APPENDIX N

GEOLOGY, TOPOGRAPHY, AND SOILS

Table N-1. Soil Types and Descriptions

Karst Type	Description
absent_1	Fissures, tubes, and caves generally absent; where present in small isolated areas, less than 50 ft (15 m) long; less than 50 ft (15 m) vertical extent; in crystalline, highly siliceous intensely folded carbonate rock
absent_2	Fissures, tubes, and caves generally absent; where present in small isolated areas, less than 50 ft (15 m) long; less than 50 ft (15 m) vertical extent; in moderately to steeply dipping beds of carbonate rock
absent_3	Fissures, tubes, and caves generally absent; where present in small isolated areas, less than 50 ft (15 m) long; less than 50 ft (15 m) vertical extent; in gently dipping to flat-lying beds of carbonate rock
long_1	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in metamophosed limestone, dolostone, and marble
long_2	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in moderately to steeply dipping beds of carbonate rock
long_3	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of carbonate rock
long_4	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of carbonate rock beneath an overburden of noncarbonate material 10 ft (3 m) to 200 ft (60 m) thick
long_5	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in moderately to steeply dipping beds of gypsum
long_6	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of gypsum
pseudo_1	Fissures and voids present to a depth of 250 ft (75 m) or more in areas of subsidence from piping in thick, unconsolidated material

Karst Type	Description
pseudo_2	Fissures and voids present to a depth of 50 ft (15 m) in areas of subsidence from piping in thick, unconsolidated material
pseudo_3	Fissures, tubes, and tunnels present to a depth of 250 ft (75m) or more in lava
pseudo_4	Fissures, tubes, and tunnels present to a depth of 50 ft. (15 m) in lava
short_1	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in metamorphosed limestone, dolostone, and marble
short_2	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in crystalline, highly siliceous, intensely folded carbonate rock
short_3	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in moderately to steeply dipping beds of carbonate rock
short_4	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; In gently dipping to flat-lying beds of carbonate rock
short_5	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; In gently dipping to flat-lying beds of carbonate rock beneath an overburden of noncarbonate material 10 ft (3 m) to 200 ft (60 m) thick
short_6	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in moderately to steeply dipping beds of gypsum
short_7	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in gently dipping to flat-lying beds of gypsum
short_8	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in gently dipping to flat-lying beds of gypsum beneath an overburden of nongypsiferous material
short_9	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in carbonate zones in highly calcitic granite
short_10	Fissures, tubes and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in moderately to steeply dipping beds of carbonate rock with a thin cover of glacial till and frost derived residual soil

Karst Type	Description
absent_1	Fissures, tubes, and caves generally absent; where present in small isolated areas, less than 50 ft (15 m) long; less than 50 ft (15 m) vertical extent; in crystalline, highly siliceous intensely folded carbonate rock

REGIONAL SEISMOLOGY AND TECTONICS

Seismic action along the northern border of the United States can occur in the following three locations:

- Cascadia Subduction zone;
- Intermountain Seismic belt; and,
- New England (unidentified ancient faults).

The first and most significant of the seismic hazard zones is called the Cascadia Subduction Zone. As part of the larger "Ring of Fire," the cause of seismic activity in this zone is the creation of the subterranean Juan de Fuca Range. The development of this range off of the coasts of Washington and Oregon force the Juan de Fuca plate to move under the North American plate in what is known as subduction plate tectonics. In this type of tectonic action, an oceanic plate slides under either a continental plate or another oceanic plate. In the Juan de Fuca region, the oceanic plate is sliding beneath, or subducting, under the North American Plate along the Cascadia subduction zone. Subduction zone earthquakes can be the most powerful quakes, at times exceeding 9.0 on the Richter scale. The last catastrophic earthquake known in this range occurred around 300 years ago but the accepted frequency for significant earthquakes in this region is about once every 400 years (Pacific Northwest Seismic Network, 2002).

The Intermountain Seismic Belt is another region with significant seismic hazard. While much of the activity occurs in central and southern Montana, earthquakes do occur in the northeastern part of the state (State of Montana, 2004). The cause of the seismic activity can be traced to the tectonic actions occurring along the western coast of the United States, although it is not along a plate boundary. The frequency of strong earthquakes in northern Montana is low when compared to southwestern portions of the state.

The cause of New England's seismic activity is not completely understood. There have not been adequate associations with specific faults to earthquakes in the region. The types of earthquakes here are known as intraplate quakes. The commonly accepted reason for seismic activity in this case is that ancient faults release strain due to modern day stresses. The ancient faults may have been created either during the creation or separation of the supercontinent, Pangaea. The potential for damaging earthquakes in this region are low, although the potential still exists (Kafka, 2004).

