Ambler Mining District Access

Geotechnical Memorandum

September 2011

AMBLER MINING DISTRICT ACCESS

GEOTECHNICAL MEMORANDUM

AKSAS 63812

Prepared for:

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1.0 INTRODUCTION

The Ambler Mining District Access project proposes to identify, design, and construct a transportation corridor from the Ambler mineral belt to either a port location on the west coast of Alaska or the surface transportation system in the Alaska Interior. The corridor is intended to provide surface transportation access to state lands and facilitate exploration and development of mineral resources along the Ambler mineral belt.

The South Flank of the Brooks Range contains extensive mineral resources. Limited exploration efforts since the 1950s have identified significant resources of copper and other base metals (Hawley and Vant, 2009). Exploration and development of these deposits has been economically and logistically curtailed by the lack of transportation infrastructure.

The project study area extends from the Ambler mineral belt south to Nenana and from the Dalton Highway to the west coast (Figure 1). Four potential routes have been identified from the Ambler mineral belt to the west coast of Alaska and four potential routes head east from the Ambler mineral belt to the Dalton Highway or the Alaska Railroad corridor (Figure 2).

1.1 Objectives

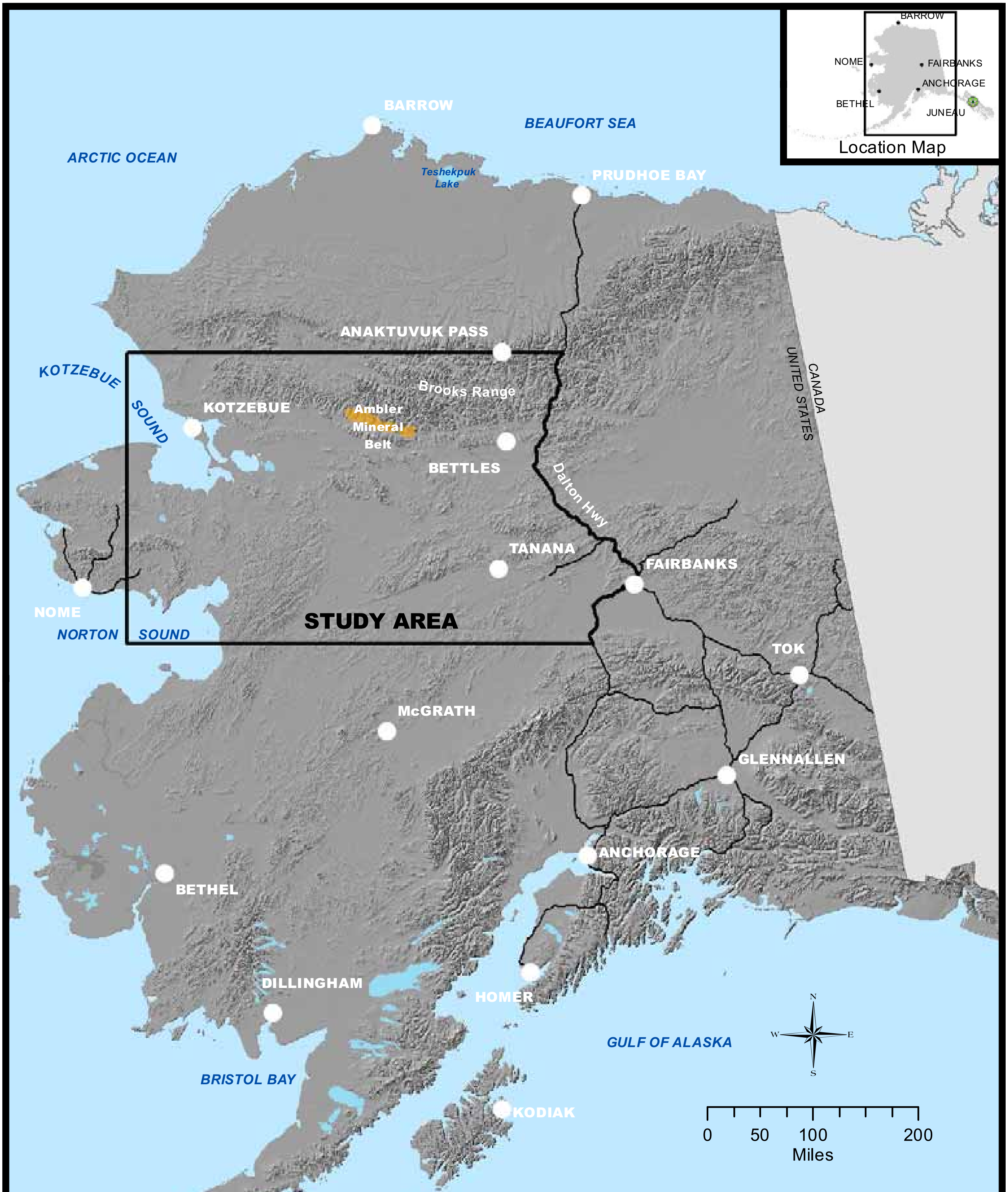
The design objective of this geologic study is to:

- Characterize the geology and geotechnical properties along each corridor to aid in selecting an optimum corridor for further study and eventual construction of a transportation system.

This geotechnical memorandum accomplishes these objectives by:

- Documenting the geologic characteristics that could affect transportation infrastructure design;
- Identifying geotechnical characteristics that will impact design elements; and
- Identifying borrow sites with the goal of one every 10 miles along the proposed corridors.

Development of this report included data collection from a variety of published sources, review, and evaluation of data collected, and identification of data gaps and proposed field studies.



Sources:
Cities: Alaska Department of Natural Resources (DNR)
Alaska Hillshade: DNR

Coordinate System: NAD 1983 Alaska Albers

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
NORTHERN REGION

AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

PROJECT LOCATION & VICINITY MAP

DATE: May 18, 2011 | **Figure 1**

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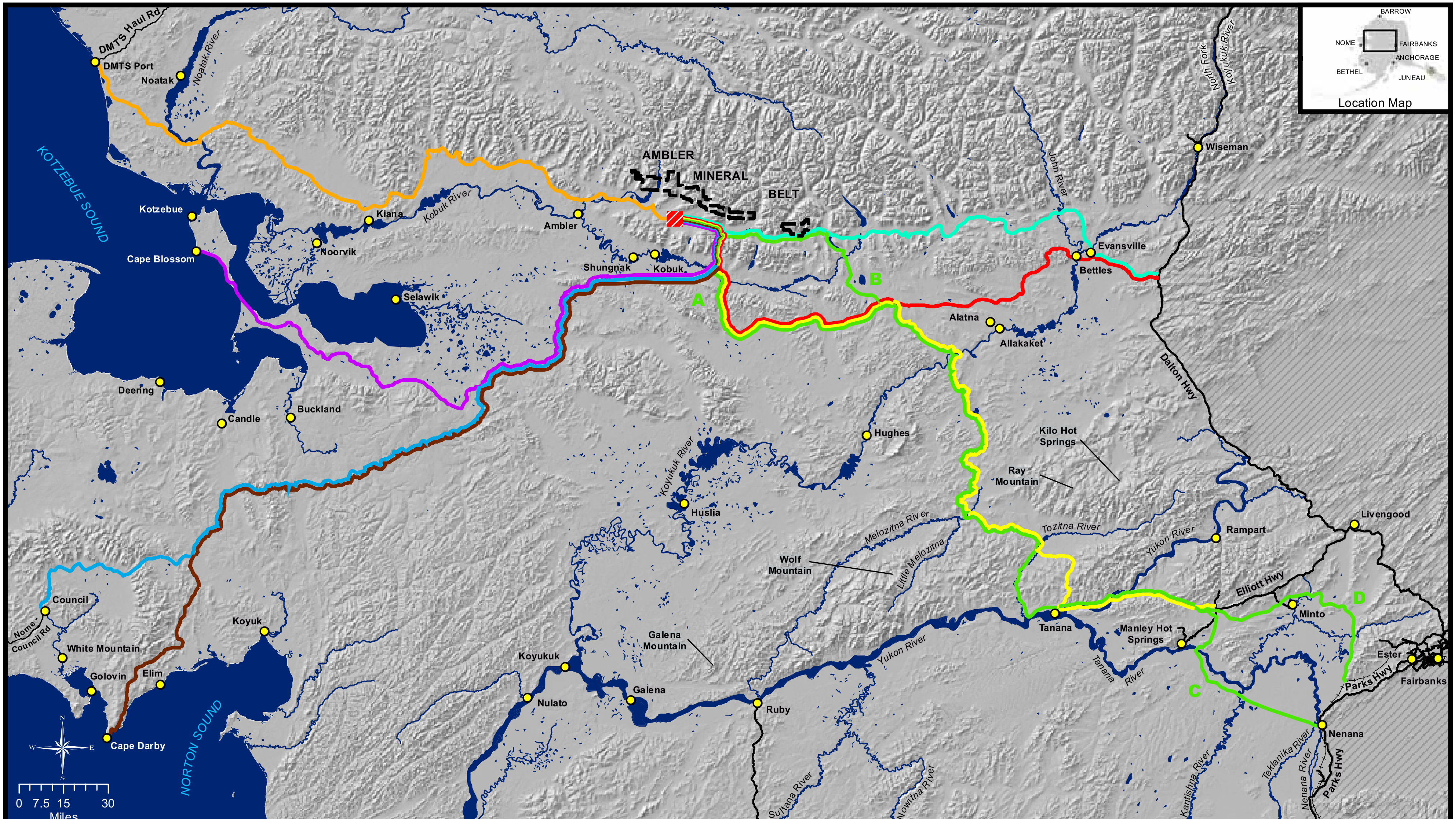

- Communities and Place Names
- Railroad
- Existing Roads
- Water
- Outside of Project Study Area
- Ambler Mineral Belt
- Proposed Staging Area
- 1-Brooks East Corridor 216 Miles (Road Only)
- 2-Kanuti Flats Corridor 241 Miles (Road Only)
- 5-DMTS Port Corridor 257 Miles (Road & Rail)
- 3-Elliott Hwy Corridor 365 Miles (Road Only)
- 4-Parks Hwy RR Corridor 420-450 Miles (Rail Only)
- 6-Cape Blossom Corridor 245 Miles (Road & Rail)
- 7-Selawik Flats Corridor 331 Miles (Road & Rail)
- 8-Cape Darby Corridor 340 Miles (Road & Rail)

Note: An end point in the approximate center of Ambler Mining District was used as the terminus for the corridors for calculating mileage.
Sources:
Commmunities and Place Names: DNR, DOT&PF
Existing Roads: DOT&PF
DMTS Haul Road: NANA
Railroad: DNR

Coordinate System: NAD 1983 Alaska Albers

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NORTHERN REGION

AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

PRELIMINARY CORRIDORS MAP

DATE: May 23, 2011 | **Figure 2**

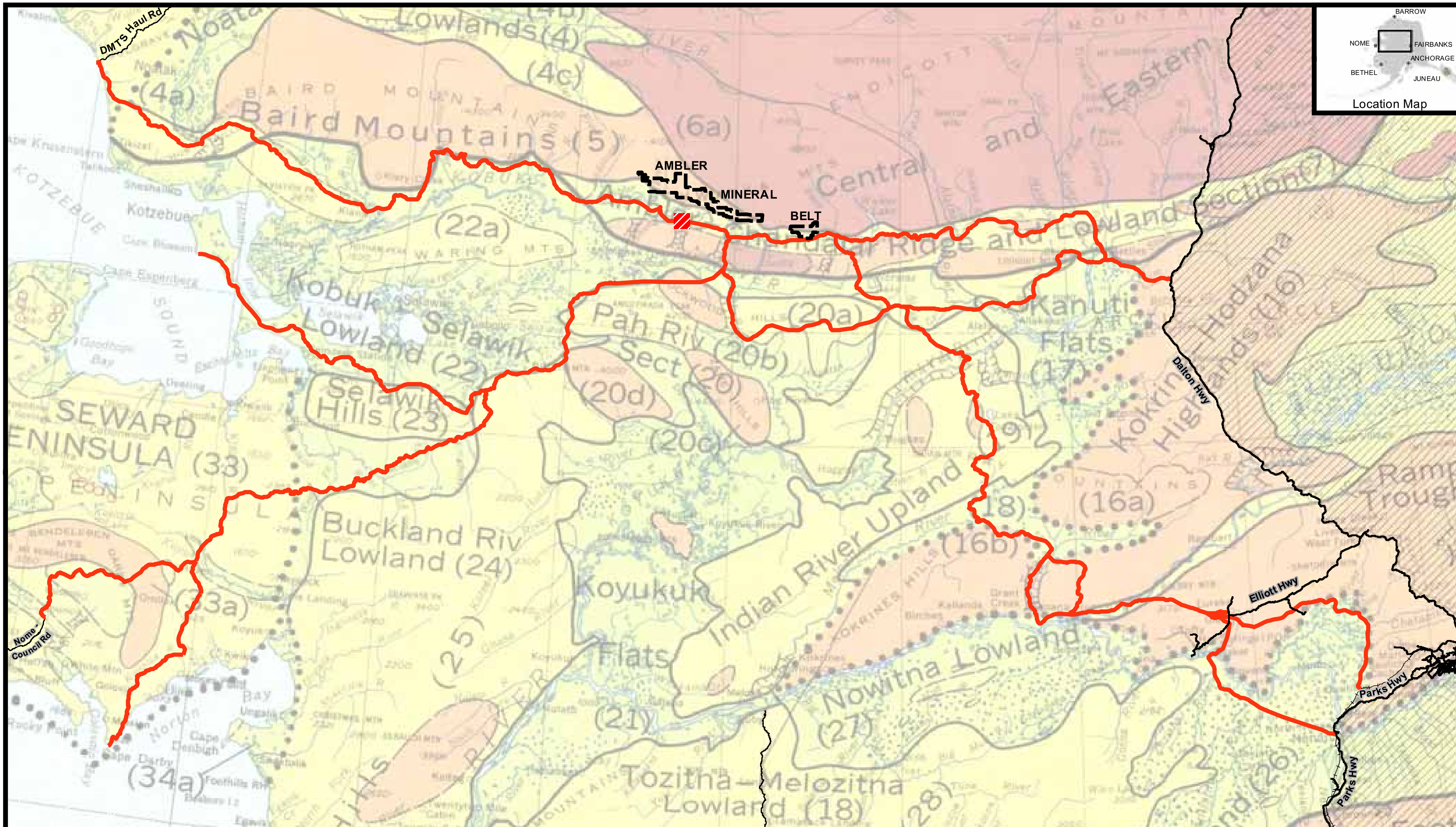
2.0 GEOLOGIC CHARACTERISTICS OF THE PROJECT STUDY AREA

The Ambler mineral belt is located in northwest central Alaska. This area is bounded by the Brooks Range to the north, the Yukon River to the south, the Dalton Highway to the east and the Seward Peninsula to the west. The project area can generally be separated into the following physiographic provinces: Arctic Mountains, Northern Plateaus, Western Alaska, and the Seward Peninsula (Figure 3). Generally, these physiographic provinces divide the state into distinct areas that are topographically and geologically homogenous (Wahrhaftig, 1965). Each physiographic sub-province is described in detail in U.S. Geological Survey (USGS) Paper 782, Physiographic Divisions of Alaska.

Arctic Mountains. This province includes the Baird Mountains, Delong Mountains, and the Ambler-Chandalar Ridge and Lowland Section. The region consists of glacier-carved mountains and hills of folded and faulted sedimentary rocks and their metamorphic equivalents. Valleys and lowlands between ranges are filled with alluvium and glacial drift. The entire region is underlain by permafrost.

Northern Plateaus. The Northern Plateaus province encompasses the Yukon-Tanana Upland, Rampart Trough, and Kokrine-Hodzana Highlands. This region is comprised of rolling hills covered with eolian deposits and V-shaped valleys filled with alluvial deposits; most of the region is underlain by permafrost.

Western Alaska. The Western Alaska province comprises the largest portion of the project study area. The general features of this province vary from rolling hills to lowlands dotted with thaw lakes and cut by meandering streams. The entire region is underlain by permafrost and includes the Kanuti Flats, Indian River Upland, Pah River Section, Kobuk-Selawik Lowland, Selawik Hills, and Buckland River Lowland.



Railroad
Existing Roads
Outside of Project Study Area
Ambler Mineral Belt
Proposed Staging Area
Preliminary Corridors

Sources:
Maps of Physiographic Divisions of Alaska: USGS 1960
PDF map was geo-referenced for the project area.

Coordinate System: NAD 1983 Alaska Albers

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AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

PHYSIOGRAPHIC PROVINCES MAP

DATE: May 23, 2011

Figure 3

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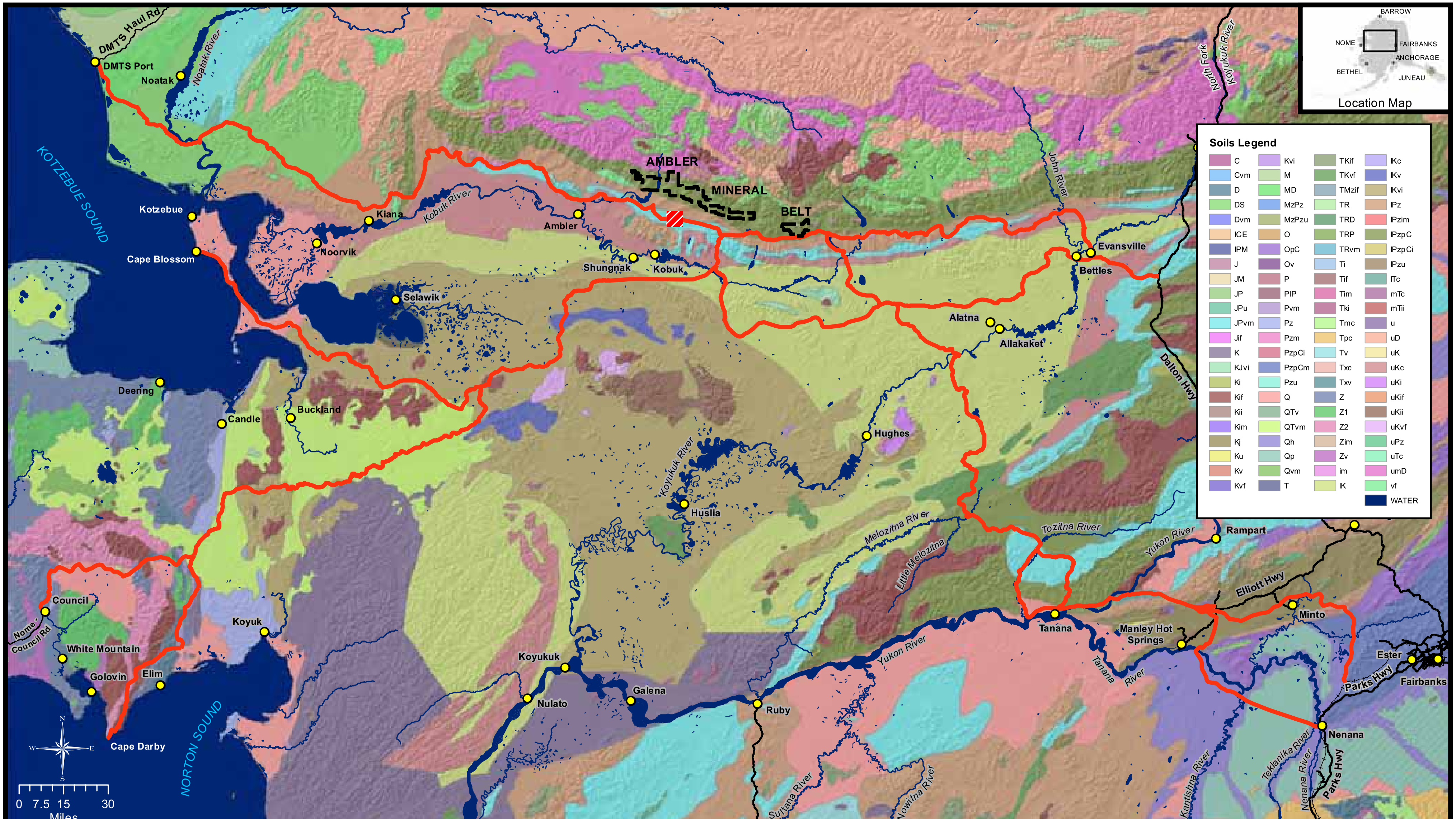
Seward Peninsula. The Seward Peninsula consists of significant uplands with craggy peaks and rolling hills surrounded by coastal lowlands and interior basins. Bedrock is exposed within the Darby and Bendeleben Mountains and is surrounded by upland eolian deposits and glacial drift with swampy soils within the basins and near major drainages, such as McCarthy's Marsh and the Koyuk River. The entire peninsula is underlain by permafrost.

General surficial geology conditions of the project study area are shown in Figure 4 (Karlstrom, et al., 1964). General geologic and geotechnical conditions anticipated along the proposed corridors are inferred from these general geologic conditions and topographic features within the project study area. This assessment is based on typical soil and rock properties associated with different geologic features, such as alluvial fans, floodplains, thaw lakes, and polygonal ground. The interpreted relationship between geologic features and engineering soil conditions is presented in Table 1 (adapted from the Public-Data File 85-42a by K. Krause, 1986).

3.0 GEOTECHNICAL DESIGN CONSIDERATIONS

Construction of a road or railroad across hundreds of miles of subarctic and arctic lands presents many geotechnical challenges. Soil types, thermal conditions, and topography can change dramatically over relatively short horizontal distances. Due to the structures required for numerous stream and river crossings, nearly every type of geotechnical analysis and design will need to be performed somewhere along the route. Table 1 lists geotechnical considerations for the various soil types and landforms that may be encountered along each of the potential corridors. The geotechnical considerations are based on typical properties of the soil types within each landform. Data adapted from PDF 85-42a was used to outline the typical geotechnical properties of the soils that would be likely be encountered along each of the corridors listed in Section 5.



