ROGERS PASS SNOW AVALANCHE CONTROL - A SUMMARY

Glacier National Park, British Columbia, Canada

ROGERS PASS
SNOW RESEARCH AVALANCHE CONTROL

V.G. Schleiss

ABSTRACT

The Rogers Pass avalanche defence operation protects a 40 km segment of highway and railway corridor centered on Rogers Pass, Glacier National Park, British Columbia, Canada. One hundred and thirty-four avalanche paths affect this corridor. Weather and snowpack information is obtained at 2 continuously manned stations, 4 secondary stations, and 3 telemetry stations. Avalanche patrols and supplementary snowpack observations throughout the control area provide additional data. Static defences include snowsheds, trigger zone defence structures, diversion dykes, mounds, retaining benches, and public information signs. Artillery fire is staged from 18 locations using a 105 mm Howitzer to engage 170 targets. For the years 1962-88, the number of control actions ranged from 18 to 60 per winter and lasted from one hour to five days. Annual ammunition usage varied from 350 to 1,900 rounds. This is one of the largest avalanche control programmes in the world.

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Front Cover: Aerial view of Rogers Pass East
Back Cover (clockwise from top): Simultaneous avalanches from Macdonald West Shoulder Number 3 (063) and Macdonald West Shoulder Number 4 (064); 105 mm howitzer during stabilization shoot; Storm Profile, 1986 February 20-27.

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ROGERS PASS SNOW AVALANCHE CONTROL - A SUMMARY

Glacier National Park, British Columbia, Canada

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ENVIRONMENT CANADA
CANADIAN PARKS SERVICE
REVELSTOKE, B.C.

FOREWORD

This summary of the avalanche control program in Rogers Pass originally appeared as part of an avalanche atlas for Glacier National Park (Schleiss 1989). Numerical references to named slide paths (e.g. Shoulder Valley - 066) are keyed to the individual slidepath descriptions and photographs presented in Schleiss (1989).

While this summary of the avalanche control program provides an overview of the topic, it is not a complete history. Snow avalanches in Rogers Pass have played a significant role in Canadian history for more than a century. Their importance to park ecology extends back through the millennia. They create fans of rock and soil; remove the snowpack and facilitate early green-up; clear swaths through the forest; and, create habitat for many species of birds and mammals. Snow avalanches are natural forces of awesome beauty and power. Their full relevance to man and nature in Rogers Pass is a story, as of yet, untold.

ACKNOWLEDGEMENTS

I would like to thank my two colleagues, W.E. Schleiss and D.A. Skjonsberg, for their major contributions to this atlas including establishment of technical data and overall support. My co-forecaster, W.E. Schleiss has played an integral part of the avalanche defence operation for many years. Bruce Haggerstone of Haggerstone and Associates, Vancouver contributed to historical research and was responsible for coordination of artwork, overall atlas design, and production. Many of the maps, diagrams and illustrations, along with production technical advice, were provided by Lester Jones of Jones Maps and Diagrams Ltd., Vancouver, B.C. John G. Woods of the Canadian Parks Service, Revelstoke, assisted in historical research, conceptual development, and editing. Without his extensive input the atlas in its present form would not have been produced.

V.G. Schleiss
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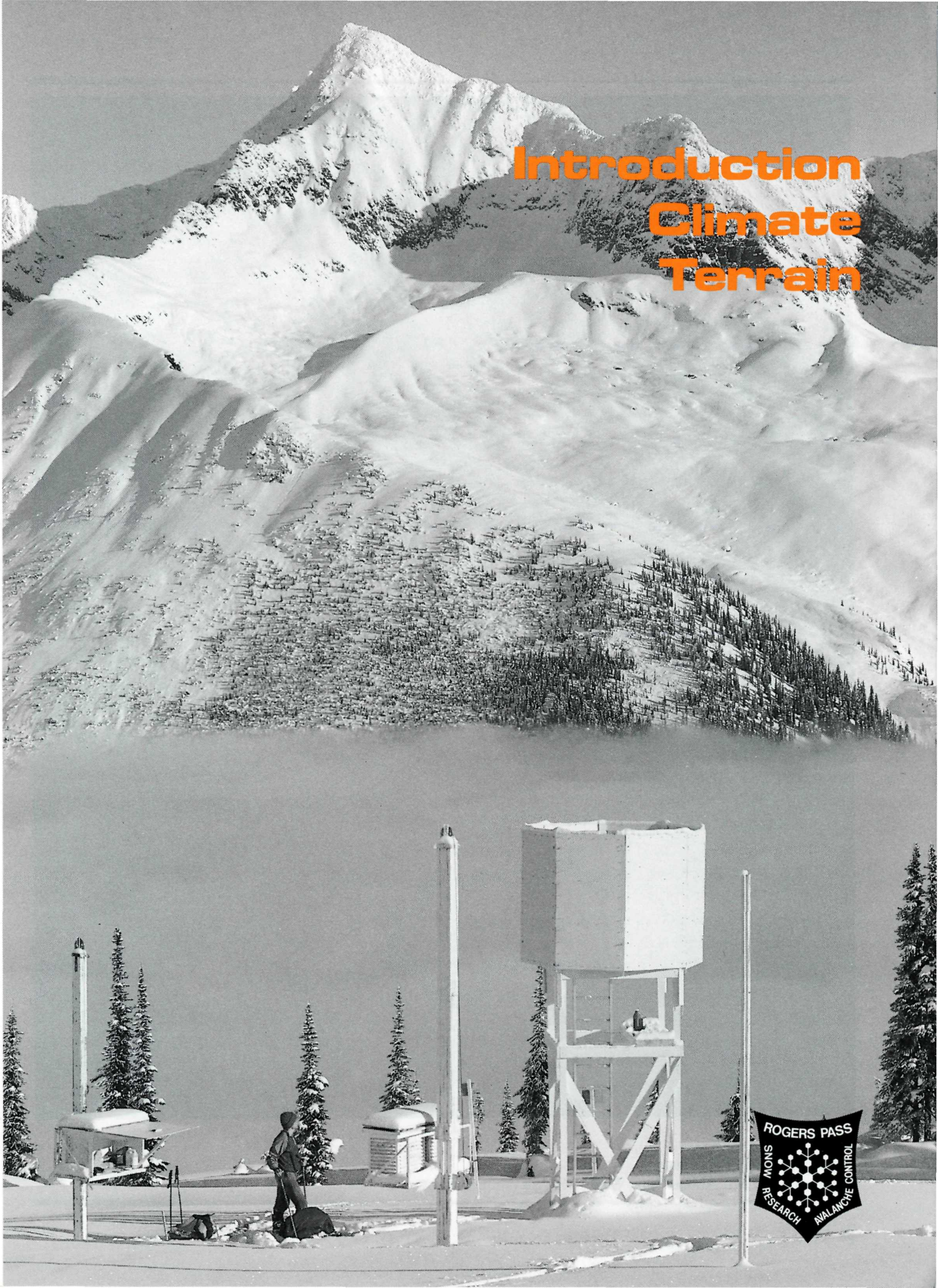
Mount Revelstoke and
Glacier National Parks

Introduction
Climate
Terrain



ROGERS PASS
SNOW RESEARCH AVALANCHE CONTROL

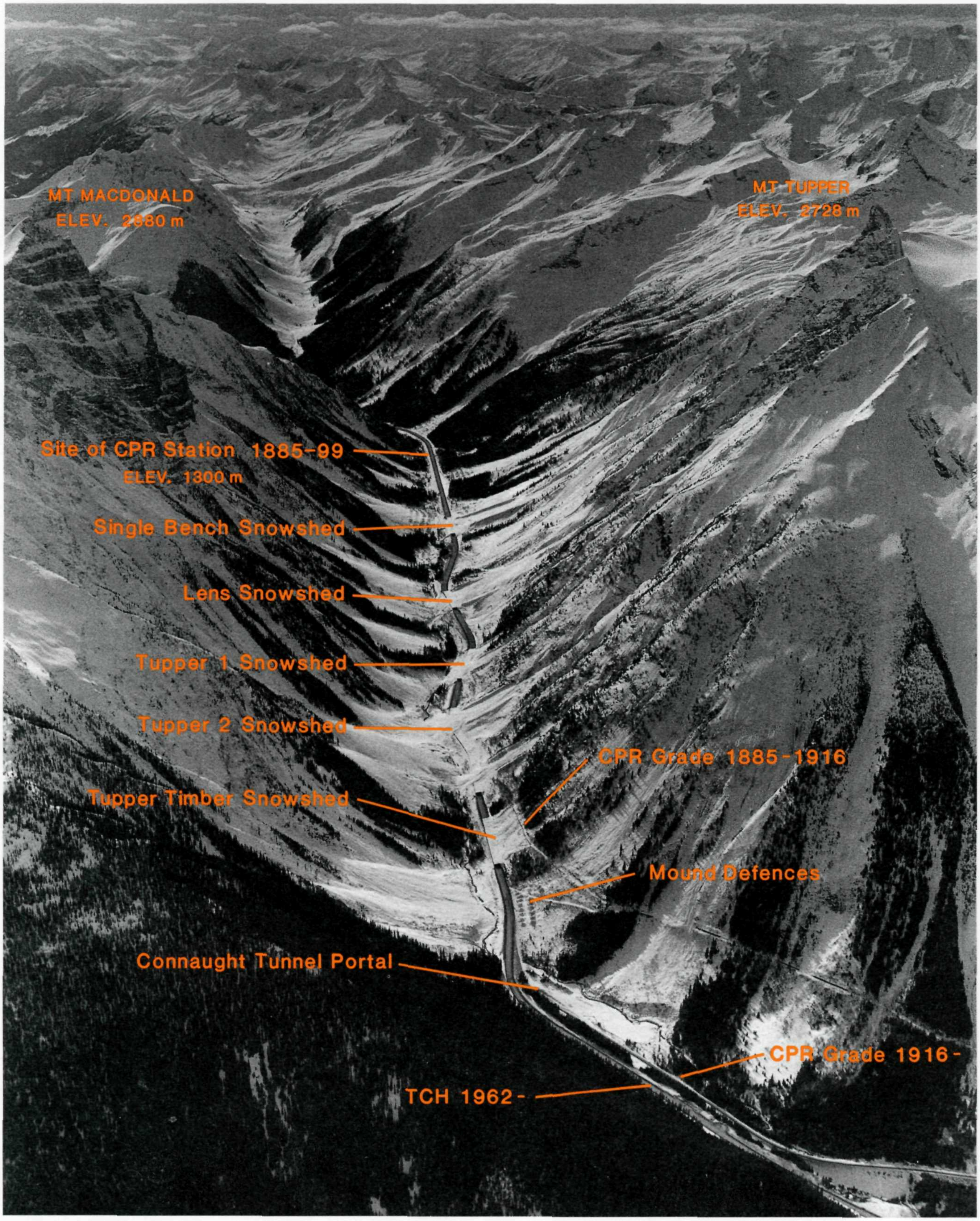


Figure 1: Rogers Pass East
Previous page: Mt. Abbott Snow Study Plot, elevation 1950 m

INTRODUCTION

The Snow Research and Avalanche Warning Section (SRAWS) in Glacier National Park operates one of the largest direct action avalanche control programmes in the world. Although there are 134 slidepaths, multiple release points within paths greatly increase the number of individual avalanches that can affect the traffic corridor occupied by the Trans-Canada Highway (TCH) and CP Rail (CPR) mainline through Rogers Pass, British Columbia, Canada (Figures 1 and 2).

