1165 HSA HB 534

In 1974 an event occurred which caused a sudden increase in avalanche awareness in Alaska. During a large storm cycle, an avalanche occurred on the Thane Road just south of Juneau. Clean-up efforts commenced at once and while plowing debris away from the first avalanche, an operator was caught and killed by a second avalanche. All of this occurred at night in an effort to keep a road open for approximately 30 residents. A ruling that operators would not be allowed to plow avalanche debris at night resulted. This ruling still holds true today.

By 1975 Department of Highways felt that control activities needed to be expanded. Because of the long ranges involved in artillery firing and lack of visibility for visual fire during most storms, it was felt best to use a 105mm recoilless rifle for control work. Negotiations were begun with the U.S. Army and eventually resulted in a cooperative agreement between the State of Alaska; Department of Highways and the U.S. Army to provide for the loan of a 105mm recoilless rifle for avalanche control. It was decided the Department of Highways employees would fire the artillery. This resulted in a general increase in avalanche control activities on the Seward Highway.

Morrow experimented with helicopter bombing in 1975 during a severe avalanche cycle and found it to be quite effective. Occasional use of this method since then has proven it to be very reliable under certain conditions. During the March, 1979 avalanches, helicopter bombing was used almost exclusively with approximately 200 10-pound charges placed in starting zones. This method of control is relatively safe, rapid, and cost-effective.

In February, 1976, the 105mm arrived. From then until today this rifle has been the mainstay of the avalanche control program and has fired approximately 800 rounds over the last three and one-half years.

Blind fire data was initially taken from the Whiskey Gulch gun mount in 1976 to allow shooting during storms and at night. This still left the majority of Bird Hill without blind fire control capability. In 1976 there was also an explosives handling school at Mt. Alyeska covering many aspects of explosives used in avalanche control, including artillery. The Department of Highways sent two employees to this school.

During the summer of 1978 a significant change in the program took place when Morrow assumed the position as Assistant Manager of Maintenance and Operations, leaving Larry Lucas directing the avalanche control work. Lucas carried the program through the severe avalanche cycle of March, 1979 (personal conversations with Jack Morrow October 1979).

Since the opening of the Seward Highway in 1952 there has been a constant and severe avalanche threat to vehicles using this major transportation corridor. Avalanche control programs established to date have responded to the threat in a sporadic and irregular manner. There was a period of only three years, 1959-1962, where full-time personnel were funded to work on research and control. Since 1969 control efforts have been expanding slowly, but have not made the transition to a full-scale, line item in any government budget. Inevitable gaps have occurred where protection of the public was compromised because of a lack of funding, manpower, and equipment.

Case History

Modern avalanche control is based on several important precepts, one of which is the threat of personal injury or death can be controlled to a large degree. Safety and economics will sooner or later necessitate active control programs to avoid loss of life and revenue. With this in mind, it would be worth documenting a situation that graphically portrays these concepts.

January of 1979 saw the Chugach Mountains covered with a 4 to 8-foot snowpack, seemingly stable for the most part. Temperatures had been moderate all winter, consequently, the snowpack was stable until the end of the month when a light freezing rain fell over the area. This rain froze forming a thin ice crust. A six-week period of very cold weather followed, allowing Temperature Gradient Metamorphism[1] just underneath the thin ice crust.

A series of snow storms hit the area March 4 and continued until March 22. During this period, at the 3,000 foot level on Mt. Alyeska, there was a total snowfall of 171 inches, which equated to 20.41 inches of water. Picture this amount of weight on an extremely fragile layer and steep slopes - the results were obvious and predictable.

Avalanches started immediately; growing in size and occurring frequently until the end of the storm. Artificial release of avalanches started on the 14th and continued until the 26th of March. During that time a lack of blind fire capabilities curtailed control activities on Bird Hill. As a result, there was considerable accumulation of snow. On March 19th avalanches started hitting the road. The next week many avalanches released on the highway with the situation reaching a climax level on the afternoon of March 23rd. Four large natural avalanches ran within fifteen minutes of each other, covering the road an average of 15 feet deep for nearly one mile. Figure 1-2 shows the approximate area of one of the natural avalanches and Figure 1-3 shows heavy machinery clearing avalanche debris.

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[1]Temperature Gradient Metamorphism - The ground is near 32°F. for the entire winter. The presence of cold air on a shallow snowpack creates a steep temperature gradient between ground level and air. Warm air rises slowly through the snowpack bringing with it water vapor that has changed directly from a solid (snow) to a gas (water vapor). This process is called <u>sublimation</u>. Water vapor then condenses onto snow crystals higher in the snowpack in such a manner that the new crystals present the maximum surface area possible in an effort to lose heat. The end result is a large grained, loosley bonded crystal commonly referred to as depth hoar. For this report all references to this process will be referred to as T.G. metamorphism.

HOTO COURTESY OF LEWIS LEONARD

FIGURE 1-2

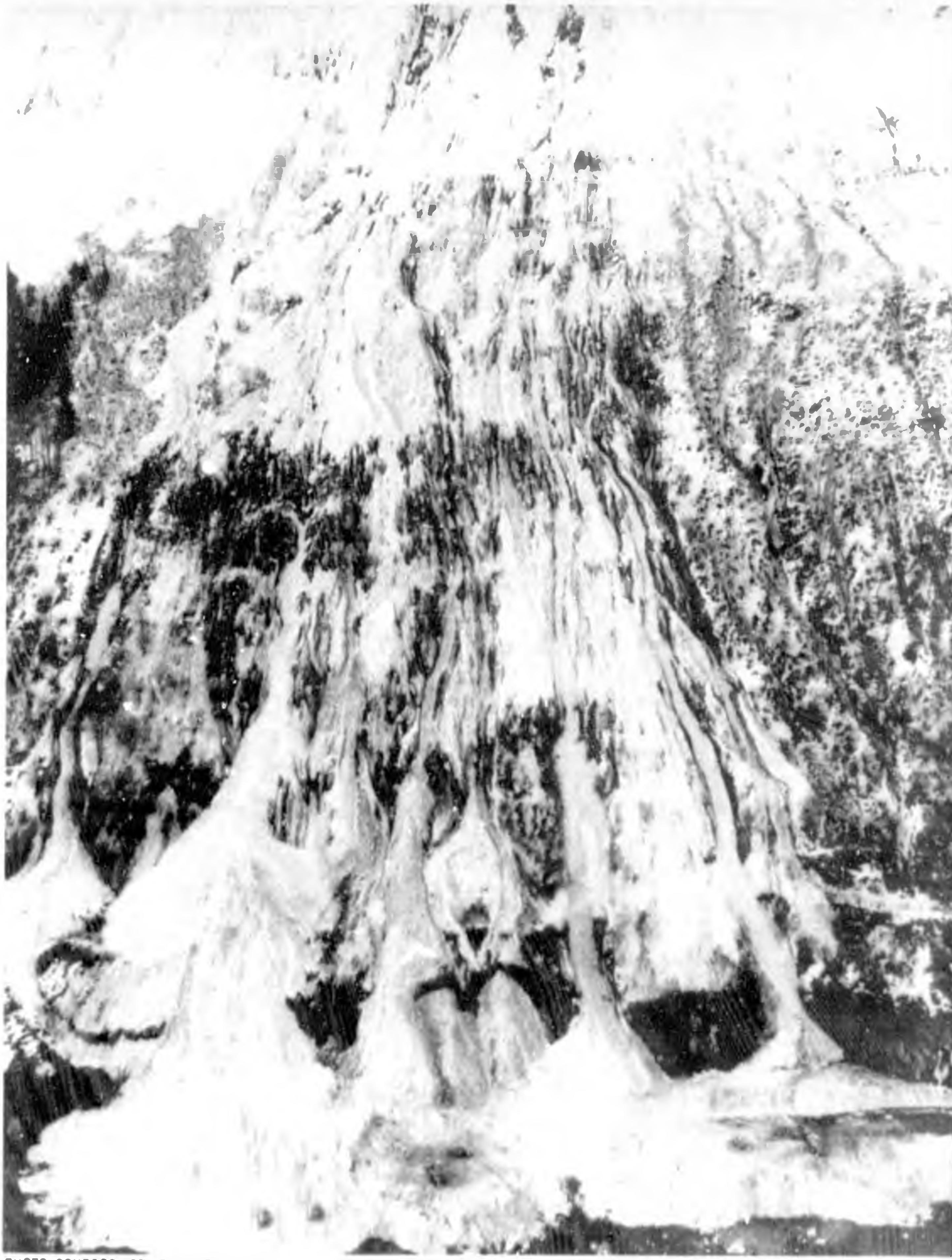


PHOTO COURTESY OF LEWIS LEONARD

FIGURE 1-3

The road was open, but fortunately there were construction activities at Potter and traffic was detained several hours. Had avalanches occurred later that day, there would certainly have been a steady flow of traffic and the outcome would have been catastrophic. Once the highway was blocked by the first natural avalanche, traffic would have backed up bumper to bumper in very short order and additional avalanche activity would have virtually inundated the roadway burying hundreds of people. The magnitude of the avalanches were such that there would have been few survivors. The first premise of avalanche control is that these situations are avoidable for the most part. This particular situation could have been avoided with an adequate avalanche control program.

