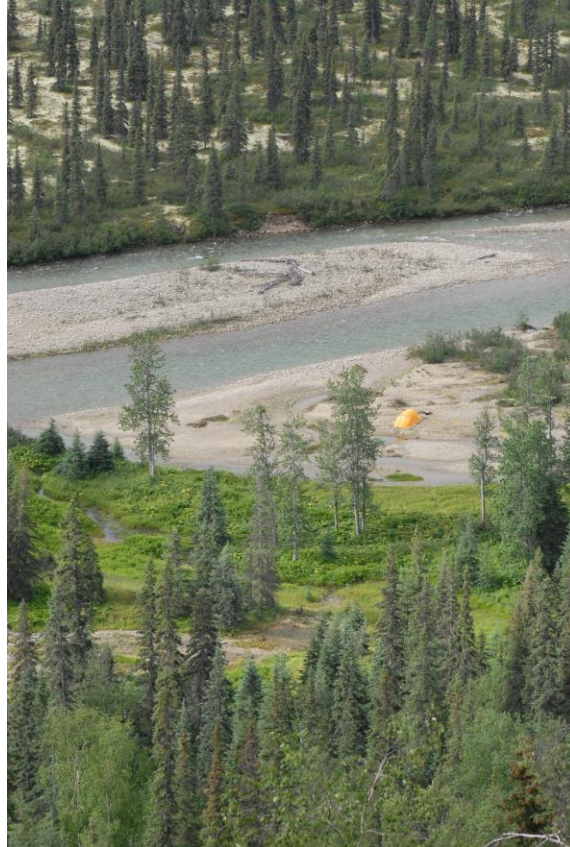




Botanical Survey at Reed River Hot Springs, Gates of the Arctic National Park and Preserve (GAAR)

Natural Resource Report NPS/GAAR/NRR—2016/1136



**ON THIS PAGE**

Photograph of two hot water outlets in the uppermost part of the A field. The hot springs are surrounded by azonal, lush fern vegetation. The central part of the A field consisted mainly of broken sinter material and very sparse vegetation.

Photograph courtesy of Lisa Strecker

ON THE COVER

Photograph of A field of the Reed River Hot Springs and the Reed River as seen from the slope above the hot springs. The bright green vegetation of the hot springs area contrasts starkly with plant cover on the other side of the Reed River which is characteristic for the area.

Photograph courtesy of Lisa Strecker

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Natural Resource Report NPS/GAAR/NRR—2016/1136

Lisa Strecker

Gates of the Arctic National Park and Preserve
4175 Geist Road
Fairbanks, AK 99709

February 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Abstract

This report describes the results of a study that described the native vegetation and investigated the level and potential risk of invasive plant infestation at the Reed River Hot Springs in Gates of the Arctic National Park and Preserve. The report gives a summary of the historical human use of the hot springs area in order to assess the potential anthropogenic impact on the physical features of the hot springs as well as the local plant composition. It also contains a description of the visible modification of the hot springs area by animals.

Due to the geothermal influence, the hot springs host a range of azonal and rare plants and potentially attract non-native plants. After giving a brief general introduction to geothermally caused azonal plant communities and vegetation zonation, the report outlines the research methods of the study. No vegetation zonation was found, however, seven plant communities and three rare species were described. The researchers did not detect any non-native plants in the entire hot springs area. It was recommended to keep anthropogenic modification at a minimum and to eliminate or reduce the risk of potential introductions of non-native plant propagules.

Acknowledgments

This study was partially funded by a fellowship from Alaska Geographic and was also substantially supported by the National Park Service and in specific, the Gates of the Arctic National Park and Preserve (GAAR). I want to thank everyone who contributed to this project and the report: Jeff Rasic for his encouragement, support and patience, Anita Fowler for being an amazing field assistant and camping partner, Andrew Baltensperger for creating the visuals for this report, Carolyn Parker for being a key reference for identifying the plants brought back, as well many others who participated in this project at its different stages. Special thanks go to my Russian research partner Olga Chernyagina who introduced me to the wonderful world of hot springs and their vegetation.

Introduction

There are more than 110 geothermal springs in Alaska of which several are located on National Park land (Motyka et al. 1983, Waring 1917). In general, the vegetation at hot springs in Alaska is not extensively studied and publications about hot springs concentrate on the geothermal energy potential of a site. Often, those reports omit a description of the vegetation (e.g. Kolker et al. 2012, Liss et al. 1989). Few reports describe the plants on geothermally heated soils, such as those by Juday (1998) and Parker, Batten, and Herriges Jr. (2003) who described the vegetation at the Big Windy Hot Springs in the Yukon-Tanana uplands of interior Alaska.

Our study of the Reed River Hot Springs (RRHS) vegetation is part of the research project entitled ‘Fragile Ecosystems: Are Hot Springs and Their Surroundings Especially Vulnerable to Plant Invasion?’ The Reed River Hot Springs are one of eight hot springs clusters in Interior Alaska chosen for this comparative research project. Within Gates of the Arctic National Park and Preserve (GAAR), RRHS are one of three hot springs known. The other two hot springs are the Lower Kugrak River Hot Springs (67.620/ -155.602) and the Alatna River Hot Springs (near Arrigetch Peaks) (67.403/ -153.883). These two hot springs are listed by Waring (1917) in his survey of Alaska’s hot springs, but are not in the USGS geothermal exploration project in the 1980s (Motyka et al. 1983). Several online travel blogs still mention all three hot springs which indicates that they exist, however, that they are not very hot and not very large, e.g. that they only are filled if nearby rivers have high waters but otherwise do not have a large amount of water. As we had limited time and resources available for explorations in GAAR, we decided on concentrating on RRHS, the site that was the most promising for our project. Nevertheless, the two other springs deserve updated description as well since their exclusion in the 1983 USGS map may be interpreted as an indication of their low geothermal potential. Still, both hot springs could play roles in creating unique local micro-climates which may support azonally-distributed species.

The broader project, of which the Reed River Hot Springs study is a part, is based on the consideration that with global change, invasive plants that predominantly originate from warmer regions are expanding their distribution ranges into Subarctic and Arctic regions. With increasing human mobility and development, hot springs ecosystems are subject to increased human modification. This makes them especially vulnerable to being invaded by new plant species. Likewise, hot springs ecosystems can also host rare and endemic species (thermophytes). Global change is thus a realistic threat to hot springs ecosystems (Bella 2009, Chernyagina 2007, Guo et al. 2012, Hierro et al. 2006, Montserrat 2007).

