APPENDIX J

SNOW AVALANCHE REPORT

JUNEAU ACCESS IMPROVEMENTS
SUPPLEMENTAL DRAFT
ENVIRONMENTAL IMPACT STATEMENT

STATE PROJECT NUMBER: 71100
FEDERAL PROJECT NUMBER: STP-000S (131)

Prepared for

Alaska Department of Transportation and Public Facilities
6860 Glacier Highway
Juneau, Alaska 99801-7999

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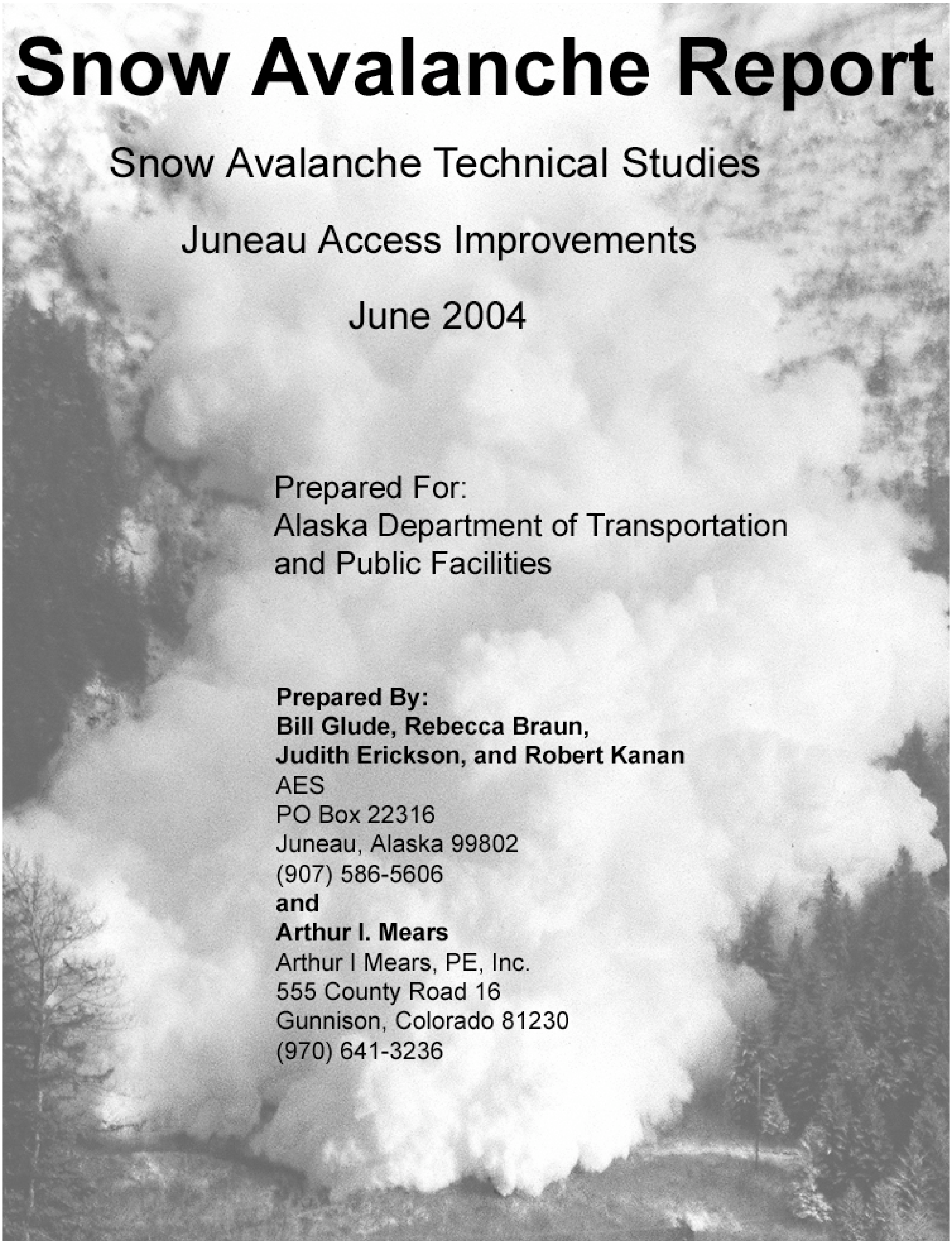
OCTOBER 2004



Snow Avalanche Report

Snow Avalanche Technical Studies

Juneau Access Improvements

June 2004

Prepared For:
Alaska Department of Transportation
and Public Facilities

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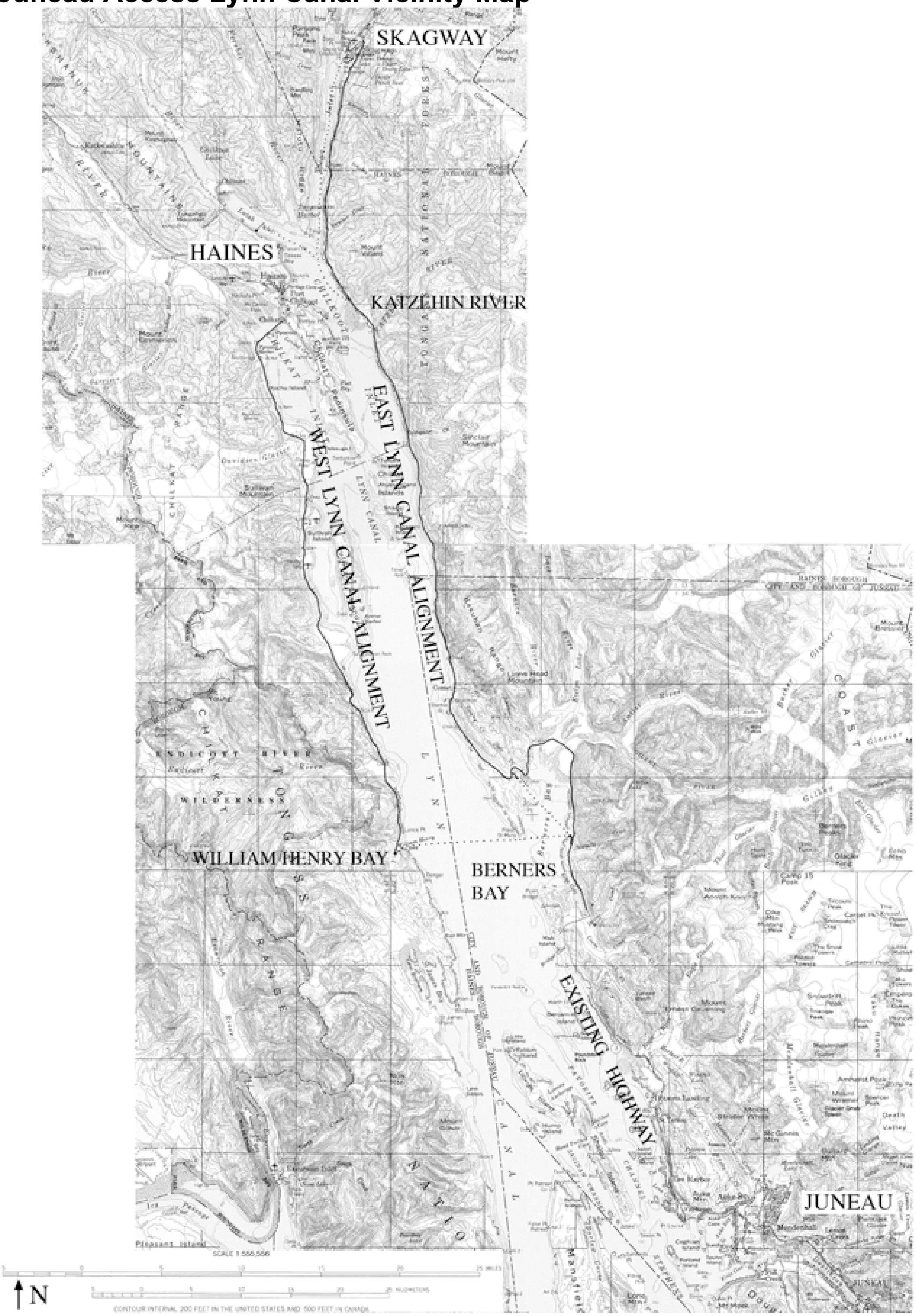
Juneau Access Lynn Canal Vicinity Map



Executive Summary

Introduction

One of the major challenges in designing and operating a highway on either of the two proposed routes out of Juneau is the snow avalanche paths along Lynn Canal. Avalanche hazard and mitigation options were evaluated for the proposed West Lynn Canal and East Lynn Canal highway alignments to find the most effective way to reduce avalanche risk to an acceptable level.

The East Lynn Canal alignment is affected by a total of 61 avalanche paths, and the West Lynn Canal alignment is affected by 17 paths.

Avalanche Hazard Index

Because avalanche paths vary widely in the size, frequency, and consequences of the slides they produce, the Avalanche Hazard Index (AHI) is preferred as a more accurate measure of risk than the total number of paths.

In the 1997 Draft Environmental Impact Statement (DEIS), the unmitigated AHI figure for the East Lynn Canal route (Alternative 2) was 369.5. Using more accurate survey data, refined alignments, long-term climate studies, and additional winter observations, the same avalanche consultants have calculated unmitigated AHI figures of 205 for the East Lynn Canal route and 100 for the West Lynn Canal route. *Both routes' unmitigated AHI figures are considered high or very high, but they are in the middle of the range for highways operated with good safety records in avalanche terrain.*

While it can be useful to compare unmitigated avalanche hazard figures, residual AHI is the most accurate measure of risk. In North America, a residual AHI of 30 or less after mitigation measures are applied is considered acceptable. ***Mitigation measures such as adjusting highway alignment, building bridges, forecasting avalanche cycles, implementing preventive closures, and using explosives could reduce the residual AHI to acceptable levels for all the alternatives and options studied here.***

Avalanche Mitigation: Hazard Reduction and Risk Management

Hazard reduction methods are physical changes such as constructing barriers or adjusting the alignment of the highway. *Risk management methods* include forecasting, warnings, highway closures, and explosives, which are used to release unstable snow while the highway is closed. Both methods would be necessary for the East and West Lynn Canal routes.

In addition, both routes could employ shuttle ferries to cross Lynn Canal and Taiya Inlet. Those ferries could carry northbound and southbound traffic between Haines, Skagway, and Juneau when the highway is closed. Very few highways in avalanche terrain have alternative transportation so readily available.

Results

The avalanche study shows that all options for the East and West Lynn Canal routes could use hazard reduction and risk management techniques to mitigate residual avalanche risk to the North American standard AHI of 30 or less.

Findings

Highway Project Overview

The Alaska Department of Transportation and Public Facilities (DOT&PF) is conducting environmental impact studies to examine the feasibility of constructing a highway north from Juneau to Haines or Skagway, both of which are connected to the North American highway system. Practical travel between Juneau and either Haines or Skagway is currently by ferry, other boats, or air.

Lynn Canal is a fjord stretching between Juneau and Haines and Skagway. Haines is on the west side of northern Lynn Canal, at the mouth of Chilkat Inlet, and Skagway is situated near the northern end of Lynn Canal, up Taiya Inlet north and east of Haines.

Two alternative highway alignments are being considered. The proposed East Lynn Canal alignment would begin at the northern end of Juneau's current road system on the south side of Berners Bay, and would extend about 68 miles (109 km) along the east side of Lynn Canal, connecting to the existing Klondike Highway in Skagway. A shuttle ferry would connect Haines and the new highway at the Katzehin River delta or Skagway.

One variation evaluated for this route, Alternative 2B, would end the highway at the Katzehin River and connect to Haines and Skagway by ferry. Another variation would bypass the head of Berners Bay with a ferry. The Berners Bay ferry variation is not evaluated separately because it would have almost no effect on avalanche concerns.

The other alternative is the West Lynn Canal alignment from William Henry Bay north, extending about 36 miles (58 km) to connect with the Mud Bay Road in Haines. The West Lynn Canal alternative would require a ferry crossing of Lynn Canal between Berners Bay and the southern end of the West Lynn Canal alignment at William Henry Bay, and a ferry from Haines to Skagway.

Avalanche Hazard

One of the major challenges to designing and operating either proposed highway is the snow avalanche paths along Lynn Canal. The proposed alignment along the east side of Lynn Canal is affected by 61 avalanche paths, including subpaths. The proposed alignment along the west side of Lynn Canal is affected by 17 avalanche paths, including subpaths.

The purpose of this document is to assess the extent and nature of the avalanche hazard, and to develop a range of programs for physically reducing that hazard where possible, and managing the residual risk to acceptable levels.

For purposes of assessing the avalanche hazard of the Lynn Canal routes and comparing them to other highways, the Avalanche Hazard Index (AHI) is used. The AHI is an index representing the probability of encounters between avalanches and vehicles on a highway and the likely damage.

The following list shows the classification of unmitigated AHI ranges. In North America, a residual AHI of 30 or less is accepted as an adequate level of mitigation.

Unmitigated AHI	Classification
<1	very low
1-10	low
10-40	moderate
40-100	high
>100	very high

Table 1, Avalanche Hazard Index (AHI) Comparison

Highway	Unmitigated AHI	Daily Obser-vations & Forecasts	Forecasting, Closure, & Explosives	Structural Mitigation	Special Explosives Methods
Rogers Pass, BC	**1004**	x	x	x	x
Red Mtn. Pass, CO	**335**	x	x	x	
* Seward Highway, AK (Anchorage-Seward, old alignment)	**331**	x	x	x	
East Lynn, AK	**205**	x	x	x	
* Seward Highway, AK (Anchorage-Girdwood, old alignment)	**188**	x	x	x	
Coal Bank/Molas, CO	**108**	x	x		
West Lynn, AK	**100**	x	x	x	
Berthoud Pass, CO	**93**	x	x		
Coquihalla, BC	**90**	x	x	x	x
Loveland Pass, CO	**80**	x	x		
Wolf Creek Pass, CO	**54**	x	x	x	
Silverton-Gladstone, CO	**49**	x	x		
Teton Pass, WY	**47**	x	x		x
Lizard Head Pass, CO	**39**	x	x		
I-70 Tunnel Approaches, CO	**27**	x	x	x	

* Historical data for AHI calculation is only available for the pre-1998 Seward Highway alignment.

Unmitigated AHI Comparison

The unmitigated AHI figures for the Lynn Canal alternatives are 205 for the East Lynn Canal route (186 for the Juneau to the Katzehin River portion only) and 100 for the West Lynn Canal route. These unmitigated AHIs are in the range considered high or very high, but are well within the range for highways that have achieved good operational risk management records through appropriate mitigation measures, as listed in Table 1.

Avalanche Mitigation

In designing an avalanche mitigation program, managers must combine two basic methods:

1.) Hazard Reduction

Hazard refers to the physical characteristics of the avalanche exposure. *Hazard reduction* encompasses any actions that reduce the hazard from avalanches, such as adjusting the highway alignment to avoid avalanche paths, or constructing physical barriers or snowsheds.

2.) Risk Management

Risk refers to the consequences of exposure to avalanches. *Risk management* practices reduce the avalanche risk to travelers through operational methods such as avalanche forecasting, warnings, highway closures, and explosives work to release unstable snow when the highway is closed. *Residual risk* is the risk that remains after mitigation through both hazard reduction and risk management.

A maximum hazard reduction program requires high initial investment but can minimize highway closures. A program based entirely on operational risk management has low initial costs but higher operating costs and highway closure times.

For example, maximum hazard reduction on the Coquihalla Highway in British Columbia has virtually eliminated the operational avalanche risk management program there. A maximum hazard reduction approach would be much more difficult in the terrain along Lynn Canal, but structural avalanche hazard reduction investments could reduce highway closure times and would be likely to reduce operational risk management costs as well.

Lynn Canal Mitigation - Options

The mitigation options evaluated here for the Lynn Canal routes combine both hazard reduction and risk management approaches to provide a range of solutions that balance cost and closure time while managing residual risk to the accepted standard.

The East and West Lynn Canal highway alignments have been adjusted to reduce the avalanche hazard. The routes avoid avalanche paths wherever possible and cross the unavoidable paths at the lowest-hazard locations. Bridges span above some slide paths. The highway alignment has been moved onto fill in shallow water to reduce avalanche hazard on some paths. Elevated fills that raise the highway above the avalanche flow level further reduce the hazard at other locations. Snowsheds that carry slides over the highway while allowing traffic to flow unimpeded through them are considered in some mitigation options.

The remaining avalanche hazard is managed in all mitigation options through an industry-standard program of risk management using a combination of forecasting, explosives, and preventive highway closures. The goal is to reduce the residual avalanche risk to levels commonly accepted on highways throughout North America, equivalent to a residual AHI value of 30 or less.

Both the East and West Lynn Canal routes have an unusual safety factor in that both could employ shuttle ferries to cross Lynn Canal and Taiya Inlet. The shuttle ferries could be used to carry north-southbound traffic when the highway is closed. Few avalanche-prone highways have alternative transportation so readily available. Avalanche closures occur during the lowest traffic season of the year, and even when the highway must be closed, travel could be possible more frequently than it is under the current ferry schedule.

The combined hazard reduction and risk management options evaluated here differ primarily in their methods of explosives delivery and in the use of snowsheds on the East Lynn Canal route. *All these mitigation options achieve the target residual AHI of 30 or less, but the methods have different initial (capital) costs, ongoing (operating) costs, and anticipated highway closure times.*

Lynn Canal Mitigation Options – Explosive Delivery

The following explosive delivery methods were used to develop the mitigation options:

Helicopter placement: Explosive charges are dropped by hand from a low-hovering helicopter with the door removed. The helicopter time is expensive, but the explosive charges are relatively cheap, and helicopter delivery has proven to be an effective, accurate, and flexible method for covering a large area in a short time. The major disadvantage in the stormy climate of northern Southeast Alaska is that helicopter delivery requires calm ridgetop winds and good visibility. The lack of such flying weather could result in substantial delays and missed opportunities.

105mm howitzer: The 105mm howitzer is the current artillery weapon of choice for avalanche work. Its accurate working range is over five miles, and it can be blind-fired under poor visibility once coordinates are developed for each position. Howitzers can be used in storms with light to moderate winds, but their accuracy suffers when winds are strong. Howitzers could be trailered to sites along the highway, or stored in secure enclosures for firing from remote locations.

Blaster boxes: Blaster boxes are secure steel cabinets mounted on a mast in avalanche-protected locations from which they can fire pre-targeted mortar rounds into avalanche starting zones by remote control. Blaster boxes are one of several special explosive delivery methods using a fixed installation. They are evaluated here as a representative example of the fixed installation methods currently available. Like many of these methods, they are relatively new technology that may prove to be limited by such coastal climate factors as rime ice buildup and heavy midwinter rains. They require helicopter flights to nearby landing zones to deliver the rounds, can fire only 10 shots before reloading, require setup and maintenance time, and have a high initial installed cost, but they allow explosive delivery by one operator, even under stormy conditions.

This report analyzes combinations of the above methods to develop six combined explosive delivery and snowshed options; four for the East Lynn Canal alignment, and two for the West Lynn Canal alignment.

The residual risk figures for all these mitigation options achieve the target residual AHI of 30 or less. All mitigation options include some elevated fills and bridges that reduce the hazard, and all are based on a standard risk management program of avalanche forecasting, explosives delivery, and preventive closure.

All East Lynn Canal mitigation options require either extended closures or snowsheds on four key paths (ELC 006,019, 020, and 021) to reach the target residual risk. The "A" options assume there would be no snowsheds, and use extended closures. The "B" options include snowsheds on the four paths with the highest AHI.

The West Lynn Canal mitigation options do not require additional mitigation to reach the target residual risk.

East Lynn Canal Mitigation Options:

ELC 1 Options, East Lynn Canal, helicopter delivery only:

a. Option ELC 1A:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, without snowsheds, using helicopter explosive delivery only*.

Helicopter explosive placement is simple, flexible, and economical, but is limited by flying weather that can result in delays and missed opportunities.

b. Option ELC 1A, Alt.2B:

This option is for an East Lynn Canal alignment from *Juneau to the Katzehin River*, across from Haines, with ferry connections to Haines and Skagway, *without snowsheds, using helicopter explosive delivery only*. This option is the only combination evaluated for this EIS alternative.

Helicopter explosive placement is simple, flexible, and economical, but is limited by flying weather that can result in delays and missed opportunities.

c. Option ELC 1B:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, with snowsheds, using helicopter explosive delivery only*.

Helicopter explosive placement is simple, flexible, and economical, but is limited by flying weather that can result in delays and missed opportunities.

ELC 2 Options, East Lynn Canal, howitzer delivery, supplemented by blaster box and helicopter:

a. ELC 2A:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, without snowsheds, using howitzer explosive delivery wherever possible*. Where howitzer delivery is not possible, a combination of blaster boxes on the more active paths and helicopter delivery on the less active paths would be used.

Howitzers could be housed in secure enclosures on Eldred Rock, Anyaka Island, and near the end of the Chilkat Peninsula to target the major Eldred Rock and North and South Yeldagalga path groups. Crews would helicopter to the howitzer locations. Storms could limit operations, but flying conditions at sea level are generally more favorable than at starting zone elevations.

Paths ELC040 A through D could be hit by a trailered howitzer fired from a pad at Tanani Point on the Lutak Road just north of Haines.

Major paths ELC002, ELC049, ELC050, and ELC051 could have blaster boxes.

The remaining paths run infrequently and could be managed with occasional helicopter missions.

This option provides explosive delivery to the major paths under most storm conditions, which could allow the highway to be open more than under the helicopter-only options, but it requires substantial helicopter time to reach the firing locations and load the blaster boxes, as well as expensive howitzer and blaster box installations.

Permits for the howitzer sites would be needed from the U.S. Coast Guard for Eldred Rock and from the Alaska Department of Natural Resources for the other sites, which are located in state parks.

b. Option ELC 2B:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, with snowsheds, using howitzer explosive delivery wherever possible*. Where howitzer delivery is not possible, a combination of blaster boxes on the more active paths and helicopter delivery on the less active paths would be used.

Howitzers could be housed in secure enclosures on Eldred Rock, Anyaka Island, and near the end of the Chilkat Peninsula to target the major Eldred Rock and North and South Yeldagalga path groups. Crews would helicopter to the howitzer locations. Storms could limit operations, but flying conditions at sea level are generally more favorable than at starting zone elevations.

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Permits for the howitzer sites would be needed from the U.S. Coast Guard for Eldred Rock and from the Alaska Department of Natural Resources for the other sites, which are located in state parks.

ELC 3 Options, East Lynn Canal, blaster box delivery, supplemented by helicopter:

a. Option ELC 3A:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, without snowsheds, using blaster boxes on all the major paths*, and helicopter delivery for the paths that require less frequent explosive work.

One person can fire the blaster boxes in storm conditions or at night. Clearing debris, however, still requires a crew and daylight.

Blaster box installation on so many paths is expensive, but it minimizes road closure time with less capital investment than the howitzer option.

b. Option ELC 3B:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, with snowsheds, using blaster boxes on all the major paths*, and helicopter delivery for the paths that require less frequent explosive work.

One person can fire the blaster boxes in storm conditions or at night. Clearing debris, however, still requires a crew and daylight.

Blaster box installation on so many paths is expensive, but it minimizes road closure time with less capital investment than the howitzer option.

ELC 4 Options, East Lynn Canal, blaster box delivery to the highest-hazard paths, supplemented by helicopter:

a. Option ELC 4A:

This option is for an East Lynn Canal alignment from *Juneau to Skagway, without snowsheds, using blaster boxes on the top 10 paths* on the avalanche hazard index, and helicopter delivery for the paths that require less frequent explosive work.

One person can fire the blaster boxes in storm conditions or at night. Clearing debris, however, still requires a crew and daylight.

Targeted use of blaster boxes on the highest AHI paths makes this option more efficient than the options that use blaster boxes on all the major paths. Several major paths, as well as the infrequent-running paths, would still require helicopter explosive delivery, so highway closures would not be reduced as much as under the options with more blaster boxes.

a. *Option ELC 4B:*

This option is for an East Lynn Canal alignment from *Juneau to Skagway, with snowsheds, using blaster boxes on the top 10 paths* on the avalanche hazard index, and helicopter delivery for the paths that require less frequent explosive work.

One person can fire the blaster boxes in storm conditions or at night. Clearing debris, however, still requires a crew and daylight.

Targeted use of blaster boxes on the highest AHI paths makes this option more efficient than the options that use blaster boxes on all the major paths. Several major paths, as well as the infrequent-running paths, would still require helicopter explosive delivery, so highway closures would not be reduced as much as under the options with more blaster boxes.

West Lynn Canal Mitigation Options

Option WLC 1, West Lynn Canal, howitzer delivery only:

A howitzer could hit all the paths on the West Lynn route from a total of five firing locations. One howitzer could be towed to the firing locations. There could be one highway-side pad on the Chilkat River crossing, and four pads on river deltas.

This option is simple, reliable, and inexpensive. Firing locations could be reached by highway in most weather conditions, and blind firing is possible, though high winds could sometimes limit operations. This option has lower total closure time than any of the East Lynn Canal options, but has more closure time than option WLC 2.

Option WLC 2, West Lynn Canal, blaster box delivery on the highest-hazard paths, supplemented by howitzer delivery:

This option uses blaster boxes on the major South Sullivan River, Sullivan, Rainbow, and Pyramid paths, and uses a howitzer for the infrequently running paths.

This option has the lowest closure time of any option studied, but has high initial capital cost and high helicopter cost for loading the blaster boxes.

Comparison of Mitigation Options

The mitigation options are compared in terms of cost, total closure days (total hours divided by 24), and residual avalanche hazard index (AHI) figures in Tables 2A-D. The capital budget covers equipment and supplies to start up the avalanche program. The operating budget includes the annual costs, including replacement costs for capital items.

Tables 2A-D are sorted for comparison by option, capital budget, operating budget, and total closure time. East and West Lynn Canal options are kept separate.

The operating savings in snow removal and explosives delivery due to snowsheds are approximately balanced by increased maintenance. The tradeoff produces no significant change in the operating budget, so the same operating budget figures are used for the A and B options.

Table 2A, Costs, Closures and Residual AHI, by Explosive Delivery Option

Explosive Delivery Option	Capital Budget	Operating Budget	Average Closure Time/yr (days)	Average Number of Closures/yr	Range of Closure Length (days)	Residual AHI
ELC 1A helicopter only, no snowsheds	$2,790,170	$749,556	34.5	16.5	0.8-8.0	29.4
ELC 1A, Alt. 2B, same as ELC1 A, but for Juneau - Katzehin Route	$2,668,070	$719,446	33.9	16.5	0.8-7.8	26.5
ELC 1B, helicopter only, with snowsheds	$20,990,170	$749,556*	23.0	11.0	0.5-5.4	17.8
ELC 2A, howitzer, plus blaster boxes & helicopter, no snowsheds	$19,899,428	$1,044,898	21.1	16.5	0.6-4.1	29.4
ELC 2B, howitzer, plus blaster boxes & helicopter, with snowsheds	$38,099,428	$1,044,898*	14.1	11.0	0.4-2.7	17.8
ELC 3A, blaster boxes, plus helicopter, no snowsheds	$9,391,170	$1,228,489	16.1	16.5	0.6-2.2	29.4
ELC 3B, blaster boxes, plus helicopter, with snowsheds	$27,591,170	$1,228,489*	10.8	11.0	0.4-1.5	17.8
ELC 4A, blaster boxes on highest-AHI, plus helicopter, no snowsheds	$8,041,170	$1,120,361	29.9	16.5	0.8-6.1	29.4
ELC 4B, blaster boxes on highest-AHI, plus helicopter, with snowsheds	$26,241,170	$1,120,361*	19.9	11.0	0.5-4.1	17.8
WLC 1, all howitzer, no snowsheds	$2,642,055	$733,969	6.4	10.8	0.4-0.9	14.6
WLC 2, blaster boxes on highest-AHI, plus howitzer, no snowsheds	$6,685,521	$912,769	5.5	8.4	0.4-0.9	14.6

* The savings due to snowsheds are approximately balanced by increased maintenance.

Table 2B, Costs, Closures and Residual Avalanche Hazard Index (AHI), by Capital Budget

Explosive Delivery Option	Capital Budget	Operating Budget	Average Closure Time/yr (days)	Average Number of Closures/yr	Range of Closure Length (days)	Residual AHI
ELC 1A, Alt. 2B, same as ELC1A, but for Juneau - Katzehin Route	**$2,668,070**	$719,446	33.9	16.5	0.8-7.8	26.5
ELC 1A helicopter only, no snowsheds	**$2,790,170**	$749,556	34.5	16.5	0.8-8.0	29.4
ELC 4A, blaster boxes on highest-AHI, plus helicopter, no snowsheds	**$8,041,170**	$1,120,361	29.9	16.5	0.8-6.1	29.4
ELC 3A, blaster boxes, plus helicopter, no snowsheds	**$9,391,170**	$1,228,489	16.1	16.5	0.6-2.2	29.4
ELC 2A, howitzer, plus blaster boxes & helicopter, no snowsheds	**$19,899,428**	$1,044,898	21.1	16.5	0.6-4.1	29.4
ELC 1B, helicopter only, with snowsheds	**$20,990,170**	$749,556*	23.0	11.0	0.5-5.4	17.8
ELC 4B, blaster boxes on highest-AHI, plus helicopter, with snowsheds	**$26,241,170**	$1,120,361*	19.9	11.0	0.5-4.1	17.8
ELC 3B, blaster boxes, plus helicopter, with snowsheds	**$27,591,170**	$1,228,489*	10.8	11.0	0.4-1.5	17.8
ELC 2B, howitzer, plus blaster boxes & helicopter, with snowsheds	**$38,099,428**	$1,044,898*	14.1	11.0	0.4-2.7	17.8
WLC 1, all howitzer, no snowsheds	**$2,642,055**	$733,969	6.4	10.8	0.4-0.9	14.6
WLC 2, blaster boxes on highest-AHI, plus howitzer, no snowsheds	**$6,685,521**	$912,769	5.5	8.4	0.4-0.9	14.6

* The savings due to snowsheds are approximately balanced by increased maintenance.

Table 2C, Costs, Closures and Residual Avalanche Hazard Index (AHI), by Operating Budget

Explosive Delivery Option	Capital Budget	Operating Budget	Average Closure Time/yr (days)	Average Number of Closures/yr	Range of Closure Length (days)	Residual AHI
ELC 1A, Alt. 2B, same as ELC 1A, but for Juneau - Katzehin Route	$2,668,070	**$719,446**	33.9	16.5	0.8-7.8	26.5
ELC 1A helicopter only, no snowsheds	$2,790,170	**$749,556**	34.5	16.5	0.8-8.0	29.4
ELC 1B, helicopter only, with snowsheds	$20,990,170	**$749,556***	23.0	11.0	0.5-5.4	17.8
ELC 2A, howitzer, plus blaster boxes & helicopter, no snowsheds	$19,899,428	**$1,044,898**	21.1	16.5	0.6-4.1	29.4
ELC 2B, howitzer, plus blaster boxes & helicopter, with snowsheds	$38,099,428	**$1,044,898***	14.1	11.0	0.4-2.7	17.8
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WLC 2, blaster boxes on highest-AHI, plus howitzer, no snowsheds	$6,685,521	**$912,769**	5.5	8.4	0.4-0.9	14.6

* The savings due to snowsheds are approximately balanced by increased maintenance.

Table 2D, Costs, Closures and Residual Avalanche Hazard Index (AHI), by Closure Time

Explosive Delivery Option	Capital Budget	Operating Budget	Average Closure Time/yr (days)	Average Number of Closures/yr	Range of Closure Length (days)	Residual AHI
ELC 3B, blaster boxes, plus helicopter, with snowsheds	$27,591,170	$1,228,489*	**10.8**	11.0	0.4-1.5	17.8
ELC 2B, howitzer, plus blaster boxes & helicopter, with snowsheds	$38,099,428	$1,044,898*	**14.1**	11.0	0.4-2.7	17.8
ELC 3A, blaster boxes, plus helicopter, no snowsheds	$9,391,170	$1,228,489	**16.1**	16.5	0.6-2.2	29.4
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ELC 2A, howitzer, plus blaster boxes & helicopter, no snowsheds	$19,899,428	$1,044,898	**21.1**	16.5	0.6-4.1	29.4
ELC 1B, helicopter only, with snowsheds	$20,990,170	$749,556*	**23.0**	11.0	0.5-5.4	17.8
ELC 4A, blaster boxes on highest-AHI, plus helicopter, no snowsheds	$8,041,170	$1,120,361	**29.9**	16.5	0.8-6.1	29.4
ELC 1A, Alt. 2B, same as ELC 1A, but for Juneau - Katzehin Route	$2,668,070	$719,446	**33.9**	16.5	0.8-7.8	26.5
ELC 1A helicopter only, no snowsheds	$2,790,170	$749,556	**34.5**	16.5	0.8-8.0	29.4
WLC 2, blaster boxes on highest-AHI, plus howitzer, no snowsheds	$6,685,521	$912,769	**5.5**	8.4	0.4-0.9	14.6
WLC 1, all howitzer, no snowsheds	$2,642,055	$733,969	**6.4**	10.8	0.4-0.9	14.6

* The savings due to snowsheds are approximately balanced by increased maintenance.

Avalanche Hazard

Avalanche Event Variability

As is customary in a study of this nature, budgets, operational decisions, and expected events are presented as averages. This is a useful convention, and over the long term, averages prove accurate.

Avalanche events, however, are by nature given to extremes. Average winters or average cycles rarely occur. DOT&PF budgets already accommodate this variability by means of supplemental budget requests in heavy-snow years.

Alaska avalanche specialist Doug Fesler notes that it is common for more active winters to have about two-and-a-half times as much avalanche activity as quieter winters. In the timeframe of the short-term variability of a ten-year cycle, this is an accurate approximation.

In the timeframe of the 30-year, 100-year, and 300-year events, there will be about 10 to 100 times as much avalanche activity in the big years as in quieter winters, and the size of the avalanches will show a similar range of variability. Operational planning for these rare but large events must maintain risk management standards as the uncompromised first priority.

Other years may have far less than average activity. It is important to avoid the human tendency to regard these short-term variations as trends, and budgetary planning should always consider the more severe winters that inevitably follow. Poor budgeting results in increased closure time.

There is a learning curve in the early years of any avalanche program. Lower efficiency should be anticipated in the first three years, as the program is developed.

Lynn Canal is a dynamic, high-energy environment, subject to constant change. During six years of avalanche observations, one new avalanche path was created by landslide activity. Changes will continue to occur. Avalanches may entrain wet or unstable ground material, and earth movements may influence avalanche activity. *The analysis in this report is for the avalanche paths as they are today. The programs outlined here have the flexibility to accommodate change, and managers should be prepared to accommodate change as well.*

Avalanche Hazard Index (AHI) Overview

The *Avalanche Hazard Index (AHI)* is a dimensionless number representing the probability of encounters between avalanches and vehicles on a highway and the resulting damage. It was developed in 1974 in Canada (Avalanche Task Force, 1974), and published in its current form by Peter Schaerer in 1989. It provides a uniform standard for comparing this probability from one avalanche path to another. Such a standard is also useful for comparing highway avalanche hazards from one region or snow climate to another.

AHIs were calculated for the proposed East and West Lynn Canal highway alignments, and for the old alignment of the Seward Highway (historical data is not yet available for the new highway) to provide an Alaskan comparison. The other highway AHIs cited for comparison come from other studies.

Following is a conceptual explanation of how an AHI is calculated. The formulae and mathematical details of AHI calculations for this study are explained and illustrated in Technical Appendices 1 through 3.

The chance of a moving vehicle being hit at any given avalanche path, or multiple paths, can be estimated based on the average size and frequency of an avalanche on a given path; the average daily traffic count (ADT) in vehicles per day; the typical vehicle size, and typical driving speeds. *For the DOT&PF-estimated winter ADT of 450 for the East Lynn Canal highway route and 300 for the West Lynn Canal route in year 2038, the encounter probability between a moving vehicle and an avalanche is quite low.*

The more complicated part develops when a fallen avalanche blocks the highway, bringing traffic flow to a halt. The encounter probability between a vehicle and avalanche then increases.

First, in winter driving conditions, a vehicle is more likely to run into the fallen avalanche debris. *Among avalanche workers, this is known as Bachman's Law: cars hit avalanches more often than avalanches hit cars.*

Second, the stalled vehicle plus those stacking up behind it are more susceptible to another avalanche on the same path or adjacent paths. This is where a major part of the encounter probability and damage risk lies. Calculating this factor involves estimating vehicle spacing, stopping distances and chances of additional avalanches.

The potential damage is taken into account by weighting the calculation by probable avalanche size. Small avalanches (light snow crossing the highway up to one meter deep) may move a light vehicle but not inflict serious damage or injury, provided there is a guardrail or wide shoulder. Such an avalanche gets a numerical weighting of 3. A bigger, faster avalanche that can exceed 1-meter depth and push or seriously damage a vehicle and inflict injury or death to occupants is weighted at 10. A more severe type, a plunging avalanche hitting the highway at high speed or tumbling vehicles off the highway with even greater damage potential, is weighted at 12.

Where a long record of avalanche occurrence exists, for instance with paths intersecting a long-established highway, the occurrence frequency (or its inverse, the return period) for different avalanche sizes is readily established. For the Lynn Canal routes, occurrence data is limited to six field seasons of observation, and the return periods must sometimes be obtained indirectly. This is done by extrapolation from the available reconnaissance data and from avalanche path data in areas around Juneau where a longer record exists.

Interpretation of avalanche path characteristics such as degree and extent of vegetation damage also plays a role. *In northern Southeast*

Alaska, for example, the limit of the last 30-year avalanche cycle is clearly visible as a line delineating trees of different ages.

These extrapolations are incorporated in the AHI calculations. They also come into play for calculating typical volumes of snow deposited on the proposed highway and consequent volumes of avalanche debris that must be removed in order to re-open the highway.

In the avalanche atlas section of this report some paths list an AHI of zero. Any paths that might possibly affect an alignment were included in the identification, mapping, and numbering. Paths avoided by the current proposed alignments have an AHI of zero, but are retained in the mapping and numbering system because they are still there, and must be considered in any further design and evaluation work.

AHI Changes from 1995 Avalanche Study

The AHIs for the East Lynn Canal route differ from those in the original 1995 study of the route (Mears and Glude, Snow Avalanche Technical Report, Environmental Impact Statement Considerations, Juneau Access Route EIS, 1995) due to several changes:

1. *A more precise alignment has been delineated.* In previous studies, it was necessary to consider any avalanche reaching a much broader corridor as a "hit." Because the previous corridor extended farther uphill and the frequency of avalanches increases with elevation, the number of avalanches reaching alignment dropped sharply when it was shifted.
2. *The alignment has been adjusted to avoid as many paths as possible.* All the avoided paths were previously counted as potentially affecting the alignment.
3. *The current alignment crosses the remaining paths at the lowest-hazard location wherever possible.* These changes reduce both avalanche frequency and severity.
4. *Data from six years of field observations and long-term climate analysis have been incorporated* to reduce the uncertainty in the frequency and type of avalanches used to calculate the AHI.

As mentioned in the summary at the beginning of this report, the unmitigated AHIs for both the East and West Lynn Canal alternatives (205 and 100, respectively) are in the "very high hazard" or "high hazard" category. *According to Schaerer (1989) and Mears (1993) a highway with an AHI over 40 should have a full program of mitigation through hazard reduction and risk management, as discussed in the mitigation section of this report, to reach the target residual AHI of 30 or less.*

Avalanche Debris Deposited on the Highway

Avalanche debris must be cleared from a highway before reopening. Debris may consist of clean snow but often also contains entrained vegetation, rocks, and soil. Avalanche debris is compressed to a density that is typically two to three times the snow density in the upper portions of the avalanche path. Transportation departments are usually able to calculate a per-unit cost estimate for snow removal; avalanche debris removal, because it is deeper, stronger, and denser, is an additional cost. *The budget calculations in this report use avalanche debris removal costs based on DOT&PF records.*

An average annual volume of avalanche debris deposited on the proposed highway alignment was estimated as part of the AHI calculations using the following procedure:

1. The annual frequency and width (length on highway) of light, deep, and plunging avalanches were calculated.

2. An average highway width of 45 feet (13.7m) was assumed for two driving lanes and shoulders that would need to be cleared of debris. Average highway width was multiplied by avalanche width to determine the highway area covered.

3. An average debris depth of four feet (1.2m) was assumed based on author Arthur I Mears' experience, understanding that the depth will usually be greater on the side of the highway closest to the avalanche and less on the downhill side; the four foot (1.2m) depth is an average of the more frequent light-snow avalanches (in the one to four foot (0.3 to 1.2m) depth range), and the less frequent deep snow avalanches.

Mitigation measures may cause the debris volumes listed in Table 3 to depart from this estimate. The volumes listed are spreadsheet output and are not rounded. Their level of precision is to the nearest thousand.

Table 3: Average Annual Debris Volumes

Alignment alternative	Average annual debris
East Lynn Canal	53,467 cubic yards (40,878 cubic meters)
East Lynn Canal, Juneau to Katzehin River	47,752 cubic yards (36,509 cubic meters)
West Lynn Canal	29,775 cubic yards (22,764 cubic meters)

Snowfall

Following are average seasonal snowfall figures from the climate database at the Juneau National Weather Service Forecast Office, listed from south to north and rounded to the nearest inch or tenth of a meter. All stations except Pleasant Camp are at sea level. These figures are for the snow season period of October 1 - April 30. The period of record varies from location to location, and includes both El Niño (a cyclical warming of sea temperature) and La Niña (a cooling sea temperature cycle) conditions.

Juneau Airport	96" (2.4m)
Lena Point	79" (2.0m)
Tee-Harbor area	145" (3.7m)
Haines downtown	79" (2.0m)

Haines Airport	171" (4.3m)
Haines Highway, Pleasant Camp	250" (6.4m)
Skagway Airport	52" (1.3m)
Skagway (harbor)	37" (0.9m)

Retired National Weather Service meteorologist Robert Kanan's best estimate of Lynn Canal average seasonal snowfall at sea level, away from the base of the mountains, is about 140" (3.6m) in the area from just north of Lena Point north to a line approximately from the Endicott River to Berners Bay. He estimates snowfall north of the Endicott River to Berners Bay line to Haines at about 100" (2.5m). This distribution is mostly due to longer duration snowfall along, and within a few miles north of, the cold air mass of the Arctic front when it becomes stationary across Lynn Canal.

Average snowfall at the Haines Highway Pleasant Camp Customs Station, at the base of the pass at 900' (274m) elevation is 316 percent of the Haines downtown figure. That is the same 3 times (3x) magnitude increase as the summer precipitation from downtown Juneau, compared to the backside of Mount Juneau at about 2500-2800 feet (760-855m), according to mid-1960s Bureau of Land Management data studied by Robert Kanan.

Thane Road avalanche studies done for DOT&PF by Fesler, Mears, and Fredston in 1990 support the 3x sea level versus mountain precipitation multiplier. They found that snow depths recorded by the Soil Conservation Service at 1650' (500m) elevation at Cropley Lake near Eaglecrest ski area were between 2.5 and 3.4 times those at 500' (150m) elevation in the same Fish Creek drainage on Douglas Island. Precipitation reported in circa-1917 Gastineau Mining Co. records for Sheep Creek, on the Juneau-area mainland at 690' (210m), and at Perseverance Mine, at 1180' (360m) in the Gold Creek valley behind downtown Juneau were roughly 2.5 times greater than those recorded in Juneau for the same period.

This precipitation difference between sea level and higher elevation of about 300 percent, especially with steep terrain, is thought by Kanan to hold consistent in similar circumstances. If two locations are reasonably near each other, and exposed to similar wind flow, the primary cause of differences in precipitation with respect to elevation is orographic lifting, which causes increased precipitation as moist air rises and cools when it moves over the mountains.

Snowfall estimates along Lynn Canal are based on sparse data. The snow gradient is probably greater across Lynn Canal from west to east over a distance of about 10 miles (16.1km) than the snow gradient along the 60 miles (96.6km) of Lynn Canal from south to north. This is because of the orographic lifting effects of the steeper terrain, especially on the east side. The Taiya Inlet area, specifically Skagway, is often under the influence of strong downslope conditions that reduce precipitation in snow events, resulting in much less snow near sea level.

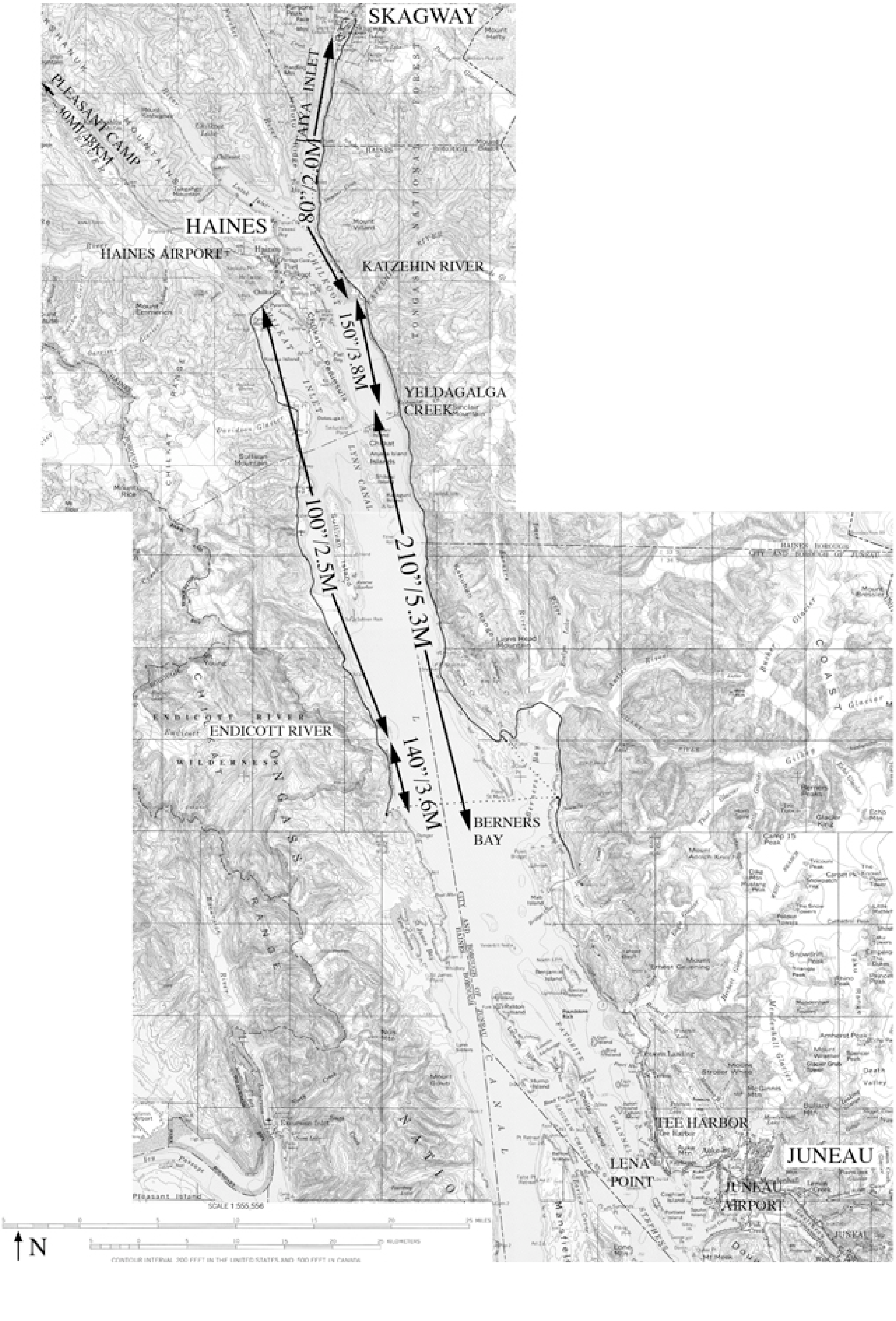
For example, Skagway had 455 consecutive days with no measurable snowfall from November 29, 1937 to December 29, 1938. The Haines area snowfall gradient increases up the Chilkat River because it also becomes closer to steep terrain. Haines can get very large snowfalls; for example, on February 1, 1991 Haines received 38" (0.97m) in one day. Proximity to steep terrain may be the most important factor for snowfall near sea level. The Annex Creek Power Plant on Taku Inlet is a good example, with an average of 244" (6.2m) of snow per year.

The contrast between Lena Point and Tee Harbor is probably the result of southerly low-level flow being diverted around Auke Mountain to create an area of low-level convergence, which increases precipitation as airmasses meet in the vicinity of Tee Harbor. A similar low-level convergence area extending farther north probably occurs due to the funneling effect of the Montana Creek to Windfall Lake corridor.

These factors suggest that the snowfall along the base of the mountains on the east side is higher than over Lynn Canal, probably not by the full 300 percent it is at altitude, but very likely 150 percent of the amount farther away from the mountains. *That 150 percent correction yields snowfall figures of 210” (5.3m) from the Berners Bay area to Yeldagalga Creek, 150” (3.8m) from Yeldagalga Creek to the Katzehin River, and 80” (2.0m) from the Katzehin up Taiya Inlet to Skagway. The average of these three figures is 147” (3.7m) for the East Lynn alignment as a whole.*

The West Lynn side is somewhat drier due to the downslope flow component there, but the close proximity of high mountains to the alignment balances that effect. Snowfall at starting zone elevations is comparable to that on the east side, but sea-level snowfall is more comparable to that over the water. *That suggests snowfall of 140” (3.6m) from William Henry Bay to the Endicott River area, and 100” (2.5m) from there to Haines. The average for the West side is thus estimated at 120” (3.0m).*

Lynn Canal Highway Snowfall Map



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Avalanche Mitigation

Avalanche mitigation is the use of *hazard reduction* and *risk management* to reduce the avalanche risk on a given highway. Table 4 shows risk-reduction figures, expressed as a proportion of the unmitigated risk, for the few highways in Switzerland (CH), British Columbia (BC) and Colorado (CO) which have documentation of the effectiveness of their avalanche programs. The range of residual risk cited in the studies for each highway is listed, as is its average. The average for all the highways studied is listed at the bottom of the table.

Table 4, Highway Residual Avalanche Hazard Index (AHI) Comparison

Highway	Residual Risk Range	Average Residual Risk	Daily Observa-tions & Forecasts	Forecasting, Closure, & Explosives	Structural Mitigation; Special Explosives Methods
Coquihalla Hwy, BC+	0.18 - 0.40	0.38	minimal	minimal	full
Icefields Parkway, BC*	0.26	0.26	intermittent	intermittent	none
Fluela Pass, CH+	0.23 - 0.29	0.26	normal	normal	explosives
Fluela Pass, CH+	0 - 0.40	0.20	normal	closures only	none
Red Mtn/Molas, CO*	0.19 - 0.24	0.22	normal	normal	1 shed
Lukmanier Pass, CH+	0.09 - 0.14	0.12	normal	prolonged	explosives
Gothard Pass, CH+	0.02 - 0.15	0.18	normal	prolonged	none
Rogers Pass, BC*	0.04	0.04	extensive	extensive	extensive
Average		0.21			

* Based on actual avalanche occurrence records.

+ Calculated, based on estimated risk reduction.

Hazard Reduction

Hazard refers to the physical characteristics of the avalanche exposure. *Hazard reduction* encompasses any actions that reduce the hazard from avalanches, such as adjusting the highway alignment to avoid avalanche paths, or constructing physical barriers or snowsheds.

Several hazard reduction techniques have been considered for each Lynn Canal highway alternative.

1. *Avoidance*

   The routes have been carefully adjusted to avoid avalanche paths wherever possible, which is the most effective mitigation measure there is.

2. *Lowest-hazard Locations*

   The alignments have also been adjusted to cross the unavoidable paths at the lowest-hazard locations. This adjustment is the second most-effective mitigation measure. The “unmitigated” AHI calculation for the East and West Lynn Canal alternatives is calculated using these adjusted alignments, even though technically the choice of alignment could be considered part of the mitigation.

3. *Bridges*

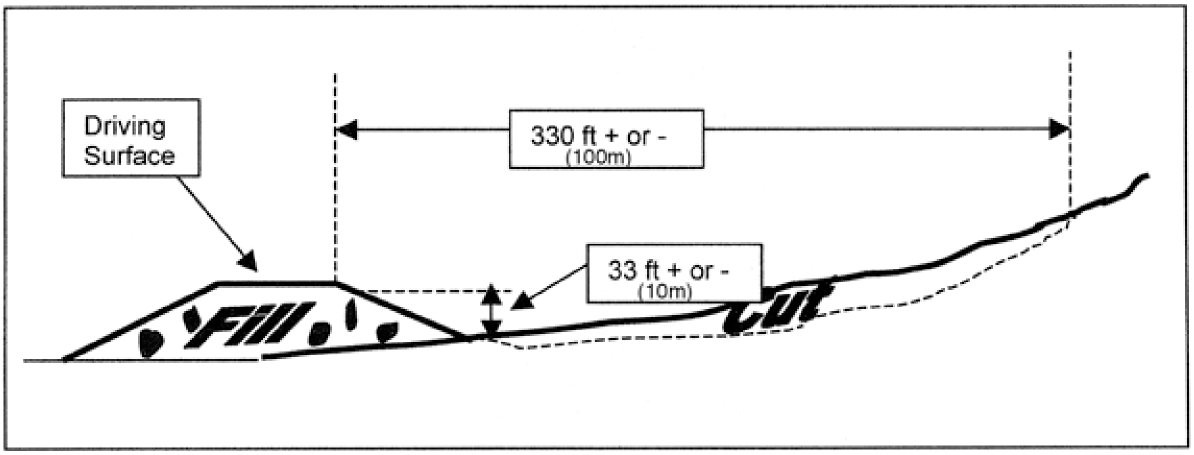
   The AHI for the West Lynn route includes frequency calculations based on bridges crossing deep gorges at paths WLC007 and WLC008, but the bridge added to East Lynn path ELC028 was not part of the original frequency calculation. The residual AHI for that bridge, over a shallower gorge, was reduced to 0.2 times the unmitigated AHI. These bridge factors reduce the residual AHI of all options.

4. *Elevated Fills*

   Elevated fills raise the highway above the normal avalanche flow level and provide a catchment basin for debris. They are proposed in all options for West Lynn Canal paths WLC006, WLC009, and WLC010, and for East Lynn Canal paths ELC002 and ELC014. Available material may allow these fills to be put in at virtually no incremental cost.

   This mitigation option is illustrated schematically below. A catchment basin approximately 330’ (100m) long uphill of each fill section and roughly 33’ (10m) high on the uphill side is created by the combination of the cut uphill and the elevated fill. This section could catch and stop most avalanches before the highway driving lanes are reached, thereby reducing the hazard from avalanches. Large avalanches would impact the uphill face of the fill producing a unit thrust pressure on the uphill face of the fill. This thrust, the estimated reduction in AHI, and the station limits where mitigation fill is used are shown in Illustration A and Table 5.

Illustration A: Elevated Fill Section



* Location should be field-verified in design phase.

** Additional topographic coverage would be needed for calculations in design phase.

Thrust must be converted to normal and shear components when fill shape is known. This should be done during the final design process.

The AHIs for the flatter runouts of the two East Lynn Canal paths proposed for elevated fills were reduced to 0.2 times the unmitigated AHI, and the AHIs for the steeper runouts of the three West Lynn Canal paths proposed for elevated fills were reduced to 0.3 times the unmitigated AHI.

Table 5: Elevated Fills

Path	Stations	AHI	Mitigated AHI	Thrust
ELC002	1465 through 1486	7.72	1.54	4,200psf (20,506 kg/cu meter)
ELC014	1688 through 1694	3.58	0.72	6,700psf (37,712 kg/cu meter)
WLC006A&B	5064 through 5087	20.03	6.01	**
WLC009A&B	5771 through 5795	49.24	14.77	**
WLC010C	5941 through 5947*	4.35	1.31	**

* Location would be field-verified in design phase.

** Additional topographic coverage would be needed for calculations in design phase.

5. Snowsheds

Expensive structural hazard reduction techniques are most cost-effective and efficient if they are targeted at the highest-hazard paths. The avalanche hazard is not uniformly distributed over all the avalanche paths. Some paths are large and frequent; others are small and infrequent.

The majority of the hazard on both alignments is concentrated in a few avalanche paths. The four highest-AHI paths, ELC021, ELC 006, ELC019, and ELC020, on which snowsheds were considered, contain over half of the total East Lynn Canal AHI.

Tables 6 and 7 list the East and West Lynn Canal paths by decreasing AHI. Paths with an AHI of 0.000 are avoided by the alignments. They are indicated by an asterisk and are not included in the number of paths affecting the alignments.

Maps, photos, and detailed information on each path are in the Avalanche Path Atlas section of this report.

Tables 6 & 7, Avalanche Paths by AHI

Table 6
East Lynn Canal Avalanche Paths by AHI

Path #	Path Group	Unmitigated AHI	Path #	Path Group	Unmitigated AHI
ELC021	S Yeldagalga	94.84	ELC047	N Dayebas	0.14
ELC006	Eldred Rock	21.18	ELC026-1	N Yeldagalga	0.13
ELC019	S Yeldagalga	17.30	ELC053	Taiya Inlet	0.13
ELC020	S Yeldagalga	10.21	ELC012	Eldred Rock	0.12
ELC002	N Kensington	7.72	ELC022	S Yeldagalga	0.12
ELC026	N Yeldagalga	7.55	ELC051-1	Taiya Inlet	0.11
ELC025	N Yeldagalga	6.41	ELC041	N Dayebas	0.11
ELC040B	Haines Area	5.48	ELC017	S Yeldagalga	0.10
ELC029	N Yeldagalga	4.60	ELC005	Eldred Rock	0.08
ELC014	Eldred Rock	3.58	ELC004	N Kensington	0.06
ELC024	S Yeldagalga	3.18	ELC040E	Haines Area	0.05
ELC049	Schubee	3.07	ELC007	Eldred Rock	0.05
ELC043	N Dayebas	2.59	ELC042	N Dayebas	0.04
ELC051	Schubee	2.21	ELC028-2	N Yeldagalga	0.04
ELC040C	Haines Area	2.12	ELC036	N Katzehin	0.03
ELC010	Eldred Rock	1.83	ELC034	S Katzehin	0.03
ELC011	Eldred Rock	1.50	ELC037	N Katzehin	0.02
ELC003	N Kensington	0.97	ELC044	N Dayebas	0.02
ELC023	S Yeldagalga	0.89	ELC032	S Katzehin	0.02
ELC046	N Dayebas	0.83	ELC031	N Yeldagalga	0.02
ELC009	Eldred Rock	0.72	ELC033	S Katzehin	0.009
ELC028	N Yeldagalga	0.61	ELC028-1	N Yeldagalga	0.007
ELC013	Eldred Rock	0.59	ELC038	N Katzehin	0.005
ELC050	Schubee	0.55	ELC055	Skagway Area	0.003
ELC001	Berners Bay	0.49	*ELC003-1	N Kensington	0.000
ELC048	N Dayebas	0.33	*ELC005-1	Eldred Rock	0.000
ELC040A	Haines Area	0.32	*ELC015	Eldred Rock	0.000
ELC008	Eldred Rock	0.31	*ELC016	S Yeldagalga	0.000
ELC045	N Dayebas	0.27	*ELC019-1	S Yeldagalga	0.000
ELC030	N Yeldagalga	0.25	*ELC039	N Katzehin	0.000
ELC040F	Haines Area	0.24	*ELC054	Taiya Inlet	0.000
ELC052	Taiya Inlet	0.17	*ELC056	Skagway Area	0.000
ELC018	S Yeldagalga	0.17	*ELC056-1	Skagway Area	0.000
ELC035	N Katzehin	0.17	*ELC056-2	Skagway Area	0.000
ELC053-1	Taiya Inlet	0.17	*ELC057	Skagway Area	0.000
ELC040D	Haines Area	0.16	*ELC058	Skagway Area	0.000
ELC027	N Yeldagalga	0.15	*ELC059	Skagway Area	0.000
				Total AHI	**205.17**
			# Paths Affecting Alignment		61.00

Table 7 West Lynn Canal Paths by AHI		
Path #	**Path Group**	**Unmitigated AHI**
WLC009B	Rainbow	31.20
WLC009A	Rainbow	18.04
WLC009C	Rainbow	11.33
WLC006B	Sullivan	10.58
WLC006A	Sullivan	9.45
WLC010C	Pyramid	4.35
WLC010B	Pyramid	3.89
WLC002A	S Endicott	3.56
WLC002B	S Endicott	3.04
WLC006C	Sullivan	2.70
WLC001A	S Endicott	0.78
WLC001B	S Endicott	0.58
WLC010D	Pyramid	0.28
WLC010A	Pyramid	0.13
WLC008	Rainbow	0.07
WLC005	Sullivan	0.07
WLC007	Sullivan	0.02
*WLC003	N Endicott	0.000
*WLC004	N Endicott	0.000
	Total AHI	**100.08**
# Paths Affecting Alignment		17.00

* Indicates avoided paths, not included in the number of paths affecting the alignment.

Snowsheds are proposed for Paths ELC006, ELC019, ELC020, and ELC021 in the East Lynn Canal "B" options. *Snowheds could nearly eliminate exposure to avalanches in the area in which they are built.* The AHIs for the paths with sheds were reduced to 0.05 times the unmitigated AHI.

Snowsheds, usually reinforced concrete, poured-in-place structures, tend to be expensive because they must be designed for large loads. A reinforced concrete shed built in 1986 in Colorado cost $8,900 per foot ($29,199 per m) for a short, 180-foot (55m) long shed over a two-lane highway. It was designed for large impact loads from the opposite direction. A concrete shed over a portion of the Coquihalla Highway, B.C., cost $10,000 Canadian per lane, per meter (equivalent to approximately $5,000 US per foot for a two-lane highway).

Assuming a higher cost in Alaska, moderate inflation (factor of 1.89 based on 5% per year for 13 years), and an average cost of $6,950 per foot ($22,802 per m) when the previous sheds were built, a cost of $13,135 per foot ($43,094 per m) is estimated for the two-lane Lynn Canal highway.

An alternative design concept is the "half culvert" illustrated schematically in Illustration B. This culvert, or metal arch shed, _must_ be buried on at least the uphill side to avoid impact loads. Large depositional loads from avalanche debris produce large static snow loads in addition to soil loads. A cost of $7,000 per foot ($22,966 per m) for culvert sheds is estimated, but this figure is highly dependent on supplier prices.

Illustration B: Culvert Snowshed

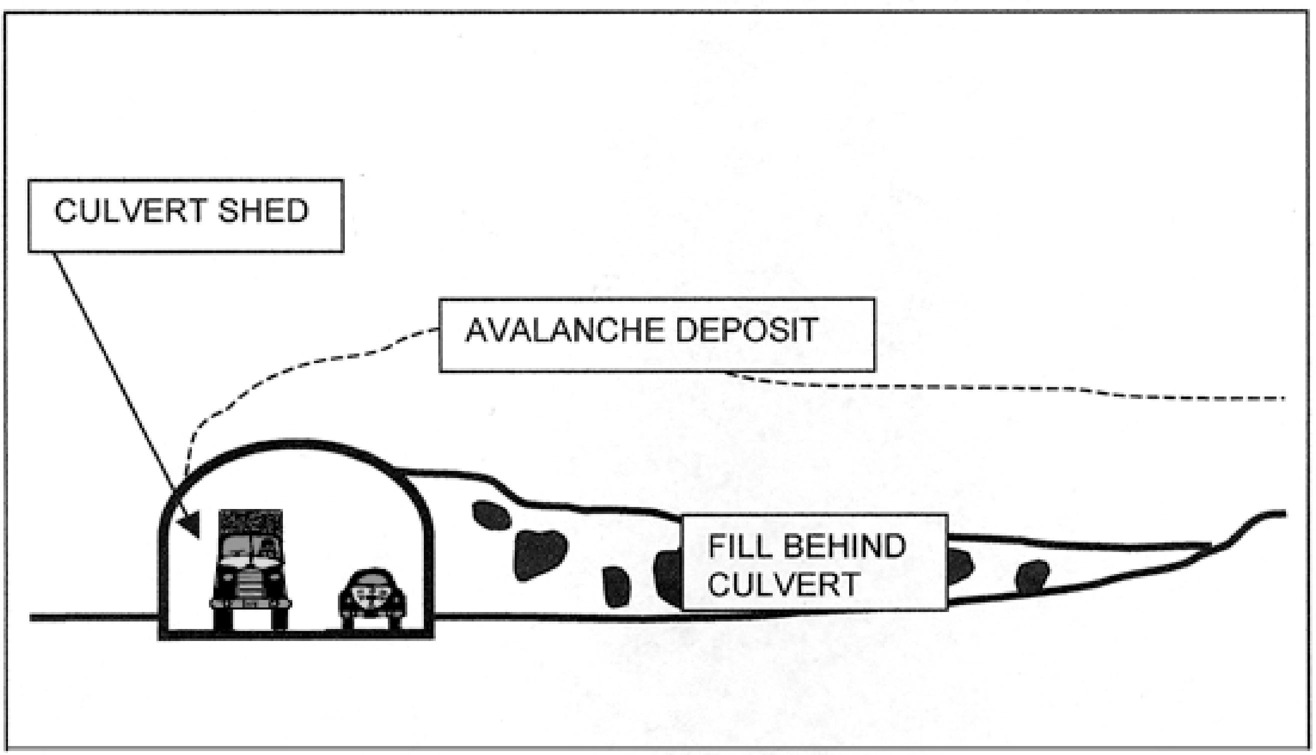


Table 8 lists shed stationing, length, and static load requirements for the 50 to 100 year return period design-magnitude avalanche that should be considered.

Table 8: Snowsheds

Path	Station Range	Length in feet	Estimated cost	Static snow load (height in meters)
ELC006	1688-1694	600 ft (183m)	$4,200,000	1,500 psf or 7,324 kg/ sq m (15m)
ELC019	2040-2044	400 ft (122m)	$2,800,000	1,250 psf or 6,103 kg/sq m (12m)
ELC020 & ELC021*	2086-2102	1600 ft (488m)	$11,200,000	1,750 psf or 8,544 kg/sq m (17m)

* Paths 20 and 21 are adjacent and a single structure is used in this analysis.

The static snow loads are based on the avalanche-debris depths calculated for Table 3 and an assumed deposit density of 31 pcf (500 kg/m^3). These numbers are based on measurements of avalanche deposit density, evaluation of the terrain in the runout zone, the tendency for lateral spreading, and observations of avalanches in recent years in this area.

The reduction in AHI at each of the paths where culvert sheds are used is estimated in Table 9. The reduced AHI is 0.05 times the unmitigated AHI, rather than zero, because of the possibility of lateral spreading over shed portals during unusually large wet-snow avalanches.

Table 9: Snowshed AHI Mitigation

Table 9: Snowshed AHI Mitigation		
Path	**AHI (unmitigated)**	**AHI (with culvert shed)**
ELC006	21.18	1.06
ELC019	17.30	0.87
ELC020 & ELC021*	105.05	5.25

- Paths ELC020 and ELC021 are adjacent and a single structure is used in this analysis

Risk Management

Risk refers to the consequences of exposure to avalanches. *Risk management* practices reduce the avalanche risk to travelers through operational methods such as avalanche forecasting, warnings, highway closures, and explosives work to release unstable snow when the highway is closed. *Residual risk* is the risk that remains after mitigation through both hazard reduction and risk management.

The key elements of an avalanche risk management program are avalanche forecasting, highway closure, and explosive delivery to clear unstable snow masses during closure periods.

The available highway risk reduction figures listed in Table 4 suggest that the AHI can be lowered to roughly 0.2 times the unmitigated level, but a more conservative residual AHI of 0.3 has been used here.

Avalanche Forecasting

The accuracy of avalanche forecasting programs is largely dependent on the accuracy of weather forecasts for the area. The locations included in Table 4 have relatively stable temperate climates and far more sophisticated weather monitoring and forecasting systems than Alaska.

Weather forecast accuracy in northern Southeast Alaska is poor due to the coastal weather pattern and its rapidly moving midwinter thaws, large variations in elevation, strong pressure gradient winds, long periods of darkness, lack of weather data to the west, and the difficulty of keeping weather stations operational, so a more conservative residual AHI factor is necessary here.

Highway Closures

All the options for the West Lynn Canal route use a highway closure standard of considerable avalanche danger level. The residual AHI of 0.30 times the structurally mitigated AHI reaches the target residual AHI of 30 or lower.

The “B” options for the East Lynn Canal route have snowsheds, but more-conservative closure criteria are necessary for that route. These options use closure at a standard of moderate avalanche danger level, with slides likely to reach low elevations. The residual AHI of 0.25 times the structurally mitigated risk reaches the target residual AHI of 30 or lower.

The “A” options for the East Lynn Canal route do not have snowsheds. Without snowsheds, the only risk management tool available to bring the residual AHI into the target range is the extension of closure periods to the next level, following the precedent set in the Swiss residual risk studies. Closure at moderate avalanche danger level is used as a very conservative standard. The residual AHI of 0.15 times the structurally mitigated AHI reaches the target residual AHI of 30 or lower. The initial capital cost is lower, but closure times are 1.5 times as long as for the “B” options.

Explosives

Explosives are used to release unstable snow accumulations during highway closure periods, allowing shorter closure periods than simply waiting for the snow to slide or stabilize. A number of options for explosive delivery have been evaluated in this report.

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Avalanche Risk Management

Goals

The goal of the Lynn Canal program outlined here is to operate the highways within acceptable limits of risk, not simply to keep the highway open. A clear understanding of that goal is crucial to the success of the risk management program. There are no written US standards for highway avalanche programs, but the proposed program would meet the established standard of care as defined by common professional practices.

Staffing

Under both the East Lynn and West Lynn Canal alternatives, two avalanche specialists and an intern would be the core staff of the avalanche program. The East Lynn Canal alternative would require an additional full-time six-month technician position (Research Analyst I) to provide support. The lead avalanche specialist should be a year-round position, and the assistant forecaster and intern should work a six-month season.

Highway maintenance crews would assist the avalanche crew with explosive delivery work, as well as with debris removal and other avalanche-related maintenance functions.

This staffing level would allow the forecasters to alternate working as the forecaster in charge for three days weekly, with the intern covering the seventh day of the workweek. The entire crew should be on duty around the clock when slides are running, as is standard with avalanche operations. At least one specialist should back up the intern during times of potential avalanche activity.

Because avalanche forecasting work is by nature skewed toward winter, with occasional periods of around-the-clock monitoring activity, flexible work arrangements are necessary.

