

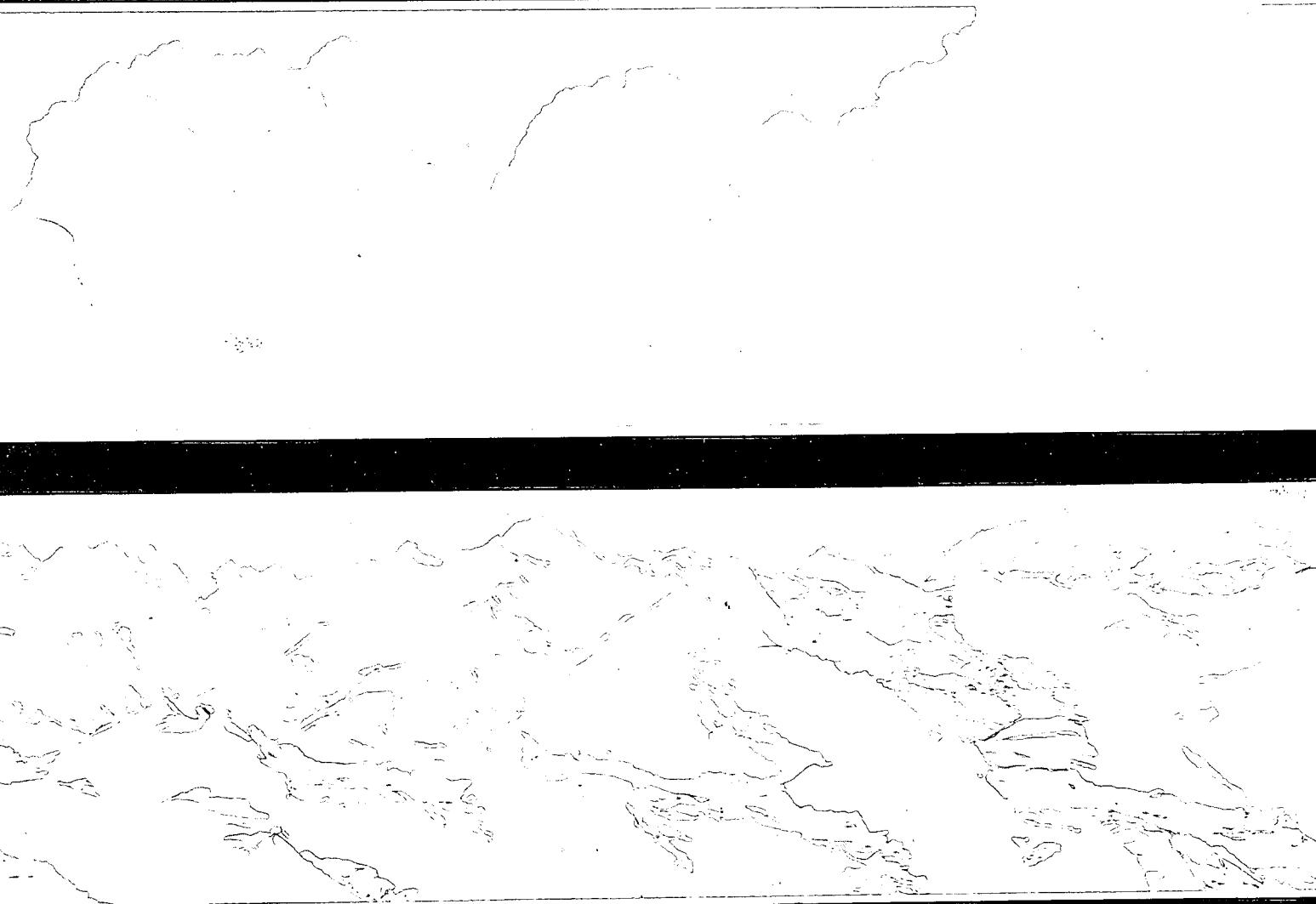


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# Glacier Surveys in British Columbia - 1973

I. A. Reid and J. O. G. Charbonneau



## REPORT SERIES NO. 66

INLAND WATERS DIRECTORATE  
WATER RESOURCES BRANCH  
OTTAWA, CANADA, 1980

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**I. A. Reid and J. O. G. Charbonneau**

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OTTAWA, CANADA, 1980**

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## **Abstract**

Glaciers act as natural regulators, storing water in winter and releasing it in summer. To gain some understanding of this phenomenon and the contribution which glaciers make to streamflow, the predecessors of the Water Survey of Canada began glacier surveys in 1945. The earlier surveys offered some clue to the role of the glacier, but the data collected were not sufficient to provide the overall picture. Following adoption of photogrammetric survey techniques, however, the glacier surveys have evolved to the extent that it is now feasible to produce a series of maps from which the linear, areal, directional and volumetric changes can be determined.

The surveys have revealed that the glaciers, in general, are becoming smaller in size; hence the regulating effect on streamflow is diminishing.

## **Résumé**

Les glaciers jouent un rôle de régularisation naturelle, emmagasinant l'eau pendant l'hiver et la laissant s'écouler durant l'été. Pour arriver à comprendre quelque chose à ce phénomène et aussi à la contribution que les glaciers apportent au ruissellement, les prédecesseurs de la Division des relevés hydrologiques du Canada avaient commencé en 1945 une étude des glaciers. Ces premières études apportèrent certains indices quant au rôle des glaciers mais les observations compilées n'étaient pas suffisantes pour donner une idée d'ensemble. À la suite de l'adoption de relevés photogrammétriques, cependant, l'étude des glaciers a évolué au point qu'il est maintenant possible de produire une série de cartes à partir desquelles on peut déterminer les changements linéaires, directionnels, de superficie et de volume.

Les études ont révélé, qu'en général, le volume des glaciers diminue et que de ce fait, l'effet de régularisation sur le ruissellement est aussi diminué.

## Introduction

An important function of the Water Resources Branch is the systematic collection of water resource data throughout Canada. This work is of vital importance in the development of Canada's water resources because the feasibility, safety and cost of water use or water control projects depend largely on the availability and reliability of such information.

Since glaciers form part of Canada's water resources, some glaciers are surveyed on a continuing basis by Water Survey of Canada (WSC) in an effort to determine the extent and pattern of a glacier's influence on surface water runoff. Of the large number of glaciers in Canada, however, only a few are surveyed (Fig. 1).

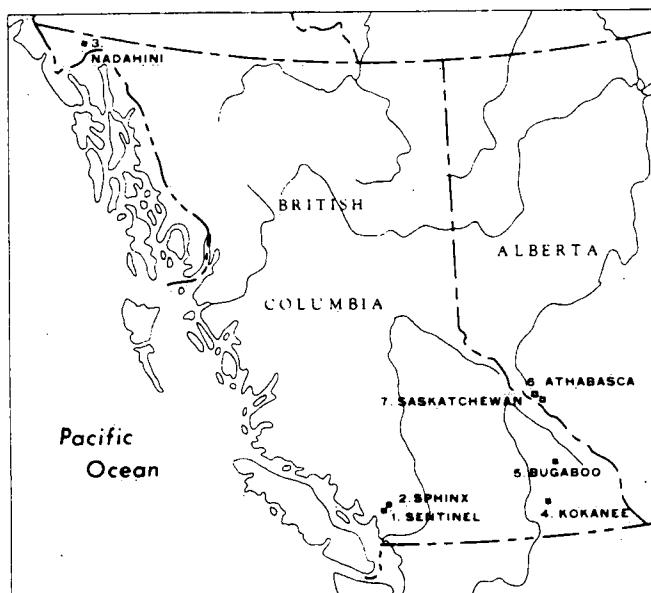


Figure 1. Key map showing location of glaciers.

This report summarizes the history of glacier surveys conducted in Canada by Water Survey of Canada and describes present glacier survey practices. Tables of results for the period of record, some interpretation of these results and the most recent glacier maps are also included. Only those surveys conducted partially by or under the supervision of WSC Headquarters Staff are described in

detail; brief reference, however, is made to surveys conducted entirely by Water Survey of Canada Regional Office staff to make the historical summary coherent and the tables of data as complete as possible.

In response to a directive recommending greater use of the metric system, the Water Survey of Canada decided to change from English to SI units in the determination of biennial glacier variations. In 1968, the year of the changeover, it was necessary to compile separate sets of maps using both English and SI units in order that data produced prior to 1968 might be compared to data obtained after 1968.

### HISTORICAL SUMMARY

Surveys of selected glaciers in the Rocky, Columbia and Coast mountains were begun in 1945. The surveys of glaciers located in the Rocky Mountains were carried out by WSC Calgary staff, and the Columbia and Coast mountain surveys were performed by the WSC Vancouver staff. These surveys, in general, were designed to determine the position of the glacier toe, to define the movement of a plaque line on the glacier's surface and to provide a transverse and a longitudinal profile for the lower portion of the glacier. Reports describing the 1945 survey and subsequent surveys conducted by the Regional Offices are available from

G. Tofte, Regional Chief,  
Water Survey of Canada,  
Inland Waters Directorate,  
Department of the Environment,  
502 - 1001 West Pender Street,  
Vancouver, British Columbia.  
V6E 2M9

and

G.H. Morton, Regional Chief,  
Water Survey of Canada,  
Inland Waters Directorate,  
Department of the Environment,  
Bag 2909, Postal Station M,  
Calgary, Alberta.  
T2P 2M7

More information concerning the evolution of the glacier surveys may be obtained from "Glacier Surveys by the Water Survey of Canada," a paper by I.A. Reid in the *Proceedings* of the Banff Symposia on "The Role of Snow and Ice in Hydrology," held in September 1972.

A glacier's contribution to the volume of runoff can be calculated if two quantities are known: (1) the change in volume of a glacier during a given period of time and (2) the amount of ice that flows from the source ice-field to the glacier during the same period of time. Surveys have been designed to measure the first quantity directly, but since no direct method of measuring the second quantity was known until recently, it has been determined only indirectly.

A paper entitled "A Simple Method of Measuring the Average Amount of Water Produced Annually by Melting of Ice on a Glacier" by I.A. Reid and W.S.B. Paterson was presented at the Symposium on "Hydrology of Glaciers" at Cambridge, England, in September 1969. The Symposium's *Proceedings* were published by the Glaciological Society, Cambridge, in 1974.

Since the information obtained for each glacier by Regional Office staff was applicable only to the lower portion of the glaciers, volumetric and linear changes could be obtained for only the lower portion. In an effort to increase the areal coverage of the glaciers surveyed, an aerial photogrammetric survey of the Athabasca Glacier was undertaken as a pilot project in July 1959 (Reid, 1961). Permanent survey plugs were established around the perimeter of the glacier and tied-in by means of a triangulation survey. From the aerial photographs, a topographic map was produced using a high-precision plotter. This was the first time that a topographical map of high quality was prepared by the Branch, and the precedent was set for later maps.

In 1963, a survey party composed of staff from the Calgary Regional Office and headquarters participated in a surveying experiment with a team from the University of New Brunswick led by Dr. G. Konecny, Head of the Department of Survey Engineering. Optical-electronic distance measuring equipment together with standard equipment and normal triangulation procedures was used to reconfirm the location of plugs in the somewhat modified triangulation network around Athabasca Glacier and to define the coordinates of the newly established plugs around Saskatchewan Glacier. Only Saskatchewan Glacier was photographed in 1963, implementing terrestrial photogrammetry in place of aerial photogrammetry for the first time. The

map was plotted under contract by the University of New Brunswick.

During the summer of 1964, high-quality maps of five selected glaciers in British Columbia were prepared by stereoscopic terrestrial photogrammetric methods. It was found by study that for the survey of glaciers, stereoscopic terrestrial survey methods have certain advantages over aerial surveys.

Since 1965 stereoscopic terrestrial photographs of the Athabasca and Saskatchewan glaciers have been taken by Calgary Regional Office and headquarters personnel in odd-numbered years. The plotting of the maps was performed by headquarters staff, using a first order plotter located at the Surveys and Mapping Branch, Department of Energy, Mines and Resources.

This method is now used to map glaciers in British Columbia in even-numbered years and to map glaciers in Alberta in odd-numbered years. From the maps, linear and volumetric changes in the glaciers are determined. Results of earlier work have also been published in this *Report Series*.

The Calgary Regional staff continues to observe plaque line movements and the position of the toe of the Athabasca and Saskatchewan glaciers in even-numbered years, i.e., 1976, 1978.

The continuation of these surveys, apart from more fundamental scientific observations made by the Department's Snow and Ice Division, is an important aspect of Branch activities for two reasons: (1) the surveys provide a basis for obtaining greater knowledge of Canada's fresh-water resources and (2) they fulfil our announced commitment<sup>1</sup> to monitor glacial changes as part of a world-wide surveillance of glacier trends. We can only speculate on the ultimate usefulness of the information being collected. Yet it could well be that the trends of a glacier's behaviour over a period of time will prove to be a very useful prediction tool in hydrological studies of the future.

These glacier surveys are closely coordinated with other activities of the Water Resources Branch. The information contained in these survey reports is provided to individuals, scientific agencies and to various libraries throughout the world.

<sup>1</sup> The commitment is to the International Commission on Snow and Ice of the International Association of Hydrological Sciences and to Unesco, Paris.

## Description of Glaciers

### **SENTINEL GLACIER**

Sentinel Glacier is located at latitude  $49^{\circ} 53'$ , longitude  $122^{\circ} 58'$ , in Garibaldi Provincial Park, British Columbia. This glacier was selected because of its accessibility. The Branch has made periodic surveys around the toe since 1945. Meltwater from the glacier flows into Howe Sound via Garibaldi Lake, Rubble Creek and Cheakamus River (Fig. 2).