Our general research goal was to look for specially adapted hot springs plants and their potential interaction with non-native and invasive plants in the vicinity of the hot springs, to record those plants, and to assess their potential risk status.

The Project

In the second half of July 2014, Lisa Strecker, ethnobotanist and principal investigator, and Anita Fowler, field assistant, spent one week at the Reed River Hot Springs to investigate the vegetation

influenced by the geothermal activity of the hot springs area. In addition to compiling a general description of the hot springs, the team attempted to answer several research questions:

1. Which plants grow in the surrounding area of the hot springs? Does Reed River Hot Springs host plants that are adapted to growing on soils with high temperatures? Does the hot springs vegetation show any typical geothermally caused vegetation zonation?
2. Are there any rare, endangered, or endemic plants (thermophytes) growing at the hot springs? If so, What kind of disturbances might cause a threat to those plants?
3. Are there any non-native or invasive plants that grow within the hot springs geothermal area? If so, do these plants have the potential to become a threat to the hot springs vegetation? How might the non-native plants change the hot spring's plant composition?
4. What suggestions can be made to protect the hot springs vegetation?

The project was funded by a grant from Alaska Geographic and our logistics were supported by the Gates of the Arctic National Park and Preserve.

Methods

The methods chosen for this study were based on the assumptions that the vegetation at Reed River Hot Springs would show vegetation patterns typically found at many other geothermal areas.

For example, in a study of the vegetation surrounding the Pauzhetka geothermal field in Kamchatka, Russia, it was shown by Samkova (2009) that high soil temperatures in geothermally heated soils are the dominant factor determining plant growth and the formation of regionally azonal plant associations at hot springs. The higher the soil temperature, the smaller the influence of all other plant growth determining factors. In this case, every geothermal plant community corresponded to a certain soil temperature range. Samkova (2009) also presented a convincing model for the development of micro-zonation along a soil heat gradient (Photos 1-3).



Photo 1. Illustration of micro-zonation on high temperature geothermal soils, Bol'she Bannye Hot Springs, Kamchatka (Russia)¹

¹ All photos courtesy of L. Strecker



Photo 2. Typical zonal vegetation, no or minor geothermal influence



Photo 3. Typical regionally azonal vegetation showing the formation of micro-zones on geothermally heated soil

For each plot the following data was collected:

- Plot ID, plot size, longitude, latitude, general description of plot and of the immediate environment
- Distances to, and temperatures of, closest water sources
- Hottest water and soil temperatures within geothermal field
- Distance to closest geothermal field, was plot obviously geothermally influenced (y/n) Soil temperature at depth of 2, 5 and 10 cm, air temperature [Hannah thermometer HI 145]
- General local weather and habitat information (time, weather, last rain, wind, etc.), slope [compass], aspect [visual estimate]
- Wetness [1- under water; 10 very dry]
- Presence / absence data for all vascular plant species (genera listed for mosses), descriptions of their vitality, height [ruler] if they are flowering, seed bearing, etc.
- Vegetation coverage of individual species and of plant categories like ‘native’, ‘non-native’, ‘endemic’, ‘typical hot springs plant’ [visual estimates]
- Disturbance factors: human and animal trampling, wildlife browsing, human modification (1 – no human impact to 10 – totally destroyed/transformed), grazing

For later comparison with other geothermal areas we added the following information to our data:

- Distance to road [steps or visual estimate, map distance], distance to nearest settlement [tachometer of car, GPS, map distance], population size of nearest settlement [official records]
- Number of visitors per day [official numbers or estimates]
- Ownership, management form and conservation status of site, conservation Botanical voucher specimens were collected to confirm plant identifications made in the field. The specimens have been deposited in the Herbarium at the University of Alaska Museum of the North (ALA). They will be digitized and publicly accessible and searchable through the Museum database ARCTOS, (<http://arctos.database.museum/home.cfm>). A list of the plants collected is included in the Appendix of this report.

Data Analysis

This study of the plants at RRHS is part of a wider research project of rare, endangered and or endemic plants at hot springs in Alaska and their possible threat through anthropogenic disturbance and invasive plants. At this point in the data collection, there is not enough data available for a comparative analysis of different hot springs in Interior Alaska. Therefore, the data reported here solely is descriptive and can serve as a baseline for later botanical investigations in Alaska.

Written accounts of the Reed River hot springs

Reed River Hot Springs are situated along the slope of a west-facing mountain ridge on the east side of Reed River which flows in a north–south direction through the region (Figure 1). The RRHS area is close to the southern boundary of the Gates of the Arctic National Park and Preserve and approximately 100 miles west of the village of Bettles.

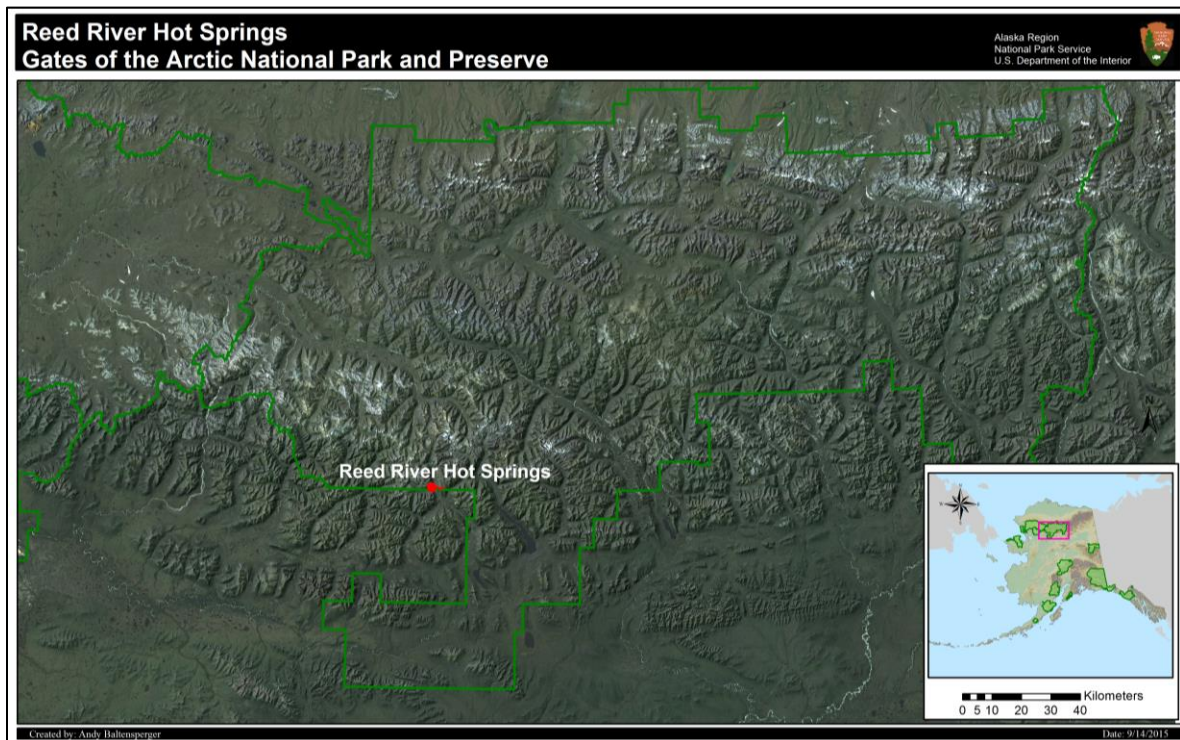


Figure 1. Reed River Hot Springs within Gates of the Arctic National Park and Preserve (A. Baltensperger, NPS)

