

IMPACTS OF RECREATIONAL USE ON ARCTIC WILDERNESS LAKESHORE VEGETATION

Walker Lake National Natural Landmark
Gates of the Arctic National Park and Preserve



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IMPACTS OF RECREATIONAL USE ON ARCTIC WILDERNESS LAKESHORE
VEGETATION, BROOKS RANGE, ALASKA

A

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ABSTRACT

Walker Lake is a large arctic wilderness lake in Alaska's central Brooks Range where, recreational use is believed to be negatively affecting natural populations and compromising National Park Service management objectives. This study was conducted to gain a better understanding of the effects recreational use has on lakeshore vegetation. The study objectives were to a) describe the plant communities of lakeshore campsites, b) determine if a measurable difference in species composition between the campsite and natural vegetation exists, c) provide recommendations for ameliorative practices so as to advance the recovery of vegetation in impacted campsites, and d) recommend potential management solutions for recreational use modification. Using a paired-plot technique for vegetation analysis to compare recreationally impacted and adjacent unimpacted areas, this study compared pre-existing campsites surrounding Walker Lake to control plots in the adjacent unimpacted forest. Three distinct vegetational communities exist among the studied sites, however few differences were found between the vegetational composition of campsites and control sites. By concentrating use on as few sites as possible in an area, and revegetating closed sites, signs of impact can be reduced, natural and healthy plant populations can be maintained and management objectives can be achieved.

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INTRODUCTION

Background

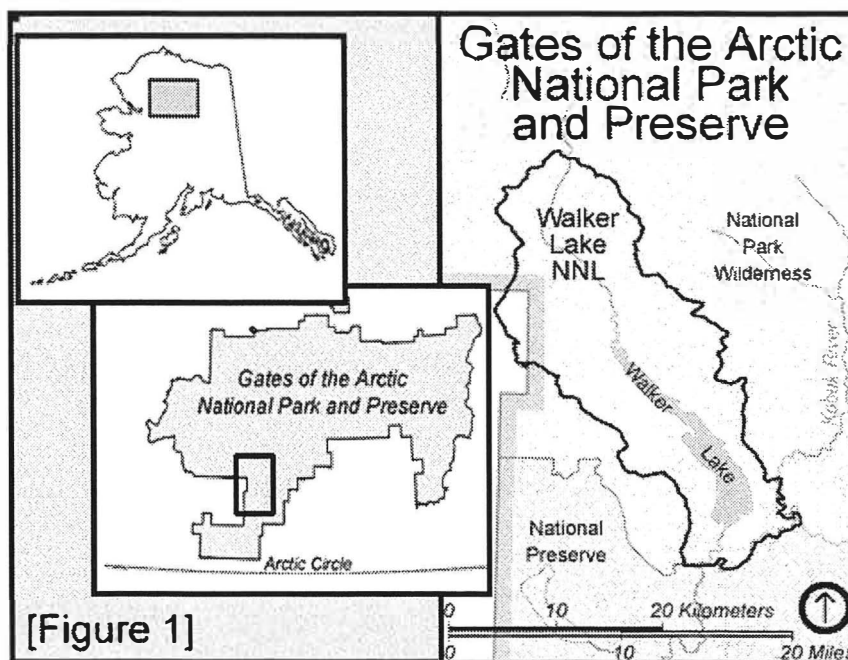
Gates of the Arctic National Park and Preserve (GAAR), located in the central Brooks Range, contains a number of sensitive ecosystems that have incurred increases in recreational use in recent decades (National Park Service 1994; Alaska Planning Group 1974). Operating under the constraints of the National Park Service Organic Act (1916), the Alaska National Interest Lands Conservation Act [ANILCA] (1980), and the GAAR General Management Plan (National Park Service 1986), land managers must comply with numerous mandates, including those that seemingly conflict:

- To provide opportunities for recreational and subsistence use;
- To maintain natural features, environmental integrity and the dynamics of natural processes within the park; and
- To determine and only allow levels of human use that park resources can withstand without impairing their natural and healthy integrity or condition...

To further complicate matters, little baseline data exists on flora and fauna within GAAR, and an inadequate understanding of the park's ecosystems and what threatens them predominates. GAAR management plans require "natural and healthy" populations of flora and fauna, but there is no agreement as to what standards are to be used (National Park Service 1994).

Threatened Areas

One area within GAAR that has experienced an increased threat level is Walker Lake, [Figure 1] a 3,800-hectare deep arctic lake in the southern foothills of the Brooks Range. Although its surface area composes only 0.1% of the area of GAAR, in the mid 1980s Walker Lake received 22 percent of the recreational use (National Park Service 1986). In the 1986 Land Protection Plan, the National Park Service (NPS) identified the protection of the high scenic, natural, and recreational values of the Walker Lake area as the number one priority for management.



The acknowledgement of threat was predominantly due to the presence of a private fishing lodge constructed on the lakeshore prior to the creation of GAAR with the passage of ANILCA in 1980. When the lodge closed in the mid 1980s, development pressure was reduced, although damage from

recreational use and exploitation still threatens at a lower rate. An average of 16 registered users visited Walker Lake annually between 1997 and 2000, or three percent of all registered visitors to GAAR¹. Because this data includes only users that registered with GAAR staff before entering the park, it is believed to represent less than half of the actual visitation.

Current Use and Management

Most visitors to Walker Lake come for a narrow range of recreational opportunities, the majority of which include sport fishing, river rafting, and wilderness travel. Current recreational use patterns at Walker Lake seem to be a function of recreational opportunities, topography, and vegetation. Because motorized transportation is not generally allowed within the park, except for traditional uses (ANILCA 1980), the main mode of transportation is via canoe or kayak. Several hours of paddling are usually required to travel between suitable camping areas. Use is therefore clustered around a few areas widely dispersed around the lake. Many camps are located on the southern shore of the Lake, where an estimated 75 percent of visitors to Walker Lake access the Kobuk Wild and Scenic River². No designated campsites exist in GAAR, and visitors are permitted to camp wherever they wish, although 'Leave No Trace' principles are formally encouraged.

The NPS Brooks Range Impact and Monitoring (BRIM) program serves to qualitatively evaluate all known camp areas within GAAR. Approximately

¹ Personal Communication: Don Pendergrast; April 2002.

² Personal Communication: Steve Ulvi; April 2002

25 campsites in various stages of use and recovery have been identified around the perimeter of Walker Lake (National Park Service 2001).

