Appendix A. Geotechnical Engineering Report

Site Reconnaissance and Construction Recommendations
for the Coos County Natural Gas Pipeline
Project

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GEOTECHNICAL ENGINEERING REPORT

Route Reconnaissance and Construction Recommendations for the Coos County Natural Gas Pipeline Project

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REGISTERED PROFESSIONAL ENGINEER
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TABLE OF CONTENTS

Introduction

Objective

The Coos County Natural Gas Pipeline ("the pipeline") is proposed for construction between Roseburg and Coos Bay, Oregon, along the route depicted in Appendix A. The route will utilize the rights-of-way of the Coos Bay Wagon Road (CBW Road) and the Bonneville Power Administration (BPA) power line and will pass through or near the communities of Lookingglass, Reston, Sitkum, Dora, McKinley, Fairview and Sumner, ending near Coos Bay.

Engineering design and construction of the pipeline will be directly affected by:

- geologic features,
- the type and thickness of soil deposits,
- depth to rock,
- gradient of soil and rock slopes within the construction limits,
- width of working space available,
- watercourses and stream crossings,
- natural and man-made obstacles.

This report presents the results of a geotechnical engineering reconnaissance survey of the proposed route. The observations and opinions presented herein are focused on constructability of the pipeline from a surface soils, i.e., geotechnical engineering, standpoint.

The original report was prepared by S. Joseph Spigolon, Ph. D., P.E. for the Coos County Board of Commissioners and Biological Information Specialists, Inc. Subsequent to preparation of the draft report and while agency review was being conducted, Dr. Spigolon succumbed to a sudden illness. Pinnacle Engineering, Inc. was then engaged to review Dr. Spigolon's report and agency review comments and to issue a final report, including responses to agency comments.

Also while agency review was being conducted, portions of the route alignment were changed from, that evaluated by Dr. Spigolon. Accordingly, geotechnical review and opinion of the revised route is also contained herein. The scope of services performed by Pinnacle for the route change were identical to those conducted for the original report.

Data presented in Dr. Spigolon's report [21] have been reviewed to the extent practical and, where appropriate, relied upon in this revised report.

Scope of Investigation

The level of investigation for this study was limited to reviewing appropriate geotechnical and geological literature and conducting a site observation and reconnaissance of the proposed pipeline route. The literature review searched for relevant information about project soils and surficial rock contained in published and unpublished geological and Soil Survey documents. Reconnaissance of the entire proposed pipeline route was conducted to observe soil and rock outcrops. morphology, limitations to construction access and evidence of existing or potential natural hazards.

Project Location and Description

Site Location and Description

The proposed natural gas pipeline will start at the Williams Gas Pipeline metering facility southwest of Roseburg and end near Coos Bay. At Coos Bay, the pipeline will connect with proposed Northwest Natural Gas (NW Natural) distribution facilities to service the surrounding communities and possibly the industrial properties on the North Spit. All of the sixty mile route is to be located within existing rights-of-way of either the CBW Road and other public roads or within existing power line corridors. The pipeline route (maps) is depicted fully in Appendix C of this EIS.

Virtually the entire length of the proposed pipeline route is within the Coast Range, a long narrow band of moderately high mountains that ends in coastal headlands at Coos Bay. The Coast Range in Oregon extends from the Columbia River to the Middle Fork of the Coquille River at the southern limits of Coos County [1][1]. The Coast Range is about fifty miles wide at the project location and the terrain, consisting of steep hills and sharp crests, ranges in height from sea level to crests at about 3,000 feet above sea level.

The Coast Range is mainly formed of weakly consolidated sandstone and siltstone and is easily weathered and eroded. The major streams in the area west of the Coast Range, including the East Fork of the Coquille River, flow westward toward the ocean or, in the Coos Bay area, north toward the bay. East of the Coast Range, the major streams flow easterly to the South Umpqua River, then north and west toward the ocean at Reedsport. The terrain is formed of a succession of ridges and small valleys. The heavily dissected erosion gullies are typically oriented north-south. Many of the valleys have differences in elevation along the BPA power line route of 1,000 feet or more between ridge crest and valley bottom.

In the eastern 75 percent of Coos County and the western part of Douglas County, the soils along the proposed pipeline route are mostly well drained and loamy or clayey and are well suited to timber production [2] except in Brewster Canyon. Some of the land adjoining the route has been clear-cut by timbering operations. The rights-of-way of both the CBW Road and the BPA power line have been cleared as a result of prior construction activity.

Description of Proposed Pipeline

The main line of the Coos County Natural Gas Pipeline will consist of a 12.75-inch outside diameter, 0.25 inch wall thickness, welded steel pipe having a design pressure of 2,039 pounds per square inch gauge (psig). The maximum allowable operating pressure will be 1,000 psig. The pipe will be coated and packaged magnesium anodes will be attached at approximate 1,000 feet intervals to limit corrosion. Where the pipeline is constructed within the power line corridor, additional measures may be taken to mitigate potential hazards due to induced current.

A number of block valves will be included in the project. Mitigation of potential geologic and geotechnical impacts along the route will be accomplished by installation of an assortment of additional automatic and/or remote control valves at strategic locations to be selected during final design. Automatic or remote control valve locations will be selected during final design. Preliminary locations are recommended in subsequent sections of this report.

Pipeline construction will best be accomplished using a working space of 25 to 30 feet, which may require a total width of up to 60 feet in steep side slope areas. Where sufficient width is not available, short sections of the project may be constructed in a more restricted width.

The pipe will be installed with 36 inches of cover where practical. In areas with less than 3 feet depth to consolidated rock, a minimum of 24 inches of cover is allowed. The existing rights-of-way will be restored to current or better condition as construction is completed.

Geologic Setting and Natural Hazards

The following discussion of surface geology and natural hazards near or affecting the project route is based on published and unpublished information from the following sources:

1. Number in brackets [ ] refer to documents included in the List of References at the end of this report.

- various bulletins and geologic maps published by the Oregon Department of Geology and Mineral Industries,
- reference texts discussing the geology of the project route,
- unpublished air photos and pedologic soil descriptions from the Douglas County Area Office of the Natural Resources Conservation Service, Roseburg,
- the Soil Survey of Coos County [2] published by the Natural Resources Conservation Service and
- various documents published by the USGS, including the Geologic Map and Database of the Roseburg Quadrangle.

General Area Geology

The bedrock forming the Coast Range consists of materials that were deposited in the ocean and later uplifted by tectonic action. Layers of basalt were deposited under water by volcanic activity and subsequently covered by sand and silt sediments eroded from the Klamath Mountains. Much later, after the sand and silt became sandstone and siltstone, the mass of rock was raised and crumpled into folds by the slow landward movement of the Pacific Ocean floor [3]. The present day outcrops of the rock show a sequence of north-south exposures consisting of a few relatively narrow bands of basalt interspersed with large, wide expanses of the sandstone and siltstone of several formations. The soils resulting from weathering of the underlying bedrock reflect the mineralogy of the parent rock. A west-east cross section of the route along U. S. Highway 42 [3, p. 106], south of and roughly parallel to the CBWR, is shown in Figure 1 as an illustration of the typical geologic section along the pipeline route.

