignment's crossing over the Owyhee River. The dominant geologic units in this area, as mapped by Ferns (1989), are Miocene Basalt to Andesite with lesser amounts of Miocene tuffaceous sandstone, siltstone, and conglomerate. We observed the tower locations from Owyhee Lake Road.

The SLIDO database does not contain any landslides mapped in areas that could impact the proposed change to the IPC Malheur South Alternate Alignment, and we did not observe indications of landslide activity. Based on our visual observations, it appears that the tower foundations along the change alignment will likely encounter shallow bedrock. Steep talus slopes, however, may make the construction of some access roads more difficult. In general, we recommend that tower foundations be set back at least 75 feet from steep breaks in slope, such as those near tower Malheur_S-119.

According to the USGS Fault and Fold Database, there are no Class A or B faults adjacent to or crossing the IPC Malheur Alternate Alignment. Ferns (1989) and the Oregon Geologic

Data Compilation (2009) do show older faults in the vicinity, but their potential for activity is relatively low.

7 MITIGATION OF SEISMIC HAZARDS

OAR 345-021-0010(h)(H): "An explanation of how the applicant will design, engineer and construct the facility to avoid dangers to human safety from the seismic hazards identified in paragraph (F). The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring for seismic hazards."

At the time of this report, areas requiring mitigation due to seismic hazards were not identified. Shannon & Wilson suggests hazard avoidance if any are identified with the route changes or based on the additional work required to complete the hazard assessment.

8 MITIGATION OF NON SEISMIC HAZARDS

OAR 345-021-0010(h)(I): "An explanation of how the applicant will design, engineer and construct the facility to adequately avoid dangers to human safety presented by the hazards identified in paragraph (G)."

At the time of this report, areas requiring mitigation due to non seismic hazards were not identified. Shannon & Wilson suggests hazard avoidance if any are identified with the route changes or based on the additional work required to complete the hazard assessment.

9 REFERENCES

Bela, J.L. (Compiler), 1982, Geologic and neotectonic evaluation of north-central Oregon: The Dalles 1^0 x 2^0 quadrangle, map scale 1:250,000, Oregon Department of Geology and Mineral Industries, Portland, OR.

Boore, D.M., Atkinson, G.M., 2008, *Ground Motion Prediction Equations for the Average Horizontal Component of PGA, PGV, and 5%-Damped PSA at Spectral Periods between 0.01 s and 10.0 s,* Earthquake Spectra, v. 24, pp 99 - 138Brooks, H.C., McIntyre, J.R., Walker, G.W., 1976, Geology of the Oregon part of the Baker 1 degree by 2 degree quadrangle, map scale 1:250,000, Geologic Map Series GMS-7, Oregon Department of Geology and Mineral Industries, Portland, OR.

Brooks, H.C., McIntyre, J.R., and Walker, G.W., 1976, Geologic Map of the Oregon Part of the Baker 1 by 2 Quadrangle; Oregon Department of Geology and Mineral Industries, Geologic Map Series, GMS-7, scale 1:250,000.

Brooks, H.C., 1979, Geologic Map of the Huntington and Part of the Olds Ferry Quadrangles, Baker and Malheur Counties, Oregon; Oregon Department of Geology and Mineral Industries, Geologic Map Series, GMS-13, scale 1:62,500.

Brooks, H.C., 2006, Geologic and mineral resources map of the Mormon Basin quadrangle, Baker and Malheur Counties, Oregon, vector digital data, scale 1:24,000, Open-File Report 06-25, Oregon Department of Geology and Mineral Industries, Baker City, OR.

Burns, W.J., Mickelson, K.A., Saint-Pierre, E.C., 2011, SLIDO-2, Statewide Landslide Information Database for Oregon, Release 2, Oregon Department of Geology and Mineral Industries, Portland, OR.

Campbell, K.W., Bozorgnia, Y., 2008, *NGA Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01 s to 10 s,* Earthquake Spectra, v. 24, pp 139 - 171

Chiou, B.S-J., Youngs, R.R., 2008, *An NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra*, Earthquake Spectra, v. 24, pp 173 - 215

Ferns, M.L., 1989, Geology and Mineral Resources Map of the Owyhee Dam Quadrangle, Malheur County, Oregon; Oregon Department of Geology and Mineral Industries, Geologic Map Series, GMS-55, scale 1:24,000.

Ferns, M.L., Brooks, H.C., Evans, J.G., Cummings, M.L., 1993a, Geologic map of the Vale 30' x 60' quadrangle, Malheur County, Oregon and Owyhee County, Idaho, vector digital data, scale 1:100,000, Geologic Map Series GMS-77, Oregon Department of Geology and Mineral Industries, Portland, OR.

Ferns, M.L., Evans, J.G., Cummings, M.L., 1993b, Geologic map of the Mahogany Mountain 30' x 60' quadrangle, Malheur County, Oregon and Owyhee County, Idaho, vector digital data, scale 1:100,000, Geologic Map Series GMS-78, Oregon Department of Geology and Mineral Industries, Portland, OR.

Ferns, M.L., Madin, I.P., Taubeneck, W.H., 2001, Reconnaissance geologic map of the La Grande 30' x 60' quadrangle, Baker, Grant, Umatilla, and Union Counties, Oregon, vector digital data, scale 1:100,000, Recon. Map Series RMS-1, Oregon Department of Geology and Mineral Industries, Portland, OR.

Ferns, M.L., McConnell, V.S., Madin, I.P., and Johnson, J.A., 2003, Geologic Map of the Upper Grande Ronde River Basin, Union County, Oregon; Oregon Department of Geology and Mineral Industries, Open-File Report O-03-11, 85p., scale 1:125,000.

IEEE Power Engineering Society and American Society of Civil Engineers, 1983, *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System*, IEEE Standard 81, Published by the Institute of Electrical and Electronics Engineers.

IEEE Power Engineering Society, 2000, *IEEE Guide for Safety in AC Substation Grounding*, IEEE Standard 80, Published by the Institute of Electrical and Electronics Engineers, January 30

IEEE Power Engineering Society and American Society of Civil Engineers, 2001, *IEEE Guide for Transmission Structure Foundation Design and Testing*, IEEE Standard 691, Published by the Institute of Electrical and Electronics Engineers, December 26.

