2.0 REGIONAL SETTING

2.1 Location

The proposed project alignment begins near the Trans-Alaska Pipeline System right-of-way, approximately two miles north of Glennallen and will extend in a westerly direction for about 148 miles to tie in with an existing pipeline located near the intersection of Nelson Road and the Glenn Highway near Palmer. The spur pipeline will generally follow the north side of the Glenn Highway from near Glennallen to a point near Eureka. At that location the alignment will follow the Squaw and Caribou Creek drainages over Chitna Pass and then follow Boulder Creek to the Matanuska Valley.

Glennallen's name was derived from the combined last names of Capt. Edwin Glenn and Lt. Henry Allen, USA, both leaders in the early explorations of the Copper River region (Orth, 1967). Palmer was established as an agricultural supply town and railroad station in about 1916. Palmer was named for George Palmer, a trader in the Knik Arm area in the late 1800s.

2.2 General Geology

The project alignment lies within the Copper River Lowland, Talkeetna Mountains, Upper Matanuska Valley and Cook Inlet-Susitna Lowland physiographic provinces (Wahrhaftig, 1965). The Copper River Lowland and Talkeetna Mountains are further divided into the Lake Louise Plateau and Talkeetna Mountains Foothills subprovinces. This portion of southcentral Alaska was covered with glacial ice during advances of middle to late Pleistocene age (Coulter, et al., 1965). The Copper River Lowland was repeatedly covered by proglacial lakes during later Pleistocene time as evidenced by local topography and soil stratigraphy.

Permafrost conditions vary along the alignment. The Copper River Lowland is considered to generally be underlain by moderately thick to thin permafrost in areas of predominantly fine-grained deposits (Ferrians, 1965). Locally, in close proximity to large water bodies, permafrost is absent. The Matanuska Valley province is generally considered to be free of permafrost while permafrost in the Talkeetna Mountains is discontinuous to sporadic.

2.2.1 Physiography and Quaternary Geology

Quaternary glacial events in the Copper River Basin, Talkeetna Mountains and Matanuska Valley have profoundly affected the landforms, soils, and terrain units occurring within the project corridor. Although this history is quite complex, several papers by Karlstrom (1964 and 1965), Péwé (1975), Ferrians and Nichols (1965), Trainer (1960), Schoephorster (1968), Williams and Ferrians (1961), and DGGS (1983) have lent much to the understanding of this area. Information from these reports has been combined with the aerial photo interpretation data in this study.

By the end of the Tertiary period, the major structural and topographic features of the general study area were established. Portions of what is now the project corridor were located in the valley of the ancestral Matanuska River which probably flowed westward toward the broad lowland now occupied by Cook Inlet and the lower Susitna River. The central portion of what would be the project corridor crossed a drainage divide and extended into the ancestral basin of the Copper River. South of the project area stood the stream dissected Chugach Mountains. The front of this range was marked by the Border Ranges and Knik faults. North of the corridor the somewhat lower Talkeetna Mountains mirrored the Chugach in that they were fluvially carved and their front was marked by the Castle Mountain-Caribou fault. During the Pleistocene the entire project area was repeatedly glaciated.

The onset of the Pleistocene period was marked by a general decrease in temperature in the northern latitudes causing a corresponding lowering of the snowline on the regions' mountains (accumulation was greater in the Chugach Mountains because of their proximity to the Gulf of Alaska and their greater heights). Continued snow buildup allowed the growth of valley glaciers, which with time expanded to flow down into the larger valleys merging with other valley glaciers.

In the central portion of the study area the Nelchina and other smaller glaciers soon spilled out of their valleys into the Copper River Basin where they coalesced to form a large Piedmont ice front flowing from the Chugach Mountains northward. The glaciers terminated in a large glacial lake created by an ice dam on the ancestral Copper River where the river flows through the Chugach Mountains. Lacustrine sediments of this lake (GL) are exposed in cuts where the Glenn Highway crosses the Little Nelchina River.