For two days after the large natural releases of Friday, March 23, control activities continued to bring down more avalanches, resulting in a total of 1.6 miles of avalanche debris along the highway. An almost continuous daytime effort to open the road resulted in the removal of all debris by Sunday afternoon. Not all costs tied to these problems can be determined. There are some figures for parts of the affected operations; snow removal and avalanche control cost DOT/PF $60,000, Alyeska Resort lost $60,000 in revenue, the Alaska Railroad did not run for two days, truck transport ceased between the Kenai Peninsula and Anchorage, and electrical transmission lines were damaged.

Had control activities occurred on a regular basis during this severe storm the result would have been that numerous smaller avalanche releases would have occurred with far less debris reaching the road, fewer possibilities for the loss of life, less damage to facilities, and a much smaller economic impact.

Traffic Volume

Annual Average Daily Traffic (AADT), Fig. 1-4 has increased from 775 vehicles per day in 1959, to 3,503 vehicles per day in 1978 at Potter Flats, just outside of Anchorage. Monthly Average Daily Traffic (MADT) for the winter of 1977-1978 ranged from 1,769 vehicles in December, 1977 to 3,795 vehicles in April,

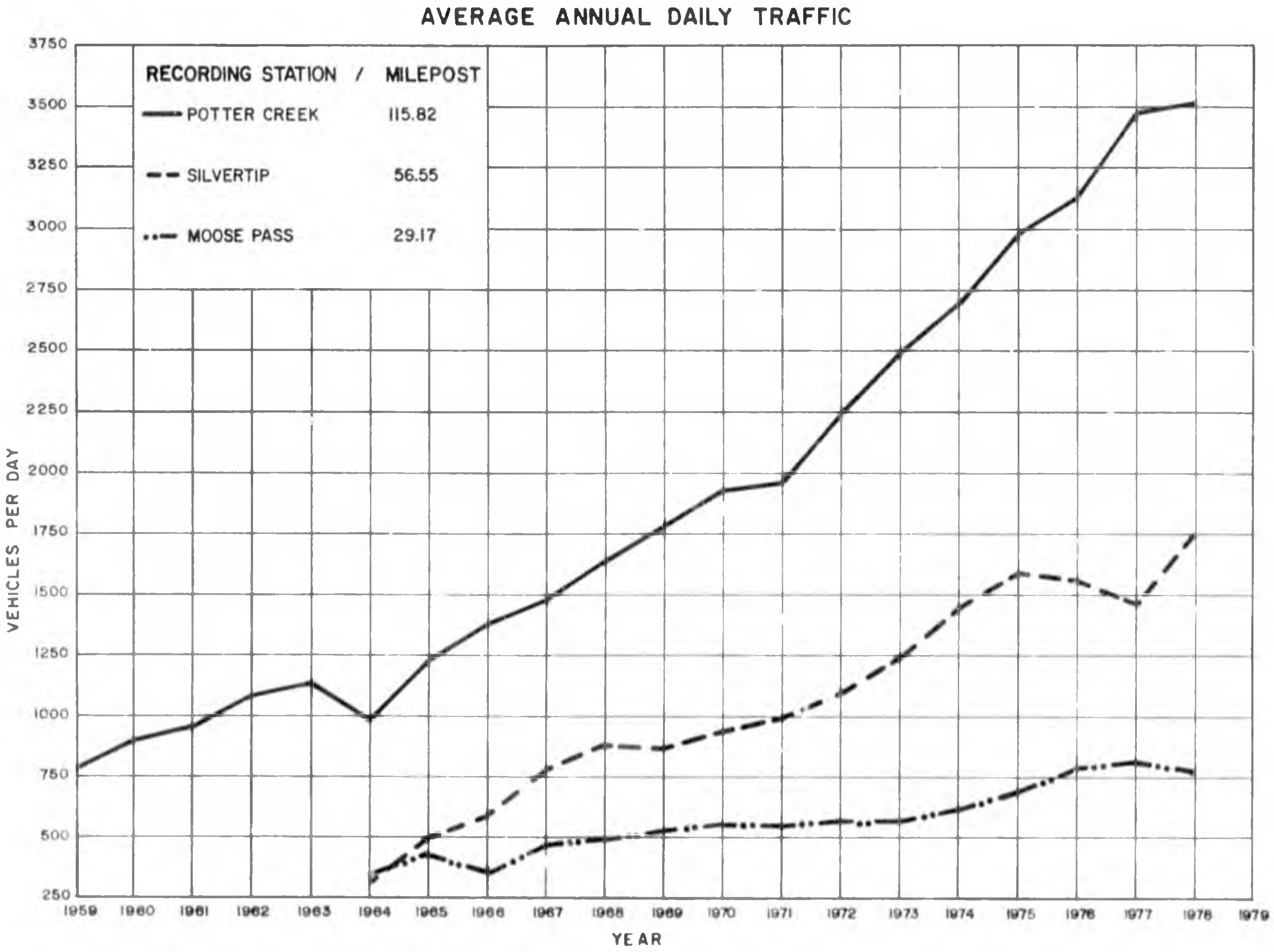

AVERAGE ANNUAL DAILY TRAFFIC
RECORDING STATION / MILEPOST
POTTER CREEK 115.82
SILVERTIP 56.55
MOOSE PASS 29.17
VEHICLES PER DAY
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
YEAR

FIGURE 1-4

1978. Peak traffic periods, occurring on weekends, are roughly 50% greater than the MADT (DOT/PF, Traffic Records 1976, 1977 1978).

This is only an average. Peak volumes must be considered in order to understand the probability of an avalanche interfering with traffic. On April 2, 1978, during the height of the avalanche season, there were 8,145 vehicles counted at Potter Creek. By statistical computation, it can be assumed that an unexpected avalanche on the highway to a width of 950 feet would have collided with traffic on that day. As traffic volumes increase, the odds grow proportionately that traffic will be affected by an avalanche.

These are the reasons for the preparation of this avalanche control plan. This plan is intended to provide a basis of information for the implementation of a control program. This is by no means a solution for all situations that will be encountered in day-to-day activities. Flexibility, responsiveness, training, and experience will allow this information to be utilized to its fullest advantage in the establishment of a full-time avalanche control program for the Seward Highway.

Chapter II

OPERATIONAL CONSIDERATIONS FOR AVALANCHE FORECASTING AND CONTROL

Avalanche forecasting and control has become a fairly exact process in several areas of the country. In these areas many years accumulation of data and knowledge among seasoned forecasters has resulted in programs which operate within small margins of error.

Forecasting and control activities go hand in hand and cannot be separated in an assignment of responsibilities. Some forecasting judgments are based upon results of control work, and control work is done on the basis of a forecast. It is quite common for a forecast to be revised during control operations because of unexpected activity or lack of activity.

There are some considerations in the operation of the more intensive control programs that need mention. When artillery control is used it should release avalanches most of the time. Efficient closures and resultant scheduling of the control operation will help keep public sentiment towards the operation on a positive note. Timing of the control operations should be done to achieve the best results, particularly if there is a severe instability, however, traffic flow will have to be considered, to a certain degree, in this timing. Avalanches could trap several thousand people at Alyeska on a heavy traffic day. These are just examples, but are representative of some of the considerations used in other control programs and is noteworthy in this situation.

A plan such as this can, at best, provide a solid basis of information for the implementation of a full-time control program. It has taken fifteen to twenty year in areas with comparable problems to amass the data and experience necessary to run a sophisticated program. These areas have also been fortunate in attracting and keeping some of the finest people in the business today. Without this continuity of personnel much of the inituitive knowledge acquired in day-to-day operations is lost. This intuitive knowledge is perhaps the most important factor in the forecasting and control operation. It is extremely difficult for even the most competent forecasters to say why they do the activities necessary at the times they are done. There is usually good input from various objective parameters such as wind speed and direction, precipitation, and snowpack analysis, but there seems to be strong input from recollections of a similar storm years ago, or the distance a particular avalanche travelled, or an observation thought to be insignificant a few days earlier. This is the kind of information that is lost by shuffling personnel regularly and is probably every bit as important as the objective data gained and recorded.

