GEODETIC ACTIVITIES DURING THE 1994 JUNEAU ICEFIELD RESEARCH PROGRAM FIELD SEASON

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JIRP OPEN FILE SURVEY REPORT—1994

Geodetic Activities During the 1994 JIRP Field Season
Compiled by Scott McGee

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Survey reports from previous field seasons of the Juneau Icefield Research Program may be obtained from the Foundation for Glacier and Environmental Research at the above address, or on the Internet at http://www.crevassezone.org.

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1. Introduction

The Juneau Icefield Research Program (JIRP) was organized in 1946 to conduct long-term, interdisciplinary research vital to understanding the total environment of arctic and mountain regions. This approach requires the coordinated involvement of various disciplines such as botany, geology, meteorology, geophysics, and surveying to describe and understand the various natural processes operating in arctic and mountain regions, and the Juneau Icefield in particular.

Perhaps the most important function of JIRP is that of quantifying, over time, the physical changes of the Icefield and its environment—advance or retreat of its glaciers, net accumulation or loss of ice, and long-term atmospheric changes. Monitoring these changes is important because the resultant data are valuable in understanding global atmospheric circulation patterns. Long-term monitoring of glacial systems is perhaps the best method available, for glaciers are extremely sensitive to both short-term and long-term atmospheric changes. One way we can detect these changes is to employ surveying to determine glacial flow rates, directions, elevations, and strain-rates. This information, coupled with that gathered by researchers in other disciplines, provides an increased understanding of the complex processes responsible for local and global atmospheric patterns.

The 1994 Juneau Icefield Research Program field season was the forty-eight consecutive year that glacier movement surveys have been conducted on the Juneau Icefield. It also was the most productive in terms of the number of surveys completed and the geographic extent over which those surveys were done. This year marked the first time that comprehensive surface movement surveys of the Taku Glacier were carried out from its terminus all the way to its source in the crestal névés of the Alaska/Canada boundary sector—a distance of some 50 km. Additional surveys were conducted in the Gilkey Trench and in the Camp 18 sector. These surveys, coupled with the Taku Glacier surveys, comprised a total of 15 profiles of 183 flags. Figure 1 shows the greater Juneau Icefield region and the locations of the profiles.

An important element of this year's survey program was the investigation of the lower Taku Glacier, which included one location at the transient firn line and two locations below. This included a resurvey of the terminal position and the first measurement of surface flow at Profile 1, which was originally established by Thomas Poutler in 1949 for seismic refraction studies. The Taku terminus was last surveyed by JIRP during the 1991 field season. Profile 1, a transverse line across the Taku Glacier at the bottleneck between Norris Mountain and the Brassiere Hills, marks the 1890 terminal position, some five kilometers upvalley from the present terminus location. Table 1 lists the profiles, survey dates, type of measurement, and number of flags in each profile.

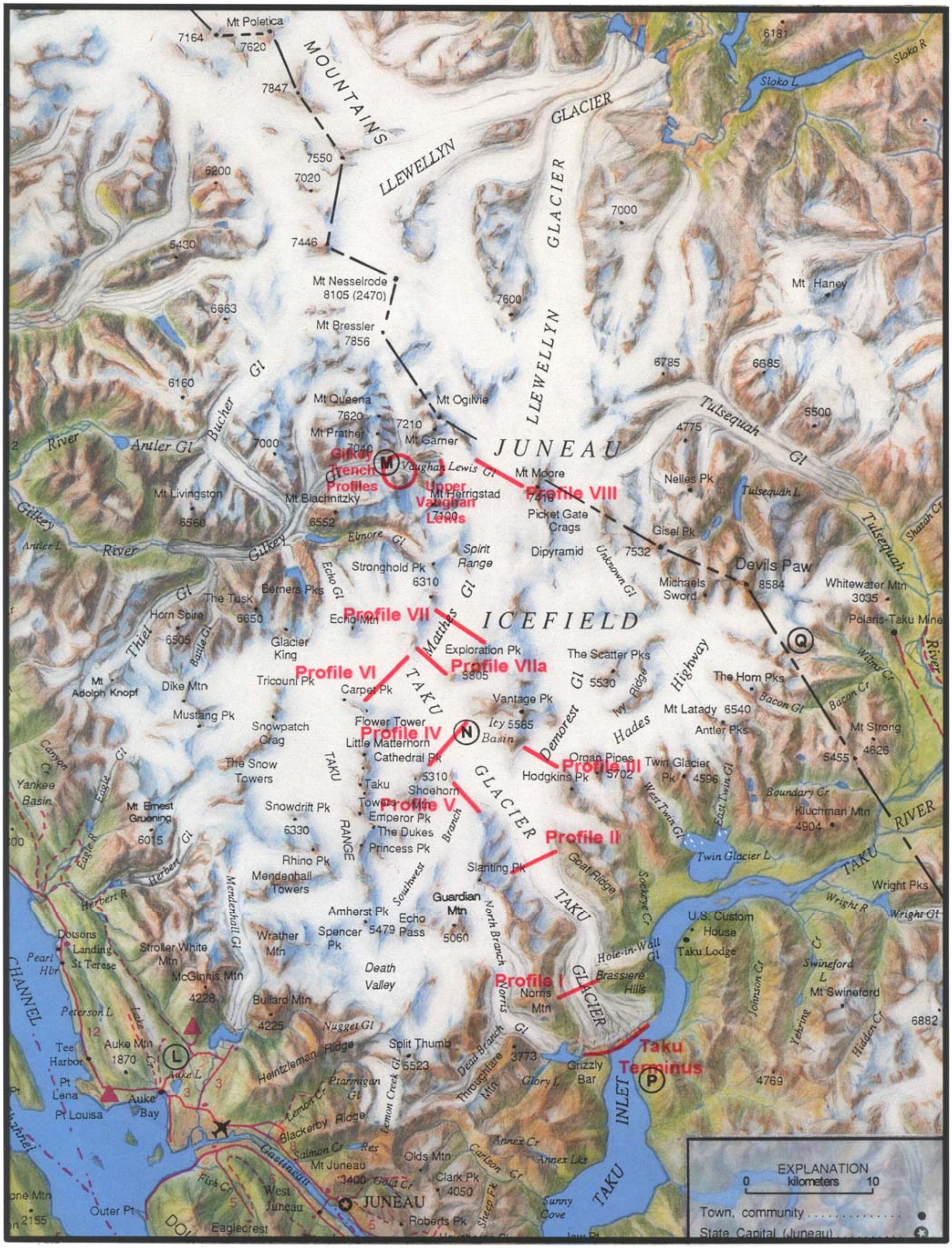

Figure 1: The Juneau Icefield, showing the locations of profiles surveyed in 1994.

Profile	Location	Survey Dates	Type of Measurement	Survey Method	# of Flags
Terminus	Taku Glacier	July 30, 1994	Terminal position	Theodolite/EDM	11
Profile 1	Taku Glacier	August 1, 1994 August 2, 1994	Surface movement Ablation	GPS	15
Profile 2	Taku Glacier	August 3, 1994 August 7, 1994	Surface movement Ablation	GPS	12
Profile 3	Demorest Glacier	July 29, 1994 August 4, 1994	Surface movement Ablation	GPS	12
Profile 4	Taku Glacier	July 25, 1994 August 5, 1994	Surface movement Strain rates Mass balance Ablation	GPS	31
Profile 5	Southwest Branch	July 27, 1994 August 4, 1994	Surface movement Ablation	GPS	12
Profile 6	Northwest Branch	July 26, 1994 August 6, 1994	Surface movement Ablation	GPS	16
Profile 7	Matthes Glacier	August 10, 1994 August 13, 1994	Surface movement	Theodolite/EDM	12
Profile 7a	Matthes Glacier	July 26, 1994 August 6, 1994	Surface movement Ablation	GPS	14
Profile 8	Matthes Glacier	August 11, 1994 August 14, 1994	Surface movement	Theodolite/EDM	14
Upper Vaughan Lewis	Vaughan Lewis Glacier	August 10, 1994 August 12, 1994	Surface movement	Theodolite/EDM	10
Gilkey B	Gilkey Glacier	August 15, 1994	Surface movement Strain rates	Theodolite/EDM	12
Gilkey C	Gilkey Glacier	August 13, 1994	Surface movement Strain rates	Theodolite/EDM	1
Gilkey D	Gilkey Glacier	August 13, 1994	Surface movement Strain rates	Theodolite/EDM	9
Gilkey E	Gilkey Glacier	August 13, 1994	Surface movement Strain rates	Theodolite/EDM	2

Table 1: Surveys conducted during the 1994 JIRP field season.

2. Survey Methods

The Juneau Icefield Research Program has historically used traditional terrestrial survey methods. This involves determining flag coordinates and movement using observation data obtained from theodolites and EDMs. Increasingly, and in the past four years in particular, GPS obtained survey data have proven valuable. Of the 15 profiles surveyed during the 1994 field season, 7 were surveyed via GPS. The remaining 8 were surveyed using terrestrial methods.

2.1 Establishment of Profiles

One of the main goals of the surveying program is to collect data which allows comparison of surface movement from year to year. In order to ensure the consistency of year-to-year movement data, all profiles were located in roughly the same general area as in past years. See Appendix 1 for the locations of the profiles.

Two methods were used to establish the profiles; estimation and surveying. The flags for all profiles, except Profile 4 and those in the Gilkey Trench, were placed by estimating where they were placed in previous years. These profiles had the same number of flags per profile as in the past. The specific flag placement for each profile was determined by local landmarks, the distance across the glacier, the number of flags, and the length of the Thiokol tracks used to set the profile. For example, Profile 5 is located on the lower Southwest Branch, approximately 600 meters upglacier from its confluence with the main Taku Glacier, between Juncture Peak and the northern spur of Peak 4066. The glacier is 2,600 meters across at this location, within which 12 flags were placed. The beginning and ending flags were approximately 300 meters from bedrock, so this equates to a flag spacing of approximately 182 meters. Since Thiokol support was used to establish this profile, the diameter of the Thiokol tracks was used to provide an easy way of measuring approximate distances. The track diameter of the particular Thiokol used in setting Profile 5 was 5.64 meters, so by simply counting the track revolutions and placing a flag every 32.3 revolutions, an approximate and fairly consistent flag spacing of 182 meters was maintained. The year-to-year positional accuracy of flags placed in this manner is estimated to be approximately 30-40 meters. One advantage of this method is that, given a known profile bearing and the location of its first flag, the profile can be set in complete whiteout conditions. Naturally, this only works in those areas that are relatively crevasse-free, and which can be safely navigated by vehicle. In areas where vehicle support cannot be utilized, it is necessary to count paces in order to estimate the flag spacing. Appendix 1 details the profile bearings, number of flags, flag spacing, and other information useful for establishing each movement profile.

Unlike the majority of the Taku system profiles, Profile 4 was established by surveying-in the flags. This was necessary in order to obtain the positional accuracy needed by the ongoing mass balance survey of this profile. This involved utilizing a theodolite and EDM to determine the flag locations. The azimuth and slope distance to each flag was recorded from the 1993 survey of Profile 4, and these were used to find the locations for the 1994 flags. A positional accuracy of 2.74 ±0.77 meters was thus obtained. If the horizontal distance rather than the slope distance is used, the positional accuracy can be increased to the sub-meter level. Appendix 2 lists the bearings and distances used in the establishment of Profile 4.

2.2 GPS Survey Methods

The major portion of the survey program this year relied on the use of GPS equipment provided by the Universität der Bundeswehr in Munich, Germany. This equipment consisted of three Wild System 200 receivers, a portable personal computer, GPS processing software, and supporting gear such as batteries, tripods, monopoles, and cables. All GPS surveys were conducted using differential methods in “rapid-static” mode in which a reference receiver was placed on a known point within the Taku Local Network—typically a benchmark—and collected data continuously. Concurrently, one or two roving receivers were placed at each flag location and collected data at 15 second intervals for 10 to 20 minutes. This process was repeated for each flag of all profiles. Data from the reference receiver and the roving receivers was then downloaded to the computer and the observations were processed using the SKI (version 1.06) software package.

The primary factors affecting the accuracy of the obtained GPS observations are the baseline distance between the reference and roving receivers, the duration of the observation time at each point, the time of day, the number of satellites tracked, and the GDOP (geometric dilution of precision) value. Table 2 gives values for these parameters, as recommended by Wild (1992), that are necessary to achieve optimal results for rapid static surveys.

GDOP <= 8			
		Duration of Observation	
Number of Satellites	Baseline length	By Day	By Night
4-5	Up to 5 km	5 to 10 min.	5 min.
4-5	5 to 10 km	10 to 20 min.	5 to 10 min.
4-5	10 to 15 km	Over 30 min.	5 to 20 min.

Table 2: Recommended GPS observation parameters.

The parameters listed in Table 2 were used for all GPS surveys on the Juneau Icefield. The GDOP is a measure of the geometry of the satellite constellation; the ideal satellite constellation is one in which 4 or more satellites are equally distributed around the azimuth and 50 gons above the horizon. This geometry provides the greatest level of accuracy in the observations. Less than ideal satellite constellations reduce the accuracy and increase the GDOP value. The maximum allowable GDOP for the surveys performed on the Icefield was 8. The reference and roving receivers maintained a lock on a minimum of four satellites at all times in order to provide a solution of both horizontal and vertical position. In most cases however, 5-8 satellites were observed. All baseline lengths were under 10 kilometers, with the exception of Profile 2, which had a baseline of 12 kilometers. Appendix 3 lists the reference receiver locations for each GPS surveyed profile, the minimum and maximum baseline lengths from the reference to the roving receiver, and the observation duration for each profile.

The accuracy of GPS surveys centers on two key issues; the absolute accuracy and the relative accuracy of the observations. The absolute accuracy is the accuracy with which an observed position coincides with the actual true point on the earth’s surface. It is the absolute position of an observed point when viewed on a global scale. Relative accuracy refers to the position of an observed point with respect to another nearby point. It is not viewed on a global scale, but rather on a smaller, local scale. Relative accuracy is greater than absolute accuracy. The typical absolute accuracy attainable with the Wild System 200 GPS equipment is 30 to 50 meters in the horizontal and vertical positions. The absolute accuracy of horizontal positions will nearly always be greater than the absolute accuracy of vertical positions. An examination of the absolute accuracy of the GPS reference receiver location at Camp 12 revealed a horizontal accuracy of approximately 20 meters and a vertical accuracy of about 30 meters (Lang, 1995). These values are typical for all GPS surveys conducted on the Juneau Icefield. While an accuracy of 20-30 meters for a short time interval glacier movement survey may at first seem quite alarming, it is important to understand that the absolute position of the movement flags is not necessary. The absolute flag position derived from the GPS observations serves only as a means of locating the flags on a topographic map or other reference system. For this purpose, an accuracy of 30 meters in absolute position is suitable. A more accurate indication of the flag positions is given by the relative accuracy of the roving receiver locations with respect to a nearby stationary reference receiver. Given a baseline length of less than 15 kilometers, a GDOP less than or equal to 8, and a minimum of four satellites tracked, the relative accuracy of the Wild System 200 GPS observations is typically 5 mm ± 1 ppm in horizontal position and about 5 cm in vertical position (Wild, 1992). These specifications were met for all GPS surveys on the Juneau Icefield, therefore the relative accuracy of the coordinate determinations presented in Appendix 5 are within this tolerance. The absolute positions are accurate to within 30-50 meters.

After post-processing of the GPS observations was completed, the final coordinates were transformed to a coordinate system based on the Universal Transverse Mercator projection. Comparison of the flag coordinates for each of the two survey epochs then revealed the total movement, daily movement, bearing of the movement, total ablation during the survey period, and the daily ablation rate. These data were determined by standard trigonometric procedures as outlined by McGee (1993) and are presented in Appendix 6. Plots of the movement are shown in Appendix 7.

2.3 Terrestrial Survey Methods

While the use of GPS equipment on the Juneau Icefield is increasing, reliance on traditional terrestrial survey methods remains necessary. Several factors contribute to this. The steep topography of the Gilkey Trench, in particular, negates the exclusive use of GPS due to vertical obstructions greater than 15° above the horizon in most directions. Expedition logistics, difficult access to the Trench, and lack of generator support for recharging GPS batteries also contribute to the continued use of terrestrial methods. The complex logistics of expedition planning often require that all GPS equipment be evacuated from the Icefield in early August, thus the traditional movement profiles in the Camp 8 and Camp 18 areas must also rely on terrestrial surveys.

All terrestrial surveys on the Icefield utilized Wild T-2 optical theodolites and electronic distance measuring devices (EDMs). While the method used is standard surveying practice, and is well known within the surveying profession, a general outline of the methodology used will be given here so as to give a complete record of the terrestrial survey activities and also to demonstrate the validity of the surveys.

All terrestrial surveys during the 1994 JIRP field season relied on the polar survey method whereby the horizontal angle, vertical angle, and slope distance were measured. Once the movement profiles were established, the theodolite and EDM were set up on a known point within the Gilkey Local Network (a point within the Taku network was used for the survey of Profile 7) and a second known point within the network was sighted. This second point served as the reference point from which the individual movement flag observations were reduced. Two to three sets of face left and face right sightings were then taken to each flag in the movement profile. Concurrently, a team of assistants occupied each flag with prisms allowing for three EDM slope distances to be measured. The instrument height, prism height, atmospheric temperature, and atmospheric pressure were also recorded, and a correction for atmospheric conditions was applied to the measured slope distances. The mean of the horizontal and vertical observations for each flag were then calculated and the horizontal angles were reduced with respect to the reference point. The mean vertical angles and slope distances were used to determine the horizontal distance from the survey point to the individual flags. Flag coordinates for each survey epoch were then calculated, and the total flag movement, daily movement, and bearing of movement were calculated using the method outlined by McGee (1993). Appendix 5 lists the flag coordinates for each epoch and Appendix 6 presents the movement data. Plots of the movement are shown in Appendix 7.

3. Results of Surveys

The surveys conducted during the 1994 field season, while maintaining the continuous record of movement surveys, also focused on several other areas of interest. Most notably, a resurvey of the terminus of the Taku Glacier was performed. This resurvey, when compared to the terminal position of previous years, reveals the recent slow advancement of the glacier. Profile 4 on the Taku Glacier, due to its close proximity to Camp 10 and its easy access, received close attention in the form of surveys to determine strain rates, and also to determine changes in mass balance of the profile from year to year. An on-going project in the Gilkey Trench was continued again during 1994 in an effort to determine actual year-to-year movement of six profiles. Unlike surveys conducted in the accumulation zone, the surveys in the Trench relied on the relocation of flags from previous years. This enabled actual yearly movement, as opposed to summertime daily movement, to be determined. One other interesting, and important aspect of the 1994 GPS surveys was the acquisition and evaluation of movement profile surface elevations. These data are particularly relevant to mass balance and climatological studies conducted by other researchers.

3.1 Movement Profiles

Profile 1

This year marked the first time that a surface movement survey was conducted on Profile 1. This profile was first established by Thomas Poulter in 1949 as part of his seismic refraction studies of glacier thickness. Extending in a line across the lower Taku Glacier between Norris Mountain and the Brassiere Hills, this profile marks the approximate terminus position of 1890. Today, the terminus is some 5 kilometers down valley to the southeast. The location of Profile 1 also coincides with the narrowest cross-section of the Taku Glacier's valley system. Not surprisingly, the maximum daily movement rate measured was among the greatest observed on the Taku Glacier, second only to the movement at Profile 2.

Because this profile was surveyed via GPS, the very long baseline between established benchmarks in the Taku Local Network in the Camp 10 sector and the location of Profile 1 dictated that a temporary GPS reference station be established. This point was located at Camp 12, giving a maximum baseline length of 3.3 kilometers. The absolute accuracy of the observed flag positions is 20 meters in the horizontal and 30 meters in the vertical. However, the accuracy of the relative horizontal positions between the reference and roving receivers is within the 5 mm ± 1 ppm tolerance cited earlier and the relative accuracy of the vertical positions is approximately 5 cm.

This profile experienced the second greatest surface velocity measured on the Taku Glacier during 1994. A maximum rate of 91 cm/day was observed at flag 5, while a minimum of 19 cm/day was found at flag 11. The maximum rate of 91 cm/day was however, extrapolated from a survey epoch of less than 24 hours. Flags 6, 7, 8, and 9 were surveyed over a longer time period and experienced remarkably consistent movement rates of 80-86 cm/day. Because flag 5 was located in the central area of the profile near these flags, and because the crevasse pattern was consistent from flag 4 to flag 9, it may be assumed that the flow rate at flag 5 is not significantly different from that at flags 6, 7, 8, and 9.

Examination of the surface flow profile reveals a rectilinear mode of surface flow across the central portion of the glacier and more of a parabolic flow profile along the margins. Velocity variations of 20 to 50 cm/day exist between the marginal ice and the central portions of the glacier, resulting in marginal shear zones on the east and west sides of the profile. This is particularly true on the eastern margin. Flag 11, located approximately 100 meters from the bedrock of the Brassiere Hills, was observed to be moving at a rate of 19 cm/day, while flag 10, located 233 meters to the west had an observed movement of 60 cm/day. A increase in crevassing between flag 10 and the base of the Brassiere Hills provided additional evidence of the marginal shear zone. The boundaries of the shear zone however, were not as clearly delineated or abrupt as would be expected from a true rectilinear flow profile — particularly when compared to the well-defined marginal shear zones at Profile 2. Movement on the western margin of the profile also reflected this characteristic, although to a slightly lesser degree. The surface flow profile is shown in the plot in Appendix 7. As can be seen, the surface movement increases from the margins along a transverse, cross-glacier line. The greatest rate of increase is seen within about 300 meters of the margins, with the rate of increase declining, and indeed remaining fairly constant, across the central area of the profile.