It is certain that Reed River Hot Springs was known to Native people living in the Kobuk River valley (Pessel 1975:2). As described later in this report, the hot springs area offers great wildlife habitat and the hot water certainly made for a welcome stopover place during long-distance travel.

The discovery of RRHS by western scientists, explorers, and travelers is recorded in fragments. The mining geologist Garnett Pessel wrote about the ‘rediscovery’ of Reed River Hot Springs in 1975. He referred to a primary discovery by ‘Ensign Reed of the U.S. Navy’ in 1886 as published by Stoney (1900). Reed with his small party travelled to the hot springs by dog sleds in March 1975. Reed

reported that there was only ‘one pool, 20 feet in circumference and two feet deep, full of water of blood-warm temperature that wells up quietly from the bottom...’ (Reed in Pessel 1975:1). Further, he gave a description of other, smaller pools. Referring to the information of his Native guides, Reed added that the temperature of the springs varied and “that sometimes it is so hot that they can cook meat in it” (Reed in Pessel 1975:1). In 1917, Waring published the Mineral Springs of Alaska with a half page summary of the Warm Springs near Reed River. The only information source he referred to is Stoney’s report (Waring 1917:70). In 1972 the springs were described by geologist Peter Shaughnessy and his wife who walked in from Walker Lake. They describe the site as a ‘sloping mud patch about 200 feet long and 50 feet wide, beginning about 150 feet from the Reed River, with a small flow of water along each side of the mud patch, joining near the bottom and flowing to the river’. The couple measured water temperatures between 22 and 38°C. (Nava & Morrison 1974:242)

In 1971 the Alaska Division of Geological and Geophysical Surveys (Alaska DGGS) tried to find the hot springs by the aid of Reed’s description, but they failed to locate the site. The helicopter pilot of another survey team ‘rediscovered’ the hot springs in 1973. Reed described only one hot springs area, however this subsequent investigation found two geothermally active fields and possibly a third. The warmest water measured had a temperature of 48.8°C. (Pessel 1975:2)

With the establishment of the Gates of the Arctic National Park and Preserve (GAAR) in 1980, RRHS was briefly visited again in 1982. A team of three ecologists and an archaeologist conducted a one-day reconnaissance of the hot springs area on June 27, 1982 and explored, described and mapped the area of the hot springs (National Park Service 1982).

We used the schematic map from the 1982 NPS report as an orientation aid in the hot springs area (Figure 2). The designation of the individual hot springs clusters as well as the name for the side arm of the Reed River at the base of the geothermal slope were taken from this report as well. Hence, from north to south the hot springs were labeled A, B, C, and D, and the creek at the bottom of the A field was labeled Hot Springs Slough. While working with this map, we discovered that the soil temperature range we measured did not always correspond to the zones of geothermal influence on the map. This might be due to the age of the map and the exploratory nature of the study this report is based on. According to our temperature measurements and the distribution of plants indicating warmer soils, the area of geothermal influence today is certainly larger than described in the 1982 NPS report.

The most recent report of RRHS is based on a brief,

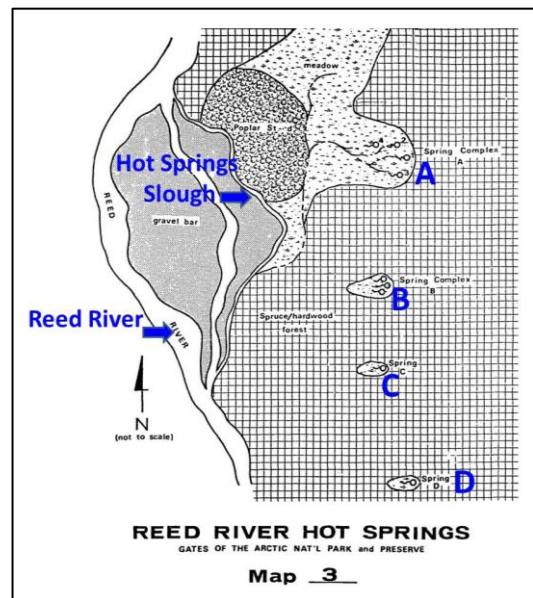


Figure 2. Schematic map of the Reed River Hot Springs area. Adapted from: National Park Service (1982).

In the B field we recorded water temperatures ranging from 32.8 to 45.6°C (average: 38 °C). The 1982 NPS report records one water temperature for the B field: 34.5 °C. We did not find the D and C fields described in this report. Walking southwards through the white spruce forest along the slope, we came across a creek covered with *Marchantia aquatica* and *Epilobium palustre* that is likely to have come down from the area labeled as C field as it showed a higher water temperature than the geothermally non-influenced water bodies in the area: 24.8°C as opposed to the Reed River: 4.3°C. Further southward, the forest showed normal, zonal vegetation and we could not see any indication for geothermal activity.

The Reed River Hot Springs Vegetation

Earlier studies and observations of the Reed River Hot Springs vegetation

Reed River Hot Springs were ‘rediscovered’ in 1973, as noted by Pessel (1975) due to the associated vegetation being in stark contrast from the surrounding vegetation: It is lush, greener, and readily visible from the air (Photo 4).



Photo 4. Reed River Hot Springs as seen from the helicopter on July 21, 2014. The bright green of the vegetation in the hot springs’ area is distinct from the surrounding vegetation, e.g. on the other side of the Reed River.

The 1982 NPS report includes a list of 11 plant species for the hot springs area, which was not clearly defined by the authors. For the adjacent spruce forest the team described 19 species (National Park Service 1982). Botanist Shelli Swanson compiled a list of plants from RRHS in the early 1990s, however, the report could not be located during the literature research for our project (Swanson 1993).