SOIL ORDERS ALONG THE NORTHERN BORDER

Soil taxonomy is the science of classifying soils based on physical qualities and characteristics. There are 12 soil orders that categorize soils for identification. Along the northern border of the United States, there are nine soil orders that have been identified (Fig. 3.4.2.2-1). These include:

- Inceptisols;
- Andisols;
- Ultisols;
- Mollisols;
- Aridisols;
- Alfisols;
- Histosols;
- Spodosols; and,
- Entisols.

In the Pacific Northwest, and specifically Washington, the dominant soil orders are inceptisols, ultisols, andisols, and mollisols. Inceptisols are the second most common soil type in the world. They are often found on steep slopes and areas that are young in terms of no horizon development. Soil orders can be further divided in to suborders. In this region, cryepts are the most common type of inceptisol. These are specific to cold climates. Typically inceptisols will not have extensive development with regard to soil horizons (University of Idaho, No Date[a]). These soils are found in almost all climates with the exception of arid climates. Mass movement (landslides, falls) and soil erosion are two processes that typically occur in this soil order (University of Wisconsin, 1999).

Andisols are soils of volcanic origin. This soil order is the least common of the classifications. Typically there is a high concentration of glass found in andisols and the ability to retain water is also a unique trait of the soil (University of Idaho, No Date[b]). These soils can be found in any climate that saw past or present volcanic activity, with the exception of permafrost environments. They develop through the weathering of volcanic parent material, mainly pyroclastic ejections (University of Wisconsin, 1999).

Ultisols are soils with a high acid content, low fertility, and have been leached of minerals by the processes of weathering. Low soil fertility is due to a lack of nutrients in the soil resulting in the decreased ability to support plant life. While not as productive as agricultural lands, ultisols are often found in highly productive forested areas (University of Idaho, No Date[c]). They can be found in any climate that has periods of time when precipitation exceeds the evapotranspiration rate and the soil's water storage capacity. A small organic layer followed by clays is typical of this soil order (University of Wisconsin, 1999).

Mollisols appear while moving westward in Washington state. These soils are common in grassland regions and are extremely agriculturally productive. In the United States, this is the most common soil order. The thick upper horizon (or layer) is a result of the decayed organic materials (University of Idaho, No Date[d]). The development of this order is most often related to the weathering of sedimentary parent rock, and in some cases the weathering of glacial deposits. Mollisol soil texture can vary to a great degree from sandy to fine loams (See table 3.4.2-1). This soil order is prone to erosion, especially by water in cultivated areas (University of Wisconsin, 1999).

Moving westward into the north-central border region, the soil order that continues to be dominant is the mollisol order. Western Montana and northwestern North Dakota have relatively small areas where there are alfisols present. Alfisols are often found in forested areas, but can also be found in prairies and grasslands. Most often located in temperate climates, they can develop in sub-tropical and tropical areas as well (University of Idaho, No Date[e]). The primary component of this soil order is clay as a result of mineral weathering (University of Wisconsin, 1999).

Aridisols can also be found in these two states in relatively small areas. This soil order is not agriculturally productive due to their location in arid regions. A major component of these soils is calcium carbonate in addition to clays, silica, and other soluble salts (University of Idaho, No Date[f]). They tend to have low permeability and low nutrient content (University of Wisconsin, 1999).

In the Great Lakes region, spodosols, alfisols, and inceptisols dominate. Small areas of northern Minnesota and Michigan also contain histosols and entisols. Spodosols are acidic soils that are found in forested areas. They are not agriculturally productive without management because of the high acid content, but have sub layers of humus, or stable organic matter (University of Idaho, No Date[g]). Spodosol textures are sandy to loamy, sometimes with clay (University of Wisconsin, 1999).

The histosols in the region are mainly found in areas of poor drainage. This water accumulation decomposes organic materials and creates peaty and mucky conditions. They have a low weight-bearing capacity and if drained of water, land subsidence may occur (University of Idaho, No Date[h]).

Entisols are soils that do not fit into any of the other 12 soil orders. These are young soils and have only an A horizon. Entisols are the most extensive soils in the world, and can be very diverse based on the parent material from which they develop (University of Idaho, No Date[i]). This soil order is often the transition layer between soils and non-soil parent rock.

The New England region’s soils are dominated by spodosols as well as alfisols. Spodosols in this area are classified further as orthods. These are well-drained and typically infertile without the application of cultivation nutrients (USDA, No Date).

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