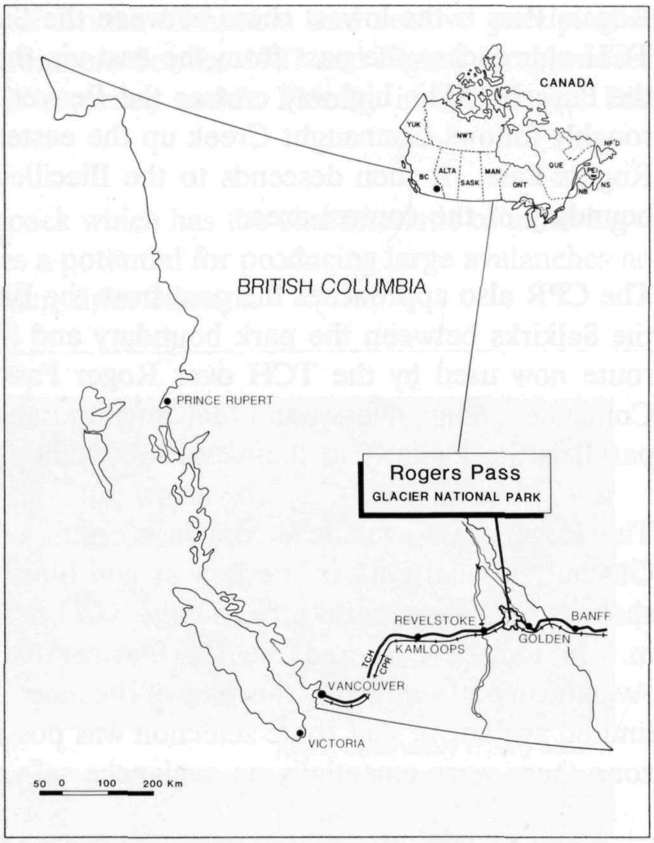


Figure 2: Orientation Map

The Rogers Pass route through the Selkirk Ranges of the Columbia Mountains has had a long history of avalanche problems. This began with the completion of the railway in 1885, and continues to this day on the CPR and TCH. From 1885 to 1962, avalanche defence of the CPR was limited to snowsheds. Since the highway was completed in 1962, an elaborate system of static and mobile defences have protected both the CPR and the TCH.

Heavy snowfall and steep terrain combine to make this an area of extreme avalanche activity. Although Rogers Pass was chosen for both the CPR and TCH because it was the best available corridor across the Selkirks, there were few opportunities for avalanche safe route selection. On the other hand, the concentration of avalanche problems facilitated the creation of a single mobile control programme.

This atlas contains an overview of the terrain, climate, and history of avalanche defence in the Rogers Pass control area. A detailed slidepath inventory forms the bulk of this report. Changes in climate, technology, and traffic volumes will continue to challenge the avalanche defence planning and operation required to protect the transportation corridor.

TERRAIN

Rogers Pass is the lowest route between the Sir Donald and Hermit ranges of the Selkirks. The TCH approaches the pass from the east via the Beaver River valley along the western slopes of the Purcells. The highway crosses the Beaver River near its confluence with Stoney Creek and roughly follows Connaught Creek up the eastern slopes of the Selkirks and into summit area of Rogers Pass. It then descends to the Illecillewaet River valley which it follows to the western boundary of the control area.

The CPR also approaches the pass from the Beaver River valley but climbs the eastern slopes of the Selkirks between the park boundary and Stoney Creek. Although it originally followed the route now used by the TCH over Roger Pass, the railway now runs beneath the pass via the Connaught, Shaughnessy, and Macdonald tunnels. It emerges in the Illecillewaet River valley and parallels the highway to the western boundary of the control area.

The Roger Pass avalanche control corridor includes the pass itself and the approaches within Glacier National Park in the Beaver and Illecillewaet valleys. The Beaver valley is relatively U-shaped. Avalanche paths affecting the TCH or CPR in this area have vertical relief of up to 1,650 m. In Rogers Pass and the Illecillewaet River valley, the terrain is continuously V-shaped. Avalanche paths affecting this part of the corridor have vertical relief of up to 1,800 m. Although limited avalanche safe route selection was possible in the Beaver valley, elsewhere in the control zone there were essentially no avalanche safe route alternatives.

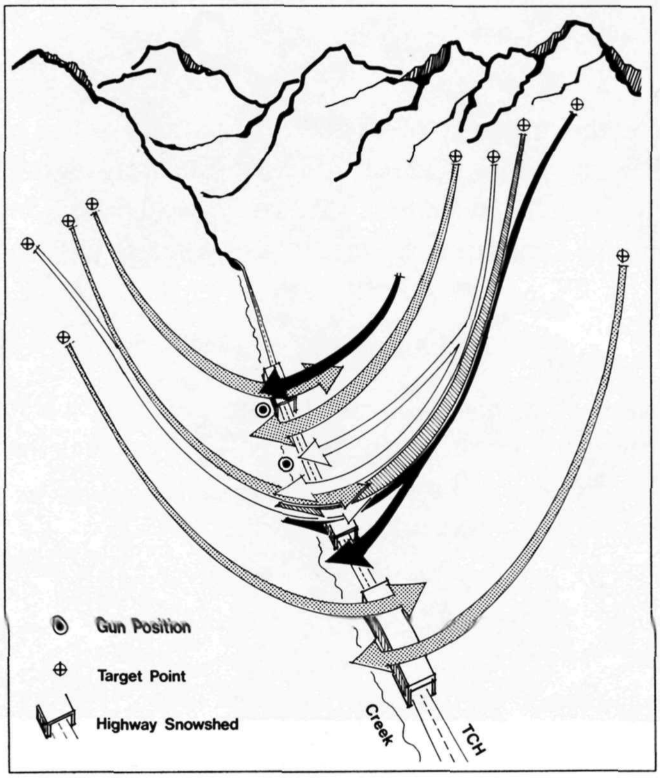


Figure 3: Avalanche cross-fire

Although 134 individual avalanche paths are described in this atlas (Section F), an important characteristic of the control area is the fact that many of these paths have overlapping runout zones and multiple trigger points (Figure 3). Sections of highway and railway can therefore be exposed to cross-fire from slides originating on opposites sides of the valley and from the multiple release of snow from the same path.

A further discussion of terrain characteristics can be found in Schaerer (1962, 1969) and Woods (1986).

CLIMATE

The Selkirk Ranges are in the interior wetbelt of British Columbia and receive precipitation second only to coastal regions (Atmospheric Environment Service 1987 and Figure 4). However, the greatest average yearly snowfall in Canada is recorded at Mt. Fidelity in the Rogers Pass avalanche control area (Phillips 1987).

Westerly flows of mild, humid air produce a snowpack which has the characteristic of adhering to extremely steep slopes (up to 60°). This establishes a potential for producing large avalanches not found in similar terrain situations in areas of colder, drier climate.