The use of GPS equipment in the surveying of this profile provided significant data pertaining to the surface elevation profile. With a relative accuracy of approximately 5 cm, the surface elevation was determined to a high degree. This is particularly significant with respect to the advancement of the Taku Glacier. As the Taku continues to advance, a corresponding rise in the surface elevation will occur, and this rise can best be detected through continued GPS monitoring. Graphic evidence of the surface rise was discovered on the eastern margin of the glacier, at the base of the Brassiere Hills. As the glacier has continued its recent advance, it has thickened and is now encroaching on, and toppling, mature spruce and hemlock on the flanks of the Brassiere Hills. At one particular location, the ice was seen bearing directly on the trunk of a living spruce tree, which under the stress had developed a 5 cm wide crack extending vertically up the trunk for about 2 meters. The ice had even advanced into the crack, undoubtedly contributing to further weakening of the tree. Several other trees in the immediate vicinity had already been toppled by the ice and had been stripped bare of all branches. Continued GPS measurements along Profile 1 can detect important surface movement and elevation changes, thus aiding in the prediction of continued advance, stagnation, or retreat of the Taku Glacier terminus 5 km away.

The mean daily ablation during the survey period was 9.7 cm and the standard deviation of the daily ablation was 4 cm.

Profile 2

This profile, located 12 kilometers downglacier from Camp 10, was at the site of the transient snow line at the time of survey. Extending across the Taku Glacier from Goat Ridge on the east to Slanting Peak on the west, it is also the current location of drilling equipment used to drill a borehole at Profile 4 in 1950. The significance of the location of this profile is that it is located just down-glacier from the convergence of all the Taku Glacier's major tributary glaciers. Thus it marks the transition between the numerous highland glaciers which converge to form the main mass of the Taku Glacier and the point at which it becomes a true valley glacier. This transition is also coincident with the transient snow line.

The Taku Glacier becomes significantly constricted as it enters the bottleneck between Goat Ridge and Slanting Peak. At Camp 10, the width of the glacier is approximately 5.4 kilometers, while its width at Profile 2 is 3.4 kilometers. This represents a 37% decrease in width over a linear distance of 12 kilometers. This, in combination with the general location of the firn line, gave the greatest measured surface movement on the Taku Glacier in 1994. Using GPS methods, a maximum movement of 93 cm/day was obtained at flag 7, while the minimum was 57 cm/day at flag 1, at the eastern end of the profile.

Surface movement at this profile reveals that the Taku Glacier has a rectilinear mode of flow at Profile 2. Well defined and heavily crevassed shear zones exist at both the eastern and western margins of the glacier. In fact, the movement for flag 12 could not be determined because it was located in a very heavily crevassed area that could not be reached on foot for the initial survey. This flag was placed with the aid of helicopter support on the day of the first survey, and unfortunately due to logistics, could not be occupied using the helicopter. Snow and ice conditions four days later were such that the flag was able to be occupied at the time of the resurvey, thus giving at least the position of the flag. A plot of the surface flow profile is shown in Appendix 7.

The surface elevation as determined by GPS reveals a mean height of 806.18 meters. The western third of the profile, beginning at flag 8, is slightly higher than the rest of the profile. Average ablation was 11.9 cm/day and the standard deviation of the daily ablation was 2.2 cm.

Profile 3

The position of Profile 3 is approximately 6 kilometers downglacier from Camp 10 on the Demorest Glacier. Located roughly one kilometer upglacier from the convergence of the Demorest and Taku, the profile stretches between Taku A and the north ridge of Peak 4785, a satellite peak of Hodgkins Peak. These two mountains (Taku A and Peak 4785) form a gateway 2.6 kilometers wide through which all ice of the eastern accumulation zone of the Taku Glacier must pass. The siting of the profile at this location is significant because it allows the flow of the entire eastern accumulation zone to be monitored.

Examination of the surface flow profile reveals a mode of flow somewhere between parabolic and rectilinear. As measured via GPS, the movement of flags 3 through 9 is remarkably consistent, ranging from 25 cm/day to 28 cm/day; this across a distance of 1,129 meters. This consistent rate of flow gives a good indication of rectilinear, or "plug" flow in the central portion of the Demorest Glacier. The flow profile along the margins however, does not reflect a true rectilinear flow mode (see Appendix 7). The lack of chaotic, well-defined marginal shear zones supports this conclusion. While there is significant crevassing at the southeast margin, this is more likely due to its close proximity to the convergence zone of the Taku and Demorest glaciers, where the strong influence of the Taku's flow is manifested in deformation and crevassing of the Demorest Glacier. The northwest end of the profile, being approximately 1.5 kilometers upglacier from the convergence zone, is not significantly affected by the movement of the Taku Glacier, and thus is not heavily crevassed. In fact, the trend of the few crevasses in the area is consistent with a parabolic mode of flow.

The maximum rate of flow measured at this profile was 28 cm/day at flag 8, while the minimum was 17 cm/day at flag 12. The average surface elevation was 1,016.39 meters. The vertical cross-section (see Appendix 9) shows a slight depression in the center of the profile, flanked by a slight rise to the northwest and a greater rise to the southeast. The mean daily ablation during the survey period was 6.3 cm with a standard deviation of 0.9 cm.

Profile 4

Profile 4 has the longest continuous record of surface movement of any profile on the Juneau Icefield, having been first surveyed in 1949 and subsequently every year since. Its close proximity to Camp 10 and easy access makes it an ideal location to carry out long-term studies. Indeed, this profile has been the focus of much previous research. The first glacier borehole drilled on the Juneau Icefield was done here in 1950; seismic refraction and ice radar studies have been conducted to determine the depth of the ice; surface strain rates have been measured; and of course a record of surface movement has been collected dating back to 1946. In terms of glaciological data gathered, Profile 4 has been an extremely valuable asset.

This profile is located in the central sector of the Taku Glacier, extending across the glacier from Camp 10 to the northeast ridge of Shoehorn Mountain, a distance of 5.4 kilometers, making it the longest profile on the Taku Glacier. All accumulation within the northern and western sectors of the Taku system passes through this profile, after which the flow from the Southwest Branch and the Demorest Glacier (representing the eastern accumulation sector of the Taku system) joins to comprise the flow of the entire accumulation area of the Taku.

This profile was the location of several interesting survey projects during 1994. In addition to surface movement, strain rate and mass balance studies were done. This required a total of 31 movement flags, arranged in two parallel lines perpendicular to the flow. These two lines, with 16 flags on the down-glacier line and 15 flags on the up-glacier line, were offset so as to form a series of triangles across the Taku Glacier. The easting, northing, and height coordinates obtained from each flag provided the basis from which the various analyses were made.

Examination of the surface flow profile appears to reveal a rectilinear mode of flow, with the possibility of a slightly parabolic mode on both the northeast and southwest margins. While Profile 4 exhibits an overall rectilinear flow mode, it is however, not as pronounced as that at Profiles II and III. The maximum rates of flow, as determined by GPS, were found to be between flags 11 and 24. With a flow variance from 50-60 cm/day (a standard deviation of 3.2 cm) over a horizontal distance of 2,277 meters, this indicates that the central portion of Profile 4 is moving as a coherent block, and is corroborated by an absence of crevasses in this area. Significant chevron crevasse patterns along both margins of the profile clearly delineate the marginal shear zones and help to identify the transition from rectilinear flow to marginal parabolic flow. These zones are easily identified by comparing the standard deviation of flow with that of the central portion of the profile. The northeast margin has a standard deviation of flow of 15.3 cm across a horizontal distance of 930 meters, while the southwest margin has a standard deviation of 16.5 cm across a horizontal distance of 1,063 meters.

The maximum movement measured was 60 cm/day at flags 17, 18, and 19, and the minimum was 1 cm/day at flag 1. Surface elevation ranged from 1,098.20 meters at flag 15 to 1,127.46 meters at flag 31. Mean daily ablation was 6.2 cm with a standard deviation of 1.4 cm.

Profile 5

Profile 5 was located on the Southwest Branch of the Taku Glacier approximately 600 meters upglacier from its confluence with the Taku. Extending between Juncture Peak and the north ridge of Peak 4066, the profile was composed of 12 flags over a distance of 2.2 kilometers.

This profile exhibited the lowest magnitude of flow of all the profiles surveyed on the Taku Glacier. With a relatively small accumulation area of 32 km^2, this low magnitude of flow is to be expected. Unlike Profiles 3, 4, 6, and 7a, which each measure the flow of multiple branches and much larger accumulation areas, this profile is on a single glacier, with no tributaries entering it. The maximum movement measured at Profile 5, as measured via GPS methods, was 9 cm/day, while the lowest was 1 cm/day. The flow profile reveals a true parabolic mode of flow, indicating that the flow regime of the Southwest Branch is not as vigorous as that of the rest of the Taku system. The absence of significant crevassing gives an indication of the low energy nature of flow at this profile, which is further corroborated by the measured flow rates.

The mean surface elevation was 1,053.3 meters. As can be seen in Appendix 8, the surface elevation of the southeast end of the profile was approximately 24 meters higher than the northwest end. Mean daily ablation was 5.4 cm and the standard deviation of the daily ablation was 0.6 cm.

Profile 6

Located between Peak 5810 (Taku D) and Taku Northwest, this profile is approximately 5 km down-glacier from a crestal divide between the southern Taku Glacier and a minor northward-flowing branch of the Taku that ultimately spills into Avalanche Canyon and the Gilkey Trench sector of the Juneau Icefield. The flow of the western accumulation area of the Taku system, out of which flow Mendenhall, Eagle, Herbert, and several other smaller glaciers, passes through Profile 6, making this profile an important element in the continued monitoring of surface elevations and flow rates. Profile 6 was 5 kilometers wide, making it the second longest profile measured on the Icefield, surpassed only by Profile 4 with a width of 5.4 kilometers.

Examination of the surface flow profile reveals a parabolic mode of flow, with a slight asymmetric shift of the maximum movement toward the southwest two-thirds of the profile. This is most likely indicative of the buried southwest ridge of Taku D, which tends to inhibit the flow of ice in the area of flags 14, 15, and 16. In fact, these flags exhibited the lowest flow rates at Profile 6, with the minimum movement of 1 cm/day observed at flag 16. The maximum movement was seen at flag 8, with a rate of 32 cm/day. Examining the flow Profile 1n Appendix 7 reveals an apparent movement anomaly at flag 5. With a mean daily movement rate of 18 cm, this is in sharp contrast with the movement observed at the adjacent flags 4 and 6, which had daily movements of 25 cm and 30 cm, respectively. This is explained by the fact that flag 5 had ablated out and fallen over between the initial survey and the resurvey. The flag was repositioned at the time of the resurvey, but was unfortunately relocated in a different position, thereby giving the anomalous movement rate.

The magnitude of crevassing at this profile was minimal, with a typical pattern of marginal shear crevasses and a central crevasse-free area seen. The absence of major crevasse zones, in conjunction with the observed moderate rates of flow, gives a strong indication of low-energy parabolic flow at this profile.

The mean surface elevation of Profile 6 was 1,260.6 meters. As shown in Appendix 8, the surface elevation of the southwest end of the profile was approximately 14 meters higher than the northeast end. Mean daily ablation was 10 cm and the standard deviation of the daily ablation was 0.7 cm. The total and mean daily movement for all flags was obtained, except for flag 2. Hardware problems with the GPS equipment prevented the initial survey of this flag on July 25. However, the flag was surveyed on August 5, giving at least the location of the flag with respect to the others in the profile.

Profile 7a

Located on the Matthes Glacier approximately 700 meters up-glacier from its confluence with the Taku Glacier, Profile 7a was composed of 14 flags spanning a distance of 2.8 kilometers. Its location between Peak 5030 (Taku C) and Peak 5810 (Taku D) formed a near right angle with respect to the orientation of Profile 6. The Matthes Glacier is an important part of the on-going flow regime and mass balance monitoring of the Taku Glacier because it encompasses the highest elevation névés of the Taku system. This area has experienced strongly positive accumulation in recent years, thus making it vitally important to determine the temporal and spatial changes in flow regime and mass balance.

The surface flow profile at Profile 7a indicates some combination of parabolic and rectilinear flow. It also suggests the presence of an asymmetric channel because the greatest rates of flow are concentrated along the southeast half of the profile. Crevassing was minimal at the northwest margin of the Matthes, with only a few typical marginal shear crevasses present. The minimum daily movement of 1 cm/day was observed at flag 1, which increased to a maximum of 43 cm/day at flags 8, 9, and 10. A central coherent “plug” of the Matthes Glacier is apparently delineated by flags 7 through 11, which had daily movements ranging from 41 cm/day to 43 cm/day. This is a deviation of only 2 cm/day over a linear distance of 890 meters. This area is free of crevasses, giving additional evidence of the absence of shear stresses. Significant crevasses were present at the southeast margin of the profile near the base of Taku C. At a distance of approximately 450 meters from the bedrock of Taku C, flag 14 had a daily movement of 28 cm/day. Contrast this with the daily movement of 4 cm/day at flag 2, also approximately 450 meters from the base of Taku D, and it can be seen that the magnitude of movement is significantly greater along the southeast half of the profile. The higher movement rates here give rise to the well defined marginal shear zone, and indicate a more rectilinear mode of flow than that seen along the northwest half of the profile.

The average surface elevation of Profile 7a was 1,275.6 meters, with the southeast end of the profile being 28 meters higher than the northwest end. The mean daily ablation was 10 cm/day, and the standard deviation of the ablation measurements was 1.5 cm.

Profile 7

Profile 7 was located on the Matthes Glacier approximately 4.7 kilometers upglacier from Profile 7a, and had 12 flags which extended 3.8 kilometers across the glacier from Camp 9 to the southeast ridge of Centurian Peak.

This was one of three profiles on the Taku Glacier system that was surveyed via terrestrial methods. As can be seen in the surface movement plot in Appendix 7, the movement vectors are more erratic than are the vectors for the GPS surveyed profiles. Unfortunately, the survey results are not consistent with the observed crevasse patterns in the area of the profile. For example, the movement of flags 4 through 9, as shown on the movement vector plot, would indicate the presence of significant shear crevasses. This was however, not the case — this area was, for the most part, free of crevasses. The movement of flags 10, 11, and 12 was estimated because these flags were beyond the range of the EDM. The estimated movement is very approximate and cannot be trusted to a high degree. Because of this, it is not possible to determine, with high confidence, the mode of flow at this profile. Judging from the crevasse patterns however, it may be assumed that a parabolic mode of flow exists here.

There are several reasons for the inaccuracies contained in this survey. The first survey was performed on August 13, with the resurvey being done only 3 days later. This, combined with the slower movement at Profile 7 and the use of terrestrial methods, meant that the movement could not be determined with a high degree of accuracy. Likewise, surface elevation and ablation measurements are only rough approximates. Future surveys at this profile should utilize GPS methods, thus giving more accurate interpretations of the surface flow regime.

Profile 8

This profile was located in the area of the highest elevation névé of the Taku Glacier at an approximate elevation of 1,800 meters, and covered a distance of 2.9 kilometers from the south ridge of Blizzard Peak to Camp 8. It was also the farthest up-glacier profile surveyed on the Taku Glacier, being only 4 kilometers from the divide between the north flowing Llewellyn Glacier and the south flowing Taku Glacier.

Like Profile 7, this profile was also surveyed via terrestrial methods, which limited the maximum distance to the furthest flag. The distance from the survey point (FFGR 39) to the base of the Camp 8 slope was 4.8 kilometers. Due to the known limited long-range capabilities of the EDM however, the last flag of the profile was placed 3 kilometers from the survey station, leaving nearly 2 kilometers of the Taku Glacier between Blizzard Peak and Camp 8 unsurveyed. Unlike the survey of Profile 7 however, atmospheric conditions were such that reflections were obtained at the extreme limit of the EDM's range.

Because this profile was surveyed with terrestrial methods, the resolution of the movement data is not as precise as that obtained via GPS methods. This makes it more difficult to interpret the flow profile to determine the mode of flow. This is particularly true in light of the fact that 40% of the profile from Blizzard Peak to Camp 8 was not surveyed. An additional complication arises from the fact that flags 1, 2, and 3 were located on the slope of the Blizzard Peak survey point. As shown on the movement vector plot in Appendix 7, it can be seen that these flags reflect the local down-slope movement rather than the movement of the Matthes Glacier proper. The measured movement at flag 14 is erroneous because the difference in flow between it and flag 13 (11 cm/day over a linear distance of 286 meters) would suggest the presence of significant shear crevassing between these two flags. Crevasses did not exist at this location. From the limited data that was collected however, it appears that a parabolic mode of flow may exist here. Future GPS surveys should be conducted here to properly quantify the flow characteristics of Profile 8.

Upper Vaughan Lewis Profile

This profile was located at the head of the Vaughan Lewis Icefall in the Camp 18 sector. This was the only profile, with the exception of the profiles in the Gilkey Trench, not located on the Taku Glacier or its tributaries. Ten flags were located approximately 1.3 kilometers upglacier from Camp 18 in the crevasse zone of the extreme upper Vaughan Lewis Icefall. This was an extensive zone of crescentic, concave down-glacier crevasses, and is characterized by extending flow. Unlike all other profiles which formed more or less straight transects, this profile followed the crescentic trend of the crevasses, forming an arc between the extreme eastern end of the Camp 18 cleaver and the northeast ridge of Mammary Peak.

Like Profiles VII and VIII, this profile was surveyed with terrestrial methods. Unlike the other two profiles however, the data collected for this profile is more reliable due to the close proximity of all ten flags to the survey point. The maximum distance from the survey point to the last flag was 1.5 kilometers — well within the EDMs 3 kilometer range.

Appendix 7 illustrates the movement vectors for the Vaughan Lewis profile. The flow lines cross each other on the plot only because of the exaggeration of the scale of movement with respect to the scale of the map. The actual movement vectors do not cross on the glacier until they have moved into the chaotic, surging flow of the icefall proper. The maximum movement rate was 35 cm/day at flag 5 and the minimum was 13 cm/day at flag 8. The direction of the movement at flags 2 and 10 is not consistent with the overall direction of movement, or with the aspect of the slopes upon which they were located. It is therefore likely that the survey data for these two flags is erroneous. The mean surface elevation, as calculated with trigonometric height methods, was 1,552.7 meters. The Gilkey local network provided the vertical datum for the height measurements.

3.2 Taku Profile 4 Mass Balance Survey

Mass balance studies on the Juneau Icefield rely on ground-based observations obtained from test pit studies and meteorological records. Focusing primarily on the accumulation regime, the objective of the mass balance program is to determine the amount of water equivalent remaining at the end of the ablation season. The methods employed provide detailed information about the stratigraphy of the firn pack and the thickness of the annual accumulation layer. Detecting changes in the surface elevation of the glacier however, cannot be ascertained with test pit methods.

With the advent of GPS-based surveying on the Juneau Icefield it has become possible to accurately monitor the surface elevation changes of the Taku Glacier. This GPS obtained survey data, in conjunction with desktop personal computers and sophisticated surface modeling software, allows detailed analyses of temporal and spatial changes of the surface morphology to be performed. Consequently, it is now possible to gain a much more detailed three-dimensional visualization and understanding of the accumulation regime of the Taku Glacier.

In 1993 Profile 4 was established as a double profile. This consisted of two parallel lines of flags set perpendicular to the glacier flow. The two lines were offset so as to form a series of triangles between the up-glacier and down-glacier lines. This configuration allowed for the collection of surface movement, strain rate, mass balance, and elevation data from one set of observations. Profile 4 survey data collected in 1993 serves as the baseline from which the 1994 data, and future mass balance survey data can be compared.

This season, the mass balance survey of Profile 4 was continued. Four additional flags (two each on the up-glacier and down-glacier lines) were added to the southwest end of the Profile 1n order to extend it to the base of Shoehorn Peak. All flags were surveyed in from the origin of the Taku Local Network at Camp 10 (FFGR 19), with FFGR 19.1 as the primary reference point. The horizontal angle, vertical angle, and slope distance obtained from the 1993 survey were used to determine the flag locations in 1994. These data are shown in Appendix 2. The mean positional accuracy of the placement of the flags in 1994, as compared to their locations in 1993, was 2.738 ± 0.772 meters. To ensure consistency of year-to-year comparisons, it is critical that all future mass balance surveys of Profile 4 be based on easting and northing flag coordinates derived from the terrestrial survey observations of July 20, 1993.