### **SPHINX GLACIER**

Sphinx Glacier is located at latitude  $49^{\circ} 53'$ , longitude  $123^{\circ} 06'$ , in Garibaldi Provincial Park, British Columbia. This glacier was selected on account of its accessibility. The Branch has made periodic surveys around the toe area since 1945. Meltwater from the glacier flows into Howe Sound via Garibaldi Lake, Rubble Creek and Cheakamus River (Fig. 3).

### **NADAHINI GLACIER**

Nadahini Glacier is located in northern British

Columbia at latitude  $59^{\circ} 44'$ , longitude  $136^{\circ} 41'$ . This glacier was selected due to its accessibility. Meltwater flows via West Nadahini Creek into Tatshenshini River and then into the Pacific Ocean via Alsek Creek (Fig. 4).

### **KOKANEE GLACIER**

Kokanee Glacier is located at latitude  $49^{\circ} 45'$ , longitude  $117^{\circ} 08'$  in Kokanee Glacier Provincial Park, British Columbia. This glacier was selected because of its accessibility. The Branch has made periodic surveys around the toe area since 1945. Meltwater from the glacier flows into Kootenay Lake via Keen Creek and Kalso River (Fig. 5).

### **BUGABOO GLACIER**

Bugaboo Glacier is located at latitude  $50^{\circ} 40'$ , longitude  $116^{\circ} 45'$ , in British Columbia. The Branch made a reconnaissance survey of the toe area of this glacier in 1946. Meltwater from the glacier flows into the Columbia River via Bugaboo Creek (Fig. 6).



Figure 2. Sentinel Glacier – August 15, 1978.



Figure 3. Sphinx Glacier – August 13, 1978.



Figure 4. Nadahini Glacier – August 10, 1978.



Figure 5. Kokanee Glacier – August 17, 1978.

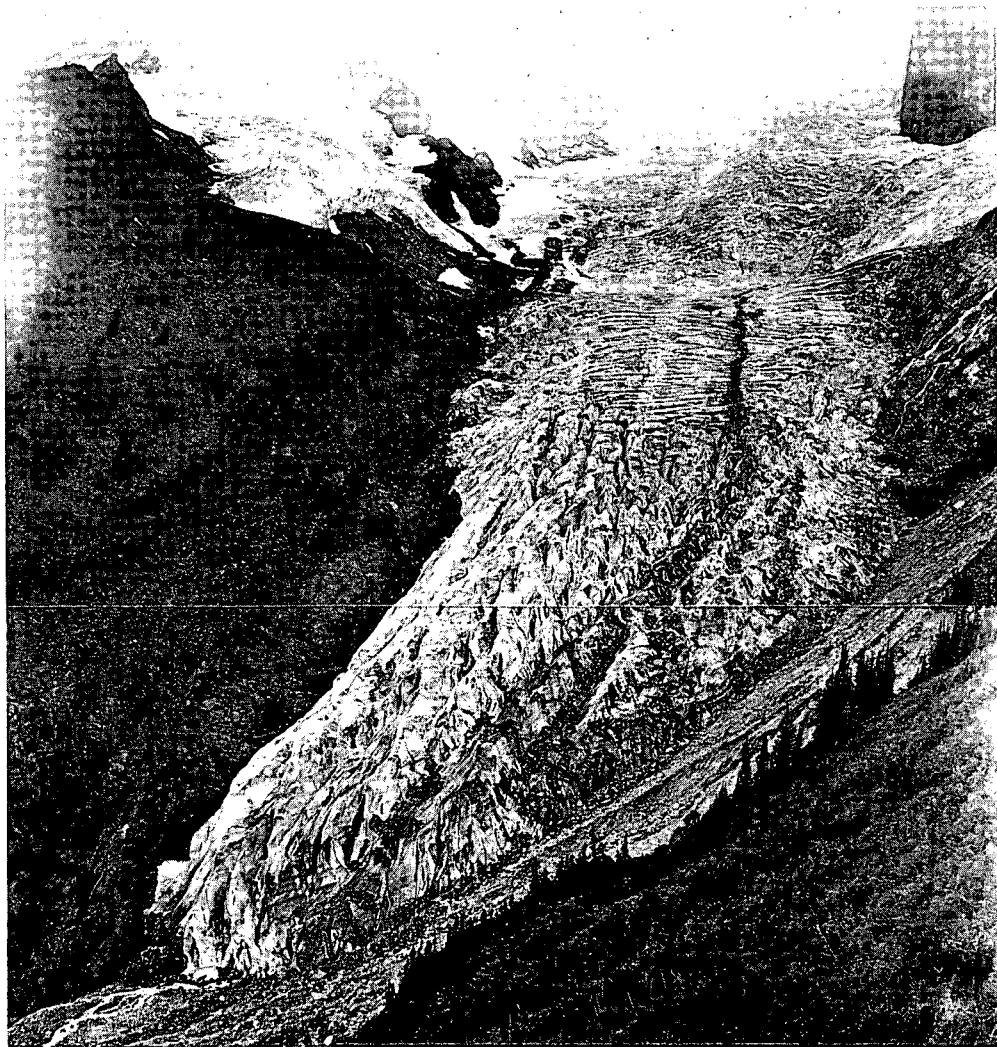


Figure 6. Bugaboo Glacier – August 19, 1978.

## Field Work

The general procedure followed in conducting the survey of the five glaciers was in accordance with the *Text Book of Photogrammetry* (Zeller, 1952).

Generally, horizontal and vertical control points are located on rock around the glacier periphery as well as on the ice surface. The positions of the control points on the ice are established during the day of photography. Photographic stations are situated, where possible, on a high ridge facing and overlooking the toe of the glacier; stereoscopic terrestrial photographs are taken from these stations.

Since the surveys for all the glaciers are essentially the same, a detailed description is given for Sentinel Glacier only. The horizontal, vertical and photographic control points are shown on the maps.

The control net for Sentinel Glacier, as for the other glaciers, is local and not connected to any other triangulation net.

### CONTROL

A schematic sketch of the control net is shown in Figure 7.

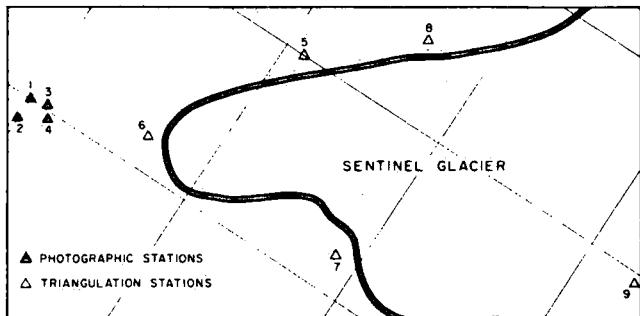


Figure 7. Sketch showing distribution of photographic and triangulation stations — Sentinel Glacier.

Triangulation stations, numbers 5, 6, 7, 8 and 9, are rock cairns located just outside of the glacier's periphery.

The photography stations, numbers 1, 2, 3 and 4, were marked by standard Water Resources Branch bench-

mark plugs cemented in bedrock (Fig. 8). Small rock cairns were built close to each plug for ease in locating them in the field.

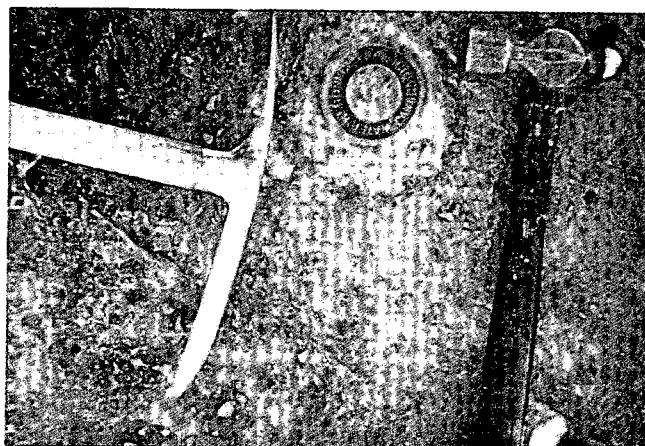


Figure 8. Photograph showing the standard WRB plugs used to locate the photographic stations.

### INSTRUMENTS AND EQUIPMENT

A Wild T-2 theodolite and a Wild P-30 phototheodolite were used to measure all horizontal and vertical angles. All readings were to the nearest second.

A Wild invar subtense bar was used to measure the base-line distances. The subtense bar was calibrated optically by the manufacturer. Prior to the survey, the accuracy of the subtense bar was checked against a fixed distance that was accurately chained with a calibrated invar tape.

The Wild P-30 phototheodolite was used to photograph the glaciers. The internal adjustments of the camera were calibrated at the National Research Council, Division of Applied Physics, before plotting the glacier maps. This calibration needs to be done only once unless the camera sustains a violent shock. Kodak spectroscopic type plates were used for the photography.

### BASE LINE

The distances between control stations 1 and 2, 2 and 4, and 3 and 4 were measured with the subtense bar according

to the manufacturer's general instructions provided with the instrument. This procedure involves measuring the angle subtended by the subtense bar. To ensure a high order of accuracy, the horizontal angle was read with the telescope in a direct and an inverted position. The horizontal circle was turned about 60 degrees before the second reading

Table 1. Sample Field Notes for Using a Subtense Bar – Sentinel Glacier Survey

Transit at Station 1	Cloudy and cool with sunny periods	Date: August 18, 1976 Transit: J.O.G.C. Notes: E.F.	
Subtense bar @ stn. 2	Reading	Angle	Distance m
L <sub>1</sub> 252° 29' 59"	72° 29' 59.5"	00° 00' 00"	
L <sub>2</sub> 72° 30' 00"			
R <sub>1</sub> 253° 56' 44"	73° 56' 42.5"	01° 26' 43"	79.285
R <sub>2</sub> 73° 56' 41"			
L <sub>1</sub> 252° 30' 01"	72° 30' 01"	00° 00' 00"	
L <sub>2</sub> 72° 30' 01"			
R <sub>1</sub> 253° 56' 45"	73° 56' 45.5"	01° 26' 44.5"	79.260
R <sub>2</sub> 73° 56' 46"			
L <sub>1</sub> 179° 34' 30"	179° 34' 30"	00° 00' 00"	
L <sub>2</sub> 359° 34' 30"			
R <sub>1</sub> 181° 01' 14"	181° 01' 13"	01° 26' 43"	79.260
R <sub>2</sub> 01° 01' 12"			
L – Left end of subtense bar		Mean distance	79.268
R – Right end of subtense bar			

and a further 60 degrees before the third. Notes of sample subtense bar readings are shown on Table 1. Horizontal distances corresponding to the mean observed parallax (subtended angle) were determined from the appropriate tables and used for computing distances in the triangulation net.

## TRIANGULATION

The party, on arriving at the glacier, first made a reconnaissance survey of the toe area to locate the best possible locations for the photographic stations. The locations of the photographic stations should be at about the same elevation and on a high ridge facing the glacier. The ratio between the distance separating the base-line stations and the distance to the area to be stereoscopically photographed should not be less than 1:4 nor greater than 1:20. To meet this criterion, measurements were made from the best general area for the photographic stations to the toe area of the glacier and the upper limit of the glacier. When these distances were known, the party established the photographic stations on a ridge to give the best possible results.

Cairns were built around the glacier periphery on bedrock whenever possible, and their positions were determined by triangulation. A 2.5 cm by 2.5 cm stake, one metre long, was centred upright and anchored in each cairn.

Table 2. Sample Field Notes for Triangulation – Sentinel Glacier Survey

Transit at Station 3	H.I. = 1.56 m	Overcast, cold, sunny intervals and windy	Date: August 18, 1976 Transit: J.O.G.C. Notes: E.F.			
Stn.	Horizontal angle	Mean	Reduced mean	Vertical angle	Mean	Remarks
4	00° 05' 48" 180° 05' 49"	00° 05' 48.5"	00° 00' 00"	97° 40' 50" 262° 20' 07"	97° 40' 21.5"	Top of tribrah
1	110° 32' 50" 290° 32' 52"	110° 32' 51"	110° 27' 02.5"	88° 33' 39" 271° 27' 40"	88° 32' 59.5"	Top of transit
4	60° 00' 35" 240° 00' 41"	60° 00' 38"	00° 00' 00"	97° 41' 05" 262° 19' 53"	97° 40' 36"	Top of tribrah
1	170° 27' 42" 350° 27' 53"	170° 27' 47.5"	110° 27' 09.5"	88° 33' 40" 271° 27' 36"	88° 33' 02"	Top of transit
4	120° 09' 48" 300° 09' 56"	120° 09' 52"	00° 00' 00"			
1	230° 36' 56" 50° 37' 05"	230° 37' 00.5"	110° 27' 08.5"			

Table 3. Sample Field Notes for Taking Photographs with a Phototheodolite – Sentinel Glacier Survey

Phototheodolite at Station 4 Backsight on Station 3 H.I. = 1.36 m			Began Finished	10:30 10:50	Clear, cool and windy	Date: August 18, 1976
Angle	Aversion (rt.)	Inclin. (grad)	Plate no.	Photo no.	Exp. time (s)	Remarks
263° 00' 00"	7°	+7	2	1	1/50	very bright sun
263° 00' 00"	7°	+7	3	2	1/5	no clouds
263° 00' 00"	7°	+7	4	3	1/10	no clouds
257° 00' 00"	13°	+7	5	4	1/10	no clouds
257° 00' 00"	13°	+7	6	5	1/5	no clouds
257° 00' 00"	13°	+7	7	6	1/50	no clouds

The stakes were flagged with brightly coloured cotton for ease in locating, and sightings were taken on the stakes to obtain the angles in the triangulation net.