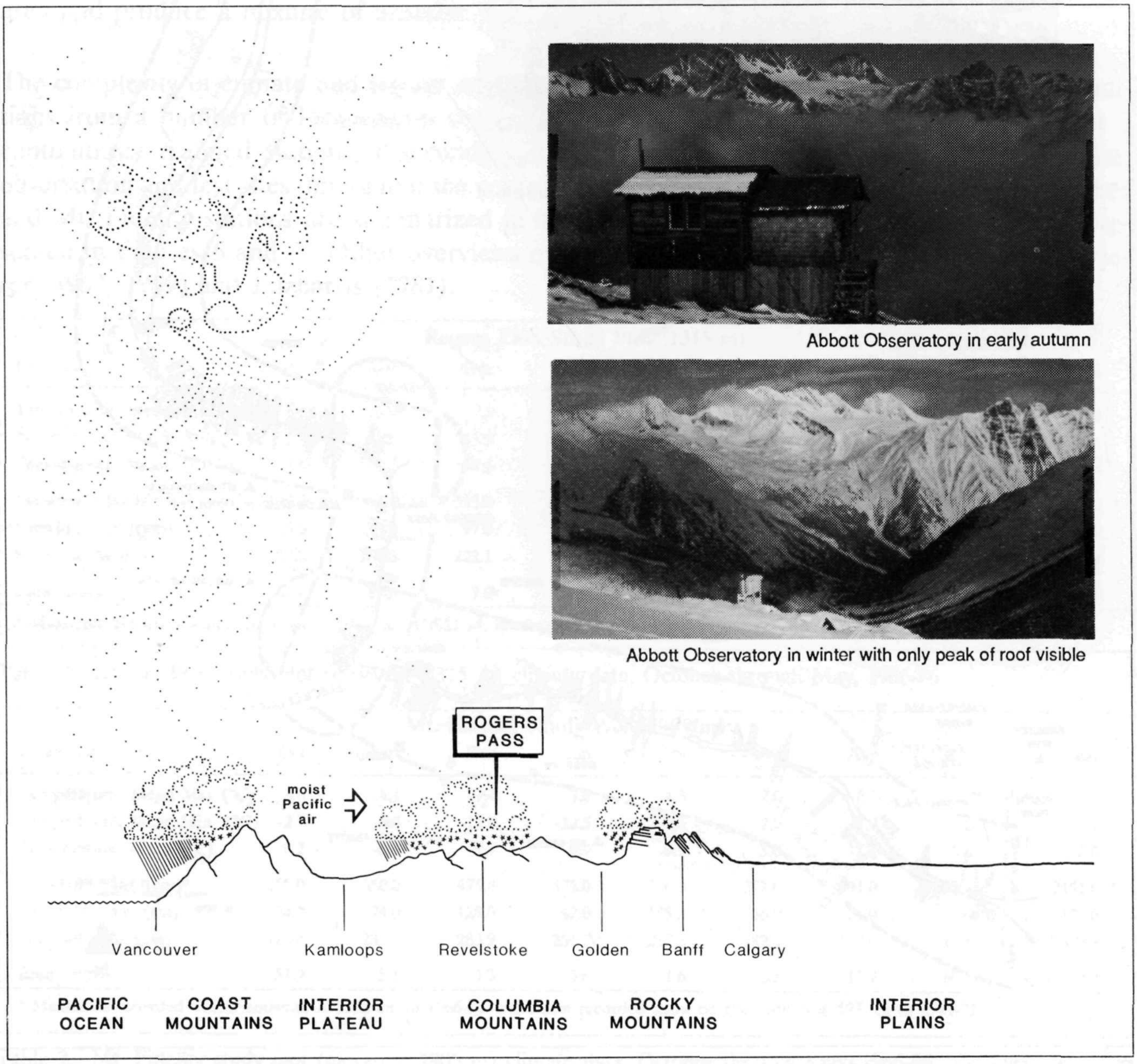


Figure 4: Rogers Pass Climate

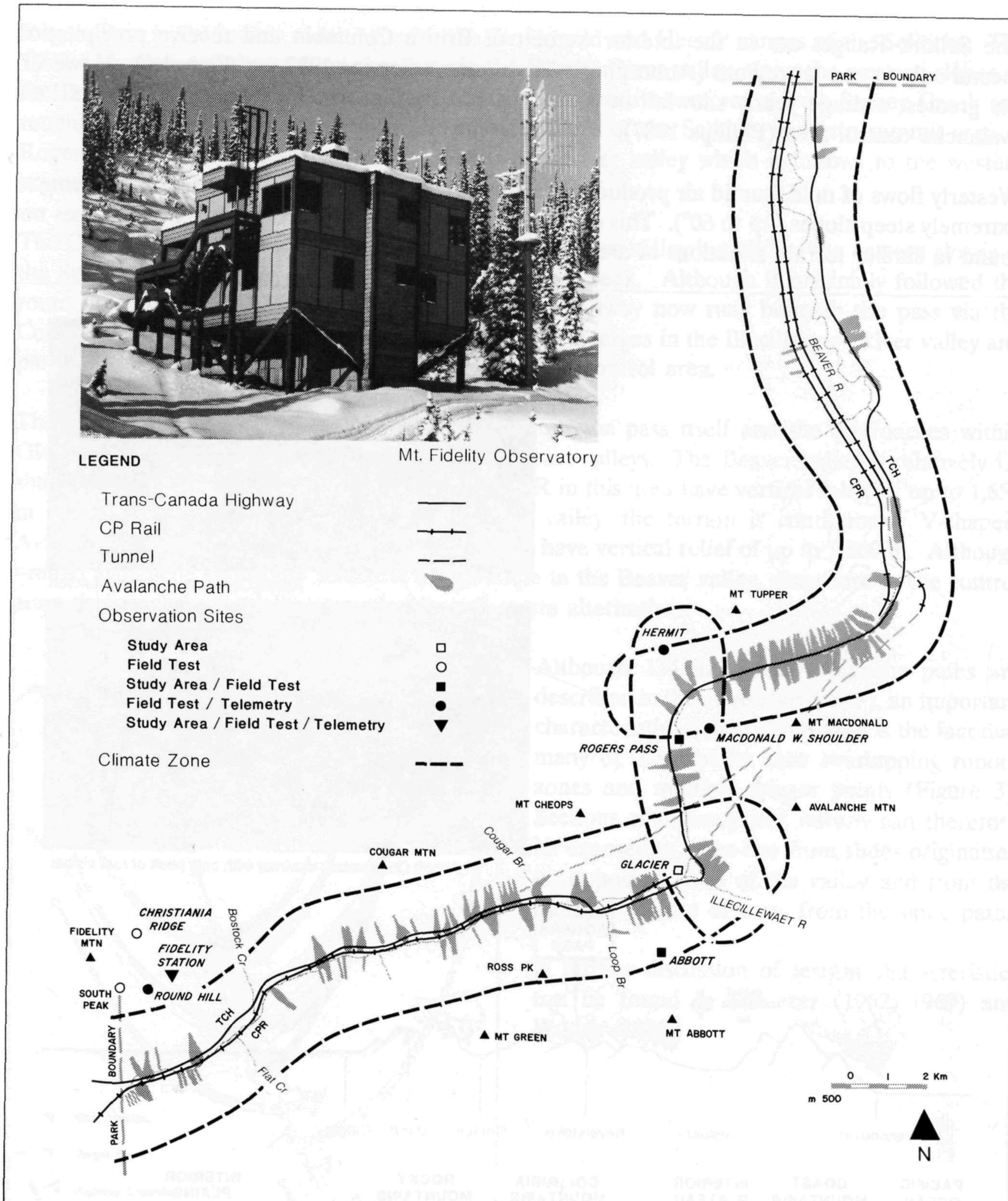


Figure 5: Climate zones and observation sites

Although westerly flows of Pacific air typically are the major influence over the control zone, the Continental air mass governs the climate to the east in the Rocky Mountains, Foothills, and Great Plains. Occasionally, this drier, colder air extends its influence to the west and can dominate the climate of the Rogers Pass area.

Within the control area, three climatological sub-zones are recognized (Figure 5): the west (the Illecillewaet valley), the summit (Rogers Pass), and the east (the Beaver valley). The western sub-zone is characterised by heavy snowfall and mild temperatures. Lighter snowfall and colder temperatures distinguish the eastern sub-zone. These two climate sub-zones clash in the summit area and produce a mixture of unstable weather.

The complexity of climate and terrain necessitates observations of weather and snowpack conditions from a number of locations in the control zone (Figure 5). Observations are made at 2 continuously manned stations, 4 secondary stations, 3 telemetry stations and numerous other observation and test sites throughout the control area. Climate characteristics for the Rogers Pass and Mt. Fidelity stations are summarized in Tables 1 and 2. Snowpack characteristics are presented in Figures 6 and 7. Other overviews of the climate of this area are presented by Schaerer (1962, 1969) and Fitzharris (1981).

Rogers Pass Study Plot (1315 m)

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Year
Temperature: Mean Max (°C)	4.7	-3.2	-7.3	-8.1	-3.4	1.5	6.2	10.8	5.8
Temperature: Mean Min (°C)	-1.6	-7.5	-11.9	-13.1	-9.6	-6.9	-3.5	-0.1	-3.1
Temperature: Mean (°C)	1.6	-5.3	-9.6	-10.7	-6.5	-2.7	1.4	5.4	1.4
Snowfall: Max (cm)	196.0	265.0	323.0	441.0	379.0	177.0	83.0	29.7	1553.0 *
Snowfall: Min (cm)	6.0	11.0	97.0	31.0	64.0	34.0	9.0	0.0	714.0
Snowfall: Av (cm)	53.5	160.3	222.1	222.0	169.0	11.2	48.9	8.5	997.4
Rain (mm)	84.6	19.6	9.0	10.0	5.4	14.4	31.6	63.7	605.5

* Maximum recorded winter snowfall is 1727 cm in 1953-54; maximum recorded snow on the ground is 319 cm in 1971-72

Table 1. Rogers Pass study plot (elevation 1315 m) climate data, October through May, 1966-86

Mt. Fidelity Study Plot (1905 m)

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Year
Temperature: Mean Max (°C)	3.0	-4.1	-7.4	-7.4	-4.3	-2.0	2.3	7.4	3.2
Temperature: Mean Min (°C)	-2.7	-8.8	-12.0	-12.5	-9.6	-7.9	-4.7	0.2	-3.2
Temperature: Mean (°C)	0.2	-6.4	-9.7	-9.9	-6.9	-5.0	-1.1	3.8	0.0
Snowfall: Max (cm)	355.0	380.0	475.0	575.0	396.0	272.0	241.0	97.7	2151.0 *
Snowfall: Min (cm)	24.0	74.0	128.0	42.0	105.0	66.0	31.0	7.0	1176.0
Snowfall: Av (cm)	124.8	233.9	283.9	256.2	217.2	182.3	119.6	47.5	1502.9
Rain (mm)	51.9	5.1	3.3	3.6	1.6	2.5	11.9	60.5	602.8

* Maximum recorded winter snowfall is 2151 cm in 1966-67; maximum recorded snow on the ground is 493 cm in 1971-72

Table 2. Mt. Fidelity study plot (elevation 1905 m) climate data, October through May, 1966-86.