International Building Code, 2006, Published by the International Code Council.

Kramer, Steven L., 1996, *Geotechnical Earthquake Engineering*, Prentice-Hall, Inc.

Madin, I.P., Ferns, M.L., 1977, Geology of the Malheur Butte quadrangle, Malheur County, Oregon, map scale 1:24,000, Open-File Report O-97-2, Oregon Department of Geology and Mineral Industries, Portland, OR.

Madin, I.P., 1994, Earthquake Database for Oregon, Open-File Report O-94-4, Oregon Department of Geology and Mineral Industries, Portland, OR.

Madin, I.P., Mabey, M.A., 1996, *Earthquake Hazard Map for Oregon, State of Oregon*, State of Oregon, Department of Geology and Mineral Industries, Geological Map Series GMS-100.

Madin, I.P., Geitgey, R.P., 2007, Preliminary geologic map of the Umatilla Basin, Morrow and Umatilla Counties, Oregon, vector digital data, scale 1:100,000, Open-File Report O-07-15, Oregon Department of Geology and Mineral Industries, Portland, OR.

National Geophysical Data Center (NGDC), 1985, Earthquake Intensity Database Search, 1683 – 1985, NOAA Satellite and Information Service. Available online at http://www.ngdc.noaa.gov/cgi-bin/hazard/util/ffq_result.pl. Accessed February, 2011

Oregon Geologic Data Compilation (OGDC), 2009, Oregon Geologic Data Compilation DVD, Release 4, Oregon Department of Geology and Mineral Industries, Portland, OR. Pacific

Northwest Seismic Network (PNSN), 2008, Earthquake Catalogs and Data. Available online at http://www.pnsn.org/HIST_CAT/catalog.html. Accessed February, 2001

Oregon Structural Specialty Code (OSSC), 2008, http://ecodes.biz/ecodes_support/free_resources/Oregon/10_Structural/10_PDFs Accessed November, 2011.

Orr, E.L. and Orr, W.N., Geology of Oregon, Fifth Ed., Kendall/Hunt Publishing Co., Dubuque, Iowa.

Pacific Northwest Seismic Network (PNSN), 2008, Earthquake Catalogs and Data. Available online at http://www.pnsn.org/HIST_CAT/catalog.html. Accessed February, 2001.

Personius, S.F., compiler, 2002, Fault number 712, Unnamed East Baker Valley faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/06/2012 04:07 PM.

Personius, S.F., compiler, 2002, Fault number 804, West Baker Valley fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/06/2012 04:08 PM.

Personius, S.F., compiler, 2002, Fault number 806, Cottonwood Mountain fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/07/2012 11:57 AM.

Prostka, H.J., 1962, Geology of the Sparta quadrangle, Oregon, map scale 1:62,500, Geologic Map Series GMS-1, Oregon Department of Geology and Mineral Industries, Portland, OR.

Prostka, H.J., 1967, Preliminary geologic map of the Durkee quadrangle, Oregon, map scale 1:62,500, Geologic Map Series GMS- 3, Oregon Department of Geology and Mineral Industries, Portland, OR.

Shaw Infrastruture….

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Baker County, Oregon. Available online at http://soildatamart.nrcs.usda.gov. Accessed March, 2011

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Malheur County, Oregon. Available online at http://soildatamart.nrcs.usda.gov. Accessed March, 2011

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Morrow County, Oregon. Available online at http://soildatamart.nrcs.usda.gov. Accessed March, 2011

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Owyhee County, Idaho. Available online at http://soildatamart.nrcs.usda.gov. Accessed March, 2011

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Umatilla County, Oregon. Available online at http://soildatamart.nrcs.usda.gov. Accessed March, 2011

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Union County, Oregon. Available online at http://soildatamart.nrcs.usda.gov Accessed March, 2011

Seed, R.B., Cetin, K.O., Moss, R.E.S., Dammerer, A.M., Wu, J., Pestana, J.M., Riemer, M.F., Sancio, R.B., Bray, J.D>, Dayen, R.E., Faris, A., 2003, *Recent Advances in Soil Liquefaction Engineering – A Unified and Consistent Framework,* 26th Annual ASCE Los Angeles Geotechnical Spring Seminar, Long Beach, California, April 30, 2003.

Swanson, D.A., Anderson, J.L., Camp, V.E., Hooper, P.R., Taubeneck, W.H., Wright, T.L., 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho map scale 1:250,000, Open-File Report 81-797, U.S. Geological Survey, Reston, VA.

U.S. Geological Survey (USGS), 2008, Earthquake Hazards Program, 2008 Interactive Deaggregation, Golden, Colorado. Available online at https://geohazards.usgs.gov/deaggint/2008/. Accessed December, 2011.

U.S. Geological Survey (USGS), 2009a, Earthquake Hazards Program, Earthquake Glossary, Golden, Colorado. Available online at http://earthquake.usgs.gov/. Accessed March, 2011.

U.S. Geological Survey (USGS), 2009b, National Earthquake Information Center, Earthquake Search Web Page, Golden, Colorado. Available online at http://neic.usgs.gov/epic. Accessed November, 2011.

U.S. Geological Survey (USGS), 2010, Quaternary Fault and Fold Database, Golden, Colorado. Available online at http://earthquake.usgs.gov/regional/qfaults/. Accessed February, 2011

U.S. Geological Survey (USGS), 2011, Earthquake Search Page, Golden, Colorado. Available online at http://earthquake.usgs.gov/earthquakes/eqarchives/epic/. Accessed November, 2011

Wald, D.J., Quitoriano, V., Heaton, T.H., Kanamori, H., 1999, *Relationship Between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California*, Earthquake Spectra, Volume 15, No. 3.

Walker, G.W., 1979, Reconnaissance geologic map of the Oregon part of the Grangeville quadrangle, Baker, Union, Umatilla, and Wallowa Counties, Oregon, map scale 1:250,000, Misc. Invest. Map 1116, U.S. Geological Survey, Reston, VA.

Walker, G.W., 1973, Reconnaissance Geologic map of the Pendleton Quadrangle, Oregon and Washington, map scale 1:250,000, Misc. Geol. Invest. Map I-727.

