APPENDIX A
EARTH RESOURCES

This appendix contains detailed technical information on earth resources that supports the content of Section 3.1, Earth Resources, in Volume 1 of the EIS. The appendix content includes more detailed description of regional and project-area geology (Section 1 of the appendix), soils (Section 2) and seismic hazards (Section 3). Five graphics, identified as Figures A-1 through A-5, are provided at the back of the appendix.

1. GEOLOGY

1.1 Regional Geology

Eroded metamorphic and igneous rocks form the basement rock on the eastern side of the Cascade Range. Tertiary sedimentary rocks derived from uplift and erosion of the basement rock and Tertiary volcanic rocks overlie most basement rock in the region. During Miocene time, the Columbia River Basalt Group (CRBG) was emplaced from eruption vents in southeast Washington, parts of Oregon, and Idaho. The basalt flowed generally westward and lapped onto the eastern margin of the Cascade Range covering over 164,000 km$^2$ of Washington, Oregon, and Idaho. Basalt flows crossed the Miocene-age equivalent of the Cascade Range along the Columbia Trans-Arc Lowland now occupied by the Columbia Gorge. The Grande Ronde Basalt was the largest of the Columbia River Basalt flows and underlies Kittitas Valley, terminating approximately 15 miles northeast of the project area. It was emplaced from approximately 15.5 to 16.5 million years ago (Tolan et al. 1989). Erosion and eruption of the Cascade Range during Miocene time generated sediment that was interfingered with the basalt flows to form the volcaniclastic and sedimentary sandstones, siltstones, and conglomerates of the Ellensburg Formation.

Regional deformation continued during the emplacement of the CRBG. North-south compression and east-west extension acted on the region contemporaneously with subsidence of the Columbia Plateau, due to emplacement of the basalt flows, and tectonic uplift of the Cascade Range. The stress regime led to the formation of folds and faults in the Columbia Plateau, creating southeast-trending ridges and valleys of the Yakima Fold Belt. The Yakima Fold Belt is characterized by a series of continuous, narrow, faulted, anticlinal ridges (outward dipping folds) that are separated by broad synclinal valleys such as the Kittitas Valley and the Wenatchee Mountains. Uplift of the Cascade Range tilted the Grande Ronde Basalt eastward. The stress regime creating the Yakima Fold Belt is likely still active today (Reidel and Tolan 1994)

The Kittitas Valley in the vicinity of the Desert Claim project is filled with Pliocene-age to Recent-age alluvial material derived from the surrounding basalt mountains and glacial deposits. Glacial geology indicates that Pleistocene-age glaciers of the upper Yakima River Basin were some of the largest alpine glaciers in the Cascade Range. Individual valley glaciers merged during some glacial advances in Pleistocene time to form extensive ice streams extending from Snoqualmie Pass to near Thorp, a few miles upstream of the project area. Porter (1976) identified three such glacial advances and argued that the outwash of the two older and larger advances extends to the central Kittitas Valley. Those glacial outwash deposits were named the Thorp Drift and the Kittitas Drift. Waitt (1979) concluded that the Thorp deposits are of Pliocene age and may not be of glacial origin. He designated these deposits as Thorp Gravel.
1.2 Project Area Geology

Geologic conditions of the project area were evaluated using data obtained from field explorations by Associated Earth Sciences, Inc. (AESI) and AESI’s review of regional geologic maps and publications. Exploration logs are available for review on request from Kittitas County. Figure A-1 presents a surficial geologic map of the project area. One cross section summarizing surface and subsurface geology relative to the project area topography is presented as Figure A-2. The location of the cross section is shown on Figure A-1. Figure A-3 shows the locations of AESI’s field explorations.

The surficial project-area geology consists of Pliocene-age sidestream alluvium, Pleistocene-age sidestream glacial outwash, and Recent-age postglacial alluvium. These surficial sediments overlie Miocene-age Grande Ronde Basalt that crops out on the northernmost property of the project and other isolated locations. A small outcrop of Miocene-age volcaniclastic Ellensburg Formation was located on the northeastern portion of the project area. The geologic units present in the project area are described below in order from oldest to youngest. Field observations of the units are also described.

Grande Ronde Basalt

The Miocene-age Grande Ronde Basalt is the oldest rock identified in the project area. The Grande Ronde consists of fine- to medium-grained basalt flows. Locally it may include thin sedimentary deposits of the Ellensburg Formation. The Grande Ronde Basalt consists of many flows which are complexly jointed and display typical basalt jointing patterns of a basal colonnade, central entablature, and in some flows, upper colonnade. Jointing patterns in much of the area are considerably affected by interaction of flows with water and sediment. (Tabor et al. 1982). Well logs, discussed in Section 3.3.1.2 of the EIS, report many fracture zones in the basalt flow.

Surface exposures of the Grande Ronde Basalt are confined to a few small portions of the project area as mapped by Tabor et al. (1982): 1) in the south half of Section 22 (Township 19 North, Range 18 East) and 2) in adjoining portions of Sections 3, 4, 9, and 10 (Township 19 North, Range 18 East). A small outcrop of basalt was encountered during field exploration in a stream drainage incised into the Thorp Gravel terrace in the center of the northern half of Section 25 (Township 19 North, Range 18 East) (see Figure A-1).