The first exploration of the Reed River Hot Springs area with an in-depth focus on plants was conducted by Parker in 2002. This report also offers a comprehensive overview of other botanical

collections in the area. In early August 2002, Carolyn Parker and Heidi Solstad collected 80 vascular plant specimens, now held at the Herbarium of the University of Alaska Museum of the North (Arctos database, <http://arctos.database.museum/home.cfm>). The total number of vascular plants known from GAAR is 556 (Parker 2006:34). The team did not intend to compile a comprehensive collection from RRHS and thus they collected only specimens that they considered noteworthy for the area or that required closer examination for identification (personal communication, Carolyn Parker).

Plant communities recorded in our 2014 fieldwork

Based on five plant communities described by Parker (2006:33), we identified the following eight dominant plant communities within the geothermally influenced area. If the soil temperature increased with depth (2 cm, 5 cm, 10 cm) we concluded that the soil must be warmed from underground heat source. In all cases, the soil temperatures measured were higher than the air temperature. The following list is not exhaustive.

Open poplar stand (*Populus balsamifera*)

The poplar stand at RRHS is a feature that is not seen in the surrounding area and their presence is likely related to the geothermal influence (Photo 5). The understory vegetation will be described in the next plant community presented. It is notable that all the young trees suffered from heavy browsing which obviously inhibits the process of rejuvenation. There are no young, fully grown poplar trees (beyond the reach of moose) in the entire area of RRHS.

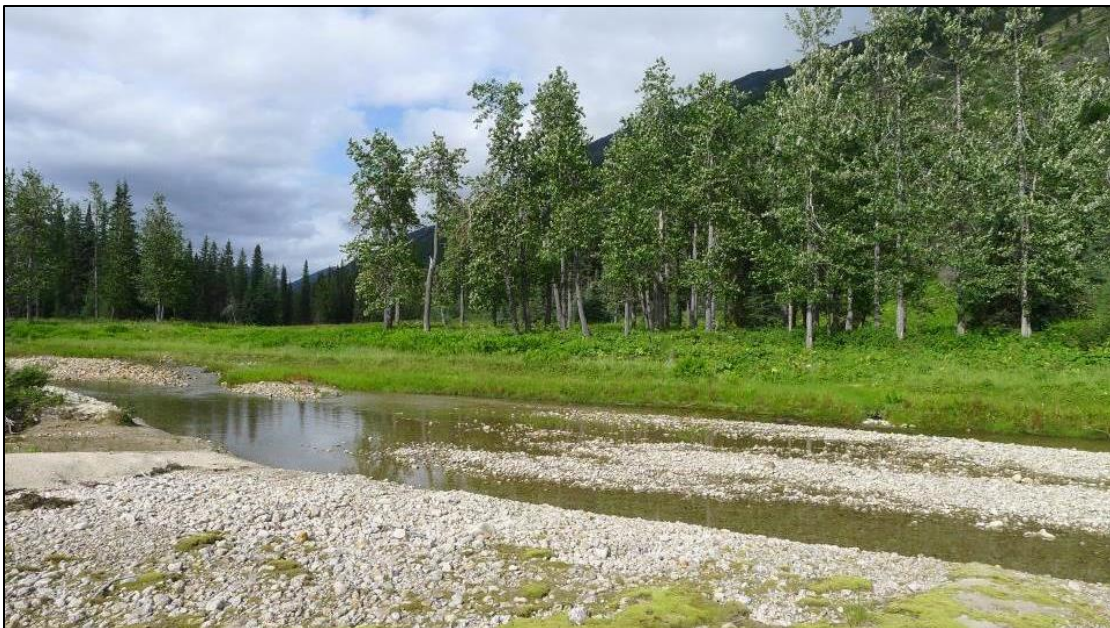


Photo 5. Poplar stand on the geothermally warmed banks of the Hot Springs Slough

Herbaceous meadow dominated by cow-parsnip (*Heracleum lanatum*)

This type of meadow was found as the understory of the poplar stand described above and as an open meadow adjacent to the poplar stand, hence are described together. Generally, the open meadow

showed taller and lusher cow-parsnip coverage: 75% coverage and an average height of 1.5 m as opposed to 40% coverage and approximately 0.9 m high observed under the poplar stand (Photo 6). The few poplars found in the open, canopy-free meadow were heavily browsed juveniles. The eye-catching herbaceous cow-parsnip at RRHS is the only record for GAAR (Parker 2002: 35). In both sampling localities we found: *Athyrium filix-femina*, *Galium boreale*, *Aconitum delphiniifolium*, and *Mertensia paniculata*. Under the balsam poplars, we recorded more woody shrubs that were relatively rare or absent in the open meadow: *Rubus idaeus* subsp. *strigosus*, *Rosa acicularis* and *Viburnum edule*, as well as the herbaceous plants: *Equisetum arvense*, *Chamaenerion angustifolium*, *Trientalis europaea*, *Viola epipsila*. The open meadow supported more graminoid elements including *Elymus trachycaulus*, *Glyceria striata*, and *Calamagrostis canadensis*. Also in the open meadow, *Circaea alpina*, a little herbaceous plant that is also the only record for GAAR (Parker 2002: 35), was found.



Photo 6. Cow-parsnip meadow growing under poplar

Open white spruce stand (*Picea glauca*)

This plant association was not sampled by us.

Rocky seepage slopes

The immediate surroundings of the hot springs pools of each hot springs cluster as well as some of the area downslope from them can be characterized as a seepage slope. The substrate consisted of loose, relatively fine, broken sinter material that was either saturated with warm, geothermal water or atmospheric water (it rained most of the time during our stay) (Photos 7-8). It can be assumed that some of the non-vegetated spots dry out very fast once precipitation stops. Very few plant species

grew directly in this sinter material; other plants species were observed on the thick moss carpet that developed in other parts of the seepage slopes. In general, this area showed a high density of moose tracks that suggested high rates of disturbance. At first glance, this area seemed comparable to the sandy patches on the gravel bank in the Reed River right below the hot springs area. However, the plant composition of the seepage slope and the gravel bank were distinctly different. Only a few plants species occurred in both habitats, like *Erigeron acris*, *Equisetum scirpoides* and *Agrostis scabra* with *A. scabra* being rare in the geothermal slopes. The vegetation on the pure sinter was extremely scarce to absent, and is not described here. The prevailing vascular plants on the moss patches were *Epilobium hornemannii*, *Parnassia palustris*, *Eurybia sibirica*, *Erigeron elatus* (on more moist habitats) and *Erigeron acris* (on drier habitats and those lacking a moss cover). The graminoids included *Carex garberi*, *Carex brunnescens*, *Juncus* sp. (thick leaves, no flowers), *Juncus filiformis*, and *Elymus trachycaulus*. In areas that were not overly wet we recorded *Arabidopsis lyrata* ssp. *kamchatica* and *Taraxacum alaskanum* (only in B field). In some ways, the mesic or drier moss patches seemed like early succession stages of the surrounding vegetation; many of the plants were juvenile and / or showed signs of reduced vitality, like *Aconitum delphiniifolium*, *Chamaenerion angustifolium*, *Polemonium acutiflorum*, *Potentilla norvegica*, *Mertensia paniculata*, *Galium boreale*, *Equisetum scirpoides* and *Picea glauca*.