Staff Qualifications

The lead avalanche specialist should have minimum qualifications of 10 winters working fulltime as an avalanche specialist, at least four years of professional-level avalanche forecasting experience in a lead position, US Level I and II avalanche training, US professional-level avalanche operations training, and familiarity with local weather patterns and snow conditions. The lead avalanche specialist should also have avalanche explosives experience and experience in developing and operating a major highway avalanche program or comparable industrial program, demonstrate a commitment to continuing education, and maintain membership in relevant professional associations.

It is recommended that the second avalanche specialist have at least four years of professional-level avalanche forecasting experience, US Level I and II avalanche training, US professional-level avalanche operations training, demonstrate a commitment to continuing education, and maintain membership in relevant professional associations.

The intern should have US Level I and II avalanche training, and be in a training program leading to a career in the field.

All avalanche workers should receive additional training in explosives handling and the particular delivery methods that will be used. Blaster school, gunner school, and manufacturer's blaster box training, as needed for the explosive delivery methods in use, should be required before operations begin.

All avalanche workers should have emergency medical training to a minimum level of Emergency Trauma Technician (ETT) or Wilderness First Responder (WFR).

All avalanche workers should be advanced skiers, snowshoe-snowboarders or splitboarders, with the skill and fitness necessary to climb to starting zone elevations, perform field tests in adverse weather conditions, and descend safely and rapidly within a winter workday.

Avalanche Forecasting Program

The forecasting program would use direct field observations of snowpack conditions in combination with weather data and forecasts to continuously monitor the avalanche danger to travelers and highway workers, and to determine the best timing for use of explosives and highway closure.

Observations

During avalanche season, regular field observations, weather logs, and records of avalanche activity would be kept, and a daily avalanche forecast issued each morning for DOT&PF crews, with updates as conditions change. Field operations, observations, and data recording should follow American Avalanche Association guidelines.

The forecasting program should include regular starting-zone-elevation field snow testing and observation to determine the presence of weak layers and the relationship between snowpack stress, strength, energy balance, and structure.

Weather Monitoring and Data Management

Three ridge-level weather stations and one mid-elevation station would be used under the East Lynn and West Lynn full-length alternatives. The purpose of the mid-elevation station is to assist in monitoring thaw and rain-on-snow events.

The East Lynn Canal ridgetop weather stations should be located near the Eldred Rock, South Yeldagalga, and Schubee paths. The mid-level station should be near the South Yeldagalga paths.

For the ELC 1A, Alt. 2B option, where the East Lynn road would extend north from Juneau to the Katzehin River, the Schubee paths weather station could be eliminated.

The West Lynn Canal ridgetop weather stations should be near the South Endicott, Sullivan, and Rainbow paths. The mid-level station should be near the Rainbow paths. Telemetry should relay weather data to Haines, where the data could be uploaded to a website.

An avalanche program requires a data management and technical support system. Good data management yields the most accurate forecasts and can incorporate such useful improvements as GIS-based nearest-neighbor data sorting.

The weather stations should be similar to the type recently installed by the Alaska Railroad, with thermoelectric generators or other best-available technology for de-icing, in order to work without AC power on ridgetop locations in the coastal Alaskan climate. These installations are costly, but ordinary weather stations are not adequate for the heavy rime icing conditions that are the norm in these mountains.

Explosives Program

Explosives are used in combination with temporary highway closures to release unstable snow so highways can be reopened once debris is cleared. Explosives handling, delivery, and security practices must follow American Avalanche Association guidelines and applicable laws.

Details of the explosive program will depend on the explosive delivery option chosen. All avalanche workers should have specific training in the explosives handling and delivery methods to be used before operations begin.

Safety should be allowed to take precedence over efficiency in the first few years, as explosive procedures are refined and practiced. Speed, safety, and efficiency will best develop from thorough training and drilling.

Avalanche explosives historically have *dud* (unexploded charge) rates of less than one percent. Dud locations must be noted and duds destroyed at the end of the season. A small chip that reflects a signal from a searching unit, known as a RECCO tag, should be attached to each charge delivered by helicopter or blaster box to help locate duds, which could otherwise be difficult to find in the thick brush of the avalanche paths. Unexploded howitzer rounds are best located with a metal detector or magnetometer.

Highway Closure Program

Conservative highway closure criteria have been chosen to reduce the risk to travelers. The goal of the combined hazard reduction and risk management program is to have a residual AHI at or below the target of 30. Good risk management for the traveling public is achieved by assuring a smooth flow of traffic through avalanche zones when the highway is open, and identifying refuge points with plowed turnouts outside the avalanche zones where travelers can wait when highways are blocked by slides or for explosive work.

If explosive work must be delayed, or if instability is developing too rapidly for explosive work to keep pace, longer highway closures would be used. For prolonged closures, both the East Lynn and West Lynn Canal routes would have shuttle ferries available to provide transportation across the closed section.

Signage

Prominent highway signs at each end of the highway should inform travelers that they are entering a route with potential avalanche hazard, advise them not to stop or stand in avalanche zones during avalanche season, and provide a key to color-coded signs along the highway. Color-coded signs with maintenance location reference, path number, path name, and a warning against stopping or standing from November 1 through May 1 should mark the edges of each avalanche zone. Suggested color-coding is yellow for entering a zone and green when leaving a zone.

Signs should be posted in winter at all turnouts, trailheads, and backcountry access areas warning of explosive work, the potential presence of duds, highway closures, and avalanche areas. Special signage should be used to warn backcountry travelers to stay clear of any areas with blaster boxes or other fixed explosive delivery installations.

Sweep

DOT&PF maintenance workers should sweep the highway to clear any travelers before closure, moving from the center out to get the DOT&PF crew out of the corridor at the same time as the traveling public. Extra time should be budgeted to deal with such typical complications as stuck or slow vehicles. Sweep crews should have two workers per vehicle whenever possible.

Steel gates at both ends of each highway section should be used to ensure that no vehicles enter the closed area. Notice should be given to the public through the news media and to aviators through the FAA before explosive work is initiated.

Strandings

There would be a ferry terminal on each route and a DOT&PF maintenance station near Kensington Mine on the East side route. These structures could serve as emergency refuges.

According to Cellular One, there is cellular phone coverage on both sides of Lynn Canal from Juneau to Haines. From about eight miles north of Haines to Skagway there is currently no coverage.

Highway Operations Procedures

Avalanche season highway operations should be conducted following a project-specific, fully detailed avalanche risk management plan, as required under Alaska case law on worker safety. Crews should be trained in avalanche procedures and equipped with avalanche emergency kits. The discussion here is a sample overview of the common provisions of avalanche plans, and is not intended as a substitute for a detailed plan.

No avalanche debris should be cleared without approval from the on-duty avalanche specialist. The specialist should consider visibility, presence of residual snow in avalanche starting zones, terrain hazards, availability of spotters and equipment and other risk factors. No avalanche debris should be cleared when visibility is poor due to darkness or conditions such as fog.

All cuts in avalanche debris should be daylighted, so the downslope side of the cut is opened as the cut is made. Cuts with vertical walls on both sides are traps for operators in the event of a secondary slide.

All heavy equipment should have enclosed cabs and should be equipped with avalanche self-rescue gear and operators should be trained in avalanche safety and rescue procedures. Operators working in avalanche zones during avalanche season should wear beacons and remain in radio communication with a dispatcher.

Radios should have frequencies for communication with law enforcement and aircraft used in the program, as well as for DOT&PF base, maintenance crew, and avalanche forecasting staff. Repeaters should provide uninterrupted radio communication throughout the alignment.

DOT&PF vehicles should carry small emergency caches and weatherproofed copies of avalanche maps for the route, referenced to maintenance location markers, with avalanche refuge areas, rescue caches, and shelters marked.

United States Avalanche Danger Descriptors can be found in Technical Appendix 5. Recommended highway operations and closure guidelines for specific avalanche danger levels are in Technical Appendices 6 and 7.

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Avalanche Path Atlas - Overview

This section has location maps for all the East and West Lynn Canal avalanche paths, followed by paired pages of photos and key information for each path.

The “ELC” East Lynn Canal path numbers are unchanged from the original 1995 study (Mears and Glude, Snow Avalanche Technical Report, Environmental Impact Statement Considerations, Juneau Access Route EIS, 1995), except for the addition of an “E” to differentiate them clearly from the West Lynn Canal paths. Paths that have been added since 1995 have a dash and sequential number following the next lower path number. The “WLC” numbers designate the newly mapped West Lynn Canal paths.

Any paths that might possibly affect an alignment are included in the atlas. Paths avoided by the current alignments have an AHI of zero, but are retained in the mapping and numbering system.

The path group provides a general location relative to the few named places along Lynn Canal, and the map number is listed to speed reference to the appropriate map. Maps for the East and West Lynn Canal alignments are at the beginning of their sections.

Latitude and longitude coordinates for the centerline of the path on the alignment are provided as a geographic locator. The coordinates are taken from DOT&PF’s master design program. Highway stationing is not used as a locator at this stage, because stationing changes as project design progresses.

Path widths are scaled from detailed DOT&PF maps. Maximum width is defined as the widest evident slide, a large but infrequent event. Typical width is the width of most of the slides that reach the bottom of the path.

Starting elevation is the highest point in the avalanche starting zone, taken from USGS topographic maps.

The width and elevation numbers are taken from maps created in US units (i.e., feet) and converted to metric units (meters). The conversions are not accurate to the meter, but are left unrounded here to avoid biasing further calculations.

Elevation class is used to group avalanches with similar starting zone elevations for quick reference. The same convention is followed in the 1995 report. Low-elevation paths start below 1200’ (370m), medium-low-elevation paths start between 1200’ and 2000’ (370m-610m), medium-high-elevation paths start between 2000’ and 3000’ (610m-910m), and high-elevation paths start above 3000’ (910m).

Path size follows the classification system used in the 1995 report:

a. *Small paths* are typically gullies, rock slabs, landslides, and talus slopes at low to middle elevations (under 1,200’ or 370m); many are in steep, cliffy areas. Snow avalanches are not the primary mass-wasting process in most of them, but they are nonetheless capable of producing avalanches when conditions are suitable. The more active small paths may produce numerous light and even deep avalanches affecting the alignment with serious consequences due to steep terrain.

b. *Medium-sized paths* are typically gullies or narrow paths at middle to high elevation (1,200-3,000 feet, or 370-910m). In these paths, the starting zones are small or the paths have other factors that limit the avalanche size and frequency.

c. *Large path*s have classic, high-elevation (3,000 feet, or 910m, and higher) starting zones, and track and runout characteristics that promote frequent and large avalanches.

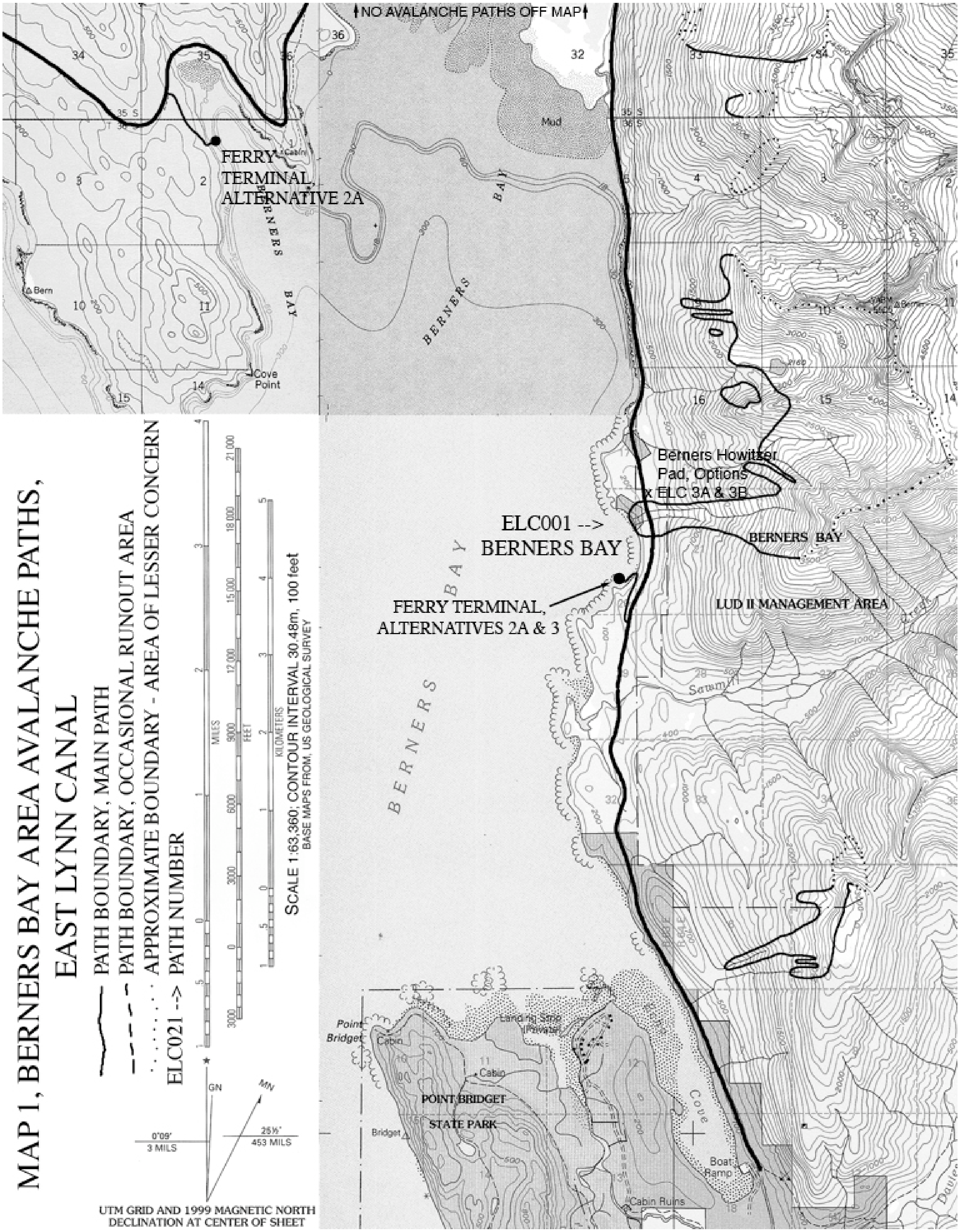
d. *Very large paths* are larger than any paths on the existing Southeast Alaska highway system; that is, they have higher and wider starting zones. They produce larger and more frequent avalanches.

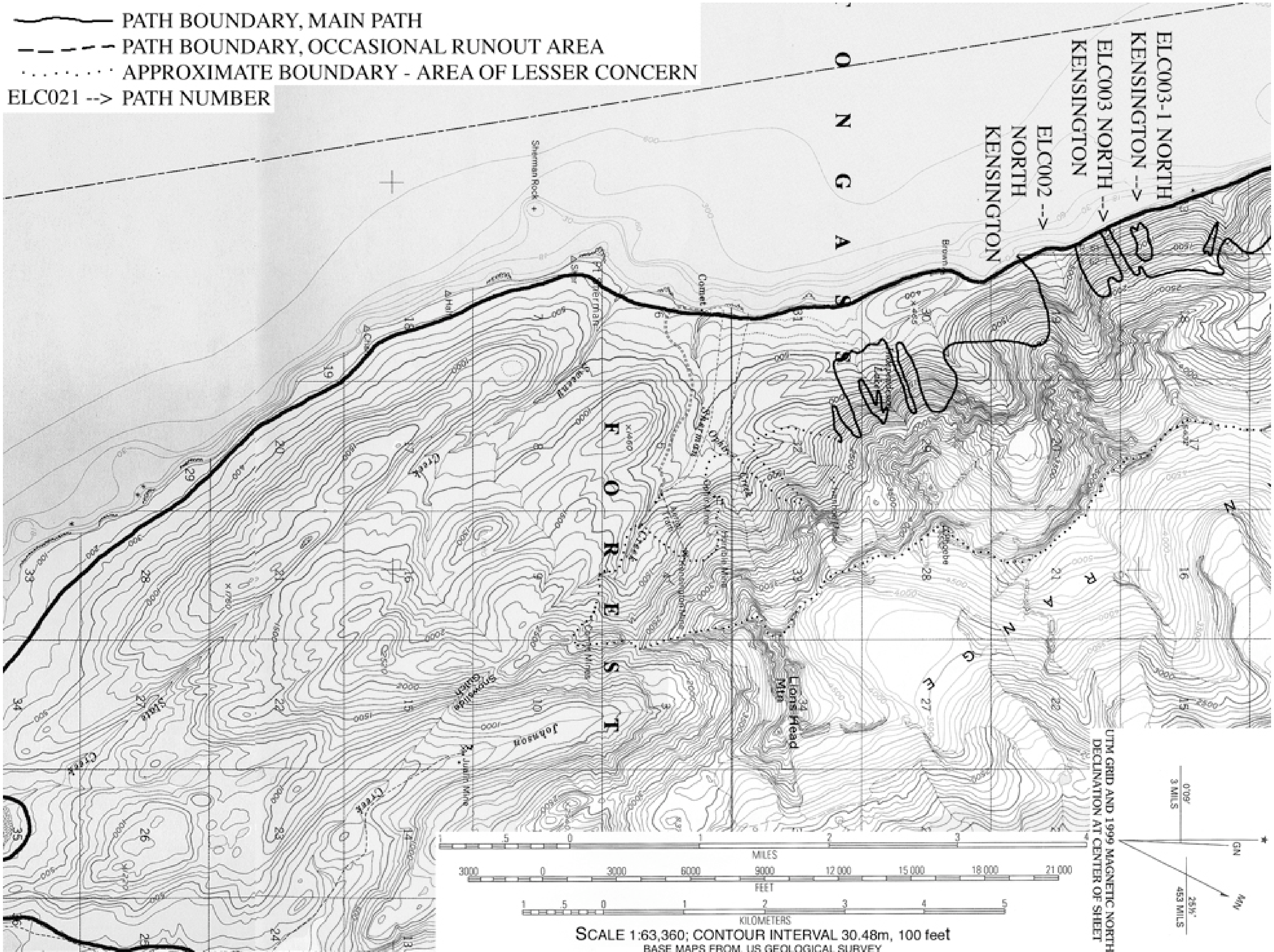
Path type and runout angle qualitatively describe the starting zone, track, and the transition to the runout zone. Detailed measurements have not been taken at this stage of study.

The unmitigated avalanche hazard index (AHI) is listed for each path. Unmitigated AHI assumes no structural hazard reduction actions or operational risk management.

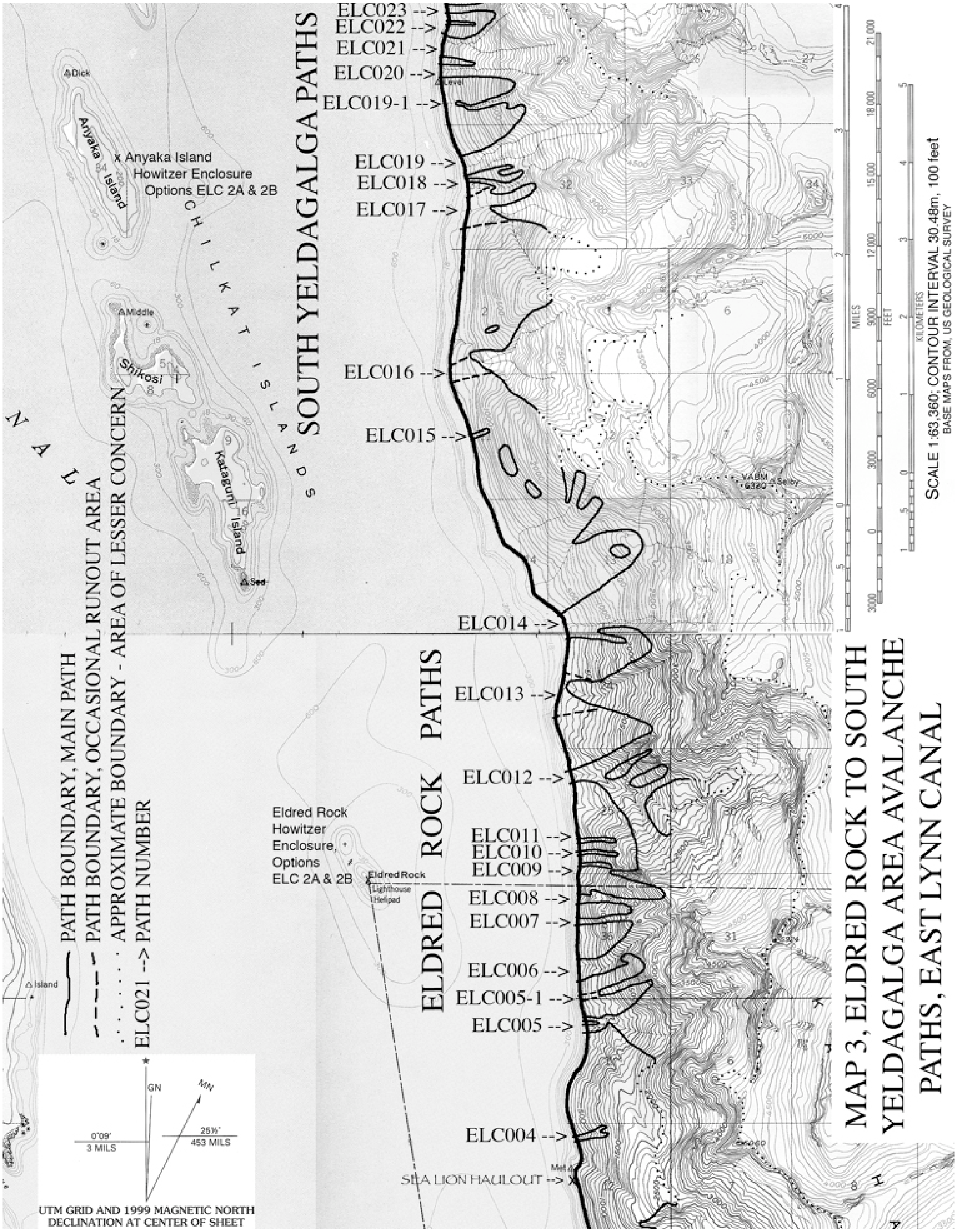
Atlas – East Lynn Canal Section

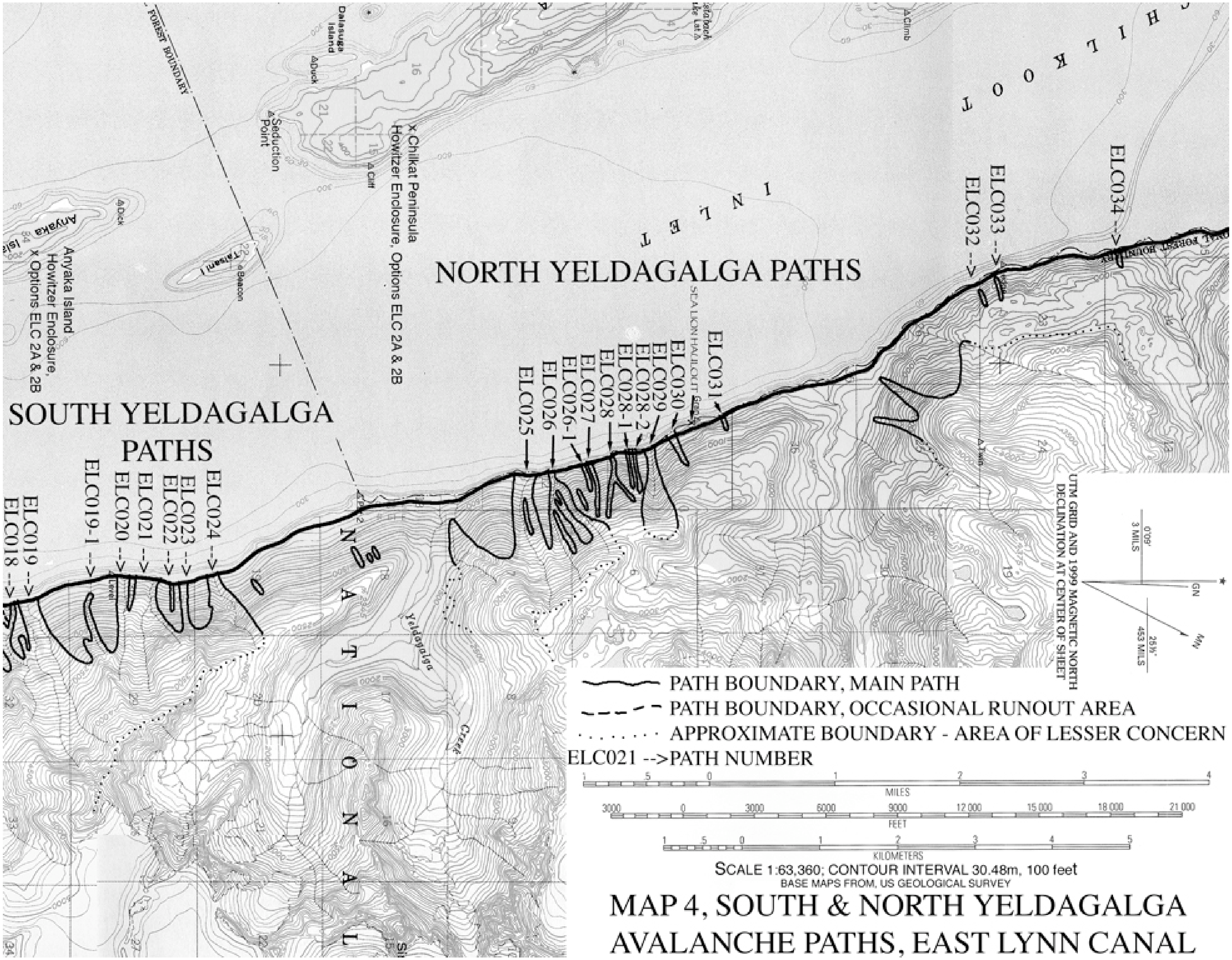
MAP 1, BERNERS BAY AREA AVALANCHE PATHS, EAST LYNN CANAL



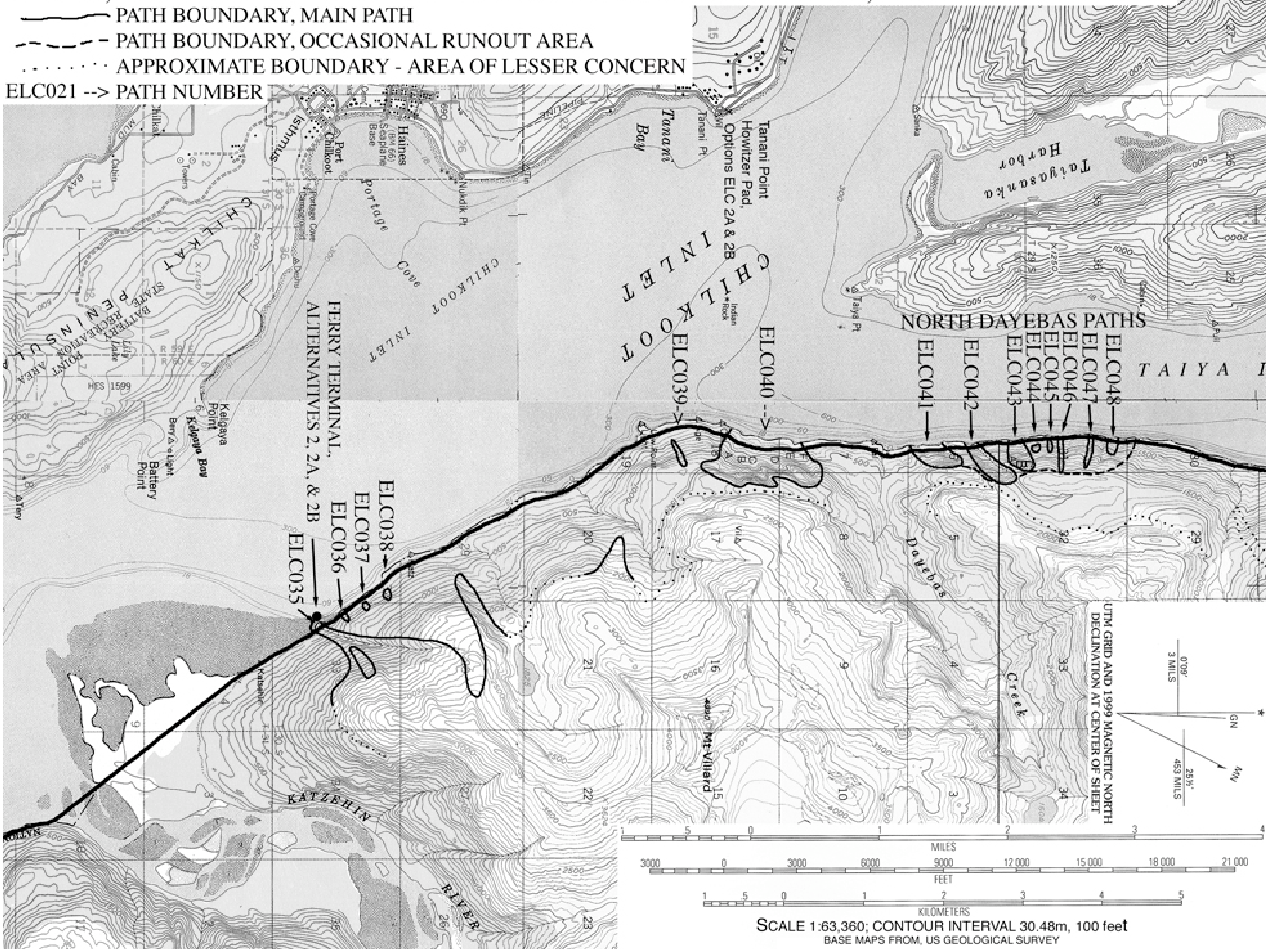


MAP 2, KENSINGTON MINE AREA AVALANCHE PATHS, EAST LYNN CANAL

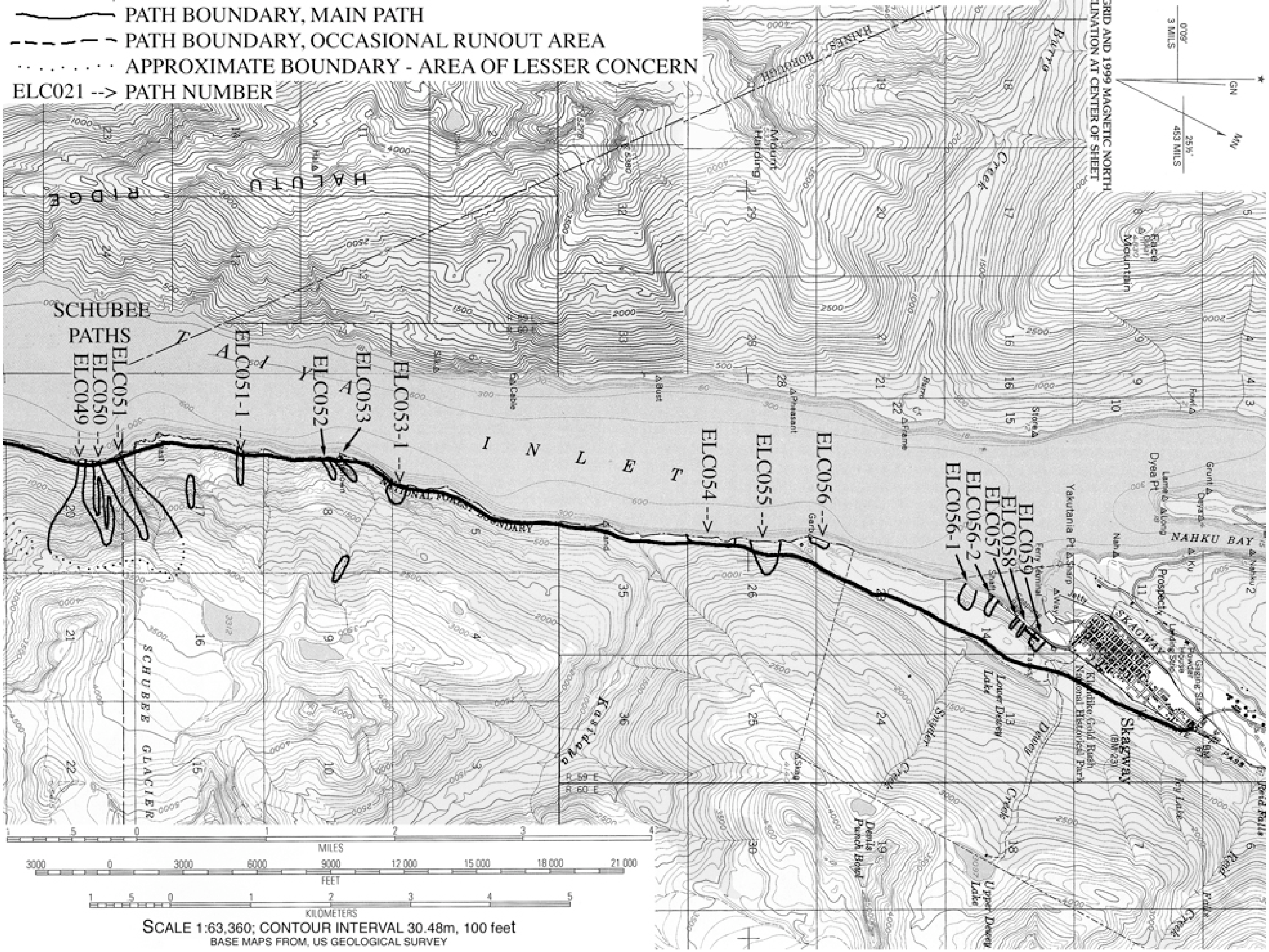

MAP 3, ELDRED ROCK TO SOUTH YELDAGALGA AREA AVALANCHE PATHS, EAST LYNN CANAL
SOUTH YELDAGALGA PATHS
ELDRED ROCK PATHS
PATH BOUNDARY, MAIN PATH
PATH BOUNDARY, OCCASIONAL RUNOUT AREA
APPROXIMATE BOUNDARY - AREA OF LESSER CONCERN
ELC021 --> PATH NUMBER
ELC023 -->
ELC022 -->
ELC021 -->
ELC020 -->
ELC019-1 -->
ELC019 -->
ELC018 -->
ELC017 -->
ELC016 -->
ELC015 -->
ELC014 -->
ELC013 -->
ELC012 -->
ELC011 -->
ELC010 -->
ELC009 -->
ELC008 -->
ELC007 -->
ELC006 -->
ELC005-1 -->
ELC005 -->
ELC004 -->
SEA LION HAULOUT --> X
x Anyaka Island Howitzer Enclosure Options ELC 2A & 2B
Eldred Rock Howitzer Enclosure, Options ELC 2A & 2B
Eldred Rock
Lighthouse
Helipad
CHILKAT ISLANDS
Anyaka Island
Shikosi
Katagunt Island
Dick
Middle
Sed
Island
GN
MN
0°09'
3 MILS
25½°
453 MILS
UTM GRID AND 1999 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:63,360; CONTOUR INTERVAL 30.48m, 100 feet
BASE MAPS FROM, US GEOLOGICAL SURVEY
MILES
FEET
KILOMETERS

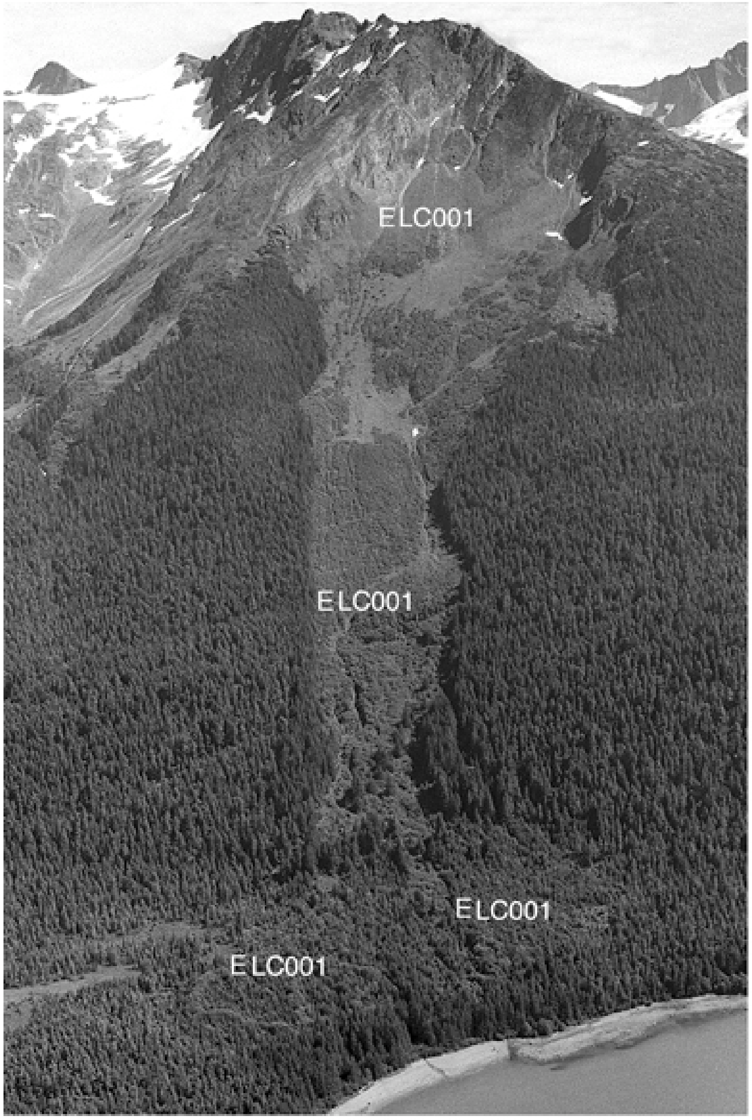

MAP 4, SOUTH & NORTH YELDAGALGA
AVALANCHE PATHS, EAST LYNN CANAL
NORTH YELDAGALGA PATHS
SOUTH YELDAGALGA
PATHS
ELC034 -->
ELC033 -->
ELC032 -->
ELC031
SEA LION HAULOUT
ELC030
ELC029
ELC028-2
ELC028-1
ELC028
ELC027
ELC026-1
ELC026
ELC025
ELC024 -->
ELC023 -->
ELC022 -->
ELC021 -->
ELC020 -->
ELC019-1 -->
ELC019 -->
ELC018 -->
C H I L K O O T
I N L E T
N A T I O N A L
x Chilkat Peninsula
Howitzer Enclosure, Options ELC 2A & 2B
Anyaka Island
Howitzer Enclosure,
x Options ELC 2A & 2B
Dalasuga Island
Duck
Seduction Point
Cliff
Beacon
Talsani I
Dick
Climb
Twin
Yeldagalga
Creek
FOREST BOUNDARY
UTM GRID AND 1999 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET
GN
MN
0°09'
3 MILS
25½°
453 MILS
PATH BOUNDARY, MAIN PATH
PATH BOUNDARY, OCCASIONAL RUNOUT AREA
APPROXIMATE BOUNDARY - AREA OF LESSER CONCERN
ELC021 -->PATH NUMBER
MILES
FEET
KILOMETERS
SCALE 1:63,360; CONTOUR INTERVAL 30.48m, 100 feet
BASE MAPS FROM, US GEOLOGICAL SURVEY

MAP 5, HAINES & TAIYA INLET AREA AVALANCHE PATHS, EAST LYNN CANAL

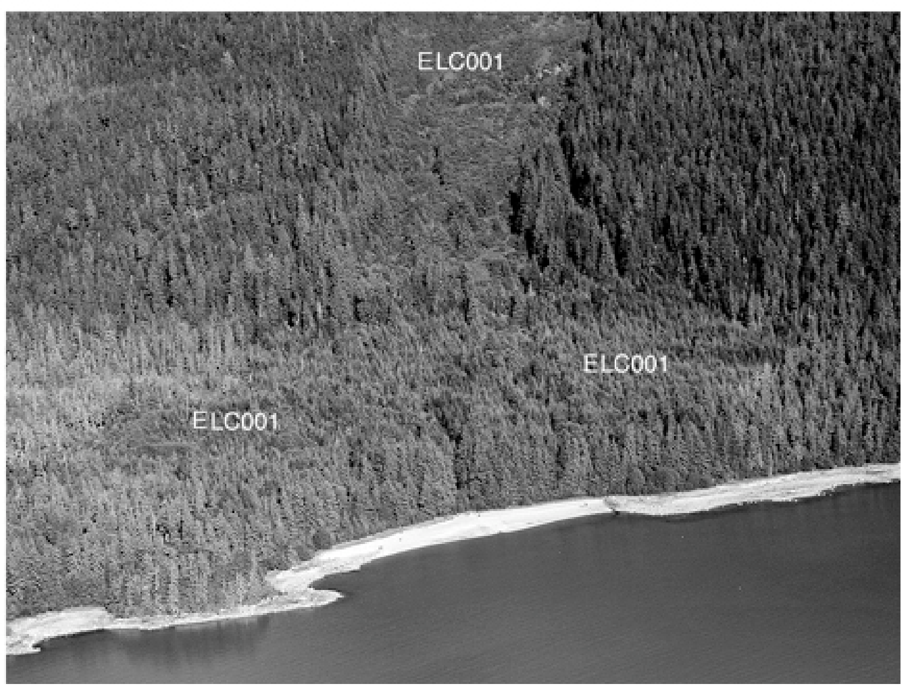


MAP 6, TAIYA INLET AREA AVALANCHE PATHS, EAST LYNN CANAL





East Lynn Canal Path ELC001 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC001

Path Group:	Berners Bay, Map 1
Latitude-Longitude:	58.441688-134.553822
Max Width (ft)	1900 feet
Max Width (m):	579 meters
Typical Width (ft):	1000 feet
Typical Width (m):	305 meters
Starting Elevation (ft):	4900 feet
Starting Elevation (m):	1493 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	W
Path Type:	classic confined; wide track
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.49
Comments:	

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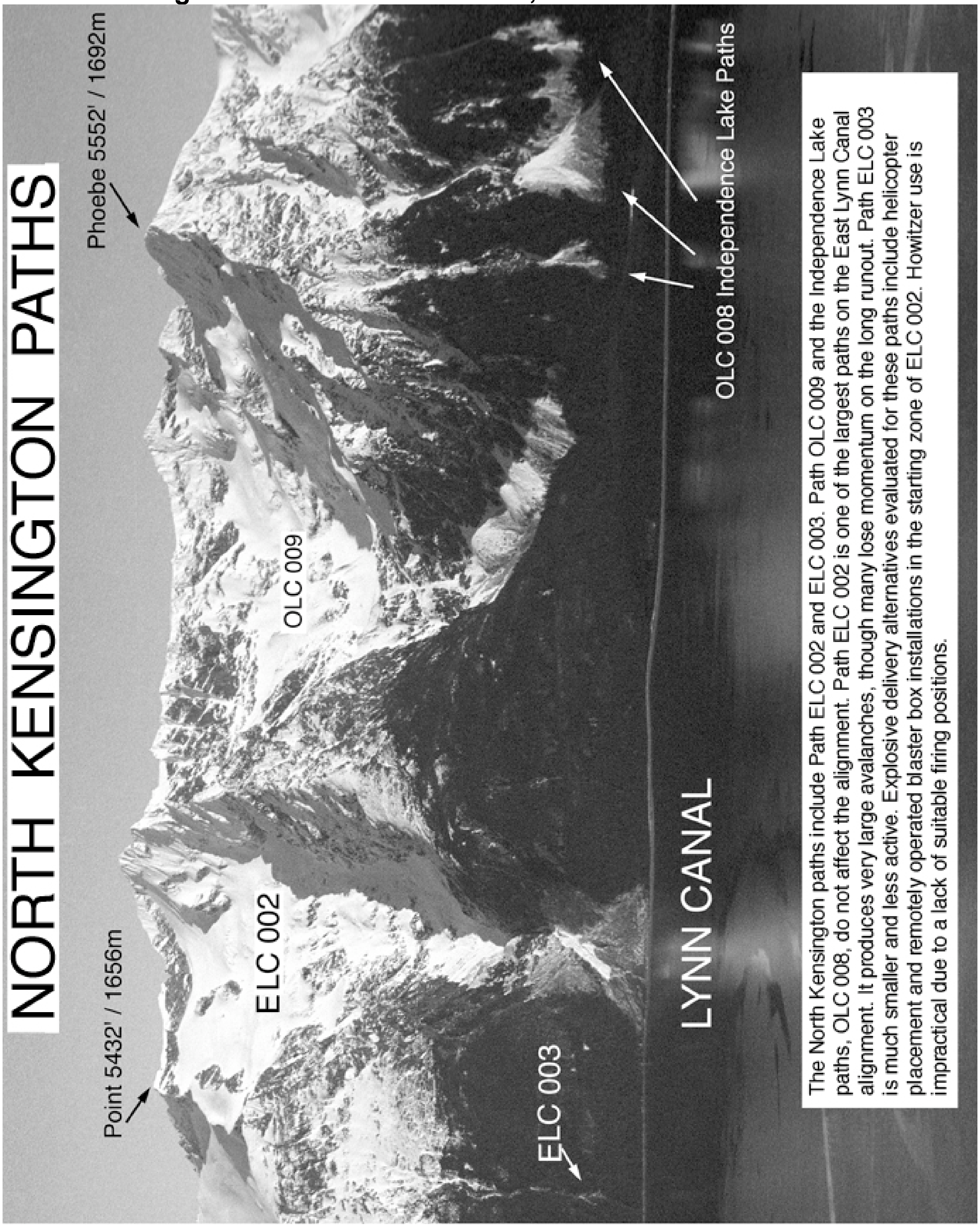
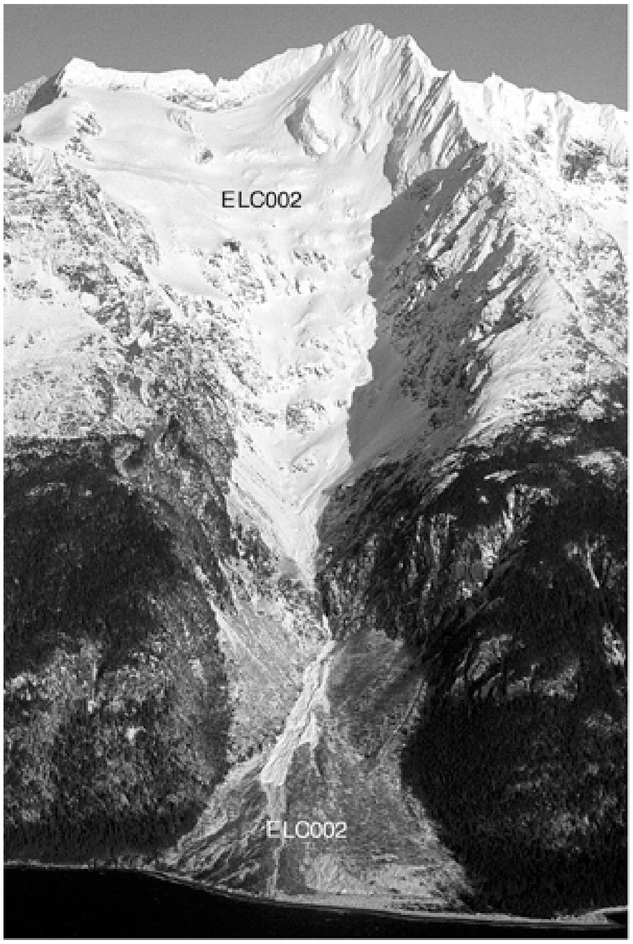
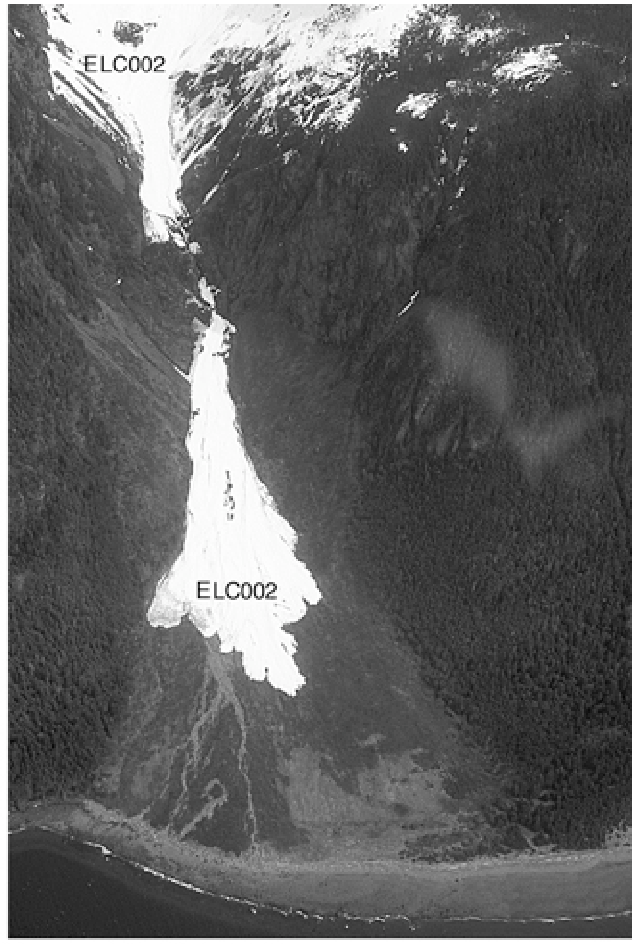
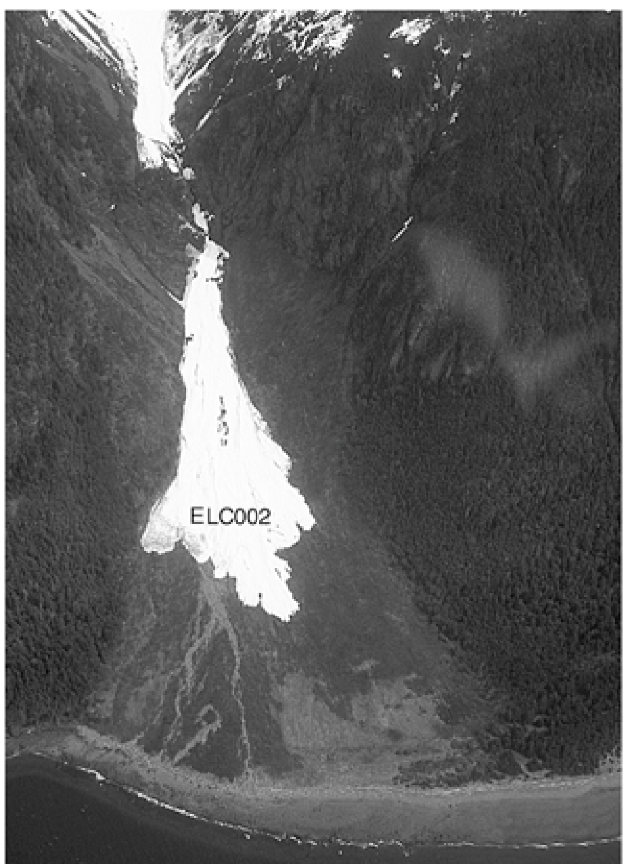
North Kensington Paths Overview Photo, ELC002 to ELC003







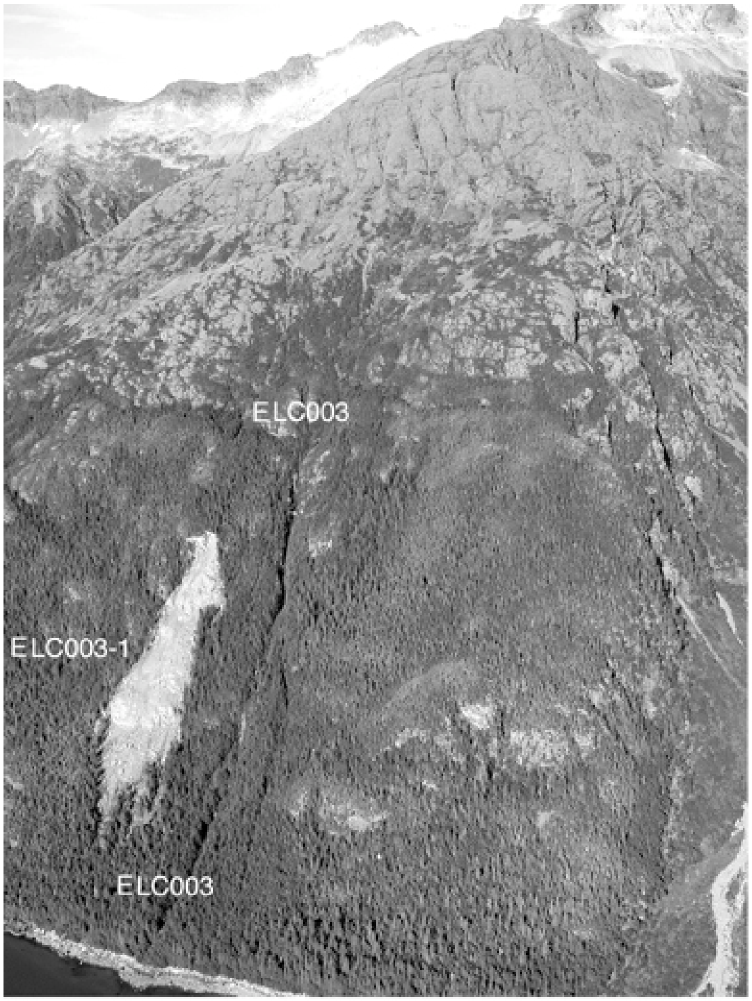
East Lynn
Canal Path
ELC002
Photos

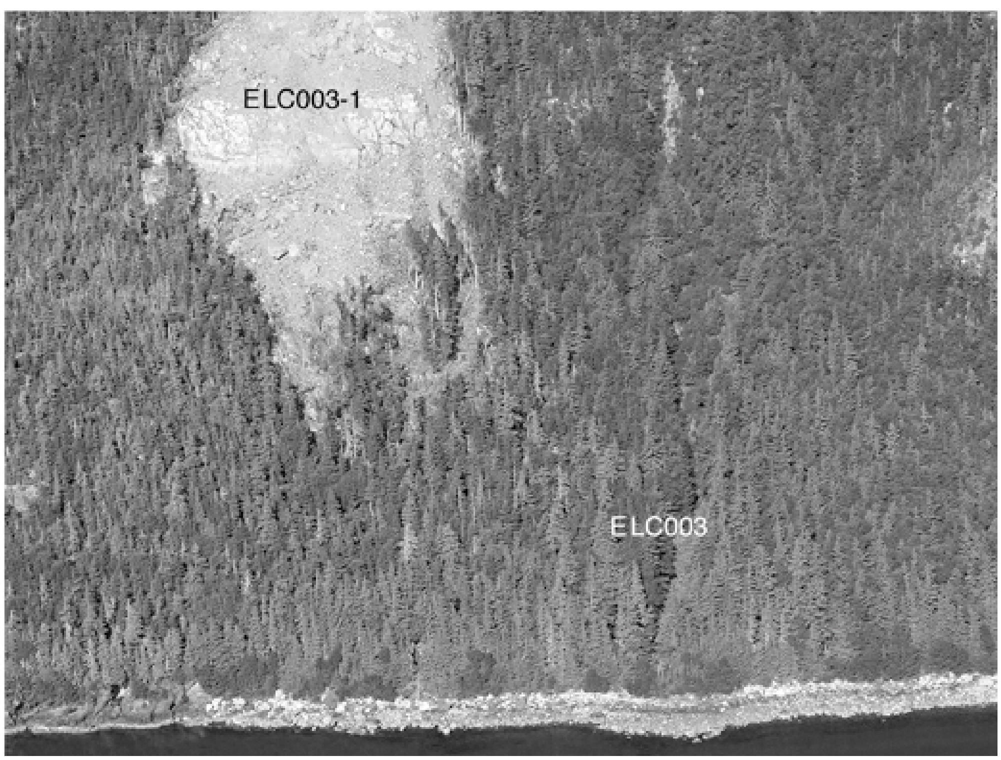


Avalanche Path Atlas - East Lynn Canal Path ELC002

Path Group:	North Kensington, Map 2
Latitude-Longitude:	58.542239 -135.091832
Max Width (ft):	2115 feet
Max Width (m):	645 meters
Typical Width (ft):	500 feet
Typical Width (m):	152 meters
Starting Elevation (ft):	5900 feet
Starting Elevation (m):	1798 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	WSW
Path Type:	classic confined; very wide track
Runout Angle:	decreases gradually
Unmitigated avalanche hazard index (AHI):	7.72
Comments:	Fifth-highest East Lynn AHI.

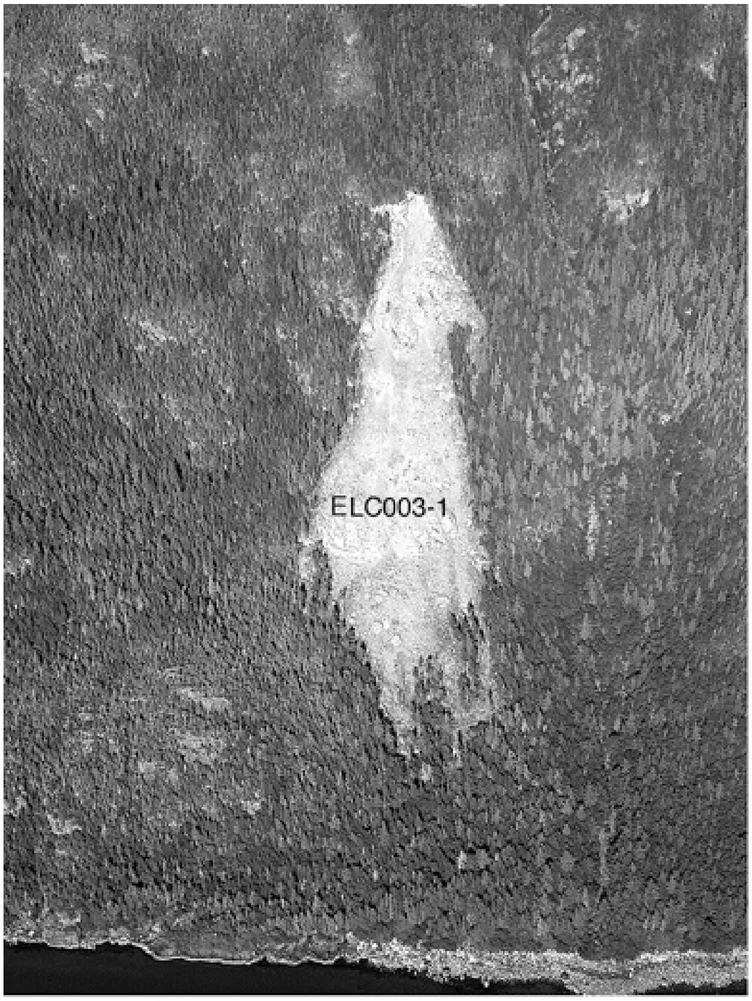
East Lynn Canal Path ELC003 Photos



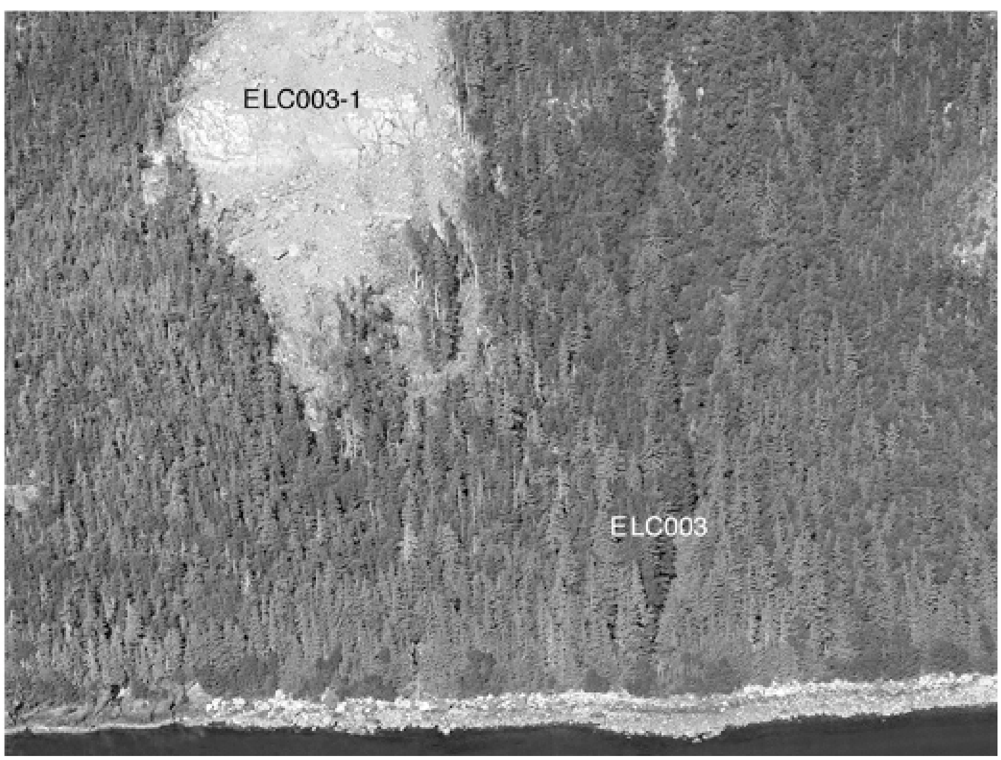


Avalanche Path Atlas - East Lynn Canal Path ELC003

Path Group:	North Kensington, Map 2
Latitude-Longitude:	58.54455 -135.09301
Max Width (ft):	130 feet
Max Width (m):	40 meters
Typical Width (ft):	130 feet
Typical Width (m):	40 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	small
Starting Zone Characteristics:	broad face
Start Aspect:	WSW
Path Type:	narrow gully
Runout Angle:	steep
Unmitigated avalanche hazard index (AHI):	0.97
Comments:	Eighteenth-highest East Lynn AHI.

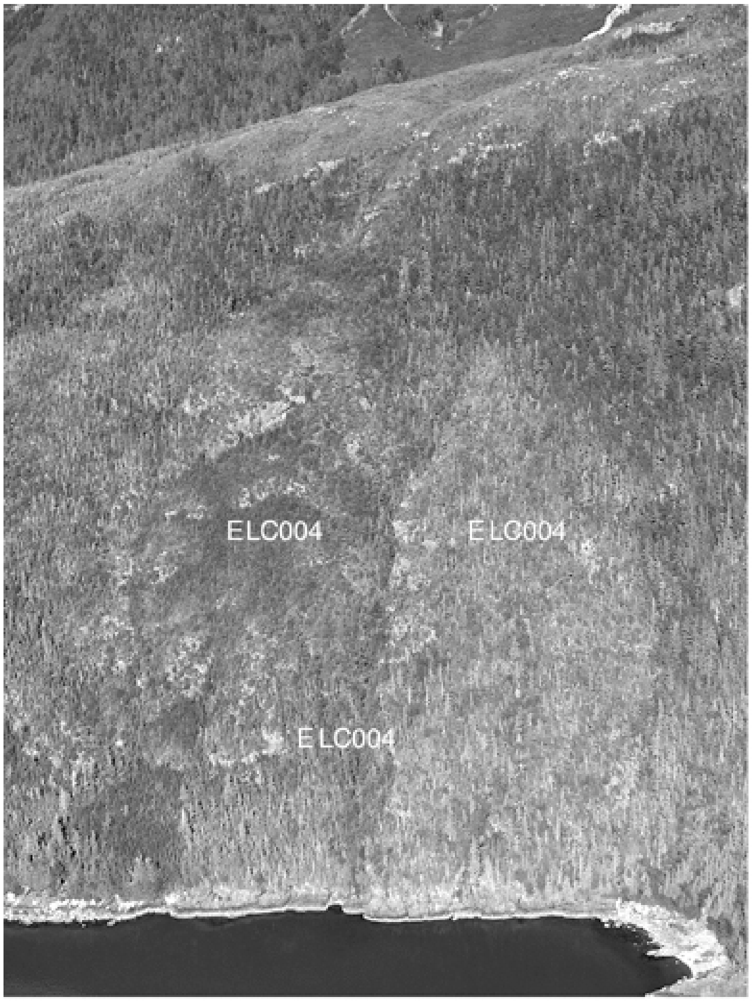


East Lynn Canal Path ELC003-1 Photos

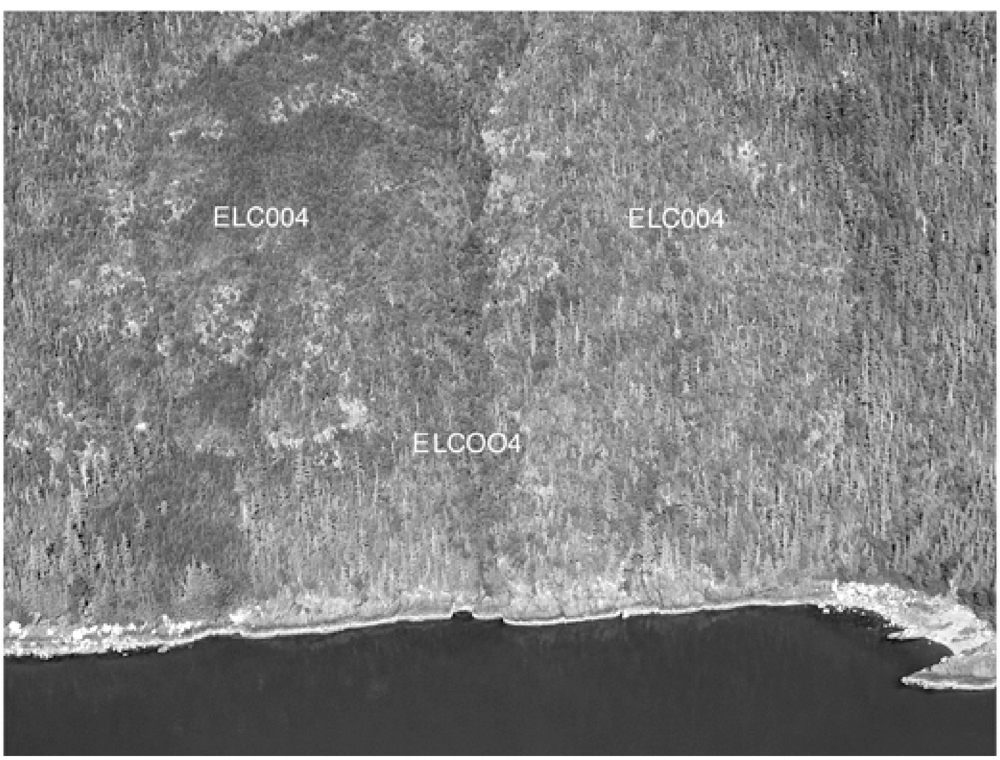


Avalanche Path Atlas - East Lynn Canal Path ELC003-1

Path Group:	North Kensington, Map 2
Latitude-Longitude:	58.544894 -135.093227
Max Width (ft):	380 feet
Max Width (m):	116 meters
Typical Width (ft):	0 feet
Typical Width (m):	0 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	landslide scar
Start Aspect:	WSW
Path Type:	2001 landslide scar
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Stops before alignment.



