Agricultural and Forestry Experiment Station

University of Alaska Fairbanks

United States Department of the Interior

Bureau of Land Management

Alaska Research Natural Areas. 4: Big Windy Hot Springs

Glenn Patrick Juday

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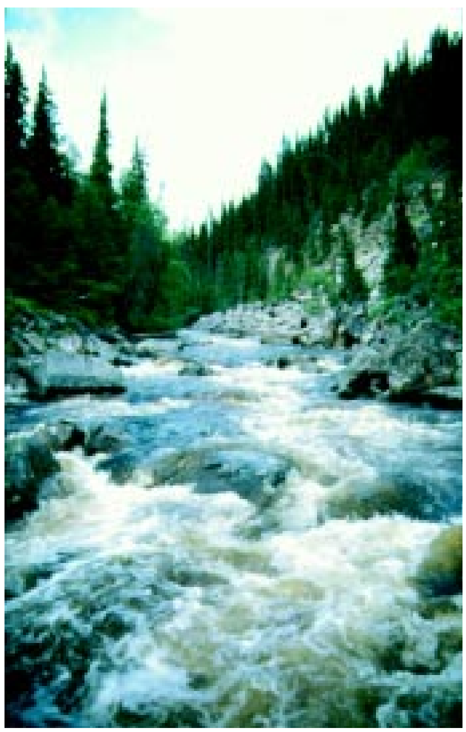

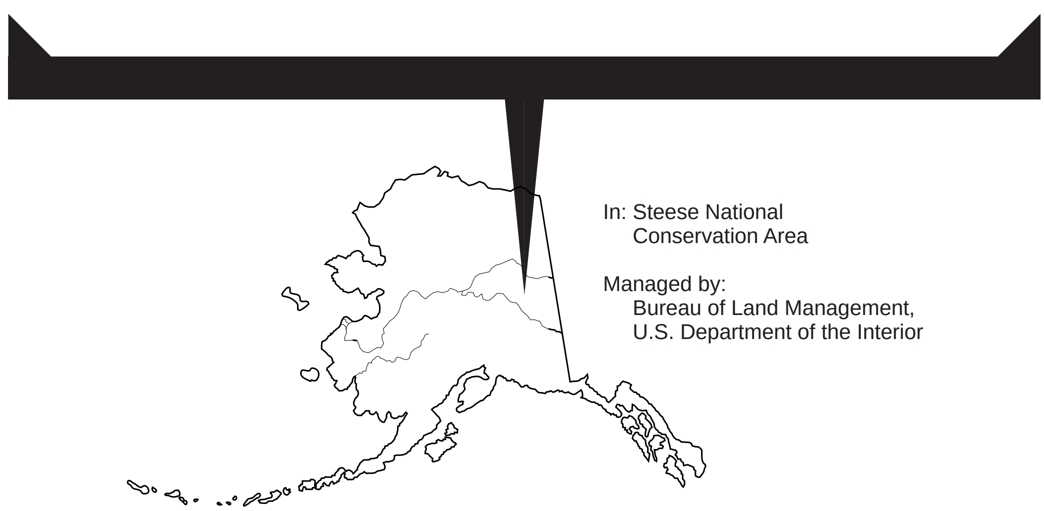

In: Steese National Conservation Area

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Cover

Big Windy Creek cascades through a narrow canyon marked by a cliff and many boulders (left). Big Windy Hot Springs emerges in one main high temperature pool (upper right), a few lower temperature pools, and a series of drip zones and marshy seeps. Dall sheep move from alpine zones south of the Research Natural Area across bouldery slopes (lower right) down to the hot springs where they obtain mineral salts. Big Windy Hot Springs contains several scientifically interesting geologic features and plant communities and rare plants and animals in a compact area.

Author

Glenn Patrick Juday is associate professor of plant ecology and Alaska ecological reserves coordinator, Agricultural and Forestry Experiment Station, University of Alaska Fairbanks, Fairbanks, Alaska 99775.

Abstract

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The 65 ha Big Windy Hot Springs Research Natural Area (RNA) in the Steese National Conservation Area of central Alaska is managed by the Bureau of Land Management. It contains a vent that issues hot water at about 61˚ C flowing at about 8 liters per minute from the largest of a system of small springs and seeps. Geothermal water seeping over the face of a cliff has intensely weathered the local granitic bedrock into gruss. The fracture of massive boulders from the possibly fault-related cliff is one of the most distinctive features of the RNA. Small boulders from the cliff have fallen into Big Windy Creek where they have been caught in the swirling current of Big Windy Creek and ground potholes into the bed of the high-gradient stream. Big Windy Creek is constricted to a narrow canyon.

The main geothermal pools are lined with thermophytic algal and cyanobacteria mats. Undescribed high-temperature aquatic species may be present. Geothermal heat in the vicinity of the main vents promotes a lush growth of vegetation including *Phalaris arundinacea* and *Ranunculus cymbalaria*, two species that occur here north of their previously reported distribution in Alaska. The RNA contains contrasting north- and south-facing canyon slopes. Diffuse geothermal heating of soil around the vents is associated with a large and productive mature white spruce forest on the south-facing slope. A paper birch forest with a minor white spruce component covers most of the south-facing slope. The north-facing slope is underlain with permafrost; areas of boulder talus are subjected to periglacial weathering processes. Low paper birch forest, black spruce woodland, and dwarf birch tundra provide the main vegetation cover.

The lowland east-central Alaska region has experienced a strong climate warming trend since the late 1970s. Radial growth of white spruce at Big Windy Hot Springs is generally negatively related to summer temperature.

The Big Windy Hot Spring site is a mineral lick heavily used by a local population of Dall sheep that roam from nearby alpine habitats into the RNA. A collection of the water shrew (*Sorex palustris*) in the RNA is several hundred km from other known populations and is the new northern limit for the species in North America.

Keywords: Alaska, hot springs, Dall sheep, ecosystems, Natural Areas (Research), granite, gruss, old-growth forest, Research Natural Area, scientific reserves, tree-ring, water shrew, white spruce, Picea glauca, Ovis dalli, Sorex palustris.

Foreword

At the recommendation of various professional and scientific societies, the federal government established a system of Research Natural Areas in 1927. RNAs are tracts of federally owned land and water established and managed for the primary purpose of research and education. RNAs are selected to contain examples of significant natural ecosystems, areas suitable for ecological study, and rare species of plants and animals. Federal and state agencies have cooperated in Alaska since 1973 in selecting, documenting, and describing RNAs. A numbered publication series documenting the natural features of Alaska RNAs was begun under a cooperative agreement by the USDA Forest Service's Pacific Northwest Research Station in 1988. This publication is the fourth in the Alaska RNA series, and the first published by the University of Alaska Fairbanks.

Contents

Introduction

Big Windy Hot Springs, located in Steese National Conservation Area (NCA), contain several medium-grade geothermal seeps and pools in a remote and scenic mountain canyon (Figure 1, Figure 2). The canyon was carved by Big Windy Creek, the source of the name for the hot spring site. Big Windy Creek was named by gold prospectors, and the name was in written use by 1904 (Orth 1967). Steese NCA (Figure 3) was established by the Alaska National Interest Lands Conservation Act (ANILCA) of 1980, and is managed by the Bureau of Land Management. Section 101 (b) of ANILCA states, "It is the intent of Congress in this Act to preserve unrivaled scenic and geological values associated with natural landscapes; ... and to maintain opportunities for scientific research and undisturbed ecosystems." The establishment of the Big Windy Hot Springs Research Natural Area was designed to meet those goals of ANILCA. Big Windy Hot Springs is one of a limited number of hot springs in a diffuse belt of geothermal features across central Alaska (Motyka et al. 1983). Before the passage of ANILCA a 64.8 ha (160 acre) site around Big Windy Hot Springs was reserved for public purposes in 1947 by a presidential Public Land Order.

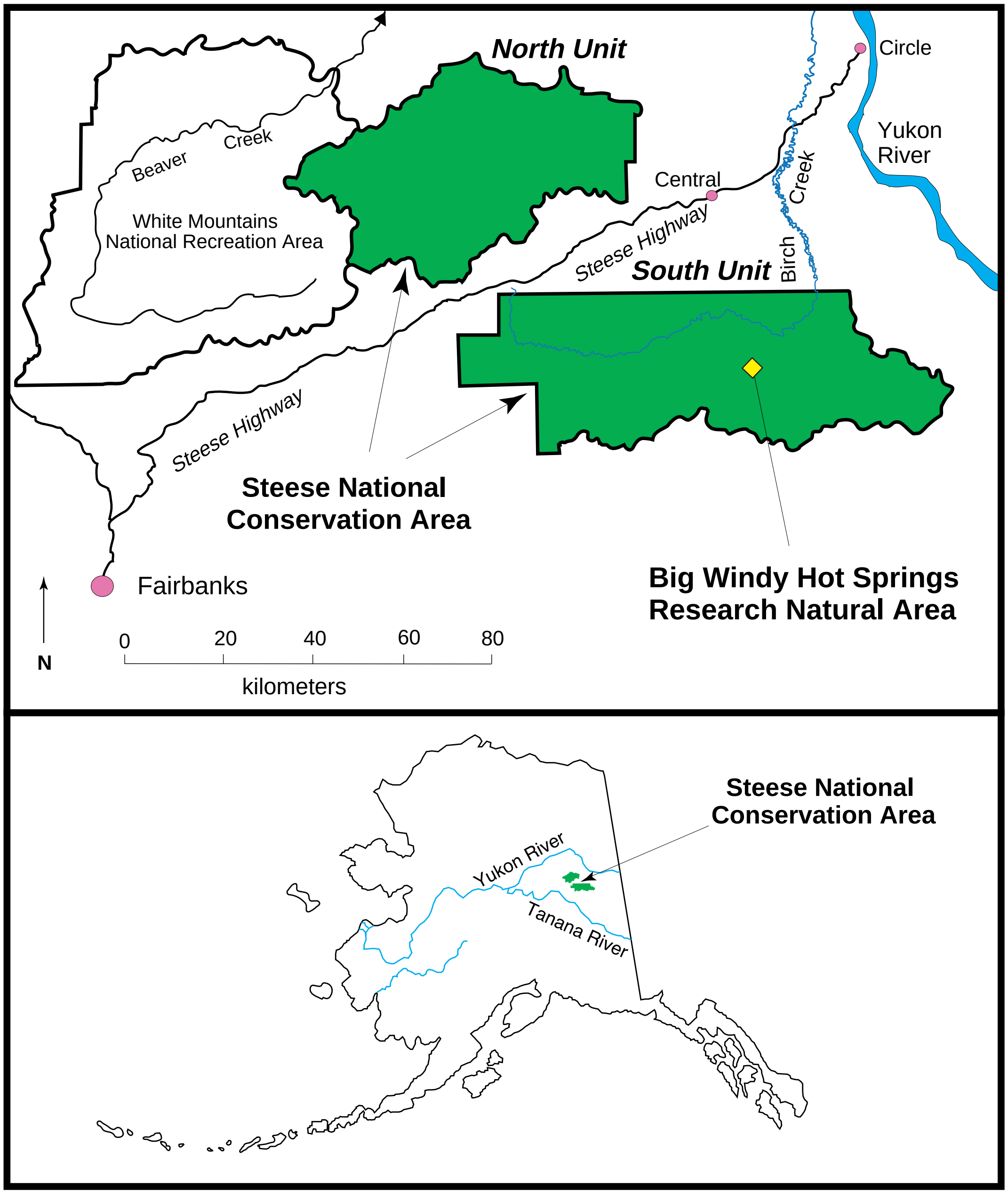
A list of natural features developed during the resource inventory phase of the planning process for the Steese NCA stimulated and guided a search for possible Research Natural Areas (RNAs). A proposal for a Big Windy Hot Springs Research Natural Area (RNA) emerged from the planning process as the best site to represent several natural features. Three other RNAs were proposed in the Steese NCA and adjacent White Mountains National Recreation Area at the same time (Juday 1988, 1989, 1992). The draft resource plan for the Steese NCA offered for public comment three size options for a Big Windy Creek Hot Springs RNA ranging from 1,781 ha (4,400 ac) to 5,155 ha (12,733 ac). Each of the RNA options included the initial 64.8 ha public land withdrawal.

The final Resource Management Plan (RMP) for the Steese NCA established a 64.8 ha Big Windy Hot Springs RNA, representing the core area. The final RMP placed most of the area of the three larger RNA size options in other special management categories. The protection of most of the sensitive features integral to the core hot spring site was accomplished by the special management

Figure 1. Big Windy Creek flowing through the center of Big Windy Hot Springs RNA. Note the granite cliff (right side of stream, upstream portion) and the pile of boulders dislodged from it that have reached the streambank. The hot springs are adjacent to both banks of Big Windy Creek along the boulder zone.

Figure 2. View of granite cliff from south bank of Big Windy Creek. The accumulation of boulders in this stretch of the stream has steepened the stream gradient, producing a series of rapids and cascades as the boulders are gradually eroded and transported downstream.

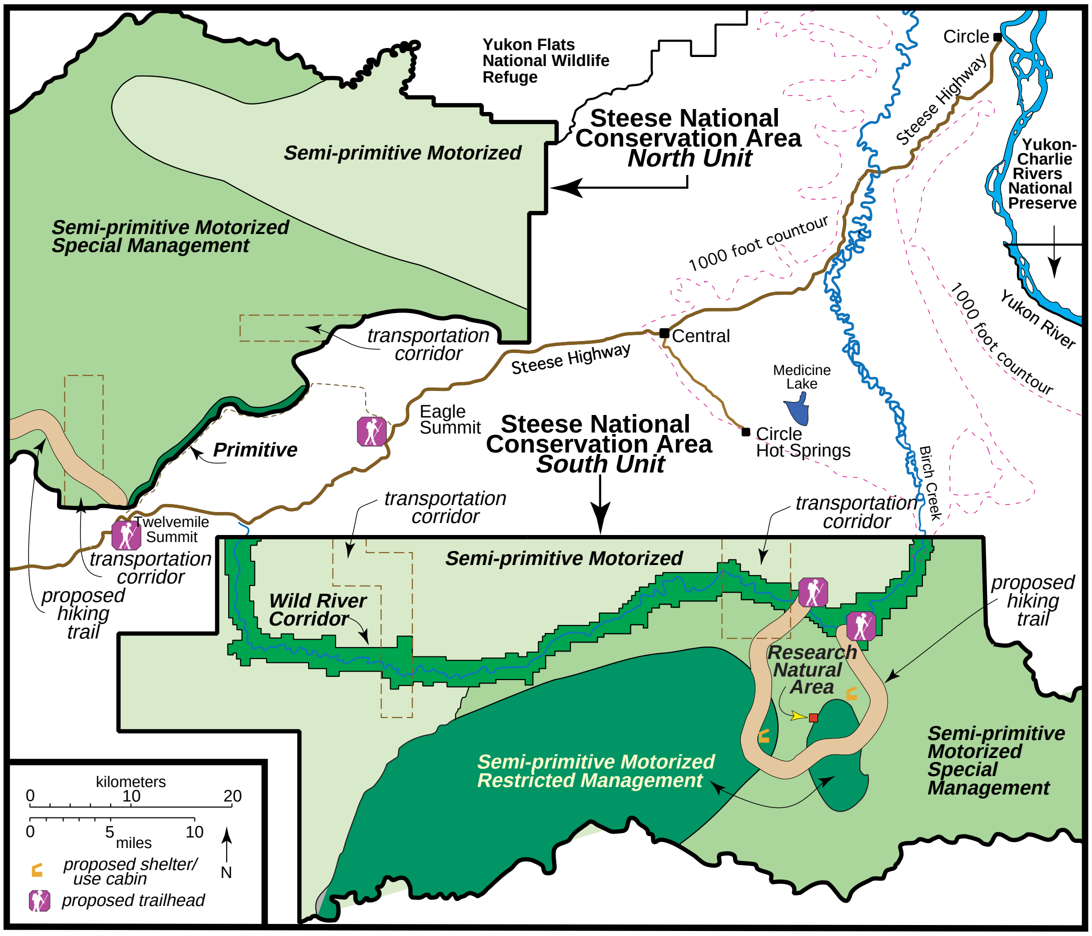
Figure 3. Location of Big Windy Hot Springs Research Natural Area in Steese National Conservation Area



categories. The special areas in the final RMP adjacent to Big Windy Hot Springs RNA include a (1) Semi-Primitive Motorized Special Management zone and (2) a Semi-Primitive Motorized Restricted Management zone (Figure 4). The final RMP also identified a potential loop trail corridor, with two proposed trail shelters, going from Birch Creek across the watershed crest south of the hot springs and then back down north to Birch Creek (Figure 4). In-depth site-specific planning and the availability of funding will determine if and where trails or shelters are constructed.