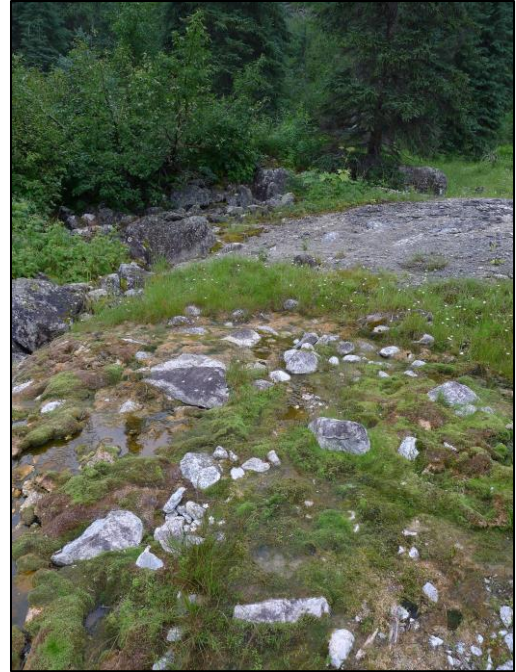


Photo 7. Examples of moss covered seepage slope



Photo 8. Examples of moss covered seepage slope

Dry graminoid meadow

These dry meadow patches showed a relatively low coverage of vascular plants. The patches that had no vascular plant coverage were either barren ground, stone or sparsely overgrown by lichens and mosses. The grasses recorded were *Agrostis scabra*, *Elymus trachycaulus*, *Festuca rubra*, and *Schizachne purpurascens*. In addition, there were a few forbs: *Eurybia sibirica*, *Solidago multiradiata*, *Antennaria alpina*, and a very low coverage (1%) of *Epilobium* (be consistent and use either *Epilobium* or *Chamaenerion* throughout report, see pp 9, and 10 too) *angustifolium*, *Galium boreale*, *Potentilla norvegica* and *Rubus idaeus* subsp. *strigosus*.

Wet graminoid meadow

This type of meadow is lush, especially when compared to the dry meadow described above. Vegetation coverage observed was 100%. On the ground, the moss and liverwort coverage was up to 80%. The prevailing vascular plant coverage consisted of graminoids like *Juncus filiformis*, *Calamagrostis canadensis*, and *Glyceria striata*. Forbs included *Epilobium hornemannii*, *Stellaria calycantha*, *Rorippa palustris*, *Viola epipsila*, *Galium boreale*, *Galium trifidum*, *Equisetum scirpoides*, *Parnassia palustris*, *Chamaenerion angustifolium* and *Athyrium filix-femina* ssp. *cyclosorum*.

Wet (swampy) meadow

The meadow patch described here is situated between the run-off from hot springs A field and a warm pool at the base of A field. The patch supported about 80% coverage of vascular plants, and the ground surface

was fully covered with mosses and liverworts. The prevailing vegetation was dominated by *Equisetum scirpoides*, *Calamagrostis canadensis*, *Comarum palustre*, *Carex utriculata* and *Platanthera aquilonis*. Additional species recorded include *Persicaria amphibia*, *Viola epipsila*, *Galium boreale*, *Galium trifidum*, *Glyceria striata* and *Carex garberi*.

Herbaceous plant community dominated by common lady fern (*Athyrium filix-femina*)

This is certainly the most conspicuous plant community at RRHS. The tall growing ferns adjacent to the hot springs contrast sharply with the low, lichen dominated zonal vegetation nearby. Randomly sampled fertile fronds were more than 1.5 m tall. In the area where the fern dominates it covers the ground completely. The very sparse vegetation under the dense ‘canopy’ of the ferns consists of sparse moss, a few single plants of *Trientalis europaea*, and single plants of *Galium boreale*, *Viola epipsila*, *Aconitum delphiniifolium*, *Circaea alpina*, and an unidentified Poaceae.

Specialized hot spring plant communities

As mentioned earlier, research at hot springs in Kamchatka, northeastern Russia, has shown that the higher the soil temperature, the more this factor dominates all other factors influencing plant growth and species composition. If the soil temperature is high enough, the plants form clearly delineated plant communities that allow a direct inference on the heat distribution in the soil (e.g. Samkova 2009; Rassohina and Ovcharenko, 2004) At Reed River Hot Springs, we could not see any comparable plant community pattern; this can be explained by the relatively moderate soil temperatures. As the soil temperature is obviously not high enough to influence species occurrences, we do not observe any plant communities formed where composition was dominated by the soil temperature. Thus, no specialized hot springs plants communities could be found.

However, the plant communities described support species occurrences that represent ten new range extensions from more southerly regions as noted by Parker (2006:104-106).

The species list of the plants found by us is very similar to that recorded by Parker (2006); The plants collected for this report are listed in the appendices of this report.

Rare, endangered or endemic plants

In addition to compiling a general floristic description of RRHS, one of the core questions of this research project was to find out whether there were specially adapted hot springs plants, so called obligatory thermophiles, at RRHS. Very likely, those plants would be classified as rare, endangered or even endemic. The classification of hot springs plants used here is elaborated by Neshataeva (2009:446-7): Obligatory thermophiles (thermophytes) are found exclusively on warm soils. Most specialized plants that grow on hot soils show physiological adaptations (‘heat shock proteins’) or protect themselves through mycorrhizal symbiosis against possible damage from the heat exposure (Al-Niemi and Stout 2002; Redman et al. 2002; Bunn et al. 2009). Facultative thermophiles are not restricted to hot springs, however they may be part of the typical hot springs vegetation. Some forest and meadow plants may show a preference for these warmer temperature pockets. Ruderal plants delineated by Neshataeva, is a classification that includes non-native plants.

