3. TOPOGRAPHY, GEOLOGY, AND SOILS

This chapter identifies topography, geology, and soils expected to be encountered during construction and operation of the approximately 80-mile proposed rail line through largely undeveloped areas in the Tanana River valley. This chapter describes the applicable regulations, existing environmental conditions, and potential environmental consequences related to topography, geology, and soils in the project area. This chapter also addresses permafrost and seismic hazards.

The proposed Northern Rail Extension (NRE) lies primarily in a western section of a broad depression between the Yukon-Tanana Uplands and the Alaska Range known as the Tanana Lowlands. Coalescing outwash fans from the Alaska Range are featured in the lowlands with rivers flowing in broad, terraced valleys near the heads of the fans, which can be up to several hundred feet deep. Glacial moraines lie on the upper end of some fans (Wahrhaftig, 1965). Thermokarst lakes are well developed on the terraces and the low-lying areas away from the heads of the fans. The Delta and Tanana Rivers are two major rivers that drain the province (U.S. Geological Survey [USGS], 2007).

The foothills of the Alaska Range south of the project area consist of a belt of flat-topped, east-trending hills that are separated by lowlands composed of moraines or outwash fans deposited by the glaciers from the Alaska Range. The hills are largely unglaciated. Thermokarst lakes develop in the lowlands. Delta River, Delta Creek, and Little Delta River are three glacier-fed streams that drain the Alaska Range into the Tanana River. The Alaska Range south of the project area is characterized by rugged glaciated terrain, with peaks over 12,000 feet. Landforms associated with alpine glaciers are common, including cirques, U-shaped valleys, moraines, outwash fans, and alluvial fans.

Immediately north of the project area, the Yukon-Tanana Uplands rise up to 2,000 feet above adjacent valley floors. Rounded, even-topped, unglaciated ridges with gentle side slopes and valley floors up to a half-mile wide are common.

3.1 Applicable Regulations

The Farmland Protection Policy Act (FPPA) was enacted in 1981 in reaction to the substantial decrease in the amount of open farmland resulting from high conversion rates in the late 1970s. The FPPA's statement of purpose states that Federal programs that contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses will be minimized. The Act addresses prime, unique, and farmland of statewide or local importance (7 U.S.C. 4201(c)(1)(A), (B), and (C)).

There are no prime farmlands in Alaska because soil temperatures do not meet the prime farmland threshold established by Congress. No unique farmlands have been designated in Alaska. No farmlands of statewide importance have been designated in Alaska.

3.2 Topography

3.2.1 Affected Environment

Many northern sections of the Tanana River are bordered by the Yukon-Tanana Uplands. The uplands north of the river can rise up to 700 feet above the elevation of the river. Along the project route, hills rise in elevation from 580 feet above sea level near Eielson Air Force Base

(AFB) to 1,200 feet above sea level at Delta Junction. The Tanana River is bordered to the south by the Tanana Lowlands and little elevation change occurs south of the river.

3.2.2 Environmental Consequences

Methodology

The objective of topographic analysis is to identify areas of the proposed rail line where modifications to the current topography would be required for the rail line to meet design goals. Track geometry and design objectives for the proposed NRE are maintenance of grades no greater than 1 percent, based on Federal Railroad Association (FRA) Class 5 track standards (49 CFR Part 213). Spatial analysis of topography was completed using the 25-foot contours identified by Alaska Railroad Corporation (ARRC) through analysis of 2005 site imagery with digital elevation modeling software. Contours were converted to a 500-foot raster grid using a Geographic Information System (GIS) and ArcGIS Spatial Analyst (software tool designed to manipulate and analyze raster data). Slope was then calculated for the grid and a slope layer was created for visual analysis. Because the geometric design goals include grades limited to 1 percent, visual analysis of the slope layer identified areas along the alignment with slopes greater than 1 percent. Distances between the 25-foot contours for each route alignment segment were estimated using ArcGIS to calculate the slope of each particular segment. See Table 3-1 and Figure 3-1. Chapter 20 of the EIS described proposed mitigation for impacts to topography.

Construction Impacts

The proposed approximately 80-mile rail line would generally follow the Tanana River from North Pole to Delta Junction, predominantly on the southwestern side of the river. Track geometry and design objectives to support proposed passenger services and reduce long-term maintenance costs use geometric design criteria that would allow FRA Class 5 track standards to be easily maintained. Geometric design goals include grades limited to 1 percent. Where these design criteria could not be met, grading and filling that would alter the natural topography would be required.

Most of the rail line alternative segments avoid sudden topographic changes, such as hills or knobs, in the vicinity of the alternative segments.