In the mid-20th century a nation-wide policy of reserving all hot spring sites on federal land was implemented. The boundary of the Big Windy Hot Springs RNA was chosen to be coincident with the boundary of the area affected by Public Land Order (PLO) 399, of August

Figure 4. Access and land use zones in Steese National Conservation Area



27, 1947. PLO 399 itself canceled the exclusion of Alaska from Executive Order 5389, of July 7, 1930. Executive Order 5389 states, “It is hereby ordered that every smallest legal subdivision of the Public Land Surveys which is vacant unappropriated, unreserved public land and contains a hot spring, or a spring, the waters of which posses curative properties, and all land within 1/4 mile of every such spring located on unsurveyed public land (exclusive of Alaska) be, and the same is hereby withdrawn from settlement, location, sale, or entry and reserved for lease under the provisions of the Act of March 3, 1925.” 43 Stat (1133). In defining the land withdrawl, Executive Order 5389 treats hot springs as a single point. The Big Windy Hot Springs site is a diffuse series of seeps, flows, and pools, so “all land within 1/4 mile” is subject to interpretation. The map of the area subject to the withdrawal as interpreted by Fairbanks District BLM is centered on Main Pool (Figure 5), and was presented in the Final Resource Management Plan for the Steese National Conservation Area.

Placer gold mining has occurred on valid claims in the watershed of Birch Creek, including South Fork, Clums Fork, Harrington Creek, and Harrison Creek (BLM 1984). Steese NCA is not currently open to filling of new mining claims. Birch Creek was congressionally-designated as a Wild River by the ANILCA.

The Big Windy Hot Springs RNA is located in the Northern District of the Bureau of Land Management. The main hot spring is located at 65º 13.65' north latitude, and 144º 29.95' west longitude (NAD27 datum). The RNA is located principally in section 29, but also in section 32, T 4 N, R 16 E, Fairbanks Meridian (Figure 5). The highest elevation is approximately 670 m (2,200 ft), the lowest elevation is approximately 472 m (1,500 ft).

Access and Accommodations

Parking, Roads, and Rights-of-Way

There is no road access to Big Windy Hot Springs RNA (Figure 4). The RNA is located in a remote wilderness region in steep mountain terrain. Visitors can reach the area by helicopter, snow machine, or cross-country foot travel. The nearest road-accessible point is Circle Hot Springs resort, about 35 km north of the RNA (Figure 4). A direct overland route from Circle Hot Springs involves crossing two steep mountain ridges and Birch Creek. Few, if any, locations near the RNA are suitable for landing fixed-wing aircraft. Most visitors arriving by helicopter in the past have landed on the travertine terrace of the main hot spring pool (Figure 6). A minor amount of damage to delicate mineral crusts is inevitable during landing and loading and unloading passengers in the saturated muddy ground in that area. However, trampling damage by Dall sheep and moose occurs in the same area and may not be much different in ultimate effect. The only other suitable helicopter landing spots are on the surrounding ridge summits which are over .6 km (1 mile) away and nearly 300 m (1,000 feet) higher in elevation. A visitor approaching from the ridge sites to the south of the RNA is required to navigate through or around difficult boulder fields. Snowmobiles face a challenge in making a track up the Big Windy Creek valley because of its steep gradient, the large rocks which form a plunge - pool system in the streambed, and open water in the winter maintained by geothermal discharge (Figure 7).

Structures and Trails

There are no man-made structures in or near the RNA. A transportation corridor, within which a road may be built, is identified in the Steese NCA land use plan (Figure 4). Currently there are no plans to build such a road. The road would extend existing access south toward Birch Creek approximately 16 km (10 mi) northeast of the RNA. The segment of Birch Creek

Figure 5. Topography and Public Land Survey location of Big Windy Hot Springs Research Natural Area

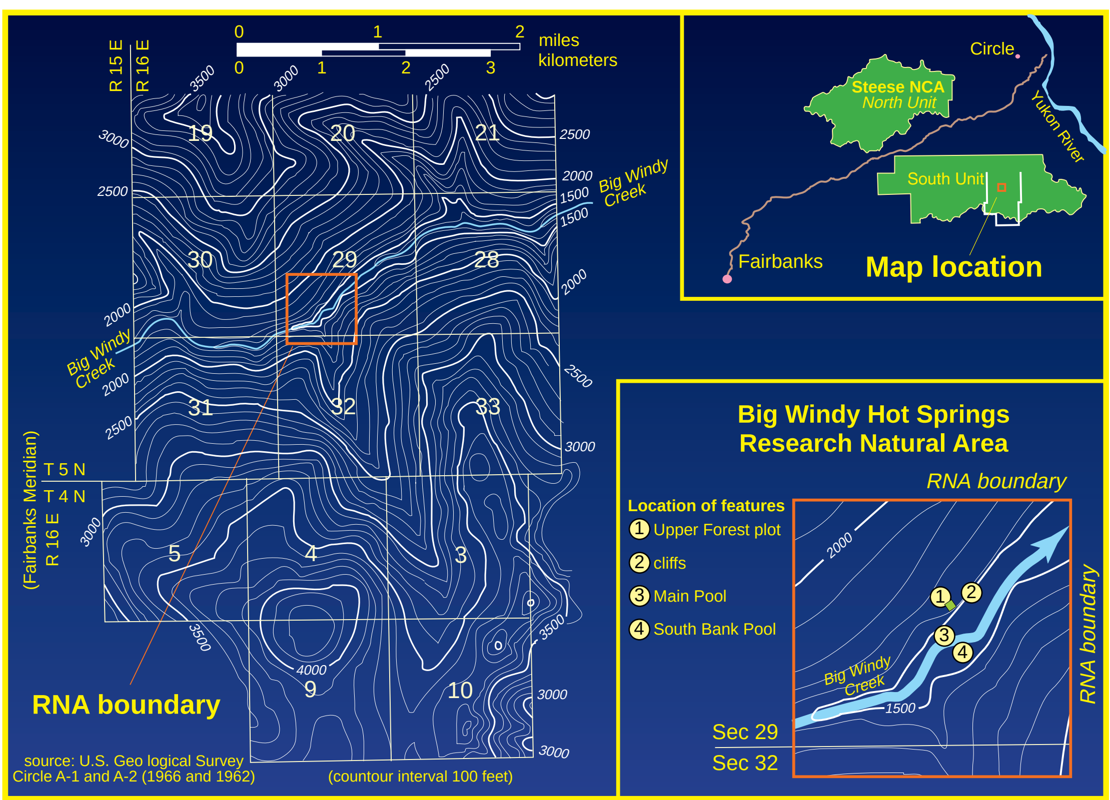


*Figure 6. Helicopter landing zone at Big Windy Hot Springs. View looking southwest up Big Windy Creek. Reed canary grass (*Phalaris arundinacea*) meadow and granite boulders are in foreground. This is the only nearly level terrain without a forest or shrub canopy in the vicinity.*

Figure 7. Winter aerial view of Big Windy Hot Springs, March 1987. Cliff and main hot springs discharge zone are located in the open treeless area in the center of this view. Patches of flowing water with no ice cover appear downstream (lower center) from the hot springs, but solid ice cover appears upstream. Note the straight edge of the white spruce dominated forest (dark trees above the cliff and opening) and paper birch dominated forest containing scattered white spruce.

within the South Unit of Steese NCA is a Congressionally designated Wild River, so any new road probably would not enter the Wild River corridor. Management of the river corridor (Figure 4) reflects guidelines of Wild River status, including a primary direction to keep management activities from becoming observable, and restricting off-road vehicles to snow machines of less than 1,500 pounds (681 kg) gross vehicle weight in the winter months (BLM 1986). The Steese plan also identifies a potential loop hiking trail from the south bank of Birch Creek at the end of the road corridor into the alpine zone south of the RNA and back to Birch Creek (Figure 4). Two trail shelters or cabins are identified for possible future construction a few kilometers north of the RNA at both ends of the loop trail (Figure 4).

Reasons for Establishing the Research Natural Area

The search for possible Research Natural Areas (RNAs) in the Steese NCA was based on pre-defined natural features of scientific interest (Juday et al. 1982). These natural features, including ecologically valuable and/or scientifically interesting plant species, geologic features, and wildlife habitats, were called "type needs" (Juday 1983). Table 1 identifies the natural feature type needs found in Big Windy Hot Springs RNA.

The principal feature on the type need list encompassed in the RNA is an undeveloped hot springs system. Big Windy Hot Springs is part of an eastern cluster of three hot springs in central Alaska. The others in this group - Circle Hot Springs and Chena Hot Springs - have been developed for commercial resort uses and are popular visitor attractions. All other central Alaska hot springs are west of Fairbanks, and most of them are either developed for resort use or have been modified for local use in a way that has substantially disturbed natural geologic features and vegetation. Many plant species at Alaska hot springs are uncommon or highly disjunct (isolated from the main area of distribution). The Big Windy Hot Springs site is essentially undisturbed by human activity.

Table 1—Natural feature types needs used in the selection of the Big Windy Hot Springs Research Natural Area

Natural feature type need	Comments and Definition
Geologic features	**Description**
Hot springs	An undisturbed spring issuing hot water and contain ing thermophytic (high temperature dependent) organisms such as green and red algae and cyanobacteria; possibly also silica cinters or travertine deposits.
Cliffs	Vertical exposures of essentially unvegetated bedrock in Yukon-Tanana uplands.
Plant communities	**Comparable Alaska Vegetation Classification Unit** (Viereck et al. 1992)
Upland white spruce dry forest	White spruce closed needleleaf forest I.A.1.j *Picea glauca/Linnaea borealis* communities
Floodplain white spruce forest	White spruce closed needleleaf forest I.A.1.j *Picea glauca/Alnus* communities
Birch dry upland dwarf shrub	Closed tall scrub birch II.B.1.c *Betula glandulosa/Ledum decumbens-Vaccinium* communities
Foliose lichen	Foliose and fruticose lichen on fellfields III.C.2.b
Animal species	Description
Dall sheep	Occurrence of the species in alpine areas of the central Yukon-Tanana uplands, isolated from the main Brooks Range and Alaska Range populations with escape terrain.

At Big Windy Hot Springs precipitation of dissolved minerals from cooling hot spring waters have formed delicate geologic structures and pools (travertine), and altered the host granite into an uncommon mineral form. These geologic features were part of the RNA type needs (Table 1), and are well represented in the site chosen. Thermophytic bacteria and algae, which thrive in water up to 61 ˚C (142 ˚F), are present at Big Windy Hot Springs. Most of these algae and cyanobacteria (primitive forms of life that are able to photosynthesize) are restricted to geothermal vents, and have not been adequately described. Careful studies of hot springs often identify species new to science. Several vascular plant species present at Big Windy Hot Springs are of scientific interest. Two species represent new distribution records within Alaska.

Figure 8. Hot water dripping over the edge of the granite cliff at Big Windy Creek Hot Springs, July 1982. In July 1996 few hot water drip zones occurred on the cliff face.

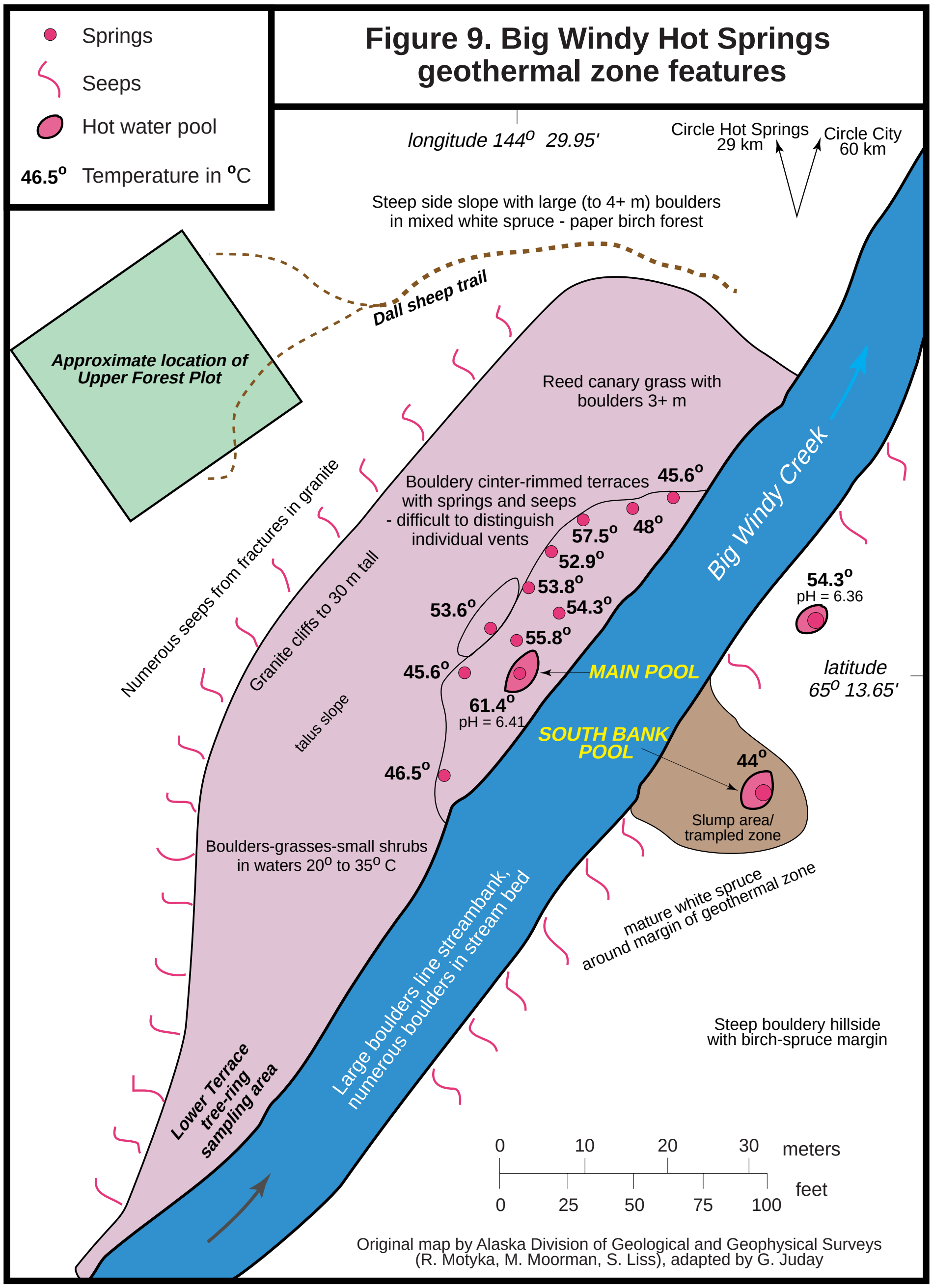


Figure 9. Big Windy Hot Springs geothermal zone features

Several species are highly disjunct, occurring hundreds of kilometers north of their contiguous distribution. Several species are at the northern limit of their distribution. Some species may be present in response to the specific chemical properties of the waters.

Several hot spring vents seep over the edge of a cliff (Figure 8, Figure 9). This cliff is a central feature of Big Windy Hot Springs RNA (Figure 10), and another component of the type needs list (Table 1). Cliffs can be important for several elements of biological diversity, especially for wildlife species. Cliffs and broken ground are much less common in the mountains of the Steese NCA than other mountain regions of Alaska.

Dall sheep in mountain regions are associated with “escape terrain” or steep cliffs and boulder slopes where they can evade predators. Dall sheep with escape terrain is another type need feature (Table 1). Dall sheep and moose are common visitors to the geothermal zone of the RNA. The waters of Big Windy Hot Springs have a high sodium content, and serve as a

Figure 10. Granite cliff zone north of Big Windy Creek. Note the large boulders that have fallen relatively recently, and the portions of the cliff that are undermined and likely to fall in the future.