The triangulation was carried out using a Wild T-2 theodolite or a Wild P-30 phototheodolite. Each horizontal and vertical angle was observed three times with the telescope in a direct position and three times in an inverted position. The horizontal circle was turned in most cases by about 60 degrees for the second reading and a further 60 degrees for the third. Sample field notes for triangulation are shown in Table 2.

### PHOTOGRAPHY

The photographs taken from stations 1 and 2 (long base) were used to plot distant areas of the glacier, and

photographs taken from stations 3 and 4 (short base) were used to plot near areas. Sample field notes for taking photographs using a phototheodolite are shown in Table 3.

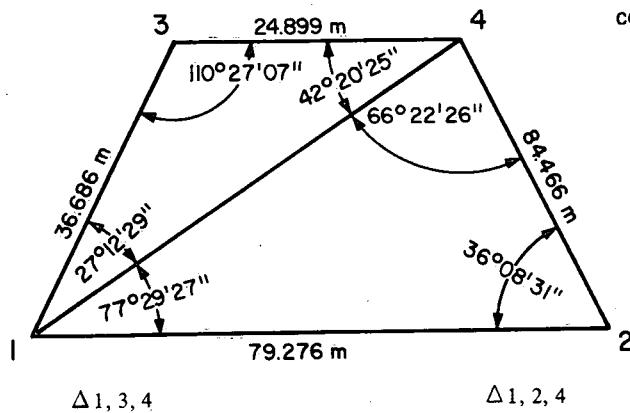
Instructions for carrying out photography are outlined in the booklet accompanying the phototheodolite. These instructions, as well as those contained in the *Text Book of Photogrammetry* (Zeller, 1952), were followed closely.

Whenever feasible the exposed photographic plates were developed and a print of each plate was made by a reputable firm as soon as possible. On receipt of the prints, members of the party identified the control points and other noteworthy features. By doing this, it was possible to see the quality of the prints at an early date and, if necessary, repeat the photography before leaving the area.

## Office Work

The method of determining coordinates for these glacier maps is known as the "plane rectangular coordinate system." In this system, the area surveyed is assumed to be perfectly level, i.e., the earth's curvature is not taken into consideration. The meridians of longitude and parallels of latitude are represented by equidistant straight lines. The coordinates of the triangulation stations are determined by plane trigonometry. This procedure is considered to be ideal for the relatively small areas being mapped.

Since the reduction of data for all of the glaciers is essentially the same, a detailed description is given for Sentinel Glacier only.



Observed angles	Observed angles	Correction	Adjusted angles
$\angle 1 = 27^\circ 12' 29''$	$\angle 1 = 77^\circ 29' 27''$	-8"	$77^\circ 29' 19''$
$\angle 3 = 110^\circ 27' 07''$	$\angle 2 = 36^\circ 08' 31''$	-8"	$36^\circ 08' 23''$
$\angle 4 = 42^\circ 20' 25''$	$\angle 4 = 66^\circ 22' 26''$	-8"	$66^\circ 22' 18''$
$180^\circ 00' 01''$	$180^\circ 00' 24''$	-24"	$180^\circ 00' 00''$

Using the sine law  $\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

For  $\Delta 1, 2, 4$ :

$$\begin{aligned} \frac{(1-4)}{\sin \angle 2} &= \frac{(1-2)}{\sin \angle 4} \quad \text{therefore} \quad (1-4) = \frac{(79.276)(0.58975638)}{(0.91616464)} = 51.030 \text{ m} \\ \frac{(1-4)}{\sin \angle 2} &= \frac{(2-4)}{\sin \angle 1} \quad \text{therefore} \quad (1-4) = \frac{(84.466)(0.58975638)}{(0.97625297)} = 51.027 \text{ m} \end{aligned}$$

For  $\Delta 1, 3, 4$ :

$$\begin{aligned} \frac{(1-4)}{\sin \angle 3} &= \frac{(3-4)}{\sin \angle 1} \quad \text{therefore} \quad (1-4) = \frac{(24.899)(0.93696559)}{(0.45722297)} = 51.024 \text{ m} \\ \frac{(1-4)}{\sin \angle 3} &= \frac{(1-3)}{\sin \angle 4} \quad \text{therefore} \quad (1-4) = \frac{(36.686)(0.93696559)}{(0.67353229)} = 51.033 \text{ m} \end{aligned}$$

## COMPUTATIONS

The computations of coordinates were carried out using a basic calculator with seven-place natural trigonometric functions.

Since the reduction of data for all of the glaciers is essentially the same, a detailed description is given for Sentinel Glacier only.

### BASE LINE

Subtense bar measurements were made between control stations 1 and 2, 2 and 4, and 3 and 4. The field

Figure 9. Computations for distance using the sine law.

notes were reduced and distances read as shown on Table 1. The distance between stations was found in the booklet entitled *Tables of Distance for Use in Connection with the Wild Precise Invar Stadia* (Wild of Canada).

### HORIZONTAL ANGLE

When the notes for all stations were reduced, the horizontal coordinate for control station no. 1 was assigned the value,  $x = 30\ 480.1$  and  $y = 30\ 480.1$ .

The azimuth of line 1 to 2 was assumed to be  $270^\circ\ 00' 00''$  and was determined by scaling from a topographic map. The orientation of the glacier is therefore referenced to an approximate true north. Computations showing an example of the use of the sine law to compute distances are shown in Figure 9, and the computations necessary to obtain the horizontal coordinates ( $x, y$ ) for station 4 are shown in Table 4. The coordinates for other reference (cut-in) points were computed, as shown in Table 4, from at least two bases, and the mean position was used for those coordinates.

Table 4. Sample Calculations for Obtaining Coordinates from a Known Point—Sentinel Glacier Survey

Stn.	Angle	Azimuth	Side (m)	Sine $\alpha$	Cosine $\alpha$	$\Delta x$ (m)	$\Delta y$ (m)	X (m)	Y (m)
1	$77^\circ 29' 19''$	$270^\circ 00' 00''$	79.276	-1.000 000 0	+0.000 000 0	-79.276	-	30 480.10	30 480.10
2	$36^\circ 08' 23''$	$126^\circ 08' 23''$	84.466	+0.807 581 21	-0.589 756 38	+68.214	-49.814	30 400.82	30 480.10
4	$66^\circ 22' 18''$	$12^\circ 30' 41''$	51.027	+0.216 633 7	+0.976 253 0	+11.055	+49.817	30 469.04	30 430.29
1								30 480.09	30 480.10

Table 5. Typical Calculations for Elevations—Sentinel Glacier Survey

Transit at Station 1			H.I. = 1.37 m		Assumed elevation Station 1 = 1524.00 m			
Stn.	Distance (m)	Vertical angle from stn. 1	Diff. of elev. (m)	Ref.* (m)	Total diff. of elev. (m)	Ht. of target (m)	Mean diff. of elev. § (m)	Elev. (Z) (m)
4	51.030	$-5^\circ 14' 22''$	-4.679	-	-4.694	1.006†	-4.323	1519.677
2	79.276	$-9^\circ 30' 11''$	-13.271	-	-13.259	on plug	-11.887	1512.118
5	448.780	$+2^\circ 57' 02''$	+23.131	-	+23.134	on plug	+24.506	1548.511
8	656.925	$+7^\circ 14' 30''$	+83.476	+0.030	+83.515	1.219‡	+83.668	1607.673

\* In the column marked Ref., corrections are obtained from Tables of Earth's Curvature and Refraction (Breed and Hosmer, 1947)

† Top of tripod

‡ Top of cairn

§ This column takes into consideration the height of instrument as well as the height of the object sighted, for example:

Stn. 8, total difference of elevation = 83.515 m

Correction is H.I. = 1.372 m and ht. of cairn = 1.219 m

Therefore, mean difference in elevation =  $83.515 + 1.372 - 1.219 = 83.668$  m

Table 6. Coordinate Summary Sheet—Sentinel Glacier Survey

Stn.	From base	X Computed (m)	X Final (m)	Y Computed (m)	Y Final (m)	From stn.	Z Computed (m)	Z Final (m)
6	5-7	30 545.70	30 545.63	30 281.07	30 281.27	1	1513.032	1512.819
	1-4	30 545.56		30 281.47		4	1512.849	
						5	1512.666	
						7	1512.758	
8	1-7	30 920.03	30 920.04	29 992.27	29 992.26	1	1607.673	1607.703
	4-7	30 920.05		29 992.25		4	1607.581	
						7	1607.825	
9	1-7	30 777.12	30 777.10	29 473.29	29 473.32	1	1716.182	1716.121
	5-7	30 777.09		29 473.35		5	1715.999	
						7	1716.182	

## ELEVATIONS

The elevation for station 1, as scaled from a topographic map, was assumed to be 1524.00 m above sea level. The elevations for the other stations were calculated by trigonometry using five-place trigonometric tables and the "tangent law for right angle triangles." The mean vertical angle was calculated from the field notes. Typical computations are shown in Table 5.

The computational results for both the horizontal and vertical positions were then compiled and the means calculated in the type of table depicted in Table 6.

## PLOTTING

The plotting of maps was carried out using a Wild A-7 plotter located at the Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

## Volumetric and Height Zone Changes

One means of determining the change in quantity of ice released or added to storage between successive surveys is by computing the volumetric change from maps. Four methods are described in the *Canadian Journal of Earth Sciences* (Brandenberger and Bull, 1966).

Early reports in this series used the Haumann method modified by adding a grid around the glacier and computing the change between successive surveys within the grid. This system seemed to work satisfactorily for computing volumetric changes, but gave slightly lower values for height zone changes. The magnitude of change depended on where the grid was placed around the glacier. If the grid paralleled the glacier's edge, the height zone changes were correct. This case seldom, if ever, happens. Because of the slightly lower values, it was decided to use the Finsterwalder method (Finsterwalder, 1954) for computing the changes in height and the Haumann method for computing the volumetric change (Fig. 8). All the tables have been revised to reflect these changes.

The decrease in height and loss of volume of the zone have been computed from the following formulas (Haumann, 1960):

$$\frac{dh}{F_1 + F_2} = \frac{\Delta F_1 + \Delta F_2}{\Delta h}$$

$$dV = F_m dh$$

$$\overline{dh} = \frac{dh}{n}$$

where  $dh$  = the loss of height during the observation period,  
 $\overline{dh}$  = the loss of height for one year,

$n$  = the number of years,  
 $\Delta h$  = the contour interval,  
 $dV$  = the loss of volume,

$F_1 = A_2 A_3 B_3 B_2$  = the area at the beginning of the period,  
 $F_2 = C_1 C_2 D_2 D_1$  = the area at the end of the period,  
 $\Delta F_1 = A_2 A_3 C_2 C_1$  the contour line displacement at the lower limit of the zone,  
 $\Delta F_2 = B_2 B_3 D_2 D_1$  the contour line displacement at the upper limit of the zone,  
 $F_1' = A_1 A_2 B_2 B_1 + A_3 A_4 B_4 B_3$  the total loss of a zone,  
 $F_1'' = A_1 A_4 B_4 B_1 = F_1 + F_1'$  the total area at the beginning of the period, and  
 $F_m = (F_2 + F_1'')/2$ .

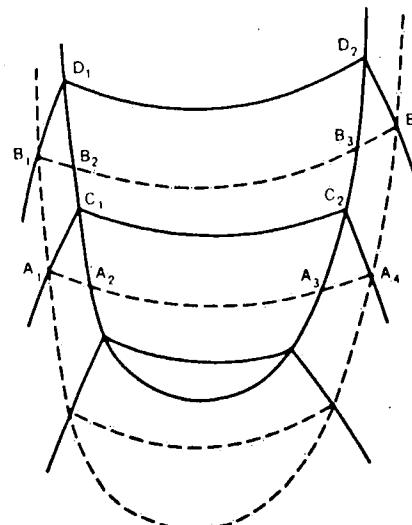


Figure 10. Sketch showing glacier at beginning and end of period (after Haumann, 1960).

### ACKNOWLEDGMENTS

The authors acknowledge the services of E.J. Fast, W. Hurst, and R. Layne, who participated in the field work.

**Table 7. Sentinel Glacier –  
Summary of Changes from 1964 to 1966**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 64 & 66 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
4970–4980	-504 700*	57 350	-8.80*	-4.40*
4980–5000	-1 417 000	56 810	-24.94	-12.47
5000–5020	-1 559 000	62 020	-25.14	-12.57
5020–5040	-1 660 000	63 320	-26.21	-13.10
5040–5060	-1 767 000	69 830	-25.31	-12.65
5060–5080	-1 777 000	84 350	-21.07	-10.53
5080–5100	-1 771 000	80 760	-21.93	-10.96
5100–5120	-1 944 000	91 160	-21.33	-10.66
5120–5140	-1 898 000	91 580	-20.72	-10.36
5140–5160	-1 803 000	95 920	-18.80	-9.40
5160–5180	-1 706 000	92 660	-18.41	-9.20
5180–5200	-1 586 000	90 070	-17.61	-8.80
5200–5220	-1 548 000	89 430	-17.31	-8.65
5220–5240	-1 584 000	88 130	-17.97	-8.98
5240–5260	-1 615 000	92 680	-17.43	-8.71
5260–5280	-1 590 000	96 140	-16.54	-8.27
5280–5300	-1 463 000	98 670	-14.83	-7.42
5300–5320	-1 399 000	99 540	-14.05	-7.03
5320–5340	-1 408 000	106 300	-13.25	-6.63
5340–5360	-1 279 000	106 000	-12.06	-6.03
5360–5380	-1 067 000	100 800	-10.58	-5.29
5380–5400	-932 400	93 900	-9.93	-4.97

\*Estimated.