East Lynn Canal
Path ELC004
Photos



Avalanche Path Atlas - East Lynn Canal Path ELC004

Path Group:	North Kensington, Map 3
Latitude-Longitude:	58.563007 -135.102606
Max Width (ft):	1330 feet
Max Width (m):	405 meters
Typical Width (ft):	140 feet
Typical Width (m):	43 meters
Starting Elevation (ft):	1000 feet
Starting Elevation (m):	305 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	open scrub forest
Start Aspect:	WSW
Path Type:	open scrub forest and small gully
Runout Angle:	steep
Unmitigated avalanche hazard index (AHI):	0.06
Comments:	

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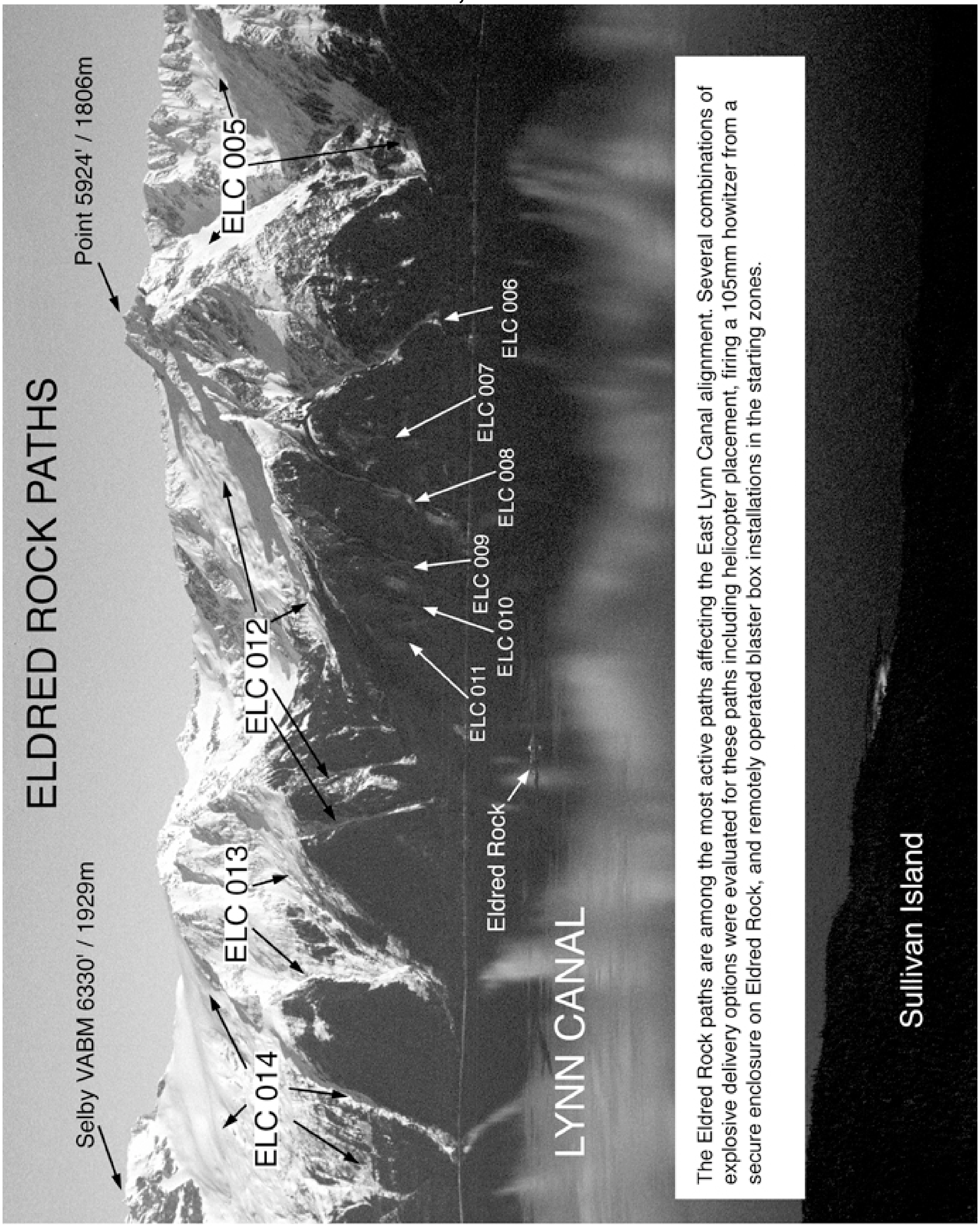
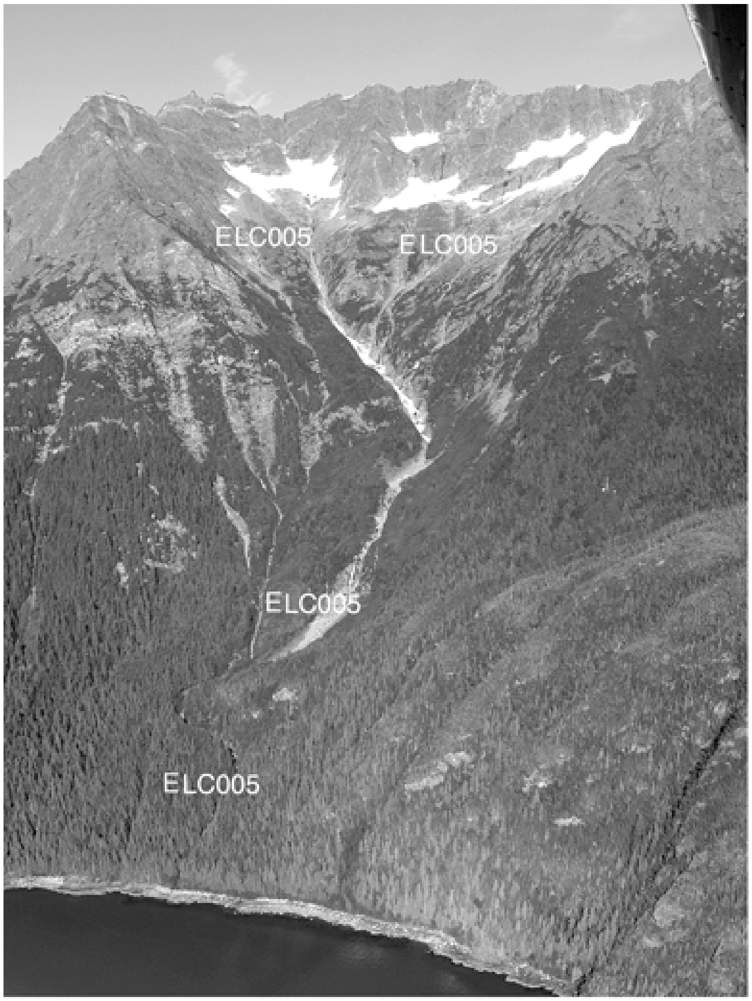
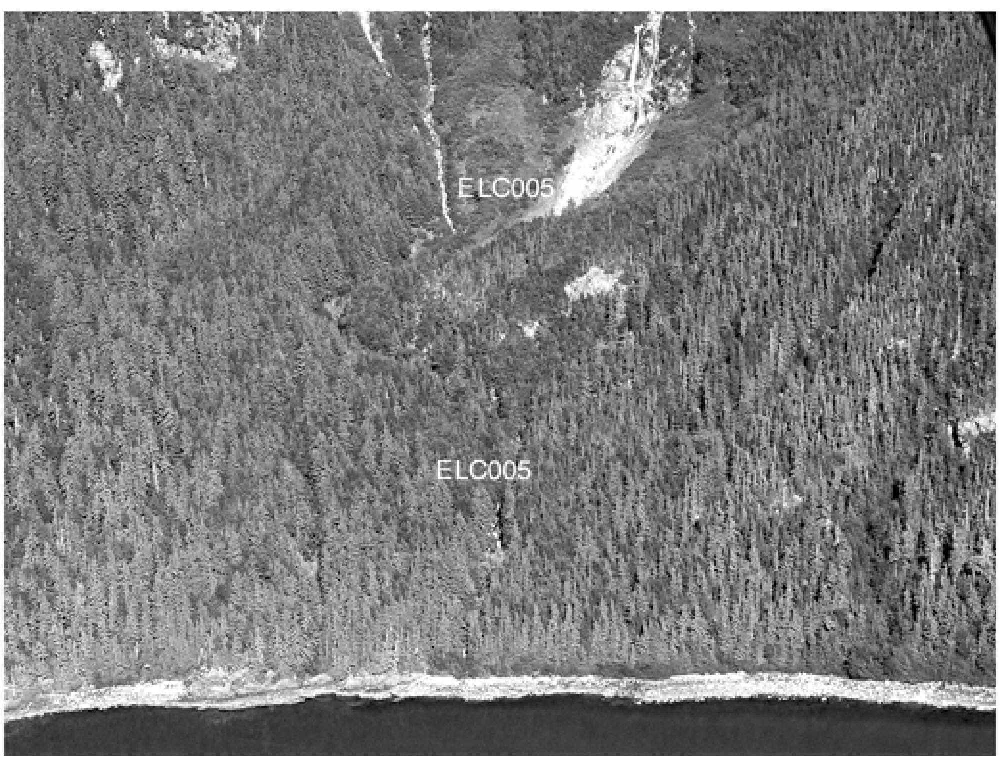
Eldred Rock Paths Overview Photo, ELC005 to ELC014



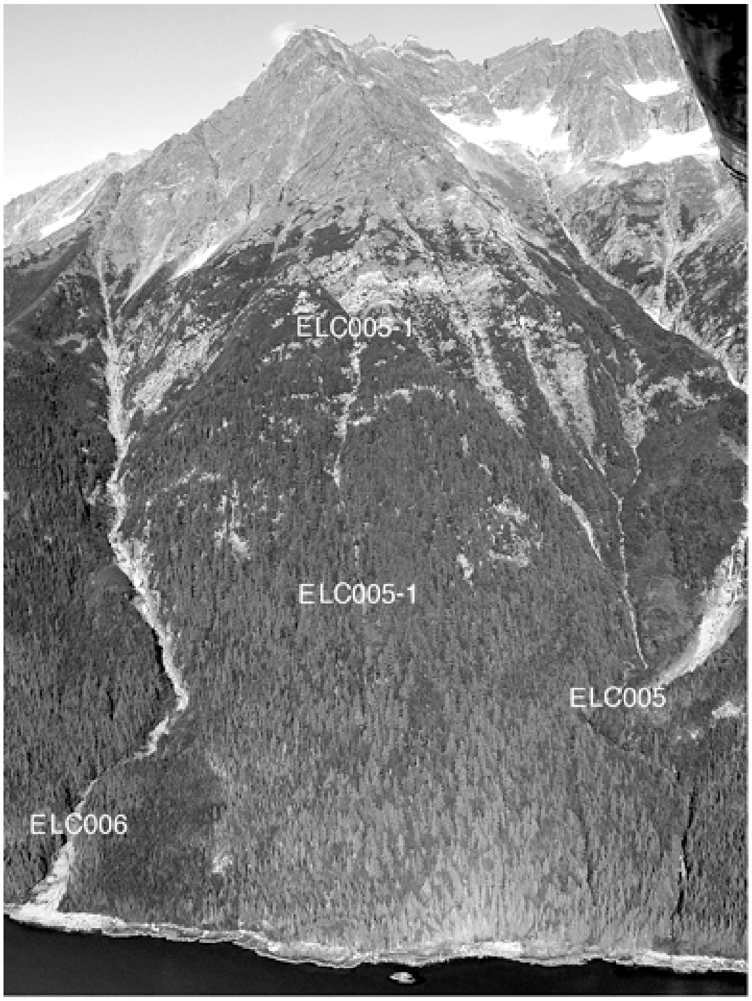


East Lynn Canal Path ELC005 Photos

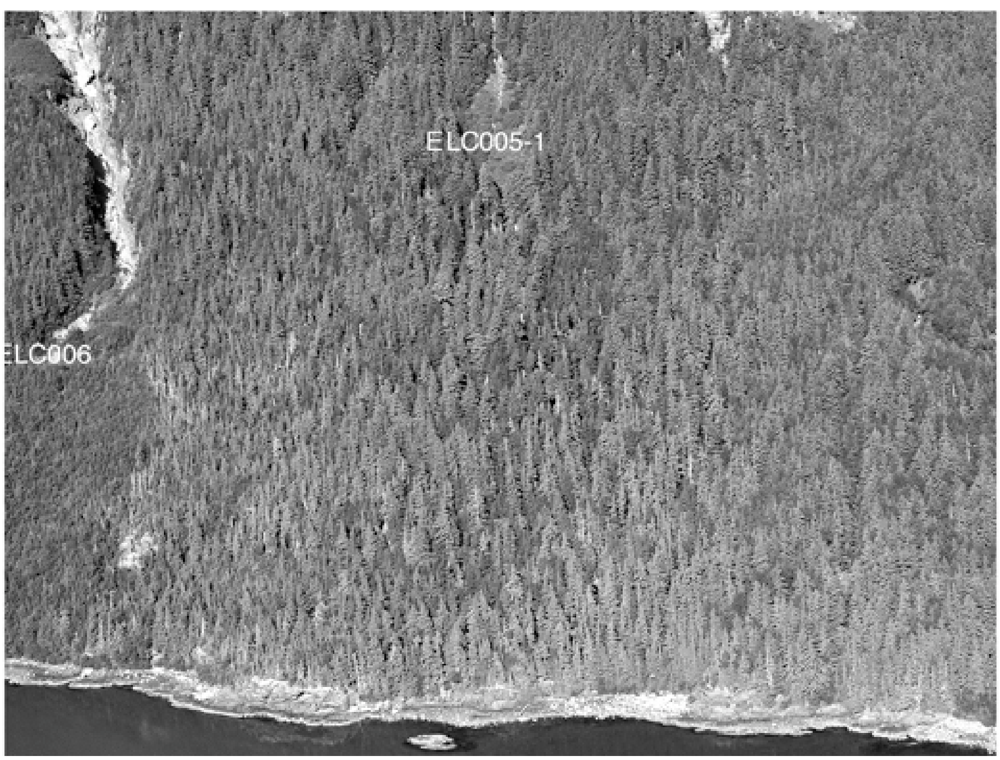


Avalanche Path Atlas - East Lynn Canal Path ELC005

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.571584 -135.101956
Max Width (ft):	1150 feet
Max Width (m):	351 meters
Typical Width (ft):	150 feet
Typical Width (m):	46 meters
Starting Elevation (ft):	5500 feet
Starting Elevation (m):	1676 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl
Start Aspect:	W
Path Type:	classic confined to bench at 600’ (183m); steep gully and spillover below
Runout Angle:	abrupt bench; steep again below
Unmitigated avalanche hazard index (AHI):	0.08
Comments:	Usually stops above alignment.

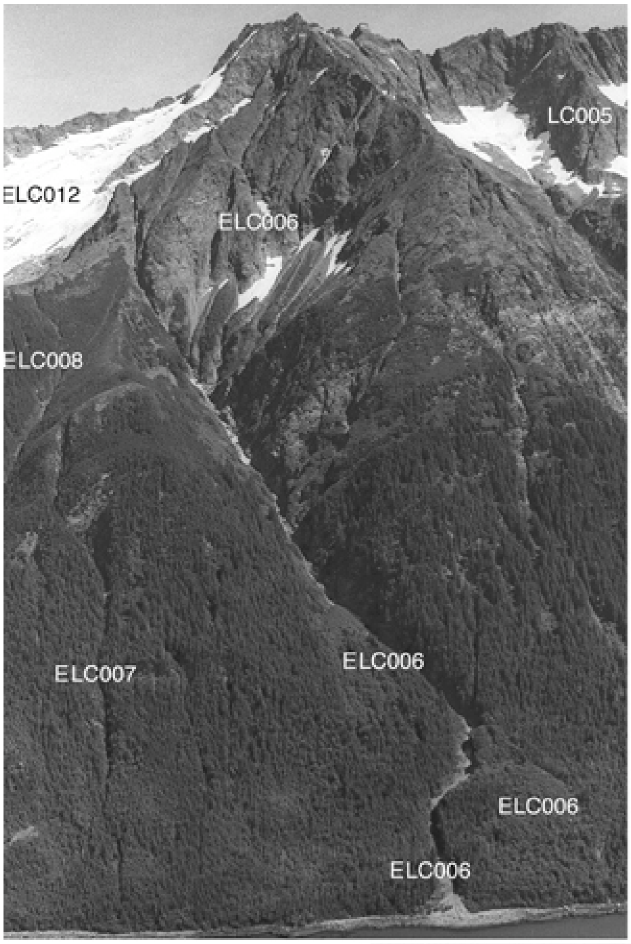


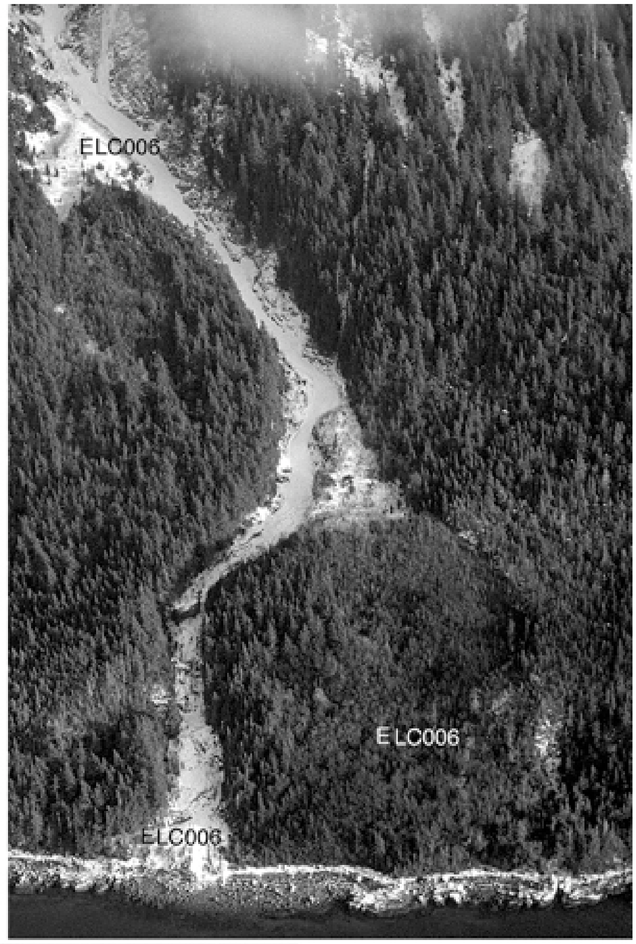
East Lynn Canal Path ELC005-1 Photos



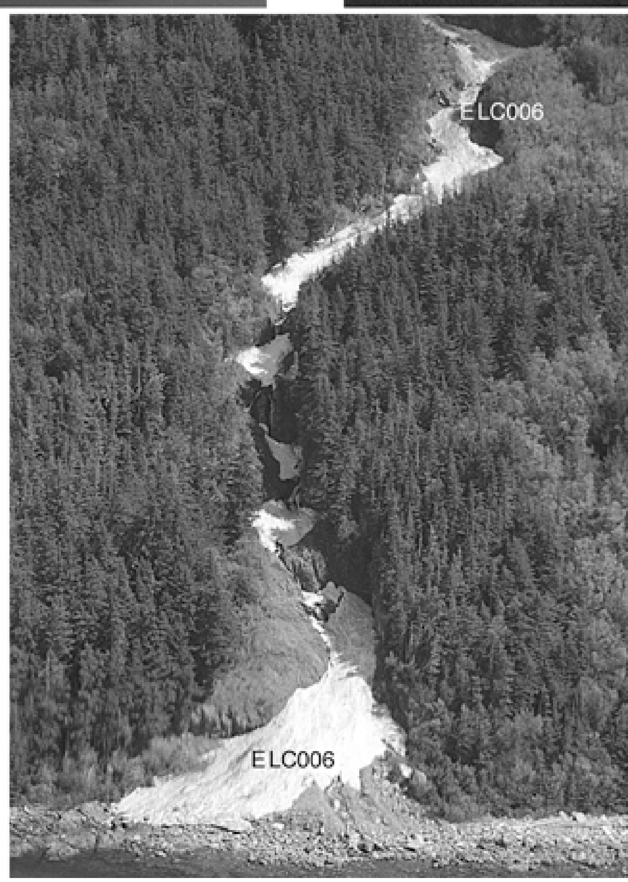
Avalanche Path Atlas - East Lynn Canal Path ELC005-1

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.572924 -135.102566
Max Width (ft):	100 feet
Max Width (m):	30 meters
Typical Width (ft):	0 feet
Typical Width (m):	0 meters
Starting Elevation (ft):	3100 feet
Starting Elevation (m):	945 meters
Elevation Class:	high
Path Size:	small
Starting Zone Characteristics:	slight gully
Start Aspect:	WSW
Path Type:	shallow gully
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Stops above alignment.



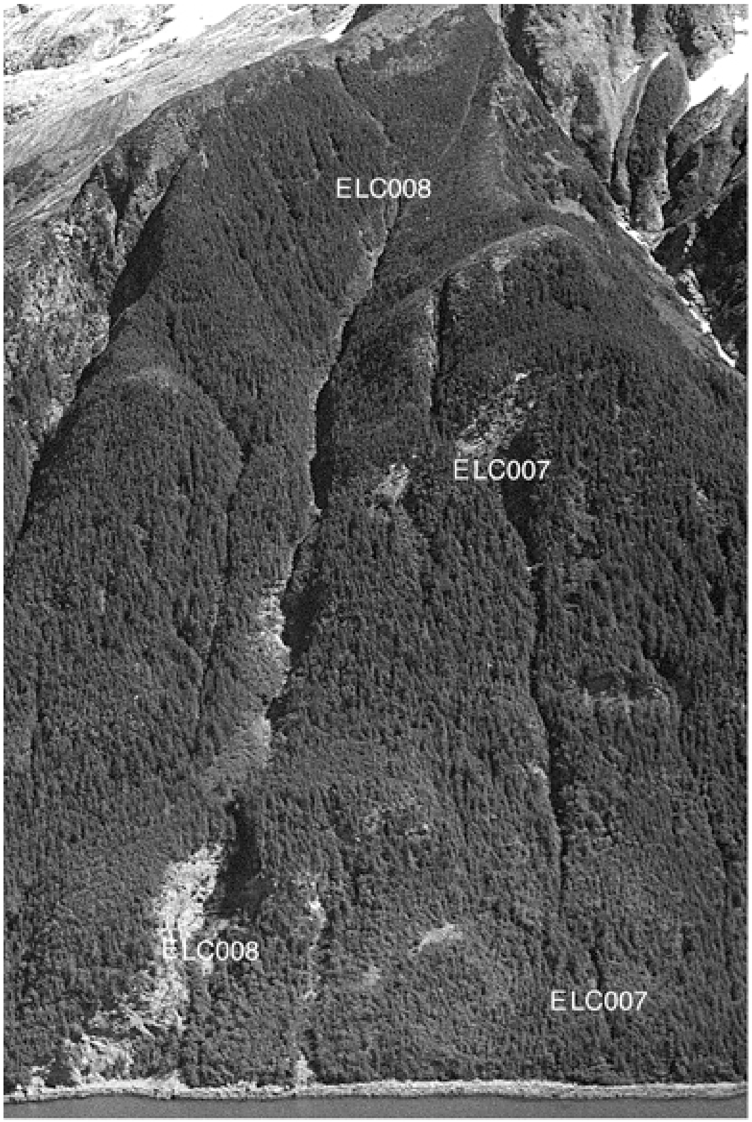


East Lynn Canal Path ELC006 Photos

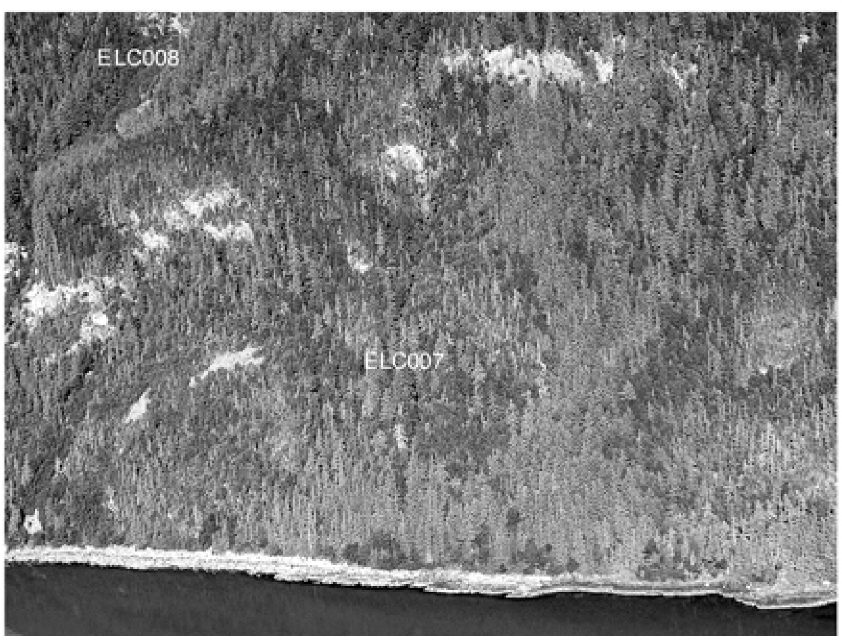


Avalanche Path Atlas - East Lynn Canal Path ELC006

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.574197 -135.102504
Max Width (ft):	1200 feet
Max Width (m):	366 meters
Typical Width (ft):	270 feet
Typical Width (m):	82 meters
Starting Elevation (ft):	5100 feet
Starting Elevation (m):	1554 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big gullied bowl
Start Aspect:	W
Path Type:	classic confined, angled track
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	21.18
Comments:	Second-highest East Lynn AHI.

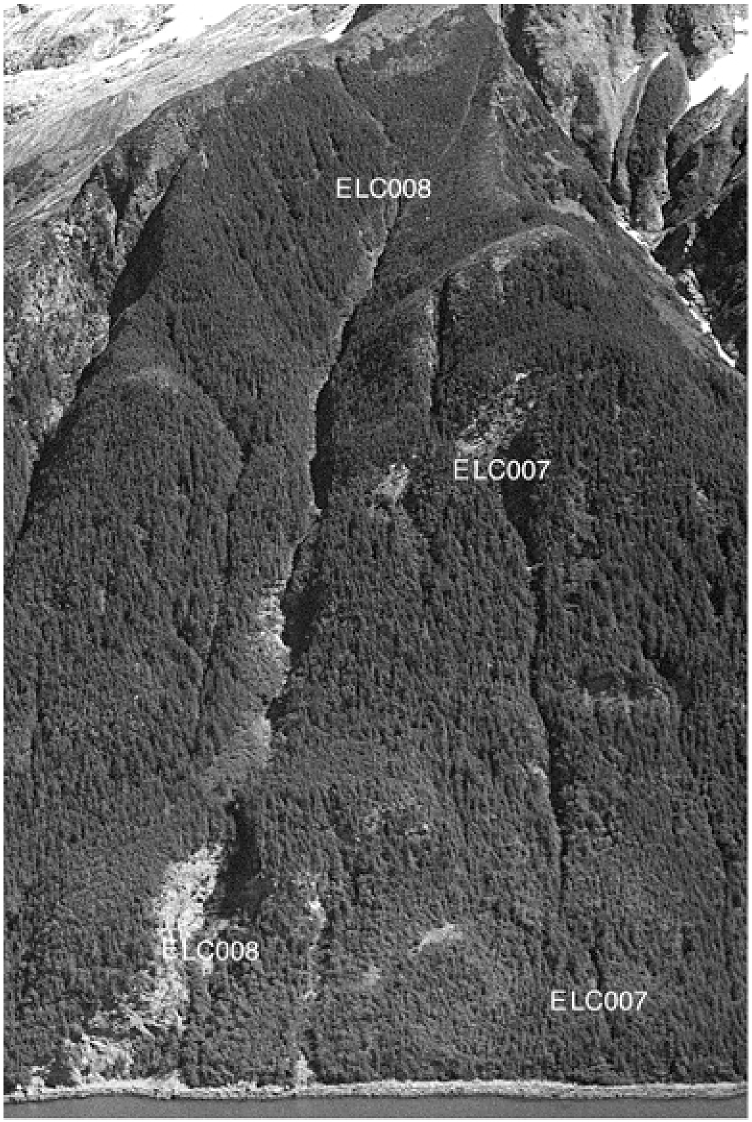


East Lynn Canal Path ELC007 Photos

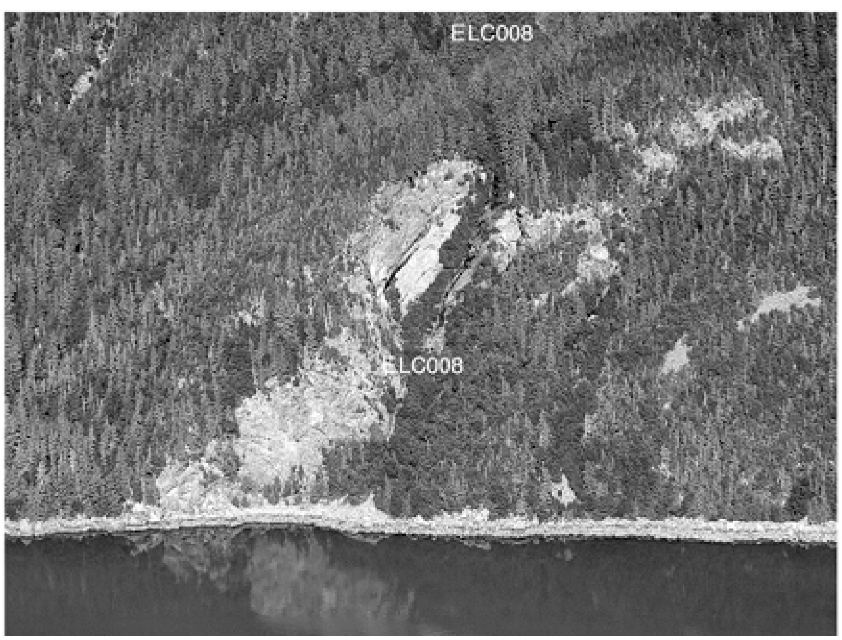


Avalanche Path Atlas - East Lynn Canal Path ELC007

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.575893 -135.102543
Max Width (ft):	380 feet
Max Width (m):	116 meters
Typical Width (ft):	75 feet
Typical Width (m):	23 meters
Starting Elevation (ft):	2100 feet
Starting Elevation (m):	640 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	small bowl/gully
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.05
Comments:	Usually stops above alignment.

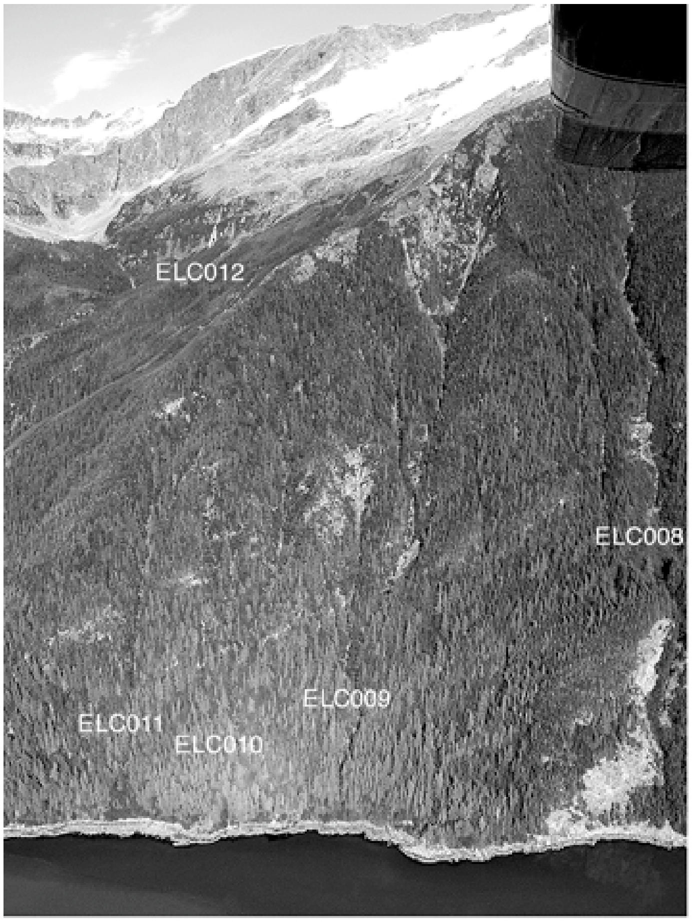


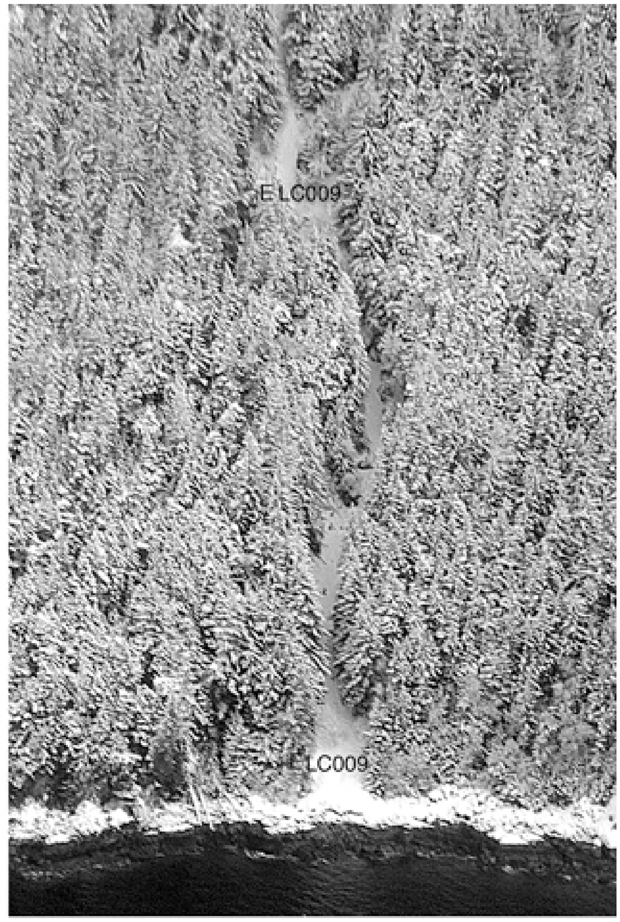
East Lynn Canal Path ELC008 Photos



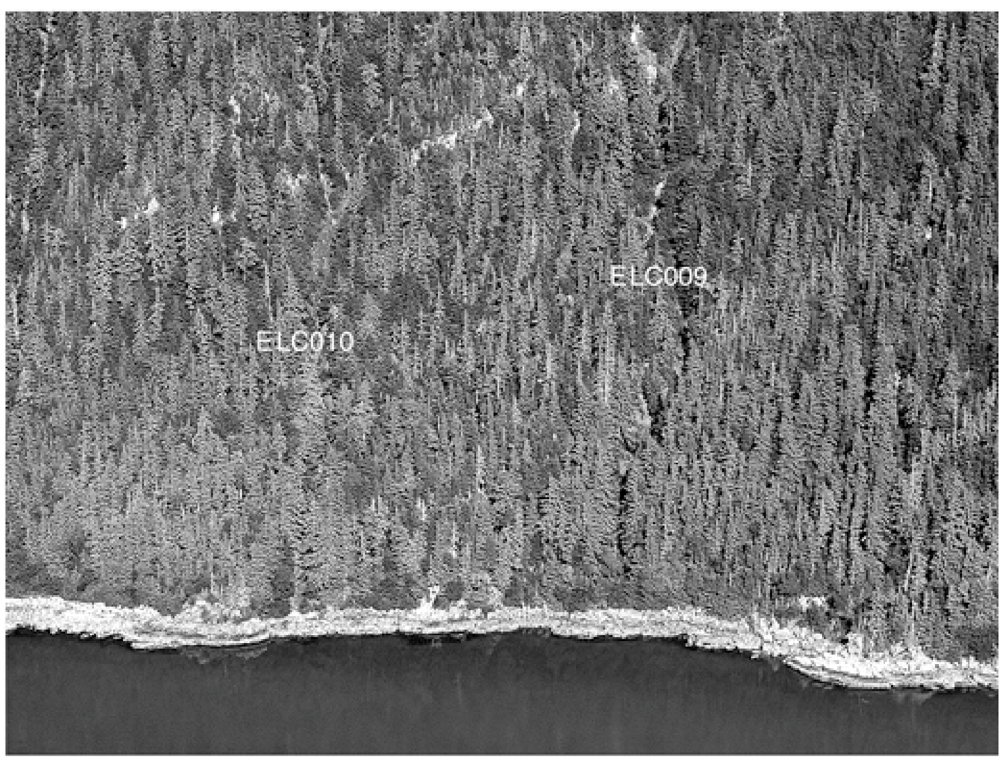
Avalanche Path Atlas - East Lynn Canal Path ELC008

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.580951 -135.102467
Max Width (ft):	1040 feet
Max Width (m):	317 meters
Typical Width (ft):	170 feet
Typical Width (m):	52 meters
Starting Elevation (ft):	3400 feet
Starting Elevation (m):	1036 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	medium bowl
Start Aspect:	W
Path Type:	classic confined
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.31
Comments:	Usually stops before alignment.



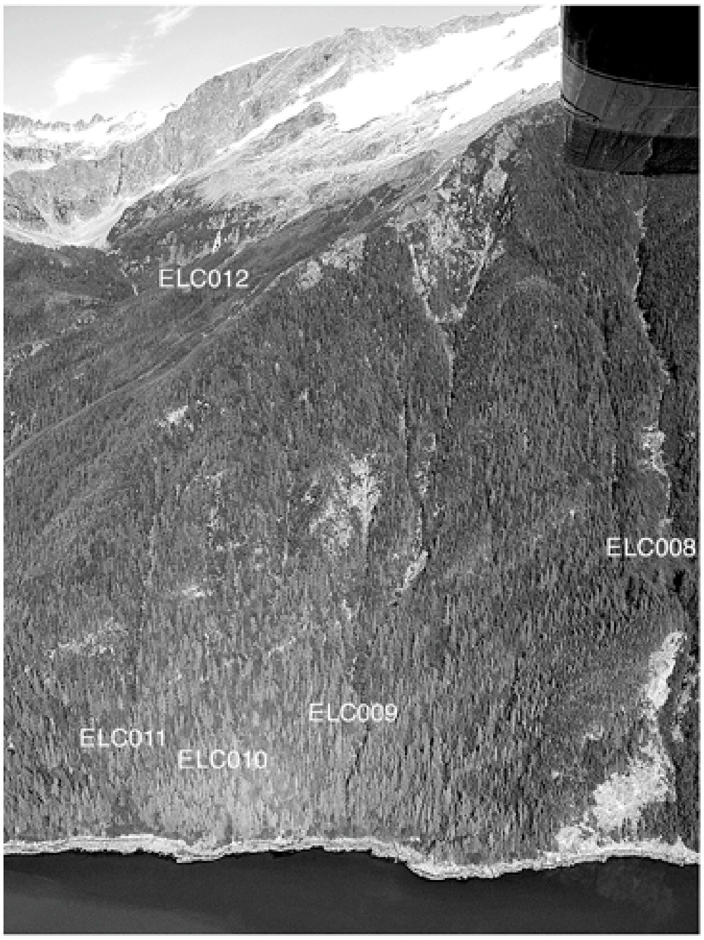


East Lynn
Canal
Path
ELC009
Photos

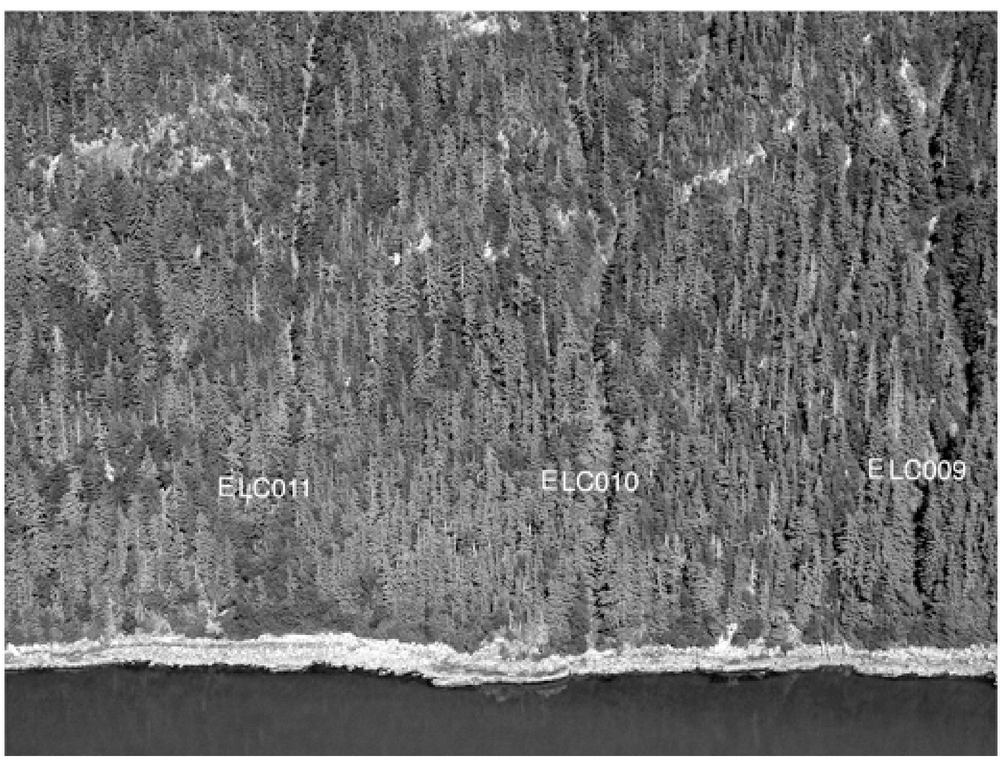


Avalanche Path Atlas - East Lynn Canal Path ELC009

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.582368 -135.102472
Max Width (ft):	110 feet
Max Width (m):	34 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	2700 feet
Starting Elevation (m):	823 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	small bowl and gullies
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	0.72
Comments:	

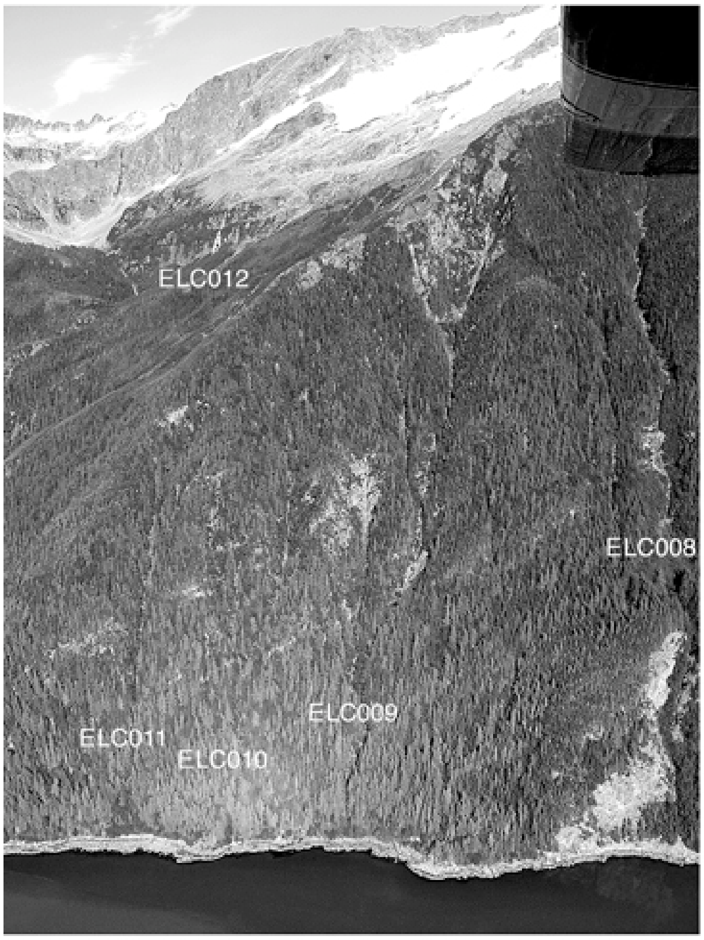


East Lynn Canal Path ELC010 Photos

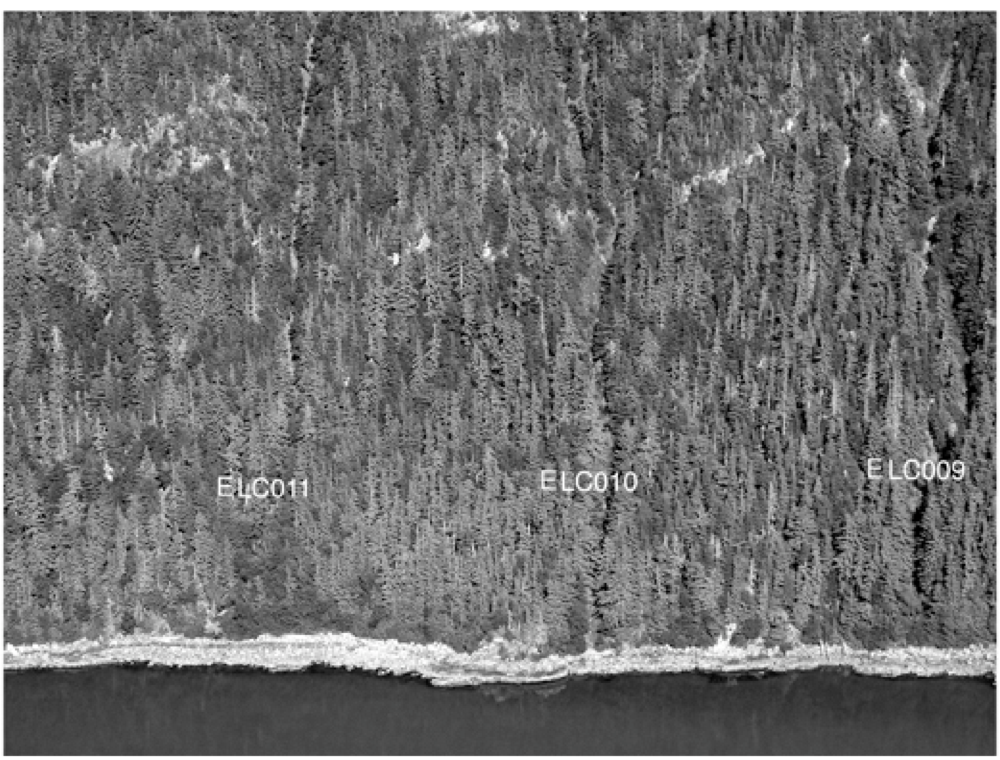


Avalanche Path Atlas - East Lynn Canal Path ELC010

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.58277 -135.102473
Max Width (ft):	100 feet
Max Width (m):	30 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	narrow gully
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	1.83
Comments:	Sixteenth-highest East Lynn AHI.

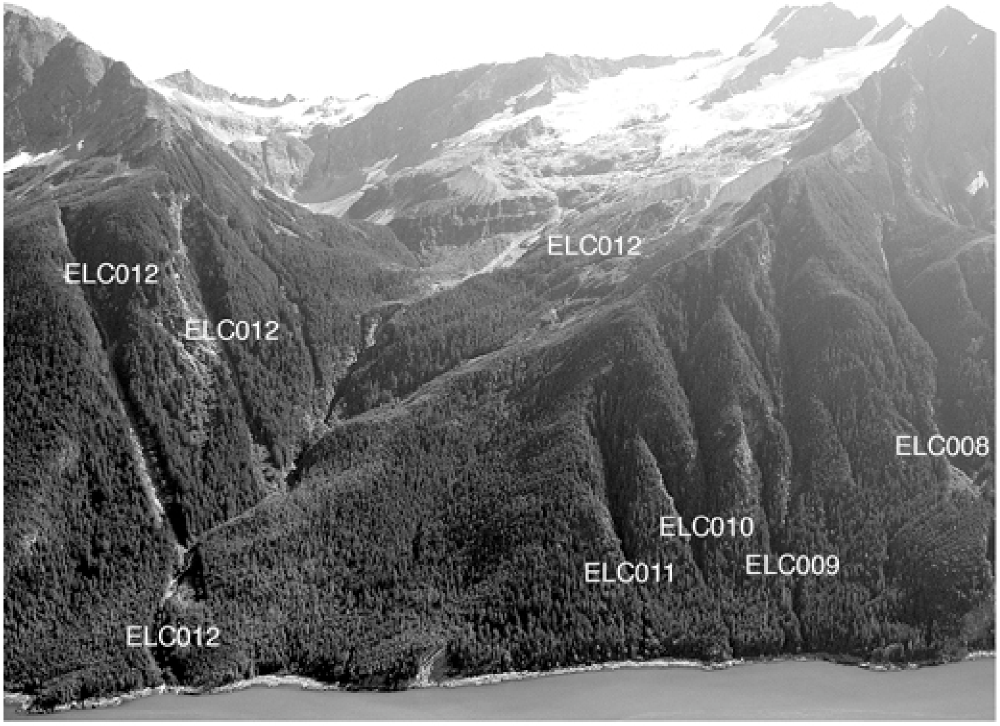


East Lynn Canal Path ELC011 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC011

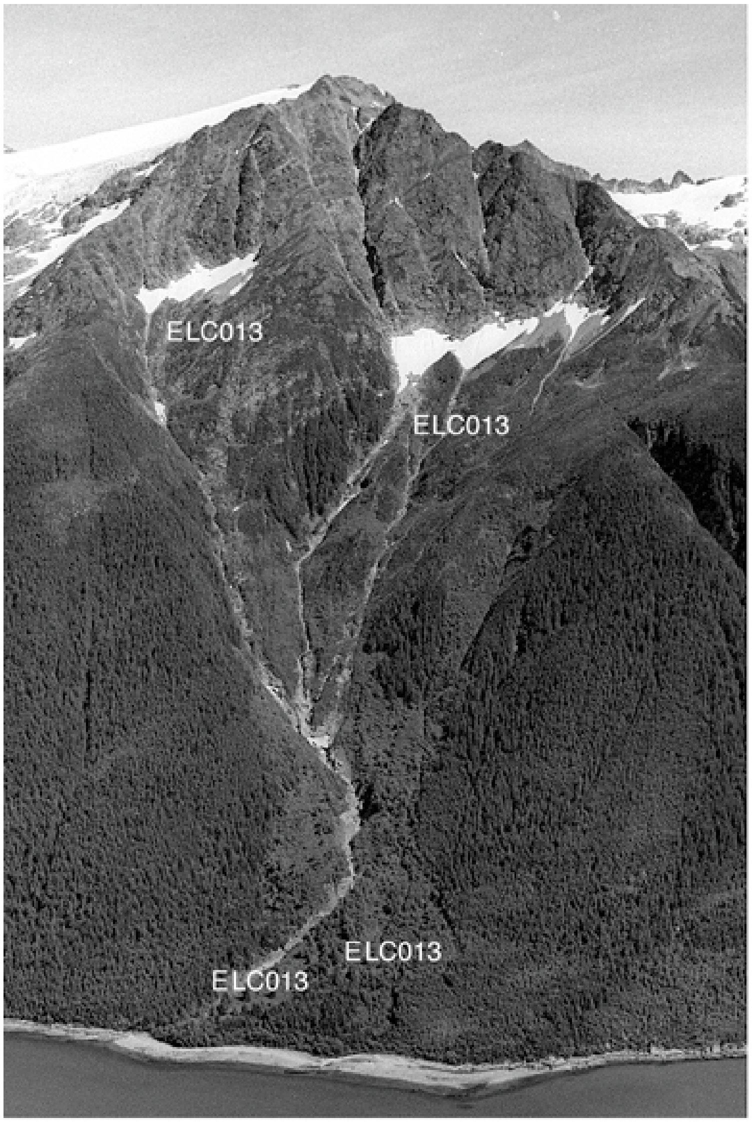
Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.583286 -135.102475
Max Width (ft):	110 feet
Max Width (m):	34 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	narrow gully
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	1.50
Comments:	Seventeenth-highest East Lynn AHI.



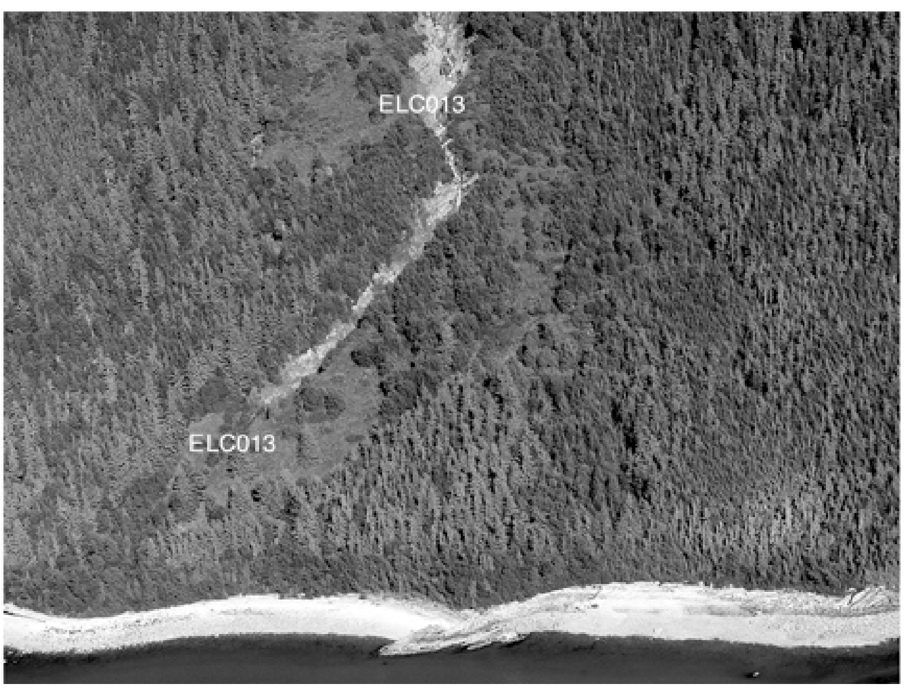
East Lynn Canal Path ELC012 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC012

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.585938 -135.102898
Max Width (ft):	1190 feet
Max Width (m):	363 meters
Typical Width (ft):	110 feet
Typical Width (m):	34 meters
Starting Elevation (ft):	5924 feet
Starting Elevation (m):	1806 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl and broad gullies
Start Aspect:	W
Path Type:	bowl and gullies to bench at 500’ (153m); narrow gully and spillover below
Runout Angle:	moderate decrease to bench; steep below
Unmitigated avalanche hazard index (AHI):	0.12
Comments:	Usually stops above alignment.

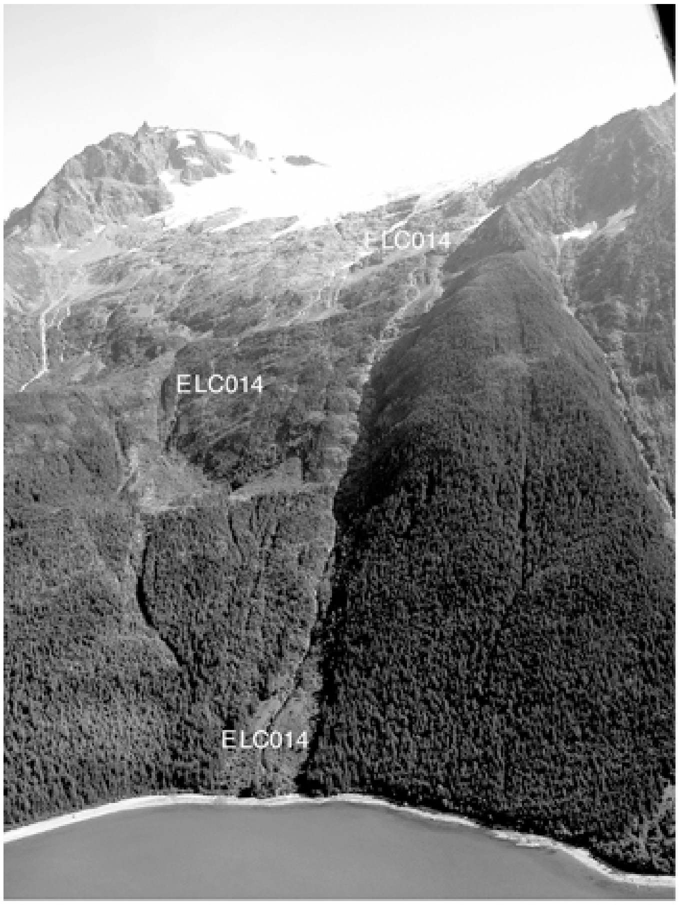


East Lynn Canal Path ELC013 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC013

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.593939 -135.103925
Max Width (ft):	2860 feet
Max Width (m):	872 meters
Typical Width (ft):	340 feet
Typical Width (m):	104 meters
Starting Elevation (ft):	5300 feet
Starting Elevation (m):	1615 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	two big gullied bowls
Start Aspect:	W
Path Type:	classic confined
Runout Angle:	decreases gradually
Unmitigated avalanche hazard index (AHI):	0.59
Comments:	

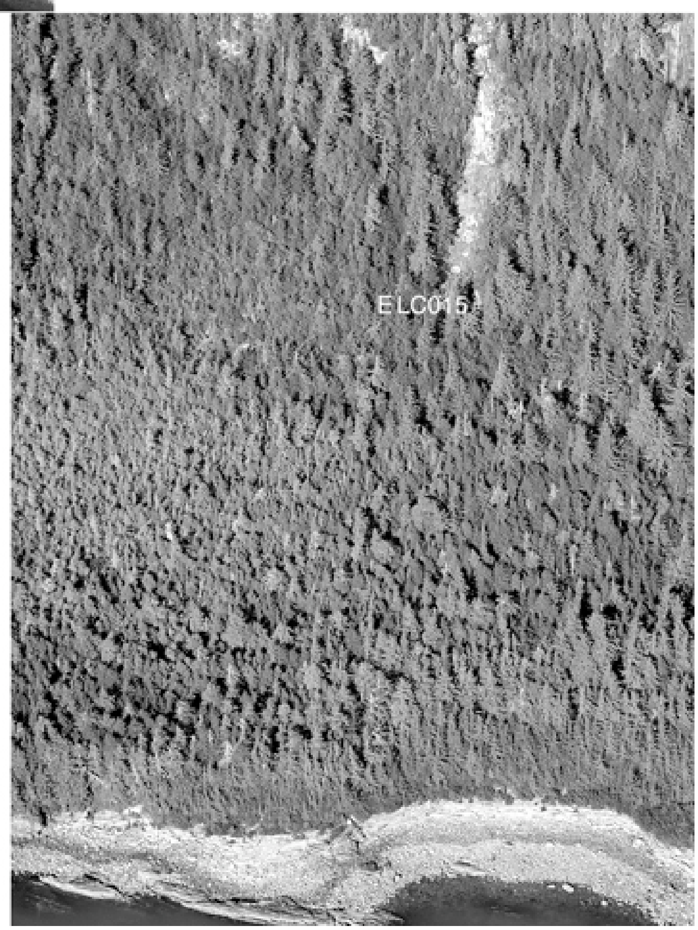


East Lynn Canal Path ELC014 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC014

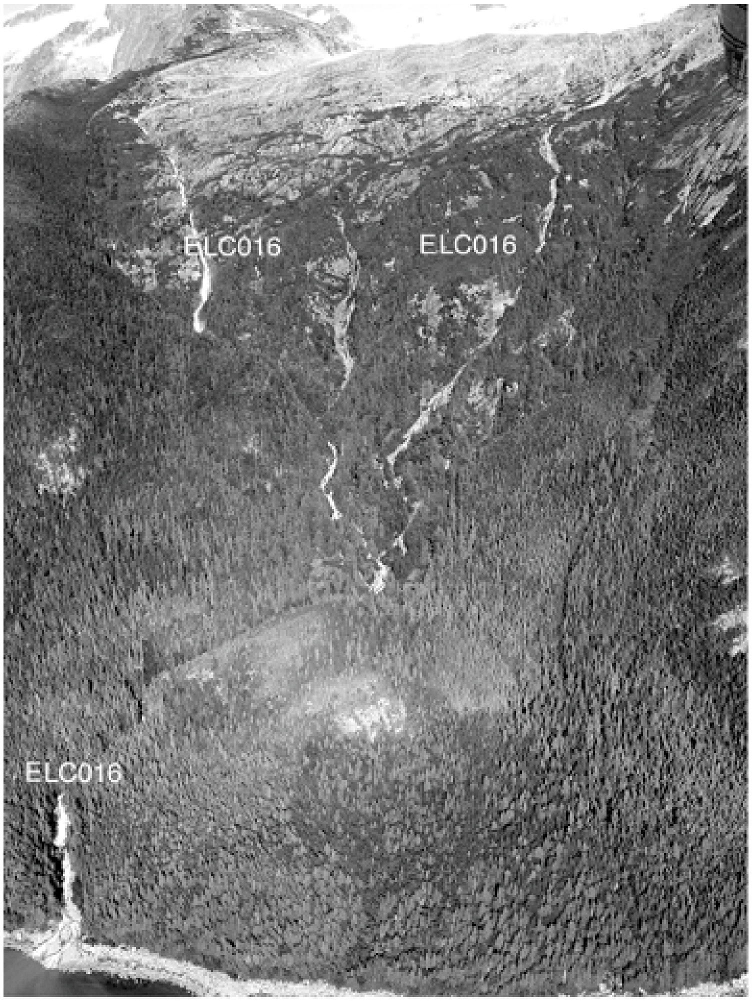
Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	58.595964 -135.103751
Max Width (ft):	750 feet
Max Width (m):	229 meters
Typical Width (ft):	120 feet
Typical Width (m):	37 meters
Starting Elevation (ft):	4700 feet
Starting Elevation (m):	1432 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	rollover, very broad bowl
Start Aspect:	W
Path Type:	classic broad confined main path; infrequent broad track
Runout Angle:	decreases gradually
Unmitigated avalanche hazard index (AHI):	3.58
Comments:	Tenth-highest East Lynn AHI.

East Lynn Canal Path ELC015 Photos

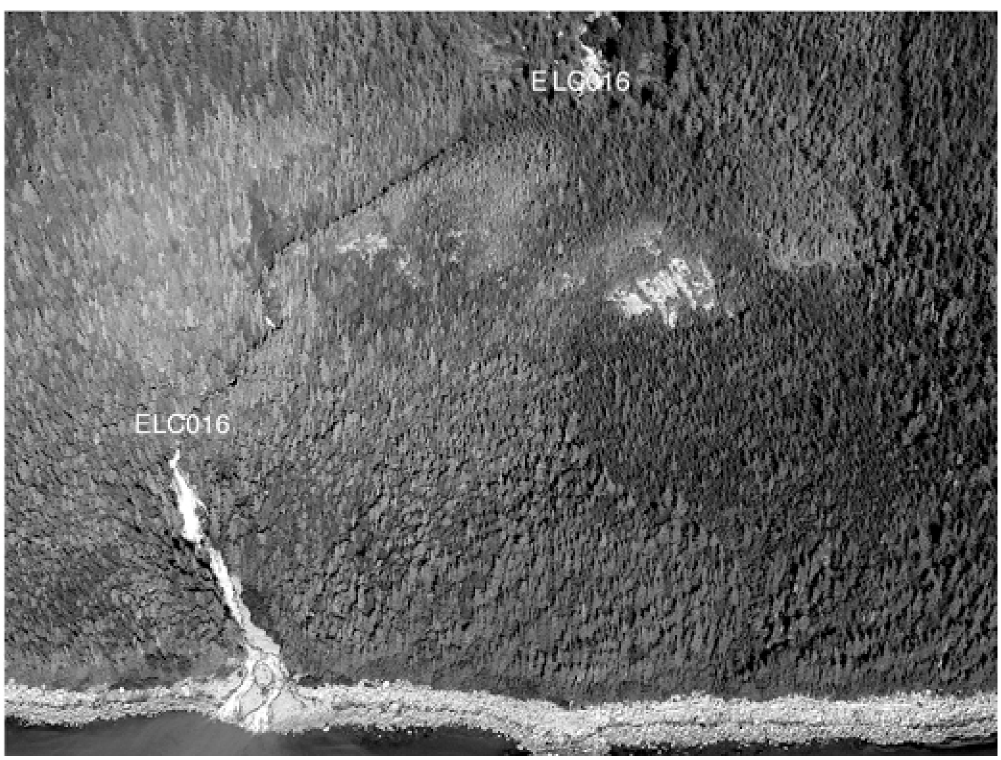


Avalanche Path Atlas - East Lynn Canal Path ELC015

Path Group:	Eldred Rock, Map 3
Latitude-Longitude:	59.012272 -135.115548
Max Width (ft):	60 feet
Max Width (m):	18 meters
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	800 feet
Starting Elevation (m):	244 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	cliff notch
Start Aspect:	WSW
Path Type:	gully in cliff
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Stops above alignment.



East Lynn Canal Path ELC016 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC016

Path Group:	South Yeldagalga, Map 3
Latitude-Longitude:	59.015936 -135.120994
Max Width (ft):	2290 feet
Max Width (m):	698 meters
Typical Width (ft):	210 feet
Typical Width (m):	64 meters
Starting Elevation (ft):	3200 feet
Starting Elevation (m):	975 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	glacier and rollover in big bowl
Start Aspect:	W
Path Type:	broad start and track; runout gully with broad spillover
Runout Angle:	decreases markedly at 700’ (213m) bench
Unmitigated avalanche hazard index (AHI):	0.02
Comments:	Former ice avalanche area; now inactive; stops above alignment.

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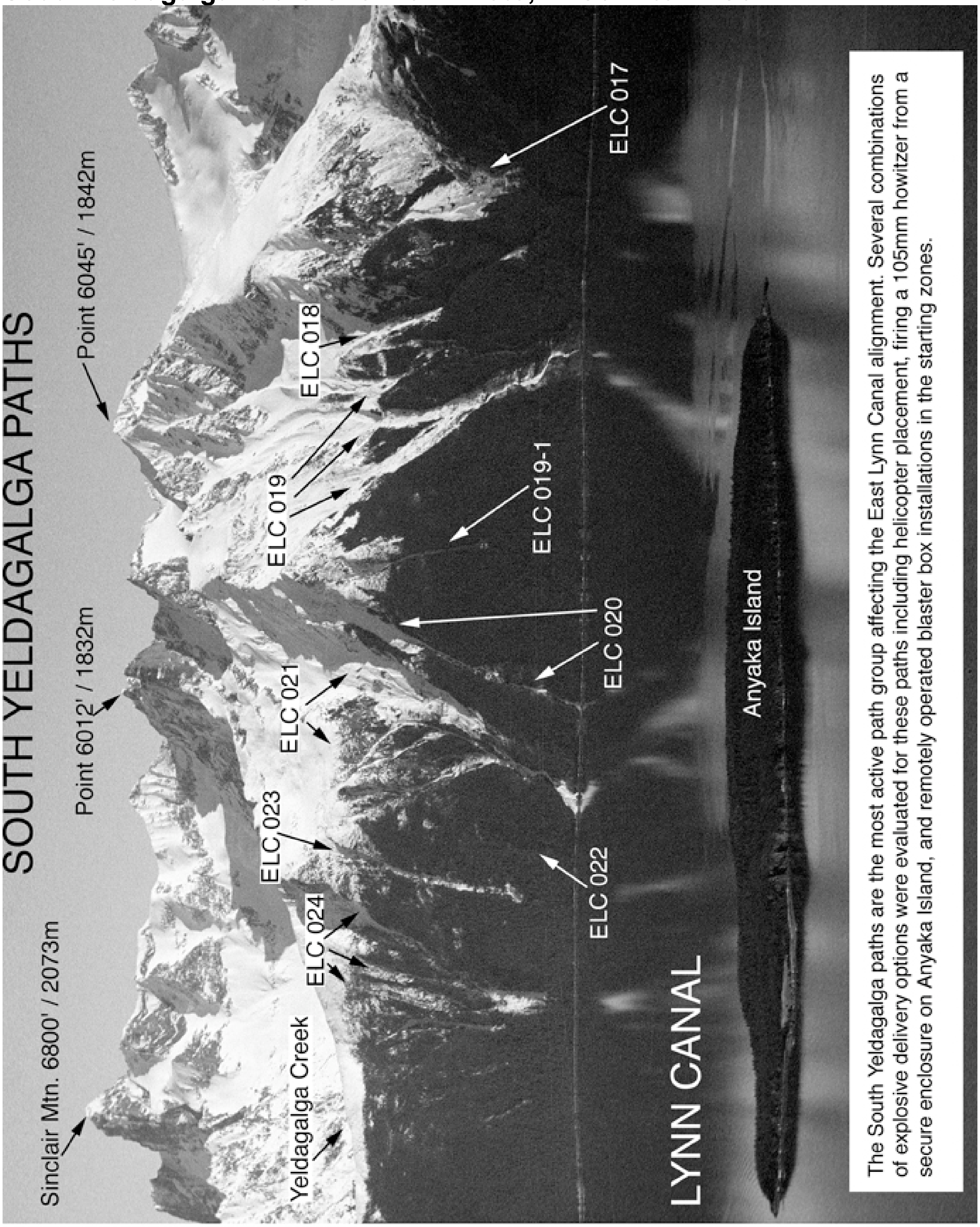
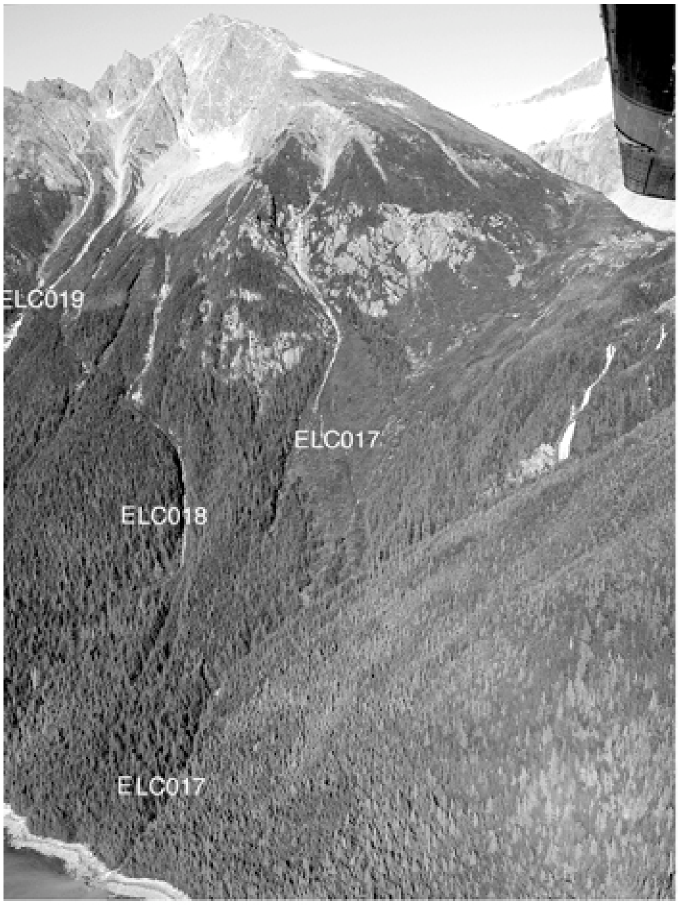
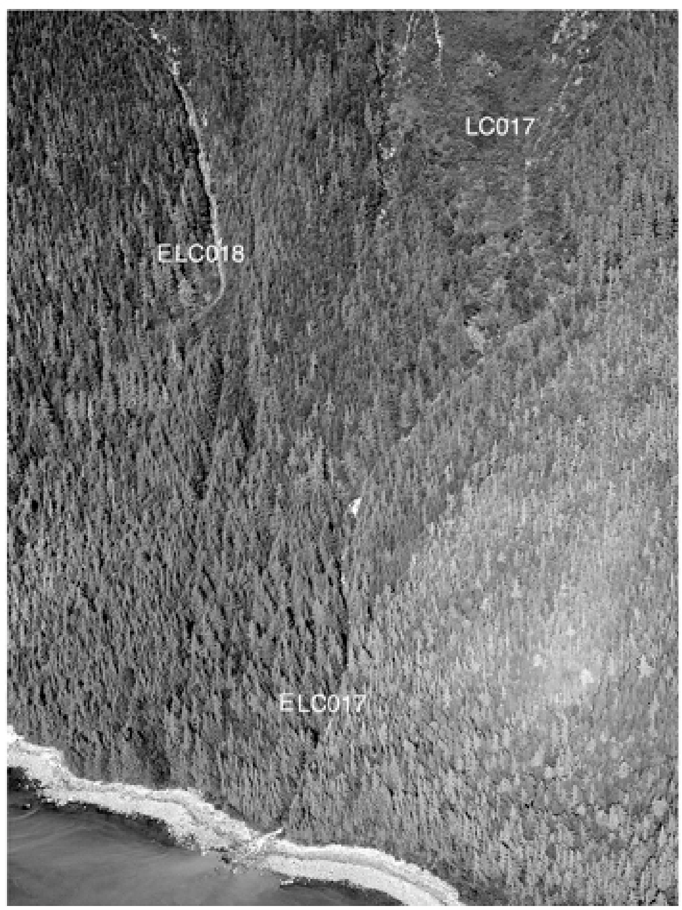
South Yeldagalga Paths Overview Photo, ELC017 to ELC024





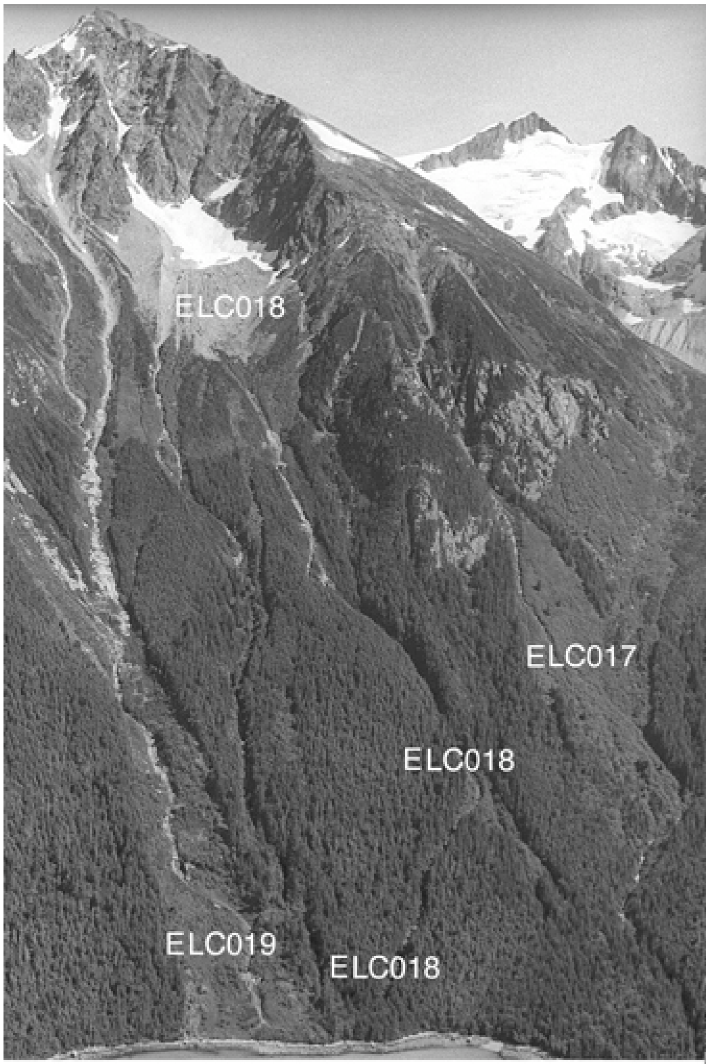
East Lynn Canal Path ELC017 Photos

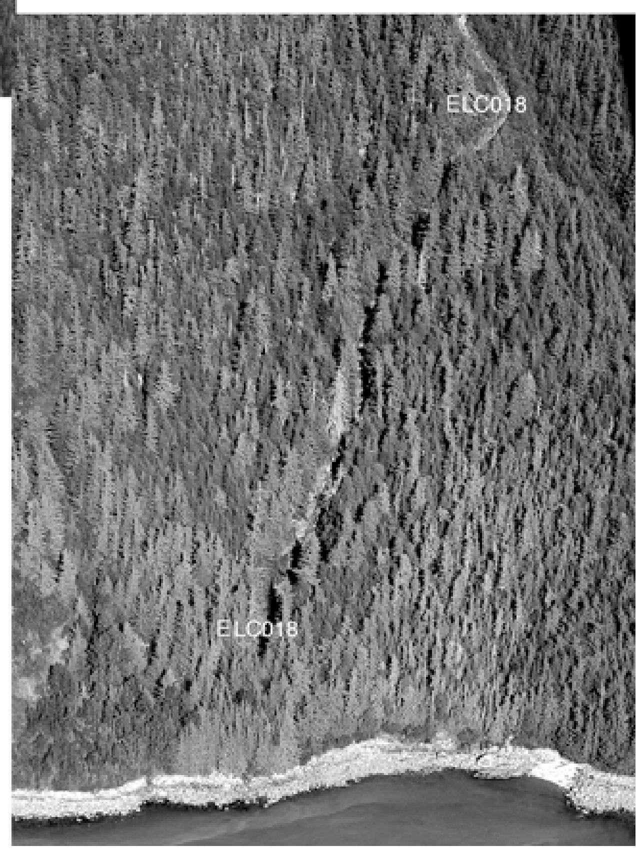


Avalanche Path Atlas - East Lynn Canal Path ELC017

Path Group:	South Yeldagalga, Map 3
Latitude-Longitude:	59.025529 -135.115683
Max Width (ft):	1420 feet
Max Width (m):	433 meters
Typical Width (ft):	170 feet
Typical Width (m):	52 meters
Starting Elevation (ft):	4800 feet
Starting Elevation (m):	1463 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	broad face
Start Aspect:	W
Path Type:	face to bowl and gullies
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.10
Comments:	Usually stops above alignment.