One exploration pit was excavated on the northern portion of the property in Section 22 and encountered basalt bedrock at 1.5 feet below ground surface at about 2,280 feet elevation. The bedrock was fine-grained and vesicular. Broken angular gravel was observed at the surface with orange staining indicating moderate weathering. The basalt outcrop encountered in the Thorp Gravel terrace drainage was also fine-grained, vesicular, and displayed complex jointing. The exposure continued from the channel bottom (2,250 feet elevation) to approximately 10 feet above the channel bottom.

Ellensburg Formation

The Miocene-age Ellensburg Formation consists of volcaniclastic sedimentary rocks derived from volcanoes in the Cascade Range. The rocks are primarily sandstone and siltstone but include conglomerate, laharc deposits, and very minor amounts of micaceous, feldspathic siltstone. The formation rocks are weakly lithified. The volcanic sediment is mostly andesitic and dacitic and clasts are commonly pumiceous. The Ellensburg Formation is observed interbedded with and overlying the Grande Ronde Basalt (Tabor et al. 1982).
Within the Kittitas Valley, surface exposures of the Ellensburg Formation are not common. However, Waitt (1979) describes the Ellensburg Formation encountered at the base of Thorp Gravel terraces in the northwestern Kittitas Valley. During field exploration, AESI encountered a thin layer of white, volcanic rock at the base of the eastern Thorp Gravel terrace in the northwest quarter of the southwest quarter of Section 24 (Township 19 North, Range 18 East) at approximately 2,300 feet elevation. This is interpreted to be the Ellensburg Formation. The exposure was encountered at the base of the terrace that was eroded by a small drainage (Figure A-1). The deposit is weakly lithified and includes pumice clasts and crystal fragments indicating the material was erupted from volcanoes in the ancestral Cascade Range, not eroded from older volcanic rocks (Tabor et al. 1982).

**Thorp Gravel**

Thorp Gravel is a thick gravel deposit that forms a conspicuous high-level terrace in the Kittitas Valley. Thorp Gravel located in the project area was deposited by Yakima River tributaries as sidestream deposits during a period of aggradation of the river, as suggested by Waitt (1979). Sidestream alluvium refers to deposits of tributary streams to the mainstream (here, the Yakima River), that grade to mainstream deposits (Waitt, personal communication 2003). The sidestream facies is composed of subangular clasts of Grande Ronde Basalt derived from the northern side of the Kittitas Valley. Both the sidestream and mainstream deposits are incised as much as 30 meters by small streams, are deeply weathered and are weakly cemented up to 10 meters with montmorillonite and hematite (Tabor et al. 1982). Waitt (1979) documents zircon fission track dating of the Thorp Gravel that gives Pliocene ages of approximately 3.6 to 3.7 million years ago, and suggests that aggradation of the river may have been caused by uplift of anticlines that cross the river to the south within the structural zone of the Olympic-Wallowa Lineament (OWL) (Tabor et al. 1982).

AESİ’s field exploration documented Thorp Gravel terraces as forming high, distinct terraces with slopes of 25 to 35 degrees. The terraces are approximately 100 to 200 feet above the surrounding topography. The tops of the terraces are covered up to 80 percent with grass and shrubs while vegetation cover on the slopes is approximately 40 percent. Slumping was not observed at the base of terrace slopes however colluvium composed of broken basalt gravel was observed to cover about half of the lower half of slopes. Subsurface exploration showed a thin soil layer as described in Section 2, Soils below. Beneath the soil, a partially cemented zone was encountered that consisted of brown to orange-brown, subrounded to subangular gravel in a sand matrix. Few cobbles and boulders were encountered. The material was heavily oxidized and weathering rinds were observed on clasts, demonstrating deep weathering. Gravels were partially cemented; iron staining and chert development were observed during site-specific field explorations.

**Kittitas Drift**

Kittitas glacial deposits in the project area are comprised of sidestream outwash of the Swauk Prairie phase. Sidestream deposition is defined above under Thorp Gravel. The maximum glacial ice advance in the upper Yakima River Valley is marked by moraines approximately 7 km upvalley of the project area and Kittitas mainstream (Yakima River) outwash can be traced about 15 km southeast of moraines, along the southern side of the valley. Terraces of basaltic sidestream gravel in the northern Kittitas Valley are correlated with the mainstream terrace on the basis of elevation. Pleistocene ages of 135,000 to 145,000 years old have been proposed for the Kittitas Drift (Porter 1976 and Waitt 1979).

AESİ’s field exploration documented Kittitas Drift terraces as forming distinct terraces of moderate height (15 to 30 feet) and gentle slopes. Thin to moderate soil development was observed and discussed
in Section 2, Soils below. The terrace sediment encountered was yellow-brown to orange sandy silt with subangular to subrounded gravel. The deposits are weakly cemented and brittle; containing some mica and chert.