**Table 8. Sentinel Glacier –  
Summary of Changes from 1966 to 1968**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 66 & 68 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
4990–5000	-391 700*	87 430	-4.48*	-2.24*
5000–5020	-1 125 000	54 960	-20.48	-10.24
5020–5040	-1 239 000	59 700	-20.76	-10.38
5040–5060	-1 352 000	66 300	-20.39	-10.19
5060–5080	-1 441 000	71 500	-20.15	-10.07
5080–5100	-1 532 000	80 980	-18.92	-9.46
5100–5120	-1 573 000	85 760	-18.34	-9.17
5120–5140	-1 489 000	82 520	-18.05	-9.03
5140–5160	-1 366 000	87 500	-15.61	-7.80
5160–5180	-1 283 000	86 750	-14.79	-7.39
5180–5200	-1 324 000	86 750	-15.26	7.63
5200–5220	-1 293 000	85 680	-15.09	-7.55
5220–5240	-1 354 000	87 400	-15.49	-7.74
5240–5260	-1 419 000	89 780	-15.81	-7.91
5260–5280	-1 328 000	92 380	-14.38	-7.19
5280–5300	-1 297 000	95 600	-13.57	-6.78
5300–5320	-1 346 000	101 700	-13.24	-6.62
5320–5340	-1 272 000	99 740	-12.75	-6.37
5340–5360	-1 043 000	94 770	-11.01	-5.50
5360–5380	-832 500	91 080	-9.14	-4.57
5380–5400	-711 400	90 860	-7.83	-3.91

\*Estimated.

**Table 9. Sentinel Glacier –  
Summary of Changes from 1968 to 1970**

Height zone (m)	dV (m <sup>3</sup> )	Mean 68 & 70 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1522–1525	-15 900*	6598	-2.41*	-1.21*
1525–1530	-42 270	3825	-11.05	-5.52
1530–1535	-44 400	4453	-9.97	-4.99
1535–1540	-49 020	4736	-10.35	-5.18
1540–1545	-57 000	5566	-10.24	-5.12
1545–1550	-57 280	5424	-10.56	-5.28
1550–1555	-55 420	5667	-9.78	-4.89
1555–1560	-57 120	5870	-9.73	-4.86
1560–1565	-57 260	5849	-9.79	-4.89
1565–1570	-56 080	5728	-9.79	-4.90
1570–1575	-50 820	5283	-9.62	-4.81
1575–1580	-50 240	5222	-9.62	-4.81
1580–1585	-48 080	5164	-9.31	-4.65
1585–1590	-49 120	5607	-8.76	-4.38
1590–1595	-54 480	6335	-8.60	-4.30
1595–1600	-54 750	6557	-8.35	-4.17
1600–1605	-55 420	6677	-8.30	-4.15
1605–1610	-55 320	6617	-8.36	-4.18
1610–1615	-52 830	6679	-7.91	-3.96
1615–1620	-45 540	6396	-7.12	-3.56
1620–1625	-39 710	6072	-6.54	-3.27
1625–1630	-37 520	6274	-5.98	-2.99
1630–1635	-37 780	6537	-5.78	-2.89
1635–1640	-35 890	6274	-5.72	-2.86
1640–1645	-33 670	6133	-5.49	-2.74
1645–1650	-31 640	6254	-5.06	-2.53

\*Estimated.

**Table 10. Sentinel Glacier –  
Summary of Changes from 1970 to 1972**

Height zone (m)	dV (m <sup>3</sup> )	Mean 70 & 72 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1522–1525	-6 324*	2997	-2.11*	-1.05*
1525–1530	-19 490	2999	-6.50	-3.25
1530–1535	-20 020	3235	-6.19	-3.09
1535–1540	-22 630	3984	-5.68	-2.84
1540–1545	-23 900	4451	-5.37	-2.69
1545–1550	-23 190	4451	-5.21	-2.60
1550–1555	-22 810	4762	-4.79	-2.39
1555–1560	-23 220	5127	-4.53	-2.26
1560–1565	-22 620	4782	-4.73	-2.36
1565–1570	-22 550	4640	-4.86	-2.43
1570–1575	-21 240	4499	-4.72	-2.36
1575–1580	-20 830	4479	-4.64	-2.32
1580–1585	-20 380	4459	-4.57	-2.28
1585–1590	-22 180	4864	-4.56	-2.28
1590–1595	-23 720	5330	-4.45	-2.22
1595–1600	-23 600	5552	-4.25	-2.13
1600–1605	-21 820	5727	-3.81	-1.91
1605–1610	-19 240	5727	-3.36	-1.68
1610–1615	-16 660	5687	-2.93	-1.46
1615–1620	-14 360	5545	-2.59	-1.29
1620–1625	-12 350	5464	-2.26	-1.13
1625–1630	-10 590	5545	-1.91	-0.96
1630–1635	-8 507	5748	-1.48	-0.74
1635–1640	-7 103	5728	-1.24	-0.62
1640–1645	-6 507	5708	-1.14	-0.57
1645–1650	-5 327	5728	-0.93	-0.46
1650–1655	-3 756	5868	-0.64	-0.32

\*Estimated.

**Table 12. Sentinel Glacier –  
Summary of Volumetric Changes in the Period 1964-78**

Period	Total volumetric Change (m <sup>3</sup> )	No. of yr	Vol. change/yr (m <sup>3</sup> )	Surface change/yr (m)
1964-66	-942 400	2	-471 200	-2.66
1966-68	-736 500	2	-368 200	-2.23
1968-70	-1 225 000	2	-612 500	-4.03
1970-72	-465 000	2	-232 500	-1.75
1972-78	- 61 020	6	- 10 170	-0.14

1974 No maps – Glacier snow-covered.

1976 No maps – Glacier snow-covered.

**Table 11. Sentinel Glacier –  
Summary of Changes from 1972 to 1978**

Height zone (m)	dV (m <sup>3</sup> )	Mean 72 & 78 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1570–1575	-29 350*	2917	-10.06*	-1.68*
1575–1580	-33 230	2978	-11.16	-1.86
1580–1585	-30 170	3143	-9.60	-1.60
1585–1590	-26 910	3588	-7.50	-1.25
1590–1595	-24 570	3913	-6.28	-1.05
1595–1600	-19 740	4237	-4.66	-0.78
1600–1605	-14 920	4428	-3.37	-0.56
1605–1610	-7 971	4529	-1.76	-0.29
1610–1615	-955	4549	-0.21	-0.04
1615–1620	+4 773	4589	+1.04	+0.17
1620–1625	+9 256	4771	+1.94	+0.32
1625–1630	+13 120	4771	+2.75	+0.46
1630–1635	+16 520	4932	+3.35	+0.56
1635–1640	+18 940	5175	+3.66	+0.61
1640–1645	+20 600	5255	+3.92	+0.65
1645–1650	+21 610	5296	+4.08	+0.68
1650–1655	+21 980	5496	+4.00	+0.67

\*Estimated.

**Table 13. Sphinx Glacier –  
Summary of Changes from 1964 to 1966**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 64 & 66 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
4890–4900	-28 870*	2 887	-10.00*	-5.00*
4900–4950	-428 900	16 540	-25.93	-12.97
4950–5000	-445 800	42 220	-10.56	-5.28
5000–5050	-478 300	61 320	-7.80	-3.90
5050–5100	-567 700	92 910	-6.11	-3.05
5100–5150	-775 500	112 100	-6.92	-3.46
5150–5200	-1 037 000	144 800	-7.16	-3.58
5200–5250	-1 375 000	189 100	-7.27	-3.63
5250–5300	-1 307 000	259 900	-5.03	-2.52
5300–5350	-1 109 000	319 500	-3.47	-1.74
5350–5400	-941 900	413 100	-2.28	-1.14
5400–5450	-158 500	528 400	-0.30	-0.15
5450–5500	+776 200	680 900	+1.14	+0.57

\*Estimated.

**Table 14. Sphinx Glacier –  
Summary of Changes from 1966 to 1968**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 66 & 68 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
4890–4900	+2 890*	289	+10.00*	+5.00*
4900–4925	+24 760	2 312	+10.71	+5.36
4925–4950	+98 500	8 671	+11.36	+5.68
4950–4975	+229 200	17 630	+13.00	+6.50
4975–5000	+389 700	19 650	+19.83	+9.91
5000–5025	+549 200	26 300	+20.88	+10.44
5025–5050	+650 100	33 530	+19.39	+9.70
5050–5075	+720 500	43 060	+16.73	+8.36
5075–5100	+753 000	50 000	+15.06	+7.53
5100–5125	+787 300	57 800	+13.62	+6.81
5125–5150	+769 600	56 920	+13.52	+6.76
5150–5175	+867 400	66 520	+13.04	+6.52
5175–5200	+1 002 000	74 900	+13.38	+6.69
5200–5225	+1 185 000	88 210	+13.43	+6.71
5225–5250	+1 379 000	99 480	+13.86	+6.93
5250–5275	+1 602 000	113 900	+14.06	+7.03
5275–5300	+1 835 000	131 600	+13.95	+6.97
5300–5325	+2 070 000	147 200	+14.06	+7.03
5325–5350	+2 362 000	166 000	+14.23	+7.12
5350–5375	+2 988 000	190 700	+15.67	+7.83
5375–5400	+3 415 000	218 500	+15.63	+7.81
5400–5425	+3 637 000	243 900	+14.91	+7.45
5425–5450	+3 889 000	270 400	+14.38	+7.19
5450–5475	+4 137 000	317 700	+13.02	+6.51
5475–5500	+4 498 000	340 300	+13.22	+6.61
5500–5525	+4 319 000	384 200	+11.24	+5.62

\*Estimated.

**Table 15. Sphinx Glacier –  
Summary of Changes from 1968 to 1970**

Height zone (m)	dV (m <sup>3</sup> )	Mean 68 & 70 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1495–1500	-670*	134	-5.00*	-2.50*
1500–1510	-3 101	859	-3.61	-1.81
1510–1520	-3 998	2 040	-1.96	-0.98
1520–1530	-5 234	2 630	-1.99	-1.00
1530–1540	-9 089	4 267	-2.13	-1.06
1540–1550	-13 710	5 690	-2.41	-1.21
1550–1560	-13 670	6 388	-2.14	-1.07
1560–1570	-13 030	6 387	-2.04	-1.02
1570–1580	-12 390	7 944	-1.56	-0.78
1580–1590	-12 960	9 527	-1.36	-0.68
1590–1600	-10 890	11 460	-0.95	-0.47
1600–1610	-1 353	13 530	-0.10	-0.05
1610–1620	+1 653	16 530	+0.10	+0.05
1620–1630	-961	19 220	-0.05	-0.02
1630–1640	-1 407	23 460	-0.06	-0.03
1640–1650	+549	27 430	+0.02	+0.01
1650–1660	+13 440	31 260	+0.43	+0.21
1660–1670	+29 190	36 950	+0.79	+0.39
1670–1680	+36 340	43 260	+0.84	+0.42
1680–1690	+26 850	49 730	+0.54	+0.27
1690–1700	+14 010	51 870	+0.27	+0.14

\*Estimated.

**Table 16. Sphinx Glacier –  
Summary of Changes from 1970 to 1972**

Height zone (m)	dV (m <sup>3</sup> )	Mean 70 & 72 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1495–1500	+1 338*	268*	+5.00*	+2.50*
1500–1510	+6 587	1 204	+5.47	+2.74
1510–1520	+6 447	2 278	+2.83	+1.41
1520–1530	+6 740	2 808	+2.40	+1.20
1530–1540	+8 914	4 391	+2.03	+1.02
1540–1550	+9 823	5 917	+1.66	+0.83
1550–1560	+11 260	6 399	+1.76	+0.88
1560–1570	+10 930	6 747	+1.62	+0.81
1570–1580	+12 440	7 977	+1.56	+0.78
1580–1590	+19 140	9 429	+2.03	+1.02
1590–1600	+24 920	11 380	+2.19	+1.10
1600–1610	+25 350	13 630	+1.86	+0.93
1610–1620	+29 880	16 600	+1.80	+0.90
1620–1630	+36 990	19 570	+1.89	+0.94
1630–1640	+49 620	23 300	+2.13	+1.06
1640–1650	+67 660	26 430	+2.56	+1.28
1650–1660	+88 830	29 030	+3.06	+1.53
1660–1670	+108 820	35 560	+3.06	+1.53
1670–1680	+112 300	43 860	+2.56	+1.28
1680–1690	+109 000	50 690	+2.15	+1.08
1690–1700	+89 790	54 090	+1.66	+0.83

\*Estimated.