Communities and Place Names
Railroad
Existing Roads
Water
Outside of Project Study Area
Ambler Mineral Belt
Proposed Staging Area
Preliminary Corridors

Sources:
Polygon Data from 1980 "Geologic Map of Alaska" compiled by H.M. Beikman and published by the US Geological Survey

Coordinate System: NAD 1983 Alaska Albers

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PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

GEOLOGIC MAP OF ALASKA
(by Beikman, 1980)

DATE: May 23, 2011

Figure 4

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Table 1: Interpreted Geological Characteristics Chart (Adapted From PDF 85-42a)

LANDFORM NAME	TOPOGRAPHY AND AREAL DISTRIBUTION	INTERPRETED ENGINEERING SOIL TYPES	SLOPE CLASS	DRAINAGE AND PERMEABILITY	EROSION POTENTIAL	GROUND-WATER TABLE	PERMAFROST DISTRIBUTION	FROST HEAVE POTENTIAL	THAW SETTLEMENT POTENTIAL	LIQUEFACTION POTENTIAL	BEARING STRENGTH	SLOPE STABILITY	SAND AND GRAVEL BORROW SOURCE POTENTIAL
all igneous, metamorphic (Bx), and sedimentary bedrock lithologies (Bx-w)	mountainous alpine areas, ridge tops and slopes, and bluffs along stream river cuts	not applicable	moderate to steep	not applicable	low	shallow to deep	not applicable	low	none to low	none to low	high to very high	moderate to high	none to poor
delta deposits (Fd) alluvial fan deposits (Ff)	where stream and rivers enter lakes and bays fan-shaped cones at the base of slopes where tributary streams enter a valley	GW and SW	gentle to moderate	good to high	low to moderate	shallow (Fd) to intermediate (Ff)	unfrozen (Fd) discontinuous to continuous (Ff)	low to moderate	low	high (Fd) low (Ff)	low (Fd) high (Ff)	low (Fd) high (Ff)	fair to good (fd) excellent (Ff)
flood-plain deposits (Fp)	stream and river valley bottoms and areas adjacent to channels	GW, GP, SW, SP, SM, ML	flat to gentle	poor to good	high	shallow	discontinuous to continuous	low in sand and gravel high in silt	usually low, but can be high	moderate to high	usually high, low in silts	high	good to excellent
braided flood-plain deposits (Fpb) braided flood-plain cover deposits (Fpb-c)	stream and river valley bottoms and areas adjacent to braided channels	GW, GP, SW, SP, SM, ML	flat to gentle	poor to good	high	shallow	discontinuous to continuous	low in sand and gravel high in silt	usually low, but can be high	moderate to high	usually high, low in silts	high	good to excellent
meander flood-plain deposits (Fpm) meander flood-plain cover deposits (Fpm-c)	stream and river valley bottoms and areas adjacent to meandering channels	GW, GP, SW, SP, SM, ML	flat to gentle	poor to good	moderate to high	shallow	discontinuous to continuous	low in sand and gravel high in silt	usually low, but can be high	moderate to high	usually high, low in silts	high	good to excellent
abandoned flood-plains terrace deposits old terrace deposits	flat, benchlike areas in stream and river valley bottoms, and flat areas adjacent to channels	GW, GP, SW, SP, SM, ML	flat to gentle	good to high	low to moderate	intermediate to shallow	usually continuous	low in sand and gravel high in silt	usually low, but can be high	low to moderate	usually high, low in silts	high	good to excellent
basin colluvium and slopewash deposits (Cbs)	at the base and on the flanks of gentle slopes and hillsides, allong low gradient piedmont slopes	surface is PT, upland tundra tussock vegetation underlain by GP, GM, SP, ML and MH	gentle to moderate	poor to moderate	moderate to high	shallow, usually frozen	usually continuous	high	high	moderate to high	low	low to moderate	poor
coarse colluvium (Cc)	found on steep upper slopes and on relatively flat upland surfaces	GW, GP, SW, SP, and angular frost-riven rock fragments	flat or steep	moderate to good	low on flat upland surface high on steep slopes	shallow	discontinuous to continuous	low to moderate	low	low	high	low to moderate	poor
gelisolifluction deposits (Cgs)	found as lobes, benches, and sheets on moderate to steep slopes	surface is PT, upland tundra tussock vegetation underlain by GP, GM, SP, ML and MH	moderate to steep	poor	high	shallow	continuous	high	high	high	low	low	poor

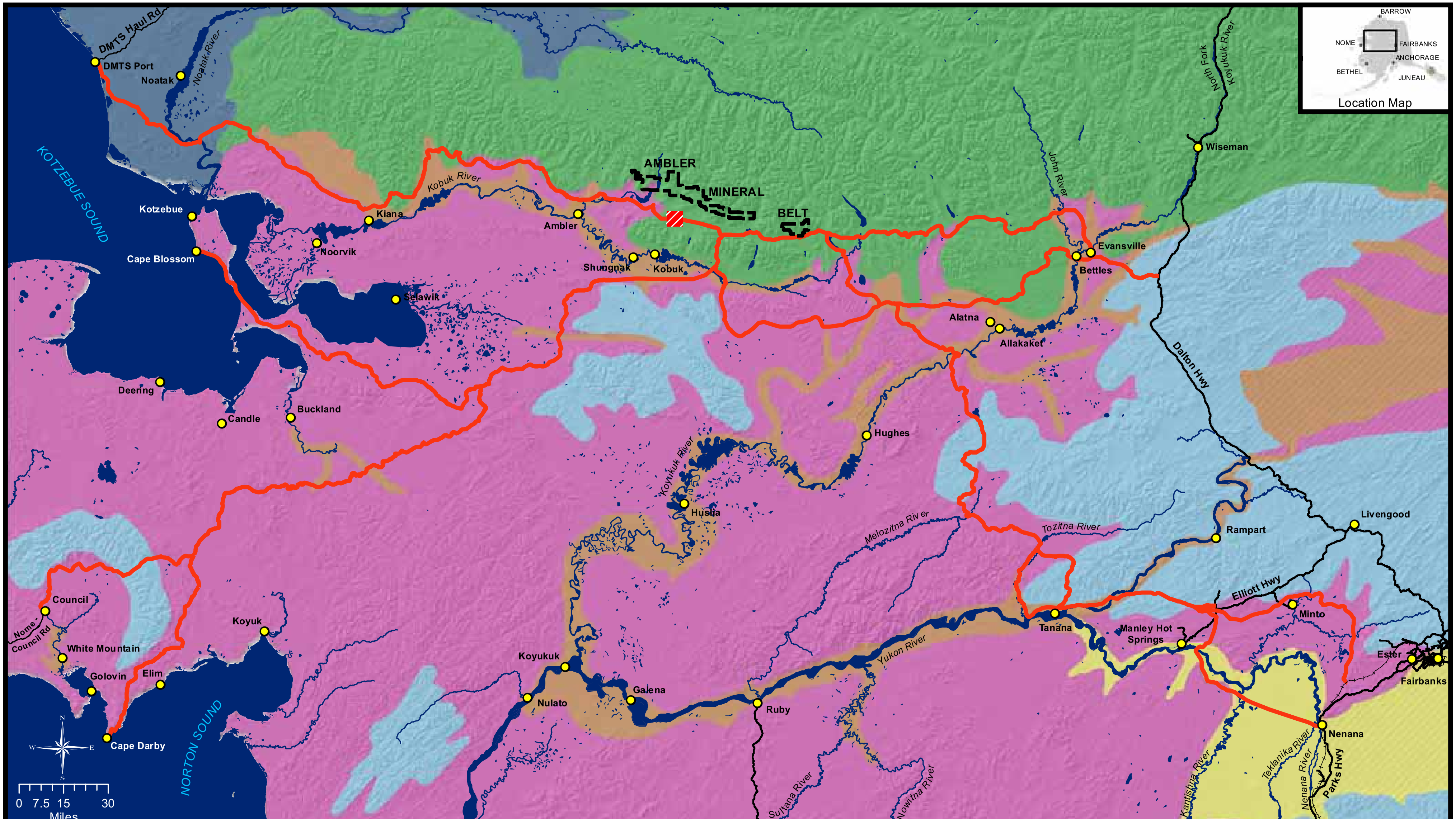
LANDFORM NAME	TOPOGRAPHY AND AREAL DISTRIBUTION	INTERPRETED ENGINEERING SOIL TYPES	SLOPE CLASS	DRAINAGE AND PERMEABILITY	EROSION POTENTIAL	GROUND-WATER TABLE	PERMAFROST DISTRIBUTION	FROST HEAVE POTENTIAL	THAW SETTLEMENT POTENTIAL	LIQUEFACTION POTENTIAL	BEARING STRENGTH	SLOPE STABILITY	SAND AND GRAVEL BORROW SOURCE POTENTIAL
rock glacier (Crg) landslide deposits (Cl) talus deposits (Ct)	rugged alpine mountainous areas, in cirques and at the base or on the flanks of steep slopes (Crg, Ct) at the base of gentle to steep slopes (Cl)	GP, GM, SP, and poorly sorted, coarse angular bedrock rubble	gentle to steep	good (Ct) poor to moderate (Crg, Cl)	high	intermediate (Ct) shallow, usually frozen (Crg, Cl)	frozen (Crg) unfrozen (Ct) discontinuous to continuous (Cl)	low (Ct, Crg) moderate to high (Cl)	high (Crg, Cl) low (Ct)	high (Cl) low (Ct, Crg)	low	very low	poor
younger glacial moraine deposits (Gmy) older glacial moraine deposits (Gmo)	ridges and mounds along the lateral and terminal margins of existing, receded, or disappeared glaciers in rugged alpine mountainous areas	GW, GM, SW, SM, ML, CL	gentle to steep	moderate to good	low to moderate	intermediate to deep	discontinuous to continuous	low to moderate	low	low	moderate to high	moderate to high	poor to fair
younger glacial till deposits (Gty) older glacial till deposits (Gto)	discontinuous and veneer on steep slopes, and is fluted, rilled, and gullied with a "plastered on" appearance - thick deposits form ridges, knolls and hummocks in valley bottoms and plains	GW, GM, SW, SM, ML, CL	gentle to steep	moderate to good	low to moderate	intermediate to deep	usually continuous	moderate	low to moderate	low	moderate	moderate	poor
loess deposits (El)	mantles most upland and lowland areas	ML	gentle to flat	good	high	shallow, usually frozen	usually continuous	high	high	moderate to high	low (unfrozen) high (frozen)	low	poor
coastal plain deposits (Mp) beach deposits (Mb) emerged beach deposits (Mbe)	Norton Sound, Kotzebue Sound, and Bering Sea coastal areas	GW, GM, SW, SM, ML, CL, MH, MH	flat to low	poor to good	high (Mb) low (Mbe, Mp)	shallow (Mb, Mbe) shallow to intermediate (Mp)	unfrozen (Mb) discontinuous to continuous (Mbe, Mp)	low (Mb) moderate (Mbe, Mp)	low to moderate	moderate to high	low (Mb) moderate to high (Mbe, Mp)	high	poor to good
organic deposits (O) man-made fill deposits (Mf)	marshes, muskeg, and swampy areas (O) dredge tailings, stream-river valley bottoms, and on coastal plain (Mf)	PT, OL, OH (O) not applicable (Mf)	flat to low	poor (O) good (Mf)	low (O) high (Mf)	at surface (O) unfrozen (Mf)	usually frozen (O) unfrozen (Mf)	high (O) low (Mf)	high (O) low (Mf)	high (O) not applicable (Mf)	low	not applicable	poor (O) fair to good (Mf)
thaw lake and thaw basin deposits (Ttl) beaded drainage deposits (Tbd)	in large valley and basin bottoms and on coastal plains	PT, OL	flat	low	moderate	continuous	continuous	high	high	moderate to high	low (unfrozen) high (frozen)	not applicable	poor
patterned ground deposits (Ppg) pingo deposits (Pp)	lowland and upland flat to gentle slopes	PT, OL (Ppg) PT, OL, GM, GC, (Pp)	flat to gentle	low	moderate	continuous	continuous	high (Ppg) very high (Pp)	high	moderate	low (unfrozen) high (frozen)	not applicable	poor

3.1 Permafrost

Perhaps the most variable and challenging geologic consideration for this project will be dealing with construction across permafrost. Permafrost consists of underground soils that has remained continuously frozen for more than two years. Typically, a layer of soil above the permafrost, called the "active layer," is seasonally frozen but thaws during periods of high temperature. Areas of continuous, discontinuous, and isolated masses of permafrost are widespread in the project area as shown in Figure 5. Corridors within areas of permafrost are susceptible to frost heave and settling that could potentially damage roads, railways, bridges, and culverts. Frost heave results when freezing underground water develops into ice lenses and causes soils to expand upward. Conversely, the thawing of frozen soils can cause significant settling and dramatically reduce the bearing capacity of the soil. The best strategy for reducing permafrost-caused failure along a corridor is to keep permafrost frozen.

Any route in the study area would traverse continuous and discontinuous permafrost in both thaw-stable and thaw-sensitive soils. Thaw-stable soils are frozen soils that generally do not exhibit significant settlement or loss of strength when thawed, whereas thaw-sensitive soils lose strength and settle excessively when thawed. Most coarse-grained soils are assumed to likely be thaw-stable and all fine-grained soils are assumed to be thaw-sensitive; however, this is a gross generalization. Design and construction techniques are available to address or minimize the impacts of each specific permafrost condition. The challenge is to have a railway or road that performs reasonably uniformly without experiencing unacceptable settlement or frost heave as varying subsurface conditions are crossed.

A review of the aerial photographs on Google Earth yielded few images of high enough quality/resolution for typical surficial permafrost features to be viewed. Although some areas of polygonal/patterned ground within the coastal deposits (along the DMTS Port Corridor) and thaw lakes and thermokarst features are visible on the aerial photographs, other features such as pingos were identifiable only on topographic maps that called out such features. Without higher resolution photographs and topography, and detailed geotechnical investigations that include test borings, the presence and amount of massive ground ice, yedomas, ice wedges, or thawed areas is almost impossible to determine.



- Communities and Place Names
- Existing Roads
- Railroad
- Water
- Outside of Project Study Area
- Ambler Mineral Belt
- Proposed Staging Area
- Preliminary Corridors
- Mountainous Area underlain by continuous permafrost
- Mountainous Area underlain by discontinuous permafrost
- Lowland and Upland Area underlain by thick permafrost
- Lowland and Upland Area underlain by moderately thick to thin permafrost
- Lowland and Upland Area underlain by discontinuous permafrost
- Lowland and Upland Area underlain by numerous isolated masses of permafrost

Source:
Permafrost: National Snow and Ice Data Center

Coordinate System: NAD 1983 Alaska Albers

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PERMAFROST MAP

DATE: May 24, 2011 | **Figure 5**

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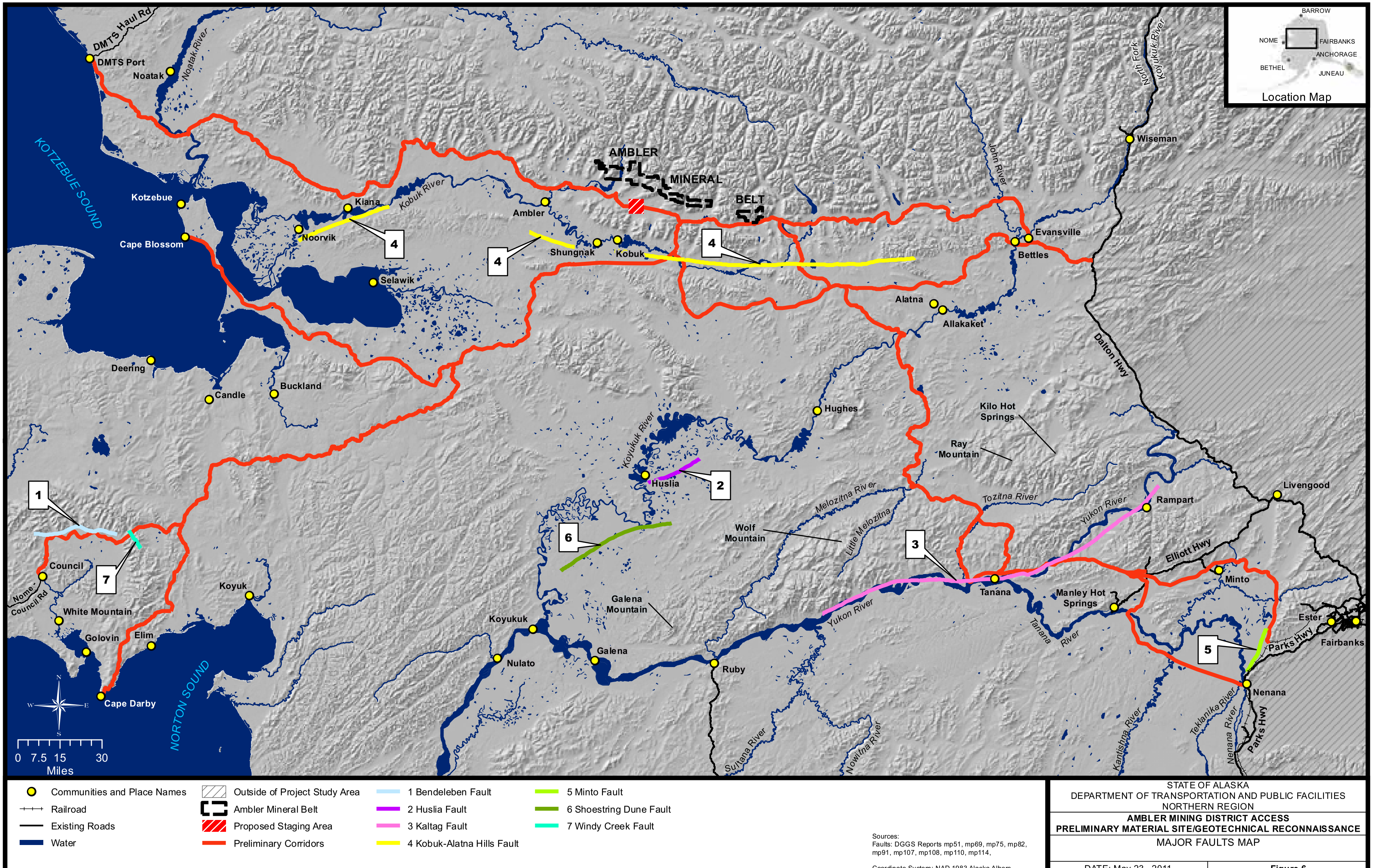
3.2 Slope Stability

A road or railway will have to cross steep terrain in some areas. The stability of steep natural slopes must be assessed for the potential risk of damage to the road or railway from natural landslides or soil creep (the slow movement of soils down a slope due to gravity). Generally, unstable slopes can be identified by surface observation of previous slides or soil slumping. Slopes at, or steeper, than the natural angle of repose of the soil are also subject to surface slumping and mudslides.

The effect on the stability of slopes by the construction must be evaluated to assure the embankment does not cause a failure. Cut and fill on sidehills can create instability in thaw sensitive soils. Cuts that lead to degradation of permafrost can result in slumping or flowing of wet, silty soils as they thaw, creating drainage and maintenance problems. The natural organic mat is generally left in place to insulate the permafrost; however, this creates a zone of weakness that can lead to failure of embankment placed on the slope.

3.3 Seismicity

The project study area is located in an area that has low to moderate seismic potential. The proposed corridors cross a number of active and inactive faults throughout the area, most significantly, the Kobuk Fault. Figure 6 illustrates the locations of active and inactive faults within the project area (from MP 129), and Figure 7 shows the peak horizontal acceleration for the project area and in relation to the proposed corridors. Potential hazards associated with seismic activity include ground shaking, liquefaction potential, fault displacement, and land spreading. Land spreading does not appear to be a significant concern, based on historic earthquake information. Fault displacement can cause damage to roads and railways constructed adjacent to or directly over an active fault line. Ground shaking can cause liquefaction of saturated, cohesionless soils; however, as the project study area is generally underlain by permafrost, liquefaction should be limited to thawed alluvial deposits near active streams.