Cultural and Historical use

Although recreation is a more recent use of Walker Lake, human use has occurred throughout the past. Kobuk and Nunamiut Eskimos, and Koyukon Athabascans have traditionally used the lake and its surrounding areas sporadically for short to moderate term hunting camps for at least the past 2000 years (Kunz et al. 1984). The first known white explorer in the area was John C. Cantwell in 1885, when he and his crew piloted a small steamship from Kotzebue Sound to the upper Kobuk River (Cantwell 1887). Although he grossly underestimated Walker Lake's size, he did provide the first published information about the area, which has been corroborated by later investigations.

The first formal recognition of the unique natural features of the area came with the 1968 designation (Bliss and Gustafson 1981) of the 73,344-hectare Walker Lake watershed as a National Natural Landmark (NNL) by the National Park Service (Dean 1967). This recognized Walker Lake as a unique and nationally significant natural area and encouraged its preservation and protection. Although GAAR did not yet exist, this designation may have been a partial impetus for its creation.

Geology

Walker Lake lies in narrow valley between steep mountains with relatively steep vertical relief. The valley was formed by a Wisconsinian glacial advance known as the Walker Lake glaciation. The glaciation left a 2-3 kilometer wide arcuate moraine spanning the valley bottom, and rising 30 to 60 meters above bedrock. This moraine effectively dammed the valley, creating Walker Lake. Since that time, a narrow valley cut has been cut through the moraine by an outlet stream draining the lake (Fernald 1964).

A major west trending, high-angle, thrust fault passes beneath Walker Lake, near its narrowest point. The fault, named the Walker Lake thrust, was mapped for at least 105 kilometers, although it is believed to continue for at least twice that distance. Bedrock surrounding the lake is predominantly Devonian or younger Greywacke-slate on the southern half of the lake, with minor intrusions of pillow lava. The bedrock surrounding the northern half of the lake is Devonian to Mississippian slate-quartzite with minor intrusions of limestone-marble (Fritts et al. 1991).

Landscape Dynamics

Vegetation within the area is predominantly determined by its cold continental climate. The closest weather station is in Allakaket, where precipitation averages 36 cm per year, including 183 cm of snow. Average summer temperatures range from 3 to 20° C, with an extreme high of 34° C, and average winter temperature range from -34 to -9° C, with an extreme low

of -58°C (State of Alaska 1976). Located at $67^{\circ} 15' \text{N}$ latitude, and 220 m in elevation, Walker Lake is situated at the tundra-taiga ecotone, the northern outpost of the interior spruce forest (Dean 1967). This produces vegetational communities found few other places in the United States. Evidence of lightning caused fires are widespread, occurring in 50-100 year cycles, and substantially influence the types and sizes of plants present (Alaska Planning Group 1974). In 1991, an approximately 15,000-hectare fire burned the south shore of Walker Lake. Kunz (1984) hypothesized that an earlier fire had also occurred on the south shore 60-100 years prior, putting the year of the fire sometime between Cantwell's 1885 visit, and approximately 1920. This was confirmed by Christiansen (1988), with the dating of fires in 1891 west of the river outlet, and 1913 east of the outlet. Christiansen also suggested an earlier fire in the 1840s.

The effects of both fire and climate on vegetation occur on relatively long chronological scales, compared to recreational use. Since campsite monitoring began in GAAR in the early 1980s, recreationally induced changes in campsite condition and vegetation have become apparent (NPS 2001), threatening their natural and healthy conditions, natural processes, and *Wilderness character*. Funded by the NPS National Natural Landmark Program, GAAR Resource Management, and Ranger Operations, in collaboration with the University of Alaska Fairbanks, this project addresses impacts of recreational use on the vegetation surrounding Walker Lake in Gates of the Arctic National Park Wilderness, in the central Brooks Range.

Objectives

The study has four objectives:

- (1) to describe the plant communities of lakeshore campsites and compare them with those of the surrounding natural forest,
- (2) to determine if there is a difference in species composition between campsites and natural areas,
- (3) to provide recommendations for ameliorative practices to advance the recovery of vegetation in impacted campsites, and
- (4) to recommend managerial solutions for the modification of recreational use patterns.

LITERATURE REVIEW

Spruce-Lichen woodlands

The vegetation surrounding Walker Lake is a potentially fire-climax spruce-lichen woodland consisting of widely spaced *Picea* spp. (Christiansen 1998, Rouse and Kershaw 1971) and an almost pure ground lichen cover of *Cladonia* spp., and *Cladina* spp..

In 1996, Neitlich and Hasselbach performed a vegetational reconnaissance of Walker Lake NNL; they identified 214 vascular plants, and 135 lichens within the watershed, with 64 new species added to the GAAR plant list, and 43 ranges significantly extended from those of Hultén (1968). However, it appears the field reconnaissance was far from complete; most

notably lacking was the presence of *Populus tremuloides*, which is common on southern shores of the lake.

Moore (1980) found the soils in spruce-lichen woodlands to be acidic, and tended to have very low amounts of available macro-nutrients (Ca, Mg, K, P, N). Nutrient inputs to the soil through precipitation, spruce canopy drip, and stem flow are low, as are leaching losses from the soil. *Picea* spp. act as major nutrient accumulators within the ecosystem, and show increased levels of nutrient availability in the areas immediately around the trees. Although burning increases the pH, and available nutrient status of the soil, the increase is short-lived (<5 yr) and smaller than observed in other ecosystems.

Fire and Adaptations

The burning of subarctic surfaces, particularly those covered by lichen is a common occurrence (Rouse and Kershaw 1971). Lichen form a dense cover on the forest floor and create a resistance to the movement of soil moisture into the atmosphere. When desiccated, lichen-covered surfaces are a ready-fuel for any ignition source (Rouse and Kershaw 1971). For several decades following a fire, lichen are absent or rare (Strang 1972). When fire is excluded from subarctic ecosystems, *Picea* spp. eventually die out, and tundra-like vegetation is thought to become dominant (Strang 1972).