Table 3-1
Slope Analysis of Route Alignment

Route Segment	Percent Slope	Linear Feet Affected
North Common Segment	*No slope contours greater than 1%*	
Eielson Alternative Segment 1	*No slope contours greater than 1%*	
Eielson Alternative Segment 2	*No slope contours greater than 1%*	
Eielson Alternative Segment 3[a]	*No slope contours greater than 1%*	
Salcha Alternative Segment 1[a]	*No slope contours greater than 1%*	
Salcha Alternative Segment 2	5	500
	17.5 average	600
	5	500
	12.5 average	1,000
	6.3 average	1,500
Central Segments 1 and 2 Central Connector Segments	*No slope contours greater than 1%*	

Table 3-1
Slope Analysis of Route Alignment (continued)

Route Segment	Percent Slope	Linear Feet Affected
Donnelly Alternative Segment 1[a]	4	650
	2	1,500
	2.5	1,000
	2.5	1,000
	2.5	1,000
	2	2,500
Donnelly Alternative Segment 2	2	1,500
	2	2,500
	2.5	1,000
	7.5 average	1,000
	2	1,500
South Common Segment	*No slope contours greater than 1%*	
Delta Alternative Segment 1[a]	4 average	1,750
Delta Alternative Segment 2	*No slope contours greater than 1%*	

[a] Components of the proposed action.

Construction Impacts by Alternative Segment

The paragraphs below describe the topographical analysis for each alternative segment listed in Table 3-1 with slope contours greater than 1 percent.

Salcha Alternative Segment 2

Salcha Alternative Segment 2 runs adjacent to three knobs or hills. There are areas along these sections with slopes greater than 1 percent (see Table 3-1 and Figure 3-1), which would require grading and fill to meet the design objectives.

Donnelly Alternative Segment 1

Donnelly Alternative Segment 1 does not encounter knobs or hills; however, the route would traverse several areas with slopes greater than 1 percent (see Table 3-1 and Figure 3-1), which would require grading and fill to meet the design objectives.

Donnelly Alternative Segment 2

Donnelly Alternative Segment 2 does not encounter knobs or hills; however, the route would traverse several areas with slopes greater than 1 percent (see Table 3-1 and Figure 3-1), which would require grading and fill to meet design objectives.

Delta Alternative Segment 1

Delta Alternative Segment 1 does not encounter knobs or hills; however, the route would traverse one area of topography with a slope greater than 1 percent (see Table 3-1 and Figure 3-1), which would require grading and fill to meet the design objectives.

Operations Impacts

Operation and maintenance of the 80-mile rail line would not have an impact on topography.

No-Action Alternative

The only impact on topography under the No-Action Alternative would be from natural processes.