**Recent-Age Alluvium - Postglacial Deposits**

Most of the Recent-age, postglacial deposits in the project area are alluvial fan or other modern stream deposits accumulating from streams that originate in the basalt mountains to the north and flow southward to the Yakima River. Erosion by these younger, postglacial streams has carved distinct terraces in the older Kittitas Drift and Thorp Gravel deposits. The alluvium is comprised of either reworked older deposits or material derived from the northern basalt mountains. Porter (1976) suggested that the postglacial alluvial deposits are probably relatively thin. Field exploration in modern stream channels encountered sediment that was generally loose to medium dense and dark brown to brown. The material was composed primarily of sand and silt with lesser amounts of gravel. Clay was encountered as the primary constituent in some excavations.

Other postglacial deposits in the project area include landslide and colluvial deposits located at the base of steep slopes and in drainages. One exploration pit was excavated in the landslide mapped in Section 9 (Figure A-1). The sediment encountered was loose and contained clay, silt, and sand with some gravel. Colluvium of broken basalt gravel was observed at the base of Thorp Gravel terraces.
2. SOILS

2.1 Overview

Physical and chemical weathering of surficial glacial deposits, nonglacial deposits, and bedrock has resulted in the formation of various types of surface soils on the project site. Surface soils data were obtained from the Natural Resource Conservation Service (NRCS) located in Spokane, Washington. The NRCS soil survey of Kittitas County has not been completed as of the date of this report. Draft versions of soil maps and descriptions were available for the project site (NRCS 2003a). Individual soil units have been mapped by the NRCS on recent orthophotoquads of the site vicinity. Figure A-4 (a, b, and c) presents a surface soils map for the project site based on the orthophotoquads obtained from the NRCS and modified as determined from site-specific subsurface investigations.

Comprehensive descriptions for map units shown in Figure A-4 are not currently available. However, draft engineering and selected physical properties of each soil unit were obtained from the NRCS and are summarized in Table A-1 (NRCS 2003a). Also, soil profiles for most on-site soils are available from the NRCS database via the Internet (NRCS 2003a). Based on this information, descriptions of each unit are presented below.

2.2 Soil Unit Taxonomy

All soil units on the project site share certain characteristics, which are represented in various levels of the soil taxonomy hierarchy. A summary of the hierarchy follows:

- Order - differentiated by horizons and features that reflect the formation of the soils
- Suborder - differentiated by the most important variable of soil formation within the order
- Great Group - differentiated by assemblage of horizons and most significant properties of the soils
- Subgroup - differentiated by subordinate features or processes that influence soil development
- Family - differentiated by physical and chemical properties
- Series - differentiated by a narrower range for one or more properties