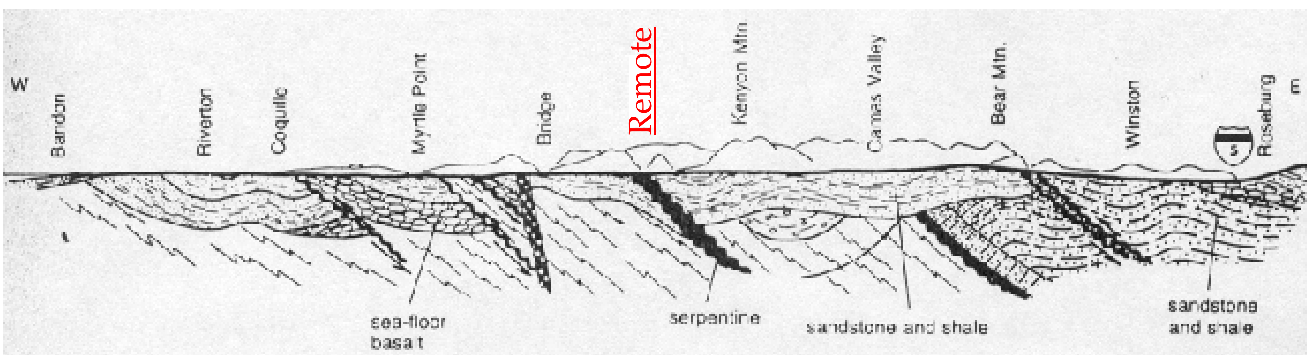

Figure A-1. West-east geologic cross-section along Oregon Highway 42, south of and parallel to the CBW Road, showing compression and tilting of strata.

The folding of the rocks illustrated in Figure A-1 resulted in a series of lineaments or fault lines, more or less oriented perpendicular to the direction of push [4, 5]. These are ancient lines of movement and are not active fault lines.

Starting at the eastern end of the project, the bedrock underlying much of the city of Roseburg, and extending westward to the west slope of the hills immediately east of Lookingglass, is a layer of basalt. This is the Roseburg Formation, the basal member of the Umpqua Formation [6].

As the route enters Lookingglass Valley, the underlying bedrock is a rhythmically bedded sandstone and siltstone of the Lookingglass Formation. Near the western edge of the Lookingglass Valley, the pipeline route crosses the inactive Reston-Bonanza Fault. Between Lookingglass and Reston the terrain is underlain by the mudstone, siltstone and fine grained sandstone of the Flournoy Formation.

West of Reston the route enters the outcropping of the Tyee Formation, an arkosic sandstone with siltstone interbeds. Arkosic sandstone is described in the geologic literature [7] as a light pink sandstone predominantly of feldspar and quartz, coarse grained, porous and easily eroded. Brewster Valley and the surrounding heavily eroded ridge and valley terrain are underlain by the Tyee Formation.

West of Dora the route enters a short north-south outcrop of the Lookingglass Formation, as described above [6].

Northwest of Dora, the area encompassing the communities of McKinley and Fairview is underlain by the Roseburg Formation. In this area, the bedrock is a rhythmically bedded sandstone and siltstone with localized, thin interbeds of basalt.

At the western end of the proposed pipeline, between Fairview and Coos Bay, the route is underlain by the sandstone and interbedded siltstone of the Coaledo Formation.

Surface geology along the route is depicted with maps at the end of this report.

Surficial Soils

Construction of the pipeline will be affected by the properties and thickness of surface and near-surface soils and the depth from the ground surface to underlying rock. Generally, the surface soils were derived from mechanical and chemical weathering of the underlying parent rock. Most of the soils within project limits are residual in nature, although significant expanses of transported soils, i.e., colluvial and alluvial material exist, especially in the western section.

Research during preparation of this report depended heavily on the soil profile descriptions contained in the soil survey documents of the Douglas County [11] and Coos County Soil Conservation Service [2] offices. Field work conducted for those studies was generally limited to a determination of the soil profile to a depth of five to six feet, the depth appropriate for this project.

Within the project limits, residual soils are typically a minimum of two to three feet thick. The underlying layer of weathered rock typically ranges from a few feet to tens of feet. Excavation within the weathered layer can be accomplished normally by use of a high energy track excavator. Along steeper slopes, the thickness of residual soils is typically less.

POTENTIAL NATURAL HAZARDS

Natural site hazards are naturally occurring conditions that may impact the completed project. Credible natural hazards include, in varying degrees of probability;

- flooding, either tidal or surface streams,
- erosion,
- mass soil movement, either creep or landslides,
- seismic activity, i.e., earthquakes, liquefaction and *tsunamis*,
- general land subsidence.

Of these potential natural hazards, only stream flooding, erosion, mass soil movement and seismic activity are considered credible potential natural hazards for the project.

Stream Flooding

Except in the alluvial floodplains around the several communities along the route and in Brewster Canyon, the proposed pipeline route is within the BPA power line right-of-way in the hillsides, well above stream levels and stream flooding is not a credible hazard. Stream flooding in the alluvial floodplains and in Brewster Canyon, however, is likely to occur during the design life of the project, but would only be significant to the extent that it affected integrity or operability of the completed pipeline.

Integrity of the pipeline would not be affected by inundation, as the pipeline will be buried, air-tight and under internal pressure. Further;

- there is no record of past flooding of rivers and major streams to a degree that would compromise integrity of the proposed pipeline.
- the CBWR in Brewster Canyon, along the East Fork of the Coquille River, is rarely flooded above roadway level.

Operability of the pipeline, specifically certain of the valves, could be affected by flooding. Potential impacts to operability can be mitigated by location of critical valves above flood elevations or by incorporating design features that would allow valve operation regardless of flood conditions.

Erosion

Since the proposed gas pipeline is anticipated to be bored beneath major stream crossings, damaging erosion will be effectively mitigated by vertical separation. Minor erosion is possible at crossings of intermittent streams, but damage to the pipeline from such erosion is not credible.

Mass Soil Movement

Slopes are susceptible to mass movement any time the weight of the soil mass acting along the slope travel angle exceeds the soil shear strength available to resist the movement. Slope movement can occur even at a very gradual slope gradient. Naturally occurring landslides, those not caused by the action of man such as loading of the top of the slope or removal of soil at the bottom, invariably result from a decrease in shear strength of the soil mass due to increased water content or by an increase in effective weight of the soil mass, such as would occur during a seismic event. Damage from mass soil movement is directly related to Landslide Velocity Class and volume of mobilized mass. Landslide Velocity Class ranges from unnoticeable (creep) to sudden.