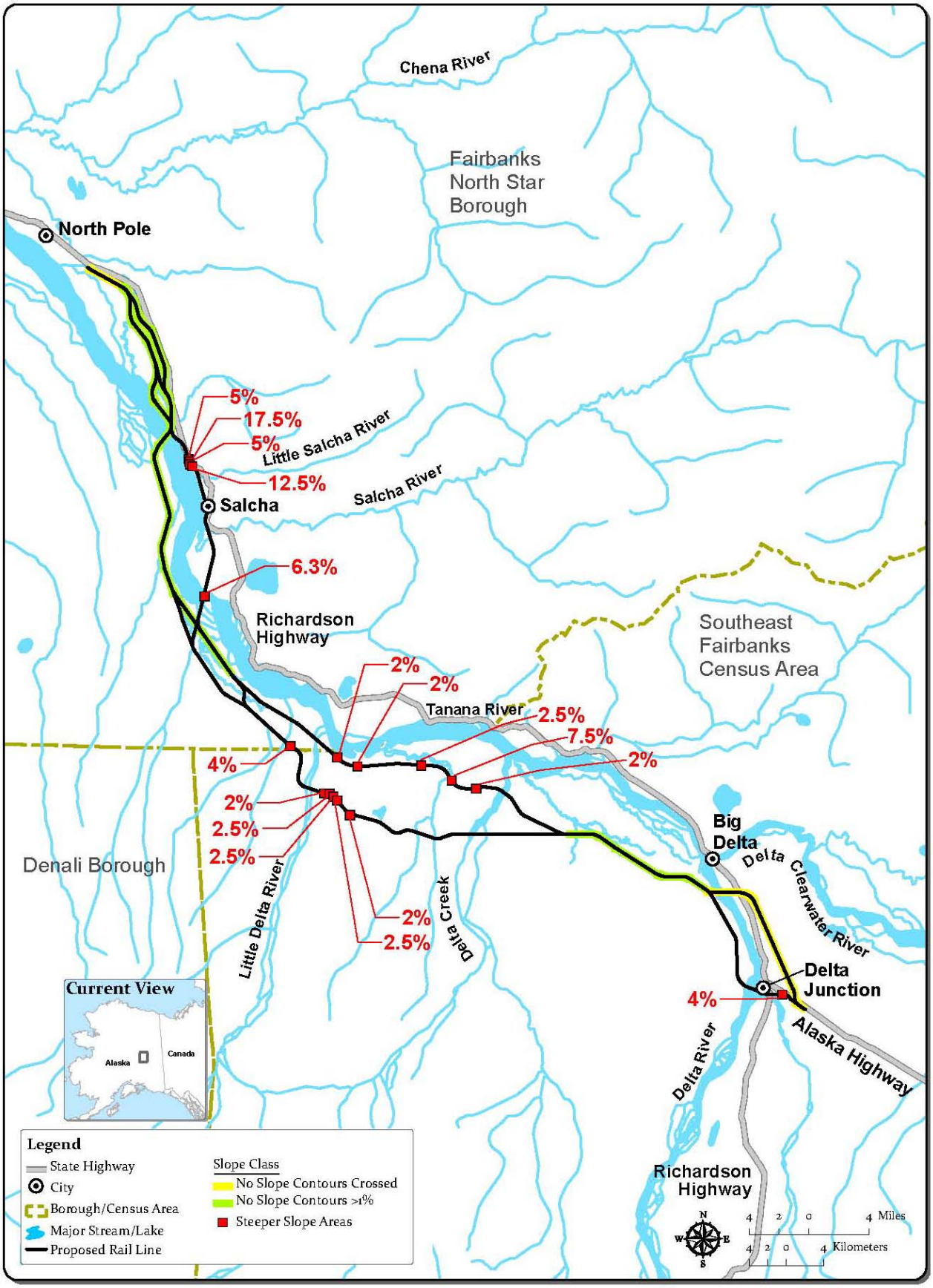

Figure 3-1 – Slope Classes

3.3 Geology

3.3.1 Affected Environment

Four types of bedrock have been identified along the proposed rail line. The four rock types and their value for use in rail line construction are as follows (Miller, 2007):

- **Rd** – dioritic igneous rock from the Flag Hill area. This relatively massive rock could be suitable for riprap and ballast.
- **Rg** – gneissic rock, occasionally interbedded with or incorporated into the large schistose deposits. This harder rock could provide a source of ballast, but the dominant bedding and parting planes would probably preclude its use as armor stone.
- **Rq** – locally, quartzite layers interbedded with the schist deposits. This material crushes well but is very limited in volume. Crushed quartzite is often used as rail line ballast.
- **Rs** – schistose rock, the most common rock type in the project area. Because of thin bedding and moderate to severe weathering, it is generally suitable for use only as unclassified fill.

3.3.2 Environmental Consequences

Methodology

The objective of geology analysis is to identify areas of the proposed rail line where bedrock needs to be removed to construct the rail line or service roads, and where nearby bedrock units could be mined for construction material. The areas of rail alternative segments that potentially encounter bedrock are identified in the project geotechnical report (Miller, 2007).

This analysis of environmental consequences briefly describes common impacts and then identifies site-specific impacts in more detail as applicable. Chapter 20 of the EIS describes proposed mitigation for impacts to geology.

Common Impacts

Throughout most of the project area, bedrock is not exposed at the surface and there would be no impacts on geology.

Construction Impacts

Construction-related impacts on geology would occur in two situations — where bedrock needs to be removed to construct the rail line or service roads, and where nearby bedrock units would be mined for construction material. These situations specific to each alternative segment are listed separately below.

Construction Impacts by Alternative Segment

Salcha Alternative Segment 2

Salcha Alternative Segment 2 would encounter schistose units at approximately mile 2.5, mile 12, and mile 21 (and approximately 0.25 north of the rail line at mile 16). Diorite, a massive igneous rock, was identified along Salcha Alternative Segment 2 at approximately mile 21 (Flag

Hill). This unit is a potential source of ballast rock. During construction, it might be necessary to remove bedrock along Salcha Alternative Segment 2 to maintain the grade of the rail line.

Donnelly Alternative Segment 2

Donnelly Alternative Segment 2 would pass through or be adjacent to a schistose-gneissic unit at approximately mile 23. During construction, it might be necessary to remove bedrock along Donnelly Alternative Segment 2 to maintain the grade of the rail line.

Other Segments/Alternatives

There would be no construction-related impact on geology for alternative segments that do not pass through bedrock deposits. These include the North Common Segment, Eielson Alternative Segment 1, Eielson Alternative Segment 2, Eielson Alternative Segment 3, Salcha Alternative Segment 1, Central Alternative Segments 1 and 2, Central Connector Segments A through E, Donnelly Alternative Segment 1, South Common Segment and Delta Alternative Segment 1 discussed above.