**Table 17. Sphinx Glacier –  
Summary of Changes from 1972 to 1978**

Height zone (m)	dV (m <sup>3</sup> )	Mean 72 & 78 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1510–1520	+27 610*	3 950	+6.99*	+1.16*
1520–1530	+71 980	4 185	+17.20	+2.87
1530–1540	+84 790	5 394	+15.72	+2.62
1540–1550	+95 760	6 627	+14.45	+2.41
1550–1560	+109 400	7 190	+15.22	+2.54
1560–1570	+98 180	7 529	+13.04	+2.17
1570–1580	+111 000	8 678	+12.79	+2.13
1580–1590	+106 600	9 728	+11.81	+1.97
1590–1600	+134 600	11 200	+12.02	+2.00
1600–1610	+159 300	13 900	+11.46	+1.91
1610–1620	+184 100	16 470	+11.18	+1.86
1620–1630	+210 700	19 930	+10.57	+1.76
1630–1640	+241 300	22 660	+10.65	+1.78
1640–1650	+279 200	24 510	+11.39	+1.90
1650–1660	+276 100	25 120	+10.99	+1.83
1660–1670	+351 800	31 780	+11.07	+1.84
1670–1680	+443 100	39 420	+11.24	+1.87
1680–1690	+535 200	48 350	+11.07	+1.84
1690–1700	+545 300	57 760	+9.44	+1.57

\*Estimated.

**Table 18. Sphinx Glacier –  
Summary of Volumetric Changes in the Period 1964-78**

Period	Total volumetric change (m <sup>3</sup> )	No. of yr	Vol. change/yr (m <sup>3</sup> )	Surface change/yr (m)
1964-66	-222 900	2	-111 500	-0.42
1966-68	+1 250 000	2	+624 900	+2.12
1968-70	+19 570	2	+9 784	+0.03
1970-72	+836 800	2	+418 400	+1.13
1972-78	+4 066 000	6	+2 033 000	+1.86

1974 No maps — Glacier snow-covered.

1976 No maps — Glacier snow-covered.

No computations available.

**Table 19. Nadahini Glacier –  
Summary of Changes from 1964 to 1966**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 64 & 66 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
3890–3900	-603 800*	70 290	-8.59*	-4.30*
3900–3920	-2 266 000	61 800	-36.66	-18.33
3920–3940	-2 605 000	80 090	-32.53	-16.26
3940–3960	-2 939 000	89 220	-32.94	-16.47
3960–3980	-3 132 000	101 900	-30.74	-15.37
3980–4000	-3 517 000	108 600	-32.38	-16.19
4000–4020	-3 796 000	132 300	-28.69	-14.35
4020–4040	-4 230 000	145 100	-29.16	-14.58
4040–4060	-4 522 000	161 000	-28.09	-14.04
4060–4080	-4 296 000	183 100	-23.46	-11.73
4080–4100	-4 464 000	184 200	-24.23	-12.11
4100–4120	-4 953 000	218 100	-22.71	-11.36
4120–4140	-5 906 000	250 100	-23.62	-11.81

\*Estimated.

**Table 20. Nadahini Glacier –  
Summary of Changes from 1966 to 1968**

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 66 & 68 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
3890–3900	-741 400*	74 140	-10.00*	-5.00*
3900–3920	-2 433 000	64 660	-37.63	-18.81
3920–3940	-2 741 000	78 450	-34.94	-17.47
3940–3960	-3 250 000	88 790	-36.60	-18.30
3960–3980	-3 521 000	96 550	-36.47	-18.24
3980–4000	-3 838 000	104 300	-36.79	-18.39
4000–4020	-4 348 000	123 300	-35.27	-17.63
4020–4040	-4 889 000	135 300	-36.12	-18.06
4040–4060	-4 965 000	145 700	-34.08	-17.04
4060–4080	-5 733 000	170 700	-33.59	-16.79
4080–4100	-6 206 000	193 100	-32.14	-16.07
4100–4120	-8 377 000	262 600	-31.90	-15.95
4120–4140	-9 352 000	289 300	-32.33	-16.17
4140–4160	-9 304 000	320 400	-29.04	-14.52
4160–4180	-11 450 000	406 800	-28.15	-14.08
4180–4200	-14 140 000	450 700	-31.37	-15.68
4200–4220	-15 440 000	442 900	-34.86	-17.43
4220–4240	-14 360 000	444 600	-32.30	-16.15
4240–4260	-13 100 000	403 100	-32.49	-16.25
4260–4280	-12 400 000	374 600	-33.10	-16.55
4280–4300	-13 710 000	427 300	-32.08	-16.04
4300–4320	-16 270 000	463 700	-35.09	-17.55
4320–4340	-15 640 000	406 600	-38.46	-19.23
4340–4360	-13 320 000	385 000	-34.60	-17.30
4360–4380	-11 330 000	341 900	-33.14	-16.57
4380–4400	-10 630 000	306 600	-34.69	-17.35

\*Estimated.

Table 21. Nadahini Glacier –  
Summary of Changes from 1968 to 1970

Height zone (m)	dV (m <sup>3</sup> )	Mean 68 & 70 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1185–1190	-26 180*	6 747	-3.88*	-1.94*
1190–1200	-79 450	10 360	-7.67	-3.83
1200–1210	-93 660	12 610	-7.43	-3.71
1210–1220	-100 560	16 300	-6.17	-3.09
1220–1230	-93 370	17 580	-5.31	-2.65
1230–1240	-115 100	20 630	-5.58	-2.79
1240–1250	-186 700	34 190	-5.46	-2.73
1250–1260	-211 200	43 200	-4.89	-2.44
1260–1270	-257 300	54 750	-4.70	-2.35
1270–1280	-326 100	77 280	-4.22	-2.11
1280–1290	-335 100	60 810	-5.51	-2.75
1290–1300	-290 300	52 590	-5.52	-2.76
1300–1310	-315 000	72 650	-4.34	-2.17
1310–1320	-292 200	58 800	-4.97	-2.48
1320–1330	-200 100	44 860	-4.46	-2.23
1330–1340	-205 000	46 070	-4.45	-2.23
1340–1350	-193 800	43 250	-4.48	-2.24
1350–1360	-168 100	40 510	-4.15	-2.08
1360–1370	-145 100	33 750	-4.30	-2.15
1370–1380	-127 700	30 120	-4.24	-2.12
1380–1390	-104 100	29 400	-3.54	-1.77
1390–1400	-93 640	27 140	-3.45	-1.73

\*Estimated.

Table 22. Nadahini Glacier –  
Summary of Changes from 1970 to 1972

Height zone (m)	dV (m <sup>3</sup> )	Mean 70 & 72 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1185–1190	-18 440*	3 689	-5.00*	-2.50*
1190–1200	-66 390	7 941	-8.36	-4.18
1200–1210	-85 720	11 710	-7.32	-3.66
1210–1220	-111 000	16 450	-6.75	-3.38
1220–1230	-127 800	16 770	-7.62	-3.81
1230–1240	-184 500	24 800	-7.44	-3.72
1240–1250	-235 500	37 500	-6.28	-3.14
1250–1260	-264 500	41 080	-6.44	-3.22
1260–1270	-376 600	62 670	-6.01	-3.00
1270–1280	-384 400	69 390	-5.54	-2.77
1280–1290	-271 100	55 100	-4.92	-2.46
1290–1300	-249 500	52 520	-4.75	-2.37
1300–1310	-227 100	72 320	-3.14	-1.57
1310–1320	-149 700	45 370	-3.30	-1.65
1320–1330	-118 700	42 230	-2.81	-1.40
1330–1340	-84 670	43 200	-1.96	-0.98
1340–1350	-58 260	39 100	-1.49	-0.75
1350–1360	-30 240	35 160	-0.86	-0.43
1360–1370	-13 380	30 410	-0.44	-0.22
1370–1380	-47 720	27 270	-1.75	-0.87
1380–1390	-77 960	25 900	-3.01	-1.50
1390–1400	-103 700	25 980	-3.99	-2.00

\*Estimated.

Table 23. Nadahini Glacier –  
Summary of Changes from 1972 to 1974

Height zone (m)	dV (m <sup>3</sup> )	Mean 72 & 74 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1195–1200	-6 500*	1 924	-3.38*	-1.69*
1200–1210	-54 860	6 731	-8.15	-4.08
1210–1220	-91 930	12 340	-7.45	-3.72
1220–1230	-117 900	15 570	-7.57	-3.78
1230–1240	-122 200	17 890	-6.83	-3.42
1240–1250	-180 900	26 480	-6.83	-3.42
1250–1260	-229 300	33 380	-6.87	-3.43
1260–1270	-253 400	45 570	-5.56	-2.78
1270–1280	-427 900	68 680	-6.23	-3.11
1280–1290	-305 400	54 240	-5.63	-2.82
1290–1300	-216 600	49 340	-4.39	-2.19
1300–1310	-101 200	51 650	-1.96	-0.98
1310–1320	+20 360	55 030	+0.37	+0.18
1320–1330	+60 040	38 000	+1.58	+0.79
1330–1340	+87 680	37 310	+2.35	+1.17
1340–1350	+120 000	36 590	+3.28	+1.64
1350–1360	+172 700	34 670	+4.98	+2.49
1360–1370	+203 100	30 000	+6.77	+3.38
1370–1380	+203 700	26 700	+7.63	+3.81
1380–1390	+234 700	25 260	+9.29	+4.64
1390–1400	+216 700	23 250	+9.32	+4.66
1400–1410	+194 100	24 050	+8.07	+4.03

\*Estimated.

Table 24. Nadahini Glacier –  
Summary of Changes from 1974 to 1976

Height zone (m)	dV (m <sup>3</sup> )	Mean 74 & 76 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1195–1200	-17 810*	5 600	-3.18*	-1.59*
1200–1210	-74 580	10 330	-7.22	-3.61
1210–1220	-85 660	13 640	-6.28	-3.14
1220–1230	-129 900	20 810	-6.24	-3.12
1230–1240	-158 400	24 980	-6.34	-3.17
1240–1250	-195 800	31 330	-6.25	-3.13
1250–1260	-347 200	55 200	-6.29	-3.15
1260–1270	-367 500	58 620	-6.27	-3.13
1270–1280	-286 200	48 760	-5.87	-2.93
1280–1290	-303 400	46 610	-6.51	-3.25
1290–1300	-259 100	53 420	-4.85	-2.42
1300–1310	-251 000	38 320	-6.55	-3.28
1310–1320	-201 000	32 050	-6.27	-3.14
1320–1330	-179 300	31 850	-5.63	-2.82
1330–1340	-150 500	30 410	-4.95	-2.48
1340–1350	-116 100	30 090	-3.86	-1.93
1350–1360	-96 520	26 300	-3.67	-1.84
1360–1370	-90 880	24 900	-3.65	-1.83
1370–1380	-90 250	23 940	-3.77	-1.88
1380–1390	-85 440	22 250	-3.84	-1.92
1390–1400	-88 340	23 620	-3.74	-1.87
1400–1410	-84 800	28 080	-3.02	-1.51

\*Estimated.

Table 25. Nadahini Glacier –  
Summary of Changes from 1976 to 1978

Height zone (m)	dV (m <sup>3</sup> )	Mean 76 & 78 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1200–1210	-51 150	9 990	-5.12*	-2.56*
1210–1220	-139 900	15 390	-9.09	-4.54
1220–1230	-194 900	22 770	-8.56	-4.28
1230–1240	-222 000	25 200	-8.81	-4.41
1240–1250	-307 600	36 270	-8.48	-4.24
1250–1260	-402 500	60 890	-6.61	-3.30
1260–1270	-416 900	47 050	-8.86	-4.43
1270–1280	-389 300	45 270	-8.60	-4.30
1280–1290	-404 700	49 050	-8.25	-4.12
1290–1300	-365 700	45 830	-7.98	-3.99
1300–1310	-208 900	29 420	-7.10	-3.55
1310–1320	-166 900	27 860	-5.99	-2.99
1320–1330	-124 100	26 410	-4.70	-2.35
1330–1340	-86 790	26 300	-3.30	-1.65
1340–1350	-67 230	25 660	-2.62	-1.31
1350–1360	-49 300	24 050	-2.05	-1.02
1360–1370	-33 880	23 530	-1.44	-0.72
1370–1380	-20 090	22 570	-0.89	-0.44
1380–1390	-15 020	21 770	-0.69	-0.34
1390–1400	-16 170	23 780	-0.68	-0.34
1400–1410	-14 080	27 070	-0.52	-0.26

Table 27. Kokanee Glacier –  
Summary of Changes from 1964 to 1966

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 64 & 66 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
7280–7300	-217 500*	34 030	-6.39*	-3.20*
7300–7320	-208 400	29 030	-7.18	-3.59
7320–7340	-230 600	34 010	-6.78	-3.39
7340–7360	-209 000	34 660	-6.03	-3.01
7360–7380	-191 500	29 460	-6.50	-3.25
7380–7400	-200 200	32 930	-6.08	-3.04
7400–7420	-192 700	36 020	-5.35	-2.69
7420–7440	-186 800	39 500	-4.73	-2.36
7440–7460	-198 300	46 880	-4.23	-2.12
7460–7480	-184 300	52 520	-3.51	-1.76
7480–7500	-171 300	61 630	-2.78	-1.39
7500–7520	-249 300	75 310	-3.31	-1.66
7520–7540	-502 600	92 900	-5.41	-2.71
7540–7560	-749 400	116 500	-6.43	-3.21
7560–7580	-897 500	167 800	-5.35	-2.68
7580–7600	-853 400	195 700	-4.36	-2.18
7600–7620	-679 600	174 300	-3.90	-1.95
7620–7640	-562 700	224 200	-2.51	-1.26
7640–7660	-352 500	203 800	-1.73	-0.87
7660–7680	-180 000	181 900	-0.99	-0.49
7680–7700	-121 400	161 900	-0.75	-0.38

\*Estimated.

