National Park Service - Alaska Region
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ECOLOGICAL SUBSECTIONS OF GATES OF THE ARCTIC NATIONAL PARK & PRESERVE

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INTRODUCTION

Gates of the Arctic National Park and Preserve (GAAR) is located in the central Brooks Range and presents a complex mosaic of biotic and abiotic components (Figures 1 and 2). The goal of this project is to integrate these components to develop an ecological subsection map for GAAR (Bailey 1980, 1995; Carpenter et al. 1999; McNab and Avers 1994). The map will be used to understand the coarse-scale ecosystems within the park, for park planning, as a stratification layer to use for species-level inventory, and to help with cover type mapping.

Hierarchical frameworks have been devised to group ecosystems into logical associations throughout Alaska and North America (Nowacki et al. 2001). The hierarchy used for this project is the "National Hierarchical Framework of Ecological Units" (Bailey 1996; Cleland et al. 1997). This framework stems from Bailey's (1996) concept of the biosphere as a series of interrelated systems within which all components are linked. Changes in one component often cause changes in other components and affect the operation of the whole system. By focusing on interrelationships among components, this approach provides a basis for understanding ecosystems and the effects of human use. As with all classification and mapping systems, it greatly simplifies highly complex patterns and phenomena for the benefit of human understanding. Unavoidably, some amount of accuracy must be sacrificed for clarity and generality. For example, biotic and abiotic factors that occur as continua across the land (Whittaker 1967) are not easily captured by mapping and classification schemes.

The National Hierarchical Framework of Ecological Units consists of eight levels (Table 1). The subsection level characterizes midsized ecosystems of 10 to 10,000 square miles. Subsections can be considered hypotheses about what constitutes ecologically significant regions in the study area. Delineation factors for subsections are detailed by Bailey (1996) and Cleland et al. (1997) and include surficial geology, lithology, geomorphic processes, soil groups, subregional climate, and potential natural communities (climax vegetation).

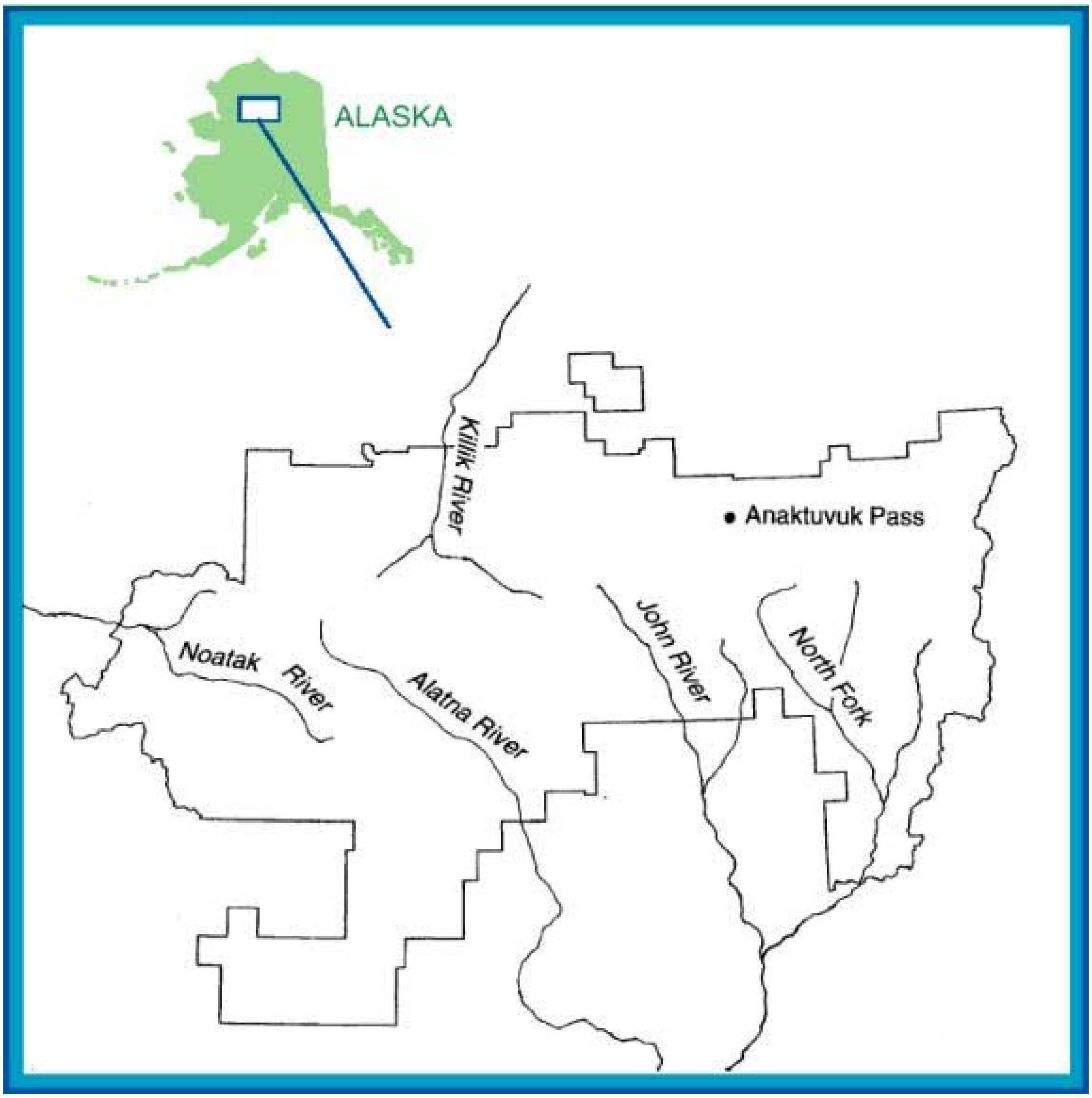


Figure 1. Location and administrative boundaries of GAAR.

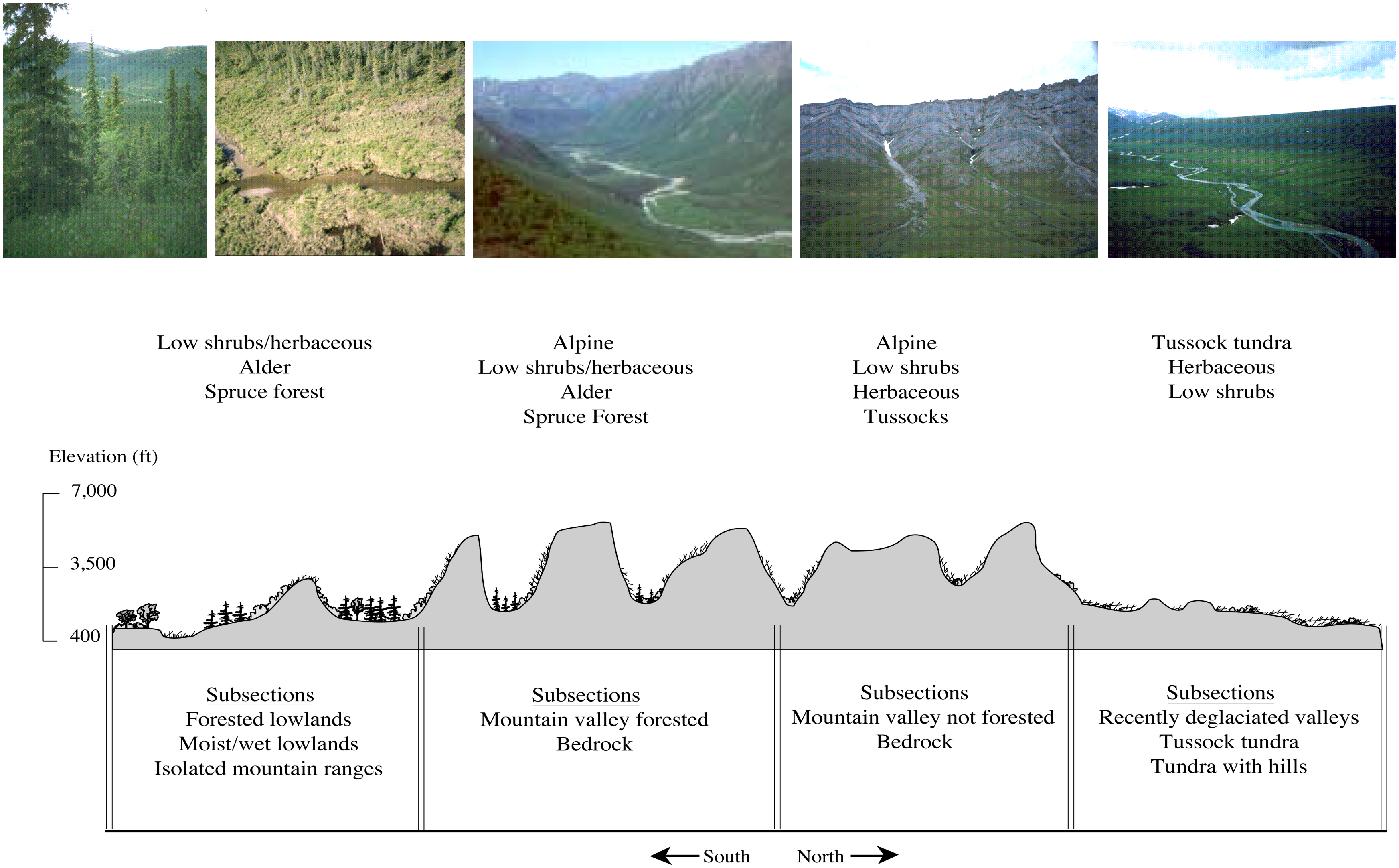


Figure 2. Idealized cross-section of GAAR's subsections, topography, and landcover.

Table 1. The National Hierarchical Framework of Ecological Units (after Cleland et al. 1997).

Planning and analysis scale	Purpose, objectives, and general use	Ecological units	General polygon size (square miles)
Ecoregion	Broad applicability for modeling and sampling.	Domain	10,000,000
	Strategic planning and assessment. International planning.	Division	1,000,000
		Province	100,000
Subregion	Strategic, multiforest, statewide, and multiagency analysis and assessment.	Sections	10,000
		Subsections	10–10,000
Landscape	Forest or area wide planning, and watershed analysis.	Landtype Association	1–10
Land Unit	Project and management area planning and analysis.	Landtype	0.1–1
		Landtype Phase	< 0.1

STUDY AREA

This section provides the reader with a general picture of the vegetation, land use, climate, geology, surficial geology, topography, and wildfire within the subsections defined for GAAR (Figure 2). GAAR is approximately 180 miles long by 90 miles wide and covers 8,202,517 acres. Its elevation ranges from approximately 500 to 8,570 feet.

The arctic foothills north of the Brooks Range consist of treeless valleys, plateaus, and hills whose elevations range up to 4,126 feet (Figure 3). The hills are bedrock outcrops with less than a 500 foot vertical rise and are typically covered by loess (Figure 4). They are primarily vegetated by tussock tundra with narrow water tracks running downslope. Water tracks are shallow depressions—dominated by open water, willows (*Salix* spp.), and sedges (*Carex* spp.)—that have significantly greater water flow than the adjacent tussock tundra.

Figure 4. Photograph of the arctic foothills north of GAAR.

Surrounding the hills are plateaus and rolling low relief hills sloping down to the north flowing rivers that drain the Brooks Range. The plateaus and hills are Holocene, Pleistocene, and older glacial till, kettle kame topography, outwash plain terraces, floodplain terraces, and sand deposits including dunes. The vegetation is predominantly tussock tundra with low and tall shrubs along the stream courses.

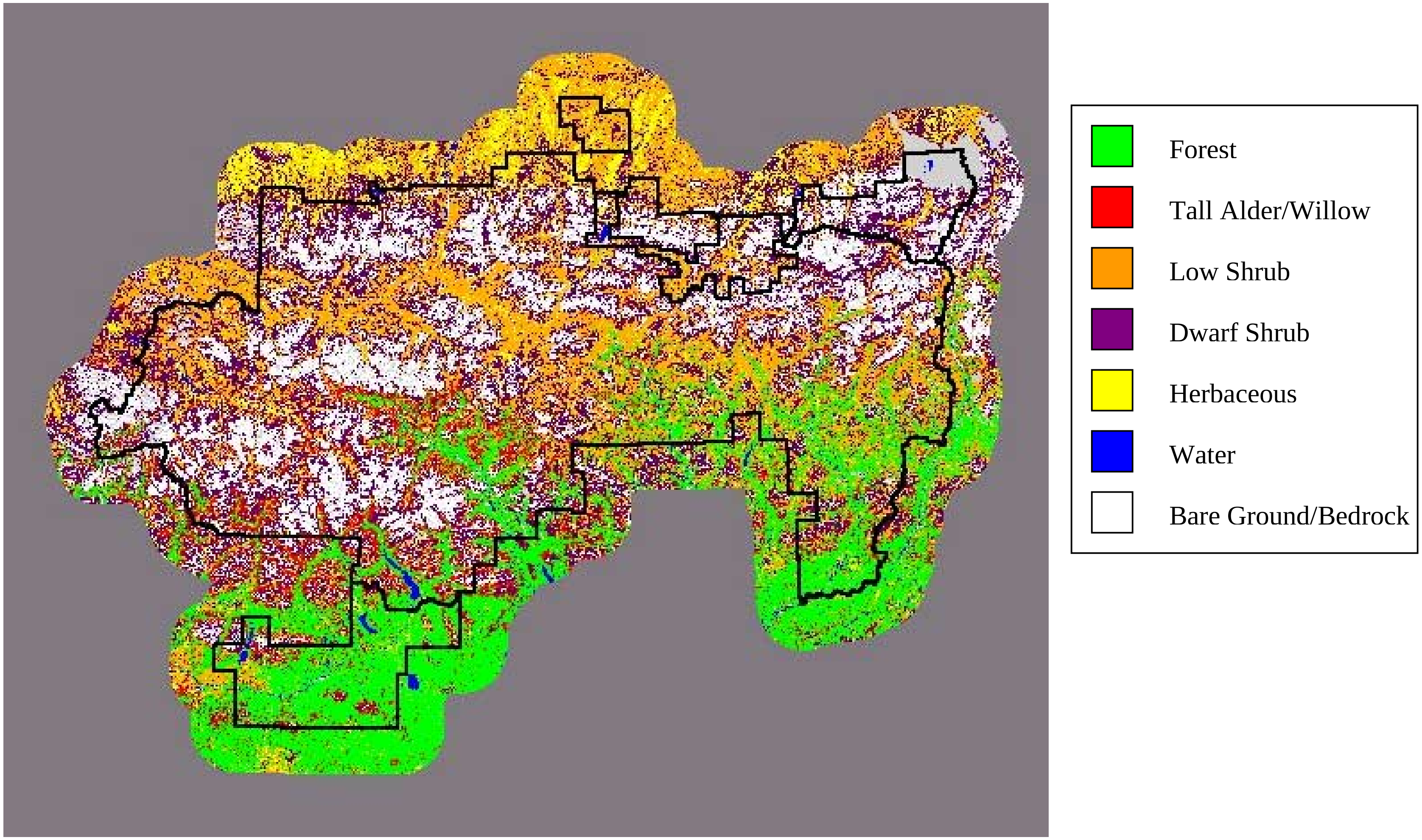


Figure 3. Landcover map for GAAR (Helt et al. 2000).

In the Brooks Range, steep walled mountain valleys have formed due to downcutting and glacial scouring over millennia (Figures 5 and 6). Small and scattered glaciers still persist within the headwaters of the higher peaks. The higher elevations are predominantly exposed bedrock. Valley slopes are covered either by alluvial fans or glacial drift deposited during the last glacial retreat, or are bedrock scoured by glaciers. Glacial till, river floodplains, lacustrine deposits, and lakes occupy the valley floors. Vegetation is dramatically different between the north and south halves of the Brooks Range. In the north half moving downslope, bedrock and talus give way to dwarf shrubs, then low shrubs, tussock tundra and, along river courses, tall shrubs. In the south half moving downslope, bedrock and talus give way to dwarf shrubs, then low or tall shrubs, and then forests.

Figure 5. Valley in the north half of the Brooks Range.

Figure 6. Valley in the south half of the Brooks Range.

South of the Brooks Range are bedrock hills interspersed with broad valleys (Figure 7). The elevation ranges from approximately 500 to 3,000 feet, and the climate is continental. Lakes are common in the valley bottoms due to thermokarst and oxbows along floodplains. Vegetation forms a complex pattern due to the effects of fire, permafrost, soils, and surface water. Dwarf shrubs and lichen dominate the ridges; the slopes support large stands of *Betula papyrifera* (paper birch), *Picea glauca* (white spruce), and *Picea mariana* (black spruce). The valley bottoms are, in general, wetter environments than the hills and support black spruce and white spruce along with peatlands. The forested landscape grades into Arctic tundra to the west.

Figure 7. Photograph of the broad valleys south of the Brooks Range.

LAND USE AND SETTLEMENT

The arctic foothills and Brooks Range are the traditional home to the Nunamiut (Inuit) peoples and are important for subsistence hunting, fishing, and wild plant gathering (Gallant 1995). Caribou, moose, bear, ground squirrel, and ptarmigan are all subsistence resources. Recreational hunting and fishing also occurs throughout the region, and edible greens, roots, and berries are harvested throughout the summer months. The Kutchin and Koyukon Athabascans also use the Brooks Range for subsistence purposes. South of the Brooks Range, both subsistence and recreational hunting occurs (Gallant 1995). People living in the uplands primarily hunt caribou and moose. People living in the lowlands rely heavily on game and freshwater fish. All peoples of the area hunt small mammals and ptarmigan. Berries, roots, and wild greens are also harvested.

CLIMATE

GAAR has long severe winters and short cool summers. The arctic foothills north of the Brooks Range have winter temperatures ranging from –29^{o}C to –20^{o}C (Gallant 1995). Summer temperatures range from 1^{o}C to 15^{o}C and occasionally reach 24^{o}C in some areas. Although freezing can occur any time of the year, July and August are usually frost free. In the Brooks Range, winter temperatures are colder and range from –30^{o}C to –22^{o}C, while summer temperatures fluctuate from 3^{o}C to 16^{o}C (based on one weather station at Anaktuvuk Pass). Freezing may occur in any month of the year. South of the Brooks Range, winter temperatures differ from west to east, with a minimum of –18^{o}C to –11^{o}C in the west and of –35^{o}C to –22^{o}C in the east. Summer temperatures range from a minimum of 8^{o}C to 11^{o}C to a maximum of 17^{o}C to 22^{o}C. June through mid-September is usually frost free at the lower elevations.

Elevation, aspect, and winds result in a highly variable climate in GAAR. Precipitation is low throughout the park. Annual precipitation in the arctic foothills is approximately 7.6 inches, and receives 52 to 60 inches of snow. In the Brooks Range at Anaktuvuk Pass, summer precipitation is 11 inches, and winter precipitation averages 64 inches of snow per year. The Noatak and Kobuk Valleys likely receive more precipitation than to the north and east because they serve as conduits for moist air masses moving inland from the Bering Sea (Hamilton 1999). South of the Brooks Range, average annual precipitation is 10 to 22 inches and increases with elevation. Convection storms in the summer provide most of the annual precipitation. Of the annual precipitation, 50 to 82 inches of it occurs as snowfall. Snow remains on the landscape for over half of the year on north facing slopes, shadowed areas, and at higher elevations.

GEOLOGY

From the mid-Paleozoic (350 million years ago) through the mid-Mesozoic (180 million years ago), the region that now constitutes the Brooks Range was a low-lying plain that, at times, was inundated by shallow seas. Sediments accumulated on the sea floor forming sandstone, shale, and carbonate sedimentary layers several thousand feet deep. Thrust faulting during the Cretaceous period (135 to 68 million years ago) uplifted these deposits to form the Brooks Range (Gallant 1995). Isolated regions of intrusive igneous (Arrigetch Peaks) and extrusive igneous rock also occur (Figure 8). During the

Cretaceous orogeny and latter, sediments eroded from the uplifting mountains and were deposited north and south of the Brooks Range, forming rolling hills and plains. A variety of physiographic maps and publications exist that describe the processes, glaciations, and bedrock geology for the Brooks Range (Avé Lallemant et al. 1998; Brown et al. 1997; Detterman et al. 1958; Ellis and Calkin 1984; Ferrians 1965; Gedney and Marshall 1981; Grantz et al. 1983; Hamilton 1982, 1984c, 1986, 1994, 1999; Hamilton and Porter 1975; Krieg and Reger 1982; Moore et al. 1994; Nilsen and Moore 1984; and Sloan et al. 1976).

PLEISTOCENE GLACIATION

Coalescing alpine glaciers covered most of the Brooks Range during the five Pleistocene glacial advances—from oldest to youngest: Gunsight Mountain, Anaktuvuk River, Sagavanirktok River Phase I and Phase II, and Itkillik (Hamilton 1989). Glaciers originated in cirques near the north flank of the Brooks Range and along the Continental Divide, and flowed north and south through deeply incised valley systems to terminate at and beyond the flanks of the range (Detterman et al. 1958; Hamilton 1978c, 1979b; Hamilton and Porter 1975; Porter 1964). These glaciers carved and sharpened mountain peaks and ridgelines, forming steep concave slopes that enclose cirque basins and U-shaped valleys. Holocene Neoglacial intervals have occurred, mainly between about 2,000 and 4,000 years ago, and there have also been glacial readvances in the past 450 years (Calkin and Ellis 1980; Porter and Denton 1967).