East Lynn Canal Path ELC018 Photos

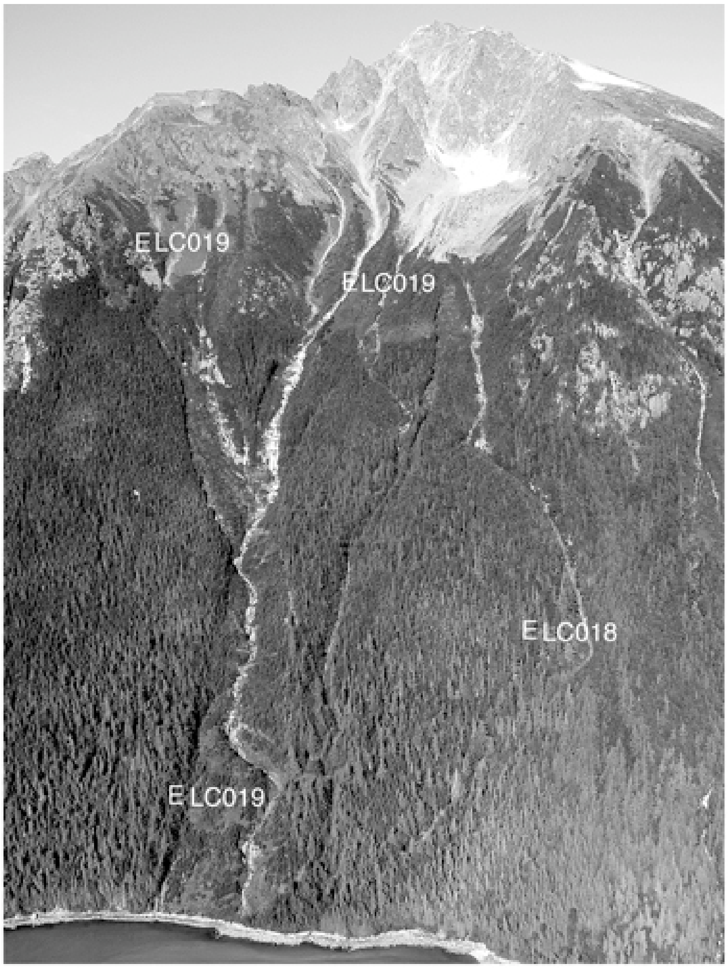


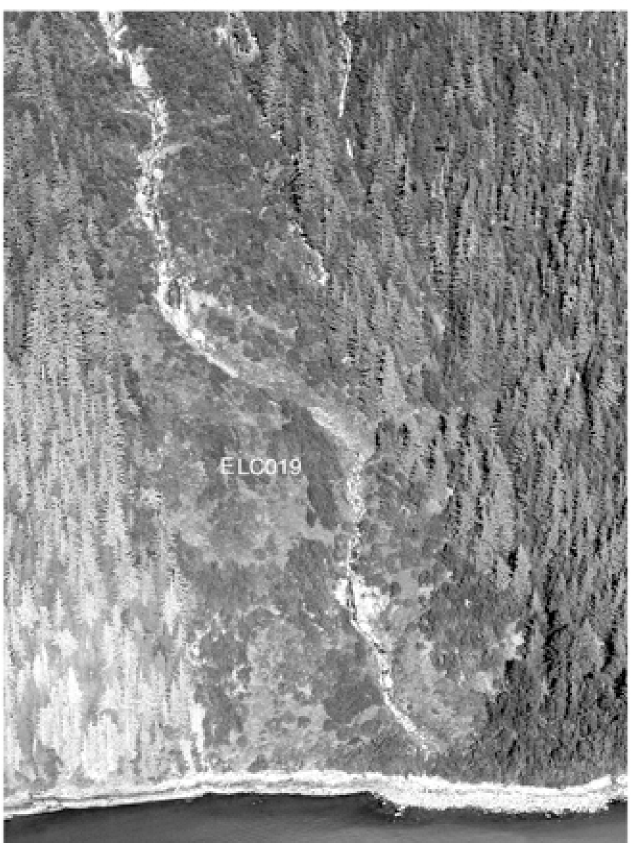


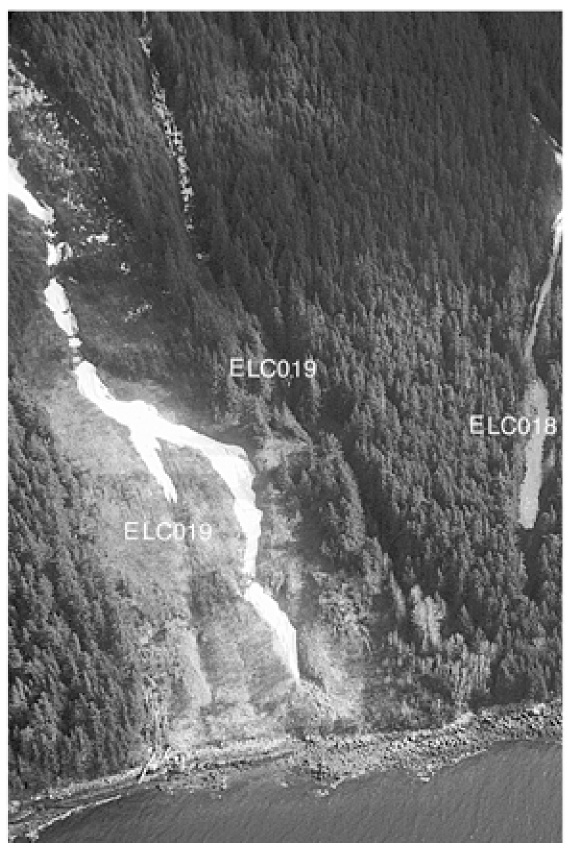
Avalanche Path Atlas - East Lynn Canal Path ELC018

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.030621 -135.115461
Max Width (ft):	980 feet
Max Width (m):	299 meters
Typical Width (ft):	110 feet
Typical Width (m):	34 meters
Starting Elevation (ft):	4700 feet
Starting Elevation (m):	1432 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	part of big bowl
Start Aspect:	W
Path Type:	bowl to narrow gully
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.17
Comments:	Unusually large events may combine with ELC019.

East Lynn Canal Path ELC019 Photos

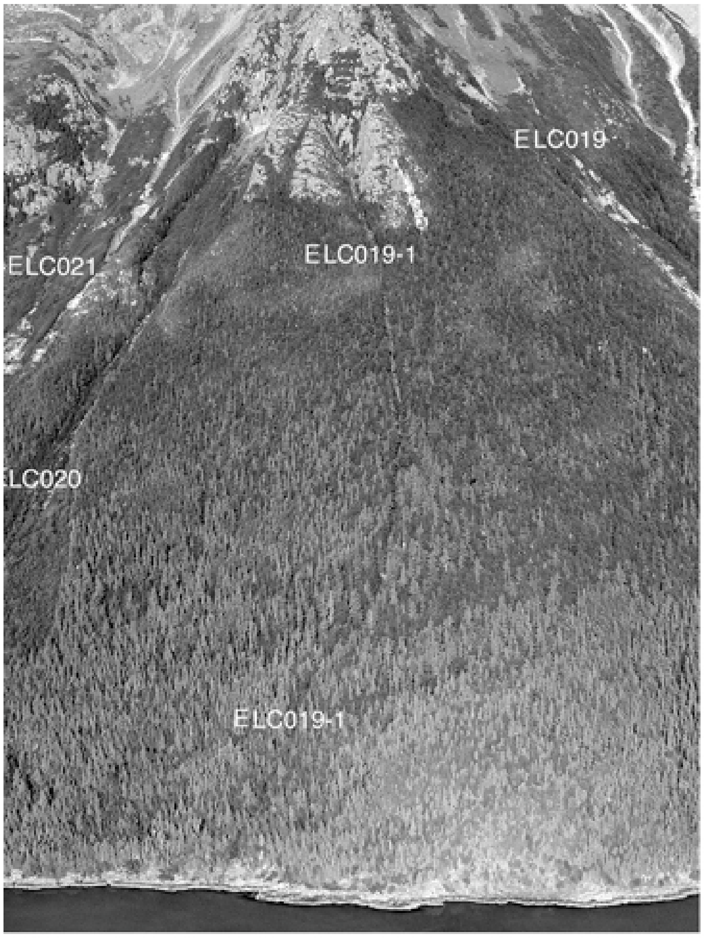




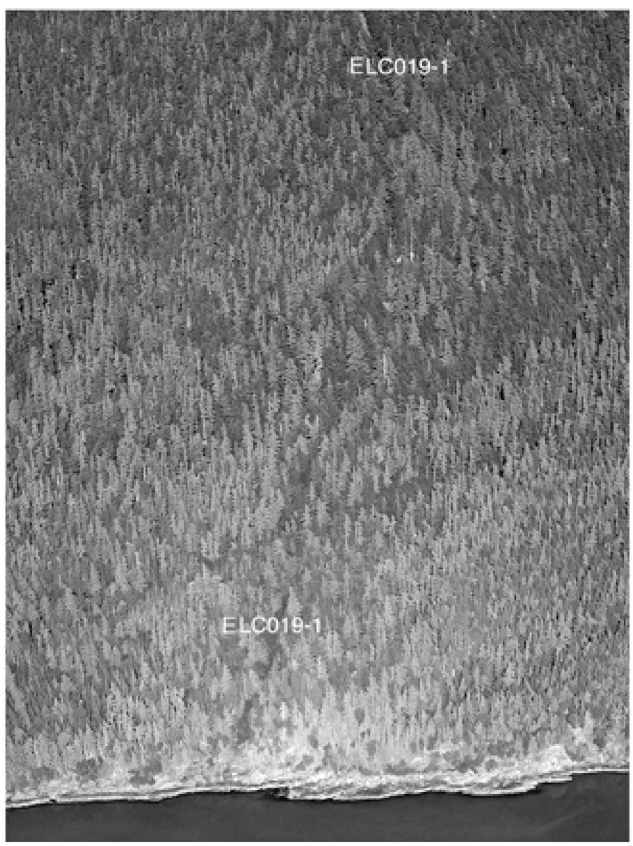


Avalanche Path Atlas - East Lynn Canal Path ELC019

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.0311 -135.11558
Max Width (ft):	980 feet
Max Width (m):	299 meters
Typical Width (ft):	500 feet
Typical Width (m):	152 meters
Starting Elevation (ft):	6300 feet
Starting Elevation (m):	1920 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	WSW
Path Type:	classic confined; broad track feeds from several areas
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	17.30
Comments:	Third-highest East Lynn AHI. Unusually large events may combine with ELC018.



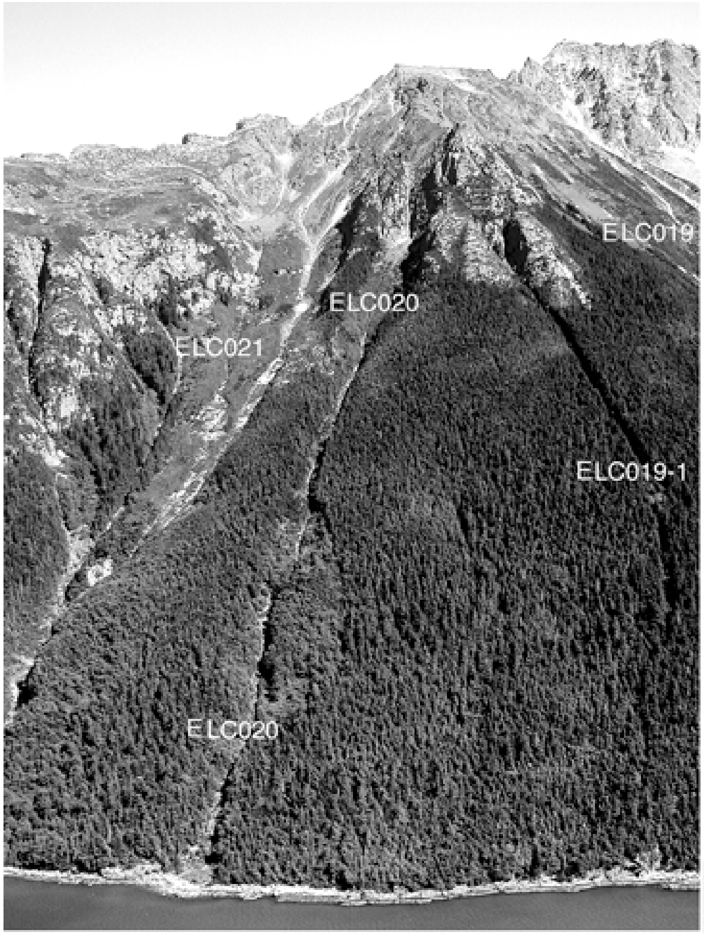
East Lynn Canal Path ELC019-1 Photos

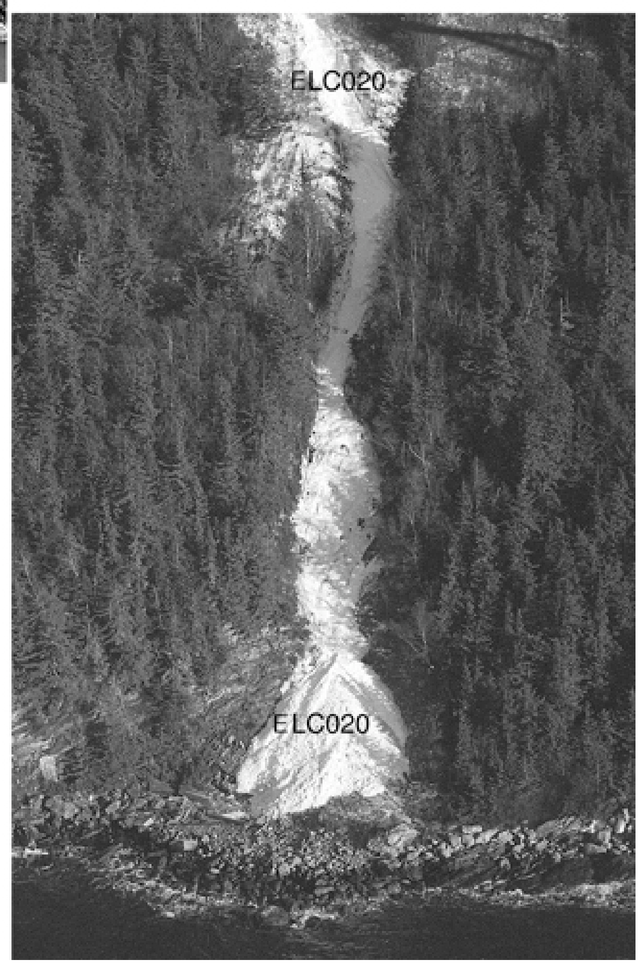


Avalanche Path Atlas - East Lynn Canal Path ELC019-1

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.033816 -135.121281
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	3200 feet
Starting Elevation (m):	975 meters
Elevation Class:	high
Path Size:	small
Starting Zone Characteristics:	small bowl
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Stops above alignment.

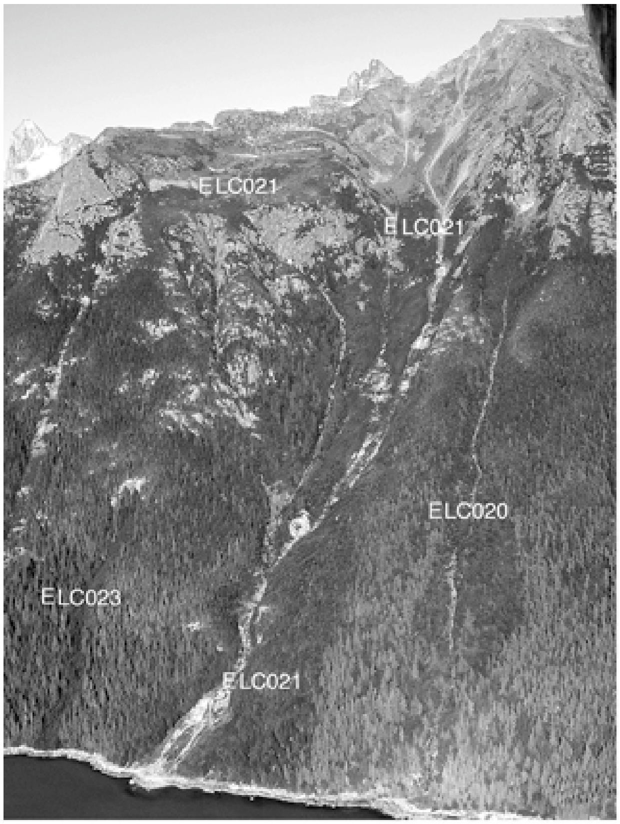
East Lynn Canal Path ELC020 Photos

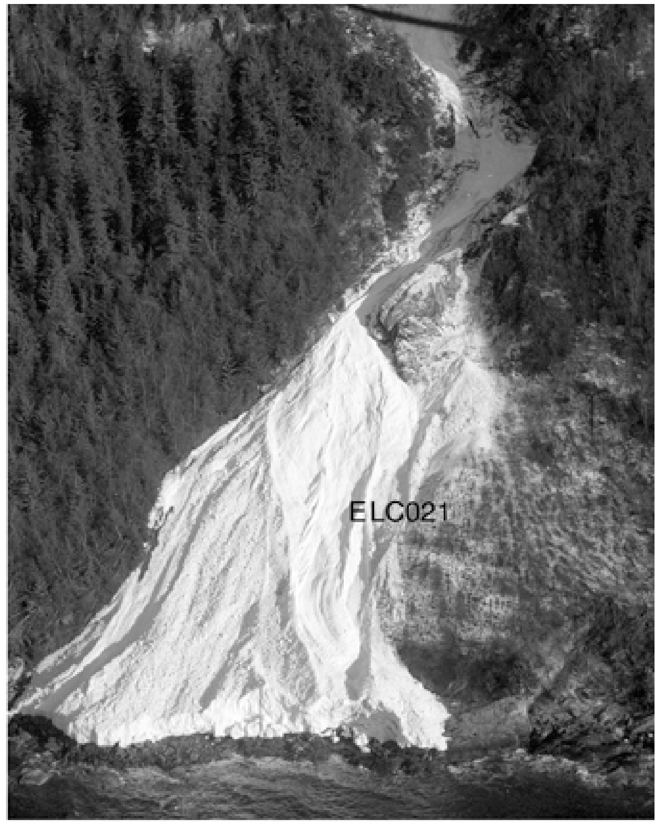




Avalanche Path Atlas - East Lynn Canal Path ELC020

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.03537 -135.121583
Max Width (ft):	400 feet
Max Width (m):	122 meters
Typical Width (ft):	160 feet
Typical Width (m):	49 meters
Starting Elevation (ft):	3700 feet
Starting Elevation (m):	1128 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	small bowl
Start Aspect:	WNW
Path Type:	classic confined, broad gully track
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	10.21
Comments:	Fourth-highest East Lynn AHI.

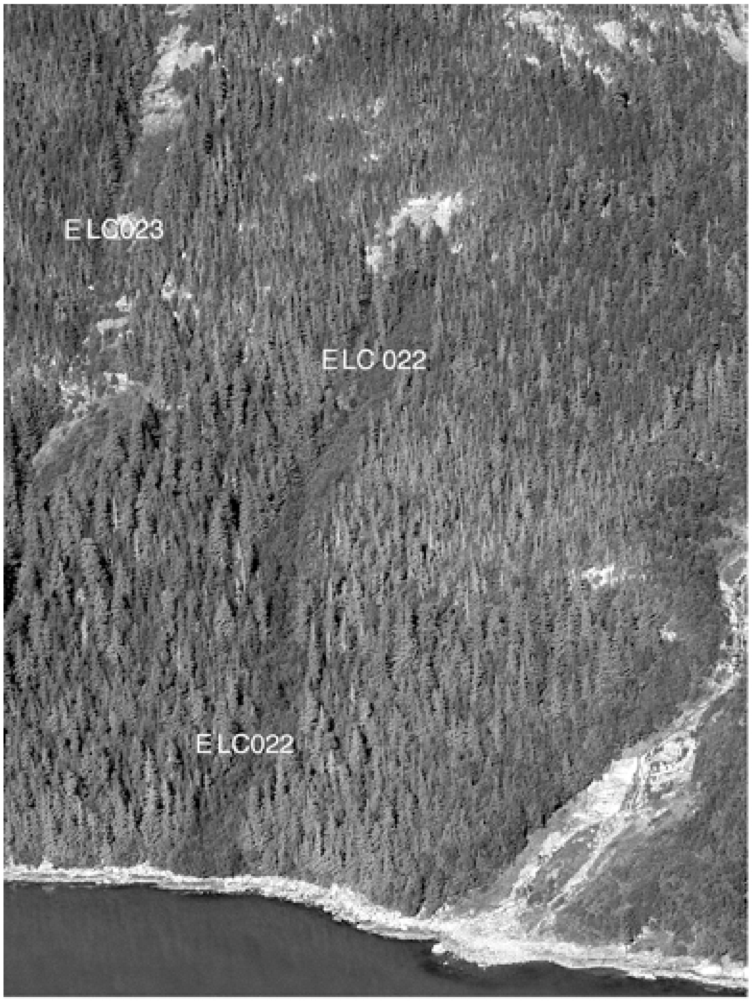




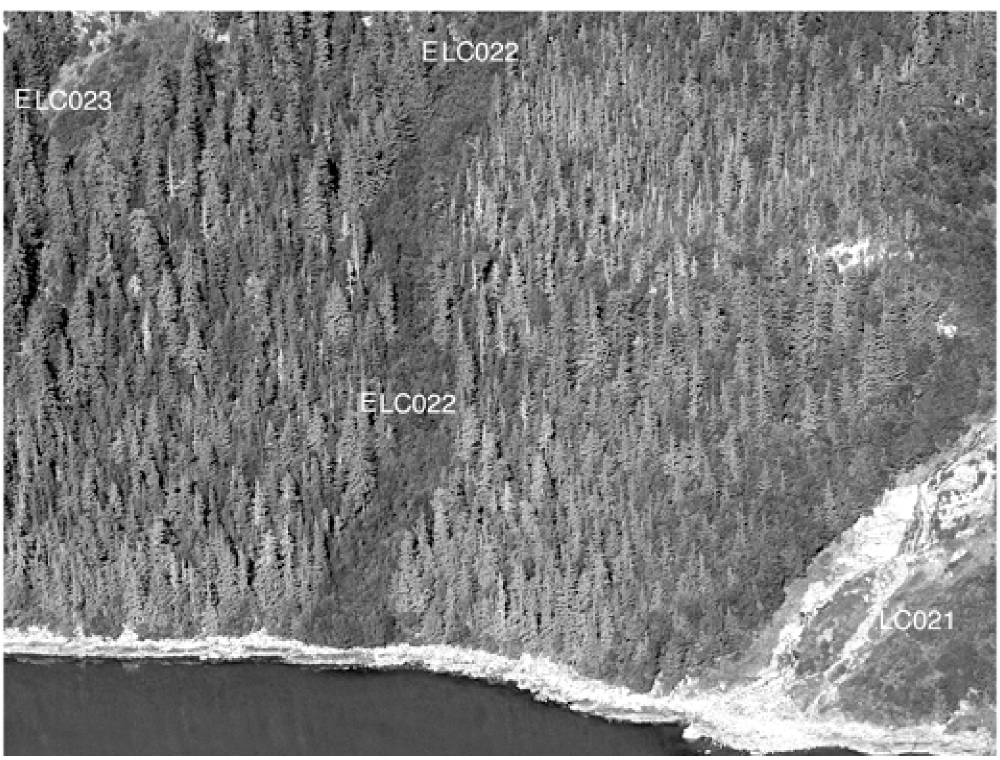
East Lynn Canal Path ELC021 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC021

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.040632 -135.121461
Max Width (ft):	1240 feet
Max Width (m):	378 meters
Typical Width (ft):	600 feet
Typical Width (m):	183 meters
Starting Elevation (ft):	4800 feet
Starting Elevation (m):	1463 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	W
Path Type:	classic confined, very large bowl to broad gully track
Runout Angle:	slight decrease
Unmitigated avalanche hazard index (AHI):	94.84
Comments:	Most active path studied. Highest East Lynn AHI.



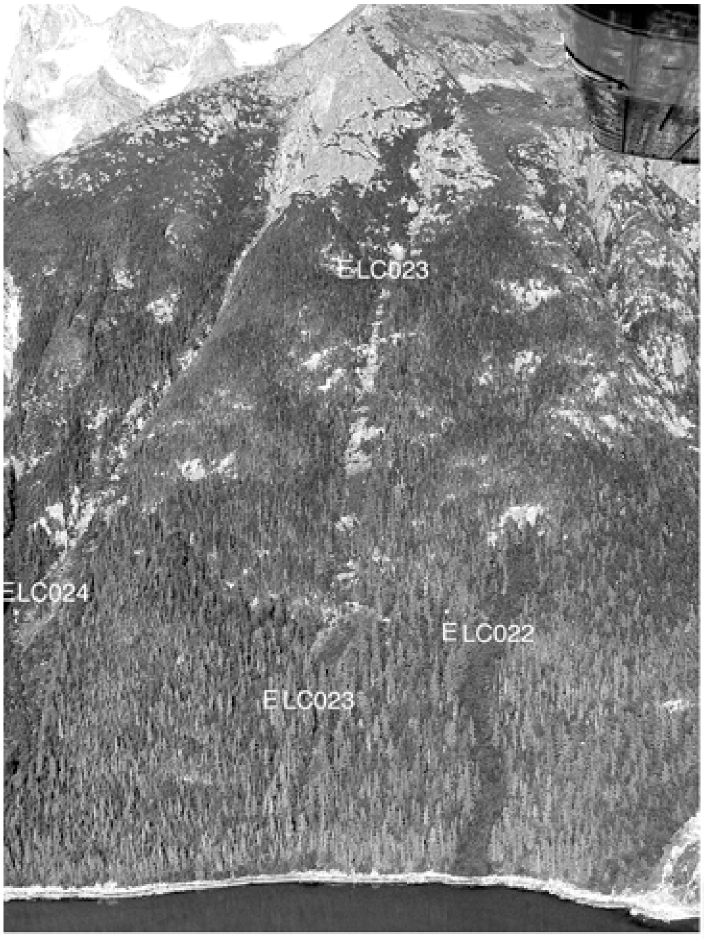
East Lynn Canal Path ELC022 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC022

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.04131 -135.121194
Max Width (ft):	110 feet
Max Width (m):	34 meters
Typical Width (ft):	110 feet
Typical Width (m):	34 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	small rock slab and talus
Start Aspect:	W
Path Type:	small unconfined track
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.12
Comments:	

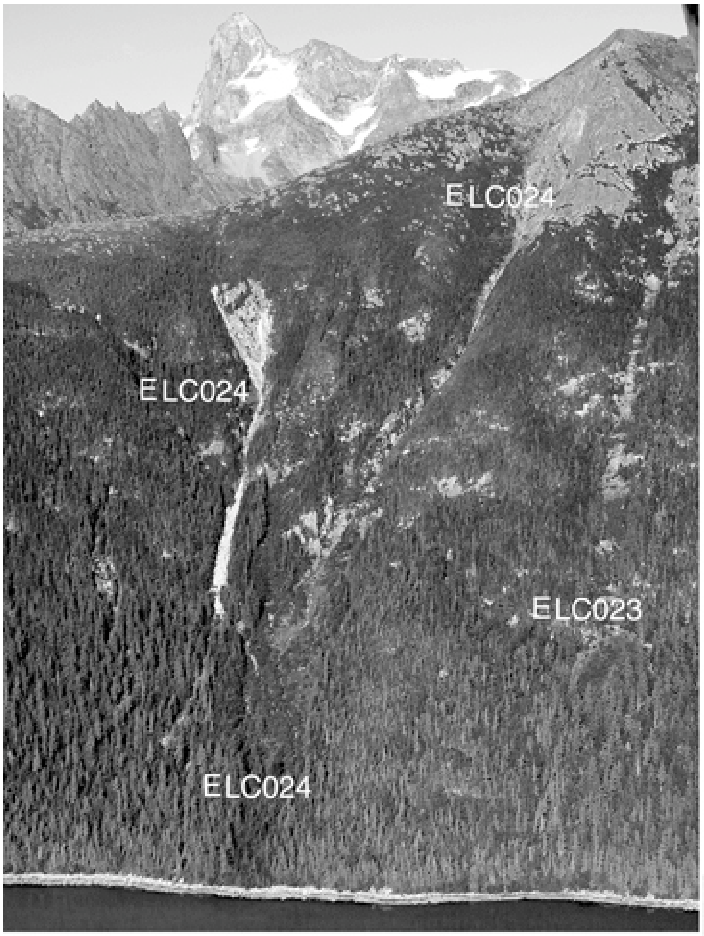
East Lynn Canal Path ELC023 Photos

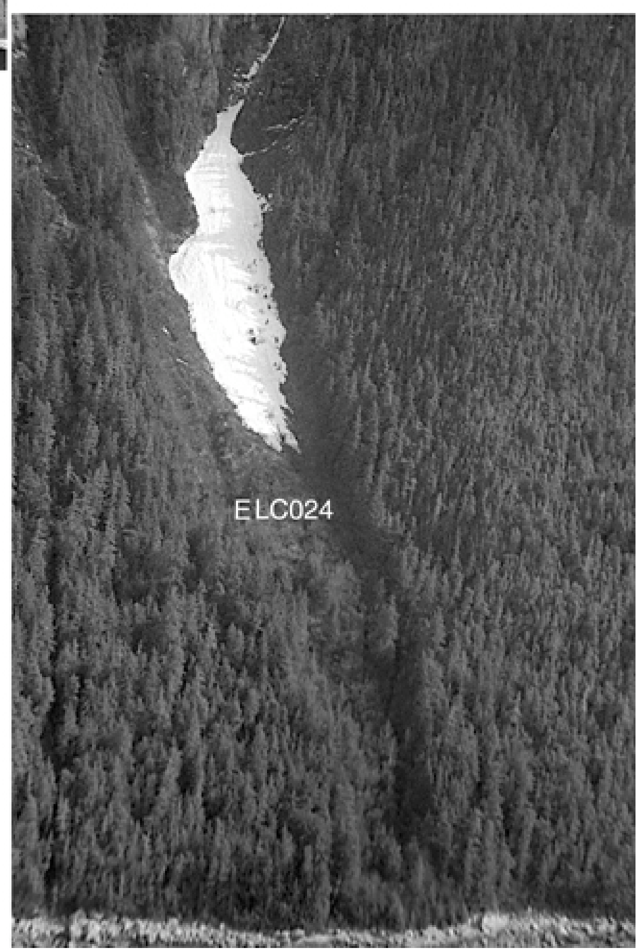


Avalanche Path Atlas - East Lynn Canal Path ELC023

Path Group:	South Yeldagalga, Maps 3 & 4
Latitude-Longitude:	59.041891 -135.121213
Max Width (ft):	210 feet
Max Width (m):	64 meters
Typical Width (ft):	120 feet
Typical Width (m):	37 meters
Starting Elevation (ft):	2900 feet
Starting Elevation (m):	884 meters
Elevation Class:	medium high
Path Size:	medium
Starting Zone Characteristics:	rock slabs and gully
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.89
Comments:	Nineteenth-highest East Lynn AHI.

East Lynn Canal Path ELC024 Photos





Avalanche Path Atlas - East Lynn Canal Path ELC024

Path Group:	South Yeldagalga, Map 4
Latitude-Longitude:	59.043096 -135.121951
Max Width (ft):	270 feet
Max Width (m):	82 meters
Typical Width (ft):	190 feet
Typical Width (m):	58 meters
Starting Elevation (ft):	3700 feet
Starting Elevation (m):	1128 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	multiple rock slabs, small bowls and gullies
Start Aspect:	W
Path Type:	wide scrub bowl to short confined track and runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	3.18
Comments:	Eleventh-highest East Lynn AHI.

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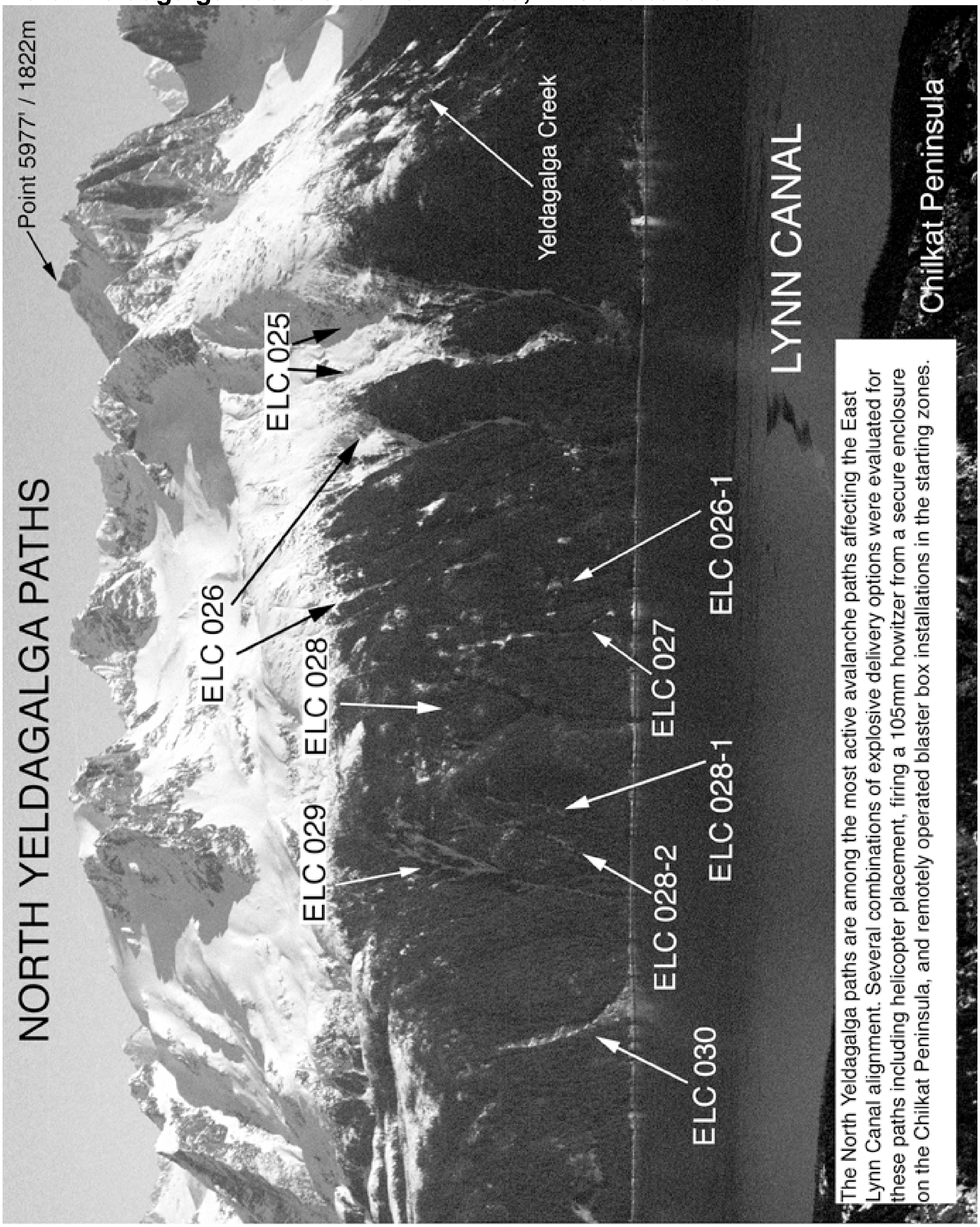
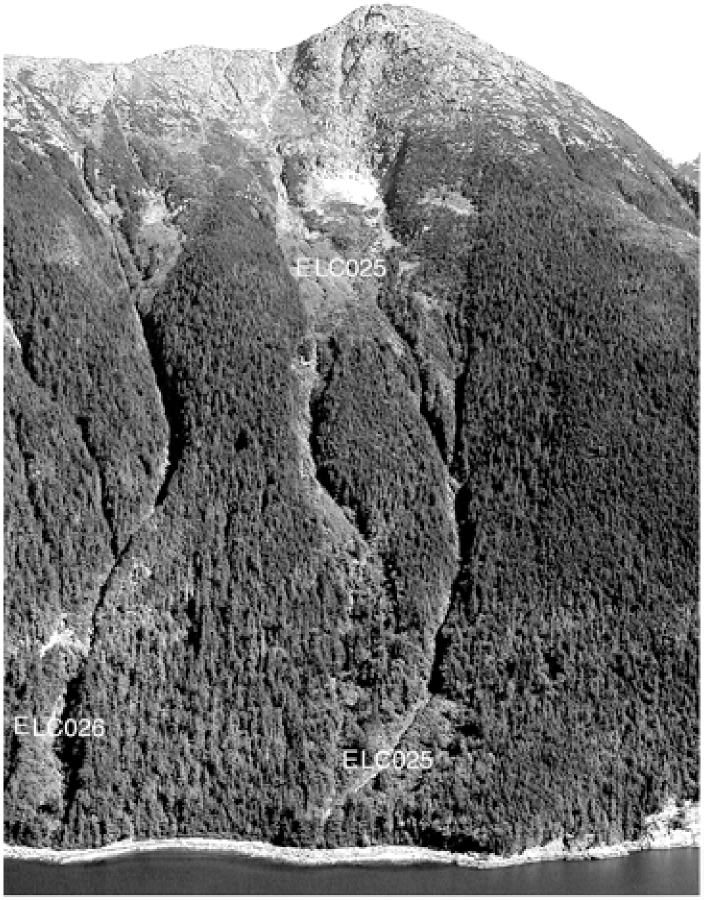
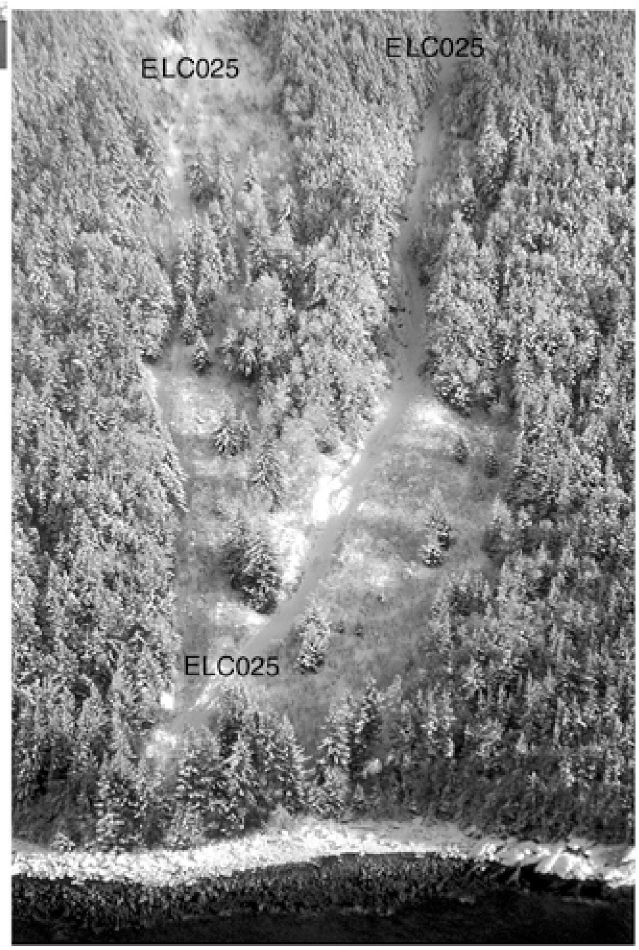
North Yeldagalga Paths Overview Photo, ELC025 to 030



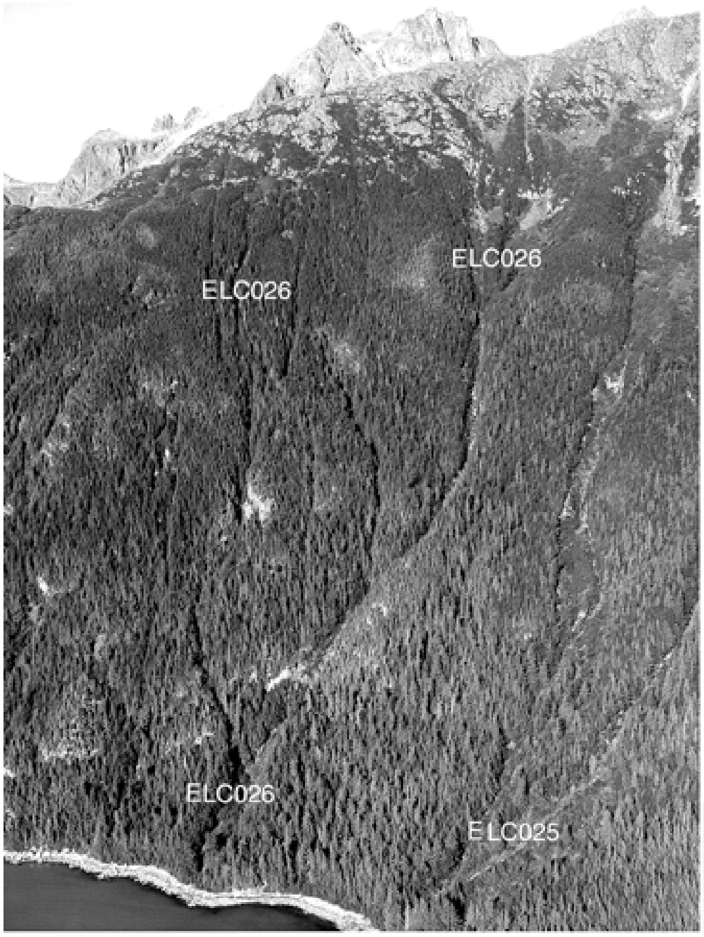


East Lynn Canal Path ELC025 Photos

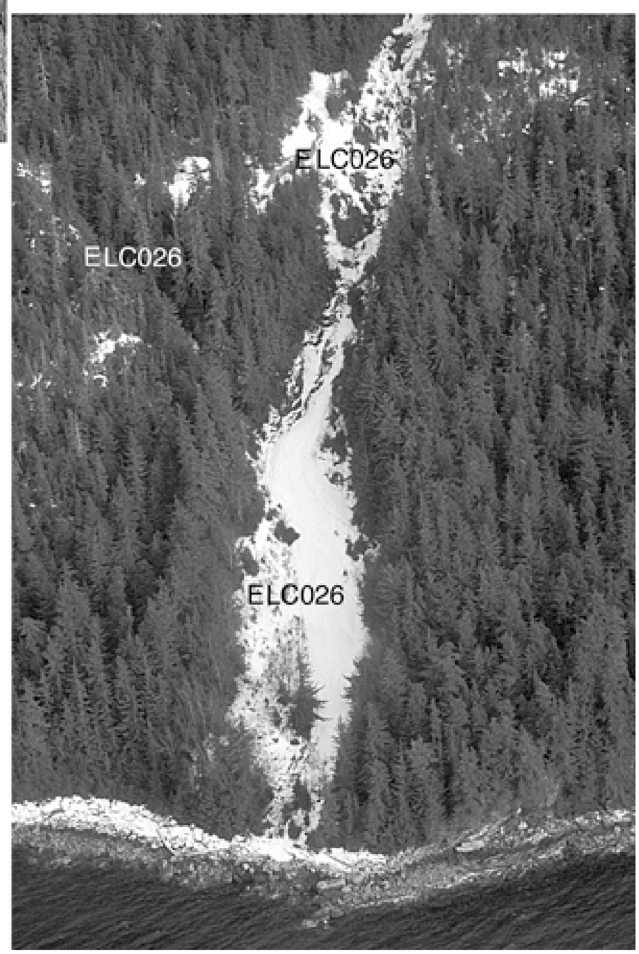


Avalanche Path Atlas - East Lynn Canal Path ELC025

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.06421 -135.133654
Max Width (ft):	780 feet
Max Width (m):	238 meters
Typical Width (ft):	190 feet
Typical Width (m):	58 meters
Starting Elevation (ft):	4300 feet
Starting Elevation (m):	1311 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	medium gullied bowl
Start Aspect:	W
Path Type:	bowl to twin gullies to single runout
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	6.41
Comments:	Seventh-highest East Lynn AHI.

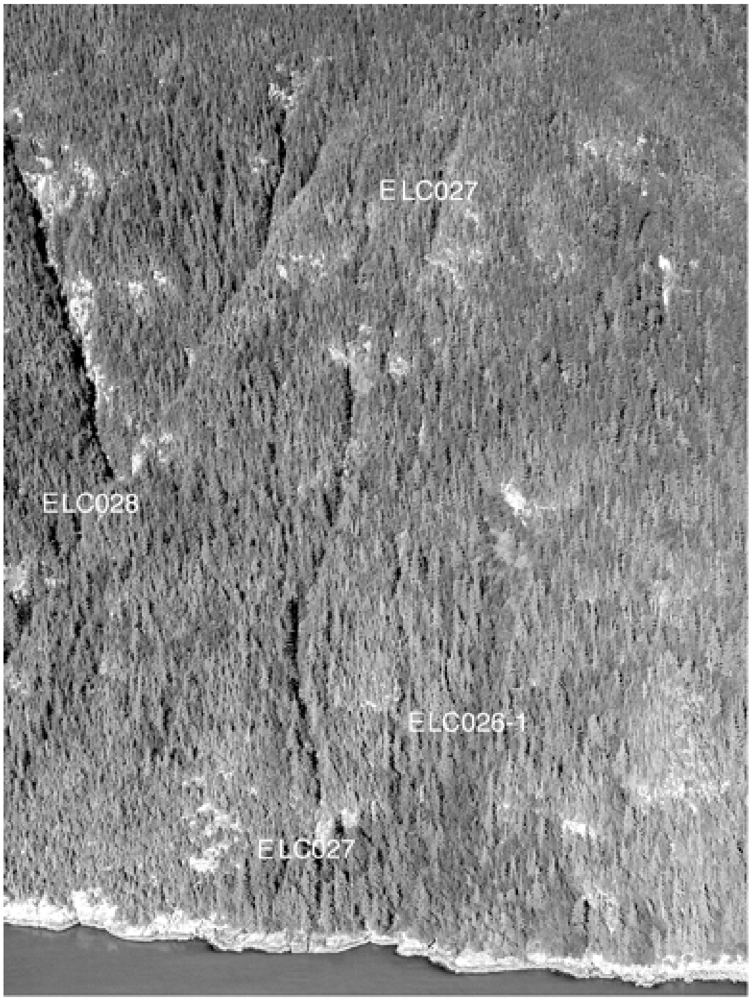


East Lynn Canal Path ELC026 Photos

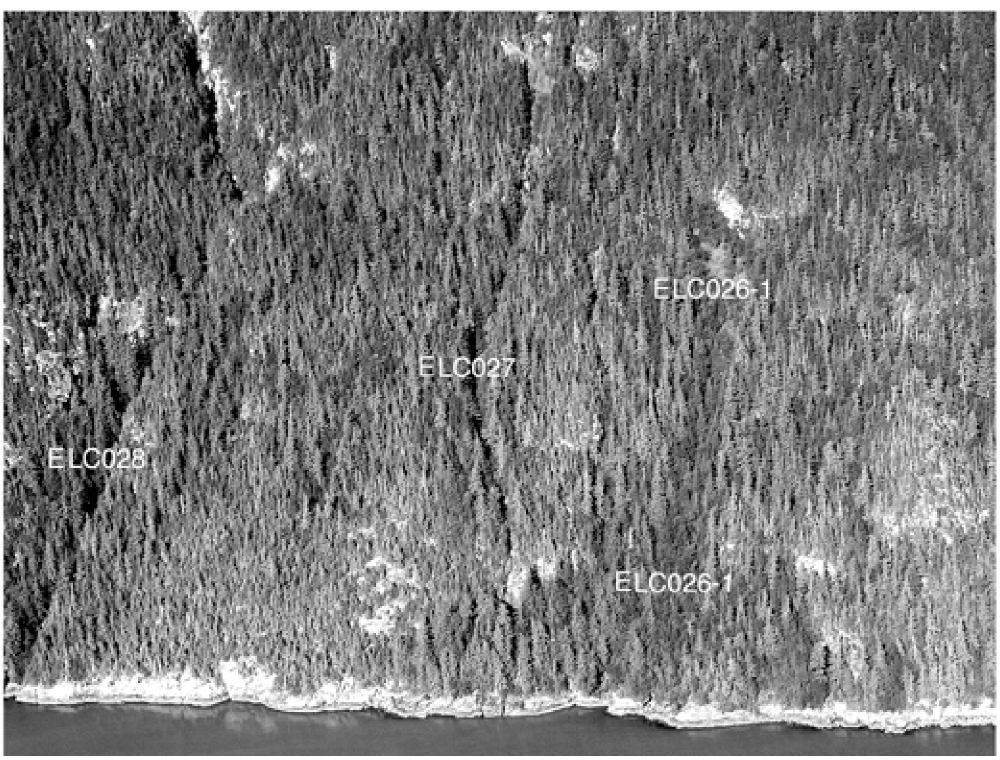


Avalanche Path Atlas - East Lynn Canal Path ELC026

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.065077 -135.133771
Max Width (ft):	470 feet
Max Width (m):	143 meters
Typical Width (ft):	200 feet
Typical Width (m):	61 meters
Starting Elevation (ft):	4000 feet
Starting Elevation (m):	1219 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	multiple gullies and small bowls
Start Aspect:	WSW
Path Type:	multiple confined gullies to single runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	7.55
Comments:	Sixth-highest East Lynn AHI.

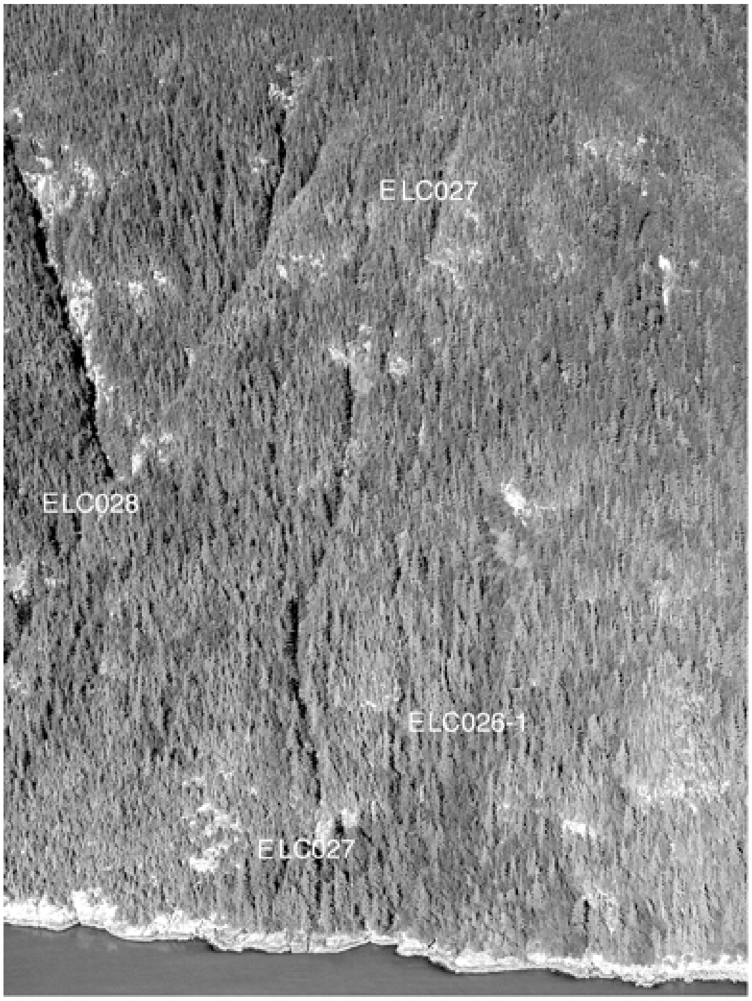


East Lynn Canal Path ELC026-1 Photos

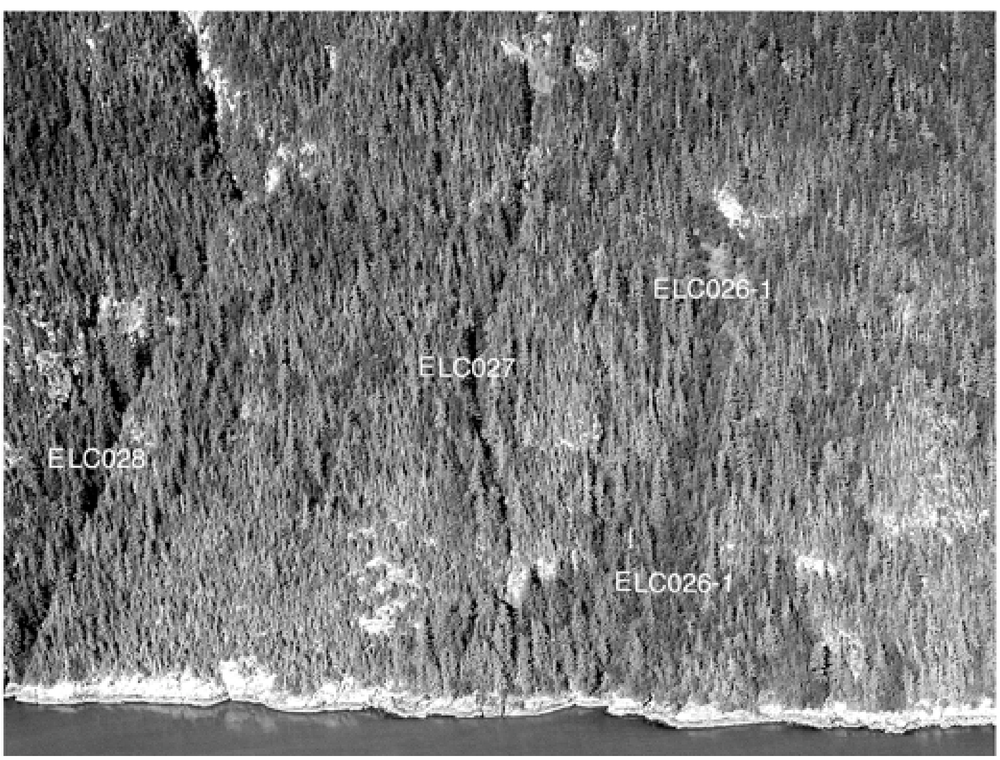


Avalanche Path Atlas - East Lynn Canal Path ELC026-1

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.06565 -135.134064
Max Width (ft):	200 feet
Max Width (m):	61 meters
Typical Width (ft):	150 feet
Typical Width (m):	46 meters
Starting Elevation (ft):	1100 feet
Starting Elevation (m):	335 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	small cliff and talus
Start Aspect:	WSW
Path Type:	small unconfined track
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.13
Comments:	



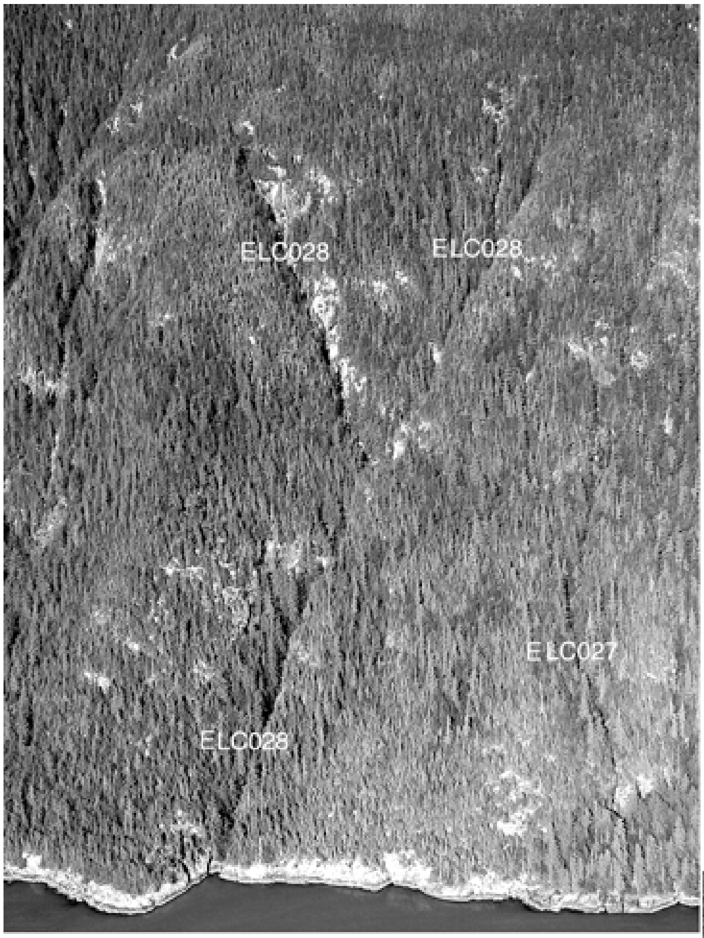
East Lynn Canal Path ELC027 Photos

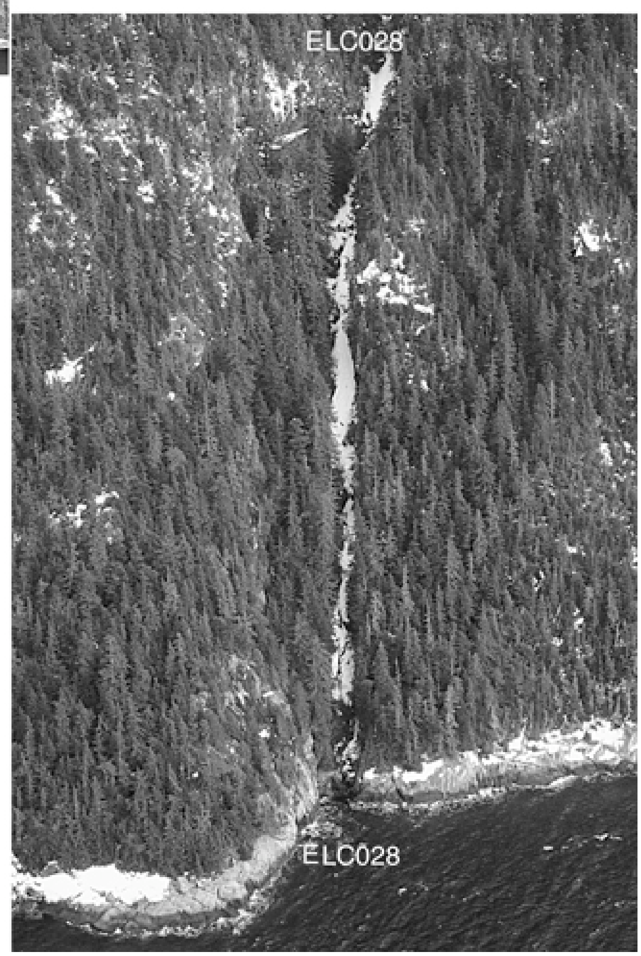


Avalanche Path Atlas - East Lynn Canal Path ELC027

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.070492 -135.134359
Max Width (ft):	90 feet
Max Width (m):	27 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	2000 feet
Starting Elevation (m):	610 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	narrow gully
Start Aspect:	WSW
Path Type:	narrow gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.15
Comments:	

East Lynn Canal Path ELC028 Photos

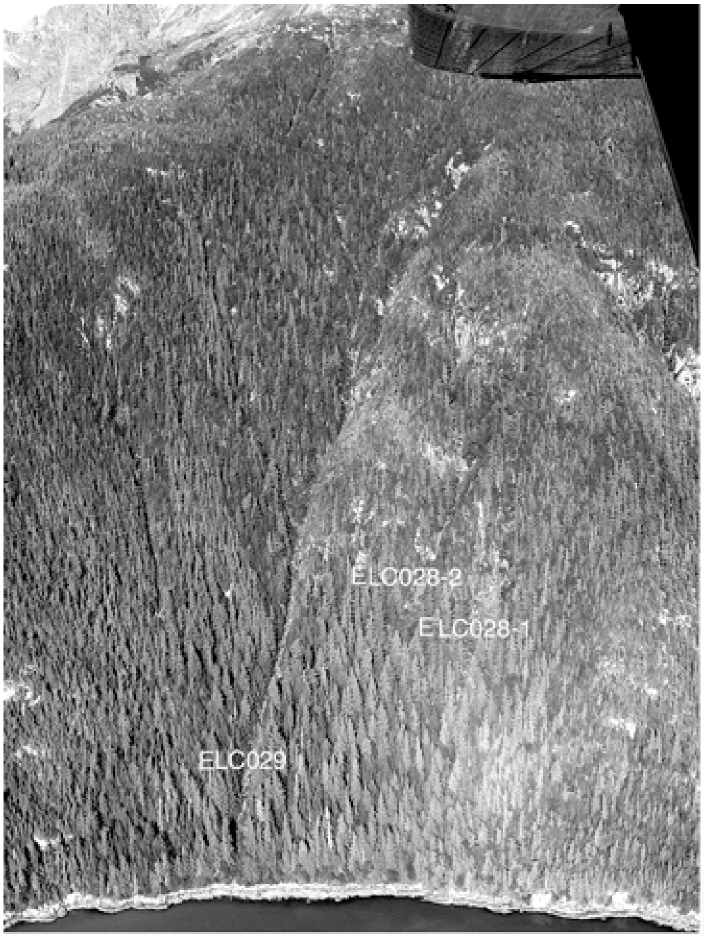


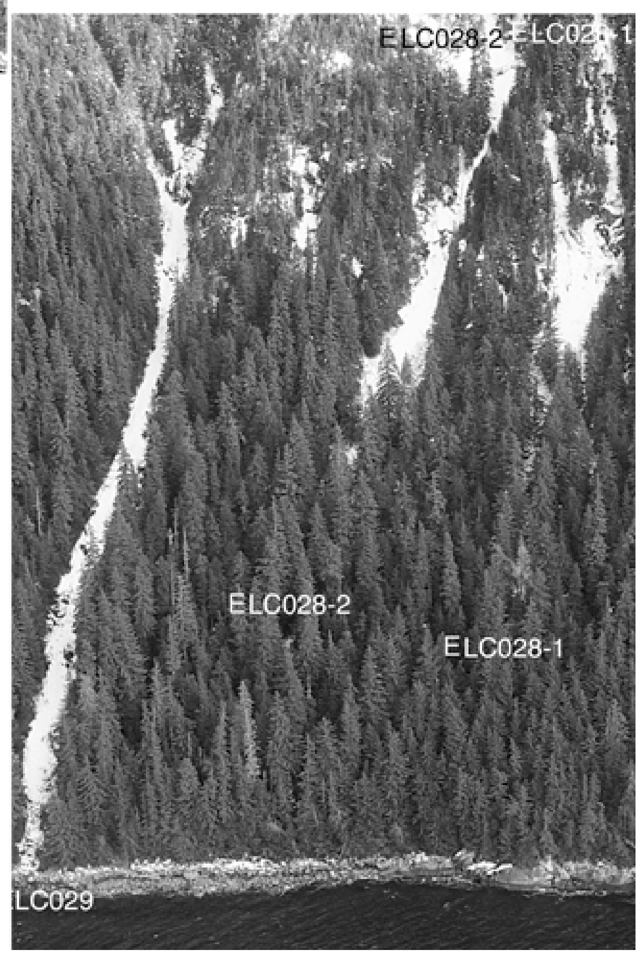


Avalanche Path Atlas - East Lynn Canal Path ELC028

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.071671 -135.135194
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	2200 feet
Starting Elevation (m):	671 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	two narrow gullies
Start Aspect:	WSW
Path Type:	narrow gully
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.61
Comments:	

East Lynn Canal Path ELC028-1 Photos

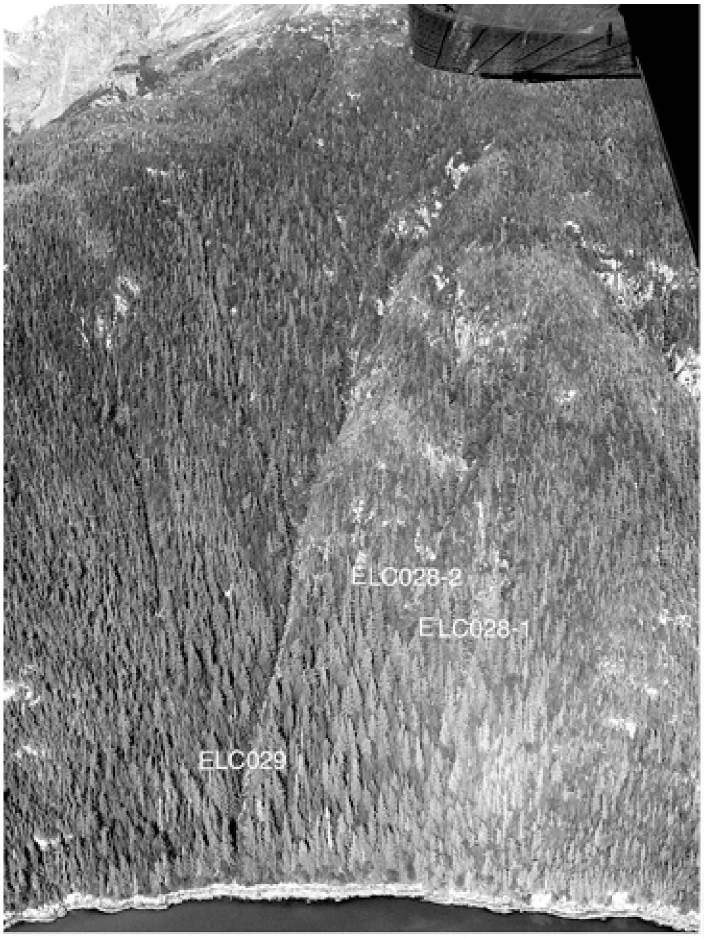


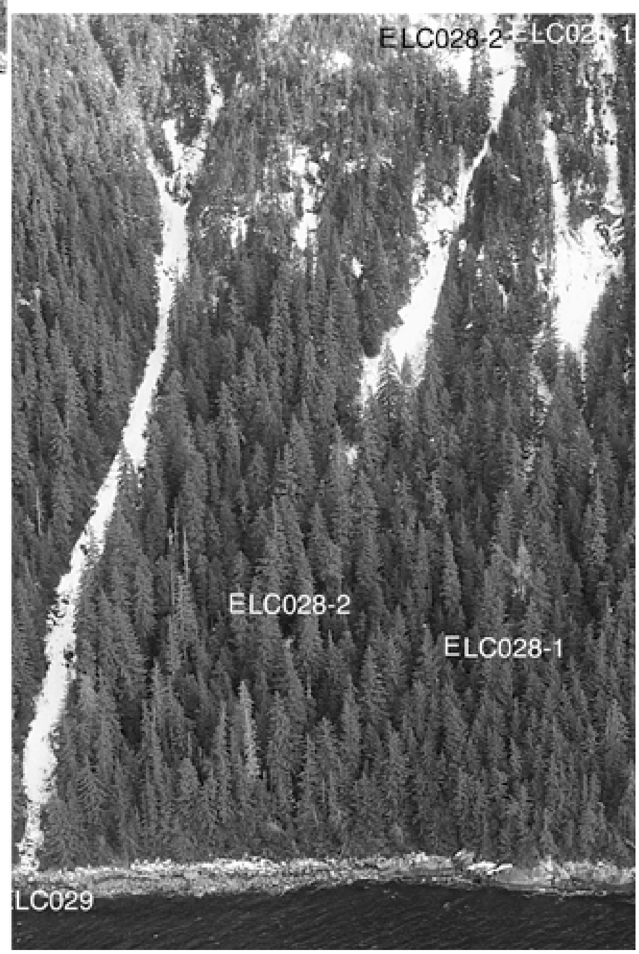


Avalanche Path Atlas - East Lynn Canal Path ELC028-1

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.072328 -135.135484
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1700 feet
Starting Elevation (m):	518 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	scrub forest, gully and cliff
Start Aspect:	WSW
Path Type:	talus and gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.007
Comments:	Usually stops above alignment.