The mass balance survey of Profile 4 was a multi-phase process. The first step was to perform the GPS survey to determine the easting, northing, and height coordinates of the flags. Using a surface modeling program called *Surfer*, these data then served as the basis of constructing a three-dimensional model of the surface of Profile 4. Refer to McGee (1994) for a detailed discussion of the application of surface modeling to mass balance studies. Briefly, the method involved constructing a 2 meter by 2 meter regularly-spaced grid from the irregularly-spaced movement data. Grid nodes (i.e., the intersection of easting and northing coordinates) not located at a surveyed data point location were interpolated with a linear krigging algorithm. The parameters used for the gridding operation are shown in Appendix 10. The generated grid covered an area of 9 km^2 and included areas outside the extent of Profile 4. Because interpolation is not accurate in those areas where survey data were not collected, it was necessary to disregard — or blank — these areas. A blanking file, containing a series of easting and northing coordinates that define a closed polygon, was used to set the Z coordinate of all grid nodes outside the area of Profile 4 to zero. This resulted in a grid of X, Y, and Z coordinates for the profile only. After creating the blanked grid, it was further refined by performing spline smoothing to increase the grid resolution to 1.5 meters. Smoothed grids were thus created from the survey data of July 25, 1993 and July 25, 1994.

Krigging is an approximate interpolator, meaning that the algorithm generates a grid based on the X, Y, and Z coordinates of the input data. It attempts to construct an optimum surface that honors the trends contained in the input data, but it does not retain the exact Z coordinate of the input except in the case where the X and Y coordinates of an input point exactly match the X and Y coordinates of an interpolated node. It is therefore very important to have an understanding of the accuracy of the interpolated surface, and this can be done by examining the residuals of the surface. Residuals are given in the same units as the input coordinates—in this case, meters—and reflect the deviation in elevation, at the same X and Y location, between the interpolated surface and the Z coordinate of an input data point. A positive residual indicates that the X, Y coordinate of the input data is above the interpolated surface, while a negative residual shows that the X, Y coordinate of the input data is below the interpolated surface. For example, assume the surveyed easting and northing coordinates of Flag 1 are 487,000 and 6,500,000 respectively, and the elevation is 1,010 meters. The elevation of the interpolated surface at 487,000 meters east and 6,500,000 meters north is 1,010.062 meters. Because the interpolated elevation is above the actual surveyed elevation, this gives a residual of -0.062 meters. By examining the residuals of an interpolated surface it is possible to get an understanding of how well the numerous gridding parameters used to create the grid actually honor the original survey data. As the standard deviation of the residuals decreases, the accuracy of the interpolation increases, thus giving a grid that approximates the true surface to a higher degree. The residuals, and other descriptive statistics, of both survey epochs are shown in Table 3 below. The low standard deviation of the residuals of the two interpolated grids gives an indication of the accuracy of the interpolation, thus providing a high degree of confidence in the generated surface models. This is critically important because the accuracy of the surface model affects the accuracy of the surface area and volume computations needed for the mass balance study. The listed standard deviations of 2.9 cm and 3.2 cm are well within the ±5 cm height tolerance of the GPS equipment, thus providing additional evidence of the fit of the interpolated surfaces to the original survey data.

	July 25, 1993	**July 25, 1994**
Standard deviation	0.029	0.032
Sum	-0.016	-0.016
Average	-0.001	-0.001
Minimum	-0.071	-0.088
Maximum	0.055	0.063

Table 3: Residuals (in meters) of interpolated surface for surveys of Taku Profile 4.

After constructing the surface models for the 1993 and 1994 surveys, the volume of the two surfaces was calculated. Basically, this involved determining the volume of firn defined in three dimensions by the interpolated surface at the top, an arbitrary horizontal reference plane at the bottom (the reference plane elevation was set at 1,095 meters), and the X and Y coordinates of the polygon that was used in the blanking operation. Using *Surfer*, the volume was then computed with the Trapezoidal Rule, Simpson's Rule, and Simpson's $^3/_8$ Rule algorithms. The mean volume for the July 25, 1993 survey was 13,619,833 ± 981 m^3 and the mean volume for the July 25, 1994 survey was 13,795,700 ± 953 m^3. Because the elapsed time between the 1993 and 1994 surveys was 366 days it was necessary to adjust the calculated volume of the 1994 survey by factoring in the mean daily ablation for one day, giving an adjusted survey period of 365 days. Between July 25, 1994 and August 5, 1994, the mean daily ablation for Profile 4 was 6.2 cm. This value was then added to the Z value of all grid nodes in the interpolated grid of July 25, 1994, giving a new grid representing the surface of the profile on July 24, 1994. The volume defined by this surface and the reference plane was 13,859,100 ± 953 m^3 and its surface area was 1,014,420 m^2.

The volume **between** the 1993 surface and the adjusted 1994 surface was then calculated with the three volume algorithms in *Surfer*. This involved specifying an upper surface (July 24, 1994) and a lower surface (July 25, 1993), between which the volume was determined. This gave a net yearly accumulation of 239,265 ± 11 m^3 over a surface area of 1,014,317 m^2 from July 25, 1993 to July 24, 1994. This equates to a mean rise in surface elevation of 23.6 cm, with the vertical tolerance being equal to the accuracy of the original GPS height determination of ±5 cm. The interpolated surface of Profile 4 is shown in Appendix 11 and depicts the surface and volume above the 1,095 meter reference plane for the July 25, 1994 survey. The surface for the July 25, 1993 survey is similar but not shown because the difference between it and the 1994 surface is not visible at the scale shown.

By constructing surface models of Profile 4 it is possible to gain an in-depth understanding of not only the temporal surface changes, but also the spatial changes. For example, we know that the surface of Profile 4 was 23.6 cm higher in 1994 than in 1993. But was this evenly distributed across the profile, or was the accumulation greater in some areas and less in others? Where was the most accumulation? Where was the least? These questions can be answered by constructing a grid of the spatial distribution of accumulation based on the height difference between the 1993 and 1994 surfaces. The net accumulation from July 25, 1993 to July 24, 1994 was positive, however the spatial distribution pattern was in fact both positive and negative. This is graphically illustrated in the spatial distribution surface map and contour map shown in Appendix 11. Referring to the contour map, those areas depicted by blue shading represent positive accumulation while the red shaded areas are those that experienced negative accumulation. This is for the time period of July 25, 1993 to July 24, 1994. The total positive volume, as calculated by the Trapezoidal Rule only, was 245,023 m^3, and the total negative volume was 5,754 m^3, giving a net accumulation of 239,269 m^3. In terms of the surface area, 92.3% of the profile had a positive balance, while 7.7% had a negative balance. See Appendix 11 for additional details concerning surface area and volume computations for each survey epoch and the mass balance regime of Profile 4 from 1993 to 1994; summary statistics are presented below.

Volume above 1,095 meters (7-25-93)	13,619,833 ± 981 m^3
Volume above 1,095 meters (7-24-94)	13,859,100 ± 953 m^3
Volume between 1993 and 1994 surfaces	239,265 ± 11 m^3
Surface area of Profile 4 (7-24-94)	1,014,420 m^2
% of surface area with positive balance	92.4%
% of surface area with negative balance	7.6%
Rise in surface elevation (7-25-93 to 7-24-94)	23.6 cm ± 5 cm

Table 4: GPS mass balance survey of Taku Profile 4. Initial survey performed on July 25, 1993. Resurvey performed July 25, 1994 (adjusted to July 24, 1994). Time interval: 365 days.

3.3 Taku Profile 4 Strain Rate Analysis

The major geodetic activities during 1994 focused on surface movement surveys and mass balance determination of Profile 4. These surveys provide important information concerning the direction and magnitude of surface movement, and on the spatial and temporal distribution of accumulation, but do not address the stress/strain regime. In order to more fully understand the dynamics of glacier movement it is necessary to determine strain rates and the direction of the maximum and minimum principle strains. An understanding of the vertical component of glacier movement is also gained by examining the strain regime.

All strain rate calculations for Profile 4 were derived from the easting and northing coordinates for each flag. These coordinates were obtained via differential GPS survey methods, with a relative accuracy of approximately 5-10 mm. The double profile configuration of Profile 4 yielded 29 individual strain triangles, the points of which were defined by the movement flags. Triangle 1 was composed of flags 1, 2, and 3; triangle 2 was composed of flags 2, 3, and 4; triangle 3 was composed of flags 3, 4, and 5; and so on to triangle 29, which was composed of flags 29, 30, and 31. For each triangle, the easting and northing coordinates were used to solve the triangle for the horizontal length of the three sides and the three interior angles. Each triangle of Profile 4 was solved for each of two survey epochs — July 25, 1994 and August 5, 1994. Strain rates and the direction of the maximum and minimum principle strains, which together define the strain ellipse, were then derived from these data using the method outlined by Welsch (1987). Briefly, this is an affine coordinate transformation method which determines the strain ellipse based on the deformation of the length of the sides and the interior angles of a triangle. Strain is defined as the change in length of a line divided by its original length, and can be either positive or negative. The maximum principle strain (E_1) is the result of tensile stress and the minimum principle strain (E_2) reflects compressional stress. Application of the strain equilibrium relationship $E_1 + E_2 + E_3 = 0$ allows the vertical component (E_3) of the three-dimensional strain ellipsoid to be determined. The direction of the maximum strain (θ) is given with respect to true north, with the minimum strain being perpendicular to the maximum strain. The strain is expressed as μstrain^{-d}.

Crevasse patterns at Profile 4 indicate the existence of marginal shear zones at the northeast and southwest ends of the profile, with the central area being free of crevasses. The magnitude of crevassing is greater at the northeast margin than at the southeast margin. These empirical observations are corroborated and quantified by the strain rate analysis, as shown by the tables and diagram in Appendix 12. As can be seen from the diagram, the principle strains are greatest in the area of flags 1 to 13. This is also the area of the greatest crevassing. The minimum strains are found in the central portion of the profile (flags 13 to 25), with a slight increase in strain from flags 25 to 31.

3.4 Taku Glacier terminus survey

The survey of the Taku terminus was part of an on-going effort by the Juneau Icefield Research Program to monitor the advance of the Taku Glacier. The last such survey conducted by the program was in 1991. This year, as part of the movement surveys on the lower Taku Glacier, the terminus was again surveyed. This survey was performed with terrestrial methods, with Taku Point serving as the survey point, and a small island on the east side of the Taku River and northeast of Taku Point serving as the reference point. The survey station on Taku Point was marked by an iron peg and ring set into the bedrock of the point. A similar iron peg and ring marked the location of the reference point on the island.

The current survey reveals a slow advance of the Taku since the 1991 survey. It must be cautioned however, that this was more of a reconnaissance survey rather than a highly-accurate geodetic survey. Briefly, the method employed utilized a theodolite and EDM at the survey point, while the points to be surveyed along the terminus were occupied with the aid of helicopter support. The need for this helicopter support constrained the time frame for the completion of the survey. Thus, in order to get any data at all, it was necessary to compromise the accuracy of the survey. One important manifestation of this was that only one set of face left readings were taken. Thus, an unknown instrumental error was introduced into the survey data. Additionally, since the observations were taken to the prism being held in the helicopter, it was important that the helicopter hover directly over the extreme edge of the ice. This was not possible at several places and the distance from the helicopter to the ice was roughly estimated by those in the helicopter. The accuracy of this estimation is roughly 5-10 meters. For these reasons, the present survey of the terminus must be considered to be only an approximation to the nearest 5-10 meters. Appendix 13 presents the reduced survey observations and a plot of the data showing the position of the 1994 terminus with respect to its location in 1971.

3.5 Gilkey Trench surveys

During the 1990 JIRP field season, six movement profiles were established in the convergence zone of the Gilkey and Vaughan Lewis glaciers. These profiles were unique in that they were located below the equilibrium line on the ice, rather than in the accumulation zone as with all other profiles on the Juneau Icefield. The purpose was to track the actual year-to-year movement of ice through the convergence zone by relocating and resurveying the flags every year.

This year, due to most of the surveying focus being placed on the Taku Glacier, time was rather limited, forcing an abbreviated survey of the Gilkey Trench profiles. Of the 50 flags within the convergence zone, only 25 flags (in three profiles), were relocated and surveyed via terrestrial methods. Because the Gilkey Trench surveys are part of a separate study, the results of the surveys are being compiled in a separate report and are not presented here. Refer to Flow Dynamics within a Glacial Convergence Zone (McGee, in progress) for a complete discussion of these surveys.

4. Prospects/recommendations for future surveys

Several shortcomings of the 1994 survey program must be addressed and corrected for the 1995 JIRP field season. Chief among these is the need to have access to GPS equipment for the entire program. Height determinations are critically important in tracking the surface elevation changes in both the accumulation and ablation zones. The accuracy of both movement and height determinations for Profiles 7, 8, and the Upper Vaughan Lewis could be dramatically improved with the application of GPS methods. Trigonometric height determinations are not reliable due to the extreme and often unpredictable effects of atmospheric refraction over ice. With the advent of GPS survey methods and equipment, these height determinations can consistently be made to an accuracy of ±5 cm.

Future surveys of the Taku Glacier terminus should be done either with GPS or terrestrial methods. If terrestrial methods are used, it is imperative that adequate time be allocated so as to make possible an accurate survey. If possible, helicopter support should be used only for transporting equipment and personnel across the Taku River to the survey and reference points. To the greatest extent possible, points to be surveyed at the terminus should be occupied by ground personnel.

With regard to future survey prospects, it is important to continue the GPS survey of Profile 1 that was started in 1994. Because of its close proximity to the terminus, detecting changes in the surface elevation here will allow greater precision in estimates of future advance of the terminus. Continued monitoring of the surface movement will give an indication of the flow regime across an east/west transect, thus making possible predictions of advance or retreat on the east and west sides of the terminus. With more area available on the west side for lateral spreading than on the east, the continued slow advance on the west side may not pose an immediate threat to closure of the Taku River valley. Continued monitoring of Profile 1 will provide critical information relating to the advance or retreat of the terminus only 5 kilometers distant.

The use of GPS equipment provides very exacting measurements of surface elevations. However, to do this, it is critical that the height of the GPS receiver above the glacier surface be consistently determined from epoch to epoch. This is illustrated by the chart in Appendix 9. The standard deviation of the ablation measurements ranges from 0.6 cm/day to 4.0 cm/day. This statistic reflects inconsistent measurements of the receiver above the glacier surface. A better method is needed to ensure that the standard deviation of the ablation measurements is consistently low from profile to profile. This can be accomplished by using a board of a standard length and width to flatten the tops of the suncups surrounding a flag to find the mean surface. Determining the antenna offset by measuring from this mean surface to the GPS receiver would help to maximize the accuracy of the ablation measurements, as evidenced by more consistent standard deviations of the ablation from profile to profile.

An interesting project to undertake, and one which would provide an unprecedented amount of movement and elevation data throughout the entire Taku Glacier accumulation zone, would be to equip an oversnow vehicle for a completely self-contained, roving 7-10 day GPS mission with two personnel. This could be accomplished simply by using two GPS receivers and moving from site to site from the lower reaches of the accumulation zone up to the crestal divide between the Llewellyn and Taku glaciers. Enough fuel could be transported by sled to provide for the vehicle and for keeping the GPS batteries charged. The massive amount of data provided by this kind of survey mission would, for the first time, make possible some fairly comprehensive GIS analyses of the flow, mass balance, and other dynamics of the Juneau Icefield.

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Appendices

Appendix 1

Movement Profile Locations

Profile	Number of Flags	Flag Spacing (meters)	Bearing From First Flag to Landmarks* (degrees)	Bearing From Last Flag to Landmarks* (degrees)	Bearing of Profile From First Flag to Last Flag (degrees)
Profile 1 (Brassiere Hills)	11	260	Brassiere Hills: 67 Norris Mt.: 267	Annex Peak: 202 Norris Mt.: 254	64
Profile 2 (Goat Ridge)	12	236	Slanting Peak: 255 Taku A: 343	Slanting Peak: 258 Taku A: 357	249
Profile 3 (Demorest Glacier)	14	215	Taku SW: 222 Taku A: 294	Taku SW: 244 Taku A: 306	132
Profile 4 (Camp 10)	31	313**	Shoehorn Pk.: 230 Taku C: 332	Shoehorn Pk.: 235 Taku C: 12	227
Profile 5 (Southwest Branch)	12	200	Taku A: 52 Taku SW: 138	Taku A: 32 Taku SW: 141	139
Profile 6 (Northwest Branch)	16	280	Taku D: 38 Taku B: 94	Taku D: 32 Taku B: 122	38
Profile 7 (Camp 9)	16	293	Exploration Pk.: 212 Taku D: 264	Exploration Pk.: 154 Taku D: 222	297
Profile 7a (Taku C to Taku D)	14	242	Centurian Pk.: 17 Taku C: 129	Taku C: 140 Centurian Pk.: 351	126
Profile 8 (Camp 8)	16	280	Mt. Moore: 121 Mammary Pk.: 245	Mt. Moore: 108 Mammary Pk.: 275	122
Upper Vaughan Lewis (C-18)	10	155	Typhoon Pk.: 54 Mammary Pk.: 193	Typhoon Pk.: 34 Mammary Pk.: 212	Profile parallels trend of crevasses

* All bearings are to the summits of the noted mountains.

** Profile 4 is composed of two parallel lines of flags. The up-glacier line has 15 flags and the down-glacier line has 16 flags. The spacing of flags on each line is approximately 313 meters.

Appendix 2

Profile 4 Flag Positions

Flag	Horizontal Angle (gons)	Vertical Angle (gons)	Slope Distance (meters)	Horiz. Distance (meters)
FFGR 19.1	0.0000	—	—	—
Taku C Upper	391.3556	—	—	—
1	280.9399	111.2461	348.635	343.209
2	316.9751	107.2506	481.750	478.629
3	281.0705	106.9325	541.761	538.552
4	305.2112	105.3700	664.096	661.735
5	281.1324	105.0839	739.977	737.619
6	298.1726	104.2454	877.870	875.919
7	281.1768	103.9288	992.744	990.854
8	294.3505	103.5406	1,069.190	1,067.537
9	281.1909	103.1371	1,232.582	1,231.086
10	291.6761	102.9980	1,267.551	1,266.146
11	281.2056	102.7177	1,412.802	1,411.515
12	289.2542	102.5273	1,521.446	1,520.247
13	281.2007	102.2201	1,735.224	1,734.169
14	288.4124	102.0243	1,869.972	1,869.027
15	281.2232	101.9951	2,047.698	2,046.693
16	287.4898	101.7149	2,214.844	2,214.040
17	281.2248	101.5685	2,440.900	2,440.159
18	286.4179	101.2900	2,660.418	2,659.872
19	281.2158	101.2190	2,815.703	2,815.187
20	285.8352	101.0184	2,999.245	2,998.861
21	281.2104	100.9475	3,193.115	3,192.761
22	285.4214	100.8367	3,331.832	3,331.544
23	281.2092	100.8232	3,515.786	3,515.492
24	285.2326	100.7465	3,685.114	3,684.861
25	281.2022	100.7162	3,904.213	3,903.966
26	285.1628	100.6633	4,024.123	4,023.905
27	281.2066	100.6461	4,282.840	4,282.619
28	285.1135	100.5808	4,473.231	4,473.045
29	281.2068	100.5365	4,631.347	4,631.183
30	285.0770	100.5236	4,809.039	4,808.876
31	281.2050	100.4535	4,967.534	4,967.408

Survey Point:	FFGR 19 (origin)	Instrument Height:	1.5 meters
Primary Reference:	FFGR 19.1	Prism Height:	0.08 meter
Secondary Reference:	Taku “C” Upper	PPM:	32

Appendix 3

GPS Movement Profile Parameters

Profile	Reference Receiver Location*	Minimum Baseline Length (km)	Maximum Baseline Length (km)	Duration of Observation (minutes)
Profile 1	Camp 12	1.3	3.3	15
Profile 2	FFGR 19.1	12	12.2	30
Profile 3	FFGR 19.1	4.7	6.9	20
Profile 4	FFGR 19.1	0.6	5.2	15
Profile 5	FFGR 19.1	6	7.2	20
Profile 6	FFGR 40	0.6	4.8	15
Profile 7a	FFGR 40	0.5	3.2	15

Appendix 4

Juneau Icefield Benchmark Coordinates

1994 GPS Survey of Primary Taku Local Network Benchmarks				
Point	Easting (m)	Northing (m)	Height (m)	Time
FGER 19	488,016.395	6,503,294.021	1,161.095	-
Camp 12	494,284.874	6,479,539.752	197.000	- *
Scott (FFGR 19.1)	487,977.884	6,503,375.520	1,170.000	-
Taku D Lower (FFGR 40)	482,616.096	6,509,096.181	1,379.471	-

* Coordinates derived from single point positioning only.