As mentioned above, there are no obligatory thermophiles at RRHS. Nevertheless Parker (2006) found three rare species for Alaska at Reed River Hot Springs:

- *Carex deflexa* (G5²S2S3) is a sedge ‘of dry, open, boreal woodlands’ that was formerly unknown in GAAR. The conditions at the RRHS provide for a habitat that allowed for a major northward range extension of this species. There, it grows on a dry herbaceous meadow adjacent to hot springs A field (Parker 2006:35, 74, Strecker field notes 2014).
- *Schizachne purpurascens* (G5S2), a grass ‘of dry, open, boreal woodlands’, was formerly unknown in GAAR. Like *C. deflexa*, it was found on the dry herbaceous meadow slope adjacent to the hot springs (Parker 2006:35, 9, Strecker field notes 2014).
- *Glyceria striata* ssp. *stricta* (G5S3) is ‘a grass of moist, open boreal habitats.’ Its presence represents a moderate northward range extension. The grass was found in the wet herbaceous meadow associated with the hot springs (Parker 2006:35, 89, Strecker field notes 2014).

At RRHS, all three species grow in a habitat that is believed to be influenced by local geothermal activity. Factors relating to the local geothermal influence may possibly be the factor that explains why the occurrence of these rare species don’t exist elsewhere nearby.

Parker and Solstad made a few more first discoveries for GAAR at Reed River Hot Springs all of which are range extensions (mostly northward). Note: species marked with an *were described first for GAAR by Parker (2006:35, 105-106).

Moderate range extensions: **Heracleum lanatum*, *Gymnocarpium dryopteris*, *Juncus filiformis*, **Circaea alpina*, *Glyceria striata* ssp. *stricta*, *Pyrola minor*, **Carex brunnescens*, **Erigeron acris*, **Stellaria boreale*; Major range extensions: *Carex deflexa*, **Athyrium filix-femina* ssp. *cyclosorum*, *Schizachne purpurascens*, **Phegopteris connectilis*;

In the classification of hot springs plants all those plants named above could be classified as facultative thermophiles (Neshatayeva 2009:446–447) for RRHS.

Non-native and invasive plants

Most invasive plants listed for the Arctic and Subarctic originate from areas further south and consequently, they are probably adapted to higher soil or ambient temperatures. Since global change and particularly global warming lead to a sharp increase in temperatures, it is seen as an important driver of biological invasions at higher latitudes (Carlson and Shephard 2007, Hellmann et al. 2008, Bella 2009, Bradley et al. 2010, Mainka and Howard 2010, Guo et al. 2012). Global change often entails greater human mobility, hence potentially increased development and tourist visitation.

² Conservation ranking by natureserve.org: G – Global, N – National, S – State / regional level on a scale from 1 to 5. 1 – species is critically imperiled, 5 – species is demonstrably secure. E.g. ‘2: species is imperiled due to rarity (6 to 20 occurrences) or due to other factors making it very vulnerable to extinction’ Parker 2006:iii. For more information see: <http://aknhp.uaa.alaska.edu/botany/rare-plant-species-information/rank-definitions/#content> (retrieved July 27, 2015; <http://explorer.natureserve.org/ranking.htm>, retrieved July 27, 2015)

Together with this increased human mobility we see propagule mobility: the more people visiting remote places, the more it is likely that they intentionally or inadvertently introduce new plant species. Increased human activity generally goes along with increased disturbance of ecosystems that may augment the introduction of non-native plants (Hierro et al. 2006, Spellmann et al. 2013). Disturbance at hot springs can occur through human activity (tourists, landing sites, trails, geothermal exploration and exploitation) as well as other animals.

These factors make hot springs and the warmer microclimate pockets surrounding them more likely to be colonized by non-native plants at higher latitudes (Whipple 2001, Chernyagina 2007). It is known that some of these geothermal habitats support highly adapted plant communities that often encompass endemic and rare plants (Samkova 2007, Rassohina and Ovcharenko 2004). Thus, there is a potential risk that the non-native plants could possibly drive rare or endemic plants to extinction by competing for their necessary habitat. This awareness requires that all people who visit hot springs habitats in the future should pay special attention to not introduce seeds or other plant propagules to a hot springs area.

None of the plants we found within the RRHS area, nor the surroundings, were non-native or declared as invasive according to the Alaska Exotic Plants Information Clearinghouse (AKEPIC).³

Potential entry vectors for non-native and invasive plants include humans hiking or traveling on a dog team or with horses, but especially those coming in by air. During an exploratory walk on July 25, 2014 with botanist Mark Winterstein on the airstrip at Dahl Creek and the vicinity, one of the potential starting points for air travel to Reed River Hot Springs, we found the following species:

- *Matricaria discoidea* DC. (pineapple weed)
- *Plantago major* L. (plantain)
- *Hordeum jubatum* L. (foxtail, nativity in question)
- *Taraxacum officinale* F.H. Wigg. (common dandelion)

Plantago major is a common plant at hot springs with high anthropogenic impact in Kamchatka, Russia. This is not proof that it would grow at Reed River Hot Springs, but it is known that this species appears at hot springs in general. The same can be said for pineapple weed and common dandelion. It is questionable if these species could become a threat to the rare plants at Reed River Hot Springs, however, their presence could certainly change the species composition of the vegetation.

Potential risk to the RRHS vegetation

Recorded and visible human impact

The Reed River was a popular historic travel route and the entire area was populated, albeit sparsely, in prehistoric times (Burch 1976 in NPS 1982). The abundance of wildlife as well as the warm water

³ <http://aknhp.uaa.alaska.edu/botany/akepic/non-native-plant-species-list/>

make the hot springs area a potentially popular resting spot during long distance travels or hunting trips.

Human visitors obviously modified the area by digging pools that allowed them to enjoy the warm water by soaking in it. One of those pools that can still be used is in the A field. Large stones had been piled up around a little pool. There is also a stone circle in the A field that has obviously been used as a fireplace.

In 1982, the NPS team discovered remains of a cabin and a rusty pipe, mentioned by other travelers as well. Pessel (1975) reported that he found survey tape that could not have been older than 10 years (2). He also found some old boards and a rusty pipe that he ascribed to an attempt to build a pool.

During our stay in 2014, we did not see any survey tape, old pipes, nor did we come across the remains of the cabin mentioned above. In total, we found two artifacts: a rusty gold pan on one of the larger rocks in the A field. Earlier visitors have described this pan; however, it is not clear where it had been originally found. On one of the level spots near Hot Springs Slough we found a key pendant from an outdoor store in Fairbanks. Thus, it can be said that the visible human impact is very moderate.