East Lynn Canal Path ELC028-2 Photos

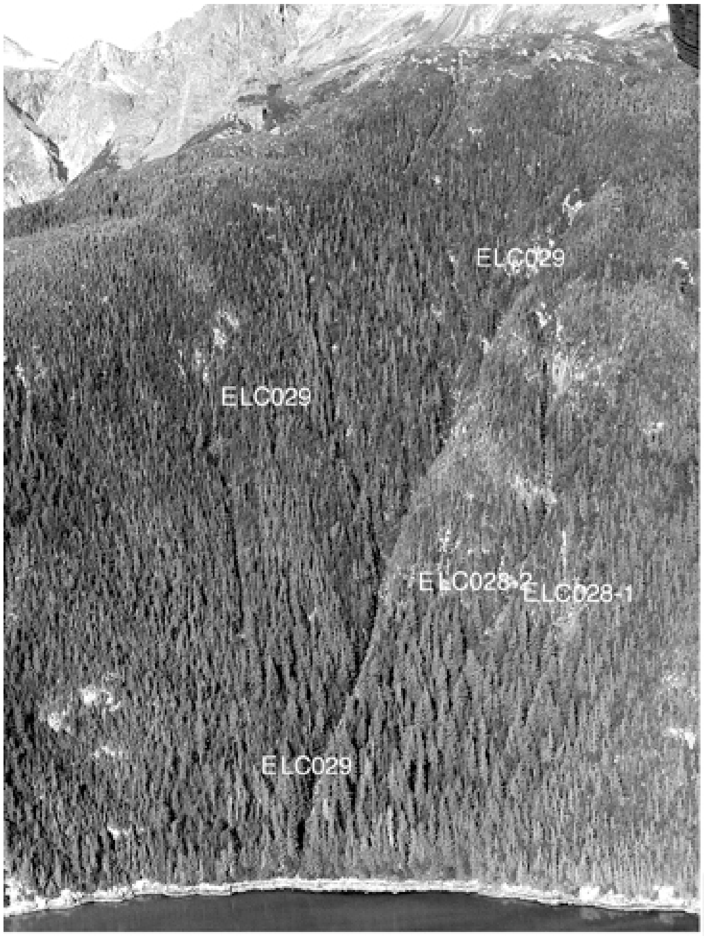




Avalanche Path Atlas - East Lynn Canal Path ELC028-2

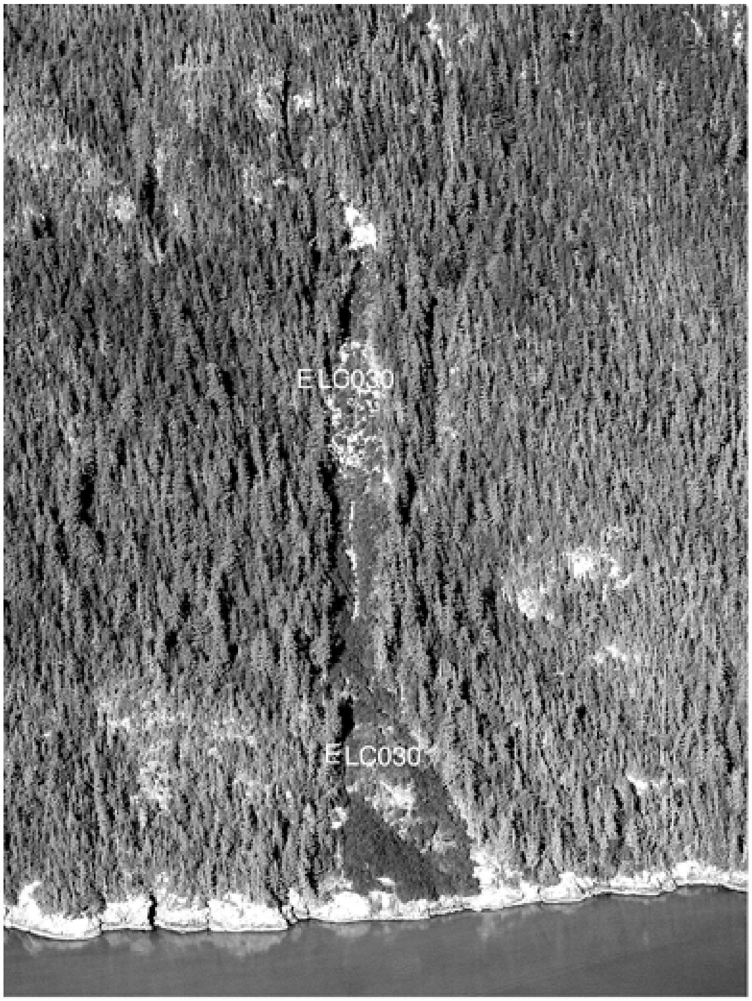
Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.072747 -135.135494
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1800 feet
Starting Elevation (m):	549 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	scrub forest, gully and cliff
Start Aspect:	WSW
Path Type:	talus and gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.04
Comments:	Usually stops above alignment.

East Lynn Canal Path ELC029 Photos

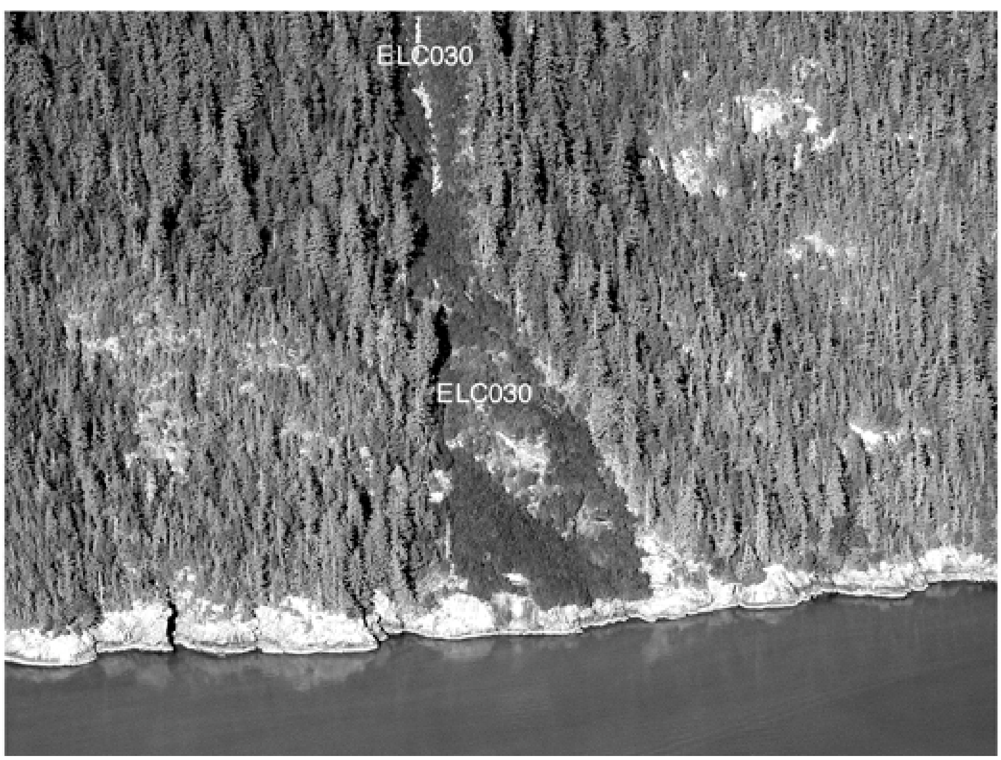


Avalanche Path Atlas - East Lynn Canal Path ELC029

Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.073302 -135.135586
Max Width (ft):	150 feet
Max Width (m):	46 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	3000 feet
Starting Elevation (m):	914 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	scrub forest bowl and gullies
Start Aspect:	WSW
Path Type:	multiple narrow gullies to single runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	4.60
Comments:	Ninth-highest East Lynn AHI.

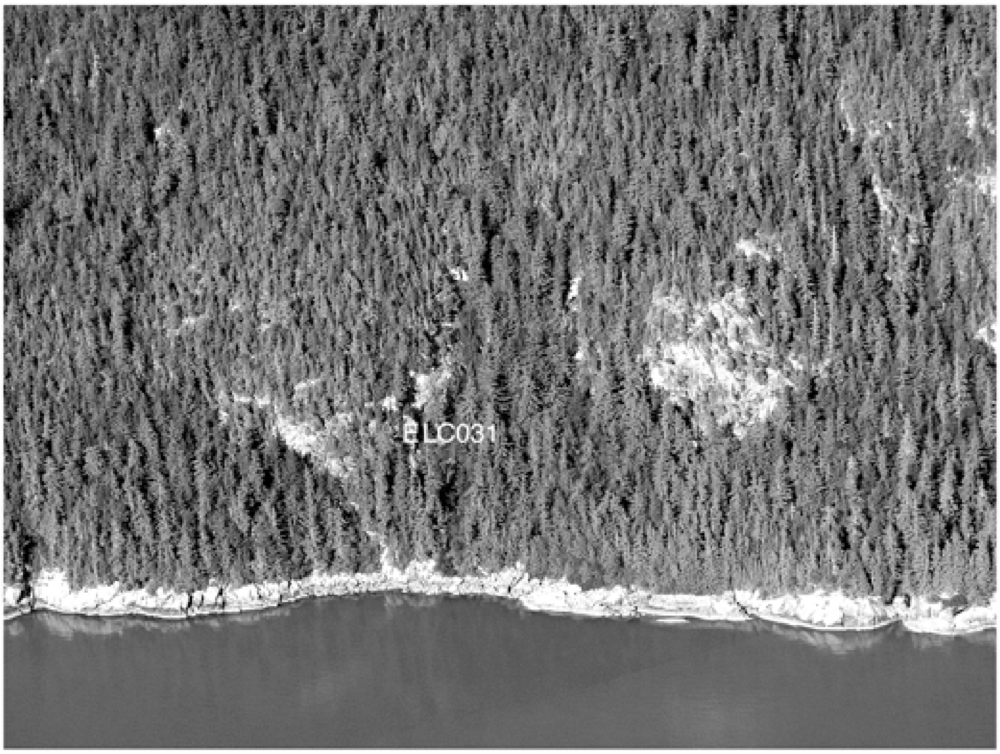


East Lynn Canal Path ELC030 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC030

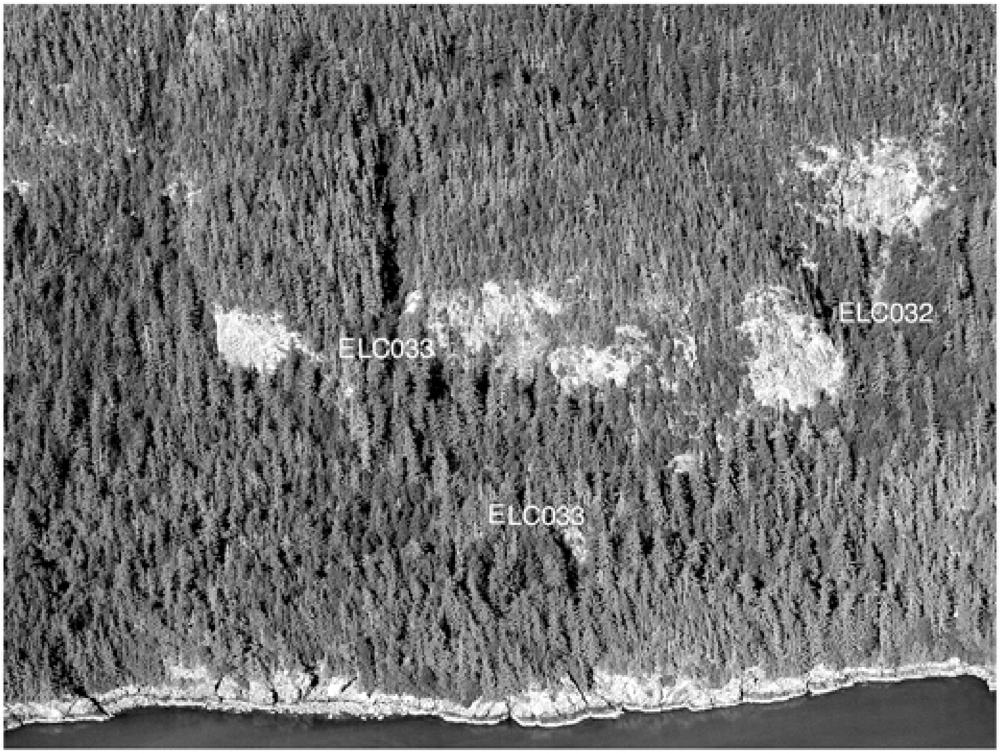
Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.074304 -135.140742
Max Width (ft):	460 feet
Max Width (m):	140 meters
Typical Width (ft):	250 feet
Typical Width (m):	76 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	landslide scar
Start Aspect:	WSW
Path Type:	landslide scar
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.25
Comments:	



East Lynn Canal Path ELC031 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC031

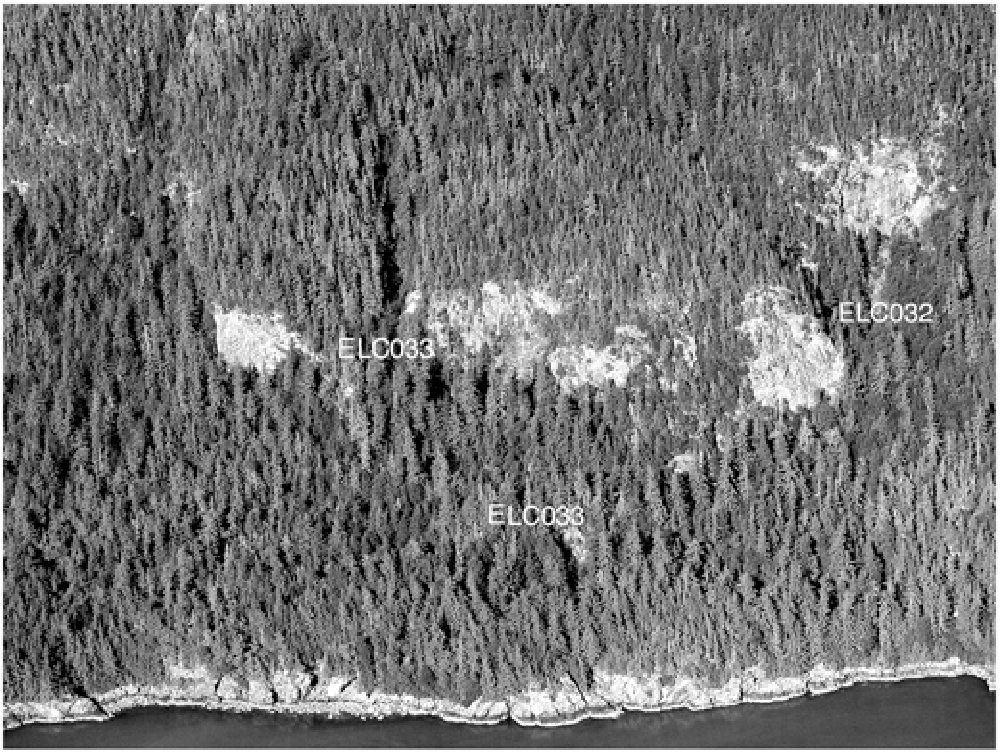
Path Group:	North Yeldagalga, Map 4
Latitude-Longitude:	59.080947 -135.142847
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	650 feet
Starting Elevation (m):	198 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	cliff gully
Start Aspect:	WSW
Path Type:	narrow gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	



East Lynn Canal Path ELC032 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC032

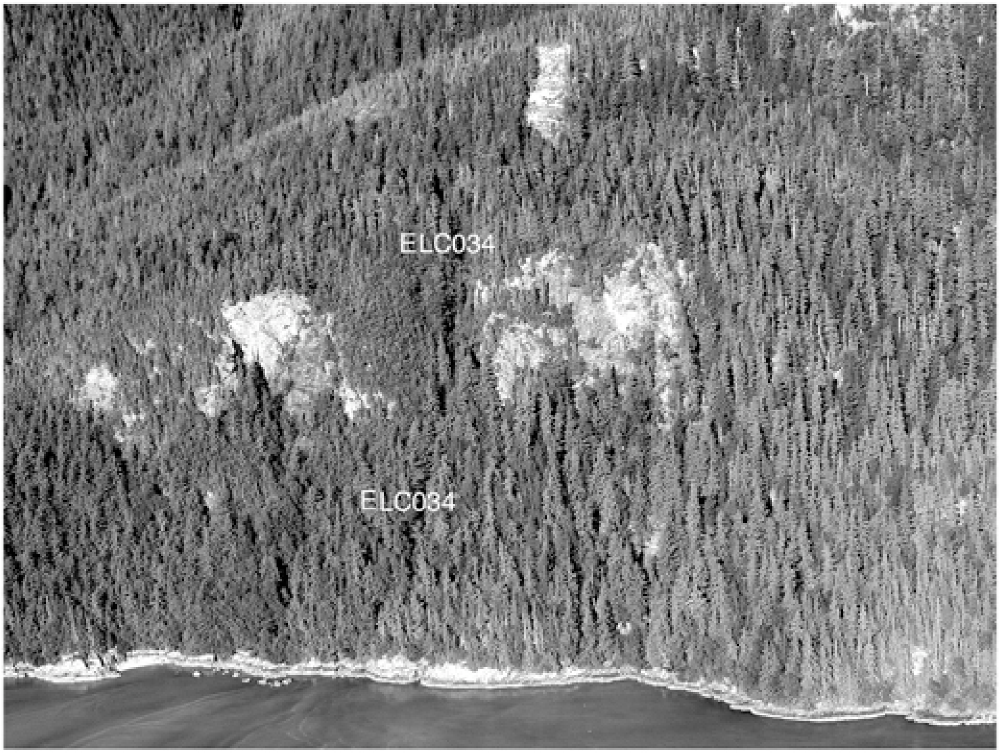
Path Group:	South Katzehin, Map 4
Latitude-Longitude:	59.094729 -135.160762
Max Width (ft):	270 feet
Max Width (m):	82 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	900 feet
Starting Elevation (m):	274 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	gully through cliffs
Start Aspect:	WSW
Path Type:	gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.02
Comments:	Usually stops above alignment.



East Lynn Canal Path ELC033 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC033

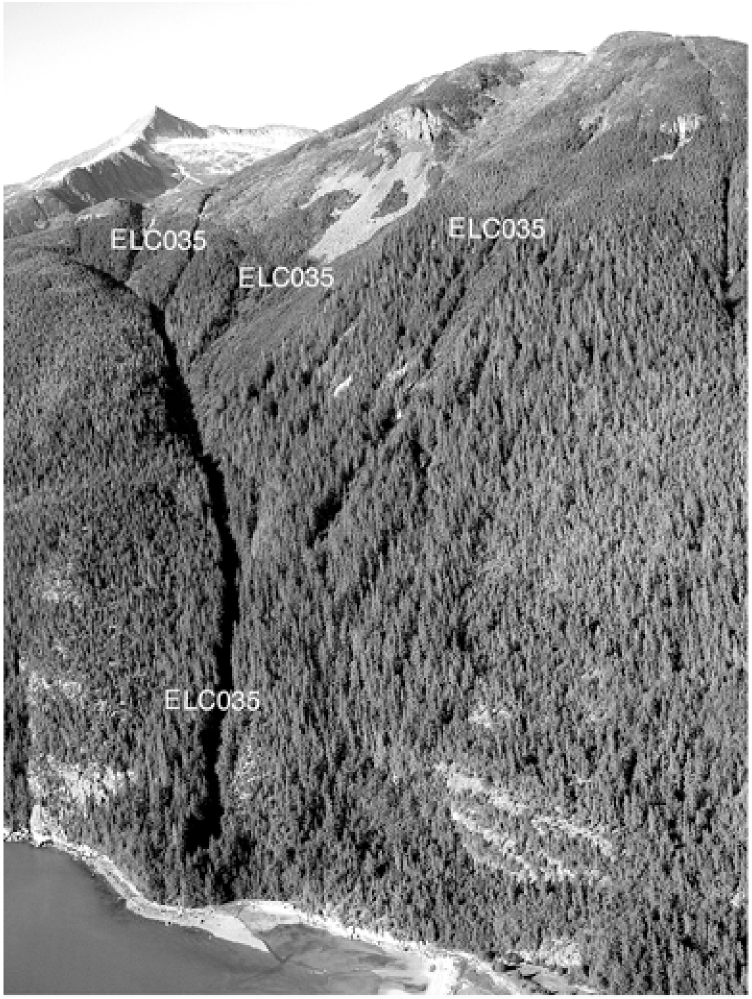
Path Group:	South Katzehin, Map 4
Latitude-Longitude:	59.095282 -135.161422
Max Width (ft):	60 feet
Max Width (m):	18 meters
Typical Width (ft):	60 feet
Typical Width (m):	18 meters
Starting Elevation (ft):	900 feet
Starting Elevation (m):	274 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	gully through cliffs
Start Aspect:	WSW
Path Type:	gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.009
Comments:	Usually stops above alignment.



East Lynn Canal Path ELC034 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC034

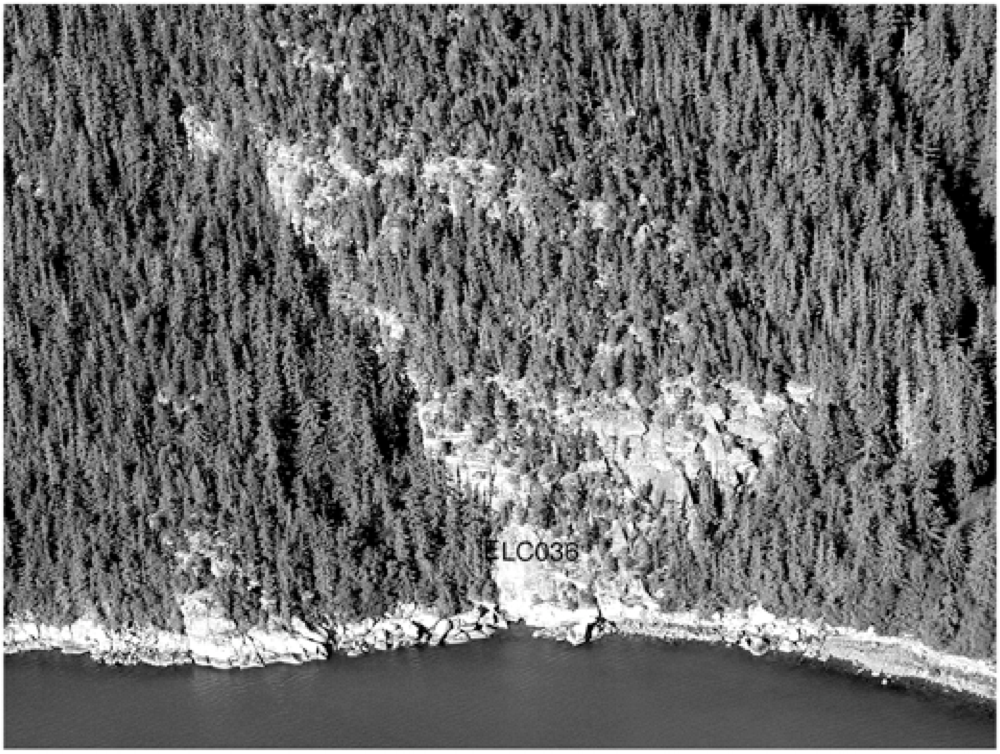
Path Group:	South Katzehin, Map 4
Latitude-Longitude:	59.104932 -135.163693
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	60 feet
Typical Width (m):	18 meters
Starting Elevation (ft):	700 feet
Starting Elevation (m):	213 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	gully through cliffs
Start Aspect:	WSW
Path Type:	gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.03
Comments:	



East Lynn Canal Path ELC035 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC035

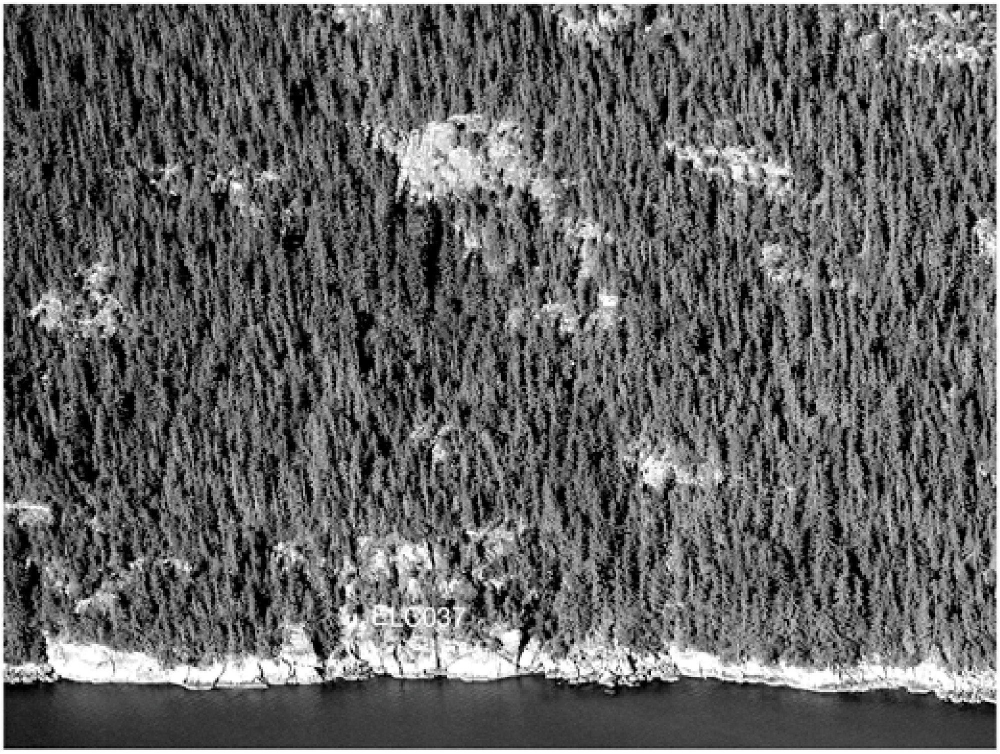
Path Group:	North Katzehin, Map 5
Latitude-Longitude:	59.133721 -135.193685
Max Width (ft):	260 feet
Max Width (m):	79 meters
Typical Width (ft):	110 feet
Typical Width (m):	34 meters
Starting Elevation (ft):	3400 feet
Starting Elevation (m):	1036 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	multiple big bowls, faces and gullies
Start Aspect:	WSW
Path Type:	confined large diagonal gully
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.17
Comments:	



East Lynn Canal Path ELC036 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC036

Path Group:	North Katzehin, Map 5
Latitude-Longitude:	59.134611 -135.19437
Max Width (ft):	240 feet
Max Width (m):	73 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	300 feet
Starting Elevation (m):	91 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs
Start Aspect:	SW
Path Type:	rock slabs
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.03
Comments:	



East Lynn Canal Path ELC037 Photo

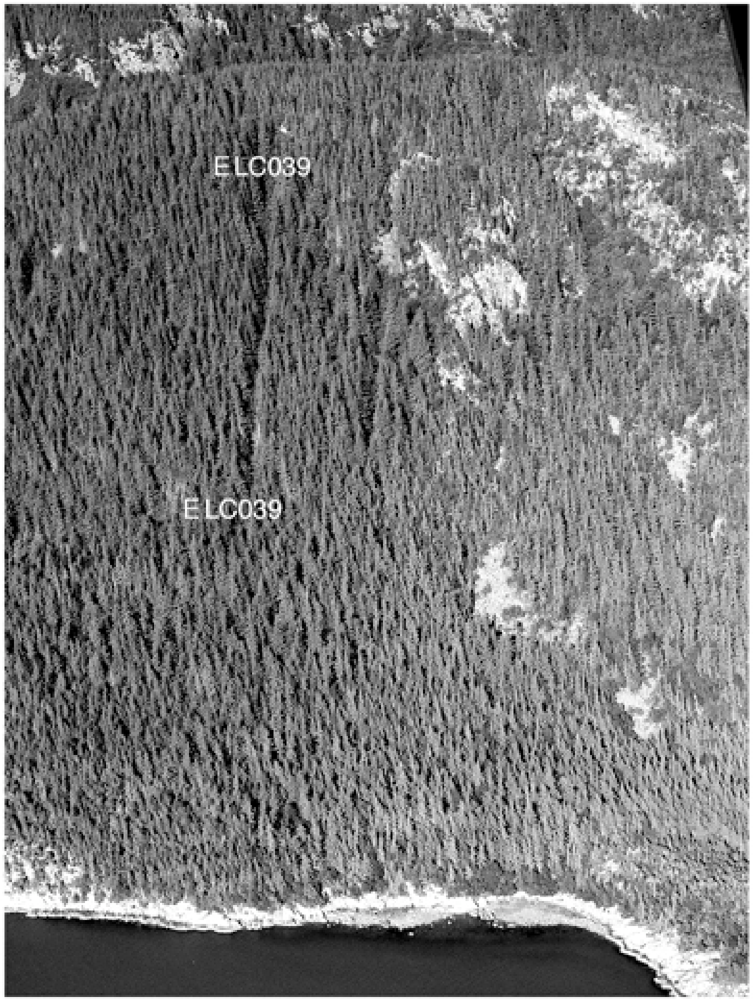
Avalanche Path Atlas - East Lynn Canal Path ELC037

Path Group:	North Katzehin, Map 5
Latitude-Longitude:	59.135147 -135.19511
Max Width (ft):	220 feet
Max Width (m):	67 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	200 feet
Starting Elevation (m):	61 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs
Start Aspect:	SW
Path Type:	rock slabs
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.02
Comments:	

East Lynn Canal Path ELC038 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC038

Path Group:	North Katzehin, Map 5
Latitude-Longitude:	59.140246 -135.200651
Max Width (ft):	90 feet
Max Width (m):	27 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs
Start Aspect:	SW
Path Type:	gully in forest
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.005
Comments:	Usually stops above alignment.



East Lynn Canal Path ELC039 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC039

Path Group:	North Katzehin, Map 5
Latitude-Longitude:	59.154646 -135.215845
Max Width (ft):	0
Max Width (m):	0
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	1300 feet
Starting Elevation (m):	396 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	narrow gully
Start Aspect:	SW
Path Type:	narrow gully
Runout Angle:	decreases markedly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Stops above alignment.

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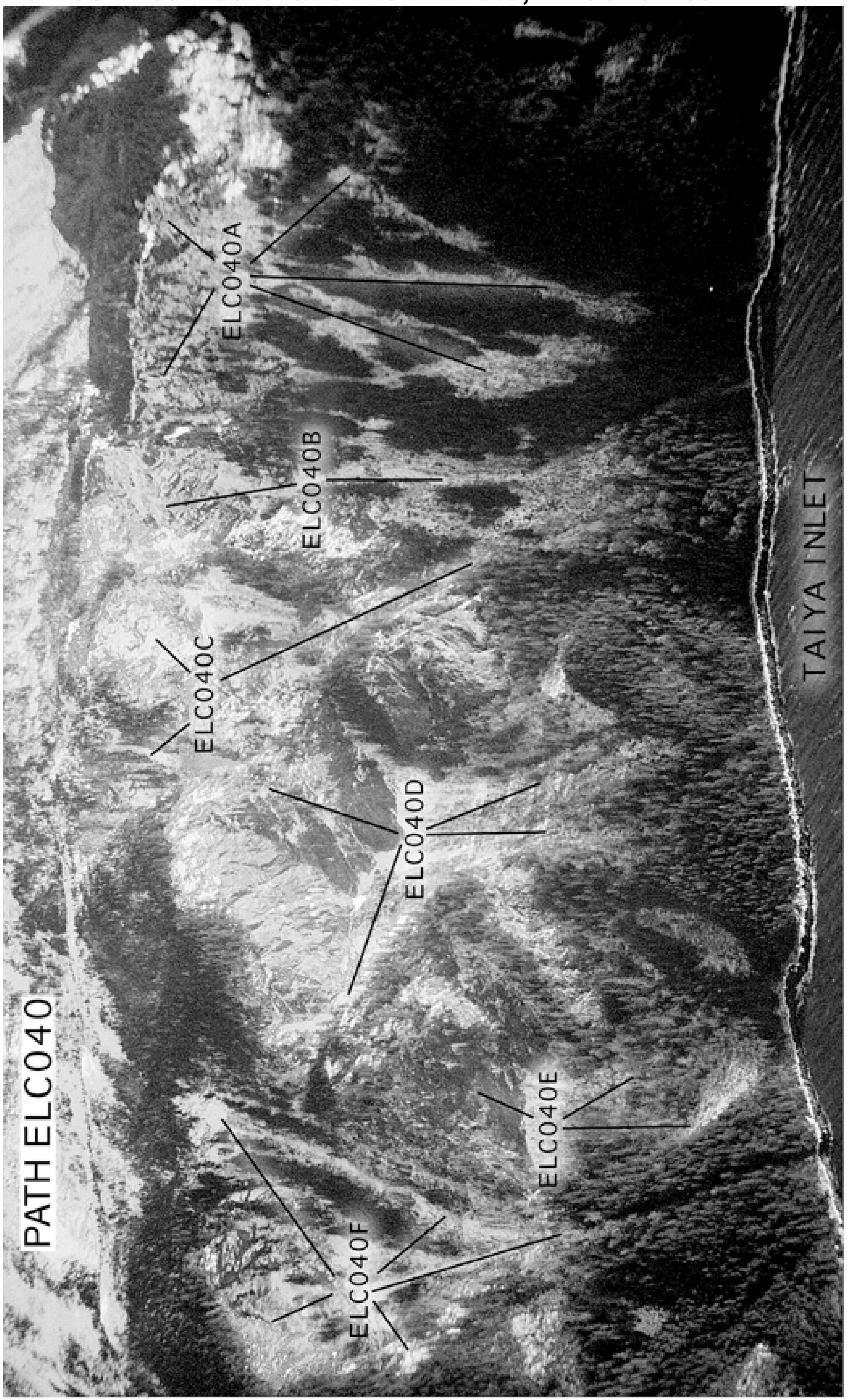
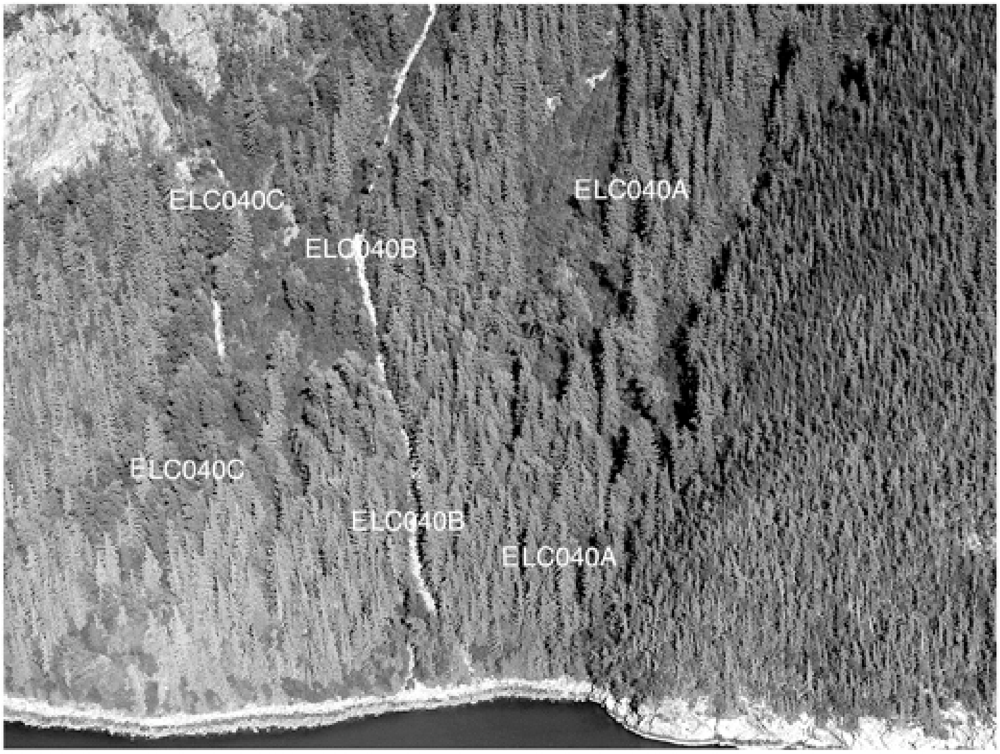
Haines Area Paths Overview Photo, ELC040A to F



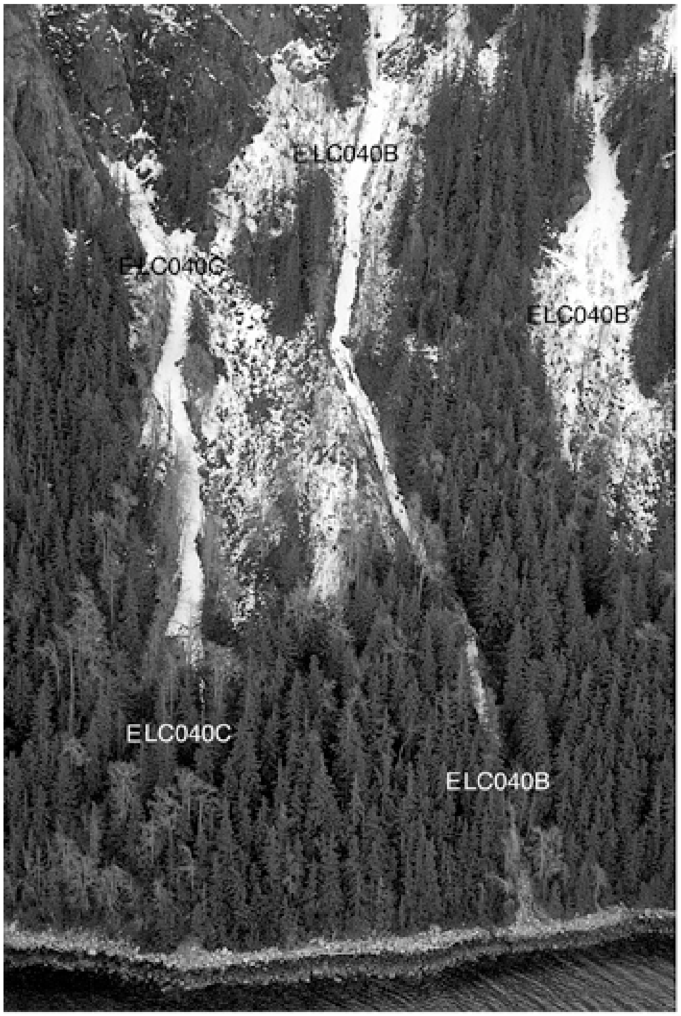
Haines area path ELC 040 has five subpaths, designated A through F. The paths are not large, but several of them run quite frequently. Explosive delivery options evaluated for these paths include helicopter placement, firing a 105mm howitzer from a turnout off the Lutak Road near Tanani Point, and remotely operated blaster box installations in the starting zones.



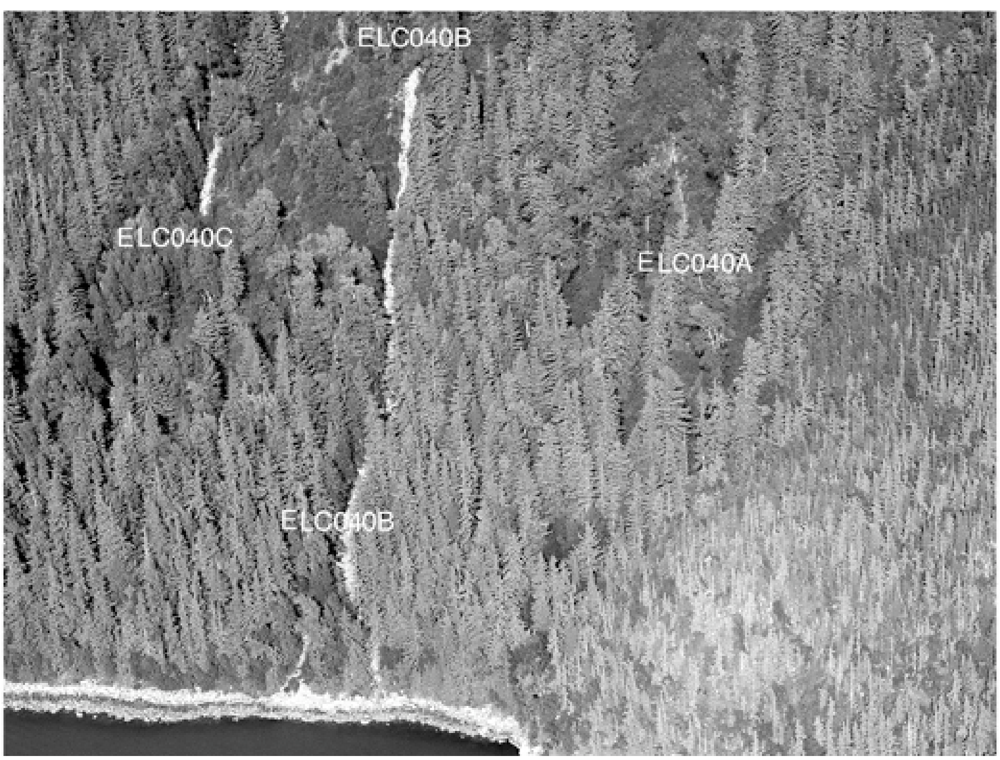
East Lynn Canal Path ELC040A Photo

Avalanche Path Atlas - East Lynn Canal Path ELC040A

Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.163035 -135.215953
Max Width (ft):	290 feet
Max Width (m):	88 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	1600 feet
Starting Elevation (m):	488 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and gullies
Start Aspect:	WNW
Path Type:	multiple openings in forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.32
Comments:	

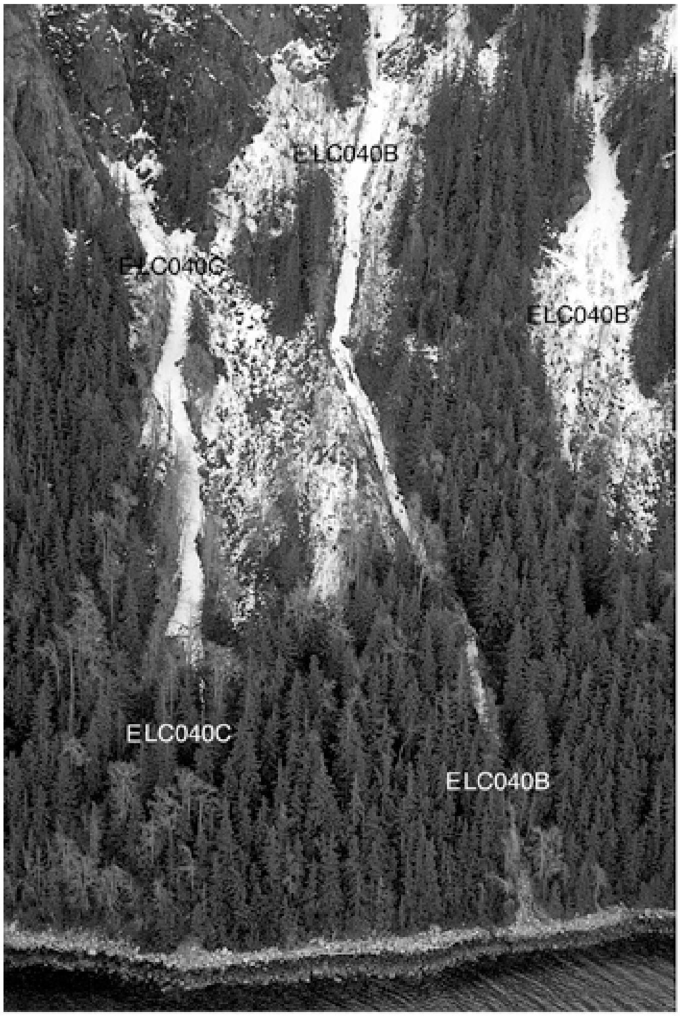


East Lynn Canal Path ELC040B Photos

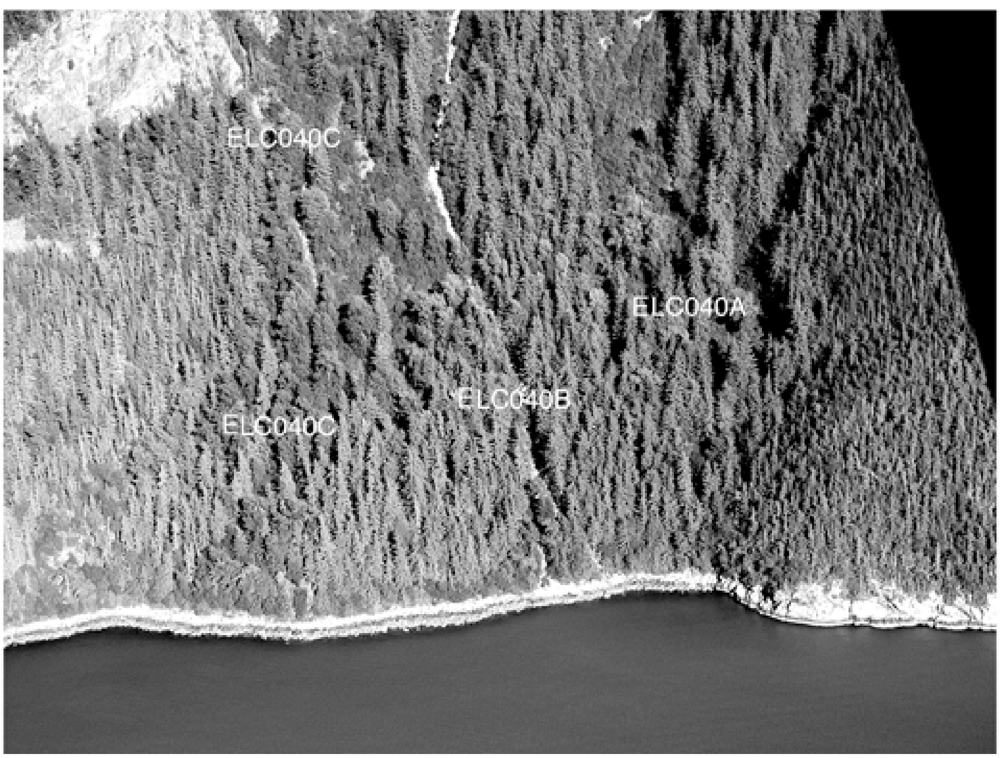


Avalanche Path Atlas - East Lynn Canal Path ELC040B

Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.16346 -135.21575
Max Width (ft):	300 feet
Max Width (m):	91 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	1900 feet
Starting Elevation (m):	579 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	gullies and rock slabs
Start Aspect:	W
Path Type:	shallow gully and openings in forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	5.48
Comments:	Eighth-highest East Lynn AHI.



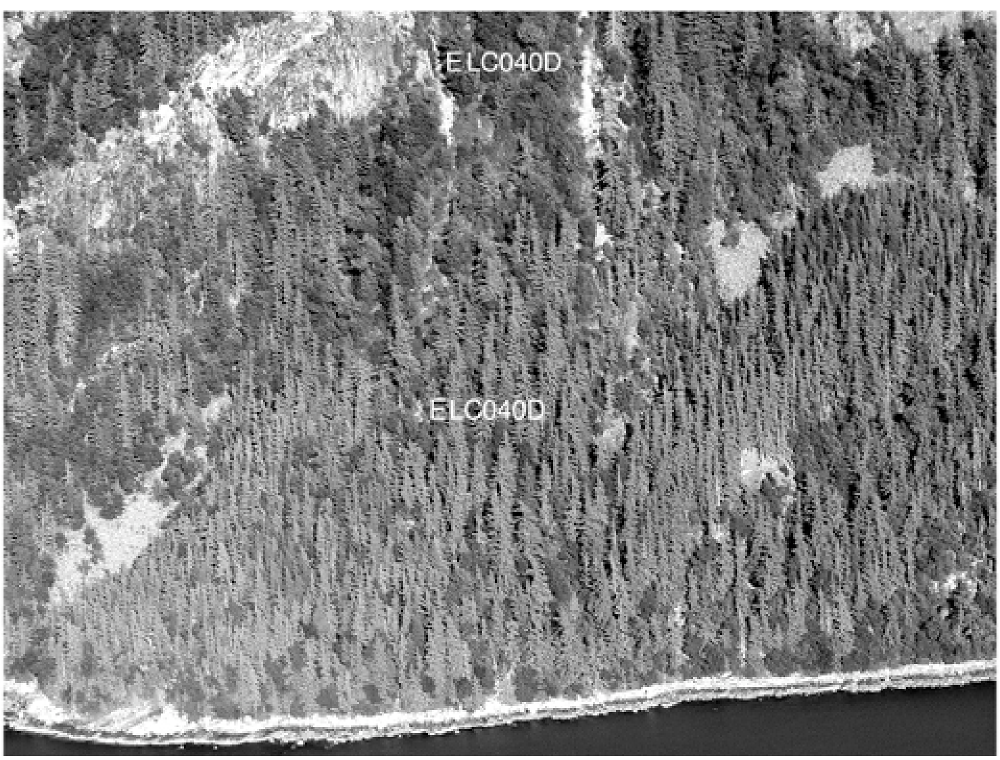
East Lynn Canal Path ELC040C Photos



Avalanche Path Atlas - East Lynn Canal Path ELC040C

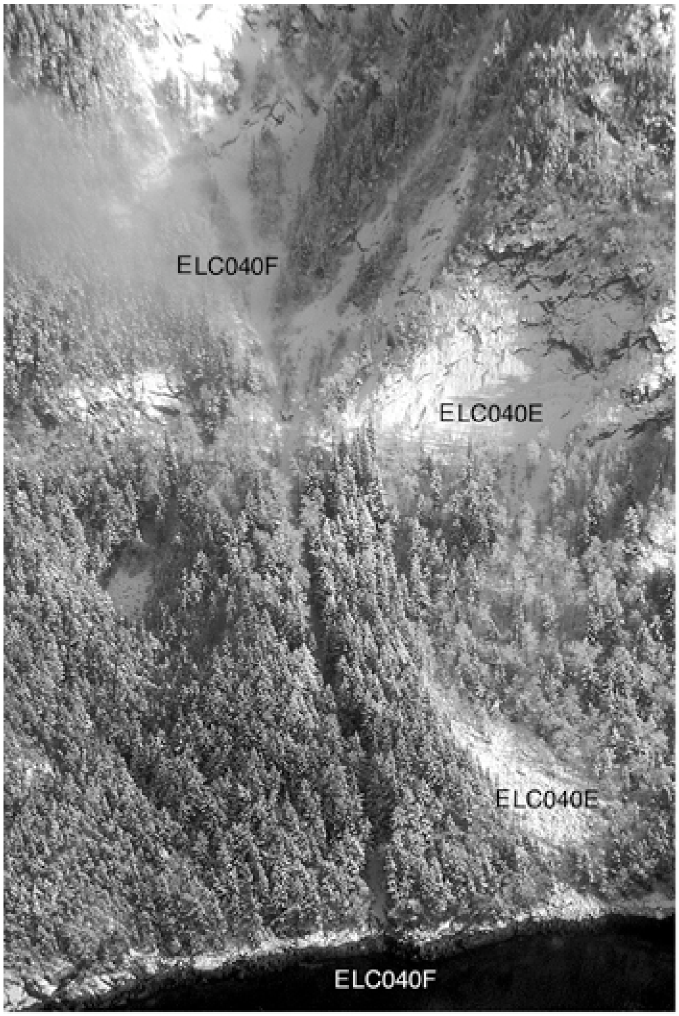
Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.164047 -135.215716
Max Width (ft):	280 feet
Max Width (m):	85 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1900 feet
Starting Elevation (m):	579 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	gullies and rock slabs
Start Aspect:	W
Path Type:	shallow gully and openings in forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	2.12
Comments:	Fifteenth-highest East Lynn AHI.

East Lynn Canal Path ELC040D Photos

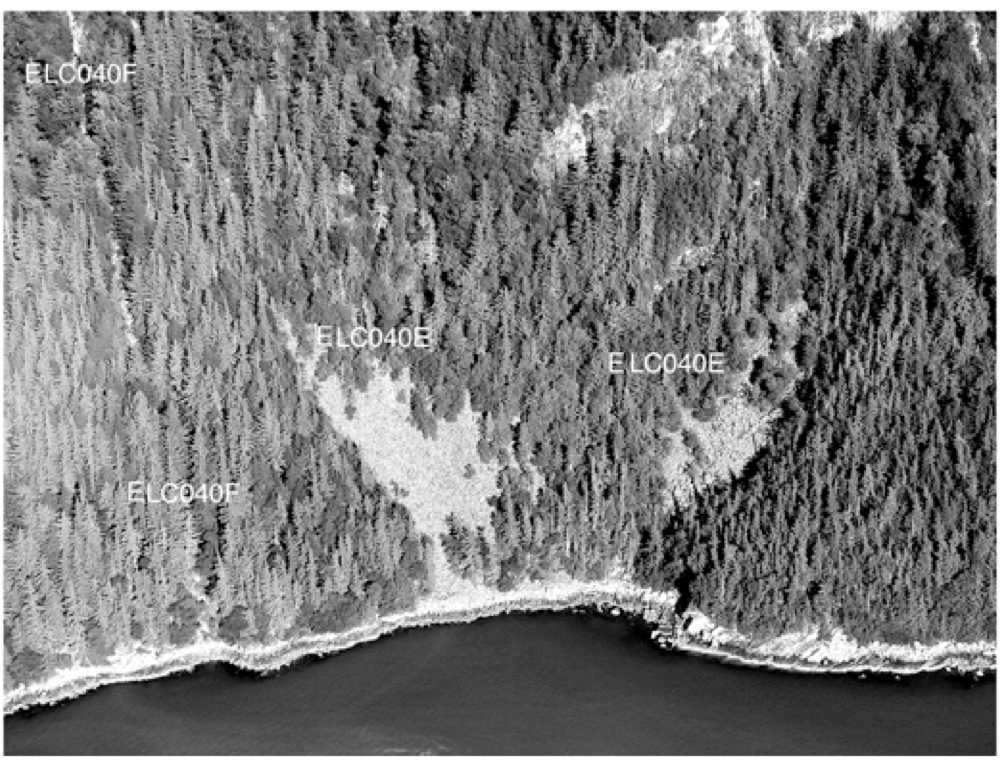


Avalanche Path Atlas - East Lynn Canal Path ELC040D

Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.164982 -135.21558
Max Width (ft):	730 feet
Max Width (m):	222 meters
Typical Width (ft):	290 feet
Typical Width (m):	88 meters
Starting Elevation (ft):	1600 feet
Starting Elevation (m):	488 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	gullies and rock slabs
Start Aspect:	W
Path Type:	deep gully and open talus and forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.16
Comments:	

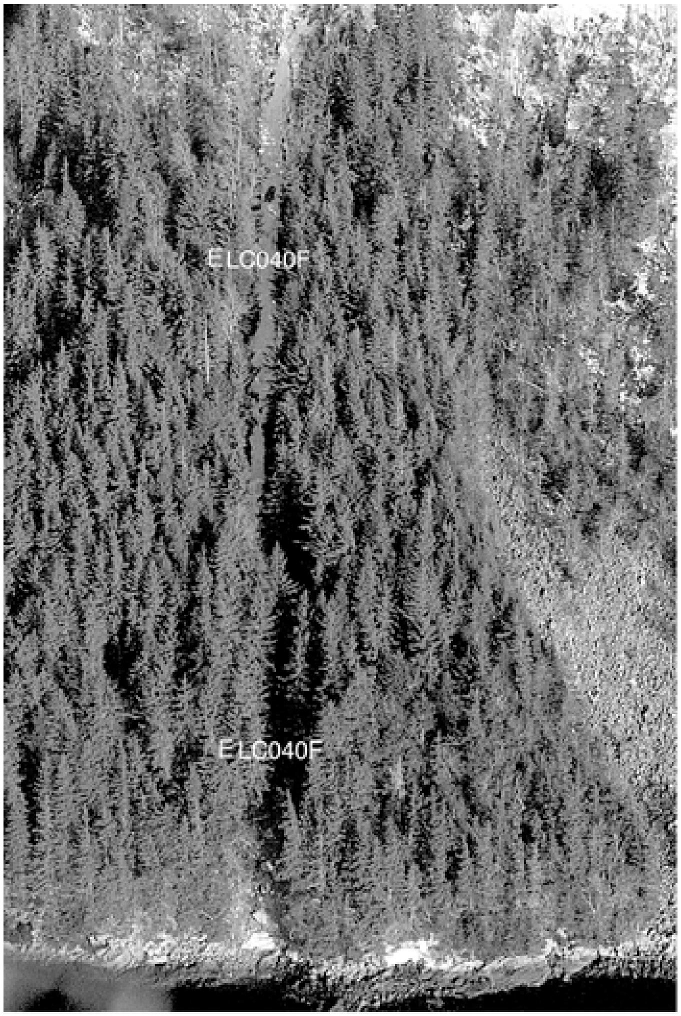


East Lynn Canal Path ELC040E Photos

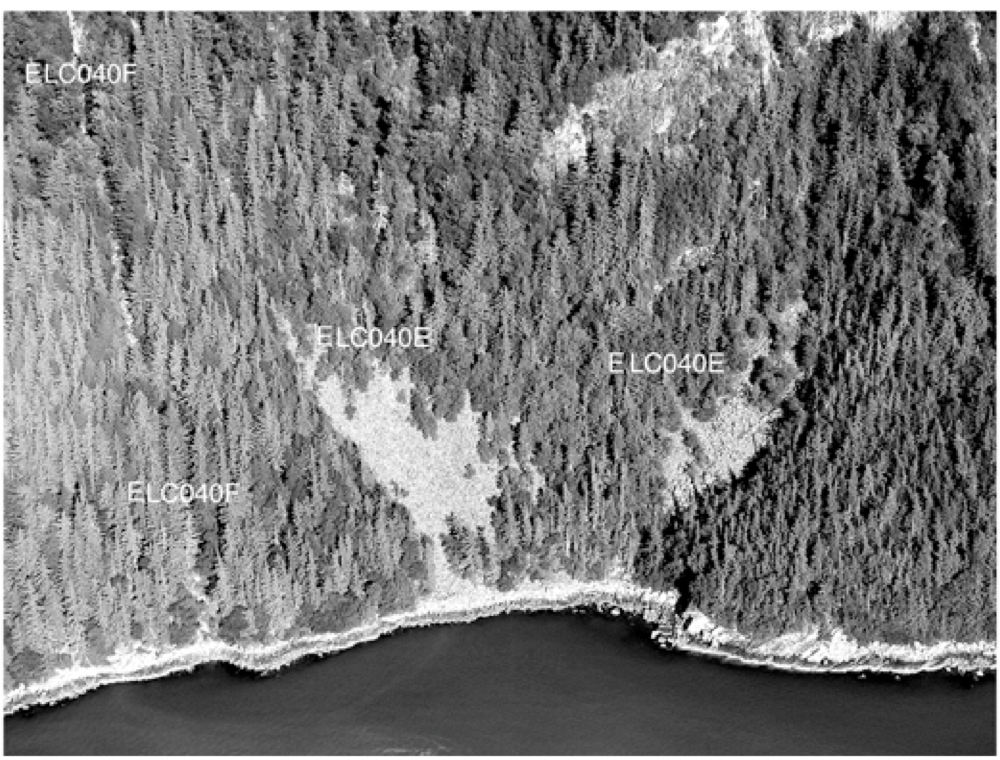


Avalanche Path Atlas - East Lynn Canal Path ELC040E

Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.165371 -135.21543
Max Width (ft):	380 feet
Max Width (m):	116 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	talus and open forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.05
Comments:	



East Lynn Canal Path ELC040F Photos



Avalanche Path Atlas - East Lynn Canal Path ELC040F

Path Group:	Haines Area, Map 5
Latitude-Longitude:	59.165858 -135.215675
Max Width (ft):	90 feet
Max Width (m):	27 meters
Typical Width (ft):	70 feet
Typical Width (m):	21 meters
Starting Elevation (ft):	2100 feet
Starting Elevation (m):	640 meters
Elevation Class:	medium high
Path Size:	small
Starting Zone Characteristics:	medium bowl with gullies
Start Aspect:	W
Path Type:	narrow gully
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.24
Comments:	

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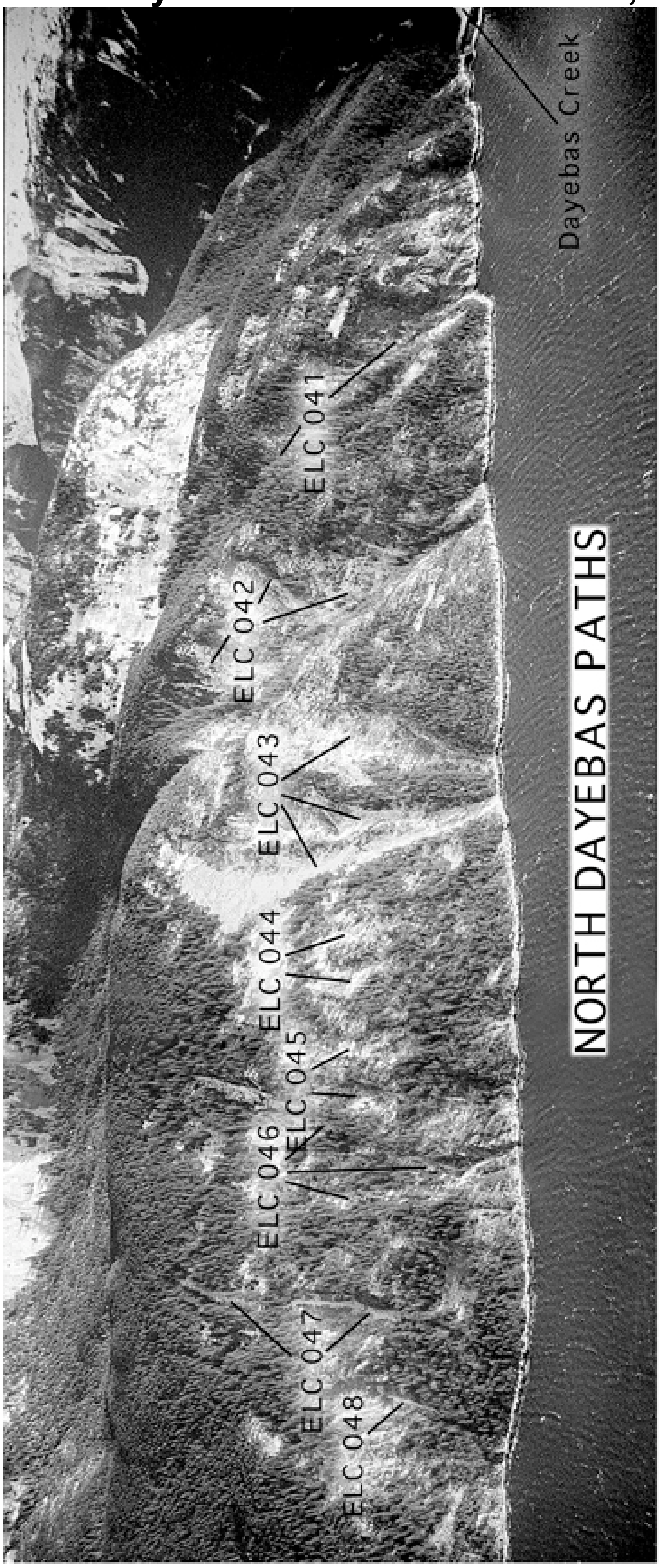
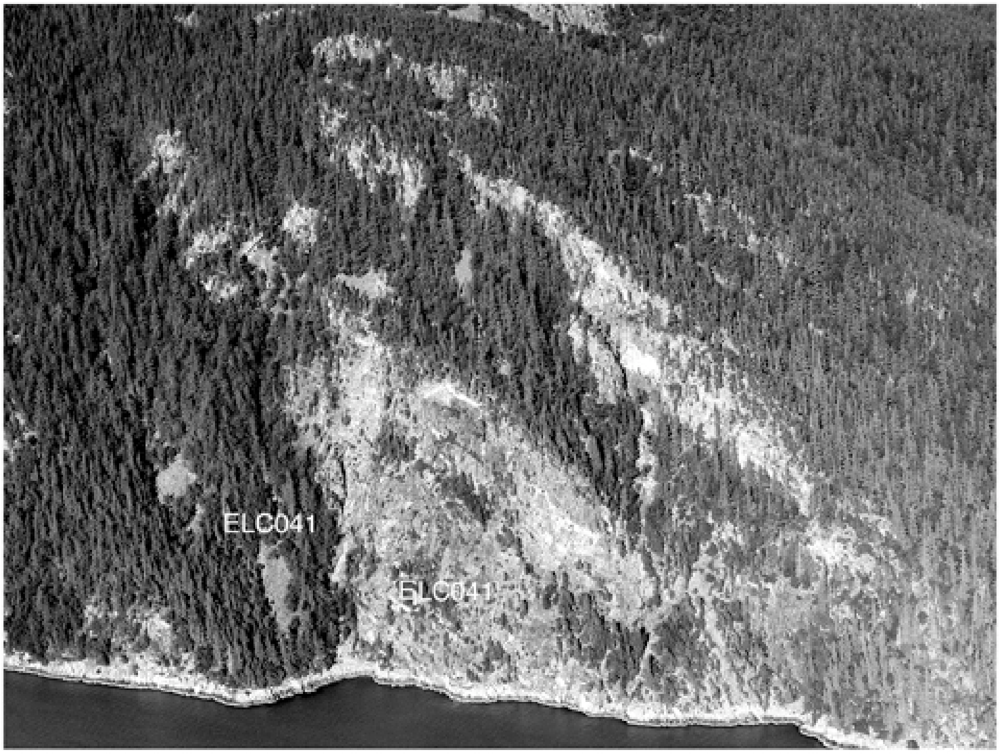
North Dayebas Paths Overview Photo, ELC041 to 048



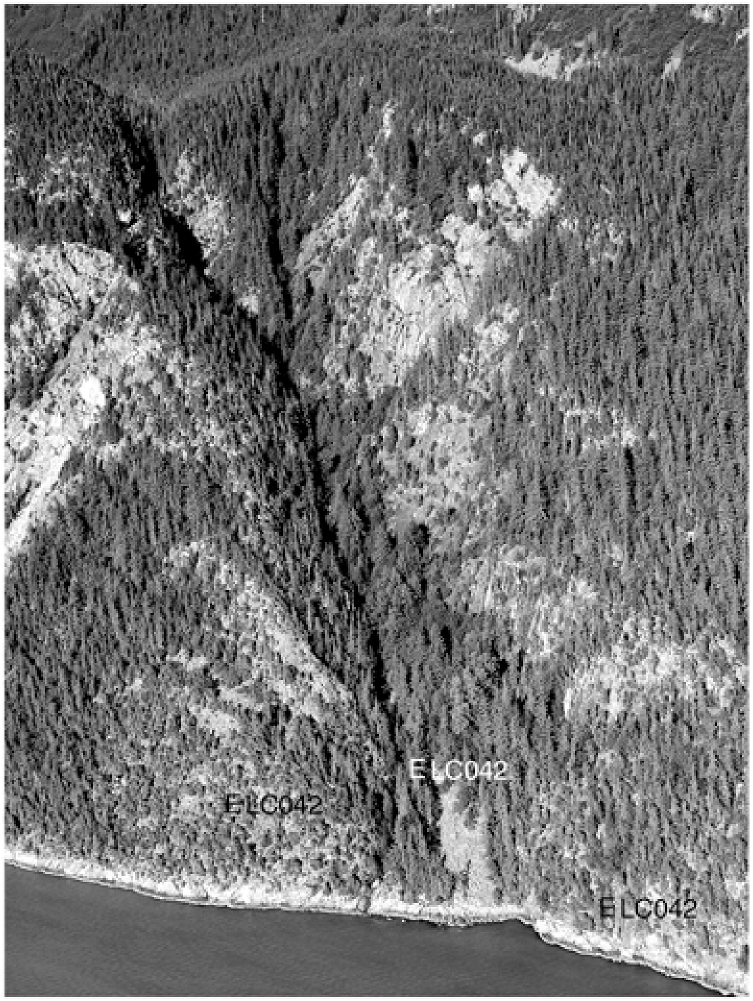
The North Dayebas paths, along Taiya Inlet, are in a relatively low-snow area in most winters, but their steep topography has the potential to produce many slides in winters that have heavy snowfall. Explosive delivery options evaluated for these paths include helicopter placement and remotely operated blaster box installations in the starting zones of the more active paths. Howitzer use is not practical due to lack of suitable firing positions.