Figure 11. Fractured south-facing cliff face with a patch of Populus tremuloides *(aspen) at the top. Other dry site plants find a small area of suitable habitat in areas with no tree cover along the upper edge of the cliff.*

significant (perhaps even critical) mineral lick for a substantial population of Dall sheep. Dall sheep in particular ingest brine-soaked soil or mineral precipitate associated with the hot springs. The presence of early season green forage, and its persistence into the fall, are additional factors evidently responsible for attracting sizable numbers of Dall sheep, moose, and wolves that prey upon them.

Upland and floodplain mature white spruce forest, two other type need features (Table 1), are found in small amounts in the RNA. Although white spruce forest is limited in extent in the RNA, it is of particular scientific interest because of the unique effects geothermal heating may have had on it. Big Windy Hot Springs RNA contains birch dwarf shrub and lichen communities (Table 1) that have developed over boulder rubble.

Environment

Climate

Big Windy Hot Springs is located in a mountain subzone of the central Interior Alaska climate region. The climate is highly continental with large changes in daily and annual temperature. No climate data have been collected at Big Windy Hot Springs RNA, but a relatively complete 17-year record (1963-79) is available from a National Weather Service station 40 km to the north-northwest at Central (65° 32' N, 144° 48' W, 265 m elevation) on the Yukon River lowlands. More fragmentary observations from Central extend back to 1949. Additional fragmentary weather data are available from Circle City (1957-92) and Circle Hot Springs (1949-1974), but missing observations prevent mean calculations in most months.

The major climatic types in the RNA also can be inferred from studies of the relation of climate to vegetation and topographic position done elsewhere in Interior Alaska (Haugen and others 1982, Slaughter and Viereck 1986). Climatic types in the RNA can be characterized as (1) permafrost and talus-dominated north-facing slopes south of Big Windy Creek; (2) permafrost-free south-facing slopes covered with taiga or boreal forest at 450 to 655 m elevation; and (3) open marshy ground, cliffs, and boulders receiving geothermal heating.

The region of Yukon River lowlands north of the RNA has reported the highest and lowest

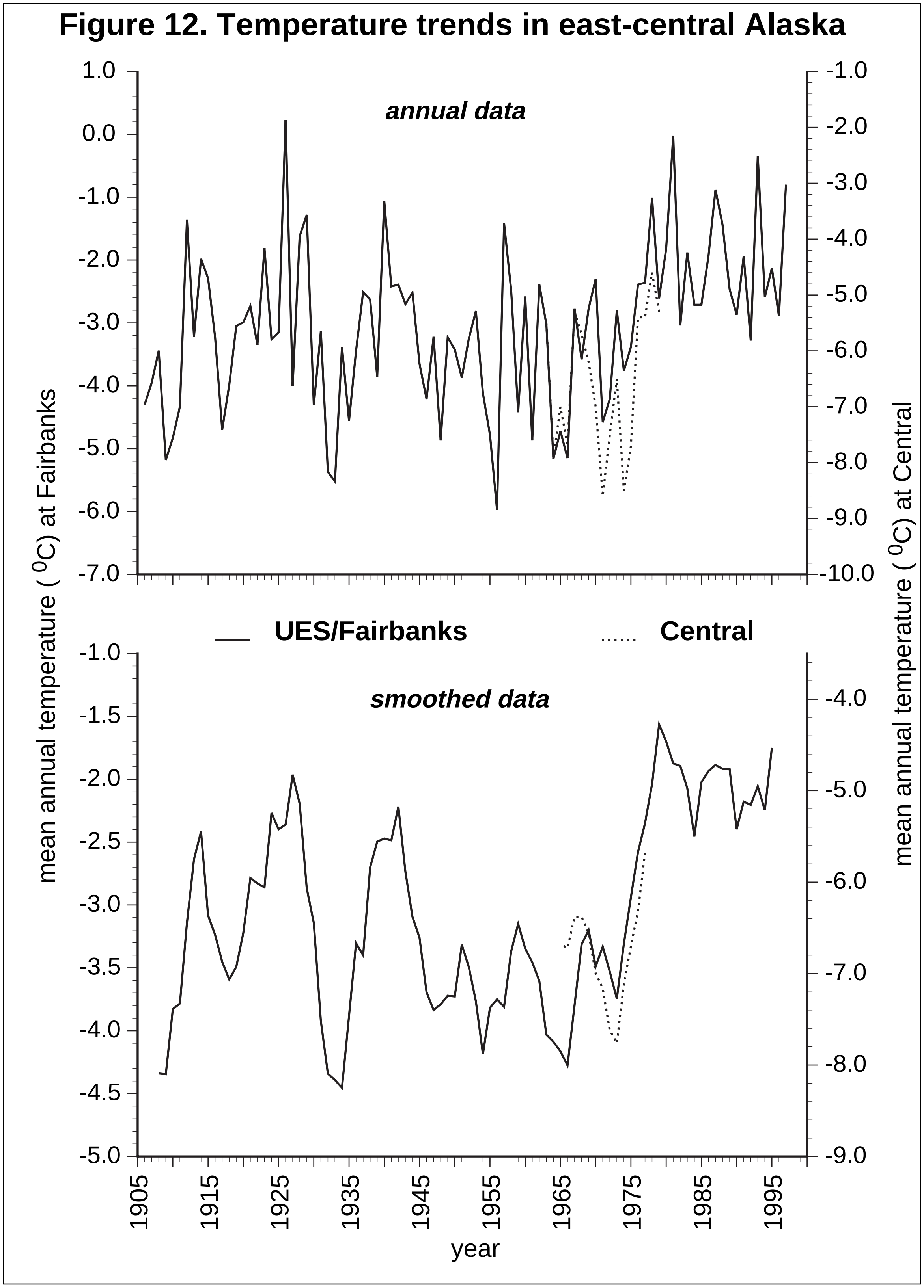


Figure 12. Temperature trends in east-central Alaska
annual data
smoothed data
UES/Fairbanks
Central
mean annual temperature (0C) at Fairbanks
mean annual temperature (0C) at Central
year
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
-1.5
-2.5
-3.5
-4.5
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995

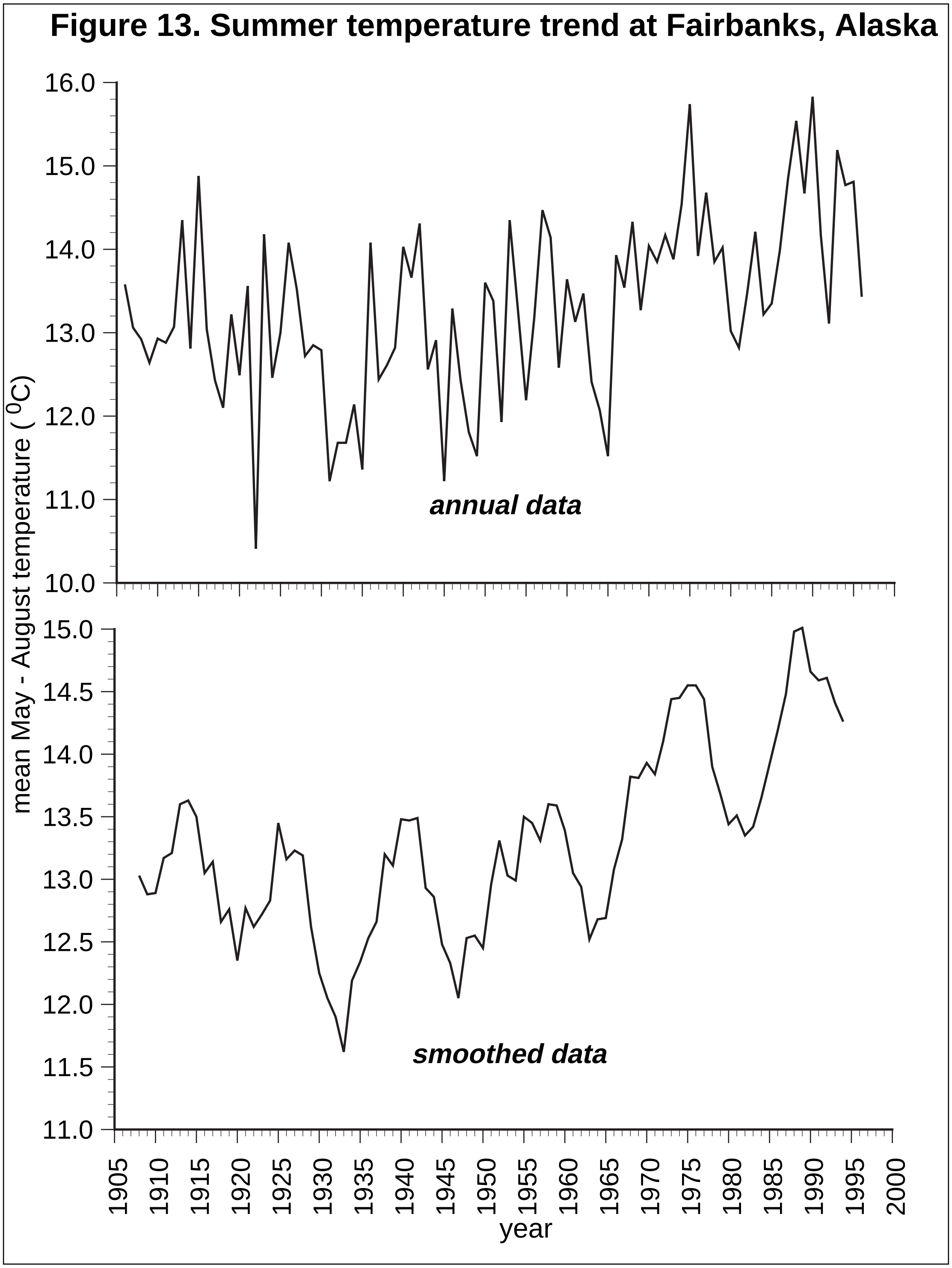
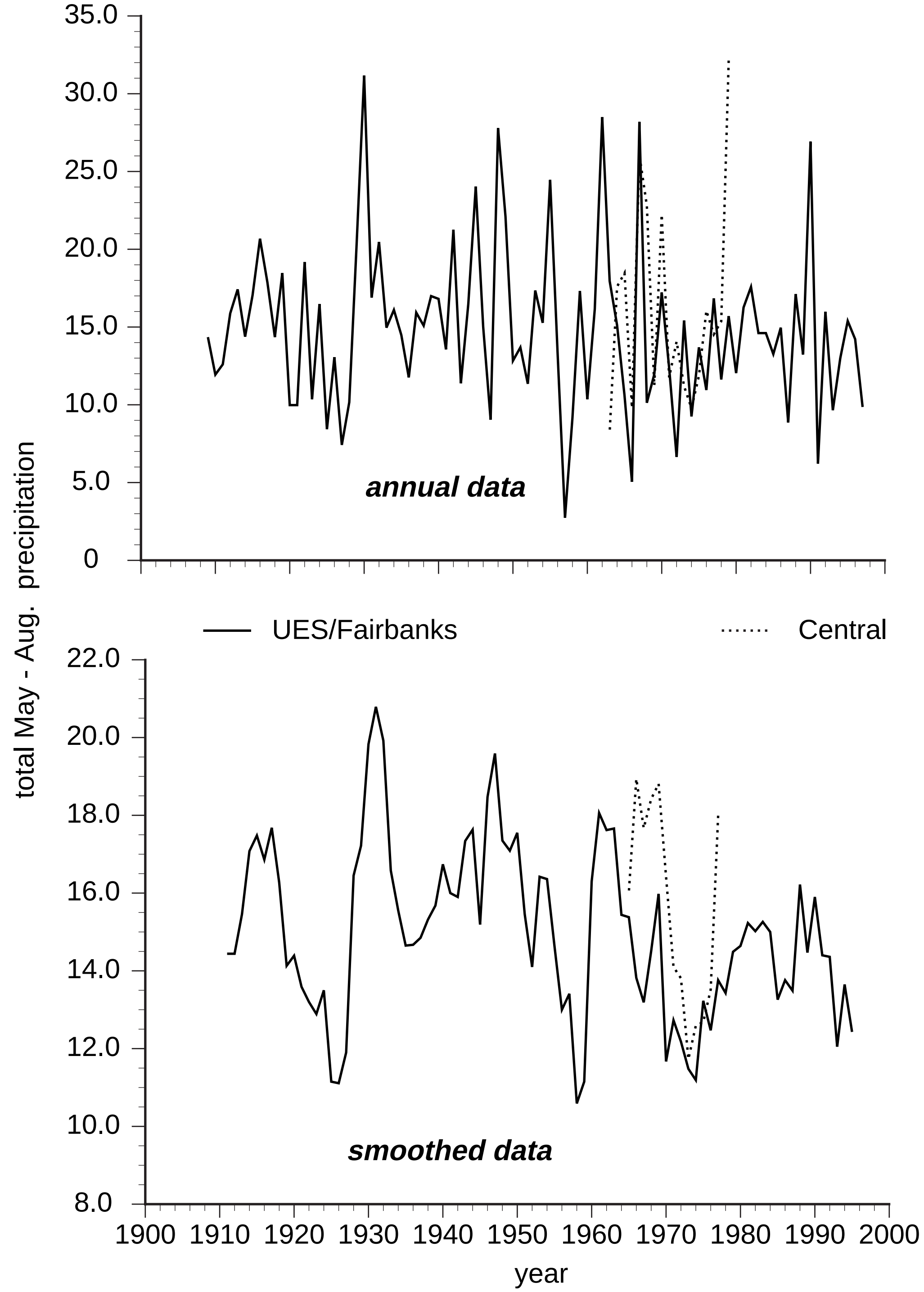


Figure 13. Summer temperature trend at Fairbanks, Alaska
mean May - August temperature (^{0}C)
annual data
smoothed data
16.0
15.0
14.0
13.0
12.0
11.0
10.0
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
year

Figure 14. Summer precipitation trends in east-central Alaska



temperatures in Alaska. The highest temperature at the Central climate station during the 17 years of record was 92 ˚F (33.3 ˚C) and the lowest was -66 ˚ F (-54.4 ˚C). However, extremes of winter low temperatures in the Yukon lowlands represent temperature inversions produced by cold air drainage. The mountain slopes of the Big Windy region are high enough to be above some of the inversion effect, and so winter temperatures are almost certainly warmer in the RNA than nearby lowlands. Summer daytime temperatures in the mountainous RNA are not as high as the Yukon lowlands because of normal adiabatic cooling and because terrain-induced convection promotes afternoon cloud buildup and convective showers over the hills while the drier lowlands remain sunny. Patric and Black (1968) calculated potential evapotranspiration and an index of aridity (potential evapotranspiration as a percentage of actual) for 322 weather stations in Alaska. Fort Yukon and Chalkyitsik in the Yukon Flats north of the RNA had the greatest moisture deficits and highest indices of aridity of all stations in Alaska. The minimum elevation at the bottom of the canyon in Big Windy Hot Springs RNA is less than 460 m (1,500 feet) and the canyon floor is directly connected to the Birch Creek lowlands (see 1,000 foot elevation contour in Figure 4) about 20 km north. Steep, south-facing habitats along the top edge of the granite cliff are clearly hot and dry (Figure 11).

Figure 12 compares the record of mean annual temperature at Central with Fairbanks. The Fairbanks data are a combination of University Experiment Station (UES) (1906-48) and the modern National Weather Service first-order station at Fairbanks Airport (1949-present). The UES/Fairbanks data make up the longest continuous climatic record that is not significantly distorted by station move available for Interior Alaska (Juday 1984). Mean annual temperatures at Central are consistently colder than UES/Fairbanks, although annual temperature trends are very closely aligned at the two stations (Figure 12). During the 1963-1979 overlap period when nearly continuous data are available from both stations, Central experienced a mean annual temperature of -6.6 °C (standard deviation $\pm$ 1.25), which is 3.8 °C (sd $\pm$ 0.51) colder than UES and well within the range of temperatures at which permafrost forms. Mean annual temperatures at Central follow the trends common to Interior Alaska stations (Juday 1984), which include a strong warming trend from 1900 to 1940, cooling until 1975, and a rapid rise in the late 1970s to record levels of sustained warmth in the 1990s (Juday 1993).