Effects of Recreational Use

Even minimal trampling of mesic tundra has been shown to result in significantly reduced species richness, particularly among lichens and bryophytes. (Forbes et al. 2001)

A disproportionately high amount of vegetation impact occurs with relatively low levels of use (Gneisser 2000, Cole 1986, Frissel and Duncan 1965). Gneisser (2000) found subarctic vascular plants to be significantly less tolerant of disturbance than mid-latitude tundra plants. A single two-night tent occupancy on previously undisturbed surfaces causes visible and lasting vegetation impacts and soil temperature changes measurable for up to a year. Lightly impacted sites that receive increasing or continued use are likely to deteriorate rapidly, and maintain levels of impact (Cole 1986). Vegetation on heavily impacted sites tends not to recover significantly, even if the site is closed (Cole 1986).

Soil bulk density (Moore 1980, Marion and Merriam 1985) and exposed soil continues to increase with campsite age (Marion and Merriam 1985); exposed mineral soil stabilizes once it reaches 50-60 percent (Cole 1986), although significant variation is common (Marion and Merriam 1985). Once damage has occurred, the timing of vegetation measurements is not critical to the analysis of recreational impacts (Overton 1991).

METHODS

To select study sites, a reconnaissance was conducted during the last week of June 2001 of all known campsites surrounding Walker Lake to determine general similarity of vegetation and landform. Unimpacted areas adjacent to each campsite were also surveyed as potential control plots. Data collected included percent cover of all dominant plant species using Daubenmire's (1959) cover-classes [table 1], soil texture, and site location using a GPS receiver. Based on reconnaissance data, two study sites thought to represent the same environmental conditions were located in each of three vegetation cover types. Campsites were chosen from BRIM sites, and were based on their degree of impact, with preference given to sites that showed the highest signs of impact. Unimpacted sites were selected to serve as controls; these were chosen randomly from adjacent areas within the same cover-type, as long as they shared essentially the same environmental conditions, provided for placement of a 20 m x 20 m plot, and were at least 10 m from any campsite.

TABLE 1 Daubenmire (1959) Cover Classes

<u>Class</u>	<u>Per Cent Coverage</u>	
	<u>Range</u>	<u>Midpoint</u>
Trace	<0.5	
1	0-5	2.5
2	5-25	15
3	25-50	37.5
4	50-75	62.5
5	75-95	85
6	95-100	97.5

For the study, a 20 m x 20 m plot was centered in the impacted area in each campsite, with sides oriented in cardinal directions, and the perimeter delineated with string run between corner posts. Because the study area is in Wilderness, GAAR managers would not allow sub surface permanent markers to be located. One-meter radius subplots were established in the plot center and 5 m inward from each corner along diagonals. GPS coordinates were taken in the southwest corner of each plot, and are reported in appendix 4. Environmental characteristics collected included: slope and aspect in degrees, distance from the nearest plot edge to lakeshore to the nearest meter, landform, drainage class, and Daubenmire cover classes for exposed mineral soil, rock, organic litter, and dead-wood.

For overstory vegetation within the plot, diameter at breast height (1.37m), total height, and length of live crown were obtained. To approximate the time since stand initiation, tree increment cores were obtained at breast height using an increment borer on the three largest diameter trees within the general vicinity of the plot.

For understory species, percent cover-class of vascular species was estimated following Daubenmire's method. Gramminoids, bryophytes, and lichens were only identified to the family level. In each of the five subplots, cover-class data was collected, as well as a tallied estimate of individual vascular plants.

A 6.35 cm x 30.5 cm cylindrical soil sample was taken from an area representative of each plot. To avoid sample deterioration after collection,

soil cores were kept cool within a series of dry-bags placed in the lake, and immediately frozen as soon as facilities were available. Samples were processed by the University of Alaska Plant and Soil Test Laboratory in Palmer, Alaska, and analyzed for total percent carbon and nitrogen, concentration in parts per million of phosphorus, potassium, calcium, magnesium, and sodium, bulk density, moisture content, and gravel content

Voucher specimens of all vascular species were collected for inclusion in the GAAR herbarium and for later identification or verification, with nomenclature following that of Cody (1996). All plot data was entered into a Microsoft EXCEL™ spreadsheet and were used to determine plant community presence and percent cover through manual sorting and manipulation. Similarity of sites was assessed using the Jaccard similarity index initially (Kent and Coker 1992), and subsequently the Sørensen similarity index (Kent and Coker 1992). The Sørensen index is generally considered a more accurate measure of between-site similarity, as it is weighted towards species occurring in both plots being compared, rather than species only occurring on one of the plots.

RESULTS

Overstory Vegetation

No pattern was established between presence of impact and mortality of mature trees. Seedlings emerged on most sites well after stand initiation, indicating regeneration was occurring. Dominant *Picea glauca* in the north,

middle, and south sections of Walker Lake averaged 162.7, 61.5, and 70.2 years old, respectively. Dominant *Picea mariana* averaged 96.6 years old in the middle section. Tree age data is reported in appendix 3.

Understory Vegetation

Studied campsites at Walker Lake, had three distinct diagnostic vegetational communities. Regardless of location, all sites contained the ubiquitous species, *Spiraea beauverdiana*, *Ledum decumbens*, dwarf birch³, *Vaccinium uliginosum*, *V. vitis-idea*, and *Empetrum nigrum*. Study sites in the northern section of the lake had an open overstory of *Picea glauca* with an understory of *Shepherdia canadensis*, *Rosa acicularis*, *Salix* spp., lichen, and grass. Study sites on the southern portion of the lake had an open overstory of *Picea glauca*, and, with an understory of *Rosa acicularis*, *Salix* spp., *Epilobium angustifolium*, and *Populus tremuloides* regeneration. Sites on the central peninsula had an open overstory of *Picea mariana*, with lichen, grass, and *Rubus chamaemorus* distributed in the understory.

Using the Jaccard and Sørensen similarity indices (Kent and Coker 1992), the plots from each geographic region of the lake were found to be dissimilar when compared to one another. The indices [table 2] revealed that the plots were far more dissimilar than similar. Because of the high percent of dissimilarity, plots could not be wholly compared to one another, even if adjacent.

³ Used to indicate either *Betula nana* or *B. glandulosa*.

Table 2 Percent Similarity of Study Plots by Location

	North		South		Middle	
	Control	Study	Control	Study	Control	Study
Jaccard*	24.1	24	28.2	28.9	26.2	25
Sørensen**	38.8	38.7	44	44.9	41.5	40

* $S_j = a/(a+b+c)$ ** $S_s = 2a/(2a+b+c)$ a=number of species common to both plots, b=number of species in plot 1, and c=number of species in plot 2

Using the change in percent cover of the species that showed differences between study and control plots, and site characteristics some generalizations can be made. However, they must be used carefully since the sites are quite different. Few patterns were observed in the analysis of diagnostic species surrounding Walker Lake.