Table 1 – 5,000-Year Return Period Peak Ground Acceleration

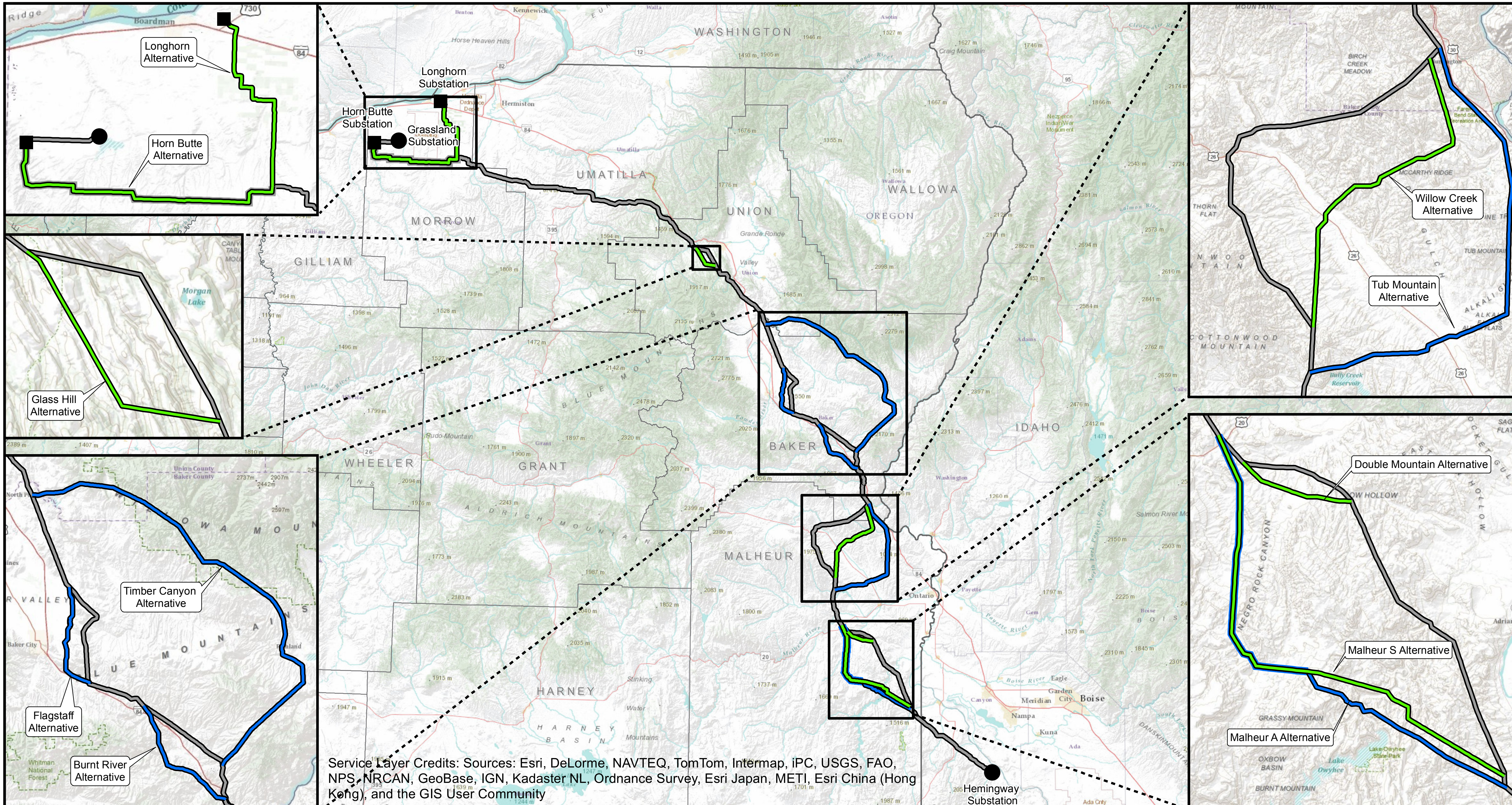
Location[1]	Latitude	Longitude	Peak Ground Acceleration (PGA), Site Class B/C (g)
North A	45.694	-119.832	0.25
North B	45.538	-119.122	0.20
Central A	45.318	-118.229	0.19
Central B	44.775	-117.761	0.21
South A	44.042	-117.477	0.21
South B	43.352	-116.661	0.15

Notes

PGA based on 2008 USGS that corresponds to Site Class B/C. For preliminary design use, values should use Site Class and Site Coefficients in accordance with ASCE/SEI 7-10.

[1] See Figure D-4 for referenced locations.

Table 2 -- USDA Soils with High Erosion Potential			
General Soil Unit ID	**General Soil Unit Name**	**Erosion Factor (K)**	**County**
s1990	Bedstead-Arbidge	0.49	Owyhee
s2026	Owsel-Gooding-Gariper-Arbidge	0.49	Owyhee
s2028	Fairylawn	0.49	Owyhee
s2031	Truesdale-Trio-Scism	0.49	Owyhee
s2033	Turbyfill-Feltham-Cencove	0.49	Owyhee
s2046	Turbyfill-Cencove-Bram	0.49	Owyhee
s6366	Owyhee-Nyssaton-Greenleaf-Garbutt	0.49	Owyhee, Malheur
s6367	Turbyfill-Powder-Garbutt	0.49	Owyhee, Malheur
s6436	Ritzville-Mikkalo	0.49	Morrow/Umatilla
s6473	Roloff-Olex-Krebs	0.43 - 0.49	Gilliam/Morrow
s6475	Warden-Sagehill-Taunton	0.55	Morrow/Umatilla
s6476	Shano-Burke	0.55	Umatilla
s6485	Klicker-Helter-Brickel-Ateron	0.43 - 0.49	Union
s6494	Umapine-Hot Lake-Hooly-Conley	0.43 - 0.55	Union
s6495	Starkey-Gwinly-Anatone	0.49	Union
s6497	Tolo-Kilmerque-Eaglecap-Dogtown-Bouldrock	0.43 - 0.49	Baker
s6501	Wingville-Umapine-Haines-Burkemont-Baldock	0.43 - 0.49	Baker
s6520	Virtue-Frohman-Chilcott	0.49	Malheur
s6521	Virtue-Frohman	0.49	Malheur



LEGEND

- IPC Proposed Route
- IPC Alternative
- NEPA Alternative
- Proposed Substation
- Alternate Substation

NOTE
Alignment(s) and substation data provided by Pike Energy.