In the more narrowly confined Matanuska Valley portion of the study corridor, glaciers advancing northward from the Chugach and southward from the Talkeetna Mountains merged and flowed as a very large valley glacier toward the area where Palmer is now. Some ice from glaciers in the Nelchina area no doubt flowed westward and contributed to the Matanuska Valley glacier. Emerging from the confines of the valley, the Matanuska Glacier coalesced with ice flowing from the Knik Valley and at times with upper Susitna Valley ice. This combined ice front frequently terminated in a glacial lake filling part of Cook Inlet. During a maximal event, ice originating in the Matanuska system formed part of a major lobe which extended down Cook Inlet and out into the Gulf of Alaska. Ice flowing northward from the Nelchina area probably met ice flowing southward from the Alaska Range, filling the Copper River Basin with glacial ice and possibly forming a large dome. Erosion of the Chugach and Talkeetna mountains by the glaciers greatly modified the fluvial terrain, carving classic bowl shaped cirques, sharp horns, arété ridges and cols. The pre-existing fluvial Matanuska Valley was gouged out to form a wide U-shaped valley with an undulating floor; except in the Long Lake - Bonnie Lake area where uplifted resistant bedrock units stand as steep cliffs which rise above the general valley profile.

Deposits of glacial till and outwash were laid down during each glacial event, however, these materials and their record of advance and retreat have generally been destroyed by subsequent events so that only recent deposits are widespread. Intervals between glacial advances would be characterized by the fluvial entrenching of the Matanuska River, however, the majority of the interstadial fluvial history has also been destroyed by subsequent glacial and fluvial activity. Most of the glacial deposits that remain and the terrain units used to describe them must then have resulted from the last major glaciation (the Late Wisconsin Naptowne event).

At the height of the Naptowne advance, ice from the Matanuska Valley spilled out of the valley confines, merged with Knik ice and flowed almost to Anchorage. The glaciers remained in that position while the Elmendorf moraines were deposited. Retreat from the moraines varied in Matanuska and Knik lobes, with the Knik ice remaining active during its retreat, whereas the Matanuska Glacier apparently stagnated. As the Naptowne advance drew to a close, the great mass of ice occupying the Palmer area received very little flow from the Matanuska Glacier system. Melting of the block buried the ice with a mantle of soil debris insulating it, and allowing it to persist without inflow for a long time. This ice mass formed a large plug, which was isolated from the retreating Matanuska Glacier, and which inhibited drainage from the glacier margin. The low gradient meltwater streams formed up-valley of the plug, deposited an outwash plain at about the 1,000-foot elevation in the area between Sutton and the Chickaloon River (Karlstrom, 1964). Continued rapid retreat of the glacier brought the ice to within a few miles of its present position by about 10,000 years B.P. (Williams and Ferrians, 1961). During the retreat, valley floor surfaces above 1,000 feet between Sutton and the area just east of the Chickaloon River were left with a blanket of Naptowne Till (Gt). The Long Lake - Bonnie Lake area was scoured by the ice and deglaciated with almost no deposition. Immediately upvalley of the strongly bedrock (Bx) controlled Long Lake area, generally thin drift was deposited over undulating bedrock terrain.

As the glacier retreated far upvalley, the Palmer area ice plug slowly melted forming large pitted outwash plains (GFo) and depositing great volumes of ice contact material (GFk, GFe). These materials dominate the present Palmer landscape. Melting of the ice plug also rejuvenated the Matanuska River and launched a fluvial entrenching event. The older outwash plain was dissected leaving only terrace remnants (recognized on the Terrain Unit Maps as GFo). Down cutting generally followed the present river course but there was some wandering of the stream as evidenced by an abandoned channel connecting Ida, Fish, and Drill Lakes and a large trench cut south of Long Lake.

Fluvial down cutting in the Matanuska Valley proceeded at a rate such that the abandoned Packsaddle and Pinochle outwash channels graded to terraces just above the present Matanuska River. These terraces have been mapped throughout the study area drainage system where they represent the post Pleistocene modification of glaciated surfaces.

Ice retreat slowed when the margin neared Packsaddle Creek, allowing the deposition of a kame terrace and the cutting of a deep meltwater channel. When the ice reached the Hundred Mile Lake area it stopped and maintained a stable front while a thick layer of till was deposited. Moraines formed during this standstill are visible north of Hundred Mile Lake and the till sheet(s) deposited is well exposed in river cuts along the present Matanuska River. Meltwater draining from the glacier flowed through Pinochle and Lake

Creeks cutting deep, steep walled channels, which were later abandoned by meltwater and are now occupied only by small underfit streams.