No relationship was established between species richness and the presence or absence of impact. Data for species richness on study and control sites is shown in Table 3. In the north section of the lake, impacted sites had a greater number of species than did control sites, whereas the inverse was true for the south section of the lake. In the middle section, impacted and control sites had equivalent species richness.

TABLE 3 Species Richness

	North		South		Middle	
	Study	Control	Study	Control	Study	Control
Richness (count)	21	32	23	16	10	10
Shared Species		19		13		8
Unshared Species	2	13	10	3	2	2

The only species that was affected consistently across all three regions was *Spiraea beauverdiana*, which was much higher on all campsite plots.

Juniperus communis occurred at increased percentages of cover on study sites

in control plots in the north and south, although it only occurred in trace amounts in the south.

In plots in the north and south sections of the lake, dwarf birch had an average of 19% more cover in impacted plots, whereas on the central peninsula, coverage was 12% greater in control plots. Exposed mineral soil was much higher in study sites than in control plots

Soil

Soils in the area are psamments⁴ with relatively shallow O horizons.

Except for calcium, no consistent trends in macronutrients were found.

Calcium levels varied heavily between regions. On campsite plots in the northern and southern section of the lake, calcium was present in a 3:2 ratio when compared to control plots. In campsite plots on the central peninsula, calcium was present in a 3:1 ratio. Bulk Density ranged from 0.04-0.99 g/cm³ (median=0.25 g/cm³; mean =0.24 g/cm³). Nutrient levels are shown in Table 4. No relationships were established between presence of impact and bulk density.

Table 4	Soil Nutrients					
	North		South		Peninsula	
	Control	Study	Control	Study	Control	Study
C (%)	4.22	3.16	4.05	6.64	7.32	7.35
N (%)	0.19	0.14	0.24	0.39	0.28	0.27
P (ppm)	12.25	6.17	31.03	26.29	4.98	8.67
K (ppm)	73.21	8.75	25.13	34.21	41.63	56.5
Ca (ppm)	2146.92	3011.79	118.6	170.67	55.45	164.21
Mg (ppm)	75.67	55.83	15	20.33	14.45	41.96
Na (ppm)	3.5	8	4.63	5	7.05	4.25

⁴ Personal Communication: Edmond C Packee, and Chien-Lu Ping; February 2002.

DISCUSSION

Overstory Vegetation

Because breast height age of trees was recorded, rather than true age, a correction factor must be added to approximate true ages. On good sites, it takes 5-6 years for *Picea glauca* seedlings to reach approximately 10 cm high (Packee 1990), with growth rates increasing thereafter (Hollingsworth 2002). To reach breast height (1.37 m), it takes trees 25-30 years on good sites (Adams 1999). Given that the Walker Lake sites are probably of lower quality, and experience harsher environmental conditions than those Adams and Packee studied, at least 30 years should be added to the age of each tree to approximate true age. Based on Christiansen 's (1988) fire data, and assuming stand initiation immediately following disturbance, site 57, on the south shore of the lake supports a 30-year correction factor. However, because of a greater time span between the year of the fire that burned the area site 48 now occupies, at least a 40-year correction may be more accurate for that area. On site 47, the lone sites with mixed *Picea glauca* and *P. mariana*, *P. mariana* averaged 44 years older at breast height than *P. glauca*.

Understory Vegetation

Differences in patterns of species richness were probably due to the different seral stages of the dominant vegetation found at each location. Plants in the southern section of the lake were probably still recovering from the 1991 stand-replacing fire. Recreational use on sites in this area may have

made these already disturbed sites more appealing to disturbance-adapted species.

Vegetation in campsites in the north section of the lake was indicative of a mature forest, near the end of its successional cycle. The *P. glauca* present in some of the sites are among the oldest in the area, and are indicative of the sporadic fire cycle in the area (Christiansen 1988).

The mature *Picea mariana-Ledum decumbens* forest of the central peninsula is probably climax, and because of the near isolation provided by the narrow attachment point of the peninsula to the shore, may continue to have limited disturbance by fire, although ignition from other sources is still probable.

Spiraea beauverdiana was the only plant species that was consistently present in campsites at high levels of coverage, compared to control plots. In southern study sites, *S. beauverdiana* had 3.5 times higher percent cover than in control plots; in the north section and on the central peninsula, it had six times the percent cover of controls. If this relationship holds for areas throughout GAAR, *S. beauverdiana* may be useful as an indicator of impact or recovery from impact. Overton (1991) used *Vaccinium scoparium* and *Potentilla diversifolia* as indicator species to assess level of impact on a site. Although no *Vaccinium* or *Potentilla* species exhibited tendencies similar to Overton's finding, her methods may be followed to incorporate *Spiraea* evaluation into existing monitoring programs.

Soil

Exposed mineral soil was the only other factor that was consistently more prevalent on campsites than control sites. It occurred on campsites from 15-26.5% and on control sites from trace amounts to 7.5%. Patterns such as this are common (Cole 1986, Marion and Merriam 1985).

No distinctive patterns emerged in soil analysis, although this study was not designed to be an intensive soil study. With the exception of calcium, the nutrient content of the soil was relatively low, which is logical, as psamments generally have low natural fertility (Brady and Weil 1999). The calcium concentration in the north section of the lake was unusually high, with the concentration of a sample 7330 ppm 14-21 cm deep. High calcium levels were found in all but one of the samples taken from this section.

Although there are some minor intrusions of limestone-marble in the north section of the lake (Fritts et al. 1991), elevated calcium concentrations such as this could normally not be obtained simply through leaching⁵, and are probably due to some other factor. Because the soil is quite sandy and porous, water flows easily through it (Brady and Weil 1999). Hence, any water soluble substance that entered into the soil could easily be transported throughout the area, especially if the water table is close to the surface, as would be expected along a lakeshore. The elevated calcium levels could have come from anything -- from an over-limed pit toilet to fecal deposits from gulls waiting out storms. If a specific answer to this question is desired, further study is recommended.

No connection was established between impact and soil bulk density. Moore (1980), and Marion and Merriam (1985) showed strong increases in bulk density with campsite use. Psamments however, have high sand content by definition (Brady and Weil 1999) and because of the larger particle size, are less compactable than silts and loams (Brady and Weil 1999).