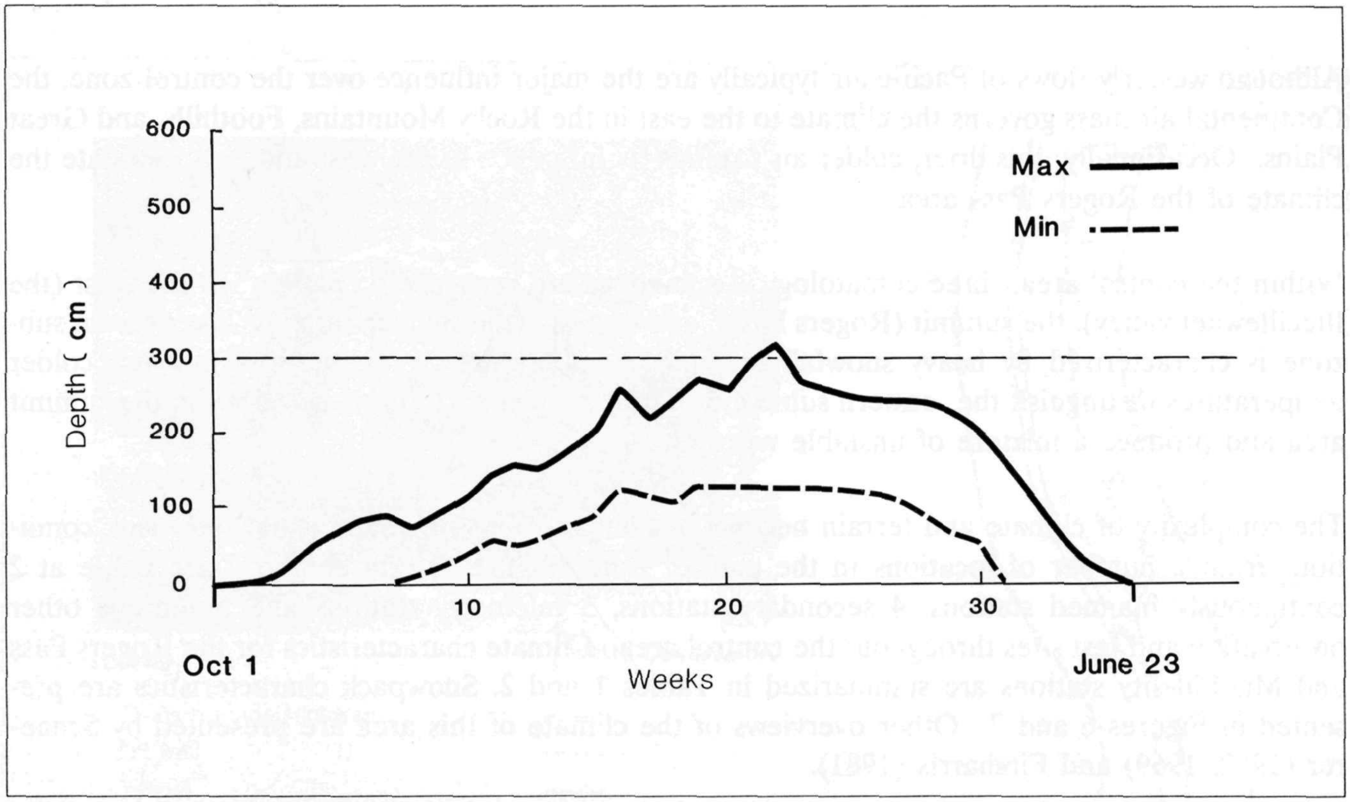


Figure 6: Rogers Pass snowpack range, 1963-87

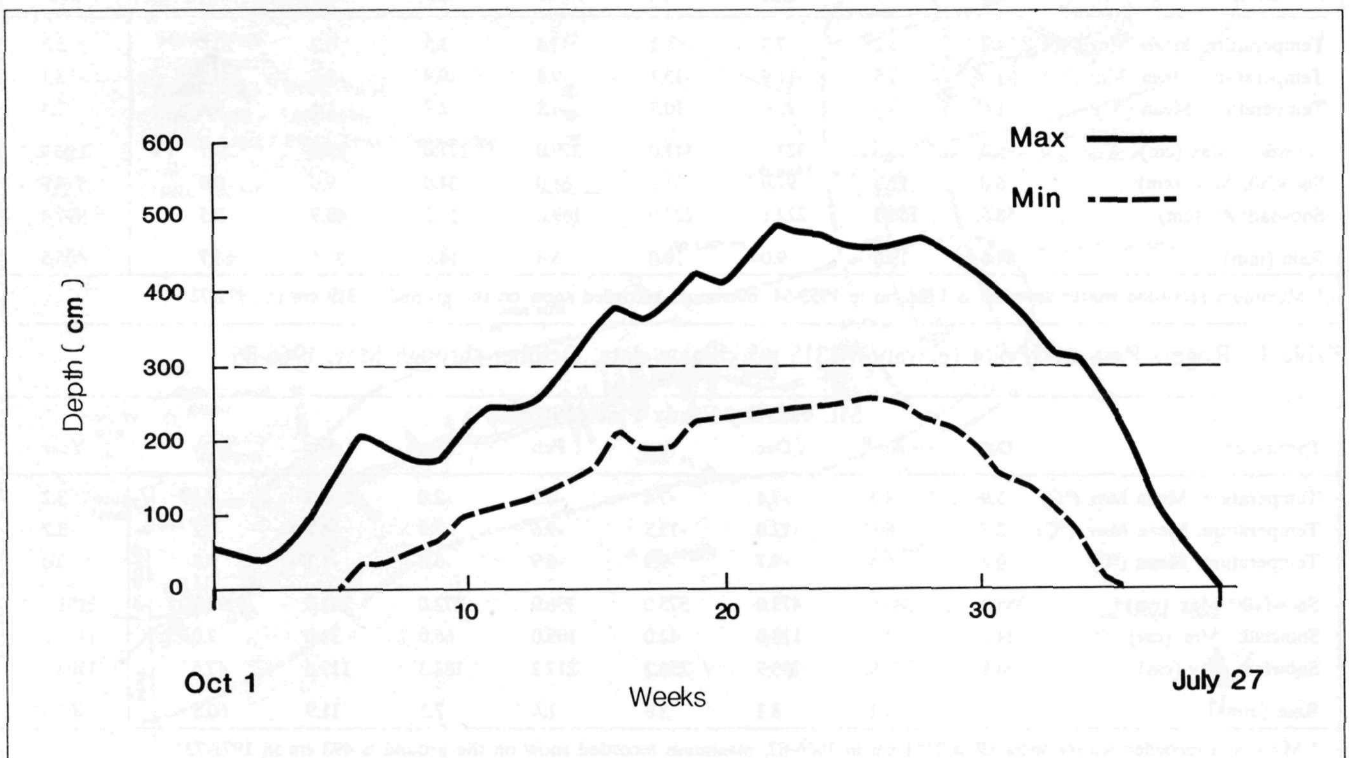
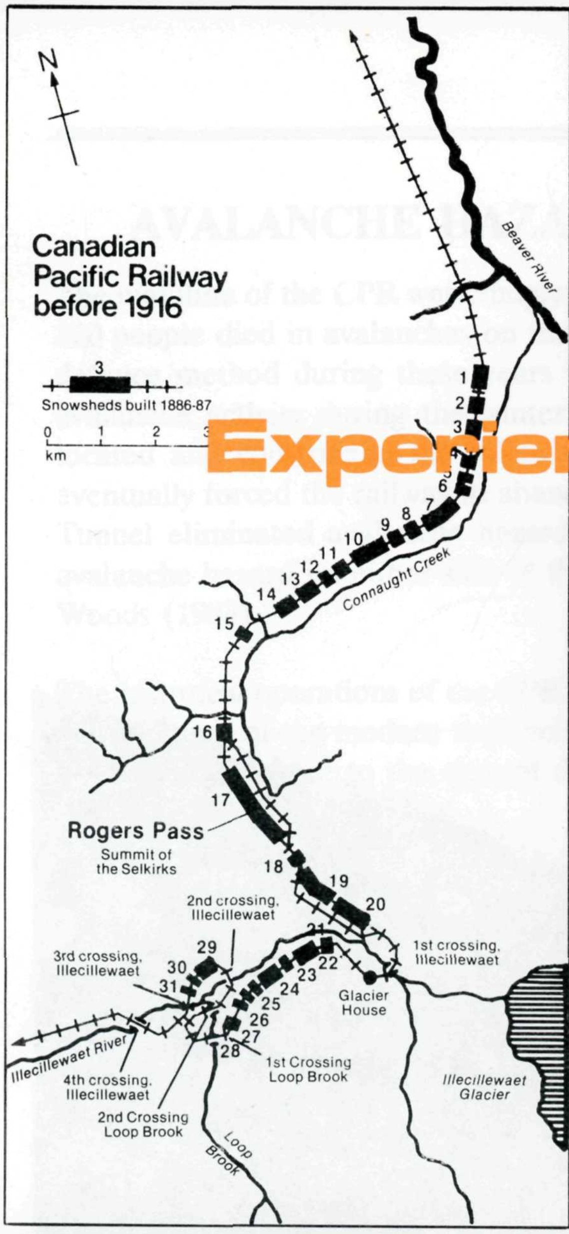
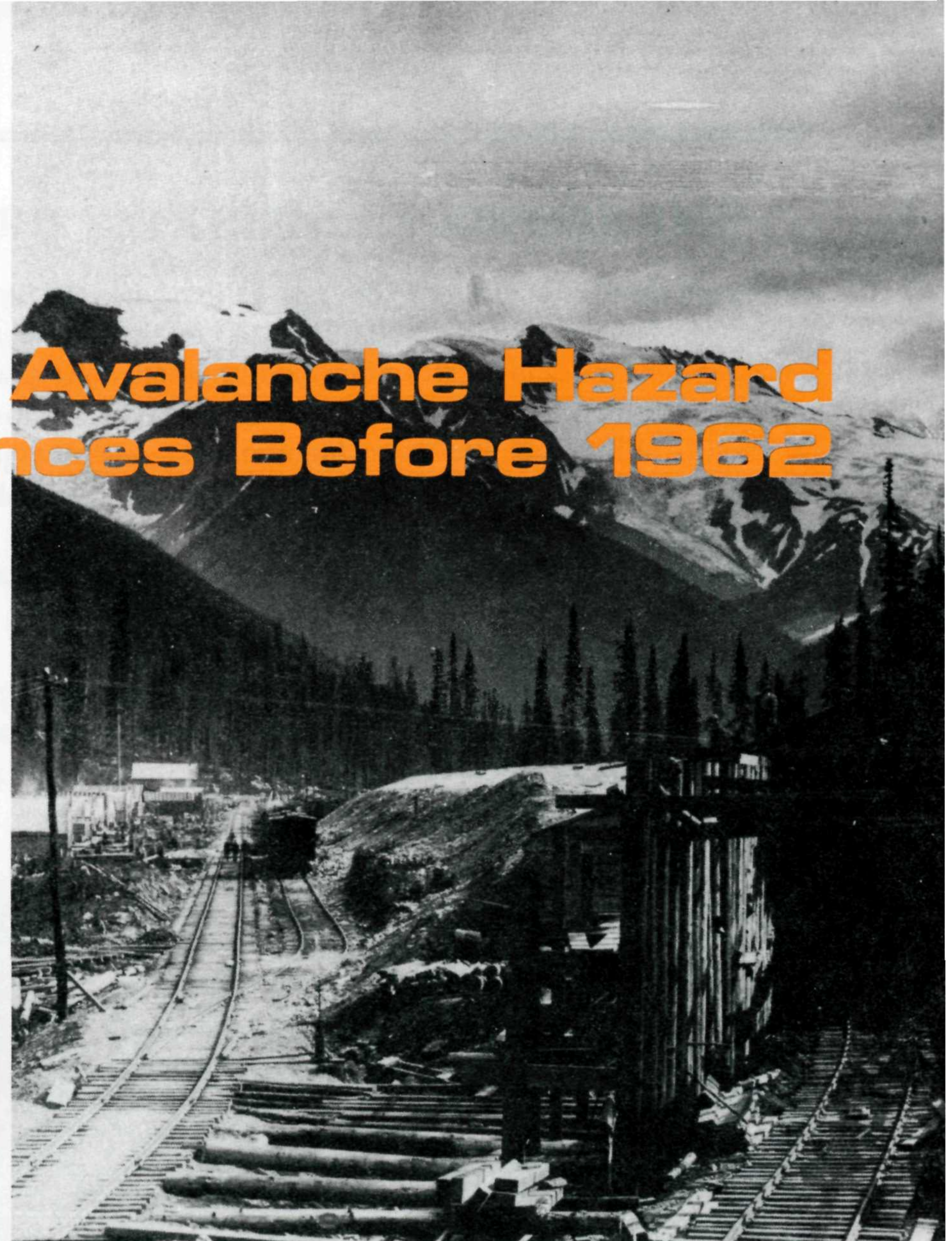
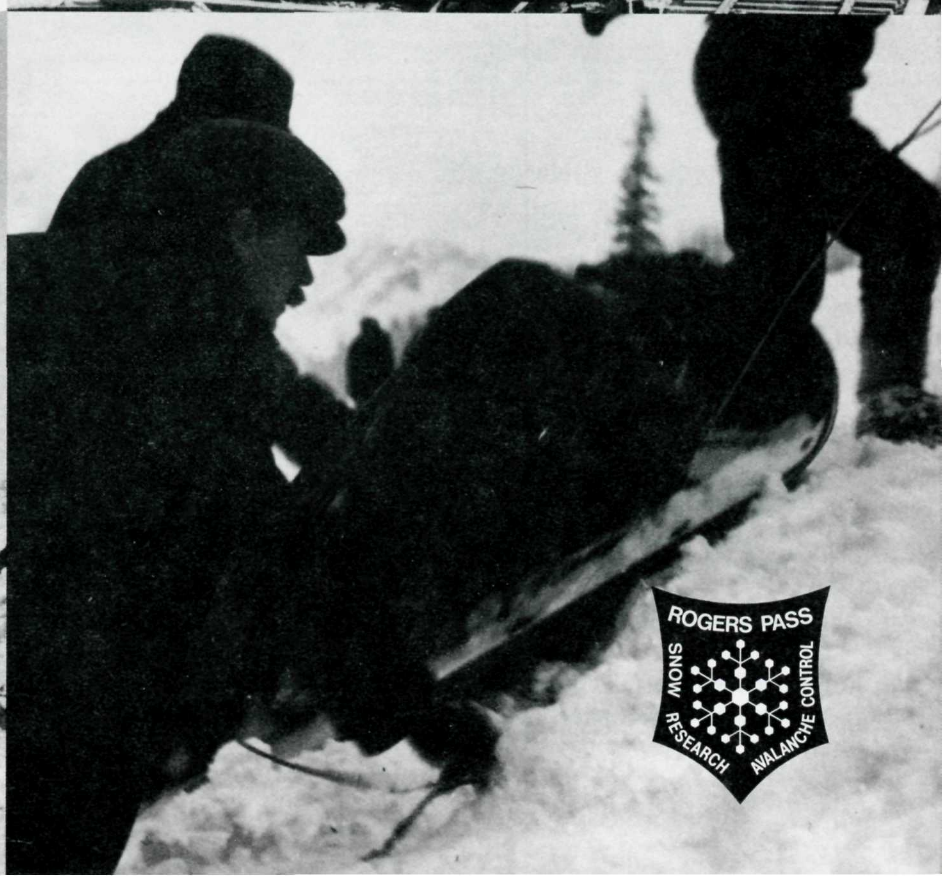