The temperature difference between Central and UES is greater in winter than summer. During the 17-year overlap period mean January temperature at Central was 6.4 °C colder than UES, and no January mean was warmer at Central than UES. By contrast mean July temperature at Central was only 0.8 °C cooler than UES, and two July monthly means were warmer at Central during the overlap period. Figure 13 shows the trend of summer mean temperature at UES/Fairbanks for most of the 20th century. Since the 1930s a strong warming trend has been underway in this part of Alaska, resulting in a rise of about 2 °C. Some ecological effects of this warming are already detectable in Alaska forests (Juday et al. 1997, Jacoby et al. 1997). Big Windy Hot Springs is a valuable location to investigate the effects of climate warming on Alaska ecosystems. Natural geothermal heating has produced a variety of effects that may be associated with sustained warmer temperatures, although many effects of climate warming are probably unique.

Annual precipitation measured at Central during the period of record ranged between 15 and 40 cm (mean 27.4 cm, sd 7.44). Because of orographic effects precipitation is almost certainly higher in the RNA than at Central, probably by a factor of 1.5 to 2 based on other studies of mountain effects on precipitation in Interior Alaska (Haugen et al. 1982). However, even a doubling of annual precipitation in the RNA compared to the Central weather station is still a modest absolute amount.

Precipitation varies more than temperature on a local scale, but a few modest differences between Central and Fairbanks can be detected. June and July precipitation were greater at

Figure 15. Close-up winter aerial view of Big Windy Hot Springs, March 1987. Main hot springs discharge zone is located in the lower left edge of the snow-covered treeless opening in the center of the picture, marked by open water in the lower meadow and stream area. A large open water pool in Big Windy Creek is visible immediately downstream (below).

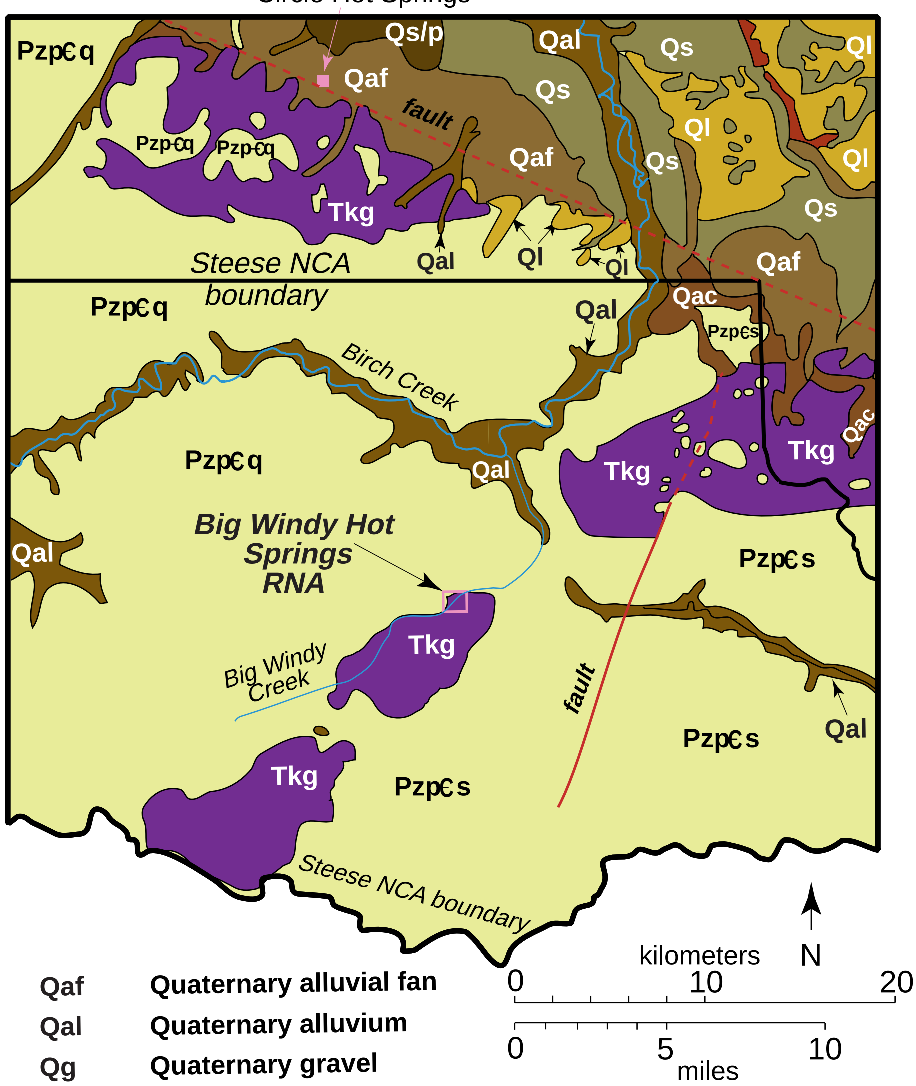
Figure 16. View from top of cliff to the southwest, July 1996. Unvegetated talus dominates slope in center and right field of view. A band of Dall sheep was later seen walking across these piles of rock, approaching Big Windy Hot Springs. Birch and spruce forest is in the foreground. Small white patch at the junction of the stream joining Big Windy Creek from the left is late-persisting aufeiss. (Photo by Jim Herriges)

Central by 1.7 cm (sd $\pm$ 2.50) and 1.2 cm (sd $\pm$ 2.95) respectively. Although isolated storms can result in a higher summer precipitation total at either station, monthly precipitation totals in June and July were greater at Central than Fairbanks 11 and 12 of the 17 years respectively. Summer precipitation has declined noticeably at Fairbanks in the late 20th century (Figure 14). Even allowing for variation between the stations in individual years, the region including Central and Big Windy Hot Springs RNA probably also has experienced decreased summer precipitation in the last few decades.

No measurements or systematic observations are available on the amount of local climatic alteration caused by Big Windy Hot Springs, although phenomena such as open water flow in the winter are obvious (Figure 7, Figure 15). Just upstream of the hot springs, aufeiss occurred in July 1996 at the mouth of the tributary stream entering Big Windy Creek from the south (Figure 16). Hot water emerges at Big Windy Hot Springs through a diffuse system, so the heat delivered to the surface is more likely to alter local climate than if the entire output were concentrated into a single pool or spring. Investigators gathering information for this report found that the atmosphere in and around the main meadow could become uncomfortably warm during periods of low or no atmospheric mixing. An area around the geothermal zone often displays a mist or haze that represents the condensation of moisture out of the warm, saturated atmosphere over the geothermally heated zone by cooler air from the surrounding region. A typical effect of geothermal warming in cold regions is to promote the early appearance of green vegetation and to delay the termination of growing season in the fall, but such observations are not available for Big Windy Hot Springs.

The hydrologic response of Big Windy Creek to warm season precipitation events is very “flashy.” Stream levels rise very quickly after storms, but drop relatively rapidly too. This flashiness is caused by limited infiltration and storage capacity of soils in the watershed, which contains extensive amounts of permafrost and bedrock near the surface. At low water stages Big Windy Creek can be crossed in the RNA by short hops from rock to rock in the

Figure 17. Bedrock and surficial geology of Steese National Conservation Area (south unit)



	Qaf	Quaternary alluvial fan
	Qal	Quaternary alluvium
	Qg	Quaternary gravel
	Ql	Quaternary loess
	Qs	Quaternary silt and organic matter (undifferentiated)
	Qs/p	Quaternary silt and peat in swamps
	Tkg	Cretaceous granite
	Pzp€q	Paleozoic and(or) Precambrian quartzite and quartzitic schist
	Pzp€s	Paleozoic and(or) Precambrian pelitic schist

(adapted from: Foster et al. 1983, Preliminary Geologic Map of the Circle Quadrangle, Alaska. U. S. Geological Survey Open-file Report 83-170-A, 24 p., 1 pl., scale 1:250,000)

Figure 18. Vertical view of pothole in granite shelf along the bank of Big Windy Creek. Boulders caught in the swirling currents in the cascade section of the stream grind into the bedrock platform of the stream, producing smooth circular depressions called potholes.

stream. In a matter of an hour or two the stream can rise nearly a meter and become a raging torrent.

Geology

Bedrock and surficial geology--- The overall pattern of bedrock and surficial geology of the south unit of Steese NCA is relatively straightforward. Larger streams flow through valleys of Quaternary alluvium eroded from the surrounding mountains. A matrix of Paleozoic or Precambrian metamorphic rock, primarily schist, is intruded by several granitic plutons (Figure 17) (Foster et al. 1983). The pluton associated with Big Windy Hot Springs is approximately 32 km^2, (11.5 mi^2) and intrudes host rock that is principally quartz-mica schist, quartzite, pelitic schist, and marble (Keith et al. 1981). The Big Windy Creek pluton is a light to medium gray, medium grained biotite-muscovite granite (Foster et al. 1983). Potassium-argon age determination on the granite gives an age of 60.6 $\pm$ 0.6 million years (Wilson and Shew 1981). East-central Alaska is extensively and complexly faulted (Foster et al. 1994). Prominent faults in the south unit of Steese NCA trend northwest-southeast north of the RNA and north-northeast east of the RNA (Figure 17).

Infiltration of water through bedrock joints and cracks comes into contact with residual heat in the plutons and returns to the surface as geothermal flow. Granitic plutons are often associated with elevated uranium levels in rock, soil, and near-surface water. Chemical analyses of rocks and/or stream sediment samples in the U.S. Geological Survey Circle map Quadrangle show no anomalous uranium values near Big Windy Hot Springs (Liss and Wiltse 1993, Wiltse 1991, Wiltse et al. 1994). The National Uranium Resource Evaluation data set shows two samples out of more than 1200 with U values over 100 ppm at the extreme eastern edge of the Circle Quad, and occasional values of 30-50 ppm associated with some of the other plutons. Uranium/Thorium-bearing plutons with mining potential typically have U values several times higher.

The granite cliff area of the RNA is one of the most constricted sections of Big Windy Creek (Figure 2). Big Windy Creek valley becomes somewhat broader upstream of the canyon section in the RNA, a classic indication of a river encountering differential erosion resistance in the bedrock it is flowing through. Big Windy Creek has effectively entrenched itself in the schist country rock, but is less effective in downcutting the granite of the Big Windy Creek pluton. Boulders dislodged from the cliff in the RNA enter Big Windy Creek, restricting streamflow and producing a cascading section of the river (Figure 1). Smaller boulders can become caught in the swirling rapids of the canyon section. Persistent circular motion of boulders caught in these powerful eddies have ground circular holes, called potholes, into the bedrock shelf along Big Windy Creek (Figure 18).

Glacial and periglacial geology--- Because glaciation is responsible for oversteepening mountain regions, the distribution of glacial versus non-glacial terrain is important for wildlife such as Dall sheep that depend on features such as cliffs and headwalls. The contrast in soil characteristics between glaciated and unglaciated areas also is great. During the

Figure 19. Slope and summit south of Big Windy Hot Springs RNA looking east. Big Windy Hot Springs is located in the center left. Area in view is the north portion of Big Windy Creek granite pluton. Note the rounded topographic contours characteristic of unglaciated terrain. Periglacial landscape processes have predominated in this landscape. Semi-circular dark vegetation feature on the left is a zone of taller woody vegetation, primarily paper birch, that stands above surrounding lichen/moss mat and shrub tundra. Sites with deeper seasonal thawed soil within this permafrost-underlain slope support taller, more productive vegetation. Gravity and frost sorting of talus rock produce these effects.

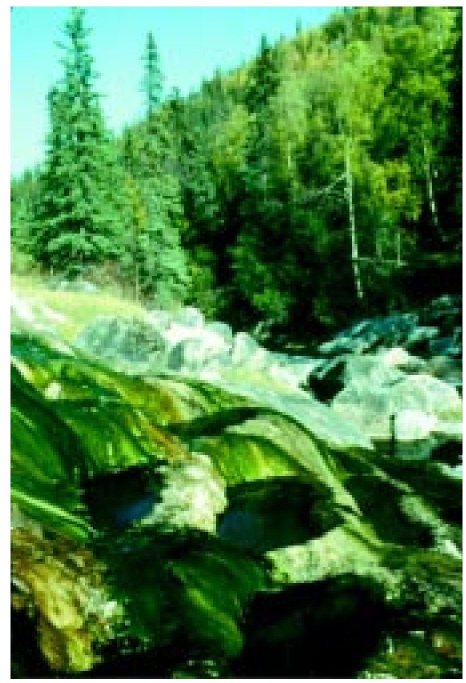


Figure 20. View of highest temperature hot spring vent, (Main Pool) September 1984, looking downstream or northeast. Hot water carries a load of dissolved minerals that come out of solution when cooled, leading to the buildup of mineral terraces (probably silica cinters in this view). Abundant high temperature algae and bacterial mats are present, especially the green mats which cover the slopes. (BLM photo)

Wisconsin glacial period the mountains of east-central Alaska supported small, isolated mountain glaciers within the large unglaciated region between the continuous ice sheets of the Alaska Range and Brooks Range mountains (Pewe et al. 1967, Porter et al. 1983, Weber 1986).

Big Windy Hot Springs RNA is near the boundary of glacial and non-glacial terrain. The largest contiguous area of mountain glaciers in the Yukon-Tanana Uplands was located 10 to 40 km southeast of the RNA (Weber 1986). Alpine areas on the ridges immediately north and south of the RNA (Figure 5) appear not to have been glaciated. Landforms there are smoothed and rounded (Figure 19), and steep headwall features characteristic of glacial plucking are absent. The middle and lower sections of Big Windy Creek valley are V-notched, typical of landscapes that have experienced predominantly water erosion, compared to the U-shaped profiles of glaciated valleys. The uppermost headwaters region of Big Windy Creek displays glaciated terrain features, and glaciation was extensive in the adjacent Chena and Salcha headwaters south of the watershed divide.

A study of the glacial landforms of Mt Prindle 100 km northwest of Big Windy Creek Hot Springs RNA recognized four glacial episodes (Weber and Hamilton 1984), with the earliest and the most extensive (Prindle glaciation) occurring more than 250,000 years ago. Extensive valley glacial deposits of the Prindle glaciation were not covered by later glacial advances. The last two glacial stages are interpreted as representing the Early Wisconsin (earlier than 40,000 years ago) and Late Wisconsin periods (Weber 1986). The area covered by Late Wisconsin glaciation is estimated to be about one fourth of the maximum glacial extent (Weber 1986) in the earlier glaciations.

During the Late Wisconsin stage most glaciers of the Yukon-Tanana Uplands originated at elevations above 1,600 m and flowed down to minimum altitudes of about 900 to 1,200 m (Weber 1986). Post-glacial weathering processes have somewhat smoothed and subdued the topography on the older glacial landforms. The steepest glacial terrain is restricted to the smaller area of Late Wisconsin glaciation.

During the period of glaciation the mountains of east-central Alaska were subjected to a severe, cold-dominated climate that produced a characteristic set of periglacial landscape features, including cryoplanation terraces (Pewe et al. 1983). Cryoplanation terraces are minor tablelike landforms made up of nearly horizontal bedrock surfaces covered by a veneer of rock debris and bounded by stair-like bedrock scarps (Pewe et al. 1983). The summit region south of the RNA is a moderately developed cryoplanation terrace formed in the Big Windy Creek pluton (Figure 9). The cryoplanation rock debris at the base of the pluton is a dominant feature of the south half of Big Windy Hot Springs RNA (Figure 16)

Geothermal features-- The first published reference to Big Windy Hot Springs is found in the U.S. Geological Survey report *Mineral Springs of Alaska*, but the author of that report did not visit the site (Waring 1917). His information was based on reports from prospectors who had been to the site, probably as a result of reports from Native people.

Keith and Foster (1979) describe the general setting and physical/chemical characteristics of Big Windy Hot Springs. They note the presence of small buff- to white-colored travertine terraces, especially on the north bank of the creek (Figure 20). There are fragments of granite and manganese oxide in the travertine. Keith and Foster (1979) reported a temperature of about 58 ^{o}C (136 ^{o}F) and a pH of about 6.9 for the main vent. Rate of flow was difficult to measure because of the diffuse and scattered nature of the many springs, but was estimated to be about 8 liters per minute from the largest springs at the time of their investigation in 1978. The standard compilation of geothermal resources of Alaska (Motyka et al. 1983) estimated the combined hot water discharge of all springs and seeps at the Big Windy site as 900 l/min. and an overall pH of 6.41.