During the major glacial advances, large ice tongues extended north and south of the Brooks Range. Thick and extensive glacial deposits filed the valleys including terminal moraines, lacustrine deposits, and sand (Hamilton 1989). Huge outwash trains also were deposited along streams that issued from the ice front. The new glacial deposits overrode the older glacial deposits, largely obscuring them beneath eolian and lacustrine silt and thaw-lake sediments. They are, however, locally exposed in river bluffs that commonly stand 120 to 150 feet high above the valley floors. South of the Brooks Range, thick peatlands also cover many of the older deposits. Surfaces north and south of the Brooks Range that lay beyond the limits of the glacial advances were covered with thick deposits of loess derived from outwash and other glacial deposits.

SURFICIAL GEOLOGY

The covering of glacial drift on mountain valley slopes and valley bottoms ranges from complete, to discontinuous, to absent on ice-scoured bedrock (Figure 9). Glacial drift is defined as material transported by a glacier and then deposited either directly from the ice or from the melt water. In GAAR, these deposits are predominantly of late Pleistocene age, however, older (Miocene) and younger (Holocene) deposits can be found. Numerous types of glacial drift occur including moraines, kettle-kame topography, eskers, drumlins, and glacial till. Glacial till is the dominant feature and is formed by sediment originating directly from glacial ice and typically has no discernible sediment stratification.

Many of the glacial drift deposits are transported downslope by solifluction. Solifluction is the flow of soil in association with frozen ground (Ritter 1986). During the spring and summer thaw, water in the active layer cannot penetrate below the permafrost table. Soils are often saturated, and the loss of friction and cohesion causes them to behave like viscous fluids. The soil thus slowly “flows.” The downslope fronts of the solifluction lobes are marked by near-vertical scarps as high as six feet (Figure 10). This form of mass wasting commonly occurs on slopes between 5% and 20%.

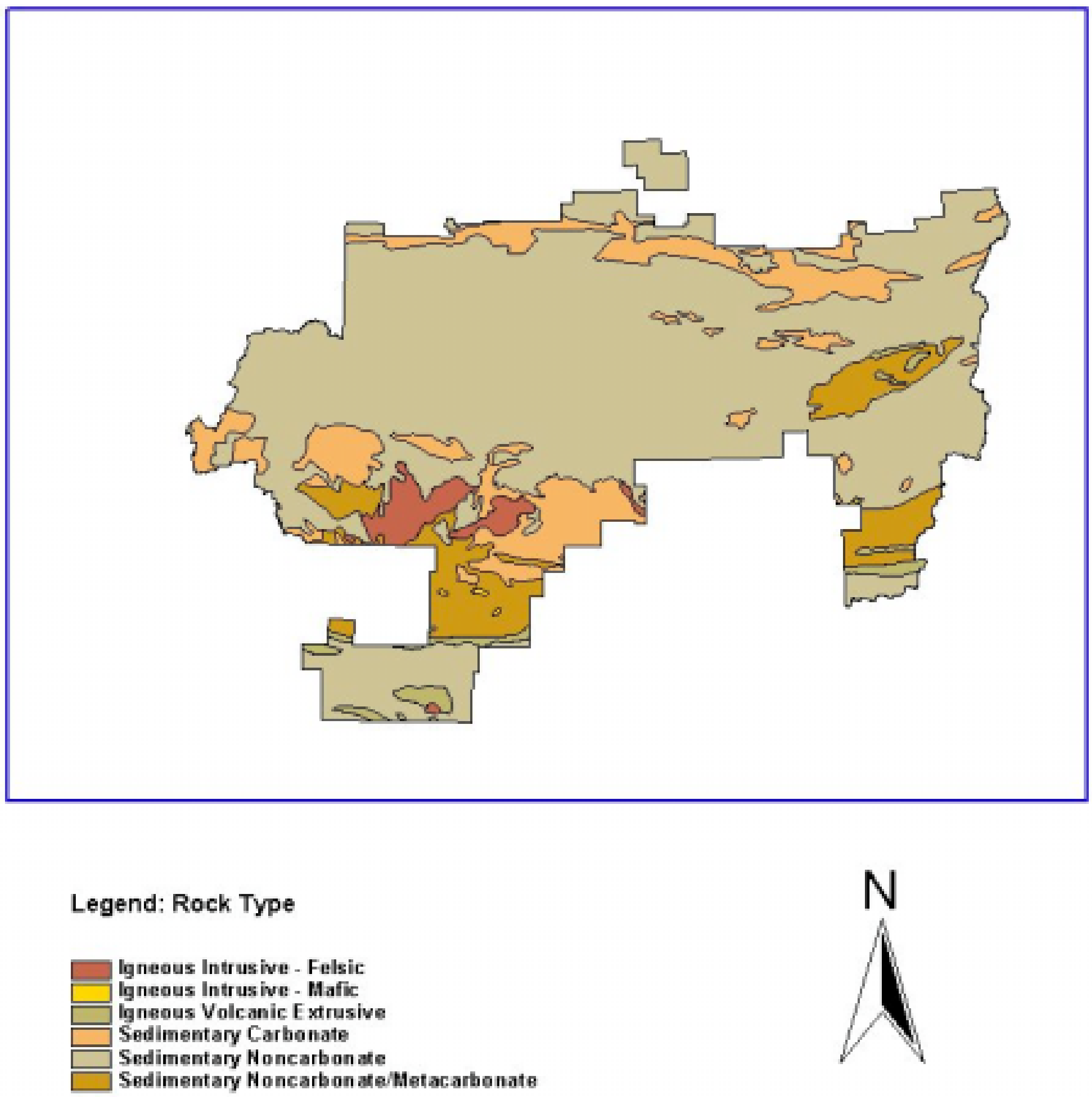


Figure 8. General geology map for GAAR (Beikman 1980).

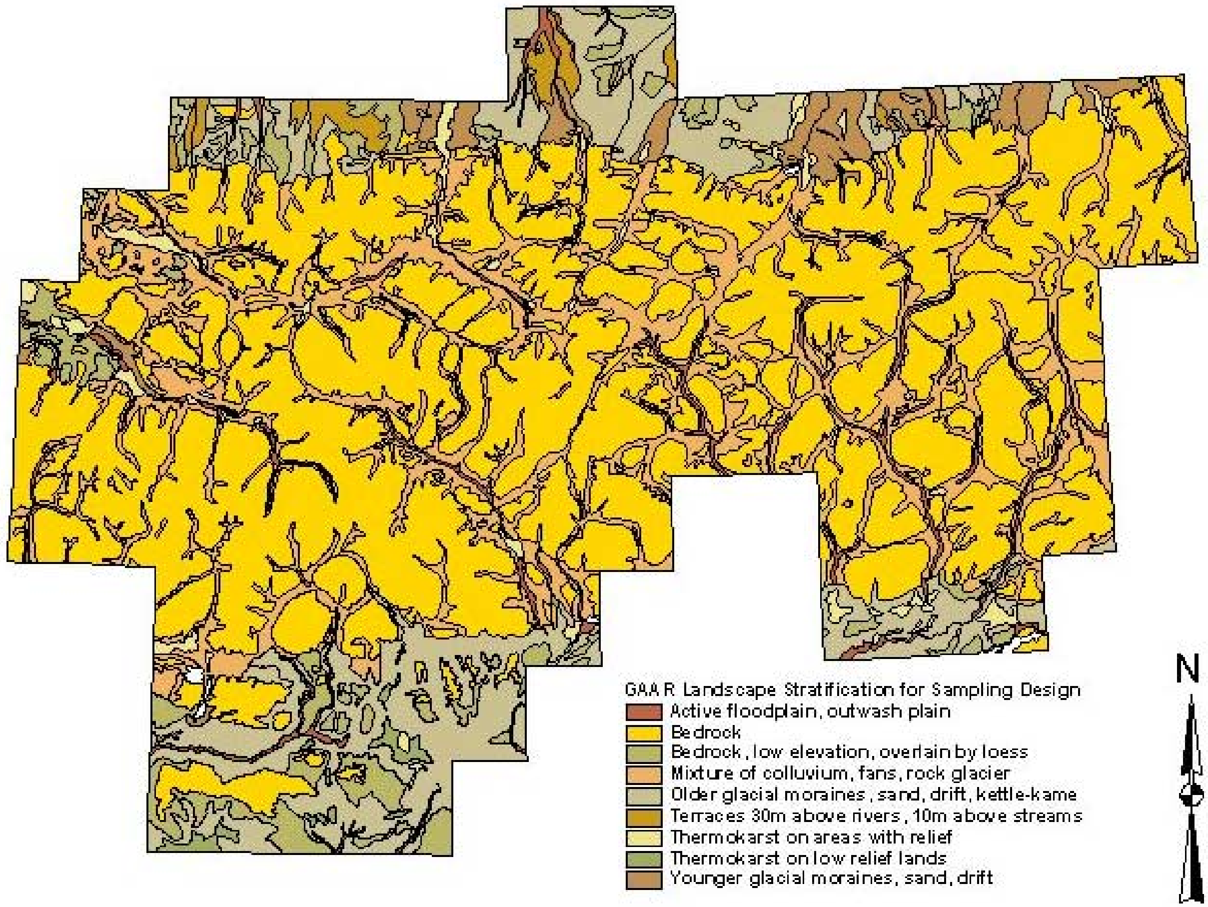


Figure 9. Surficial geology for GAAR (Hamilton 1999).

Steeper slopes tend to drain off excess water. Silty soils are the most susceptible to solifluction, whereas gravelly and sandy soils are so permeable and easily drained that they rarely flow.

Figure 10. Photograph of solifluction in GAAR.

Alluvial fans are common throughout the mountainous portions of GAAR and arise from nearly every side drainage (Figure 11). They are an erosional-depositional system in which rock and sediment are transported down-valley and deposited where they emerge from the confines of a narrow valley into a larger valley or plain. They tend to be fan-shaped in plan view; a segment of a cone radiating away from a single point source. On an alluvial fan, some areas are actively forming whereas other areas are inactive. The point of deposition can shift away from the mountain front to well down the original fan surface if the stream has become entrenched. The stream emerges down-fan and deposits its material forming a new fan on top of the older deposits. The slope of an alluvial fan decreases as you move down-fan (Ritter 1986).

Figure 11. Lichen covered alluvial fan in GAAR.

Slush flows and flooding in side canyons can add significant debris to alluvial fans. In winter, snow avalanches strip the frost-loosened bedrock from the valley walls and deposit it in narrow canyons. Both slush flow and flooding remove this debris and deposit it on alluvial fans. Slush flows occur when rapid snowmelt during May and June causes wet-snow avalanches that flush the debris out of the canyons onto the alluvial fans. Flooding may occur if late summer heavy rains funnel water into steep channels. The flooding picks up soil, rocks, and vegetation and scours out the channels. The debris is then deposited in fans at the base of the mountain.

Rock glaciers are another type of colluvium and, although uncommon, are distinctive features in the high mountains. They are tongue-shaped or lobate masses of unsorted, angular frost-rived material with interstitial ice (Figure 12). They typically originate in cirques or in high, steep-walled recesses.

Figure 12. Rock glacier in GAAR.

Lacustrine deposits also occupy the valley bottoms, as do glacial drift and floodplains. These deposits are derived from materials deposited in lake water and exposed when the water level is lowered or the land is raised. They are also formed during past glaciations when some valleys were dammed by ice, causing glacial lakes to form along their length. Lacustrine deposits have a high percentage of thermokarst-formed lakes.

Floodplains occur in nearly all mountain valleys and extend north and south of the Brooks Range. They are formed by nonglacial-fed rivers and often rework lacustrine and glacial drift deposits. The formation of new land on floodplains is well documented. Along a meandering river—meandering rivers have one or two main channels—alluvium is deposited on convex curves in the river channel (Figure 13). The opposing concave bank is cut, providing sediment for deposition on convex curves downstream and creating a series of similar bands of alluvial deposits. The channel thus meanders laterally across the floodplain. Vegetation growing on new deposits near the river may be contrasted with that on older deposits inland to recognize and measure successional processes. Alluvium is also deposited on the soil surface during flooding further raising the soil surface height, but because surface height is a function of floodwater height, it eventually stabilizes. Ponds, such as meander scrolls and oxbows, are also common on floodplains.

Braided rivers—consisting of multiple, wide, shallow channels characterized by rapid erosion, deposition, and channel shifts—are uncommon in GAAR due to the scarcity of large sediment sources via glaciers or significant erosion (such as landslides). Braided rivers form when river water deposits its sediment in stream channels and the associated plain. Due to continual channel shifting, the sediment is spread across an area called an outwash plain when the headwaters contain glaciers.

Terraces play a major role in plant community structure and composition. Deposits with high permeability become progressively drier as they are vertically and horizontally removed from the active channels. This is due to decreased soil water recharge from channel seepage. Vegetation responds to these gradients in soil moisture with changes in composition and structure. On older terraces, in contrast, ground ice (permafrost) forms and creates an impermeable layer that, in turn, leads to a wetter environment.

Permafrost strongly influences many of the landscape features occurring in GAAR including solifluction, thermokarst, pingos, and patterned ground. All of GAAR is likely underlain by permafrost. Its upper surface ranges in depth from only a few inches in poorly drained deposits beneath thick moss and sod cover, to about 1.5 feet in permeable coarse-grained sediments, and to tens of feet beneath the larger lakes and rivers (Hamilton 1999). The base of permafrost in the arctic foothills, although exact thicknesses are unknown, may lie at

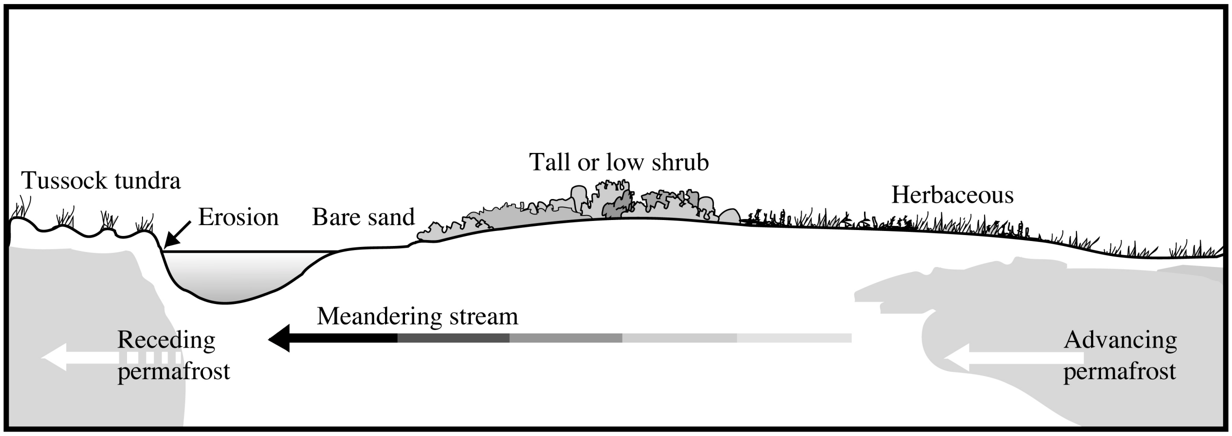


Figure 13. Idealized cross section of a floodplain within the Arctic regions of GAAR.

depths between about 450 to 900 feet as suggested from records from the northern Brooks Range and arctic foothills (Ferrians 1965; Williams 1970). In valleys south of the Brooks Range, the base of permafrost may lie at depths of 100 m, although permafrost may be absent beneath some sections of the Koyukuk River and lower courses of its principal tributaries.

One distinctive result of permafrost is thermokarst occurring in areas with low relief and level land such as in the mountain valleys and regions north and south of the Brooks Range. Thermokarst is the collapse of the soil surface due to the thawing of ice-rich permafrost (Figure 14). The ground around thermokarst is supersaturated—often with ice lenses and layers—because it contains more water in the solid state than the ground could possibly hold if the water were in the liquid state. The melting of ground ice is due to either vertical soil degradation when the surface thermal properties are altered, or lateral degradation such as where lake water laterally erodes its banks, including ground ice. Many of the processes that lead to thermokarst are initiated by broad climate changes, but minor events such as fires, clearing of forest vegetation, shifting stream channels, and removal of the peat surface will upset the thermal balance and produce thermokarst.

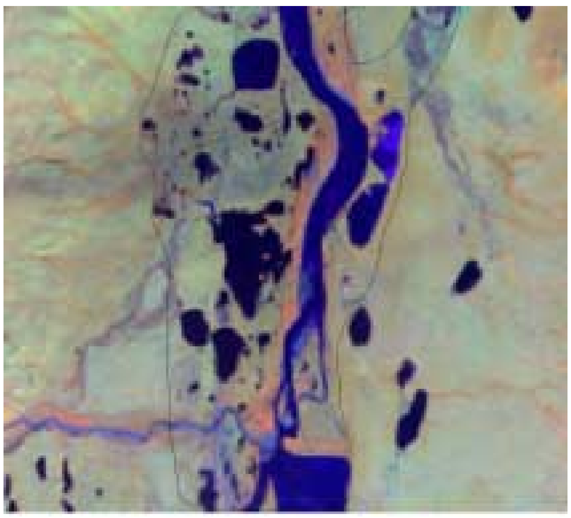


Figure 14. LandSat image of thermokarst lakes—and kettle lakes—in GAAR.

Patterned ground is also a result of permafrost and likely occurs throughout GAAR and is visually evident in the arctic foothills. Three types of patterned ground are described below: sorted polygons, ice wedge polygons, and frost boils (Ritter 1986 and Washburn 1956).

Sorted polygons occur on rounded foothills to level areas. In general, the geometric pattern changes with increasing slope from polygons and circles on level ground, to nets and then vertical stripes on steeper surfaces (Figure 15). Sorting separates the coarse from the fine soil particles, and typically produces a surface feature of fine materials bordered by stones. Polygons are bounded by straight segments of stones that surround a central core of finer material. They range up to 30 feet in diameter. One general theory behind the formation of sorted polygons is that soil heaving separates the coarse and fine sediments, and repeated freezing and thawing moves the stones upward and outward (Ballard 1973). The smaller grains with greater cohesion contract farther inward and downward during thawing. The process continues until the adjacent polygons meet. This process also leads to sorted circles that are circular in outline and sorted stripes that are vertical linear alignments of soil, vegetation, and stones on slopes. The strips are up to several feet in width and 300 feet in length.

Figure 15. Sorted polygons north of the Brooks Range.

Ice wedge polygons are a common feature north and south of the Brooks Range on level ground of glacial drift, lacustrine, and floodplain deposits. They also occur in the larger mountain valley bottoms of the Brooks Range on glacial drift and lacustrine deposits. Ice wedge polygons are typically connected in a polygonal pattern that is similar to the pattern produced by mud cracks. They are formed by large masses of ice—called ice wedges—that grow in thermal contraction cracks in permafrost. The diameter of ice wedge polygons ranges from several feet to greater than 90 feet. Some polygons have perimeters that are elevated relative to the center of the polygon and are termed low-center polygons. These polygon centers often have standing water and support emergent or tussock vegetation. Other polygons have depressed perimeters relative to the center of the polygon and are termed high-center polygons. Their centers do not have standing water and may be dominated by dwarf shrubs and their edges by low shrubs. Low-center polygons indicate that ice wedges are actually growing and that sediments are being actively upturned. High-center polygons indicate that erosion, deposition, or thawing is more prevalent than the up-pushing of the sediments along the sides of the wedge.

Frost boils occur on river terraces and on low angle hills on the north edge of the Brooks Range. They are areas of bare soil that are sufficiently disturbed by frost action to prevent plant colonization. On slopes, fine material in unsorted circles moves slowly downslope producing banked or “stepped” frost boils (Gabriel and Talbot 1984).

WILDFIRE

Fire occurrence is low in the arctic foothills; an average wildfire is 457 acres and they range up to 4,000 acres (Gallant 1995). Fires are common in the Brooks Range ranging in size from < 1 acre to 273,162 acres according to fire records, with an average size of 4,475 acres. Fires occur frequently in the interior south of the Brooks Range from June to early August. Average fire size is 4,075 acres, ranging up to 652,000 acres. The high number of fires is related to low precipitation, warm summers, lightening storms, and the large number of trees with low-lying branches.

METHODS

Methods used to define subsections for GAAR follow those outlined by Bailey (1996) and named by conventions outlined in Cleland et al. (1997). Subsections were defined by a qualitative review and interpretation of the available pertinent data and the authors' knowledge of the study area. The scale was generally at 1:250,000 and the unit size was generally between 10 and 10,000 square miles. The information needed to interpret subsections was climate, lithology, surficial geology, geomorphic processes, potential plant community distributions, topography, hydrology, soils, and soil-forming processes. The following describes this information and its availability.