The soils on the project site belong to the order Mollisols. These soils are present in mid-latitudes on prairie regions. They are usually part of a grassland ecosystem. Mollisols typically have a thick, dark surface horizon (mollic epipedon). Soils on the project site are classified in the Xeroll suborder. They are typical to areas that have moist, cold winters and dry, warm summers. Sometimes, as in this case, these soils are present in semiarid regions. These soils form in late-Pleistocene loess, tertiary lake sediments, older crystalline rocks, and alluvium (NRCS 2003b).
<table>
<thead>
<tr>
<th>Soil Name</th>
<th>Texture</th>
<th>Percent Slope</th>
<th>Runoff Rate*</th>
<th>Erosion Hazard*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapkin-Rubble</td>
<td>cobbly/very stony loam</td>
<td>30 to 75</td>
<td>slow to rapid</td>
<td>slight to severe</td>
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<tr>
<td>Stemilt</td>
<td>ash loam</td>
<td>25 to 45</td>
<td>very slow to rapid</td>
<td>very slight to severe</td>
</tr>
<tr>
<td>Pits, Mine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mippon</td>
<td>very cobbly loam</td>
<td>0 to 5</td>
<td>very slow or slow</td>
<td>very slight to slight</td>
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<td>Argabak</td>
<td>very cobbly loam</td>
<td>15 to 30</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
</tr>
<tr>
<td>Tanksel-Camaspatch</td>
<td>very gravelly/cobbly clay loam</td>
<td>15 to 30</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
</tr>
<tr>
<td>Argixerolls-Durixerolls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pachneum</td>
<td>ash loam</td>
<td>2 to 5</td>
<td>slow to rapid</td>
<td>slight to severe</td>
</tr>
<tr>
<td>Argixerolls-Durixerolls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varodale</td>
<td>clay</td>
<td>2 to 5</td>
<td>slow</td>
<td>slight</td>
</tr>
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<td>Vanderbilt</td>
<td>ash loam</td>
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<td>slow</td>
<td>slight</td>
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<td>Argixerolls</td>
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<td></td>
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<td>Camaspatch-Whiskeydick</td>
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<td>15 to 30</td>
<td>slow to very rapid</td>
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<td>Whiskeydick-Tronsen-Camaspatch</td>
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<td>30 to 70</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
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<td>Laufer-Theissen</td>
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<td>30 to 45</td>
<td>medium to rapid</td>
<td>moderate to severe</td>
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<tr>
<td>Argabak-Whiskeydick</td>
<td>very cobbly loam/clay</td>
<td>3 to 15</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
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<td>Argabak-Mozen</td>
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<td>3 to 15</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
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<td>Reeser-Labblue</td>
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<td>3 to 15</td>
<td>slow to medium</td>
<td>slight to moderate</td>
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<tr>
<td>Reeser-Labblue-Sketter</td>
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<td>3 to 10</td>
<td>slow to medium</td>
<td>slight to moderate</td>
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<tr>
<td>Modsel</td>
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<td>Reeser-Reelow-Sketter</td>
<td>ash/very gravelly sandy loam</td>
<td>2 to 5</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Reelow-Reeser-Sketter</td>
<td>ash/very gravelly sandy clay loam</td>
<td>2 to 10</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Metmill</td>
<td>ash/very gravelly sandy clay loam</td>
<td>0 to 5</td>
<td>slow</td>
<td>slight</td>
</tr>
</tbody>
</table>
### Soil Name | Texture | Percent Slope | Runoff Rate* | Erosion Hazard* |
<table>
<thead>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>Modsel-Metser</td>
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<td>0 to</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Reelow-Reeser</td>
<td>ashy clay/gravelly sandy loam</td>
<td>5 to 10</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Reelow-Skeeter-Labblue</td>
<td>very gravelly ashy/sandy loam</td>
<td>2 to 10</td>
<td>slow to medium</td>
<td>slight to moderate</td>
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<tr>
<td>Sketter-Reelow-Reeser</td>
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<td>2 to 5</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Reelow</td>
<td>very cobbly ashy loam</td>
<td>3 to 15</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Reelow-Labblue</td>
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<td>3 to 10</td>
<td>slow to medium</td>
<td>slight to moderate</td>
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<td>Weirman</td>
<td>gravelly sandy loam</td>
<td>0 to 5</td>
<td>very slow to slow</td>
<td>very slight to slight</td>
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<tr>
<td>Sketter-Millhouse-Labblue</td>
<td>gravelly ashy loam/extremely gravelly sand</td>
<td>0 to 5</td>
<td>slow to medium</td>
<td>slight to moderate</td>
</tr>
<tr>
<td>Reeser-Skeeter-Weirman</td>
<td>ashy clay loam/very gravelly sandy loam</td>
<td>3 to 15</td>
<td>very slow to slow</td>
<td>very slight to slight</td>
</tr>
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<td>Maxhill</td>
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<td>0 to 5</td>
<td>slow</td>
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<td>Patron</td>
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<td>15 to 45</td>
<td>medium to very rapid</td>
<td>moderate to very severe</td>
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<td>Weirman-Kayak</td>
<td>very gravelly loamy sand/gravelly ashy sandy loam</td>
<td>0 to 5</td>
<td>very slow to slow</td>
<td>very slight to slight</td>
</tr>
<tr>
<td>Maxhill</td>
<td>very cobbly ashy loam</td>
<td>0 to 5</td>
<td>slow</td>
<td>slight</td>
</tr>
<tr>
<td>Vantage-Palerf-Rubble</td>
<td>very gravelly/cobbly clay loam/clay</td>
<td>30 to 75</td>
<td>slow to very rapid</td>
<td>slight to very severe</td>
</tr>
</tbody>
</table>

* Range in Runoff Rate and Erosion Hazard is due to their relationship to slope. Since many soils are encountered with a wide range of slopes, the associated runoff and erosion hazard will also vary.

### Agixerolls and Durixerolls

Some soil units are characterized in their Great Group instead of Series due to their wide ranges in key properties. The Agixerolls and Durixerolls are Great Groups of soils that belong to the suborder Xerolls. Durixerolls have a duripan, a silica-cement layer of sediment that is slowly permeable. On-site, this duripan is cemented basalt gravel with iron and manganese staining. Agixerolls have an argillic horizon which is a layer that has a higher percentage of phyllosilicate clay than the overlying soil material (NRCS 2003b). Soils defined by these Great Groups are located on recent alluvium overlying Thorp Gravel on the easternmost properties (Figure A-4c). These soils have moderately steep to steep slopes.

Characteristics of the following soil units are listed in Table A-1 and the map units are located in Figure A-4 (a, b and c). Information for the descriptions below was provided by NRCS (2003a and 2003b).
Stemilt Ashy Loam

The Stemilt soils are composed of very deep and deep, well-drained soils. These soils are characterized by dark-grayish-brown, brown and pale-brown, ashy loam developed over a substratum of material that has weathered from basalt. There is some influence from volcanic ash and loess. Stemilt soils are found on mountains at elevations of 3,200 to 3,500 feet with slopes of 25 to 75 percent. Permeability is moderately slow and runoff varies from very slow to rapid with slope. Stemilt soils cover a small area on the northernmost property (Figure A-4a).

Mippon Very Cobbly Loam

The Mippon soils are composed of very deep, moderately well-drained soils. These soils are characterized by dark-grayish-brown and brown, very cobbly loam developed over a substratum of material that has weathered from recent alluvium. On-site Mippon soils are present on stream terraces on the northernmost properties, at elevations of 2,300 to 3,500 feet, with slopes of 0 to 5 percent (Figure A-4a). Permeability is moderate to very rapid and runoff varies from very slow to slow with slope.