During the Hundred Mile Lake standstill period, the Caribou Creek drainage was occupied by a lake which was impounded behind an ice dam lying between Sheep Mountain and Lion Head. Fine-grained frozen lacustrine sediments (L) of this lake are mapped north of My Lake and in the Dan Creek tributary drainage. Additional sandy sediments of possible lacustrine origin are visible in road cuts just north of Lion Head.

Further retreat of the Matanuska Glacier to near its present position permitted the drainage of the glacial lake occupying Caribou Creek and initiated entrenchment of Caribou Creek and the South and East forks of the Matanuska River.

Deglaciation of the project corridor by the Nelchina and its adjacent glaciers was somewhat more simple than in the Matanuska Valley. These ice masses underwent an active retreat, depositing till sheets (Gt) which blanket the bedrock in the Eureka Summit and Tahneta Pass area. As the glaciers receded, the Copper River glacial lake level dropped. The majority of the meltwater from the Nelchina glacier probably entered the Copper River system, however, outwash channels leading from the South Fork Glacier, and possibly from the western margin of the Nelchina, cross the flats south of Gunsight Mountain and enter the Matanuska drainage. Rejuvenation of the Nelchina and Little Nelchina rivers did occur; however, due to a lower stream gradient downcutting does not appear to have been as great as in the Matanuska Valley.

Numerous modifications of the glaciated surfaces and the development of non-glacial landforms have characterized the spur line corridor since the Pleistocene. The stream incision previously discussed has produced a V-shaped or rectangular valley within the broad U-shaped glaciated valley floor. Several low terraces (Fpt) have been formed above the modern floodplain and tributaries to the Matanuska River typically deposited fans (Ffg) at their confluence. The largest of these is the very active, Granite Creek Fan. Other fans have formed away from the river where steep small drainages flow onto the glaciated valley floor. The best example of this situation is on the southern flank of Sheep Mountain where several coalescing fans overlie glacial till.

Actually occurring during the early stages of deglaciation and continuing into post glacial periods has been the deposition of a blanket of wind blown silt (El) and/or sand (Es) over much of the landscape. The eolian deposits are most significant in the Palmer area where they frequently reach thicknesses of 5 to 30 feet.

Frost cracking (physical weathering) and gravity have combined to form numerous steep rubbly talus cones (Ct) below cliffs in the project area. On slightly less precipitous slopes undifferentiated colluvial deposits (C) have formed and on gentle slopes, and east of Lion Head, solifluction (Cs) has modified the surficial glacial till.

The development of a number of landslides (Cl) may be of major importance to this project. The majority of the large slides appear to be deep-seated block and slump failures occurring in shaly bedrock units. Examples of these failures include the area immediately west of Packsaddle Creek and along the East Fork of the Matanuska River. Mass wasting of unconsolidated material has also occurred as typified by the large till slump near Hundred Mile Lake.

Several recent (post glacial) deposits of lesser importance are found within the study corridor. Revegetation of low, poorly drained portions of the landscape has produced numerous scattered deposits of organic materials (O). Fluctuation of water levels in Knik Arm has left some marine estuarine deposits (Me) south of the Palmer area. Also, the Matanuska Glacier has not been dormant, but instead has shown several margin fluctuations. The ice has only recently (since 1800) retreated to near its present position and parts of the present glacier are advancing. Finally, man's actions have produced mine tailing piles, artificial fills and some lakes (only tailings (Ht) are identified on the terrain unit maps as man-made features).

2.2.2 Bedrock Geology

The bedrock geology of the Glennallen to Palmer Spur Line Project Corridor is quite complex, and although several papers have been published concerning the area, most are of limited scope. Several recent geologic investigations in adjacent areas have indicated that southern Alaska developed by the accretion of a number of north-westward drifting continental blocks onto the North American plate. Each of these terrains had a somewhat independent and varied geologic history, consequently many lithologies with abrupt and complex contacts are found. In many instances, the boundary between accretionary terrains is thought to be marked by major faults. The contacts between the Matanuska Valley bedrock units and the Chugach and Talkeetna Mountains' formations are marked by the Knik-Border Ranges faults, to the south and Castle Mountain - Caribou fault, to the north. A graphic explanation of bedrock units is presented in Table 2. It should be noted that not all of the formations listed in the table are mapped along proposed centerline, but are exposed nearby.