—Climate data were limited but adequate for interpreting subsections.
—Lithology had been mapped for Alaska by Beikman (1980).
—A series of 1:250,000 scale surficial geology maps had been developed for GAAR by Hamilton (1978a, 1978b, 1979a, 1979b, 1980, 1981, 1984a and 1984b). The mapping comprised ten 1:250,000 quadrangle sheets plus part of one additional sheet, and subsequently had been combined into a single GIS product for GAAR plus a 10-mile peripheral buffer zone.
—General geomorphic processes were understood and, to a degree, could be linked to the mapped surficial geology units.
—Descriptions of potential plant communities were not available. A landcover map and vegetation classification, however, were available. Using Landsat Thematic Mapper multi-spectral imagery as the primary data source, landcover was mapped by Helt et al. (2000) at intermediate scales (1:63,360–1:100,000) with 30 classes following a modified version of the Alaska Vegetation Classification (Viereck et al. 1992) system at levels III and IV. The principal results included a digital thematic landcover map, landcover class descriptions, and plant association descriptions.
—Topography was evaluated using existing U.S. Geological Survey topographic maps (digital raster graphic mosaic of 1:250,000 and 1:63,360 scale).
—Hydrology maps were not available for the region.
—Two soil maps were available for GAAR (Rieger et al. 1979; Swanson 1995). The statewide soil survey (Rieger et al. 1979) provided coarse level soils information for Alaska but was too coarse to be useful for subsection mapping purposes. The second map was developed by Swanson (1995) for the Kobuk Preserve Unit of GAAR and was valuable for mapping subsections. Its major results included physiographic map unit descriptions (similar to surficial geology units described by Hamilton 1981), soil descriptions, and vegetation site type descriptions.

Subsection polygons were delineated by interpreting new polygons and using both (1) existing digital polygons from the surficial geology map (Hamilton 1999), and (2) line-work from the statewide geology map (Beikman 1980). All digital work was conducted in ArcView 3.2a (Copyright 1992–2000, Environmental Systems Research Institute, Inc.). A Thematic Mapper satellite image was used as the base map for new polygons. The on-screen scale used when locating polygon vertices by clicks with the mouse was at about 1:60,000 to 1:100,000, and line placement was accurate to within about 750 feet.

Ecologic units that occurred in GAAR were extended beyond the park boundary to whichever came first, their natural limits or the edge of Thematic Mapper satellite image. Consequently, placement of some ecologic unit boundaries outside of the park should be considered tentative.

LOGIC USED TO DELINEATE SUBSECTIONS

The first major criterion used to separate subsections was the separation of mountains from lowlands. Consequently, the Brooks Range mountain mass and the isolated mountains south of the Brooks Range were separated from the adjacent lowlands. Within the mountain ranges, mountain valleys were separated from the upper elevational exposed bedrock such as peaks, cirques, headwalls, and ridges. The physiographies of the valleys were significantly different containing glacial till, moraines, ground-ice features, and floodplains, all of which did not occur in the bedrock upper elevation units. Where surficial deposits occurred, they effectively masked the effects of the underlying bedrock within the valleys. In addition, mountain valleys, moving downslope, supported lusher vegetation. The lower elevational boundaries of bedrock were based on Hamilton's (1999) bedrock digital lines. Ice-scoured bedrock that occurred in valleys was included with mountain valleys. This was done because vegetation growing on exposed bedrock was similar to that growing on surficial deposits, and because ice-scoured bedrock often had discontinuous surficial deposits.

The Brooks Range as a whole was also divided into north and south halves using the two major climatic zones of the region: continental and arctic. A line was drawn separating the forested valleys—representing the continental climate—from the nonforested valleys— representing the arctic climate. This line started on ridge tops along the southern border of the Noatak Valley and moved east eventually following the Continental Divide.

Lithology as defined by Beikman (1980) was used to further divide bedrock. The lithology units were: sedimentary carbonate, sedimentary noncarbonate, igneous volcanic/extrusive, igneous intrusive-felsic/interm plutonic, igneous intrusive-mafic/ultramafic plutonic, metamorphic metacarbonate, and sedimentary metamorphic metanoncarbonate. Many lithologic bodies (plutons, ultramafic intrusions) too small to distinguish at the subsection scale were grouped into larger adjacent rock bodies. The basis for using lithology was that it was known to affect terrestrial and aquatic patterns and productivity. For example, appreciable differences in water chemistry were associated with the type of bedrock from which they originated or contacted (Wissmar et al. 1997), including carbonate rocks that supported more productive plant communities than noncarbonate rocks. These effects are described in the subsection descriptions.

The mountain valley subsections were distinguished using the following factors. The eleven major watersheds of the region (Noatak, Nigu, Etivluk, Killik, Chandler, Anaktuvuk, Itkillik, Koyukuk, John, Alatna, and Kobuk) formed the boundaries of each subsection. As stated earlier, bedrock formed the upper elevational boundaries of the subsections using Hamilton's (1999) bedrock delineations. Valley mouths where they exit the Brooks Range formed the lower elevational boundary of each mountain valley subsection. The watershed boundaries effectively expressed the two major climatic zones of the Brooks Range. The continental-interior climate was reflected in watersheds with forests, whereas the arctic climate was reflected in nonforested watersheds to the north and west. Mountain valleys included floodplains and ice-scoured bedrock in the valley bottoms and lower side slopes. The minimum valley width for polygon delineation was one mile wide.

In the arctic foothills north of the Brooks Range, three major physiographic types were used to define subsections:

—Recently deglaciated valleys
—Older rolling landscapes without hills
—Older landscapes with hills

The recently deglaciated valleys were covered by the Itkillik glaciation whose two major glacial advances peaked 53,000 and 20,000 years ago (Fernald 1964 and Hamilton 1982). Each valley tended to be lobate in outline formed by the northern extension of glaciers flowing north from the major valleys of the Brooks Range. The boundaries were formed by terminal and lateral moraines as delineated by Hamilton (1999). This landscape was further subdivided by major watershed (Anaktuvuk River, Chandler River, Etivluk River, Itkillik River, Killik River, and Nigu River). A unique vegetation characteristic of the subsection was that tussock tundra was, in general, not as well developed as in the adjacent subsections. Also, the soils tended to be shallower with less organic matter than on the adjacent rolling landscapes.

Older rolling landscapes without hills—north of the Brooks Range—were comprised of deposits older than the Itkillik glaciation. Surficial deposits included till, solifluction, terrace gravels, small floodplains, and larger outwash deposits. Tussock tundra was well developed, surface organic matter buildup was common, and obvious thermokarst was uncommon. This landscape was further subdivided by major watershed (Anaktuvuk River, Chandler River, Etivluk River, Itkillik River, Killik River, and Nigu River).

The last landscape north of the Brooks Range was of older age than the Itkillik glaciation and had many hills—exposed bedrock outcrops. The hills tended to occur in clusters or as extensions of the Brooks Range. When hills were common they were used to define the hill-dominated subsections. This landscape was further subdivided by major watershed (Anaktuvuk River, Chandler River, Etivluk River, Itkillik River, Killik River, and Nigu River).

In the Noatak River valley and south of the Brooks Range, subsections were separated based on the following factors (mountains south of the Brooks Range have already been separated out):
—Lacustrine deposits often with peat
—Low rounded mountains
—Lowlands and rolling hills
—Large modern alluvium (floodplains)

The lacustrine and peat deposits were distinct from the remaining lowlands and rolling hills. The landscape was relatively level, and thermokarst, kettle lakes, and peatlands were common. Surficial geology was either peat or glaciolacustrine as defined and delineated by Hamilton (1999). Geographic distance was also used to separate subsections.

Low rounded mountains occurred in the Noatak Valley and were a distinct subsection. The lowlands and rolling hills in the Noatak Valley and south of the Brooks Range were a mixture of colluvium, terraces, moraines, and glacial drift of various ages. The upper elevational limit was based on the beginning of exposed bedrock based on Hamilton's (1999) bedrock delineations. The major watersheds were also used to divide these subsections. This landscape was not divided based on "time since last glaciation" as was done north of the Brooks Range. This was because the differences in vegetation and soils between landscape ages were not as distinct as north of the Brooks Range.

Three large modern alluvial deposits—the Noatak River floodplain, Kobuk River floodplain, and Koyukuk River floodplain—were delineated as subsections. The remaining floodplains were too narrow to be considered subsections, however, they were delineated and described as detailed-subsections. Floodplains within the Brooks Range—ending where the river exited the mountains—and those outside the mountains were considered distinct detailed-subsections. The major watersheds were used to further separate the floodplains into distinct detailed-subsections. ArcView line work was partially based on Hamilton's (1999) surficial geology polygons listed as modern alluvium, alluvium-sand facies, and alluvium undifferentiated. Small disjunct floodplain reaches were eliminated.

After the subsections were defined, the researchers familiar with the subsection methodologies reviewed them. Subsections were also cross-walked with the Noatak National Park and Preserve subsection mapping effort by Jorgenson (2002).

NOMENCLATURE

Scientific binomials and common names follow Hulten (1941) and Viereck and Little (1972). The common name is used in the text for well-known species, and scientific binomials are included for lesser-known species. Both the common name and scientific binomial are given the first time a species is referred to in the text.

SUBSECTIONS

Fifty-one subsections were identified for GAAR and are described, in alphabetical order, within the major sections of the region: arctic foothills, arctic Brooks Range, Subarctic Brooks Range, interior forested lowlands, and interior highlands (Figure 16 and Table 2). Detailed-subsection descriptions follow the subsection section. Each subsection description includes a representative photograph of the subsection, location, surficial geology, lithology, processes, vegetation, and climate. Table 2 also gives the area (in acres) per subsection.

Table 2. Classification and area (acres) of sections, subsections, and detailed-subsections within GAAR.

Section	Subsection	Acres	Detailed-Subsection	Acres
Arctic Brooks	Anaktuvuk Mountain Valley	64,876	Upper Anatuvuk River Floodplain	8,683
Range			Upper Nanushuk River Floodplain	2,549
	Chandler Mountain Valley	60,655	Encampment Creek Floodplain	330
			Upper Chandler River Floodplain	955
	Endicott Mountains Noncarbonate	1,348,901		
	Etivluk Mountain Valley	46,185	Upper Etivluk River Floodplain	4,682
			Upper Outwash Creek Floodplain	2,086
	Itkillik Mountain Valley	46,731	Upper Itkillik River Floodplain	9,206
	Kavachurak Foothills	105,588		
	Kavachurak Glaciated Uplands	136,128		
	Kavachurak Mountains	225,539		
	Killik Mountain Valley	404,993	Okpikruak River Floodplain	1,376
			Upper Killik River Floodplain	28,341
			Upper Okokmilaga River Floodplain	6,249
	Nigu Mountain Valley	125,788	Nigu River Floodplain	12,707
	Noatak Mountain Valley	150,428	Upper Noatak River Floodplain	12,889
	Nukatpiat Hills	93,823		
	Nukatpiat Mountains	111,809		
	Oyukak Carbonate Mountains	143,405		
	Thibodeaux Noncarbonate Mtns.	574,920		
	Upper Noatak Floodplain	79,104		
	Utikok Carbonate Mountains	350,133		
Subarctic	Alatna Mountain Valley	29,644	Alatna River Floodplain	4,242
Brooks Range	Arrigetch Peaks Granitics	360,319		
	Blind Pass Mountains	43,028		
	Huntfork Noncarbonate Mountains	2,372,244		
	John Mountain Valley	470,403	John River Floodplain	42,241
	Kobuk Mountain Valley	157,302	Kaluluktok Creek Floodplain	13,275
			Reed River Floodplain	8,741
	Koyukuk Mountain Valley	642,548	Middle Fork Koyukuk River Floodplain	34,716

			North Fork Koyukuk River Floodplain	39,021
			Wild River Floodplain	11,837
	Mount Doonerak Mountains	166,595		
	Shulakpachak Noncarbonate Mtns.	69,864		
	Skajit Carbonate Mountains	418,544		
	Southern Foothills-Metanoncarbonates Range	1,218,213		
	Ulaneak Mountains	160,443		
Arctic	Anaktuvuk Foothills	101,155		
Foothills	Anaktuvuk Glaciated Lowlands	241,670	Anaktuvuk River Floodplain	13,476
			Nanushuk River Floodplain	3,642
	Anaktuvuk Lowlands	74,593		
	Chandler Foothills	181,616		
	Chandler Glaciated Lowlands	31,223	Siksikpuk River Floodplain	15,855
	Chandler Lowlands	379,391		
	Etivluk Foothills	294,656		
	Etivluk Lowlands	296,529	Etivluk River Floodplain	9,025
			Outwash Creek Floodplain	8,410
	Itkillik Glaciated Lowlands	207,476	Itkillik River Floodplain	7,295
	Killik Foothills	25,315		
	Killik Glaciated Lowlands	168,722	Killik River Floodplain	27,809
			Okokmilaga River Floodplain	5,722
	Killik Lowlands	263,032		
Interior	Klikhtentotzna Creek Lowlands	117,088		
Forested	Kobuk Lowlands-Forested	341,132		
Lowlands	Kobuk Lowlands-Tundra	159,707		
	Kobuk River Floodplain	87,750		
	Koyukuk Lowlands	292,845		
	Koyukuk River Floodplain	71,838		
	Norutak Lake Lowlands	25,063		
Interior	Angayucham Mountains	468,825		
Highlands	Jack White Range	23,882		
	Lockwood Hills	255,383		

ARCTIC BROOKS RANGE SECTION

Anaktuvuk Mountain Valley Subsection
This subsection is dominated by the short, wide Anaktuvuk River valley within the mountains of the Brooks Range and also includes four smaller valleys (Figure 16). The upper elevational limit is formed by exposed bedrock and the northern boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 64,876 acres, and elevation ranges up to 4,200 feet.

The sideslopes typically consist of glacial till, lateral moraines, and sand deposits, and alluvial fans arise from side drainages sometimes extending to the valley floors (Figure 17). Some of the finer (silt) deposits have moved downslope due to solifluction. Permafrost likely underlies most of the subsection, especially on poorly drained deposits such as silt. Most valley floors are dominated by floodplains and terraces, sand deposits, alluvial fans and, to a lesser extent, glacial till. Lakes are common on the north edge of the subsection. Bedrock geology is sedimentary carbonate.

Vegetation. The higher slopes are dominated by dwarf shrubs, primarily *Dryas octopetala* (white mountain avens), and strong associates include *Salix arctica* (arctic willow), *Cassiope tetragona* (four-angled cassiope), *Vaccinium uliginosum* (bog blueberry), and *Carex bigelowii* (Bigelow sedge) (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa* (resin birch), *Salix lanata* subspecies *richardsonii* (Richardson willow), *Salix planifolia* subspecies *pulchra* (diamondleaf willow), *Vaccinium uliginosum,* and *Ledum palustre* (Labrador tea). Tussock-forming graminoids include *Carex aquatilis* (water sedge), *Carex bigelowii, Eriophorum vaginatum* (tussock cottongrass), and *Calamagrostis canadensis* (bluejoint grass). Tall shrubs occur along stream courses and include *Salix lanata* subspecies *richardsonii* (Richardson willow) and *Salix alaxensis* (feltleaf willow). A wet herbaceous class is common on the valley floors dominated by *Carex aquatilis, Arctophila fulva, Equisetum fluviatile,* and *Eriophorum angustifolium* (tall cottongrass).

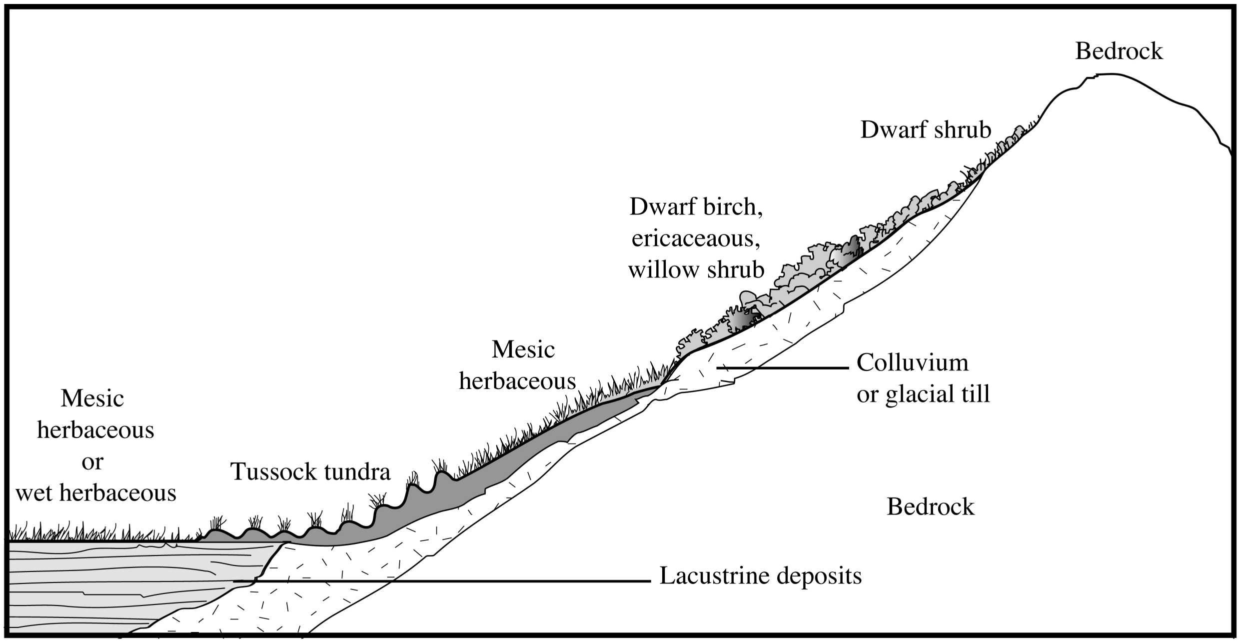


Figure 17. Idealized cross section of a mountain valley in the north half of GAAR showing various surficial geology deposits and landcover types.

Chandler Mountain Valley Subsection

This subsection is dominated by the short wide Chandler River valley within the mountains of the Brooks Range and also includes two smaller valleys (Figure 16). The upper elevational limit is formed by exposed bedrock and the northern boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 60,655 acres, and elevation ranges from 3,110 to 5,239 feet.

Surficial geology types on the sideslopes are glacial till, lateral moraines, and some upper slopes have bedrock scoured by receding glaciers. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors covering the glacial till. Permafrost likely underlies most of the subsection, and sorted polygons and thermokarst occur. Glacial till and lakes, including Chandler Lake, dominate most valley floors. Floodplains, terraces, and lacustrine deposits also occur in smaller amounts. Bedrock geology is sedimentary noncarbonate on the south half of the subsection and sedimentary carbonate on the north half.

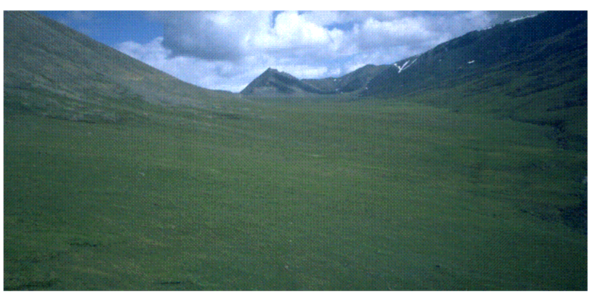
Vegetation. Dwarf shrubs dominate the higher slopes, primarily *Dryas octopetala,* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria*, and *Alectoria*.

Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* dominate stream courses. The wet herbaceous class is common on the valley floors dominated by *Carex aquatilis, Arctophila fulva, Equisetum fluviatile,* and *Eriophorum angustifolium.*

Endicott Mountains Noncarbonate Subsection

This large subsection is comprised of rugged mountains formed from noncarbonate sedimentary bedrock in the northwest half of GAAR. It occurs at higher elevations than in mountain valley subsections and has little or no soil development. Numerous disjunct units occur, separated by mountain valleys and other bedrock types. Topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). Bedrock is shale, sandstone, chert, conglomerate, and quartzite of upper Devonian age (400 to 350 million years ago). Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. Inclusions of surficial deposits and carbonate sedimentary lithology are common. It covers 1,348,901 acres, and elevation ranges up to 7,335 feet.

Weathering of sedimentary rocks produces semi-angular fragments that easily break down. Planes of weakness exist due to the process in which the rock is formed, primarily layering sediments into bedding planes and structural joints. Erosion by glaciers and streams often follows the geologic structure and bedding orientation. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. When soils do develop, they reflect the original texture of the bedrock; for example, course-textured soils form from sandstones and fine-textured soils result from siltstones and mudstones.



Surficial deposits are scattered across the higher elevation bedrock and also occur in a few valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Deposits on high-elevation bedrock include talus rubble, rock glaciers, and patches of glacial drift. The narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, solifluction, and alluvial fans.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. At lower elevations, the dwarf shrub map class occurs dominated by *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occurs including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous classes (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.*

Etivluk Mountain Valley Subsection

This subsection includes four relatively small, treeless, mountain valleys within the Brooks Range that drain into the Etivluk River and Kurupa River (Figure 16). The upper elevational limit is formed by exposed bedrock and the northern boundaries by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 46,185 acres, and elevation ranges up to 4,200 feet.

The sideslopes are typically bedrock scoured by receding glaciers from the last major glaciation (20,000 years ago) or glacial till. Many of the slopes have solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors. Floodplains and terraces dominate the valley floors, and lacustrine deposits are uncommon. Permafrost likely occurs on most of the subsection. Bedrock geology is predominantly sedimentary noncarbonate with inclusions of sedimentary carbonate on the north edge of the subsection.

Vegetation. Dwarf shrubs cover the higher slopes, dominated by *Dryas octopetala,* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous classes (Helt et al. 2000). Typical shrub species include *Betula glandulosa*, *Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* are common along stream courses.

Itkillik Mountain Valley Subsection

This subsection is a wide treeless mountain valley (Figure 16). The upper elevational limit is formed by exposed bedrock and the northern boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 46,731 acres, and elevation ranges up to 5,000 feet.