- **Soil Creep.** Soil creep is a very slow downhill movement of soil that is typically a continuous movement which proceeds at an average rate of less than a foot per decade [20]. It occurs more commonly in deep deposits of high plasticity soils on moderate slopes. Shrinkage cracks may form in the soil during the dry season, becoming partially filled with drier soil particles. During the following wet season, moisture content of the clayey soil increases, usually more at the surface than below. The moisture increase decreases the shear strength to a nearly critical state where shear failure is imminent and a slight movement can occur, greater at the surface than at depth. This combination of effects usually leads to very slow downhill movement. Over a period of many years, the movement can become noticeable and significant damage can occur. Severity of damage experienced is directly dependent upon Landslide Velocity Class [20]. Soil creep is not considered a credible hazard, as the probable rate of movement would allow many years for mitigation to be accomplished.
- **Sudden Movement.** Sudden movement of soil masses ranging in size from small to medium are likely to occur at several locations within the project limits during its design life. Locations of most concern are described in subsequent sections of this report, as are recommended mitigation measures.

Earthquake

Earthquakes are the result of a sudden differential displacement of a portion of the earth along a fault plane. The movement releases elastic energy that causes violent shaking of the earth's surface in both the horizontal and vertical directions. Such shaking can induce mass soil movement. As noted above, the historical record of earthquakes in Oregon only extends back to 1833 [15].

Earthquakes in Oregon originate from one of three different source areas [13, 14, 22]:

- **Crustal earthquakes**, that occur along relatively short and shallow faults that exist within the upper 6 to 12 miles of the surface. These are faults, such as those illustrated in Figure A-1, that are sometimes, but not always, visible at the surface and, therefore, may not create horizontal displacements at the ground surface. The resulting earthquake can reach a magnitude as large as 6.5 to 7. The March 1993 Scotts Mills earthquake, magnitude 5.6, and the September 1993 Klamath Falls main shocks, magnitude 5.9 and 6.0, were crustal earthquakes.

Intraplate earthquakes occur within the remains of the ocean floor, the San Juan de Fuca Plate, that has been subducted under the North American Plate. These are deep movements, occurring at depths of 25 to 37 miles below the ground surface, that can reach a magnitude as large as 7 to 7.5. The Puget Sound earthquakes of 1949 and 1965 were intraplate earthquakes.

- **Cascadia Subduction Zone (CSZ) slippage.** Great subduction zone earthquakes occur around the world when tectonic plates collide. The dipping interface between the two plates is the origin of some of the most powerful earthquakes ever recorded, often having magnitudes of 8 to 9 [22]. In the northwest, the Cascadia Subduction Zone has been recognized for many years, but no earthquakes have occurred during our 200 year recorded history. In the CSZ, the San Juan de Fuca Plate is slowly moving under the North American Plate along a line about 40 to 50 miles offshore extending from British Columbia to northern California. Sliding friction between the two plates is believed to be causing the edge of the North American Plate, in the region of the coastal area of the Coast Range, to bow upward. Periodically, the friction is believed to be overcome along a section of the CSZ, allowing that portion to drop a short distance and cause violent shaking.

Although no CSZ earthquakes have occurred in the past 200 years, there is widespread evidence that very large earthquakes have occurred repeatedly in the past, most recently about 300 years ago. The best available evidence indicates that CSZ earthquakes occur on average about every 500 to 540 years, with an interval between individual events ranging from 100 - 300 years to about 1,000 years.

Discussion. Crustal earthquakes of low magnitude are common in northern and eastern Oregon, but not in the Coos-Douglas County area. Jacobson [16] plotted the Oregon earthquake database record on a map of Oregon and showed that there have been no earthquakes recorded within 50 miles of the proposed pipeline route except for a magnitude 3.0 quake in central Douglas County. Geologic evidence of fault movement has been summarized in the map by Madin and Mabey [17]. They showed that there has been no known fault movement within the past 1,600,000 years along the route of the proposed pipeline. There are, however, a few faults that have moved within the past 10,000 years south of Coos Bay.

The major earthquake concern along the southern Oregon region is the potential for a CSZ displacement and the damage that would result. Geologic evidence of such events [18] indicates that at least five such earthquakes have occurred within the past 300 to 3,500 years, each occurring along a limited, 150 to 300 miles, length of the coast in the region between Vancouver, B.C. and northern California. It is estimated that the most recent event occurred about 300 years ago.

Estimates of coastal subsidence [18] for a subduction zone event are on the order of a maximum of 1.5 to 3 feet. This will create a ground acceleration of about 0.4 g (gravity) along the coast at Coos Bay [19] if that part of the coast is included in the CSZ slippage zone. The acceleration rate is attenuated by distance from the slippage so that acceleration of the bedrock at Roseburg would be reduced to about 0.2 g from the same event. A similar attenuation will occur at Coos Bay if the slippage occurs at some distance north or south along the length of the subduction zone.

The most severe damage due to earthquakes is commonly localized and generally caused by one or more of the following;

- Amplification of ground shaking by a soft soil column.
- Liquefaction of water-saturated sand, silt or gravel, creating areas of "quicksand".
- Landslides triggered by shaking, even on relatively gentle slopes.
- Amplification is not deemed a credible risk, as;
- The depth of soft soil and properties conducive to amplification do not generally exist along the alignment.
- Damage from amplification is most critical to above ground structures, where the fundamental site period and first period of vibration of the structure are similar.

Liquefaction can occur in deep, saturated deposits of loose, clean sand, gravel or silt if shaking causes the grain structure of the soil to lose inter-particle friction and collapse, i.e., a temporary loss of shear strength. When liquefied, the soil deposit behaves like a viscous liquid. Since deposits subject to liquefaction are not likely to exist along the proposed pipeline route, liquefaction is not considered a credible risk to the project.

Landslides triggered by shaking, although low probability, are deemed the most likely seismically induced hazard that could affect the project. Mitigation measures for seismically induced landslides are identical to those recommended for landslides induced by increased moisture and are described in subsequent sections of this report.

Observations and Recommendations

Route Reconnaissance Observations

Six visual reconnaissance trips [21] along the proposed route of pipeline were made for this report, four by vehicle on the Coos Bay Wagon Road and one each by helicopter and airplane along the BPA power line route. The objective of each reconnaissance trip was to observe soil and rock outcrops, slopes, width available for construction, and to discover evidence of existing or potential natural hazards. In addition, several segments of the BPA right of way, where potentially significant problem areas were noted by aerial or photo reconnaissance, were observed on foot.

A tabulated summary of the near-surface soils along the route is contained in Table A-1, Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline, included subsequently in this report. The information and observations contained in Table 1 were derived from a combination of;

- field and office interpretations of geologic features along the route,
- field and office interpretations of the Douglas County and Coos County Soil Survey data cited above and
- field observations made during the six reconnaissance trips.