Gilkey Local Network Benchmarks and Coordinates								
		Easting (m)		Northing (m)			St. Dev. (m)	
No.	FFGR	1984	1986	1984	1986	Height (m)	1984	1986
1	45	10,000.00	9,996.26	10,000.00	9,994.09	1,583.06	0.07	0.01
2	C8	18,480.30		10,000.00	10,000.00		0.57	
2.1		18,477.30	18,477.48	9,995.63	9,995.63	1,883.86		0.08
4	39	12,900.16	12,908.47	11,167.37	11,153.44	1,821.25	0.31	0.11
5	68	10,103.65	10,103.67	10,039.16	10,038.88	1,588.48	0.08	0.01
6	24	9,901.52	9,901.52	9,910.67	9,910.67	1,570.29	0.07	
7	43	9,724.82	9,724.73	9,815.97	9,816.18	1,540.64	0.08	0.01
8	44	9,609.27	9,609.08	9,689.25	9,689.52	1,506.41	0.09	0.02
9	31	9,490.60		9,638.69		1,458.61	0.06	
11	49	9,290.01		9,261.48			0.13	
12	48	9,156.11		9,240.95			0.13	
14	C19	8,766.81		7,532.72			0.12	
15	18	8,882.11		7,462.77			0.12	
16	12	8,761.79	8,758.74	7,536.02	7,536.46	1,129.73	0.11	1.03
18	Mam	11,210.57	11,209.02	8,614.24	8,612.84	1,765.13	0.14	0.08
22	63	10,041.30		9,902.01			0.20	
23	64	9,943.28		9,887.49			0.07	
24	Rub	9,909.40		9,719.44			0.18	
25	C19TL	8,766.03		7,529.61			0.12	
26	4	9,187.79		9,336.88		1,224.19	0.13	
27	53	8,718.01		7,571.27		1,113.02	0.17	
28	42	9,296.85		9,400.40		1,262.80	0.12	
29	N1		9,836.29		9,765.22	1,535.32		0.01
30	N2		9,737.09		9,698.66	1,519.09		0.01
	34		10,225.06		10,080.62			

TAKU LOCAL NETWORK BENCHMARKS AND COORDINATES					
NO.	NAME	EASTING (M)	NORTHING (M)	ST. DEV. (M)	HEIGHT (M)
1	Camp 10, FFGR 19	100,000.00	100,000.00		1,177.14
1.1	19B	100,347.05	100,402.87	0.04	1,238.31
1.2	19D	100,220.58	100,427.22	0.01	1,250.62
1.3	19C	99,971.16	100,117.29	0.01	1,194.31
1.4	Taku B Lower	100,247.46	100,479.56	1.52	
1.5	Camp 10 North	99,941.78	100,103.19	0.01	
2	SW Taku, Guard. Pt.	100,000.00	92,581.72		1,139.84
2.1	Guard. Pt. East	99,978.76	92,584.29	0.01	
2.2	SW Taku Lower	99,980.25	92,644.09	1.05	
3	Taku A	102,664.95	98,597.12	0.65	1,508.29
4	Taku B	100,467.56	101,298.03	0.52	1,586.43
4.1	Taku B Cairn	100,466.84	101,297.81	0.52	
5	Taku C Upper	97,384.33	103,314.84	0.40	1,542.01
5.1	Taku C Lower	97,343.84	103,197.43	0.38	1,524.93
6	Sunday Point	102,485.17	97,534.08	0.01	
6.1	Sunday Point Cairn	102,460.14	97,603.07	0.03	
7	Taku D Upper	94,374.47	106,005.12	0.42	1,770.94
7.1	Taku D Upper Cairn	94,375.15	106,008.10	0.40	
8	FFGR 40 (Taku D Lower)	94,099.23	105,295.02	0.52	
9	Camp 9	100,770.22	107,475.65	0.72	1,552.54
9.1	Camp 9 Cairn	100,771.08	107,474.00	0.72	
10	NW Taku	91,051.45	101,055.17	0.46	1,399.05
10.1	NW Taku Cairn	91,051.17	101,053.26	0.46	
11	Shoehorn	94,946.68	96,534.88	0.56	1,323.10
12	Juncture Peak	97,487.55	95,081.10	0.65	1,335.91
12.1	Juncture Peak Lower	97,889.58	94,718.64		
13	Bavaria Point	101,585.83	98,219.66	0.01	
14	Glacier King	86,228.98	104,936.52	0.84	1,478.55
14.1	Glacier King Cairn	86,230.73	104,935.48	0.85	
15	Camp 10 A	101,301.55	98,703.29	0.02	1,102.17
16	Vantage	102,289.21	101,212.45	1.35	1,706.03
17	Twin Peak Geodetic	112,440.50	97,641.87	4.44	
18	Mt. Moore	102,822.99	118,267.14	1.64	2,173.16
18.1	Mt. Moore Cairn	102,824.38	118,270.55	1.64	
19.1	Camp 10 Staff Shack	99,954.11	100,077.60		

Appendix 5

Movement Profile Flag Coordinates

TAKU PROFILE 1 (C-12) — EPOCH 0					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	494,217.168	6,480,527.259	330.751	08-01-94	18:33
2	494,443.178	6,480,626.168	331.385	08-01-94	18:08
3	494,608.114	6,480,718.216	333.713	08-01-94	17:31
4	494,879.170	6,480,869.278	336.512	08-01-94	16:51
5	495,083.051	6,480,983.097	339.987	08-01-94	16:16
6	495,257.907	6,481,058.543	339.851	07-31-94	14:02
7	495,495.717	6,481,187.963	336.950	07-31-94	14:43
8	495,705.124	6,481,277.956	333.624	07-31-94	15:17
9	495,974.764	6,481,442.704	327.356	07-31-94	15:54
10	496,300.384	6,481,629.596	314.442	07-31-94	16:32
11	496,522.673	6,481,700.827	308.242	07-31-94	17:05
A	494,159.708	6,480,459.049	323.803	08-01-94	14:59
B	494,117.870	6,480,421.168	300.707	07-31-94	17:48
C	494,090.784	6,480,389.767	299.325	07-31-94	18:08
D	494,067.078	6,480,363.448	286.532	07-31-94	18:32

TAKU PROFILE 1 (C-12) — EPOCH 1					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	494,217.152	6,480,527.050	330.688	08-02-94	11:19
2	494,443.249	6,480,625.851	331.371	08-02-94	11:49
3	494,608.336	6,480,717.745	333.681	08-02-94	12:20
4	494,879.495	6,480,868.683	336.448	08-02-94	12:52
5	495,083.414	6,480,982.351	339.848	08-02-94	14:04
6	495,258.746	6,481,057.171	339.692	08-02-94	13:08
7	495,496.649	6,481,186.614	336.726	08-02-94	12:40
8	495,706.074	6,481,276.803	333.411	08-02-94	12:03
9	495,975.654	6,481,441.552	327.137	08-02-94	11:34
10	496,300.991	6,481,628.714	314.217	08-02-94	11:04
11	496,522.876	6,481,700.567	308.026	08-02-94	10:34
A	494,159.770	6,480,458.774	323.782	08-02-94	10:51
B	494,117.954	6,480,420.995	300.546	08-02-94	10:26
C	494,090.759	6,480,389.714	299.373	08-02-94	09:54
D	494,067.076	6,480,363.328	286.442	08-02-94	09:30
Seismic 4	494,802.304	6,480,937.805	337.124	08-02-94	13:19
Seismic 5	494,992.661	6,481,068.503	341.411	08-02-94	13:50

TAKU PROFILE 2 (GOAT RIDGE) — EPOCH 0					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	493,236.085	6,492,503.346	800.892	08-03-94	16:21
2	493,053.888	6,492,609.357	804.600	08-03-94	15:30
3	492,828.956	6,492,503.699	803.598	08-03-94	14:39
4	492,606.669	6,492,445.184	803.673	08-03-94	13:41
5	492,419.298	6,492,389.169	804.838	08-03-94	13:21
6	492,167.727	6,492,276.542	802.401	08-03-94	14:07
7	491,840.129	6,492,151.444	803.505	08-03-94	14:50
8	491,593.829	6,492,067.870	807.154	08-03-94	15:42
9	491,460.983	6,492,028.453	807.546	08-03-94	16:27
10	491,305.680	6,491,993.779	808.168	08-03-94	17:11
11	491,085.826	6,491,908.687	808.242	08-03-94	17:49

TAKU PROFILE 2 (GOAT RIDGE) — EPOCH 1					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	493,236.880	6,492,501.230	800.532	08-07-94	16:20
2	493,054.628	6,492,606.688	804.210	08-07-94	15:48
3	492,829.835	6,492,500.478	803.274	08-07-94	15:10
4	492,607.570	6,492,441.971	803.207	08-07-94	14:34
5	492,420.786	6,492,385.869	804.295	08-07-94	13:57
6	492,168.822	6,492,273.049	801.817	08-07-94	13:14
7	491,841.198	6,492,147.949	803.049	08-07-94	13:08
8	491,594.953	6,492,064.499	806.674	08-07-94	13:54
9	491,462.012	6,492,025.049	806.985	08-07-94	14:33
10	491,306.639	6,491,990.499	807.623	08-07-94	15:20
11	491,086.880	6,491,905.972	807.756	08-07-94	16:11
12	490,779.201	6,491,788.063	819.578	08-07-94	17:12

TAKU PROFILE 3 (DEMOREST) — EPOCH 0					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	492,023.112	6,500,847.545	1,006.809	07-29-94	11:57
2	492,203.159	6,500,683.509	1,010.738	07-29-94	12:23
3	492,366.652	6,500,529.542	1,011.643	07-29-94	12:49
4	492,495.693	6,500,407.794	1,009.832	07-29-94	13:16
5	492,616.579	6,500,294.793	1,008.171	07-29-94	14:02
6	492,742.285	6,500,176.400	1,008.807	07-29-94	14:24
7	492,870.910	6,500,054.973	1,012.828	07-29-94	14:48
8	493,023.924	6,499,910.594	1,019.695	07-29-94	15:10
9	493,189.442	6,499,755.526	1,026.086	07-29-94	15:33
10	493,341.808	6,499,612.160	1,028.323	07-29-94	15:57
11	493,462.744	6,499,498.783	1,027.855	07-29-94	16:19
12	493,630.907	6,499,339.598	1,025.875	07-29-94	16:44

TAKU PROFILE 3 (DEMOREST) — EPOCH 1					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	492,022.214	6,500,846.885	1,006.444	08-04-94	18:47
2	492,201.928	6,500,682.812	1,010.416	08-04-94	18:16
3	492,365.381	6,500,528.602	1,011.262	08-04-94	17:46
4	492,494.444	6,500,406.910	1,009.486	08-04-94	17:13
5	492,615.092	6,500,293.926	1,007.874	08-04-94	16:25
6	492,741.004	6,500,175.640	1,008.430	08-04-94	15:49
7	492,869.605	6,500,054.135	1,012.432	08-04-94	15:20
8	493,022.528	6,499,909.685	1,019.282	08-04-94	14:52
9	493,188.168	6,499,754.556	1,025.759	08-04-94	14:21
10	493,340.814	6,499,611.506	1,027.862	08-04-94	13:50
11	493,461.684	6,499,497.998	1,027.456	08-04-94	13:09
12	493,630.127	6,499,338.961	1,025.424	08-04-94	12:35

Taku Profile 4 (C-10) — Epoch 0					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	487,763.573	6,503,062.779	1,099.972	07-25-94	11:38
2	487,545.331	6,503,210.735	1,107.272	07-25-94	12:02
3	487,617.351	6,502,932.266	1,103.229	07-25-94	12:14
4	487,397.026	6,503,060.721	1,106.406	07-25-94	12:35
5	487,471.112	6,502,798.346	1,103.226	07-25-94	13:17
6	487,235.705	6,502,896.786	1,103.874	07-25-94	13:08
7	487,283.723	6,502,627.286	1,101.142	07-25-94	13:52
8	487,096.069	6,502,753.500	1,103.134	07-25-94	13:37
9	487,105.729	6,502,466.337	1,101.860	07-25-94	14:22
10	486,953.252	6,502,607.515	1,103.014	07-25-94	14:01
11	486,972.422	6,502,344.713	1,102.522	07-25-94	14:46
12	486,771.938	6,502,421.586	1,102.161	07-25-94	14:28
13	486,733.587	6,502,127.880	1,101.921	07-25-94	15:15
14	486,501.058	6,502,201.775	1,103.908	07-25-94	14:54
15	486,501.690	6,501,918.115	1,098.200	07-25-94	15:40
16	486,240.012	6,501,974.141	1,102.478	07-25-94	15:20
17	486,210.268	6,501,654.276	1,102.494	07-25-94	16:03
18	485,908.611	6,501,672.647	1,108.595	07-25-94	15:57
19	485,933.062	6,501,401.977	1,108.664	07-25-94	16:31
20	485,656.278	6,501,444.237	1,114.956	07-25-94	16:21
21	485,653.890	6,501,147.926	1,115.129	07-25-94	16:58
22	485,408.867	6,501,222.934	1,118.945	07-25-94	16:53
23	485,489.081	6,500,998.666	1,116.888	07-25-94	17:21
24	485,138.213	6,500,994.571	1,119.782	07-25-94	17:19
25	485,127.275	6,500,670.076	1,119.284	07-25-94	17:47
26	484,875.869	6,500,780.493	1,121.754	07-25-94	17:41
27	484,846.549	6,500,416.496	1,119.669	07-25-94	18:16
28	484,526.551	6,500,497.328	1,121.417	07-25-94	18:05
29	484,587.388	6,500,182.492	1,123.159	07-25-94	19:17
30	484,266.051	6,500,285.441	1,122.906	07-25-94	18:28
31	484,338.380	6,499,956.576	1,127.457	07-25-94	18:54

TAKU PROFILE 4 (C-10) — EPOCH 1					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	487,763.713	6,503,062.778	1,099.340	08-05-94	11:12
2	487,545.417	6,503,210.614	1,106.787	08-05-94	11:23
3	487,617.627	6,502,932.069	1,102.661	08-05-94	11:37
4	487,397.240	6,503,060.516	1,105.844	08-05-94	11:46
5	487,471.634	6,502,797.851	1,102.624	08-05-94	11:55
6	487,236.635	6,502,895.948	1,103.322	08-05-94	12:10
7	487,285.728	6,502,625.607	1,100.572	08-05-94	12:13
8	487,097.882	6,502,751.834	1,102.492	08-05-94	12:34
9	487,110.021	6,502,464.734	1,101.314	08-05-94	12:32
10	486,956.276	6,502,604.857	1,102.447	08-05-94	12:55
11	486,976.889	6,502,340.099	1,101.899	08-05-94	12:50
12	486,775.971	6,502,417.936	1,101.536	08-05-94	13:45
13	486,738.166	6,502,123.800	1,101.193	08-05-94	13:38
14	486,505.727	6,502,197.828	1,103.207	08-05-94	14:14
15	486,506.610	6,501,913.983	1,097.402	08-05-94	13:59
16	486,245.068	6,501,970.049	1,102.332	08-05-94	14:37
17	486,215.370	6,501,650.185	1,101.637	08-05-94	14:20
18	485,913.910	6,501,668.702	1,107.786	08-05-94	15:03
19	485,938.288	6,501,397.938	1,107.735	08-05-94	14:39
20	485,661.437	6,501,440.271	1,114.046	08-05-94	15:29
21	485,658.930	6,501,144.092	1,114.247	08-05-94	14:58
22	485,413.939	6,501,219.210	1,118.135	08-05-94	15:52
23	485,494.030	6,500,995.106	1,116.006	08-05-94	15:16
24	485,142.709	6,500,991.306	1,119.081	08-05-94	16:14
25	485,131.081	6,500,667.370	1,118.502	08-05-94	15:39
26	484,879.196	6,500,778.132	1,120.987	08-05-94	16:37
27	484,848.616	6,500,415.319	1,118.923	08-05-94	16:02
28	484,527.971	6,500,496.474	1,120.730	08-05-94	17:05
29	484,587.945	6,500,182.334	1,122.593	08-05-94	16:22
30	484,266.485	6,500,285.316	1,122.243	08-05-94	17:36
31	484,338.563	6,499,956.737	1,126.734	08-05-94	16:42

Taku Profile 5 (Southwest Branch) — Epoch 0					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	485,752.436	6,498,033.281	1,041.358	07-27-94	13:46
2	485,871.268	6,497,877.221	1,044.112	07-27-94	14:16
3	485,980.050	6,497,734.339	1,047.301	07-27-94	14:43
4	486,121.833	6,497,548.421	1,049.709	07-27-94	15:13
5	486,286.835	6,497,355.626	1,049.387	07-27-94	15:41
6	486,463.491	6,497,151.090	1,049.029	07-27-94	16:09
7	486,597.824	6,496,994.288	1,052.231	07-27-94	16:42
8	486,705.782	6,496,869.016	1,056.598	07-27-94	17:10
9	486,820.791	6,496,735.451	1,060.112	07-27-94	17:39
10	486,916.542	6,496,622.944	1,061.497	07-27-94	18:07
11	487,022.924	6,496,494.431	1,062.541	07-27-94	18:35
12	487,131.905	6,496,361.018	1,065.698	07-27-94	19:01

Taku Profile 5 (Southwest Branch) — Epoch 1					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	485,752.512	6,498,033.309	1,040.829	08-04-94	11:16
2	485,871.481	6,497,877.335	1,043.704	08-04-94	11:46
3	485,980.412	6,497,734.657	1,046.906	08-04-94	12:10
4	486,122.206	6,497,548.909	1,049.274	08-04-94	12:33
5	486,287.272	6,497,356.222	1,048.992	08-04-94	12:57
6	486,463.938	6,497,151.657	1,048.656	08-04-94	13:47
7	486,598.185	6,496,994.858	1,051.858	08-04-94	14:10
8	486,706.099	6,496,869.583	1,056.133	08-04-94	14:33
9	486,821.108	6,496,736.000	1,059.733	08-04-94	14:54
10	486,916.905	6,496,623.480	1,061.066	08-04-94	15:16
11	487,023.172	6,496,494.849	1,062.110	08-04-94	15:38
12	487,132.074	6,496,361.293	1,065.223	08-04-94	16:01

Taku Profile 6 (Northwest Branch) — Epoch 0					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	479,601.466	6505444.721	1265.489	07-26-94	19:49
2	*	*	*	*	*
3	479,969.144	6,505,908.811	1,264.944	07-26-94	19:10
4	480,159.415	6,506,143.806	1,266.360	07-26-94	18:46
5	480,350.026	6,506,380.187	1,268.028	07-26-94	18:26
6	480,541.480	6,506,616.357	1,266.074	07-26-94	18:04
7	480,731.839	6,506,853.614	1,263.649	07-26-94	17:41
8	480,908.349	6,507,073.841	1,261.669	07-26-94	17:14
9	481,085.451	6,507,293.609	1,259.412	07-26-94	16:08
10	481,259.493	6,507,509.711	1,256.426	07-26-94	15:42
11	481,435.146	6,507,726.086	1,254.967	07-26-94	15:21
12	481,611.604	6,507,943.595	1,254.456	07-26-94	14:59
13	481,788.204	6,508,159.791	1,255.452	07-26-94	14:35
14	481,966.327	6,508,377.815	1,255.302	07-26-94	14:13
15	482,145.411	6,508,594.487	1,258.423	07-26-94	13:52
16	482,212.058	6,508,676.502	1,258.940	07-26-94	13:31

Taku Profile 6 (Northwest Branch) — Epoch 1					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	479,602.490	6,505,444.379	1,262.442	08-06-94	12:29
2	479,782.845	6,505,672.631	1,262.112	08-06-94	13:37
3	479,971.572	6,505,908.000	1,263.814	08-06-94	14:03
4	480,161.965	6,506,142.808	1,265.198	08-06-94	14:29
5	480,351.844	6,506,379.356	1,265.010	08-06-94	14:55
6	480,544.550	6,506,615.166	1,264.883	08-06-94	15:20
7	480,734.853	6,506,852.312	1,262.519	08-06-94	15:45
8	480,911.596	6,507,072.381	1,260.487	08-06-94	16:11
9	481,088.498	6,507,292.198	1,258.432	08-06-94	16:37
10	481,262.256	6,507,508.396	1,255.312	08-06-94	17:03
11	481,437.249	6,507,724.922	1,253.888	08-06-94	17:29
12	481,613.021	6,507,942.795	1,253.366	08-06-94	17:57
13	481,789.084	6,508,159.302	1,254.382	08-06-94	18:26
14	481,966.731	6,508,377.559	1,254.231	08-06-94	18:51
15	482,145.550	6,508,594.296	1,257.290	08-06-94	19:16
16	482,212.226	6,508,676.497	1,257.940	08-06-94	19:34

Taku Profile 7 (C-9) — Epoch 0					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	100,166.58	107,754.34	1,429.00	08-10-94	-
2	99,860.76	107,886.62	1,425.62	08-10-94	-
3	99,516.99	108,036.20	1,425.82	08-10-94	-
4	99,128.55	108,205.14	1,423.66	08-10-94	-
5	98,793.18	108,350.41	1,421.02	08-10-94	-
6	98,484.79	108,484.86	1,411.14	08-10-94	-
7	98,195.54	108,610.13	1,410.17	08-10-94	-
8	97,884.12	108,744.63	1,420.09	08-10-94	-
9	97,681.03	108,832.91	1,418.40	08-10-94	-
(10)	(97,272.32)	(109,010.94)	(1,413.36)	08-10-94	-
(11)	(96,969.19)	(109,141.39)	(1,437.29)	08-10-94	-
(12)	(96,666.59)	(109,273.05)	(1,451.89)	08-10-94	-

( ) Estimated. Flag was beyond EDM range.