Surficial geology types on the sideslopes include glacial till, lateral moraines, and sand deposits; alluvial fans arise from side drainages sometimes extending to the valley floors. Some of the finer (silt) deposits have moved downslope due to solifluction. Permafrost underlies most of the subsection. Valley floors are dominated by floodplain and terrace deposits and lakes occur. Bedrock geology is sedimentary noncarbonate.

Vegetation. The higher slopes are dominated by dwarf shrubs, primarily *Dryas octopetala,* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* dominate stream courses. A wet herbaceous class is common on the valley floors dominated by *Carex aquatilis, Arctophila fulva, Equisetum fluviatile,* and *Eriophorum angustifolium.*

Kavachurak Foothills Subsection

This subsection was described by Jorgenson (2002) as "Round hills (385–1264 m) in the western Schwatka Mountains, comprised of noncarbonate sedimentary rocks including shale and conglomerate. Barren ridges are uncommon. Colluvial slopes have moist, acidic, organic-rich soils that support shrub birch-ericaceous shrub and willow scrub. Drainages support low willow scrub. Permafrost is continuous and has a low ice content." It covers 105,588 acres.

Kavachurak Glaciated Uplands Subsection

This subsection was described by Jorgenson (2002) as "Subdued knob and kettle topography (363–768 m) in the upper Noatak Basin derived from the Itkillik glaciation. Drainage is poorly integrated and isolated depressions are common. Well-drained, gravelly soils on upper slopes and ridges support *Dryas* tundra, shrub birch-ericaceous shrub, and low willow scrub. Lower slopes and flats have wet organic-rich soils that support tussock tundra. Kettle lakes are abundant and shores support willow scrub and wet sedge meadows. Permafrost is continuous with low-moderate ice content." It covers 136,128 acres.

Kavachurak Mountains Subsection

This subsection was described by Jorgenson (2002) as "Rugged mountains (344–1865 m) in the northwestern Schwatka Mountains comprised of mixed carbonate and noncarbonate rocks, including limestone, other carbonates, conglomerate, quartzite, phyllite, and shale. Most of the area is covered by barren fellfields and talus slopes. More stable slopes have *Dryas* tundra. Colluvial slopes have moist to wet, organic-rich soils that support *Dryas*-sedge tundra shrub, birch-ericaceous shrub, and willow scrub. Drainages and alluvial fans have willow scrub. Permafrost is continuous with low ice content." It covers 225,539 acres.

Killik Mountain Valley Subsection

An extensive network of treeless mountain valleys within the Killik River watershed and the Okokmilaga River watershed (Figure 16) characterize this subsection. The upper elevational limit is formed by exposed bedrock and the northern boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 404,993 acres, and elevation ranges from 2,000 to 5,070 feet.

Surficial geology on sideslopes includes glacial till, lateral moraines, and sand deposits; many upper slopes have bedrock scoured by receding glaciers. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors. Floodplains, terraces, lacustrine deposits, and lakes dominate most valley floors. Dunes are also common in the lower Killik River valley. Permafrost likely underlies most of the subsection, and sorted polygons and lakes occur. Bedrock geology is predominantly sedimentary noncarbonate with inclusions of sedimentary carbonate on the subsection's north edge.

Vegetation. The higher slopes are dominated by dwarf shrubs, primarily *Dryas octopetala,* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria*, and *Alectoria*. Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* dominate stream courses. A wet herbaceous class is common on the valley floors, and common species include *Carex aquatilis, Arctophila fulva, Equisetum fluviatile,* and *Eriophorum angustifolium.*

Nigu Mountain Valley Subsection

The wide treeless mountain valleys of the Nigu River watershed (Figure 16) characterize this subsection. The upper elevational limit is formed by exposed bedrock and the western boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. The subsection covers 125,788 acres, and elevation ranges from 1,800 to 3,400 feet.

Downcutting and glacial scouring over millennia formed the wide and steep walled mountain valleys. The sideslopes are typically bedrock scoured by receding glaciers from the last major glaciation (20,000 years ago) or glacial till. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors. The valley floors are dominated by vegetated bedrock, floodplains, terraces, and glacial drift. Lacustrine deposits are uncommon and kettle lakes and thermokarst occur. Permafrost likely underlies most of the subsection. Bedrock geology is sedimentary noncarbonate rock.

Vegetation. Dwarf shrubs cover the upper slopes dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope and on the valley bottoms, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* are common along stream courses.

Noatak Mountain Valley Subsection

The wide treeless mountain valleys of the Noatak River watershed (Figure 16) characterize this subsection. The upper elevational limit is formed by exposed bedrock and the western boundary by the edge of the Brooks Range. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. The Noatak and Kobuk Valleys may also serve as conduits for moist air masses moving inland from the Bering Sea that result in higher snowfall—as evidenced by avalanche tracks—than the rest of the Brooks Range. The subsection covers 150,428 acres, and elevation ranges up to 5,490 feet.

Downcutting and glacial scouring over millennia formed the wide and steep walled mountain valleys. The sideslopes are typically bedrock scoured by receding glaciers from the last major glaciation (20,000 years ago) or glacial till. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors. The valley floors are dominated by vegetated alluvial sand sheets and dunes, floodplains, terraces, glacial drift and, sometimes, scoured bedrock. Lacustrine deposits are uncommon and kettle lakes and thermokarst occur. Permafrost likely underlies most of the subsection. Bedrock geology is predominantly sedimentary noncarbonate and sedimentary carbonate, with inclusions of sedimentary and metamorphic metanoncarbonate and igneous intrusive-felsic rocks.

Vegetation. Dwarf shrubs cover the upper slopes dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope and on the valley bottoms, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous (Helt et al. 2000). Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.* The tall shrubs *Salix lanata* subspecies *richardsonii* and *Salix alaxensis* are common along stream courses.

Nukatpiat Hills Subsection

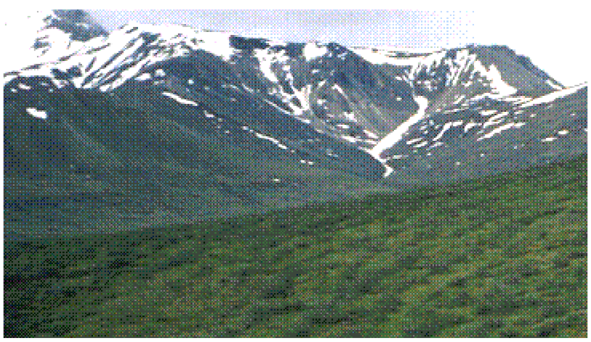
This subsection was described by Jorgenson (2002) as "Rounded low mountains and gentle hills (630–1251 m) in the western Endicott Mountains, comprised of shale and sandstone. Most areas are mantled by geliflution deposits and old (Sagavanirktok) glacial drift. Isolated low mountains have fellfields or dry rocky soils with sparse vegetation or *Dryas* tundra. Long gentle slopes have wet soils with tussock, birch-ericaceous shrub, and willow scrub. Drainages have willow scrub. Permafrost is continuous and has low to moderate ice content." It covers 93,823 acres.

Nukatpiat Mountains Subsection

This subsection was described by Jorgenson (2002) as "Rugged mountains (493–1465 m) in the western Endicott Mountains comprised of conglomerate, sandstone, and shale. Fellfields and talus cover the ridges and upper slopes and colluvium mantles the lower slopes. The fellfields are actively disturbed by frost shattering and are mostly barren with some *Dryas* tundra. Upper slopes have non-sorted stripes, wet soils, and shrub birch-ericaceous shrub and willow scrub. Lower slopes have gelifluction lobes, poorly drained organic-rich soils, and dense willow scrub. Gentle lower slopes support tussock tundra and drainages support tall willow scrub. Permafrost is continuous and has a low ice content." It covers 111,809 acres.

Oyukak Carbonate Mountains Subsection

This small subsection is characterized by rugged mountains made of exposed carbonate sedimentary bedrock. There are also inclusions of sedimentary noncarbonate bedrock. Topography includes jagged rocky ridges, peaks, cirques, cirque basins, and mountain valleys (Figure 16). Bedrock is limestone, dolomite, marble, and shale (Beikman 1980). Glaciation has shaped and exposed the bedrock, although presently only small headwater glaciers exist in the subsection. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. Surficial deposits are scattered across the high elevation bedrock and include talus rubble, rock glaciers, and patches of glacial drift. The narrow valleys are also mantled with thin or discontinuous glacial till, talus, and alluvial fans. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 143,405 acres, and elevation ranges up to 7,310 feet.

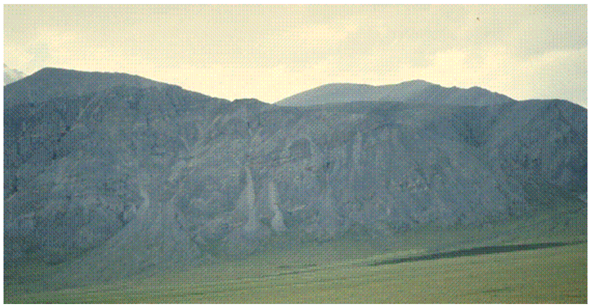


Vegetation. The species composition of alpine vegetation in the Brooks Range is reported by Cooper (1986) to be different on acid versus basic soils. For example, *Salix lanata* subspecies *richardsonii* dominates willow thickets on carbonate rocks whereas *Salix planifolia* subspecies *pulchra* is dominant on acid rocks. The carbonates in the sedimentary bedrock typically result in highly alkaline soils.

In this subsection, vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and shallow or no soils. At lower elevations, the dwarf shrub map class occurs and is dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous classes. Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Vaccinium uliginosum* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.*

Thibodeaux Noncarbonate Mountains Subsection

This subsection is characterized by rugged mountains formed from noncarbonate sedimentary bedrock. It occurs at higher elevations than mountain valley subsections and has little or no soil development. Topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). Bedrock is shale, sandstone, chert, conglomerate, and quartzite of upper Devonian age (400 to 350 million years ago). Inclusions of surficial deposits and carbonate sedimentary lithology are common. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 574,920 acres, and elevation ranges up to 7,610 feet.



Weathering of sedimentary rocks produces semi-angular fragments that easily break down. Planes of weakness exist due to the process in which the rock is formed, primarily layering sediments into bedding planes and structural joints. Erosion by glaciers and streams often follows the geologic structure and bedding orientation. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. When soils do develop, they reflect the original texture of the bedrock; for example, course-textured soils form from sandstones and fine-textured soils result from siltstones and mudstones.

Surficial deposits are scattered across the higher elevation bedrock and also occur in a few valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Deposits on high-elevation bedrock include talus rubble, glaciers, and patches of glacial drift. The narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, and alluvial fans.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. At lower elevations, the dwarf shrub map class occurs dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous classes. Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.*

Upper Noatak Floodplain Subsection

This subsection is formed by the floodplain of the Noatak River (Figure 16). The Noatak Floodplain Subsection is distinct from the floodplain detailed-subsections' because it is much larger and flows through a wide mountain valley. It includes the Noatak River and its sandbars, active floodplain, and low inactive—no longer flooded—terraces (Hamilton 1999). These terraces are included because they may be eroded in the near future (500 years) and thus are a seral stage in the floodplain ecosystem. Meander scrolls and oxbows are common. Permafrost is discontinuous, typically forming in the older deposits with ground ice reshaping oxbows and perching the water table on terraces. The climate is arctic with cold dry winters and cool dry summers. It covers 79,104 acres, and elevation ranges up to 1,000 feet.

Vegetation. New sandbars or exposed alluvium are invaded by river beauty *(Epilobium latifolium),* arctic wormwood *(Artemisia arctica),* and shrub species such as feltleaf willow *(Salix alaxensis)* and grayleaf willow *(Salix glauca).* If the soils remain well drained, then the willows may continue to dominate. However, if ground ice forms—leading to poorly drained soils—then tussock tundra forms dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii,* and *Carex bigelowii.* Wet herbaceous meadows are also common dominated by *Carex aquatilis* and *Eriophorum angustifolium.* On small streams, the narrow floodplains are dominated by open and closed shrub stands consisting of *Salix planifolia* subspecies *pulchra, Betula glandulosa,* and herbaceous vegetation.

Utikok Carbonate Mountains Subsection

This subsection is distinguished by the mountainous region running along the north flank of the Brooks Range dominated by carbonate sedimentary bedrock. It occurs at higher elevations than mountain valley subsections and has little or no soil development. Topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). Bedrock is of Mississippian age (350 to 325 million years ago) and is composed of conglomerates, shale, and limestone with subordinate chert and dolomite (Beikman 1980). Glaciation has shaped and exposed the bedrock, although presently only small headwater glaciers exist in the subsection. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. Surficial deposits are scattered across the high elevation bedrock and include talus rubble, rock glaciers, and patches of glacial drift. The narrow valleys are also mantled with thin or discontinuous glacial till, talus, and alluvial fans. Climate is typical of arctic Alaska—dry and cold in winter and dry and cool in summer. It covers 350,133 acres, and elevation ranges up to 7,610 feet.

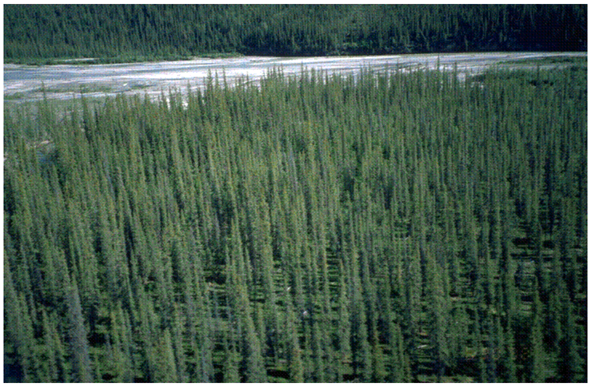
Vegetation. The species composition of alpine vegetation in the Brooks Range is reported by Cooper (1986) to be different on acid versus basic soils. For example, *Salix lanata* subspecies *richardsonii* dominates willow thickets on carbonate rocks whereas *Salix planifolia* subspecies *pulchra* is dominant on acid rocks. The carbonates in the sedimentary bedrock typically result in highly alkaline soils.

In this subsection, vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and shallow or no soils. At lower elevations, the dwarf shrub map class occurs and is dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Moving downslope, a mixture of landcover classes occur including shrub birch-willow-tussock tundra, shrub birch-ericaceous-willow, and mesic herbaceous classes. Typical shrub species include *Betula glandulosa, Salix lanata* subspecies *richardsonii, Vaccinium uliginosum,* and *Ledum palustre.* Tussock-forming graminoids include *Carex aquatilis, Carex bigelowii, Eriophorum vaginatum,* and *Calamagrostis canadensis.*

SUBARCTIC BROOKS RANGE SECTION

Alatna Mountain Valley Subsection

This subsection is an extensive network of broad forested mountain valleys within the Alatna River watershed (Figure 16). The upper elevational limit is formed by exposed bedrock and the southern boundary by the edge of the Brooks Range. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 364,744 acres, and elevation ranges from 1,000 to 4,770 feet.



On valley sideslopes, the receding glaciers from the last major glaciation (20,000 years ago) deposited glacial till and lateral moraines. The lower valleys, however, were often scoured down to bedrock by the receding glaciers. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from nearly every side drainage often extending to the valley floors. Vegetated sand sheets and dunes, floodplains, terraces, and glacial drift dominate the valley floors. Lakes and lacustrine deposits are uncommon. Permafrost underlies most of the subsection. The underlying bedrock geology is predominantly sedimentary noncarbonate and sedimentary carbonate, with inclusions of igneous intrusive-felsic and sedimentary and metamorphic metanoncarbonate rock.

Vegetation. Dwarf shrubs cover the upper slopes dominated by *Dryas octopetala* and strong associates include *Salix arctica*, *Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000) (Figure 18). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Moving downslope, the landcover classes change from low shrub, or mesic herbaceous, to tall shrub and coniferous forest. Low shrub classes are dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The mesic herbaceous class ranges from mountain meadows dominated by *Calamagrostis canadensis, Epilobium angustifolium* (fireweed), and other herbaceous species, to moist areas dominated by *Carex bigelowii, Eriophorum russeolum* (russett cottongrass), and *Eriophorum vaginatum.* The dominant tall shrub is American green alder. Stands of white spruce and black spruce occur in the valley bottoms. Paper birch and quaking aspen forests are uncommon.

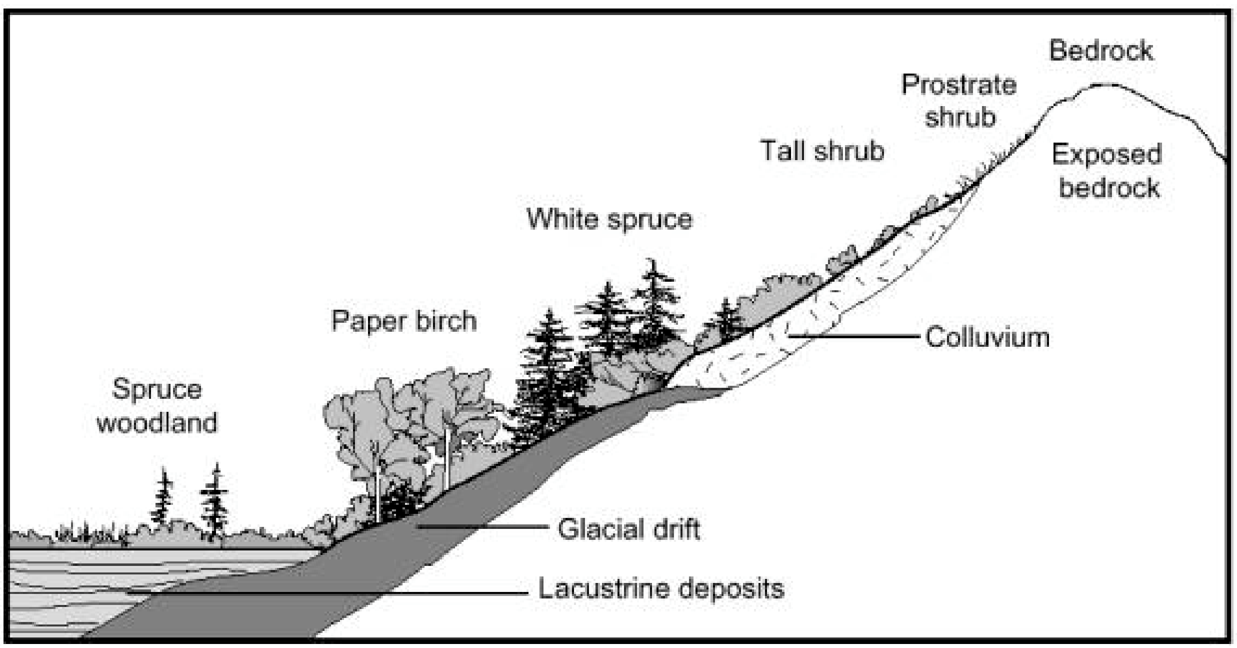


Figure 18. Idealized cross section of a mountain valley in the forested half of GAAR showing various surficial geology deposits and landcover types.

Arrigetch Peaks Granitics Subsection

This subsection is distinguished by the steep rugged mountains composed of igneous intrusive-felsic bedrock in the Arrigetch Peaks region. Significant inclusions of sedimentary carbonate bedrock and surficial deposits are also common. This subsection occurs at higher elevations than mountain valley subsections and has little or no soil development. Topography includes jagged rocky ridges, peaks, cirques, cirque basins, and upper valley slopes (Figure 16). Repeated glaciations of the igneous bedrock have resulted in steep slopes due to granite's resistance to erosion and proneness to exfoliation. The rocks range from gray in color and coarse grained—felsic referring to well-developed mineral grains such as feldspar, quartz, and muscovite—to darker in color and coarse grained. The rocks are of Cretaceous age (135 to 68 million years old). Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 360,319 acres, and elevation ranges up to 8,510 feet.

Surficial deposits are scattered across the higher elevation bedrock and include talus rubble, rock glaciers, small headwater glaciers, and patches of glacial drift. Thin or discontinuous glacial till, talus, and alluvial fans also mantle the valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Soils that do develop from the bedrock tend to be shallow, gravelly, and nutrient poor. Granite is resistant to physical and chemical weathering and soils tend to have relatively low pH levels, low alkalinity, and high soluble aluminum concentrations (Bohn et al. 1985).

Vegetation. Vegetation is sparse or absent in the higher elevations due to the harsh climatic conditions and general lack of soils. Downslope, dwarf shrubs dominate. Due to soil infertility, vegetation tends to be depauparate, species poor, and ericaceous plants often dominate (Helt et al. 2000). The dominant dwarf shrub is *Dryas octopetala* and strong associates include *Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii.* Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous classes. The dominant tall shrub is American green alder and low shrubs include *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* In tussock regions, similar low shrub species dominate in association with *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.*

Blind Pass Mountain Subsection

This small subsection is characterized by rugged mountains composed of igneous intrusive-felsic bedrock. Inclusions of sedimentary noncarbonate bedrock and surficial deposits are also common. It occurs at higher elevations than mountain valley subsections and has little or no soil development. Topography includes jagged rocky ridges, peaks, cirques, cirque basins, and upper valley slopes (Figure 16). Repeated glaciations of the igneous bedrock have resulted in steep slopes due to granite's resistance to erosion. The rocks are of Cretaceous age (68 to 135 million years old), range from gray to dark in color, and are coarse grained. The sedimentary rocks are conglomerate, graywacke, phyllite, shale, sandstone, siltstone, and limestone of Devonian age (350 to 400 million years old). Climate is typical of interior

Alaska—dry and cold in winter and dry and warm in summer. It covers 43,028 acres, and elevation ranges up to 4,765 feet.