Animal occurrence and use of the hot springs

Snails

In 1886, Reed made the observation that “about the edges of the main spring were thousands of small snails” (Reed in Pessel 1975:1). This is the first and only notation of the occurrence of snails at RRHS.

During our visit to the Reed River Hot Springs area we found snails only in some pools in the A field (Photo 9). They were especially abundant in a pool with a water temperature of 23.4°C. Some snails were found in the tracks of moose near this pond that were filled with warm water (20°C). The water was clear, odorless and the bottom was either clear, or covered with light-colored mineral matter (possibly broken calcite deposits), some of the pools and track imprints had a carpet of algae of the genus *Chara* which was also collected by Parker in 2002.⁴ We could not see any snails in the B field. Further, the same type of snail was seen in the warmer, shallow water in little bays associated with Hot Springs Slough (9.4°C). The warmth of this water originated from the warm ground directly underneath. Few snails were seen in the adjacent, unheated water of Hot Springs Slough.

The snail specimens we collected are now curated at the University of Alaska Museum of the North (UAM:Inv), and have been identified in 2014 by A.R. Gastaldi from the University of Alaska Museum as frigid limnaea, or Alaskan Pond snail, *Lymnaea atkaensis*.⁵ According to the Arctos distribution map for this species, it is not restricted to geothermally heated waters, nor is this the northernmost known location in Alaska. Additional Alaskan collections of this species come from

⁴ <http://arctos.database.museum/guid/UAM:Alg:714>

⁵ <http://arctos.database.museum/guid/UAM:Inv:11209>

Galbraith Lake and Umiat.⁶ It has been noted that these mollusks can pass through the guts of fish alive and thus, fish can be seen as a possible vector for distribution of this species (Brown 2007).



Photo 9. *Lymnaea atkaensis* at Reed River Hot Springs

Moose, wolves and caribou

In 1973, Pessel did not report finding the snails, however, his party observed abundant moose tracks (Pessel 1975:2).

The lush vegetation at RRHS certainly offers great browse for moose, and possibly other wildlife. Several well frequented game trails go through the hot springs area and the vegetated as well as the barren parts of the hot springs area showed numerous moose tracks. Young poplar trees were severely browsed and there was not a single leaf left on older trees that had fallen to the ground recently. The poplar stand did not show any rejuvenation, which may be due to heavy browsing pressure.

There were some areas in the lush vegetation with trampled plants that might have indicated resting spots for wildlife, but we did not see any associated tracks. We found a few caribou tracks and wolf scat in the surrounding areas, however, the dominant animal sign was of moose.

⁶ <http://arctos.database.museum/name/Lymnaea%20atkaensis>

Summary

Reed River Hot Springs hosts a unique vegetation with many species that are otherwise not part of the known flora of GAAR. During our investigation, we did not find any thermophytes, that is, plants that grow exclusively at hot springs. Many of the plants that are part of the distinct vegetation at RRHS can be classified as azonal and disjunct and include range extensions of species occurring in more southern parts of Alaska. In addition, we did not find any non-native or invasive plants that could possibly become a threat to the local hot springs vegetation.

Data collected by the principal investigator during her 2013 fieldwork at hot springs in Kamchatka suggest that a) non-native plants in northern regions often have a habitat preference for hot springs and b) there is a direct correlation between human activity, the presence of invasive plants, and the diversity of typical hot springs plants, rare hot springs plants and endemic hot springs plants (Strecker & Chernyagina 2013). One has good reason to assume that these findings hold true for Alaska as well (Parker 2006; Juday 1998). For a few plant species, there is strong evidence to believe that the hot springs facilitated the process of the establishment of new plant species not only at the hot springs itself but also in the surrounding ecosystem (Chernyagina & Strecker 2012).

For the protection of the RRHS vegetation it is essential to keep anthropogenic disturbance and the introduction of non-local plants at a minimum.

At this point, only the vascular plants at RRHS have been studied. In-depth investigations of the animals, microorganisms, non-vascular plants, lichens and fungi remain lacking from the geothermal area of RRHS.

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Appendix

Plants collected during fieldwork

All plants are deposited at the University of Alaska Museum of the North Herbarium (ALA) in Fairbanks, AK.

Species	Characterization of habitat / location where plant was found
<i>Aconitum delphiniifolium</i> DC. (Ranunculaceae)	Moist, geothermally heated meadow on river terrace below hot springs A field // Old-growth medium height white spruce forest
<i>Agrostis scabra</i> Willd. (Poaceae)	Gravel bank along Reed River
<i>Antennaria alpina</i> (L.) Gaertn. (Asteraceae)	Dry graminoid meadow, geothermally heated soil
<i>Arabidopsis lyrata</i> ssp. <i>kamchatica</i> (Fisch. ex DC.) O'Kane & Al-Shehbaz (Brassicaceae)	Several plants in moss patches on geothermally heated mineral soil
<i>Artemisia tilesii</i> Ledeb. (Asteraceae)	Gravel bank along Reed River
<i>Athyrium filix-femina</i> (L.) Roth (Woodsiaceae)	Lush fern vegetation
<i>Boykinia richardsonii</i> (Hook.) Rothr. (Saxifragaceae)	Gravel bank along Reed River
<i>Calamagrostis canadensis</i> (Michx.) P. Beauv. (Poaceae)	Stand of poplar trees on riverbank below hot springs
<i>Carex brunnescens</i> (Pers.) Poir. (Cyperaceae)	Geothermal field, A field
<i>Carex garberi</i> Fernald (Cyperaceae)	Geothermal field, A field
<i>Carex scirpoidea</i> Michx. (Cyperaceae)	Gravel bank along Reed River
<i>Carex utriculata</i> Boott (Cyperaceae)	Geothermal swamp adjacent to the small geothermally heated pond at the base of A field
<i>Chamaenerion latifolium</i> (L.) Holub (Onagraceae)	Gravel bank along Reed River
<i>Circaea alpina</i> L. (Onagraceae)	Lush fern vegetation
<i>Comarum palustre</i> L. (Rosaceae)	Geothermal swamp adjacent to the small geothermally heated pond at the base of A field
<i>Cornus unalaschkensis</i> Ledeb. (Cornaceae)	Old-growth medium height white spruce forest
<i>Eleocharis mamillata</i> (H. Lindb.) H. Lindb. (Cyperaceae)	Geothermal swamp adjacent to the small geothermally heated pond at the base of A field
<i>Elymus trachycaulus</i> (Link) Gould ex Shinnars (Poaceae)	Moist, geothermally heated meadow on river terrace below hot springs A field
<i>Epilobium ciliatum</i> ssp. <i>glandulosum</i> (Lehm.) Hoch & P.H. Raven (Onagraceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field on side arm of Reed River (Hot Springs Slough), 30 cm above water level