Figure 9 displays temperature measurements from the site investigation of Big Windy Hot Springs by the Alaska Division of Geological and Geophysical Surveys (DGGS) (Shirley Liss personal communication) in 1981. Some hot water springs

Figure 21. Cliff face at Big Windy Hot Springs, July 1996. The green color on the cliff is caused by the growth of high-temperature algae, white color represents a light crust of mineral precipitate. Note the accented vertical and horizontal joints in the cliff face. (Photo by Jim Herriges)

Figure 22. View of highest temperature hot spring vent, July 1987, looking north. At this time the flow of hot water is noticeably less than in 1984. Only a small area of green high temperature algal mat remains, although some water movement through pinkish mats is taking place.

Figure 23. View of highest temperature hot spring vent, July 1996, looking upstream or south southwest. Very little hot water flow was present at this time. The slope in the lower right was completely dry and all high-temperature algal and bacterial mats there are dead and crusted.

Figure 24. Close view of dead and crusted algal or bacterial mats at highest temperature hot spring vent, July 1996. Thin evaporite mineral crusts are present. Churned condition of mud is caused by Dall sheep trampling and ingesting of mud and mineral crusts as a "salt lick."

pour over the cliff face (Figure 8) or seep over the cliff face (Figure 21). The hottest waters have been measured at 61 °C (142 °F) in the main pool (Figure 9, Figure 20, Figure 22, Figure 23). DGGS data, as well as measurements made during the site visits for this report, indicate that water temperatures are more typically in the 40° to 48 °C range (104 to 118 °F) in the smaller pools and seeps.

Most of the hot water is slightly saline, primarily from an elevated sodium chloride content. The geothermally heated water of Big Windy Hot Springs also has a high carbonate content, especially when compared with Chena Hot Springs and Circle Hot Springs. Elevated carbonates can be explained by the deep movement of groundwater and its leaching of marble interbeded in the metamorphic country rock (Keith and Foster 1979). Isotope values of dissolved carbon in the water indicate an origin in marine limestone (Miller 1973). Additional solutes reported include potassium, sulfate, fluoride, silicon oxide, and boron (Keith and Foster 1979). A thin coating of amorphous silica covers travertine. The presence of silica in this form is significant, as it provides a model for the occurrence of laumontite, a hydrous calcium aluminum silicate mineral, in the nearby area (Keith et al. 1981).

The DGGS team used their data to compute an estimate of reservoir temperature using a number of silica and cation geothermometers. The best estimate of reservoir temperature is 153 °C (307 °F), based on close agreement between one of the quartz and the Na-K-Ca geothermometers (Shirley Liss personal communication). USGS isotope analyses confirm that the major component of hot spring discharge is meteoric (water circulating at depth) as is the case with most Interior Alaska hot springs. Given the reservoir temperatures, the waters probably circulate to a depth of 5-6 km before emerging at the surface (Shirley Liss personal communication).

At all hot springs the gradual accumulation of mineral precipitate eventually constricts the flow of hot water from specific individual vents and forces hot water to emerge at other vents, either new or re-activated. The effects of the process of redirected flow can be seen at Big Windy Hot Springs in the occurrence of two or three dormant vents that are dried out, have decomposing mineral precipitate crusts, and lack live mats of high temperature-dependent algae and bacteria.

However, during the 1996 site visit (July 12 -14) for this report a generally reduced volume and flow of hot water in all vents was observed. Evidence included dead and desiccated algal mats along the upper edge of most hot spring pools (Figure 22, Figure 23, Figure 24) and reduced (or absent) hot water flow over the cliff (Figure 8) and downstream of hot spring pools (Figure 23). A widespread evaporite crust was present around most hot spring pools. Ground that had previously been saturated with tepid water in the open marsh zone was dry enough to support foot traffic. The general reduction of hot water seen in 1996 could be the result either of fault movement altering the location of fracture zones in the rock along which the water flows, or a reduction of groundwater because of a change in regional climate. Climate warming and drying in east-central Alaska discussed earlier in this report is consistent with the second interpretation. No large earthquakes that might have changed flow patterns have occurred in the vicinity of the RNA since 1980 (Shirley Liss personal communication).

Soils

No intensive soil surveys have been done in the RNA. The topography of Big Windy Hot Springs RNA includes rough, mountainous terrain and a small area of high terrace on the flood plain of Big Windy Creek. South-facing slopes in the RNA appear to be permafrost-free, based on forest types occurring there (Figure 15). North-facing slopes are underlain by permafrost.

Mass wasting processes have caused talus to accumulate in lobate formations south of Big Windy Creek around the margin of the erosion-resistant core of the Big Windy Creek pluton (Figure 19). Areas of granite talus and bedrock knobs at the highest elevations south of the RNA exhibit poor soil development and are virtually unvegetated (Figure 16). Soils in talus materials are Lithic Cryorthents derived from granite. They are well drained, variable depth over bedrock, and may be frozen at the base although they are not ice-rich. Areas of stable granite talus are covered with a continuous vegetation cover and well developed organic layer (Figure 25). These sites are characterized by Histic Pergelic Cryorthepts.

The soils of the Big Windy Creek canyon floodplain and terraces occur over poorly sorted alluvium with an abundant coarse fraction, including rounded river gravel and boulders and angular colluvial material. These soils appear to be well-drained, permafrost-free Cryorthepts. Geothermal heating may be partly responsible for the permafrost-free condition in the bottom of Big Windy canyon; upstream of the RNA the lowlands of Big Windy Creek appear to be entirely permafrost, probably because of elevation and shading effects.

Figure 25. View from top of cliff to the southeast, July 1996. Open vegetation type on mid and upper slope is shrub tundra and open black spruce woodland. (Photo by Jim Herriges)

Table 2—Properties of low elevation soils in Big Windy Hot Springs Research Natural Area

Sample locality	pH	Organic Matter	Coarse Fraction (> 2 mm)	CEC	P	K	Ca	Mg
		percent	percent		p/m	p/m	p/m	p/m
Trampled Slope	8.76	0.94	48.61	5.8	8	162	7210	63
Forest Slope	5.84	6.16	10.54	20.9	161	777	1932	356

Samples analyzed at Forest Soils Laboratory, University of Alaska Fairbanks.

Steep south-facing lower slopes in the RNA include areas of Typic Cryochrepts with moderate to abundant coarse fraction. A light silt cap is generally present, especially near the base of the slope. Limited areas of deeper silty deposits on south-facing toe slopes and benches are Loamy Aeric Cryorthepts.

Table 2 gives the results of lab analysis of soils at a geothermal and forest location in the RNA. The Trampled Slope soil sample was collected just below (east of) the South Bank Pool location (Figure 9 and Figure 26). The Forest Slope soil sample was collected in the Upper Slope forest plot (Figure 9 and Figure 21). The Trampled Slope soil contains a considerable coarse fraction and little organic matter, partially due to the unvegetated condition of the soil at the time of collection. The high pH and elevated calcium level probably reflect a high evaporative rate and thin surface crust, partially visible in Figure 8, from geothermal heating. The Forest Slope soil has the pH, organic content, and coarse fraction typical of mountain forest soils in Interior Alaska, but the level of base cations is also elevated. The Forest Slope soil is productive as indicated by white spruce annual radial growth rates of 0.5 to 1.0 mm/year on a sustained basis.

Granite is generally an erosion- and weathering- resistant rock, but when feldspar minerals in granite weather to clay particles they expand, contributing to fragmentation of the rock. Water freezing in joints and cracks in granite expands, contributing to the breakup and eventual weathering of the rock. Most chemical weathering reactions in soils are temperature dependent, so the elevated temperatures of hot spring discharge intensifies bedrock and soil weathering processes. Several good examples of granite gruss (in-situ products of granular disintegration of granite) can be found along the hot water drip zone at the base of the granite cliff (Figure 27).

Biota

Vegetation

***Flora*—**Table 3 is a list of 106 vascular plants collected or observed in Big Windy Hot

Figure 26. Dall sheep trampling zone around south bank hot spring pool, July 1987. Note the position of the recently fallen log across the top, flow of hot water in upper right, and general lack of ground vegetation.

Figure 27. Deeply weathered granite boulders, also called gruss, at the base of cliff. These rocks crumble into pebbles when handled. Hot water dripping over granite appears to have accelerated weathering of feldspar minerals, undermining strength of the rock. Infiltration of hot water along joints and fractures in the rock could lead to accelerated sectioning of boulders off the cliff.

Figure 28. Close view of the tall coarse grass Phalaris arundinacea *in the wet hot spring meadow. This species is primarily found in the temperate and southern boreal forest regions of North America. Big Windy Hot Springs is about 800 km north of the area of its general distribution. The species occurs at only a few sites in Alaska.*

Springs RNA. Thirty-seven plants are common, widespread species whose presence was noted in the field. Voucher specimens of 69 additional species are have been deposited in the University of Alaska Herbarium. Most of the observations and collections were made on the north bank of Big Windy Creek in the immediate vicinity of the main hot spring vents, and the lower south-facing slopes nearby. Some observations were made on the south bank in lower elevation forest near the stream and near secondary geothermal seeps. Notes and collections were made during site visits in 1982, 1987, and 1996. Initial collections and notes in 1982 and 1987 were made by the author during one-day site visits. Subsequent assistance in taxonomic identification was provided by Alan Batten and Carolyn Parker at the University of Alaska Herbarium. Carolyn Parker carried out the principal 1996 collection (July 12 to 14) and identification effort for vascular plants. Big Windy Hot Springs was one of several sites in the Steese NCA and White Mountains National Recreation Area surveyed in 1996 for vascular plants (Parker et al. in preparation). Most mosses and bryophytes present in Big Windy Hot Springs were collected in 1996, but identification of the collection awaits additional support.

The geothermal zone at Big Windy Hot Springs RNA supports several floristic anomalies of scientific interest. One species ranked as “state-sensitive” was found in the RNA, *Phalaris arundinacea*, Reed canary grass (Figure 28). This species dominates the meadow vegetation in the main geothermal zone (Figure 29). The species is about 800 km disjunct northwest of its contiguous distribution in the temperate forest and southern boreal forest (Hulten 1968). *Phalaris arundinacea* is ranked S3 (rare statewide) by the Alaska Natural Heritage Program. It is also found at Kanuti Hot Springs (66° 21'N, 150° 51'W; collections of the University of Alaska Herbarium) and the species has also been observed at Tolovana Hot Springs (65° 16'N, 148° 52'W; Carolyn Parker personal communication), two similarly disjunct sites in Interior Alaska. Species with this type of distribution are often dispersed by migratory birds that transport seeds to isolated pockets of suitable habitat.

Patches of *Thelypteris phegopteris*, the northern beech fern (Figure 30) and scattered occur-

Table 3—Vascular plants collected or observed in Big Windy Hot Springs Research Natural Area

Species	Collection and habitat notes
Achillea sibirica	s.n.
Aconitum delphinifolium	6619; forest openings
Actaea rubra	6627
Adoxa moschatellina	6632
Agrostis mertensii	6642
Agrostis scabra	6622
Alnus crispa	s.n.
Arabis divaricarpa	6597
Arabis hirsuta	6616
Artemisia alaskana	6599
Artemisia tilesii	s.n.
Aster sibiricus	Obs3, stony terrace, rocky south slopes
Betula glandulosa	Obs2,
Betula papyrifera	Obs3
Bistorta vivipara	Obs3
Bromus pumpelliana ssp. *arctica*	6614
Calamagrostis canadensis	6639, dominant grass of forest understory
Calamagrostis lapponica	s.n.
Calamagrostis purpurascens	6646
Carex capillaris	6638
Carex media	6643
Chenopodium album	6596, 6648
Chrysosplenium tetrandrum	6625
Circaea alpina	s.n., 6607
Cornus canadensis	Obs3
Cornus stolonifera	6617, pockets of soil/boulders, Big Windy Creek
Cystopteris fragilis	s.n., 6637
Delphinium glaucum	6645
Dryopteris expansa (dilatata?)	s.n.
Dryopteris fragrans	s.n.
Eleocharis palustris	s.n., wet, peaty soils near geothermal vents & seeps
Elymus macrourus	6635
Elymus trachycaulus ssp. *major*	6592, 6608
Elymus trachycaulus ssp. *novae-angliae*	6615
Elymus trachycaulus ssp. *violaceus*	6644
Empetrum nigrum	Obs2,
Epilobium angustifolium	Obs3
Epilobium ciliatum ssp. *adenocaulon*	6591
Epilobium ciliatum ssp. *glandulosum*	6631
Epilobium hornemannii	s.n., geothermally-heated, wet ground near vents
Epilobium latifolium	Obs2,
Equisetum arvense	s.n.
Equisetum pratense	Obs1, understory, south bank Big Windy Creek
Erigeron acris	6618
Erysimum cheiranthoides	6598
Galium boreale	Obs3, white spruce forest understory
Gentianella propinqua	s.n.
Geocaulon lividum	Obs2,
Gymnocarpium dryopteris	s.n., 6628
Halimolobus mollis	6593
Hedysarum alpinum	Obs3
Hierochloe odorata	6603
Huperzia selago	s.n.
Juncus bufonius	6595
Juncus castaneus	6630
Juniperus communis	Obs3
Ledum decumbens	Obs2,
Ledum palustre	Obs2
Linnea borealis	Obs2

Lycopodium annotinum	s.n.
Mertensia paniculata	Obs3
Minuartia rubella	6611
Moehringia lateriflora	Obs3
Parnassia kotzebuei	Obs3
Parnassia palustris	Obs3, wet open ground, organic soils
Petasites frigidus	Obs2,
Phalaris arundinacea	6612, geothermally-heated ground
Picea glauca	Obs1
Picea mariana	Obs1
Poa alpigena	s.n.
Poa glauca	6601
Poa pratensis	6634
Polygonum alaskanum	s.n.
Populus balsamifera	Obs3
Populus tremuloides	Obs3
Potentilla fruiticosa L.	Obs1, rocky skree slopes
Potentilla pensylvanica	6613
Puccinellia borealis	6594
Puccinellia interior	6605
Pyrola asarifolia	6629
Ranunculus cymbalaria	6606, , brackish water, spread by disturbance
Ranunculus hyperboreus	6623
Rhodiola integrifolia	Obs3
Ribes lacustre	6647
Ribes triste	s.n.
Rosa acicularis	Obs3, dry white spruce forest understory
Rubus idaeus	Obs3, thickets, south slope, forest edge
Salix alaxensis	Obs3
Salix bebbiana	Obs3
Saxifraga nelsoniana	s.n.
Saxifraga punctata	specimen,
Saxifraga tricuspidata	Obs3
Sedum rosea	specimen,
Senecio pauciflorus	s.n., 6620
Shepherdia canadensis	6604
Solidago multiradiata	s.n.
Sorbus scopuliana	Obs2,
Spirea beauvardiana	Obs1, south slopes above hot springs, dry soil
Stellaria calycantha	6633A
Taraxacum ceratophorum	s.n.
Thelypteris phegopteris	6626
Trientalis europaea	6640
Trisetum spicatum	6641
Vaccinium uliginosum	Obs3
Viburnum edule	Obs3
Viola biflora	6624
Viola renifolia	6636
Wilhelmsia physodes	6633
Zygadenus elegans	Obs1, dry openings, top of cliff edge

106 total species
Obs1 = plant observed in field (but not collected) during first site documentation visit, July 1982.
Obs2 = observed during second site documentation visit, July 1987.
Obs3 = observed during third site documentation visit, July 1996.
s.n. = sans number, collected July 1987, in collection of University of Alaska Herbarium
6633 = accession number of University of Alaska Herbarium, collected July 1996.

Figure 29. Wet hot spring meadow with granite boulders, located between the cliff and Big Windy Creek. Meadow is dominated by the grass Phalaris arundinacea*.*

Figure 30. Close view of the northern beech fern Thelypteris phegopteris*. The Big Windy Creek location is about a 200 km extension northward of the previously known distribution limit of the species.*

rences of *Viola renifolia* in the moist shady forest understory around South Bank Pool (Figure 9) represent moderate northward range extensions of ca. 200 km for both taxa beyond the distribution limits indicated in Hulten (1968).