Figure 7: Mt. Fidelity snowpack range, 1963-87

Avalanche Hazard Experiences Before 1962







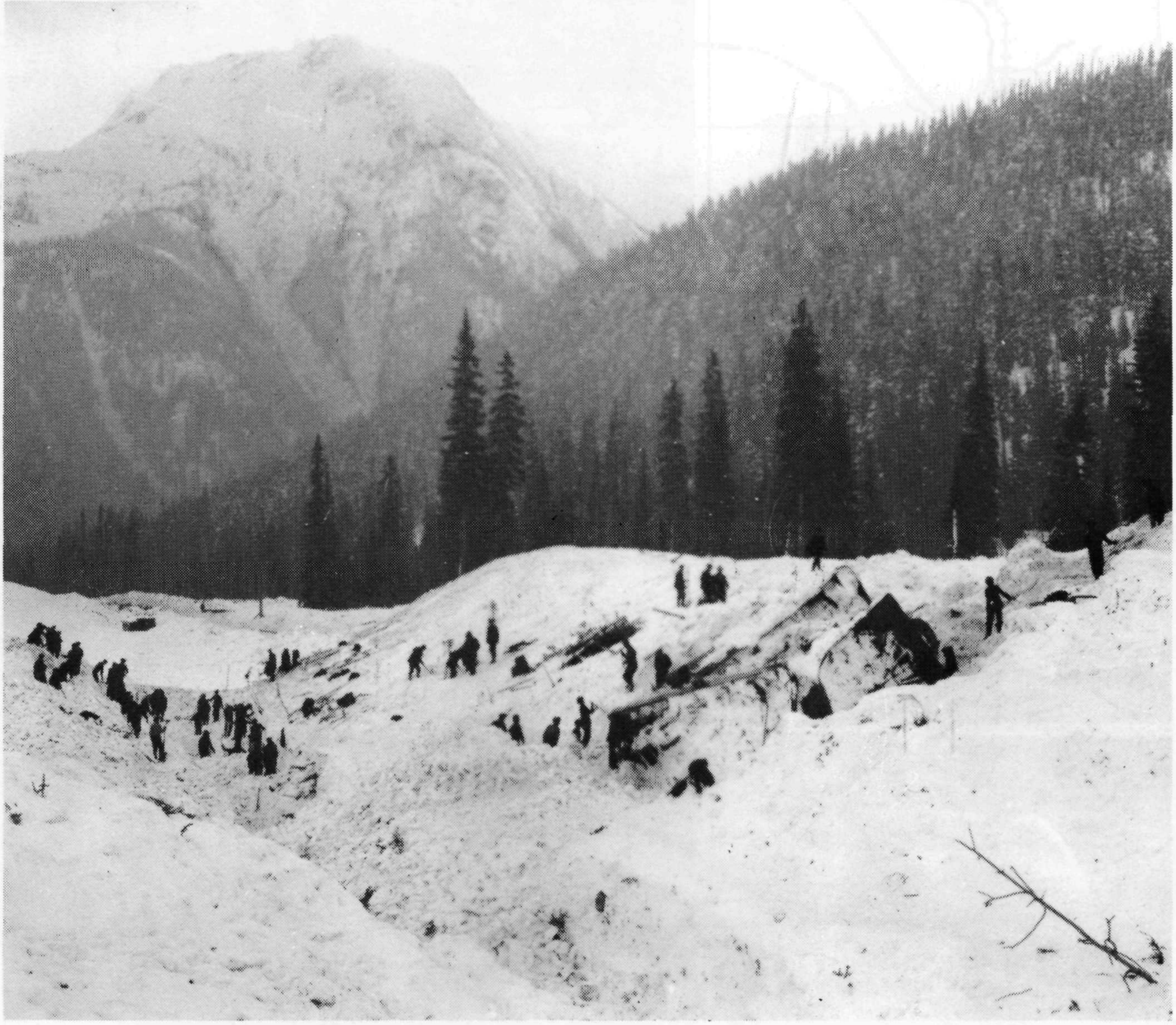


Figure 8: 1910 Disaster at 17 Shed

Previous page (clockwise from top right): 17 Shed under construction in 1887; body recovery, 1910 disaster; clearing avalanche debris after the 1910 disaster; CPR snowsheds before 1916.

AVALANCHE HAZARD EXPERIENCES BEFORE 1962

The mainline of the CPR was completed over Rogers Pass in 1885. From 1885 to 1962, more than 200 people died in avalanches on the railway line in Glacier National Park. The only avalanche defence method during these years was snowsheds. Cunningham (1886) observed weather and avalanche activity during the winter of 1885-86 and as a result of his survey snowsheds were located and constructed the following summer. Operational costs and loss of life (Figure 8) eventually forced the railway to abandon the surface route over the pass. In 1916, the Connaught Tunnel eliminated avalanche hazard in the pass, but the railway continued to be exposed to avalanche hazard on either side of the tunnel. An overview of the railway history is available in Woods (1983).