2.2.2.1 Talkeetna Formation

The oldest bedrock within the corridor is the lower Jurassic Talkeetna Formation (Jtk). The formation is described as bedded, dominantly marine andesitic flows, flow breccias and tuffs which are interlayered with sandstone and argillite in the upper part of the formation (Grantz, 1964). The total thickness of the formation is about 1,000 to 2,000 m (Detterman, et al., 1976).

Within the project corridor the Talkeetna formation is exposed near Boulder Creek. Most of Sheep Mountain is composed of this material. Units which have been strongly altered by hydrothermal solutions have been mapped separately as Jtka. The alteration has produced a greenstone with quartz-sericite, gypsum and clay alteration products. Carbonate veins are also common. Similar alteration has been mapped by Grantz (1961) in the central part of Sheep Mountain.

TABLE 2

EXPLANATION OF MAPPED BEDROCK UNITS

Qu	UNDIFFERENTIATED SURFICIAL DEPOSITS. Talus, landslides, glacial till, colluvium, alluvium, loess and lacustrine deposits, etc..	Pleistocene and Recent	QUATERNARY
Tt	TSADAKA FORMATION. Poorly indurated cobble - boulder fanglomerate with thin interbeds of sandstone, siltstone, and shale. Pebbles and boulders mainly of granitic rocks. Confined to Moose Creek and Wishbone Hill.	Miocene	TERTIARY
Tim	MAFIC INTRUSIVE ROCKS. Dikes, sills and plugs of diabase, basalt and gabbro.	Middle -Tertiary (?)	TERTIARY
Tif	FELSIC INTRUSIVE ROCKS. Dikes and plugs of quartz porphyry and feldspar porphyry.	Middle -Tertiary (?)	TERTIARY
Tw	WISHBONE FORMATION. Well indurated pebbles of fine-grained igneous and metamorphic rocks, chert, vein quartz, and jasper in sandy matrix. Includes thick interbeds of sandstone, siltstone, and some claystone. Confined to Wishbone Hill.	Eocene (?) and Paleocene	TERTIARY
Tc (Tcco, Tcsh, Tcss, Tccg)	COAL BEARING FORMATION (Tc). Well indurated sedimentary rocks differentiated in some areas on the basis of lithology. Mapped as the Chickaloon formation. Lithologic Units: Tcco. Contains units of interbedded bituminous coal. Tcsh. Shale, claystone or siltstone. Tcss. Sandstone, frequently feldspathic and with carbonate concretions and lentils. Tccg. Conglomerate	Paleocene	TERTIARY
Tv	LAYERED VOLCANIC ROCKS. Interbedded sequence of andesite and basalt flows, with minor intercalated sedimentary rocks.	Paleocene	TERTIARY

(continued)

TABLE 2 (continued)

EXPLANATION OF MAPPED BEDROCK UNITS

MATANUSKA FORMATION (Km). Predominantly dark shale and siltstone in lower part with interbedded dark shale and sandstone, locally conglomeratic in the upper part. Differentiated in some areas on basis of lithology. In other areas individual mappable units have been defined.

Lithologic Units: Kmsh. Shale, claystone or siltstone
Kmss. Sandstone
Kmcg. Channel conglomerate