There is no set procedure for running an avalanche forecasting and control program. Snow and weather conditions change constantly and as a consequence the flexibility of the program must be maintained to have the ability to re   nd to problems as conditions dictate. No plan can encompass al. the potential problems and this plan specifically avoids doing that.

There are some specific limitations to the set-up of this control program. These various topics are discussed below:

Limitations to Controllability

Occasional conditions occur which result in widespread, destructive avalanching commonly referred to as climax avalanches. These occur as extreme avalanches with longer than thirty years average return interval. Vegetation along the Seward Highway is relatively sparse due to climate factors and for the most part does not present much resistance to large avalanches. For this reason it is entirely possible that over a long period of time there will be climax avalanches occurring, opening new avalanche paths. Several areas along the highway present evidence of vegetation damage indicating that this has occurred. This plan does not include all potential locations where this can occur, but an attempt was made to identify some of them. These are listed in the avalanche mapping by a slide path number (Chapter VI). It has been noted that a common misconception is that control work eliminates the possibility of these climax avalanches. While it is true that control work can reduce the effect of these widespread avalanches a good proportion of the time, there will always be conditions occurring that are resistant to the shock of artillery explosions, but react to other disruptive factors such as rapid accumulation of new snow.

Uncontrolled Avalanche Paths

Attempts were made in this study to locate gun positions that would effectively control all avalanche release zones. For the most part this was accomplished leaving some exceptions.

Until all of the fixed mounts are installed there will be problems in blind firing at certain avalanche paths. The U.S. Army should be contacted this winter to aid in setting up a means of using the mobile gun truck in conjunction with predetermined marks on the highway pavement and triangulation stakes for blind fire. This should be done at all locations requiring blind fire data (these locations are explained under Control Criteria) and at as many locations not specifically requiring blind fire data as time will allow. Eventually blind fire data should be accomplished on all avalanche paths, however, this will take a considerable amount of time.

Before Gun No. 3 is emplaced Slide Path (SP) 15 cannot be controlled effectively without considerable risk to the gun crew.

Without this mount the only means of firing on this release zone is from the highway immediately underneath the runout zone of the area being controlled.

On the Rocky Creek slide path (SP93) there are three large basins that constitute the release zone. Any of these three basins can independently reach the roadway. When emplaced, Gun No. 7 will be capable of firing on the north facing wall of the central basin; and there is a location 200 yards north of SP93 that the mobile gun truck could be used to fire on the south facing wall of the central basin. This still leaves an area approximately one-half mile across facing west that cannot be controlled from any position due to terrain features. Gun No. 8 controls the north and south basins. This area in the central basin could reach the road by itself so considerable care will have to be given to forecasting in this location.

SP1A cannot be controlled due to terrain features. Helicopter bombing can be used on any of these paths under favorable conditions, but is not reliable as the sole means of control.

Selection of Control Criteria

In order to establish a priority level for dealing with the avalanche paths on the highway, they were delineated into four different classifications: Infrequent or Frequent occurrence with an approximate return interval of three years dividing the two; and High or Low hazard according to the relative degree of hazard to a vehicle.

THIS CLASSIFICATION IS STRICTLY FOR PURPOSES OF ESTABLISHING CONTROL PRIORITIES AND DOES NOT IMPLY THAT HAZARD DOES NOT EXIST IN A LOW HAZARD AREA.

In low hazard areas avalanches usually occur infrequently, there are terrain features that somewhat buffer impact from avalanches, or the area is on the edge of maximum vegetation damage or run-out distance. The high hazard areas commonly have a run-out into water, or there is a steep bluff, bank, or cliff above which assures maximum impact to a vehicle.

Frequent Return Interval, High Hazard

Fixed mounts are recommended for firing on these paths. This will allow very accurate blind fire data to be taken for control work to be done at any time of the day or night. Guns for these fixed mounts should be brought in by a gun truck when control is needed. This has an obvious drawback in that avalanches can occur which prevent movement of artillery for control work. There may be a problem with security on the highway and therefore guns cannot be left on the platforms. Gun Position No. 2 is the exception to this if regulations will allow for a permanent storage facility and gun emplacement at a reasonable distance from the highway and public view. These fixed mounts are:

Gun Position No.	Type Weapon	Milepost
1	105 RR	99
2	105 How or 75 How	96
3	105 RR	92.7
4	105 RR	90.8
5	105 RR	44
7	105 RR	22.6
8	105 RR	20.5

RR - Recoilless Rifle; How - Howitzer

The availability of weaponry will determine the type and location of the No. 2 mount. This mount is extremely important for it controls the highest hazard area of the highway, Bird Hill, in such a manner that weapons do not have to be moved across the three miles of continuous avalanche path on the Hill. It provides the mechanism to assure control activities on this section even in the most severe storm cycles.

Frequent Return, Low Hazard

An additional mount in conjunction with the previous ones cover these paths from the following location:

Gun Position No.	Type Weapon	Type Mount	Milepost
6	105 RR	Fixed	37.4 (see attached gun position sheet)

Infrequent Return, High Hazard

These paths are covered by previously mentioned mounts or are controlled during visual fire conditions. Pavement marks and blind fire data should be acquired as time permits, but on a lower priority than the previous classifications. Some of these paths will present a significant hazard during large storm cycles.

Infrequent Return, Low Hazard

These can usually be controlled by visual firing. There may be paths that the lead forecaster requires artillery control on during storms, therefore, blind fire marks on the pavement and data can be acquired. By firing on these paths after large storms the control crews should be able to accomplish releases, reducing the volume of snow in the starting zone sufficient enough that hazards to the road will be reduced, if not controlled, for the remainder of the winter.

Following are some topics pertinent to the forecasting and control program.

Avalanche Forecasting and Control Office

A central office for the collection of information and dissemination of forecasts, control activities, and all related work needs to be established. This should be somewhere in the vicinity of Bird Hill, hopefully at the location of Gun No 2. This would not only provide for security of the gun, but would allow control work to be accomplished through the most critical section of the highway regardless of avalanche conditions. Due to the fact that the entire Bird Hill section is subject to some degree of avalanche hazard, moving control equipment through this area would be very hazardous during critical periods. By stationing a gun crew and equipment in Girdwood, and maintaining the forecasting office near Bird Point and Gun Position Nos. 1 and 2, the possibility of running into a situation where plowing cannot be accomplished because of a lack of control, and control cannot be accomplished because of a lack of plowing, is sufficiently reduced. The siting of Gun No. 2, which is dependent on the type of weapon available, will probably determine the location of this office.

Living quarters could be built to allow for 24-hour coverage. This set-up will allow for continual control activities to take place on the most hazardous section of the highway, security of the weapons and ammunition, and a rapid response to a rescue call-out. Any reference to this headquarters will hereafter be termed S.H.A. (Seward Highway Avalanche) forecast office.

Staffing Requirements

A minimum of five persons should be hired to cover the full-time staffing requirements; including a lead forecaster to coordinate the program, two assistant forecasters and two gunners. These people would probably need to work for nine months, seven months, and six months a year, respectively. This arrangement would have to be augmented by the use of two assistant gunners on an on-call basis. There is a large quantity of data that needs to be gathered to have a sophisticated forecasting system. Much of this is gathered on a daily basis, but more is acquired on a regular schedule by field observations. These field trips must include two people for safety purposes. The forecast office must be staffed by at least one person on a 24-hour basis. Considering the necessity for time off and field observations, any less than five people full-time for the avalanche season would be compromising the integrity of the system. Since all facilities will not be built this year there may not be need for all of the projected positions to be filled. It may be more advantageous to wait until well-qualified personnel are available than to move too hastily to fill key positions with personnel not fully qualified.

Hazard to Highway Maintenance and Avalanche Control Crews

Hazards to these people are very high because of the long periods of exposure in avalanche run-out zones. More than ten miles of roadway between SP1 and SP97 is capable of being buried by avalanche activity. This leaves a one-in-eight chance of being in an avalanche path along this part of the roadway. Add to this the amount of time spent clearing avalanche debris by stationary equipment and the exposure level becomes critical. Some of this exposure is part of the job and a certain amount of risk is accepted. The rest of this exposure must be relieved by the control program. There can be no hard and fast rules applied to this situation, but procedures can be forged by a time-tested and proven control program. This is where the importance of establishing a team of professionals on both crews is evident. Well-qualified and trained personnel are indispensible to an operation of this nature.

A few simple guidelines will help lower the risk factor. A three-level personnel warning system could be initiated and posted in strategic locations. In order to identify hazard they would be white (low hazard), yellow (moderate hazard), and red (high hazard). A sample sheet from British Columbia containing the information to be included in a red hazard sheet is contained in the following page. During periods requiring display of the yellow or red sheet, crews should not move through hazard zones without making the forecasting office aware of its objectives. There should always be an avalanche watch posted when crews are clearing debris. This watch must have a fool-proof method of warning crews should the need arise. All crews should wear functioning electronic locators during yellow and red hazard periods. Light rescue equipment such as collapsible probes and a shovel should be carried on all vehicles operating through avalanche zones. Radios are needed in all equipment.