Surficial deposits are scattered across the higher elevation bedrock and include talus rubble, rock glaciers, avalanche tracks, and patches of glacial drift. Thin or discontinuous glacial till, colluvium, and alluvial fans mantle the valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Soils that do develop from the bedrock tend to be shallow, gravelly, and nutrient poor. Granite is resistant to physical and chemical weathering and soils tend to have relatively low pH levels, low alkalinity, and high soluble aluminum concentrations (Bohn et al. 1985).

Vegetation. Vegetation is sparse or absent in the higher elevations due to the harsh climatic conditions and general lack of soils. Moving downslope, dwarf shrubs dominate and the species composition includes *Dryas octopetala, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Due to soil infertility, vegetation tends to be less robust and species poor; ericaceous plants often dominate.

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous classes. The dominant tall shrub is American green alder and low shrubs include *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* White spruce and black spruce stands occur in the valley bottoms.

Huntfork Noncarbonates Mountain Subsection

This large subsection is composed of rugged mountains formed from noncarbonate sedimentary bedrock in the forested central area of the Brooks Range in GAAR. It occurs at higher elevations than mountain valley subsections and has little or no soil development. Numerous disjunct units occur separated by mountain valleys. Topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). The rocks are shale, sandstone, chert, conglomerate, and quartzite of upper Devonian age (350 to 400 million years old). Small and isolated inclusions of carbonate sedimentary lithology and igneous intrusive-mafic/ultramafic plutonic lithology also occur. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 2,372,244 acres, and elevation ranges up to 7,310 feet.

Weathering of sedimentary rocks produces semi-angular fragments that easily break down. Planes of weakness exist due to the process in which the rock is formed, primarily layering of sediments into bedding planes and structural joints. Erosion by glaciers and streams often follow the geologic structure and bedding orientation. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. When soils do develop, they reflect the original texture of the bedrock; for example, course-textured soils form from sandstones and fine-textured soils result from siltstones and mudstones.

Surficial deposits are scattered across the higher elevation bedrock, and also occur in a few valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Deposits on high-elevation bedrock include talus rubble, rock glaciers, and patches of glacial drift. The narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, solifluction, and alluvial fans.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving down slope, dwarf shrub classes dominate and include *Dryas octopetala, Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* A low shrub-tussock tundra class also occurs, but primarily in the upper drainage areas. The same low shrub species occur and are complemented by tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Further downslope and in the valley bottoms, white spruce and black spruce stands occur.

John Mountain Valley Subsection
This subsection is an extensive network of broad mountain valleys within the John River and Allen River watersheds (Figure 16). The lower valley reaches are forested and the upper valleys are alpine landscapes. The upper elevational limit is formed by exposed bedrock and the southern boundary by the edge of the Brooks Range. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 470,403 acres, and elevation ranges from 1,000 to 5,880 feet.

The steep walled mountain valleys were formed by downcutting and glacial scouring over millennia. The receding glaciers from the last major glaciation (20,000 years ago) deposited glacial till and lateral moraines on most of the side slopes. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from nearly every side drainage often extending to the valley floors. Floodplains, terraces, and glacial drift dominate the valley floors. Lakes and lacustrine deposits are uncommon. Significant portions of the valley sideslopes and floors are exposed bedrock scoured during the last glaciation. Permafrost underlies most of the subsection. The underlying bedrock geology is predominantly sedimentary noncarbonate with lesser amounts of sedimentary and metamorphic metanoncarbonate, igneous intrusive mafic, and sedimentary carbonate rocks.

Vegetation. Dwarf shrubs cover the upper slopes dominated by *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, the landcover classes change from low shrub (or mesic herbaceous) to tall shrub and coniferous forest. Low shrub classes are dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The mesic herbaceous class ranges from mountain meadows dominated by *Calamagrostis canadensis,* fireweed, and other herbaceous species, to moist areas dominated by *Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum.* The dominant tall shrub is American green alder. Stands of white spruce and black spruce occur in the valley bottoms along with *Populus balsamifera* (balsam poplar). Paper birch and quaking aspen forests are uncommon. A low shrub-tussock tundra class also occurs, but primarily in the upper drainage areas.

Kobuk Mountain Valley Subsection

This subsection is a series of short and broad, forested mountain valleys within the Kobuk River, Reed River, Beaver Creek, and Mauneluk River watersheds (Figure 16). The upper elevational limit is formed by exposed bedrock and the southern boundary by the edge of the Brooks Range. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. The Noatak and Kobuk River valleys serve as conduits for moist air masses moving inland from the Bering Sea, probably resulting in high snowfall. The subsection covers 157,302 acres, and elevation ranges up to 3,400 feet.

The sideslopes are predominantly bedrock scoured by receding glaciers from the last major glaciation (20,000 years ago). Glacial till was deposited, especially in the smaller side drainages. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from side drainages sometimes extending to the valley floors. Permafrost underlies most of the subsection. Snow-avalanche tracks are common.

The valley floors are predominately scoured bedrock and vegetated alluvial sand sheets, and dunes are also common. Walker Lake covers most of the Kobuk River valley, and floodplains are uncommon. Bedrock geology is sedimentary and metamorphic metanoncarbonate with inclusions of sedimentary noncarbonate, igneous intrusive-felsic, and sedimentary carbonate.

Vegetation The upper valley slopes are covered by dwarf shrubs (Helt et al. 2000). The dominant shrub is *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii.* Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The mesic herbaceous class ranges from mountain meadows dominated by *Calamagrostis canadensis*, fireweed, and other herbaceous species, to moist areas dominated by *Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum.* A low shrub-tussock tundra class also occurs, but primarily in the upper drainage areas. Further downslope and in the valley bottoms, white spruce and black spruce stands occur including balsam poplar on floodplains. Paper birch and quaking aspen forests are uncommon.

Koyukuk Mountain Valley Subsection

This subsection is an extensive network of forested, broad mountain valleys within the Wild River, Middle Fork Koyukuk River, and North Fork Koyukuk River watersheds (Figure 16). The upper elevational limit is formed by exposed bedrock and the southern boundary by the edge of the Brooks Range. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 642,548 acres, and elevation ranges from 1,000 to 4,000 feet.

Downcutting and glacial scouring over millennia formed the steep walled mountain valleys. The receding glaciers from the last major glaciation (20,000 years ago) deposited glacial till and lateral moraines on most of the side slopes. Some of the finer (silt) deposits have moved downslope due to solifluction, and alluvial fans arise from nearly every side drainage often extending to the valley floors. Floodplains, terraces, and glacial drift dominate the valley floors. Portions of the valley sideslopes and floors are exposed bedrock scoured during the last glaciation. Lacustrine deposits are uncommon and occur along the lower portion of the watershed. Lakes are relatively uncommon and permafrost likely underlies most of the subsection. The underlying bedrock geology is predominantly noncarbonate sedimentary and metamorphic metanoncarbonate, with inclusions of igneous volcanic, igneous intrusive mafic, and sedimentary carbonate rock.

Vegetation. The upper valley slopes are typically covered by dwarf shrubs, predominantly *Dryas octopetala,* and strong associates including *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Moving downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The mesic herbaceous class ranges from mountain meadows dominated by *Calamagrostis canadensis,* fireweed, and other herbaceous species, to moist areas dominated by *Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum*. A low shrub-tussock tundra class also occurs, but primarily in the upper drainage areas. Further downslope and in the valley bottoms, white spruce and black spruce stands occur including balsam poplar on floodplains. Paper birch and quaking aspen forests are uncommon.

Mt. Doonerak Mountain Subsection

This subsection is composed of rugged mountains formed from sedimentary and metamorphic and metanoncarbonate bedrock in the eastern portion of GAAR. The subsection occurs at higher elevations than mountain valley subsections and the topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). Narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, and alluvial fans. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. Bedrock is primarily of lower Paleozoic age (350 to 600 million years old) metamorphosed to green schist and amphibolite facies (Beikman 1980). Sedimentary rocks include limestone, dolomite, argillite, chert, and graywacke; metasedimentary rocks include schist, quartzite, slate, greenstone, carbonate rocks, and phyllite. There are also small pockets of Ordovician (440 to 500 million years ago) undifferentiated volcanic and sedimentary noncarbonate rocks. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 166,595 acres, and elevation ranges up to 7,457 feet.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, the vegetation often forms continuous mats of dwarf shrub. The dominant dwarf shrub is *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous classes. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* These shrubs are often complemented with tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Further downslope and in the valley bottoms, white spruce and black spruce stands occur.

Shulakpachak Noncarbonate Mountains Subsection

This small subsection is composed of rugged mountains formed from noncarbonate sedimentary bedrock in the forested western region of the Brooks Range in GAAR. It occurs at higher elevations than mountain valley subsections and has little or no soil development. Topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). The rocks are shale, sandstone, chert, conglomerate, and quartzite of upper Devonian age (350 to 400 million years old). Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 69,864 acres, and elevation ranges from 1,000 to 5,880 feet.

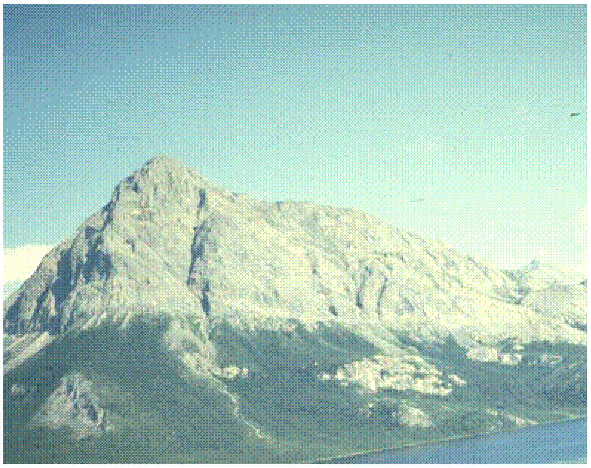
Weathering of sedimentary rocks produces semi-angular fragments that easily break down. Planes of weakness exist due to the process in which the rock is formed, primarily layering of sediments into bedding planes and structural joints. Erosion by glaciers and streams often follow the geologic structure and bedding orientation. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. When soils do develop, they reflect the original texture of the bedrock; for example, course-textured soils form from sandstones and fine-textured soils result from siltstones and mudstones.

Surficial deposits are scattered across the higher elevation bedrock, and also occur in one valley too narrow (< 1 mile wide) to be included in the mountain valley subsections. Deposits on high-elevation bedrock include talus rubble, glaciers, and patches of glacial drift. The narrow valley inclusions include floodplains, and discontinuous colluvium and glacial drift.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, dwarf shrub classes dominate and include *Dryas octopetala, Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.* Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* These low shrub species are often complemented with tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Further downslope and in the valley bottoms, white spruce and black spruce occur.

Skajit Carbonate Mountain Subsection

This subsection is distinguished by rugged mountains comprised of carbonate sedimentary bedrock in the south half of the Brooks Range. Numerous disjunct units occur, separated by mountain valleys and other bedrock types. It occurs at higher elevations than mountain valley subsections and the topography includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes (Figure 16). Bedrock is sedimentary carbonate with limestone, dolomite, marble, and shale of Devonian and Silurian age (350 to 440 million years ago) (Beikman 1980). Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. Surficial deposits are scattered across the higher elevation bedrock and also occur in a few narrow mountain valley inclusions (< 1 mile wide). Deposits on bedrock include talus rubble, landslides, alluvial fans, and patches of glacial drift. The narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, and alluvial fans. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 418,544 acres, and elevation ranges up to 6,620 feet.



Vegetation. The species composition of alpine vegetation in the Brooks Range is reported by Cooper (1986) to be different on acid versus basic soils. For example, *Salix lanata* subspecies *richardsonii* dominates willow thickets on carbonate rocks whereas *Salix planifolia* subspecies *pulchra* is dominant on acid rocks. The carbonates in the sedimentary bedrock typically result in highly alkaline soils.

In this subsection, vegetation is generally absent at the higher elevations or sparse due to the harsh climatic conditions and shallow or no soils. At lower elevations, the dwarf shrub map class occurs dominated by *Dryas octopetala;* strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria,* and *Alectoria.*

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous classes. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa*, *Salix lanata* subspecies *richardsonii, Vaccinium uliginosum,* and *Ledum palustre.* Further downslope and in the valley bottoms, stands of white spruce and black spruce occur.

Southern Foothills-Metanoncarbonates Subsection

This subsection is composed of foothills and mountains on the south flank of the Brook Range in GAAR, formed from sedimentary and metamorphic, metanoncarbonate bedrock (Figure 16). Bedrock has been metamorphosed to quartz-mica schist, mafic green schist, calcareous schist, chloritic schist, phyllite, and quartzite of lower Paleozoic age (225 to 600 million years ago) and Precambrian age (600+ million years ago). The subsection occurs at higher elevations than mountain valley subsections and has little soil development. Numerous disjunct units occur separated by mountain valleys. Topography includes rounded and jagged ridges, peaks, cirque headwalls, cirque basins, and upper valley slopes. Small and isolated inclusions of igneous, volcanic extrusive lithology also occur. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 1,218,213 acres, and elevation ranges up to 6,480 feet.

Surficial deposits are scattered across the higher elevation bedrock and also occur in a few valleys too narrow (< 1 mile wide) to be included in the mountain valley subsections. Deposits on high-elevation bedrock include talus rubble, rock glaciers, and patches of glacial drift. The narrow valley inclusions are mantled with thin or discontinuous glacial till, talus, solifluction, lacustrine deposits, and alluvial fans.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, the vegetation often forms continuous mats of dwarf shrubs and lichens. The dominant dwarf shrub is *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens are also common including the genera *Cladonia, Cetraria*, and *Alectoria*.

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* On the lower slopes and valley bottoms, white spruce and black spruce occur.

Ulaneak Mountains Subsection

This subsection is composed of rugged mountains on the southwest edge of the Brooks Range in GAAR (Figure 16). It extends from the mountain peaks to the valley bottoms and includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, valley slopes, and floodplains. Surficial geology includes discontinuous patches of glacial till, alluvial fans, and floodplains. The subsection's lithology is mixed, formed from carbonate sedimentary, noncarbonate sedimentary, and igneous intrusive felsic rock. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 160,443 acres, and elevation ranges from 600 to 4,370 feet.

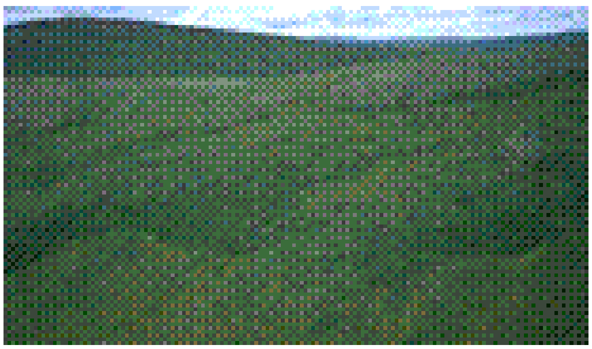
Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, the vegetation often forms continuous mats of dwarf shrubs and lichens. The dominant dwarf shrub is *Dryas octopetala* and strong associates include *Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000). Lichens genera include *Cladonia, Cetraria,* and *Alectoria.*

Further downslope, a mixture of landcover classes occur including tall shrub, low shrub, and mesic herbaceous. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* On the lower slopes and valley bottoms, stands of white spruce and black spruce occur.

ARCTIC FOOTHILLS SECTION

Anaktuvuk Foothills Subsection

This subsection consists of tundra-covered hills and rolling landscapes located north of the Brooks Range (Figure 16). The hills are bedrock outcrops with less than a 500-foot vertical rise and are often mantled with a discontinuous layer of loess. Bedrock lithology is predominately sedimentary noncarbonate of Cretaceous or Triassic age (68 to 225 million years ago). Surrounding the bedrock outcrops are rolling low-relief landscapes sloping down to the north flowing rivers that drain the Brooks Range. Surficial deposits are primarily solifluction and small floodplains, plus glacial drift, terraces, and outwash deposits that predate the Itkillik glaciation. The area is underlain by permafrost and ice-related surface features are present such as patterned ground. Climate is arctic with cold dry winters and cool dry summers. It covers 101,155 acres, and elevation ranges up to 3,610 feet.



Vegetation. The crests and upper slopes of the bedrock outcrops are a mixture of bare gravel and dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Below the upper slopes, the landscape is dominated by a mixture of low shrub, shrub tussock tundra, and graminoid tussock tundra map classes (Helt et al. 2000). The low shrub class is dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The shrub tussock tundra class has similar shrub species with the addition of high coverage tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra also has a similar species composition except the shrub cover is much less (< 25%). Water tracks are common and are dominated by *Salix planifolia* subspecies *pulchra* and *Carex* (sedge) species.

Anaktuvuk Glaciated Lowlands Subsection

During the last major glacial advances (Itkillik glacial advances peaked 53,000 and 20,000 years ago), large ice tongues extended north from the Brooks Range helping to carve valleys (Figure 16). The valleys are lobate in outline formed by the northern extension of glaciers and bordered by terminal and lateral moraines. Thick and extensive glacial deposits fill the valleys resulting in landforms such as kettle kame topography, sand deposits including active dunes, drift, and patterned ground (Hamilton 1989). Portions of the valley bottoms have extensive floodplains. The subsection is underlain by thick permafrost, and many ice-related surface features are present such as patterned ground and thermokarst. The two disjunct areas of the subsection are drained by the Anaktuvuk River and the Nanushuk River. Climate is arctic with cold dry winters and cool dry summers. It covers 241,670 acres, and elevation ranges from 1,600 to 3,500 feet.

Vegetation. The vegetation and site characteristics in this subsection are distinct from adjacent subsections. Tussock tundra is, in general, not as well developed, and the soils tend to be shallower with less organic matter than on the adjacent rolling landscapes. The slopes of the valleys are dominated by dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Patterned ground and the herbaceous tussock map class are also common. Tussock-forming herbaceous species include *Carex membranacea* (fragile sedge), *Carex lugens, Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum* (Helt et al. 2000).

Anaktuvuk Lowlands Subsection

This subsection consists of rolling tundra located in the Anaktuvuk River watershed north of the Brooks Range (Figure 16). The Kanayut River—a tributary of the Anaktuvuk River—drains the subsection. The landscape is composed of drift, outwash, and terraces that predate the Itkillik glaciation, plus floodplains. Bedrock outcrops are rare or absent. It is underlain by thick permafrost, and ice-related surface features are present such as patterned ground. Climate is arctic with cold dry winters and cool dry summers. The subsection covers 74,593 acres, and elevation ranges from 1,800 to 3,400 feet.

Vegetation. Both low shrub tussock tundra and graminoid tussock tundra dominate the subsection (Helt et al. 2000). Shrub tussock tundra is dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre* plus tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra has a similar species composition except the shrub cover is less than 25%. Other map classes include dwarf shrub, low shrub, and water tracks.

Chandler Foothills Subsection

This subsection consists of tundra-covered hills and rolling landscapes in the Chandler River watershed north of the Brooks Range (Figure 16). The hills are bedrock outcrops with less than a 500-foot vertical rise and are often mantled with a discontinuous layer of loess. Bedrock lithology is predominately sedimentary noncarbonate of Cretaceous age (68 to 135 million years ago) with an inclusion of sedimentary carbonate. Surrounding the bedrock outcrops are rolling low-relief landscapes sloping down to the north flowing rivers that drain the Brooks Range. Surficial deposits are primarily solifluction, small floodplains, glacial drift, terraces, and outwash deposits that predate the Itkillik glaciation. The area is underlain by permafrost and ice-related surface features are present such as patterned ground. The climate is arctic with cold dry winters and cool dry summers. The subsection covers 181,616 acres, and elevation ranges up to 3,611 feet.

Vegetation. The crests and upper slopes of the bedrock outcrops are a mixture of bare gravel and dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* The rolling landscape is dominated by a mixture of low shrub, shrub tussock tundra, and graminoid tussock tundra map classes (Helt et al. 2000). The low shrub class is dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The shrub tussock tundra class has similar shrub species with the addition of tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra also has a similar species composition except the shrub cover is less than 25%. Water tracks are common and are dominated by open water, *Salix planifolia* subspecies *pulchra,* and sedge species.

Chandler Glaciated Lowlands Subsection

During the last major glacial advances (Itkillik glacial advances peaked 53,000 and 20,000 years ago), large ice tongues extended north from the Brooks Range helping to carve large valleys (Figure 16). The subsection is composed of two valleys drained by the Chandler River and the Siksikpuk River. The valleys are lobate in outline formed by the northern extension of Pleistocene age glaciers and bordered by terminal and lateral moraines. Thick and extensive glacial deposits fill the valleys and landforms, such as kettle kame topography, sand deposits, active dunes, drift, and patterned ground, are common (Hamilton 1989). Large and small active floodplains also occur. The subsection is underlain by thick permafrost, and many ice-related surface features are present such as patterned ground and thermokarst. Climate is arctic with cold dry winters and cool dry summers. It covers 31,223 acres, and elevation ranges from 2,400 to 3,200 feet.