Sources:
Faults: DGGS Reports mp51, mp69, mp75, mp82, mp91, mp107, mp108, mp110, mp114,

Coordinate System: NAD 1983 Alaska Albers

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MAJOR FAULTS MAP

DATE: May 23, 2011 | **Figure 6**

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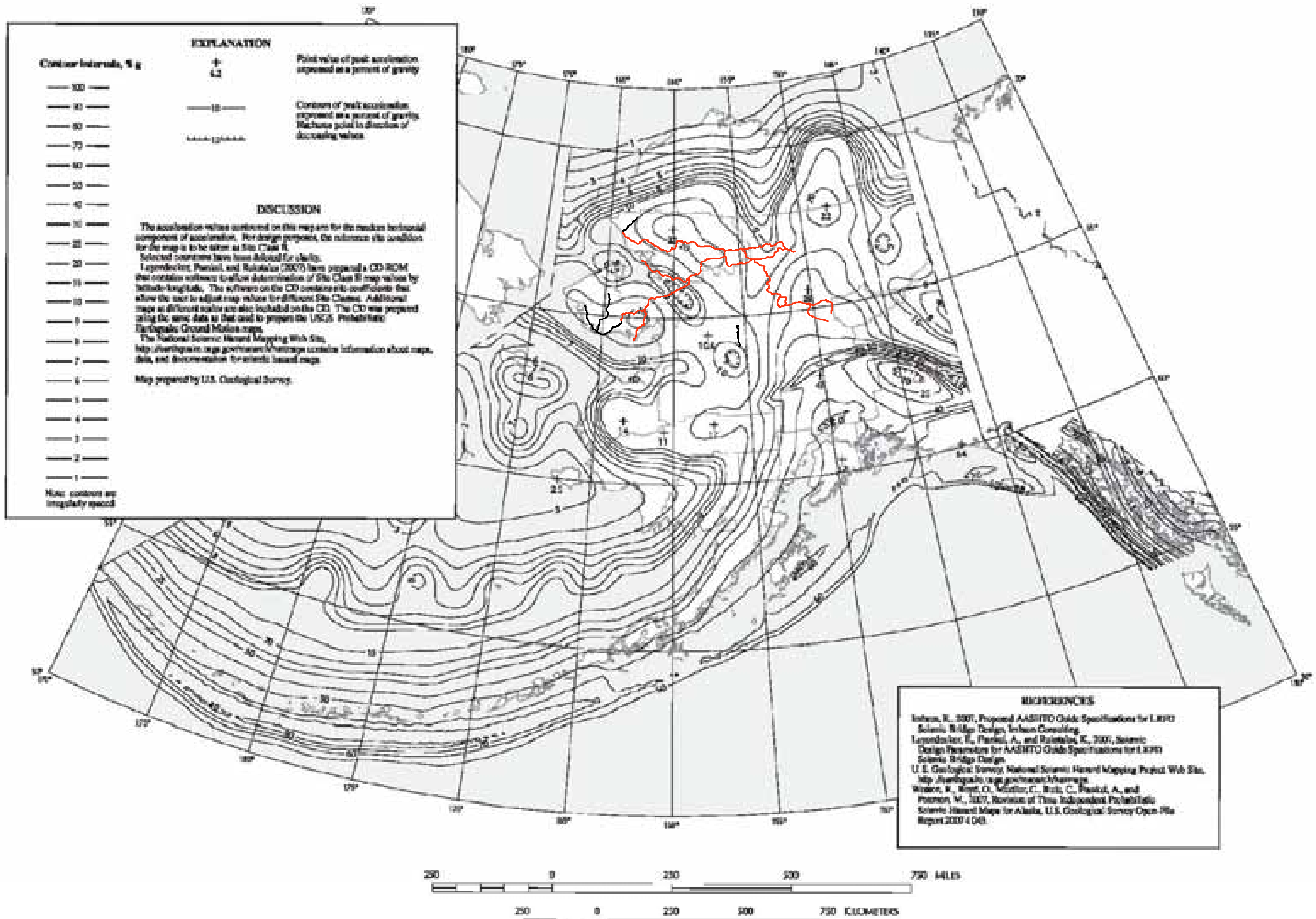
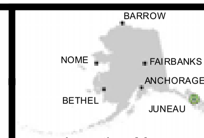
PEAK HORIZONTAL ACCELERATION FOR ALASKA
WITH 7 PERCENT PROBABILITY OF EXCEEDANCE IN 75 YEARS





Location Map

Preliminary Corridors

Coordinate System: NAD 1983 Alaska Albers

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PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

PEAK HORIZONTAL ACCELERATION MAP

DATE: May 23, 2011 | **Figure 7**

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3.4 Rock and Aggregate Borrow Sources

A primary objective of this study is to identify borrow sources for embankment construction and crushed aggregate road surfacing and railway ballast. Rock quality requirements for road and railway are similar as shown in Table 2. Therefore, the method used to identify potential borrow sources at this reconnaissance level applies to both road and railways.

Table 2: Comparison of Aggregate Quality Specifications

Aggregate Property	DOT&PF Surface Course[1]	ARRC Ballast
LA Abrasion	45 max	30 max
Magnesium Sulfate Soundness	—	1 max
Sodium Sulfate Soundness	9 max	—
Bulk Specific Gravity	—	2.60 min
Absorption	—	1 max
Degradation	45 min	—

[1] ARRC uses the DOT&PF specifications for embankment materials.

3.5 Asbestos

Naturally occurring asbestos (NOA) is known to be present within the Ambler mineral belt, specifically near the confluence of the Kobuk and Shungnak Rivers. Asbestos can cause health risks through inhalation of asbestos fibers and any activity that would create airborne dust of asbestos containing soil or bedrock deposits must be avoided or performed with adequate safety controls. Testing should be performed for the presence of NOA when evaluating the suitability of borrow sources. Serpentinites (asbestos bearing rocks) are altered ultramafic (low-silica content) rocks containing magnesium-rich minerals (olivines, pyroxenes, and amphiboles) and are present in the project area. Asbestos has been identified in a number of borrow sources near the villages of Ambler and Kobuk; for example, asbestiform fibers are present in the main gravel borrow source at Ambler. The presence of NOA in detrital sources in these areas is most likely due to erosion and the parent rock may be located in the Cosmos Hills and the southern Brooks Range. Extensive investigations have been completed for NOA deposits within the Cosmos Hills, and some asbestiform material was mined from the area during the 1940s.

In general, alluvial deposits that contain asbestiform materials are likely to be found in any watershed that drains ultramafic rock formations.

3.6 Acid Rock Drainage

Acid rock drainage (ARD) is acidic runoff from exposed iron-bearing rock or ore that contains high concentrations of metals, usually iron. It is generally identified by orange and reddish colored stream beds or stained surfaces as the iron hydroxide precipitates out of solution. Iron-rich rock, volcanogenic massive sulfides (VMS), and minerals (pyrite) exposed to air and water are sources of naturally occurring ARD. The effects of ARD vary depending on the metal being leached and its concentration. ARD can cause pH imbalances in water systems, adversely affect fish (reducing gill function and reproduction), create a highly corrosive environment for metal culverts, and introduce toxic metals into the water system, such as arsenic, mercury, and selenium.

A number of sites along the proposed corridors may have potential for ARD based on the geochemistry of specific rock types and a review of aerial photographs. VMS are generally the parent material that causes ARD are typically associated with felsic volcanic rocks and deep ocean sedimentary rocks (shale). VMS rocks are also associated with gold, silver, copper, lead, and zinc ore deposits, which have been identified in the Council, Ambler, and Tanana areas. The schist belt of the Southern Brooks Range has also been shown to contain VMS deposits. A review of aerial photography along proposed corridors reveals several segments that show large areas of iron staining. If these formations are determined to have a potential for ARD, it may limit the use of the material for certain applications, such as embankment fill.

A panel of acid/base accounting tests should be performed to determine a borrow source's potential for ARD. If a source is determined to have ARD potential, methods can be implemented to prevent ARD, including covering exposed surfaces, preventing exposure of iron-rich sources, and preventing water run-off across iron-rich materials (stream diversion).

4.0 GEOTECHNICAL CHARACTERIZATION AND BORROW SOURCE IDENTIFICATION METHODOLOGY

4.1 DGGS Miscellaneous Publication 129

The methodology used to identify subsurface conditions and potential borrow sources builds on the work performed by the State of Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS) as published in *Miscellaneous Publication (MP)*

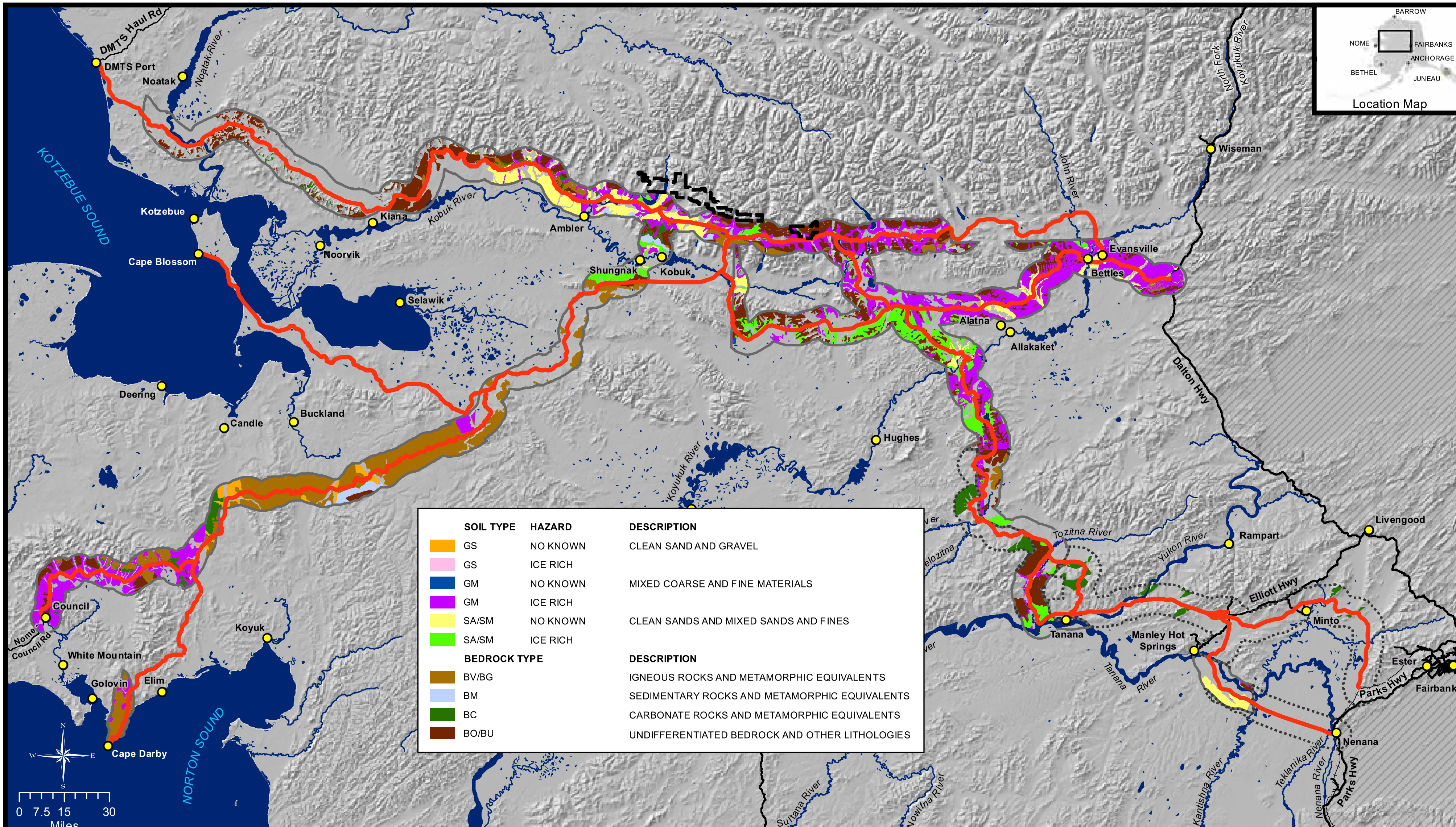
129, Survey of Geology, Geologic Materials, and Geologic Hazards in Proposed Access Corridors, Alaska (Reger, et al, 2003). Miscellaneous Publication 129 is accompanied by maps presented in Miscellaneous Publications 45 through 122.

MP 129 was not subjected to rigorous review by DGGS prior to publication and digital data has not been publicly released. DGGS provided digital copies of their mapping for use in this study but cautioned there may be errors in the data. DOWL HKM has found the DGGS data to be sound, although some minor errors/omissions have been found in the course of our analysis.

DGGS prepared 1:250,000-scale maps of the geology, geologic materials and geologic hazards for 10-mile-wide corridors in Alaska, including several in the project study area. Corridors through the following quadrangles are applicable to the current study area: Ambler River, Baird Mountains, Bendeleben, Bettles, Candle, Fairbanks, Hughes, Kantishna River, Kateel River, Livengood, Noatak, Selawik, Shungnak, Solomon, Survey Pass, Tanana, and Wiseman.

The rationale and methodology used by DGGS is explained in detail in MP 129 and this publication should be considered essential background for this geological and geotechnical work. Briefly summarizing the DGGS study, geologic maps were gathered and interpreted, and supplemented where necessary, along the corridors being studied. The geologic units were then related to geologic materials of interest for geotechnical design and construction. Maps of geologic hazards that could affect the design, construction, and operation of road and railway along each corridor were developed. The perceived quality of the data used to prepare the geologic maps, and thereby the quality of the work products derived from interpreting those maps, was rated in classes ranging from poor to very good.

The corridors studied by DGGS cover much of the area along the corridors considered in this current study (Figure 8). Where the current corridors deviate outside the DGGS study area, DOWL HKM has produced interpreted geologic materials and hazard maps using the DGGS methodology and existing geologic maps (see detailed discussion in Section 4.3).



Sources:
DGGS Reports mp45, mp47, mp51, mp54, mp57, mp58, mp69, mp75, mp80, mp82, mp86, mp91, mp97, mp98, mp107, mp108, mp110, mp111, mp114, mp122, mf2408, mf2409 and OF 98-133-A

Coordinate System: NAD 1983 Alaska Albers

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AVAILABLE DGGS DATA MAP

DATE: May 17, 2011	**Figure 8**

P:\Projects\D60693\GIS\Geotech\MATERIAL SITE GEOTECHNICAL RECONNAISSANCE\DDGS DATA.mxd May 17, 2011 10:33:18 AM User: chris.harrington

4.2 DOWL HKM Methodology for Identifying Potential Borrow Sources

The purpose of this section is to explain the procedure used by DOWL HKM to manipulate the DGGS data discussed in Section 4.1, to identify potential borrow sources. The advantages and limitations of the procedure are discussed.

As discussed above, DGGS prepared four sets of maps for their study areas: geologic maps; geologic materials maps; hazard maps; and data quality maps. The DGGS maps provide a wealth of information and identify individual features as small as about 20 acres in size. DOWL HKM's premise, for the purpose of this report, is that the DGGS data would be easier to interpret along the hundreds of miles of corridor studied if the number of individually identified geologic materials and geologic hazards could reasonably be reduced to those of interest for design of road or railway embankment and development of sources of construction materials. This would make it possible to plot the materials of interest at a scale readily visible on the complete corridor maps presented in this report.

DGGS performed the first step in simplifying the geologic data by relating multiple geologic units to a single geologic material. Twenty nine geologic units were reduced to five geologic material units. For example, DGGS reduced 10 geologic units (Qa, Qsm, Qo, Qat, Qam, Qis, Qld, Qlb, Qmb, and Qmt) to a single geologic material unit, GS. Table 3 (adapted from MP 129, pg 12-13) presents the relations between soil material unit, land form and geologic unit developed by DGGS. (It is important to note that the material unit designations used by DGGS are not the standard Unified Soil Classification System (USCS) designations. Table 3 presents the USCS designations that relate to each material unit.) DOWL HKM further reduced the number of geologic units to four by combining SA and SM (chiefly sand and chiefly fine materials, both potentially suitable for unclassified fine fills.)

DGGS performed the same type of simplification for rock materials. DGGS reduced 21 rock geologic units to 6 material units as shown in Table 4. For the purposes of this study, DOWL HKM reduced the 6 rock units to 4 by combining BV and BG (medium jointed, fine grained and coarse jointed, coarse grained igneous lithologies) and BO and BU (all other lithologies and undifferentiated, unknown bedrock).

Table 3: Relations between Soil Material Unit, Landform and Geologic Unit

Material Unit	Composition	Potential Products	Component Landforms	Geologic Unit
GS	Chiefly (estimated >80%) clean sand and gravel Rare oversized material Includes GW and GP (USCS)	Drain rock Crushed surface course Crushed ballast Classified and unclassified fills	Active floodplains Inactive floodplains Outwash plain, fan Large abandoned melt water channel Stream terrace Esker, Kame, Kame terrace Complex ice stagnation topography Granular delta and fan-delta Beach, spit bar Tailings mound or ridge	Alluvium (Qa, QSM) Outwash/inwash (Qo) Terrace alluvium (Qat, Qsm) Ice stagnation deposits (Qis) Fan-delta deposits (Qld) Lake/marine beach deposits (Qlb, Qmb) Placer-mine tailings (Qmt)
GM	Mixed coarse and fine material Estimated 20-80% coarse, granular deposits with considerable oversized material Includes GM and GC (USCS)	Unclassified fills Classified fills where clean	Alluvial fans Rock glaciers Talus/Colluvium Thaw lakes	Undifferentiated drift (Qd) Alluvial fan (Qaf) Solifluction (Qcs) Rock Glacier (Qrg) Talus (Qt) Thaw lake (Qtl) Undifferentiated colluvium (Qc) Undifferentiated surficial deposits (Qu)
SA	Chiefly (estimated 80%) sand Includes SW and SP (USCS)	Unclassified fine fills	Eolian sand dune, sheet, dune complex Retransported sand fan, apron, sheet	Eolian sand (Qes) Undifferentiated eolian sand and silt (Qe) Reworked eolian deposits (Qer)
SM	Chiefly fine materials Estimated > 80% sand, silt and clay Includes SM, SC, ML, MH, CL and CH (USCS)	Unclassified fine fills	Fine-grained delta, fandelta Retransported loess fan, apron, sheet Loess blanket Lake plain, basin Glaciolacustrine plain Tidal flat, elevated tidal flat	Deltaic, lagoonal deposits (Qml) Undifferentiated eolian sand and silt (Qe) Reworked eolian deposits (Qer) Loess (Qel) Undifferentiated lacustrine deposits (Ql) Estuarine deposits (Qme)
OR	Chiefly organic materials Estimated > 50% peat, organic sand, or organic silt Includes PT (USCS)	Insulation Slope vegetation Reclamation	Thaw-lake basin Swamp	Thaw-lake deposits (Qtl) Swamp deposits (Qs)

Source: adapted from MP 129, pg 12-13

Table 4: Relations between Rock Material Unit, Landform and Geologic Unit

Material Unit	Composition	Potential Products	Component Landforms	Geologic Unit
BV	Medium-jointed, fine-grained igneous rocks and their metamorphic equivalents	Riprap Drain rock Crushed surface course Crushed ballast Classified and unclassified fills	Volcanic flow rock outcrop Welded tuff outcrop Greenstone outcrop	Volcanic rocks (Biv) Greenstone (Bmg)
BG	Coarse-jointed, coarse-grained igneous lithologies	Riprap Crushed surface course Crushed ballast Classified and unclassified fills	Pluton outcrop Granite/migmatite outcrop Gneiss outcrop	Granitic rocks (Big) Migmatite (Big) Coarse-grained Gneiss (Big)
BC	Medium-jointed, fine to coarse-grained sedimentary carbonate rocks and their metamorphic equivalents	Classified and unclassified fills Potential crushed rock products	Limestone outcrop Dolostone outcrop Travertine outcrop Marble outcrop	Limestone (Bsl) Dolostone (Bsl, Bmm) Limestone (Bsl) Marble (Bmm)
BM	Medium-jointed, fine to medium-grained quartzose sedimentary rocks and their metamorphic equivalents	Riprap Drain rock Crushed surface course Crushed ballast Classified and unclassified fills	Quartzose sandstone, conglomerate outcrop Quartzite outcrop	Sandstone (Bsa) Conglomerate (Bsc) Quartzite (Bmq)
BO	All other lithologies	Classified and unclassified fills	Outcrops of all bedrock classes not included in above groups	Chert (Bsch) Shale (Bsh) Siltstone (Bsi) Schist, serpentine, phyllite, fine-grained gneiss (Bms)
BU	Undifferentiated, unknown bedrock	Classified and unclassified fills	Undifferentiated bedrock	Undifferentiated igneous rock (Biu) Undifferentiated sedimentary rock (Bsu) Undifferentiated metamorphic rock (Bmm) Undifferentiated, unknown rock (Bu)

DGGS identified 16 geologic hazard and combinations of hazards. DOWL HKM grouped these 16 hazards/hazard combinations into 3 broad categories: no identified hazards; minor hazards; and significant hazards, as shown in Table 5.

Table 5: Geologic Hazards

Description
No Identified Hazards
Hazards possibly present but unknown
No identified hazards
Minor Hazards
Significant liquefaction potential and ground-ice content
Significant ground-ice content
Significant Hazards
Rapid mass movements
Seasonal flooding
Rapid mass movements and snow avalanching
Significant liquefaction potential and seasonal flooding
Significant ground-ice content and seasonal flooding
Rapid mass movements, seasonal flooding, and snow avalanching
Rapid mass movements, seasonal flooding, and snow avalanching
Significant liquefaction potential, significant ground-ice content and seasonal flooding
Rapid mass movements, significant ground-iced content, seasonal flooding, and snow avalanching
Lake
Snow Avalanches
Auefis

No Identified Hazards. The two hazard units making up this category may contain hazards, but none are known of at this time.

Minor Hazards. Minor hazards combine the two hazard categories of 'significant ground-ice content' and 'significant ground-ice content and significant liquefaction potential'. Significant ground-ice content is a subsurface condition that will require engineering controls to assure adequate performance of road and railway embankments. The majority of the corridors pass through permafrost conditions and will require site specific engineering designs that depend on the lateral and vertical extent of the permafrost, the thaw stability of the soil, and the thermal regime. The presence of 'significant ground-ice' will typically require thicker embankments and implies the potential presence of silty, highly frost susceptible soils that are not suitable for classified fills.

Significant Hazards. Twelve geologic hazards and combinations of hazards identified by DGGS were grouped into the significant hazard category. These 12 hazards actually contain only 7 unique types of events or subsurface conditions and the remaining 5 are various combinations of the 7 unique types. The unique types of hazards and the rationale for inclusion in significant hazards is discussed below.