HIGH
AVALANCHE HAZARD

Date:
Time:

Snowpack: Special layers ______________________

____

Temperatures ______________________

____

____

____

Weather: New snow ________ inch ________

Storm snow ________ inch ________

Temperature: Maximum ________ °F ________

Minimum ________ °F ________

Present ________ °F ________

Wind: Speed ________ m/hr ________

Direction ______________________

Avalanche Occurrences:
(Slope tests) ______________________

____

____

Stability of snow: ______________________

____

____

Hazard to Highways: ______________________

____

____

Weather Forecast: ______________________

____

____

Hazard Prognosis: ______________________

Avalanche Control: Road Closu.e at ________ hours
Control begins at ________ hours
Order of gun positions ________

Plowing Avalanche Debris at Night

This plan specifically avoids encouraging or discouraging the practice of plowing avalanche debris at night. Control work or closure will be necessary at night, therefore, without debris removal the road would remain closed all night. On the other hand, the avalanche watch will probably be unable to see an impending avalanche, thereby reducing the safety margin for the crew.

Plowing at night is an accepted practice at Roger's Pass, B.C. where a high level of integrity in a difficult situation has been maintained for a number of years in the forecasting and control operation.

Coordination with the Alaska Railroad

The Alaska Railroad runs parallel to the Seward Highway from Anchorage to Portage and again around Kenai Lake. The same avalanche paths that threaten the highway create a hazard to the railroad.

This would not be a major problem if not for the fact that the railroad has numerous operational contingencies they are required to follow which inhibit the timing of avalanche control operations on the highway. When a rail barge arrives in Whittier it must be off-loaded at the high tide. The train must then make the passage to Anchorage in less than eight hours, including barge off-load time, or it is left sitting.

Union regulations are cited as being the cause for such a situation. If avalanche control operations delay the train the DOT/PF could be charged for expenses incurred. This plan does not encompass any operational consideration for this as there is no way of knowing what working relationship can be established.

Weather in Avalanche Formation

Climate patterns in Southcentral Alaska vary radically in a relatively short distance. (Figure 2-1). Take for example the difference in annual precipitation between Whittier (175 in./yr.)

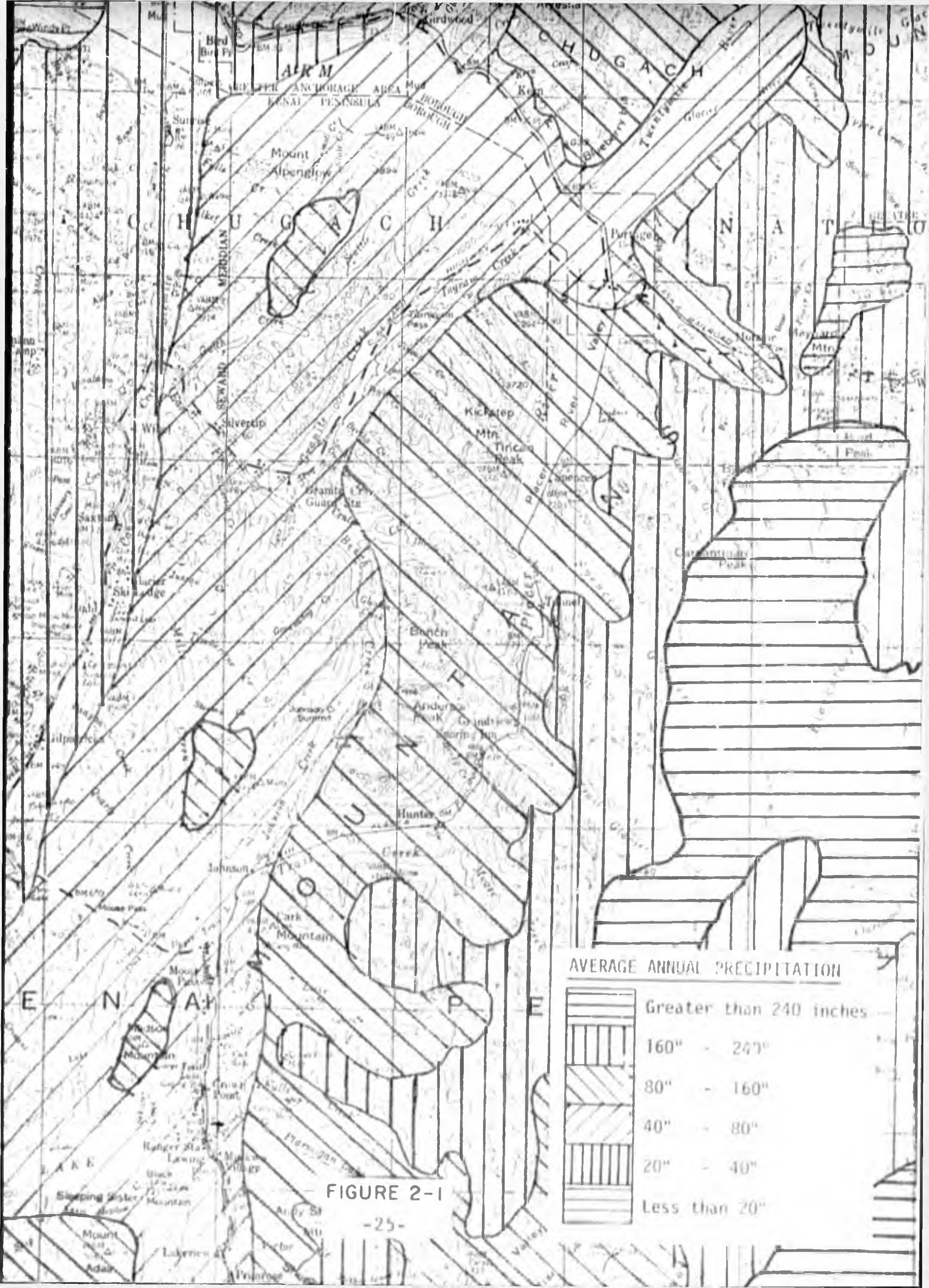
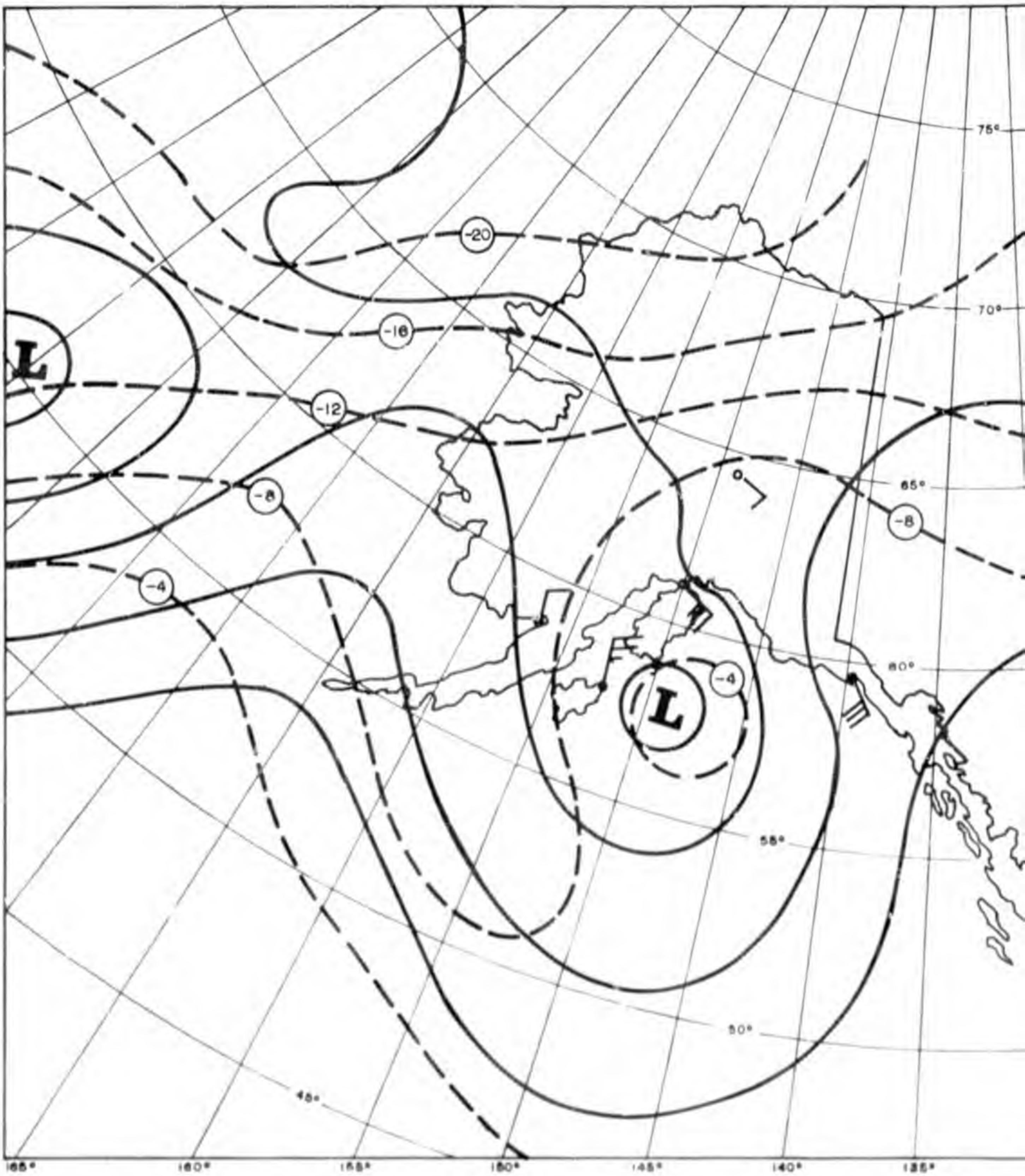
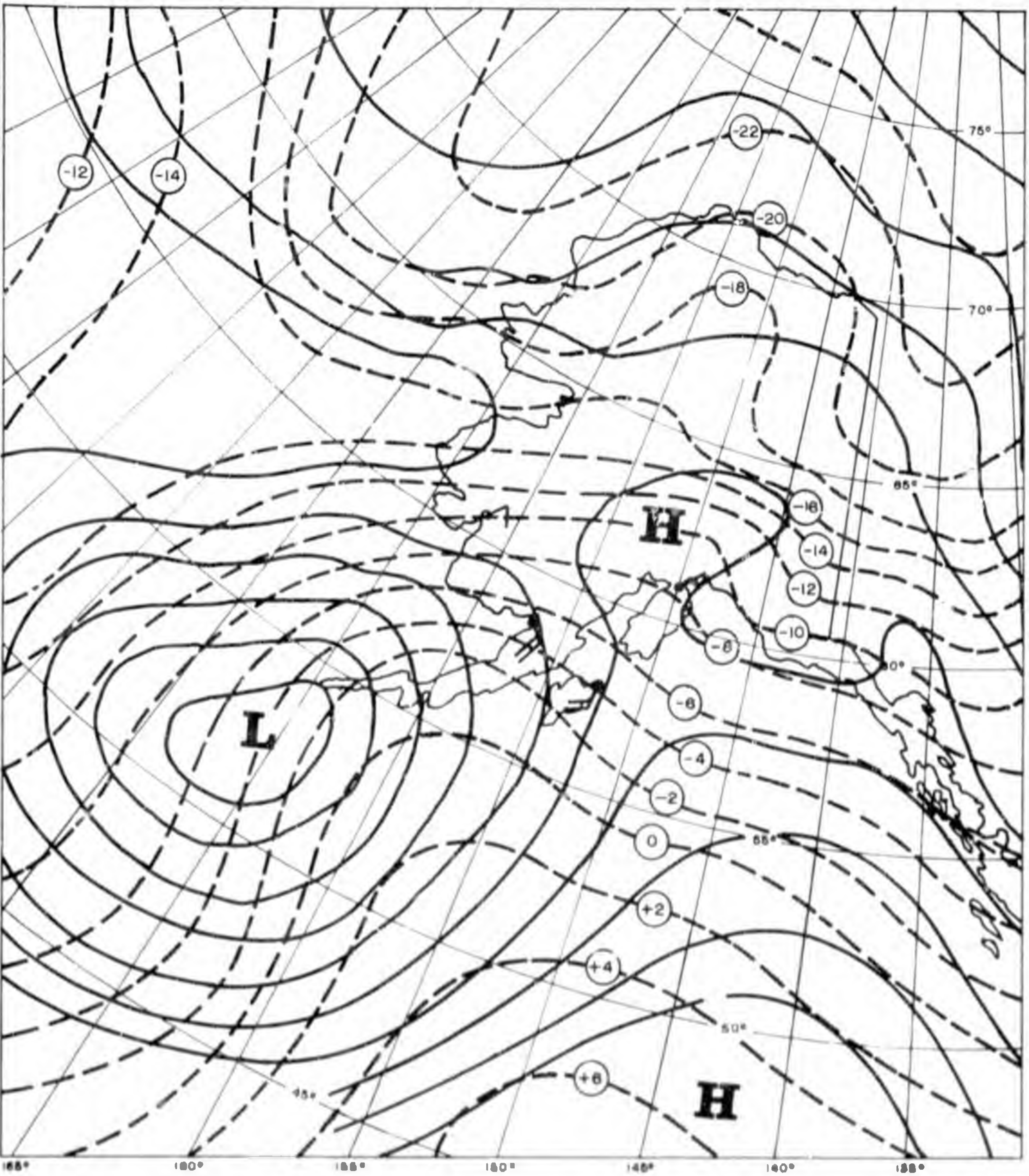