Taku Profile 7 (C-9) — Epoch 1					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	100,166.54	107,754.37	1,428.86	08-13-94	-
2	99,860.66	107,886.54	1,425.44	08-13-94	-
3	99,516.66	108,035.83	1,425.64	08-13-94	-
4	99,128.05	108,204.30	1,423.33	08-13-94	-
5	98,792.75	108,349.87	1,420.89	08-13-94	-
6	98,484.28	108,483.99	1,411.04	08-13-94	-
7	98,195.07	108,609.30	1,410.04	08-13-94	-
8	97,883.71	108,743.78	1,419.81	08-13-94	-
9	97,680.79	108,832.53	1,418.28	08-13-94	-
(10)	(97,271.95)	(109,010.09)	(1,413.41)	08-13-94	-
(11)	(96,969.08)	(109,141.14)	(1,437.26)	08-13-94	-
(12)	(96,666.46)	(109,272.74)	(1,451.71)	08-13-94	-

( ) Estimated. Flag was beyond EDM range.

Taku Profile 7A (Lower Matthes) — Epoch 0					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	483,098.793	6,509,160.893	1,263.099	07-26-94	13:38
2	483,277.144	6,509,029.201	1,263.667	07-26-94	13:59
3	483,457.535	6,508,896.378	1,265.996	07-26-94	14:24
4	483,655.268	6,508,749.004	1,266.623	07-26-94	14:46
5	483,839.686	6,508,612.787	1,265.685	07-26-94	15:06
6	484,020.575	6,508,478.384	1,267.263	07-26-94	15:27
7	484,200.093	6,508,346.402	1,269.529	07-26-94	15:48
8	484,376.834	6,508,215.557	1,270.998	07-26-94	16:09
9	484,555.330	6,508,084.725	1,279.397	07-26-94	16:34
10	484,736.755	6,507,953.131	1,288.282	07-26-94	16:56
11	484,916.731	6,507,819.677	1,290.227	07-26-94	17:38
12	485,096.036	6,507,686.669	1,291.391	07-26-94	18:03
13	485,267.056	6,507,561.181	1,289.779	07-26-94	18:28
14	485,377.382	6,507,475.800	1,286.897	07-26-94	18:57

Taku Profile 7A (Lower Matthes) — Epoch 1					
Flag	Easting (m)	Northing (m)	Height (m)	Date	Time
1	483,098.848	6,509,160.885	1,262.360	08-06-94	12:17
2	483,276.800	6,509,028.877	1,262.781	08-06-94	13:07
3	483,456.443	6,508,895.059	1,265.039	08-06-94	13:33
4	483,653.252	6,508,746.804	1,265.668	08-06-94	14:03
5	483,837.122	6,508,610.029	1,264.680	08-06-94	14:29
6	484,017.805	6,508,475.542	1,266.170	08-06-94	14:57
7	484,197.099	6,508,343.051	1,268.413	08-06-94	15:23
8	484,373.622	6,508,212.105	1,269.788	08-06-94	15:49
9	484,551.986	6,508,081.357	1,278.102	08-06-94	16:15
10	484,733.548	6,507,949.725	1,286.999	08-06-94	16:40
11	484,913.709	6,507,816.407	1,288.994	08-06-94	17:04
12	485,093.098	6,507,683.767	1,290.149	08-06-94	17:33
13	485,264.629	6,507,558.550	1,288.571	08-06-94	17:59
14	485,375.317	6,507,473.553	1,285.770	08-06-94	18:25

Taku Profile 8 (C-8) — Epoch 0					
Flag	**Easting (m)**	**Northing (m)**	**Height (m)**	**Date**	**Time**
1	13,140.83	11,074.38	1,764.44	08-11-94	-
2	13,355.85	11,045.34	1,722.98	08-11-94	-
3	13,542.04	11,017.83	1,688.19	08-11-94	-
4	13,799.57	10,975.89	1,672.85	08-11-94	-
5	14,005.90	10,939.47	1,662.83	08-11-94	-
6	14,204.99	10,905.51	1,657.57	08-11-94	-
7	14,423.87	10,864.44	1,654.30	08-11-94	-
8	14,609.21	10,827.21	1,651.45	08-11-94	-
9	14,823.92	10,787.57	1,647.99	08-11-94	-
10	15,012.94	10,752.28	1,646.16	08-11-94	-
11	15,235.60	10,711.63	1,643.80	08-11-94	-
12	15,432.97	10,674.96	1,640.51	08-11-94	-
13	15,680.34	10,629.45	1,636.26	08-11-94	-
14	15,961.27	10,575.88	1,635.43	08-11-94	-

Taku Profile 8 (C-8) — Epoch 1					
Flag	**Easting (m)**	**Northing (m)**	**Height (m)**	**Date**	**Time**
1	13,140.92	11,074.42	1,764.09	08-14-94	-
2	13,355.97	11,045.33	1,722.62	08-14-94	-
3	13,542.18	11,017.79	1,687.87	08-14-94	-
4	13,799.68	10,975.57	1,672.58	08-14-94	-
5	14,006.04	10,939.16	1,662.73	08-14-94	-
6	14,205.02	10,904.83	1,657.29	08-14-94	-
7	14,423.87	10,863.79	1,653.91	08-14-94	-
8	14,609.23	10,826.27	1,651.08	08-14-94	-
9	14,823.97	10,786.94	1,647.75	08-14-94	-
10	15,012.99	10,751.58	1,645.93	08-14-94	-
11	15,235.62	10,710.98	1,643.20	08-14-94	-
12	15,433.00	10,674.43	1,640.22	08-14-94	-
13	15,680.39	10,629.06	1,636.12	08-14-94	-
14	15,961.23	10,575.84	1,634.94	08-14-94	-

UPPER VAUGHAN LEWIS PROFILE — EPOCH 0					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	10,645.11	10,177.22	1,551.15	08-10-94	-
2	10,699.17	10,134.91	1,549.40	08-10-94	-
3	10,863.11	10,010.83	1,546.53	08-10-94	-
4	10,977.24	9,899.14	1,546.04	08-10-94	-
5	11,083.87	9,738.25	1,547.66	08-10-94	-
6	11,187.35	9,575.70	1,548.69	08-10-94	-
7	11,245.71	9,413.74	1,545.64	08-10-94	-
8	11,262.28	9,276.63	1,554.27	08-10-94	-
9	11,221.71	9,170.25	1,564.70	08-10-94	-
10	11,177.50	9,098.00	1,574.64	08-10-94	-

UPPER VAUGHAN LEWIS PROFILE — EPOCH 1					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	10,645.13	10,176.82	1,551.11	08-12-94	-
2	10,699.36	10,134.62	1,549.31	08-12-94	-
3	10,862.83	10,010.28	1,546.36	08-12-94	-
4	10,976.80	9,898.62	1,546.03	08-12-94	-
5	11,083.31	9,737.83	1,547.49	08-12-94	-
6	11,186.83	9,575.41	1,548.59	08-12-94	-
7	11,245.32	9,413.64	1,545.59	08-12-94	-
8	11,262.02	9,276.58	1,554.00	08-12-94	-
9	11,221.31	9,170.42	1,564.42	08-12-94	-
10	11,177.66	9,098.55	1,574.58	08-12-94	-

GILKEY PROFILE B					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
2	8,213.792	7,789.197	891.572	08-15-94	-
3	8,291.684	6,815.552	867.314	08-15-94	-
4	7,889.411	7,774.588	878.404	08-15-94	-
5	7,664.362	7,537.993	861.439	08-15-94	-
7	7,379.354	7,715.168	854.489	08-15-94	-
8	7,708.302	7,858.066	869.754	08-15-94	-
9	7,360.632	7,804.258	857.168	08-15-94	-
10	7,487.847	8,013.305	869.381	08-15-94	-
11	7,171.516	7,922.245	857.419	08-15-94	-
12	7,334.552	8,210.467	865.759	08-15-94	-
14	7,181.195	8,496.138	869.042	08-15-94	-
15	6,958.989	8,466.341	861.889	08-15-94	-

GILKEY PROFILE C					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
4	8,035.391	8,950.475	931.648	08-13-94	-

GILKEY PROFILE D					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	8,496.884	9,292.518	943.190	08-13-94	-
2	8,426.834	9,412.285	951.815	08-13-94	-
3	8,360.340	9,149.859	945.510	08-13-94	-
4	8,167.235	9,364.420	955.730	08-13-94	-
5	8,182.554	9,106.708	944.538	08-13-94	-
6	7,999.656	9,291.804	953.470	08-13-94	-
7	7,899.782	9,048.594	933.821	08-13-94	-
8	7,868.547	9,218.619	951.184	08-13-94	-
9	7,762.612	9,072.115	936.213	08-13-94	-

GILKEY PROFILE E					
FLAG	EASTING (M)	NORTHING (M)	HEIGHT (M)	DATE	TIME
1	8,753.313	9,505.229	949.833	08-13-94	-
3	8,761.761	9,345.311	946.267	08-13-94	-

Appendix 6

Movement Vectors and Ablation

TAKU PROFILE 1 (C-12) JULY 31 AND AUGUST 1 TO AUGUST 2					
	MOVEMENT			ABLATION	
FLAG	TOTAL (M)	DAILY (M)	BEARING (GONS)	TOTAL (CM)	DAILY (CM)
1	0.21	0.30*	204.86	6.3	9.0*
2	0.32	0.44*	185.97	1.4	1.9*
3	0.52	0.66*	171.96	3.2	4.1*
4	0.68	0.81*	168.17	6.4	7.7*
5	0.83	0.91*	171.17	13.9	15.3*
6	1.61	0.82	165.06	15.9	8.1
7	1.64	0.86	161.51	22.4	11.7
8	1.49	0.80	156.13	21.3	11.4
9	1.46	0.80	158.12	21.9	12.1
10	1.07	0.60	161.63	22.5	12.7
11	0.33	0.19	157.80	21.6	12.5
A	0.28	0.34*	185.88	2.1	2.5*
B	0.19	0.11	171.22	16.1	9.5
C	0.06	0.04	228.06	-4.8?	-2.9?
D	0.12	0.07	201.06	9.0	5.6

* Extrapolated—measurement period was less than 24 hours.
? Results uncertain

TAKU PROFILE 2 (GOAT RIDGE) AUGUST 3 TO AUGUST 7					
	MOVEMENT			ABLATION	
FLAG	TOTAL (M)	DAILY (M)	BEARING (GONS)	TOTAL (CM)	DAILY (CM)
1	2.26	0.57	177.12	36.0	9.0
2	2.77	0.69	182.78	39.0	9.7
3	3.34	0.83	183.04	32.4	8.1
4	3.34	0.83	182.59	46.6	11.5
5	3.62	0.90	173.03	54.3	13.5
6	3.66	0.92	180.66	58.4	14.7
7	3.65	0.93	181.10	45.6	11.6
8	3.55	0.91	179.51	48.0	12.2
9	3.56	0.91	181.31	56.1	14.3
10	3.42	0.87	181.89	54.5	13.9
11	2.91	0.74	176.43	48.6	12.4

Taku Profile 3 (Demorest) July 29 to August 4					
	Movement			Ablation	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	1.11	0.18	259.65	36.5	5.8
2	1.41	0.23	267.20	32.2	5.2
3	1.58	0.25	259.46	38.1	6.1
4	1.53	0.25	260.79	34.6	5.6
5	1.72	0.28	266.40	29.7	4.9
6	1.49	0.25	265.91	37.7	6.2
7	1.55	0.26	263.66	39.6	6.6
8	1.67	0.28	263.26	41.3	6.9
9	1.60	0.27	258.57	32.7	5.5
10	1.19	0.20	262.95	46.1	7.8
11	1.32	0.22	259.42	39.9	6.8
12	1.01	0.17	256.40	45.1	7.7

Taku Profile 4 (C-10) July 25 to August 5					
	Movement			Ablation	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.14	0.01	100.45	63.2	5.8
2	0.15	0.01	160.66	48.5	4.4
3	0.34	0.03	139.46	56.8	5.2
4	0.30	0.03	148.63	56.2	5.1
5	0.72	0.07	148.31	60.2	5.5
6	1.25	0.11	146.69	55.2	5.0
7	2.62	0.24	144.38	57.0	5.2
8	2.46	0.22	147.31	64.2	5.9
9	4.58	0.42	122.76	54.6	5.0
10	4.03	0.37	145.90	56.7	5.2
11	6.42	0.59	151.03	62.3	5.7
12	5.44	0.50	146.83	62.5	5.7
13	6.13	0.56	146.34	72.8	6.7
14	6.11	0.56	144.68	70.1	6.4
15	6.42	0.59	144.47	79.8	7.3
16	6.50	0.59	143.32	14.6?	1.3?
17	6.54	0.60	143.03	85.7	7.8
18	6.61	0.60	140.74	80.9	7.4
19	6.60	0.60	141.89	92.9	8.5
20	6.51	0.59	141.72	91.0	8.3
21	6.33	0.58	141.40	88.2	8.1
22	6.29	0.57	140.32	81.0	7.4
23	6.10	0.56	139.70	88.2	8.1
24	5.56	0.51	139.99	70.1	6.4
25	4.67	0.43	139.35	78.2	7.2
26	4.08	0.37	139.29	76.7	7.0
27	2.38	0.22	132.95	74.6	6.8
28	1.66	0.15	134.47	68.7	6.3
29	0.58	0.05	117.60	56.6	5.2
30	0.45	0.04	117.85	66.3	6.0
31	0.24	0.02	54.07	72.3	6.6

? One or both height readings during GPS measurement incorrect. Ablation data not reliable.

Taku Profile 5 (Southwest Branch) July 27 to August 4					
	Movement			Ablation	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.08	0.01	77.53	52.9	6.7
2	0.24	0.03	68.72	40.8	5.2
3	0.48	0.06	54.11	39.5	5.0
4	0.61	0.08	41.55	43.5	5.5
5	0.74	0.09	40.28	39.5	5.0
6	0.72	0.09	42.50	37.3	4.7
7	0.67	0.09	35.94	37.3	4.7
8	0.65	0.08	32.45	46.5	5.9
9	0.63	0.08	33.34	37.9	4.8
10	0.65	0.08	37.90	43.1	5.5
11	0.49	0.06	34.09	43.1	5.5
12	0.32	0.04	35.08	47.5	6.0

Taku Profile 6 (Northwest Branch) July 26 to August 6					
	Movement			Ablation	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	1.08	0.10	120.52	304.7?	28.5?
2	-	-	-	-	-
3	2.56	0.24	120.52	113.0	10.5
4	2.74	0.25	123.75	116.2	10.7
5	2.00	0.18	127.29	301.8?	27.8?
6	3.29	0.30	123.56	119.1	10.9
7	3.28	0.30	125.96	113.0	10.3
8	3.56	0.32	126.90	118.2	10.8
9	3.36	0.30	127.61	98.0	8.9
10	3.06	0.28	128.28	111.4	10.1
11	2.40	0.22	132.18	107.9	9.7
12	1.63	0.15	132.72	109.0	9.8
13	1.01	0.09	132.29	107.0	9.6
14	0.48	0.04	135.96	107.1	9.6
15	0.24	0.02	159.95	113.3	10.1
16	0.17	0.01	101.89	100.0	8.9

? One or both height readings during GPS measurement incorrect. Ablation data not reliable.

Taku Profile 7 (C-9) August 13 to August 16					
	Movement			Ablation*	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.050	0.017	340.9665	14*	4.7*
2	0.128	0.043	257.0445	19*	6.3*
3	0.496	0.165	246.3660	17*	5.7*
4	0.978	0.326	234.1807	33*	11.0*
5	0.690	0.230	242.8112	13*	4.3*
6	1.008	0.336	233.7545	11*	3.7*
7	0.954	0.318	232.8014	13*	4.3*
8	0.944	0.315	228.6116	28*	9.3*
9	0.449	0.150	235.8618	13*	4.3*
10	(0.927)	(0.309)	(226.1368)	(-5)*	(-1.7)*
11	(0.273)	(0.091)	(226.3883)	(3)*	(1)*
12	(0.336)	(0.112)	(225.2788)	(19)*	(6.3)*

* Flag heights were determined by trigonometric height determination. Ablation figures are rough approximates and are not as accurate as ablation determined via GPS methods.

( ) Estimated. Flag was beyond EDM range.

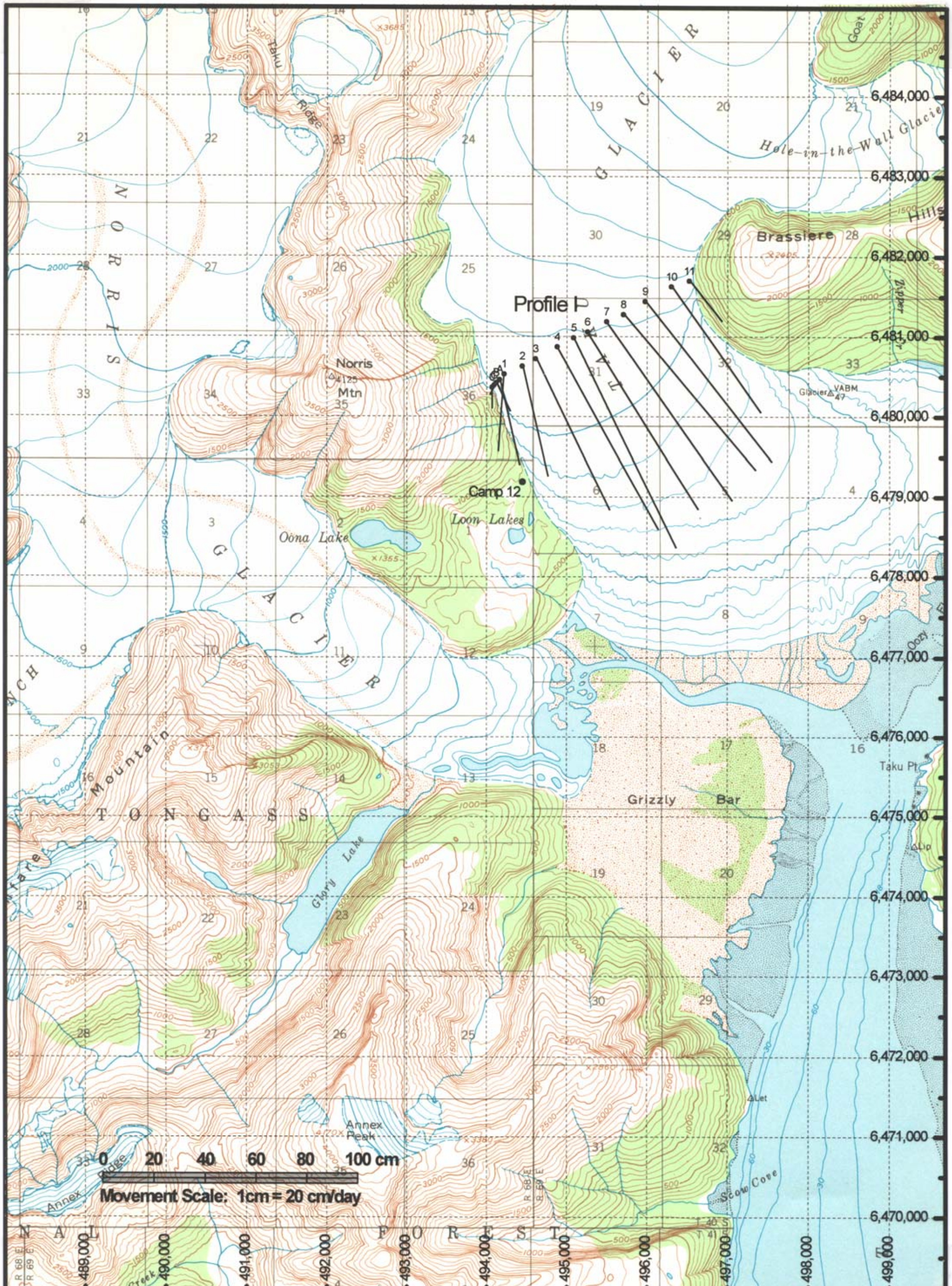
Taku Profile 7a (Lower Matthes) July 26 to August 6					
	Movement			Ablation	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.06	0.01	109.20	73.9	6.8
2	0.47	0.04	251.91	88.6	8.1
3	1.71	0.16	244.02	95.7	8.7
4	2.98	0.27	247.22	95.5	8.7
5	3.77	0.34	247.68	100.5	9.2
6	3.97	0.36	249.18	109.3	10.0
7	4.49	0.41	246.42	111.6	10.2
8	4.72	0.43	247.71	121.0	11.0
9	4.75	0.43	249.77	129.5	11.8
10	4.68	0.43	248.08	128.3	11.7
11	4.45	0.41	247.49	123.3	11.2
12	4.13	0.38	250.39	124.2	11.3
13	3.58	0.33	247.43	120.8	11.0
14	3.05	0.28	247.31	112.7	10.3

Taku Profile 8 (C-8) August 11 to August 14					
	Movement			Ablation*	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.098	0.033	73.3749	0.35	0.12
2	0.120	0.040	105.2929	0.35	0.12
3	0.146	0.049	117.7171	0.32	0.11
4	0.338	0.113	178.9216	0.27	0.09
5	0.340	0.113	172.9948	0.10	0.03
6	0.681	0.227	197.1930	0.28	0.09
7	0.650	0.217	200.0002	0.38	0.13
8	0.940	0.313	198.6455	0.37	0.12
9	0.632	0.211	194.9578	0.24	0.08
10	0.702	0.234	195.4602	0.23	0.08
11	0.650	0.217	198.0416	0.60	0.20
12	0.531	0.177	196.4001	0.28	0.09
13	0.393	0.131	191.8823	0.14	0.05
14	0.057	0.019	249.9999	0.49	0.16