Operations Impacts

Because of the generally resilient characteristics of bedrock geology, the impact on geology as a result of rail operations and maintenance would be negligible.

No-Action Alternative

The only impact on geology under the No-Action Alternative would be from natural processes.

3.4 Soils

3.4.1 Affected Environment

Soil units along the proposed rail line were identified during a 2006 geophysical investigation (Miller, 2007). Table 3-2 lists and describes the soil units.

Table 3-2
Mapped Soil Series in Project Area

Soil Unit	Description
Aa	Active floodplain deposits. Gray stratified gravel, sand and silt, often with cobbles and boulders
Ab	Abandoned floodplain deposits. Similar material to active floodplains, except more likely to be frozen with a thick silt cover
Ac	Active channel deposits. Gray stratified gravel, sand and silt, often with cobbles and boulders
Af	Alluvial fan deposits. Gray to brown stratified material that accumulates from draining streams
Afw	Alluvial fan Wisconsin Age. Outwash deposits from most recent (Wisconsin Age) glacial retreat
Afi	Alluvial fan Illinoisan Age. Outwash deposits from Healy and Donnelly (late Illinoisan Age) glacial retreat
Aft	Alluvial fan torrent. Deposits from torrential stream flow and rapid melt associated with end of Healy glaciation
Cu	Reworked loess and undifferentiated frozen silt. Dark brown organic rich silt from colluvial mixing
EL	Loess. Light brown eolian (windblown) silt
Es	Dune sand. Light brown eolian sand

Table 3-2
Mapped Soil Series in Project Area (continued)

Soil Unit	Description
G	Glacial deposits. Yellowish gray to brown moraine deposits
Gw	Glacial Wisconsin. Glacial deposits from Wisconsin glaciation
Gi	Glacial Illinoisan. Glacial deposits from Illinoisan glaciations
O	Glacial outwash deposits. Outwash laid down by melt water from retreating glaciers
Ow	Outwash Wisconsin. Outwash deposits from Wisconsin glaciation
Oi	Outwash Illinoisan. Outwash deposits from Illinoisan glaciation
S	Swamp deposits. Dark brown to black peat and organic silt more than four feet deep and poorly drained

In general, the soil units closer to the Tanana River have depositional origins related to the river or its tributaries. The units farther from the river were commonly deposited by glaciation or other alluvial processes. The units are sometimes intermixed and might overlie each other.

3.4.2 Environmental Consequences

Methodology

The general engineering properties of each soil unit were considered in the context of the proposed project to identify impacts to soils and constraints presented by soil engineering properties.

This analysis of environmental consequences briefly reviews common impacts and then identifies site-specific impacts in more detail as applicable. Chapter 20 of the EIS describes proposed mitigation for impacts to soil.

Construction Impacts

Impacts on soil during rail line construction would mostly be associated with excavation and fill of soils to maintain the grade of the railbed or with removal of unsuitable construction material. The existing soil profile would be eliminated in areas subject to excavation or filling. In addition, some soil units with high sand and gravel content could be suitable for use as borrow material to construct the railbed. Active floodplain deposits are the most likely source of borrow material along the rail line (Miller, 2007). Use of these deposits as borrow material would require Federal and state permits. Therefore, availability of these deposits for borrow areas could be limited by regulations. Soils would also be affected by the construction of service roads. Like the railbed, some sections of service roads could be in areas unsuitable to support a road. In these cases, the unsuitable soil would be removed and replaced with gravel from another source. In a few locations along the proposed rail line, a proposed segment could encounter hills or slopes where soils would need to be cut away, potentially affecting the stability of the slope. Table 3-1 and Figure 3-1 list and show these locations specific to each alternative segment.

Construction Impacts by Alternative Segment

North Common Segment

North Common Segment would traverse active floodplain deposits (Aa). This segment would not encounter significant hills or slopes.

Eielson Alternative Segments 1, 2, and 3

Eielson Alternative Segment 1, Eielson Alternative Segment 2, and Eielson Alternative Segment 3 would traverse active floodplain deposits (Aa). These segments would not encounter significant hills or slopes.

Salcha Alternative Segment 1

Salcha Alternative Segment 1 would traverse active floodplain deposits (Aa) and active channel deposits (Ac). This segment would not encounter significant hills or slopes.

Salcha Alternative Segment 2

The soils Salcha Alternative Segment 2 would traverse include active floodplain deposits (Aa), abandoned floodplain deposits (Ab), and loess (El). Abandoned floodplains could also provide borrow material, but overburden depths are generally greater than active floodplain deposits and abandoned floodplains are more likely to be frozen (Miller, 2007). This segment would encounter several areas of slope where excavation of soils would be required to accomplish design grades.