0 25 50 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

VICINITY MAP

October 2012 22-1-02947-100

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FIG. 1

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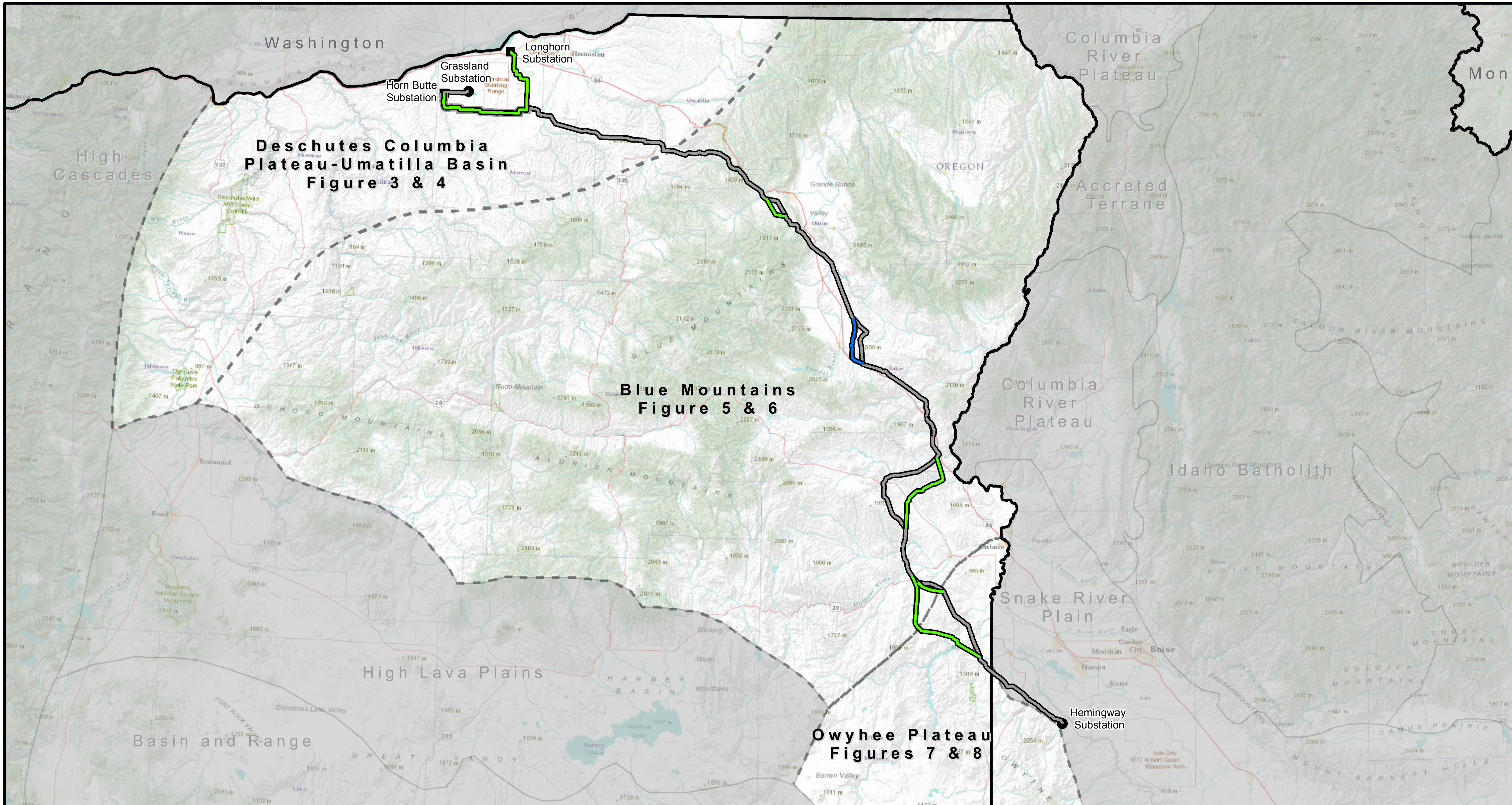

LEGEND

- IPC Proposed Route
- IPC Alternative
- NEPA Alternative
- Proposed Substation
- Alternate Substation
- Geologic Province Boundaries (approximate)
- State Boundaries

NOTE
1. Alignment(s) and substation data provided by Pike Energy.
2. Geologic province boundaries are approximate.

0 25 50 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGIC PROVINCE PAGE INDEX