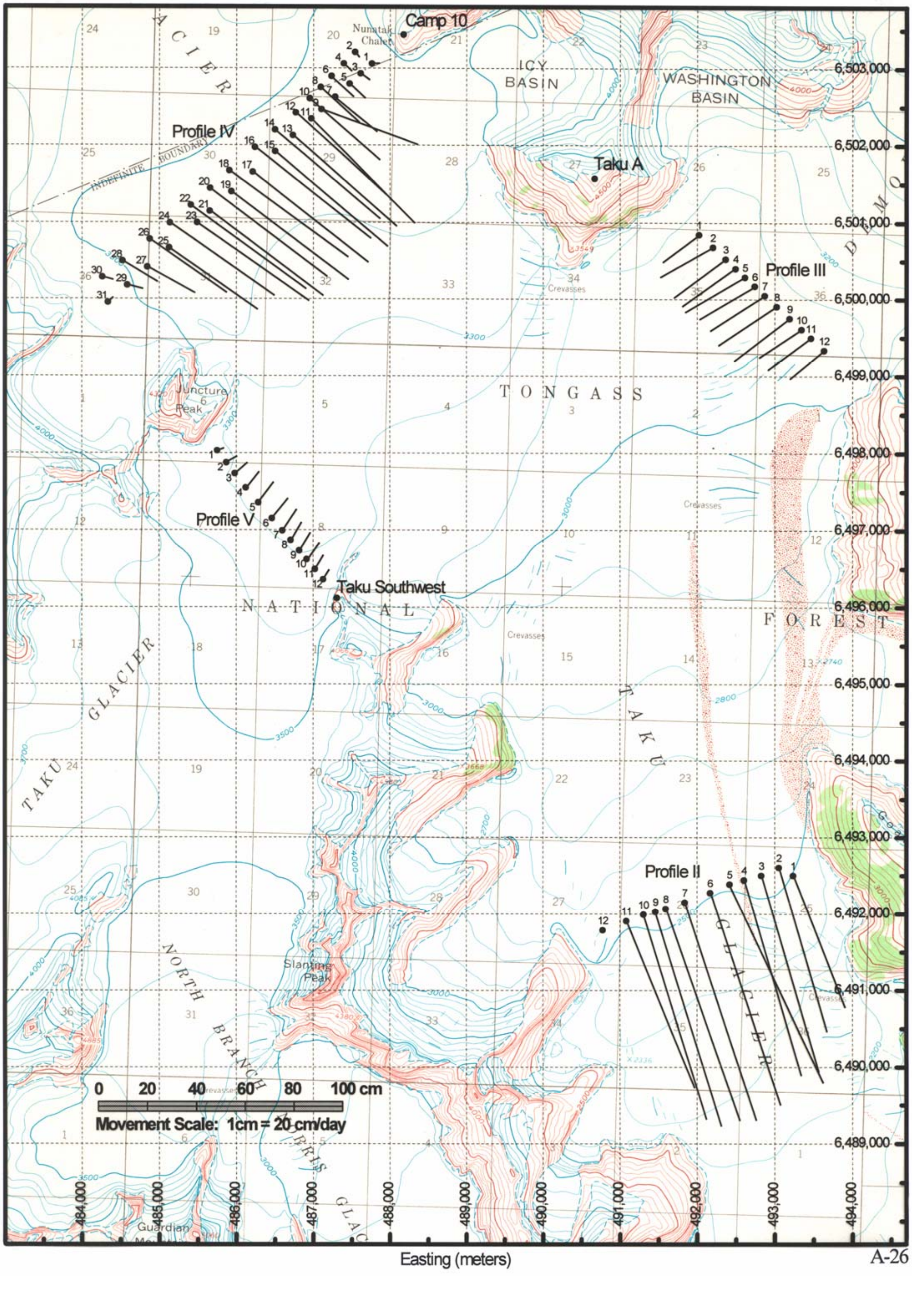
* Flag heights were determined by trigonometric height determination. Ablation figures are rough approximates and are not as accurate as ablation determined via GPS methods.

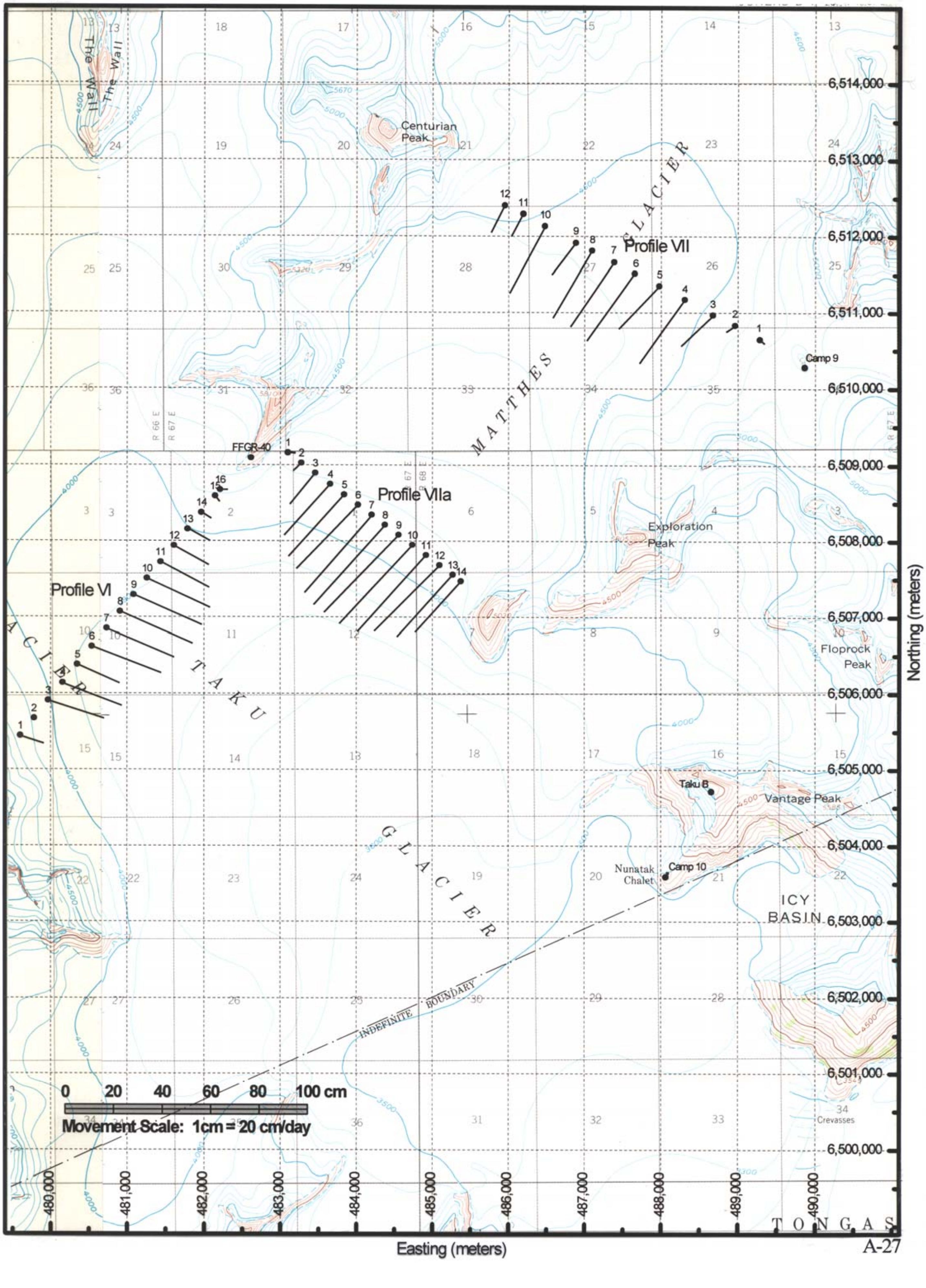
Upper Vaughan Lewis August 10 to August 12					
	Movement			Ablation*	
Flag	Total (m)	Daily (m)	Bearing (gons)	Total (cm)	Daily (cm)
1	0.400	0.200	196.8194	0.04	0.02
2	0.347	0.174	163.0757	0.09	0.05
3	0.617	0.309	229.9780	0.17	0.09
4	0.681	0.341	244.7070	0.01	0.00
5	0.700	0.350	259.0333	0.17	0.09
6	0.595	0.298	267.6131	0.10	0.05
7	0.403	0.202	284.0205	0.05	0.03
8	0.265	0.133	287.9048	0.27	0.14
9	0.435	0.218	325.5838	0.28	0.14
10	0.573	0.287	18.0224	0.05	0.03

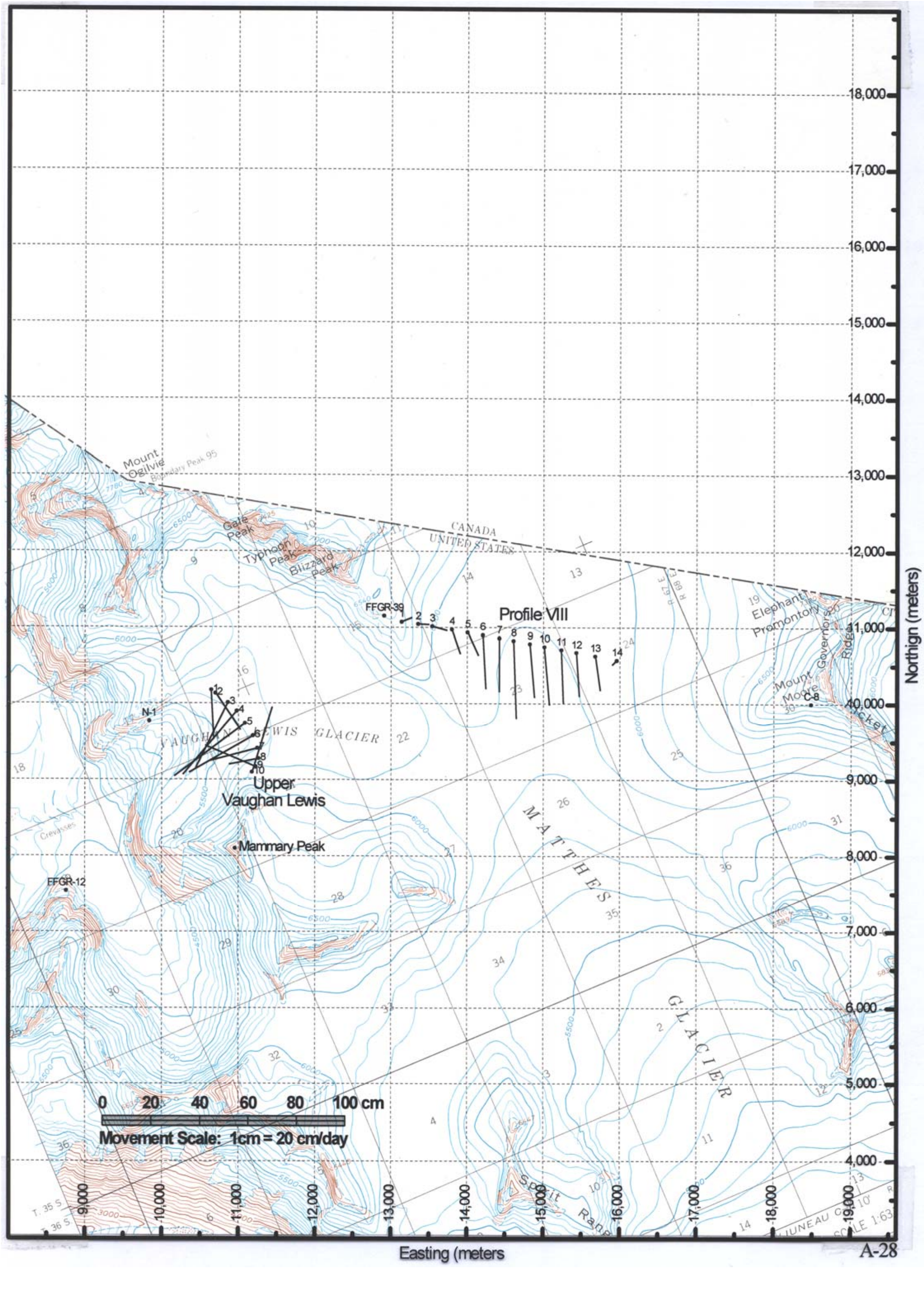
* Flag heights were determined by trigonometric height determination. Ablation figures are rough approximates and are not as accurate as ablation determined via GPS methods.



Profile P
Camp 12
Norris Mtn
Brassiere Hills
Hole-in-the-Wall Glacier
TAKU GLACIER
NORRIS GLACIER
Loon Lakes
Oona Lake
Grizzly Bar
Glory Lake
Annex Peak
Mountain
TONGASS NATIONAL FOREST
Taku Pt
Scow Cove
0 20 40 60 80 100 cm
Movement Scale: 1cm = 20 cm/day
6,484,000
6,483,000
6,482,000
6,481,000
6,480,000
6,479,000
6,478,000
6,477,000
6,476,000
6,475,000
6,474,000
6,473,000
6,472,000
6,471,000
6,470,000
Northing (meters)
489,000
490,000
491,000
492,000
493,000
494,000
495,000
496,000
497,000
498,000
499,000
Easting (meters)


Camp 10
Numatak Chalet
ICY BASIN
WASHINGTON BASIN
Profile IV
Taku A
Profile III
TONGASS
Juncture Peak
Profile V
Taku Southwest
NATIONAL
FOREST
TAKU GLACIER
TAKU
Crevasses
Profile II
GLACIER
Slanting Peak
NORTH BRANCH
0 20 40 60 80 100 cm
Movement Scale: 1cm = 20 cm/day
Northing (meters)
Easting (meters)
6,503,000
6,502,000
6,501,000
6,500,000
6,499,000
6,498,000
6,497,000
6,496,000
6,495,000
6,494,000
6,493,000
6,492,000
6,491,000
6,490,000
6,489,000
484,000
485,000
486,000
487,000
488,000
489,000
490,000
491,000
492,000
493,000
494,000

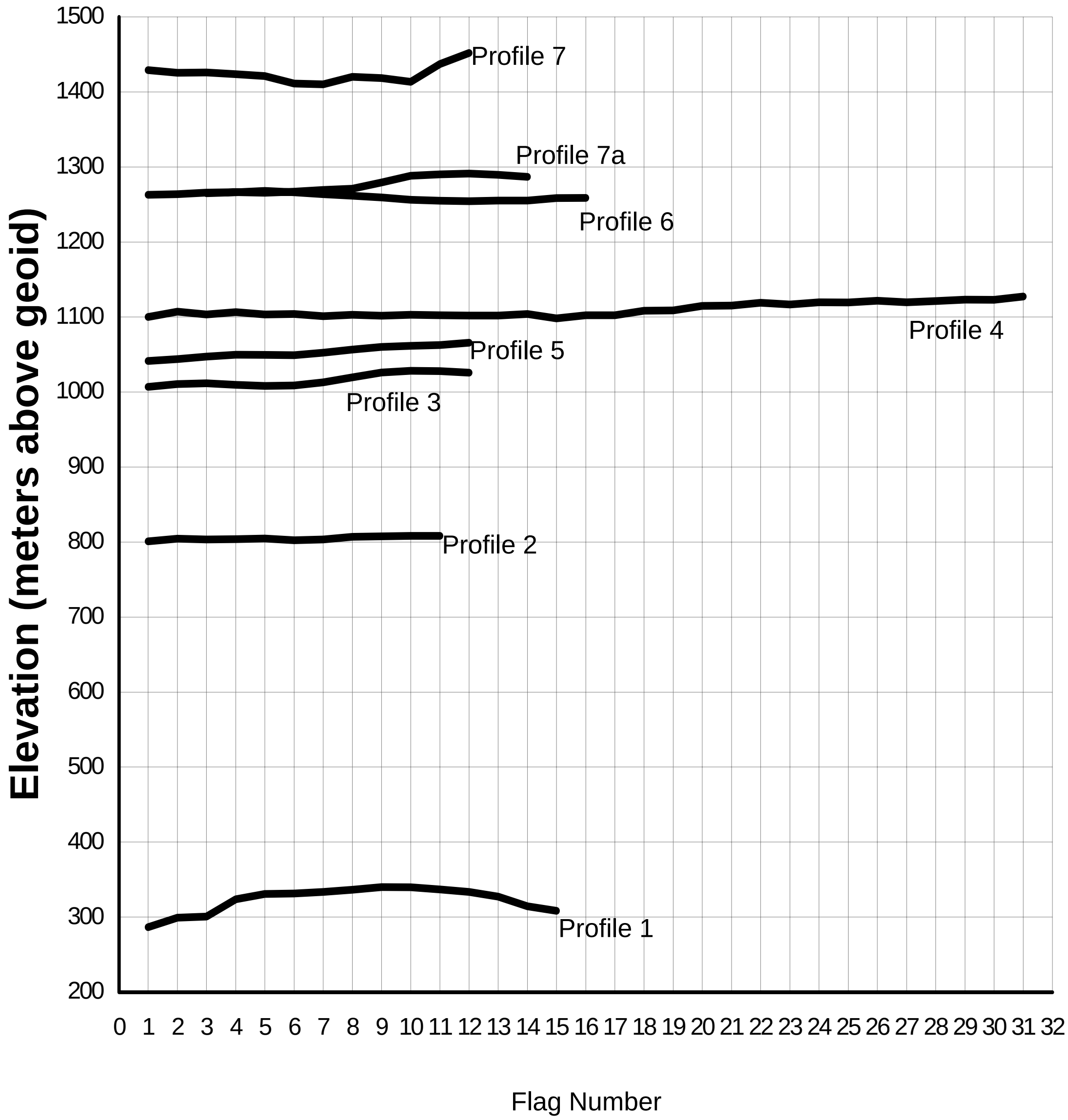

The Wall
Centurian Peak
MATTHES GLACIER
Profile VII
Camp 9
FFGR-40
Profile VIIa
Profile VI
TAKU GLACIER
Exploration Peak
Floprock Peak
Taku B
Vantage Peak
Nunatak Chalet
Camp 10
ICY BASIN
INDEFINITE BOUNDARY
Crevasses
TONGAS
0 20 40 60 80 100 cm
Movement Scale: 1cm = 20 cm/day
6,514,000
6,513,000
6,512,000
6,511,000
6,510,000
6,509,000
6,508,000
6,507,000
6,506,000
6,505,000
6,504,000
6,503,000
6,502,000
6,501,000
6,500,000
480,000
481,000
482,000
483,000
484,000
485,000
486,000
487,000
488,000
489,000
490,000
Easting (meters)
Northing (meters)



Profile VIII
FFGR-39
Upper Vaughan Lewis
Mammary Peak
FFGR-12
N-1
C-8
Mount Ogilvie
Gale Peak
Typhoon Peak
Blizzard Peak
CANADA
UNITED STATES
Elephant Promontory
Mount Moore
Mount Governor
VAUGHAN LEWIS GLACIER
MATTHES GLACIER
0 20 40 60 80 100 cm
Movement Scale: 1cm = 20 cm/day
Northign (meters)
Easting (meters
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000

Appendix 8

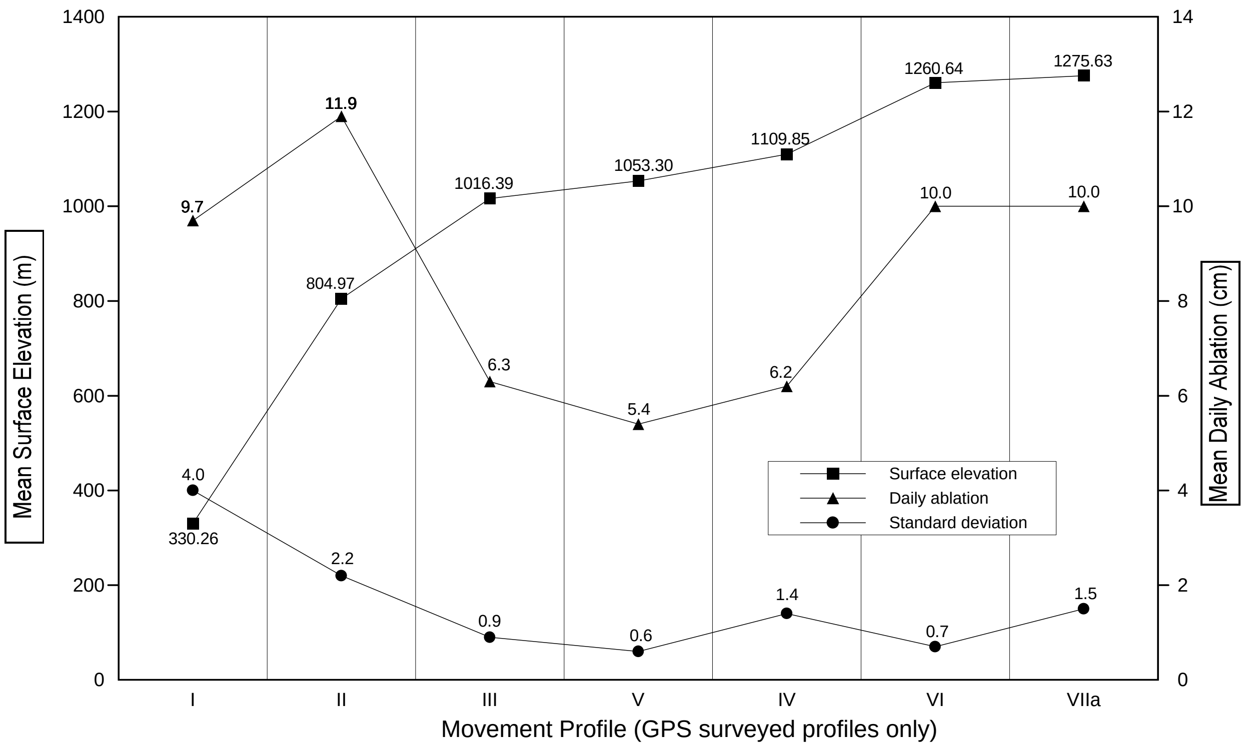
Comparison of Movement Profile Surface Elevations



The surface elevations of the various Taku Glacier movement profiles are shown above. This cross-sectional view graphically illustrates the variation in elevation of the profiles. All profiles, with the exception of Profile 7, were surveyed using GPS methods. This makes elevation comparisons of the profiles consistent with each other. Elevations reported are relative to the geoid, rather than absolute elevations above mean sea level. Profile 7 was surveyed via theodolite/EDM methods, thus the elevations reported for this profile were not measured with respect to the same vertical datum as were the elevations for the GPS surveyed profiles. Profile 7 is presented here only as a rough estimation of its elevation in relation to the other profiles.