Patron Landslide Complex

The Patron soils are composed of very deep, well-drained soils. These soils are characterized by dark-grayish-brown, brown and yellowish-brown, gravelly silt loam developed over a substratum of landslide material. On-site Patron soils are located on the northwest ¼ of Section 9 (Figure A-4a). These soils are at elevations of 2,700 to 3,300 feet, with slopes of 15 to 45 percent. Permeability is slow and runoff varies from medium to very rapid with increasing slope.

Kayak and Weirman Complexes

The Kayak and Weirman soils are composed of very deep soils. Kayak soils are characterized by grayish-brown and brown, gravelly, ashy loam. Weirman soils are characterized by grayish-brown and brown, fine sandy loam. These soils are developed over a substratum of material that has weathered from recent alluvium and are found in floodplains. On-site, Weirman and Kayak soils are present in the floodplain of Green Canyon Creek in Sections 17 and 20 (Figure A-4b). The elevation range of Kayak soils is 2,100 to 2,500 feet with slopes of 0 to 5 percent. The Weirman soils are also located on low terraces and in stream channels and floodplains overlying Thorp Gravel (Figure A-4c). Weirman soils are present at elevations from 1,900 to 2,500 feet, with the slopes ranging from 0 to 15 percent. Permeability is moderate for Kayak soils and rapid for Weirman soils. Runoff varies from very slow to slow with slope.

Lablue, Reelow, Reeser, and Sketter Complexes

The Lablue, Reelow, Reeser, and Sketter soils are composed of very shallow and moderately deep, well-drained soils. They are present in old uplifted fan remnants, old terraces, and old till plains. Lablue soils are characterized by yellowish-brown, brown and pale-brown, very gravelly ashy loam. Reelow soils are characterized by dark-brown to very-pale-brown and light-yellowish brown, very gravelly, ashy loam. Reeser soils are characterized by grayish-brown, brown, yellowish-brown, and very-pale to pale-brown, ashy loam. Sketter soils are characterized by very-dark-grayish-brown, dark-yellowish-brown to light-yellowish-brown, and very-pale-brown, gravelly loam. On-site, these soils are developed over a substratum of material that has weathered from the Thorp Gravel and the Kittitas Drift. Lablue, Reelow, Reeser, and Sketter soils are located at elevations of 1,900 to 3,100 feet with slopes of 0 to 15 percent. Permeability is slow to moderately slow and runoff is medium to slow depending on slope.
Reelow, Reeser, and Sketter soils are located throughout the project area and cover most of the easternmost properties (Figure A-4a, b, and c)

**Palerf, Sapkin, and Vantage Complexes**

The Palerf, Sapkin, and Vantage soils are composed of shallow and moderately deep, well-drained soils. Palerf soils are characterized by brown, gravelly loam. Vantage soils are characterized by dark-brown, brown, and dark-yellowish-brown, very cobbly loam. Sapkin soils are characterized by brown and yellowish-brown, very stony loam. On-site, these soils are developed over a substratum of residuum and colluvium composed of Grande Ronde Basalt and some loess. Palerf and Sapkin also have an influence of volcanic ash. Palerf and Vantage soils are found on hillslopes of the northeast ¼ of Section 21 (Figure A-4c). Sapkin soils are located on ridgetops and mountainside slopes of the northernmost property (Figure A-4a). Palerf soils are located at elevations of 1,900 to 2,500 feet, Sapkin soils are found at elevations of 2,100 to 3,000 feet, and Vantage soils are found at elevations of 2,400 to 5,600 feet. These soils have slopes of 30 to 75 percent. Permeability is slow for Palerf and Vantage soils and moderate for Sapkin soils. Runoff is slow to rapid depending on slope.

**Metmill and Modsel Complexes and Varodale Clay**

The Metmill, Modsel, and Varodale soils are composed of very deep soils. Metmill soils are somewhat poorly drained, and Modsel and Varodale soils are moderately well drained. Metmill soils are characterized by dark-grayish-brown, ashy loam. Modsel soils are characterized by dark-grayish-brown, brown and yellowish-brown, ashy loam. Varodale soils are characterized by dark-grayish-brown, grayish-brown, and light-brownish-gray clay. These soils are developed over a substratum of recent alluvium with volcanic ash. Metmill soils are also present on inset fans. Modsel soils cover large areas of the western properties (Figure A-4b). Metmill and Varodale are also located throughout the western properties, covering a smaller area (Figure A-4c). Varodale soils are also developed over Kittitas Drift on Section 26 (Figure A-4c). Metmill and Modsel soils are located at elevations of 2,060 to 2,500 feet, and Varodale soils are located at elevations of 1,900 to 2,400 feet. These soils have slopes of 0 to 5 percent. Permeability is slow for Modsel and Varodale soils and moderately slow for Metmill soils. Runoff off from these soils is slow.