- <u>Rapid Mass Movements</u>. Landslides, mudslides, and slope failures can happen suddenly without warning. This presents a life-safety threat to workers in quarry sites and threat of significant property damage to road or railway transportation systems. Any area designated by DGGS to pose a threat of rapid mass movement fall in the significant hazard grouping.
- <u>Snow Avalanching</u>. Avalanches are significantly less of a life-safety threat than rapid mass movements. However, snow avalanches do present an economic threat to use of a road or railway during the avalanche season and could be an impediment to borrow areas due to deep snow cover or avalanche threat in the spring that could delay safe borrow operations. Note in Table 5 that there is only one DGGS hazard category that contains snow avalanching as a single item and it rarely, if at all, shows up on the DGGS hazard maps.
- <u>Seasonal Flooding, Lake, and Aufeis</u>. Each of these hazards indicates the area is submerged in ice or water at least sometime during the year. The predominance of the data having this designation are within active floodplains. Many Alaska communities obtain borrow materials from within active floodplains and even by dredging from waterways. Often economics dictate borrow materials must come from the immediate vicinity of the village and it is often not feasible to develop an upland borrow site some distance away. However, for this corridor study, development of borrow sites within floodplains and rivers are avoided due to the potential environmental impacts of mining in these areas and the associated permitting difficulties. It may be deemed reasonable for a floodplain borrow area to be permitted in a village, but less reasonable when the borrow

material will be used for a road or railway embankment that is traversing usable upland borrow materials. Therefore, these geologic hazards are included in the significant hazards category.

- Significant Liquefaction Potential, Significant Ground-Ice Content. These two hazards make up the remaining 2 of the 7 unique types grouped into the significant hazards. As discussed previously, these conditions alone were included in the minor hazard group. The DGGS combined these hazards with the hazards discussed above that are grouped in the significant hazards and by association, also classify as significant hazards.

4.2.1 Data Filtering and Presentation

It has been explained that multiple geologic units have been reduced to five geologic material units and four bedrock units and that geologic hazards have been reduced to three hazard units. This data was further filtered for presentation on the graphics presented in this report. Only potentially usable materials that are outside of significant hazard areas are shown on the graphics. All OR (chiefly organic materials) material units and all significant hazard units are filtered out of the drawings and show as blank, uncolored areas within the DGGS data boundaries on the graphics. This filtering was performed by assigning arbitrary numerical values to each geologic material and hazard unit and summing these values using the GIS software. Different values could be assigned to the units and/or hazards in the GIS database developed for this study to present the data in a variety of different ways.

The filtering reduced the plotted material types to three geologic material (soil) types, subject to two hazard classifications, and four bedrock types. These materials are color coded and presented with a key on the pertinent graphics of this report. The materials and potential uses are presented in Table 6.

4.2.2 Advantages and Disadvantages

Advantages. The primary advantage of the method used by DOWL HKM to reduce and filter the geologic data down to a handful of material types is that the filtered materials are readily plotted on corridor maps and are easily visually interpreted. The material types are useful for identifying road and railway embankment foundation conditions and potential borrow sources.

Table 6: Soil and Bedrock Materials

Soil Type	Hazard	Description	Potential Uses
GS	No Known	Clean Sand and Gravel. This is the best available soil material. These soils have high strength and will provide excellent support for road and railway embankments. USCS GW, GP	Crushed Surface Coarse and Ballast, Classified and Unclassified fill
GS	Ice Rich	The quality and use of this material is not affected by being ice rich. Typically these soils are thaw stable.	Crushed Surface Coarse and Ballast, Classified and Unclassified fill
GM	No Known	Mixed Coarse and Fine Material. This is the second best soil material. It is expected to vary from clean GS type material to siltier, but high strength gravelly materials. This material will provide good foundation support for road and railway embankments. Siltier materials will be frost susceptible and this must be factored into embankment designs. USCS GW, GP to GM and GC.	Unclassified fills Classified fill where clean
GM	Ice Rich	Ice rich material may or may not be thaw stable depending on actual gravel content and ice content. This material must be thoroughly investigated in the field and laboratory to determine strength and compressibility on thawing. Engineering controls will be necessary where the material is not thaw stable.	Being ice rich may not affect this material's suitability for use as fill if it can be stockpile and allowed to thaw and drain sufficiently to allow placement
SA/SM	No Known	Sands and Silty and Clayey Sands. This material is the least desirable for use as construction materials. These soils, particularly the finer materials, have relatively low strength and high compressibility. Detailed engineering will be required to assure the material can support planned embankment loading without excessive settlement. Removal and replacement may be required in some areas. USCS SM, SC, ML, MH, CL, CH	Possible Unclassified Fill
SA/SM	Ice Rich	Ice rich material is likely not usable due to high water content and low strength on thawing. This material must be kept frozen to provide adequate support for embankments. This will require thicker embankments, possibly insulation and possibly artificial measures to promote permafrost preservation.	Only sandier materials that will adequately drain on thawing will likely be usable for unclassified materials
Bedrock Type			
BV/BG	N/A	Igneous Rocks and Metamorphic Equivalents These are the most desirable bedrock materials. These rocks are expected to have high strength and durability.	Crushed aggregate for road surfacing and ballast Classified fill Unclassified fill
BM	N/A	Sedimentary Rocks and Metamorphic Equivalents These rock units are expected to have a range of properties, but predominately should provide good construction materials, particularly the quartzites and conglomerates	Harder materials: Crushed aggregate for road surfacing and ballast, All materials: Classified fill and Unclassified fill
BC	N/A	Carbonate Rocks and Metamorphic Equivalents The rock units are likely to provide good quality general fill materials	Classified fill Unclassified fill Limited quantities of crushed aggregates
BO/BU	N/A	Undifferentiated Bedrock and Other Lithologies As the name implies, not much is known about these rock units, but most should provide adequate fill materials	Classified fill Unclassified fill

Another advantage is the methodology could be applied to all the corridors under study without being biased toward one corridor over another.

The GIS database developed for this study contains the unfiltered data. Therefore, the data can be filtered in other ways to show different items of interest with little extra effort should this proved useful in future studies.

Disadvantages. The primary disadvantage of the method is that areas of unsuitable materials and significant hazards are shown as blank, uncolored areas on the corridor maps. This can be confused with areas that had little or poor quality data available for used in this analysis. This is discussed further in the report and steps are taken to clarify where there are data gaps, but without reading and understanding these issues, the graphics do not always stand on their own.

Another disadvantage is that the geologic mapping that all this work is based on varies in quality and consistency. The graphics show some abrupt changes in material type due to the original geologic interpretation being performed by different individuals with different views. Field investigation is required to resolve these data conflicts.

DOWL HKM believes the advantages clearly outweigh the disadvantages and that the methodology used to filter and present a large amount of data can be used to fairly evaluate the study corridors.

4.3 Filling In Data Gaps

DGGS data on geologic materials and hazards did not cover all of the potential corridors in the project study area. Gaps in the data were filled using available geologic sources and USGS topography and assigning geologic material and hazard classes consistent with the methodology developed by DGGS. DOWL HKM skipped producing separate geologic material and hazard maps, as produced by DGGS, and moved directly to mapping potential borrow sources. Tables 3 to 6 present the relationship of geologic unit and topography with geologic material and hazard data used by DOWL HKM.

GIS data on select 1:63,360-scale quadrangle maps were downloaded from the DGGS Publications website to fill in some data gaps. The breakdown of the GIS data included within these files differed from that of the MP 129 report, making the assignment of soil and rock types/hazards within the data difficult to classify, particularly in the Tanana Quadrangle, near Nenana and Minto (from Open File Report 98-133-A). These areas are indicated with a dotted boundary line.

A statewide surficial geology map at 1:1,584,000-scale was used for most data gaps (Karlstrom, 1964). Bedrock outcrops/deposits are not shown on the surficial geology mapping and the deposits shown are not mapped at as refined a scale as the quadrangle maps used for the DGGS data. Figure 4 shows the surficial geologic data from the Karlstrom map with unique values assigned to show desired material for potential borrow sites.

Figure 8 shows the DGGS data available for the entire project area, outlined with a solid, dark gray boundary line. Blank areas within this boundary along some of the corridors indicate that few borrow sites are available along that section of corridor due to material quality or hazard potential. Blank areas outside of this boundary indicate that data was not available through the DGGS GIS data or at a similar quality of detail. These are areas that will require additional research and fieldwork to determine the geological soil and rock conditions, once a preferred corridor is selected.

5.0 CORRIDOR ANALYSIS

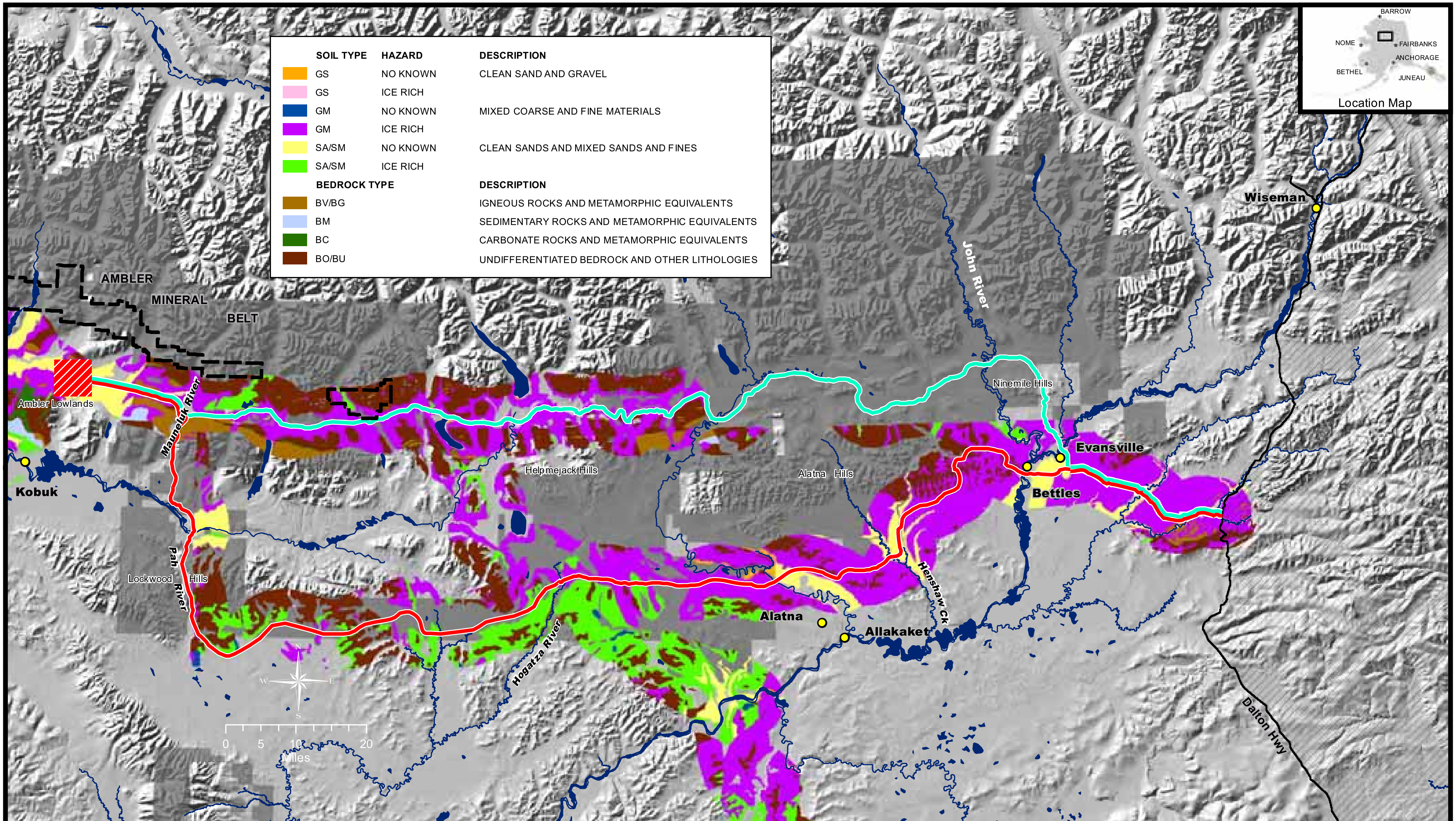
The potential borrow source maps for potential corridors are presented in Figures 9 through 12.

A summary of the typical geotechnical conditions and potential borrow sources is outlined below by corridor and presented in Tables 7 through 13. The assumed geologic and geotechnical conditions along the routes as determined by typical soil types along the corridors is also discussed. The physiographic subprovince descriptions from USGS Paper 782, Physiographic Divisions of Alaska have been included below to generally describe the geology of segments of each proposed corridor. PDF 85-42a was used to help outline the typical geotechnical properties of the soils likely to be encountered along each proposed corridor.

5.1 1-Brooks Corridor East (Figure 9, Table 7)

5.1.1 <u>Typical Geology</u>

From the Dalton Highway to near Evansville and north across the Koyukuk River Valley, the predominant soils are expected to be morainal silty sands and gravels from Pleistocene (Illinoian



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ACCESS EAST CORRIDORS MAP

DATE: May 23, 2011 | **Figure 9**

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Table 7: Brooks Corridor East (Figure 9), 216 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Dalton Highway (near Pump Station #5) to Evansville/Bettles, 24 miles **Both Corridors 1 and 2 follow the same alignment through this section and diverge south of Evansville**										
GM	19	Continuous, thick to thin	10	Fair	20	Clean GS within Jim River and Koyukuk River floodplains	10	None Known	None Known	Corridor traverses rolling hills. Thaw lakes and organic and silty deposits are present in the lowlands which will require thicker embankments.
SA/SM	3	Discontinuous	14	Poor	5					
BV/BG to BO/BU	3					Bedrock sources at Gobler's Knob and Jack White Range				
Evansville/Bettles, up the John River Valley , through Ninemile Hills, to Alatna Hills, 70 miles										
GM	70	Continuous	50	Good	50	Silty alluvial gravels, with potential clean gravels in the floodplains of the John River and John River Forks	10	None Known	None Known	Much of the corridor traverses rolling hills with continuous permafrost and silty gravel soils. The embankment thickness should be consistent, except in areas ice rich silts and silty sands, organic soils, pingos and thaw lakes in the lowlands where it must be thicker.
Ice rich SA/SM	15	Discontinuous	20	Fair	10					
BO/BU	30			Poor	10	Bedrock sources along the hill				
Alatna Hills through Helpmejack Hills and Ambler Lowlands to Ambler, 120 miles **Corridors 1 and 2 converge on the east side of the Mauneluk River crossing**										
GM	120	Continuous	120	Good	90	Silty alluvial gravels are available throughout this section with clean GS materials in the floodplains	5 - 10	Potential ARD Risk	Ultramafic rocks may contain NOA	The floor of this rift valley has several large swampy areas. Thicker embankment depths will be required where the alignment must cross these low-lying areas. Otherwise, there should be good support for embankments of normal thickness. Aerial photographs indicate iron staining through the Alatna and Helpmejack Hills and through the Brooks Range schist belt.
GS	5									
Ice rich SA/SM	20									
SA/SM	10			Poor	30	Numerous bedrock sources throughout the route with several BV/BG sources				
BV/BG	40									
BO/BU	80									
SUMMARY		Continuous	85%	Good	65%	Average Distance between borrow sites	<10			
		Discontinuous	15%	Fair	15%					
				Poor	20%					

and Wisconsinan) glaciations, with cleaner Quaternary alluvial and glacial outwash gravels. Muskeg terrain is present along the south side of the Koyukuk River.

Between Ninemile Hills and Ambler mining belt, the corridor follows a rift valley containing numerous Quaternary glacial drift and moraine deposits. The drift is expected to be comprised of relatively clean sands and gravels, but in limited quantities. The moraines are likely to be a mixture of coarse and fine soil materials with considerable cobbles and boulders from the Illinoian and Wisconsinan glaciations. The soils deposited in terminal and lateral glacial moraines are expected to have high silt content and to be ice-rich. The valley slopes are reported to be wet and poorly drained in some areas.

Folded cretaceous sedimentary bedrock (conglomerate, sandstone) may be shallow through the Ambler-Chandalar lowland in some areas; however, the topography is irregular and fine materials have been deposited behind old glacial dams resulting in random pockets of ice-rich, silty soils.

5.1.1.1 Dalton Highway to Evansville/Bettles

From the Dalton Highway, the corridor passes along the north side of Gobbler's Knob, south of the Jack White Hills. Bedrock from these hills may be used as borrow material and will most likely consist of schist and gneiss. Most of this stretch of corridor will traverse glacial moraine and alluvial deposits with discontinuous permafrost, which will provide proper foundation soils with generally low thaw settlement potential. Over approximately 10 miles, this stretch of corridor crosses over numerous drainages, namely the meandering South Fork Koyukuk River, that contain alluvial deposits (cleaner sands and gravels) that may be used as borrow material; however, some longer haul distances may be required if organic deposits in the river floodplains make borrow source development uneconomical. Approaching Evansville/Bettles, a large muskeg area can be found immediately to the south of the community with numerous thaw lakes and meandering streams. These areas may contain deep organics, therefore, a thicker embankment and geotextile may be needed for construction of the road.

Borrow sources should be available at approximately 10-mile intervals along this corridor segment.

5.1.1.2 Evansville/Bettles to Alatna Hills

The corridor passes through the Ninemile hills approximately 10 miles north of Evansville/Bettles before turning west along the base of the rugged, abrupt peaks of the Brooks Range to the north. Glacial drift along the base of the hills and alluvial deposits through the John River and John River Forks valleys should provide proper foundation soils and possibly suitable borrow sources; however lower lying areas may contain isolated muskeg deposits that are generally ice-rich with high thaw settlement potential. Continuous permafrost is expected throughout the area and pingos have been noted in the area of Henshaw Creek, near the base of the Alatna Hills.

Borrow sites along this portion of the corridor can be expected at 10-mile intervals, with increasing availability approaching the Alatna Hills.

5.1.1.3 Alatna Hills to Ambler Lowland

This section of the corridor continues through the Ambler-Chandalar Ridge and Lowland section, with the steep slopes of the Brooks Range to the north and rolling hills, such as the Helpmejack Hills, to the south. These mountains are comprised of bedrock consisting of lower Paleozoic greenstone with some isolated areas of similar age schist and should provide proper borrow material at about 5- to 10-mile intervals along the corridor. However, some of the bedrock, specifically the ultramafic volcanics and their metamorphic equivalents, may contain NOA and may not be suitable for use. Ultramafic rocks also have the potential for ARD, specifically through the Alatna and Helpmejack Hills and the schist belt along the Brooks Range; some iron staining was observed on the aerial photographs in these areas.

Glacial moraine deposits along the valley floor and lower elevations of the valley walls will provide good foundation soils. Narrow valleys through the mountains area may raise concerns of slope instability. Although continuous permafrost is expected along this entire section of the corridor, thawed areas near larger water bodies, such as lakes and river, may be present.

5.2 2-Kanuti Flats Corridor (Figure 9, Table 8)

5.2.1 Typical Geology

From the Dalton Highway to near Evansville and north across the Koyukuk River Valley, predominant soils are expected to be morainal silty sands and gravels, from Pleistocene (Illinoian and Wisconsian) glaciations, with cleaner Quaternary alluvial and glacial outwash gravels. Muskeg terrain is present along the south side of the Koyukuk River.

Through and along the Alatna Hills to the Alatna River Valley, predominant soil types are expected to be Pleistocene morainal and colluvial silty sands along the edges of the slopes and clean Quaternary alluvial and glacial outwash deposits along the drainages.

There are extensive muskeg areas across the Alatna River Valley; soft silts are anticipated in this area. Better foundation soil conditions are found along the hills bordering the valley. Selection of an alignment through this valley will require weighing soils conditions, material haul distances, and corridor length.

From Alatna River Valley to the Pah River, predominant soils are Pleistocene morainal and colluvial silty sands and gravels along the edges of the slopes. Poorly drained conditions closely border the toes of the slopes through this area.

Along the Pah River, predominant soils are morainal and colluvial silty sands and gravels along the edges of the slopes. Cleaner sands and gravels are present in the Quaternary alluvial outwash fans at mouths of drainages and in river terraces.

In the Kobuk River Valley, fairly well drained sands and gravels are present, although some areas of muskeg and silty soils will likely be encountered on the valley floor.