Vegetation. The vegetation and site characteristics in this subsection are distinct from the adjacent subsections. Tussock tundra is, in general, not as well developed, and the soils tend to be shallower with less organic matter than on the adjacent rolling landscapes. The upper slopes of the valleys are dominated by tussock-forming herbaceous species such as *Carex membranacea, Carex lugens, Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum* (Helt et al. 2000). Downslope, the landscape is dominated by dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Low shrub tussock tundra also occurs, dominated by *Betula nana* (dwarf arctic birch), *Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra,* and tussock-forming graminoids.

Chandler Lowlands Subsection

This subsection is located north of the Brooks Range and consists of rolling tundra sloping down to the north flowing rivers that drain the Brooks Range (Figure 16). Bedrock outcrops are rare or absent. The landscape is composed of drift, outwash, and terraces that predate the Itkillik glaciation, plus solifluction and floodplains. The Chandler and Siksikpuk Rivers and numerous small tributaries drain the subsection. It is underlain by thick permafrost and ice-related surface features are present such as patterned ground. Climate is arctic with cold dry winters and cool dry summers. The subsection covers 379,391 acres, and elevation ranges from 1,855 to 3,400 feet.

Vegetation. Both low shrub tussock tundra and graminoid tussock tundra dominate the subsection (Helt et al. 2000). The shrub tussock tundra is dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre* and by tussock-forming graminoids such as *Carex aquatilis*, *Carex bigelowii*, and *Eriophorum vaginatum*. Graminoid tussock tundra has a similar species composition except the shrub cover is less than 25%. Other map classes include dwarf shrub, low shrub, and water tracks.

Etivluk Foothills Subsection
This subsection is located north of the Brooks Range and consists of tundra-covered hills and rolling landscapes (Figure 16). The hills are bedrock outcrops with less than a 500-foot vertical rise and are often covered by loess and, to a lesser extent, various glacial-derived landforms. Bedrock lithology along the north flank of the Brooks Range is sedimentary carbonate composed of conglomerate, shale, limestone, chert, and dolomite. Further north, the lithology is sedimentary noncarbonate shale, siltstone, chert, and greywacke. Surrounding the bedrock outcrops are rolling low-relief landscapes sloping down to the north flowing rivers. The rolling landscapes are primarily composed of solifluction and Pleistocene age terraces. Other deposits include glacial till, kettle kame topography, organic silts, sand deposits, and active small floodplains. The area is underlain by permafrost and ice-related surface features are present such as patterned ground. The climate is arctic with cold dry winters and cool dry summers. It covers 294,656 acres, and elevation ranges from 1,600 to 4,126 feet.

Vegetation. The crests and upper slopes of the bedrock outcrops are a mixture of bare gravel and dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Below the upper slopes, the landscape is dominated by shrub or graminoid tussock tundra. The shrub tussock tundra is dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre* and tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* The graminoid tussock tundra has a similar species composition except that shrub cover is less than 25%. Water tracks are also common and are dominated by open water, *Salix planifolia* subspecies *pulchra,* and sedge species.

Etivluk Lowlands Subsection

This subsection is located north of the Brooks Range and consists of rolling tundra sloping down to the north flowing rivers that drain the Brooks Range (Figure 16). Bedrock outcrops are rare or absent and are composed of Pleistocene age terraces, outwash plains, and solifluction. Ivotuk Creek, Kurupa River, and numerous small streams drain the subsection. It is underlain by thick permafrost and ice-related surface features are present such as patterned ground and ice-cored hills. Climate is arctic with cold dry winters and cool dry summers. The subsection covers 296,529 acres, and elevation ranges from 1,600 to 3,400 feet.

Vegetation. Both low shrub tussock tundra and graminoid tussock tundra cover the subsection. Shrub tussock tundra is dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre,* and also tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra has a similar species composition except that the shrub cover is less than 25%. Water tracks are common and are dominated by open water, *Salix planifolia* subspecies *pulchra,* and sedge species.

Itkillik Glaciated Lowlands

During the last major glacial advances (Itkillik glacial advances peaked 53,000 and 20,000 years ago), large ice tongues extended north from the Brooks Range helping to carve large valleys (Figure 16). These valleys are lobate in outline formed by the northern extension of glaciers and bordered by terminal and lateral moraines. The Itkillik River drains the subsection. Thick and extensive glacial deposits fill the valleys including kettle kame topography, sand deposits including active dunes, and drift (Hamilton 1989). Large and small active floodplains also occur. The subsection is underlain by thick permafrost and many ice-related surface features are present such as patterned ground and thermokarst. Climate is arctic with cold dry winters and cool dry summers. It covers 207,476 acres, and elevation ranges from 1,600 to 3,800 feet.

Vegetation. Dwarf shrub, herbaceous tussock, and low shrub map classes dominate the subsection. Dwarf shrubs include *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Tussock-forming herbaceous species include *Carex membranacea, Carex lugens, Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum* (Helt et al. 2000). Species in the low shrub class include *Betula glandulosa, Vaccinium uliginosum, Ledum palustre, Empetrum nigrum* (crowberry), and *Salix planifolia* subspecies *pulchra.*

Killik Foothills Subsection

This subsection consists of tundra-covered hills and rolling landscapes within the Killik River watershed north of the Brooks Range (Figure 16). The hills are bedrock outcrops with less than a 500-foot vertical rise and are often mantled with a discontinuous layer of loess. Bedrock lithology is sedimentary noncarbonate of Cretaceous age (68 to 135 million years ago) with a small inclusion of sedimentary carbonate rock. Surrounding the bedrock outcrops are rolling low relief landscapes sloping down to the north flowing rivers that drain the Brooks Range. Surficial deposits are primarily solifluction, glacial drift, organic silts, and small floodplains. The area is underlain by permafrost and ice-related surface features are present such as patterned ground. The climate is arctic with cold dry winters and cool dry summers. The subsection covers 25,315 acre, and elevation ranges to up 2,300 feet.

Vegetation. The crests and upper slopes of the bedrock outcrops are a mixture of bare gravel and dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* The rolling landscapes are mantled by a mixture of the low shrub, shrub tussock tundra, and graminoid tussock tundra map classes (Helt et al. 2000). The low shrub class is dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The shrub tussock tundra class has similar shrub species with the addition of high coverage of tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra also has a similar species composition except the shrub cover is less than 25%. Water tracks are common and are dominated by open water, *Salix planifolia* subspecies *pulchra,* and sedge species.

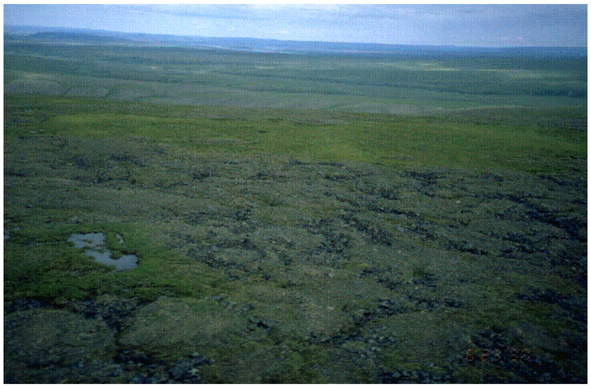
Killik Glaciated Lowlands

During the last major glacial advances (Itkillik glacial advances peaked 53,000 and 20,000 years ago), large ice tongues extended north from the Brooks Range helping to carve large valleys (Figure 16). The two disjunct valleys that form this subsection are lobate in outline formed by the northern extension of glaciers and bordered by terminal and lateral moraines. The valleys are drained by the Killik River, Verdant Creek and the Okokmilaga River. Thick and extensive glacial deposits fill the valleys including kettle kame topography, sand deposits including active dunes, and drift (Hamilton 1989). Small active floodplains also occur. The subsection is underlain by thick permafrost, and many ice-related surface features are present such as patterned ground and thermokarst. Climate is arctic with cold dry winters and cool dry summers. It covers 168,722 acres, and elevation ranges from 1,400 to 3,250 feet.

Vegetation. The vegetation and site characteristics in this subsection are distinct from the adjacent subsections. Tussock tundra is, in general, not as well developed, and the soils tend to be shallower with less organic matter than on the adjacent rolling landscapes. The upper slopes of the valleys are dominated by tussock-forming herbaceous species such as *Carex membranacea, Carex lugens, Carex bigelowii, Eriophorum russeolum,* and *Eriophorum vaginatum* (Helt et al. 2000). Downslope, the landscape is dominated by dwarf shrubs such as *Dryas octopetala, Salix arctica, Cassiope tetragona,* and *Vaccinium uliginosum.* Low shrub tussock tundra also occurs dominated by *Betula nana* (dwarf arctic birch), *Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra,* and tussock-forming graminoids. The valley bottom is dominated by low shrubs with intermittent shrub and graminoid-dominated tussock tundra.

Killik Lowlands Subsection

This subsection consists of rolling tundra sloping down to north flowing rivers and is located north of the Brooks Range in the Killik River watershed (Figure 16). Bedrock outcrops are rare or absent. The landscape is comprised of drift and terraces that predate the Itkillik glaciation, plus solifluction and floodplains. The Killik River, Okokmilaga River, and numerous small streams drain the subsection. It is underlain by thick permafrost and ice-related surface features are present such as patterned ground. Climate is arctic with cold dry winters and cool dry summers. The subsection covers 263,032 acres, and elevation ranges from 1,000 to 4,000 feet.



Vegetation. Both low shrub tussock tundra and graminoid tussock tundra cover the subsection (Helt et al. 2000). Shrub tussock tundra is dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre,* and tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Graminoid tussock tundra has a similar species composition except the shrub cover is less than 25%. Other map classes include dwarf shrub, low shrub, and water tracks.

INTERIOR FORESTED LOWLANDS SECTION

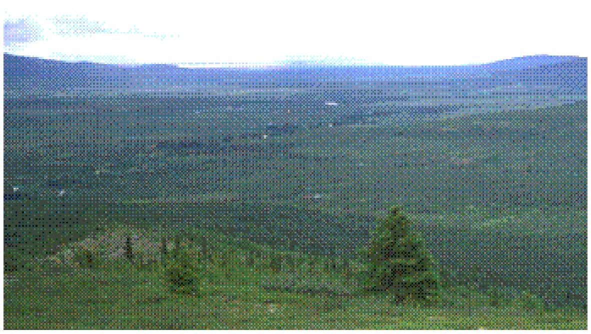
Klikhtentotzna Creek Lowland Subsection

This subsection consists of the mountain sideslopes and valley drained by Klikhtentotzna Creek south of the Brook Range (Figure 16). Thick glacial lake deposits, loess, drift, and deltas were deposited during the Pleistocene glacial retreat. Most of the subsection is underlain by continuous permafrost, and permafrost features occur such as patterned ground. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. The subsection covers 117,088 acres, elevation ranges up to 1,200 feet, and topography ranges from level to rolling hills to mountain sideslopes.

Vegetation. This subsection is dominated by large stands of white spruce and black spruce especially on the side slopes. The valley bottoms are, in general, wetter environments than the hills and support black and white spruce, along with herbaceous communities dominated by *Calamagrostis canadensis, Carex bigelowii, Eriophorum russeolum,* and *E. vaginatum.* White and black spruce cover is sparse (10–25% cover) with an understory dominated by either lichens or shrubs.

Kobuk Lowlands-Forested Subsection

This subsection comprises the level lowlands—excluding the Kobuk River Floodplain and Norutak Lake Lowlands Subsections—and lower mountain slopes in the Kobuk basin (Figure 16). It is drained by two rivers—the Reed and Kobuk—that arise from large glaciated valleys of the Brooks Range. During major glacial advances, large ice tongues that were generated in the Brooks Range converged in the Kobuk basin depositing thick glacial material (Hamilton 1989). A wide variety of surficial deposits now occur including moraines, drift, outwash, lacustrine, deltas, kettles, terraces, and colluvium (Hamilton 1989). Most of the subsection is underlain by continuous permafrost, although permafrost may be absent beneath some sections of the Kobuk River. Permafrost features occur such as patterned ground. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 341,132 acres, and elevation ranges up to 1,660 feet.



Vegetation. Vegetation in this subsection forms a complex pattern due to the effects of fire, permafrost, soils, and surface water. The slopes support large stands of white spruce and black spruce and minor amounts of paper birch and quaking aspen. Some landscapes, such as terminal moraines, support extensive stands of white spruce/lichen. The valley bottoms are, in general, wetter environments than the hills and support black and white spruce, along with herbaceous communities dominated by *Calamagrostis canadensis,* fireweed, *Carex bigelowii, Eriophorum russeolum,* and *E. vaginatum.*

Kobuk Lowlands-Tundra Subsection

This subsection consists of the valley slopes and lowlands—excluding the Kobuk River Floodplain Subsection—in the Kobuk basin dominated by tussock tundra and low shrubs (Figure 16). During major glacial advances, large ice tongues that were generated in the Brooks Range converged in the Kobuk basin depositing thick glacial material (Hamilton 1989). A wide variety of surficial deposits now occur including moraines, drift, outwash, kettle lakes, terraces, and colluvium (Hamilton 1989). Most of the subsection is underlain by continuous permafrost. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 159,707 acres, and elevation ranges up to 1,400 feet.

Vegetation. The valley bottoms are dominated by low shrubs and low shrub tussock tundra (Helt et al. 2000). The low shrub class species include *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.* The low shrub tussock tundra class has similar shrub species with the addition of tussock-forming graminoids such as *Carex aquatilis, Carex bigelowii,* and *Eriophorum vaginatum.* Herbaceous communities are also common and dominated by *Calamagrostis canadensis, Carex bigelowii, Eriophorum russeolum,* and *E. vaginatum.* The mountain slopes support large stands of white spruce and black spruce and minor amounts of paper birch. Some landscapes, such as terminal moraines, support extensive stands of white spruce/lichen.

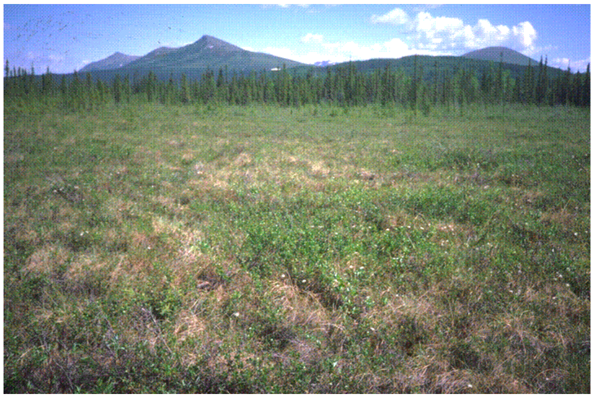
Kobuk River Floodplain Subsection

This subsection is formed by floodplains of the Reed and Kobuk Rivers. The Kobuk River Floodplain Subsection is distinct from the mountain valley floodplain detailed-subsections because it is much larger and flows through open areas, as opposed to flowing through mountain valleys (Figure 16). This subsection includes the rivers and their sandbars, active floodplains, and low inactive—no longer flooded—terraces (Hamilton 1999). Terraces are included because they may be eroded in the near future (500 years) and thus are a seral stage in the floodplain ecosystem. Meander scrolls and oxbows are common. The north boundary of this subsection is formed by where the rivers exit the Brooks Range and the west boundary by the edge of the base map. Permafrost is discontinuous (Brown et al. 1997; Ferrians 1965) typically forming in the older deposits, reshaping oxbows and perching the water table on terraces. The climate is continental with cold dry winters and warm-hot dry summers. It covers 87,750 acres, and elevation ranges up to 600 feet.

New alluvial bars or abandoned stream channels are invaded by sapling balsam poplar, white spruce, willow species, and alder species (Figure 19). In time, balsam poplar and white spruce dominate the sites and form sparse to dense forests. If the soils remain well drained then white spruce will eventually dominate as balsam poplar reaches senescence. However, when permafrost forms leading to poorly drained soils, then black spruce will invade along with moisture-tolerant genera such as *Sphagnum* (peat moss).

Koyukuk Lowlands Subsection

This subsection consists of level to rolling hills to mountain sideslopes—excluding the Koyukuk River floodplain—in the Koyukuk basin south of the Brooks Range (Figure 16). It is drained by three south flowing rivers—the Alatna, John, and Koyukuk—that arise from large glaciated valleys of the Brooks Range. During major glacial advances, large ice tongues that were generated in the Brooks Range converged in the Koyukuk basin from these valley systems depositing thick glacial material (Hamilton 1989). These include lateral and terminal moraines, till, lacustrine, sand, kettles and kames, and outwash (Hamilton 1989). Peatlands are also common. The climate is continental with cold dry winters and warm-hot dry summers. The mean annual temperature is –5.8^{o} based on climate data for Bettles Field (Cowan 1995). Most of the Koyukuk basin is underlain by continuous permafrost, although it may be absent beneath some sections of the Koyukuk River (Brown et al. 1997; Ferrians 1965). Permafrost features occur such as patterned ground. The subsection covers 292,845 acres, and elevation ranges up to 2,800 feet.



Vegetation. Vegetation forms a complex pattern due to the effects of fire, permafrost, soils, and surface water. The slopes support large stands of white spruce, black spruce, paper birch, and quaking aspen. The valley bottoms are, in general, wetter environments than the hills and support black spruce and white spruce, along with peatlands dominated by low shrubs and herbaceous species such as *Calamagrostis canadensis.*

Koyukuk River Floodplain Subsection

This subsection is formed by the floodplains of three south flowing major rivers: the Middle Fork Koyukuk River, North Fork Koyukuk River, and Wild River (Figure 16). The Koyukuk River Floodplain Subsection is distinct from mountain valley floodplain detailed-subsections because it is much larger and flows through open areas, as opposed to flowing through mountain valleys. This subsection includes the rivers and their sandbars, active floodplains, and low inactive—no longer flooded—terraces (Hamilton 1999). Terraces are included because they may be eroded in the near future (500 years) and thus are a seral stage in the floodplain ecosystem. Meander scrolls and oxbows are common. The north boundary of this subsection is formed by where the rivers exit the Brooks Range and the south boundary at the confluence with the John River. The climate is continental with cold dry winters and warm-hot dry

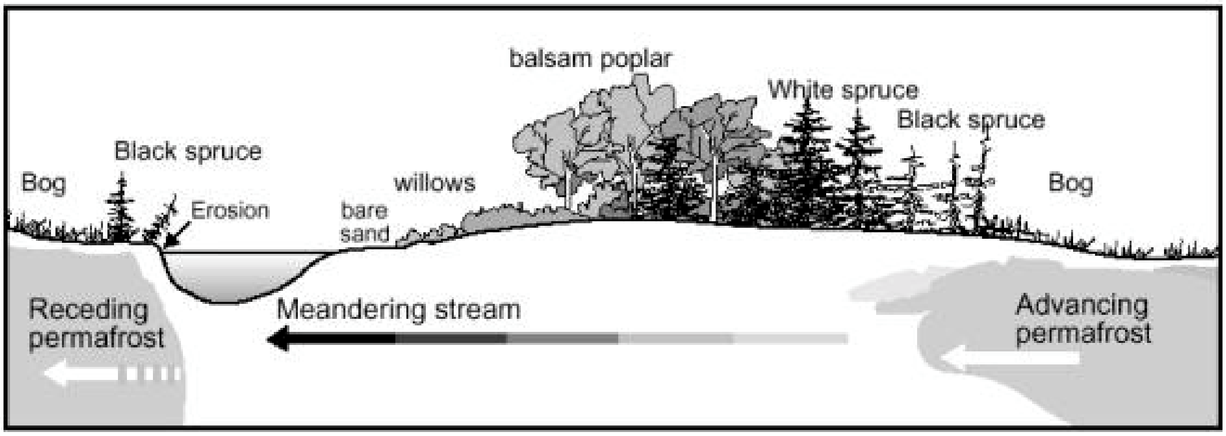


Figure 19. Idealized cross section of a floodplain within the forested regions of GAAR.

summers. The mean annual temperature is –5.8° based on climate data for Bettles Field (Cowan 1995). Permafrost is discontinuous (Brown et al. 1997; Ferrians 1965) and, on the older deposits, often reshapes oxbows and perches the water table on terraces. It covers 71,838 acres, and elevation ranges up to 1,000 feet.

New alluvial bars or abandoned stream channels are invaded by sapling of balsam poplar, white spruce, willow species, and alder species. In time, balsam poplar and white spruce dominate the sites and form sparse to dense forests. If the soils remain well drained, then white spruce will eventually dominate as balsam poplar reaches senescence. However, when ground ice forms, leading to poorly drained soils, then black spruce will invade along with moisture-tolerant genera such as *Sphagnum.*

Norutak Lake Lowlands Subsection

This subsection occupies the lower valley position within the area and is wetter than upslope subsections due to fine-grained lacustrine deposits (Figure 16). The lacustrine sediments were deposited in a glacial lake during the Pleistocene (Hamilton 1989). Numerous lakes, wetlands, and peatlands are scattered throughout the subsection. Most of the subsection is underlain by continuous permafrost, and patterned ground occurs. The climate is continental with cold dry winters and warm-hot dry summers. It covers 25,063 acres, elevation ranges up to 800 feet, and topography is level to slightly sloping.

Vegetation. White spruce and black spruce dominate the subsection with inclusions of the spruce/lichen map class. The wetter environments support herbaceous communities dominated by *Calamagrostis canadensis, Eriophorum russeolum, E. vaginatum, Carex aquatilis,* and *Sphagnum* species. Aquatic species include pond lilies (*Nuphar* species), *Sparganium* species, and *Potamogeton* (pondweed) species.