Management Recommendation

Relatively low levels of use cause disproportionately high amounts of vegetational damage (Gneisser 2000; Cole 1986; Frissel and Duncan 1965) measurable for long periods of time (Gneisser 2000; Cole 1986). Exposed mineral soil is thought to stabilize once it reaches 50-60% of the area of a site (Cole 1986). It follows that to avoid widespread damage, use should be concentrated on as few sites as possible within an area. Moore (1980) and Marion and Merriam (1985) argue that increased use will result in increased soil compaction, however because of high sand and gravel content in the soils surrounding Walker Lake, the risk of soil compaction is minimal.

By concentrating use on as few sites as possible within an area, unnecessary sites can be reduced, and vegetation can be given the opportunity to recover, helping to meet NPS objectives, among which are the objectives of maintaining natural and healthy conditions, while simultaneously allowing recreational use. With this, the *Wilderness character* of the area can be maintained with human presence confined to a minimum number of sites.

⁵ Personal Communication: David Valentine, and Edmond C. Packee; February 2002.

If some of the campsites are closed, and use is concentrated, impact can be ameliorated by simply allowing the vegetation to recover on its own, or by planting local, native vegetation according to NPS guidelines. Because of the short growing season and extreme climatic conditions the time span for the former would be long, and planting local native vegetation is recommended.

If no campsites are closed, local, native vegetation could be planted according to NPS guidelines on open sites. With this option however, the risk of trampling to the newly transplanted vegetation would be high and the plants would most likely be destroyed quickly.

If an amelioration option is chosen, an interpretive program of some sort must be implemented to reduce the likelihood of the impacts reoccurring. This interpretive program could occur either before visitors reach Walker Lake, once they arrive. If it occurred before visitors reached Walker Lake, it could be incorporated into the backcountry orientation that GAAR visitors complete before entering the park. Alternatively, a simple informational brochure could be given to visitors to make them aware of the role they can play in ensuring that the sensitive ecosystems of the park are protected.

An interpretive program located at Walker Lake could be much simpler, with signs indicating the closure of a site, although this method may diminish the *Wilderness character* of the area and may be less favorable than other methods. Another option for redirecting use would be to place large,

immovable obstructions such as trees or boulders around the impacted areas in campsites to reduce their appeal to users.

Conclusions

Because of the wide variation in vegetational communities surrounding Walker Lake, the low number of sites within each community to sample, and the wide variety of impact levels within each community, this study is by no means conclusive. It provides just a brief glimpse of the impacts humans are having on Walker Lake, on a few sites, although the sites studied tended to be the most impacted ones on the lake.

Three distinct vegetational communities were found among the studied campsites surrounding Walker Lake. Vegetation was highly variable between campsites within a cover type, as well as in unimpacted areas adjacent to campsites. An analysis of the vegetation in the campsites showed that measurable vegetational impact occurs with recreational use. Most specifically, there was obvious vegetational trampling resulting in increased exposed mineral soil. However, sites studied showed no consistent patterns of increased or decreased percent cover on impacted sites, with one exception. This may have been due to the perceived differences in time since the last major disturbance in each location. *Spiraea beauverdiana* was the only plant species that showed a consistent pattern between all locations, and responded to recreationally induced disturbance with increased percent cover. By concentrating use on a few heavily impacted sites in an area, NPS

management objectives can be reached, and the *Wilderness character* of the area can be maintained.

[APPENDIX 1 – a] Plants found in Northern plots and their estimated percent cover based on midpoint of Daubenmire (1959) cover class

Plot numbers correspond to BRIM site numbers; C indicates control plot

	North			
	35	35 C	41	41 C
<i>Picea glauca</i> (Moench) Voss s.l [regeneration]	15	2.5	2.5	2.5
<i>Picea glauca</i> (Moench) Voss s.l [overstory]	15	15	15	15
<i>Picea mariana</i> (Mill.) B.S.P. [regeneration]	--	--	--	--
<i>Picea mariana</i> (Mill.) B.S.P. [overstory]	--	--	--	--
<i>Populus balsamifera</i> L. [regeneration]	0.5	--	--	--
<i>Populus balsamifera</i> L. [overstory]	--	--	--	--
<i>Betula neoalaskana</i> Sarg. [regeneration]	--	--	--	--
<i>Betula neoalaskana</i> Sarg. [overstory]	--	--	--	--
<i>Populus tremuloides</i> Michx. [regeneration]	--	--	--	--
<i>Populus tremuloides</i> Michx. [overstory]	--	--	--	--
<i>Alnus crispa</i> (Dryander ex Ait.) Pursh	--	0.5	--	--
<i>Arabis kamchatica</i> (Fisch.) Ledeb.	0.5	--	--	--
<i>Artemisia</i> spp.	--	--	--	--
<i>Aster sibericus</i> L.	2.5	2.5	--	--
<i>Astragalus alpinus</i> L.	--	0.5	--	--
Dwarf Birch	--	0.5	37.5	37.5
<i>Dryas octopetala</i> L.	62.5	15	--	0.5
<i>Empetrum nigrum</i> L.	15	2.5	0.5	2.5
<i>Epilobium angustifolium</i> L. s.l.	--	--	--	--
<i>Epilobium latifolium</i> L.	--	2.5	--	--
<i>Equisetum arvense</i> L.	--	2.5	--	0.5
<i>Geocaulon lividum</i> (Richards) Fern.	2.5	2.5	0.5	2.5
<i>Juniperus communis</i> L. s.l.	2.5	15	--	0.5
<i>Ledum decumbens</i> (Ait.) Lodd.	--	--	37.5	37.5
<i>Linnaea borealis</i> L.	--	--	0.5	2.5
<i>Lycopodium clavatum</i> L.	--	2.5	--	--
<i>Mertensia paniculata</i> (Ait.) G. Don	--	--	--	0.5
<i>Oxycoccus microcarpus</i> Turcz.	--	--	--	--
<i>Oxytropis campestris</i> (L.) DC.	0.5	2.5	--	--
<i>Oxytropis deflexa</i> (Pall.) DC.	--	--	--	0.5
<i>Oxytropis</i> spp.	--	--	--	--
<i>Potentilla fruticosa</i> L.	--	2.5	--	--
<i>Rosa acicularis</i> Lindl. s.l	--	--	2.5	2.5
<i>Rubus chamaemorus</i> L.	--	--	2.5	0.5
<i>Salix</i> spp.	15	15	2.5	15
<i>Selaginella sibirica</i> Beauv.	--	--	--	0.5
<i>Senecio cymbalaria</i> Pursh	--	--	--	--
<i>Shepherdia canadensis</i> (L.) Nutt.	15	15	--	--
<i>Silene acaulis</i> L.	2.5	15	--	--
<i>Solidago multiradiata</i> Ait.	2.5	2.5	--	0.5
<i>Spirea beauverdiana</i> Schneid.	--	--	15	2.5
<i>Vaccinium uliginosum</i> L. s.l	0.5	37.5	15	15
<i>Vaccinium vitis-idaea</i> L. ssp. minus (Lodd.) Hultén	0.5	15	2.5	15
<i>Zygadenus elegans</i> Pursh	--	2.5	--	--
unknown 1	--	0.5	--	--
unknown 2	--	0.5	--	--
unknown 3	--	0.5	--	--
Lichen	15	37.5	62.5	37.5
Grasses	15	15	2.5	2.5
Mosses	2.5	2.5	2.5	15
Deadwood	0.5	0.5	2.5	2.5
Litter	2.5	2.5	2.5	2.5
Mineral soil	37.5	0.5	15	0.5