Central Segment 1

Central Segment 1 would traverse abandoned floodplains deposits (Ab) and alluvial fan deposits (Afw). This segment would not encounter significant hills or slopes.

Central Segment 2

Central Segment 2 would traverse active floodplain deposits (Aa). This segment would not encounter significant hills or slopes.

Connector Segments A through E

Connector Segments A through E would traverse active floodplain deposits (Aa). These segments would not encounter significant hills or slopes.

Donnelly Alternative Segment 1

Donnelly Alternative Segment 1 would traverse dune sand (Es), active floodplain deposits (Aa), abandoned floodplain deposits (Ab), active channel deposits (Ac), glacial outwash of Wisconsin age (Ow), glacial outwash of Illinoisan age (Oi), and alluvial fan deposits (Af). Active channel deposits are also a potential source of borrow material, but permitting concerns could limit availability (Miller, 2007). This segment would encounter several areas of slope where excavation of soils would be required to accomplish design grades.

Donnelly Alternative Segment 2

Donnelly Alternative Segment 2 would traverse active floodplain deposits (Aa), abandoned floodplain deposits (Ab), active channel deposits (Ac), reworked loess, and undifferentiated frozen silt (Cu), loess, and glacial outwash of both Wisconsin age (Ow) and Illinoisan age (Oi). This segment would encounter several areas of slope where excavation of soils would be required to accomplish design grades.

South Common Segment

South Common Segment would traverse glacial outwash of Illinoisan age (Oi) and dune sand (Es). This segment would not encounter significant hills or slopes.

Delta Alternative Segment 1

Delta Alternative Segment 1 would traverse dune sands (Es), active floodplain deposits, abandoned floodplain deposits (Ab), active channel deposits (Ac), and glacial outwash of Illinoisan age (Oi). This segment would encounter several areas of slope where excavation of soils would be required to accomplish design grades.

Delta Alternative Segment 2

Delta Alternative Segment 2 would traverse dune sands (Es), abandoned floodplain deposits (Ab), active channel deposits (Ac), and glacial outwash of Illinoisan age (Oi). This segment would not encounter significant hills or slopes.

Operations Impacts

Impacts on soils during rail line operations and maintenance would include excavation of soils from borrow sites used for maintenance of the railbed and service roads. Also, use of service roads during maintenance would cause dust and other fine-grained sediments to become airborne and deposited downwind of the road.

No-Action Alternative

The only impact on soils under the No-Action Alternative would be from natural processes.

3.5 Permafrost

3.5.1 Affected Environment

Permafrost is defined as soil, silt, and rock that remain frozen year-round. It is characterized as a thermal condition in which the temperature of the ground remains below 32 degrees Fahrenheit (°F) (0 degrees Celsius [°C]) for 2 or more years. Areas underlain by permafrost are classified as belonging to either the continuous zone or the discontinuous zone. Continuous permafrost refers to areas that have a constant layer of permafrost. Discontinuous permafrost occurs in patches. Discontinuous permafrost exists at various depths throughout the project alignment, ranging from less than 1.6 to more than 66 feet to its upper surface, with the base commonly ranging from as little as 39 to more than 148 feet below the ground surface (Williams, 1970).

Permafrost is a major factor influencing human activities and the distribution of flora in Alaska. Permafrost is an important contributor to soil processes including cryoturbation, rapid runoff, subsidence, and restriction to drainage. Cryoturbation is the mixing of soil by freezing and thawing, resulting in broken soil horizons. Runoff occurs on slopes with permafrost because the frozen ground prevents water infiltration. Subsidence of the ground surface can occur if permafrost melts. The impermeable surface of the permafrost table can create a barrier to water flow and often causes permafrost to remain very wet or saturated during the summer season.

The presence and maintenance of permafrost depends strongly on climate and disturbance activities. The weather stations at Fairbanks and Big Delta both show a warming trend since the 1940s. The recorded increase in the mean annual seasonal temperature is between 5 °F and 7 °F per 100 years for the two stations.

3.5.2 Environmental Consequences

Methodology

Permafrost along the proposed rail line was analyzed through soil borings and collecting core samples during the geotechnical investigation. The results indicate that permafrost is present throughout the project area, but its distribution varies depending on soil type, moisture content, slope aspect, surface cover, and other factors. Where permafrost was encountered, the depth of thaw was generally less than 2 feet below ground surface. Slightly deeper thaw was found at some locations with drier soil conditions (Miller, 2007).

Table 3-3 lists the amount of permanently frozen ground expected to be present in each mapped soil unit as a percentage. The range of thickness of overburden (organic silt and silt overlying a soil unit) is also tabulated. Overburden is the primary source of thaw settlement if the permafrost thaws (Miller, 2007).