Table 8: Kanuti Flats Corridor (Figure 9) 241 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Dalton Highway (near Pump Station #5) to Evansville/Bettles, 24 miles **Both Corridors 1 and 2 follow the same alignment through this section and diverge south of Evansville**										
GM	19	Continuous, thick to thin	10	Fair	20	Clean GS within Jim River and Koyukuk River floodplains	10	None Known	None Known	Corridor traverses rolling hills. Thaw lakes and organic and silty deposits are present in the lowlands which will require thicker embankments.
SA/SM	3	Discontinuous	14	Poor	5					
BV/BG to BO/BU	3					Bedrock sources at Gobler's Knob and Jack White Range				
South of Evansville, Crossing the Koyukuk River at Bettles and to the Alatna Hills, 10 miles										
SA/SM	10	Discontinuous	10	Fair	5	Clean GS within Koyukuk River floodplain	5	None Known	None Known	This section primarily crosses the Koyukuk river lowland and active floodplain. Thicker embankments will be required to accommodate the silty soils and discontinuous permafrost.
				Poor	5					
Alatna Hills, 25miles										
GM	25	Continuous	25	Good	25	Silty Gravels throughout this section	<10	None Known	None Known	This section winds through the Alatna Hills where good foundation conditions predominate. The valleys likely contain organic deposits where thicker embankment depths will be required.
BO/BU	25					Numerous bedrock sources				
Alatna Hills through Henshaw (Sozhekla) River Valley through Alatna River Valley to the Hogatza River, 65 miles										
GM	40	Continuous	40	Good	30	Silty gravels along upland areas	10	Potential ARD Risk	None Known	This segment presents thaw lakes and ice rich silt soils in the Alatna River Valley and between Alatna River and Siruk Creek and areas of discontinuous permafrost which will require thicker embankments. More and normal exploration will be required in the lowlands to sufficiently characterize the subsurface conditions to allow the embankment depths to be optimized for actual conditions. Aerial photographs indicate iron staining along the southern face of the Alatna Hills and in the Henshaw River Valley.
SA/SM	15			Fair	15					
Ice rich SA/SM	5			Poor	20	Clean GS within the Henshaw Creek and Alatna River floodplains				
GS	<5	Discontinuous	25							
BO/BU	<5					Limited bedrock sources between Henshaw Creek and the Alatna River				
Hogatza River through Lockwood Hills along Pah River flats to Pah River, 60 miles										
Ice rich SA/SM	45	Continuous thick to thin	55	Good	20	Silty gravels in the uplands through and along the edges of the Lockwood Hills	10 - 15	Potential ARD Risk	None Known	After crossing the Hogatza River, this section traverses segments of low lying ground with numerous thaw lakes and organic soils which will require thicker embankment depths. After passing through the Lockwood Hills, the corridor skirts the Pah River Flats where again there are numerous thaw lakes and organic soils. Aerial photographs indicate iron staining along the eastern edge of the Lockwood Hills.
GM	15	Discontinuous	5	Poor	40	Bedrock sources within the Lockwood Hills				
BO/BU	15									
Pah River Valley across Kobuk River to Manuneluk River and Ambler River Lowland, 55 miles **Corridors 1 and 2 converge on the east side of the Mauneluk River crossing**										
GM	15	Continuous	45	Good	35	Silty alluvial gravels are available along the edges of the Lockwood Hills and along the mountains north of the Kobuk River. Clean GS materials may be present in the floodplains and old river terraces	10	None Known	Ultramafic rocks may contain NOA	Foundation conditions improve through this section, except for along the Kobuk River and the Ambler Lowlands where thicker embankments will be required
Ice rich SA/SM	5									
SA/SM	15	Discontinuous	10	Poor	20	Numerous bedrock sources throughout the route with BV/BG sources along the Mauneluk River				
BV/BG	10									
BO/BU	20									
SUMMARY		Continuous	75%	Good	45%	Average Distance between borrow sites	<10			
				Fair	15%					
		Discontinuous	24%	Poor	40%					

5.2.1.1 Dalton Highway to Evansville/Bettles

From the Dalton Highway, the corridor passes along the north side of Gobbler's knob, south of the Jack White Hills. Bedrock may be used from these hills as borrow material and will most likely consist of schist and gneiss. Most of this stretch of corridor will traverse glacial moraine and alluvial deposits with discontinuous permafrost, which will provide proper foundation soils with generally low thaw settlement potential. Over approximately 10 miles, this stretch of corridor crosses over numerous drainages, namely the meandering South Fork Koyukuk River, that contain alluvial deposits (cleaner sands and gravels) that may be used as borrow material; however, some longer haul distances may be required if organic deposits in the river floodplains make borrow source development uneconomical. Approaching Evansville/Bettles, a large muskeg area can be found immediately to the south of the community with numerous thaw lakes and meandering streams. These areas may contain deep organics, therefore, a thicker embankment and geotextile may be needed for construction of the road.

Borrow sources should be available at approximately 10-mile intervals along this corridor segment.

5.2.1.2 Bettles to Alatna Hills

As the route crosses the meandering Koyukuk River west of Bettles, deep, ice-rich organic deposits are likely within the floodplain. However, Quaternary alluvial terrace deposits along the edges of the floodplain may provide proper borrow source material. Discontinuous permafrost is expected along this area with thawed areas along the Koyukuk River floodplain.

5.2.1.3 Alatna Hills

The corridor briefly passes through the Alatna Hills, comprised of lower Cretaceous sedimentary rocks (conglomerate, greywacke, siltstone, and shale) immediately west of Bettles and the Koyukuk River; limited bedrock exposures may provide borrow source material. The slopes of the hills are anticipated to be covered with colluvium and glacial drift deposits, which can provide good foundation soils, however, slope stability should be evaluated where the corridor cuts into the hillsides. Lower lying areas may have organic soil cover, which has no bearing strength. This section of the corridor is expected to be underlain by continuous permafrost.

5.2.1.4 Alatna Hills to Hogatza River

This corridor segment follows along the southern face of the Alatna Hills before traversing across the thaw-lake dotted plain near Henshaw Creek. This entire section of the corridor is expected to be underlain with permafrost; polygonal ground through low-lying areas indicate ice-rich, fine grained soils. The meandering Hogatza and Alatna Rivers will yield Quaternary alluvial terrace deposits and Pliestocene glacial drift deposits can be found in upland areas and along hillsides, both of which will provide suitable foundation soils and borrow material at the desired 10-mile intervals.

Aerial photographs along this section of the corridor indicate iron staining along the southern face of the Alatna Hills and in the Henshaw River Valley.

5.2.1.5 Hogatza River to Pah River

This section of the corridor can be described as compact groups of hills and low mountains surrounded by broad lowland flats. Organic soil deposits are expected in the low lying areas with minimal borrow sites. Pleistocene glacial drift deposits should be available along the flanks of the hills and mountains; the glacial drift soils should provide sufficient material at desired 10-mile intervals, although some haul distance may be required through the Pah River flats. The section of the corridor is underlain by moderately thick to thin permafrost, except in areas of flooplains and where numerous thaw lakes are present (i.e. the Pah River). Aerial photographs along this section of the corridor indicate iron staining along the eastern edge of the Lockwood Hills, which are comprised of Cretaceous-Jurassic andesitic volcanic rocks with some mid-Cretaceous greywacke.

5.2.1.6 Pah River Valley to Ambler River Lowland

As the corridor passes along the Pah River, through the east-west trending Lockwood Hills, Quaternary alluvial terrace deposits flanked by glacial drift deposits may provide borrow sites at the desired 10-mile intervals as well as suitable foundation soils. The Kobuk and Mauneluk Rivers are both meandering streams with wide floodplains that contain deep muskeg deposits and thaw lakes. Some of the bedrock, specifically the Paleozoic ultramafic volcanic and their metamorphic equivalents, may contain NOA and may not be suitable for use.

5.3 3-Elliott Highway Corridor (Figure 10, Table 9)

5.3.1 Typical Geology

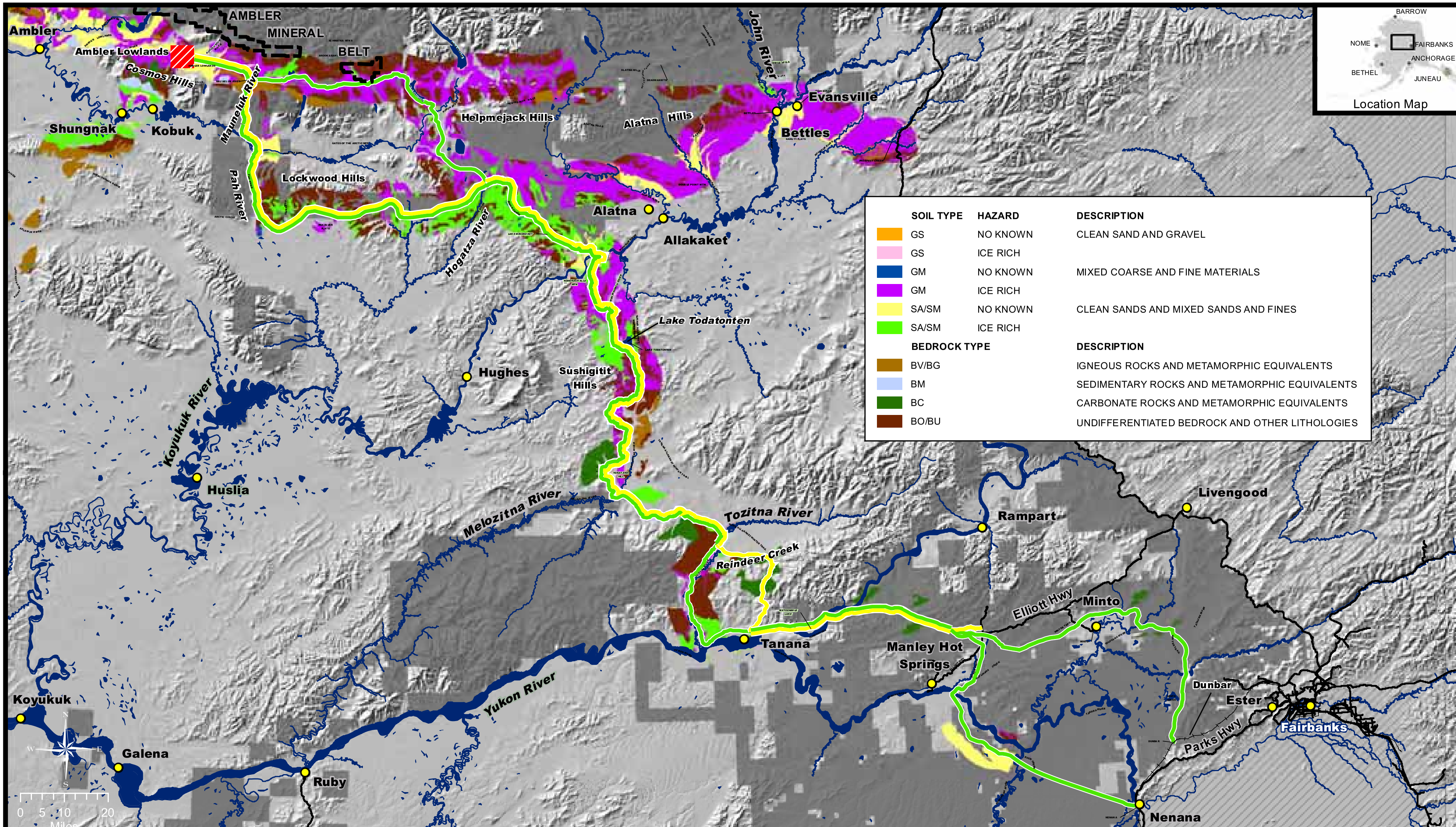
From Eureka to the Yukon River, soils are expected to consist primarily of relatively clean sand and gravel, Quaternary alluvium, and glacial outwash from numerous drainages in adjacent hills. Soils along much of the Yukon River consist of alluvial sands and silts.

From Tanana to the Tozitna River, the corridor follows well-drained higher ground, so thin soil deposits over bedrock are expected until approaching the Tozitna River, where muskeg and ice-rich silts will be encountered.

From the Tozitna River to the intersection with the Kanuti Flats Corridor, this corridor skirts extensive sections of low-lying muskeg areas. Staying above the wet areas, soils are expected to be thin, silty colluvial sands and gravels. The corridor unavoidably traverses muskeg areas near Lake Todatonten, in the Koyukuk River Valley near the mouths of Discovery and Henry Creeks, between Discovery and Siruk Creeks, and along sections of Siruk Creek.

5.3.1.1 Elliott Highway to Tanana

This section of the corridor generally skirts the base of low mountains, such as Serpentine Ridge. Alluvial fan and glacial drift deposits are anticipated in these areas, providing suitable foundation soils. In addition, bedrock consisting of Paleozoic metamorphosed sedimentary and volcanic rocks (schist, quartzite, and basalt) may be present through the mountain valleys for borrow source material. Quaternary alluvial terrace deposits along the Yukon River floodplain should yield clean sand and gravel borrow material at the desired 10-mile intervals. This section of the corridor is anticipated to be underlain by discontinuous permafrost with thawed areas near larger rivers. Aerial photographs along this section of the corridor indicate iron staining near Texas and Stevens Creeks.



SOIL TYPE	HAZARD	DESCRIPTION
GS	NO KNOWN	CLEAN SAND AND GRAVEL
GS	ICE RICH	
GM	NO KNOWN	MIXED COARSE AND FINE MATERIALS
GM	ICE RICH	
SA/SM	NO KNOWN	CLEAN SANDS AND MIXED SANDS AND FINES
SA/SM	ICE RICH	

BEDROCK TYPE	DESCRIPTION
BV/BG	IGNEOUS ROCKS AND METAMORPHIC EQUIVALENTS
BM	SEDIMENTARY ROCKS AND METAMORPHIC EQUIVALENTS
BC	CARBONATE ROCKS AND METAMORPHIC EQUIVALENTS
BO/BU	UNDIFFERENTIATED BEDROCK AND OTHER LITHOLOGIES

Communities and Place Names
Railroad
Existing Roads
Water
Outside of Project Study Area
Ambler Mineral Belt
State Land
Proposed Staging Area
3-Elliott Hwy Corridor
365 Miles (Road Only)
4-Parks Hwy RR Corridor
420-450 Miles (Rail Only)

Coordinate System: NAD 1983 Alaska Albers

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
NORTHERN REGION

AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

ACCESS SOUTHEAST CORRIDORS MAP

DATE: May 24, 2011

Figure 10

P:\Projects\D60693\GIS\Geotech\MATERIAL SITE GEOTECHNICAL RECONNAISSANCE\Ambler Access Southeast.mxd May 24, 2011 1:04:04 PM User: chris.harrington

Table 9: Elliott Highway Corridor (Figure 10), 365 miles and 4-Parks Highway RR Corridor (Figure 10), 420-450 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Elliott Highway (Eureka) across Yukon river to Tanana, 55 miles										
GS	15	Continuous moderately thick to thin	5	Fair	40	Silty gravel through much of this segment.	10	Potential ARD Risk	None Known	Generally fair foundation conditions with granular soils and discontinuous permafrost. Embankment depths will vary depending on specific frost and soil conditions. Areas of silts and ice rich silts in low lying areas along the Yukon River. These areas will require thicker embankments. Aerial photographs indicate iron staining near Texas and Stevens Creeks.
GM	15									
SA/SM	15	Discontinuous	50	Poor	15	Clean gravel in alluvial fans near mountain streams and in terraces along the Yukon River				
Ice Rich SA/SM	10									
Tanana to Tozitna River and Reindeer Creek confluence, 35 miles **This highway corridor diverges from the RR corridor at Tanana and converges with the RR corridor at the Tozitna River**										
GM		Continuous moderately thick to thin	15	Fair	20	Silty Gravels through the mountains	10	None Known	None Known	Fair foundation conditions through the mountains with granular soils and discontinuous permafrost. Low lying ice rich silts and swampy ground in the Ptarmigan Creek, Reindeer Creek and Tozitna River low lying areas
Ice Rich SA/SM										
BC		Discontinuous	20	Poor	15	Volcanic bedrock may supply surfacing aggregates. BO/BU will provide embankment				
BO/BU										
Tozitna River to Sushgitit Hills, 75 miles										
GM		Continuous moderately thick to thin	65	Good	60	Silty Gravels along the hills	10	None Known	None Known	Generally good foundation conditions with granular soils and continuous permafrost. The corridor skirts ice rich silty lowlands with patches of discontinuous permafrost, thaw lakes and polygonal ground. Embankments will be thicker in these areas. Altiplanation terraces and stone polygons have been reported in the Kokrine Hills.
Ice Rich SA/SM										
BV/BG		Discontinuous	10	Poor	15	Numerous bedrock sources including volcanic suitable for surfacing and ballast aggregates				
BC										
BO/BU										
Sushgitit Hills to Hogatza River Valley, 90 miles										
GM	35	Continuous moderately thick to thin	40	Good	25	Silty gravels in uplands	10 - 20	Potential ARD Risk	None Known	Good to fair foundation conditions in uplands areas however much of this section skirts or traverses ice rich silty and organic soils with discontinuous permafrost. Thicker embankments will be required for much of this segment. Aerial photographs indicate iron staining near Lake Todatonten.
SA/SM	5									
Ice Rich SA/SM	30	Discontinuous	50	Fair	30	Scattered bedrock sources of BO/BU				
BO/BU	20			Poor	35					
Hogatza River through Lockwood Hills along Pah River flats to Pah River, 60 miles **Corridors 3 and 4 converge with Corridor 2 at the Hogatza River**										
Ice rich SA/SM	45	Continuous thick to thin	55	Good	20	Silty gravels in the uplands through and along the edges of the Lockwood Hills	10 - 15	Potential ARD Risk	None Known	After crossing the Hogatza River, this section traverses segments of low lying ground with numerous thaw lakes and organic soils which will require thicker embankment depths. After passing through the Lockwood Hills, the corridor skirts the Pah River Flats where again there are numerous thaw lakes and organic soils. Aerial photographs indicate iron staining along the eastern edge of the Lockwood Hills.
GM	15	Discontinuous	5	Poor	40	Bedrock sources within the Lockwood Hills				
BO/BU	15									
Pah River Valley across Kobuk River to Manuneluk River and Ambler River Lowland, 55 miles **Corridors 1, 2, 3 and 4 converge on the east side of the Mauneluk River crossing**										
GM	15	Continuous	45	Good	35	Silty alluvial gravels are available along the edges of the Lockwood Hills and along the mountains north of the Kobuk River. Clean GS materials may be present in the floodplains and old river terraces	10	None Known	Ultramafic rocks may contain NOA	Foundation conditions improve through this section, except for along the Kobuk River and the Ambler Lowlands where thicker embankments will be required. NOA is known to be present near Kobuk and Ambler.
Ice rich SA/SM	5									
SA/SM	15	Discontinuous	10	Poor	20	Numerous bedrock sources throughout the route with BV/BG sources along the Mauneluk River				
BV/BG	10									
BO/BU	20									
SUMMARY Highway Corridor 3		Continuous	60%	Good	40%	Average Distance between borrow sites	10-15	Potential ARD Risk	Ultramafic rocks may contain NOA	Aerial photographs indicate iron staining along segments of the corridor. NOA is known to be present near Kobuk and Ambler.
		Discontinuous	40%	Fair	20%					
				Poor	40%					

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
RR Corridor 4A Tanana through Tozitna River Valley to Tozitna River/Reindeer Creek Confluence, 40 miles **This RR corridor diverges from the Highway corridor at Tanana and converges with the Highway corridor at Reindeer Creek**										
GM	20	Continuous	10	Good	10	Silty gravel sources along the Tozitna River	5-10	None Known	None Known	Design and construction of this segment will be challenging. Ice rich silty soils and discontinuous permafrost along the Yukon River and the Tozitna river will require deeper embankments. The Tozitna River Valley is narrow and numerous cuts and fills will likely be required to avoid construction within the floodplain on poor foundation soils
Ice rich SA/SM	20			Fair	10	Bedrock sources along the Tozitna River consisting of BO/BU				
BO/BU	20	Discontinuous	30	Poor	20					
RR Corridor 4B Hogatza River to north of Nutuvukti Lake, 40 miles **This RR corridor diverges from the Highway corridor at Hogatza River and converges with the Highway Corridor 1 north of Nutuvukti Lake**										
GM	15	Continuous	35	Good	15	Silty gravel sources in the Norutak Hills and Akoliakruich Hills	10-15	None Known	None Known	This segment traverses silty ice rich soils in the headwaters of the Hogatza River to across the continental divide and across the Kobuk River lowlands. Thicker embankments will be required through this area.
Ice rich SA/SM	25									
BV/BG	10	Discontinuous	5	Poor	25	Bedrock sources in the Hills with volcanic suitable for surfacing and ballast aggregates near Nutuvukti Lake				
BO/BU	5									
RR Corridor 4B north of Nutuvukti Lake through Ambler Lowlands to Ambler, 70 miles **This RR corridor and Corridor 1 at Hogatza River Converges with the Highway Corridor 2 on the east side of the Mauneluk River Crossing**										
GM	70	Continuous	70	Good	60	Silty alluvial gravels are available throughout this section with clean GS materials in the floodplains	5 - 10	None Known	Ultramafic rocks may contain NOA	The floor of this rift valley has several large swampy areas. Thicker embankment depths will be required where the alignment must cross these low-lying areas. Otherwise, there should be good support for embankments of normal thickness.
Ice rich SA/SM	20									
SA/SM	10			Poor	10	Numerous bedrock sources throughout the route with several BV/BG sources				
BV/BG	30									
BO/BU	50									
RR Corridor 4C Nenana to Elliott Highway, 80 miles **This RR corridor and converges with Highway Corridor and RR Corridor 4A/B at the Elliott Highway**										
GM	20	Continuous thick to thin	15	Good	20	Silty gravels and bedrock sources in uplands between the Tanana River and the Elliot Highway	30	None Known	None Known	Poor foundation conditions between Nenana and the Tanana River crossing near Manley Hot Springs. Long stretches of organic soils and swampy ground and silty soils in discontinuous permafrost
GS	5									
Ice rich SA/SM	15									
SA/SM	15	Discontinuous in numerous isolated masses	60	Poor	60	Scattered GS alluvial deposits in the floodplains				
OR	30									
BO/BU	20									
RR Corridor 4D Dunbar to Elliott Highway, 95 miles **This RR corridor alternate to 4C converges with Highway Corridor and RR Corridor 4A/B at the Elliott Highway**										
GM	85	Continuous thick to thin	95	Good	85	Silty gravel along the hills with some clean material available in alluvial deposits in the drainages	10	None Known	None Known	This segment skirts the edge of the Minto Flats and numerous cuts and fills will be required. The foundation conditions are generally good with granular soils and continuous permafrost. The corridor traverses portions of the Flats where there are ice rich silty and organic soils. Thicker embankments will be required in these areas.
Ice rich SA/SM and OR	10					Bedrock sources consisting of BO/BU along the hills				
BO/BU	85			Poor	10					
SUMMARY RR 4A and 4C		Continuous	50 %	Good	35 %	Average Distance between borrow sites	15	None Known	None Known	
		Discontinuous	50 %	Fair	15 %					
				Poor	45 %					

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
SUMMARY RR 4A and 4D		Continuous	65 %	Good	50 %	Average Distance between borrow sites	10-15	None Known	None Known	
		Discontinuous	35 %	Fair	15 %					
				Poor	35 %					
SUMMARY RR 4B and 4C		Continuous	60 %	Good	40 %	Average Distance between borrow sites	15	None Known	Ultramafic rocks may contain NOA	NOA is known to be present near Ambler.
		Discontinuous	40 %	Fair	20 %					
				Poor	40 %					
SUMMARY RR 4A and 4D		Continuous	70 %	Good	55 %	Average Distance between borrow sites	10	None Known	None Known	
		Discontinuous	30 %	Fair	15 %					
				Poor	30 %					

5.3.1.2 Tanana to Tozitna River & Reindeer Creek Confluence

This section of the corridor follows along the Tanana-Allakaket winter trail, cutting across the mountains north of Tanana – even-topped rounded hills with alluviated valley floors. The Quaternary alluvial terrace, glacial drift, and colluvium soils on the valley walls and floors are generally considered to be suitable foundation soils. Most of the area is underlain by discontinuous permafrost, with thawed areas along large streams. Thaw lakes dot the flatter plain areas north of the Tozitna River-Reindeer Creek confluence.