Appendix 9

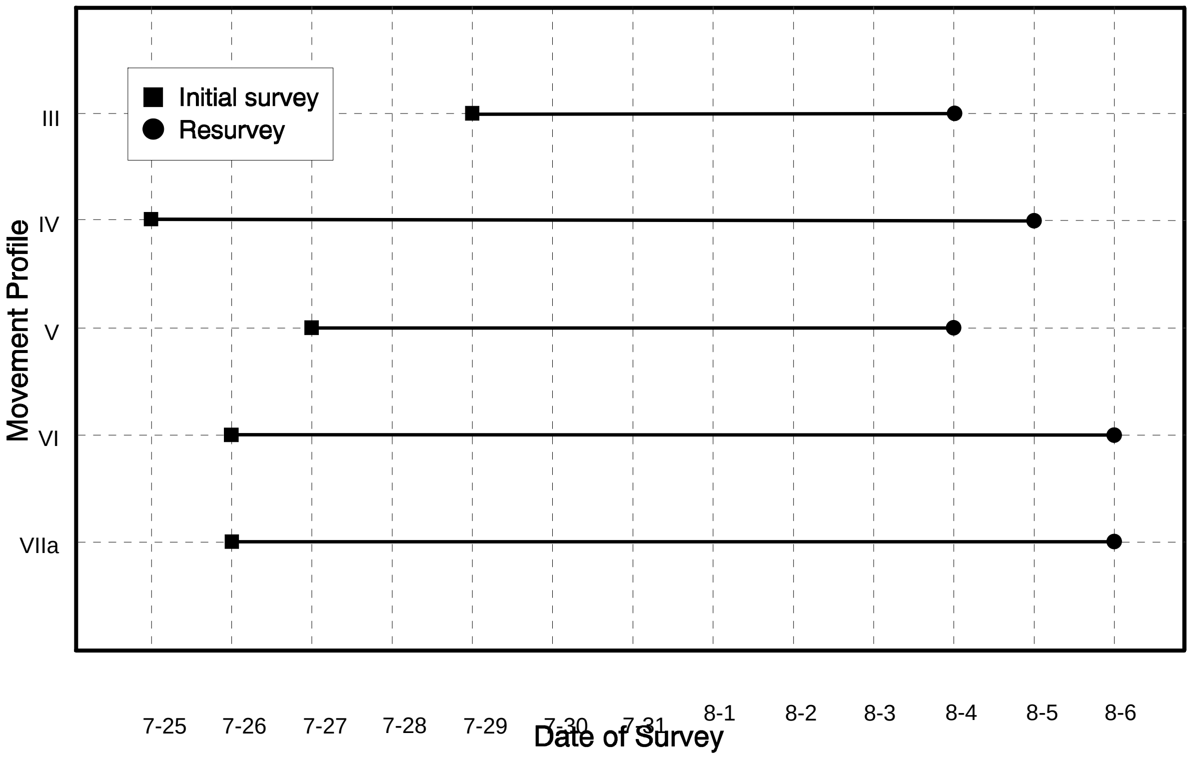
Surface elevation of movement profiles
versus daily ablation



This chart shows the relationship between the mean surface elevation and the mean daily ablation of all GPS surveyed movement profiles. Elevations are in meters above the geoid as shown on the left Y-axis. Ablation is given in centimeters on the right Y-axis. The standard deviation of the daily ablation for all flags in each Profile 1ndicates the relative accuracy of field measurements of the GPS receiver above the snow surface, and is also given in centimeters on the right Y-axis. As the standard deviation decreases, the accuracy of the daily ablation data increases.

Theoretically it can be assumed that as the surface elevation increases the daily ablation will decrease. Results of GPS surveys for these seven profiles demonstrate that this is not always the case. The mean elevation of Profiles III, IV, and V is 1,059.8 meters and the mean daily ablation is 6 cm. The mean elevation of Profiles VI and VIIa is 1,268.1 meters and the mean daily ablation is 10 cm. Thus, the ablation at an elevation of 1,268 meters is 4 cm/day **greater** than the ablation at an elevation 208 meters lower.

Some of this apparent anomaly may be explained by the fact that the five profiles involved did not have the same time period between the first survey and the resurvey. While the majority of the epochs did overlap each other, some profiles were surveyed either before or after others, or both (see following chart). Daily temperature and cloud cover variations therefore most likely contributed to some of the anomaly. However, the extent of the influence is not quantifiably known. Given the amount of overlap between the initial survey and the resurvey of the five profiles (6 of 12 days), it seems likely that some other factor has contributed to greater ablation at the higher elevation of Profiles VI and VIIa.



Timeline of GPS surveys (July 25 to August 6, 1994)

Appendix 10

Taku Profile 4 Grid Generation Parameters

Files...

Data file used:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.dat
	d:\data\jirp\jirp-94\1994mass.bal\t4-72594.dat
Blanking file used:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.bln
	d:\data\jirp\jirp-94\1994mass.bal\t4-72594.bln
Grid file:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.grd
	d:\data\jirp\jirp-94\1994mass.bal\t4-72594.grd
Blanked grid file:	d:\data\jirp\jirp-94\1993mass.bal\t472093b.grd
	d:\data\jirp\jirp-94\1994mass.bal\t472594b.grd
Smoothed grid file:	d:\data\jirp\jirp-94\1993mass.bal\t472093s.grd
	d:\data\jirp\jirp-94\1994mass.bal\t472494s.grd
	d:\data\jirp\jirp-94\1994mass.bal\t472594s.grd

Parameters used to create the grid files...

Scattered Data Interpolation settings:

X minimum	=	484,800
Y minimum	=	487,800
X maximum	=	6,500,400
Y maximum	=	6,503,400
X spacing	=	2
Y spacing	=	2
X number of lines	=	1,501
Y number of lines	=	1,501
Gridding method	=	krigging

Gridding Options settings:

Type	=	linear
Scale	=	36
No drift	=	checked
Linear drift	=	n.a.
Quadratic drift	=	n.a.
Error variance	=	0

Micro variance	=	0
Radius 1	=	1,000
Radius 2	=	1,000
Angle	=	0
Duplicates	=	delete
Ignore date outside grid	=	not checked

Search Options settings:

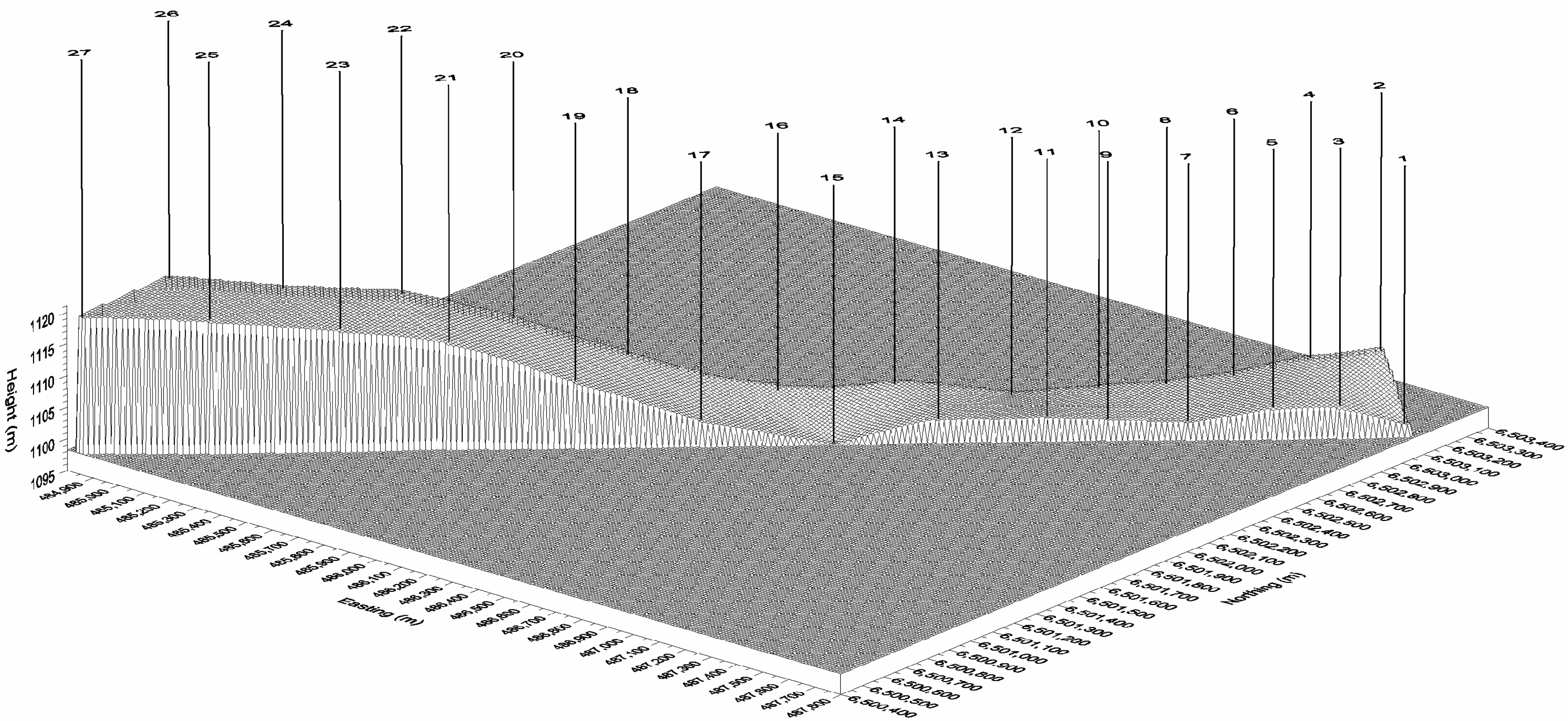
All data	=	checked
Simple	=	n.a.
Quadrant	=	n.a.
Octant	=	n.a.
Data per sector	=	n.a.
Minimum total data	=	n.a.
Max. empty sectors	=	n.a.
Radius 1	=	n.a.
Radius 2	=	n.a.
Angle	=	n.a.

Parameters used to create the smoothed file...

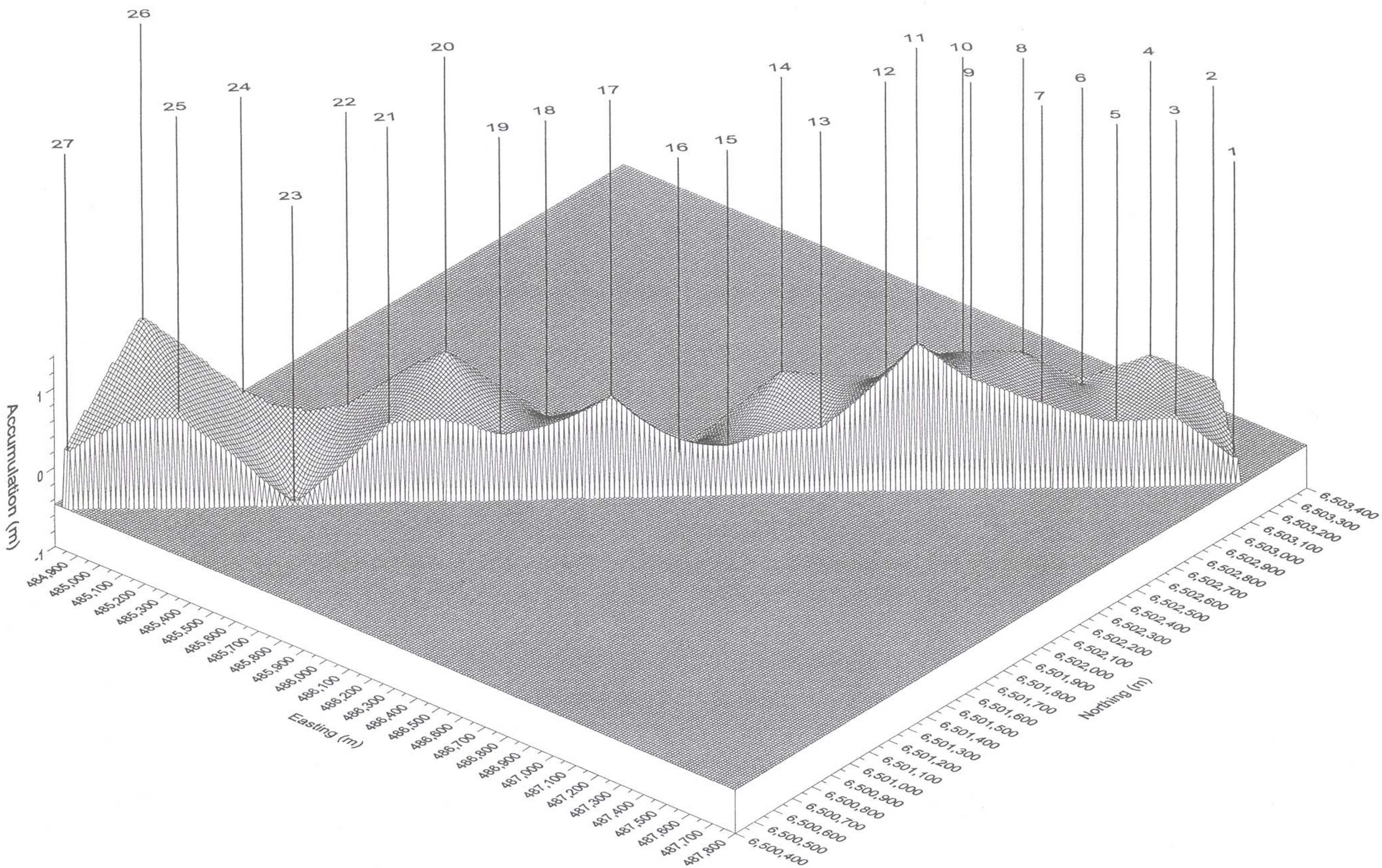
Spline Smooth settings:

Insert nodes	=	n.a.
Recalc grids	=	checked
Between rows	=	n.a.
Between cols	=	n.a.
# rows	=	2,000
# cols	=	2,000

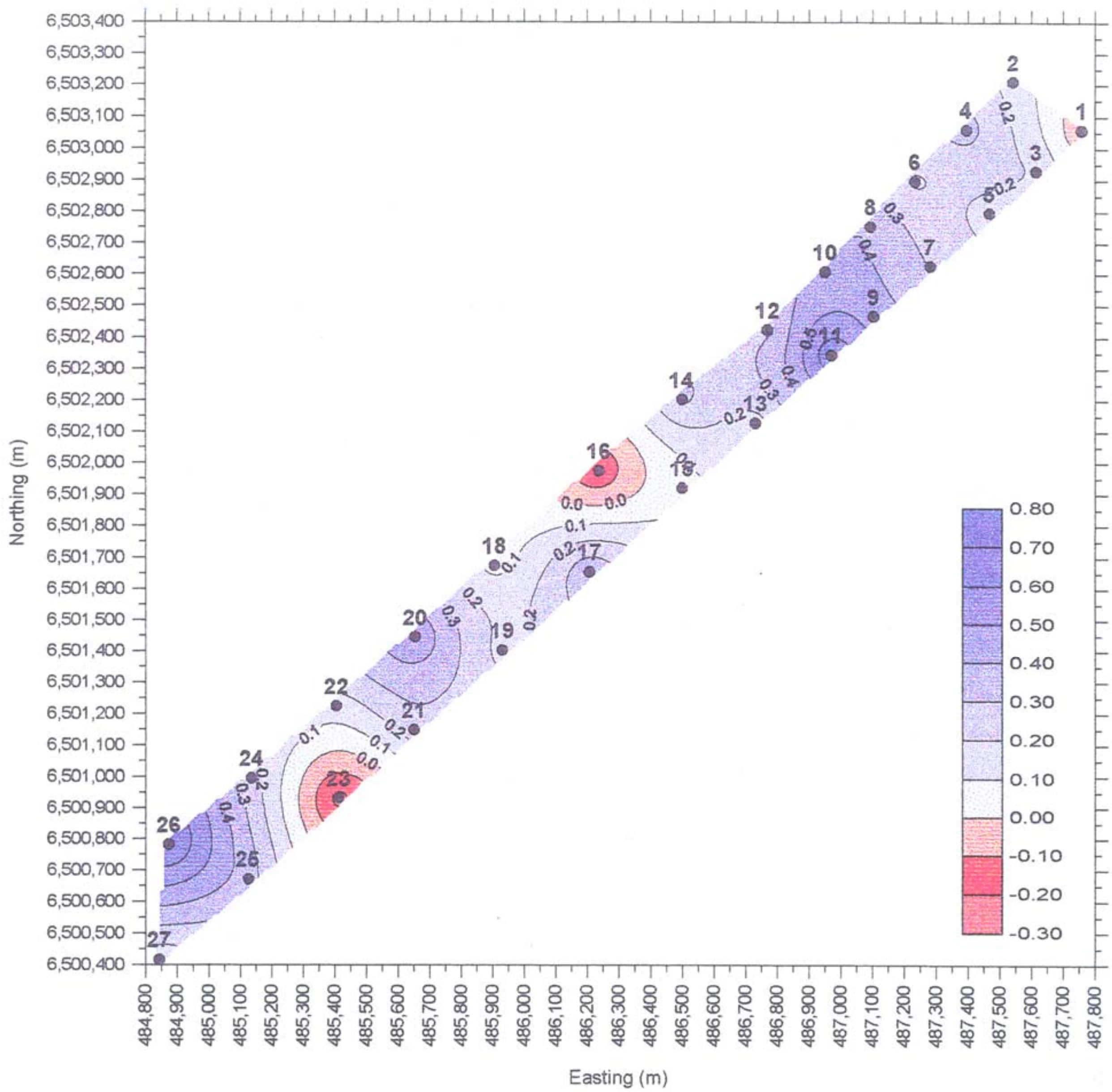
Appendix 11
Surface Analysis of Taku Profile IV



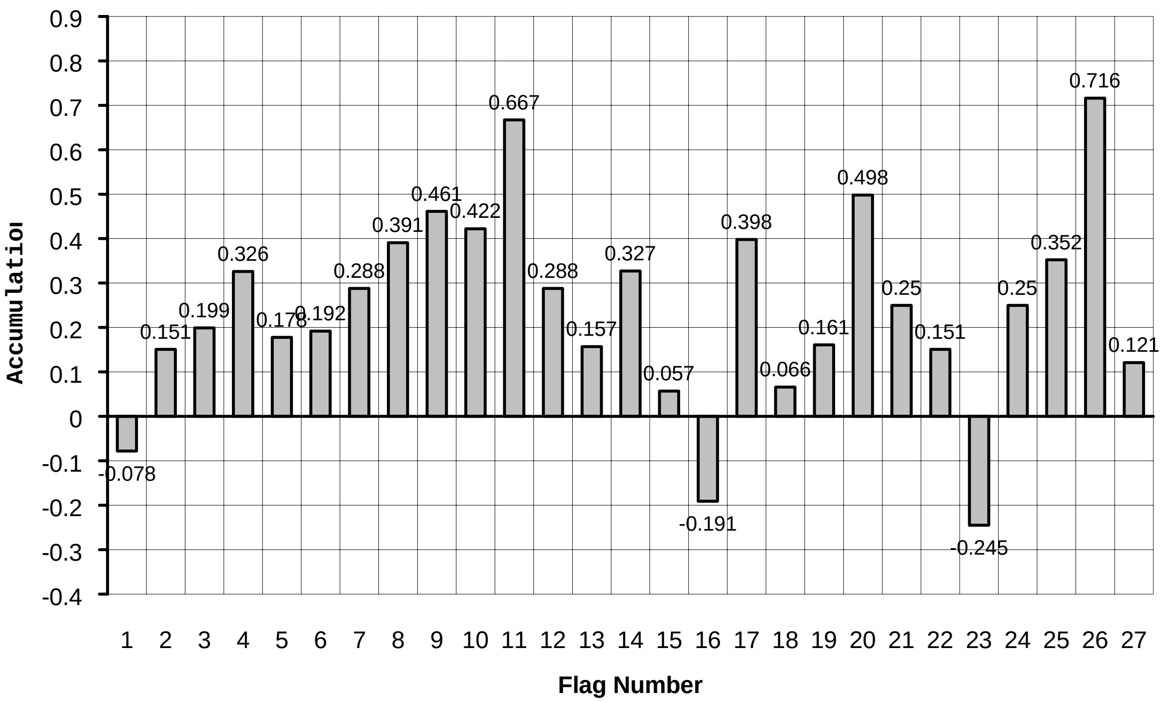
Surface of Profile IV as derived from the interpolation method. This shows the surface as surveyed on July 25, 1994. The surface as surveyed one year earlier is similar, however it is not shown because the elevation difference is too small to be depicted at this scale. Vertical scale is exaggerated 20x.