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FIG. 2

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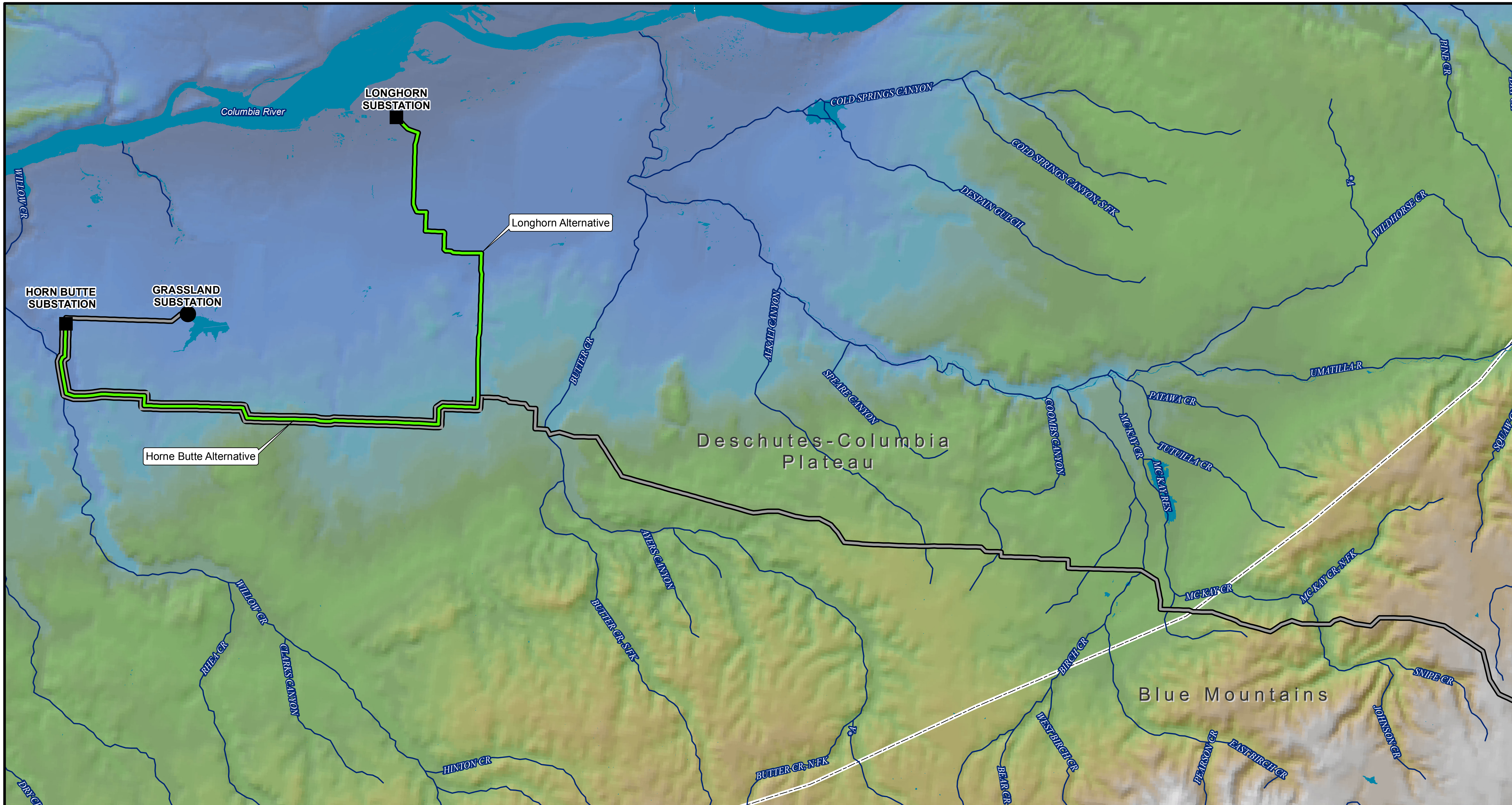

LEGEND

IPC Proposed Route

IPC Alternative

Major River

Proposed Substation

Alternate Substation

ELEVATION (feet)

~5000 (ft)

0 (ft)

0 5 10 Miles

N S E W

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

DESCHUTES-COLUMBIA PLATEAU TOPOGRAPHY AND DRAINAGE

August 2012 22-1-02947-200

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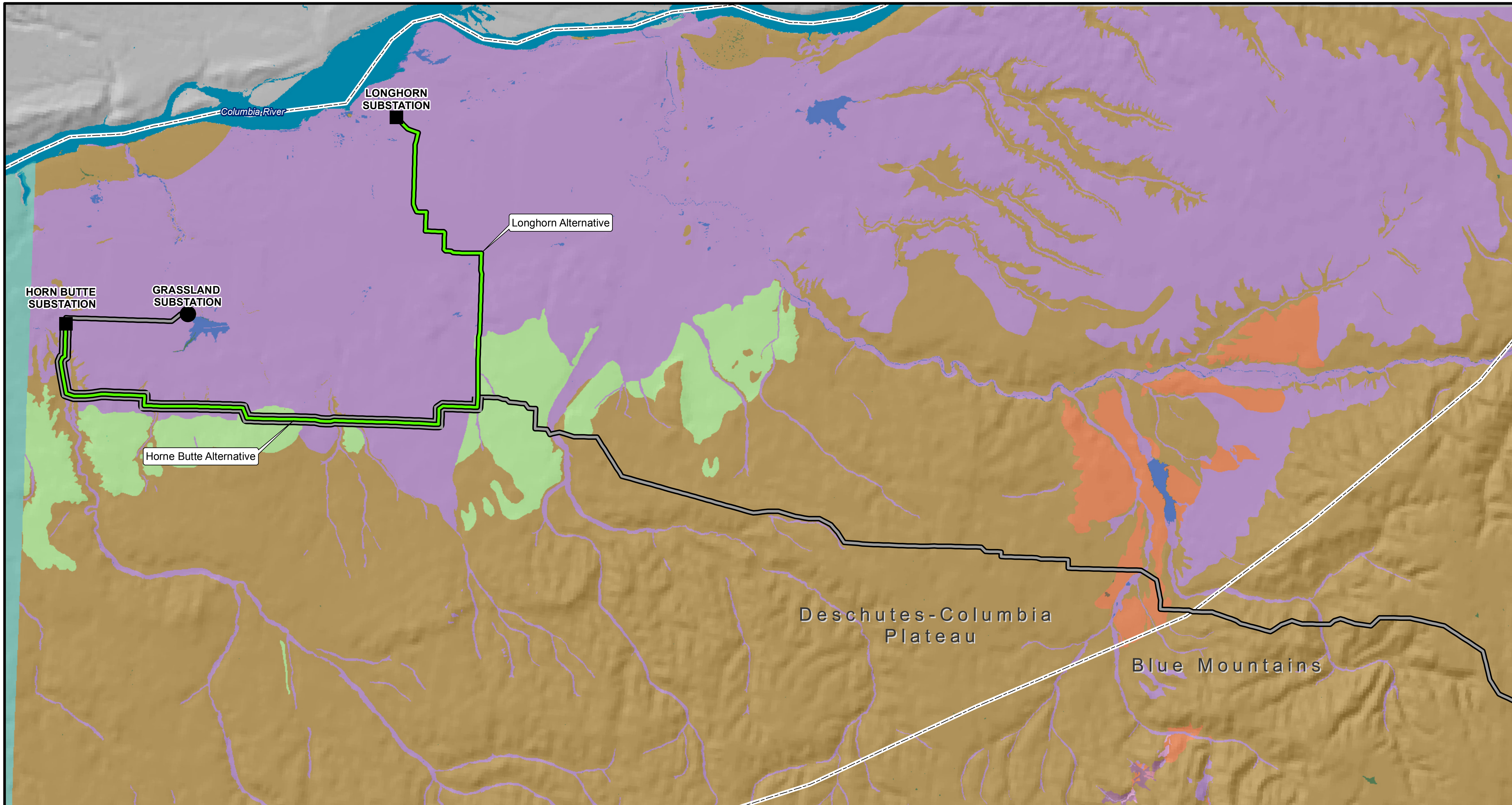
FIG. 3

T:\Projects\22-1\2947_B2H\Avmxd\H-1\Deschutes-Columbia\Topo_Drainage.mxd 8/15/2012 atj



LEGEND

- IPC Proposed Route
- IPC Alternative
- Geologic Province Boundary (Approximate)
- Proposed Substation
- Alternate Substation

NOTES
1. Alignment(s) and substation data provided by Pike Energy.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.