AVERAGE ANNUAL PRECIPITATION
Greater than 240 inches
160" - 240"
80" - 160"
40" - 80"
20" - 40"
Less than 20"

FIGURE 2-1



TYPE 1

FIGURE 2-2



TYPE 2

FIGURE 2-3

Collection of a Data Base

There are probably numerous records related to avalanche problems on the highway; considerable data was collected from 1958 to 1963, however, somehow misplaced or lost over the years. All of these records need to be acquired and assimilated into existing data. Future climate studies should take place to aid in forecasting. Specifically, this would include water content survey in all avalanche release zones this coming March (1980) to establish a set of parameters to judge storm accumulation in starting zones using the base level observations. Snowpack and water content observations can be gathered at various levels in the area to aid in establishing an idea of the relative difference in precipitation caused by local orographics. Combining this information with 850mb air flow patterns would be helpful for the development of an overall view of the orographical effects in the entire Chugach Range.

Chapter III

AVALANCHE FORECASTING FOR THE SEWARD HIGHWAY

Successful avalanche hazard forecasting in any area requires a good background in avalanche meteorology. Changes in the weather provide the most accurate warning as to when and where avalanches are likely to occur. With current technology, it is possible to directly observe subtle changes in the snowpack that signal the onset of failure and avalanche release. Avalanche workers are not required to have a knowledge of weather forecasting, however, they must be able to communicate with meteorologists at the National Weather Service. Avalanche workers are supplied with a forecast, and in return, supply the meteorologists with data to improve forecasts. This exchange works best when avalanche workers and meteorologists are familiar with one another's work.

Storm Watch and Analysis

It is a known fact that the vast majority of avalanches release during or shortly after storm periods. In this text, the term "storm period" is used in its broadest sense to include periods of snowfall, snow transport, or both. Each storm is a unique combination of meteorological variables. The combinations are almost infinite. Meteorological data cannot be gathered at every avalanche path of interest, therefore, for practical reasons, wind, precipitation, temperature, etc., are measured at strategic locations.

There are two broad categories in storm trends -- the standard trends and inverted trends. In the standard trends, initial storm temperatures are relatively high and temperature falls as the storm progresses. In the inverted trend, the initial temperatures are relatively cold and temperature rises as the storm progresses. There are times when, for instance, a northwesterly flow will hover over the Anchorage area and predominate through to the Turnagain Pass area producing a cold cap over that region. Precipitation, in the form of snow, is possible during this time. This is a storm in the standard trend. It is common in the Seward area for a heavy low front to move in with a southeasterly air flow. The end result is a storm in the inverted trend. These two situations would produce a different set of circumstances for the forecaster's consideration, both in areas of snow build-up and in the stability factor of the snow itself. This points out the need for good meteorological avalanche data from two or three strategic sites along the Seward Highway.

Stability Evaluation

Stability evaluations are based on six different categories of information. These include quantitative meteorological measurements, such as study plot precipitation and ridge crest winds, as well as such qualitative observations as explosive tests, test skiing, and visual observations of avalanche path loading. Several categories require close liaison between the control team and the person who makes the evaluation. At most of the sites, stability evaluation for a slope must be based on knowledge of recent avalanche activity on the nearby slopes.