[APPENDIX 1 – b] Plants found in central plots and their estimated percent cover based on midpoint of Daubenmire (1959) cover class

Plot numbers correspond to BRIM site numbers; C indicates control plot

	Central			
	47	47 C	106	106 C
<i>Picea glauca</i> (Moench) Voss s.l [regeneration]	--	--	--	--
<i>Picea glauca</i> (Moench) Voss s.l [overstory]	--	--	--	--
<i>Picea mariana</i> (Mill.) B.S.P. [regeneration]	15	15	15	15
<i>Picea mariana</i> (Mill.) B.S.P. [overstory]	15	15	15	15
<i>Populus balsamifera</i> L. [regeneration]	--	--	--	--
<i>Populus balsamifera</i> L. [overstory]	--	--	--	--
<i>Betula neoalaskana</i> Sarg. [regeneration]	--	--	--	--
<i>Betula neoalaskana</i> Sarg. [overstory]	--	--	--	--
<i>Populus tremuloides</i> Michx. [regeneration]	--	--	--	--
<i>Populus tremuloides</i> Michx. [overstory]	--	--	--	--
<i>Alnus crispa</i> (Dryander ex Ait.) Pursh	--	15	--	--
<i>Arabis kamchatica</i> (Fisch.) Ledeb.	--	--	--	--
<i>Artemisia</i> spp.	--	--	--	--
<i>Aster sibericus</i> L.	--	--	--	--
<i>Astragalus alpinus</i> L.	--	--	--	--
Dwarf Birch	37.5	37.5	37.5	62.5
<i>Dryas octopetala</i> L.	--	--	--	--
<i>Empetrum nigrum</i> L.	2.5	2.5	--	--
<i>Epilobium angustifolium</i> L. s.l.	--	--	--	--
<i>Epilobium latifolium</i> L.	--	--	--	--
<i>Equisetum arvense</i> L.	--	--	--	--
<i>Geocaulon lividum</i> (Richards) Fern.	2.5	--	--	--
<i>Juniperus communis</i> L. s.l.	--	--	--	--
<i>Ledum decumbens</i> (Ait.) Lodd.	37.5	62.5	37.5	37.5
<i>Linnaea borealis</i> L.	0.5	--	--	--
<i>Lycopodium clavatum</i> L.	--	--	--	--
<i>Mertensia paniculata</i> (Ait.) G. Don	--	--	--	--
<i>Oxycoccus microcarpus</i> Turcz.	--	--	--	2.5
<i>Oxytropis campestris</i> (L.) DC.	--	--	--	--
<i>Oxytropis deflexa</i> (Pall.) DC.	--	--	--	--
<i>Oxytropis</i> spp.	--	--	--	--
<i>Potentilla fruticosa</i> L.	--	--	--	--
<i>Rosa acicularis</i> Lindl. s.l.	--	--	--	--
<i>Rubus chamaemorus</i> L.	2.5	2.5	--	--
<i>Salix</i> spp.	--	--	--	--
<i>Selaginella sibirica</i> Beauv.	--	--	--	--
<i>Senecio cymbalaria</i> Pursh	--	--	--	--
<i>Shepherdia canadensis</i> (L.) Nutt.	--	--	--	--
<i>Silene acaulis</i> L.	--	--	--	--
<i>Solidago multiradiata</i> Ait.	--	--	--	--
<i>Spirea beauverdiana</i> Schneid.	15	2.5	--	--
<i>Vaccinium uliginosum</i> L. s.l.	37.5	37.5	15	15
<i>Vaccinium vitis-idaea</i> L. ssp. minus (Lodd.) Hultén	15	15	15	15
<i>Zygadenus elegans</i> Pursh	--	--	--	--
unknown 1	--	--	--	--
unknown 2	--	--	--	--
unknown 3	--	--	--	--
Lichen	62.5	85	85	62.5
Grasses	0.5	--	--	--
Mosses	15	2.5	2.5	2.5
Deadwood	2.5	2.5	0.5	2.5
Litter	2.5	15	2.5	2.5
Mineral soil	15	0.5	15	2.5

[APPENDIX 1 – c] Plants found in Southern plots and their estimated percent cover based on midpoint of Daubenmire (1959) cover class