Table 26. Nadahini Glacier –  
Summary of Volumetric Changes in the period 1964-78

Period	Total volumetric change (m <sup>3</sup> )	No. of yr	Vol. change/yr (m <sup>3</sup> )	Surface change/yr (m)
1964-66	-1 337 000	2	-668 700	-4.03
1966-68	-6 550 000	2	-3 280 000	-5.04
1968-70	-3 960 000	2	-1 980 000	-2.38
1970-72	-3 287 000	2	-1 644 000	-2.09
1972-74	-595 000	2	-297 500	-0.42
1974-76	-3 660 000	2	-1 830 000	-2.69
1976-78	-3 697 000	2	-1 848 000	-2.91

Table 28. Kokanee Glacier –  
Summary of Changes from 1966 to 1968

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 66 & 68 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
7280–7300	-327 100*	20 820	-15.71	-7.86
7300–7320	-629 800	21 010	-29.97	-14.99
7320–7340	-476 200	31 410	-15.16	-7.58
7340–7360	-436 900	30 110	-14.51	-7.26
7360–7380	-440 800	30 980	-14.23	-7.11
7380–7400	-488 100	32 500	-15.02	-7.51
7400–7420	-491 100	34 540	-14.22	-7.11
7420–7440	-560 600	38 660	-14.50	-7.25
7440–7460	-630 600	45 830	-13.76	-6.88
7460–7480	-703 100	54 080	-13.00	-6.50
7480–7500	-867 800	66 240	-13.10	-6.55
7500–7520	-1 059 000	82 530	-12.83	-6.41
7520–7540	-1 186 000	100 600	-11.79	-5.89
7540–7560	-1 427 000	126 800	-11.25	-5.63
7560–7580	-1 617 000	169 000	-9.57	-4.78
7580–7600	-1 579 000	185 900	-8.49	-4.24
7600–7620	-1 789 000	181 800	-9.84	-4.92
7620–7640	-2 303 000	232 600	-9.90	-4.95
7640–7660	-2 172 000	174 000	-12.48	-6.24
7660–7680	-1 541 000	168 800	-9.13	-4.56
7680–7700	-470 300	148 400	-3.17	-1.59

\*Estimated.

**Table 29. Kokanee Glacier –  
Summary of Changes from 1968 to 1970**

Height zone (m)	dV (m <sup>3</sup> )	Mean 68 & 70 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
2220–2225	-4 351*	1 700	-2.56*	-1.28*
2225–2230	-7 585	1 174	-6.46	-3.23
2230–2235	-10 410	1 620	-6.43	-3.22
2235–2240	-11 160	2 004	-5.57	-2.79
2240–2245	-11 650	2 085	-5.59	-2.80
2245–2250	-13 260	2 429	-5.46	-2.73
2250–2255	-13 860	2 489	-5.57	-2.78
2255–2260	-13 340	2 550	-5.23	-2.62
2260–2265	-14 430	2 975	-4.85	-2.43
2265–2270	-15 790	3 441	-4.59	-2.29
2270–2275	-19 810	4 393	-4.51	-2.26
2275–2280	-25 290	5 162	-4.90	-2.45
2280–2285	-34 830	6 378	-5.46	-2.73
2285–2290	-51 880	9 415	-5.51	-2.76
2290–2295	-80 720	15 890	-5.08	-2.54
2295–2300	-92 250	18 830	-4.90	-2.45
2300–2305	-101 700	19 290	-5.27	-2.64
2305–2310	-105 100	18 900	-5.56	-2.78
2310–2315	-93 240	19 260	-4.84	-2.42
2315–2320	-89 570	17 220	-5.20	-2.60
2320–2325	-89 400	19 270	-4.64	-2.32
2325–2330	-78 730	18 660	-4.22	-2.11
2330–2335	-70 890	15 790	-4.49	-2.24
2335–2340	-63 190	15 160	-4.17	-2.08
2340–2345	-48 910	13 700	-3.57	-1.79
2345–2350	-44 300	13 840	-3.20	-1.60

\*Estimated.

**Table 30. Kokanee Glacier –  
Summary of Changes from 1970 to 1972**

Height zone (m)	dV (m <sup>3</sup> )	Mean 70 & 72 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
2220–2225	-2 371*	1 581	-1.50*	-0.75*
2225–2230	-5 222	1 277	-4.09	-2.04
2230–2235	-5 633	1 723	-3.27	-1.63
2235–2240	-5 468	1 925	-2.84	-1.42
2240–2245	-6 383	2 128	-3.00	-1.50
2245–2250	-7 295	2 331	-3.13	-1.56
2250–2255	-6 852	2 168	-3.16	-1.58
2255–2260	-7 137	2 371	-3.01	-1.51
2260–2265	-7 846	2 939	-2.67	-1.34
2265–2270	-9 076	3 425	-2.65	-1.33
2270–2275	-16 410	4 661	-3.52	-1.76
2275–2280	-15 140	6 585	-2.30	-1.15
2280–2285	-28 680	9 077	-3.16	-1.58
2285–2290	-51 160	13 530	-3.78	-1.89
2290–2295	-61 970	15 770	-3.93	-1.97
2295–2300	-57 980	19 460	-2.98	-1.49
2300–2305	-50 890	18 850	-2.70	-1.35
2305–2310	-36 220	15 750	-2.30	-1.15
2310–2315	-26 100	17 630	-1.48	-0.74
2315–2320	-29 790	18 500	-1.61	-0.80
2320–2325	-33 310	18 300	-1.82	-0.91
2325–2330	-36 370	17 570	-2.07	-1.04
2330–2335	-33 230	14 510	-2.29	-1.15
2335–2340	-24 800	12 850	-1.93	-0.97
2340–2345	-24 050	12 730	-1.89	-0.94
2345–2350	-20 340	12 870	-1.58	-0.79

\*Estimated.

**Table 31. Kokanee Glacier –  
Summary of Volumetric Changes in the Period 1964-72**

Period	Total volumetric change (m <sup>3</sup> )	No. of yr	Vol. change/yr (m <sup>3</sup> )	Surface change/yr (m)
1964-66	-207 800	2	-103 900	-0.55
1966-68	-600 100	2	-300 100	-1.63
1968-70	-1 206 000	2	-602 800	-2.38
1970-72	-609 700	2	-304 900	-1.22

1974 No maps – Glacier snow-covered.

1976 No maps – Glacier snow-covered.

1978 Map produced – Glacier snow covered –  
No computations available.

Table 32. Bugaboo Glacier –  
Summary of Changes from 1964 to 1966

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 64 & 66 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
6450–6500	+1 024 000*	31 340	+32.67*	+16.33*
6500–6550	+1 365 000	28 030	+48.70	+24.35
6550–6600	+1 658 000	40 300	+41.13	+20.57
6600–6650	+1 799 000	51 030	+35.36	+17.68
6650–6700	+1 890 000	66 130	+28.58	+14.29
6700–6750	+1 977 000	72 280	+27.35	+13.68
6750–6800	+1 478 000	71 770	+20.59	+10.30
6800–6850	+1 127 000	67 780	+16.62	+8.31
6850–6900	+1 428 000	80 250	+17.80	+8.90
6900–6950	+1 507 000	96 660	+15.59	+7.80
6950–7000	+1 478 000	113 600	+13.01	+6.51
7000–7050	+1 406 000	127 400	+11.04	+5.52
7050–7100	+1 472 000	143 300	+10.27	+5.13
7100–7150	+1 294 000	141 900	+9.12	+4.56
7150–7200	+1 069 000	129 100	+8.28	+4.14
7200–7250	+1 174 000	155 900	+7.53	+3.77
7250–7300	+1 101 000	157 400	+7.00	+3.50
7300–7350	+1 145 000	173 800	+6.59	+3.30

\*Estimated.

Table 33. Bugaboo Glacier –  
Summary of Changes from 1966 to 1968

Height zone (ft)	dV (ft <sup>3</sup> )	Mean 66 & 68 areas (ft <sup>2</sup> )	Surface change (ft)	Surface change (ft/yr)
6450–6500	+867 200*	58 400	+14.85*	+7.42*
6500–6550	+1 228 000	32 300	+38.01	+19.00
6550–6600	+1 477 000	46 950	+31.46	+15.73
6600–6650	+1 595 000	56 340	+28.31	+14.15
6650–6700	+1 714 300	70 750	+24.23	+12.12
6700–6750	+1 760 500	82 270	+21.40	+10.70
6750–6800	+1 601 000	91 630	+17.47	+8.74
6800–6850	+1 192 000	76 560	+15.57	+7.79
6850–6900	+1 166 000	82 710	+14.10	+7.05
6900–6950	+1 453 000	101 700	+14.29	+7.15
6950–7000	+1 843 000	116 200	+15.86	+7.93
7000–7050	+2 274 000	139 500	+16.30	+8.15
7050–7100	+2 400 000	155 700	+15.42	+7.71
7100–7150	+2 070 000	164 200	+12.61	+6.30
7150–7200	+1 976 000	141 100	+14.01	+7.01
7200–7250	+1 796 000	178 000	+10.09	+5.04
7250–7300	+1 656 000	167 100	+9.91	+4.96
7300–7350	+1 860 000	180 000	+10.33	+5.16

\*Estimated.

Table 34. Bugaboo Glacier –  
Summary of Changes from 1968 to 1970

Height zone (m)	dV (m <sup>3</sup> )	Mean 68 & 70 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1940–1950	+12 430*	2 293	+5.42*	+2.71*
1950–1960	+13 710	1 368	+10.02	+5.01
1960–1970	+10 750	1 813	+5.93	+2.97
1970–1980	+9 957	2 040	+4.88	+2.44
1980–1990	+9 119	2 291	+3.98	+1.99
1990–2000	+9 073	2 452	+3.70	+1.85
2000–2010	+10 800	3 396	+3.18	+1.59
2010–2020	+9 890	3 678	+2.69	+1.35
2020–2030	+12 240	4 121	+2.97	+1.49
2030–2040	+13 580	4 381	+3.10	+1.55
2040–2050	+15 730	4 824	+3.26	+1.63
2050–2060	+14 930	6 069	+2.46	+1.23
2060–2070	+12 750	6 190	+2.06	+1.03
2070–2080	+12 490	5 527	+2.26	+1.13
2080–2090	+11 370	4 945	+2.30	+1.15
2090–2100	+15 390	4 750	+3.24	+1.62
2100–2110	+19 740	5 877	+3.36	+1.68
2110–2120	+19 460	6 319	+3.08	+1.54
2120–2130	+24 440	7 085	+3.45	+1.73
2130–2140	+30 050	7 929	+3.79	+1.89
2140–2150	+30 040	9 076	+3.31	+1.65
2150–2160	+34 120	9 862	+3.46	+1.73
2160–2170	+40 410	10 610	+3.81	+1.90
2170–2180	+44 200	9 821	+4.50	+2.25
2180–2190	+36 310	9 920	+3.66	+1.83
2190–2200	+31 550	9 560	+3.30	+1.65
2200–2210	+40 890	10 540	+3.88	+1.94
2210–2220	+47 540	9 490	+5.01	+2.51
2220–2230	+47 620	10 680	+4.46	+2.23
2230–2240	+52 240	11 510	+4.54	+2.27
2240–2250	+51 070	12 040	+4.24	+2.12
2250–2260	+49 290	13 920	+3.54	+1.77
2260–2270	+50 340	15 630	+3.22	+1.61

\*Estimated.

**Table 35. Bugaboo Glacier –  
Summary of Changes from 1970 to 1972**

Height zone (m)	dV (m <sup>3</sup> )	Mean 70 & 72 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1925–1930	+821*	543	+1.51*	+0.75*
1930–1940	+6 170	906	+6.81	+3.41
1940–1950	+8 320	1 491	+5.58	+2.79
1950–1960	+5 907	1 893	+3.12	+1.56
1960–1970	+6 644	1 915	+3.47	+1.73
1970–1980	+7 550	2 405	+3.14	+1.57
1980–1990	+6 616	2 555	+2.59	+1.29
1990–2000	+4 961	2 756	+1.80	+0.90
2000–2010	+8 841	3 579	+2.47	+1.24
2010–2020	+16 180	3 781	+4.28	+2.14
2020–2030	+16 900	4 204	+4.02	+2.01
2030–2040	+15 770	4 586	+3.44	+1.72
2040–2050	+15 200	4 886	+3.11	+1.55
2050–2060	+17 160	6 576	+2.61	+1.30
2060–2070	+20 440	6 214	+3.29	+1.65
2070–2080	+21 320	5 731	+3.72	+1.86
2080–2090	+21 530	5 008	+4.30	+2.15
2090–2100	+18 690	4 793	+3.90	+1.95
2100–2110	+19 270	5 617	+3.43	+1.71
2110–2120	+26 930	6 234	+4.32	+2.16
2120–2130	+29 900	6 858	+4.36	+2.18
2130–2140	+31 690	7 883	+4.02	+2.01
2140–2150	+35 100	9 311	+3.77	+1.89
2150–2160	+34 860	9 552	+3.65	+1.82
2160–2170	+36 890	10 280	+3.59	+1.80
2170–2180	+40 060	9 653	+4.15	+2.08
2180–2190	+51 070	10 010	+5.10	+2.55
2190–2200	+59 410	9 371	+6.34	+3.17
2200–2210	+57 640	10 350	+5.57	+2.79
2210–2220	+54 100	10 000	+5.41	+2.70
2220–2230	+47 510	11 130	+4.27	+2.13
2230–2240	+44 840	11 040	+4.06	+2.03
2240–2250	+43 670	13 000	+3.36	+1.68
2250–2260	+40 770	13 680	+2.98	+1.49
2260–2270	+41 270	15 810	+2.61	+1.31

\*Estimated.