Table 3-3
Estimated Permafrost Percentages and Overburden Thickness[a]

Soil Unit	Percent Frozen	Overburden in Feet		
		Minimum	Most Common	Maximum
Aa	25	2.0	5.0	10.0
Ab	75	2.5	7.0	12.0
Ac	5	0.0	2.0	4.0
Af	90	3.0	14.0	26.0
Cu	85	4.0	12.0	30.0
EL	15	2.0	6.0	15.0
Es	50	0.5	3.0	5.0
Gw	80	1.0	3.0	8.0
Oi	85	0.5	4.0	10.0
Ow	75	0.0	4.0	8.0
S	5	4.0	8.0	12.0

[a] Source: Miller, 2007.

This analysis of environmental consequences reviews common impacts briefly, and then identifies segment-specific impacts in more detail as applicable. Chapter 20 describes proposed mitigation for impacts to permafrost.

Construction Impacts

Construction-related impacts on permafrost potentially include any removal of surface vegetation for construction of the railbed and service roads, construction of the railbed embankment, and excavation of sources that contain permafrost.

Any activity that removes the insulating vegetation mat above the permafrost layer allows the ice mass to melt and irregular subsidence to occur. Thermokarst is the process and range of features that form from irregular subsidence. These features can include hummocks and mounds, water-filled depressions, flooded forests, mudflows on sloping ground, or other land forms. The thawing process is difficult to control, and after it has begun, thermokarst features persist (Berger and Iams, 1996).

As a standard rail line construction practice, the railbed would be built above grade. Construction of an embankment would reduce the surface albedo (reflectance of solar energy) and increase the ground surface temperature in the summer. This would result in a deeper thaw depth. For a gravel embankment 5 feet thick, the depth of thaw would extend into the frozen soils below the natural depth of thaw. Under the shoulders of the embankment, the depth of thaw would be even greater. If the soils are thaw-unstable (high silt content), the embankment and its shoulders would settle. If railbed construction occurred on permafrost with a high potential for subsidence, the rate of thaw could be slowed by the use of insulating mats and gravel embankments of appropriate thickness to keep frozen substrates frozen, and therefore able to bear loads.

Specific construction methods that would be employed in areas of permafrost would depend highly on site conditions. Minor shifts of the alignment to avoid or minimize impacts to permafrost could be possible in some areas. In other areas, the depth and thickness of the permafrost layer might allow total excavation down to unfrozen substrate and backfilling with gravel. Above-grade insulating mats or gravel embankments could also be utilized in areas where the required above-grade embankment thickness would not conflict with rail grade requirements.

The known permafrost characteristics specific to each alternative segment are listed separately below and in Table 3-4. Additional detailed analysis of permafrost characteristics would be conducted prior to construction to determine appropriate construction methods designed to minimize permafrost thaw and subsidence.

Table 3-4
Estimated Permafrost Percentages and Overburden Thickness for Alternative Segments[a]

	Permafrost (based on soil unit characteristics)	
Alternative Segment	**Percentage of Frozen Ground**	**Depth (in feet) of Overburden (ice content)**
North Common Segment	25	5
Eielson Alternative Segment 1	25	5
Eielson Alternative Segment 2	25	5
Eielson Alternative Segment 3[b]	25	5
Salcha Alternative Segment 1[b]	5 to 25	2 to 5
Salcha Alternative Segment 2	5 to 75	2 to 7
Central Alternative Segment 1	75 to 90	7 to 14
Central Alternative Segment 2	25	5
Central Connector Alternative Segments A through E	25	5
Donnelly Alternative Segment 1[b]	5 to 90	2 to14
Donnelly Alternative Segment 2	4 to 12	4 to 12
South Common Segment	50 to 85	3 to 4
Delta Alternative Segment 1[b]	5 to 85	3 to 7
Delta Alternative Segment 2	5 to 85	2 to 7

[a] Source: Miller, 2007.
[b] Components of the proposed action.

Construction Impacts by Alternative Segment

North Common Segment

North Common Segment would be wholly within an active floodplain. On average, the active floodplain is likely to contain 25 percent permafrost and, where permafrost exists, 5 feet unfrozen overburden.

Eielson Alternative Segments 1, 2, and 3

Eielson Alternative Segments 1, 2, and 3 would be wholly contained within an active floodplain (Aa, 25 percent permafrost and 5 feet overburden). The eastern section of Eielson Alternative Segment 1 would approach the active channel deposits of the Tanana River, where permafrost percentage and overburden would decrease.

Salcha Alternative Segment 1

Salcha Alternative Segment 1 would immediately cross the active channel deposits (Ac, 5 percent permafrost and an average of 2 feet overburden) of the Tanana River. Salcha Alternative Segment 1 would then continue east within the active floodplain (Aa, 25 percent permafrost and 5 feet overburden) south of the river.