N E S W

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

DESCHUTES-COLUMBIA PLATEAU GEOLOGY

August 2012 22-1-02947-200

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FIG. 4

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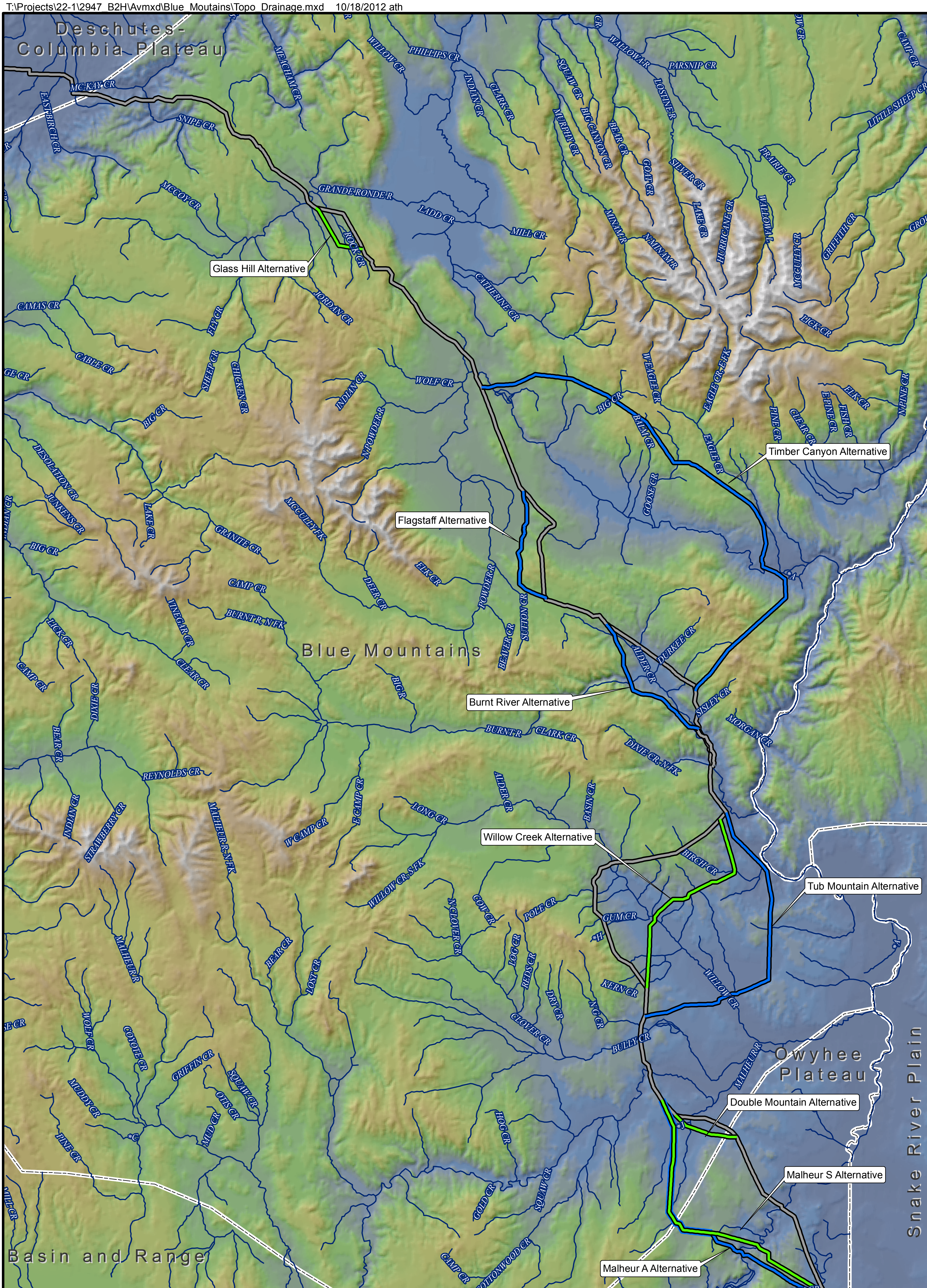

LEGEND

- IPC Proposed Route
- IPC Alternative
- NEPA Alternative
- Geologic Province Boundary (Approximate)
- Major River