The location of the Mt. Alyeska ski area is certainly a boon to the Seward Highway Safety Program. This is where a close working relationship between the Alyeska Avalanche Technician, the

Forest Service Snow Ranger there, and the Seward Highway lead forecaster will be of great and mutual benefit. Stability evaluation and control work are generally performed either by the same team or by teams working in close cooperation. Often stability evaluation and control work are so interlinked that the boundary is not clear. This interlinking is a unique feature of avalanche technology in contrast to the forecasting and control of wildfires, earthquakes, and other natural hazards. Generally, working systems of mountain rangers around the world follow similar lines. An experienced forecaster issues broad directives about the likelihood of instability and, in most cases, supervises the control work. These systems rely almost entirely on human judgment.

Snow Cover Distribution, Current and Past Avalanches

For the most part, these are simple, visual observations, however, they form the basis for the most reliable stability evaluations. Snow cover distribution is determined by direct, visual observation of whether an avalanche path is filled with snow primed for release. To begin with, significant avalanches cannot occur on a path until terrain irregularity such as boulders and brush is covered with snow, and then additional snow is deposited on this smooth foundation. For most paths, this requires about 2-1/2 to 3 feet of snow in the starting zone and track. The exceptions are paths on permanent snow fields, smooth rocks, dirt, grass, etc. where avalanches may run with as little as 6 inches coverage in the starting zone. Normally, the beginning of an avalanche season on a particular slope can be anticipated from visual observations of snow cover amount and distribution and conditions in the starting zone and track. Most of the 68 slide paths along the Seward Highway have good visual observations from the highway.

It is also helpful to statistically correlate the earliest significant avalanche on a given path. Mr. Jack Morrow has compiled a report from his diary which gives valuable information on avalanche occurrence along the Seward Highway from 1968 to 1978. This information is contained in Appendix II. No other specific material is available for this time period for the entire length of the Seward Highway. After the beginning of the avalanche season direct observation continues to provide the most reliable information on snow build-up in the starting zones. Periodic visits by use of helicopter into areas above Bird Hill slide paths should begin on a regular basis since it would allow the forecaster to dig study pits near the actual areas of release. The proposed remote weather site on Bird Hill is an excellent location to be used as a study plot. That location is quite large, flat and the snow depth there would be fairly uniform.

Observation of Slopes with Common Aspects

Loading is sensitive to wind direction so avalanches tend to occur on slopes that have a common aspect. For example, after a storm it may be noted that avalanches or avalanche activity is most intense on south-facing slopes as would be the case on Bird Hill slide paths 1 through 6. South-facing slopes that did not avalanche during the storm should be suspected of instability. In fact, the slide paths beyond Bird Point 7-20 would also be suspect.

Observation of Slopes with Common Elevations

In an area that has a wide range of starting elevations, it may be observed that avalanche activity is confined to a particular elevation zone. For example, the higher zones may be relatively inactive, but serious instability may exist at lower elevations. This phenomenon is usually caused by wind or temperature patterns and could be particularly true on Bird Hill. When avalanche control activities are underway this fact should be kept in mind.

Forecasting Relationship between Frequent and Infrequent Paths

Based on historical data, avalanche paths can be classified according to frequency of occurrence. It is an accepted practice in a control program to defer the stability evaluation of infrequently running paths until the stability conditions of more frequently running paths are known. If frequently running paths are moderately unstable, instability can be expected on other paths. Conversely, if frequently running paths are stable, it is usually possible to evaluate the stability of infrequently running paths.

Thaw Warnings

As spring approaches, free water will accumulate within the snowpack. Many small, wet avalanches will appear in loose snow or wet slab to give ample warning that wet avalanches of increasing size can be expected. Explosives are often not an effective tool when attempting to trigger this type of avalanche. A useful remedy is to close off the area of concern during the warmest part of the day.

Snowpack Structure

During storms the forecaster keeps track of storm parameters. Between storms the forecaster has time to investigate the conditions of the deeper snowpack. This could be accomplished at the remote weather site on Bird Hill. Diagnosis of snowpack structure involves searching for weak layers; some kinds of weak layers that are definitely correlated with instability are those that contain TG grains, loose cold snow, surface hoar, graupel, radiation crystals, weak recrystalized grains, or wet snow.

Local Meteorological Data

Field observations of snow build-up on or near avalanche release zones are not often feasible because of weather. When conditions are especially critical, it is rarely possible to tour release zones of high elevation paths that threaten highways. Therefore, it is necessary to rely heavily on meteorology study plots, precipitation measurements and ridge top wind measurements. The requirement for catastrophic snow failure is rapid loading to a critical level Thus, the basic problem in making stability evaluations from meteorological measurements is to infer from the study plot and ridge top wind data whether the rate of loading and total load are approaching critical levels in the avalanche paths in question. The simplest way to use the numerical data furnished by instruments is to identify for each path or group of paths the following critical conditions: (1) wind directions that load the paths in question, (2) wind speed requirement for leeslope loading, (3) critical precipitation intensity, (4) critical total water equivalent. Each storm is monitored and analyzed. The slopes in question are evaluated as unstable when the four critical conditions mentioned above are satisfied simultaneously. The critical level of the four conditions for each path or group of paths is derived from at least three to five years of records of meteorological measurements and avalanche conditions. New data is used continually to improve awareness of critical conditions. The success of this method depends on careful record keeping of meteorological and avalanche observations. For avalanche problems in general, the importance of good records cannot be overemphasized.

Meteorological measurements are useful for evaluating wet snow instability. The important variables to monitor, at least qualitatively, are rainfall, radiation and air temperature. Heavy rain causes wet snow instability by adding weight, decreasing cohesion in the surface layer and lubricating a potential sliding surface. The amount of rain required for instability depends on the temperature of the top layers of the snowpack. If these layers are near zero centigrade before the rain, relatively little rain can cause avalanches. Cold snowpacks have a high capacity for absorbing rain. Wet snow instability grows more intense from mid-afternoon on, shortly after solar radiation reaches its peak. The melting process accelerates because wet snow absorbs far more solar radiation than dry snow, therefore the onset of wet snow instability may seem to occur rapidly. Usually wet snow instability is confined to the most recently deposited layers, to a depth of about three feet. Prolonged thawing occasionally triggers deeper or even full depth slabs. These deep, wet slabs may release any time during a prolonged thaw. As mentioned earlier, explosives seem to have little effect in activating wet avalanches; they release when ready.

Air temperature trends are known to correlate with slab stability. Rising air temperature during a storm is considered an unstable trend because heavy snow is being deposited on lighter snow. This trend would be true more often than not along the Seward Highway. Falling air temperature is considered a stable trend. This was mentioned earlier in this report as standard storm trends and inverted trends, an important factor for the forecaster to be aware of along the Seward Highway slide paths.

National Weather Service Data

The National Weather Service may assist the forecaster by providing data on wind, temperature, and humidity at the upper levels. Short-term forecasts are provided to guide immediate control decisions and extended forecasts for operational planning. Balloon wind data supplements local measurements for estimating the avalanche path loading in a large region. When local wind instruments are rendered inoperative by rime, lightning, or some other cause, balloon wind measurements must be used as a backup. Weather service personnel should, without a great deal of effort, be able to supply the raw balloon data to the avalanche forecaster. However interpreting the data and issuing forecasts for specific avalanche areas requires some effort and time on the part of the Weather Service and a reciprocal effort by the avalanche forecaster. It is easy to understand that interpretations and forecasts of small scale or local weather are inaccurate.

Forecasting mountain weather is especially complex. Nevertheless, with existing physical models, reporting networks and experience, weather forecasters usually do an effective job of predicting air temperatures, wind speeds and directions and the likelihood of precipitation. Forecasters still have trouble, however, determining the amount of precipitation for mountainous areas. Good communication between the field and the forecast center, especially during storm periods, help forecasters to adjust the precipitation forecasts and, in the long run to improve their forecasting skills. This communication is established first by working through appropriate channels; the avalanche forecaster must determine which weather center is in position to issue special forecasts and exchange information directly.

A pre-season meeting is then set up between the avalanche forecaster and the meteorologist in charge of the designated station. This could involve two stations in different locations when both have input determined valuable to the control effort. A plan for exchanging information should be developed. There will no doubt be need for renewal and improvement each year. Routine communication should involve telephone, radio, or teletype. A direct telephone link to the forecast center would seem most logical and limit operational problems. Unlisted telephone numbers which insure prompt service may be obtained, if agreed to by the meteorologist.

It may help for Weather Service personnel to visit the avalanche forecaster's areas of concern and the avalanche forecaster may benefit from inspection of the weather center. Generally, the communication plan should provide for a morning exchange of routine information with updates during emergencies. Each morning, at an established time after the balloon data is available, the avalanche forecaster should phone the Weather Service. The purpose of this call will be to furnish the Weather Service with local weather information following a format set up in a pre-season meeting.