The proposed route of the Coos County Natural Gas Pipeline, consists of six distinct sections:

a) from the connection to the Williams pipeline south of Roseburg to about the Coos County line, west of Reston, it will follow the Pacificorp/ BPA rights-of-way.

b) at the Coos/Douglas County line, the pipeline will follow the right-of-way of the CBWR through Brewster Canyon to three miles west of Dora.

c) from three miles west of Dora to the Lone Pine Bridge, it will follow the BPA right of way.

d) from the Lone Pine Bridge to McKinley, it will follow the CBWR.

e) from McKinley to Fairview it will first follow the power line right of way, then from Fairview to the Coos City Bridge, it will follow the CBWR.

f) the final segment will rejoin the BPA right-of-way and continue to the end of the pipeline near Coos Bay.

Physical conditions along the pipeline route are generally described as;

1. **Section from Williams Pipeline to Lookingglass.** This five-mile section of the project passes through a hill of basalt with an overlying layer of high plasticity clay soil. Slopes along the roadway and the Pacificorp power line are typically less than 10 percent, although a short section of between 20 and 40 percent slope exist as the route descends into the Lookingglass Valley.

   The soil is estimated to be over five feet thick along the power line. There are two rock quarries at ground level near the alignment, indicating a possible thin soil overburden at isolated locations. The soil in Lookingglass Valley is quaternary alluvium, typically firm, with depth to rock greater than five feet.

   Between the Williams sub-station and Lookingglass, the pipeline will cross a small remnant of an ancient landslide and a localized seepage area along the east slope of Powderhouse Canyon. Neither of these features are likely to impact project integrity or constructability.

2. **Section from Lookingglass to Reston.** At the Lookingglass Valley, bedrock is sandstone and siltstone of the Flournoy Formation and the residual soils are sandy clay and silty clay of low plasticity. Because of low resistance to erosion, the rocks in this region and the remainder of the route are at an increased slope gradient and the valleys are deeper. Both the CBWR and the power line sometimes follow hillsides. Slopes along the paved roadway and the BPA power line are typically less than 10 percent, although short sections exist where the slope is between 20 and 45 per-

cent. Soil thickness over rock is generally greater than five feet along both the CBWR and power line routes. The roadway is a full two lanes wide in this section of the project.

West of Lookingglass, as the pipeline joins the road, a hummocky area was noted on the south side of the road. At Reston, a short stretch of recent slumps were noted. Neither of these features are likely to impact project integrity or constructability, however, the slumps should be further investigated during final design and mitigated conventionally.

3. **Section from Reston to Sitkum.** West of Reston the CBWR enters hillier terrain, the most rugged along the proposed route. Bedrock is soft sandstone and siltstone of the Tyee Formation and is heavily eroded. Residual soils over the rock are either sandy or silty clay of low to moderate plasticity. Depth of soil along the steep hillside route of the BPA power line is generally more than five feet.

   Hillside slopes along the power line are typically greater than 20 percent and reach as much as 33 percent. Short stretches exist that are steeper. Ridges can be as much as 1,000 and more feet apart with 1,000 feet of elevation change from ridge top to valley bottom.

   The power line route crosses a small slump and a large hummocky area before descending to join the CBWR. At the junction of the power line right of way and the CBWR, the alignment passes longitudinally through an ancient landslide. None of these features are likely to affect project integrity or constructability, although landslide mitigation measures discussed more fully herein should be incorporated.

   The CBWR enters Brewster Canyon near the Coos County line. Between the Coos County line and Sitkum, the Brewster Valley route of the CBWR is in a deep valley created by the East Fork of the Coquille River. The roadway is unpaved and is at the bottom of a series of steep, nearly vertical, rock cliffs. The width of the roadway varies from one lane to barely two lanes and the width from cliff face to river drop-off is occasionally less than 30 feet. The road generally follows very close to the river which is typically at some depth below roadway level. The river bottom is exposed and appears to be unweathered rock. The depth of soil along the roadway is unknown but is probably less than five feet except, perhaps, at the edge away from the cliff face. The roadway generally is at a gentle grade and crosses the Coquille River twice over bridges. Sitkum is at the entrance to the Brummit Creek valley.

   Except for short sections where competent rock may be within three feet of surface, there are no features of geotechnical concern in the CBWR segment.

4. **Section from Sitkum to Dora.** This section of the CBWR also follows Brewster Canyon and the Tyee Formation, but is slightly less rugged. Roadway widths continue to be narrow and rock cliffs still form one side of the unpaved roadway. Soil depth along the roadway is still probably less than five feet. Slopes along the BPA power line remain steep, often reaching 26 percent to 28 percent, with long distances between ridge lines. Depth to fractured sandstone in the hillside soils is occasionally less than five feet.

   A geologic map [5] of the area indicates that there are small sections, each between 100 and 3,000 feet long, along either the CBWR or the East Fork of the Coquille River, that consist of landslide deposits of geologically recent (Holocene and Pleistocene epochs, i.e., within the past 1,600,000 years) age. These deposits are described as "fragments of bedrock mixed with gravel, sand, silt or clay." Observations of these "landslide" areas concluded that they are mainly characterized by more gentle slopes than the surrounding hills and large, over 15 feet wide, boulders scattered about. This is typical of the debris at the lower part of a slide in the soft sandstone and siltstone bedrock. The slides are ancient, as demonstrated by formation of the Coquille River floodplain at several areas at the bases of the slides and weathering of the exposed surface of the boulders. These slides appear to be stable and are not likely to impact project integrity or constructability.

5. **Section from Dora to McKinley and Fairview.** At Dora the CBWR and the BPA power line leave the valley of the East Fork of the Coquille River and Brewster Canyon and turn northwest. Bedrock is the Roseburg Formation consisting of sandstone and siltstone with localized, thin interbeds of basalt. The residual soils are a sandy or silty clay of low to moderate plasticity. Soil depths appear to be greater than five feet. The terrain is less rugged than along the Brewster Canyon segment, although hillside slopes along the BPA power line route can reach as much as 15 percent to 20 percent. The roadway becomes two-lane and paved at McKinley and remains paved to just beyond Fairview.

One mile west of Dora, an ancient landslide similar to that described above is located north of the CBWR. A recent rockfall was noted clear of the route, south of the CBWR about 1.1 miles northwest of McKinley. Neither of these features are likely to impact project integrity or constructability.

6. **Section from Fairview to Sumner.** At Fairview, the pipeline continues along the CBWR, which is unpaved for several miles but is at least two lanes wide. The terrain continues to be more gentle than that to the east, with hillside slopes ranging from 5 percent to 12 percent. Short sections of steeper topography exist. Soil depths are expected to be greater than five feet.

   There are no features of geotechnical concern which would impact project constructability or integrity in this segment.

7. **Section from Sumner to near Coos Bay.** After passing South Slough Road, the BPA power line and the proposed pipeline route leave the CBWR and continue along the Coos-Sumner Road, finally reaching and crossing Isthmus Slough and U. S. Highway 101. West of the highway the BPA power line turns north to the end of the proposed pipeline near Coos Bay. Bedrock is Coaledo Formation sandstone and siltstone and continues to be less rugged, with much more gentle slopes.