5.3.1.3 Tozitna River to Sushgitit Hills

From the Reindeer Creek confluence, the corridor skirts along the foothills of the Kokrine Hills to the west side of the Melozitna River, a meandering stream surrounded by thaw lakes. Alluvial fans and colluvium along the base of the hills can provide suitable foundation soils, as well as potential borrow sources at the desired 10-mile intervals. This section of the corridor is underlain by continuous permafrost, except in floodplains. Through the Kokrine Hills, altiplanation and stone polygons are evidence of periglacial activity in the area.

5.3.1.4 Sushgitit Hills to Hogatza River Valley

The Koyukuk River is the approximate southern limit of Pleistocene glaciations. Glacial moraine soils are generally suitable foundation soils, however, low-lying areas may have organic soil cover and may be ice-rich, specifically near Lake Todatonten and the Koyukuk River. Thaw lakes and beaded streams are also present adjacent to Lake Todatonten. Where the corridor passes between Lake Mingkoket and the adjacent hill, colluvium is anticipated to be present along the base of the slopes and slope stability should be evaluated in this area. Discontinuous permafrost is anticipated along this section of the corridor, with thawed areas near large lakes and rivers.

Aerial photographs along this section of the corridor indicate iron staining near Lake Todatonten.

5.3.1.5 Hogatza River to Pah River

This section of the corridor can be described as compact groups of hills and low mountains surrounded by broad lowland flats. Organic soil deposits are expected in the low lying areas with, minimal borrow sites. Pleistocene glacial drift deposits should be available along the flanks of the hills and mountains; the glacial drift soils should provide sufficient material at the desired 10-mile intervals, although some haul distance may be required through the Pah River flats. The section of the corridor is underlain by moderately thick to thin permafrost, except in areas of flooplains and where numerous thaw lakes are present (i.e. the Pah River). Aerial photographs along this section of the corridor indicate iron staining along the eastern edge of the Lockwood Hills, which are comprised of Cretaceous-Jurassic andesitic volcanic rocks with some mid-cretaceous greywacke.

5.3.1.6 Pah River Valley to Ambler River Lowland

As the corridor passes along the Pah River, through the east-west trending Lockwood Hills, Quaternary alluvial terrace deposits flanked by glacial drift deposits may provide borrow sites at the desired 10-mile intervals as well as suitable foundation soils. The Kobuk and Mauneluk Rivers are both meandering streams with wide floodplains that contain deep muskeg deposits and thaw lakes. Some of the bedrock, specifically the Paleozoic ultramafic volcanic and their metamorphic equivalents, may contain NOA and may not be suitable for use.

5.4 4-Parks Highway Railroad Corridor (Figure 10, Table 9)

5.4.1 Typical Geology

From Dunbar to Eureka, the corridor skirts the east and northern edges of Minto Flats and crosses the Tolovana River about 10 miles east of Minto, then proceeds west toward Eureka. Much of the muskeg and silty ice-rich soils can be avoided, except at the Tatalina and Tolovana River crossings. The soils at toes of mountain slopes are expected to be silty colluvial sands and gravels with cleaner alluvial materials at mouths of major drainages.

The section of the corridor from Nenana to Eureka crosses the relatively low ground between Nenana and the Kantishna River and proceeds up the Tanana River, crossing near Manley Hot Springs and proceeding north toward Eureka. Soils are expected to be silty floodplain deposits.

From Tanana to the Tozitna River, silts and silty sands are expected along the Yukon River. Along Tozitna River, the soils are expected to be silty colluvial and glacial moraine sands and gravels, with cleaner sands and gravels at mouths of drainages.

5.4.1.1 Nenana to Elliott Highway

Between Nenana and the Elliott Highway, the corridor crosses through large muskeg areas, up to 30 miles wide, through the Tanana River and Kantishna River floodplains. The Quaternary alluvial deposits should provide suitable borrow source material, depending on silt content, where muskeg deposits are not substantial. In the area between Manley Hot Springs and Eureka, Pleistocene eolian deposits in the Baker and Hutlinana Creeks Lowlands will possibly be ice-rich with organic surface deposits and unsuitable for use as embankment material. Permafrost is discontinuously present along this section of the corridor, with thaw bulbs near the Tanana and Kantishna Rivers and in porous gravel outwash areas. Numerous thaw lakes are present in the Baker and Hutlinana Creek Lowlands

5.4.1.2 Dunbar to Eureka

This section of the corridor skirts along the boundary of the Tanana-Kuskokwim Lowland and the Yukon-Tanana Upland. Minto Flats is a broad, low-lying plain with numerous thaw lakes (most likely associated with polygonal ground) surrounded by rolling hills; the corridor hugs these hills on the east and north side of Minto Flats.

Before reaching Eureka, the corridor passes through the Dugan Hills; colluvium and alluvial fan deposits along the base of these hills will provide suitable foundation soils and potential borrow sites at the desired 10-mile intervals, however, alluvial fans are at risk for rapid mass movements and avalanches. This section of the corridor is underlain by discontinuous permafrost and may be thawed in areas of lakes and large rivers.

5.4.1.3 Elliott Highway to Tanana

This section of the corridor generally skirts the base of low mountains, such as Serpentine Ridge. Alluvial fan and glacial drift deposits are anticipated in these areas, providing suitable foundation soils. In addition, bedrock consisting of Paleozoic metamorphosed sedimentary and volcanic rocks (schist, quartzite, and basalt) may be present through the mountain valleys for borrow source material. Quaternary alluvial terrace deposits along the Yukon River floodplain should yield clean sand and gravel borrow material at the desired 10-mile intervals. This section of the corridor is anticipated to be underlain by discontinuous permafrost with thawed areas near larger rivers. Aerial photographs along this section of the corridor indicate iron staining near Texas and Stevens Creeks.

5.4.1.4 Tanana through Tozitna River Valley to Tozitna River/Reindeer Creek Confluence

As the corridor passes through the Tozitna River Valley, it is tightly bounded by the Tozitna River and steep-sloped mountains. Colluvium along the valley walls will provide silty sand and gravel borrow sources at approximately five to ten-mile intervals; colluvium is also a suitable foundation soil as it has high bearing strength and low potential for thaw settlement and frost heave. The Gold Hills are comprised of Paleozoic and Precambrian schist and gneiss bedrock and are likely to provide suitable material borrow sources where exposed.

5.4.1.5 Tozitna River to Sushgitit Hills

From the confluence, the corridor skirts along the foothills of the Kokrine Hills to the west side of the Melozitna River, a meandering stream surrounded by thaw lakes. Alluvial fans and colluvium along the base of the hills can provide suitable foundation soils, as well as potential borrow sources at the desired 10-mile intervals. This section of the corridor is underlain by continuous permafrost, except in floodplains. Through the Kokrine Hills, altiplanation and stone polygons are evidence of periglacial activity in the area.

5.4.1.6 Sushgitit Hills to Hogatza RiverValley

The Koyukuk River is the approximate southern limit of Pleistocene glaciations. Glacial moraine soils are generally suitable foundation soils, however, low-lying areas may have organic soil cover and may be ice-rich, specifically near Lake Todatonten and the Koyukuk River. Thaw lakes and beaded streams are also present adjacent to Lake Todatonten. Where the corridor passes between Lake Mingkoket and the adjacent hill, colluvium is anticipated to be present along the base of the slopes and slope stability should be evaluated in this area. Discontinuous permafrost is anticipated along this section of the corridor, with thawed areas near large lakes and rivers.

Aerial photographs along this section of the corridor indicate iron staining near Lake Todatonten.

5.4.1.7 Hogatza River to Pah River

This section of the corridor can be described as compact groups of hills and low mountains surrounded by broad lowland flats. Organic soil deposits are expected in the low lying areas with minimal borrow sites. Pleistocene glacial drift deposits should be available along the flanks of the hills and mountains; the glacial drift soils should provide sufficient material at the desired 10-mile intervals, although some haul distance may be required through the Pah River flats. The section of the corridor is underlain by moderately thick to thin permafrost, except in areas of flooplains and where numerous thaw lakes are present (i.e. the Pah River). Aerial photographs along this section of the corridor indicate iron staining along the eastern edge of the Lockwood Hills, which are comprised of Cretaceous-Jurassic andesitic volcanic rocks with some mid-cretaceous greywacke.

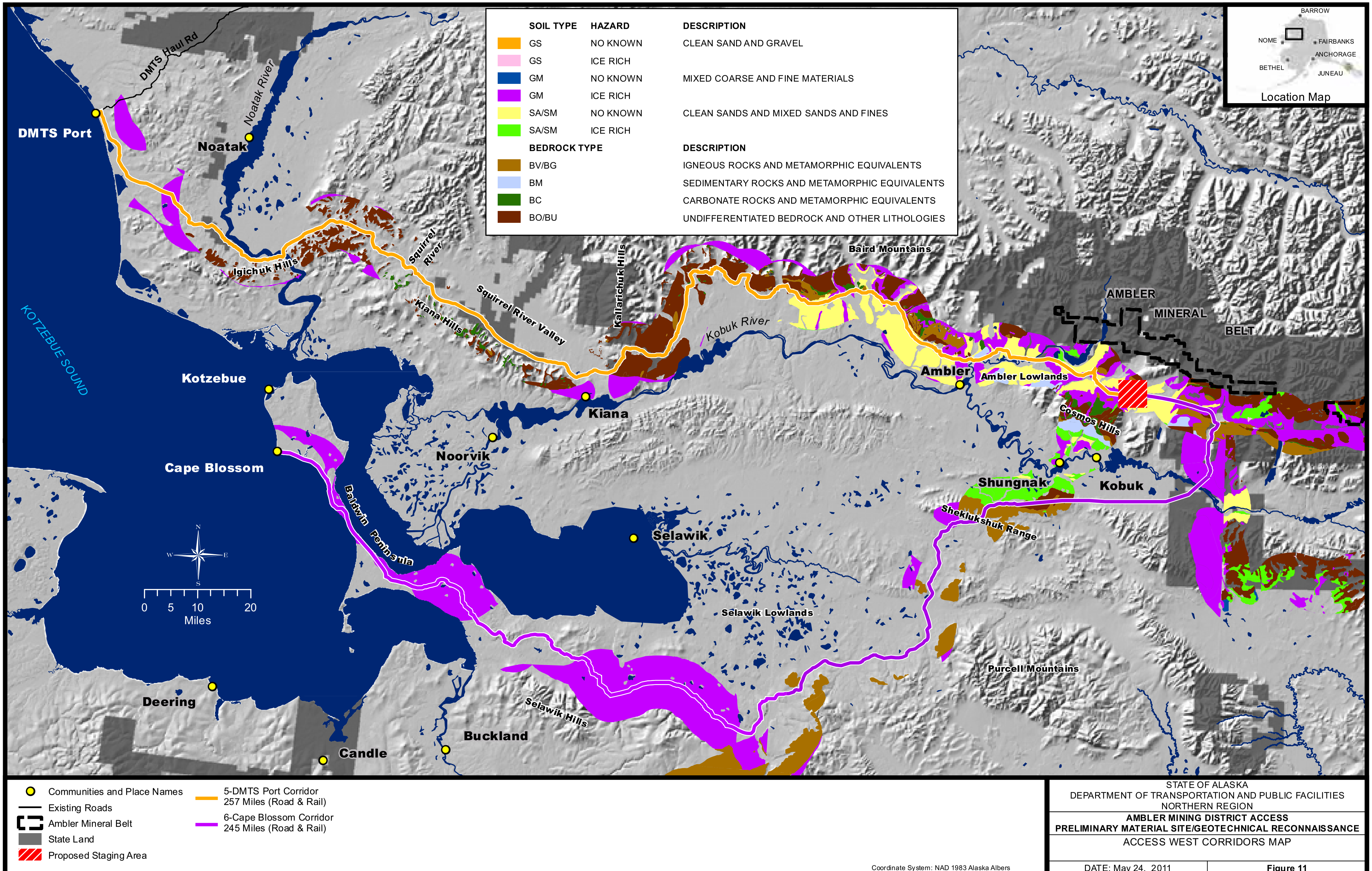
5.4.1.8 Pah River Valley to Ambler River Lowland

As the corridor passes along the Pah River, through the east-west trending Lockwood Hills, Quaternary alluvial terrace deposits flanked by glacial drift deposits may provide borrow sites at the desired 10-mile intervals as well as suitable foundation soils. The Kobuk and Mauneluk Rivers are both meandering streams with wide floodplains that contain deep muskeg deposits and thaw lakes. Some of the bedrock, specifically the Paleozoic ultramafic volcanic and their metamorphic equivalents, may contain NOA and may not be suitable for use.

5.5 5-DMTS Port Corridor (Figure 11, Table 10)

5.5.1 Typical Geology

From the DMTS Port along the coast of the Chukchi Sea to the Noatak River, the gently sloped coastal plains of old beach and delta deposits show polygonal pattering. Muskeg is expected in low lying areas and surrounding lagoons. From the Noatak River to Kiana, silty glacial moraine sands and gravels with alluvial and glacial outwash deposits in drainages are expected. Alluvial fan and colluvial material with considerable amounts of rubble and cobbles/boulders is likely present along the base of the Kiana and Igichuk Hills. Shallow bedrock may be present where the corridor crosses through mountain passes. This corridor traverses an area covered by the eastern reaches of Illinoian glaciations in the region.



STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
NORTHERN REGION

AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

ACCESS WEST CORRIDORS MAP

DATE: May 24, 2011 **Figure 11**

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Table 10: DMTS Corridor (Figure 11), 257 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
DMTS Port to Noatak River, ~35 miles										
GM	5	Continuous, thick	35	Fair	5	Recent beach deposits along the Chukchi coastline	20	None Known	None Known	Polygonal ground is present in frozen coastal deposits with deep organic cover. Embankment construction will require keeping the tundra frozen to prevent frost heave/thaw settlement.
Ice-rich SA/SM	30			Poor	30					
Noatak River to Squirrel River Valley, ~50 miles										
Ice rich GM	45	Continuous moderately thick to thin	50	Good	5	Quaternary alluvial terrace deposits along the Noatak River	10	None Known	None Known	Thaw lakes within the Squirrel River Plain will have significant amounts of peat and organic silts.
BO/BU	5			Fair	25	Glacial drift along the lower Igichuk Hills				
				Poor	20	Paleozoic sedimentary bedrock of Igichuk Hills				
Squirrel River Valley to Kallarichuk Hills, 40 miles										
Ice rich GM	40	Continuous	20	Fair	30	Quaternary alluvial terrace deposits along the Squirrel River	>10	None Known	None Known	The Squirrel River floodplain, approximately 10-miles wide near Kiana, is comprised of Quaternary alluvial terrace deposits with significant peat and organic silt deposits (thaw lakes)
		Discontinuous	20	Poor	10	Paleozoic bedrock sources in the Kiana Hills				
Kallarichuk Hills to Ambler River Lowland, 135 miles										
GM	30	Continuous	100	Good	90	Paleozoic bedrock sources in the Baird Mountains and Kallarichuk Hills	<10	None Known	Yes- known NOA deposits in the Cosmos Hills north of Kobuk	Alluvial fan deposits along valley drainages are at risk for flooding, rapid mass movement, and avalanches.
SA/SM	50	Discontinuous	35	Fair	30	Quaternary alluvial terrace and glacial drift deposits along lower valley walls				Frozen eolian deposits can be suitable foundation soils if they remain frozen, however, they are a poor borrow source material.
BO/BU	40			Poor	15					
BV/BG	5									
SUMMARY		Continuous	80%	Good	35%	Average Distance between borrow sites	15			
		Discontinuous	20%	Fair	35%					
				Poor	30%					

Between Kiana and Kobuk, predominant soils are Quaternary alluvium and glacial outwash. Silty colluviums and glacial moraine sands and gravels become more prevalent to the west along the corridor, specifically near the base of Baird Mountains. Oxbow Lakes and abandoned meander channels of the Kobuk River generally contain silty sands with some muskeg areas. These are also encountered at stream crossings, such as the Squirrel River (a mature meandering stream).

5.5.1.1 DMTS Port to Noatak River

This corridor segment skirts along the Arctic Foothills near the coast of the Chukchi Sea. The area is comprised of old beach and delta deposits with organic soil cover, limiting the availability of suitable borrow sources to less than one every 15 to 20 miles, with off alignment haul distances of about five miles. Polygonal ground along these coastal lowlands indicate the presence of continuous permafrost with ice features, such as ice wedges, and numerous thaw lakes are present near lagoons and rivers. Recent beach deposits along the Chukchi Sea may provide clean sands; however, this may require dredging in intertidal zones.

5.5.1.2 Noatak River to Squirrel River

Where this section of the corridor crosses the Noatak River and approaches the Squirrel River, Quaternary alluvial terrace and recent alluvium will provide suitable foundation soils, as well as clean sand and gravel borrow material. The numerous thaw lakes present in the Noatak and Squirrel River floodplains indicate that areas of peat and organic silts are present and may affect the amount of available suitable construction materials. Along the Igichuk Hills between the Noatak and Squirrel Rivers, Pleistocene glacial drift deposits may be present along the flanks of the hills, and Paleozoic sedimentary rocks (shale and limestone) may be available. Suitable borrow sources along this section of the corridor should be available at about 10-mile intervals.

5.5.1.3 Squirrel River Valley to Kallarichuk Hills (Kiana)

This section of the corridor runs along the north side of the Kiana Hills, hugged by the Squirrel River. The Squirrel River floodplain is likely underlain by Quaternary alluvial terrace deposits covered with thaw lake deposits comprised of peat and organic silts. Along the Kiana Hills, Pleistocene glacial drift deposits with isolated areas of Paleozoic bedrock (schist, quartzite, and limestone) should provide suitable borrow sources at the desired 10-mile intervals; however, where the Squirrel River meanders south toward Kiana, the river floodplain becomes about 10-miles wide with little to no suitable borrow sources. This section of the corridor is underlain by discontinuous permafrost with thawed areas near large lakes and rivers.

5.5.1.4 Kallarichuk Hills to Ambler River Lowland

This approximately 135 mile stretch of the corridor is bounded to the north by the steep slopes and rugged peaks of the Baird mountains and to the south by the Kobuk River, a meandering river surrounded by oxbow and thaw lakes with large areas of muskeg along its 10-mile with floodplain. Alluvial fan deposits from drainages coming out of the hills will be common. Along the south side of the alignment, Quaternary alluvial terraces are present along drainages and Pleistocene eolian deposits with isolated areas of glacial drift are present through the Kobuk River Valley. Through the Kallarichuk Hills and along the base of the Baird Mountains, numerous bedrock borrow sources consisting of Paleozoic schist, quartzite, and limestone may be present at the desired 10-mile intervals. Some bedrock through this area, specifically the ultramafic volcanic and their metamorphic equivalents within the Cosmos Hills, north of Kobuk, may contain NOA and may not be suitable for use.

5.6 6-Cape Blossom Corridor (Figure 11, Table 11)

5.6.1 Typical Geology

The predominant soils between Kotzebue and the Ambler Lowland are expected to be deltaic silts and sands with some cleaner alluvium and old marine deposits near the higher elevations. The Baldwin Peninsula appears to be the end moraine of an Illinoian glacial advance. Swampy, low-lying areas are common along this corridor with numerous thaw lakes and drainages, specifically in the Selawik Basin and on the Baldwin Peninsula. Colluvium and alluvial fan deposits may be prevalent where the corridor skirts the Selawik Hills. The Selawik Hills are comprised of the Selawik Hills Pluton, a mid-cretaceous assemblage of intermediate, alkaline igneous rocks that had intruded the surrounding Andesitic Volcanic country rock (Miller, 1970).

Table 11: Cape Blossom Corridor (Figure 11), 245 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Cape Blossom to the Selawik Hills ,90 miles										
Ice rich SA/SM	35	Continuous moderately thick to thin	90	Fair	55	Sand and silt coastal plain and beach deposits along Baldwin Peninsula	20	None Known	None Known	Corridor traverses along Baldwin Peninsula, thought to be the terminal moraine of westernmost Illinoian glacial advance.
GM	55			Poor	35	Silty gravels along upland areas				Coastal plain and beach deposits are at high risk for liquefaction where thawed.
The Selawik Hills to Selawik Lowlands, 25 miles										
GM	20	Continuous moderately thick to thin	25	Fair	20	Silty sands and gravels of glacial moraine and colluvium along base of hills	15	None Known	None Known	Low-lying areas may have deep organic soil cover and/or ice-rich.
SA/SM	5			Poor	5	Quaternary alluvial terrace deposits along drainages				
Selawik Lowlands to Ambler River Lowland, 130 miles **Corridors 6, 7, and 8 converge on the east side of Tagagawik River**										
GM	15	Continuous moderately thick to thin	105	Good	20	Intermediate volcanic bedrock sources within the Purcell Mountains, Lockwood Hills, and Sheklukshuk Range	20	None Known	None Known	The Selawik Lowlands are predominately thaw lake deposits (peat and organic silts)
Ice rich SA/SM	80			Fair	20					
SA/SM	5	Discontinuous	25	Poor	90	Silty sands and gravels of glacial moraine and colluviums along base of hills				Upland eolian deposits within the Ambler River Lowland may be suitable foundation soils if they remain frozen; however, not suitable as borrow source material.
BV/BG	15									
BO/BU	10									
SUMMARY		Continuous	90%	Good	10%	Average Distance between borrow sites	20			
		Discontinuous	10%	Fair	40%					
				Poor	50%					

5.6.1.1 Cape Blossom to Selawik Hills

The length of the Baldwin Peninsula is comprised of recent coastal plain and beach deposits. As the Baldwin Peninsula is thought to be the westernmost extent of Pleistocene Glaciations, remnants of the terminal moraine are visible along the northeastern side of the Peninsula as low, rolling hills. A majority of the peninsula consists of low-lying muskeg areas with numerous thaw lakes, and some areas of the peninsula are less than one mile wide. Borrow sources will be limited along the peninsula (approximately 20 to 30-mile intervals) to recent beach deposits and Pleistocene glacial moraine deposits at higher elevations. As the corridor approaches the Selawik Hills, comprised of Cretaceous intermediate volcanics, borrow source intervals increase to about one every 10 miles.