Formation	Lithologic units	Unit	Description	Epoch	Period
Km		Kms	Claystone and siltstone with limestone concretions. Lower half characterized by limestone concretions with cone-in-cone structure and very large and thick shells. In many places includes siltstone mapped elsewhere as Kst. Contact with Kst approximate.	Upper Cretaceous	CRETACEOUS
		Kst	Siltstone with predominantly small and medium sized limestone concretions, many of which are sandy. At southern margin of corridor contains some graded sandstone beds. Contacts with Kms are approximate.	Upper Cretaceous	CRETACEOUS
	Kmsh / Kmss / Kmcg	Kssc	Siltstone, siltstone with graded sandstone beds, sandstone, and conglomerate. Contact with Kst, into which this unit grades laterally, is arbitrary.	Upper Cretaceous	CRETACEOUS
		Kssx	Pebbly sandstone. Along north front of Chugach Mountains. Appears to be basal unit of Kssc and Kst, but may be correlative with Kss.	Upper Cretaceous	CRETACEOUS
		Kss / Kssb	Greenish - and olive-gray sandstone, and siltstone. Kss, pebbly sandstone in north part of map area, fine-grained sandstone and coarse siltstone in Sheep Mountain area. Kssb, siltstone, in places with sandstone at base.	Upper Cretaceous	CRETACEOUS
		Kcs	Sandstone. Contains plant fossils. Exposed only on Caribou Creek above the mouth of Chitna Creek.	Lower Cretaceous	CRETACEOUS
Jn			NAKNEK FORMATION. Interbedded sedimentary rocks including siltstone, shale, sandstone and conglomerate.	Upper Jurassic	JURASSIC
Jc			CHINITINA FORMATION. Interbedded sedimentary rocks, including siltstone, shale, sandstone and conglomerate.	Middle Jurassic	JURASSIC
Jtk / Jtka			TALKEETNA FORMATION. Lavas and pyroclastic rocks of predominantly intermediate composition, sandstone, and argillite. All dominantly marine. Sedimentary rocks are dominant in upper part of the formation. Areas mapped Jkta strongly hydrothermally altered to greenstone, quartz-sericite rock, gypsiferous rock, or clay.	Lower Jurassic	JURASSIC

The Talkeetna formation is commonly cut by numerous faults and intensely sheared in the Caribou Creek region. However, some flow units may locally be adequate as a source for riprap or armor stone. This formation is overlain conformably by the Cretaceous and Tertiary sedimentary formations of the valley floor.

2.2.2.2 Chinitna and Naknek Formations

The Chinitna and Naknek formations are similar and thus grouped together along Caribou Creek. The Chinitna formation (middle Jurassic) is described as shallow-marine shale, siltstone, and subordinate sandstone containing numerous large limestone concretions; crops out near traces of Caribou fault in Talkeetna Mountains. The Chinitna formation incorporates volcanic and plutonic detritus. The Chinitna formation is as much as 600 m thick, but its thickness varies locally (Winkler, 1992).

The Naknek formation (late Jurassic) is described as thin- to thick-bedded, fossiliferous marine siltstone, shale, and lithofeldspathic sandstone and conglomerate; crops out near traces of Caribou fault. The Naknek is composed principally of plutonic and volcanic detritus. The Naknek is more than 1,400 m thick locally, but varies laterally in thickness and in distribution of facies (Winkler, 1992).

2.2.2.3 Matanuska Formation

The Matanuska formation is comprised of clastic marine sediments of the Cretaceous age and form more than one-third of the bedrock outcrops in the Matanuska Valley. An interlayered series of sandstone and mudstone units form a section more than 4,000 feet thick on Granite Creek. Neither the top nor base of this formation has been recognized in the Matanuska Valley (Martin, 1926). A more complete section is exposed in the Nelchina area, at the head of the Matanuska River drainage where the formation is over 14,000 feet in aggregate thickness (Grantz, 1964).

Between Moose Creek and about Caribou Creek, this formation has been mapped in literature as a single unit “Km” (Barnes, 1962 and Detterman, et al., 1976). From Caribou Creek to approximately the east end of Gunsight Mountain, Grantz (1961) has mapped 16 separate units and three unconformities. The Matanuska formation consists of graywackes, characterized by dark claystone and siltstone, greenish-gray sandstone, and some conglomeratic mudstone and sandstone. In most places, the lithologies of the Matanuska formation are readily distinguishable from other formations.

West of Caribou Creek, outcrops, road cuts, and other sites which expose the Matanuska formation have been subdivided into three units on the basis of lithology. Bedrock composed of clay and silt-sized particles has been labeled

Kmsh. Where sandstone is predominant, the term Kmss has been used. The designation Kmcg is used where conglomerate units are found. Frequently, two or all three symbols are used to indicate a combination of the various rock types at one location. Because of the level of detail present in the mapping by Grantz (1961), for the interval from Caribou Creek to Gunsight Mountain, his terminology is retained and has been applied to some of the exposures encountered further east along the corridor.