   There are no features of geotechnical concern which would impact project constructability or integrity in this segment, although the horizontal bore beneath Isthmus Slough will require typical scrutiny during final design.

POTENTIAL CONSTRUCTION PROBLEMS

There are no particularly unusual or difficult construction problems anticipated for the proposed pipeline project. Soils over most of the route will be deep enough and firm enough to stand open without bracing the three to four foot deep trench necessary for construction and will not be below the groundwater level, except at isolated locations. Where the pipeline is located within the roadway, short sections may be encountered where depth to competent rock is less than five feet. We anticipate, however, that most of these areas can be excavated to a satisfactory depth using a high energy track hoe.

Final design is expected to be typical for the size, type and location of the proposed project. Of normal concern are;

1. **Sideslope Construction.** Along several locations, the BPA power line was constructed on relatively steep sideslopes, illustrated by Figure A-2. Since pipeline construction equipment will require a reasonably level working space of 25 to 30 feet wide, as much as 60 feet in width will be required to allow excavation and leveling of the work area. Except for minor impacts on schedule, this feature does not present unusual complexity.
2. **Steepness of Slopes.** The heavily eroded ridge and valley ground surface along the route from Reston to Dora has resulted in very steep slopes with large elevation differences between the ridge top and valley bottom. Steep slopes reaching, and occasionally exceeding, 20 percent grade exist along the sections of the pipeline originally proposed to be placed in the BPA power line right-of-way. This is illustrated in Figure A-3.

Figure A-2. View of BPA powerline on steep hillside at Mile 10 on CBW Road.

Figure A-3. Rise of BPA powerline up steep 20 percent slope at Mile 13 on CBW Road

Figure A-4. View along Brewster Canyon at Mile 21 on CBW Road. Left side of road leads down at steep angle to the East Fork of the Coquille River

Figure A-5: View Along Brewster Canyon on CBW Road.

3. **Shallow Depth to Rock.** At a few locations along the Coos Bay Wagon Road, especially in Brewster Canyon, the depth to rock along the centerline of the roadway may require isolated use of air tools to achieve the desired three feet of cover. Sections of the CBWR that may have rock very close to the roadway surface are illustrated in Figure 3 and 4 and are more fully delineated in Table A-1. Since depth of competent rock has not been verified by field test, inferred instead from the appearance of rock along the side of the road at roadway level and from the probable method of construction used during the 1870's, locations determined to be especially problematic or to pose unacceptable budgetary uncertainty should be explored using an auger drill during design.

   Considering the recent experience gained during construction of a separate underground utility project, for which a trencher was used with little difficulty to excavate a three to four feet deep trench, we anticipate that rock excavation requirements will not be unusually difficult.

4. **Rock in Coquille River.** At two locations in Brewster Canyon, the CBWR crosses the East Fork of the Coquille River. At both locations the exposed river bottom is composed of apparently unweathered sandstone-siltstone bedrock. We recommend that these two crossings be accomplished by either direct excavation and burial or by suspending the pipeline from the two existing bridge structures, since directional drilling will be very difficult.

Discussion of Potential Geologic Hazards

The steel, continuously welded and buried pipeline is similar to a long elastic string and can sustain some general lateral and/or vertical movement or direct tension. The potential causes of rupture of the pipeline along the proposed route are either shearing movement of the supporting soil, in which there is an abrupt lateral and/or vertical displacement of soil and pipeline, or a tensile failure resulting from the pipeline being "stretched" as it resists a sliding soil mass. Shear or tensile forces are most likely to result from landslides.

Seismic Activity

Earthquake shaking of the ground causes general ground movement but does not normally cause surface shearing movements. The principal source of earthquake induced shear displacement at the surface is landslides, which can be triggered by a seismic acceleration of the soil mass.

The probability of an earthquake-induced landslide resulting in shearing of the pipeline is dependent on earthquake recurrence interval. As noted in preceding sections of this report, the principal seismic concern is a CSZ event originating along a line about 40 to 50 miles off the coast of Oregon, resulting in lateral accelerations between 0.2 and 0.4 g. Although the probability of a CSZ event occurring during the design life of the project is highly speculative, if one does occur, it is more probable than not that landslides will result. Accordingly, mitigation of potential landslide impacts should be incorporated into the design.

Moisture Induced Landslides

Moisture induced landslides is deemed no more likely along the proposed route than in any other route that would logically serve the project. Considering the high ductility of the pipe material and the considerable tensile strength of the completed pipeline, along with the probable size of conceivable instabilities, we believe that landslide induced failure of the pipeline is of low probability.

Although landslide induced failure of the pipeline is of low probability, several past instabilities were noted during project reconnaissance, as more fully described in the preceding Route Reconnaissance Observations. Mitigation measures are recommended subsequently herein.

The effect of recent timbering clear cuts on the inducement or probability of landslides along the route cannot be assessed adequately with the limited information available for this study. Generally, however, we anticipate that timber activities will have no impact on stability of the pipeline.

Erosion

The potential for erosion exists along the pipeline alignment at virtually any of the stream crossings. Considering the very short sections of pipe at most crossings, along with the pipe's ductility, few of the crossings should require special attention during design. At most locations, if permit conditions allow, we recommend that the pipeline should be buried beneath the stream bottom using conventional excavation instead of boring.

Several of the crossings under more substantial streams should be bored. Preliminarily, the recommended boring locations include;

- Brummit Creek
- Cherry Creek
- Middle Creek
- North Fork of the Coquille
- Isthmus Slough
- Blossom Gulch Creek

MITIGATION

The proposed project is of average or less complexity. There is little risk of impact to constructability or integrity due to geotechnical considerations. Seismically induced impacts are of low probability. To the extent that short term pipeline integrity is compromised by any of the hazards noted herein, however, mitigation is recommended. All potential impacts, regardless of probability or source can best be mitigated by installation of automatic or remotely controlled valves at strategic locations.

Although the final location, type and special features, if any, of the valves are best addressed during final design, we recommend that automatic or remote control valves be considered at the following locations;

- Williams sub-station connection
- east side of Douglas County Road 52
- Reston
- Dora
- Isthmus Slough at Ross Slough Road

RECOMMENDATIONS FOR FUTURE WORK

As a result of this reconnaissance level study, we are satisfied that no additional geotechnical work is necessary for the current phase. During final design, a number of other efforts, including site specific geotechnical exploration, will be beneficial.

REPORT LIMITATIONS

Exclusivity of Report. This report has been prepared for the exclusive use of the Coos County Board of Commissioners and Coquille, Oregon, and/or their designees for specific application to the proposed Coos Bay Natural Gas Pipeline, Coos-Douglas Counties, Oregon. No other use is authorized without the written permission of Pinnacle Engineering, Inc., Roseburg, Oregon.