East Lynn Canal Path ELC041 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC041

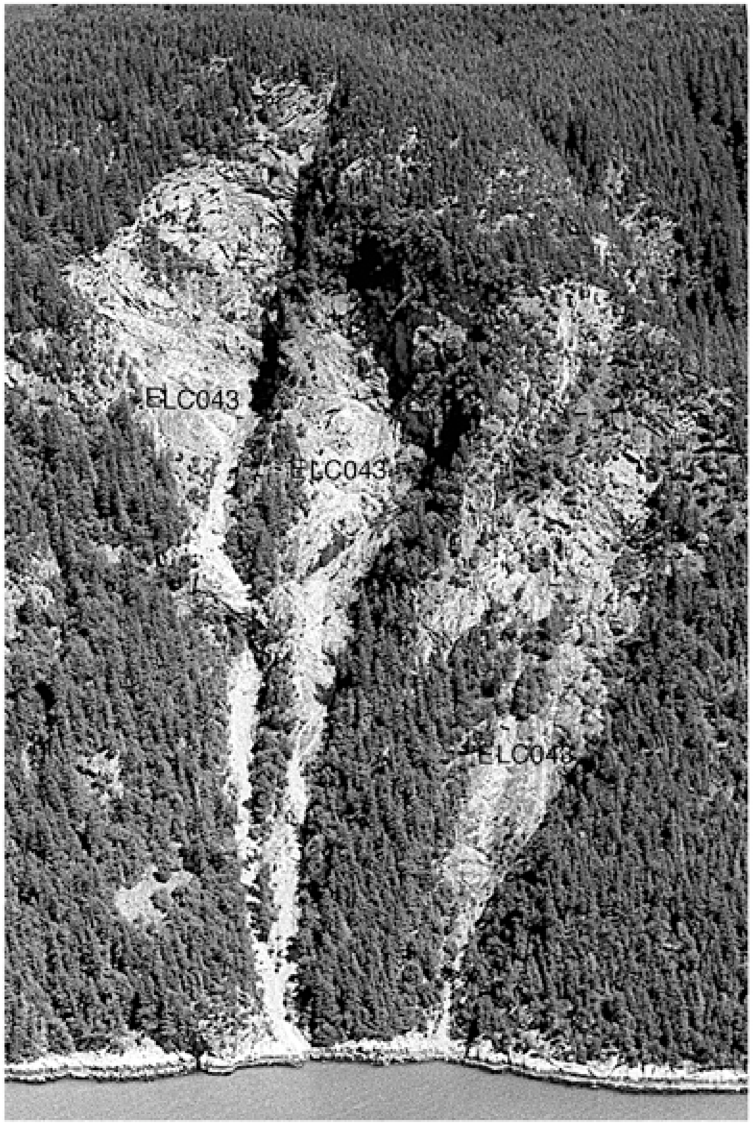
Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.17462 -135.215539
Max Width (ft):	1020 feet
Max Width (m):	311 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	1100 feet
Starting Elevation (m):	335 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	rock slabs and talus
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.11
Comments:	



East Lynn Canal Path ELC042 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC042

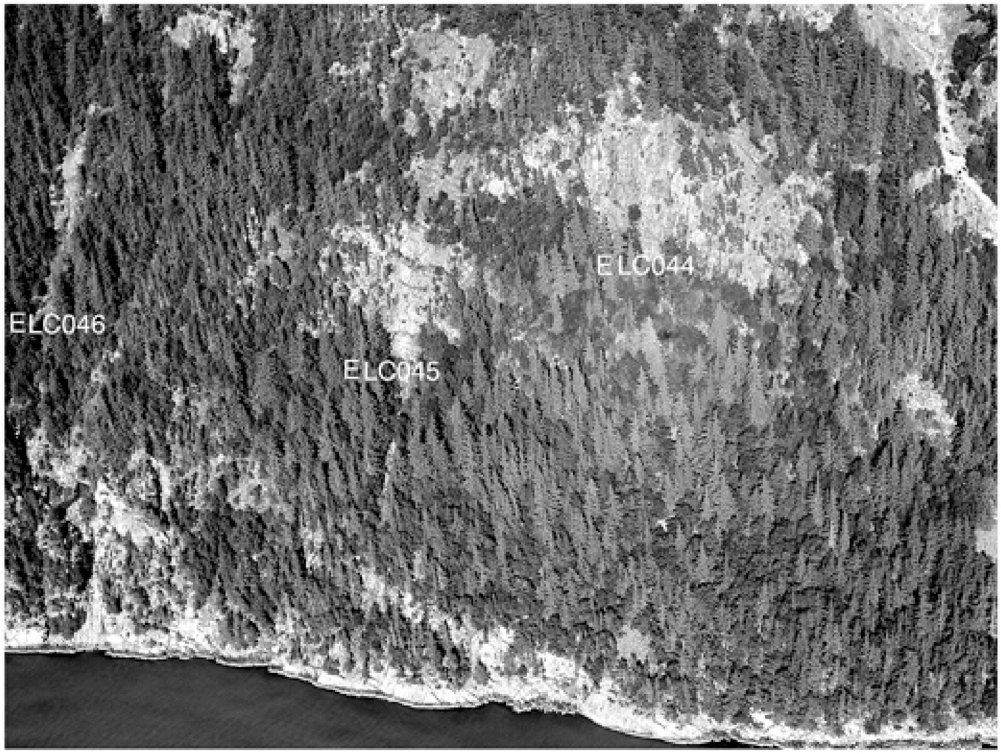
Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.180815 -135.215816
Max Width (ft):	320 feet
Max Width (m):	98 meters
Typical Width (ft):	70 feet
Typical Width (m):	21 meters
Starting Elevation (ft):	1500 feet
Starting Elevation (m):	457 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	rock slabs and talus
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.04
Comments:	



East Lynn Canal Path ELC043 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC043

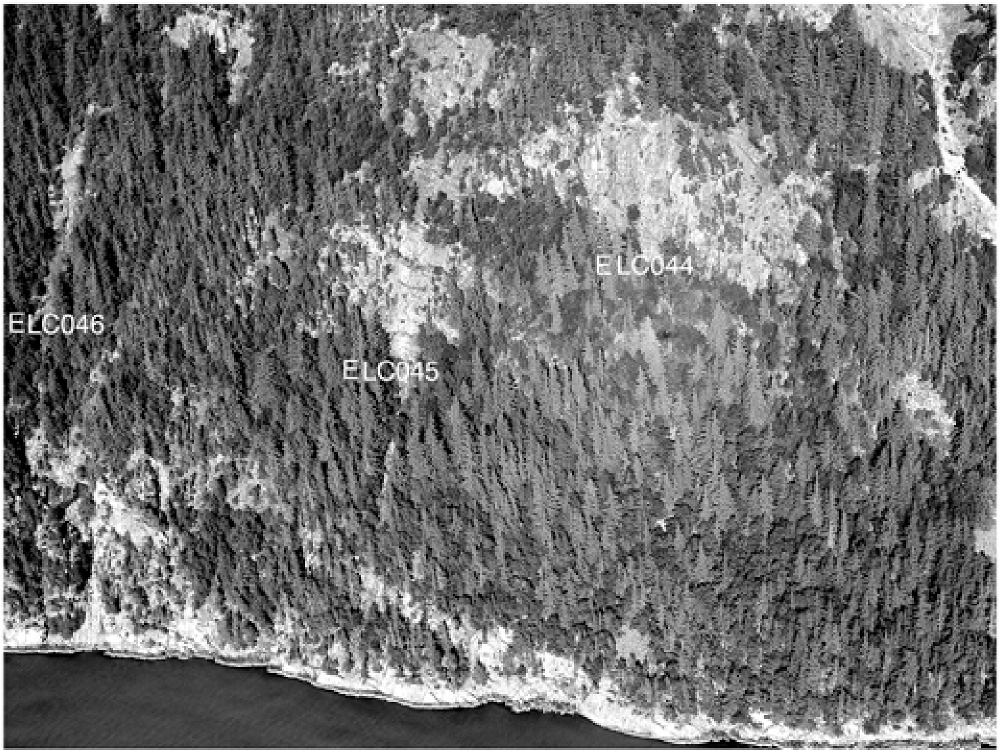
Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.182255 -135.22001
Max Width (ft):	260 feet
Max Width (m):	79 meters
Typical Width (ft):	120 feet
Typical Width (m):	37 meters
Starting Elevation (ft):	1700 feet
Starting Elevation (m):	518 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs
Start Aspect:	W
Path Type:	three shallow rock slab gullies
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	2.59
Comments:	Thirteenth-highest East Lynn AHI.



East Lynn Canal Path ELC044 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC044

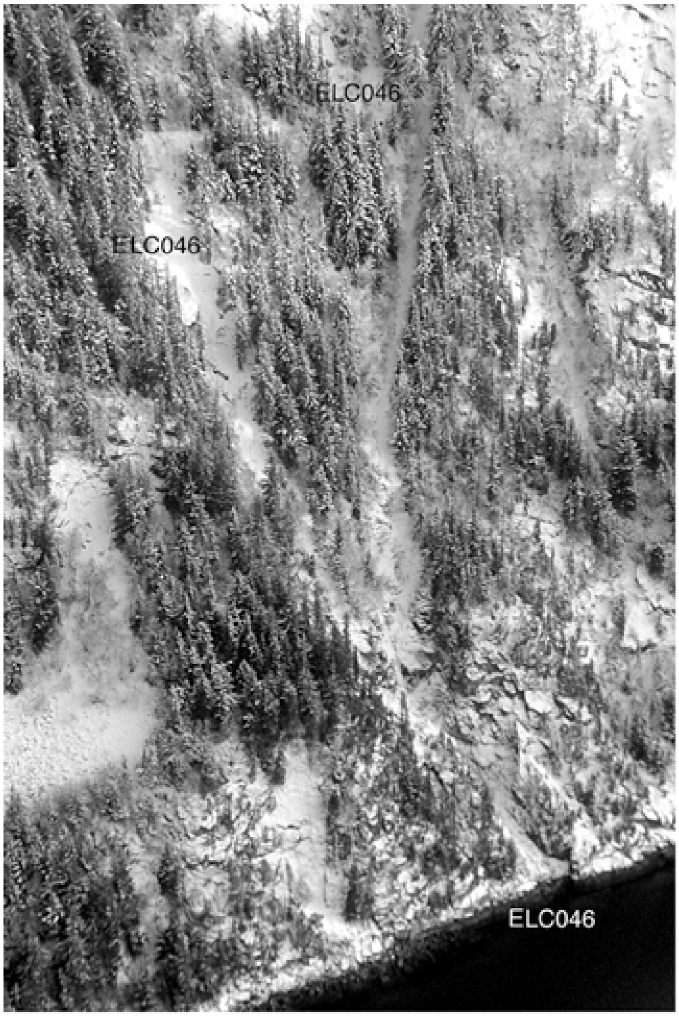
Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.183061 -135.220372
Max Width (ft):	490 feet
Max Width (m):	149 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	talus and open forest
Runout Angle:	decreases moderately
Unmitigated avalanche hazard index (AHI):	0.02
Comments:	Usually stops above alignment.



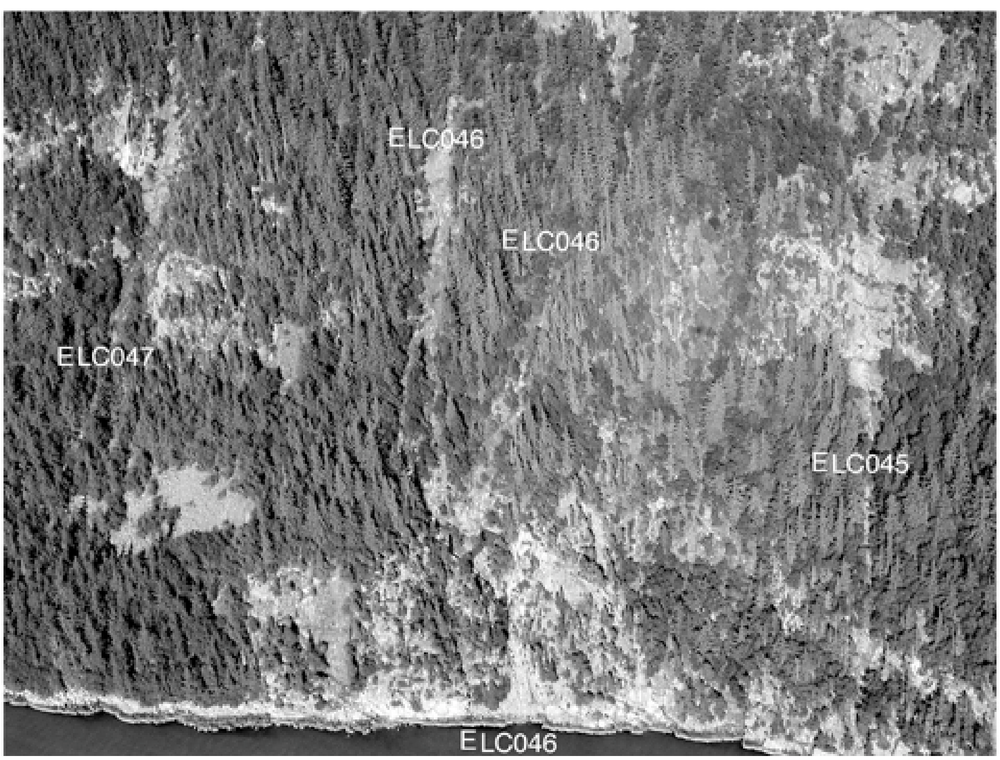
East Lynn Canal Path ELC045 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC045

Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.183832 -135.220367
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	talus and open forest
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.27
Comments:	

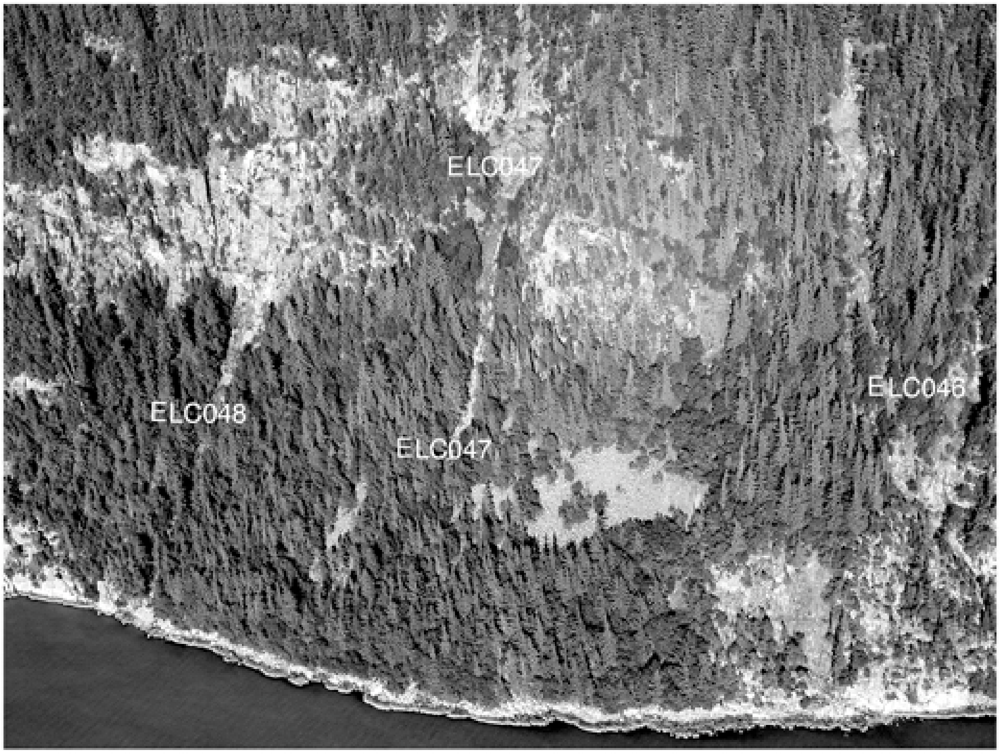


East Lynn Canal Path ELC046 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC046

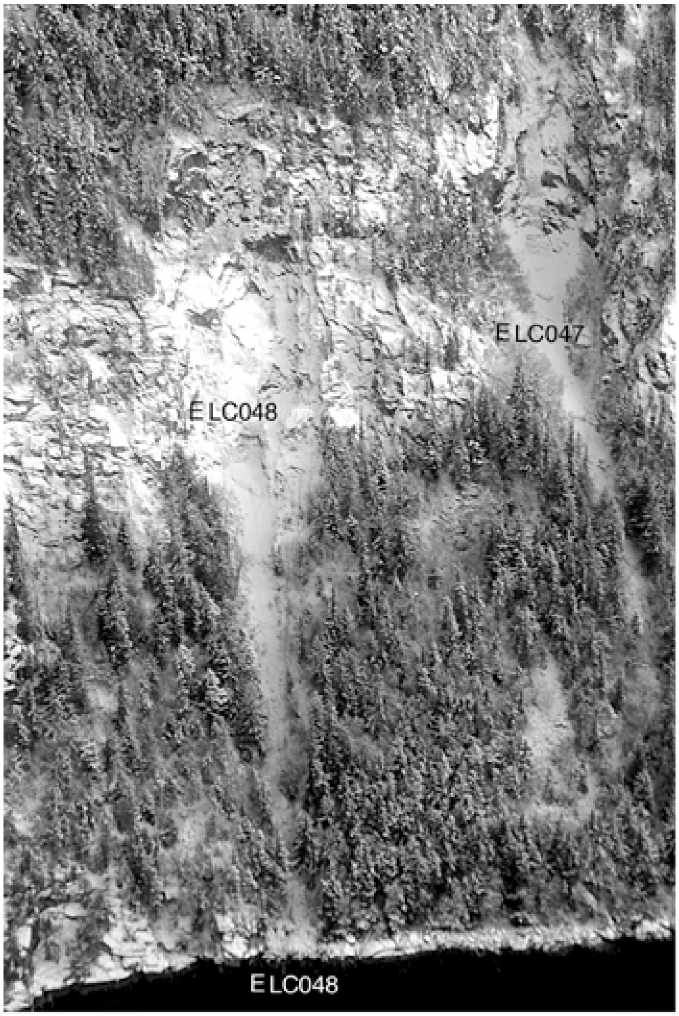
Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.184384 -135.220434
Max Width (ft):	110 feet
Max Width (m):	34 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	1700 feet
Starting Elevation (m):	518 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and gullies
Start Aspect:	W
Path Type:	narrow gullies
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.83
Comments:	Twentieth-highest East Lynn AHI.



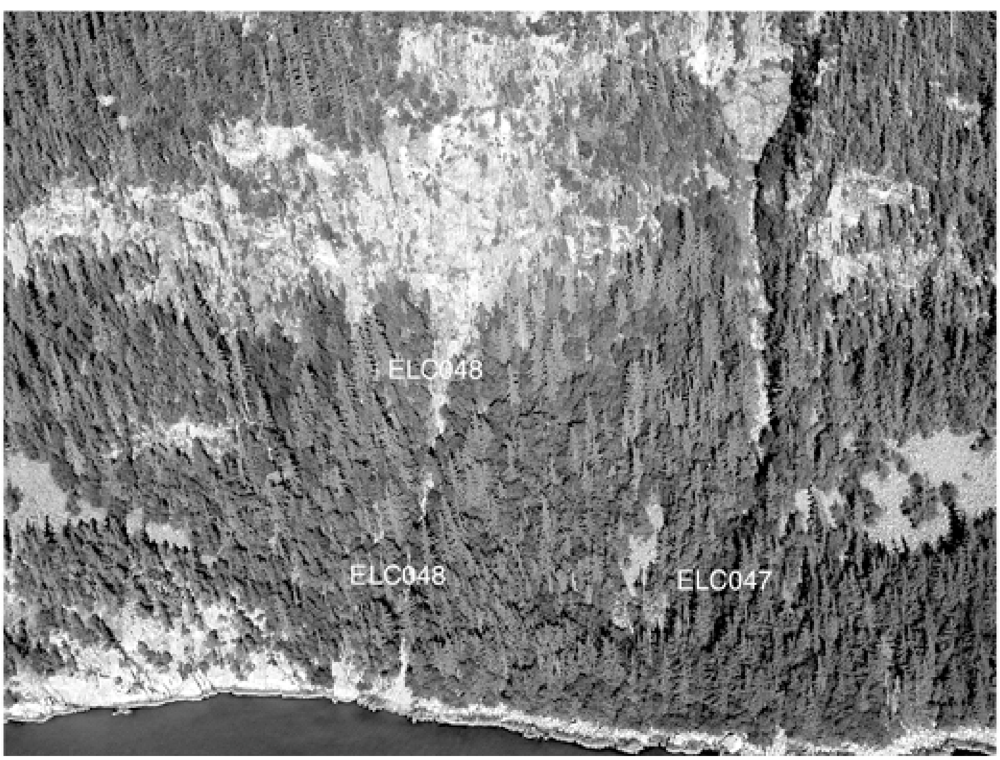
East Lynn Canal Path ELC047 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC047

Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.185181 -135.220596
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	70 feet
Typical Width (m):	21 meters
Starting Elevation (ft):	1600 feet
Starting Elevation (m):	488 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	narrow gully
Start Aspect:	W
Path Type:	cliffs and narrow gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.14
Comments:	



East Lynn Canal Path ELC048 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC048

Path Group:	North Dayebas, Map 5
Latitude-Longitude:	59.190067 -135.220202
Max Width (ft):	80 feet
Max Width (m):	24 meters
Typical Width (ft):	70 feet
Typical Width (m):	21 meters
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	medium low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	talus and gully in forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.33
Comments:	

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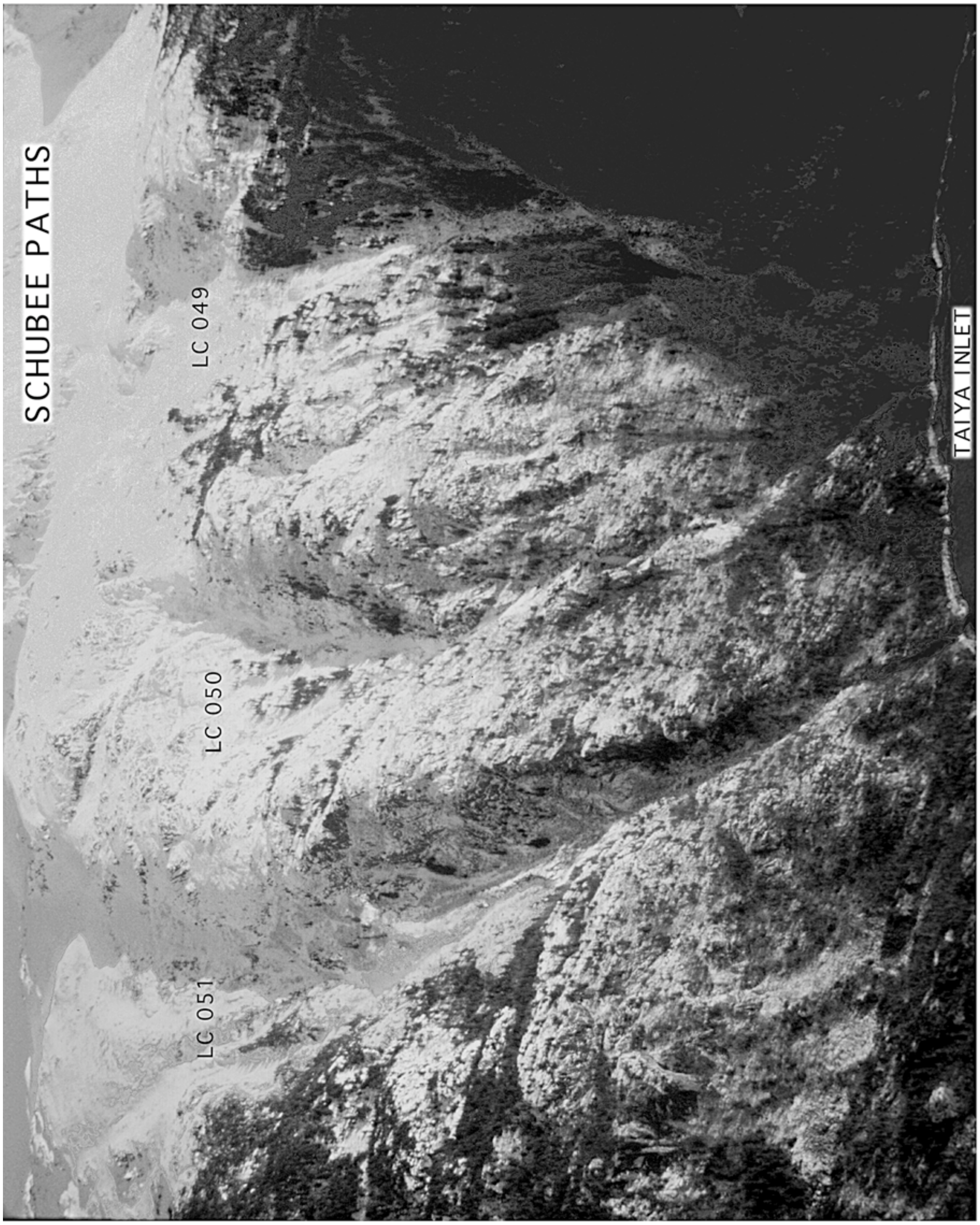
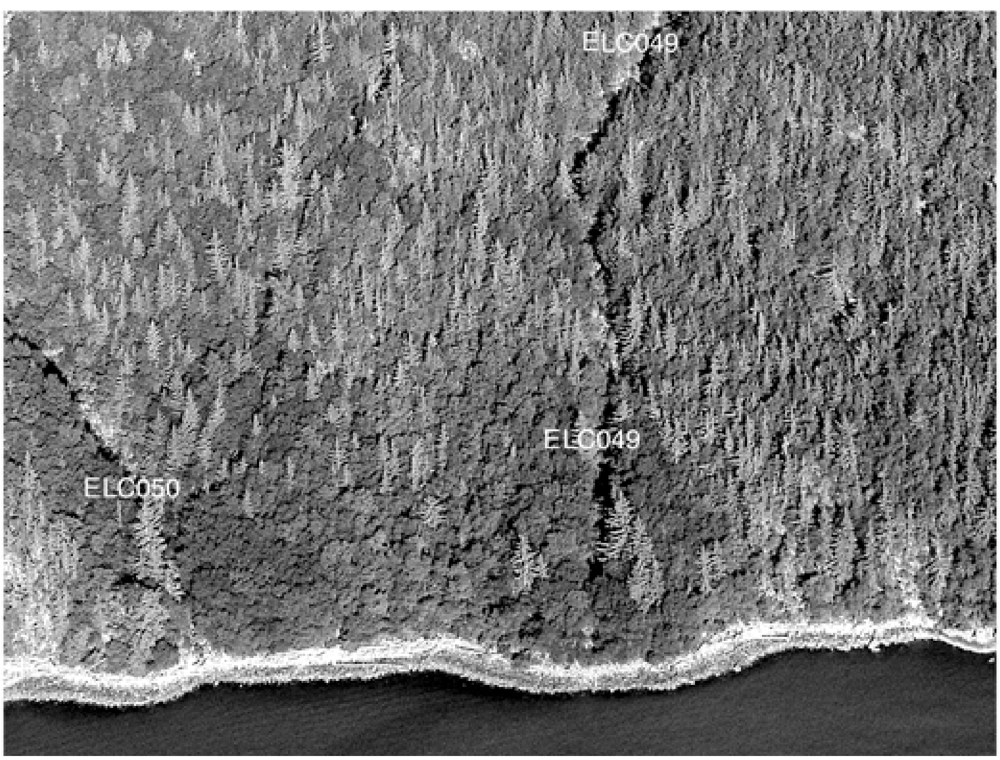
Schubee Paths Overview Photo, ELC049 to ELC051



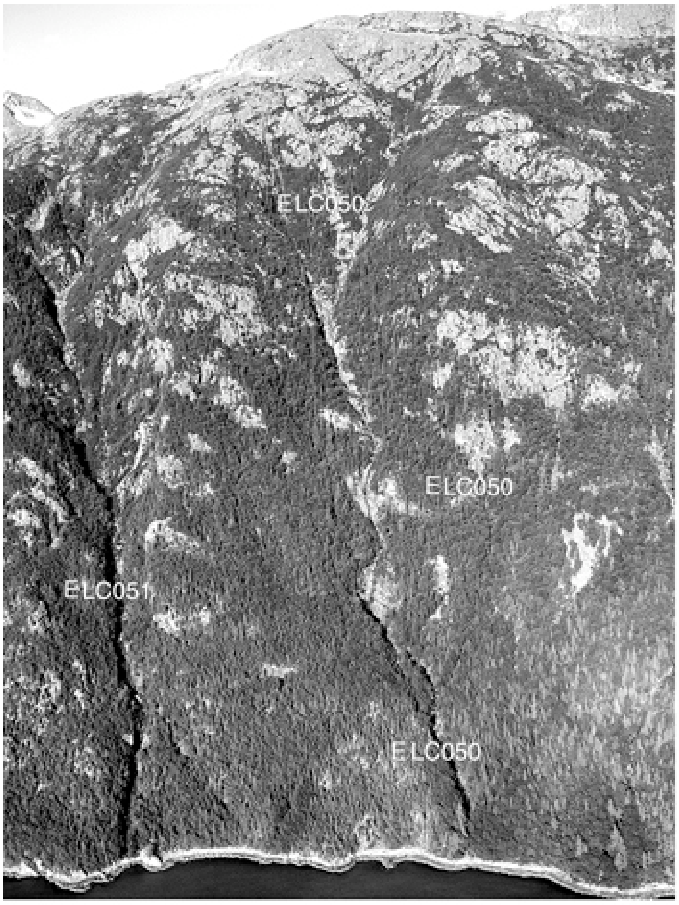
The Schubee paths are the only high-elevation paths along Taiya Inlet. They are not very wide, but they produce frequent slides to low elevation. Among the explosive delivery options evaluated for these paths were helicopter placement and remotely-operated blaster box installations in the starting zones. Howitzer use is impractical due to lack of suitable firing positions.

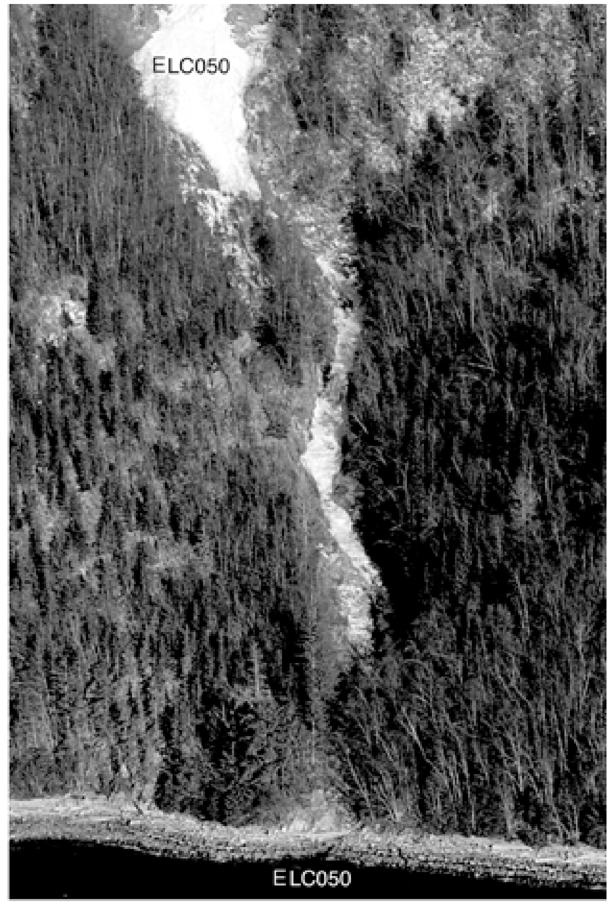
East Lynn Canal Path ELC049 Photos

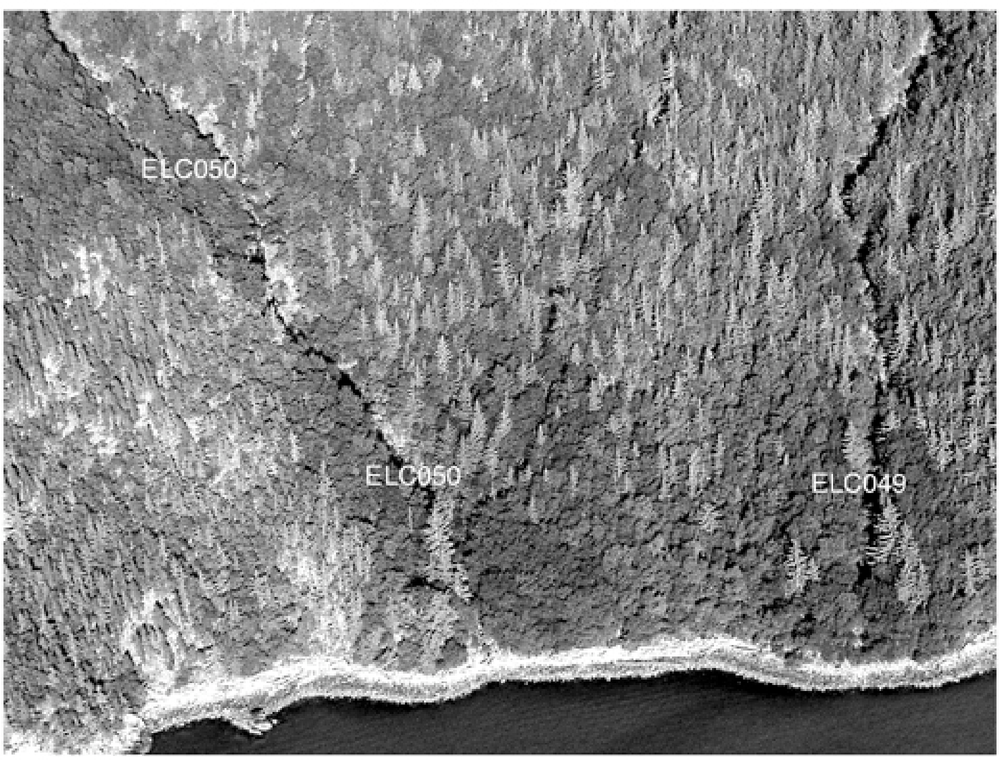


Avalanche Path Atlas - East Lynn Canal Path ELC049

Path Group:	Schubee, Map 6
Latitude-Longitude:	59.203092 -135.212273
Max Width (ft):	260 feet
Max Width (m):	79 meters
Typical Width (ft):	120 feet
Typical Width (m):	37 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	big gullied bowl
Start Aspect:	W
Path Type:	broad gullies to single gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	3.07
Comments:	Twelfth-highest East Lynn AHI.



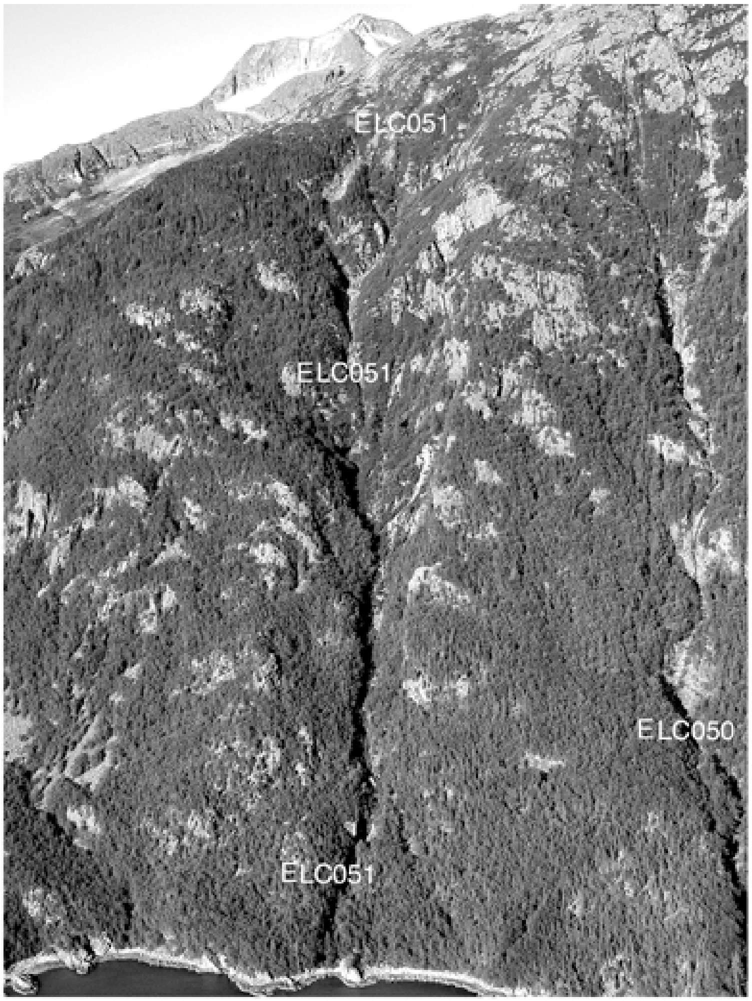




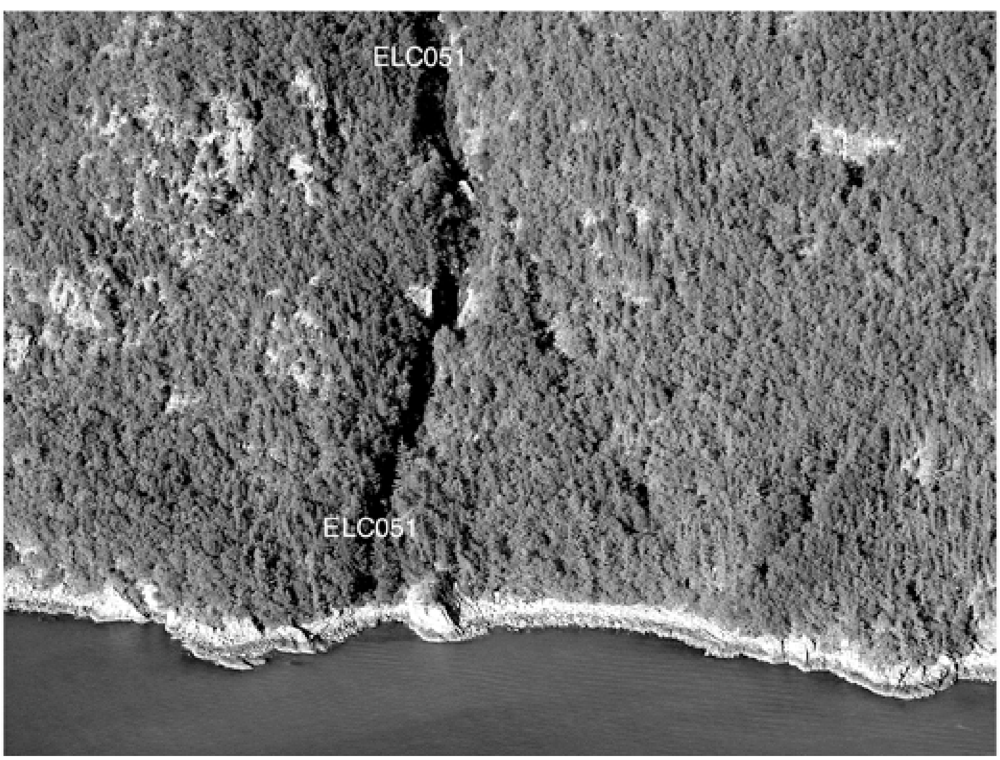
East Lynn Canal Path ELC050 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC050

Path Group:	Schubee, Map 6
Latitude-Longitude:	59.20353 -135.212189
Max Width (ft):	120 feet
Max Width (m):	37 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	rock slabs and gullies
Start Aspect:	W
Path Type:	broad incised gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.55
Comments:	

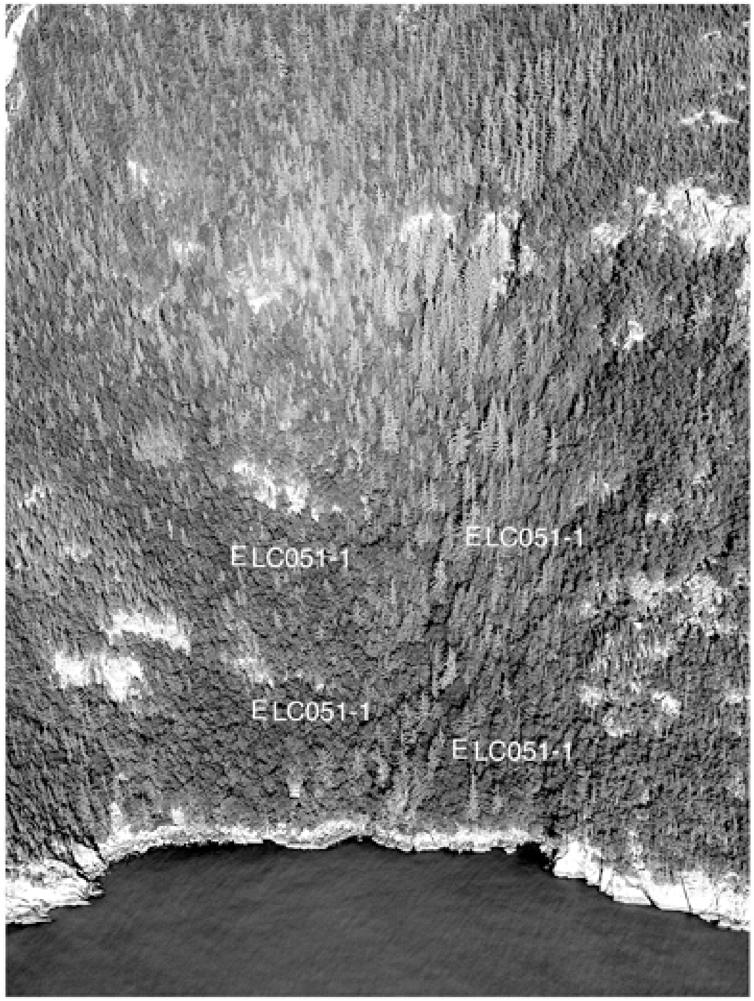


East Lynn Canal Path ELC051 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC051

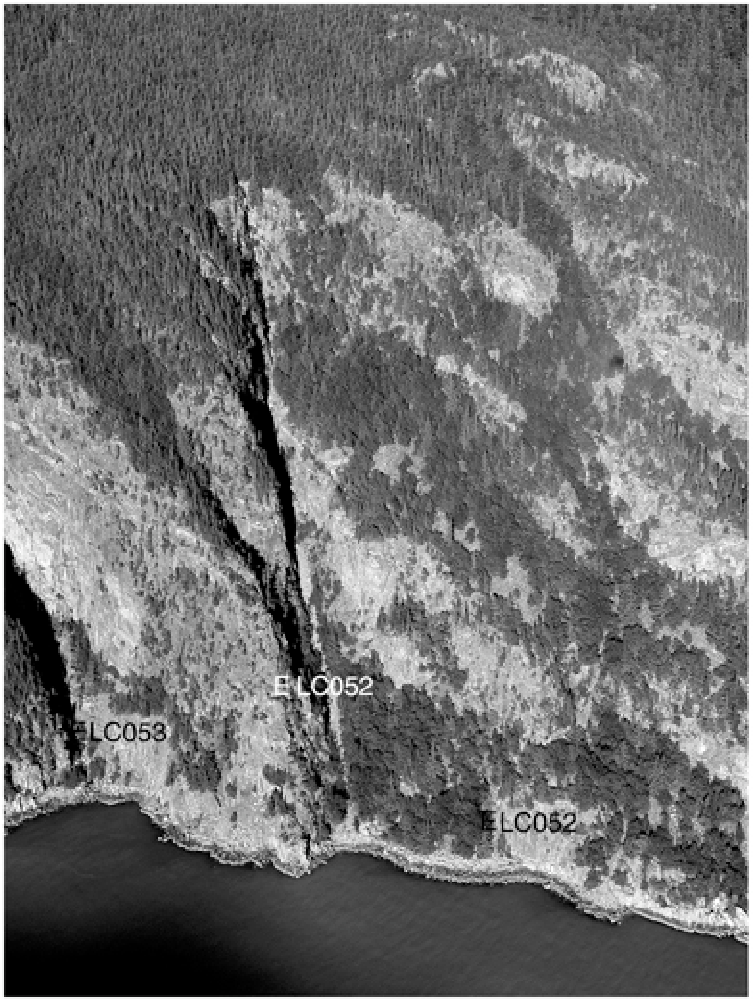
Path Group:	Schubee, Map 6
Latitude-Longitude:	59.204595 -135.212741
Max Width (ft):	150 feet
Max Width (m):	46 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	rock slabs and gullies
Start Aspect:	W
Path Type:	broad incised gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	2.21
Comments:	Fourteenth-highest East Lynn AHI.



East Lynn Canal Path ELC051-1 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC051-1

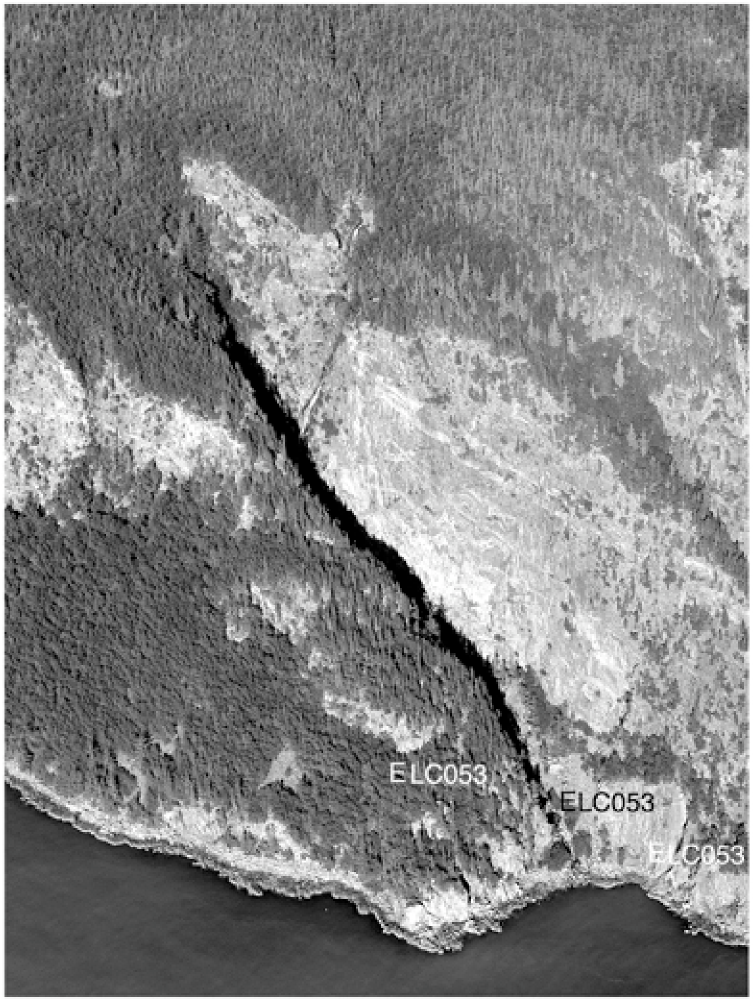
Path Group:	Taiya Inlet, Map 6
Latitude-Longitude:	59.213711 -135.212892
Max Width (ft):	540 feet
Max Width (m):	165 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	900 feet
Starting Elevation (m):	274 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	open forest and shallow gullies
Start Aspect:	W
Path Type:	open forest and shallow gullies
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.11
Comments:	



East Lynn Canal Path ELC052 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC052

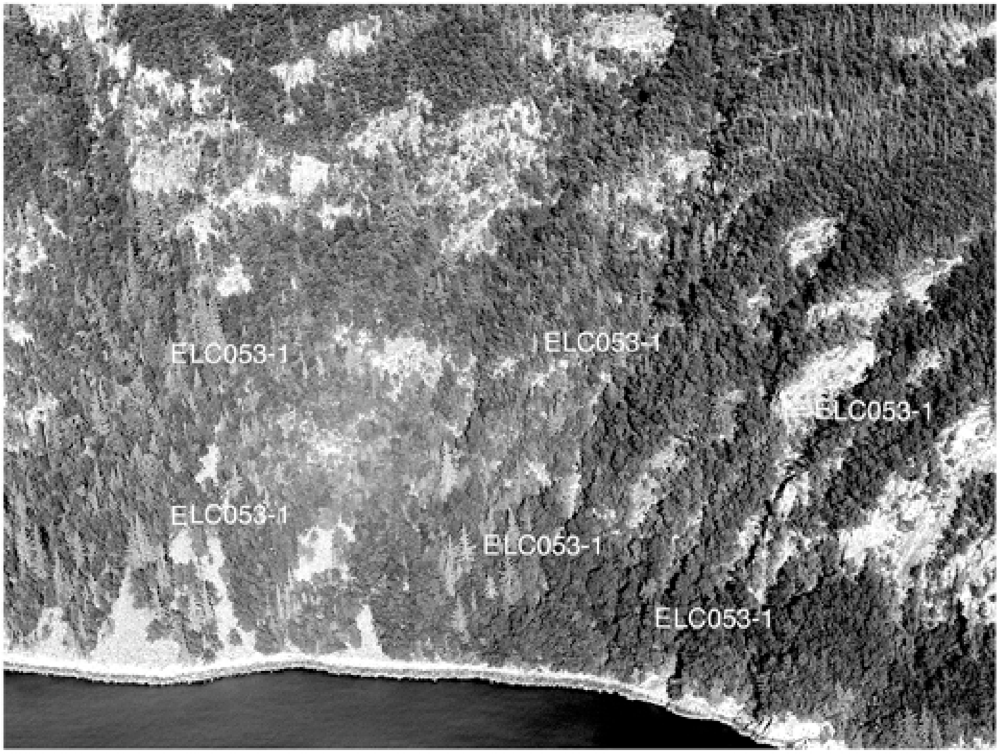
Path Group:	Taiya Inlet, Map 6
Latitude-Longitude:	59.215586 -135.212615
Max Width (ft):	280 feet
Max Width (m):	85 meters
Typical Width (ft):	90 feet
Typical Width (m):	27 meters
Starting Elevation (ft):	900 feet
Starting Elevation (m):	274 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	rock slabs and talus
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.17
Comments:	



East Lynn Canal Path ELC053 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC053

Path Group:	Taiya Inlet, Map 6
Latitude-Longitude:	59.221308 -135.212677
Max Width (ft):	160 feet
Max Width (m):	49 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	700 feet
Starting Elevation (m):	213 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	WSW
Path Type:	rock slabs and talus
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.13
Comments:	



East Lynn Canal Path ELC053-1 Photo

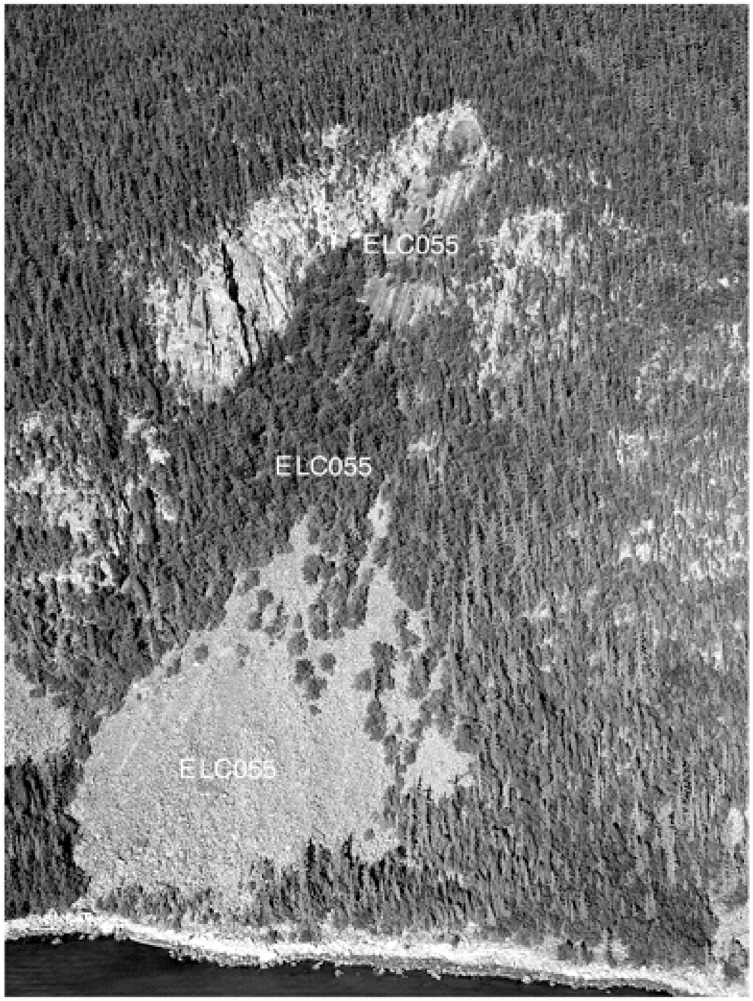
Avalanche Path Atlas - East Lynn Canal Path ELC053-1

Path Group:	Taiya Inlet, Map 6
Latitude-Longitude:	59.223748 -135.210577
Max Width (ft):	140 feet
Max Width (m):	43 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	900 feet
Starting Elevation (m):	274 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs, talus and open forest
Start Aspect:	WNW
Path Type:	rock slabs, talus and open forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.17
Comments:	

East Lynn Canal Path ELC054 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC054

Path Group:	Taiya Inlet, Map 6
Latitude-Longitude:	59.244046 -135.201995
Max Width (ft):	0
Max Width (m):	0
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	300 feet
Starting Elevation (m):	91 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	rock slabs and talus
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.



East Lynn Canal Path ELC055 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC055

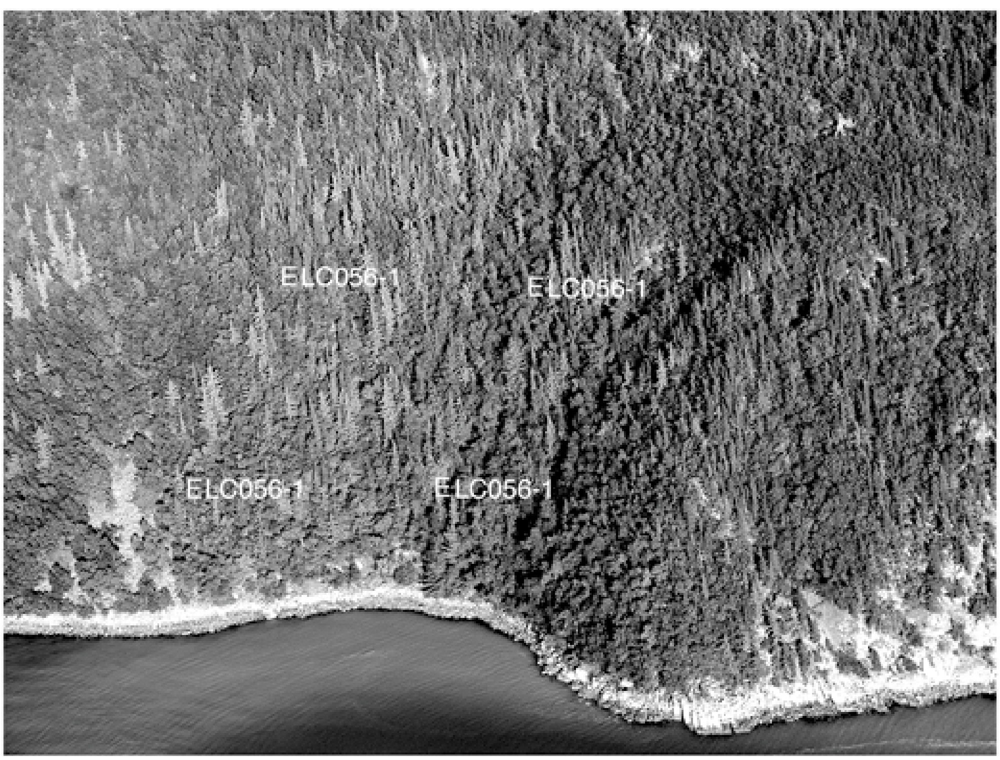
Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.250089 -135.201422
Max Width (ft):	760 feet
Max Width (m):	232 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	1000 feet
Starting Elevation (m):	305 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	W
Path Type:	rock slabs and talus
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.003
Comments:	Alignment crosses high on path.

East Lynn Canal Path ELC056 Photo

Avalanche Path Atlas - East Lynn Canal Path ELC056

Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.252974 -135.195995
Max Width (ft):	530 feet
Max Width (m):	162 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	300 feet
Starting Elevation (m):	91 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	WNW
Path Type:	rock slabs and talus
Runout Angle:	minimal decrease
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

East Lynn Canal Path ELC056-1 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC056-1

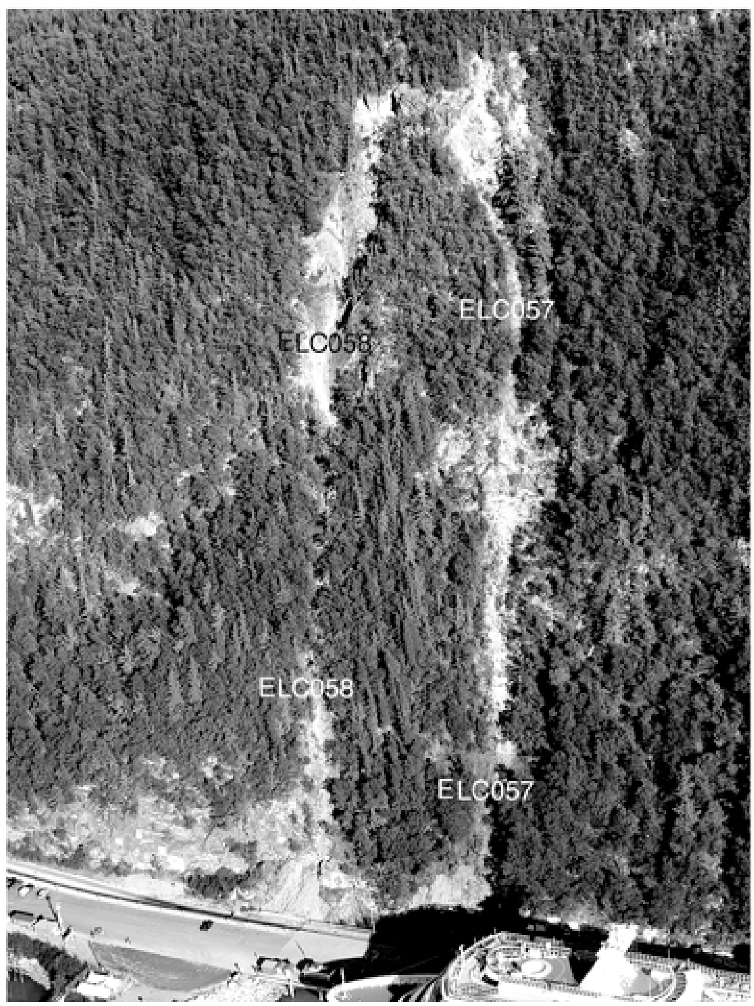
Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.261909 -135.193089
Max Width (ft):	380 feet
Max Width (m):	116 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	450 feet
Starting Elevation (m):	137 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	talus and open forest
Start Aspect:	WNW
Path Type:	talus and open forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

East Lynn Canal Path ELC056-2 Photos

Avalanche Path Atlas - East Lynn Canal Path ELC056-2

Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.26272 -135.191613
Max Width (ft):	520 feet
Max Width (m):	158 meters
Typical Width (ft):	50 feet
Typical Width (m):	15 meters
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	talus and open forest
Start Aspect:	WNW
Path Type:	talus and open forest
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

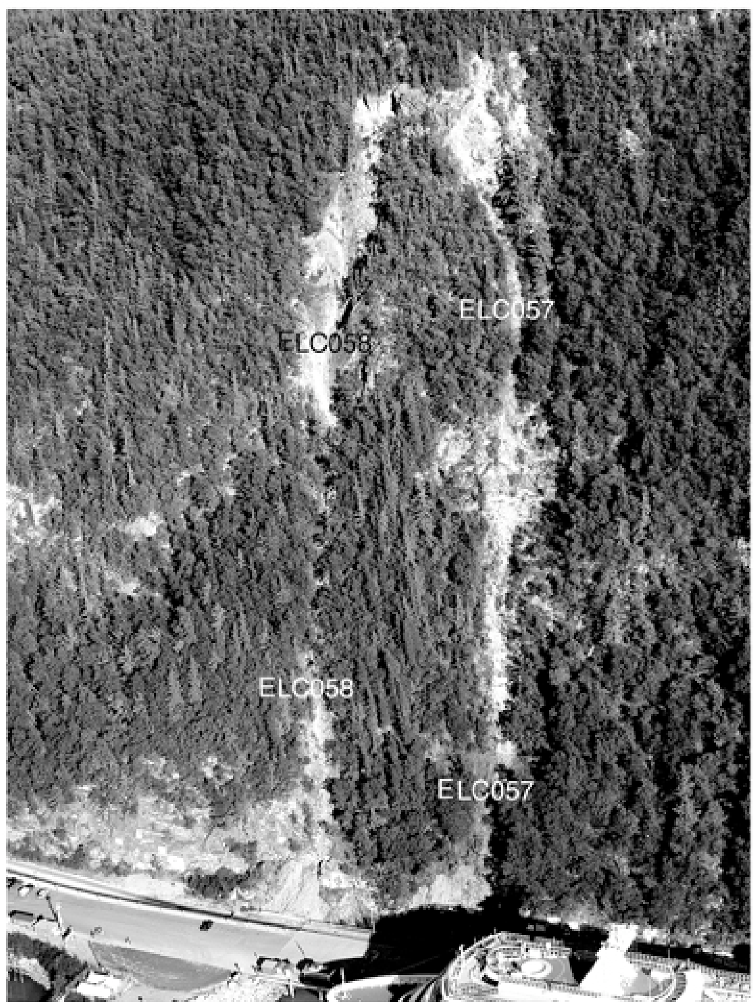
East Lynn Canal Path ELC057 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC057

Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.264102 -135.185204
Max Width (ft):	190 feet
Max Width (m):	58 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	gully and open forest
Start Aspect:	WNW
Path Type:	gullies and talus
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

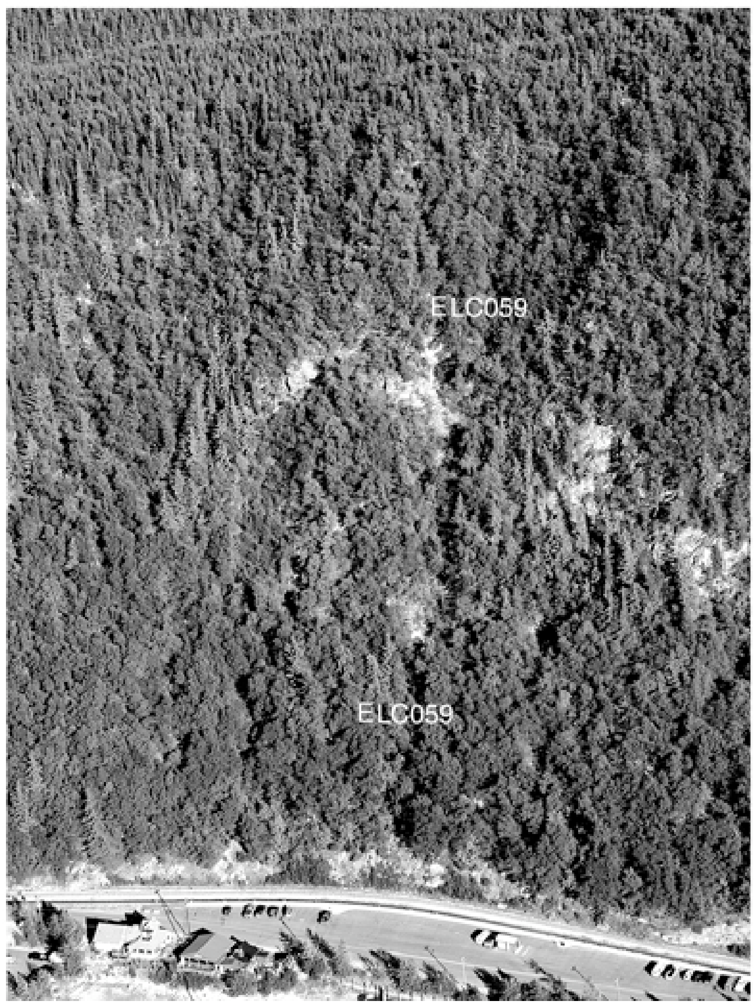
East Lynn Canal Path ELC058 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC058

Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.264588 -135.184623
Max Width (ft):	120 feet
Max Width (m):	37 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	gully and open forest
Start Aspect:	WNW
Path Type:	gullies and talus
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

East Lynn Canal Path ELC059 Photos



Avalanche Path Atlas - East Lynn Canal Path ELC059

Path Group:	Skagway area, Map 6
Latitude-Longitude:	59.26507-135.18421
Max Width (ft):	600 feet
Max Width (m):	183 meters
Typical Width (ft):	80 feet
Typical Width (m):	24 meters
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	talus and open forest
Start Aspect:	WNW
Path Type:	talus and open forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.