Plot numbers correspond to BRIM site numbers; C indicates control plot

	South			
	48	48 C	57	57 C
<i>Picea glauca</i> (Moench) Voss s.l [regeneration]	0.5	2.5	2.5	2.5
<i>Picea glauca</i> (Moench) Voss s.l [overstory]	15	--	15	--
<i>Picea mariana</i> (Mill.) B.S.P. [regeneration]	0.5	--	--	--
<i>Picea mariana</i> (Mill.) B.S.P. [overstory]	2.5	--	--	--
<i>Populus balsamifera</i> L. [regeneration]	--	--	0.5	--
<i>Populus balsamifera</i> L. [overstory]	--	--	--	--
<i>Betula neoalaskana</i> Sarg. [regeneration]	--	--	0.5	2.5
<i>Betula neoalaskana</i> Sarg. [overstory]	--	--	--	--
<i>Populus tremuloides</i> Michx. [regeneration]	0.5	2.5	0.5	--
<i>Populus tremuloides</i> Michx. [overstory]	--	--	--	--
<i>Alnus crispa</i> (Dryander ex Ait.) Pursh	--	--	--	--
<i>Arabis kamchatica</i> (Fisch.) Ledeb.	--	--	--	--
<i>Artemisia</i> spp.	0.5	--	--	--
<i>Aster sibericus</i> L.	--	--	--	--
<i>Astragalus alpinus</i> L.	--	--	--	--
Dwarf Birch	15	2.5	62.5	37.5
<i>Dryas octopetala</i> L.	--	--	--	--
<i>Empetrum nigrum</i> L.	0.5	--	2.5	0.5
<i>Epilobium angustifolium</i> L. s.l.	2.5	2.5	2.5	2.5
<i>Epilobium latifolium</i> L.	--	--	--	--
<i>Equisetum arvense</i> L.	2.5	--	--	--
<i>Geocaulon lividum</i> (Richards) Fern.	--	--	0.5	--
<i>Juniperus communis</i> L. s.l.	--	0.5	--	--
<i>Ledum decumbens</i> (Ait.) Lodd.	15	2.5	2.5	2.5
<i>Linnaea borealis</i> L.	0.5	--	--	--
<i>Lycopodium clavatum</i> L.	--	--	--	--
<i>Mertensia paniculata</i> (Ait.) G. Don	0.5	0.5	--	--
<i>Oxycoccus microcarpus</i> Turcz.	--	--	0.5	--
<i>Oxytropis campestris</i> (L.) DC.	--	--	--	--
<i>Oxytropis deflexa</i> (Pall.) DC.	--	--	--	--
<i>Oxytropis</i> spp.	0.5	--	--	--
<i>Potentilla fruticosa</i> L.	--	--	--	--
<i>Rosa acicularis</i> Lindl. s.l.	--	2.5	0.5	2.5
<i>Rubus chamaemorus</i> L.	--	--	--	--
<i>Salix</i> spp.	15	15	15	--
<i>Selaginella sibirica</i> Beauv.	--	--	--	--
<i>Senecio cymbalaria</i> Pursh	--	0.5	--	--
<i>Shepherdia canadensis</i> (L.) Nutt.	--	--	--	--
<i>Silene acaulis</i> L.	--	--	--	--
<i>Solidago multiradiata</i> Ait.	0.5	--	--	--
<i>Spirea beauverdiana</i> Schneid.	15	--	2.5	2.5
<i>Vaccinium uliginosum</i> L. s.l.	15	15	15	--
<i>Vaccinium vitis-idaea</i> L. ssp. minus (Lodd.) Hultén	2.5	0.5	2.5	2.5
<i>Zygadenus elegans</i> Pursh	--	--	--	--
unknown 1	0.5	--	--	--
unknown 2	--	--	--	--
unknown 3	--	--	--	--
Lichen	15	0.5	37.5	0.5
Grasses	37.5	97.5	62.5	62.5
Mosses	2.5	15	15	15
Deadwood	2.5	15	15	15
Litter	15	2.5	15	15
Mineral soil	15	--	15	15

[APPENDIX 2 – a] Soil data

Plot numbers correspond to BRIM site numbers; C indicates control plot

Plot #	Section	Length (mm)	Wet Wt(g)	Tube Wt(g)	w/bag		% C	% N	Mehlich 3				
					Air dry Wt(g)	%			ppm P	ppm K	ppm Ca	ppm Mg	ppm Na
106	1	92.0	143.02	15.96	54.09	22.71	0.73		14	232	430	220	15
106	2	54.0	198.77	9.59	143.48	2.42	0.14		<1	15	29	9	4
106	3	47.0	179.75	9.82	122.24	1.87	0.10		<1	16	27	8	5
106	4	37.0	113.98	6.67	81.84	8.50	0.26		2	9	25	4	2
106 C	1	21.5	74.70	6.01	42.82	3.60	0.19		4	116	105	33	5
106 C	2	65.5	333.28	13.17	245.10	1.68	0.09		2	32	16	6	3
106 C	3	58.0	239.57	10.84	197.83	1.89	0.09		3	29	24	6	12
106 C	4	48.0	233.09	8.53	211.85	8.14	0.24		1	26	27	4	15
106 C	5	25.0	105.33	4.87	85.31	14.02	0.39		1	22	25	3	8
35	1	52.0	238.65	10.84	199.94	2.00	0.12		3	16	2941	49	<1
35	2	88.0	353.43	14.98	321.56	1.88	0.03		<1	5	6406	104	<1
35	3	71.0	289.04	12.47	259.49	1.86	0.01		<1	5	7330	134	<1
35	4	77.0	302.00	14.85	271.64	1.43	0.01		<1	4	7164	125	<1
35 C	1	54.0	95.60	8.89	47.19	10.14	0.40		8	241	1464	124	3
35 C	2	83.0	299.57	14.80	243.52	1.10	0.10		1	13	949	39	<1
35 C	3	88.0	362.84	15.21	318.56	1.61	0.02		<1	6	7515	108	<1
41	1	38.0	130.88	6.72	103.68	5.99	0.32		16	23	156	14	16
41	2	95.0	351.91	17.21	316.59	4.23	0.23		5	4	19	6	<1
41	3	85.0	296.82	18.38	263.32	3.38	0.17		7	3	15	6	<1
41 C	1	52.0	144.47	8.45	43.18	12.46	0.56		49	169	2754	153	3
41 C	2	50.0	217.74	10.76	135.70	1.37	0.12		27	19	526	33	2
41 C	3	53.0	198.96	10.20	118.14	1.74	0.10		1	36	412	32	7
41 C	4	104.0	442.50	22.48	287.27	1.07	0.08		3	15	246	26	<1
47	1	52.0	101.23	7.70	57.59	8.39	0.30		13	108	264	48	4
47	2	84.0	377.69	14.96	340.75	2.21	0.10		10	13	22	14	1
47	3	70.0	363.99	13.42	330.79	6.89	0.32		5	14	316	9	1
47 C	1	47.0	117.93	9.55	90.92	14.33	0.56		20	111	199	54	9
47 C	2	52.0	190.35	8.39	159.23	5.07	0.25		6	21	34	11	4
47 C	3	54.0	247.03	9.80	217.63	5.06	0.23		4	10	22	5	2
47 C	4	90.0	331.38	15.41	278.83	10.63	0.43		1	11	31	4	7
48	1	42.0	118.99	7.55	93.10	14.29	0.55		38	71	224	34	13
48	2	78.0	348.79	14.45	321.15	0.48	0.01		14	9	12	6	<1
48	3	75.0	292.47	12.44	266.13	0.52	<0.1		21	6	14	10	1
48 C	1	20.0	49.46	3.98	35.96	12.76	0.74		111	60	435	33	5
48 C	2	53.0	156.96	7.56	142.91	3.13	0.07		7	10	34	6	1
48 C	3	70.0	274.56	12.28	253.10	2.12	0.07		7	4	32	8	<1
48 C	4	83.0	329.08	14.12	302.18	0.34	<0.1		6	3	65	10	<1
48 C	5	69.0	308.00	13.47	280.24	0.16	<0.1		8	3	65	8	<1
57	1	27.0	41.22	3.31	24.21	28.99	0.92		43	147	1001	88	6
57	2	67.0	277.04	12.90	253.58	3.14	0.09		17	6	16	4	2
57	3	80.0	303.32	14.53	279.61	0.21	<0.1		19	3	8	3	2
57	4	95.0	409.41	16.58	381.54	0.39	<0.1		34	3	7	1	2
57 C	1	21.0	49.76	3.22	33.57	13.84	0.50		66	114	398	53	13
57 C	2	50.0	181.91	8.59	159.90	1.47	0.11		20	14	23	6	7
57 C	3	105.0	421.17	17.96	382.68	1.28	0.08		20	5	13	4	3
57 C	4	91.0	425.83	18.92	391.39	1.04	0.08		31	4	10	5	2