**Maxhill, Millhouse, and Metser Complexes and Vanderbilt Ashy Loam**

The Maxhill, Millhouse, Metser, and Vanderbilt soils are composed of very deep, moderately well-drained and well-drained soils. Maxhill soils are characterized by dark-grayish-brown, dark brown and brown, ashy loam. Millhouse soils are characterized by dark-grayish-brown and brown, gravelly ashy loam. Metser soils are characterized by dark-grayish-brown and grayish-brown, clay loam. Vanderbilt soils are characterized by dark-grayish-brown, brown and grayish-brown loam. These soils are developed over a substratum of recent alluvium or glacial outwash and overlie Kittitas Drift. They are present on the western properties and portions of the eastern properties (Figure A-4b and c). Maxhill and Millhouse soils are located at elevations of 2,060 to 3,100 feet. Metser and Vanderbilt soils are located at elevations of 2,060 to 2,500 feet. These soils have slopes of 0 to 5 percent. Permeability is slow to moderate, and runoff is slow.

**Argabak, Pachneum, and Tanksel Complexes**

The Argabak, Pachneum, and Tanksel soils are composed of well-drained soils. Argabak soils are very shallow, Tanksel soils are moderately deep, and Pachneum soils are very deep. Argabak soils are
characterized by yellowish-brown and dark brown, very cobbly loam. Pachneum and Tanksel soils are characterized by dark-grayish-brown, grayish-brown, yellowish-brown and brown loam. These soils are developed over a substratum of loess with volcanic ash, residuum, colluvium, and alluvium composed of Grande Ronde Basalt. Argabak, Pachneum, and Tanksel soils overlie the Kittitas Drift. They are present on slopes and benches on Section 26 (Figure A-4c). Argabak and Pachneum soils are located at elevations of 2,060 to 3,500 feet. Tanksel soils are located at elevations of 2,500 to 3,500 feet. Argabak soils have slopes of 3 to 30 percent, Pachneum soils have slopes of 2 to 5 percent, and Tanksel soils have slopes of 15 to 30 percent. Permeability is slow to moderately slow, and runoff varies with slope.

**Camaspatch, Laufer, Mozen, Thiessen, Tronsen, and Whiskeydick Complexes**

The Camaspatch, Laufer, Mozen, Thiessen, Tronsen, and Whiskeydick soils are composed of well-drained soils. Camaspatch and Laufer soils are shallow, Mozen, Thiessen, and Whiskeydick soils are moderately deep, and Tronsen soils are very deep. Laufer and Thiessen soils are characterized by brown, very stony silt/clay loam. Camaspatch and Mozen soils are characterized by dark-gray, dark-grayish-brown, brown, and pale brown, silt loam and very cobbly silt loam. Tronsen soils are characterized by dark-grayish-brown, brown, yellowish-brown, and pale-brown, stony ashy silt loam. Whiskeydick soils are characterized by dark-brown and yellowish-brown, very cobbly loam. These soils are developed over a substratum of residuum, colluvium, and slope alluvium composed of Grande Ronde Basalt with some loess and volcanic ash. These soils overlie the Kittitas Drift. They are present on slopes, mountainsides, and benches over large areas of the northern properties (Figure A-4a). Camaspatch, Laufer, Mozen, Thiessen, Tronsen, and Whiskeydick soils are located at elevations of 2,500 to 3,200 feet. These soils have slopes that vary from 3 to 70 percent. Permeability is slow to moderate in these soils, and runoff varies with slope.
3. SEISMIC HAZARDS

3.1 Historical Seismic Activity

The Desert Claim wind power project location is in an area of low to moderate historical seismicity. Table A-2 summarizes historical and recorded seismic events greater than magnitude (M) 3.0 in the vicinity of the site as obtained from the University of Washington’s Pacific Northwest Seismograph Network (PNSN). The historic record of earthquakes in the Pacific Northwest dates from about 1840. Much of the early record was provided by newspaper reports of structural damage or human perception of shaking. Seismograph networks did not start providing locations and magnitudes of earthquakes in the Pacific Northwest until about 1960 and the PNSN began operation in 1970. Magnitudes, locations, and depths before this time are less precise. Figure A-5 shows the locations and magnitudes for earthquakes listed in Table A-2. Nearly 200 seismic events between M 2.0 and M 2.9 have been recorded in the project vicinity since 1970. Earthquakes of magnitude less than 3.0 pose little to no hazard, however, they provide information about regional structure and faulting.

Two earthquakes within an area of approximately 1 degree latitude by 1 degree longitude surrounding the project area had a measured magnitude of 5.0 or greater (M 5.0 and M 6.8). The M 5.0 event occurred in 1943 and is located just north of Table Mountain in the Wenatchee Mountains of the Cascade Range, about 14 to 17 miles north of the project area. The M 6.8 event occurred in 1872 and is located approximately 55 miles northwest of the project area. All other earthquakes are M 4.3 or less. Both the M 5.0 and the M 6.8 earthquakes occurred prior to the operation of the PNSN. Two M 4.3 earthquakes located about 27 miles southwest and 34 miles northeast of the project area are the largest seismic events recorded in the site vicinity since the installation of the PNSN. One earthquake (M 3.0) is located in the project area (Figure A-5) and is discussed under Surfacial Fault Zones below.