The historical operations of the CPR provided valuable experiences which were considered in the development of the modern avalanche defence plan. These can be summarized in four historical lessons of relevance to the current defence operations.

1. Hazard Magnitude.

Numerous accidents and loss of life on the railway underscored the extreme potential avalanche hazard to a highway built over Rogers Pass.

2. Snowshed Inadequacies.

Although approximately 6 km of wooden snowsheds were built along the railway, they did not provide adequate control. In addition, they were very expensive to build and presented constant maintenance problems (fire, repair to structural damage etc).

3. Recognition of Avalanche Path Boundaries.

The railway construction engineers failed to recognize the boundaries of several slidepaths and the potential for overlapping slidepath runout zones. Construction and operation in these areas ultimately led to several serious avalanche accidents.

4. Climatic variability.

Inactivity of various slidepaths over the years led the CPR to re-evaluate the avalanche hazard in some areas along the line. As a result, when the track was re-aligned some snowsheds were not reconstructed. In later years, activity in these slidepaths resulted in accidents. Fitzharris (1981) reviewed the history of avalanche activity and weather patterns relevant to the early operation of the CPR.

The importance of these lessons is illustrated in the following case histories of CPR accidents before 1962.

A. DESTRUCTION OF ROGERS PASS STATION, 1899.

From 1885 to January 1899, the first Rogers Pass railway station was located in the overlapping runout zones of the slidepaths now named Tractor Shed Minor (056) and Hermit (057) (Figures 9 and 10). On January 31, 1899 a major slide from Hermit destroyed the station and killed 7 people (Figure 11). Apparently, when the CPR built the station in this location they did not realize the potential size of these avalanche paths.

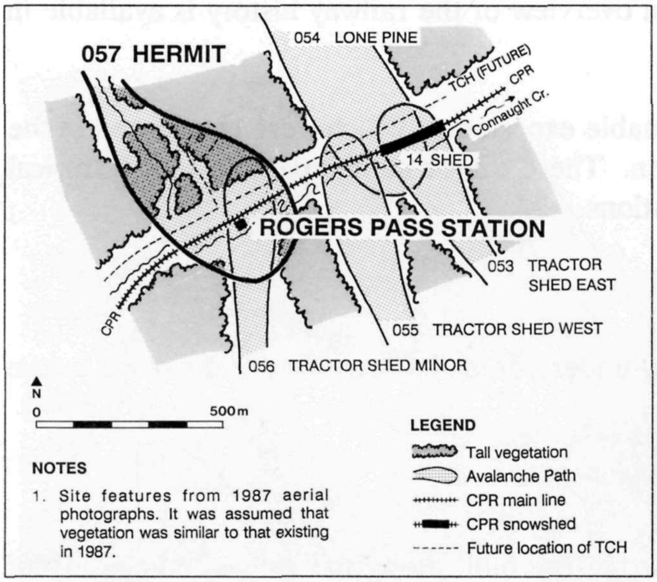


Figure 9: Slidepath involved in the destruction of the first Rogers Pass station in 1899

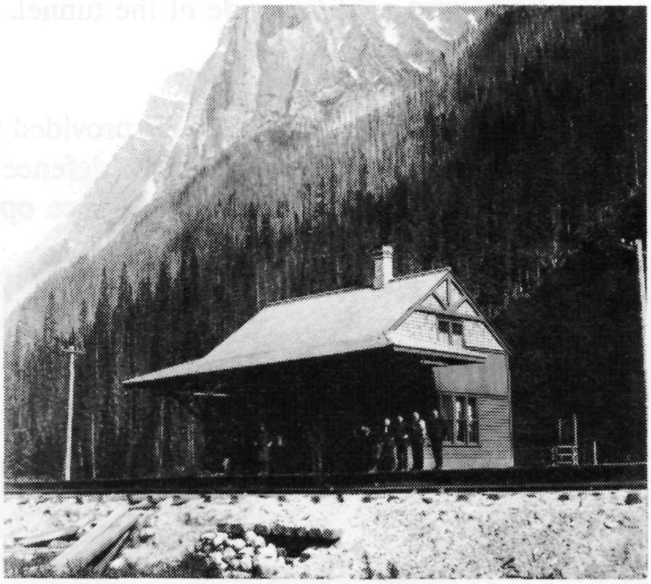


Figure 10: Rogers Pass station, 1885-99

Rogers Pass station with Mount Macdonald in the background. The avalanche path immediately behind the station is now named Tractor Shed Minor.

Figure 11: Destruction of first Rogers Pass station, 1899

The remains of the station after the 1899 avalanche from Hermit Slide (057). The highway now runs roughly parallel to and slightly behind the rail line shown in the photograph. Hermit Pit is now located in the right central area of the photo.

B. THE 1910 DISASTER.

From 1886 to 1909 a "valley shed" protected the railway in the overlapping runout zones of Shoulder Valley (065) and Cheops 1 (066) slidepaths (Figure 12). When the track was re-aligned outside 17 Shed in 1909, they did not protect it with a snowshed. This decision was made as a result of the inactivity of these slidepaths during the previous years. On March 4th, 1910 Cheops 1 slidepath covered the railway line. A crew working to clear snow and forest debris from the track was buried by another slide from Shoulder Valley slidepath (Figures 13 and 14). Sixty-two workers died in this incident.

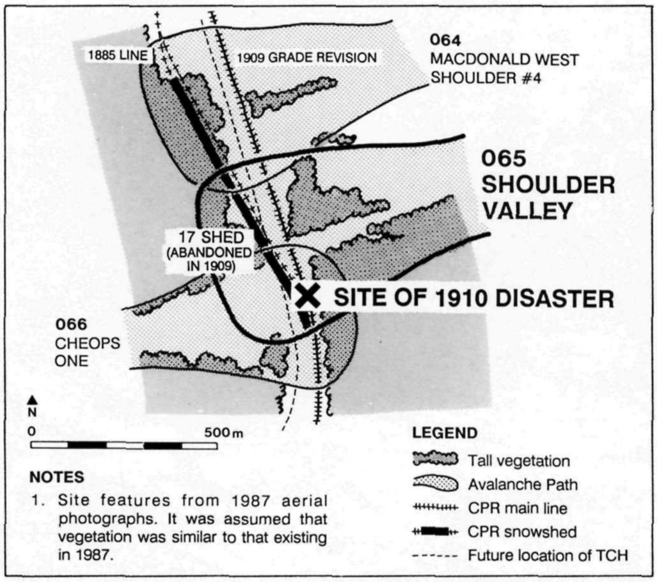


Figure 12: Slidepaths involved in the 1910 disaster

Figure 13: The 1910 disaster site, view to south

The slide swept down the slopes of Macdonld West Shoulder (to the left). The force of the avalanche lifted a rotary snowplow, weighing more than 100 tons, onto the roof of the recently abandoned 17 Shed.

Figure 14: The 1910 disaster site, view to north

C. THE DESTRUCTION OF 14 SHED.

Throughout the CPR's operation over Rogers Pass, 14 Shed protected the line across part of the Lone Pine (054) and Tractor Shed East (053) slidepaths (Figure 15). On March 5th, 1910 slides at this point covered 400 m of track to a depth of 5 m (Figure 16). The shed provided inadequate avalanche defence in two respects. First, it only protected approximately one half of the effective avalanche area. Second, its design strength was insufficient and the entire structure was badly damaged.

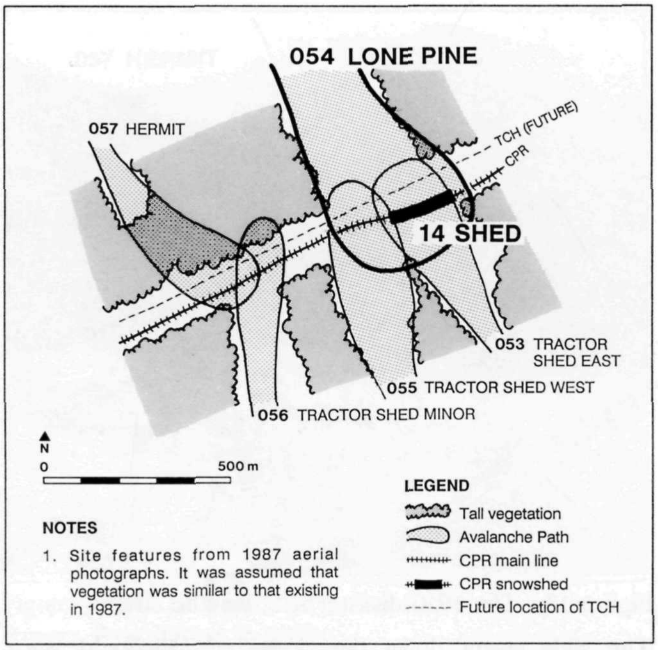
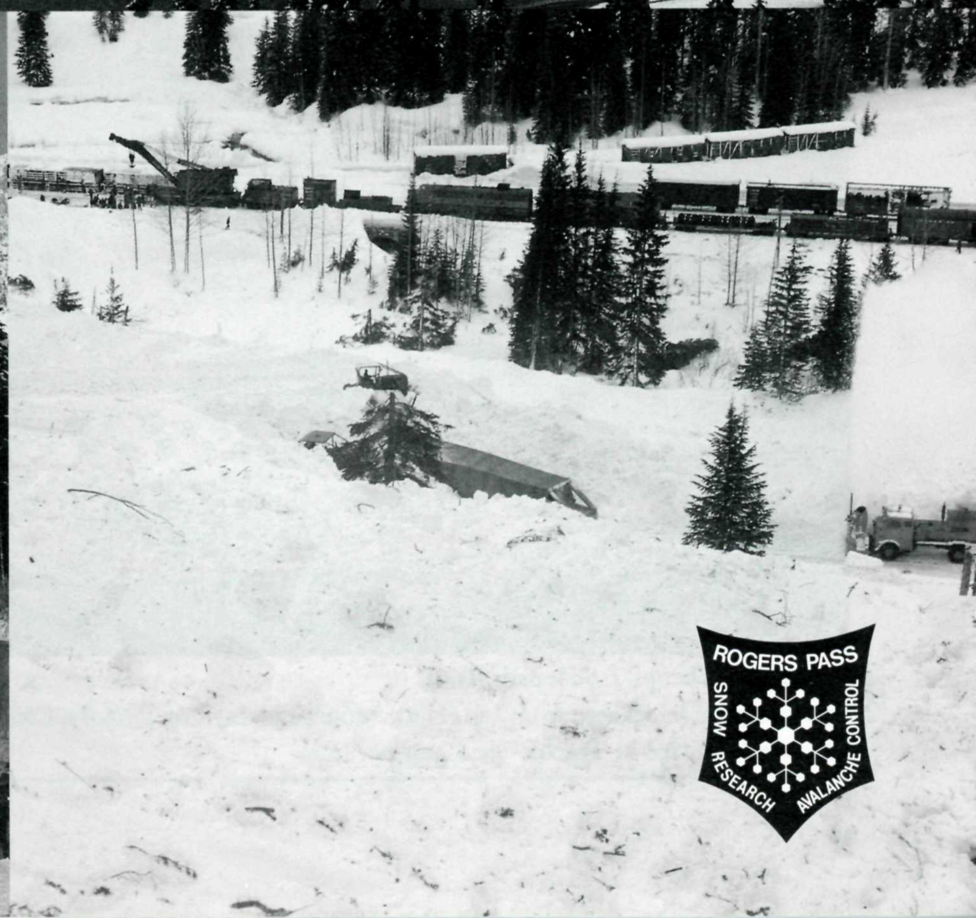