Species	Characterization of habitat / location where plant was found
<i>Epilobium palustre</i> L. (Onagraceae)	Growing in creeklet (in a carpet of <i>Marchantia polymorpha</i>) that seemed to be geothermally heated (24.8°C vs. ca. 5°C in Reed River river)
<i>Equisetum arvense</i> L. (Equisetaceae)	Stand of poplar trees on riverbank below hot springs
<i>Equisetum scirpoides</i> Michx (Equisetaceae)	Gravel bank along Reed River, sandy patch
<i>Erigeron acris</i> L. (Asteraceae)	Gravel bank along Reed River, in area of geothermal hot springs A field
<i>Erigeron elatus</i> (Hook.) Greene (Asteraceae)	Wet area of geothermal hot springs A field
<i>Eurybia sibirica</i> (L.) G.L. Nesom (Asteraceae)	Dry graminoid meadow, geothermally heated soil
<i>Festuca rubra</i> L. (Poaceae)	Dry graminoid meadow, geothermally heated soil
<i>Galium boreale</i> L. (Rubiaceae)	Moist, geothermally heated meadow on river terrace below hot springs A field
<i>Galium trifidum</i> L. (Rubiaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field, on side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Glyceria striata</i> (Lam.) Hitchc. (Poaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field, on side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Gymnocarpium dryopteris</i> (L.) Newman (Woodsiaceae)	Old-growth medium height white spruce forest
<i>Hedysarum alpinum</i> L. (Fabaceae)	Gravel bank along Reed River
<i>Juncus castaneus</i> Sm. (Juncaceae)	Gravel bank along Reed River
<i>Juncus filiformis</i> L. (Juncaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field, on side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Juniperus communis</i> L. (Cupressaceae)	Herbaceous meadow with berry shrubs
<i>Linnaea borealis</i> L. (Linnaeaceae)	Old-growth medium height white spruce forest
<i>Luzula multiflora</i> (Ehrh.) Lej. (Juncaceae)	Low growing meadow with lichens and mosses
<i>Marchantia polymorpha</i> L. (Marchantiaceae)	Growing in tiny creek that was geothermally heated (24.8°C vs. ca. 5°C in Reed River)
<i>Mertensia paniculata</i> (Aiton) G. Don (Boraginaceae)	Herbaceous meadow with berry shrubs
<i>Moehringia lateriflora</i> (L.) Fenzl (Caryophyllaceae)	Stand of poplar trees on riverbank below hot springs
<i>Oxytropis campestris</i> (L.) DC. (Fabaceae)	Gravel bank along Reed River, next to alder
<i>Parnassia palustris</i> L. (Celastraceae)	In wet area of geothermal springs A field
<i>Persicaria amphibia</i> (L.) Delarbre (Polygonaceae)	Geothermal swamp adjacent to the small geothermally heated pond at base of the A field

Species	Characterization of habitat / location where plant was found
<i>Phegopteris connectilis</i> (Michx.) Watt (Thelypteridaceae)	On warm rocks above hottest spring in A field
<i>Phegopteris connectilis</i> (Michx.) Watt (Thelypteridaceae)	Old-growth medium height white spruce forest
<i>Platanthera aquilonis</i> Sheviak (Orchidaceae)	Geothermal swamp adjacent to the little geothermally heated pond at the base of A field
<i>Poa alpina</i> L. (Poaceae)	Gravel bank along Reed River
<i>Poa arctica</i> R. Br. (Poaceae)	Gravel bank along Reed River
<i>Poa glauca</i> Vahl (Poaceae)	Gravel bank along Reed River
<i>Polemonium caeruleum</i> ssp. <i>villosum</i> (J.H. Rudolph ex Georgi) Brand (Polemoniaceae) (=P. <i>acutiflorum</i> Willd.)	Old-growth medium height white spruce forest
<i>Populus balsamifera</i> L. (Salicaceae)	Stand of poplar trees on riverbank below hot springs
<i>Potentilla norvegica</i> L. (Rosaceae)	In dry area of geothermal springs A field
<i>Ribes triste</i> Pall. (Grossulariaceae)	Old-growth medium height white spruce forest
<i>Rorippa palustris</i> ssp. <i>hispida</i> (Desv.) Jonsell (Brassicaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field, on side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Rosa acicularis</i> Lindl. (Rosaceae)	Old-growth medium height white spruce forest
<i>Rubus arcticus</i> ssp. <i>acaulis</i> (Michx.) Focke (Rosaceae)	In area of geothermal springs A field
<i>Rubus arcticus</i> ssp. <i>acaulis</i> (Michx.) Focke (Rosaceae)	Gravel bank along Reed River
<i>Rubus idaeus</i> subsp. <i>strigosus</i> (Michx.) Focke (Rosaceae)	Stand of poplar trees on riverbank below hot springs
<i>Rumex acetosa</i> L. (Polygonaceae)	Herbaceous meadow with berry shrubs
<i>Salix alaxensis</i> (Andersson) Coville (Salicaceae)	Gravel bank along Reed River
<i>Saxifraga oppositifolia</i> L. (Saxifragaceae)	Gravel bank along Reed River
<i>Schizachne purpurascens</i> (Torr.) Swallen (Poaceae)	Dry graminoid meadow, geothermally heated soil
<i>Solidago multiradiata</i> Aiton (Asteraceae)	Dry graminoid meadow, geothermally heated soil
<i>Spiraea stevenii</i> (C.K. Schneid.) Rydb. (Rosaceae)	Old-growth medium height white spruce forest
<i>Stellaria calycantha</i> (Ledeb.) Bong. (Caryophyllaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field, on side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Stellaria longipes</i> Goldie (Caryophyllaceae)	Gravel bank along Reed River, sandy patch

Species	Characterization of habitat / location where plant was found
<i>Taraxacum alaskanum</i> Rydb. (Asteraceae)	Several vascular plants in moss patch on geothermally heated mineral soil
<i>Vaccinium uliginosum</i> L. (Ericaceae)	Herbaceous meadow with berry shrubs
<i>Viburnum edule</i> (Michx.) Raf. (Adoxaceae)	Old-growth medium height white spruce forest
<i>Viola epipsila</i> Ledeb. (Violaceae)	Moist meadow on narrow, lowermost terrace of slope below hot springs A field. On side arm of Reed River (Hot Springs Slough), 30 cm above water level
<i>Wilhelmsia physodes</i> (Fisch. ex Ser.) McNeill (Caryophyllaceae)	Gravel bank along Reed River, sandy patch

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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