Report Limited to Scopes of Service. The observations and conclusions described in this report are based solely on the scope of service described in and implemented pursuant to the Agreement of August 27, 2000, between Biological Information Specialists, Camas Valley, Oregon, and Dr. S. Joseph Spigolon, P.E. as supplemented by contract dated October 17, 2001, between Pinnacle Engineering, Inc. and Coos County, Oregon. Neither Spigolon nor Pinnacle have performed any observation, investigation, study or testing that is not specifically listed in the scope of service and, therefore, shall not be liable for failing to discover any condition whose discovery required the performance of services not authorized by the Agreement.

Conceptual-level Study. The visual reconnaissance and evaluative approaches used in this limited, preliminary study are believed to be consistent with those normally used in geotechnical engineering practice for preparation of environmental documents. The scope of our effort was intentionally less than that required for design purposes, but is deemed are sufficient for developing preliminary design guidelines. When design concepts have been better defined, soil/rock sampling and testing, and additional evaluation should be considered for use in final design.

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
0.0	0.0	William's Northwest Pipeline; start of Coos County pipeline. Enter Section 28.	Dark brown clay; high plasticity; residuum derived from basalt bedrock; depth to rock < 5 ft. No evidence of soil creep - trees are vertical. Road is paved in Douglas County.	Pacificorp transmission line. Same as CBW Road; average 10 percent slopes.
	1.2	Powderhouse Canyon.	Same as above.	Same as above; slopes about 6 percent.
1.9		Basalt rock quarry.	Rock at or very near road surface. Slopes about 6 percent.	
	1.7	Tributary of Marsters Creek.		Black clay; alluvium from weathered basalt; high plasticity; depth > 5 ft.
3.0	2.8	Slope down to enter Lookingglass Valley.	Gray brown gravelly silty clay; moderate plasticity; alluvium from sandstone; flat; depth > 5 ft.	Same as CBW Road; slopes average 10 percent.
3.2	3.1	Tributary of Lookingglass Creek; in valley.	Brown sandy clay; moderate to high plasticity; mixed alluvium; flat; depth > 5 ft.	Same as CBW Road; flat grade; depth > 5 ft.
	3.6	Tributary of Lookingglass Creek; in valley.	Brown clay; moderate plasticity; alluvium; flat; depth > 5 ft.	Same as CBW Road; flat grade; depth > 5 ft.
4.5	3.9	Downtown Lookingglass; intersection of Lookingglass Road and CBW Road; CBW Road turns west; enter Sec. 35.	Brown clay; moderate to high plasticity; mixed alluvium; flat; depth > 5 ft.	Same as CBW Road; flat grade; depth > 5 ft.
4.6 to 5.1	4.0 to 4.5	Three tributaries of Lookingglass Creek; valley.	Brown clay; moderate to high plasticity; mixed alluvium; flat; depth > 5 ft.	Same as CBW Road; flat grade; depth > 5 ft.
5.9	5.4	Power line crosses road; substation.	Brown silty clay; moderate to high plasticity; colluvium; road in hillside several feet above floodplain level; depth > 5 ft.	Same as CBW Road; on hillside above roadway; depth > 5 ft.
				(Sheet 1 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
7.2	6.6	Power line goes up and down hills. Minor gullies.	Brown silty clay; moderate to high plasticity; colluvium; road starts vertical curves; several rock outcrops at side of road; depth > 5 ft.	Same as CBW Road. On hillside above roadway; depth > 5 ft.
8.2	7.5	Cross Rock Creek.	Gravelly sand; alluvium; non-plastic; depth > 5 ft.	Same as CBW Road.
8.3	7.6	Power line crosses road.	Brown gravelly silty clay; residuum from siltstone; moderate plasticity; no rocks showing in road cuts; depth > 5 ft.	Same as CBW Road.
8.6		Tributary of Rock Creek.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock = 5 ft.	
8.7	8.0	Reston substation; start BPA power lines.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock 5 ft.	Brown gravelly sand; alluvium of Flournoy Valley; non-plastic; depth > 5 ft.
	8.8	Tributary of Rock Creek.		Dk. brown clay; alluvium; high plasticity; depth > 5 ft.
10.2		Rock Creek.	Gravelly sandy clay; colluvium from sandstone; none to low plasticity; depth > 5 ft.	Ridge and steep valley terrain; 12 percent slope.
	10.1	Rock Creek.	Sandstone showing in steep road cut on south side of CBW Road.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock = 5 ft.
12.0	11.1	Hillside; downgrade toward Reston.	Sandstone-siltstone rock in road cuts on side of roadway.	Hillsides reach 10 percent grade.
12.8	12.0	Intersection with Reston Road. Substation.	Sandy clay; alluvium; depth > 5 ft.; hills; no rock.	Power line close to road; gentle.
13.8	12.8	Power line crosses road. Tenmile Creek crossing.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock = 5 ft.	Same as CBW Road; 8 percent grade.
	13.2	Tributary of Tenmile Creek.	Pass Iverson County Park; curvy road.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock = 5 ft.

(Sheet 2 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
15.0	13.8	Power line crosses road. Roadway very curvy.	Dk. red silty clay; residuum from siltstone; hillside; moderate plasticity; depth to rock = 5 ft.	Same as CBW Road.
15.1	13.9	Steep hill.	Same as above; road grade reaches 15 percent.	Same as CBW Road; slopes reach 18 percent to 20 percent.
17.5 & 17.9		Cross East Fork of Coquille River.	Brown sandy clay; low plasticity; colluvium and residuum over sandstone; depth > 5 ft.	Gravelly sandy clay; colluvium from sandstone; depth = 3 - 4 ft. over fractured sandstone; slopes of 10 percent to 22 percent.
18.1	15.3	Tributary of Coquille River.	Brown sandy clay; low plasticity; colluvium and residuum over sandstone; depth > 5 ft.	Same as CBW Road; slopes range 14 percent to 18 percent.
19.0	16.3	Coos County Line; road is no longer paved. Enter Brewster Canyon.	Same as above; steep canyon wall on north side; depth to rock is shallow.	Same as CBW Road; slopes range from 27 percent to 32 percent in crossing East Fork of Coquille River.
19.5	16.6	Cross Knapper Creek.	Soil in roadway unknown; narrow roadway - about 15 - 20 ft. wide; steep side wall; exposed rock to road bed; depth to rock is very shallow; East Fork of Coquille River on south side.	Brown sandy clay; low plasticity; colluvium and residuum over sandstone; depth > 5 ft.
20.1		Milepost 35.	Same as above	Same as above
21.1	17.7	Power line crosses road.	Same as above; small slide in road south toward river; sandstone in the vertical, north-side wall.	Sandy clay; colluvium and residuum from sandstone; low plasticity; soil depth = 3 to 6 ft.
22.4	18.8	Cross small stream.	Same as above, except no slide; about 30 ft. above river and steep slope to river.	Same as above.
23.0	19.5	Milepost 32. Bridge; cross East Fork of Coquille River.	Sandstone-siltstone rock exposed in river bottom and river banks; no soil.	Same as above.
23.5		Lost Creek enters river from the north.	Soil in roadway unknown; narrow roadway - about 15 - 20 ft. wide; steep side wall; exposed rock to road bed; depth to rock is very shallow; East Fork of Coquille River on north side.	Same as above; slopes reach 27 percent to 33 percent.