ELEVATION (feet)
~9000 ft
0 ft

0 10 20 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

BLUE MOUNTAINS TOPOGRAPHY AND DRAINAGE

October 2012 22-1-02947-100

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FIG. 5

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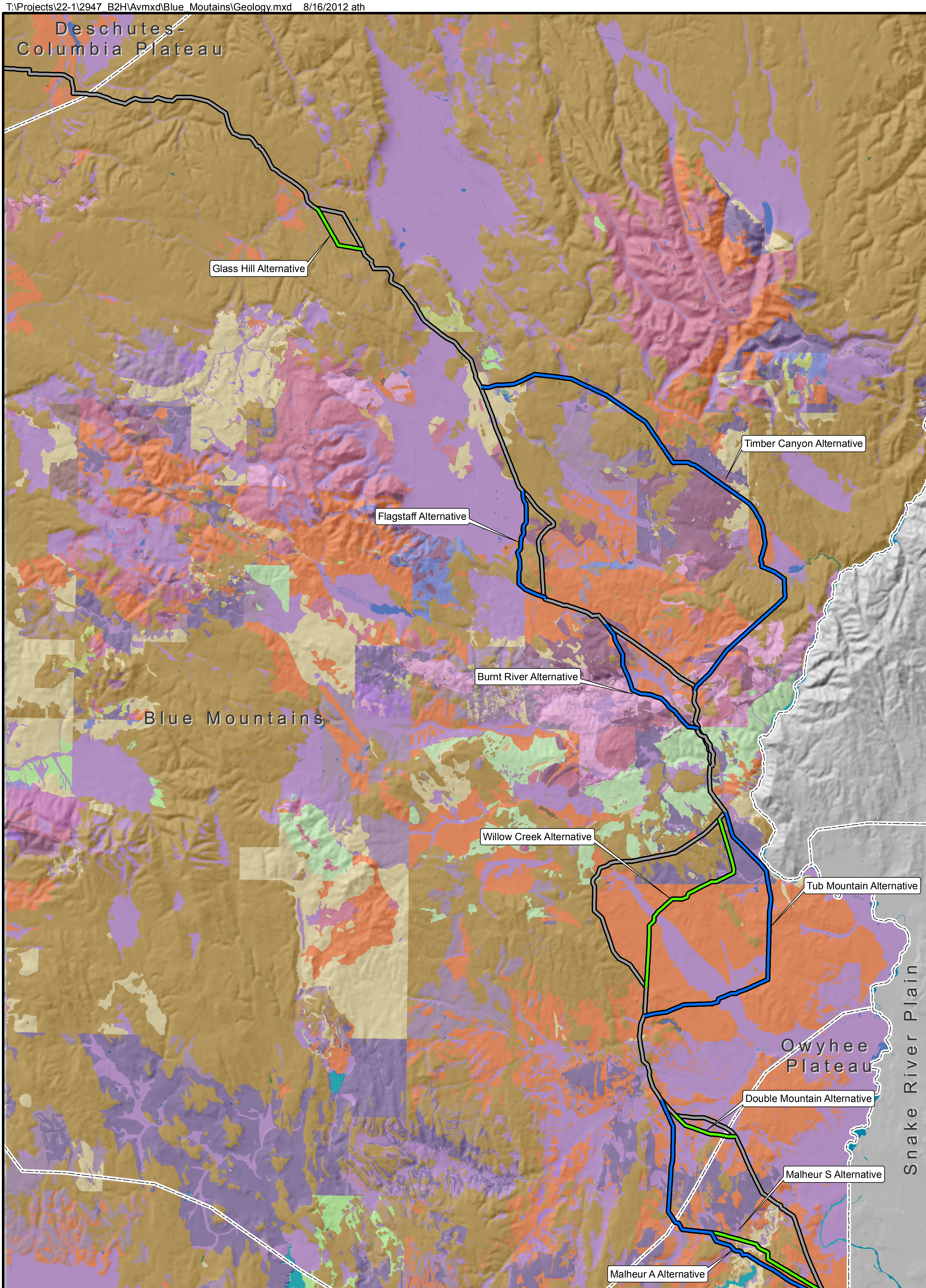

LEGEND

- IPC Proposed Route
- IPC Alternative
- NEPA Alternative
- Geologic Province Boundary (Approximate)

NOTES

1. Alignment(s) and substation data provided by Pike Energy.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.

N E S W

0 10 20 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

BLUE MOUNTAINS GEOLOGY

October 2012 22-1-02947-100

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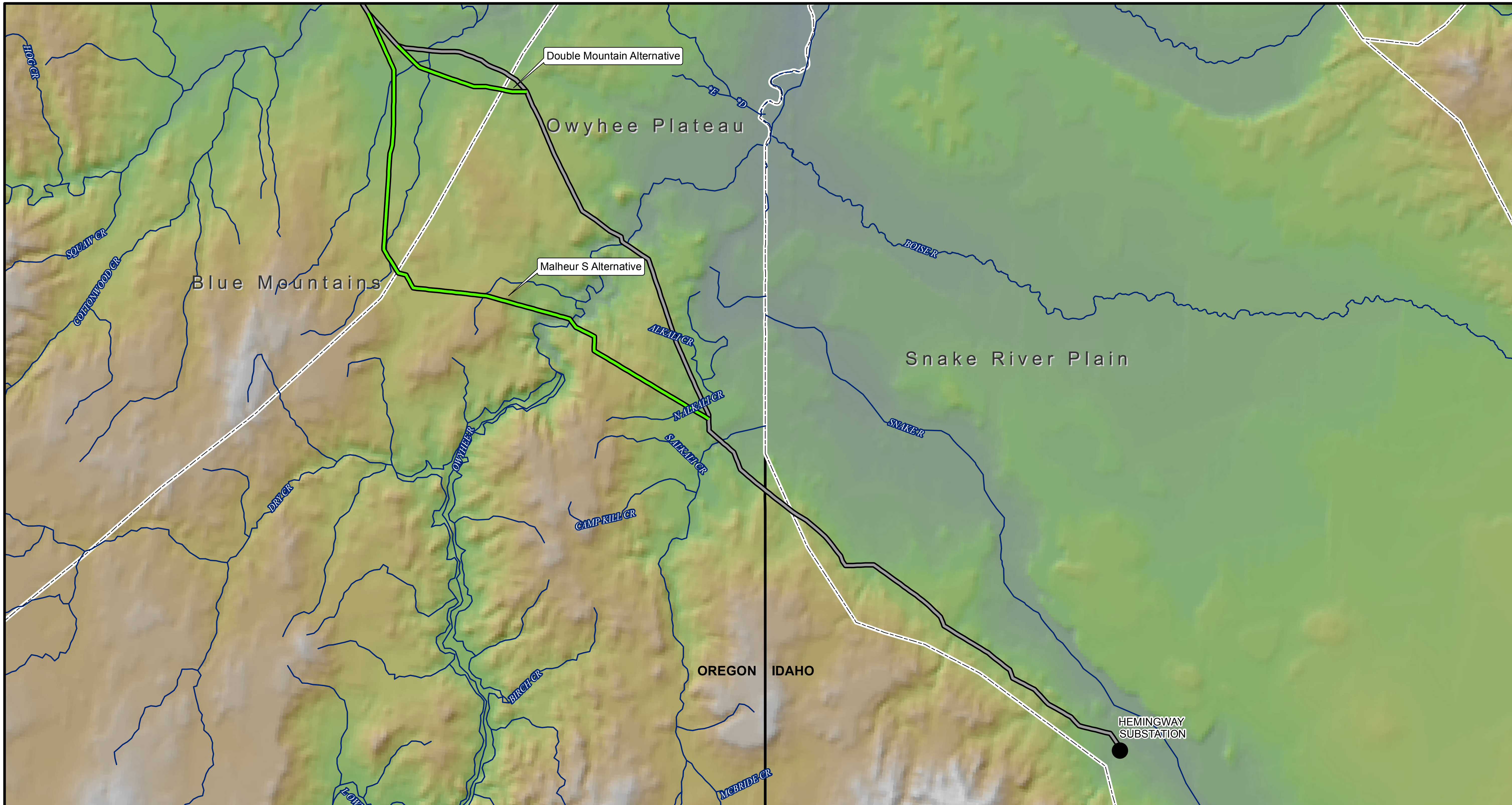
FIG. 6