Ranunculus cymbalaria has a highly fragmented distribution in Alaska, with a few populations in widely scattered areas of the state. It is known to occur in moist areas and brackish water, and to be spread by human disturbance (Hulten 1968). At Big Windy Hot Springs, it is found on ground disturbed by Dall sheep and moose trampling immediately adjacent to hot springs. *Epilobium hornemannii* has been found at other Alaska hot springs and is at its northern distribution limit in the RNA (Figure 31). *Puccinellia borealis* and *Circaea alpina* are common in wet herbaceous meadows or openings but have widely fragmented or disjunct distributions in Interior Alaska. *Gymnocarpium dryopteris* (oak fern) was collected in the forest understory on the south bank of Big Windy Creek just beyond the warm pools but probably within a diffuse geothermal heating zone. The species is also at or near the northern limit of its distribution. The spike rush *Eleocharis palustris* and *Parnassia palustris* occur on wet, peaty soils near the geothermal vents.

The granite cliff above the springs supports small patches of *Populus tremuloides* and *P. balsamifera* and some floristic elements of dry graminoid vegetation (Figure 11). The very limited treeless area at the top edge of the granite cliff supports steppe vegetation elements including *Poa glauca, Calamagrostis purpurascens, Artemisia alaskana, Artemisia tilesii, Arabis divaricarpa, Potentilla pensylvanica, Halimolobus mollis,* and *Zygadenus elegans.* This cliff edge showed evidence of frequent use by Dall sheep as a bedding site.

On the north bank of Big Windy Creek in the vicinity of the hot springs, the vegetation grades from open mixed white spruce-paper birch with a shrub understory dominated by *Cornus stolonifera* (Figure 32), *Rosa acicularis,* and *Alnus viridis* ssp. *crispa* to an open meadow near the springs dominated by *Phalaris arundinacea, Equisetum arvense, Eleocharis palustris,* and other herbs

The few geothermal seeps on the south bank of Big Windy Creek are found in the lush

Figure 31. Close view of the willow-herb Epilobium hornemanii*, a species at the northern limit of its distribution at this site.*

Figure 32. Cornus stolonifera *(Red osier dogwood) in flower, along Big Windy Creek.*

Figure 33. Same location as in Figure 26 July 1996. Fallen log across the top is still present, but no flow of water is present, and ground is generally covered by the grass Calamagrostis canadensis*.*

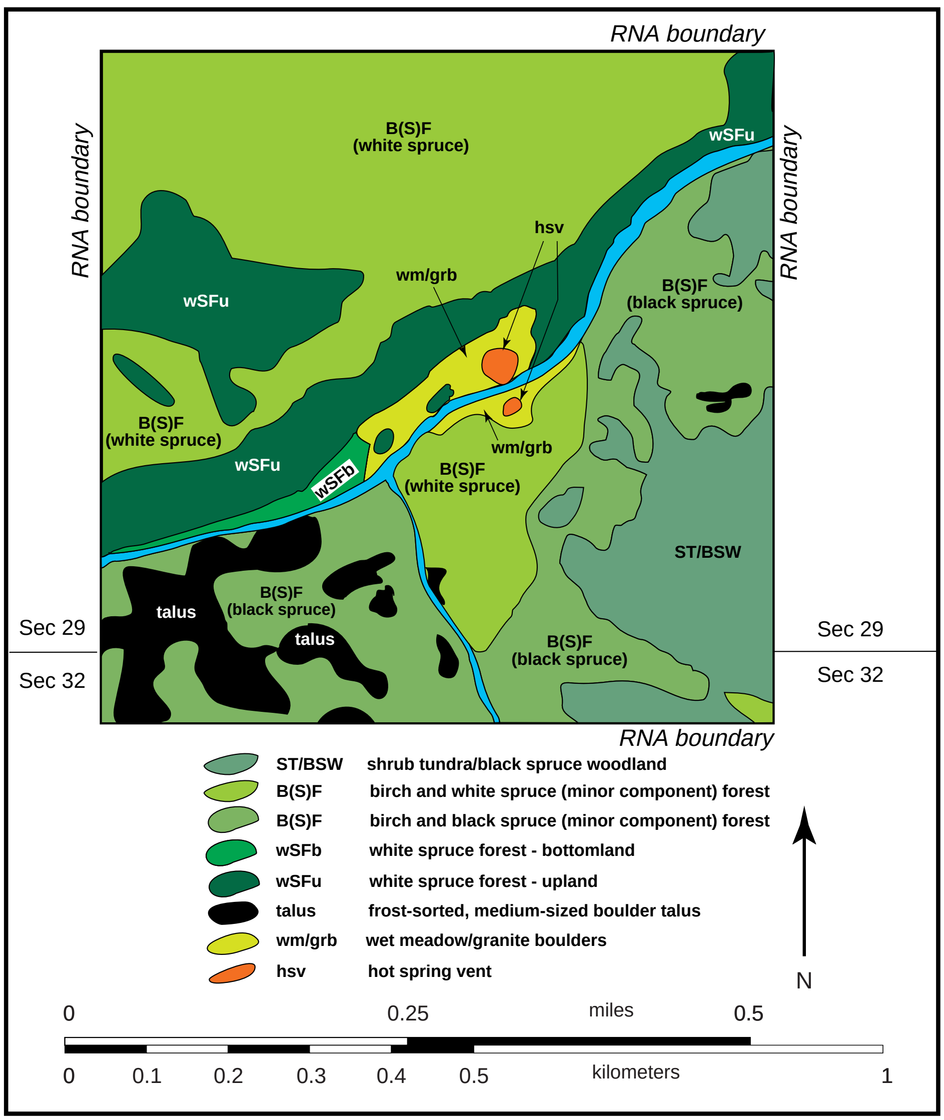
understory of a closed white spruce-paper birch forest. South Bank Pool and a sparsely vegetated seepage slope form a forest gap that is highly disturbed by concentrated moose and Dall sheep activity. *Calamagrostis canadensis* (bluejoint grass) increased in cover and dominance in the forest understory on the south bank of Big Windy Creek between 1987 and 1996 (Figure 26 and Figure 33). Trampling activity appears to have been reduced during the nine years between visits, possibly because of reduced mineral availability.

Plant communities- White spruce upland forest (Figure 34) was defined in the type needs list (Table 1). Despite its small size, which would ordinarily not allow it to adequately represent a forest type, the white spruce forest at Big Windy Hot Springs is of scientific interest because of geothermal ground heating. Cold soils are generally a limiting factor in forest growth in central Alaska (Van Cleve and Yarie 1986, Van Cleve et al. 1983). However, diffuse geothermal heating of the ground some distance from the immediate hot spring vents may affect forest growth at Big Windy Hot Springs. The geothermal ground heating can be looked at as a sort of natural experiment which overcomes one of the most important natural environmental limitations to forest growth in the region.

Figure 35 shows the distribution of the main vegetation communities in Big Windy Hot Springs RNA. Big Windy Creek canyon generally lacks a well developed floodplain or terraces, but just upstream of the hot springs is a tiny area of bottomland white spruce forest. A mature upland white spruce forest with a *Linnaea borealis* and/or *Rosa acicularis* under-

Figure 34. Productive white spruce upland forest near the upper edge of the cliff in Big Windy Hot Springs RNA, July 1996. Upper Forest plot is located in this stand and tree ring samples were collected here. Note the dead trees (center) killed by bark beetles.

Figure 35. Vegetation cover map of Big Windy Hot Springs Research Natural Area (1996)



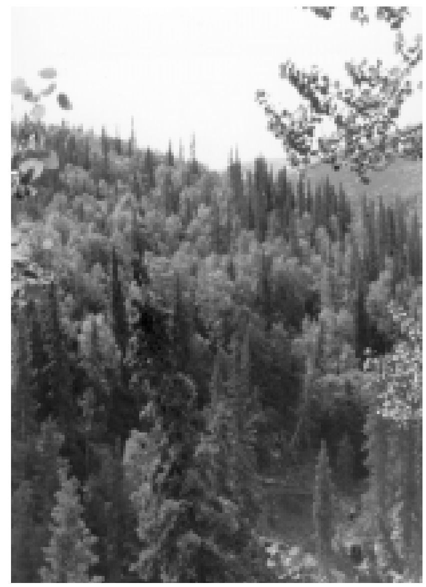
Map produced by G.Juday from field notes, ground photos, vertical and oblique air photos

Figure 36 Understory of Upper Forest plot, July 1987. Dominant plants are moss and Linnaea borealis *(twinflower).*

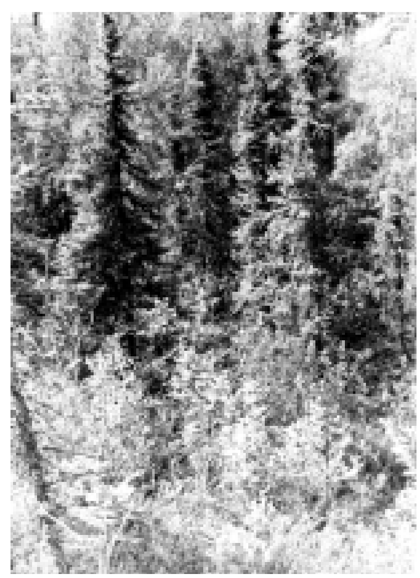
Figure 37. Birch and scattered white spruce on the east-facing slope south of Big Windy Creek in the center of Big Windy Hot Springs RNA. Lower elevations in this view probably receive some diffuse geothermal soil heating, increasing the site productivity compared to similar nearby slopes.

Figure 38. Black spruce woodland and glandular birch shrubs in the southeast portion of Big Windy Hot Springs RNA. The ground is generally stony but mostly covered with a moss/lichen mat and organic litter.

story (Figure 36) occurs in a strip at low elevations on the south-facing slope above Big Windy Creek. A sharp boundary (Figure 7) marks the upper edge of the upland white spruce forest and a paper birch forest with a minor component of white spruce. The birch forest with minor white spruce occupies most of the south-facing slope above (north of) the strip of white spruce forest along Big Windy Creek.

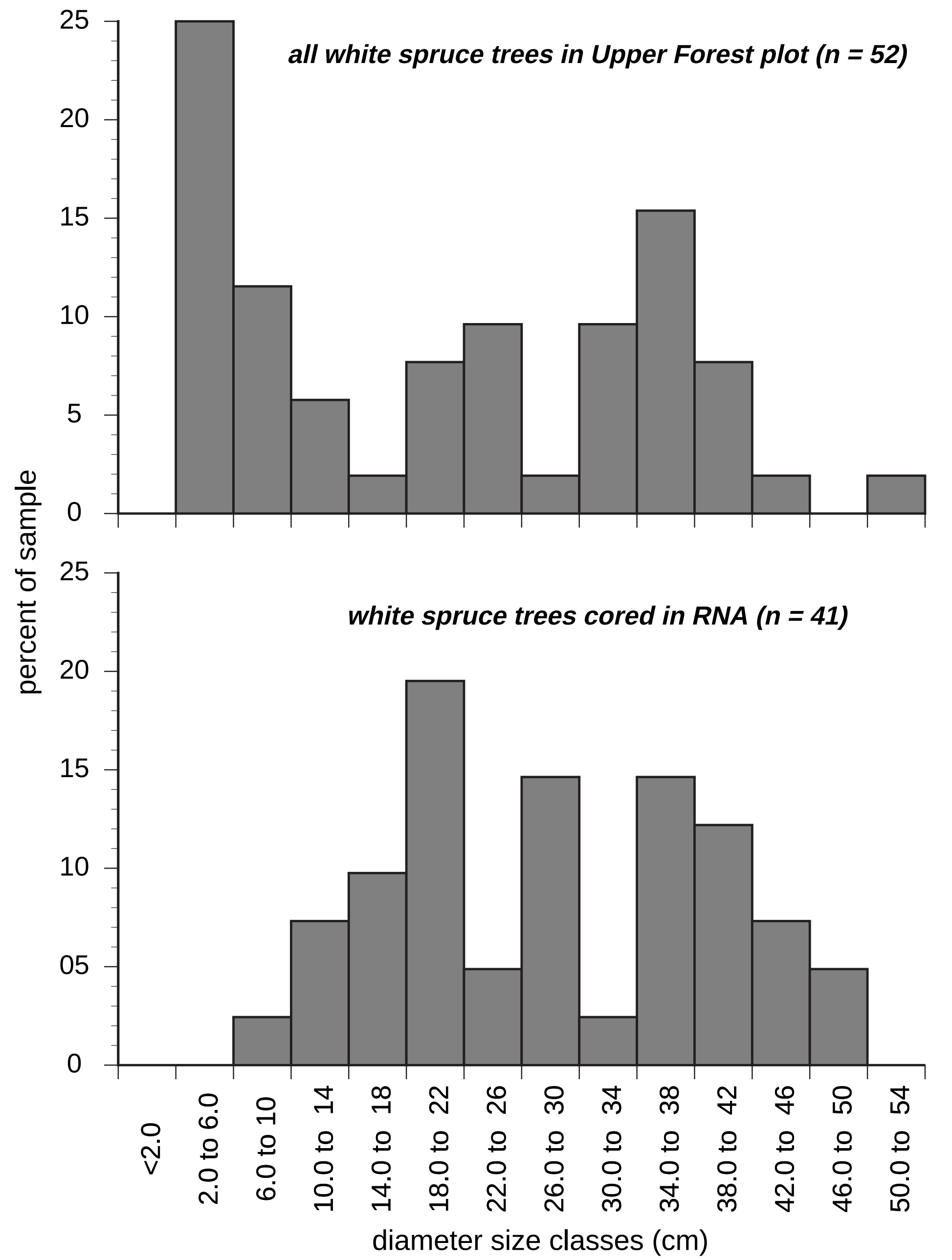


South of Big Windy Creek the paper birch forest with minor white spruce is also found on west-facing slopes and the vicinity of the hot spring discharge zone (Figure 37). A less productive and shorter birch forest with a black spruce component is found on much of the northwest-facing slopes of the RNA and it grades into a glandular birch shrub tundra/black spruce woodland (Figure 38). North-facing slopes in the south half of the RNA include talus piles with very little vegetation cover (Figure 16). In the southeast corner of the RNA a fruticose and foliose lichen/moss mat covers an organic mat over stable talus.



Forest growth— In 1987 a 25 m by 25 m reference plot was established in mature white stand in the area above the cliff (Figure 9). All trees were mapped and diameters were measured. Metal conduit posts were placed at the corners. Table 4 gives the size and structural characteristics of the Upper Forest plot. In 1987 dominant white spruce trees in the Upper Forest plot were 30 to 35+ m in height, and co-dominant spruce were 25 to 30 m. Figure 39 gives the diameter size class distribution of white spruce from the plot. Two size class peaks occur, with the larger class at the 34 to 38 cm range and the smaller group mostly below 10 cm. Based on a few tree cores that date at a minimum to the 1860s, the results indicated that it was one of the more productive white spruce stands in the Alaska RNA network (Juday 1989, Juday 1992). A record high total snowfall in the winter of 1990-91 and an early, heavy snowfall across Interior Alaska on September 12, 1992 resulted in heavy

Figure 39. White spruce diameter distribution at Big Windy Hot Springs



loading of tree crowns. Many tree tops snapped under the load (Figure 40). Spruce bark beetle attacks on the weakened trees followed, causing additional tree death. Additional stress to trees could result in further attacks and more mortality (Werner et al. 1978).

Although the general vicinity of the 25 m by 25 m plot was identified in 1996, the metal conduit posts could not be relocated and time did not permit relocating trees using the 1987 stand map. A large tree-ring sample was collected in 1996 to examine the age structure of white spruce throughout Big Windy Hot Springs RNA and the relationship of the growth of those trees to the long-term Fairbanks temperature and precipitation record. Trees were cored in a variety of situations including large trees growing on excellent soils above the cliff

Table 4—Structural attributes of old-growth forest reference plots at Big Windy Hot Springs Research Natural Area, July 1987[a]

Species	Total live trees	d.b.h. Maximum	d.b.h. Mean[b]		Total basal area
	Number	Centimeters	Centimeters		Square meters per hectare
White spruce	52	52.0	20.6	(± 14.3)	41.0
Paper birch	9	28.0	13.5	(± 6.8)	2.5
Total tree form	61				43.5

[a] Plot is 25 x 25 m (1/16th hectare)
[b] ± standard deviation

Figure 40. Pocket of dead white spruce in mixed white spruce and paper birch forest above Upper Forest plot. Heavy snow load in 1991 or 1992 snapped the tops of some white spruce (center). These weakened trees served as attractants for spruce bark beetles that have killed neighboring spruce trees.

within the general area of Upper Forest plot, and small trees growing on boulders and in the hot spring meadow. Figure 39 allows a comparison of the diameter distribution of trees in the Upper Forest plot versus all cored trees. The general distributions are similar, except that the smallest size class trees were not cored. Cored trees were marked with numbered metal tags (table 5).