The following types of local information may be useful to the forecaster: present state of weather, present precipitation rate, cloud cover, present temperature, dew point, local wind speed and directions, observed freezing levels, maximum and minimum temperatures during the last twenty-four hours, precipitation rate during the last twenty-four hours, evidence of front passage or other special weather phenomena. Other information that could be communicated by the Weather Service to the public includes, highway conditions, avalanche warnings, possible highway closures for control work and the times work will take place.

In return, the Weather Service may supply the following information to the avalanche forecaster: maximum and minimum forecast temperatures for the next twenty-four hours, expected amount of precipitation in the next twenty-four hours and expected times of precipitation surges, trends in ridge top wind speed and direction, freezing levels, cloud cover, and extended forecast of general weather for the next two days, three days, and seven days. How well the weather forecaster can pinpoint precipitation surges or lulls may depend on his experience and knowledge of local effects. Weather stations often have personnel with special interest in mountain weather, avalanches, skiing, etc. The avalanche forecaster should learn who these people are and work with them during critical periods.

Since weather patterns can differ at times between the Alyeska area and Seward, it would be wise to set up a system or a network of observers. People living in or near areas of concern could provide support by reporting storm progress, taking snow samples for water content and density, monitoring the temperature, cruising the highway in their area, and checking for any kind of instability of the snowpack. Information would then be transmitted to the S.H.A. Forecast Office. Some of these persons could be on a part-time basis-some would be volunteers. As the area of known avalanche activity is vast and the responsibility for forecasting and control so critical, it is recommended there be a lead forecaster and two assistant forecasters. It would be necessary that they live in the area of concern.

Control by Explosives

The strategy of artificially releasing avalanches above highways is intended to produce small avalanches that clear out the track and either stop short of the road or deposit only small loads on the road bed. Ideally, the avalanche should stop just short of the road. Experience demonstrates that it is much more efficient to plow off many small deposits than one very large deposit. Also, the release of many small avalanches in the winter prevents large avalanches from running in the spring thaw. This type of control program is in effect in Little Cottonwood Canyon, Utah, and has proven very effective over the years. In highway control, the release of many small avalanches has a strategic advantage over waiting for one large avalanche.

Hazard forecasters, called upon to blast with artillery, hand charges, etc. must be released from liability before control begins. This may require a civil ordinance delegating authority to perform control on specific slopes for general public welfare, in full understanding of risks and uncertainty of results, since the slide paths could effect something other than the highway itself, such as power lines, railroads or personal property.

Inaccessible avalanche paths over highways are routinely controlled by artillery or helicopter. Of these two principal techniques, artillery is apt to be the more expensive since artillery ammunition combined with the purchase and maintenance of weapons entails a greater expense than hand-thrown charges and the helicopter time. It should be noted that helicopters are limited to favorable weather conditions. Since visibility constraints should not be imposed if control is to be most effective, helicopters are best used in combination with artillery, rather than as a sole technique. The avalauncher is a weapon being widely used now by ski areas throughout the west. This particular weapon has been tested to some extent in Little Cottonwood Canyon, Utah. For the most part, it did not have sufficient accuracy or range. The maximum range is 1400 yards and most shot points in Little Cottonwood Canyon run over 2000 yards. This is also true for most all ranges on shot points along the Seward Highway.

Because range is a problem, most highway control is performed with artillery weapons. Whenever possible, weapons should be fired from fixed mounts that permit accurate indirect aiming during poor visibility. Firing positions should be chosen to minimize avalanche hazard to firing crews. Recoilless rifles and howitzers, 75mm to 105mm, are suitable. Fixed mount locations for the Seward Highway, type of weapons and number of weapons are discussed in another section of this report.

Chapter IV

DESCRIPTION OF ROUTINE FORECASTING AND CONTROL OPERATIONS

Since the Seward Highway crosses 68 slide paths in its distance between Anchorage and Seward, a good cooperative effort among various agencies must be established to provide adequate public safety.

Several agencies will most likely be involved in the operation of a control program. At the time of this writing, a formalized structure of responsibilities and authority have not been established. The following is an attempt to define the roles and responsibilities of various agencies that will most likely be involved. This could change once formal agreements are placed in affect, but it does constitute a general scope of combined responsibilities. Should one of the agencies mentioned below decide against involving themselves with the control program then the outlined work will have to be done by another agency.

Outline of Public and Private Entities Involved in Avalanche Safety on the Seward Highway:

A. U.S. Forest Service; Division of State and Private Forestry
B. Alaska State Department of Transportation and Public Facilities
C. U.S. Weather Service
D. Alaska State Troopers
E. Alaska State Parks; Chugach State Park
F. Private Entities
   1. Alyeska Resort
   2. Summit Lake Lodge
   3. Bird House or Scottish Inn

Summary of Roles, Responsibilities and Authority of Agencies

A. U.S. Forest Service; Division of State and Private Forestry

Responsibility for avalanche forecasting and control has been assumed by the U.S. Forest Service in several areas of the country. This agency has the greatest expertise in dealing with avalanche problems of any public agency.

1. Maintain weather and snowpack records, make daily weather and snowpack observations, consult daily with U.S. Weather Service in Anchorage, and prepare avalanche forecasts on a site specific basis for the Seward Highway.
2. Recommend road closures for DOT/PF based on hazard forecasts; advise DOT/PF of weather, snow, and avalanche conditions.
3. Supervise and implement avalanche control activities including use of artillery and helicopter borne explosives on starting zone targets above the highway.
4. Via the S.H.A. Forecast Office, keep other agencies and the general public informed with regard to weather and avalanche conditions, timetables of impending road closures and openings, and give status of on-going avalanche work.
5. At the request of the Alaska State Troopers, or in their absence, provide leadership and technical assistance in avalanche searches and rescues.
6. Provide training and supervision necessary for the safety of all personnel involved in avalanche control operations.
7. Procure artillery ordinance from the U.S. Army and supervise its transportation, storage, and use.

B. Alaska Department of Transportation/Public Facilities

The DOT/PF has ultimate responsibility for highway safety, and consequently has final authority to decide road closures and openings necessitated by avalanche hazard.

Specific responsibilities are:

1. Remove snow and avalanche debris from Seward Highway as service priorities permit.
2. Notify other cooperating agencies and the general public of planned road closures or openings; through recorded telephone messages or electronic message boards, keep the general public informed of road conditions and avalanche control activities.
3. Maintain avalanche signing system, avalanche closure gates, and other public warning devices.
4. Participate with the U.S. Forest Service and other agencies to cover the direct cost of avalanche protection on the Seward Highway.

C. U.S. Weather Service

Through its Anchorage office weather forecasts are issued for much of Southcentral Alaska. Due to the extensive area covered by the highway, a reliable exchange of weather information will benefit all agencies and the general public.

1. Issue weather forecasts on a locality specific basis to the S.H.A. Forecast Office.
2. Provide technical assistance for the construction and maintenance of remote weather recording installations.
3. Provide interfacing necessary to establish high-speed data exchange and other related cooperative weather information exchange and recording.

D. Alaska State Troopers

All rescue activities, including avalanche, are under the Troopers jurisdiction.

1. Direct all avalanche rescue in cooperation with U.S. F.S., Division of State and Private Forestry; S.H.A. Forecast Office.
2. Provide communications facilities as needed.
3. Provide hel copter on a cost basis for snow studies work.
4. Respond to emergency situations as requested by the S.H.A. Forecast Office.

E. Chugach State Park

1. Provide permits necessary for forecasting and control activities arks land.
2. Relay avalanche and weather data to S.H.A. Forecast Office.
3. Maintain weather recording facility in Bird Creek.

F. Private Entities

1. Alyeska Resort
   a. Voluntarily relay avalanche and weather data to S.H.A. Forecast Office.
2. Summit Lake Lodge
   a. Voluntarily maintain weather recording facility.
   b. Voluntarily close avalanche gates at Summit Lake in emergency situations.
3. Bird House or Scottish Inn
   a. Voluntarily close avalanche gate at Bird Flat in emergency situations.

The success of an avalanche program on the Seward Highway depends on (1) flexibility of response to changing conditions, (2) cooperation among responsible public and private agencies. The following description of events is entirely hypothetical with regard to times and locations of personnel and equipment.

Night storms. The lead forecaster for the Division of State and Private Forestry, stationed at the S.H.A. Forecast Office, has been on a storm watch during most of the night. The amount of precipitation he has noted since the start of the storm at 10 p.m. is the indicator of the rate of hazard formation and the density an indicator of the nature of snow buildup. He has also been checking the ambient air temperature and wind speed and direction, with this information coming from a remote site on Bird Hill and Andy Simons Mountain above Kenai Lake. The anemometer readings are indicators of specific locations of hazard formation.

At 4 a.m. the hazard forecaster will start his calls; possibly his first call will be to the National Weather Service for another check on the direction of the storm. After he has gathered information from his own [illegible]vations, he may also have received some calls from the part-time observers and volunteers located toward Seward.