LEGEND

- IPC Proposed Route
- IPC Alternative
- Geographic Province Boundary
- Major River
- Proposed Substation

ELEVATION (feet)

~6000 ft

0 ft

N S E W

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

OWYHEE PLATEAU TOPOGRAPHY AND DRAINAGE

August 2012 | 22-1-02947-200

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FIG. 7

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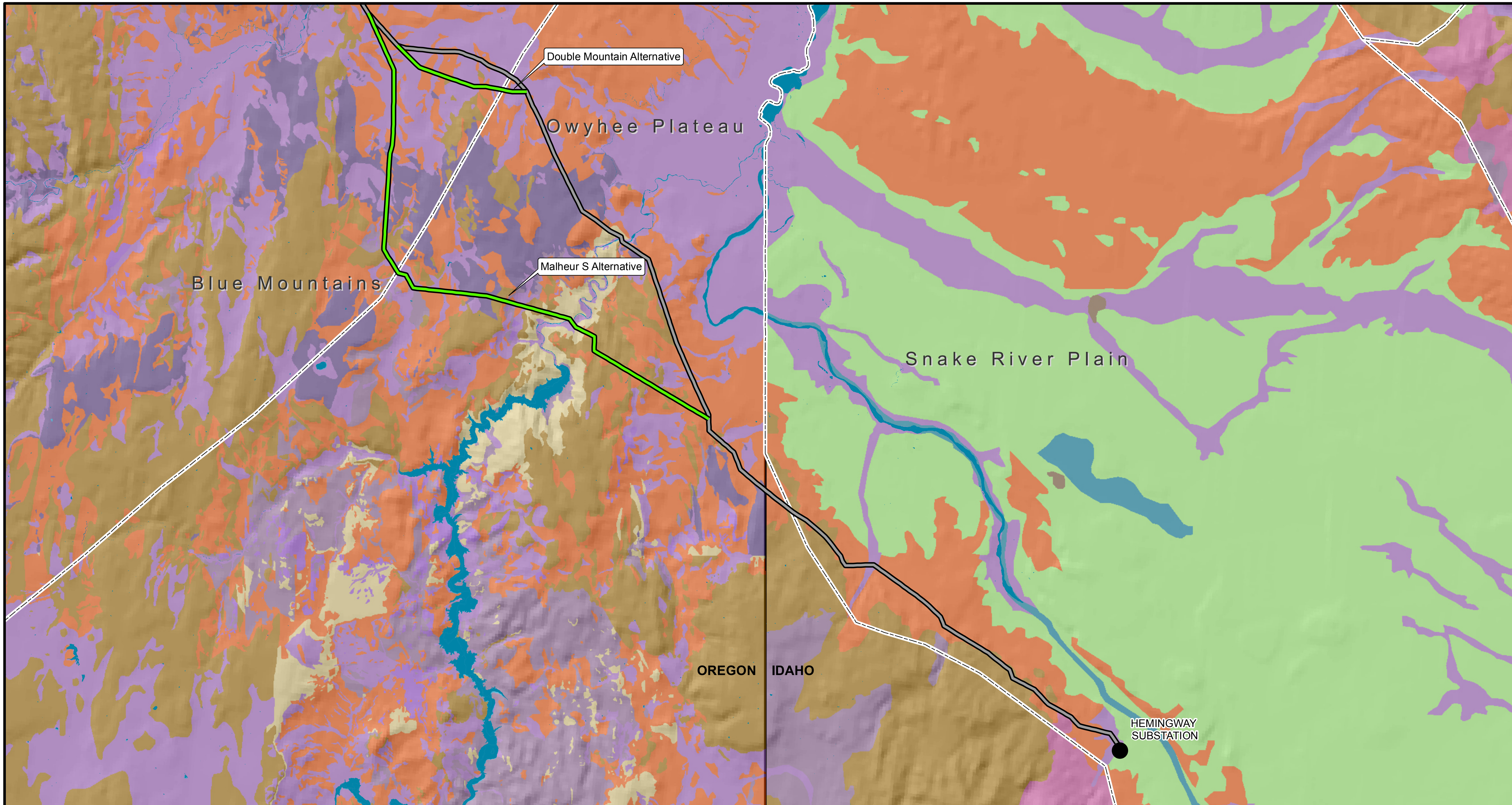

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LEGEND

- IPC Proposed Route
- IPC Alternative
- Geographic Province Boundary
- Proposed Substation

NOTES
1. Alignment(s) and substation data provided by Pike Energy.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

OWYHEE PLATEAU GEOLOGY

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FIG. 8

ROCK TYPE

- Water
- intrusive rocks
- intrusive/sedimentary/volcanic rocks
- intrusive/volcanic rocks
- lava flows
- metamorphic rocks
- metamorphic/plutonic/sedimentary rocks
- metamorphic/sedimentary/volcanic rocks
- metamorphosed intrusive rocks
- metamorphosed plutonic rocks
- metamorphosed plutonic/sedimentary/volcanic rocks
- metamorphosed plutonic/volcanic rocks
- metamorphosed sedimentary rocks
- metamorphosed sedimentary/volcanic rocks
- metamorphosed volcanic rocks
- plutonic rocks
- sedimentary rocks
- sedimentary/volcanic rocks
- sediments
- ultramafic rocks
- ultramafic/volcanic rocks
- unconsolidated rocks
- volcanic rocks
- volcaniclastic rocks

NOTE
Legend only applies to
Shannon & Wilson figures.

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGY LEGEND

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FIG. 9

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