2.2.2.4 Volcanic Rocks

Volcanic bedrock (Tv) is exposed in the Chitna Pass portion of the alignment and is described as a nearly flat lying sequence of volcanic and minor intercalated sediments. The upper part of sequence consists of andesite and basalt flows, and minor rhyolitic tuff, lithofeldspathic sandstone, and fluviatile conglomerate. The lower part consists of stocks, dikes, lenticular flows, and pyroclastics, chiefly of quartz latite, latite, and rhyolite, and minor andesite and basalt. Stocks, rhyolite domes, and breccia mounds are particularly prominent near Chitna Pass. Unit Tv is estimated to be more than 1,500 m thick (Winkler, 1992).

2.2.2.5 Coal-Bearing Formation

Continental clastic sedimentary bedrock of Tertiary age occurs throughout the corridor. In the west, Barnes (1962) has separated this formation into three units: the Tsadaka formation (Tt), the Wishbone formation (Tw), and the Chickaloon formation (Tc). Between about the Chickaloon River and Caribou Creek, Detterman, et al. (1976) assigns the formation name Chickaloon to all Tertiary sedimentary bedrock. East of Caribou Creek, Grantz (1964) uses the term Coal-bearing formation, but retains the symbol Tc. The discussion below applies to all areas mapped Tc.

The formation in the Wishbone Hill and Chickaloon districts consists of at least 5,000 feet of interbedded claystone, siltstone, feldspathic sandstone, conglomerate, and many beds of bituminous coal.

Within the Wishbone Hill district the coal beds are in the upper 1,400 feet of the formation (Barnes and Payne, 1956); in the Chickaloon District they appear to be about in the center of the formation (Capps, 1927). Conglomerate is exposed only in the lower part of the formation, except for a few scattered thin beds which grade into pebbly sandstone. Massive beds of conglomerate as much as 50 feet thick are interbedded with shale and sandstone.

The Chickaloon formation is overlain conformably by the Wishbone formation in the Wishbone district, into which it grades by upward increase in the proportion of conglomerate and sandstone (Barnes and Payne, 1956). The age of the Chickaloon appears to be Eocene or Paleocene on the basis of plant fossils (Martin and Katz, 1912).

As with the Matanuska formation, the lithologies in outcrops studied within this formation have been mapped as separate units. Four lithologic variations have been defined: Coal-bearing units (Tcco), shale, siltstone or claystone (Tcsh), sandstone (Tcss) and conglomerate (Tccg). Frequently, an outcrop has been mapped using a combination of the above symbols.

2.2.2.6 Intrusive Rocks

Numerous Tertiary stocks, dikes, and sills are found within the corridor. Kings Mountain is a large volcanic plug composed of rhyolite. Dikes and other nearby units are composed of similar material. West of Kings River, Barnes (1962) has reported the presence of dioritic and trachytic bedrock. Trachyte porphyry is exposed near the north side of Kings Mountain. Intrusive bedrock has been differentiated into felsic (Tif) and mafic varieties (Tim). Detterman, et al., (1976) mapped intrusive bedrock northwest of Kings River as being mafic. To the east large elongated cliff bounded ridges of gabbro characterize the terrain around Bonnie and Long lakes, extending as far east as Purinton Creek. These mafic units typically range in texture from fine- to coarse-grained. Medium- and coarse-grained varieties weather spheroidally and form extensive scree slopes.

To the east, around Caribou Creek, units of Quartz porphyry and feldspar porphyry, such as Lion Head, are exposed (Grantz, 1961).

2.2.2.7 Wishbone Formation

Within the alignment corridor, the Wishbone formation (Tw) is exposed along the southern flanks of Wishbone Hill. The formation is composed predominantly of conglomerate with many interbedded units of crossbedded feldspathic sandstone, a few lenticular beds of siltstone, and some claystone. The conglomerate is composed of firmly cemented pebbles of fine-grained igneous and metamorphic origin, vein quartz, chert and jasper in a sandy matrix. A maximum thickness of about 650 m is found on Wishbone Hill. The formation is overlain unconformably by the Tsadaka formation, and at the base it grades into the Chickaloon formation. The age of the formation is considered to be Paleocene (?) or early Eocene (?) (Barnes, 1962).