Salcha Alternative Segment 2

Salcha Alternative Segment 2 would cross active floodplains (Aa, 25 percent permafrost and 5 feet average overburden), active channel deposits (Ac, 5 percent permafrost and 2 feet overburden), and abandoned floodplain deposits (Ab, 75 percent permafrost and 7 feet overburden). The segment would also cross the corner of a loess deposit, characterized by permafrost at 15 percent and overburden of 6 feet.

Central Alternative Segment 1

Central Alternative Segment 1 would cross abandoned floodplain deposits (Ab, 75 percent permafrost and 7 feet overburden), and alluvial fan deposits (Afw, 90 percent permafrost and 14 feet overburden).

Central Alternative Segment 2

Central Alternative Segment 2 would be wholly contained within the active floodplain (Aa, 25 percent permafrost and 5 feet overburden) south of the Tanana River.

Connector Segments A through E

Central Connector Segments A through E would cross active floodplains (Aa, 25 percent permafrost and 5 feet overburden) south of the Tanana River. Connector A exhibits permafrost at a depth of approximately 1 foot to 2 feet below the soil surface (Miller, 2007).

Donnelly Alternative Segment 1

Donnelly Alternative Segment 1 would begin in the active floodplain south of the Tanana River, where it would break south and west through dune sand (Es, 50 percent permafrost and 3 feet average overburden), active floodplain (Aa), active channel deposit (Ac), and abandoned floodplain (Ab), until it crossed the Little Delta River. As Donnelly Alternative Segment 1 ran farther south of the Tanana river, it would traverse glacial outwash deposits of Illinoisan and Wisconsin age (Oi, 85 percent permafrost and 4 feet overburden; Ow, 75 percent permafrost and 4 feet overburden), then an alluvial fan deposit (Af, 90 percent permafrost and 14 feet overburden). Donnelly Alternative Segment 1 would cross more Wisconsin glacial outwash

before crossing Delta Creek and into Illinoisan glacial outwash, where the segment would meet Delta Alternative Segment 2 and form South Common Segment.

Donnelly Alternative Segment 2

Donnelly Alternative Segment 2 would be contained within the active and abandoned floodplains (Aa, Ab) of the Tanana River until it crossed the Little Delta River and traversed a deposit of reworked loess and undifferentiated frozen silt (Cu, 85 percent permafrost and 12 feet overburden) and Wisconsin age glacial outwash (Ow) before crossing Delta Creek into glacial outwash of Illinoisan age (Oi) and connecting with Donnelly Alternative Segment 1 to form the South Common Segment.

South Common Segment

South Common Segment would continue to traverse Illinoisan age glacial deposits (Oi, 85 percent permafrost and an average 4 feet overburden) west of the Tanana River. The segment would enter a sand dune unit (Es, 50 percent permafrost and 3 feet overburden) as it approached the Delta River and divided into Delta Alternative Segment 1 and Delta Alternative Segment 2.

Delta Alternative Segment 1

Delta Alternative Segment 1 would begin at the margin of the dune sand unit (Es, 50 percent permafrost and an average 3 feet overburden) before crossing into the abandoned floodplain (Ab, 75 percent permafrost and 7 feet overburden) of the Delta River. The segment would parallel the Delta River south until it cut east across a small active floodplain (Aa, 25 percent permafrost and 5 feet overburden) before crossing the river and its active floodplain deposits (Ac, 5 percent permafrost and 5 feet overburden). On the east side of the Delta River, the segment would cross an abandoned floodplain (Ab) before terminating in an Illinoisan age glacial outwash plain (Oi, 85 percent permafrost and 4 feet overburden).

Delta Alternative Segment 2

Delta Alternative Segment 2 would begin at the margin of the dune sand unit (Es, 50 percent permafrost and an average 3 feet overburden), then run east, crossing the thin, abandoned floodplain unit (Ab, 75 percent permafrost and 7 feet overburden) before crossing the Delta River and its active channel deposits (Ac, 5 percent permafrost and 2 feet overburden). On the east side of the river, the segment would traverse south across a glacial outwash deposit of Illinoisan age (Oi, 85 percent permafrost and 4 feet overburden) before terminating.

Operations Impacts

Operations impacts on permafrost would result from temperature changes in the sub-base related to compaction and friction produced by trains and other equipment utilized for rail line ROW maintenance. These operations impacts to permafrost would be expected to be nominal.

No-Action Alternative

The only impact on permafrost under the No-Action Alternative would be from natural processes.