Surface model showing the spatial distribution of accumulation from July 25, 1993 to July 24, 1994. Negative values indicate a net loss of firn at the noted flag, while positive values show a net gain of firn at the flag.



Contour map showing the spatial distribution of accumulation for Taku Profile 4 from July 25, 1993 to July 24, 1994. Elapsed time between GPS surveys was 365 days. Blue shading represents positive balance, while red shaded areas show negative balance. Flags 1, 16, and 23 experienced a lowering of the surface elevation; the surface elevation at all other flags increased during the survey period. Easting and northing coordinates are given in meters and accumulation is given in centimeters. Flag numbers and contour values are noted on the map.



This chart shows the rise in surface elevation of the Taku Glacier at each of the 27 flags in Profile 4 from July 25, 1993 to July 24, 1994. The surface at each flag, with the exception of flags 1, 16, and 23, was higher in 1994 than in 1993. The average increase in surface elevation was 23.6 cm.

Surface Area and Volume Computations
for
Taku Profile 4
(Surveyed July 25, 1993)

FILES

Data file:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.dat
Blanking file:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.bln
Grid file:	d:\data\jirp\jirp-94\1993mass.bal\t4-72593.grd
Blanked grid file:	d:\data\jirp\jirp-94\1993mass.bal\t472593b.grd
Smoothed grid file:	d:\data\jirp\jirp-94\1993mass.bal\t472593s.grd

RESIDUALS OF THE BLANKED AND SMOOTHED GRID

Standard deviation	=	0.0285672003
Sum	=	-0.01624
Average	=	-0.00060
Minimum	=	-0.07117
Maximum	=	0.05505

VOLUME COMPUTATIONS
UPPER SURFACE

Grid File:	d:/data/jirp/jirp-94/1993mass.bal/t472593s.grd
Rows:	0 to 32,766
Cols:	0 to 32,766
Grid size as read:	2,000 cols by 2,000 rows
Delta X:	1.50075
Delta Y:	1.50075
X-Range:	484,800 to 487,800
Y-Range:	6,500,400 to 6,503,400
Z-Range:	1,098.23 to 1,121.1

LOWER SURFACE

Level Surface defined by Z = 1,095

VOLUMES

Volume Approximated by:

Trapezoidal Rule:	13,620,400	
Simpson's Rule:	13,618,700	13,619,833 ± 981
Simpson's 3/8 Rule:	13,620,400	

CUT & FILL VOLUMES

Positive Volume [Cuts]:	13,620,400
Negative Volume [Fills]:	0
Cuts minus Fills:	13,620,400

AREAS

Positive Planar Area (Upper above Lower):	1,014,320
Negative Planar Area (Lower above Upper):	0
Blanked Planar Area:	7,985,680
Total Planar Area:	9,000,000

Positive Surface Area (Upper above Lower):	1,014,410
Negative Surface Area (Lower above Upper):	0

Surface Area and Volume Computations
for
Taku Profile 4
(Adjusted survey - July 24, 1994)

FILES

Data file:	d:\data\jirp\jirp-94\1994mass.bal\t4-72494.dat
Blanking file:	d:\data\jirp\jirp-94\1994mass.bal\t4-72494.bln
Grid file:	d:\data\jirp\jirp-94\1994mass.bal\t4-72494.grd
Blanked grid file:	d:\data\jirp\jirp-94\1994mass.bal\t472494b.grd
Smoothed grid file:	d:\data\jirp\jirp-94\1994mass.bal\t472494s.grd

RESIDUALS OF THE BLANKED AND SMOOTHED GRID

Standard deviation	=	0.0323359095
Sum	=	-0.00165
Average	=	-0.00061
Minimum	=	-0.08765
Maximum	=	0.06250

VOLUME COMPUTATIONS
UPPER SURFACE

Grid File:	d:/data/jirp/jirp-94/1994mass.bal/t472494s.grd
Rows:	0 to 32,766
Cols:	0 to 32,766
Grid size as read:	2,000 cols by 2,000 rows
Delta X:	1.50075
Delta Y:	1.50075
X-Range:	484,800 to 487,800
Y-Range:	6,500,400 to 6,503,400
Z-Range:	1,098.29 to 1,121.8

LOWER SURFACE

Level Surface defined by Z = 1,095

VOLUMES

Volume Approximated by:

Trapezoidal Rule:	13,859,600	
Simpson's Rule:	13,858,000	13,859,100 ± 953
Simpson's 3/8 Rule:	13,859,700	

CUT & FILL VOLUMES

Positive Volume [Cuts]:	13,859,600
Negative Volume [Fills]:	0
Cuts minus Fills:	13,859,600

AREAS

Positive Planar Area (Upper above Lower):	1,014,320
Negative Planar Area (Lower above Upper):	0
Blanked Planar Area:	7,985,680
Total Planar Area:	9,000,000

Positive Surface Area (Upper above Lower):	1,014,420
Negative Surface Area (Lower above Upper):	0

Mass Balance
of
Taku Profile 4
(July 25, 1993 to July 24, 1994)

VOLUME COMPUTATIONS
UPPER SURFACE

Grid File:	d:/data/jirp/jirp-94/1994mass.bal/t472494s.grd
Rows:	0 to 32,766
Cols:	0 to 32,766
Grid size as read:	2,000 cols by 2,000 rows
Delta X:	1.50075
Delta Y:	1.50075
X-Range:	484,800 to 487,800
Y-Range:	6,500,400 to 6,503,400
Z-Range:	1,098.29 to 1,121.8

LOWER SURFACE

Grid File:	d:/data/jirp/jirp-94/1993mass.bal/t472593s.grd
Rows:	0 to 32,766
Cols:	0 to 32,766
Grid size as read:	2,000 cols by 2,000 rows
Delta X:	1.50075
Delta Y:	1.50075
X-Range:	484,800 to 487,800
Y-Range:	6,500,400 to 6,503,400
Z-Range:	1,098.23 to 1,121.1

VOLUMES

Volume Approximated by

Trapezoidal Rule:	239,269	
Simpson's Rule:	239,253	239,265 ± 11
Simpson's 3/8 Rule:	239,273	

CUT & FILL VOLUMES

Positive Volume [Cuts]:	245,023
Negative Volume [Fills]:	5,754
Cuts minus Fills:	239,269

AREAS

Positive Planar Area (Upper above Lower):	936,769	
Negative Planar Area (Lower above Upper):	77,547	
Blanked Planar Area:	7,985,680	
Total Planar Area:	8,999,996	
Positive Surface Area (Upper above Lower):	936,770	(92.4%)
Negative Surface Area (Lower above Upper):	77,547	(7.6%)
Total Surface Area:	1,014,317	

NET ACCUMULATION

Accumulation = Volume / Surface Area:	23.6 cm

Appendix 12

Taku Profile 4 Strain Rate Analysis

Profile 4 Strain (July 25, 1994 to August 5, 1994)					
Triangle	**Flags**	**E_1**	**E_2**	**E_3**	**Theta**
1	1 2 3	46.43	-24.34	-22.08	205.82
2	2 3 4	39.75	-21.94	-17.81	174.40
3	3 4 5	124.70	-46.98	-77.72	191.53
4	4 5 6	157.28	-230.42	73.14	202.17
5	5 6 7	342.23	-344.31	2.07	192.91
6	6 7 8	338.83	-188.66	-150.17	188.64
7	7 8 9	230.28*	-698.72*	468.45*	165.20*
8	8 9 10	94.32*	-62.63*	-31.69*	144.05*
9	9 10 11	1044.33*	53.23*	-1097.57*	234.53*
10	10 11 12	811.39	-139.75	-671.64	174.43
11	11 12 13	434.52	-125.45	-309.07	153.18
12	12 13 14	162.94	-113.85	-49.09	179.29
13	13 14 15	82.39	-83.98	1.59	175.85
14	14 15 16	71.76	-76.99	5.23	181.41
15	15 16 17	3.36	-51.75	48.39	186.72
16	16 17 18	12.87	-69.06	56.19	178.40
17	17 18 19	29.46	-60.11	30.65	191.66
18	18 19 20	32.24	23.88	-56.12	235.31
19	19 20 21	27.88	-40.68	12.80	97.11
20	20 21 22	0.98	-41.88	40.90	112.67
21	21 22 23	4.64	-92.54	87.90	105.80
22	22 23 24	117.06	-94.10	-22.97	97.56
23	23 24 25	127.89	-167.13	39.24	87.17
24	24 25 26	255.41	-150.82	-104.59	100.47
25	25 26 27	304.09	-279.01	-25.08	97.55
26	26 27 28	266.92	-291.54	24.62	92.45
27	27 28 29	272.89	-243.14	-29.74	90.56
28	28 29 30	148.65	-242.97	94.32	83.41
29	29 30 31	65.49	-91.69	26.20	90.53

Values of the strains E_1, E_2, and E_3 are in $\mu strain^{-d}$. The angle theta is in gons clockwise from grid north.
* Results are unreliable. Flag 9 fell over and was incorrectly repositioned for the August 5 survey.

Solution of Taku Profile 4 Triangles (July 25, 1994 survey)							
		Length of Sides (m)			Interior angles (gons)		
Triangle	**Date**	**a**	**b**	**c**	**Alpha**	**Beta**	**Gamma**
1	07-25-94	287.631	195.996	263.667	84.3180	45.9604	69.7217
2	07-25-94	255.037	210.947	287.631	65.7471	50.2846	83.9683
3	07-25-94	272.634	198.294	255.037	80.8061	48.8765	70.3174
4	07-25-94	255.161	229.998	272.634	67.0083	57.2654	75.7263
5	07-25-94	273.744	253.725	255.161	72.3166	63.5602	64.1232
6	07-25-94	226.150	200.073	273.744	60.4039	51.0811	88.5150
7	07-25-94	287.325	239.972	226.150	84.4949	60.1655	55.3395
8	07-25-94	207.799	204.226	287.325	51.4424	50.3076	98.2500
9	07-25-94	263.500	180.453	207.799	94.6362	47.8127	57.5511
10	07-25-94	214.717	259.701	263.500	53.8356	72.0548	74.1096
11	07-25-94	296.199	322.581	214.717	70.2381	84.9563	44.8056
12	07-25-94	243.988	348.845	296.199	48.3359	88.6775	62.9866
13	07-25-94	283.661	312.694	243.988	66.4010	80.2697	53.3293
14	07-25-94	267.608	346.356	283.661	54.4878	86.4307	59.0816
15	07-25-94	321.245	393.113	267.608	60.2676	92.4754	47.2569
16	07-25-94	302.216	448.024	321.245	47.1032	102.0307	50.8662
17	07-25-94	271.772	374.831	302.216	50.8799	90.3924	58.7277
18	07-25-94	279.992	340.357	271.772	58.9007	84.6191	56.4802
19	07-25-94	296.321	377.464	279.992	56.6486	90.8675	52.4840
20	07-25-94	256.247	331.945	296.321	53.0293	81.6011	65.3695
21	07-25-94	238.181	222.352	256.247	65.7627	59.2207	75.0166
22	07-25-94	350.892	354.123	238.181	77.2498	78.8756	43.8746
23	07-25-94	324.679	488.748	350.892	46.1965	102.8881	50.9154
24	07-25-94	274.585	338.606	324.679	54.2825	75.7996	69.9179
25	07-25-94	365.176	378.299	274.585	73.1139	78.7714	48.1147
26	07-25-94	330.049	449.673	365.176	51.5175	89.3653	59.1172
27	07-25-94	320.660	349.174	330.049	62.5069	72.0965	65.3966
28	07-25-94	337.426	335.792	320.660	68.6803	68.1100	63.2097
29	07-25-94	336.725	336.219	337.426	66.6451	66.4798	66.8751

Solution of Taku Profile 4 Triangles (August 5, 1994 Survey)							
		Length of Sides (m)			Interior Angles (gons)		
Triangle	Date	a	b	c	Alpha	Beta	Gamma
1	08-05-94	287.753	196.025	263.645	84.3636	45.9552	69.6813
2	08-05-94	255.086	210.917	287.753	65.7382	50.2577	84.0041
3	08-05-94	272.997	198.314	255.086	80.9205	48.8352	70.2443
4	08-05-94	254.652	229.949	272.997	66.7948	57.2544	75.9507
5	08-05-94	274.762	253.434	254.652	72.7476	63.3889	63.8634
6	08-05-94	226.317	200.053	274.762	60.2298	50.8972	88.8730
7	08-05-94	287.357	238.229	226.317	84.8627	59.6433	55.4941
8	08-05-94	208.019	204.094	287.357	51.5054	50.2588	98.2358
9	08-05-94	265.559	182.368	208.019	94.9533	48.0024	57.0443
10	08-05-94	215.468	259.710	265.559	53.7997	71.5238	74.6765
11	08-05-94	296.556	322.140	215.468	70.3949	84.6081	44.9970
12	08-05-94	243.943	348.539	296.556	48.3488	88.5091	63.1421
13	08-05-94	283.846	312.476	243.943	66.4957	80.1733	53.3311
14	08-05-94	267.484	346.159	283.846	54.4771	86.3584	59.1645
15	08-05-94	321.240	392.951	267.484	60.2986	92.4503	47.2512
16	08-05-94	302.028	447.745	321.240	47.1044	101.9884	50.9072
17	08-05-94	271.859	374.704	302.028	50.9208	90.3782	58.7010
18	08-05-94	280.069	340.475	271.859	58.8964	84.6240	56.4796
19	08-05-94	296.190	377.464	280.069	56.6160	90.8792	52.5048
20	08-05-94	256.249	331.848	296.190	53.0493	81.5985	65.3522
21	08-05-94	237.986	222.236	256.249	65.7155	59.2085	75.0761
22	08-05-94	351.342	354.268	237.986	77.3633	78.8374	43.7993
23	08-05-94	324.145	489.022	351.342	46.0686	102.9728	50.9586
24	08-05-94	275.162	338.943	324.145	54.4138	75.9102	69.6761
25	08-05-94	364.099	378.571	275.162	72.7556	78.9791	48.2653
26	08-05-94	330.756	450.211	364.099	51.6166	89.5718	58.8116
27	08-05-94	319.814	349.616	330.756	62.2147	72.2091	65.5762
28	08-05-94	337.553	336.099	319.814	68.7629	68.2536	62.9835
29	08-05-94	336.392	336.282	337.553	66.5517	66.5158	66.9326

Taku Profile 4
Magnitude and Orientation of Strain Ellipses

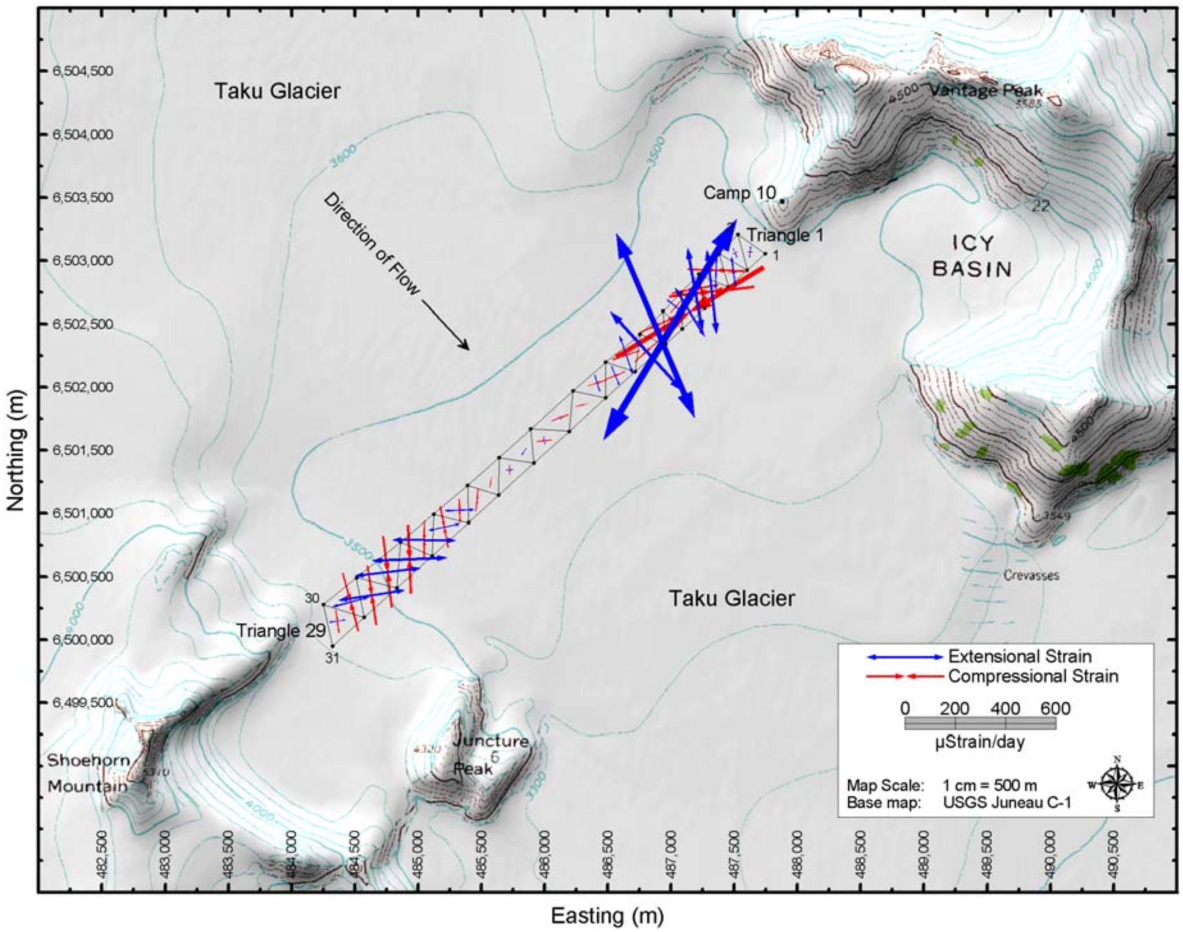


Figure 40: Surface strain at Profile 4, Taku Glacier, from July 25 to August 5, 2001. Crevasse zones along the margins are clearly defined by the large magnitude of strain relative to the central sector, while the central portion of the glacier undergoes minimal stress and is crevasse-free. Arrows for Triangles 7-10 are unreliable due to data collection errors.

This diagram shows the magnitude and orientation of the strain ellipses for each triangle of Profile 4. The magnitude of extensional and compressional strain is reported as microstrain per day. The direction of the maximum extensional strain is in gons from grid north.

Flag number 9 ablated out and fell over between survey epochs, and was reset in the wrong position for the resurvey. For this reason, the strain ellipses shown for the three triangles (7, 8, and 9) affected by flag 9 are not reliable. Additionally, a data collection errors at triangle 9 give inconsistent and unreliable results for this triangle.

Appendix 13

Taku Glacier Terminus Survey
July 30, 1994

Survey Point: Taku Point (See map for location)
Reference Point: Taku "B" (See map for location)

POINT	HORIZONTAL ANGLE (gons)	VERTICAL ANGLE (gons)	SLOPE DISTANCE (m)	HORIZONTAL DISTANCE (m)
Taku "B"	0	---	---	---
1	124.8	99.987	2,989.50	2,989.50
2	121.2	99.774	2,480.36	2,480.34
3	117.4	100.033	2,203.70	2,203.70
4	108.2	99.991	1,931.03	1,931.03
5	90.8	99.306	1,699.88	1,699.78
6	73.9	99.962	1,662.22	1,662.22
7	52.8	99.791	1,987.29	1,987.28
8	41.2	99.040	2,215.72	2,215.62
9	30.8	99.993	2,651.06	2,651.06
10	24.8	99.986	3,071.84	3,071.84
11	22.2	99.910	3,468.06	3,468.06

Notes:

The line from Taku Point to Taku "B" is the reference line from which the horizontal angles are measured.

Horizontal angles reflect one set face left readings only. Face right readings were not taken, thus introducing an unknown instrumental error into the survey data.


TAKU GLACIER
Hole-in-the-Wall Glacier
Goat Ridge
Seaplane Base
TAKU RIVER
Brassiere Hills
Zipper Cr
PROFILE I
Norris Mtn
Glacier VABM 47
CAMP 12
Loon Lakes
Joyce
Swede Point
Mud
TAKU INLET
1971
1994
Oozy Flats
Mary
REFERENCE POINT
Taku Pt
SURVEY POINT
Grizzly Bar
Lip
Lake
Let
SCALE: 1:63,360