2.2.2.8 Tsadaka Formation

Units of the Tsadaka formation (Tt) are exposed within the corridor along the upper part of Moose Creek in Tsadaka Canyon, where they overlie strongly folded Chickaloon strata. Along the southwestern flanks of Wishbone Hill the formation rests unconformably on more strongly folded beds of the Wishbone formation.

The formation consists of poorly indurated conglomerate with thin interbeds of sandstone, siltstone and shale. The conglomerate is composed of cobbles and boulders of coarse-grained granitic origin. The formation is of Miocene age and has a total thickness of about 200 m (Detterman, et al., 1976).

2.2.2.9 Quaternary Deposits

All Quaternary deposits have been mapped as one deposit: Quaternary Undifferentiated (Qu). These deposits are shown in detail on the Route Soil Conditions sheets.

2.3 General Seismicity

It is understood that certain fault studies are currently being completed for the Glennallen to Palmer Spur Line project. The following discussion is presented in order to provide further detail on the bedrock geology of the area.

The project area is located in a very active seismic region associated with the collision of two tectonic plates. The Pacific Plate is being thrust under the North American Plate along a northwestward-dipping Aleutian subduction zone. This under-thrusting produces compression in the crust of the overlying North American Plate, expressed as folds and high-angle reverse and thrust fault systems. Evaluations of seismic hazards in southcentral Alaska typically recognize four faults or faulting zones, including: the Megathrust and Benioff segments of the Aleutian subduction zone, the Castle Mountain Fault System, and the Border Ranges Fault Zone.

The Aleutian subduction zone is represented as two distinct planes, Megathrust and Benioff, each with different characteristic earthquakes. From the Aleutian Trench, about 200 miles southeast of Palmer, the subduction plane maintains a shallow dip to the northwest extending to a depth of about 12 to 15 miles (Megathrust zone). The seismicity of the Megathrust zone is characterized by shallow, very large magnitude, but infrequent earthquakes. The 1964 Great Alaska Earthquake (Moment Magnitude, 9.2 Mw) occurred within this zone, with the epicenter about 70 miles southeast of Palmer in Prince William Sound. At a depth of about 25 to 30 miles, the subducting Pacific plate dips steeply to the northwest (Benioff or Intra-Plate zone). The seismicity of the Benioff zone is characterized by deep (>30 miles), moderate magnitude and frequent earthquakes. Anchorage overlies the transition between the Megathrust and Benioff zones, at a depth of about 20 miles.

The Castle Mountain Fault is a prominent, right-lateral strike-slip, reverse fault which traces from the Talkeetna Mountains northeast of the Matanuska Glacier, southwesterly through the lowlands along the Susitna River and southern flank of Mount Susitna (Detterman et al., 1974). A magnitude 5.2 Ms earthquake in 1984 about 15 miles north-northeast of Palmer was attributed to a rupture along this fault (Lahr et al., 1986).

The Border Ranges Fault zone is a major reverse fault, locally positioned along the western flank of the Chugach and Kenai Mountains, and interpreted to be an ancient subduction zone from the Mesozoic or early Tertiary time (MacKevett and Plafker, 1974).

2.4 Climate

The regional climate of the Copper River Basin area is categorized as continental, being dominated by the proximity of the surrounding high mountain ranges. The weather is characterized by long, cold winters and short, warm summers. The mean annual air temperature at the Gulkana FAA AMDS is about 27.2°F (indicating the potential for the occurrence of permafrost). The mean annual precipitation is about 11 inches (including equivalent snow fall), with about 51 inches of snow. The prevailing and strongest winds are from the southeast. The average annual wind speed is about 5.9 knots at Gulkana Airport and the mean strongest is about 45 knots. The design freezing index, or degree days below freezing, is about 5,500 degree days. The design thawing index is about 3,500 degree days.