INTERIOR HIGHLANDS SECTION

Angayucham Mountains Subsection

These low-elevation mountains and valleys occur south of the Brooks Range in the Kobuk Boot portion of GAAR (Figure 16). The lithology is mixed including igneous volcanic extrusive rock, sedimentary and metamorphic-metanoncarbonate bedrock, and sedimentary noncarbonate rock. Bedrock typically has little or no soil development and occurs at higher elevations; it includes jagged rocky ridges, peaks, cirque headwalls, cirque basins, and upper sideslopes. Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. Surficial deposits are scattered across the higher elevation bedrock and include talus rubble and patches of glacial drift. The valleys are mantled with glacial till, alluvial fans, lakes, and colluvium. The climate is continental with cold dry winters and warm-hot dry summers. It covers 468,825 acres, and elevation ranges up to 4,765 feet.

Vegetation. Vegetation is generally absent or sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, the vegetation often forms continuous mats of dwarf shrubs dominated by *Dryas octopetala*, *Salix arctica*, *Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000).

Further downslope and in the valley bottoms, white spruce and black spruce stands dominate. Other landcover classes include tall shrub and low shrub. The dominant tall shrub is American green alder. Low shrub classes are dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.*

Jack White Range Subsection

This subsection includes the low-lying glaciated mountains and valleys of the Jack White Range south of the Brooks Range (Figure 16). Much of the landscape is exposed noncarbonate sedimentary bedrock. Surficial geology deposits include glacial till and lateral and terminal moraines on most of the side slopes. Some of the finer (silt) deposits have moved downslope due to solifluction. The valley floors are dominated by small floodplains, terraces, and glacial drift. Permafrost likely underlies most of the subsection, especially on poorly drained deposits such as silt. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. It covers 23,882 acres, and elevation ranges up to 2,286 feet.

Vegetation. The slopes support large stands of white spruce and black spruce, and some paper birch and quaking aspen. The valley bottoms are, in general, wetter environments than the hills, but black spruce and white spruce still dominate.

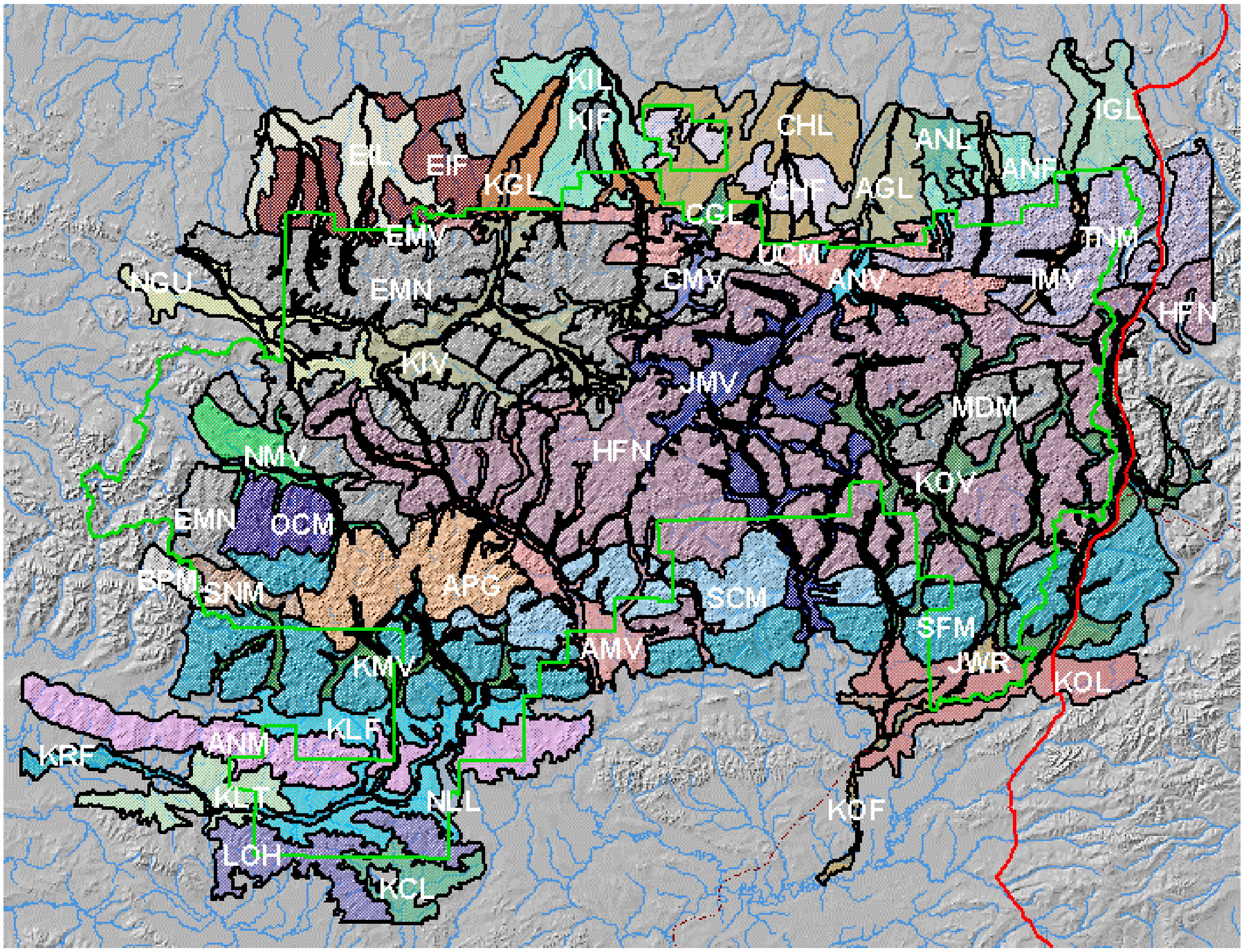
Lockwood Hills Subsection

These low-elevation mountains and valleys occur south of the Brooks Range in the Kobuk Boot portion of GAAR. Bedrock typically has little or no soil development and occurs at higher elevations; it includes jagged rocky ridges, peaks, cirque headwalls, and cirque basins (Figure 16). Frost action and weathering continue to fracture rock, causing continued rock fall and erosional landforms such as altiplanation terraces (mountain terraces), scarps, and cliffs. The lithology is predominantly sedimentary noncarbonate or igneous volcanic extrusive rock, with an inclusion of igneous intrusive felsic rock. Surficial deposits are scattered across the higher elevation bedrock and include talus rubble and patches of glacial drift. The valleys are mantled with glacial till, alluvial fans, lakes, and colluvium. Climate is typical of interior Alaska—dry and cold in winter and dry and warm in summer. The elevation ranges up to 2,630 feet, and it covers 255,383 acres.

Vegetation. Vegetation is sparse in the higher elevations due to the harsh climatic conditions and lack of soils. Moving downslope, the vegetation often forms continuous mats of dwarf shrubs dominated by *Dryas octopetala, Salix arctica, Cassiope tetragona, Vaccinium uliginosum,* and *Carex bigelowii* (Helt et al. 2000).

Further downslope and in the valley bottoms, white spruce and black spruce dominate. Other landcover classes include tall shrub and low shrub. The dominant tall shrub is American green alder. The low shrub class is dominated by *Betula glandulosa, Salix planifolia* subspecies *pulchra, Vaccinium uliginosum,* and *Ledum palustre.*

Figure 20. Ecological Subsections Map of Gates of the Arctic National Park & Preserve



DETAILED-SUBSECTIONS

All detailed-subsections that were defined for GAAR are floodplains. Floodplains that occur in the arctic climate (nonforested north half of GAAR) have similarities in vegetation and vegetation succession, as do floodplains that occur in the interior-continental climate (forested south half of GAAR).

On forested floodplains, new alluvial bars or abandoned stream channels are invaded by sapling balsam poplar, white spruce, willow species, and alder species. In time, balsam poplar and white spruce dominate the sites and form sparse to dense forests. If the soils remain well drained, then white spruce will eventually dominate as balsam poplar reaches senescence. However, if ground ice forms leading to poorly drained soils, then black spruce will invade along with moisture-tolerant genera such as *Sphagnum.* Willow and alder species also dominate the narrow floodplains of small streams.

On nonforested floodplains that occur in the Arctic, exposed alluvium is invaded by river beauty *(Epilobium latifolium),* arctic wormwood *(Artemisia arctica),* and shrub species such as *Salix alaxensis* (feltleaf willow) and *Salix glauca* (grayleaf willow). If the soils remain well drained, then the willows may continue to dominate. However, if ground ice forms leading to poorly drained soils, then tussock tundra—dominated by *Betula glandulosa, Salix lanata* subspecies *richardsonii,* and *Carex bigelowii*—and wet herbaceous meadows—dominated by *Carex aquatilis* and *Eriophorum angustifolium*—form. On small streams, the narrow floodplains are dominated by open and closed shrub stands composed of *Salix planifolia* subspecies *pulchra, Betula glandulosa,* and herbaceous vegetation.

Table 3. Detailed-subsections that occur in GAAR are listed and described below in alphabetical order.

Detailed-Subsection	Topography, geology, and boundaries
Alatna River Floodplain	This detailed-subsection includes an extensive network of forested floodplains within the Alatna River watershed of the Brooks Range. The southern boundary is formed by the edge of the Brooks Range. It is part of the Alatna Mountain Valley Subsection, covers 45,657 acres, and elevation ranges up to 3,000 feet. Underlying bedrock geology is predominantly sedimentary noncarbonate and sedimentary carbonate with inclusions of sedimentary noncarbonate, igneous intrusive-felsic, and sedimentary and metamorphic metanoncarbonate.
Anaktuvuk River Floodplain	This detailed-subsection is comprised of floodplains of the Anaktuvuk River upon exiting the Brooks Range and flowing north through the arctic foothills. It covers 13,476 acres, and elevation ranges up to 2,000 feet. Bedrock geology is sedimentary noncarbonate with small inclusions of sedimentary carbonate rock. Surficial geology is predominantly floodplains and terraces, however, sand deposits occur where the river exits from the Brooks Range.
Encampment Creek Floodplain	This detailed-subsection includes floodplains within the Encampment Creek watershed of the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary carbonate with an inclusion of noncarbonate sedimentary rock. It covers 330 acres, and elevation ranges up to 2,600 feet.
Etivluk River Floodplain	This detailed-subsection is comprised of the Etivluk River and Ivotuk Creek floodplains after they exit the Brooks Range and flow north through the arctic foothills. It covers 9,025 acres, and elevation ranges up to 2,600 feet. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on its south edge. Surficial geology includes floodplains and terraces.

Itkillik River Floodplain	This detailed-subsection is comprised of floodplains of the Itkillik River after exiting the Brooks Range and flowing north through the arctic foothills. It covers 7,295 acres, and elevation ranges up to 2,200 feet. Bedrock geology is sedimentary noncarbonate rock. Surficial geology is predominantly floodplains and terraces, however, sand deposits occur where the river exits from the Brooks Range.
John River Floodplain	This detailed-subsection includes an extensive network of forested floodplains within the John River watershed of the Brooks Range. Floodplains occur throughout the watershed and the downstream boundary is formed where the river exits the Brooks Range. It is part of the John Mountain Valley Subsection. Underlying bedrock geology is predominantly sedimentary noncarbonate with lesser amounts of sedimentary and metamorphic metanoncarbonate, igneous intrusive mafic, and sedimentary carbonate. It covers 42,241 acres, and elevation ranges up to 3,000 feet.
Kaluluktok Creek Floodplain	This detailed-subsection includes forested floodplains of Kaluluktok Creek within the Brooks Range. It is part of the Kobuk Mountain Valley Subsection, covers 13,275 acres, and elevation ranges up to 1,200 feet. The southern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary and metamorphic metanoncarbonate with inclusions of sedimentary noncarbonate, igneous intrusive-felsic, and sedimentary carbonate.
Killik River Floodplain	This detailed-subsection is comprised of the Killik River floodplain after it exits the Brooks Range and flows north through the arctic foothills. It covers 27,809 acres, and elevation ranges up to 1,600 feet. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on its south edge. The southern portion of the detailed-subsection has extensive lakes and sand deposits, including active dunes that are often eroded by the Killik River. Further downstream, the land is predominantly floodplains and terraces.
Middle Fork Koyukuk River	This detailed-subsection includes forested floodplains of the Middle Fork Koyukuk River within the Brooks Range. The downstream boundary is formed where the river exits the Brooks Range. It is part of the Koyukuk Mountain Valley Subsection. Underlying bedrock geology is noncarbonate sedimentary and metamorphic metanoncarbonate with inclusions of igneous volcanic, igneous intrusive mafic, and sedimentary carbonate. It covers 34,716 acres, and elevation ranges up to 3,000 feet.
Nanushuk River Floodplain	This detailed-subsection consists of the floodplain of the Nanushuk River upon exiting the Brooks Range and flowing north through the arctic foothills. It covers 3,642 acres, and elevation ranges up to 3,000 feet. Bedrock geology is sedimentary noncarbonate, and the surficial geology is predominantly floodplains and terraces.
Nigu River Floodplain	This detailed-subsection is comprised of floodplains and terraces of the Nigu River, which flows through the broad Nigu River valley. It covers 12,707 acres, and elevation ranges up to 3,200 feet. Bedrock geology is sedimentary noncarbonate.
North Fork Koyukuk River Floodplain	This detailed-subsection includes forested floodplains of the North Fork Koyukuk River within the Brooks Range. The downstream boundary is formed where the river exits the Brooks Range. It is part of the Koyukuk Mountain Valley Subsection. Underlying bedrock geology is noncarbonate sedimentary and metamorphic metanoncarbonate with inclusions of igneous volcanic, igneous intrusive mafic, and sedimentary carbonate. It covers 39,021 acres, and elevation ranges up to 3,400 feet.
Okokmilaga River Floodplain	This detailed-subsection is composed of the Okpikruak River, Verdant Creek, and Okokmilaga River floodplains after they exit the Brooks Range and flow north through the arctic foothills. It covers 5,722 acres, and elevation ranges up to 2,000 feet. Bedrock geology is sedimentary noncarbonate. Surficial geology is predominantly floodplains and terraces, and sand deposits occur where the Okokmilaga River exits the Brooks Range.
Okpikruak River Floodplain	This detailed-subsection includes floodplains within the Okpikruak River watershed of the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary carbonate and noncarbonate rock. It covers

	1,376 acres, and elevation ranges up to 3,000 feet.
Outwash Creek Floodplain	This detailed-subsection includes the Outwash Creek floodplain after it exits the Brooks Range and flows north through the arctic Foothills. The southern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on its south edge. It covers 8,410 acres, and elevation ranges up to 2,800 feet.
Reed River Floodplain	This detailed-subsection includes forested floodplains of the Reed River within the Brooks Range. It is part of the Kobuk Mountain Valley Subsection, covers 8,741 acres, and elevation ranges up to 1,200 feet. The southern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary and metamorphic metanoncarbonate with inclusions of sedimentary noncarbonate, igneous intrusive-felsic, and sedimentary carbonate.
Siksikpuk River Floodplain	This detailed-subsection is comprised of floodplains of the Siksikpuk River and its tributaries after they exit the Brooks Range and flow north through the arctic Foothills. It covers 15,855 acres, and elevation ranges up to 2,400 feet. Bedrock geology is sedimentary noncarbonate with small inclusions of sedimentary carbonate rock. Surficial geology is predominantly floodplains and terraces.
Upper Anaktuvuk River Floodplain	This detailed-subsection includes a short stretch of floodplain within the Anaktuvuk River watershed. The northern boundary is formed by the edge of the Brooks Range, it covers 8,693 acres, and elevation ranges up to 2,200 feet. Bedrock geology is sedimentary carbonate.
Upper Chandler River Floodplain	This detailed-subsection includes a short stretch of floodplain within the Chandler River watershed. The northern boundary is formed by the edge of the Brooks Range, it covers 955 acres, and elevation ranges up to 3,000 feet. Bedrock geology is sedimentary carbonate and noncarbonate.
Upper Etivluk River Floodplain	This detailed-subsection includes floodplains of the Etivluk River and Ivotuk Creek within the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on the north edge of the detailed-subsection. It is part of the Etivluk Mountain Valley Subsection, covers 4,682 acres, and elevation ranges up to 3,000 feet.
Upper Itkillik River Floodplain	This detailed-subsection includes floodplains within the Itkillik River watershed of the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate. It covers 9,206 acres, and elevation ranges up to 3,400 feet.
Upper Killik River Floodplain	This detailed-subsection includes an extensive network of floodplains from the Killik River watershed within the Brooks Range. The northern boundary is formed by the north edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on the north flank of the detailed-subsection. Dunes are common in the northern Killik River valley and are often eroded by the Killik River. This detailed-subsection is part of the Killik Mountain Valley Subsection. It covers 28,341 acres, and elevation ranges up to 3,600 feet.
Upper Nanushuk River Floodplain	This detailed-subsection includes floodplains within the Nanushak River watershed of the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate with a small inclusion of sedimentary carbonate rock. It covers 2,549 acres, and elevation ranges up to 3,400 feet.
Upper Noatak River Floodplain	This detailed-subsection includes floodplains in the Noatak River watershed. The western boundary is formed by the edge of the Brooks Range. It is part of the Noatak Mountain Valley Subsection, covers 12,889 acres, and elevation ranges up to 2,000 feet. Bedrock geology is sedimentary noncarbonate and sedimentary carbonate, with inclusions of sedimentary and metamorphic metanoncarbonate and igneous intrusive-felsic rock.

Upper Okokmilaga River Floodplain	This detailed-subsection includes an extensive network of floodplains from the Okokmilaga River watershed within the Brooks Range. The northern boundary is formed by the north edge of the Brooks Range. Bedrock geology is sedimentary noncarbonate with inclusions of sedimentary carbonate on the north flank of the subsection. It covers 6,249 acres, and elevation ranges up to 3,400 feet.
Upper Outwash Creek Floodplain	This detailed-subsection includes floodplains of Outwash Creek within the Brooks Range. The northern boundary is formed by the edge of the Brooks Range. Bedrock geology is predominantly sedimentary noncarbonate with inclusions of sedimentary carbonate on the north edge of the subsection. It is part of the Etivluk Mountain Valley Subsection, covers 2,086 acres, and elevation ranges up to 3,600 feet.
Wild River Floodplain	This detailed-subsection includes forested floodplains of the Wild River within the Brooks Range. Floodplains occur throughout the watershed and the downstream boundary is formed where the river exits the Brooks Range. It is part of the Koyukuk Mountain Valley Subsection. Underlying bedrock geology is noncarbonate sedimentary and metamorphic metanoncarbonate with inclusions of igneous volcanic, igneous intrusive mafic, and sedimentary carbonate. It covers 11,837 acres, and elevation ranges to 2,800 feet.

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GLOSSARY

Most of the definitions provided below are from Allaby 1998; Anderson et al. 1998; Barnhart and Barnhart 1990; Cowardin et al. 1979; Fairbridge 1968; Gabriel and Talbot 1984; Gallant et al. 1995; Hamilton 1999; MacDonald and Cook 1996; Matthews 1992; Paustian 1992; Viereck et al. 1992; and Woolf 1977.

Abiotic—Having no life; applied to the nonliving components of the environment such as bedrock, soil, water, solar radiation, etc.

Ablation till—Glacial deposits left by the slow, in situ melting of debris-rich glaciers at high altitude. These melt-out deposits consist of coarse-textured debris within and on top of glaciers (englacial and supraglacial debris, respectively) and may overlie tills that formed first beneath glaciers (subglacial tills).

Accretion (accreted)—The accumulation of sediments from any cause, representing an excess of deposition over erosion. The addition of material to the edge of a continent, thus enlarging it.

Aeolian—Wind-transported sediment. See loess.

Albedo—Same as reflectivity. The percentage of incoming radiation that is reflected by a natural surface such as a ground, ice, snow, water, clouds, or particulates in the atmosphere.

Alliance—A physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species, which as a rule are found in the uppermost stratum of the vegetation (Grossman et al. 1998).

Alluvial fans—Erosional-depositional system in which rock and sediment are transported down-valley and deposited where it emerges from the confines of the valley into a larger valley or plain. They tend to be fan-shaped in plan view; a segment of a cone radiating away from a single point source.

Alluvium (alluvial)—Applied to the environments, processes, and products of rivers or streams. Alluvial deposits are formed through sediment transfer by surface runoff.

Alpine—The zone on mountain tops between permanent snow and the cold limits of trees.

Anaerobic—An environment where oxygen is lacking or absent.

Annual—Plant species that complete their life cycle within a single growing season.

Aquatic—Refers to sites with vegetation that is submerged, floating, or growing in permanent water.

Arête—A knife-edged, steep-sided ridge found in upland areas that have been or are being glaciated.

Bare-ground—Refers to a landcover class with less than 15% vegetation cover or to a soil surface devoid of vegetation.

Batholith—A large, shield-shaped body of intrusive, igneous rock exposed by the removal of its rock cover.

Bedrock—Refers to exposed rock typically at higher elevations and includes all the jagged rocky ridges, peaks, cirque headwalls, and cirque basins. It has little or no soil development.
Boreal—Northern biogeographical region typically referring to subpolar and cold temperate areas.

Braided stream (braided channel, braided river)—A stream that consists of a number of small channels separated by sand and gravel bars.

Breccia—A rock made up of highly angular coarse fragments.

Broad-leaved—Describes a plant with leaves that have well-defined leaf blades and are relatively wide in outline (shape) as opposed to needle-like or linear.