Figure 15: Slidepaths involved in destruction of 14 Shed

Figure 16: 14 Shed after the slide of 1910 March 10

Clearing debris near the west portal of 14 shed. Shovel gangs like these were very exposed to avalanche hazard - the previous night, 62 men in another gang died in an avalanche at the summit of Rogers Pass. Lone Pine slide (054) is on the left, Tractor Shed East (053) on the right.

Avalanche Control After 1962



ROGERS PASS
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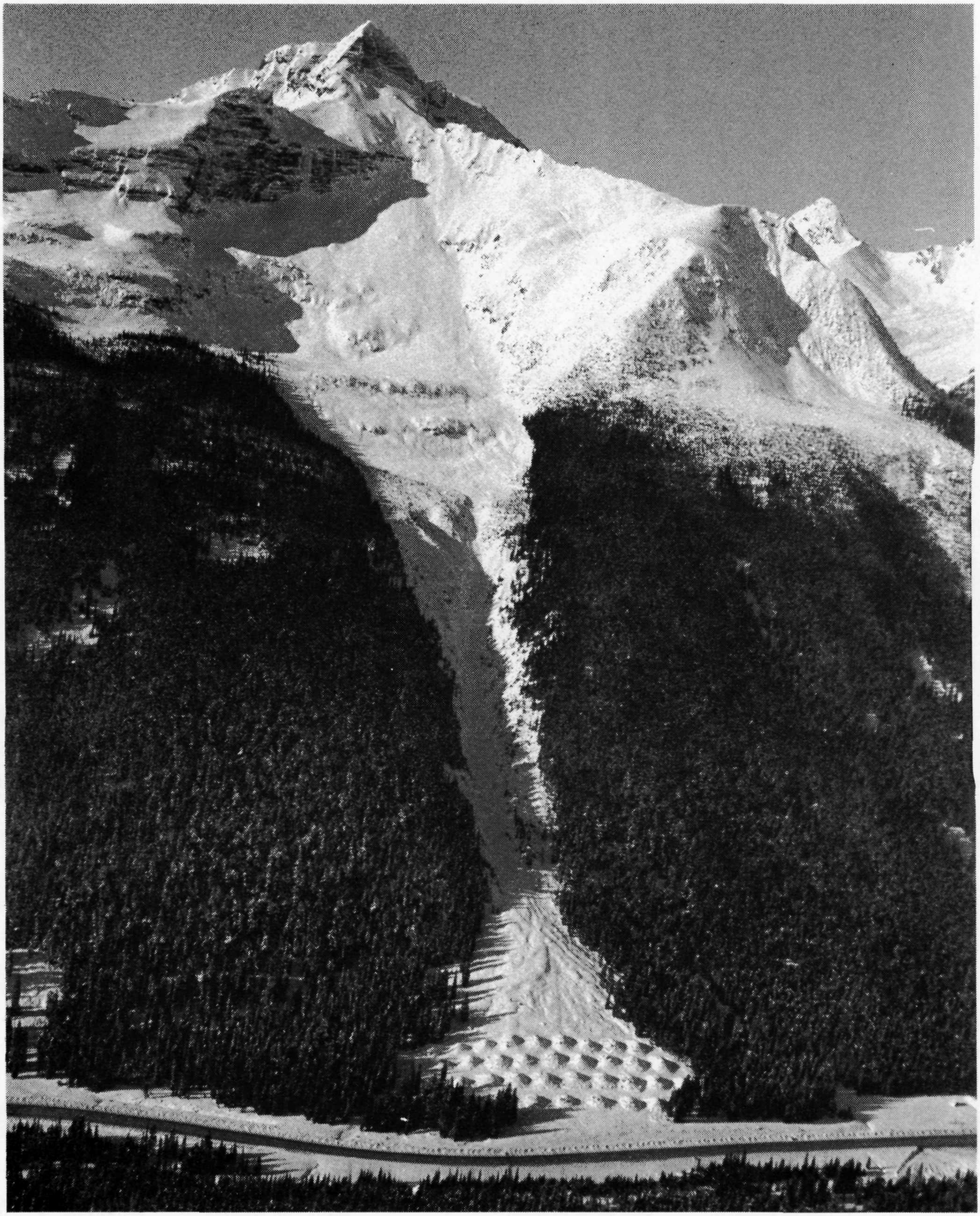

Figure 17: Cheops 1 Slidepath (066)

Previous page (clockwise from top right): Mount Fidelity Observatory; Clearing avalanche debris from TCH and CPR; 105 mm Howitzer at Tractor Shed gun position

AVALANCHE CONTROL AFTER 1962

In the 1950s, analysis of the need for an all Canadian highway from coast to coast identified Rogers Pass as the route for the TCH across the Selkirks. The right-of-way would again challenge the Rogers Pass, abandoned in 1916 by the CPR because of the steep grades, loss of human lives, and cost of maintaining the line over the pass. It was understood that successful all year-round operation of the highway depended on an operational solution to the avalanche problem.

In 1953, engineers and scientists began studying the avalanche situation and the resulting defence requirements. As a result, a complex array of static defences were designed and installed (Tables 3, 4, and 5 and Figure 18). However, the magnitude of the avalanche exposure -- over 200 avalanches could affect the traffic corridor at 134 sites -- made control by static defences alone economically unacceptable. This made it necessary to attempt mobile avalanche control, a technique which was unproven on this scale at the time.

Name	Length (m)	Built in path #	Protects TCH from path #	Partially protects TCH from path #	Protects CPR from path #
Tupper Timber	258	025	025		
Tupper #2	591	029	029	030	
		031	031	032	
		033	033		
Tupper #1 *	272	037	037		
		038	038		
Lens *	183	044	044	043	
				045	
				046	
Single Bench *	215	050	050	051	
CPR Shed #1	172	123			123
		124			124
CPR Shed #2	126	125			125

* gunfire stabilization required to supplement snowshed defence

Table 3. Snowshed Inventory (1988) Glacier National Park, B.C.

Built in path #	Rows of mounds	Total # mounds	Protects TCH from path #	Protects CPR from path #
022	2	21	022	
051	4	54	051	
052	3	20	052	
054	4	46	054	
058	3	21	058	
066	4	36	066	
108	2	18	108	108
110	3	42	110	110
121	4	55	121	

* gunfire stabilization required to supplement mound defences

Table 4. Mound defence inventory (1988) Glacier National Park, B.C.

Type of defence structure	Built in path #	Protects TCH from path #	Protects CPR from path #
Diversion Dam	010, 079	010, 079	094
	094	094	
Retaining Dam	045, 046	045, 046	080, 113
	080, 113	080, 113	
Retaining Benches	001, 040	001, 040	
	049	049	
Retaining Basin	041, 042	041, 042	
	047	047	
Retaining Fences	006, 008	006, 008	

* Gunfire stabilization required to supplement the above defences

Table 5. Slidepaths protected by defence structures other than snowsheds or mounds (1988) Glacier National Park, B.C.