The Matanuska Valley has a transitional climate typical of the slightly inland regions of southcentral Alaska. In the transitional zone, weather conditions average between the continental and maritime zones. Temperature extremes most resemble the continental zone while precipitation most resembles the maritime zone. The mean annual temperature at the Matanuska Agricultural Experiment Station is 35.6°F. The mean annual precipitation is about 15.3 inches. The design freezing index is near 1,650 degree days. The design thawing index is near 2,200 degree days (Hartman & Johnson, 1984). Precipitation is light during late winter and early spring, and increases to maximum amounts from August through December.

A summary of climatological data obtained from three separate recording stations located along the proposed alignment (Gulkana, Eureka Lodge and Matanuska) is presented in Table 3. Most notable from the table are the differences in elevation and the mean annual snowfall.

TABLE 3

CLIMATOLOGICAL DATA

Location (Station)	Gulkana FAA AMDS	Eureka Lodge	Matanuska AES
Period of Record (mm/yy)	9/49 – 3/05	7/53 – 9/68	7/17 – 3/05
Elevation (ft.)	1,570	3,330	150
Mean Annual Temperature (°F)	27.2	24.3	35.6
Mean Max. Temperature (°F)	37.4	33.4	44.8
Mean Min. Temperature (°F)	17.0	15.1	26.5
Record High Temperature (°F)	91 (Jul., 1953)	87 (Jul., 1953)	91 (Jun., 1936)
Record Low Temperature (°F)	-58 (Dec., 1964)	-44 (Feb., 1968)	-41 (Feb., 1947)
Mean Annual Precipitation (in.)	10.95	15.46	15.30
Maximum Monthly Precipitation (in.)	4.34 (Sep., 1969)	5.97 (Jun., 1961)	7.55 (Sep., 1925)
Mean Annual Snowfall (in.)	51.2	110.1	47.5
Maximum Monthly Snowfall (in.)	38.3 (Feb., 1996)	43.0 (Jan., 1962)	36.0 (Feb., 1932)

After http:/www.wrcc.dri.edu//summary/climsmak.html

2.5 Topography

As shown on the climatological data table presented above, the ground surface elevation varies considerably along the proposed spur line alignment. The highest point along the alignment is at Chitna Pass which has an elevation of about 4,800 feet. The low point is near the spur line terminus which has an elevation of about 50 feet.

A more detailed description of topography is presented in Section 4.0. Additionally, contour lines are shown on the Route Soil Conditions sheets presented in Appendix A.

2.6 Vegetation

Similar to topography, vegetation types vary considerably along the alignment. Vegetation can be an indicator of the thermal state of the underlying soils, the presence or absence of near-surface water and the relative activity of various parts of a floodplain (Frost, 1950; Stoeckleler, 1952; Department of Army, 1966 and Hunter et al., 1981). While differences in the specific type of vegetation are often useful on a relatively small site, these factors are probably most useful when combined with airphoto interpretation and used as a tool for route selection and evaluation.

Generalized descriptions of vegetation are provided in Section 4.0 following AEIDC (1976). ASRC (April, 2005) present various vegetation data including a listing of common plant species found along the ANGDA Spur Gas Pipeline Corridor.

2.7 Geologic Hazards

Within the Glennallen to Palmer Spur Line alignment a variety of potential geologic hazards exist. This section briefly addresses the major hazards and directs attention to other sections of the report for further discussion. The principle geologic hazards identified for the project include permafrost, slope stability and seismic activity.

The distribution of permafrost along the alignment is interpreted to range from generally frozen within the Copper River Lowland to generally absent in the Upper Matanuska Valley. Both thaw degradation/settlement of frozen soils and frost heave potential of unfrozen soils will need to be addressed during future project design phases.

Numerous landslides have been mapped and all of the mapped areas should be thought of as capable of failing again. Active landslides were observed in the Chitna Pass area and appear to be related to continued long-term ground warming within frozen ground segments containing excess ice, moisture, and having over-steepened slopes. In general, the greatest landslide hazard areas are related to shale bedrock units. Landslide areas with possible impacts on spur line routing are discussed in Sections 4.0 and 5.0.

Fault studies are currently in progress by others. Additionally, it is assumed that flooding, icing potential (aufeis), snow drifting, glacial advance and avalanches will be evaluated during future project design phases.