Stresses that cause earthquakes in western and central Washington are due, in part, to the interaction of tectonic plates that meet near the western edge of Washington State. The Juan de Fuca oceanic plate, which forms the floor of the northeastern Pacific Ocean, moves northeastward with respect to the North American continental plate at an average rate of about 4 centimeters per year. Differences in density of the two plates cause the Juan de Fuca plate to sink or subduct beneath the North American plate. The interaction of the plates forms the Cascade volcanoes and potentially large earthquakes.

Recent tectonic research reveals regional tectonic stresses, in addition to the stresses created by the subduction of the Juan de Fuca plate, that affect western and central Washington, including the Yakima Fold Belt. Studies using the Global Positioning System (GPS) show that a small tectonic block of North America that includes part of Oregon is experiencing rotation and general northward movement relative to Washington State. Regionally this motion may be driven by a combination of extension in the Basin and Range region to the southeast, northward push from the Eastern California shear zone, and from drag created by resistance of the subduction zone to northward movement (McCaffrey et al. 2000, 2003; Savage et al. 2000). GPS studies have confirmed that northward motion of approximately 1 centimeter per year (cm/year) is occurring along the Cascadia margin (McCaffrey et al. 2000, 2003; Savage et al. 2000). McCaffrey et al. (2000) suggests the rotating Oregon block appears to converge with North America in Washington State along the OWL and across Puget Sound. The deformation is accommodated by north to south shortening in Washington State and Canada, including the Yakima Fold Belt and Puget Sound.
Three types of earthquakes occur in the Pacific Northwest that affect Washington. The Juan de Fuca plate must bend as it subducts beneath the North American plate causing deep intraplate earthquakes within the Juan de Fuca plate. Three such events have been recorded in western Washington: the recent Nisqually earthquake (2001 M=6.8), the 1965 earthquake (M~6.8), and the 1949 (M~7.1) earthquake.

Deep interplate (or subduction zone) ruptures occur between the Juan de Fuca plate and the North American plate. Records provided by buried soil layers, dead trees, and deep-sea deposits indicate that a

*Seismic event occurred prior to operation of the Pacific Northwest Seismograph Network.

A subduction earthquake such as this occurred in the year 1700 with a magnitude of approximately 8.9. A documented tsunami occurred in Japan that has been correlated to this earthquake. A recurrence interval of 500 to 600 years is estimated for this type of earthquake (Satake et al. 1996, Atwater and Hemphill-Haley 1997).

The third type of event is a shallow, crustal earthquake occurring within the North American plate due to tectonic stress regimes. Crustal faults and structural lineaments are mapped in central Washington in the vicinity of the project area. Many document movement during Late Tertiary but not during Quaternary time. Ongoing studies suggest that east-west trending faults in the Yakima Fold Belt are actively accommodating north to south compression of Washington (McCaffrey et al. 2000, 2003).

The Kittitas County CAO (Section 17A.02.260) defines seismic hazard areas as, “…geologically hazardous areas subject to risk of earthquake damage.” Four types of potential geologic hazards are usually associated with large seismic events: ground rupture along a surficial fault zone; ground motion response; liquefaction; and seismically induced landslides.

### 3.2 Surficial Fault Zones

Geologic structures that relate to surficial fault zones near the project area are described in Section 3.1.1.3. The anticlines of the Yakima Fold Belt are underlain and often caused by thrust faults. Recent studies indicate that the Yakima Fold Belt is actively accommodating north-south shortening of central Washington (McCaffrey et al. 2000) as discussed in Appendix A, Section 3.1. Several generally east-west trending faults are mapped within the Yakima Fold Belt (Bakun et al. 2002, Tabor et al. 1982). However, evidence of Quaternary deformation has not been identified to date.

The 1872 earthquake (M 6.8) is important in quantifying the seismic hazard in central and eastern Washington because it is the largest historical earthquake in Washington east of the crest of the Cascade Range. Bakun et al. (2002) suggest that the earthquake was shallow, based on aftershock patterns, and the epicenter was located south of Lake Chelan (as shown on Figure A-5). The rupture plane of the 1872 earthquake has not been located and may represent a recent rupture within the Yakima Fold Belt or deeper Cascade Range crystalline rock that does not have surface expression. Bakun et al. (2002) suggest that events as large as M 6.8 can reasonably be expected over most of south to central Washington.

There are northwest-southeast trending faults that cross the project area as mapped by Tabor et al. (1982) (the inferred fault traces are shown on Figure A-1). Currier Creek drainage patterns appear to be influenced by this fault near the center of the project area in Section 22 (Township 19 North, Range 18 East). The fault is not visible under recent alluvial deposits but may be continuous from Section 22, trending northwest to cut diagonally across Section 9 (Township 19 North, Range 18 East). In Section 9, the fault trace crosses a landslide deposit mapped by Tabor et al. (1982). The landslide block was observed in the field and the mapped area on Figure A-1 was adjusted as per field and aerial photography observations. The landslide material is part of the Kittitas Drift; therefore the material was deposited approximately 130,000 to 140,000 years before present. The landslide is fully vegetated and does not represent a recent disturbance. Landslide movement may have been due to seismicity along the fault at some time after deposition.