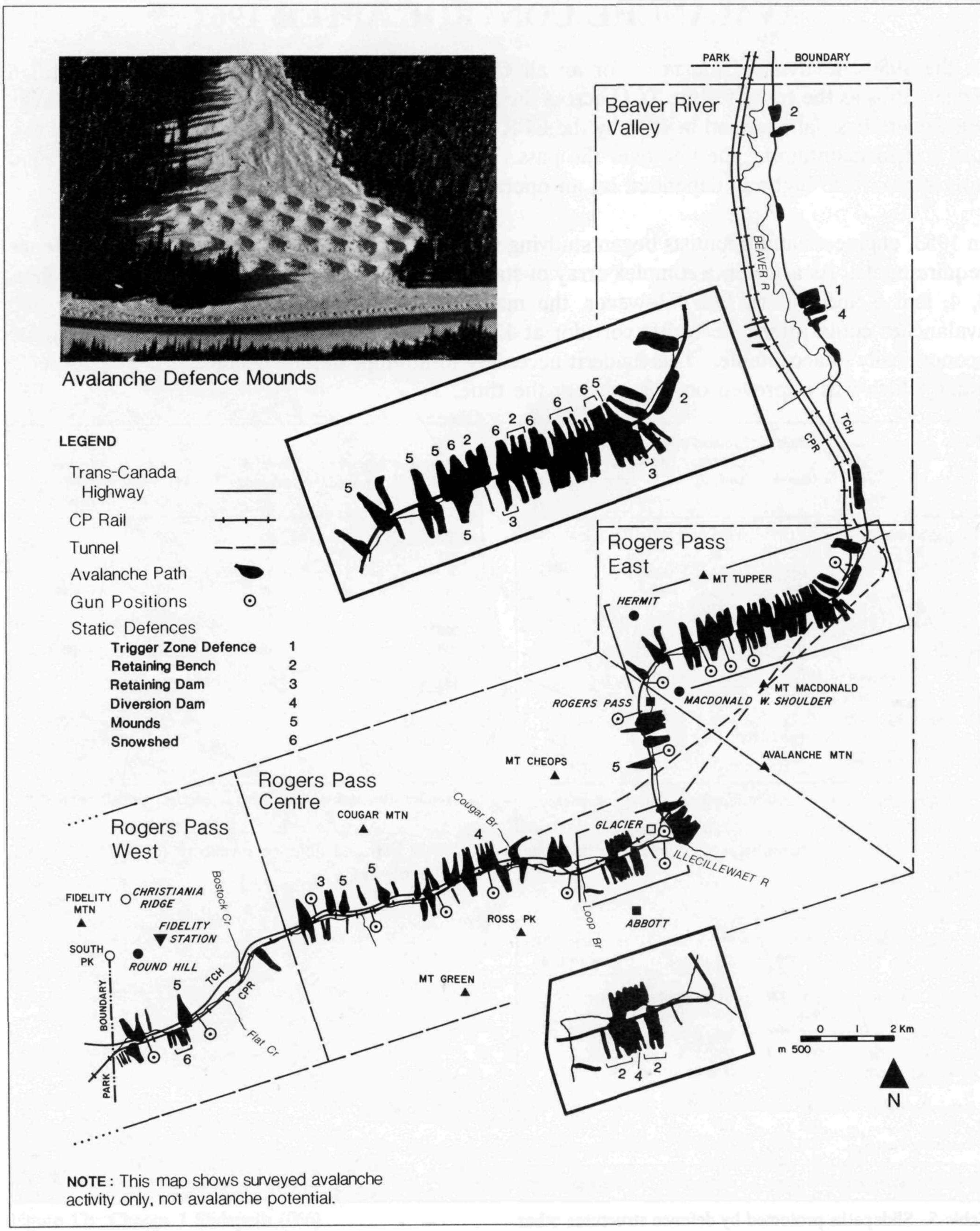

Figure 18: Static defence structures and gun positions, 1989

The national parks administration created SRAWS in 1959 to develop and operate a mobile control programme to protect the traffic corridor. This became a unit unique to Glacier National Park within the Canadian Parks Service. The unit was given 6 operational goals:

1. To develop an efficient method for evaluating and forecasting avalanche hazard conditions;
2. To develop a workable mobile avalanche control method for the TCH;
3. To incorporate all known and applicable defence methods into a comprehensive avalanche defence programme;
4. To implement and operate the avalanche defence programme;
5. To provide avalanche control for slidepaths which affect the CPR under the terms of a co-operative agreement; and,
6. To improve, update, and expand the programme as necessary.

SRAWS researched and developed a method (Schleiss and Schleiss 1970) of evaluating and forecasting avalanche hazard based on a combination of the Swiss method (profile evaluation) and the American method (ten point system). However, the scale of the Rogers Pass operation required additional techniques to facilitate the transmission of objective data on weather and snowpack instability from remote high elevation locations to avalanche forecasters stationed at the highway level.

The "shear test" was developed as an operational tool for this purpose. The scale of the avalanche control programme also required that the forecasters work shifts which lasted three to four days -- including rotation of forecasters during storms.

Research into numerous different mobile control methods resulted in the choice of artillery fire, carried out with a 105 mm Howitzer, as the optimal available means. The system was implemented on a trial basis from 1959 to 1962 (prior to the opening of the TCH) and results during the three winters confirmed the choice as a workable solution.

From 1962 to present, traffic has been protected from avalanches on a 24 hour a day basis during the avalanche season (October 1 to May 31) by an elaborate three part avalanche defence programme.

1. Mobile control.

Mobile control consists of artillery fire and road closures. The objective of this control is the timely removal of unstable snow under controlled conditions during the winter period. This accomplishes two goals. First, it reduces the avalanche hazard during the winter months. And secondly, by removing snow from the avalanche accumulation zones, it reduces the hazard in the spring when the snowpack becomes isothermal and impossible to stabilize using artillery fire.

Under the direction of the duty avalanche forecaster, the CPR and TCH are closed as required. Most closures are of short duration (less than three hours). The forecaster coordinates closures at manned gates, automated signs, and mobile roadblocks. This allows control actions for specific segments of the highway and railway while minimizing delays to traffic.

On a target-by-target basis, the forecaster directs a special detachment of the Canadian Army to fire the gun. When reasonable control has been achieved, the highway and railway are reopened. The forecaster may close the TCH when avalanche hazard conditions exceed the control parameters.

Artillery fire is used for the majority of avalanche paths in the control corridor. One hundred and seventy targets are engaged from 18 gun positions (Figure 18). Line-of-sight distances between the gun and the targets are up to 5 km over a vertical rise of up to 1.8 km. Operational demands necessitate blind firing capability since most control actions are required during storms and at night. Targets are registered with reference to aiming stakes in periods of good visibility.

2. Avalanche warnings signs.

Avalanche warning signs were installed where avalanches affect the TCH. Operational personnel can work in specific locations only after the forcaster has confirmed low avalanche hazard. The public may not stop in these areas at any time.

3. Static defences.

Static defences (Tables 3, 4, and 5 and Figure 18) were built where terrain features made control by artillery fire impossible or where mobile control alone was inadequate.

The TCH and CPR routes through Rogers Pass are the most heavily used highway and railway lines across Canada's western mountains. Despite this volume of traffic and the magnitude of the potential avalanche hazard, the control programme has been very successful. During 1962-88, the number of control actions ranged from 18 to 60 per winter and lasted from one hour to five days.

Ninety percent of the closures have been less than 3 hours in length. Although no member of the travelling public has been hurt, the potential for an accident always exists. An operational incident described in Woods (1986) illustrates the complexity of the operation and the variability of avalanches. The National Film Board movie production "Snow War" (1980) depicts the operational setup.

Increasing traffic volumes on both the TCH and CPR since 1962 have necessitated continual refinement of the defence programme (Table 6). Continued increases in traffic over the next twenty years could jeopardize the success of the control programme in the future.

Characteristic	1962/63	87/88	Change
Traffic per day (eastbound and westbound combined)	400	2069	+518 %
Avalanche paths with static defences	23	36	+156 %
Avalanche paths with mobile control (artillery)	47	68	+145 %
Number of targets for mobile control	70	170	+243 %
Seasonal Ammunition expenditure for stabilization	300	805*	+265 %

* seasonal ammunition useage during 1962-88 ranged from 300 to 1900

Table 6. Changes in key parmeters that affected the avalanche control programme in Glacier National Park, B.C. over the 25 year period from 1962-63 to 1987-88.

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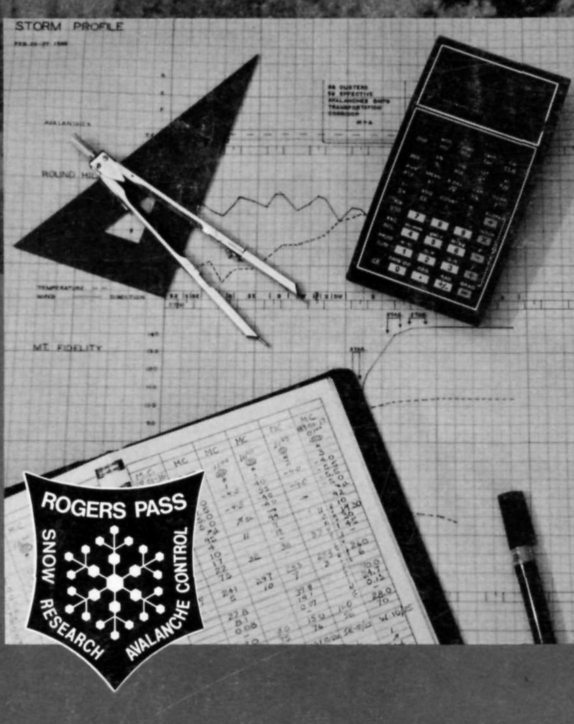

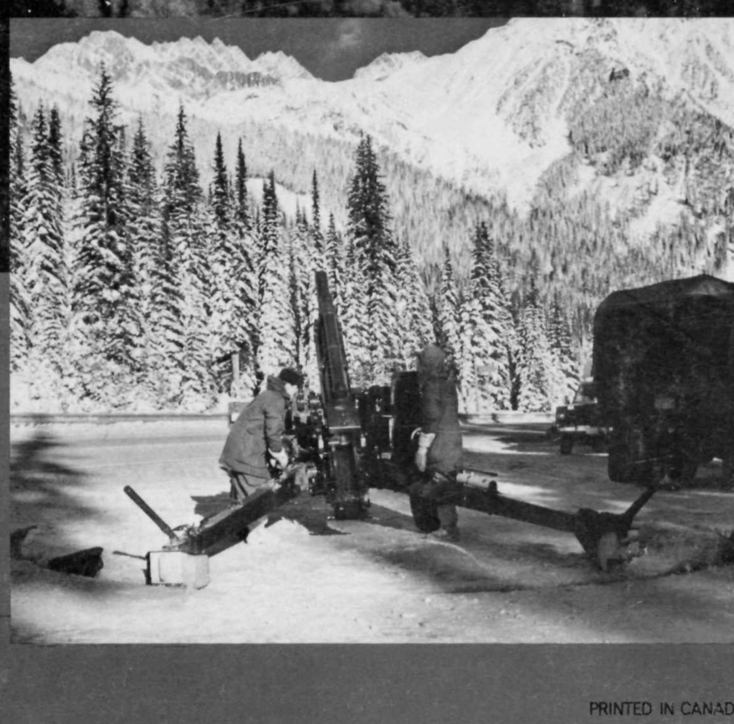

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