3.6 Seismic Hazards

3.6.1 Affected Environment

Assessments of seismic potential, along with information on surface geology, can be used to determine the seismic hazard in a particular area and to design and build structures accordingly. A seismic hazard can be evaluated to estimate the probabilities that various levels of earthquake ground motion would be exceeded at a site in a period of time. The evaluation uses three inputs—seismic source, seismicity, and a ground motion attenuation function (a function of earthquake magnitude and distance) (U.S. Department of the Interior [USDOI], 2002).

The tectonic framework of Alaska is dominated by subduction of the Pacific plate underneath the North American plate. Stresses resulting from plate convergence are transmitted across great distances (more than 300 miles) into Interior Alaska, where the deformation causes substantial crustal seismicity. While some of the earthquakes in the project area are clearly associated with the large-scale, strike-slip fault systems of Denali in the south and Kaltag and Tintina in the north, most of the shocks are located in a zone of distributed shear deformation between the two fault systems. These earthquakes are aligned in three major north-northeast-trending zones, one of which (the Salcha seismic zone) crosses both Salcha Alternative Segment 1 and Salcha Alternative Segment 2 (Page *et al.*, 1991).

Little is known about geological structures that produce this broadly distributed seismicity. The area between the Tintina and Denali fault systems is occupied by the Yukon-Tanana terrain, an assemblage of Paleozoic and older metasedimentary, metavolcanic, and metaplutonic rocks that are multiply deformed and regionally metamorphosed (Foster *et al.*, 1994). These rocks are cut by a suite of Cenozoic northeast-striking lineaments and sinistral-slip faults. Several of these faults show evidence suggestive of late Cenozoic displacement. Suggestive, but not definitive, evidence from trenching studies and geomorphic features suggests late Pleistocene displacements (Page *et al.*, 1995; Hansen *et al.*, 2001).

The 1937 Salcha magnitude 7.3 earthquake was one of the largest ever recorded in Interior Alaska. Its epicenter was less than 10 miles from Salcha Alternative Segment 2.

3.6.2 Environmental Consequences

Methodology

Probabilistic seismic hazard maps of Alaska were prepared in 1999. An effort was begun in 2005 to revise and extend the previous maps, taking into account new and improved information about the earthquake hazard in the region and improvements in methodology. The most significant development since preparation of the 1999 maps was the occurrence of the November 3, 2002, Denali earthquake (Moment Magnitude 7.9), with the epicenter about 50 miles south of Donnelly Alternative Segment 1. Ground motion was felt most strongly north of the Alaska Range. This was the largest earthquake recorded in Interior Alaska (USGS Earthquake Hazards Program, 2006; Trans-Alaska Pipeline System [TAPS] Owners 2001). Because of the high seismic activity in the area, all segments in the project area could be affected by seismic events. Salcha Alternative Segment 1 and Salcha Alternative Segment 2 would cross the Salcha seismic zone, which increases the potential for impacts. Chapter 20 of the EIS describes proposed mitigation for impacts to the proposed rail line from seismic activity.

Common Impacts

Seismic impacts on the project area would likely be common to all the segments. Seismic impacts would be the same during rail line operations and maintenance, and proportionally less during construction, depending on when a seismic event occurred. The most likely impact on the rail line from seismic activity would be misalignment or damage to the tracks, railbed, or service roads. This could be caused by ground shaking, offset lateral movement or soil subsidence. Mass wasting events such as landslides, rockslides, or slump are possible impacts on Salcha Alternative Segment 2, which would within the Salcha seismic zone and pass through and adjacent to significant relief. If strong enough, ground shaking could also cause derailment of a train. Salcha Alternative Segment 1 and Salcha Alternative Segment 2 would cross the Salcha seismic zone, and would therefore have the potential for train derailment resulting from a seismic event.

Soil liquefaction that could result from earthquakes is an additional risk to the stability and integrity of the proposed rail line. Soil liquefaction describes the behavior of loose, saturated, unconsolidated soils that go from solid state to the heavy liquid as a consequence of increasing porewater pressures, decreasing in volume when subject to earthquake loading (Yould *et al.*, 2001). Subsidence and movement of subsurface deposits beneath the railbed could result. Liquefaction is most likely to occur in loose to moderate granular soils with poor drainage, such as silty sands or sands and gravels capped or containing seams of impermeable sediments. Deposits of sands and silts along riverbeds are known to be susceptible to liquefaction.

When the Trans-Alaska Pipeline was designed, the 800-mile route was divided into five seismic zones on the basis of the expected Richter magnitude of a design contingency earthquake in that zone. The division was based on the findings of a USGS study (Alyeska Pipeline Service Company [APSC], 2001). The proposed NRE falls within Zone B (pipeline Milepost 258 to 560), with an expected Richter magnitude of 7.5 (U.S. Department of the Interior [USDOI], 2002, Table 3.4-1).

No-Action Alternative

The only seismic impacts under the No-Action Alternative would be from natural processes.