All trees were cored near the base to obtain a count as close as possible to date of origin. Multiple radii (2 to 4) were collected for all trees cored on or near the Upper Forest plot site to obtain precise measurements of yearly tree growth free from the influence of any distorted radii. Table 5 gives the age, size, location, canopy status and identification number of the 41 white spruce that were cored. The oldest tree, located on the small floodplain terrace, was just over 200 years-old. The youngest was a minimum 32 year-old canopy gap replacement tree near the edge of the cliff.

Figure 41 is the frequency distribution of ages for all cored trees. The age distribution shows that canopy dominant and co-dominant trees in the Upper Forest plot belong to two distinct age groups. The older dominants probably originated from a fire before 1820. Co-dominant trees probably originated from a disturbance, possibly a partial burn in the older stand, sometime after 1850.

Tree ring-width was measured for 15 dominant and six co-dominant white spruce in the Upper Forest plot. The radial growth pattern appears as a typical negative exponential curve for both groups once the full number of trees in each group is contributing to the average growth for each year (Figure 42). The shape of the curves is very similar for the years that all trees overlap (since 1930).

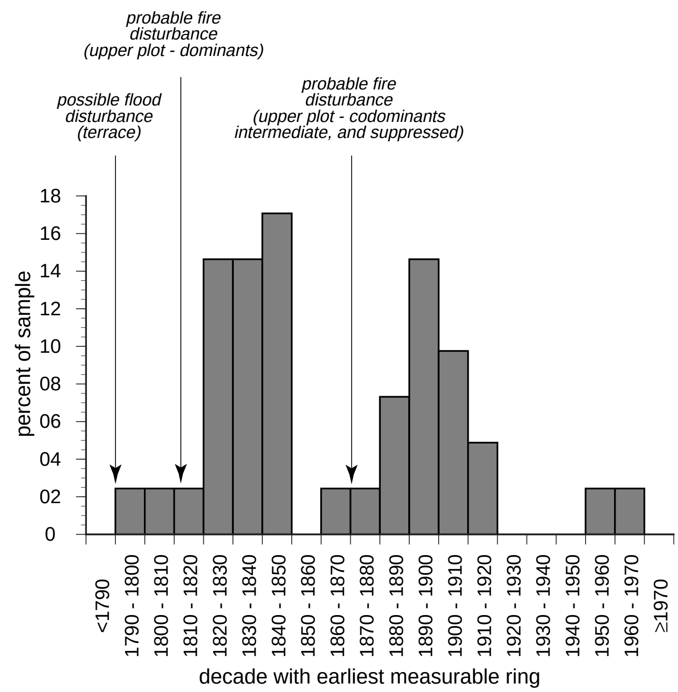


Figure 41. White spruce age distribution at Big Windy Hot Springs (41 trees)

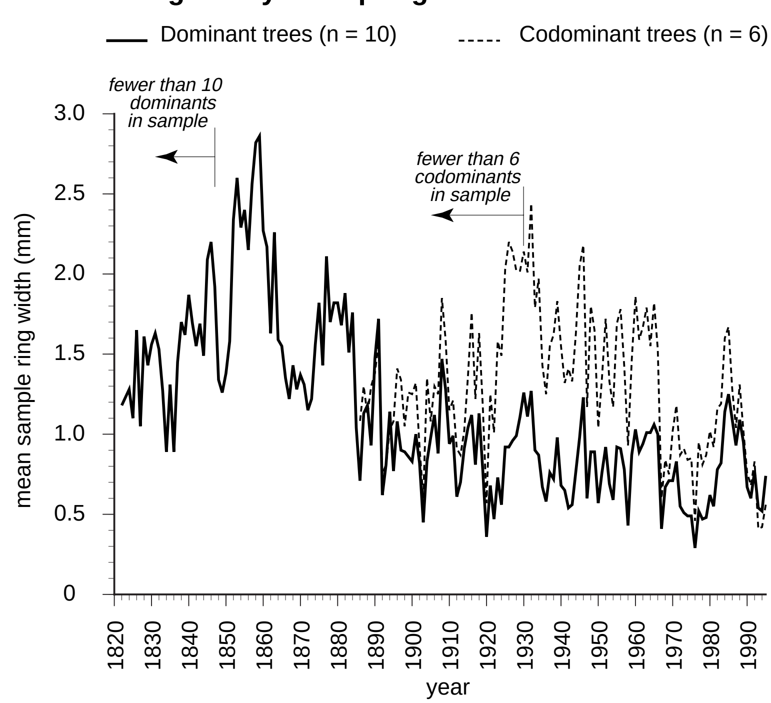


Figure 42. Radial growth history of Upper Forest plot at Big Windy Hot Springs Research Natural Area

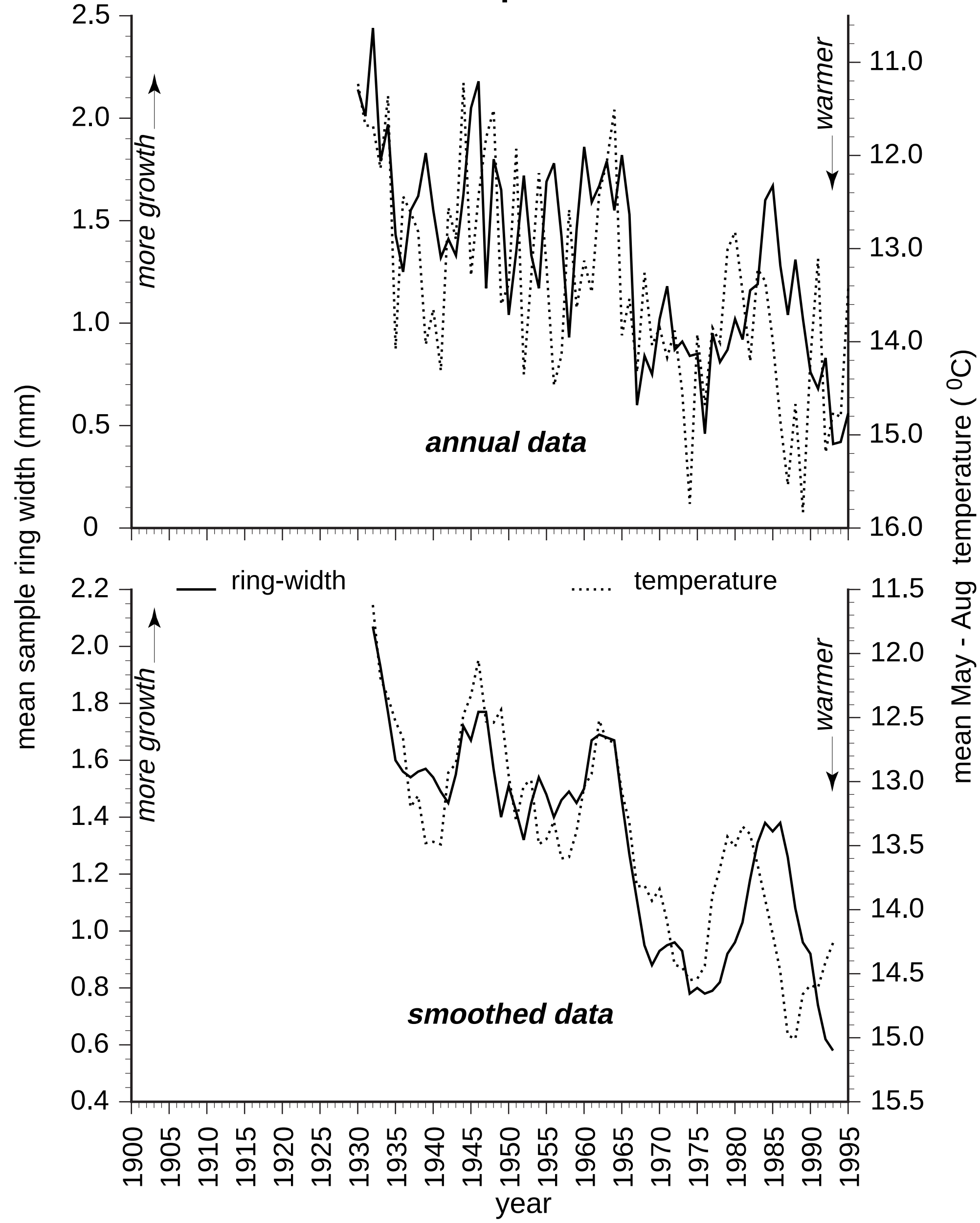


Figure 43. Relationship of radial growth of co-dominant white spruce (n = 5) in Upper Forest plot to Fairbanks mean summer temperature

Studies elsewhere in Alaska suggest that climatic conditions in Interior Alaska have been particularly unfavorable for the growth of white spruce in the late 20th century (Barber et al. 1997, Juday and Marler 1997). The relationship of dominant white spruce growth at Big Windy Hot Springs with climate factors was examined by correlating annual ring-widths with UES/Fairbanks monthly climate data. Growth of dominant trees at Big Windy Hot Springs generally was not sensitive to monthly precipitation, but showed a moderately strong negative relationship to monthly temperature at the beginning (April and May) and the end (August and September) of the growing season. Except for the early 1920s and late 1980s

Table 5—Tree-ring samples collected in 1996 at Big Windy Hot Springs Research Natural Area

Year of first ring	Minimum Age in 1996	d.b.h. (cm)	Canopy status	Site	Tree tag ID
1795	201	36.7	dominant	camp terrace	56
1807	189	16.4	open	hot spring meadow	32
1818	178	39.2	dominant	upper plot	49
1820	176	45.7	dominant	upper plot	52
1820	176	37.0	dominant	upper plot	36
1820	176	22.2	dominant	on boulder	Rock
1823	173	46.5	dominant	upper plot	11
1824	172	44.5	dominant	upper plot	53
1827	169	20.9	co-dominant	camp terrace	28
1830	166	24.0	co-dominant	camp terrace	30
1833	163	45.3	dominant	upper plot	54
1835	161	29.8	dominant	camp terrace	26
1837	159	36.1	dominant	upper plot	35
1839	157	38.6	dominant	upper plot	42
1839	157	37.7	dominant	upper plot	43
1840	156	36.2	dominant	camp old talus	55
1840	156	21.0	co-dominant	camp terrace	31
1840	156	16.4	intermediate	camp old talus	27
1841	155	28.6	open	upper cliff edge	48
1842	154	46.0	dominant	upper plot	37
1842	154	37.0	dominant	upper plot	13
1844	152	39.2	dominant	upper plot	14
1863	133	27.2	co-dominant	upper plot	15
1879	117	29.8	co-dominant	upper plot	20
1885	111	39.9	co-dominant	upper plot	50
1887	109	20.7	co-dominant	upper plot	45
1889	107	30.4	open	upper cliff edge	46
1890	106	39.2	dominant	upper plot	12
1892	104	20.4	co-dominant	upper plot	38
1893	103	12.9	dominant	on boulder	57
1894	102	15.3	co-dominant	upper plot	41
1894	102	21.3	intermediate	upper plot	19
1899	97	21.9	open	upper cliff edge	47
1900	96	17.0	intermediate	upper plot	34
1900	96	12.0	suppressed	camp terrace	29
1903	93	28.6	co-dominant	upper plot	44
1909	87	18.3	intermediate	upper plot	40
1916	80	20.2	intermediate	upper plot	39
1919	77	29.7	co-dominant	upper plot	51
1952	44	13.0	open	hot spring meadow	33
1964	32	6.7	canopy gap	upper plot	17

growth of dominant spruce increased in cool years and declined in warm years. Dominant tree growth has been relatively high since the mid 1980s probably because of growth release effects from the death of neighboring trees in the snow breakage events of the early 1990s (Figure 40). Co-dominant white spruce show a strong negative relationship to mean summer temperature (Figure 43). The growth of white spruce at this possibly geothermally heated site is not enhanced by greater summer warmth, suggesting that additional climate warming in this region could stress low elevation white spruce and depress growth.

Fauna

Birds— A systematic effort was not made to document the occurrence of all bird species in Big Windy Hot Springs RNA. A few species of birds were noted when they were seen, heard, or their sign was observed. Many Alaska birds have predictable enough relationships to their habitat that their presence can be inferred with confidence (Kessel 1979). Table 6 lists 69 birds known to occur or that may occur based on the kinds of habitats in Big Windy Hot Springs RNA.

One of the most visible species seen during site documentation visits was the violet-green swallow. Swallows were abundant along the granite cliff where they fed intently on insects that they captured on the wing. During the site visits at certain times dense concentrations of insects would rise over the Reed canary grass meadow in the main hot spring zone, providing insectivorous birds such as the violet-green swallow with excellent feeding opportunities.

A probable sighting of an American dipper was made at Big Windy Hot Springs. Several habitat features of Big Windy Creek are particularly suitable for dippers. The American dipper is a year round resident bird that inhabits small, clear, and fast-flowing mountain streams. It feeds almost exclusively under water on larval stages of aquatic insects (Armstrong and O'Clair 1989). Dippers spend their lives in one watershed, and are highly territorial, defending stretches of stream in summer and winter (Armstrong and O'Clair 1989). In northern Alaska dippers move to winter feeding areas that are ice-free springs along their streams (Armstrong and O'Clair 1989). The dipper "Nests on a rock wall or perpendicular bank bordering a stream, often behind a waterfall." (Armstrong 1983). The nest is a globular structure constructed of an outer layer moss in a water splash zone and an inner zone of dried grass; adequate nesting sites for dippers may be limiting (Armstrong and O'Clair 1989). The cascade section of Big Windy Creek, the steep banks, and the open winter water conditions of Big Windy Creek provide good examples of important habitat features for dippers.

Other bird species seen or heard in the RNA include Townsend's warbler, dark-eyed junco, yellow-rumped warbler, orange-crowned warbler, and least sandpiper along Big Windy Creek. Sharp-shined hawk and ruby-crowned kinglet were heard in white spruce forest. Sharp-shinned hawks frequently nest in 25 to 45 year-old white spruce trees, building a bulky twig nest close to the trunk midway up the crown (Clarke 1989).

Mammals—Table 7 is a list of 29 mammals known to occur or that may occur based on the results of trapping, observations, and inference based on habitats present in Big Windy Hot Springs RNA. The two mammalian features of greatest scientific interest at Big Windy Hot Springs RNA are: (1) the importance of the area for Dall sheep, and (2) the occurrence of the water shrew, a species relatively uncommon in Alaska, in a disjunct population at the most northern location known in North America.

A number of critical habitat factors that support Dall sheep are found in close proximity in the RNA and immediately adjacent land use zones (Figure 4). As a result, unusual large numbers of Dall sheep occasionally congregate in the area. For example, a 1962 Alaska Department of Fish and Game inventory reported a band of 76 Dall sheep "near the hot springs on Big Windy Creek" on June 8, 1962. The group included 19 "legal" (huntable size) rams, 14 young rams, 28 ewes, 10 lambs, and 5 yearlings (ADF&G 1962).