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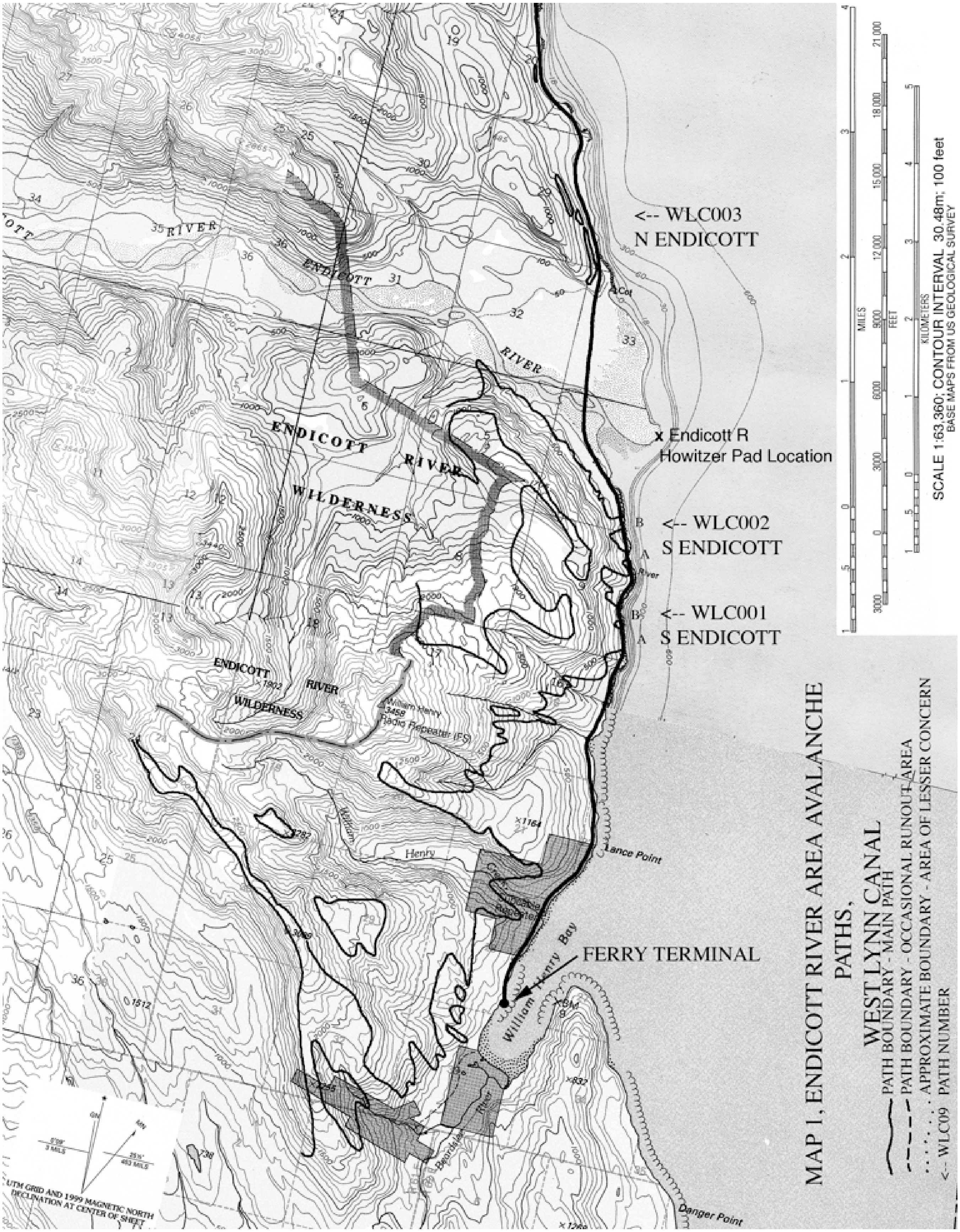
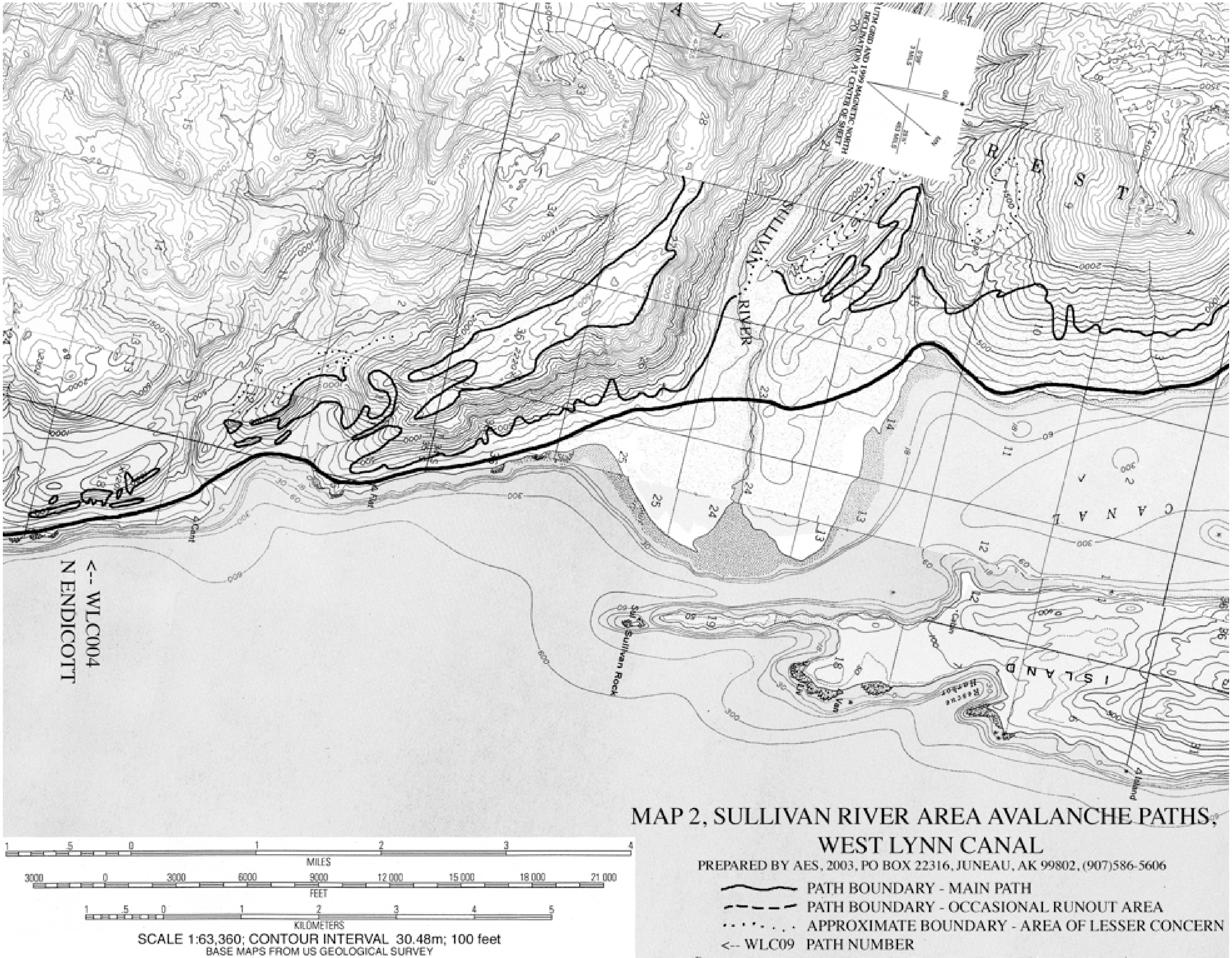
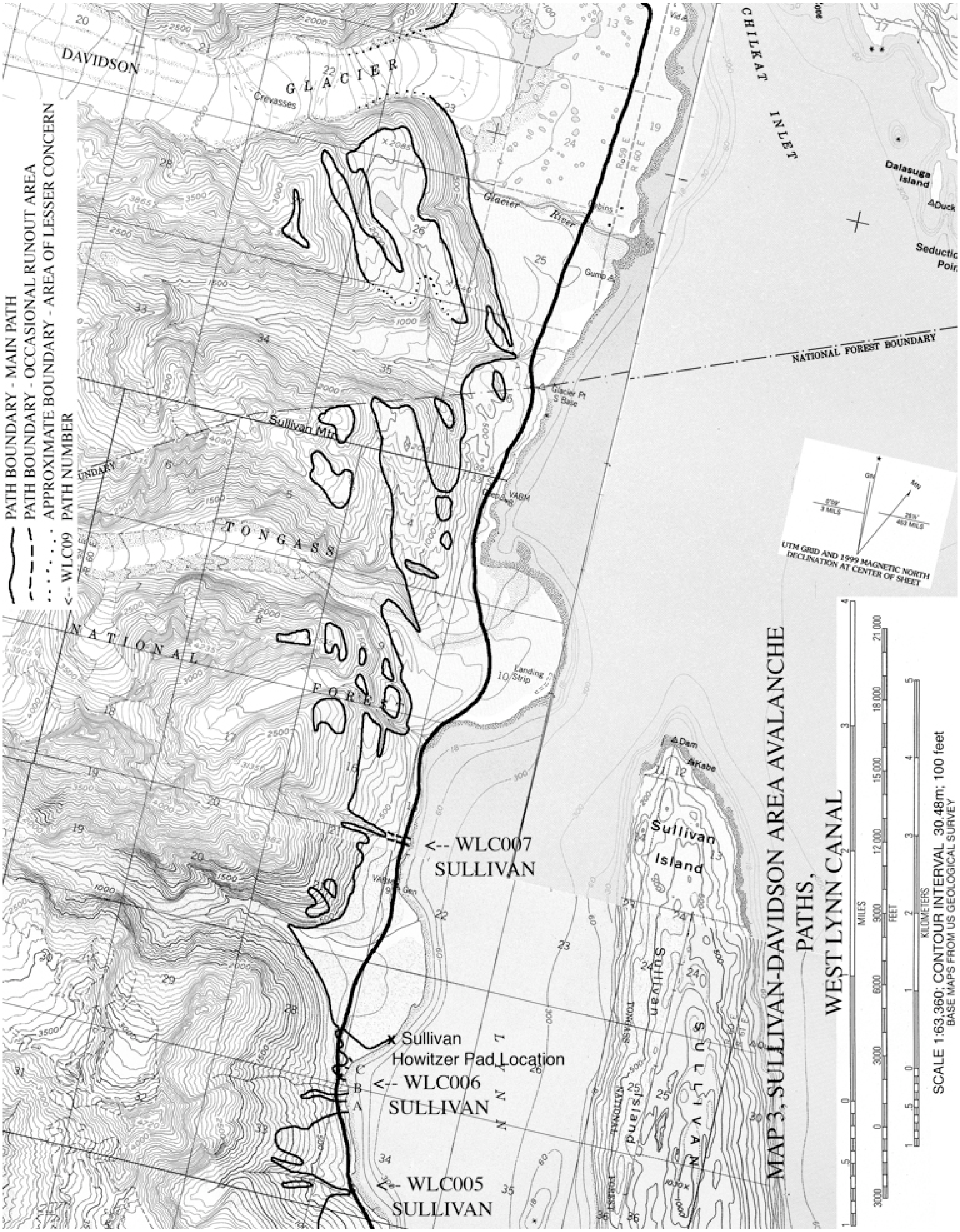
Atlas – West Lynn Canal Section


MAP 1, ENDICOTT RIVER AREA AVALANCHE PATHS, WEST LYNN CANAL
PATH BOUNDARY - MAIN PATH
PATH BOUNDARY - OCCASIONAL RUNOUT AREA
APPROXIMATE BOUNDARY - AREA OF LESSER CONCERN
<-- WLC09 PATH NUMBER
SCALE 1:63,360; CONTOUR INTERVAL 30.48m; 100 feet
BASE MAPS FROM US GEOLOGICAL SURVEY
MILES
FEET
KILOMETERS
<-- WLC003
N ENDICOTT
x Endicott R
Howitzer Pad Location
<-- WLC002
S ENDICOTT
<-- WLC001
S ENDICOTT
FERRY TERMINAL
ENDICOTT RIVER WILDERNESS
ENDICOTT RIVER
Lance Point
Danger Point
William Henry Bay
UTM GRID AND 1999 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

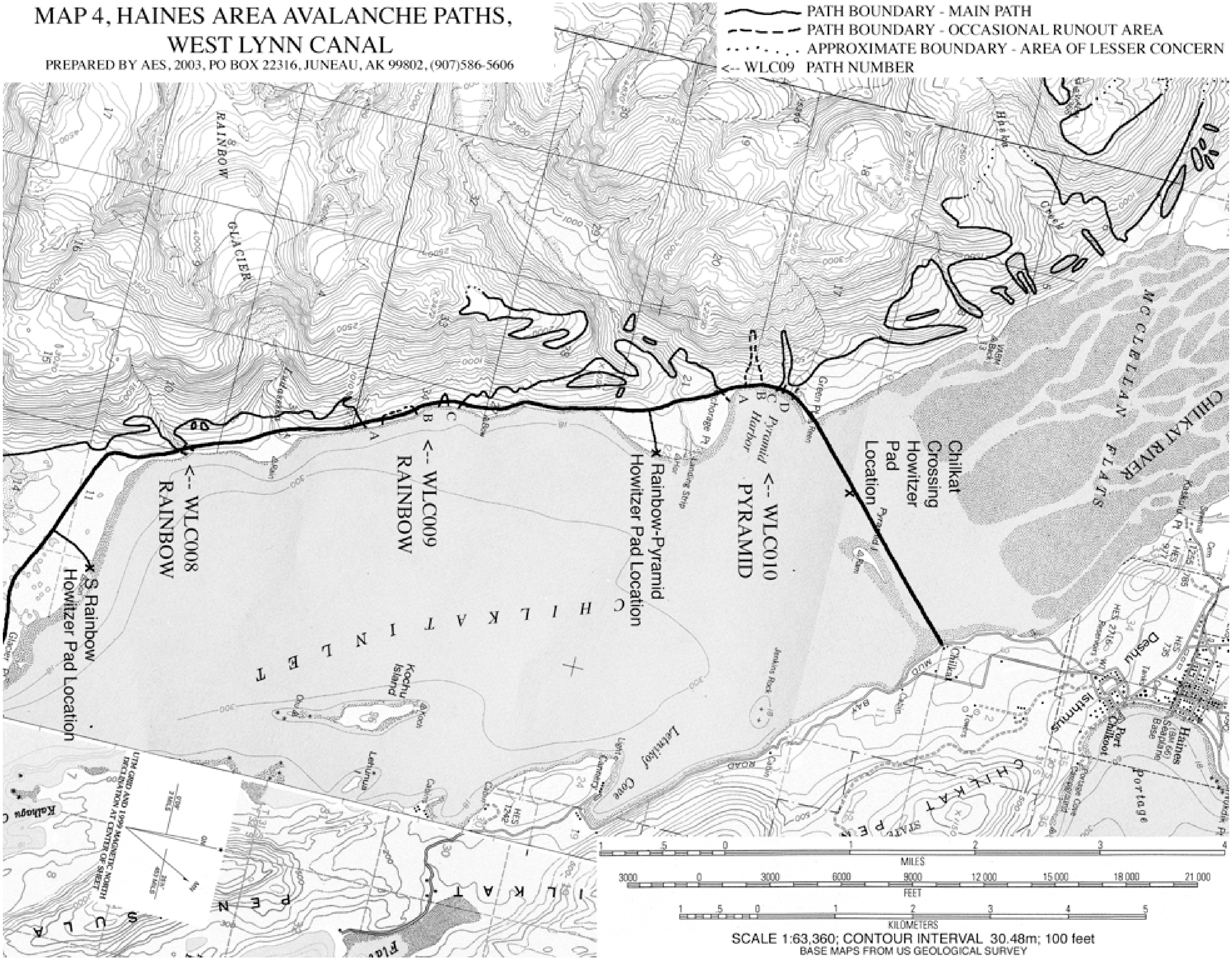

MAP 2, SULLIVAN RIVER AREA AVALANCHE PATHS, WEST LYNN CANAL
PREPARED BY AES, 2003, PO BOX 22316, JUNEAU, AK 99802, (907)586-5606
PATH BOUNDARY - MAIN PATH
PATH BOUNDARY - OCCASIONAL RUNOUT AREA
APPROXIMATE BOUNDARY - AREA OF LESSER CONCERN
<-- WLC09 PATH NUMBER
<-- WLC004
N ENDICOTT
SULLIVAN RIVER
CANAL
ISLAND
Rescue Harbor
Sullivan Rock
MILES
FEET
KILOMETERS
SCALE 1:63,360; CONTOUR INTERVAL 30.48m; 100 feet
BASE MAPS FROM US GEOLOGICAL SURVEY
UTM GRID AND 1999 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



PATH BOUNDARY - MAIN PATH
PATH BOUNDARY - OCCASIONAL RUNOUT AREA
APPROXIMATE BOUNDARY - AREA OF LESSER CONCERN
<-- WLC09 PATH NUMBER
DAVIDSON
GLACIER
Crevasses
CHILKAT INLET
Dalasuga Island
Glacier River
Gump
NATIONAL FOREST BOUNDARY
Glacier Pt
Sullivan Mtn
TONGASS
NATIONAL
FOREST
Landing Strip
UTM GRID AND 1999 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
Sullivan Island
<-- WLC007
SULLIVAN
x Sullivan
Howitzer Pad Location
<-- WLC006
SULLIVAN
<-- WLC005
SULLIVAN
LYNN
SULLIVAN
MAP 3, SULLIVAN-DAVIDSON AREA AVALANCHE PATHS,
WEST LYNN CANAL
MILES
FEET
KILOMETERS
SCALE 1:63,360; CONTOUR INTERVAL 30.48m; 100 feet
BASE MAPS FROM US GEOLOGICAL SURVEY

MAP 4, HAINES AREA AVALANCHE PATHS, WEST LYNN CANAL

PREPARED BY AES, 2003, PO BOX 22316, JUNEAU, AK 99802, (907)586-5606

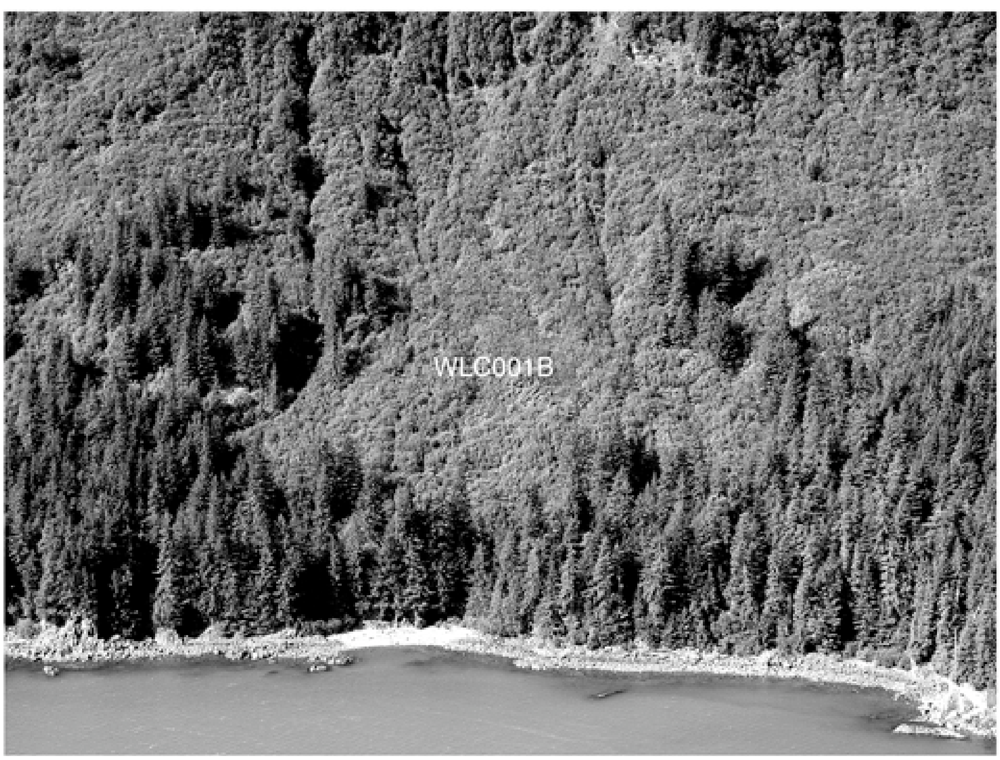


West Lynn Canal Path WLC001A Photos

Avalanche Path Atlas - West Lynn Canal Path WLC001A

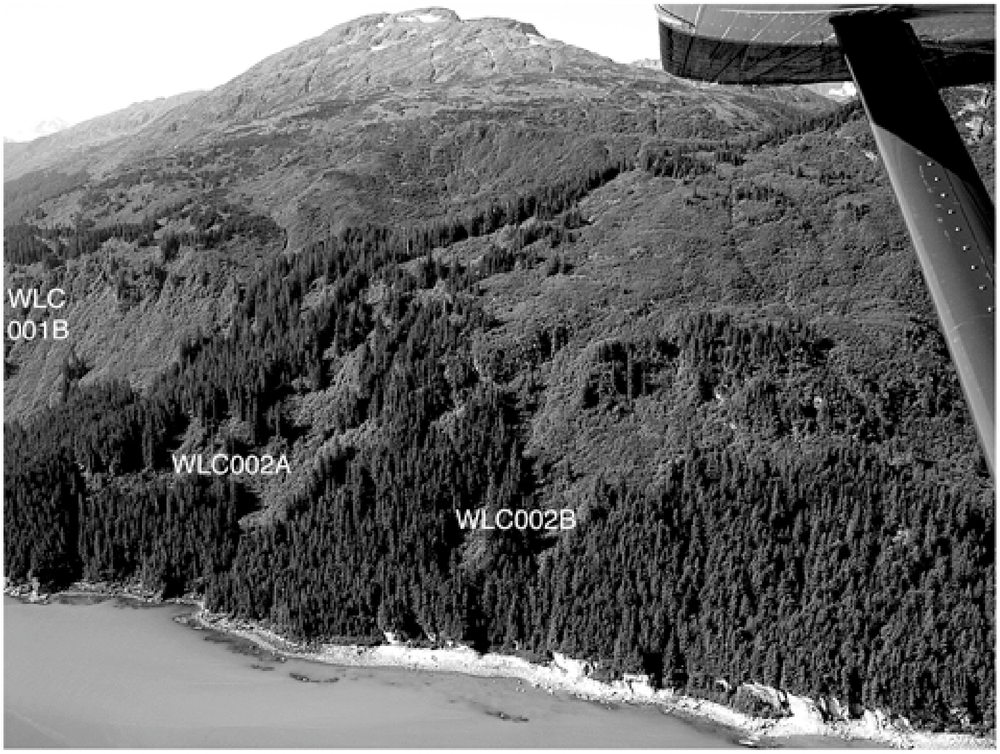
Path Group:	South Endicott, Map 1
Latitude-Longitude:	59.084274 -135.281424
Max Width (ft):	1000 feet
Max Width (m):	305 meters
Typical Width (ft):	175 feet
Typical Width (m):	53 meters
Starting Elevation (ft):	1300 feet
Starting Elevation (m):	396 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.78
Comments:	

West Lynn Canal Path WLC001B Photos

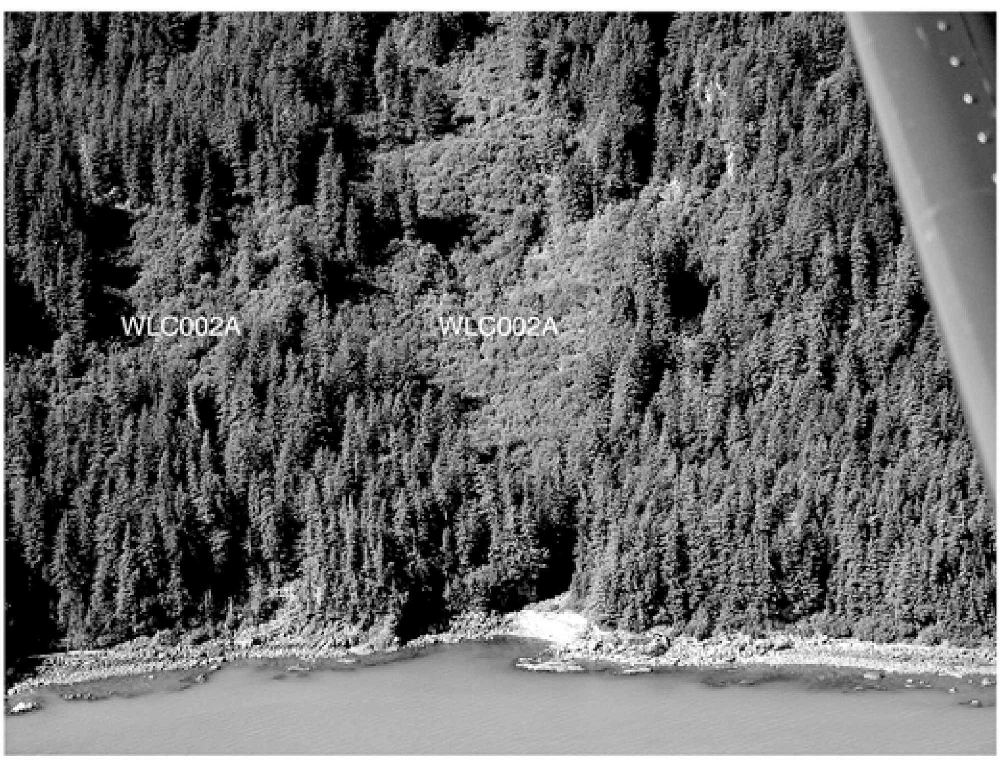


Avalanche Path Atlas - West Lynn Canal Path WLC001B

Path Group:	South Endicott, Map 1
Latitude-Longitude:	59.084274 -135.281424
Max Width (ft):	1000 feet
Max Width (m):	305 meters
Typical Width (ft):	125 feet
Typical Width (m):	38 meters
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.58
Comments:	

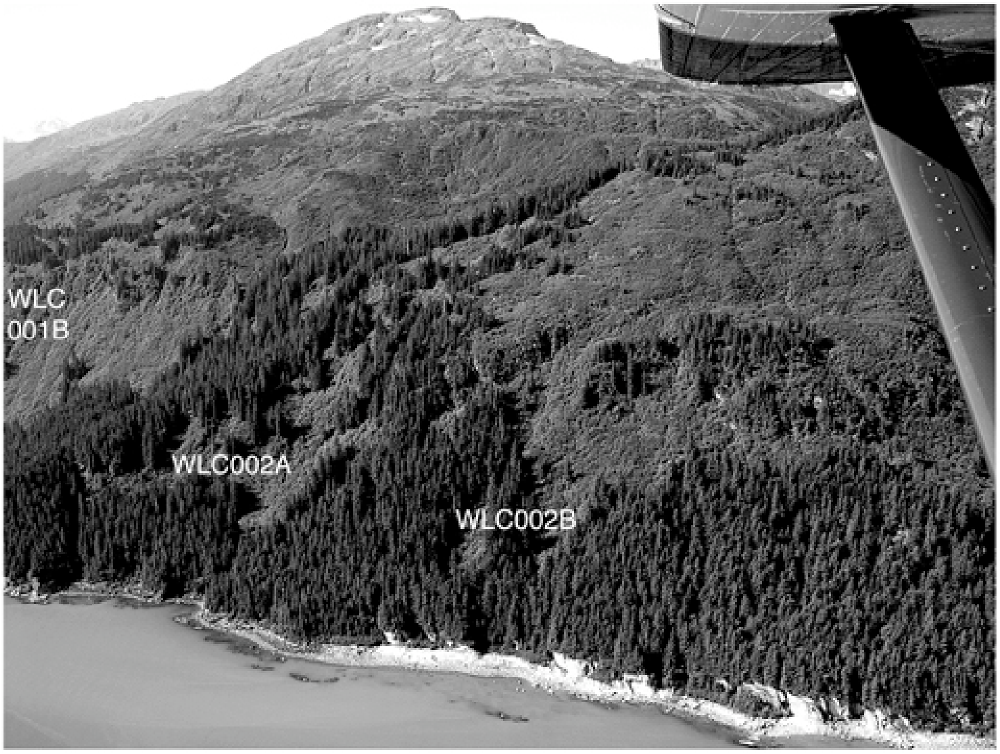


West Lynn Canal Path WLC002A Photos



Avalanche Path Atlas - West Lynn Canal Path WLC002A

Path Group:	South Endicott, Map 1
Latitude-Longitude:	58.453329 -135.142467
Max Width (ft):	940 feet
Max Width (m):	286 meters
Typical Width (ft):	410 feet
Typical Width (m):	125 meters
Starting Elevation (ft):	1000 feet
Starting Elevation (m):	305 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	3.56
Comments:	Eighth-highest West Lynn AHI.



West Lynn Canal Path WLC002B Photos

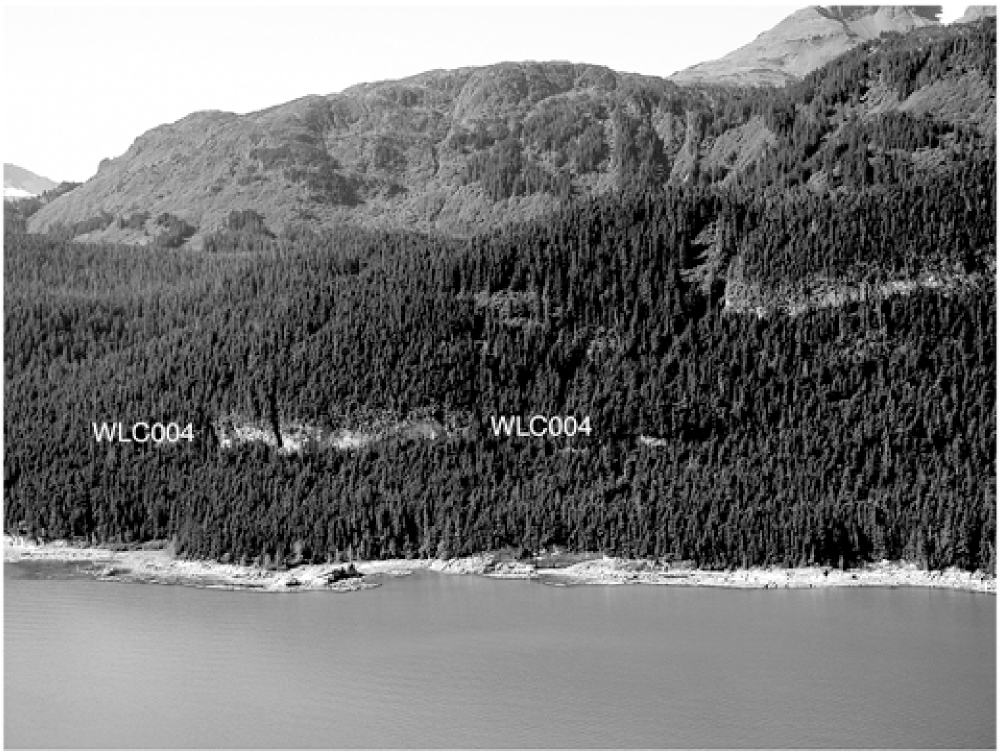
Avalanche Path Atlas - West Lynn Canal Path WLC002B

Path Group:	South Endicott, Map 1
Latitude-Longitude:	58.453329 -135.142467
Max Width (ft):	590 feet
Max Width (m):	180 meters
Typical Width (ft):	350 feet
Typical Width (m):	107 meters
Starting Elevation (ft):	1300 feet
Starting Elevation (m):	396 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	3.04
Comments:	Ninth-highest West Lynn AHI.

West Lynn Canal Path WLC003 Photos

Avalanche Path Atlas - West Lynn Canal Path WLC003

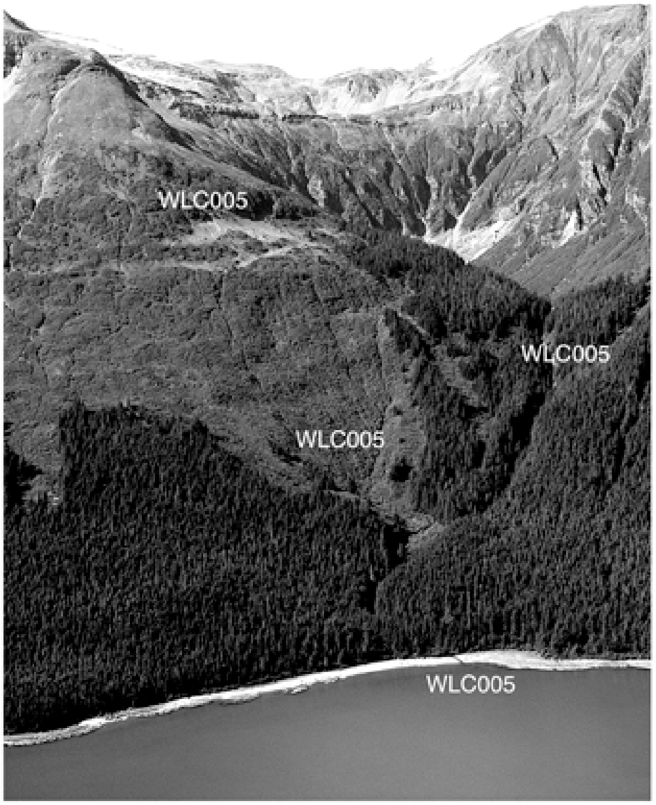
Path Group:	North Endicott, Map 1
Latitude-Longitude:	58.46005 -135.143254
Max Width (ft):	0
Max Width (m):	0
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	600 feet
Starting Elevation (m):	183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	ENE
Path Type:	rock slabs and talus
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.



West Lynn Canal Path WLC004 Photos

Avalanche Path Atlas - West Lynn Canal Path WLC004

Path Group:	North Endicott, Map 2
Latitude-Longitude:	58.481183 -135.160027
Max Width (ft):	0
Max Width (m):	0
Typical Width (ft):	0
Typical Width (m):	0
Starting Elevation (ft):	1200 feet
Starting Elevation (m):	366 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	ENE
Path Type:	rock slabs and talus
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.00
Comments:	Alignment avoids path.



West Lynn Canal Path WLC005 Photos

Avalanche Path Atlas - West Lynn Canal Path WLC005

Path Group:	Sullivan, Map 3
Latitude-Longitude:	58.500775 -135.175661
Max Width (ft):	240 feet
Max Width (m):	73 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	3300 feet
Starting Elevation (m):	1006 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	broad face and big bowl
Start Aspect:	NE
Path Type:	bowl and gullies
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.07
Comments:	

West Lynn Canal Path WLC006A Photos

Avalanche Path Atlas - West Lynn Canal Path WLC006A

Path Group:	Sullivan, Map 3
Latitude-Longitude:	58.573821-135.234129
Max Width (ft):	960 feet
Max Width (m):	293 meters
Typical Width (ft):	580 feet
Typical Width (m):	177 meters
Starting Elevation (ft):	4600 feet
Starting Elevation (m):	1402 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl and big face
Start Aspect:	ENE
Path Type:	broad face with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	9.45
Comments:	Fifth-highest West Lynn AHI.

West Lynn Canal Path WLC006B Photos

Avalanche Path Atlas - West Lynn Canal Path WLC006B

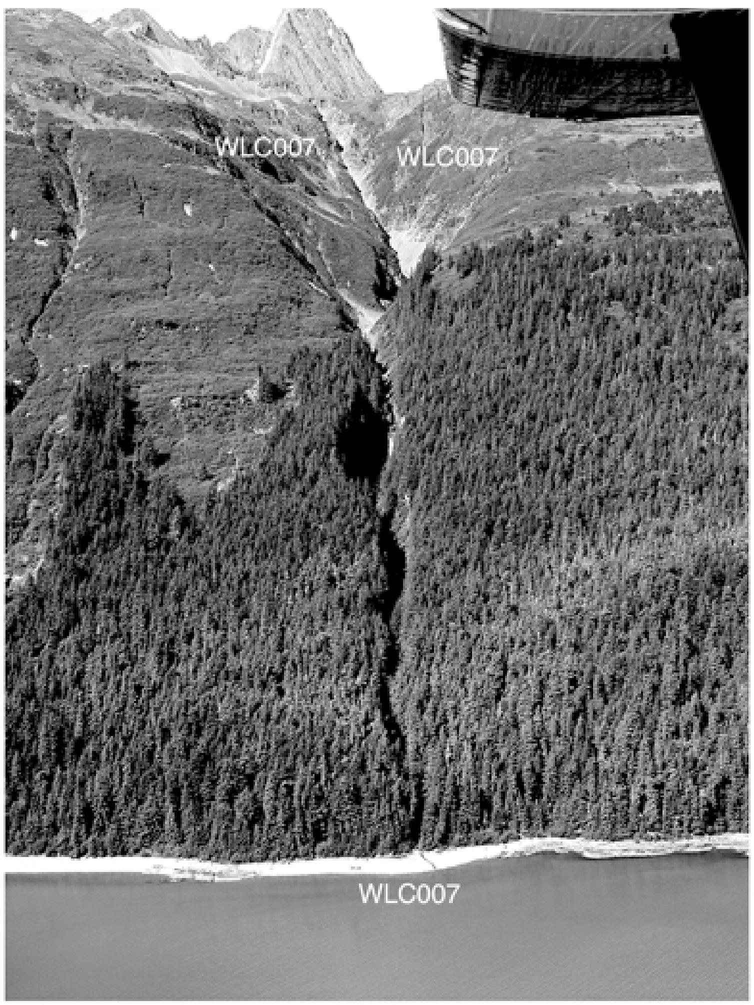
Path Group:	Sullivan, Map 3
Latitude-Longitude:	58.573821-135.234129
Max Width (ft):	960 feet
Max Width (m):	293 meters
Typical Width (ft):	650 feet
Typical Width (m):	198 meters
Starting Elevation (ft):	4400 feet
Starting Elevation (m):	1341 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl and big face
Start Aspect:	ENE
Path Type:	broad bowl with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	10.58
Comments:	Fourth-highest West Lynn AHI.

West Lynn Canal Path WLC006C Photos

Avalanche Path Atlas - West Lynn Canal Path WLC006C

Path Group:	Sullivan, Map 3
Latitude-Longitude:	58.573821-135.234129
Max Width (ft):	960 feet
Max Width (m):	293 meters
Typical Width (ft):	510 feet
Typical Width (m):	155 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big face
Start Aspect:	E
Path Type:	broad bowl with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	2.70
Comments:	Usually stops above alignment. Tenth-highest West Lynn AHI.

West Lynn Canal Path WLC007 Photos



Avalanche Path Atlas - West Lynn Canal Path WLC007

Path Group:	Sullivan, Map 3
Latitude-Longitude:	58.581881 -135.241298
Max Width (ft):	120 feet
Max Width (m):	37 meters
Typical Width (ft):	70 feet
Typical Width (m):	21 meters
Starting Elevation (ft):	3500 feet
Starting Elevation (m):	1067 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl with gullies
Start Aspect:	E
Path Type:	deeply incised big gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.02
Comments:	Alignment crosses on high bridge.

West Lynn Canal Path WLC008 Photos

Avalanche Path Atlas - West Lynn Canal Path WLC008

Path Group:	Rainbow, Map 4
Latitude-Longitude:	59.070038 -135.264214
Max Width (ft):	260 feet
Max Width (m):	79 meters
Typical Width (ft):	150 feet
Typical Width (m):	46 meters
Starting Elevation (ft):	4000 feet
Starting Elevation (m):	1219 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big broad face and medium gullied bowl
Start Aspect:	ENE
Path Type:	gullied bowl into deeply incised big gully
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.07
Comments:	Alignment crosses on high bridge.

West Lynn Canal Path WLC009A Photos

Avalanche Path Atlas - West Lynn Canal Path WLC009A

Path Group:	Rainbow, Map 4
Latitude-Longitude:	59.000429-135.241143
Max Width (ft):	1433 feet
Max Width (m):	437 meters
Typical Width (ft):	1420 feet
Typical Width (m):	433 meters
Starting Elevation (ft):	5000 feet
Starting Elevation (m):	1524 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	ENE
Path Type:	gullied big bowl into broad gullied unconfined runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	18.04
Comments:	Second-highest West Lynn AHI.

West Lynn Canal Path WLC009B Photos

Avalanche Path Atlas - West Lynn Canal Path WLC009B

Path Group:	Rainbow, Map 4
Latitude-Longitude:	59.000429-135.241143
Max Width (ft):	1433 feet
Max Width (m):	437 meters
Typical Width (ft):	1080 feet
Typical Width (m):	329 meters
Starting Elevation (ft):	3400 feet
Starting Elevation (m):	1036 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big broad face
Start Aspect:	ENE
Path Type:	big broad face into broad unconfined runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	31.20
Comments:	Highest West Lynn AHI.

West Lynn Canal Path WLC009C Photos

Avalanche Path Atlas - West Lynn Canal Path WLC009C

Path Group:	Rainbow, Map 4
Latitude-Longitude:	59.000429-135.241143
Max Width (ft):	1433 feet
Max Width (m):	437 meters
Typical Width (ft):	890 feet
Typical Width (m):	271 meters
Starting Elevation (ft):	3400 feet
Starting Elevation (m):	1036 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	medium bowls
Start Aspect:	ENE
Path Type:	broad unconfined track and runout with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	11.33
Comments:	Third-highest West Lynn AHI.

West Lynn Canal Path WLC010A Photos

Avalanche Path Atlas - West Lynn Canal Path WLC010A

Path Group:	Pyramid, Map 4
Latitude-Longitude:	59.105158-135.29264
Max Width (ft):	630 feet
Max Width (m):	192 meters
Typical Width (ft):	100 feet
Typical Width (m):	30 meters
Starting Elevation (ft):	3800 feet
Starting Elevation (m):	1158 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl and big broad face
Start Aspect:	ENE
Path Type:	broad bowl into broad unconfined runout with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.13
Comments:	Alignment on flats avoids usual runout.

West Lynn Canal Path WLC010B Photos

Avalanche Path Atlas - West Lynn Canal Path WLC010B

Path Group:	Pyramid, Map 4
Latitude-Longitude:	59.105158-135.29264
Max Width (ft):	630 feet
Max Width (m):	192 meters
Typical Width (ft):	340 feet
Typical Width (m):	104 meters
Starting Elevation (ft):	3100 feet
Starting Elevation (m):	945 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	small bowls and gullies
Start Aspect:	ENE
Path Type:	broad gully to unconfined gullied runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	3.89
Comments:	Seventh-highest West Lynn AHI.

West Lynn Canal Path WLC010C Photos

Avalanche Path Atlas - West Lynn Canal Path WLC010C

Path Group:	Pyramid, Map 4
Latitude-Longitude:	59.105158-135.29264
Max Width (ft):	630 feet
Max Width (m):	192 meters
Typical Width (ft):	380 feet
Typical Width (m):	116 meters
Starting Elevation (ft):	3700 feet
Starting Elevation (m):	1128 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	big gully
Start Aspect:	ENE
Path Type:	broad gully to unconfined gullied runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	4.35
Comments:	Sixth-highest West Lynn AHI.

West Lynn Canal Path WLC010D Photos

Avalanche Path Atlas - West Lynn Canal Path WLC010D

Path Group:	Pyramid, Map 4
Latitude-Longitude:	59.105158-135.29264
Max Width (ft):	630 feet
Max Width (m):	192 meters
Typical Width (ft):	340 feet
Typical Width (m):	104 meters
Starting Elevation (ft):	4200 feet
Starting Elevation (m):	1280 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	medium bowl, medium face and big gullied bowl
Start Aspect:	ENE
Path Type:	gullies and face to broad unconfined runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	0.28
Comments:	Usually stops above alignment.

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Technical Appendices

Appendix 1: Avalanche Hazard Index (AHI) Calculation

Introduction

The avalanche hazard index (AHI) is a dimensionless numerical expression representing damage and loss potential as the result of an interaction between snow avalanches and vehicles on a highway (Schaerer, 1989). The concept was first developed in Canada (Avalanche task force, 1974), and has been applied at various locations in North America and New Zealand (Fitzharris and Owens, 1980; Armstrong, 1981; Mears, 1993; Mears and Newcomb (unpublished); Fesler, Mears and Fredston, 1990; Mears, 1995.

Avalanche hazard on a highway contains two elements: (a) the frequency (or probability) of an encounter, and (b) the nature, magnitude, and severity of the resulting damage from the avalanche.

Damage Potential and Weighting the Consequences

The severity of the potential damage is used to define three idealized types of avalanches as follows:

1. Light snow avalanches. Flowing avalanches of light snow cross and block the highway, deposit snow approximately one to three feet (0.3 to 1.0m) deep, and could push a car off the highway but not bury it. *Light snow avalanches are assigned a weighting factor of 3.*

2. Deep snow avalanches. Flowing avalanches of deep snow deposit snow to a depth of more than 3 feet (1.0m) could bury or push vehicles off the highway and could severely damage a vehicle and injure or kill occupants. *Deep snow avalanches are assigned a weighting factor of 10.*

3. Plunging snow avalanches. Plunging snow avalanches fall onto a highway at high speeds after descending steep terrain *<u>or</u>* tumble vehicles off the highway down a steep slope or into the water. *Plunging snow avalanches are assigned a weighting factor of 12.* Many of the avalanche paths considered on East and West Lynn Canal and the Seward Highway produce avalanches that at times must be considered the plunging-snow type.

Avalanche Frequency and Width

Avalanche frequency and width (length of highway covered) must be estimated for each path for light snow, deep snow, and plunging snow avalanche types. Frequency, F, is expressed as the average number or occurrences of a given class of avalanche (light, deep, or plunging) in each path per year. F is computed as the reciprocal of the average return period, P, thus F = 1/P. For example, an avalanche (light, deep, or plunging type) with a return period of 10 years has an annual frequency of 0.10.

Calculating the AHI

The AHI is calculated by multiplying the damage-weighting factor (discussed above) by the frequencies of moving and stationary vehicles in avalanche paths. The encounter probability, P, is calculated

$P = P_M + P_W$, where

(1) P_M is the probability of a moving vehicles being hit by an avalanche and P_W is the probability of a waiting vehicle being hit by a second avalanche in the same path or by adjacent avalanches. When avalanches are closely spaced, as they are in the avalanche terrain of both the East and West Lynn Canal alignment alternatives, P increases because the P_W term is large. Even if traffic is light, a long queue of traffic can back up below avalanche paths.

The moving vehicle encounter probability, P_M is calculated

$P_M = f(N,L,D,F,V)$, where

(2) N = average daily winter traffic (450 vehicles per day on the East Lynn route and 300 vehicles per day on the West Lynn route, using projected year 2038 traffic counts), L = average highway length covered by avalanches of a given class, D = vehicle stopping distance (a function of speed and driver reaction time), F = frequency of avalanches of a given class, in years, and V = average vehicle speed (which also controls D). The calculation in (2) is repeated for each avalanche path and each class of avalanche in that path. The term P_M becomes an important factor only if traffic volume is very high (generally in excess of 10,000 vehicles per day) and is therefore not an important term on the Juneau access alternatives.

The waiting vehicle encounter probability P_W is calculated

$P_W = f(p_s,N,F) + 0.5\, f(p'_s, N,F)$, where

(3) p_s = probability of an avalanche in an adjacent path hitting traffic that is backed up until emergency response arrives (assumed one hour response time due to the remoteness of the route). The length of a queue of vehicles stopped on the highway depends on traffic volume and response time. When avalanche paths are closely spaced and of relatively high frequency the probability p_s of vehicles in the queue being hit by an avalanche increases. In equation (3), N is the number of vehicles exposed in avalanche terrain, F is the avalanche frequency in years, and p'_s is the probability of a second avalanche in the path that caused the traffic blockage.

The AHI is calculated for *each path, i,* as follows:

$AHI_i = \Sigma\, W_j\, (P_{mj} + P_{wj})$, where

(4) The subscript j refers to the three classes of avalanches (light, deep, and plunging).

Finally, a cumulative AHI_H was calculated for the entire East and West Lynn Canal routes, based on current proposed alignments as follows:

$AHI_H = \Sigma\, AHI_i$, where

(5) $1 \leq i \leq n$ and n is the number of paths on each highway alignment considered.

As discussed by Schaerer (1989), each avalanche path (together with its neighboring paths) was assumed to be independent of other paths on the highway. Therefore, the same avalanche was assumed capable of hitting both moving and waiting traffic each time it occurred after another avalanche had blocked the highway. It could be argued that the AHI could be made more realistic by taking into account that traffic stops after one avalanche occurrence and that each avalanche can strike vehicles only once. However, this “more realistic” assumption would not allow a comparison between individual avalanche paths that is one of the primary objectives of this analysis. Therefore, the simpler approach was used to calculate the index. Furthermore, the AHI calculation assumes a uniform flow of traffic regardless of conditions. In fact, traffic would certainly be heavier on some days and would probably decrease during severe conditions. Both would change vehicle exposure to avalanches.

The standard AHI calculating procedure was applied because (a) it enables comparison between different paths, (b) it enables “problem areas” to be quantified, and (c) it enables the East and West Lynn Canal routes to be compared to each other and to other highways in the United States and Canada that have AHI values calculated. The AHI values computed for both East and West Lynn Canal routes assume *no mitigation* beyond alignment choice is used to reduce the hazard.

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Appendix 2: AHI Data Collection and Reliability

The results of the analysis are only as reliable as the data used. Where available, actual avalanche sizes and return intervals were used, with correction factors applied to normalize the figures to consistency with longterm climate and avalanche records.

Where there were no avalanche occurrences within the period of observation, the return period of the missing avalanche types was estimated to the nearest “half-order of magnitude” or approximately to within a factor of 3. The half-order of magnitude steps used have return periods of $10^{0.0}$ (1 year); $10^{0.5}$ (3 years); $10^{1.0}$ (10 years); $10^{1.5}$ (30 years); $10^{2.0}$ (100 years); $10^{2.5}$ (300 years).

Avalanche types that did not occur during the six years of field observations were given a minimum return interval of 10 years, the next half-order of magnitude step up from six years.

The longer return interval estimates were determined in part by comparison with other paths in the region for which frequency data was available, and in part by path characteristics and vegetation patterns. Air photos and detailed laser-surveyed topographic maps allowed thorough study of vegetation patterns and terrain features that indicate path boundaries.

In northern Southeast Alaska, the limit of the most recent 30-year avalanche cycle on many paths is clearly visible as a sharp difference in the age of the trees where they have regrown since they were last destroyed in the early 1970s. This boundary yields good information for 30-year avalanche events on those paths.

Vegetation damage from the most recent 100-year to 300-year cycle is also visible on many paths. Some paths produced 200 year avalanches in the early 1970s cycle (Fesler, November 2003 note) and others show trimlines from earlier cycles in the 1920s or 1930s. Paths with no evidence of 100-year or more-frequent events fall into the 300-year return interval category, unless the characteristics of the path are such that the avalanche type in question does not occur at all.

The precision of these estimates is greatest for the shortest return interval events, which are the ones that have the greatest influence on the avalanche hazard index. Paths with longer than 30-year return intervals, which have the least reliable data, also have minimal impact on the AHI results.

Actual avalanche frequency data has been used wherever it is available. No observations are available for the West Lynn Canal alternative, but fixed-wing aerial observations were conducted along the East Lynn Canal route for six of the eight avalanche seasons since the original 1995 study. In four of these winters (1995-96, 1997-98, 2000-01, and 2001-02), flights were made on a regular basis throughout the winter, and frequencies can be reliably determined from the observations.

In 1996-97 and 1999-2000, flights were made only at the end of the season. Debris piles indicated which paths had produced large avalanches in those seasons, but the number of slides contributing to the piles could not be determined. Avalanche frequency was estimated for these two seasons by assuming that the paths that slid had as many avalanches as their average in the other years of observation.

While the observations data are very useful, six years is a short period of record for climate-related phenomena. Making good use of the data requires evaluating how representative a sample it is, and how it can best be corrected for any known bias.

The key to this analysis is determining how the period of study fits into long-term climate patterns. While there is no guarantee that past climate patterns will continue into the future, climate history is the best tool available for predicting future trends.

Robert Kanan, a recently retired National Weather Service meteorologist and climatologist with long experience studying the climate of northern Southeast Alaska, analyzed long-term weather patterns and climate trends in the region for this study.

Appendix 3: AHI Input Data Analysis

Long- term Climatology: Tropical Pacific Ocean El Niño-Southern Oscillation (ENSO), and Effects on Southeast Alaska Snowfall

Robert A. Kanan

Juneau, Alaska, August, 2003

1. Brief overview of ENSO.

El Niño-Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. It has a strong influence on seasonal snowfall totals at Juneau and northern Southeast Alaska. ENSO is a 2- to 6-year cycle of warmer and colder sea surface temperatures, and tilting of the near-surface thermocline along the equator from 150 degrees west to the date line. More details are available on many Internet web sites, such as the NOAA/NWS Climate Diagnostic Center: www.cdc.noaa.gov/ENSO/, and the Climate Prediction Center at: www.cpc.noaa.gov/

2. How ENSO is measured.

The standard monitoring of ENSO is the Multivariate ENSO Index (MEI). The MEI uses the six main observed variables over the tropical Pacific: sea level pressure (Darwin to Tahiti), zonal and meridional components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky. Complete data are available from 1950 to present. Another, less complete measure of ENSO is the Southern Oscillation Index (SOI), the single-variable Darwin-to-Tahiti surface pressure difference. Except for a few missing years, data go back to 1882.

Other variables, such as precipitation and temperature climate, exhibit time-dependent behavior that is sensitive to some aspect of ENSO. Long-term records on the periphery of the Indian and Pacific Oceans have been constructed from historical sources, tree-ring reconstructions (summer temperature and winter rainfall), and annual record of oxygen isotope composition for a high-elevation glacier in Peru. ENSO estimates can be made back to the late 16th century, and at least a portion of the Medieval Warm Period (~A.D. 950-1250). In general, spectral power on time scales of about two to six years is statistically significant and persists throughout most of the time intervals sampled. Assuming that the ENSO phenomenon is the source of much of the variability at these time scales, this indicates that ENSO has been an important part of interannual climatic variations over broad areas of the circum-Pacific region throughout the last millennium. Significant correlations were found between El Niño and reconstructed Sierra Nevada winter precipitation at about two to four years throughout much of their common record (late 16th century to present), and between six and seven years from the mid-18th to early 20th century.

3. ENSO life cycle, and the longer decadal oscillations.

The ENSO cycle of two to four years also has a longer (~20 years) oscillation of prevailing warm and cold events. The prevailing very cold La Niña period from 1954-1976 had only three seasonal warm events greater than one standardized departure (1958,1966, and 1973). That cold period was followed by a very warm prevailing El Niño from 1977-1998 with only one cold departure (1988). Extending this longer decadal ENSO oscillation back farther in time becomes much less exact. The MEI data date back only to 1950, so the less useful SOI must be used to reconstruct earlier periods. There is at least some indication the decadal oscillation of about 20 years continues with an overall warm El Niño from about 1934-1954, prevailing cold La Niña from about 1915-1933, warm from 1894-1914, and perhaps a weak prevailing cold period prior to about 1893.

Besides the lack of MEI data, the difficulty in accurately extending the decadal ENSO oscillation to the first half of the last century and earlier is that the magnitude of the ENSO events was much weaker than those in modern time (since about 1950). There are other much longer period oscillations that may reinforce or reduce the magnitude, and/or alter the length of some of the shorter-period ENSO decadal oscillations.

4. ENSO effects on winter weather in Southeast Alaska

Juneau winter temperature and snowfall data show a strong correlation to ENSO. This is also the case for northern Southeast Alaska, especially north of the average position of the quasi-stationary Arctic front (a discontinuous line from Cape Spencer to Cape Fanshaw) after intense cold air outbreaks from Canada. The average position of the 500 millibar (MB) ridgeline is normally along the west coast of North America. But during warm El Niño events this average ridgeline position is displaced about 500 miles eastward into Canada. This allows a more frequent southwesterly flow aloft over Southeast Alaska, with the storm track across the north Pacific bringing warm, moist tropical source air onshore over the Southeast Alaska panhandle. Conditions are warmer and wetter, with less of the precipitation in the form of snow at sea level. Then, during cold La Niña conditions, the 500MB ridge line is displaced about 1000 miles westward to the eastern Aleutian Islands and the eastern Bering Sea. This pattern blocks storms from moving into the eastern Gulf of Alaska and allows Arctic high pressure to build over northwestern Canada. This is the prerequisite for outbreaks of cold air over northern Southeast Alaska so that the next southwesterly warm air overrunning flow produces both longer duration and larger amounts of snowfall before the snow changes to rain as the Arctic air is mixed with the warmer maritime-source air.

5. ENSO plot and Juneau snowfall

The longer-term shifts of the decadal oscillation are outlined on a plot of ENSO (using the MEI) from 1950 to the present. Then the seasonal (October 1 through –April 30) 25 years of highest and lowest snowfall at Juneau International Airport are plotted. The connection between snowfall and ENSO is very strong. La Niña (cold) events have the highest snowfall seasons, and El Niño (warm) has the lowest snowfall. The La Niña period from 1954 to 1977 had 16 of the 25 greatest seasonal snowfalls during the last 60 years in Juneau, and only four of the lowest snowfalls. The seasonal snowfall anomalies often are near the transition of brief ENSO shifts from the prevailing longer term decadal condition, or where shorter periods (one month or so) displacement of the 500MB ridge-line altered prevailing conditions.

Another way to look at the ENSO impact on the average (96.2 inches, or 2.44m) seasonal snowfall at Juneau airport during the last 60 years is to consider only the 20 greatest and 20 lowest snowfall totals. The following chart plots these differences, and the standard departure from normal temperatures. Seventeen of 40 years fell during cold La Niña conditions for an average of 126.2 inches, or 3.21m (or 131 percent of all seasons). Twenty-three seasons occurred during warm El Niño conditions with an average of 76.0 inches, or 1.93m (79 percent of all seasons). The average variability between El Niño and La Niña years is 50.2 inches, or 1.28m.

The chart shows standardized departure from normal winter temperatures.

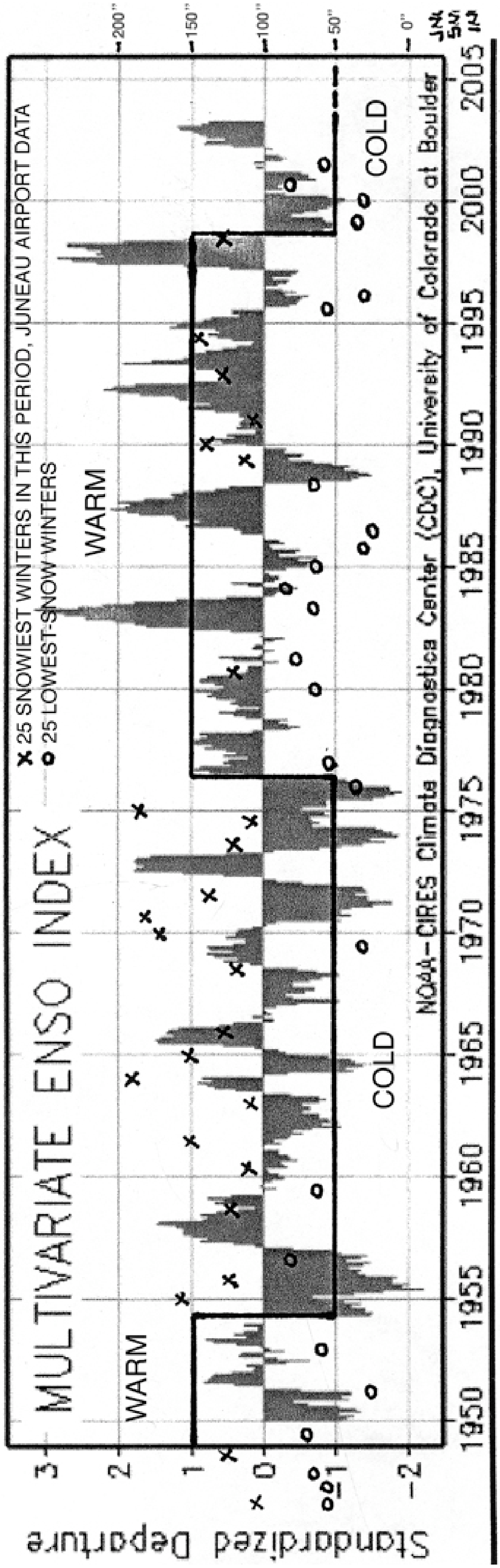

CHART PREPARED BY BOB KANAN

6. Looking ahead from the present (2003)

The ENSO – PDO decadal oscillation most likely made a shift in 1998 from the strong prevailing warm (El Niño) conditions entered into during 1977 that lasted about 21 years. This shift to another long-term cold (La Niña) cycle in 1998 was confirmed in a 1999 conversation with Dr. Aants Leetmaa, director of the NWS Climate Prediction Center. If that is the case, the prevailing ENSO condition should be a series of cold La Niña events through the year 2018 or so. The major shift to colder La Niña conditions in 1998 initially lasted only through 2001, and then went to warm El Niño levels in 2002. That is not unlike how the cold 1954-1976 ENSO period started. The present 2003 status of ENSO is neutral, with no strong indications of warm or cold trends. The highest probability remains that the next 15 years will be mostly La Niña conditions. If the cold La Niña prevails, the average seasonal snowfall in northern Southeast Alaska will be significantly above average during that period.

AHI Input Data

Given Robert Kanan's long-term analysis, the question is where in the ENSO – PDO cycle the six years of study fall. It happens there were three years nominally in the warm half of the cycle (1995-96, 1996-97, and 1997-98) and three years nominally in the cold half (1999-00, 2000-01, and 2001-02). If they were representative years, it would be a simple matter to average them directly. Are they?

The warm-cycle winters appear to be representative of their warm cycle, which ran from 1976-77 through 1998-99. Comparison of winter (November through April) Juneau Airport National Weather Service Data available online for the winters of study with the 1976-99 warm period winters shows that the winters of study had sea-level snowfall 70 percent of the warm period average, precipitation 120 percent of the warm period average, and temperature 0.3°F (0.17°C) below the warm period average. This is a reasonable match, well within the standard deviation. In comparison with the long-term Juneau Airport averages, the sea-level snowfall was 60 percent of normal, the precipitation 80 percent of normal, and the temperature 1.6°F (0.89°C) above normal, about as expected for warm cycle years.

The cold-cycle winters are more problematic. They do not yet have the rest of their cycle for comparison, but Juneau Airport data shows sea-level snowfall at 50 percent of the long-term winter average, precipitation at 70 percent of average, and temperature 1.9°F (1.06°C) above normal. The temperature has obviously not dropped to what would be expected in a cold cycle. It appears that some correction for the last three years' data may be necessary.

What about avalanche activity?

A key to the analysis is the strong correlation Kanan demonstrates between weather in northern Southeast Alaska and the 20-year El Niño–Southern Oscillation (ENSO) and the related Pacific Decadal Oscillation (PDO) warm and cold cycles. Winters in northern Southeast Alaska show a bimodal pattern; they tend to be either cold and snowy, or warm and rainy, without much in-between.

Kanan extended the ENSO and Pacific Decadal Oscillation cycles back far enough to compare with the available recorded Juneau-area avalanche history, going back to 1890. The ENSO PDO cycle was extended using Kanan's analysis of pressure gradients in the South Pacific Ocean, not as accurate as the multivariate index (MEI) used in modern climatology, but the best available parameter for historical data.

The avalanche record was compiled by Bill Glude from the historical records available at the time of this study. Those included Doug Fesler and Jill Fredston's reports for the City & Borough of Juneau in 1992, for the A-J Mine in 1989, and for a DOT&PF Thane Road study in 1990. Fesler and Fredston's data came from historical newspaper articles, mining records, and highway records. Recent observations for the Lynn Canal and A-J Mine studies by Bill Glude were also incorporated.

This long-term avalanche history consists of slides big enough to have been recorded in the newspapers, by highway crews, or by other sources. Because slides large enough to reach a highway at low elevation are the concern, the bias of the data set is consistent with our interest. It is an incomplete record by people who were for the most part untrained in avalanche observation, but it is the most accurate long-term data set available.

Other data sets were considered, but rejected as unsuitable. The Juneau Icefield Research Project has records dating back to the 1940s, but they are primarily glacial mass balance and summertime climate records, and are not currently available in a usable format. There is avalanche data from the avalanche program on Bear Pass on the Stewart-Hyder highway northeast of Ketchikan, but that is 300 miles (480km) away, on a pass rather than along a fjord, in an area with roughly twice the precipitation on the coastal side of the mountains, in a much milder climate, and far from the influence of the arctic front which is key to northern Southeast Alaska winter weather patterns. There is avalanche data from the Seward Highway, but that is 700 miles (1130km) away and in a cooler area where the dynamics of the interplay between the arctic front and coastal storms from the Gulf of Alaska are much different.

The historical record below lists the total number of recorded slides by winter, broken into cold and warm ENSO – PDO periods. The avalanche rating is the highest rating assigned to a slide in that season. Because the cycles differ in length, the average number of slides per winter is calculated for each period. Finally, a ratio or multiplier is calculated at the bottom of the spreadsheet comparing avalanche frequency between the warm and cold ENSO – PDO periods.

Juneau-Area Avalanche History Analysis

Avalanche season from...	to...	Number of avalanches	Largest size avalanche	Avg. annual # of avalanches for period	Average size avalanche for period	Period type
1889	1890	0.0				
1890	1891	3.0	5.0			
1891	1892	0.0				
1892	1893	1.0				
1893	1894	2.0	3.0	1.2	4.0	**cold period**
1894	1895	5.0	4.0			
1895	1896	0.0				
1896	1897	0.0				
1897	1898	0.0				
1898	1899	1.0				
1899	1900	0.0				
1900	1901	0.0				
1901	1902	0.0				
1902	1903	1.0	3.0			
1903	1904	0.0				
1904	1905	0.0				
1905	1906	0.0				
1906	1907	0.0				
1907	1908	0.0				
1908	1909	0.0				
1909	1910	1.0	4.0			
1910	1911	0.0				
1911	1912	0.0				
1912	1913	0.0				
1913	1914	0.0				
1914	1915	0.0		0.4	3.7	**warm period**
1915	1916	6.0	3.0			
1916	1917	4.0	5.0			
1917	1918	1.0	3.0			
1918	1919	1.0	3.0			
1919	1920	1.0	3.0			
1920	1921	2.0	4.0			
1921	1922	1.0	4.0			
1922	1923	3.0	4.0			
1923	1924	2.0	4.0			
1924	1925	0.0				
1925	1926	1.0	4.0			
1926	1927	0.0				
1927	1928	1.0	3.0			
1928	1929	1.0	5.0			
1929	1930	0.0				
1930	1931	0.0				
1931	1932	3.0	4.0	1.6	3.8	**cold period**
1932	1933	0.0				
1933	1934	2.0	3.0			
1934	1935	1.0	4.0			
1935	1936	1.0	3.0			
1936	1937	0.0				
1937	1938	0.0				
1938	1939	7.0	4.0			
1939	1940	0.0				
1940	1941	0.0				
1941	1942	0.0				
1942	1943	0.0				
1943	1944	0.0				
1944	1945	1.0	3.0			
1945	1946	1.0	3.0			
1946	1947	3.0	3.0			
1947	1948	1.0	3.0			
1948	1949	2.0	4.0			

Avalanche frequency in the historical data set for the Juneau area shows a strong correlation with the 20-year El Niño – Southern Oscillation and Pacific Decadal Oscillation (ENSO – PDO) cycles, with 2.6 times as many slides recorded during cold cycles as in warm cycles.

Avalanche size does not show a correlation.

If the cold cycle years in the period of study were consistent with the long-term averages, there should be 2.6 times as many slides as in the warm cycle years. The records show 2.2 times as many observed hits to the alignment, a significant increase in avalanche frequency from the warm cycle winters, but lower than the long-term figure of 2.6.

The figures for cold cycle frequencies were corrected to eliminate the sample bias and normalize them to the long-term average multiplier of 2.6. The warm and cold cycle years' data were then averaged to calculate the frequencies for the avalanche hazard index.

For AHI calculation purposes, a standard relationship between total path width and the widths of plunging, deep, and light avalanches is often assumed. For these calculations, width ratios for each type of avalanche were derived based on field observations in the Lynn Canal terrain and snow climate, and applied those locally derived ratios for greater accuracy.

There is one other correction to the data. The data set did not include any of the rare but very large avalanche cycles, so an estimate was made to determine how significant that absence would be to the average frequencies used for the AHI calculations.

It has been demonstrated (Birkeland and Landry, 2002) that the size-frequency relationship of avalanches follows a power law, as do many other natural phenomena. That means that the number of events increases logarithmically as the size decreases, or that large events are much more rare than moderate or small events. A straight line with a characteristic slope can be fitted to the data for a given locality and used to characterize its avalanche behavior as a system.

This power-law relationship can be a useful tool, but no existing data sets for northern Southeast Alaska are complete enough to use it. The observation flight data is unsuitable because the observations are not daily, the primary concern is large slides, and the small slides are difficult to record accurately from the air. No daily records including the full range of sizes exist in the region.

A similar principle was used to determine the influence of very large but rare events on a frequency average. The following theoretical spreadsheet of relative avalanche size (on a scale of one to 5, relative to path capability) in relation to return interval and frequency was constructed. Avalanche size as listed in the spreadsheet over the full 300-year return period was averaged and compared to a three-year sample, the closest half-order of magnitude step to the six years of record. Relative size three and larger slides, which are the ones that will reach a low-elevation highway, were the focus. The difference in the averages was only 0.5 percent.

Although the difference is negligible, a factor of +0.005L was applied as a size-correction multiplier to the AHI factor L for avalanche width, expressed in the AHI calculations as length of the slide on the highway.

Avalanche Size-Frequency Averages for 300-Year Period

return interval	frequency	size	number	number times size
300.000	0.003	5.00	1	5.0
100.000	0.010	4.50	3	13.5
30.000	0.033	4.00	10	40.0
10.000	0.100	3.75	30	112.5
3.000	0.333	3.50	100	350.0
1.000	1.000	3.25	300	975.0
0.333	3.000	3.00	900	2700.0
0.100	10.000	2.75	3000	8250.0
0.033	30.000	2.50	9000	22500.0
0.010	100.000	2.25	30000	67500.0
0.003	300.000	1.00	90000	90000.0
		avg 3 and larger, 300 years		3.122
		avg 3 and larger, 3 years		3.096
		difference on a scale of 1-5		0.026
		difference as multiplier, used to adjust widths		0.005

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Appendix 4: Highway Closures

Closure periods were calculated using the weather logs and avalanche observations from the same six years of field studies as were used in the AHI calculations, with the same correction factors applied.

Each avalanche cycle was evaluated to determine how long the highway would have been closed, and what level of explosive work would have been conducted. Weather events that would have been forecasted as avalanche cycles but turned out to be false alarms were also tallied, but given lower figures for closure time and explosive operations as would have occurred once forecasters realized the expected activity was not materializing.

The “B” options for the East Lynn Canal route use conservative closure criteria combined with snowsheds on the four highest-AHI paths to achieve an operational residual risk factor of 25 percent. That level of reduction requires nighttime closures when the avalanche hazard is “moderate” or higher and avalanches are likely to reach low elevations. Night closures were tallied for these options when forecasters would have expected a sizable avalanche cycle to begin that night.

The “A” options for the East Lynn Canal route do not have snowsheds. Without snowsheds, the only operational risk management tool available to bring the residual AHI into the target range is to extend the closure periods. The next step is to close the highway at “moderate” avalanche danger, regardless of time of day and likely runout distance. This option lowers the initial capital cost, but sharply increases closures. Closure times were multiplied by 1.5 times those for the “B” options.

Highways with AHIs comparable to the West Lynn Canal route are left open at night at “low” through “considerable” hazard levels, unless natural avalanches are forecasted to reach low elevations. If avalanches are likely to reach low elevations, and explosive work is not completed, the West Lynn Canal route should be closed at night. Night closures were tallied for the major avalanche cycles.

In the daytime, the West Lynn Canal alternative uses spot closures for explosive work when the danger level is increasing but instability is limited. The highway is closed when the instability is increasing more rapidly than explosive work can proceed. Prolonged closures were tallied under these conditions.

Limitations of darkness and storm conditions were factored into the initial tallies for all options. Corrections are added as follows:

e. An additional 20 percent was taken from the explosive delivery mission tally for helicopter-based programs, because many days that appear suitable based only on the weather records would in fact be too windy, foggy, or stormy. The mission tally was simply reduced, as the window of opportunity would pass and the snowpack would either slide or stabilize on its own.

f. All blaster box figures were reduced 30 percent because the raw mission tally reflects only their capability for being fired in storm conditions. Operations using blaster boxes report that the high cost of ammunition and its delivery by helicopter necessitate using them conservatively.

g. Howitzer use figures for the West Lynn Canal WLC1 option were only reduced ten percent, as weather would not have much effect on transporting a trailered howitzer on the highway.

The tallies for missions and highway closure times under all options were further adjusted by 20 percent for crew limitations. It is often impossible to conduct explosive operations because the entire maintenance crew is tied up with other urgent work, or is working 40 miles (64km) in the other direction and cannot get back in time, or conditions develop too rapidly to respond, or because of budget and workforce limitations. Some other highway operations reported even greater limitations due to crew factors, but it is assumed here that safety and reliability of this highway would be a high enough priority to merit adequate funding. Short funding would increase closure time.

Appendix 5: United States Avalanche Danger Descriptors

LOW (green)

Natural avalanches very unlikely. Human triggered avalanches unlikely.

Generally stable snow. Isolated areas of instability.

Travel is generally safe. Normal caution is advised.

MODERATE (yellow)

Natural avalanches unlikely. Human triggered avalanches possible.

Unstable slabs possible on steep terrain.

Use caution in steeper terrain on certain aspects (defined in accompanying statement).

CONSIDERABLE (orange)

Natural avalanches possible. Human triggered avalanches probable.

Unstable slabs probable on steep terrain.

Be increasingly cautious in steeper terrain.

HIGH (red)

Natural and human triggered avalanches likely.

Unstable slabs likely on a variety of aspects and slope angles.

Travel in avalanche terrain is not recommended. Safest travel on windward ridges or lower angle slopes without steeper terrain above.

EXTREME (black)

Widespread natural or human triggered avalanches certain.

Extremely unstable slabs certain on most aspects and slope angles. Large, destructive avalanches possible.

Travel in avalanche terrain should be avoided and travel confined to low angle terrain well away from avalanche path run-outs.

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Appendix 6: Highway Closure and Operation Criteria for East Lynn Canal "A" Options

These guidelines are a sample of the kind of material that is part of a project-specific operational avalanche plan, but are not a substitute for such a detailed plan. A project-specific plan is required under Alaska case law for worker safety before construction or operation of an avalanche-exposed facility may proceed. Planning at that level is beyond the scope of this report.

LOW (green)

Generally stable snowpack; avalanche activity unlikely.

Highway open.

Normal highway plowing operations are not required to call in their locations.

Stationary snow removal operations, clearing avalanche debris or collection areas, must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter.

If danger level is Low, but trend is toward increasing avalanche danger, crews prepare for possible sweep and closure. Preventive explosive work and spot closures initiated if danger level is increasing but instability is limited. Highway can stay open except for spot closures if explosive work on paths threatening highway can keep danger level to Low. Worker precautions change to:

Normal highway plowing operations call in their location every 30 minutes.

Stationary snow removal operations must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter. No clearing of avalanche debris or collection areas.

Workers must stay inside vehicles when working in avalanche areas.

Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity.

MODERATE (yellow)

Natural avalanches possible; may or may not reach lower elevations. Areas of unstable snow exist.

Highway swept and closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.

Crews plowing or sweeping call in when entering and leaving every avalanche path, identifying their location specifically to dispatch.

Stationary snow removal operations must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter. No clearing of avalanche debris or collection areas.

Workers must stay inside vehicles when working in avalanche areas.

Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity.

Explosive work initiated or continued if possible and practical.

Highway can be reopened with careful monitoring only after explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for all paths affecting the highway can be reduced to Low.

CONSIDERABLE (orange)

Highway closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.

Explosive work initiated or continued if practical. Forecaster in charge may permit explosives work with strict precautions. Crews passing through avalanche zones must be spotted and must maintain constant communications.

Plowing operations are allowed only in support of explosives missions, under the same rules. Workers must stay inside vehicles when working in avalanche areas, keep moving within avalanche areas, and remain on the main highway and shoulders.

HIGH (red)

Highway closed to all traffic. No exceptions.

The forecaster in charge, as always, has the discretion to reduce the danger level when appropriate.

EXTREME (black)

Highway closed to all traffic. No exceptions.

The forecaster in charge, as always, has the discretion to reduce the danger level when appropriate.

Appendix 7: Highway Closure and Operation Criteria for East Lynn Canal "B" Options and all West Lynn Canal Options

These guidelines are a sample of the kind of material that is part of a project-specific operational avalanche plan, but are not a substitute for such a detailed plan. A project-specific plan is required under Alaska case law for worker safety before construction or operation of an avalanche-exposed facility may proceed. Planning at that level is beyond the scope of this report.

LOW (green)

Generally stable snowpack; avalanche activity unlikely.

Highway open.

Normal highway plowing operations are not required to call in their locations.

Stationary snow removal operations, clearing avalanche debris or collection areas, must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter.

MODERATE (yellow)

If natural avalanches are possible, but are not forecast to reach lower elevations, the highway is open. Areas of unstable snow exist, but are not widespread. Large avalanches are unlikely.

Normal highway plowing operations call in their location every 30 minutes.

Stationary snow removal operations must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter. No clearing of avalanche debris or collection areas.

Workers must stay inside vehicles when working in avalanche areas.

Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity.

If status is Moderate without avalanches to lower elevations, but trend is toward increasing avalanche danger, crews prepare for possible sweep and closure. Preventive explosive work and spot closures initiated if danger level is increasing but instability is limited. Highway can open if explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

If danger level is Moderate but natural avalanches may reach lower elevations, highway is swept and closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge. Crew precautions for Considerable danger level are in effect. Explosive work initiated if possible. Highway can reopen if explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

CONSIDERABLE (orange)

Natural avalanches are possible. Instability more widespread.

Highway closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.

Workers must stay inside vehicles when working in avalanche areas, and remain on the main highway and shoulders.

Crews plowing or sweeping call in when entering and leaving every avalanche path, identifying their location to dispatch. No stationary equipment within avalanche areas.

Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity, and should contact the forecaster immediately if there is any new avalanche activity.

Explosive work initiated or continued if possible.

Highway can be reopened with careful monitoring only after explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

HIGH (red)

Generally unstable snowpack. Widespread avalanche activity has not yet begun, or is ending, but slides may reach the highway.

Highway closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.

Explosive work initiated only if practical. Forecaster in charge may permit explosives work with strict precautions. Crews passing through avalanche zones must be spotted and must maintain constant communications.

Plowing operations are allowed only in support of explosives missions, under the same rules. Workers must stay inside vehicles when working in avalanche areas, keep moving within avalanche areas, and remain on the main highway and shoulders.

Highway can be reopened with careful monitoring only after explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

These criteria would generally be difficult to meet during high danger level periods. The highway must remain closed if there is any doubt.

EXTREME (black)

Widespread avalanche cycle reaching low elevations is imminent or in progress.

Highway closed to all traffic. No exceptions.

The forecaster in charge, as always, has the discretion to reduce the danger level when appropriate.

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Appendix 8: Explosive Delivery Operations Spreadsheets

Operational Spreadsheets Overview

The operational spreadsheets provide details of each explosive delivery option. In order to provide data in both US and metric units, conversions have been made from one system to the other. The original units, which were in some cases US units and in some cases metric, are at the appropriate level of precision. Users should round the conversions and calculated outputs; they are purposely left unrounded here to avoid magnification of error as the data are manipulated.

The number of shots for each delivery method is calculated by studying each path from the air and on oblique and vertical airphotos, as well as on detailed topographic maps, to determine how many target areas are needed to ensure release.

The frequency weighting corrects for how often a particular path would be part of an explosive delivery mission. The greatest-threat, most-active paths are part of every mission, so their frequency weighting is one. Paths that would need explosive work on half the missions have a frequency weighting of 0.5, those that would need work on one third of the missions have a weighting of 0.3, and so on. The “weighted average shots per mission” is the total number of shots multiplied by the frequency weighting, and the “weighted shots per year” is the weighted shots per mission multiplied by the number of missions per year, which is calculated separately based on the weather and highway closure analysis.

Charge sizes are 50lb (23kg) ammonium nitrate – fuel oil (ANFO) bags for helicopter placement, 8lb (3kg) high explosive for howitzer rounds, and 6lb (3kg) mortar rounds for the blaster boxes.

To evaluate explosive use for Alternative 2B, in which the highway would extend only from Juneau to the Katzehin River, use the figures from the table for Option ELC 1 from Path ELC 001 through Path ELC 035.

Note that a few minor paths that are avoided by the alignment are still listed in the tables. The alternatives that bypass Berners Bay are also not listed separately, because they only avoid one infrequently running path. Explosive quantities for all these paths are small enough that explosive delivery operations will not differ significantly from the figures in the accompanying tables.

The firing locations for options with howitzers would be open pads for sites the gun could be trailered to, or secure garages at remote sites where the gun would be left between missions. The firing location would be a highwayside turnout where the site is located along the highway, a pad on a spur road (approximate spur road length given) if it is near the highway, or helicopter access if it is a remote site. For ELC 2, the only howitzer option for the East Lynn alternative, three howitzers would be located at remote sites and one howitzer would be trailered to one of several locations for firing from an open pad.

The field of fire for a howitzer is the total side-to-side, or horizontal, angle between the farthest left and farthest right shot from that location. It is listed because howitzer capabilities vary, and repositioning may be required with some models to cover the full width of the field of fire.

The longest howitzer shot is listed because range is a concern. The 105mm howitzer is routinely used up to 3 to 3.5 miles (4800-5600m) range, and can hit targets at over five miles (8000m) with good accuracy. All targets listed in the options are within howitzer range.

The elevation of the highest howitzer shot is listed because elevation and distance determine the necessary trajectory. All shot points could be hit with relatively flat trajectories that stay below 10,000' (3050m). No shots have trajectories where overshooting would target inhabited areas.

Airspace must be closed in the vicinity of howitzer explosive delivery operations to avoid risk to aircraft. These closures are coordinated through the Federal Aviation Administration.

For options with blaster boxes, the width of the starting zone in meters is listed as "start zone (m)", and is divided by the 300m range of a mast with two cabinets mounted on it to arrive at the number of masts. Numbers ending in decimal points would be rounded up or down, but as a spreadsheet-driven system wide estimate of the number of masts needed, they are left as they are. Determination of individual mast locations is a design-level choice beyond the scope of this study.

ELC 1 Explosive Quantities and Locations (Helicopter explosive delivery)				
path	**number of shots**	**frequency weighting**	**weighted average shots per mission**	**weighted average shots per year**
ELC001	5.0	0.5	2.5	6.3
ELC002	8.0	1.0	8.0	20.2
ELC003	3.0	0.2	0.6	1.5
ELC003-1	2.0	0.1	0.1	0.3
ELC004	1.0	0.1	0.1	0.1
ELC005	15.0	0.5	7.5	18.9
ELC005-1	2.0	0.5	1.0	2.5
ELC006	12.0	1.0	12.0	30.3
ELC007	2.0	0.5	1.0	2.5
ELC008	4.0	0.5	2.0	5.0
ELC009	3.0	1.0	3.0	7.6
ELC010	2.0	1.0	2.0	5.0
ELC011	3.0	1.0	3.0	7.6
ELC012	15.0	0.5	7.5	18.9
ELC013	15.0	0.8	12.0	30.3
ELC014	10.0	1.0	10.0	25.2
ELC015	1.0	0.1	0.1	0.3
ELC016	5.0	0.1	0.3	0.6
ELC017	4.0	0.3	1.2	3.0
ELC018	5.0	1.0	5.0	12.6
ELC019	10.0	1.0	10.0	25.2
ELC019-1	2.0	0.3	0.6	1.5
ELC020	4.0	1.0	4.0	10.1
ELC021	12.0	1.0	12.0	30.3
ELC022	1.0	0.2	0.2	0.5
ELC023	1.0	0.5	0.5	1.3
ELC024	8.0	1.0	8.0	20.2
ELC025	4.0	1.0	4.0	10.1
ELC026	6.0	1.0	6.0	15.1
ELC026-1	1.0	0.1	0.1	0.1
ELC027	1.0	0.5	0.5	1.3
ELC028	2.0	0.8	1.6	4.0
ELC028-1	1.0	0.1	0.1	0.1
ELC028-2	1.0	0.1	0.1	0.1
ELC029	2.0	0.5	1.0	2.5
ELC030	1.0	0.1	0.1	0.1
ELC031	1.0	0.1	0.1	0.1
ELC032	1.0	0.1	0.1	0.1
ELC033	1.0	0.1	0.1	0.1
ELC034	1.0	0.1	0.1	0.1
ELC035	5.0	0.5	2.5	6.3
ELC036	1.0	0.1	0.1	0.1
ELC037	1.0	0.1	0.1	0.1
ELC038	1.0	0.1	0.1	0.1
ELC039	1.0	0.1	0.1	0.1
ELC040A-F	12.0	1.0	12.0	30.3
ELC041	3.0	0.1	0.2	0.4
ELC042	3.0	0.1	0.2	0.4
ELC043	3.0	0.5	1.5	3.8
ELC044	2.0	0.1	0.1	0.3
ELC045	2.0	0.1	0.1	0.3
ELC046	2.0	0.1	0.2	0.5
ELC047	1.0	0.1	0.1	0.3
ELC048	1.0	0.1	0.1	0.3
ELC049	5.0	1.0	5.0	12.6
ELC050	5.0	1.0	5.0	12.6
ELC051	4.0	1.0	4.0	10.1
ELC051-1	3.0	0.1	0.2	0.4
ELC052	3.0	0.1	0.2	0.4
ELC053	3.0	0.1	0.2	0.4
ELC053-1	3.0	0.1	0.2	0.4
ELC054	2.0	0.1	0.1	0.3
ELC055	3.0	0.1	0.2	0.4
ELC056	3.0	0.1	0.2	0.4
ELC056-1	3.0	0.1	0.2	0.4
ELC056-2	3.0	0.1	0.2	0.4
ELC057	1.0	0.1	0.1	0.1
ELC058	1.0	0.1	0.1	0.1
ELC059	1.0	0.1	0.1	0.1
TOTAL	259.0		160.2	403.9
ANFO needed (pounds/year)			20,196.0	

ELC 2 Howitzer Operations

(Howitzer-helicopter-blaster box explosive delivery)

path	Howitzer firing location	explosive delivery?	field of fire	longest shot (m)	longest shot (mi)	highest shot (m)	highest shot (ft)
ELC001	Berners	howitzer	25°	2600	1.6	1371.5	4500
ELC002	none	blaster boxes		300	0.2	1798.2	5900
ELC003	none	helicopter			0.0	0.0	
ELC003-1	none	helicopter			0.0	0.0	
ELC004	none	helicopter			0.0	0.0	
ELC005	Eldred Rock	howitzer	80°	5600	3.5	1645.8	5400
ELC005-1	Eldred Rock	howitzer	80°	4100	2.5	1280.1	4200
ELC006	Eldred Rock	howitzer	80°	4500	2.8	1554.4	5100
ELC007	Eldred Rock	howitzer	80°	3500	2.2	762.0	2500
ELC008	Eldred Rock	howitzer	80°	4100	2.5	1219.1	4000
ELC009	Eldred Rock	howitzer	80°	3100	1.9	396.2	1300
ELC010	Eldred Rock	howitzer	80°	3300	2.0	457.2	1500
ELC011	Eldred Rock	howitzer	80°	3400	2.1	487.7	1600
ELC012	Eldred Rock	howitzer	80°	5600	3.5	1798.2	5900
ELC013	Eldred Rock	howitzer	80°	5400	3.4	1615.4	5300
ELC014	Eldred Rock	howitzer	80°	6500	4.0	1310.6	4300
ELC015	none	helicopter			0.0	0.0	
ELC016	none	helicopter			0.0	0.0	
ELC017	Anyaka Isl.	howitzer	40°	6700	4.2	1615.4	5300
ELC018	Anyaka Isl.	howitzer	40°	6900	4.3	1676.3	5500
ELC019	Anyaka Isl.	howitzer	40°	7100	4.4	1798.2	5900
ELC019-1	Anyaka Isl.	howitzer	40°	4400	2.7	1036.3	3400
ELC020	Anyaka Isl.	howitzer	40°	5700	3.5	1219.1	4000
ELC021	Anyaka Isl.	howitzer	40°	6300	3.9	1463.0	4800
ELC022	Anyaka Isl.	howitzer	40°	4900	3.0	274.3	900
ELC023	Anyaka Isl.	howitzer	40°	5700	3.5	1066.7	3500
ELC024	Anyaka Isl.	howitzer	40°	5900	3.7	1097.2	3600
ELC025	Chilkat Pen.	howitzer	30°	6500	4.0	1341.1	4400
ELC026	Chilkat Pen.	howitzer	30°	6500	4.0	1341.1	4400
ELC026-1	Chilkat Pen.	howitzer	30°	5300	3.3	335.3	1100
ELC027	Chilkat Pen.	howitzer	30°	5600	3.5	640.0	2100
ELC028	Chilkat Pen.	howitzer	30°	5700	3.5	670.5	2200
ELC028-1	Chilkat Pen.	howitzer	30°	5600	3.5	548.6	1800
ELC028-2	Chilkat Pen.	howitzer	30°	5600	3.5	518.1	1700
ELC029	Chilkat Pen.	howitzer	30°	6300	3.9	914.4	3000
ELC030	Chilkat Pen.	howitzer	30°	5600	3.5	396.2	1300
ELC031	none	helicopter			0.0	0.0	
ELC032	none	helicopter			0.0	0.0	
ELC033	none	helicopter			0.0	0.0	
ELC034	none	helicopter			0.0	0.0	
ELC035	none	helicopter			0.0	0.0	
ELC036	none	helicopter			0.0	0.0	
ELC037	none	helicopter			0.0	0.0	
ELC038	none	helicopter			0.0	0.0	
ELC039	none	helicopter			0.0	0.0	
ELC040A-F	Tanani Pt.	howitzer	20°	5100	3.2	548.6	1800
ELC041	none	helicopter			0.0	0.0	
ELC042	none	helicopter			0.0	0.0	
ELC043	none	helicopter			0.0	0.0	
ELC044	none	helicopter			0.0	0.0	
ELC045	none	helicopter			0.0	0.0	
ELC046	none	helicopter			0.0	0.0	
ELC047	none	helicopter			0.0	0.0	
ELC048	none	helicopter			0.0	0.0	
ELC049	none	blaster boxes		300	0.2	1066.7	3500
ELC050	none	blaster boxes		300	0.2	1066.7	3500
ELC051	none	blaster boxes		300	0.2	1066.7	3500
ELC051-1	none	helicopter			0.0	0.0	
ELC052	none	helicopter			0.0	0.0	
ELC053	none	helicopter			0.0	0.0	
ELC053-1	none	helicopter			0.0	0.0	
ELC054	none	helicopter			0.0	0.0	
ELC055	none	helicopter			0.0	0.0	
ELC056	none	helicopter			0.0	0.0	
ELC056-1	none	helicopter			0.0	0.0	
ELC056-2	none	helicopter			0.0	0.0	
ELC057	none	helicopter			0.0	0.0	
ELC058	none	helicopter			0.0	0.0	
ELC059	none	helicopter			0.0	0.0	

ELC 2 Explosive Quantities and Locations

(Howitzer-helicopter-blaster box explosive delivery)

path	explosive delivery?	start zone (m)	# masts	# Howitzer shots	# blaster box shots	# heli shots	freq. weighting	weighted Howitzer shots/yr	weighted blaster shots/yr	weighted heli shots/yr
ELC001	howitzer			12.0	0.0	0.0	0.5	57.6	0.0	0.0
ELC002	blaster box	1600	5.3	0.0	15.0	0.0	1.0	0.0	148.5	0.0
ELC003	helicopter		0.0	0.0	0.0	3.0	0.2	0.0	0.0	1.1
ELC003-1	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.2
ELC004	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC005	howitzer		0.0	15.0	0.0	0.0	0.5	72.0	0.0	0.0
ELC005-1	howitzer		0.0	2.0	0.0	0.0	0.5	9.6	0.0	0.0
ELC006	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
ELC007	howitzer		0.0	2.0	0.0	0.0	0.5	9.6	0.0	0.0
ELC008	howitzer		0.0	6.0	0.0	0.0	0.5	28.8	0.0	0.0
ELC009	howitzer		0.0	4.0	0.0	0.0	1.0	38.4	0.0	0.0
ELC010	howitzer		0.0	4.0	0.0	0.0	1.0	38.4	0.0	0.0
ELC011	howitzer		0.0	3.0	0.0	0.0	1.0	28.8	0.0	0.0
ELC012	howitzer		0.0	15.0	0.0	0.0	0.5	72.0	0.0	0.0
ELC013	howitzer		0.0	20.0	0.0	0.0	0.8	153.6	0.0	0.0
ELC014	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
ELC015	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.2
ELC016	helicopter		0.0	0.0	0.0	5.0	0.1	0.0	0.0	0.5
ELC017	howitzer		0.0	7.0	0.0	0.0	0.3	20.2	0.0	0.0
ELC018	howitzer		0.0	8.0	0.0	0.0	1.0	76.8	0.0	0.0
ELC019	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
ELC019-1	howitzer		0.0	3.0	0.0	0.0	0.3	8.6	0.0	0.0
ELC020	howitzer		0.0	6.0	0.0	0.0	1.0	57.6	0.0	0.0
ELC021	howitzer		0.0	18.0	0.0	0.0	1.0	172.8	0.0	0.0
ELC022	howitzer		0.0	2.0	0.0	0.0	0.2	3.8	0.0	0.0
ELC023	howitzer		0.0	3.0	0.0	0.0	0.5	14.4	0.0	0.0
ELC024	howitzer		0.0	10.0	0.0	0.0	1.0	96.0	0.0	0.0
ELC025	howitzer		0.0	6.0	0.0	0.0	1.0	57.6	0.0	0.0
ELC026	howitzer		0.0	7.0	0.0	0.0	1.0	67.2	0.0	0.0
ELC026-1	howitzer		0.0	1.0	0.0	0.0	0.1	0.5	0.0	0.0
ELC027	howitzer		0.0	2.0	0.0	0.0	0.5	9.6	0.0	0.0
ELC028	howitzer		0.0	4.0	0.0	0.0	0.8	30.7	0.0	0.0
ELC028-1	howitzer		0.0	1.0	0.0	0.0	0.1	0.5	0.0	0.0
ELC028-2	howitzer		0.0	2.0	0.0	0.0	0.1	1.0	0.0	0.0
ELC029	howitzer		0.0	4.0	0.0	0.0	0.5	19.2	0.0	0.0
ELC030	howitzer		0.0	2.0	0.0	0.0	0.1	1.0	0.0	0.0
ELC031	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC032	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC033	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC034	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC035	helicopter		0.0	0.0	0.0	5.0	0.5	0.0	0.0	4.6
ELC036	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC037	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC038	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC039	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC040A-F	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
ELC041	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC042	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC043	helicopter		0.0	0.0	0.0	3.0	0.5	0.0	0.0	2.7
ELC044	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.2
ELC045	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.2
ELC046	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.4
ELC047	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.2
ELC048	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.2
ELC049	blaster box	500	1.7	0.0	6.0	0.0	1.0	0.0	59.4	0.0
ELC050	blaster box	500	1.7	0.0	6.0	0.0	1.0	0.0	59.4	0.0
ELC051	blaster box	500	1.7	0.0	5.0	0.0	1.0	0.0	49.5	0.0
ELC051-1	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC052	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC053	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC053-1	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC054	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.2
ELC055	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC056	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC056-1	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC056-2	helicopter		0.0	0.0	0.0	3.0	0.1	0.0	0.0	0.3
ELC057	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC058	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC059	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
Total shots				229.0	32.0	71.0		1722.0	316.9	14.4

ELC 3 Operations and Explosives (Blaster boxes for all major paths, helicopter back-up)										
path	**explosive delivery**	**start zone (m)**	**# blast masts**	**# blast shots**	**# heli shots**	**freq. weighting**	**weighted avg. heli shots/ mission**	**weighted blaster shots/ mission**	**weighted blaster shots/yr**	**weighted heli shots/yr**
LC001	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.6
LC002	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC003	helicopter			0.0	3.0	0.2	0.6	0.0	0.0	1.1
LC003-1	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC004	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC005	helicopter			0.0	10.0	0.5	5.0	0.0	0.0	9.1
LC005-1	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC006	blaster box	1100	3.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC007	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC008	helicopter			0.0	4.0	0.5	2.0	0.0	0.0	3.7
LC009	blaster box	50	1.0	4.0	0.0	1.0	0.0	4.0	39.6	0.0
LC010	blaster box	50	1.0	4.0	0.0	1.0	0.0	4.0	39.6	0.0
LC011	blaster box	50	1.0	4.0	0.0	1.0	0.0	4.0	39.6	0.0
LC012	helicopter			0.0	15.0	0.5	7.5	0.0	0.0	13.7
LC013	helicopter			0.0	15.0	0.8	12.0	0.0	0.0	21.9
LC014	blaster box	500	1.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC015	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
LC016	helicopter			0.0	5.0	0.1	0.3	0.0	0.0	0.5
LC017	helicopter			0.0	4.0	0.3	1.2	0.0	0.0	2.2
LC018	blaster box	900	3.0	8.0	0.0	1.0	0.0	8.0	79.2	0.0
LC019	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC019-1	helicopter			0.0	2.0	0.3	0.6	0.0	0.0	1.1
LC020	blaster box	600	2.0	6.0	0.0	1.0	0.0	6.0	59.4	0.0
LC021	blaster box	1700	5.7	18.0	0.0	1.0	0.0	18.0	178.3	0.0
LC022	helicopter			0.0	1.0	0.2	0.2	0.0	0.0	0.4
LC023	helicopter				2.0	0.5	1.0	0.0	0.0	1.8
LC024	blaster box	800	2.7	10.0	0.0	1.0	0.0	10.0	99.0	0.0
LC025	blaster box	800	2.7	6.0	0.0	1.0	0.0	6.0	59.4	0.0
LC026	blaster box	1100	3.7	7.0	0.0	1.0	0.0	7.0	69.3	0.0
LC026-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC027	helicopter			0.0	1.0	0.5	0.5	0.0	0.0	0.9
LC028	helicopter			0.0	2.0	0.8	1.6	0.0	0.0	2.9
LC028-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC028-2	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC029	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC030	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC031	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC032	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC033	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC034	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC035	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.6
LC036	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC037	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC038	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC039	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC040A-F	blaster box	800	2.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC041	helicopter		0.0	0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC042	helicopter		0.0	0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC043	helicopter		0.0	0.0	3.0	0.5	1.5	0.0	0.0	2.7
LC044	helicopter		0.0	0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC045	helicopter		0.0	0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC046	helicopter		0.0	0.0	2.0	0.1	0.2	0.0	0.0	0.4
LC047	helicopter		0.0	0.0	1.0	0.1	0.1	0.0	0.0	0.2
LC048	helicopter		0.0	0.0	1.0	0.1	0.1	0.0	0.0	0.2
LC049	blaster box	500	1.7	6.0	0.0	1.0	0.0	6.0	59.4	0.0
LC050	blaster box	500	1.7	5.0	0.0	1.0	0.0	5.0	49.5	0.0
LC051	blaster box	500	1.7	5.0	0.0	1.0	0.0	5.0	49.5	0.0
LC051-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC052	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC053	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC053-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC054	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC055	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC056	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC056-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC056-2	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
LC057	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC058	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC059	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
Totals		13150	43.8	158.0	142.0		45.2	158.0	1564.7	82.6

ELC 4 Operations and Explosives

(Blaster boxes for 10 highest-hazard paths, helicopter back-up)

path	explosive delivery	start zone (m)	# blast masts	# blast shots	# heli shots	freq. weighting	weighted avg. heli shots/ mission	weighted blast shots/ mission	weighted blast shots/yr	weighted heli shots/yr
ELC001	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.2
ELC002	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
ELC003	helicopter			0.0	3.0	0.2	0.6	0.0	0.0	1.0
ELC003-1	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
ELC004	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC005	helicopter			0.0	15.0	0.5	7.5	0.0	0.0	12.6
ELC005-1	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.7
ELC006	blaster box	1100	3.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
ELC007	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.7
ELC008	helicopter			0.0	4.0	0.5	2.0	0.0	0.0	3.4
ELC009	helicopter			0.0	3.0	1.0	3.0	0.0	0.0	5.1
ELC010	helicopter			0.0	2.0	1.0	2.0	0.0	0.0	3.4
ELC011	helicopter			0.0	3.0	1.0	3.0	0.0	0.0	5.1
ELC012	helicopter			0.0	15.0	0.5	7.5	0.0	0.0	12.6
ELC013	helicopter			0.0	15.0	0.8	12.0	0.0	0.0	20.2
ELC014	blaster box	500	1.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
ELC015	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
ELC016	helicopter			0.0	5.0	0.1	0.3	0.0	0.0	0.4
ELC017	helicopter			0.0	4.0	0.3	1.2	0.0	0.0	2.0
ELC018	helicopter			0.0	5.0	1.0	5.0	0.0	0.0	8.4
ELC019	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
ELC019-1	helicopter			0.0	2.0	0.3	0.6	0.0	0.0	1.0
ELC020	blaster box	600	2.0	6.0	0.0	1.0	0.0	6.0	59.4	0.0
ELC021	blaster box	1700	5.7	18.0	0.0	1.0	0.0	18.0	178.3	0.0
ELC022	helicopter			0.0	1.0	0.2	0.2	0.0	0.0	0.3
ELC023	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.7
ELC024	helicopter			0.0	8.0	1.0	8.0	0.0	0.0	13.5
ELC025	blaster box	800	2.7	6.0	0.0	1.0	0.0	6.0	59.4	0.0
ELC026	blaster box	1100	3.7	7.0	0.0	1.0	0.0	7.0	69.3	0.0
ELC026-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC027	helicopter			0.0	1.0	0.5	0.5	0.0	0.0	0.8
ELC028	helicopter			0.0	2.0	0.8	1.6	0.0	0.0	2.7
ELC028-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC028-2	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC029	blaster box	900	3.0	6.0	0.0	0.5	0.0	3.0	29.7	0.0
ELC030	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC031	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC032	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC033	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC034	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC035	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.2
ELC036	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC037	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC038	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC039	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC040B	blaster box	900	3.0	6.0	0.0	1.0	0.0	6.0	59.4	0.0
ELC040A, C-	helicopter			0.0	9.0	1.0	9.0	0.0	0.0	15.2
ELC041	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC042	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC043	helicopter			0.0	3.0	0.5	1.5	0.0	0.0	2.5
ELC044	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
ELC045	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
ELC046	helicopter			0.0	2.0	0.1	0.2	0.0	0.0	0.3
ELC047	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
ELC048	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
ELC049	helicopter			0.0	5.0	1.0	5.0	0.0	0.0	8.4
ELC050	helicopter			0.0	5.0	1.0	5.0	0.0	0.0	8.4
ELC051	helicopter			0.0	4.0	1.0	4.0	0.0	0.0	6.7
ELC051-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC052	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC053	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC053-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC054	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
ELC055	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC056	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC056-1	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC056-2	helicopter			0.0	3.0	0.1	0.2	0.0	0.0	0.3
ELC057	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC058	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC059	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
Totals		10,800	36.0	109.0	189.0		90.7	106.0	1049.7	152.6

WLC 1 Howitzer Operations (Howitzer explosive delivery)										
path	firing location	type	access	spur road length (m)	spur road length (mi)	field of fire	longest shot (m)	longest shot (mi)	highest shot (m)	highest shot (ft)
WLC001A & B	Endicott R.	open pad	spur road	800	0.5	30°	3000	1.9	396	1300
WLC002 A & B	Endicott R.	open pad	spur road	800	0.5	"	1900	1.2	488	1600
WLC003	*none*	*alignment avoids path*								
WLC004	*none*	*alignment avoids path*								
WLC005	Sullivan	open pad	spur road	500	0.3	70° (in 1st position)	3700	2.3	1311	4300
WLC006 A-C	Sullivan	open pad	spur road	500	0.3	"	3100	1.9	1402	4600
WLC007	Sullivan	open pad	spur road	500	0.3	10° (in 2nd position)	2900	1.8	1036	3400
WLC008	S. Rainbow	open pad	spur road	500	0.3	25° (in 1st position)	4000	2.5	1402	4600
WLC009 A-C	S. Rainbow	open pad	spur road	500	0.3	20° (in 2nd position)	4900	3.0	1219	4000
WLC009 A-C	Rainbow-Pyramid	open pad	spur road	400	0.2	25° (in 1st position)	4800	3.0	1219	4000
WLC010 A-D	Rainbow-Pyramid	open pad	spur road	400	0.2	40° (in 2nd position)	2900	1.8	1128	3700
WLC010 A-D	Chilkat Crossing	open pad	roadside turnout	0	0.0	depends on loc'n	depends on loc'n	depends on loc'n		3700
Total spur road length (approx.)				4900	3.0					

WLC 1 Explosive Quantities and Locations (Howitzer explosive delivery)				
path	**# shots**	**frequency weighting**	**weighted average shots/ mission**	**weighted average shots/ year**
WLC001 A & B	6.0	1.0	6.0	64.8
WLC00 2A & B	6.0	1.0	6.0	64.8
WLC003	0.0	0.0	0.0	0.0
WLC004	0.0	0.0	0.0	0.0
WLC005	8.0	0.5	4.0	43.2
WLC006 A-C	20.0	1.0	20.0	216.0
WLC007	10.0	0.1	1.0	10.8
WLC008	20.0	0.3	6.0	64.8
WLC009 A-C	20.0	1.0	20.0	216.0
WLC010 A-D	15.0	1.0	15.0	162.0
Totals	105.0		78.0	842.3

WLC 2 Howitzer Operations

(Howitzer-blaster box explosive delivery)

path	howitzer firing location	type	access	spur road length (m)	spur road length (mi)	field of fire	longest shot (m)	longest shot (mi)	highest shot (m)	highest shot (ft)
WLC001 A & B	*blaster boxes*						300	0.2	396	1300
WLC002 A & B	*blaster boxes*						300	0.2	488	1600
WLC003	*none*	*alignment avoids path*								
WLC004	*none*	*alignment avoids path*								
WLC005	Sullivan	open pad	spur road	500	0.3	70° (in 1st position)	3700	2.3	1311	4300
WLC006 A-C	*blaster boxes*						300	0.2	1402	4600
WLC007	Sullivan	open pad	spur road	500	0.3	10° (in 2nd position)	2900	1.8	1036	3400
WLC008	S. Rainbow	open pad	spur road	500	0.3	25° (in 1st position)	4000	2.5	1402	4600
WLC009 A-C	*blaster boxes*						300	0.2	1219	4000
WLC010 A-D	*blaster boxes*						300	0.2	1128	3700
Total spur road length (approx.)				1500	0.9					

WLC 2 Explosive Quantities and Locations (Howitzer-blaster box explosive delivery)										
path	**explosive delivery**	**start zone (m)**	**# blaster box masts**	**# how. shots**	**# blaster box shots**	**freq. weight ing**	**weighted avg. how. shots/ mission**	**weighted avg. how. shots/ yr**	**weighted average blaster shots/ mission**	**weighted average blaster shots/ yr**
WLC001 A & B	blaster boxes	700	2.3	0	6	1.0	0.0	0.0	6.0	50.4
WLC002 A & B	blaster boxes	700	2.3	0	6	1.0	0.0	0.0	6.0	50.4
WLC003	*alignment avoids path*									
WLC004	*alignment avoids path*									
WLC005	howitzer			8	0	0.5	4.0	33.6	0.0	0.0
WLC006 A-C	blaster boxes	2200	7.3	0	20	1.0	0.0	0.0	20.0	168.0
WLC007	howitzer			10	0	0.1	1.0	8.4	0.0	0.0
WLC008	howitzer			20	0	0.3	6.0	50.4	0.0	0.0
WLC009 A-C	blaster boxes	2800	9.3	0	20	1.0	0.0	0.0	20.0	168.0
WLC010 A-D	blaster boxes	1600	5.3	0	15	1.0	0.0	0.0	15.0	126.0
Totals		8000	26.7	38	67		11.0	92.4	67.0	562.7

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Appendix 9: Avalanche Program Budget Projections

These budget spreadsheets reflect efforts to catalog and price all components related to a viable avalanche program. Whenever possible, cost estimates from DOT&PF or other state employees most knowledgeable about the particular item or service in question were used. The source of each estimate is given on the spreadsheets.

Following are some of the assumptions used:

This budget is based on having the entire avalanche program managed by DOT&PF employees.

Helicopter ferry time from Juneau to the Lynn Canal area is estimated to be 1.2 hours round-trip for a typical mission, the average of 0.8 hours roundtrip from the helicopter bases to the southern end of either the East or West Lynn Canal highway, and flight time to the north end at Skagway of 1.6 hours roundtrip. Since all destinations should be between these points, the ferry time used here is the average of 1.2 hours.

Standby time and additional flying time based on distance and typical rate of climb and travel were added to the ferry time in accordance with the type of mission; e.g., explosives work, weather station maintenance, blaster box reloading.

Monthly operating and replacement costs for DOT&PF heavy equipment are as supplied by DOT&PF staff.

Annual replacement costs for equipment are figured based on the following formula: new cost adjusted for inflation divided by useful life in years. This methodology is the same basic methodology DOT&PF uses to calculate monthly replacement costs for heavy equipment. Including replacement costs in the annual operating budget is meant to amortize the cost of recapitalization, so that there is no need for extra funds when equipment reaches the end of its useful life.

Labor costs were calculated based on current wages.

The time for temporary flaggers is estimated based on highway closure times during explosive delivery and snow removal time. While there should be gates to keep travelers out of avalanche zones during highway closures, highway flaggers could be needed in certain circumstances, such as when the highway is partially closed but one lane of traffic has been opened.

Only the helicopter explosives delivery option was evaluated for ELC 1, Alt. 2B, in which the highway extends from Juneau to the Katzehin River and ferries could connect from there to Haines and Skagway. By the time this alternative was evaluated, it had been determined that helicopter delivery would be the most flexible and reliable explosives delivery option.

The alternatives that bypass Berners Bay with ferries only avoid one infrequently running path. Their budgets will not differ significantly, so are not evaluated separately.

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Appendix 9A: Capital Budget Spreadsheets

Capital budget

East Lynn Canal options 1A and 1B (ELC 1A and 1B): Helicopter only

Item	Notes	Equipment type	Number	Cost	Total	Information source
Ammunition storage units	2-Kensington, 2-Skagway		4	$30,000	$120,000	G. Patz/AES
RECCO detection system			1	$7,000	$7,000	D. Howlett, RECCO US rep.
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$18,350	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Loaders	1- Kensington, 1-Skagway	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling costs
Chains for loaders		chains for Cat 988G	2	$200	$400	G. Patz
Bulldozers	1- Kensington, 1-Skagway	D9R	2	$595,000	$1,190,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates	1-Kensington, 1-Skagway, 2-Katzehin	manual swing gates	4	$1,500	$6,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$280	$4,200	G. Patz
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Kensington, 1-Skagway		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			12	$1,550	$18,600	See budget detail spreadsheet
Signage		avalanche zone signs	196	$100	$19,600	G. Patz
Signage		trailhead warning signs	40	$20	$800	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL ELC 1A					**$2,790,170**	
Snowsheds	located at paths 6, 19, 21	steel arch	3	$5,000,000	$15,000,000	AES
TOTAL ELC 1B					**$17,790,170**	

Capital budget

East Lynn Canal option 1A (ELC 1A) - Alt. 2B Katzehin: Helicopter only

Item	Notes	Equipment type	Number	Cost	Total	Information source
Ammunition storage units	2-Kensington, 2-Katzehin		4	$30,000	$120,000	G. Patz/AES
RECCO detection system			1	$7,000	$7,000	D. Howlett, RECCO US rep.
Weather stations	ridge-top		2	$100,000	$200,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		2	$10,000	$20,000	ARR costs
Forecasting office		office equipment			$18,350	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Loaders	1- Kensington, 1-Skagway	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling costs
Chains for loaders		chains for Cat 988G	2	$200	$400	G. Patz
Bulldozers	1- Kensington, 1-Skagway	D9R	2	$595,000	$1,190,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates	1-Kensington, 1-Katzehin	manual swing gates	2	$1,500	$3,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$280	$4,200	G. Patz
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Kensington, 1-Katzehin		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			12	$1,550	$18,600	See budget detail spreadsheet
Signage		avalanche zone signs	106	$100	$10,600	G. Patz
Signage		trailhead warning signs	35	$20	$700	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL ELC 1A, Alt. 2B					**$2,668,070**	

Capital budget

East Lynn Canal options 2A and 2B (ELC 2A and 2B): Howitzer-blaster box-helicopter

Item	Notes	Equipment type	Number	Cost	Total	Information source
Blaster boxes	number of masts	Doppelmayr	10	$200,000	$2,000,000	ARR costs
105mm Howitzer shipping	1 mobile, 3 stationary		4	8000	$32,000	T. Onslow
concrete Howitzer enclosures w/magazine	Eldred Rock, Anyaka Island, Chilkat Peninsula		3	$5,000,000	$15,000,000	Liam Fitzgerald; Greens Creek Mine
Concrete pad with cutout for Howitzer	for mobile Howitzer		1	$30,000	$30,000	G. Patz
Ammunition for Howtizer targeting	First year only. Per round cost plus shipping		458	$101	$46,258	AES
Ammunition storage units	2-Kensington, 2-Skagway		4	$30,000	$120,000	G. Patz, AES
Dud detection	includes equipment and software			$1,000	$1,000	AES
RECCO Detection System			1	$7,000	$7,000	D. Howlett, US RECCO rep.
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$18,350	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Loaders	1- Kensington, 1-Skagway	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling costs
Chains for loaders		chains for Cat 988G	2	$200	$400	G. Patz
Bulldozers	1- Kensington, 1-Skagway	D9R	2	$595,000	$1,190,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates	1-Kensington, 1-Skagway, 2-Katzehin	manual swing gates	4	$1,500	$6,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$280	$4,200	G. Patz
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Kensington, 1-Skagway		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			12	$1,550	$18,600	See budget detail spreadsheet
Signage		avalanche zone signs	196	$100	$19,600	G. Patz
Signage		trailhead warning signs	40	$20	$800	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL ELC 2A					**$19,899,428**	
Snowsheds	located at paths 6, 19, 21	steel arch	3	$5,000,000	$15,000,000	AES
TOTAL ELC 2B					**$34,899,428**	

Capital budget

East Lynn Canal options 3A and 3B (ELC 3A and 3B): Blaster box on all major paths, heli back-up

Item	Notes	Equipment type	Number	Cost	Total	Information source
Blaster boxes	number of masts	Doppelmayr	44	$200,000	$6,600,000	ARR costs less 25% for economies of scale
Ammunition storage units	2-Kensington, 2-Skagway		4	$30,000	$120,000	G. Patz
Dud detection	includes equipment and software			$1,000	$1,000	AES
RECCO Detection System			1	$7,000	$7,000	D. Howlett, US RECCO rep.
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$18,350	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Loaders	1- Kensington, 1-Skagway	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling costs
Chains for loaders		chains for Cat 988G	2	$200	$400	G. Patz
Bulldozers	1- Kensington, 1-Skagway	D9R	2	$595,000	$1,190,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates	1-Kensington, 1-Skagway, 2-Katzehin	manual swing gates	4	$1,500	$6,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$280	$4,200	G. Patz
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Kensington, 1-Skagway		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			12	$1,550	$18,600	See budget detail spreadsheet
Signage		avalanche zone signs	196	$100	$19,600	G. Patz
Signage		trailhead warning signs	40	$20	$800	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL ELC 3A					**$9,391,170**	
Snowsheds	located at paths 6, 19, 21	steel arch	3	$5,000,000	$15,000,000	AES
TOTAL ELC 3B					**$24,391,170**	

Capital budget

East Lynn Canal options 4A and 4B (ELC 4A and 4B): Blaster box on top 10 paths, helicopter elsewhere

Item	Notes	Equipment type	Number	Cost	Total	Information source
Blaster boxes	number of masts	Doppelmayr	35	$200,000	$5,250,000	ARR costs minus 25 % for economies of scale
Ammunition storage units	2-Kensington, 2-Skagway		4	$30,000	$120,000	G. Patz
Dud detection	includes equipment and software			$1,000	$1,000	AES
RECCO Detection System			1	$7,000	$7,000	D. Howlett, US RECCO rep.
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$18,350	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Loaders	1- Kensington, 1-Skagway	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling costs
Chains for loaders		chains for Cat 988G	2	$200	$400	G. Patz
Bulldozers	1- Kensington, 1-Skagway	D9R	2	$595,000	$1,190,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates	1-Kensington, 1-Skagway, 2-Katzehin	manual swing gates	4	$1,500	$6,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$280	$4,200	G. Patz
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Kensington, 1-Skagway		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			12	$1,550	$18,600	See budget detail spreadsheet
Signage		avalanche zone signs	196	$100	$19,600	G. Patz
Signage		trailhead warning signs	40	$20	$800	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL ELC 4A					**$8,041,170**	
Snowsheds	located at paths 6, 19, 21	steel arch	3	$5,000,000	$15,000,000	AES
TOTAL ELC 4B					**$23,041,170**	

Capital budget
West Lynn Canal option 1 (WLC 1): Howitzer only

Item	Notes	Equipment type	Number	Cost	Total	Information source
105mm Howitzer shipping			1	$8,000	$8,000	T. Onslow
Spur roads for Howitzer shots	number of road miles needed	2-lane gravel road with turnout	3.04	$250,000	$760,000	J. Beedle
Concrete pad with cutout for Howitzer			5	$30,000	$150,000	G. Patz
Ammunition storage units	2-Kensington, 2-Skagway		4	$30,000	$120,000	G. Patz, AES
Ammunition for Howtizer targeting	First year only. Per round cost plus shipping		210	$101	$21,210	AES
Dud detection	includes equipment and software			$1,000	$1,000	AES
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters (for weather station telemetry)			3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$17,125	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Forecasting office		data management contract		$20,000	$20,000	AES
Loader		Cat 988G	1	$450,000	$450,000	G. Patz specs./G. Darling costs
Chains for loader		chains for Cat 988G	1	$200	$200	G. Patz
Bulldozer		D9R	1	$595,000	$595,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	1-maintenance, 1-forecasters	3/4 ton 4WD extended cab	2	$30,000	$60,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates		manual swing gates	2	$1,500	$3,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		10	$280	$2,800	G. Patz
Headsets	gear for DOTPF crew		6	$150	$900	G. Patz
Avalanche caches	1-Haines, 1-ferry landing		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			10	$1,550	$15,500	See budget detail spreadsheet
Signage		avalanche zone signs	32	$100	$3,200	G. Patz
Signage		trailhead warning signs	20	$20	$400	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL					**$2,642,055**	

Capital budget

West Lynn Canal option 2 (WLC 2): Howitzer-blaster box

Item	Notes	Equipment type	Number	Cost	Total	Information source
Blaster boxes	Number of masts	Doppelmayr	27	$200,000	$4,050,000	ARR costs minus 25% for economies of scale
105mm Howitzer shipping			1	$8,000	$8,000	T. Onslow
Spur roads for Howitzer shots	number of road miles needed	2-lane gravel road with turnout	3.04	$250,000	$760,000	J. Beedle
Concrete pad with cutout for Howitzer			5	$30,000	$150,000	G. Patz
Ammunition for Howtizer targeting	First year only. Per round cost plus shipping		76	$101	$7,676	AES
Ammunition storage units			4	$30,000	$120,000	G. Patz, Bill Glude
Dud detection	includes equipment and software			$1,000	$1,000	Estimate
RECCO Detection System			1	$7,000	$7,000	D. Howlett, US RECCO rep.
Weather stations	ridge-top		3	$100,000	$300,000	ARR costs
Weather stations	mid-elevation		1	$20,000	$20,000	AES
Repeaters	for weather station telemetry		3	$10,000	$30,000	ARR costs
Forecasting office		office equipment			$17,125	See budget detail spreadsheet
Forecasting office		field equipment			$20,440	See budget detail spreadsheet
Forecasting office		data management contract		$20,000	$20,000	AES
Loader		Cat 988G	1	$450,000	$450,000	G. Patz specs./G. Darling costs
Chains for loader		chains for Cat 988G	1	$200	$200	G. Patz
Bulldozer		D9R	1	$595,000	$595,000	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	1-maintenance, 1-forecasters	3/4 ton 4WD extended cab	2	$30,000	$60,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$8,500	$17,000	AES
Snowmobile transportation equipment		double trailer	1	$1,200	$1,200	AES
Road closure gates		manual swing gates	2	$1,500	$3,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		10	$280	$2,800	G. Patz
Headsets	gear for DOTPF crew		6	$150	$900	G. Patz
Avalanche caches	1-Haines, 1-ferry landing		2	$12,040	$24,080	See budget detail spreadsheet
Vehicle caches			10	$1,550	$15,500	See budget detail spreadsheet
Signage		avalanche zone signs	32	$100	$3,200	G. Patz
Signage		trailhead warning signs	20	$20	$400	AES
Signage		highway entry signs	2	$500	$1,000	G. Patz
TOTAL					**$6,685,521**	

Capital budget detail

ELC Options: Forecasting office equipment	Item	Number	Price per item	Total Cost	Source
	desks/chairs	4	$500	$2,000	AES
	desktop computer	1	$2,000	$2,000	AES
	laptop computers	3	$3,500	$10,500	AES
	external hard drives	4	$300	$1,200	AES
	fax	1	$200	$200	AES
	phones	4	$425	$1,700	DOA
	scanner	1	$450	$450	AES
	misc. supplies	1	$300	$300	AES
	Total			**$18,350**	

WLC Options: Forecasting office equipment	Item	Number	Price per item	Total Cost	Source
	desks/chairs	3	$500	$1,500	AES
	desktop computer	1	$2,000	$2,000	AES
	laptop computers	3	$3,500	$10,500	AES
	external hard drives	3	$300	$900	AES
	fax	1	$200	$200	AES
	phones	3	$425	$1,275	DOA
	scanner	1	$450	$450	AES
	misc. supplies	1	$300	$300	AES
	Total			**$17,125**	

Forecasting field equipment	Item	Number	Price per item	Total Cost	Source
	density kit	1	$7,200	$7,200	AES
	digital camera	1	$1,200	$1,200	AES
	binoculars	2	$200	$400	AES
	snow kits	3	$65	$195	AES
	shovels	3	$60	$180	AES
	snow saws	3	$70	$210	AES
	Avalungs	3	$90	$270	AES
	helmets	3	$150	$450	AES
	laser flares	3	$90	$270	AES
	skis or splitboards w/poles, bindings	3	$1,400	$4,200	AES
	parkas	3	$450	$1,350	AES
	bibs	3	$250	$750	AES
	packs	3	$250	$750	AES
	avalanche transceivers	3	$280	$840	AES
	probes	3	$75	$225	AES
	HT1250 VHF radios	2	$775	$1,550	Motorola
	Big Ear microphones	2	$25	$50	Transtronics
	First Aid kits	3	$50	$150	AES
	First Aid trauma kits	2	$100	$200	AES
	Total			**$20,440**	

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Appendix 9B: Operating Budget Spreadsheets

Operating Budget - East Lynn Canal Option 1 (ELC 1): helicopter only

							Total annual cost	**Information source**	**Notes**
Explosives		Equipment		Cost per shot		Annual number of shots	Annual cost		
		Heli explosives		$37.86		404	$15,295	Atlas Alaska	includes $2.00 per round for RECCO reflectors
		Heli explosives shipping fee		$100		2	$200	Atlas Alaska	two shipments annually
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		
	Explosive delivery	flight time		$1,320		21.8	$28,776	Hourly rates from	
		standby		$400		5.4	$2,160	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	16	32	$42,240		
		standby	4	$400	16	64	$25,600		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	2		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	4				$41,800	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$126	$378	12	$4,536	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$330	$990	12	$11,880	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		replacement figured with 3%inflation
	Chains for loaders		2	$200	$400	3	$138		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		
	Forecasting office equipment						$10,516		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,608		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	40	$20	$800	8	$106		
	Weather station maintenance	replacement parts					$16,000	Mark Moore, NWAC	15% of equipment cost annually

Operating Budget - East Lynn Canal Option 1 (ELC 1): helicopter only, cont'd.									
							Total annual cost	**Information source**	**Notes**
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	includes utlities
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		research asst. I	Range 13A (GGU)		$51,189	0.58	$29,689	S. Saviers	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$25,311	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow: estimate	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$749,556**		

Operating Budget - East Lynn Canal Option 1A, Alt. 2B (ELC 1A, Alt. 2B): helicopter only									
							Total annual cost	**Information source**	**Notes**
Explosives		Equipment		Cost per shot		Annual number of shots	Annual cost		
		Heli explosives		$37.86		328	$12,418	Atlas Alaska	includes $2.00 per round for RECCO reflectors
		Heli explosives shipping fee		$100		2	$200	Atlas Alaska	two shipments annually
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		
	Explosive delivery	flight time		$1,320		18.3	$24,156	Hourly rates from	
		standby		$400		4.6	$1,840	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	16	24	$31,680		
		standby	4	$400	12	48	$19,200		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	2		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	4				$41,800	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$126	$378	12	$4,536	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$330	$990	12	$11,880	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		replacement figured with 3%inflation
	Chains for loaders		2	$200	$400	3	$138		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		
	Forecasting office equipment						$10,516		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,288		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	35	$20	$700	8	$93		
	Weather station maintenance	replacement parts					$11,000	Mark Moore, NWAC	15% of equipment cost annually

Operating Budget - ELC 1A, Alt. 2B: helicopter only, cont'd.

							Total annual cost	**Information source**	**Notes**
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	includes utilities
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		research asst. I	Range 13A (GGU)		$51,189	0.58	$29,689	S. Saviers	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$25,311	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow: estimate	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$719,446**		

Operating budget - East Lynn Canal option 2 (ELC 2): Howitzer-blaster box-helicopter

							Total annual cost	Information source	Notes
Explosive delivery		Equipment	Number	Cost			**Annual cost**		
	Annual lease of 105mm Howitzer	available model	4	$3,800			$15,200	S. Back, US Army	The Army is in the process of setting an annualHowitzer lease rate. It could be higher than this estimate or lower, pending Congressional legislation.
Explosives				Cost per round		Number of rounds	Annual cost		Annual number of rounds
	Howitzer			$111		1722	$191,142	G. Patz	per round cost w/shipping plus 10 percent for emergency shipments
	Blaster boxes			$55.50		317	$17,594	ARR	$535 per box (includes freight), 10 in box. Cost per round includes $2.00 per round for RECCO reflectors
	Heli explosives		14	$37.86			$530	Atlas Alaska	cost includes $2.00 per round for RECCO reflectors
	Heli explosives shipping fee			$100		2	$200	Atlas Alaska	two shipments annnually
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		
	Explosive delivery	flight time		$1,320		20	$26,400	Hourly rates from	includes time to access Howitzer sites
		standby		$400		21	$8,400	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	18	36	$47,520		includes two trips annually for blaster box loading/ unloading
		standby	4	$400	18	72	$28,800		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	2		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	4				$41,800	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$126	$378	12	$4,536	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$330	$990	12	$11,880	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	1000 miles per mo. @ $0.25/mi

Operating budget - ELC 2: Howitzer-blaster box-helicopter, cont'd.

							Total annual cost	Information source	Notes
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Blaster box annualized costs		10	$200,000	$2,000,000	30	$73,828		10 masts
	Chains for loaders		2	$200	$400	3	$138		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		
	Forecasting office equipment						$10,516		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,608		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	40	$20	$800	8	$106		
	Weather station maintenance	replacement parts					$16,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	includes utlities
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		research asst. I	Range 13A (GGU)		$51,189	0.58	$29,689	S. Saviers	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$25,311	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$1,044,898**		

Operating Budget - East Lynn Canal option 3 (ELC 3): Blaster boxes on all major paths, heli backup

							Total annual cost	Information source	Notes
Explosives				Cost per round		Number of rounds	Annual cost		Annual number of rounds.
	Blaster boxes			$55.50		1565	$86,858	ARR	$535 per box (includes freight), 10 in box. Cost per round includes $2.00 per round for RECCO reflectors
	Heli explosives			$37.86		83	$3,142	Atlas Alaska	cost includes $2.00 per round for RECCO reflectors
	Heli explosives shipping fee			$100		2	$200	Atlas Alaska	two shipments annually
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Explosive delivery	flight time		$1,320		53	$69,960	Hourly rates from	
		standby		$400		79.7	$31,880	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	18	36	$47,520		includes two trips annually for blaster box loading and unloading
		standby	4	$400	18	72	$28,800		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	2		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	4				$41,800	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$126	$378	12	$4,536	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$330	$990	12	$11,880	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Blaster boxes		44	$200,000	$8,800,000	30	$324,844		44 masts
	Chains for loaders		2	$200	$400	3	$138		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		

Operating Budget - ELC 3: Blaster boxes on all major paths, heli backup, cont'd.									
							Total annual cost	**Information source**	**Notes**
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Forecasting office equipment						$10,516		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,608		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	40	$20	$800	8	$106		
	Weather station maintenance	replacement parts					$16,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	Includes utilities
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		research asst. I	Range 13A (GGU)		$51,189	0.58	$29,689	S. Saviers	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr. plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$25,311	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow: estimate	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$1,228,489**		

Op. Budget - East Lynn Canal option 4 (ELC 4): Blaster boxes top 10 paths, heli. elsewhere									
							Total annual cost	**Information source**	**Notes**
Explosive delivery	Equipment			**Cost oer round**		Number of rounds	Annual cost		Annual number of rounds
	Blaster boxes			$55.50		1159	$64,325	ARR	$535 per box (includes freight), 10 in box. Cost per round includes $2.00 per round for RECCO reflectors
	Heli explosives			$37.86		134	$5,073	Atlas Alaska	cost includes $2.00 per round for RECCO reflectors
	Heli explosives shipping fee			$100		2	$200	Atlas Alaska	2 shipments annnually
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Explosive delivery	flight time		$1,320		43	$56,760	Hourly rates from	
		standby		$400		60	$24,000	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	18	36	$47,520		includes two trips annually for blaster box loading and unloading
		standby	4	$400	18	72	$28,800		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	2		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	4				$41,800	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$126	$378	12	$4,536	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$330	$990	12	$11,880	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Blaster boxes		35	$200,000	$7,000,000	30	$258,399		35 masts
	Chains for loaders		2	$200	$400	3	$138		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		

Operating Budget - ELC 4: Blaster boxes on top 10 paths, helicopter elsewhere, cont'd.

							Total annual cost	**Information source**	**Notes**
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Forecasting office equipment						$10,516		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,608		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	40	$20	$800	8	$106		
	Weather station maintenance	replacement parts					$16,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	includes utlities
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		research asst. I	Range 13A (GGU)		$51,189	0.58	$29,689	S. Saviers	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$25,311	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$1,120,361**		

Operating Budget - West Lynn Canal option 1 (WLC 1): Howitzer only

							Total annual cost	Information source	Notes
Explosive delivery		Equipment	Number	Cost			Annual Cost		
	Annual lease of 105mm Howitzer	available model	1	$3,800			$3,800	S. Back, US Army	The Army is in the process of setting an annualHowitzer lease rate. It could be higher than this estimate or lower, pending Congressional legislation.
Explosives				Cost per round		Annual number of shots	Annual cost		
		Howitzer		$111		842	$93,462	G. Patz	per round cost w/shipping plus 10 percent for emergency shipments
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Weather station maintenance	flight time	2	$1,320	16	32	$42,240	Hourly rates from	
		standby	4	$400	16	64	$25,600	Coastal Helicopters	
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	1		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	1		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	2				$20,900	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	2	$126	$252	12	$3,024	G. Darling costs, G. Patz specs.	1-forecasters, 1-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	2	$330	$660	12	$7,920	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	2	$250	$500	12	$6,000	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Chains for loaders		1	$200	$200	3	$69		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		
	Forecasting office equipment						$10,337		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	32	$100	$3,200	8	$426		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	20	$20	$400	8	$53		
	Weather station maintenance	replacement parts	4				$16,000	Mark Moore, NWAC	15% of equipment cost annually

Operating Budget - West Lynn Canal option 1 (WLC 1): Howitzer only, cont'd.

							Total annual cost	**Information source**	**Notes**
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Space and utilities	250 sq. feet	250	$2.10	$525	12	$6,300	B. Reiche, DOA	includes utlities
	Telephones		3	$35	$105	12	$1,260	DOA	
	Long distance				$100	12	$1,200	AES	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$20,858	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow	avalanche and ammunition safety training
		forecasters	2	$1,500	$3,000	annually	$3,000	AES	professional development
Total Annual Operating Budget							**$733,969**		

Operating Budget - West Lynn Canal option 2 (WLC 2): Howitzer-blaster box

							Total annual cost	Information source	Notes
Explosive delivery		Equipment	Number	Cost	Total monthly costs	Number of months	**Annual cost**		
	Annual lease for 105mm Howitzer	available model	1	$3,800			$3,800	S. Back, US Army	The Army is in the process of setting an annualHowitzer lease rate. It could be higher than this estimate or lower, pending Congressional legislation.
Explosives				Cost per round		Number of rounds	Annual cost		Annual number of rounds.
	Howitzer			$111		92	$10,212	G. Patz	per round cost w/shipping plus 10 percent for emergency shipments. Includes rounds needed for targeting.
	Blaster boxes			$55.50		563	$31,247	ARR	$535 per box (includes freight), 10 in box. Cost per round includes $2.00 per round for RECCO reflectors
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Explosive delivery	flight time		$1,320		17	$22,308	Hourly rates from	
		standby		$400		28	$11,240	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,320	18	36	$47,520		includes two trips annually for blaster box loading and unloading.
		standby	4	$400	18	72	$28,800		
	Snow study	flight time	2.5	$1,320	8	20	$26,400		
		standby	2	$400	8	16	$6,400		
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	1		$4,500	12	$54,000	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Monthly rate	D9R dozer	1		$5,900	12	$70,800	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Equipment loss	Cat 988G loader, D9R dozer, pickups	2				$20,900	discussion w/G. Darling	2 % of purchase cost per year to offset occasional loss or burial of equipment
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	2	$126	$252	12	$3,024	G. Darling costs, G. Patz specs.	1-forecasters, 1-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	2	$330	$660	12	$7,920	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	2	$250	$500	12	$6,000	G. Patz	1000 miles per mo. @ $0.25/mi

Operating Budget - West Lynn Canal option 2 (WLC 2): Howitzer-blaster box, cont'd.									
							Total annual cost	**Information source**	**Notes**
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3%inflation
	Blaster boxes		27	$200,000	$5,400,000	30	$199,336		27 masts
	Chains for loaders		1	$200	$200	3	$69		
	Avalanche caches		2	$12,040	$24,080	5	$5,054		
	Forecasting office equipment						$10,337		see budget detail spreadsheet
	Forecasting field equipment						$4,621		see budget detail spreadsheet
	Signage	avalanche zone signs	32	$100	$3,200	8	$426		
		highway entry signs	2	$500	$1,000	8	$133		
		trailhead warning signs	20	$20	$400	8	$53		
	Weather station maintenance	Replacement parts	4 stations				$16,000	Mark Moore, NWAC	15% of equipment cost annually
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting office	lead forecaster	Range 17E (GGU)		$80,489	1	$80,489	N. Slagle	
		forecaster	Range 17B (GGU)		$72,392	0.58	$41,987	N. Slagle	
		intern (hourly, no benefits)	Range 12, college intern IV	$17		975	$16,575	J. Beedle: $15 per hr plus $2 SBS	975 hours per year
		administrative overhead	15% of personnel costs				$20,858	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$77,937	0.5	$155,874	G. Patz	four operators
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		Temp. flagger	Wage group 56 (hourly)	2	$33.33	50.8	$3,387	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		Forecasters and DOT&PF crew	10	$1,200	$12,000	every 3 years	$4,000	T. Onslow: estimate	avalanche and ammunition safety training
		Forecasters	2	$1,500	$3,000	annually	$3,000	AES; estimate	professional development
Total Annual Operating Budget							**$912,769**		

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Appendix 10: Budget Information Sources

Information Sources	
Alaska Dept. of Administration	Becky Reiche, Southeast Region Contract Office, Division of General Services
	Tanci Mintz, State Facilities Manager, Division of General Services
	Shelly Saviers, Divison of Personnel
Alaska Dept. of Transportation and Public Facilities	Jack Beedle, Engineer/Architect IV, project manager
	Gene Darling, Statewide Equipment Manager
	Greg Patz, SE Region Maintenance and Operations Director
	Nancy Slagle, Administrative Services Director
	Terrence Onslow, Safety and Emergency Support Specialist
	Kerby Wright, Equipment Operator
	Doug Lewis, Equipment Operator
	Reid Bahnson, Equipment Operator
	Brad Bylsma, Equipment Operations Analyst
	Frank Richards, Engineer/Architect IV
Alaska Railroad Corporation	Dave Hamre
Atlas Alaska	Tony (operations manager) or Melody McAllister
BC Ministry of Transportation and Highways (MOTH)	Mike Boissonneault, avalanche specialist
Coastal Helicopters	Jim Wilson
Colorado Avalanche Information Center (CAIC)	Knox Williams, director
	Nick Logan, associate director
	Andy Gleason and Jerry Roberts, Silverton forecasters
	Mark Mueller, Wolf Creek Pass forecaster
	Lee Metzger and Stu Schafer, Loveland/Berthoud forecasters
Colorado Dept. of Transportation	Greg Roth
Northern Communications Company	Motorola pricing
Northwest Avalanche Center (NWAC)	Mark Moore, forecaster
Parks Canada (British Columbia)	Dave Skjonsberg and Bruce McMahon, avalanche specialists
Snowbird Ski Area, Utah	Dean Cardinel, avalanche control
Southeast Alaska Avalanche Center	Bill Glude, director and lead avalanche specialist
U.S. Army	Sue Back
Utah Dept. of Transportation	Liam Fitzgerald

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Appendix 11: Avalanche Dynamics and Impact Loads on Exposed Bridges

Purpose of the Dynamics Analysis

The East Lynn Canal Highway alignment includes three bridges that cross avalanche paths (at Paths ELC028, ELC029, and ELC041), and two bridges on the West Lynn Canal alignment (at Paths WLC007 and WLC008) that are exposed to avalanches. Because bridges are expensive structures that are necessary for the operation of either highway, the design-magnitude[1] avalanche at bridge locations was calculated to determine their exposure to flowing and powder avalanches and the magnitude of the impact and/or stagnation pressures.

Bridges can be designed for avalanche impact loads or structurally protected. The following avalanche-dynamics parameters are necessary to determine pressures (and ultimately the forces) on bridges.

a. The avalanche starting zone[2] size and location and the design-magnitude avalanche stopping position along the path profile;

b. The avalanche speed at the bridge site, which is computed by an avalanche-dynamics modeling procedure after the stopping position is determined;

c. The avalanche flow depth at the bridge site (which determines if the proposed bridge is reached by the flowing or powder design avalanche);

d. The avalanche flowing bulk density;

e. The avalanche impact pressure and/or stagnation pressure[3] at the bridge site.

Procedures Used to Compute these Dynamics Parameters

Determining the Starting and Stopping Positions: The stopping positions for the design-magnitude events were determined by creating an avalanche path profile from the starting zone to sea level. These profiles were constructed from the detailed topography (25-foot contour intervals) provided by DOT&PF. Because all East Lynn Canal paths of concern stop in the water, the actual runout position could not be computed. Therefore, “synthetic” profiles that extended from the edge of the water on slopes of 10% (5.7°) were constructed to calibrate the parameters used in the dynamics model. This slope corresponded to

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[1] *The design-magnitude event has a return period of 100 years for bridges. This estimate of the return period is accurate to the nearest “half order of magnitude,” or to $10^{0.5}$ years. A “100 year return period”, therefore will lie between $10^{1.5}$ and $10^{2.5}$ years (approximately 30 to 300 years). Specifying a higher level of accuracy would not be reliable given the limitations of the database used in this analysis.*

[2] *Steep terrain at the top of the avalanche path where avalanches begin, accelerate and increase in mass; these areas are usually in excess of 30° inclination and discharge snow into the avalanche tracks and runout zones lower in the path.*

[3] *Impact and stagnation pressures are reference pressures rather than design pressures; final design pressures require details about bridge shape and the derived coefficients of drag and lift which are ultimately used to compute drag, lift, and thrust forces.*

typical runout-zone slopes of a large number of major avalanche events documented in coastal regions of Alaska. The stopping positions along these synthetic profiles (the α-angle or average path slope) was then computed based on the steepness of the avalanches above the 10° point (the β-angle) using a statistical regression equation, derived from the databases of Alaska coastal and Southeast region avalanches.

Avalanche Speeds at the Bridge Sites: Avalanche speeds were computed through use of a 3-component, stochastic, avalanche-dynamics model (Perla, et. al. 1984 [with 2001 revisions, unpublished]). This model simulated avalanches along the centerline profile, starting at the top of the path (the starting zone) and stopping at the point determined in the previous step.

Avalanche Flow Depth at the Bridge Site: The cross sectional area (for the denser flowing snow portion of the avalanche) was computed by dividing the computed discharge (in m^3/sec) by the speed (in m/sec). The shape of the cross sectional areas below the bridges, determined from the detailed topographic maps, was then converted to flow depth. This flow depth does not include the impact of the powder-avalanche portion of the flow, which was considered separately.

Avalanche Bulk Density: A density of 200 kg/m^3 was used for the density of the flowing lower core of the avalanche, assuming the design avalanche would consist of dry snow, even at sea level in the coastal climate of Southeast Alaska. Wet-snow avalanches could have densities two to three times greater than those assumed, but speed (which is the most important parameter in computing pressures) would be substantially less than those of the dry-snow avalanches. The powder-avalanche portion, which may extend as much as 100-130 feet (30-40m) above the flowing snow, was assumed to have a density of 10 kg/m^3.

Impact and Stagnation Pressures: Impact pressure from flowing snow and stagnation pressures from the powder avalanche were both computed as follows: $P = \_ \rho V^2$, where ρ = density (200 kg/m^3 flowing, 10 kg/m^3 powder) and V is the computed speed (in meters/sec) at the bridge site. It should be noted that the impact and stagnation pressures are not design pressures. Final design pressures would depend on structure shape, which is currently not known. The impact and stagnation pressures can be used to assess the feasibility of construction.

Additional Factors: Multiple events during a single avalanche season can raise the effective avalanche-running surface and create possible impact with structures at a higher level than snow-free topographic mapping will indicate. The possibility of deep snow deposits from previous avalanches was considered in the analysis.

Results of the Analysis

Figure 12-1 illustrates the various dimensions and parameters at each bridge site. These are:

- H: Clearance range of the bottom of the bridge above the gully
- Hp: Flow height of the powder avalanche (ft & m)
- Hf: Flow height of the flowing avalanche (ft & m)

- Ps: Powder-avalanche stagnation pressure (lbs/ft^2 & kPa)
- Pf: Flowing avalanche impact pressure (lbs/ft^2 & kPa)

The vertical clearance, C, of the bridge *above the avalanche*, if any, is the difference between the height range, H and the flowing or powder-avalanche height (i.e., C = H – Hf or C = H – Hp respectively), for clearances of the flowing and powder avalanche portions.

The following additional comments refer to the analysis and data presented in Table 12-1:

a. The pressures given should not be used for deriving final-design forces until the final bridge shape and clearance above the terrain is determined; both shape and clearance could change loads;

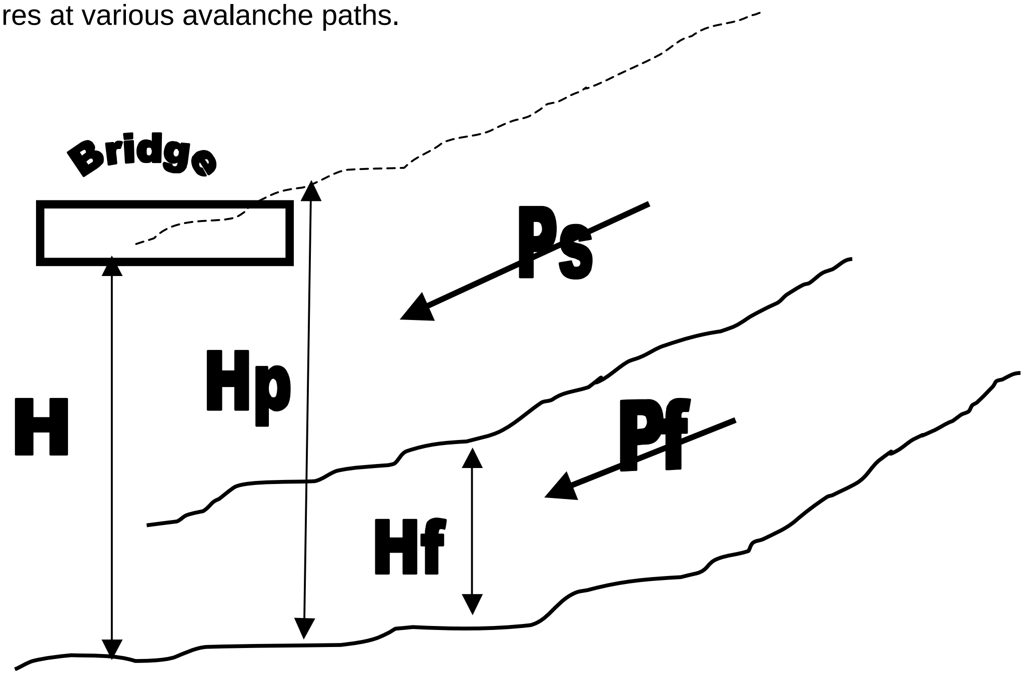
b. Design pressures (Ps or Pf) may also require adjustment by an impact factor, Fi; the final unit loads would therefore be Fi*Ps when exposed to powder avalanches and Fi*Pf when exposed to flowing avalanches; the magnitude of Fi usually is between 1.0 and 2.0 but depends critically on the free period of the bridge and the rise time of the avalanche impact, factors that must be considered in final design.

c. Bridges exposed to powder avalanches will also have vehicles exposed to powder avalanches; when Ps is > or = 80 psf (hurricane-force winds are usually less than 50 psf) they may be capable of pushing (or lifting and pushing) a vehicle off the bridge even if the vehicle is not exposed to the larger flowing-avalanche pressures.

Table 12-1: Avalanche Heights and Pressures at Bridge Locations

Path	H	Hp	Hf	Ps	Pf	Comments	Stations
ELC028	55 ft (17m)	98 ft (30m)	44 ft (13m)	119 psf (581kg/m2)	2,382 psf (11,629kg/m2)	A	2305+75
ELC029	20 ft (6m)	131 ft (40m)	57 ft (17m)	101 psf (493kg/m2)	2,015 psf (9,837kg/m2)	B	2323+00
ELC041	43 ft (13m)	0 (0m)	7 ft (2m)	0 (0kg/m2)	2,212 psf (10,799kg/m2)	C	3033+30
WLC007	75 ft (23m)	98 ft (30m)	4 ft (1.2m)	22 psf (107kg/m2)	440 psf (2,148kg/m2)	A	5188+20
WLC008	75 ft (23m)	131 ft (40m)	31 ft (9m)	97 psf (474kg/m2)	1,943 psf (9,486kg/m2)	B	5688+37

Figure 12-1: Schematic drawing showing dimensions and avalanche pressures on bridges that span gullies. H = deck above gully; Hp = powder-avalanche height; Hf = flowing-avalanche height. Refer to Table 12-1 for magnitudes of lengths and pressures at various avalanche paths.



A: Stagnation pressure (Ps) only at driving surface; flowing avalanche pressure (Pf) at exposed piers.

B: *Both* stagnation pressure and flowing-avalanche pressures (Ps & Pf) affect driving surface and exposed piers.

C: Bridge is not currently shown at this location.

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