**Table 36. Bugaboo Glacier –  
Summary of Changes from 1972 to 1974**

Height zone (m)	dV (m <sup>3</sup> )	Mean 72 & 74 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1925–1930	+1 088*	465	+2.34*	+1.17*
1930–1940	+4 905	1 274	+3.85	+1.93
1940–1950	+9 713	1 819	+5.34	+2.67
1950–1960	+15 750	1 999	+7.88	+3.94
1960–1970	+18 240	1 978	+9.22	+4.61
1970–1980	+19 550	2 523	+7.75	+3.87
1980–1990	+21 130	2 806	+7.53	+3.77
1990–2000	+21 270	3 109	+6.84	+3.42
2000–2010	+21 990	3 169	+6.94	+3.47
2010–2020	+21 660	3 946	+5.49	+2.75
2020–2030	+20 380	4 450	+4.58	+2.29
2030–2040	+19 860	4 718	+4.21	+2.11
2040–2050	+21 010	4 968	+4.23	+2.12
2050–2060	+28 920	6 205	+4.66	+2.33
2060–2070	+35 640	6 145	+5.80	+2.90
2070–2080	+38 240	5 812	+6.58	+3.29
2080–2090	+38 680	5 109	+7.57	+3.79
2090–2100	+38 100	4 955	+7.69	+3.84
2100–2110	+44 110	5 804	+7.60	+3.80
2110–2120	+47 180	6 266	+7.53	+3.76
2120–2130	+46 880	6 668	+7.03	+3.51
2130–2140	+52 970	8 074	+6.56	+3.28
2140–2150	+53 420	9 439	+5.66	+2.83
2150–2160	+55 620	9 741	+5.71	+2.85
2160–2170	+55 960	10 500	+5.33	+2.67
2170–2180	+52 970	9 773	+5.42	+2.71
2180–2190	+51 860	10 520	+4.93	+2.47
2190–2200	+41 510	9 371	+4.43	+2.21
2200–2210	+47 100	9 793	+4.81	+2.40
2210–2220	+53 910	9 593	+5.62	+2.81
2220–2230	+66 590	10 520	+6.33	+3.16
2230–2240	+76 360	10 740	+7.11	+3.56
2240–2250	+86 870	12 270	+7.08	+3.54
2250–2260	+101 300	13 010	+7.79	+3.89
2260–2270	+120 100	15 140	+7.93	+3.97

\*Estimated.

**Table 37. Bugaboo Glacier –  
Summary of Changes from 1974 to 1976**

Height zone (m)	dV (m <sup>3</sup> )	Mean 74 & 76 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m/yr)
1950–1960	+48 190*	5 610	+8.59*	+4.29*
1960–1970	+64 930	2 822	+23.01	+11.51
1970–1980	+57 170	2 923	+19.56	+9.78
1980–1990	+55 510	3 306	+16.79	+8.39
1990–2000	+52 140	3 467	+15.04	+7.52
2000–2010	+48 070	3 870	+12.42	+6.21
2010–2020	+38 200	4 586	+8.33	+4.16
2020–2030	+32 730	5 028	+6.51	+3.26
2030–2040	+26 120	5 396	+4.84	+2.42
2040–2050	+24 140	5 202	+4.64	+2.32
2050–2060	+27 330	5 839	+4.68	+2.34
2060–2070	+31 850	6 101	+5.22	+2.61
2070–2080	+34 350	6 189	+5.55	+2.77
2080–2090	+30 390	5 745	+5.29	+2.64
2090–2100	+26 660	5 846	+4.56	+2.28
2100–2110	+25 030	6 134	+4.08	+2.04
2110–2120	+24 740	6 033	+4.10	+2.05
2120–2130	+23 470	7 381	+3.18	+1.59
2130–2140	+23 800	7 933	+3.00	+1.50
2140–2150	+34 490	9 221	+3.74	+1.87
2150–2160	+41 620	10 030	+4.15	+2.08
2160–2170	+43 510	10 690	+4.07	+2.03
2170–2180	+39 280	10 790	+3.64	+1.82
2180–2190	+36 120	10 260	+3.52	+1.76
2190–2200	+37 550	9 960	+3.77	+1.89
2200–2210	+31 090	10 160	+3.06	+1.53
2210–2220	+27 460	9 879	+2.78	+1.39
2220–2230	+25 410	10 630	+2.39	+1.20
2230–2240	+23 900	10 530	+2.27	+1.14
2240–2250	+22 250	12 160	+1.83	+0.91
2250–2260	+12 440	13 230	+0.94	+0.47
2260–2270	+11 080	13 850	+0.80	+0.40

\*Estimated.

**Table 38. Bugaboo Glacier –  
Summary of Changes from 1976 to 1978**

Height zone (m)	dV (m <sup>3</sup> )	Mean 76 & 78 areas (m <sup>2</sup> )	Surface change (m)	Surface change (m)
1930–1940	+12 790*	2 284	+5.60*	+2.80*
1940–1950	+11 980	2 020	+5.93	+2.97
1950–1960	+17 000	2 604	+6.53	+3.27
1960–1970	+26 140	3 537	+7.39	+3.69
1970–1980	+32 090	3 558	+9.02	+4.51
1980–1990	+34 160	3 963	+8.62	+4.31
1990–2000	+35 150	4 145	+8.48	+4.24
2000–2010	+39 050	4 751	+8.22	+4.11
2010–2020	+44 670	5 053	+8.84	+4.42
2020–2030	+53 050	5 538	+9.58	+4.79
2030–2040	+59 770	5 820	+10.27	+5.13
2040–2050	+62 530	5 844	+10.70	+5.35
2050–2060	+50 330	6 876	+7.32	+3.66
2060–2070	+38 110	6 571	+5.80	+2.90
2070–2080	+28 190	7 340	+3.84	+1.92
2080–2090	+20 890	6 469	+3.23	+1.61
2090–2100	+20 170	6 246	+3.23	+1.62
2100–2110	+21 350	6 569	+3.25	+1.62
2110–2120	+21 390	6 327	+3.38	+1.69
2120–2130	+21 940	7 781	+2.82	+1.41
2130–2140	+23 900	7 812	+3.06	+1.53
2140–2150	+24 170	8 885	+2.72	+1.36
2150–2160	+19 730	10 610	+1.86	+0.93
2160–2170	+15 720	10 770	+1.46	+0.73
2170–2180	+19 700	11 390	+1.73	+0.87
2180–2190	+19 960	10 730	+1.86	+0.93
2190–2200	+19 050	10 080	+1.89	+0.94
2200–2210	+26 570	10 380	+2.56	+1.28
2210–2220	+31 320	10 040	+3.12	+1.56
2220–2230	+35 200	10 830	+3.25	+1.63
2230–2240	+37 900	10 860	+3.49	+1.74
2240–2250	+39 090	12 530	+3.12	+1.56
2250–2260	+51 630	13 070	+3.95	+1.98
2260–2270	+52 020	14 330	+3.63	+1.82

\*Estimated.

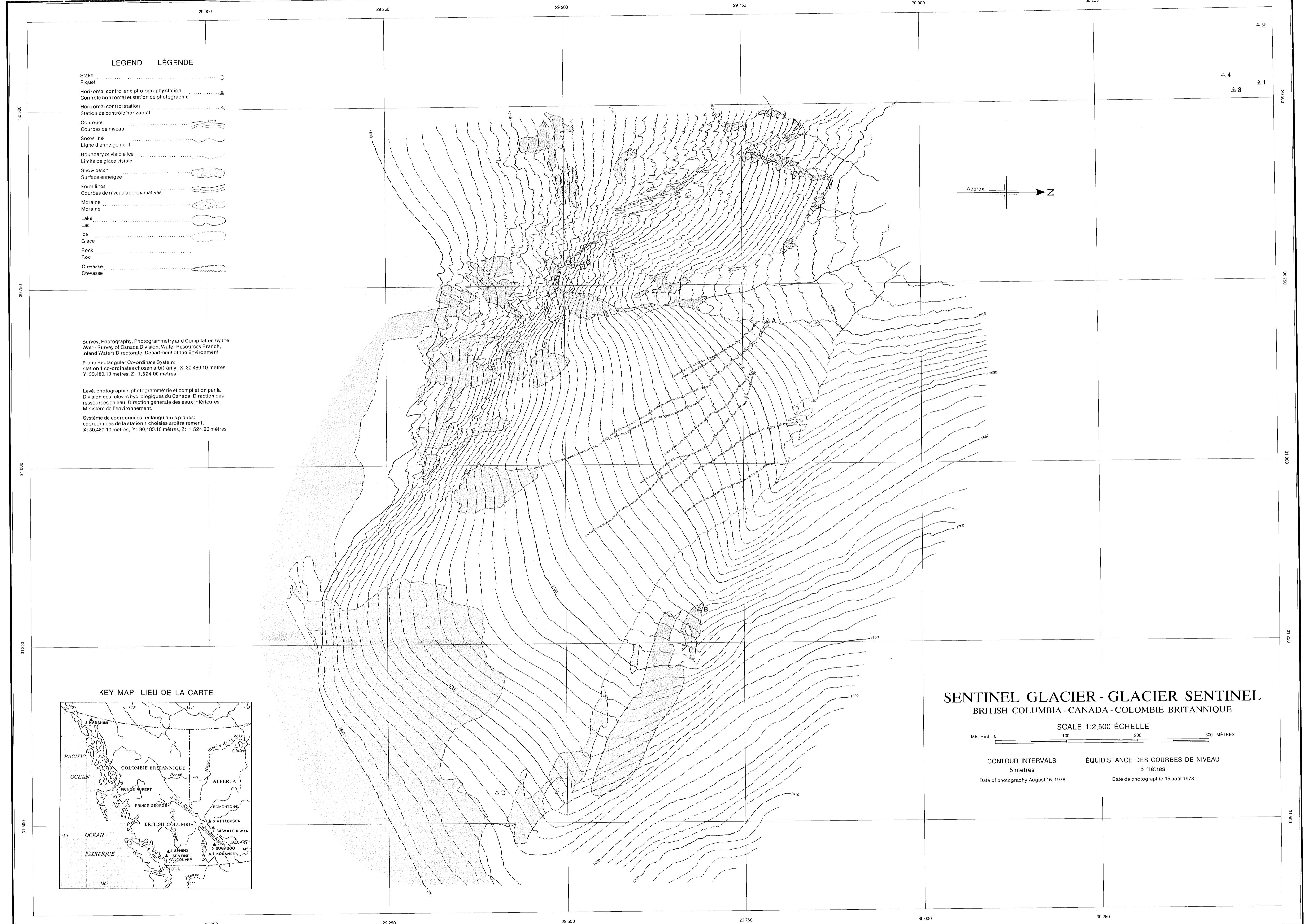
**Table 39. Bugaboo Glacier –  
Summary of Volumetric Changes in the Period 1964-78**

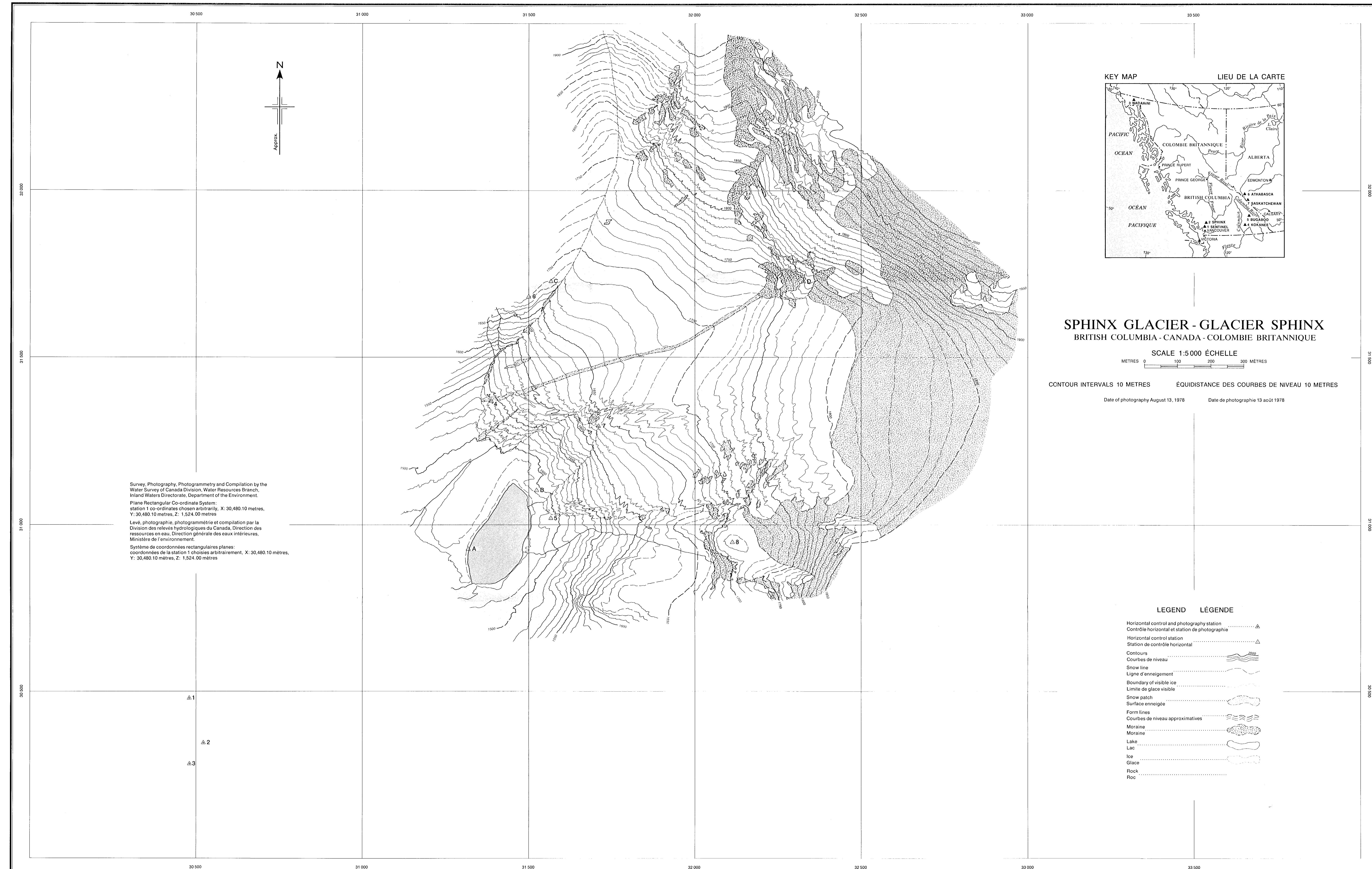
Period	Total volumetric change (m <sup>3</sup> )	No. of yr	Vol. change/yr (m <sup>3</sup> )	Surface change/yr (m)
1964-66	+719 000	2	+359 500	+2.21
1966-68	+847 500	2	+423 800	+2.35
1968-70	+843 500	2	+421 800	+1.83
1970-72	+914 000	2	+457 000	+1.96
1972-74	+1 451 000	2	+725 500	+3.12
1974-76	+1 081 000	2	+540 500	+2.24
1976-78	+1 067 000	2	+533 500	+2.07