(Sheet 3 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
24.3	20.1 & 20.3	Tributary to Coquille River.	Same as above.	Same as above; rock depth is < 3 ft.
25.2		Dead Horse Creek enters river from north.	Same as above.	Same as above.
25.5	20.9 & 21.4	Tributary to Coquille River.	Same as above.	Same as above.
25.7		Bridge; cross East Fork of Coquille River.	Same as above. River on south side of road.	Same as above.
26.7		Hamilton County Park	Same as above.	Same as above. Rock depth varies.
27.5	22.8	Cross Camas Creek; roadway paved.	Enter broad valley. Road on hillside; sandy clay and fine sand; alluvium; low plasticity; depth > 5 ft.	Same as above.
	23.3	Enter Brewster Valley.	Same as above.	Enter broad valley. Sandy clay and fine sand; alluvium; low plasticity; depth > 5 ft.
29.4		Cross Brummit Creek. Enter Sitkum.	Sandy clay and fine sand; alluvium; low plasticity; depth > 5 ft.; road at base of hill, 10 ft. above plain.	Same as above.
	25.4	Cross Coquille River.	Brown silty clay; hillside; residuum from siltstone; depth to rock varies from 4 ft. and more.	Same as above.
31.5	26.1	Road re-enters Brewster Canyon.	Same as above; one lane road; hillside; depth > 5 ft.	Same as above.
32.9	27.6	Milepost 22.	Gravelly sandy clay; colluvium derived from sandstone; rock in road cut at road level; depth to rock about 3 ft. in hillside.	Same as CBW Road.
34.1	28.5	Tributary of Coquille River.	Soil in roadway unknown; narrow roadway - about 15 - 20 ft. wide; steep side wall; exposed rock to road bed; depth to rock is very shallow. East Fork of Coquille River on south side.	Brown silty clay; residuum and colluvium derived from sandstone; slopes reach 26 percent to 28 percent; soil depth > 5 ft.

(Sheet 4 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
34.9	30.2	Enter broad Flood-plains at Dora.	Brown fine sandy clay; mixed alluvium; soil depth > 5 ft.	Same as CBW Road.
37.2	32.3	Pass Frona County Park; Power line cross road.	Brown silty clay; hillside; resid-uum from siltstone; depth to rock > 5 ft.	Same as CBW Road; slopes reach 15 percent to 20.
39.2	33.1	Road crosses Cherry Creek and Cherry Creek Road; power line crosses upper reach of E. F. Coquille River.	Brown silty clay; mixed alluvium; soil depth > 5 ft.	Brown gravelly sandy clay; residuum from sandstone; depth to fractured rock < 5 ft.
40.2	34.1	Power line crosses road.	Brown silty clay; mixed alluvium; soil depth > 5 ft.	Same as CBW Road. Power line in hillside; sandy clay from sandstone; low plasticity; depth > 5 ft.
41.5	35.0	Power line crosses road; road crosses Middle Creek.	Brown silty clay; mixed alluvium; soil depth > 5 ft.	Same as CBW Road. Power line starts up steep hill with 15 percent to 19 percent slope.
41.5 to 44.3	35.0 to 37.5	Hilly terrain.	Brown silty clay; hillside; resid-uum from siltstone; depth to rock > 5 ft. Slopes reach 8 percent to 10 percent.	Same as CBW Road. Slopes reach 15 percent to 20 percent.
44.3	37.5	Power line crosses road. Steep hill down to Bolton Prairie.	Dk. red silty clay; residuum from siltstone; hillside; moderate plas-ticity (PI = 20-30); depth to rock = 5 ft. Slope about 11 percent.	Same as CBW Road. Slope about 11 percent.
45.4	38.0	Cross bridge; North Fork of Coquille River.	Brown silty clay; mixed alluvium; low plasticity; depth > 5 ft.	Same as CBW Road.
45.7	38.3	Cross Fairview Road; enter Fairview; power line crosses road.	Same as above.	Same as above.
46.0		Rejoin CBW Road, parallel Evans Creek on right.	Dark brown silty clay; mixed, alluvium; low plasticity; organic; slopes 3 percent; depth to rock. 5 ft.	
46.1		Continue northwest-erly parallel Evans Creek.	Dark gray silty clay; mixed allu-vium; moderate plasticity; slopes < 8 percent; depth to rock > 5 ft.	
				(Sheet 5 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
46.4		Continue parallel to Evans Creek.	Dark brown silty clay; mixed alluvium; low plasticity; organic; slopes < 3 percent; depth to rock > 5 ft.; some areas more organic.	
46.5		Begin parallel to. Steinman Creek	Dark gray silty clay; mixed alluvium; moderate plasticity; slopes < 8 percent; depth to rock > 5 ft.	
46.6		Continue parallel to Steinman Creek.	Reddish brown organic silty clay; mixed colluvium; slopes 3 to 30 percent; generally non-plastic; depth to rock > 5 ft.	
47.0		Continue parallel to Steinman Creek.	Dark gray silty clay; mixed alluvium; moderate plasticity; slopes < 8 percent; depth to rock > 5 ft.	
47.5		Pass confluence of west fork of Steinman Creek parallel west fork.	Reddish brown organic silty clay; mixed colluvium; slopes 3 to 30 percent; generally non-plastic; depth to rock > 5 ft.	
48.1		Leave west fork of Steinman Creek, begin climbing to north.	Reddish brown organic silty clay; occasional mixed alluvium; slopes 3 to 30 percent (occasional 30 to 50 percent); generally non-plastic; depth to rock > 5 ft.	
48.4		Continue	Reddish brown organic silty clay; mixed colluvium, becoming dark red clay; moderately plastic; depth to rock > 5 ft.	
48.5		Continue	Reddish brown organic silty clay; mixed colluvium; slopes 3 to 30 percent; generally non-plastic; depth to rock > 5 ft.	
48.8 to 49.0		Continue	Reddish brown organic silty clay; mixed colluvium, becoming dark red clay; moderately plastic; depth to rock > 5 ft. Occasional rock < 5 ft.	