AESI identified northwest-trending lineaments on stereo pair aerial photographs on the eastern Thorp Gravel terrace (Section 25, Township 19 North, Range 18 East and Sections 30 and 31, Township 19 North, Range 19 East). However, these lineaments were not visible during field exploration. The 1995 M 3.0 earthquake that occurred in the project area is located on the eastern side of the property on the
Thorp Gravel terrace near a fault mapped by Tabor et al. (1982). Deformation along the fault affects the Pliocene-age Thorp Gravel terrace. More recent activity along the fault system is possible, however, offset has not been documented in post-Pliocene-age deposits.

### 3.3 Ground Motion Response

Ground motion from an earthquake results from shear, pressure, and surface waves propagating through the earth’s crust from the earthquake’s hypocenter. The ground motion caused by these waves is the seismic shaking felt during an earthquake. The intensity of the shaking felt at a given location during and immediately after an earthquake, is a result of several variables including: 1) the magnitude of the earthquake; 2) distance from the earthquake; 3) depth of the earthquake; 4) the type of rocks and unconsolidated sediments underlying a given site; and 5) attenuation of the seismic energy between the earthquake and a given site. Although the project site is located in an area of relatively low to moderate historical seismicity, as shown in Table A-2, there are several sources of large earthquakes in western Washington and possibly within central Washington as indicated by the 1872 event.

The Nisqually 2001 earthquake provided direct observation of ground motion during a large regional earthquake. The University of Washington’s PNSN created a “shake map” of peak acceleration and velocity from wave forms collected during the earthquake. Peak acceleration is the maximum acceleration experienced by a particle at the earth’s surface during the course of the earthquake motion. The event was located between Olympia and Tacoma, 33 miles deep, approximately 95 miles east of the project areas. The shake map shows light shaking within 20 miles of the project area (peak acceleration of 1 to 4 percent of the acceleration of gravity (g) \[g = 9.8 \text{ meters per second}\]) (http://www.ess.washington.edu/shake/0102281854/intensity.html).

The United States Geological Survey (USGS) has created seismic hazard maps to predict the expected peak ground acceleration from earthquakes (Frankel et al. 2002). According to this work, in the next 50 years there is a 10 percent chance that ground motions will exceed 15 percent g in the vicinity of the project. This work contributed to the 1997 Uniform Building Code (UBC) determinations of seismic zones in the Pacific Northwest. The UBC’s seismic zone classifications are used to determine the strengths of various components of a building or structure needed to resist earthquake damage caused by ground motion. Design guidelines for minimizing earthquake damage to structures based on anticipated ground motions for a specific region are included in the UBC. The seismic zones used by the UBC range from Seismic Zone 0 (area of low seismic risk) to Seismic Zone 4 (area of high seismic risk). The project is located within Seismic Zone 2B as defined by the 1997 UBC.

Unconsolidated young deposits may amplify ground motion. Ground motions in these areas will likely be more intense than predicted for hard rock sites.

### 3.4 Liquefaction

Liquefaction is the process in which soil loses strength or stiffness during vibratory shaking, such as that caused by earthquakes, and temporarily behaves as a liquid. Shaking during an earthquake can cause an increase in pore water pressure in the soil, and decrease the soil shear strength. Soils are considered to liquefy when nearly all of the weight of the soil is supported by the pore water pressure and becomes relatively unstable. The seismically induced loss of soil strength can result in failure of the ground surface and can be expressed as landslides or lateral spreads, surface cracks and settlement, and/or sand boils. Seismically induced liquefaction typically occurs in loose, saturated, non-cohesive sandy and silty
soils commonly associated with recent river, lake, and beach sedimentation. In addition, seismically induced liquefaction can be associated with areas of loose, saturated fill.

AESI’s field exploration and review of area well logs indicate that much of the project area is underlain by unconsolidated sediments up to 300 feet thick. Some material is young stream deposits that are relatively loose and fine-grained and may be subject to liquefaction under strong seismic shaking, however these sediments are expected to be thin. The majority of the property is underlain by well-drained sand and gravel deposits which are not susceptible to liquefaction. Based on the results of our field exploration program, our experience with similar soil types, and our understanding of the regional seismicity, it is our opinion that the potential for liquefaction at the project area is low. However, unconsolidated soils underlying wetlands and stream corridors may be susceptible to liquefaction during larger seismic events, although most of the susceptible soil layers are likely relatively thin.

3.5 Seismically-Induced Landslides

Earthquake vibration may cause unstable material to fail by influencing existing planes of weakness within bedrock (such as bedding planes or fault planes) or within unconsolidated material. The USGS documented many earthquake-induced landslides throughout the Puget Lowland that occurred due to shaking from the 2001 Nisqually event and several researchers have correlated previous mass movements in Lake Washington to the A.D. 900 earthquake on the Seattle Fault (Jacoby et al. 1992; Karlin and Abella 1992, 1996). Although landslides were identified on the project area, it is unknown whether these landslides were induced by associated seismic events. The risk of seismically induced landslides occurring on the site is generally interpreted to be low due to the relatively moderate slope gradients and soil characteristics. Locally, along steep slopes, the risk of seismically induced landslides is considered moderate.