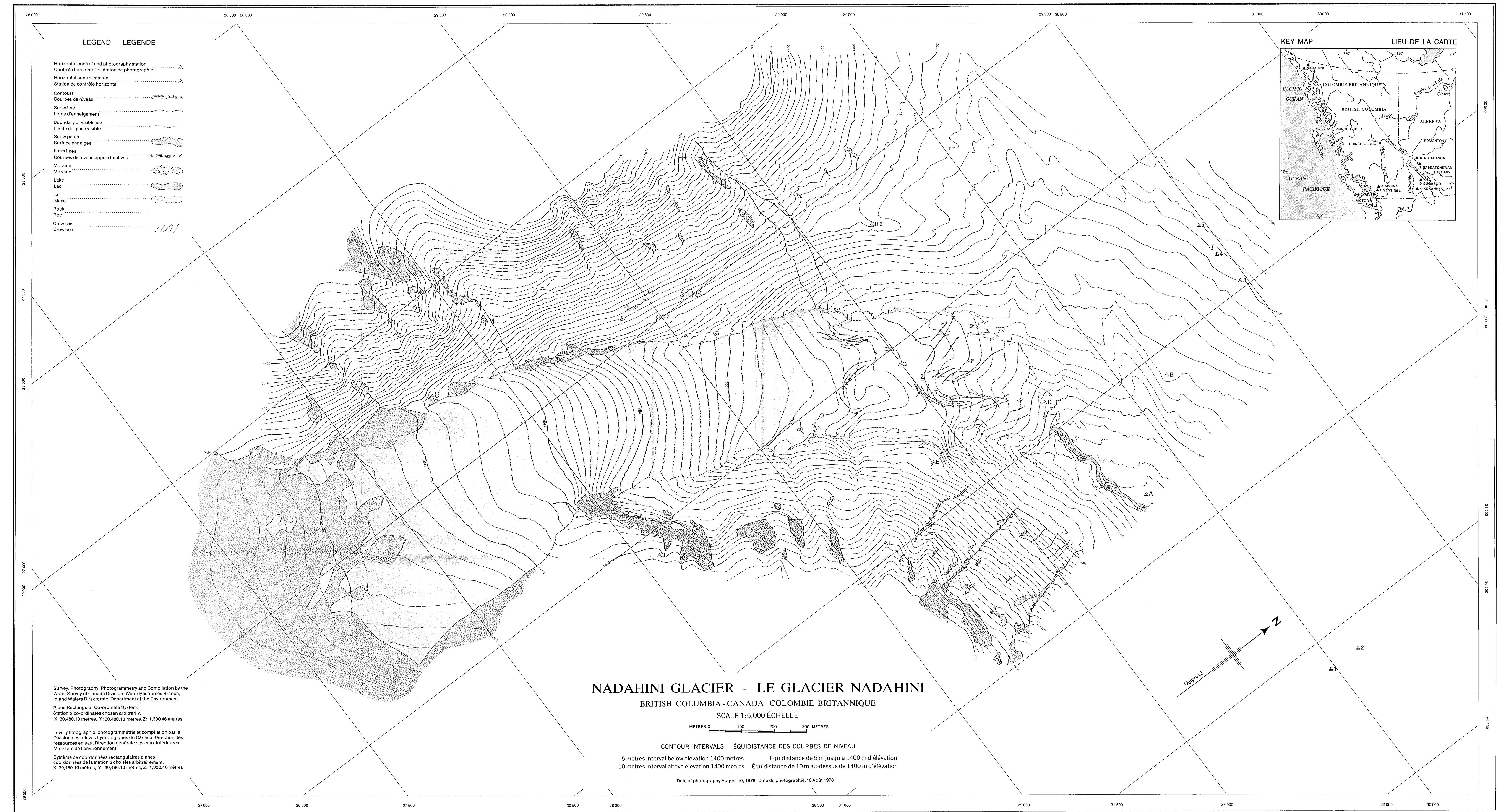
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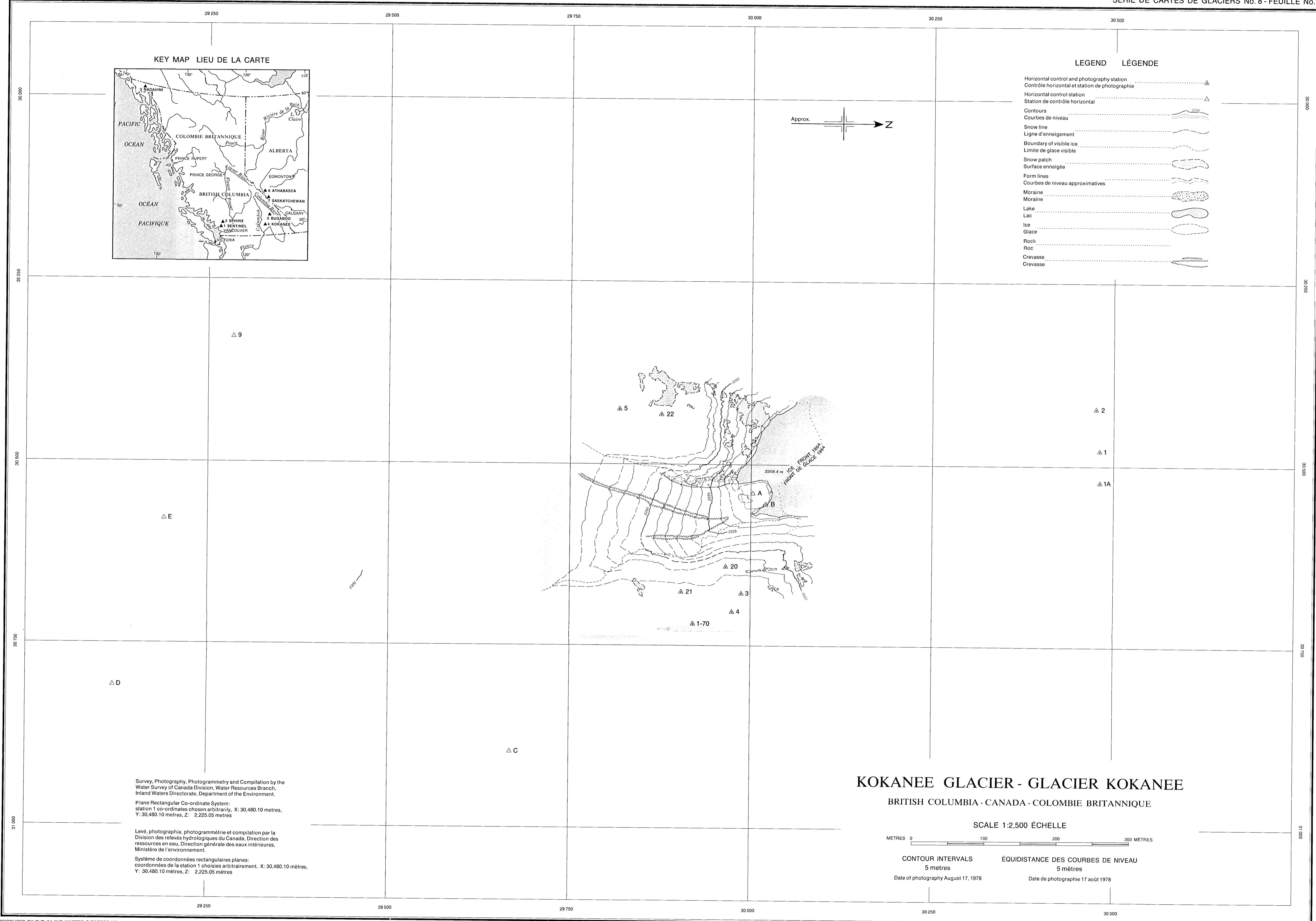
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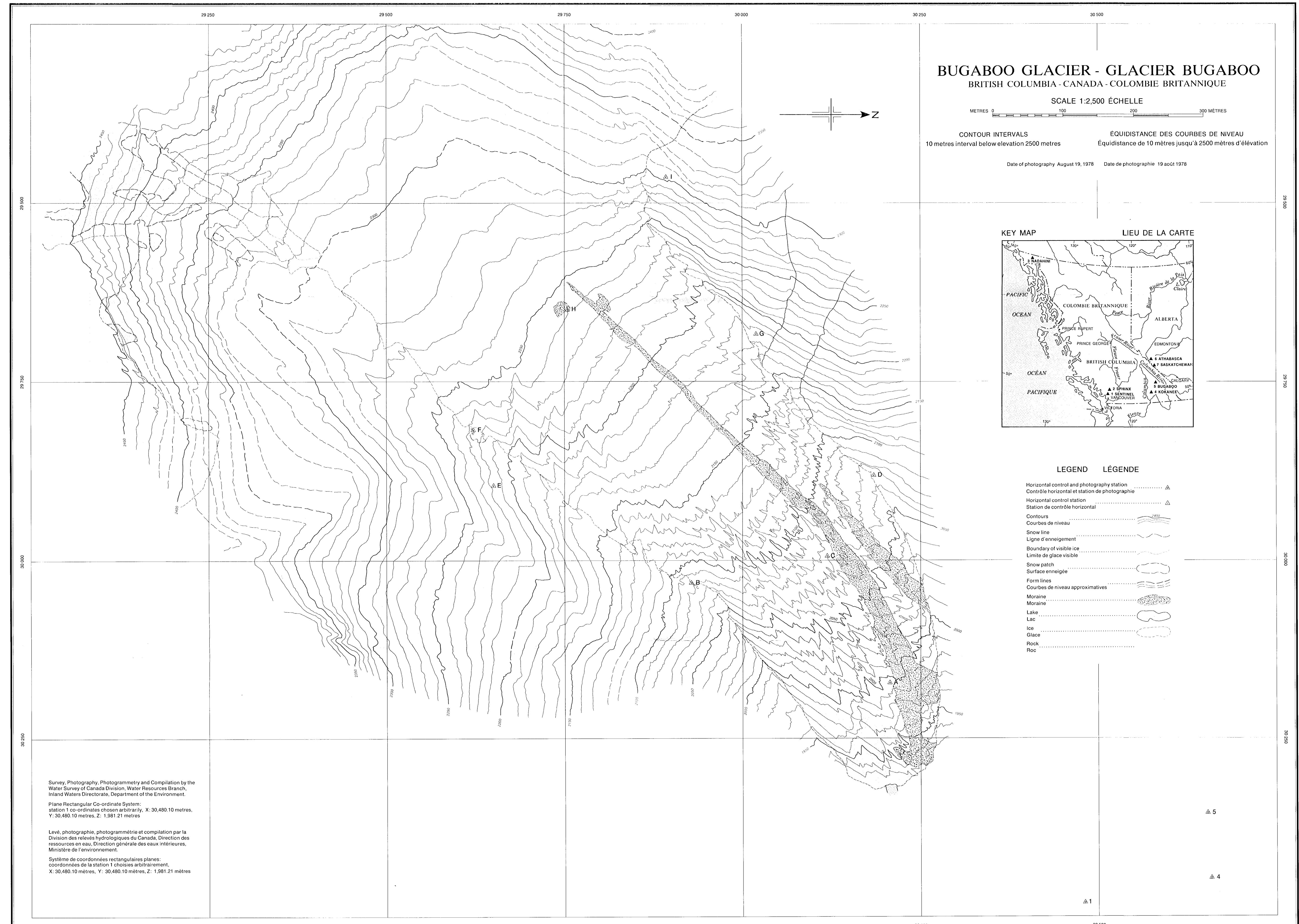
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