Bag Wt 2.64 g

[APPENDIX 2 - b] Soil data

Plot numbers correspond to BRIM site numbers; C indicates control plot

Plot #	Section	Subsample		% Moisture	
		Air dry Wt(g)	Oven dry Wt(g)	air dry to oven dry	% Gravel >2mm
106	1	1.52	1.48	2.70	1.4
106	2	4.06	4.01	1.25	15.3
106	3	3.80	3.73	1.88	7.4
106	4	4.33	4.22	2.61	28.8
106 C	1	2.93	2.88	1.74	11.4
106 C	2	3.80	3.75	1.33	5.5
106 C	3	4.21	4.17	0.96	60.8
106 C	4	5.11	5.01	2.00	87.9
106 C	5	5.02	4.90	2.45	54.6
35	1	4.73	4.70	0.64	6.7
35	2	5.86	5.85	0.17	6.0
35	3	5.73	5.71	0.35	5.0
35	4	5.82	5.81	0.17	14.1
35 C	1	2.23	2.19	1.83	<.1
35 C	2	4.66	4.65	0.22	0.3
35 C	3	5.48	5.47	0.18	<.1
41	1	4.49	4.47	0.45	4.8
41	2	5.67	5.66	0.18	0.3
41	3	5.83	5.82	0.17	7.8
41 C	1	2.03	1.95	4.10	<.1
41 C	2	2.97	2.94	1.02	1.5
41 C	3	3.05	3.00	1.67	<.1
41 C	4	3.24	3.20	1.25	0.4
47	1	2.27	2.22	2.25	14.7
47	2	5.70	5.67	0.53	44.8
47	3	5.79	5.71	1.40	56.3
47 C	1	3.12	3.07	1.63	45.4
47 C	2	4.38	4.34	0.92	54.9
47 C	3	5.22	5.17	0.97	56.8
47 C	4	4.93	4.80	2.71	39.2
48	1	3.31	3.28	0.91	20.2
48	2	5.46	5.44	0.37	33.6
48	3	5.72	5.71	0.18	25.2
48 C	1	3.24	3.21	0.93	<.1
48 C	2	5.30	5.29	0.19	1.3
48 C	3	5.66	5.65	0.18	<.1
48 C	4	6.13	6.12	0.16	<.1
48 C	5	6.04	6.03	0.17	<.1
57	1	1.84	1.78	3.37	<.1
57	2	5.44	5.42	0.37	4.1
57	3	5.83	5.79	0.69	18.2
57	4	6.40	6.39	0.16	38.3
57 C	1	2.57	2.53	1.58	7.9
57 C	2	4.78	4.76	0.42	8.0
57 C	3	5.52	5.50	0.36	21.2

[APPENDIX 3] Tree ages

Plot numbers correspond to BRIM site numbers; C indicates control plot

North					Middle				South			
35		41			48†		57††		106		47	
Study	Control	Study	Control		Study	Control	Study	Control	Study	Control	Study	Control
Breast-Height Age	82	165	106	109	42	70	58	44	41	84	46	80
	178	174	132	205	52	72	59	49	56	84	55	119
	188	180	230	203	111	--	--	58	97	68	58	
											80	
Year Breast-Height achieved											100	
											104	
	1919	1836	1895	1892	1959	1931	1943	1957	1960	1917	1955	1921
	1823	1827	1869	1796	1949	1929	1942	1952	1945	1917	1946	1882
Estimated year of establishment (BH Year - 30)	1813	1821	1771	1798	1890	--	--	1943	1904	1933	1943	
											1921	
											1901	
											1897	
	1889	1806	1865	1862	1929	1901	1913	1927	1930	1887	1925	1891
	1793	1797	1839	1766	1919	1899	1912	1922	1915	1887	1916	1852
	1783	1791	1741	1768	1860	--	--	1913	1874	1903	1913	
											1891	
												1871
												1867

[APPENDIX 4] Site coordinates in decimal degrees

Coordinates taken in Southwest corner of each plot

Plot numbers correspond to BRIM site numbers; C indicates control plot

Plot	Latitude	Longitude
35	67 12 03.68	-154 32 07.69
35 C	67 12 01.55	-154 32 08.59
41	67 09 46.04	-154 25 16.78
41 C	67 09 47.01	-154 25 16.44
47	67 07 39.44	-154 19 24.88
47 C	67 07 39.50	-154 19 27.71
106	67 07 34.70	-154 19 37.03
106 C	67 07 35.80	-154 19 34.22
48	67 03 50.33	-154 20 22.60
48 C	67 03 47.72	-154 20 11.67
57	67 03 46.05	-154 17 35.89
57 C	67 03 44.87	-154 17 37.81

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