In general, mountain sheep do not make extensive use of even productive areas of alpine forage unless escape terrain (cliffs and rugged ground) is available (Nichols 1978a, 1978b). Escape by climbing across cliffs and very steep ground is their principal form of defense

Table 6—Checklist of birds known to occur or that may occur in the Big Windy Hot Springs Research Natural Area[a]

Order and common name	Scientific name	Comments
Anseriformes:		
Canada goose	*Branta canadensis*	Possible migrant
Snow goose	*Chen caerulescens*	Possible migrant
Mallard	*Anas platyrhynchos*	Possible migrant
Blue-winged teal	*Anas discors*	Possible migrant
Falconiformes:		
Goshawk	*Accipiter gentilis*	Probable in white spruce forest
Sharp-shinned hawk	*Accipiter striatus*	Heard in RNA
Golden eagle	*Aquila chrysaetos*	Nest nearby in Steese NCA
Bald eagle	*Haliaeetus leucocephalus*	Seen over Birch Creek
Peregrine falcon	*Falco peregrinus anatum*	Nest along Birch Creek in Steese NCA
American kestrel	*Falco sparverius*	Probable in RNA
Galliformes:		
Spruce grouse	*Canachites canadensis*	[b]
Willow ptarmigan	*Lagopus lagopus*	[b]
Rock ptarmigan	*Lagopus mutus*	[b]
Charadriiformes:		
Semipalmated plover	*Charadrius semipalmatus*	Possible on Big Windy Creek flood plain
Lesser yellowlegs	*Tringa flavipes*	
Long-billed dowitcher	*Limnodromus scolopaceus*	Probable migrant
Surfbird	*Aphriza virgata*	Probable breeder in nearby tundra
Semipalmated sandpiper	*Calidris pusilla*	Possible migrant
Least sandpiper	*Calidris minutilla*	Seen in RNA
Baird’s sandpiper	*Calidris bairdii*	Possible migrant
Pectoral sandpiper	*Calidris melanotos*	Possible migrant
Long-tailed jaeger	*Stercorarius longicaudus*	Possible breeder in alpine tundra
Mew gull	*Larus canus*	
Arctic tern	*Sterna paradisaea*	
Strigiformes:		
Great horned owl	*Bubo virginianus*	Probable breeder, year-round resident
Hawk owl	*Surnia ulula*	Tree cavity nester, possible in RNA
Great gray owl	*Strix nebulosa*	
Short-eared owl	*Asio flammeus*	Possible in tundra above, hot spring marsh
Boreal owl	*Aegolius funereus*	
Piciformes:		
Common flicker	*Colaptes auratus*	Common in Interior Alaska forests
Hairy woodpecker	*Picoides villosus*	Seen in bottom-land white spruce forest
Downy woodpecker	*Picoides pubescens*	Sign seen in RNA, white spruce forest
Black-backed woodpecker	*Picoides arcticus*	Probable in old-growth white spruce
Northern three-toed woodpecker	*Picoides tridactylus*	Heard in old-growth white spruce
Passeriformes:		
Alder flycatcher	*Empidonax alnorum*	
Hammond’s flycatcher	*Empidonax hammondii*	
Olive-sided flycatcher	*Nuttallornis borealis*	
Violet-green swallow	*Tachycineta thalassina*	Seen in RNA

Table 6. con't...

Tree swallow	*Iridoprocne bicolor*	
Cliff swallow	*Petrochelidon pyrrhonota*	
Gray jay	*Perisoreus canadensis*	Seen in RNA
Common raven	*Corvus corax*	Probable
Black-capped chickadee	*Parus atricapillus*	
Boreal chickadee	*Parus hudsonicus*	
American Dipper	*Cinclus mexicanus*	Probable/seen in Big Windy Creek above RNA
American robin	*Turdus migratorius*	
Varied thrush	*Ixoreus naevius*	
Swainson's thrush	*Catharus ustulatus*	
Gray-cheeked thrush	*Catharus minimus*	
Mountain bluebird	*Sialia currucoides*	Possible, uncommon
Ruby-crowned kinglet	*Regulus calendula*	Heard in RNA in white spruce forests
Water pipit	*Anthus spinoletta*	
Northern shrike	*Lanius excubitor*	
Orange-crowned warbler	*Vermivora celata*	Seen in RNA
Yellow warbler	*Dendroica petechia*	
Yellow-rumped warbler	*Dendroica coronata*	Seen in RNA
Townsend's warbler	*Dendroica townsendi*	Seen near cliff in RNA
Wilson's warbler	*Wilsonia pusilla*	
Pine grosbeak	*Pinicola enucleator*	
Hoary redpoll	*Carduelis hornemanni*	
Common redpoll	*Carduelis flammea*	
White-winged crossbill	*Loxia leucoptera*	
Savannah sparrow	*Passerculus sandwichensis*	
Dark-eyed junco	*Junco hyemalis*	Seen in RNA, bottom-land white spruce
Tree sparrow	*Spizella arborea*	
Fox sparrow	*Passerella iliaca*	
Lincoln's sparrow	*Melospiza lincolnii*	
Lapland longspur	*Calcarius lapponicus*	Seen south of RNA
Snow bunting	*Plectrophenax nivalis*	Probable migrant

69 total species

[a] Nomenclature follows USDA Forest Service (1979) and American Ornithologists' Union (1957).

[b] Mapped as occurring in area by Alaska Department of Fish and Game (1978).

against predators, primarily wolves (Nichols 1978b). The central and western Yukon-Tanana Uplands, being mostly unglaciated, generally lack cliffs and steep or rough, broken ground. The scarcity of cliffs and steep ground within sheep habitat in these areas ensures that the escape terrain that does exist is highly important. A small area of cliff or talus slope may enable sheep to utilize a large adjacent area of gentle topography. Also, given the scattered nature and scarcity of escape habitat, sheep are likely more sensitive to disturbance in the Steese NCA than sheep occupying areas with more abundant rugged terrain.

The Bureau of Land Management began a study of Dall sheep in the Steese NCA and White Mountains National Recreation Area in cooperation with the Alaska Department of Fish and Game in 1983 (Durtsche et al. 1990). Several animals were radio-collared; their movements were followed for as long as the radios functioned. One band of Dall sheep was found to occupy a distinct general use area extending from Big Windy Creek in the vicinity of the RNA south about 70 km to West Point, a 1,800 m mountain summit in glacial terrain (Durtsche et al. 1990). Dall sheep in Steese NCS were found to generally forage across the rolling alpine uplands through the spring and early summer. They move upward in elevation as the snow melts and new green forage appears. In general, Dall sheep in the Steese NCA

Table 7—Checklist of mammals known to occur or that may occur in the Big Windy Hot Springs Research Natural Area [a]

Order and common name	Scientific name	Comments
Insectivora:		
Masked shrew	*Sorex cinereus*	
Water shrew	*Sorex palustris*	Seen in RNA
Pygmy shrew	*Microsorex hoyi*	
Chiroptera:		
Little brown myotis	*Myotis lucifugus*	
Lagomorpha:		
Snowshoe hare	*Lepus americanus*	
Rodentia:		
Red squirrel	*Tamiasciurus hudsonicus*	Heard in RNA
Northern flying squirrel	*Glaucomys sabrinus*	Probable
Northern red-backed vole	*Clethrionomys rutilus*	Seen in RNA
Meadow vole	*Microtus pennsylvanicus*	
Tundra Vole	*Microtus oeconomus*	Seen in RNA
Long-tailed Vole	*Microtus longicaudus*	Seen in RNA
Yellow-Cheeked Vole	*Microtus xanthognathus*	
Singing Vole	*Microtus miurus*	
Brown Lemming	*Lemmus sibiricus*	
Collared Lemming	*Dicrostonyx torquatus*	
Meadow Jumping Mouse	*Zapus hudsonius*	Would represent range extension
Porcupine	*Erethizon dorsatum*	
Carnivora:		
Gray Wolf	*Canis lupus*	Probable as opportunistic predator of moose and Dall Sheep
Red Fox	*Vulpes vulpes*	
Black Bear	*Ursus americanus*	
Grizzly Bear	*Ursus arctos*	Wide ranging in region
Marten	*Martes americana*	
Ermine	*Mustela erminea*	
Least Weasel	*Mustela nivalis*	
River Otter	*Lutra canadensis*	Probable in Big Windy Creek
Lynx	*Felis lynx*	
Artiodactyla:		
Moose	*Alces alces*	Seen in RNA
Dall Sheep	*Ovis dalli*	Seen in RNA

29 total species

[a] Nomenclature follows U.S. Department of Agriculture Forest Service (1979).

Figure 44. Dall sheep trail eroded into slope on north side of Big Windy Creek, July 1996. (Photo by Jim Herriges)

*Figure 45. Small mammals trapped at Big Windy Hot Springs, July 1996. Water shrews (*Sorex palustris*), in this view first and second from left and far right, are relatively uncommon in Alaska. The Big Windy Hot Springs population is 250 km north of the previously documented distribution of the species, and represents the northernmost limit of the species in North America. The red-backed vole (*Clethrionomys rutilus*) is distributed generally north of 60 degree north latitude. (Photo by Jim Herriges)*

and White Mountains National Recreation Area appear to have made some of the greatest adjustments to using habitat without good escape terrain of all sheep populations in North America (Durtsche et al. 1990), but an elevated rate of loss to predation may be a consequence.

Visits to mineral licks are an important feature of the winter-to-summer movement of Dall sheep on their home ranges (Nichols 1978a). In the Yukon-Tanana uplands region, sheep movements which are distant from secure escape habitats are most often associated with use of mineral licks (Durtsche et al. 1990). Ewes with lambs may remain in the vicinity of licks for periods of time ranging from days to most of the summer. A large proportion of adult sheep return to previously occupied seasonal ranges year after year (Geist 1971), so traditional travel routes are usually well established. The traditional trails used by Dall sheep to move between the RNA and the uplands are very distinct and well-worn (Figure 44). Dall sheep use the rock outcrops in the highlands to the south of the RNA as a mineral lick and probably a staging area for trips to the hot springs. The barren bouldery talus south of Big Windy Creek appears to favor the movement of Dall sheep from the alpine summits to Big Windy Hot Springs.

Dall sheep populations in the Yukon-Tanana Uplands, the likely ancestral habitat for the species, were estimated to total about 1,000 out of an Alaska population of about 70,000 (Heimer 1989). Yukon-Tanana Upland Dall sheep are isolated from genetic interchange with larger populations of the species in the Alaska Range and Brooks Range (Nichols 1978b, Durtsche et al. 1990) and occur at low densities. Large mammals in such circumstances typically require special conservation measures such as protection of sensitive habitat and careful monitoring and control of mortality, especially to avoid rapid decreases in the population that may require a long recovery time (Durtsche et al 1990).

Moose tracks and trampling in the immediate vicinity of the hot springs are abundant. Among the moose tracks are wolf tracks, indicating a concentrated wildlife use of the area. The presence of early season green forage, and its persistence into the fall, are additional factors likely responsible for attracting sizable numbers of Dall sheep, moose, and wolves that prey upon them. There is limited evidence (occasional observations in the vicinity, trails and track through the RNA) of concentrated black bear and grizzly bear use of the RNA.

Small mammal trapping was carried out by Jim Herriges during site documentation of Big Windy Hot Springs RNA July 12-14, 1996. Total trapping effort over three consecutive nights was about 120 trap nights, consisting of 23 cone pitfall trap nights and 97 museum special trap nights (Cook et al. 1997). Traps were placed in 17 stations along one trapline and eight stations in a second trapline. Both traplines were laid out in a line across the Reed canary grass granite boulder wet meadow area and the shrub and forest habitat immediately adjacent to it (Figure 29, Figure 6, Figure 35).

Three male and five female water shrews were collected and three additional rodent species, northern red-backed vole, tundra vole, and long-tailed vole were also collected (Figure 45). Specimens have been preserved at the University of Alaska Museum (Cook et al. 1997). The Big Windy Creek locality is the farthest north documented occurrence of the water shrew in North America (Cook et al. 1997).

The water shrew is not encountered frequently in Alaska, even in surveys of small mammals. Of the 4,897 specimens of all Alaska species of shrews archived at the University of Alaska Museum, only 21 are water shrew (Cook et al. 1997). Intensive trapping due west of Big Windy Hot Springs has not produced this species, which suggests that the Big Windy Hot Springs locality is actually unusual and not the result of a gap in knowledge.

Big Windy Creek RNA is within the historical and current year-round range of the Fortymile caribou herd and within the 1984 calving area of caribou (BLM 1984). The marten is probably present in the RNA because of the occurrence of mature white spruce forest habitat. Red squirrels are present in mature spruce forest of the RNA. Big Windy Creek is a suitable habitat for the wide-ranging river otter.

History of Disturbance and Future Conditons

Big Windy Hot Springs RNA and its immediate surroundings are seldom visited by humans. The known historical human uses of the Big Windy Hot Springs Research Natural Area primarily have been the RNA site documentation reported here, wilderness adventure trips to the site in the winter by dog sled, and a sporadic series of helicopter-borne geologic reconnaissance studies. Prospectors and miners may have used the site. Nothing is known of prehistoric use of the springs by Native people.

Fire management of the Steese NCA is designed to promote diversity of plant communities and visual resources, and to improve habitat for wildlife that depend on early successional conditions. The vast majority of the Steese NCA, including the RNA, is in a “limited” fire protection zone, meaning that suppression of naturally-ignited fires will generally not be attempted. Prescribed fire is allowed, but pre-ignition planning is required to identify any critical protection sites and the measures that would be taken to protect them from fire (BLM 1986).

The area of the mountain summit south of Big Windy Hot Springs south to the southern boundary of Steese NCA is mapped as a tungsten mineral occurrence area (BLM 1984). Tungsten is a strategic mineral. The north and south margins of Big Windy Creek pluton are also mapped as an Igneous-Granite Mineral Terrane, with potential for tin, tungsten, molybdenum, gold, silver, and antimony (BLM 1984). The Bureau of Land Management is assigned administrative control over mineral claims and mineral leasing in Steese NCA by ANILCA.

Current administrative direction is for Big Windy Hot Springs site to remain in a wilderness setting. The Wild River status of Birch Creek means that road access to or along the Wild River corridor will be avoided or limited to a single access point. Road access from areas south of Big Windy Hot Springs RNA is physically limited by steep terrain and administratively restricted by the Semi-primitive Motorized Restricted Management and Semi-primitive Motorized Special Management zones (Figure 4).

During the 1996 site visit the sensitivity of Dall sheep to the presence of visitors became obvious. A band of at least 8 sheep were seen walking across the bouldery talus toward the hot springs late in the evening (Figure 16). As the sheep crossed the RNA boundary in the southwest corner of the area they became aware of the presence of the camp made up of three small tents in the floodplain white spruce forest. The people in the camp were quiet and unobtrusive, but the sheep immediately reversed direction, headed back up the slope, and were not seen again.

Management Direction

The Record of Decision (RoD) and Resource Management Plan(RMP) for the Steese National Conservation Area were published as one document which describes the following management direction for Research Natural Areas (BLM 1986). Hiking, hunting, and nature appreciation are allowed in RNAs. Natural processes will be allowed to continue, including wildfire, with as little interference as possible.

Informal or primitive campsites can be established outside the boundaries of the RNAs. No surface-disturbing activities are allowed in RNAs except the construction of hiking trails and permitted research projects. Access into RNAs is allowed through developed trails and helicopter landing spots (helispots). RNAs are closed to off-road vehicles and camping to avoid disturbing research and monitoring projects.

The Steese NCA RMP/RoD provides that all Research Natural Areas remain closed to mineral entry (transfer of ownership to claimants) and all types of mineral leasing (public ownership retained with mining conducted by lessors). This decision continued the mineral withdrawal of Big Windy Hot Springs RNA that was initially accomplished by Public Land Order 399 in 1947. In managing land use in the area, it should be recognized that activities occurring outside the RNA boundaries can impact the area itself, especially given its small size.

Research

Big Windy Hot Springs support several thermophytic algae, cyanobacteria, and possibly bacterial mats. These should be collected to determine the species present, and whether any are new to science. The concentrated Dall sheep use of the hot springs as a mineral lick offers the opportunity to conduct airborne monitoring of population numbers and productivity, seasonal movements, and habitat use. The regional geology of the Big Windy Creek area, especially the possible relation of a fault system and its activity to the hot spring, is another topic of interest.

Big Windy Hot Springs offers an outstanding opportunity to study the influence of a natural hot spring system on microclimate, especially in the winter. Consideration should be given to placing a recording climate data collection system in the RNA. Continued studies of the response of forests to climate change should be a priority, especially taking advantage of the geothermally heated zone as a natural warming experiment.

Vegetation studies that should be conducted include identification of the species of mosses, and liverworts collected in July 1996. Additional efforts should be made to re-locate the exact boundaries of the Upper Forest plot to allow monitoring of future forest changes, especially effects of insect-caused tree mortality.

Construction of a new Birch Creek access road and the loop trail shelters identified in the Steese NCA Plan (Figure 4) would provide a feasible staging area and make scientific research easier and less expensive. Increased access generally is associated with increased risk of alteration of geothermal sites by visitors and involves issues of managing sensitive wildlife populations (Durtsche et al. 1990).

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METRIC AND ENGLISH UNITS OF MEASURE

When you know:	Multiply by:	To find:
Celsius (˚C)	1.8 (then add 32)	Fahrenheit (˚F)
Centimeters (cm)	0.394	Inches
Grams (g)	0.3527	Ounces
Hectares (ha)	2.471	Acres
Kilometers (km)	0.621	Miles
Meters (m)	3.281	Feet
Millimeters (mm)	0.0394	Inches

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