(Sheet 6 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
49.0 to 50.3		Parallel Wilson Creek. Joins from S. side of road.	Gray brown sandy clay; heavy organic, well drained; non-plastic; slopes 30 to 60 percent; depth to rock > 5 ft.	
50.7		Pass Panther Creek and Caldwell Creek.	Dark gray brown silty clay; heavy organic; alluvial; non-plastic; slopes < 3 percent; depth to rock > 5 ft.	
50.9			Dark brown silty clay; heavy organic content; low plasticity; slopes 3 to 7 percent; depth to rock > 5 ft.	
51.3			Dark gray brown silty clay; heavy organic; alluvial; non-plastic; slopes < 3 percent; depth to rock > 5 ft. occasional clayey silt; organic; low plasticity; occasional depth to rock < 5 ft.	
51.4		Enter Sumner.	Dark brown to yellowish brown organic silty clay overlying sandy gravel; non-plastic; slopes < 8 percent; depth to rock > 5 ft.	
51.5 to 516		Cross Catching Creek.	Dark gray brown silty clay; heavy organic; alluvial; non-plastic; slopes < 3 percent; depth to rock > 5 ft. with occasional silty loam; non-plastic; depth to rock > 5 ft.	
52.1		Cross Slough Road Intersection.	Dark grayish brown silty clay; heavy organic; low plasticity; slopes < 3 percent; depth to rock > 5 ft.	
52.3		Head of Wilson Creek.	Dark reddish brown silty clay; heavy organic; non-plastic; slopes 50 to 75 percent; depth to rock > 5 ft.	
52.4			Dark reddish brown silty clay overflying occasional shallow weathered bedrock (< 5 ft.); low plasticity; slopes 30 to 50 percent.	
				(Sheet 7 of 8)

Table A-1. Survey of Foundation Soil and Rock, Coos County Natural Gas Pipeline

CBW Road miles	Power line miles (approx.)	Route Features	CBW Road Soils/Rock and Comments	BPA Power line Soils/Rock and Comments
52.6			Dark reddish brown silty clay; heavy organic; non-plastic; slopes 50 to 75 percent; depth to rock > 5 ft.	
52.7			Dark reddish brown silt; heavy organics; generally low plasticity; slopes 12 to 30 percent; depth to weathered rock = 5 ft.	
52.7		Cross Cardwell Creek; CBW Road pavement starts.	Same as above.	Same as CBW Road.
53.5		Sumner.	Brown silty clay; mixed alluvium; soil depth > 5 ft.	
55.2	46.3	Power line crosses road.	Brown silty clay; residuum from sandstone; low plasticity; slopes range 5 percent to 12 percent.	Same as CBW Road.
56.7	47.8	Cross Ross Slough Road.	Same as above.	Same as above.
57.7	48.1	Cross Isthmus Slough.	Gravelly sandy clay; alluvium; depth > 5 ft.	Same as at left.
57.8	48.2	Cross Hwy 101.	Same as above.	Same as at left.
	49.5	Cross Shinglehouse. Slough.		Brown silty clay; residuum from sandstone; low plasticity; slopes < 5 percent.
	60.1	Reach Coos Bay area. End of Coos County Natural Gas Pipeline.	Same as above until reach Coos Bay area; then enter sandy clay alluvium of Coalbank Slough.	
				(Sheet 8 of 8)

LIST OF REFERENCES

1. Orr, E. L. and Orr, W. N. (1999). Geology of Oregon, Fifth Edition, Kendall/Hunt Publishing Co., Dubuque, Iowa.

2. Haagen, J. T. (1989). Soil Survey of Coos County, Oregon, USDA Soil Conservation Service (renamed Natural Resources Conservation Service), Portland, Oregon.

3. Alt, D. D. and Hyndman, D. W. (1978). Roadside Geology of Oregon, Mountain Press Publishing Co., Missoula, Montana.

4. Black, G. L. (1990). "Geologic Map of the Reston Quadrangle, Douglas County, Oregon," Geological Map Series GMS-68, Oregon Department of Geology and Mineral Resources, Portland.

5. Wiley, T. J. (1995). "Reconnaissance Geologic Map of the Dora and Sitkum Quadrangles, Coos County, Oregon," Geological Map Series GMS-98, Oregon Department of Geology and Mineral Resources, Portland.

6. Baldwin, E.M. and Beaulieu, J. D. (1973). "Geology and Mineral Resources of Coos County, Oregon," Bulletin 80, Oregon Department of Geology and Mineral Industries. Portland.

7. Goodman, R. E. (1993). Engineering Geology, John Wiley and Sons, New York.

8. Spigolon, S. J. (1993). "Geotechnical Site Investigation Strategy for Dredging Projects," Report 2 of "Geotechnical Factors in the Dredgeability of Sediments." Contract Report DRP-93-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, October.

9. Terzaghi, K., Peck, R. B., and Mesri, G. (1996). Soil Mechanics in Engineering Practice, Third Edition, John Wiley & Sons, New York.

10. Sowers, G. F. (1979). Introductory Soil Mechanics and Foundations.- Geotechnical Engineering, Fourth edition, Macmillan Publishing, New York.

11. Douglas County Area Office of the Natural Resources Conservation Service. Unpublished soil survey data sheets, Roseburg, Oregon.

12. Deere, D. U. and Patton, F. D. (1971). "Slope Stability in Residual Soils." Fourth Pan-American Conference on Soil Mechanics and Foundation Engineering, American Society of Civil Engineers, New York.

13. Madin, I. P. and Mabey, M. A. (1996). "Earthquake Hazard Maps for Oregon," Geological Map Series GMS-100, Oregon Department of Geology and Mineral Resources. Portland.

14. Building Codes Structures Board, State of Oregon. (1998). "Seismic Zonation for the Oregon Coast." Final Report to the State of Oregon Building Codes Structures Board, Salem, Oregon. February 12.

15. Johnson, A.G., Scofield, D.H., and Madin, I. P. (1994). "Earthquake Database for Oregon, 1833 through October 25, 1993." Open File Report OFR 94-04, Oregon Department of Geology and Mineral Industries, Portland.

16. Jacobson, R. S. (1986). "Map of Oregon Seismicity, 1841-1986," Geological Map Series GMS-49, Oregon Department of Geology and Mineral Resources, Portland.

17. Madin, I. P. and Mabey, M. A. (1996). "Earthquake Hazard Maps for Oregon," Geological Map Series GMS-100, Oregon Department of Geology and Mineral Resources, Portland.

18. Peterson, C. D., Barnett, E. T., Briggs, G. C., Carver, G. A.,. Clague, J. J., and Darienzo, M. E. (1997). "Estimates of Coastal Subsidence from Great Earthquakes in the Cascadia Subduction Zone, Vancouver Island. B.C. Washington, Oregon. and Northernmost California," Open File Report 0-97-5, Oregon Department of Geology and Mineral Resources, Portland.

19. Wang, Y. (1998). "Earthquake Damage and Loss Estimate for 0regon," Open File Report O-98-3, Oregon Department of Geology and Mineral Resources, Portland.

20. Transportation Research Board, National Research Council. (1996). "Landslides - Investigation and Mitigation.", National Academy Press, Washington, D.C.

21. Spigolon, S. Joseph, Ph D., Route Reconnaissance and Construction Recommendations for the Coos County Natural Gas Pipeline Project Coos and Douglas Counties, Oregon, February, 2001.

22. Madin, I. P. and Wang, Z. (1999. "Relative Earthquake Hazard Maps for selected urban areas in western Oregon," Geological Map Series IMS- 9, Oregon Department of Geology and Mineral Resources, Portland.

Numbers in brackets [ ] refer to documents included in the List of References at the end of this report