5.6.1.2 Selawik Hills to Selawik Lowlands

This section of the proposed corridor skirts along the base of the Selawik Hills, above the muskeg and thaw lake dotted lowlands to the north. Pleistocene glacial drift, with isolated areas of Quaternary alluvial terrace deposits near streams and along the base of the hills, may provide suitable borrow sources at about 10- to 20-mile intervals in the upland areas.

5.6.1.3 Selawik Lowlands to Ambler River Lowland

The corridor traverses along the east side of the Selawik Lowlands, skirting along the foothills of the Purcell Mountains and Sheklukshuk Range. Few borrow sites (less than one every ten miles) are present along this corridor segment through the Selawik Lowlands, as this area is predominately organic and fine-grained soils. Where the corridor nears the Purcell Mountains and Sheklukshuk Range, bedrock borrow sites consisting of Cretaceous intermediate volcanics that have undergone regional metamorphism may be present at about 10-mile intervals.

Near the Lockwood Hills, composed of Cretaceous andesitic volcanic rocks, colluvium and alluvial fan deposits will be present near the base of the hills. However, haul distances of about six to ten miles may be required from the corridor. As the corridor approaches the Ambler Lowland, upland eolian deposits can be found, although, these soils tend to be ice-rich and have a high potential for frost heave and thaw settlement and are therefore not desirable as borrow material.

5.7 7-Selawik Flats Corridor (Figure 12, Table 12)

5.7.1 Typical Geology

Between Council and the Koyuk River, the soils consist of glacial moraine and colluvium (silty sands and gravels) along edges of slopes, and alluvial and glacial outwash deposits (clean sand and gravel) within drainages.

Shallow bedrock covered with colluvium is expected through the hills north of Council.

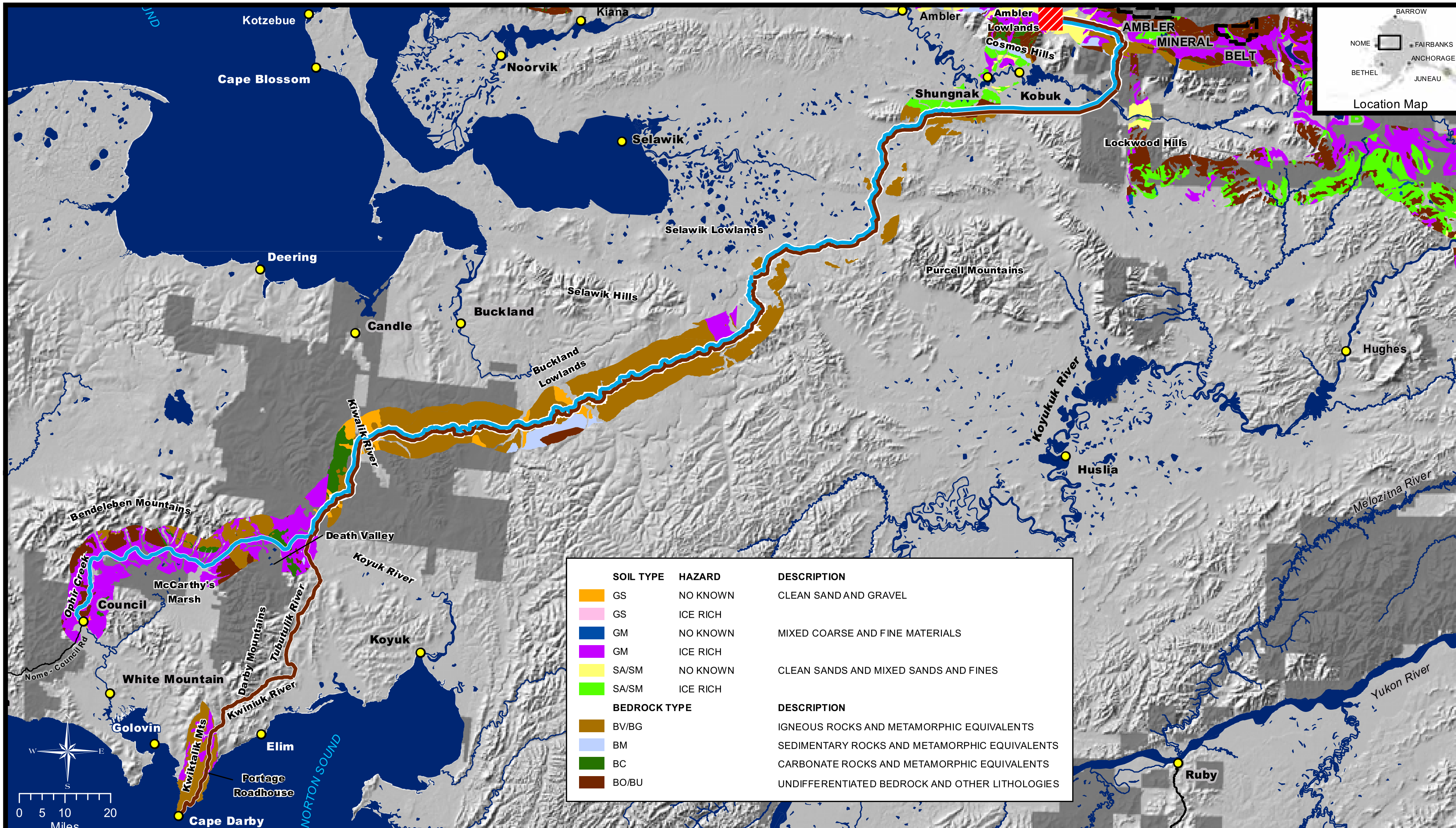
Swampy soils, consisting of deep organics and silt deposits, are to be expected where the corridor crosses the Koyuk River and through McCarthy's Marsh. Alluvial fan deposits are likely present at mouths of drainages at the base of the Bendeleben Mountains and into McCarthy's Marsh.

From Koyuk River to Selawik Hills, upland Pleistocene eolian deposits (silts and fine sands) and glacial moraine (from limited Pleistocene glaciation on the Seward Peninsula) and colluvium deposits (silty sands and gravels) at toes of slopes are expected. The predominant soils between the Selawik Hills and Ambler River Lowland are expected to be deltaic silts and sands.

Swampy, low-lying areas are common along this portion of the corridor with numerous thaw lakes and drainages

5.7.1.1 Council, along Ophir Creek to McCarthy's Marsh

Leaving Council, abundant mine tailings are present within the fluvial plain of Ophir Creek; mine tailings are suitable for use as borrow source material as they have low frost heave, thaw settlement, and liquefaction potential. Along the valley walls of Ophir Creek, colluvium and alluvial fan deposits will provide suitable foundation soils for construction along this section of the corridor. Quaternary alluvial terrace deposits may be present along the stream channels and is likely to be suitable borrow source material. The hills north of Council are comprised of Paleozoic schist and some outcrops are likely along the steeper faces of the hills. There appears to be sufficient borrow material along this section of the corridor.



Communities and Place Names
Existing Roads
Water
Ambler Mineral Belt
State Land
Proposed Staging Area

7-Selawik Flats Corridor
331Miles (Road & Rail)
8-Cape Darby Corridor
340 Miles (Road & Rail)

Coordinate System: NAD 1983 Alaska Albers

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
NORTHERN REGION

AMBLER MINING DISTRICT ACCESS
PRELIMINARY MATERIAL SITE/GEOTECHNICAL RECONNAISSANCE

ACCESS SOUTHWEST CORRIDORS MAP

DATE: May 24, 2011 | **Figure 12**

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Table 12: Selawik Flats Corridor (Figure 12), 331 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Council, along Ophir Creek to McCarthy's Marsh, 15 miles										
GS	10	Continuous moderately thick to thin	15	Good	10	Mine tailings in Ophir Creek, Quaternary alluvial terrace deposits	<10	None Known	None Known	Colluvium and alluvial fan deposits on the lower valley walls should provide suitable foundation soils.
GM	5			Fair	5	Paleozoic schist bedrock sources from hills north of Council				
McCarthy's Marsh to the Darby Mountains, 35 miles										
GM	35	Continuous moderately thick to thin	30	Fair	30	Silty sand and gravels from glacial drift deposit along lower hillsides	5-10	Potential ARD risk	None Known	Iron staining observed on aerial photographs in Bendeleben Mountains.
		Discontinuous		Poor	5	Paleozoic schist bedrock sources along the Bendeleben Mountains				Thaw lakes and meandering streams in McCarthy's Marsh. Solifluction is known to occur in the Bendeleben Mountains.
Darby Mountains, through Death Valley, to the Koyuk River, 25 miles										
GM	15	Continuous moderately thick to thin	15	Good	5	Bedrock sources along the Darby Mountains	5-10	None Known	None Known	Death Valley is covered with thaw lakes and deep organic deposits. Ice-wedge polygons are reported to be common.
BV/BG	5	Discontinuous	10	Fair	10	Silty gravels from basin colluviums deposits on valley floors				
BC	5			Poor	5					
Koyuk River to Buckland Lowland, 50 miles **Corridors 7 and 8 converge at the Koyuk River**										
GM	5	Continuous moderately thick to thin	50	Good	35	Quaternary alluvial terrace sands and gravels along rivers	10	None Known	None Known	Ice-wedge polygons are reported to be common through this area.
GS	10			Fair	5	Bedrock sources along the mountains				
BV/BG	30			Poor	10					
BC	5									
Buckland Lowland to Selawik Lowland, 80 miles										
GS	5	Continuous moderately thick to thin	75	Good	60	Quaternary alluvial terrace deposits along West Fork and Buckland Rivers	>10	None Known	None Known	Quaternary alluvial terrace deposits will be covered with organic deposits and the lowlands will be dotted with thaw lakes.
BV/BG	65	Discontinuous	5	Poor	20	Basalt rock sources near edges of the lowlands				The Buckland lowland is comprised of flat-lying basalt flows covered with eolian deposits. Eolian deposits within the Ambler River Lowland may be suitable foundation soils if they remain frozen; however, not suitable as borrow source material.
BM	5									
Selawik Lowland to Ambler River Lowland, 130 miles **Corridors 6, 7, and 8 converge on the east side of Tagagawik River**										
GM	15	Continuous moderately thick to thin	105	Good	20	Intermediate volcanic bedrock sources within the Purcell Mountains, Lockwood Hills, and Sheklukshuk Range	10	None Known	None Known	The Selawik Lowlands are predominately thaw lake deposits (peat and organic silts)
Ice rich SA/AM	80			Fair	20					
SA/SM	5	Discontinuous	25							Upland eolian deposits within the Ambler River Lowland may be suitable foundation soils if they remain frozen; however, not suitable as borrow source material.
BV/BG	15			Poor	90	Silty sands and gravels of glacial moraine and colluviums along base of hills	30			
BO/BU	10									

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
SUMMARY		Continuous	85%	Good	40%	Average distance between borrow sites	>10			
		Discontinuous	15%	Fair	20%					
				Poor	40%					

5.7.1.2 McCarthy's Marsh to the Darby Mountains

This corridor segment skirts along the north side of McCarthy's Marsh against, the base of the Bendeleben Mountains, which are comprised of Paleozoic schist. McCarthy's Marsh contains numerous thaw lakes and meandering streams with oxbow lakes. Pleistocene glacial drift deposits will be present in the low-lying areas and may have organic soil cover and be ice-rich. This section of the corridor is underlain by continuous permafrost; periglacial processes are reported to be apparent and ice-wedge polygons are common. Solifluction has been known to occur in the Bendeleben Mountains. Borrow sites are expected at approximately five- to 10-mile intervals, however, some longer haul distances may be required through McCarthy's Marsh. Aerial photographs indicate iron staining through the Bendeleben Mountains.

5.7.1.3 Darby Mountains, through Death Valley, to Koyuk River

Through the Darby Mountains, which are cut with V-shaped valleys, the bedrock transitions from Paleozoic intermediate volcanics to Cenezoic granitic intrusions; all are suitable materials for surface course and embankment construction. Some isolated areas contain Paleozoic metamorphic rocks such as dolostone or marble. Through the valley floors, basin colluviums deposited along the base of the gentle slopes should provide fair foundation soils. Death Valley, west of the Darby Mountains, is dotted with thaw lakes and likely covered with significant muskeg deposits.

This section of the corridor is underlain by both areas of discontinuous and continuous permafrost; periglacial processes are apparent and ice-wedge polygons are common. Sufficient borrow sources should be available at the desired 10-mile interval through this section of the corridor and consist of bedrock and colluvium.

5.7.1.4 Koyuk River to Buckland Lowland

The Koyuk and Kwiglik Rivers are meandering streams surrounded with oxbow lakes and muskeg covered floodplains dotted with thaw lakes. Quaternary alluvial terrace deposits may provide sands and gravels just above the river floodplain. Where the corridor passes through the unnamed mountains west of the Koyuk River, bedrock outcrops consisting of Paleozoic schist, gneiss, and metamorphosed volcanic rocks, should be available at approximately 10-mile intervals. This section of the corridor is underlain by continuous permafrost; periglacial processes are apparent and ice-wedge polygons are common.

5.7.1.5 Buckland Lowland to Selawik Lowland

The Buckland and Selawik Lowlands are flat, broad plains abundantly dotted with thaw lakes and crossed by meandering streams. These basins are separated by the Selawik Hills and continental divide. Quaternary alluvial terrace deposits will be present near some streams and rivers, however, the suitability of this material for use in construction or as foundation soils will depend on the silt content and depth of the organic soil cover. The Buckland Lowlands are covered by flat-lying Quaternary lava flows (basalt) overlain by Pleistocene eolian deposits. The basalt formations, exposed at the edges of the Lowlands, should provide suitable borrow material at the desired 10-mile intervals. This section of the corridor is underlain by continuous permafrost with thawed areas near large lake and rivers.

5.7.1.6 Selawik Lowland to Ambler River Lowland

The corridor traverses along the east side of the Selawik Lowlands, skirting along the foothills of the Purcell Mountains and Sheklukshuk Range. Few borrow sites (less than one every ten miles) are present along this corridor segment through the Selawik Lowlands, as this area is covered predominately with organic and fine-grained soils. Where the corridor nears the Purcell Mountains and Sheklukshuk Range, bedrock borrow sites consisting of Cretaceous intermediate volcanics that have undergone regional metamorphism may be present at about 10-mile intervals.

Near the Lockwood Hills, composed of Cretaceous andesitic volcanic rocks, colluvium and alluvial fan deposits will be present near the base of the hills. However, haul distances of about six to ten miles may be required from the corridor. As the corridor approaches the Ambler Lowland, upland eolian deposits can be found, although, these soils tend to be ice-rich and have a high potential for frost heave and thaw settlement and are therefore not desirable as borrow material.

5.8 8-Cape Darby Corridor (Figure 12, Table 13)

5.8.1 Typical Geology

Between Cape Darby and the Selawik Hills, upland Pleistocene eolian deposits (silts and fine sands), and moraine and colluvium (silty sands and gravels) at toes of slopes are expected.

Swampy soils should be expected where the corridor crosses the Koyuk River, and upland eolian deposits (silts and fine sands), Pleistocene glacial moraine, and colluvium deposits (silty sands and gravels) will be present at toes of slopes.

The predominant soils between Selawik Hills and the Ambler mineral belt are expected to be deltaic silts and sands. Swampy, low-lying areas are common along this portion of corridor with numerous thaw lakes and drainages. The Selawik Hills are the approximate southern boundary for Pleistocene glaciation in this region, with some limited glacial activity on the Seward Peninsula (Pewe).

5.8.1.1 Cape Darby to Portage Roadhouse

Between Cape Darby and Portage Roadhouse, the alignment skirts the Kwiktalik and Darby Mountains, which are composed of Paleozoic schist, gneiss, and metamorphosed volcanics. Colluvial and talus deposits will be present along the steep slopes of these mountains. This section of the corridor is underlain by continuous permafrost; periglacial processes are apparent and ice-wedge polygons are common.

5.8.1.2 Portage Roadhouse, Along Kwiniuk River to Koyuk River

Along this section, the corridor crosses through the broad valleys of the Darby Mountain foothills. Colluvium along these slopes may provide suitable borrow source material of silty sands and gravels. Through some of the valleys, rivers, such as the Kwiniuk and Tubutulik Rivers, have deposited fluvial deposits and approaching the Koyuk River, will yield material consisting of ice-rich fluvial and deltaic sands. This section of the corridor is underlain by continuous permafrost; periglacial processes are apparent and ice-wedge polygons are common. It appears that material should be available at the desired 10-mile intervals along this section of the corridor.

Table 13: Cape Darby Corridor (Figure 12), 340 miles

Material Type	(mi)	Permafrost	(mi)	General Foundation Conditions	(mi)	Borrow Material	Miles Between Sites	ARD	NOA	Comments
Cape Darby to Portage Roadhouse, 10 miles										
BV/BG	10	Continuous moderately thick to thin	10	Fair	10	Metamorphic Rocks along Kwiktalik Mountains	5-10	None Known	None Known	The road will likely be founded along the slopes of the Kwiktalik Mountains, on colluviums and talus deposits; talus deposits have low bearing capacity.
Portage Roadhouse, Along the Kwiniuk River to the Koyuk River, 70 miles										
GM	60	Continuous moderately thick to thin	70	Good	5	Silty sand and gravel colluvium	10	None Known	None Known	The Kobuk River floodplain is comprised of ice-rich fluvial and deltaic sands, which have low bearing strength and high liquefaction potential.
BV/BG	5			Fair	60	Fluvial sands and gravels in river and stream channels				
				Poor	5					Ice-wedge polygons are reported to be common through this area.
Koyuk River to Buckland Lowland, 50 miles **Corridors 7 and 8 converge at the Koyuk River**										
GM	5	Continuous moderately thick to thin	50	Good	35	Quaternary alluvial terrace sands and gravels along rivers	10	None Known	None Known	Ice-wedge polygons are reported to be common through this area.
GS	10			Fair	5	Bedrock sources along the mountains				
BV/BG	30			Poor	10					
BC	5									
Buckland Lowland to Selawik Lowland, 80 miles										
GS	5	Continuous moderately thick to thin	75	Good	60	Quaternary alluvial terrace deposits along West Fork and Buckland Rivers	>10	None Known	None Known	Quaternary alluvial terrace deposits will be covered with organic deposits and the lowlands will be dotted with thaw lakes.
BV/BG	65	Discontinuous	5	Poor	20	Basalt rock sources near edges of the lowlands				The Buckland lowland is comprised of flat-lying basalt flows covered with eolian deposits. Eolian deposits within the Ambler River Lowland may be suitable foundation soils if they remain frozen; however, not suitable as borrow source material.
BM	5									
Selawik Lowland to Ambler River Lowland, 130 miles **Corridors 6, 7, and 8 converge on the east side of Tagagawik River**										
GM	15	Continuous moderately thick to thin	105	Good	20	Intermediate volcanic bedrock sources within the Purcell Mountains, Lockwood Hills, and Sheklukshuk Range	20	None Known	None Known	The Selawik Lowlands are predominately thaw lake deposits (peat and organic silts)
Ice rich SA/AM	80			Fair	20					
SA/SM	5	Discontinuous	25	Poor	90	Silty sands and gravels of glacial moraine and colluvium along base of hills				Upland eolian deposits within the Ambler River Lowland may be suitable foundation soils if they remain frozen; however, not suitable as borrow source material.
BV/BG	15									
BO/BU	10									
SUMMARY		Continuous	95%	Good	35%	Average Distance between borrow sites	>10			
		Discontinuous	5%	Fair	25%					
				Poor	40%					

5.8.1.3 Koyuk River to Buckland Lowland

The Koyuk and Kwiglik Rivers are meandering streams surrounded with oxbow lakes and muskeg covered floodplains dotted with thaw lakes. Quaternary alluvial terrace deposits may provide sands and gravels just above the river floodplain. Where the corridor passes through the unnamed mountains west of the Koyuk River, bedrock outcrops consisting of Paleozoic schist, gneiss, and metamorphosed volcanic rocks, should be available at approximately 10-mile intervals. This section of the corridor is underlain by continuous permafrost; periglacial processes are apparent and ice-wedge polygons are common.

5.8.1.4 Buckland Lowland to Selawik Lowland

The Buckland and Selawik Lowlands are flat, broad plains abundantly dotted with thaw lakes and crossed by meandering streams. These basins are separated by the Selawik Hills and continental divide. Quaternary alluvial terrace deposits will be present near some streams and rivers, however, the suitability of this material for use in construction or as foundation soils will depend on the silt content and depth of the organic soil cover. The Buckland Lowlands are covered by flat-lying Quaternary lava flows (basalt) overlain by Pleistocene eolian deposits. The basalt formations, exposed at the edges of the Lowlands, should provide suitable borrow material at the desired 10-mile intervals. This section of the corridor is underlain by continuous permafrost with thawed areas near large lake and rivers.