Bryophyte—Nonvascular, terrestrial green plant including mosses, hornworts, and liverworts.

Caespitose (cespitose)—Describes a low branching pattern from near the base that forms a multistemmed or a bunched appearance.

Canopy cover—The percent of the ground in the polygon covered by the gross outline of an individual plant's foliage (canopy), or the outline collectively covered by all individuals of a species or life-form within the polygon (Daubenmire 1959).

Chronosequence—A sequence of related vegetation and/or soils that differ in their degree of development because of differences in their age.

Cirque—A half-open, steep-sided hollow in a mountain region that is formed by glacial scouring.

Classification—Process of assigning individual pixels of an image to categories, generally on the basis of spectral reflectance characteristics.
Cliff—Any high, very steep to perpendicular, or overhanging face of a rock outcrop.

Colluvium—Unconsolidated surface materials that have been transported downslope and deposited on the lower slopes. Colluvium is moved by landslides, flow slides, talus rubble, rock-glaciers, solifluction, and unconsolidated runoff.

Creeping—Describes the pattern of stems growing at or just beneath the surface of the ground and usually producing roots at nodes.

Crustose lichen—Lichen life-form that grows in intimate contact with its substrate, lacks a lower cortex and rhizoids (root-like structures), and is impossible to separate from the substrate without destroying the thallus; lichen with an unlobed, flattened thallus, growing adnate (joined) to the substrate.

Cushion plant—A low, woody, plant life-form so densely branched that it forms a compact canopy that is pad- or bolster-like in appearance; usually with microphyllous foliage; characteristic of alpine and tundra plants.

Deciduous—Describes a woody plant that seasonally loses all of its leaves and becomes temporarily bare-stemmed.

Delta (deltaic)—An alluvial deposit, usually triangular or fan-shaped, at the mouth of a river. A deposit of sediment formed where a sediment-laden current enters an open body of water.

Dominant—An organism, group of organisms, or taxon that by its size, abundance, or coverage exerts considerable influence upon an association's biotic (such as structure and function) and abiotic (such as shade and relative humidity) conditions.

Drumlin—A smooth, oval-shaped landforms resulting from glacial override, which deposits unconsolidated materials on the leeside of surface protrusions and streamlines them. Normally occurring in large groups (drumlin fields), the long axis of a drumlin lies parallel to the direction of glacial advance.

Dwarf shrub—Shrub life-form growing less than eight inches tall.

Ecoregions—Landscape units defined based on similar patterns in potential natural communities, soils, hydrologic function, landform, topography, lithology, climate, and natural processes such as nutrient cycling, productivity, succession, and natural disturbance regimes associated with flooding, wind, or fire. (Climate, as modified by topography, is the dominant criterion at the scale mapped for Denali.)

Eolian—Wind blown sand and silt deposits.

Ericaceous shrubs—Low- to moderate-growing shrubs in or closely related to the heath family (Ericaceae).

Evapotranspiration—A combined term for water lost as vapor from soil or open water (evaporation) and water lost from the surface of a plant, mainly via leaf pores (transpiration).

Evergreen—Describes a plant that has green leaves year-round.

Evolution—Change with continuity in successive generations of organisms; descent with modification.

Exfoliation (exfoliate)—The breaking- or peeling-off of outer layers or plates, as concentric sheets from bare rock surfaces, by the action of either physical or chemical forces.

Felsic (felsitic)—A geologic term applied to dense, light-colored igneous rocks made up of crystals that are too small to be readily seen by the unaided eye. Fine-grained light-colored igneous rocks include rhyolite, felsite (feldspar and quartz), and andesite (if light colored). These rocks weather to form acidic soils.

Floodplains—Floodplains are formed by nonglacial-fed rivers. The formation of new land on floodplains is well documented. Along a meandering river, alluvium is deposited on convex curves in the river channel. The opposing concave bank is cut, providing sediment for deposition on convex curves downstream and creating a series of similar bands of alluvial deposits. Alluvium is also deposited on the soil surface during flooding further raising the soil surface height, but because surface height is a function of floodwater height it eventually stabilizes.

Fluvial (fluvial processes)—Pertaining to a river. The set of mechanisms that operate as a result of water flow within a stream channel, bringing about the erosion, transfer, and deposition of sediment.

Foliose lichen—Lichen life-form that is leafy in appearance and loosely attached to its substrate; lichen with a lobed, flattened thallus growing loosely attached to the substrate, the lobes are flattened or inflated with distinctly differentiated upper and lower surfaces; umbilicate lichens are included.

Forb—A broad-leaved herbaceous plant.
Fresh water—Water with a salinity of less than 0.5 parts per thousand.

Frost boils—Areas of bare soil that are sufficiently disturbed by frost action to prevent plant colonization. On slopes, fine material in unsorted circles moves slowly downslope producing banked or "stepped" frost boils (from Gabriel and Talbot. 1984).

Frost scar—Exposed bare mineral soil formed by frost action in the soil.

Fruticose lichen—Lichen life-form that is bunched, shrubby, or "hairy" in appearance and loosely attached to its substrate; lichen with the thallus branched, the branches solid, or hollow and round, or flattened without distinctly differentiated upper and lower surfaces; squamulose lichens are included.

Geographic Information System (GIS)—A data-handling and analysis system based on sets of data distributed spatially in two dimensions. The data sets may be map oriented—when they comprise qualitative attributes of an area recorded as lines, points, and areas often in vector format—or image oriented—when the data are quantitative attributes referring to cells in a rectangular grid usually in raster format. It is also known as a geobased or geocoded information system.

Geomorphology (geomorphic processes)—The scientific study of the landforms of the earth's surface and of the processes that have fashioned them.

Glacial drift—The material transported by a glacier and then deposited either directly from the ice or from the meltwater. Numerous types of glacial drift occur including moraines, kettle-kame topography, eskers, drumlins, glacial till, and outwash.
Glacial outwash—Fluvial plains formed when glacially fed rivers deposit their sediment in stream channels and the associated plain. Due to continual channel shifting the sediment is spread across an area called an outwash plain. Outwash plains typically have braided rivers consisting of multiple, wide, shallow channels characterized by rapid erosion, deposition, and channel shifts.

Glacial till—A surface formed by sediment originating directly from glacial ice that typically has no discernible sediment stratification.

Glacio-—A prefix denoting formation by or relationship to glaciers.

Glaciofluvial—Pertaining to streams flowing from glaciers or to the deposits made by such streams.

Glaciolacustrine—Pertaining to glacial-lake conditions, as in glaciolacustrine deposits, sediment deposited in glacier-margin lakes by glacial melt waters.

Global Positioning System (GPS)—The GPS is a worldwide satellite navigation system that is funded and supervised by the U.S. Department of Defense. GPS satellites transmit specially coded signals. These signals are processed by a GPS receiver that computes extremely accurate measurements, including three-dimensional position, velocity, and time on a continuous basis.

Graminoid—Grasses and grasslike plants, including sedges and rushes.

Graywacke—An old rock name that has been variously defined but is now generally applied to a dark and very hard coarse sandstone in an abundant and compact (sometimes partially metamorphosed) clayey matrix having the composition of slate.

Ground layer—Applies to the herbaceous layer.

Growth form—The shape or appearance of a plant; it primarily reflects the influence of growing conditions.

Herbaceous—A vascular plant without significant woody tissue above or at the ground; an annual, biennial, or perennial plant lacking significant thickening by secondary woody growth, with perennating buds borne at or below the ground surface (hemicryophytes, geophytes, helophytes, and therophytes of Raunkier).

Horn—A high pyramidal peak with steep sides formed by the intersecting walls of three or more cirques.

Ice wedge polygons—Refers to patterned ground with polygons typically connected in a polygonal pattern that is similar to the pattern produced by mud cracks. They are formed by large masses of ice—called ice wedges—that grow in thermal contraction cracks in permafrost.

Infrared (IR) color photograph—Color photograph in which the red-imaging layer is sensitive to photographic IR wavelengths, the green-imaging layer is sensitive to red light, and the blue-imaging layer is sensitive to green light. Also known as camouflage detection photographs and false-color photographs.

Karst (karstlands)—The dissolution of limestone forms a distinctive undulating landscape of sinkholes, dolines, vertical shafts, and caves. Here, surface water is curiously lacking, being captured by surface depressions and piped through underground drainage systems.

Krumholtz—Growth form assumed by tree species at the upper tree line or in the alpine zone; characterized by a creeping and multistemmed growth pattern due to desiccation and physical damage caused by wind and blowing ice crystals near the upper tree line; the same species grows as an erect, single-stemmed tree at lower elevation.

Lacustrine—Lacustrine deposits are derived from materials deposited in lake water and exposed when the water level is lowered or the land is raised. They are also formed during past glaciations when some valleys were dammed by ice, causing glacial lakes to form along their length.

Landsat (formerly ERTS)—The Landsat program, first known as the Earth Resources Technology Satellite (ERTS) Program, is a development of the National Aeronautics and Space Administration in association with NOAA, USGS, and Space Imaging. The activities of these combined groups led to the concept of dedicated Earth-orbiting satellites, the defining of spectral and spatial requirements for their instruments, and the fostering of research to determine the best means of extracting and using information from the data. The first satellite, ERTS 1, was launched on July 23, 1972. The second satellite was launched on January 22, 1975. Concurrently, the name of the satellites and program was changed to emphasize its prime area of interest (land resources). The first two satellites were designated as Landsats 1 and 2. Landsat 3 was launched on March 5, 1978. Landsat 4 was launched on July 16, 1982. Landsat 5 was launched March 1, 1984, and is currently in service providing selected data to worldwide researchers.

Lichen—An organism generally recognized as a single plant that consists of a fungus and an alga or cyanobacterium living in symbiotic association.

Life-form—The shape or appearance of a plant that mostly reflects inherited or genetic influences.

Lithology—The study and description of rocks. Also used loosely to mean the composition and texture of rocks.

Little Ice Age—A period of worldwide glacier expansion and contraction spanning from approximately 1450 to 1850. This is considered one of several neoglacial pulses of ice.

Loess—Unconsolidated, wind-deposited sediment composed largely of silt-sized particles and showing little or no stratification. Soils derived from these wind-blown materials are quite fertile.

Low shrub—Low-growing shrub life-form between 8 inches and 4.5 feet tall.

Mafic—Pertaining to or composed dominantly of the magnesium rock-forming silicates; dark-colored igneous rocks.

Matted—Describes a creeping plant that by reiterative growth has overlapping stems and forms a low, dense ground cover.

Mesic—Sites are moist and tussocks may dominate. Permanent standing water is not present.

Metamorphism (metamorphosed)—In geology, any change in the texture or composition of a rock due to heat, pressure, and chemicals. The recrystallization of pre-existing rocks in response to exterior forces.

Micaceous—Consisting of, containing, or like mica (mica is a mineral that divides into thin, partly transparent layers).

Mixed forest—Describes vegetation in which evergreen and deciduous species each generally contribute 25–75% to the total canopy cover.

Montane—Describes the zone in mountainous regions where the influence of altitude (vertical relief) results in local climatic regimes that are sufficiently different from those in the adjacent lowlands as to cause a complex vertical climate-vegetation-soil zonation; includes vegetation at the base of a mountain when it is different from lowland vegetation.

Mosaic—Composite image or photograph made by piecing together individual images or photographs covering adjacent areas.

Neoglacial—This term refers to glacier expansions subsequent to maximum ice retraction of the hypsithermal climatic optimum. Pulses of neoglacial ice have occurred during the last 5,000 years.

Nonvascular plant—A plant without specialized water or fluid conductive tissue (xylem and phloem); includes bryophytes, lichens, and algae.

Nunatak—A mountain peak or range that was formerly surrounded but not overridden by glacial ice. A mountaintop that protrudes through the surface of a glacier or ice field.

Orographic—Applied to the rain or cloud caused by the effects of mountains on air streams that cross them. Orographic clouds and rain are produced by the condensation of moist air during its ascent over mountains.

Oxbow—A crescent-shaped lake formed in an abandoned river bend that has become separated from the main stream by a change in the course of the river.

Patterned ground—Regions with perennially frozen ground often have their surface materials arranged into distinct geometric shapes. The features, collectively known as patterned ground, include polygons, nets, circles, and stripes (Washburn 1956). In general, the geometric pattern changes with increasing slope from polygons and circles on level ground, to nets and then stripes on steeper surfaces.

Pavement—A relatively flat surface of consolidated material, generally exposed bedrock.

Peatlands—Peatlands (i.e. muskeg) are composed of three to six feet of accumulated peat in areas of restricted drainage with water tables at or close to the peat surface (Hamilton 1999). These organic deposits are most common in forested areas beyond the south flank of the Brooks Range. They occupy former lake basins and other closed depressions, alluvium along some valley floors, and are abundant on older glacial drift deposits within the boreal forest.

Perennial—Plant species with a life cycle that characteristically lasts more than two growing seasons and persists for several years.

Pingo—These are ice-filled conical hills or mounds, 60 to 1,200 feet in diameter, and 30 to 210 feet high.

Plant association—The finest level of both the Viereck et al. (1992) and National Vegetation Classification System (Grossman et al. 1998) classifications. It is defined as "a plant community type of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (Flahault and Schroter 1910).

Pleistocene—The first of two epochs of the Quaternary period, lasting from approximately 1.64 million years ago to the beginning of the Holocene, about 10,000 years ago. This epoch is marked by several glacial and interglacial episodes in the northern hemisphere and is also called the glacial epoch.

Plucking—The loosening and removal of rock fragments or larger blocks by glaciers that involves several different mechanisms such as crushing and fracturing, freezing-on, ice movement, and variations in water pressure.

Plutonic (pluton)—Of igneous origin. A body of igneous rock that has formed beneath the surface of the earth from cooled magma. A class of igneous rocks that have crystallized at great depth and possessing a granitic texture.

Potential natural community (potential natural vegetation)—The vegetation type that represents the end point of succession on a given land area; an assemblage of plants representing the climax of vegetative succession.

Pyroclastic—A general term applied to detrital volcanic materials that have been explosively or aerially ejected from a volcanic vent. A class of rocks made up of volcanic aerial ejecta.

Refugium (pl. refugia)—An isolated area where extensive changes, most typically due to changing climate and glaciation, have not occurred. Plants and animals formerly characteristic of the region find a refuge in these areas until favorable conditions return.

Remote sensing—Collection and interpretation of information about an object without being in physical contact with the object.

Resolution—Ability to separate closely spaced objects on an image or photograph. Resolution is commonly expressed as the most closely spaced line-pairs per unit distance that can be distinguished. Also called spatial resolution.

Riparian—Pertaining to a riverbank or banks along a body of water.

Rock glacier—Tongue-shaped or lobate masses of unsorted, angular frost-rived material with interstitial ice. They typically originate in cirques or in high, steep-walled recesses.

Sand-silt deposits—Sand-silt deposits may be formed by slow-moving streams within basins partly dammed by end moraines, loess, and wind blown sands. The main source of sand and silt is the sediment load delivered by the various rivers and deposited on outwash plains, floodplains, or deltas. Once the sediment is deposited, winds form the dunes and deposit silt.

Satellite—An object in orbit around a celestial body.

Scene—Area on the ground that is covered by an image or photograph.

Scree—A sheet of coarse rock debris covering a mountain slope without an adjacent cliff. This term is basically interchangeable with talus.

Scrub—Vegetation dominated by shrubs, including thickets.

Seasonal—Showing periodicity related to the seasons; applied to vegetation exhibiting pronounced seasonal periodicity marked by conspicuous physiognomic changes.

Shrub—A perennial woody species that typically has several stems arising from or near the ground.

Solifluction (or gelifluction)—The flow of soil in association with frozen ground. During the spring and summer thaw, water in the active layer cannot penetrate below the permafrost table. Soils are often saturated, and the loss of friction and cohesion causes them to behave like viscous fluids. The soil thus slowly “flows.” The downslope fronts of the solifluction lobes are marked by near-vertical scarps as high as 6 feet.

Sorted circles—Similar to sorted polygons but circular in outline.

Sorted polygons—Refers to patterned ground where sorting separates the coarse from the fine soil particles, and typically produces a surface feature of fine materials bordered by stones in a variety of geometric shapes; polygons, circles, nets, and stripes.

Sorted stripes—Refers to patterned ground that consists of linear alignments of soil, vegetation, and stones on slopes. Often strips of stone separated by broad zones of finer sediment and vegetation. The strips are up to several feet in width and 300 feet in length.

Sparsely vegetated—Describes vegetation with low total plant cover (between 15% and 25%) that is scattered; areas with high cover of crustose lichen and no other vegetation are included here.

Spectral reflectance—Reflectance of electromagnetic energy at specified wavelength intervals.

Subalpine—Upper mountain vegetation immediately below the cold limits of tree and tall shrub growth.

Surficial geology—The study and description of unconsolidated surface deposits of fluvial, colluvial, aeolian, or glacial origin.

Tall shrub—Tall-growing shrub life-form greater than 4.5 feet tall.

Talus—A sloping accumulation of coarse rock fragments at the base of a cliff.

Tectonics—Of, pertaining to, or designating the rock structure and external landforms resulting from the deformation or warping of the Earth’s crust. Often applied to earthquakes.

Temperate—Geographically, the region between the polar and tropical regions; climatically, the region is moderate with distinct seasons of alternating long, warm summers and short, cold winters.

Terraces—Floodplains and outwash plains removed from frequent flooding due to down-cutting of the river.

Terrain—A geographical area with a particular physical character; the tract or region of ground immediately under observation.

Terrane—A rock formation or group of rock formations; the area or surface over which a particular rock or groups of rocks is prevalent.

Texture—Frequency of change and arrangement of tones on an image.

Thematic Mapper (TM)—A cross-track scanner deployed on Landsat that records seven bands of data from the visible through the thermal IR regions.

Thermokarst—Thermokarst is the collapse of the soil surface due to the thawing of ice-rich permafrost. The ground around thermokarst is supersaturated—often with ice lenses and layers—because it contains more water in the solid state than the ground could possibly hold if the water were in the liquid state.

Till—An unsorted mix of unconsolidated sediments and rocks carried and deposited by a glacier.

TM—Thematic mapper.

Topographic Map—Map that presents the horizontal and vertical positions of the features represented; distinguished from a plainimetric map by the addition of relief in measurable form.

Topography—Configuration (relief) of the land surface; the graphic delineation or portrayal of that configuration in map form, as by contour lines; in oceanography the term is applied to a surface such as the sea bottom or a surface of given characteristics within the water mass.

Tree line—A zone where the normal growth of trees is limited; cold temperatures often combined with drought form the upper or arctic tree line, and drought combined with hot temperatures form lower or arid tree line.

Tuff—A rock formed of compacted volcanic fragments.

Tundra—The treeless region north of the Arctic Circle (arctic tundra) or above the tree line of high mountains (alpine tundra) and on some sub-Antarctic islands; characterized by very low winter temperatures, short cool summers, permafrost below a surface layer subject to summer melt, short growing season, and low precipitation.

Tussock—Graminoid life-form consisting of bunch like tufts, sometimes more than three feet tall, in which the hard, old, withered leaves are intermingled with the fresh, young, green leaves.

Understory—General term that in this document applies to the shrub and herbaceous layers of a vegetation type, as well as the tree regeneration layer. (We have tried to use "shrub layer" or "herbaceous layer" in most cases, but understory is used in some places. "Undergrowth" is the more specific term used for shrub and herbaceous layers in forests or woodland vegetation types, and has been little used in these descriptions.)

Undivided—A mixture of rock types that are not differentiated by geologic mapping; referred to as complexes.

Unsupervised classification—Digital information extraction technique in which the computer assigns pixels to categories with no instructions from the operator.

Upland—A terrestrial surface devoid of or lacking wetlands [National Wetland Inventory].

Vascular plant—Plant with water and fluid conductive tissue (xylem and phloem); includes seed plants, ferns, and fern allies.

Water tract—Many of the rolling hills and mountain sideslopes covered by tussock tundra have narrow water tracks running downslope. Water tracks are shallow depressions that have significantly greater water flow than the adjacent tussock tundra. They also commonly have horizontal soil ridges that pool the water.

Wet—Refers to sites where the dominant vegetation is emergent—not submerged or floating—and semi-permanent or standing water is present.

Woody plant—Plant species life-form with woody tissue and buds on that woody tissue near or at the ground surface or above; plants with limited to extensive thickening by secondary woody growth and with perennating buds.

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ABSTRACT

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As part of the National Park Service's Inventory and Monitoring Program in Alaska, the Service's Alaska Support Office in cooperation with the Alaska Natural Heritage Program, developed a map and descriptions of ecoregional subsections that occur in Gates of the Arctic National Park and Preserve. The subsections will be used to understand the coarse-scale ecosystems within the park, for park planning, as a stratification layer to use for species-level inventory, to help with cover type mapping, and to assist with the ongoing water inventory program.

Methods used to define subsections for Gates of the Arctic National Park and Preserve follow those outlined by Bailey (1996). Subsections were defined by a qualitative review and interpretation of the available pertinent data and the authors' knowledge of the study area. The scale was generally at 1:250,000 and the unit size was generally between 10 and 10,000 square miles. To interpret subsections information was needed on climate, lithology, surficial geology, geomorphic processes, potential plant community distributions, topography, hydrology, soils, and soil-forming processes. Fifty-one subsections and 27 detailed subsections were identified for Gates of the Arctic National Park and Preserve.

Keywords—Alaska, Gates of the Arctic National Park and Preserve, subsection, ecoregion, classification