5.8.1.5 Selawik Lowland to Ambler River Lowland

The corridor traverses along the east side of the Selawik Lowlands, skirting along the foothills of the Purcell Mountains and Sheklukshuk Range. Few borrow sites (less than one every ten miles) are present along this corridor segment through the Selawik Lowlands, as this area is predominately organic and fine-grained soils. Where the corridor nears the Purcell Mountains and Sheklukshuk Range, bedrock borrow sites consisting of Cretaceous intermediate volcanics that have undergone regional metamorphism may be present at about 10-mile intervals.

Near the Lockwood Hills, composed of Cretaceous andesitic volcanic rocks, colluvium and alluvial fan deposits will be present near the base of the hills. However, haul distances of about six to ten miles may be required from the corridor. As the corridor approaches the Ambler

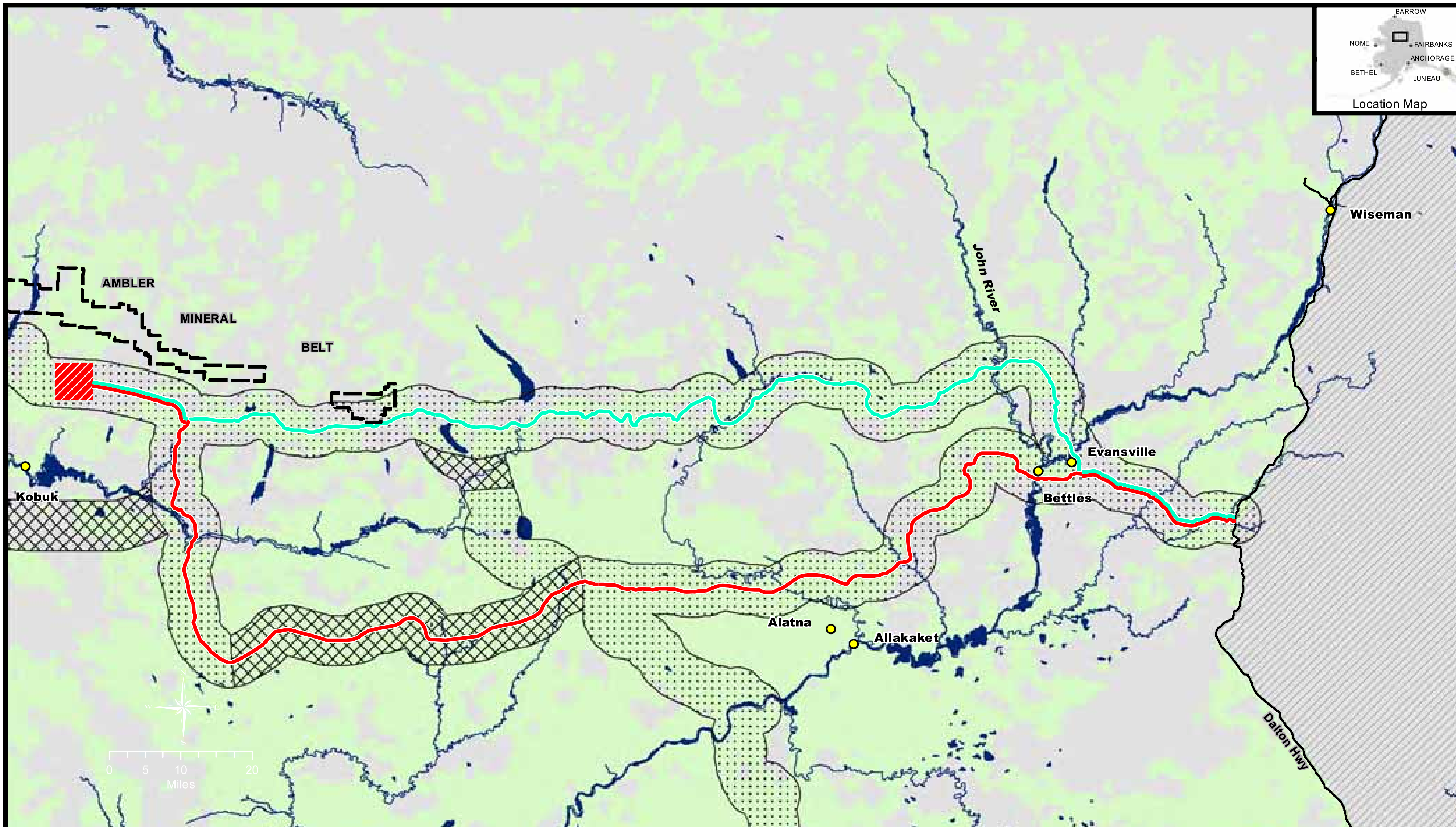
Lowland, upland eolian deposits can be found, although, these soils tend to be ice-rich and have a high potential for frost heave and thaw settlement and are therefore not desirable as borrow material.

5.9 Corridor Summary

Figures 13 through 16 illustrate which segments of each corridor have borrow sites at 10-mile intervals, and which segments have borrow sites at greater than ten mile intervals.

Table 14 below is a ranking of the proposed corridors based on the values determined in the previous tables. Corridors were given a relative score between 1 and 11 for each criterion, with 1 being most favorable and 11 being least favorable. The criterion included route length, the distance between borrow sites is found to be a more limited criteria than the length of the corridor, foundation conditions, permafrost conditions, and material site availability.

Each category is weighted equally in this summary; however, if during corridor selection, certain criteria are determined to be more critical (for example, if the distance between borrow sites is found to be a more limiting criteria than the length of the corridor), then the overall ranking value can easily be adjusted by weighing the criteria in the scoring table. As shown in Table 14, the Brooks East Corridor ranks the highest, followed by the Kanuti Flats and Cape Darby Corridors.



Communities and Place Names
Existing Roads
Water
Outside of Project Study Area
Ambler Mineral Belt
Proposed Staging Area
1-Brooks East Corridor 216 Miles (Road Only)
2-Kanuti Flats Corridor 241 Miles (Road Only)
Wetland Vegetation
Corridor Segments with Material Sites at Less than 10 Mile Intervals
Corridor Segments with Material Sites at Greater than 10 Mile Intervals

Sources:
Statewide Vegetation/Land Cover Available at:http://agdc.usgs.gov/data/usgs/erosafo/veg/vegetation.html
ADF&G Anadromous Streams

Coordinate System: NAD 1983 Alaska Albers

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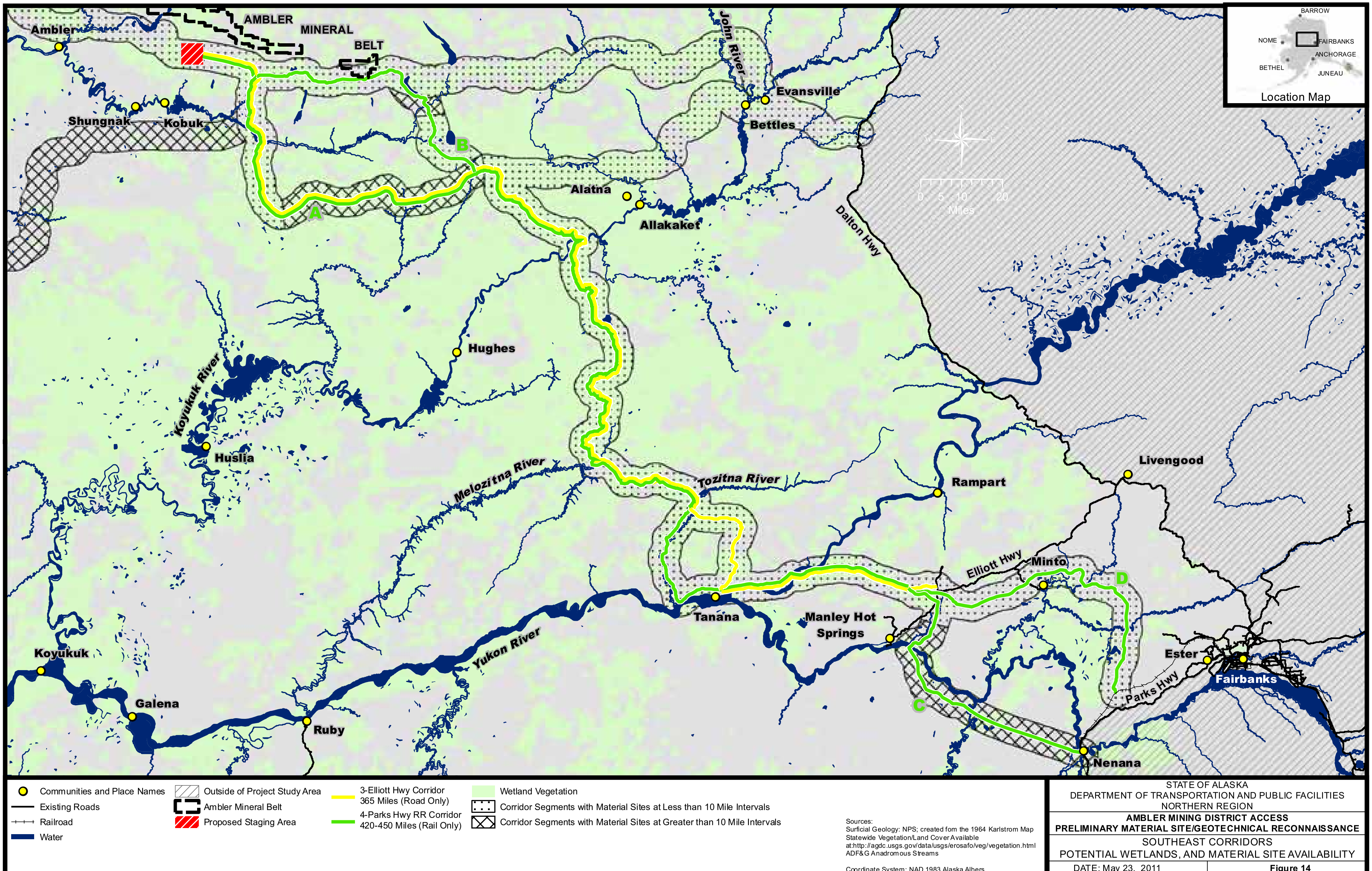
EAST CORRIDORS
POTENTIAL WETLANDS, AND MATERIAL SITE AVAILABILITY

DATE: May 23, 2011

Figure 13

P:\Projects\D60693\GIS\Geotech\MATERIAL SITE GEOTECHNICAL RECONNAISSANCE\East Wet&Geo.mxd May 23, 2011 3:27:51 PM User: chris.harrington



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SOUTHEAST CORRIDORS
POTENTIAL WETLANDS, AND MATERIAL SITE AVAILABILITY

DATE: May 23, 2011 | **Figure 14**

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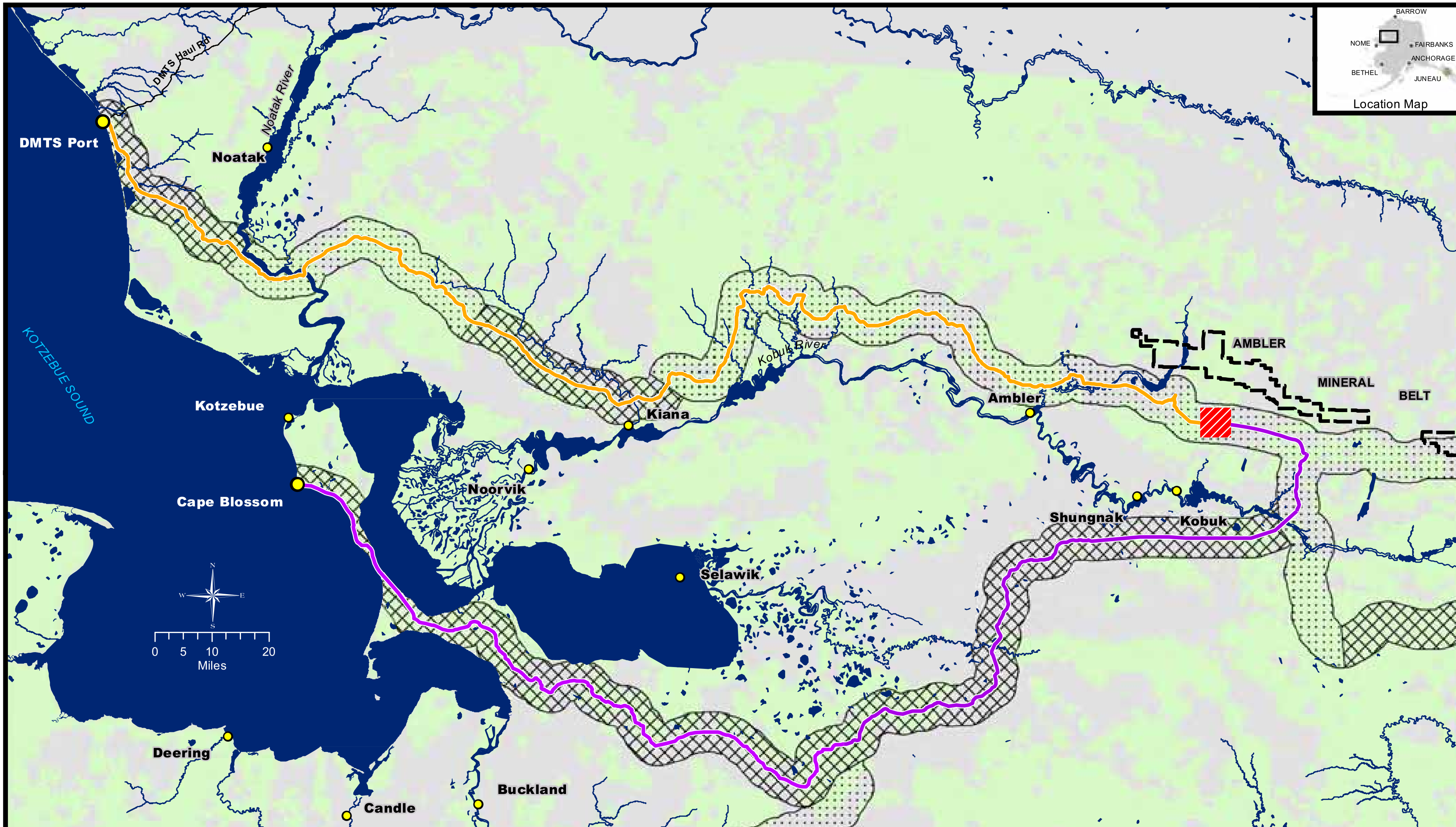

- Communities and Place Names
- Existing Roads
- Water
- Ambler Mineral Belt
- Proposed Staging Area
- 5-DMTS Port Corridor 257 Miles (Road & Rail)
- 6-Cape Blossom Corridor 245 Miles (Road & Rail)
- Wetland Vegetation
- Corridor Segments with Material Sites at Less than 10 Mile Intervals
- Corridor Segments with Material Sites at Greater than 10 Mile Intervals

Sources:
Statewide Vegetation/Land Cover Available at:http://agdc.usgs.gov/data/usgs/erosafo/veg/vegetation.html
ADF&G Anadromous Streams

Coordinate System: NAD 1983 Alaska Albers

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WEST CORRIDORS
POTENTIAL WETLANDS, AND MATERIAL SITE AVAILABILITY

DATE: May 23, 2011 | **Figure 15**

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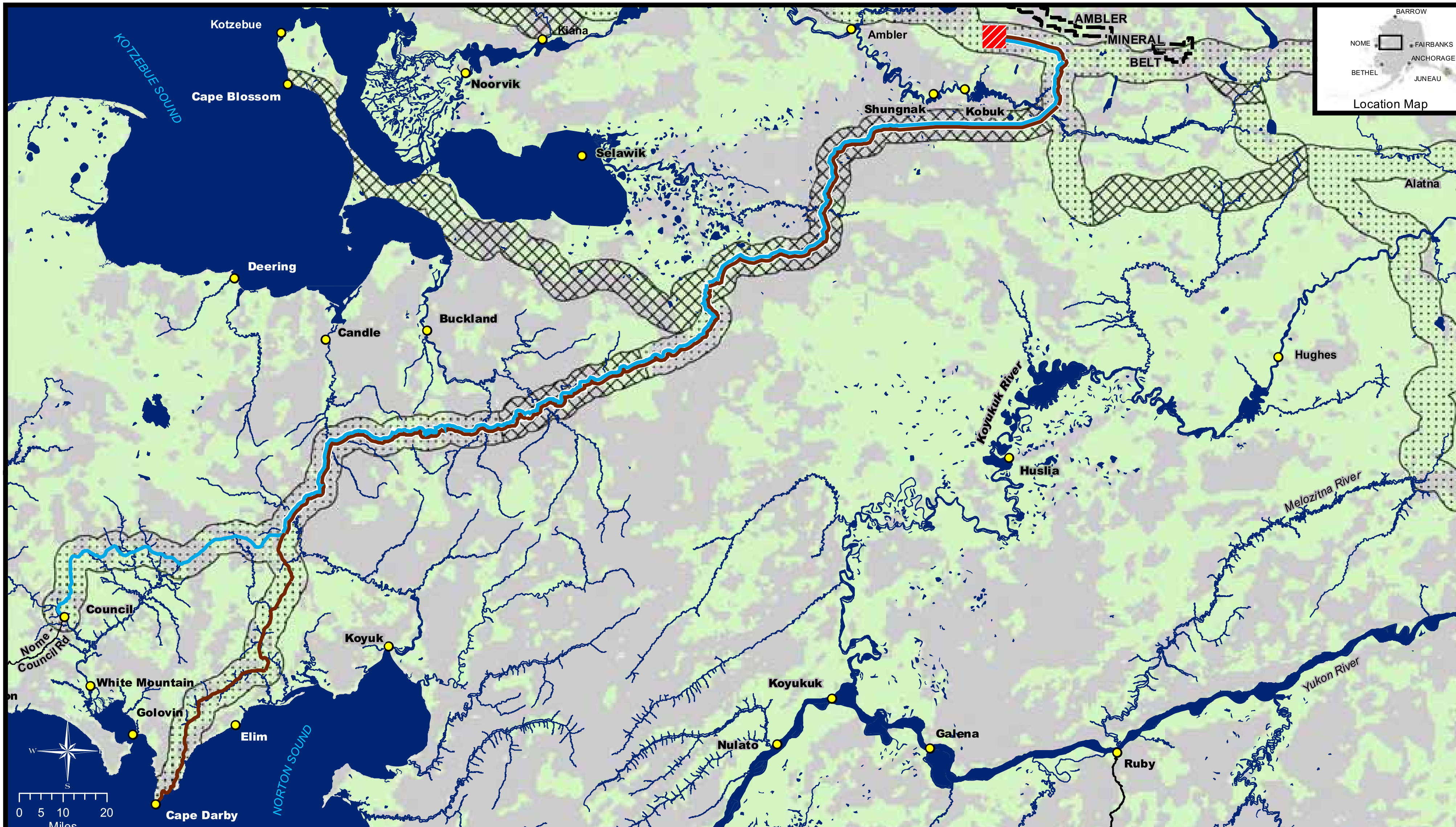

Communities and Place Names
Existing Roads
Water
Ambler Mineral Belt
Proposed Staging Area
7-Selawik Flats Corridor 331 Miles (Road & Rail)
8-Cape Darby Corridor 340 Miles (Road & Rail)
Wetland Vegetation
Corridor Segments with Material Sites at Less than 10 Mile Intervals
Corridor Segments with Material Sites at Greater than 10 Mile Intervals

Sources:
Statewide Vegetation/Land Cover Available at:http://agdc.usgs.gov/data/usgs/erosafo/veg/vegetation.html
ADF&G Anadromous Streams

Coordinate System: NAD 1983 Alaska Albers

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SOUTHWEST CORRIDORS
POTENTIAL WETLANDS, AND MATERIAL SITE AVAILABILITY

DATE: May 23, 2011 | **Figure 16**

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Table 14: Comparison of Corridors from a Geotechnical Viewpoint

Corridor	Length (miles)	Foundation Conditions	Permafrost Conditions	Material Site Availability	Total Score	Overall Ranking
Highway 1-Brooks East	1	1	3	1	6	1
Highway 2-Kanuti Flats	2	4	4	1	11	2
Highway 3-Elliott Hwy	7	4	7	3	21	8
RR Parks Hwy 4A/C	9	5	8	4	26	10
RR Parks Hwy 4A/D	11	3	6	3	23	9
RR Parks Hwy 4B/C	8	4	7	4	23	9
RR Parks Hwy 4B/D	10	2	5	2	19	7
Highway/RR 5-DTMS Port	4	2	7	4	17	6
Highway/RR 6-Cape Blossom	3	5	2	5	15	5
Highway/RR 7-Selawik Flats	5	3	2	3	13	4
Highway/RR 8-Cape Darby	6	2	1	3	12	3

6.0 DATA GAPS AND RECOMMENDED FIELD STUDIES

Once a preferred corridor has been selected, additional studies are needed to determine specific geotechnical conditions. Additional corridor-specific information including recent, high quality aerial photographs and topographic data is necessary to further define geologic/geotechnical conditions and structures along the preferred corridor. Aerial photographic interpretation will allow the geotechnical engineer/geologist to determine the most appropriate locations and intervals to perform an on-foot field reconnaissance. The field reconnaissance will help to confirm assumed conditions and allow the geotechnical engineer/geologist to select test boring locations to maximize the value of data obtained during field investigations. Test borings are anticipated to initially be located at widely spaced intervals to verify borrow source quantity and quality and general subsurface soil and permafrost conditions. Additional borings would be performed at closer intervals where the initial data indicates that subsurface conditions are quite variable and where the cost of the borings can be offset by varying embankment thickness as appropriate rather than conservatively designing for the worst-case conditions.

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