He has, by this time, made his evaluation; control is necessary. It would mean control by indirect (blind) fire onto indicator shot points or specific locations of hazard formation. The hazard forecaster's next call, then, would be to the Department of Transportation. The time would be 4:30 a.m., asking for a road closure at 6 a.m. so control work can start at that time at gun position No. 1 firing indicator shot points 102, 107, 116, and gun position No. 2, shot point 204, 206, 212, and 218. Gun position No. 4 might shoot points 404 and 408 if a high hazard exists. The Department of Transportation, after receiving this information from the hazard forecaster, calls the State Troopers, informing them of the road closure. They could possibly ask for assistance in sweeping the highway, making sure no automobiles or pedestrians are in the area and actually close the gates.

Concurrent with the above, the lead forecaster will have to make decisions regarding control activities for the highway south of Girdwood based on field observations from the weather reporting network. Arrangements will need to be made to implement the closures and control work necessary. At this point, the Department of Transportation relays a message to the public through the Weather Service regarding road closure. Gun crews and maintenance crews are dispatched for implementation of control activities and in preparation for clearing of avalanche debris.

After firing the indicator shot points from gun positions #1 and #2, the hazard forecaster makes a quick visual assessment and decides immediately if more control is needed. If hazards show up as extreme, little decision is needed. Full control is implemented. In this case, road closure will have to be extended. If hazard is not extreme the highway will be opened to traffic by 08:30. In this case, more control work could be carried on from 10:00 a.m. to noon, when traffic volume is not increasing. If big avalanches occur in the area of control work, the maintenance crews are there to clear and open the road as soon as possible.

If a moderate hazard exists control work may be deferred until 10 a.m. This allows Girdwood-Anchorage commuters into work and Alyeska skiers to the ski area. There is a drop-off in traffic volume from 10 a.m. to noon, as noted in Appendix I. This is a good time to do major control work as there is continual daylight. DOT/PF does not remove avalanche debris at night. Exact details of control activity timing will have to be worked out as the program becomes operational but this gives some general guidelines for control of night storms.

Day storms. Storms that build a hazard during the day will require a somewhat different tactic. If it is anticipated that a hazardous level will be reached in the late afternoon or evening control activities will have to be timed to allow for clean-up of avalanche debris before dark. This would mean road closure would occur at 1:30 and graduate to a later time as daylight allows during the latter part of February, March, and April. Control activities could commence at 2:00 firing from all gun positions simultaneously to be done with control at 2:20, allowing 40 minutes for avalanche debris removal. If debris is not removed by dark the road will remain closed all night. If it is decided to forego control activities during day storms, a road closure will have to be put into effect sometime during the night. It should be obvious there are many problems with these procedures that can only be worked out after the control program becomes operational.

The lead forecaster and his assistants would collect and record weather, snow cover and avalanche data, analyze all technical data and prepare forecasts of avalanche hazards, order closures for the highway, determine when and where to use artillery or helicopter bombing, conduct avalanche control activities and do research for improving forecasts.

Public Information and Warning. An important part of avalanche hazard control is public information and education, convincing the public that zoning ordinances, ski run closures or highway restrictions are in their best interest. The avalanche worker has much on his side. Avalanches are spectacular and can be portrayed in exciting and convincing presentations via television, radio, newspapers, ski magazines, films, lectures and pamphlets. Besides the general public, some groups that may benefit from avalanche information and education include ski clubs, public utilities crews, state highway crews, ski area operators, snowmobile clubs, rescue organizations, sheriff's departments, state and federal agencies, ski schools, mountaineering clubs, local planning commissions and mining corporations. The more avalanche education for all of the public, the easier it is for the DOT/PF to close the highway for periods of control. The information program should underscore the common sense of avalanche safety.

Chapter V

AVALANCHE RESCUE

In order for a rescue to be successful, the utmost speed must be used in running the operation. Statistically, a victim's chance of being recovered alive falls to less than 50% after one-half hour. In all probability the fact that the victim of a highway avalanche is in their vehicle increases the likelihood of a live rescue and consequent time values, but the half-hour figure does reflect the necessity for speed.

As there is not a large staff of professional rescue people available to the Seward Highway control program, any rescue operations will probably involve a large variety of volunteers, DOT/PF personnel, avalanche control crews, U.S. Forest Service, and State Troopers. The latter has full responsibility for all rescue operations within the state, including avalanche. Cooperative training efforts betweeen the State Troopers, DOT/PF personnel, and the control crews could result in a reasonably efficient response to call-out. Much effort must be put forth to establish communications links, lines of authority, and layout of equipment and manpower for rescue operations in order to have the speed necessary to perform a live rescue.

In the set-up of rescue operations, the ability to utilize personnel immediately adjacent to the affected area is important. Because of the large distances involved, responses will have to come from Girdwood for the Portage-Bird series of avalanche paths, and from Moose Pass for the 19-mile-Summit Lake series. Transportation times involved from any other location, with the exception of Summit Lake itself, will preclude the probability of a live rescue. A net of potential rescuers could be established in each location to accomplish a minimal response time by utilizing the Girdwood Mountain Rescue Group, U.S. Forest Service personnel stationed in Moose Pass, and supplementing these with local volunteers.

Protection of rescue personnel is of the highest priority. It is unacceptable to place severe risks on the large number of people associated with a rescue team. For this reason the lead forecaster should be the person that guides rescue activities, as he is the most qualified to make the critical decisions involved. This is contrary to the mandate of the State Troopers requiring them to run all rescue operations, but cooperative ties can and should be worked out to allow this practice to take place under the direct or indirect supervision of designated troopers. There is a limited number of troopers acquainted with directing an avalanche rescue, therefore, in an effort to eliminate miscommunications, designated troopers should be involved. Local troopers could become trained to perform this function from Girdwood or Moose Pass in conjunction with the base rescue operations in Anchorage.

Guidelines need to be established as to the degree of hazard to which rescue operations can be committed. Each situation will be different and demand individual attention, but a few generalities can be made. Control work may be necessary in order to commit personnel; always a difficult proposition because of the likelihood of worsening the situation of the victims. Avalanche paths with multiple release zones should be dealt with very cautiously as there is a good chance that only part of these areas will have had activity, with the rest of the release zone being very prone to avalanching. Many accidents have occurred during rescues due to this situation. Regeneration of snow deposits in the release zone presents a hazard to long-term rescue. In a case where it seems certain that a vehicle is caught with a high hazard of more avalanches, it could be deemed justifiable to commit a small group of professionals to a rapid search, provided backup manpower is immediately available. This type of decision is extremely difficult to make without a solid background in avalanche forecasting, control, and rescue.

Continual training will be necessary to establish the efficiency of movement necessary for a speedy response. Call-outs should take place several times a year to keep a polished edge on the rescue operation.

Equipment must be purchased and stored at Moose Pass and Girdwood to expedite a call-out. A cache could also be established at Summit Lake to facilitate any problems there, but this would not have to be as extensive as the Level 1 caches at the other two locations. Periodic checks should be made to insure the readiness of this equipment.

Night rescue operations present unique difficulties and hazards. It would be difficult to commit personnel to such a rescue without substantial evidence of vehicle entrapment. Nevertheless, it will be necessary to make arrangements for emergency lighting facilities should the circumstance arise.

Speed and safety are the most important concepts in an avalanche rescue. Training of personnel, cooperative ties among agencies, and use of the most qualified people in decision making can accomplish duality of purpose.

Following is a listing of the positions in the chain of command of a rescue and a description of the responsibilities of each position. A list of necessary equipment follows.

There should be instructions for each phase of the rescue contained in either manila envelopes or binders at various locations. In communications stations these instructions could be centrally located so they could be readily accessible to highway crews and other people involved.

These instructions are:

1. Immediate Action: The first person to learn of an avalanche will probably notify either a government agency in the vicinity or a public facility. Basically, the person receiving this notice should: hold the witness to accompany the search party and sound the general alarm which will notify qualified rescue leaders on a priority basis.

2. Person Receiving General Alarm: The first qualified rescue leader reached by the general alarm proceeds to the nearest communications station and becomes dispatcher unless relieved by a superior in the plan's structure. Contained in this person's instructions is a list of procedures used for the immediate dispatch of columns of rescuers to the scene and a series of follow-up actions.

3. First Column Leader: Instructions for the person appointed by the rescue leader to lead the search column must be available in each avalanche rescue cache, including guidelines for screening volunteers, selecting a safe route to the accident site, and procedures used in searching for the victim. Several methods could be used according to the resources available, including dog search, use of a metal detector, course probing, or use of an electronic locator.

4. Accident Site Commander: Instructions for the person designated by the rescue leader to assume command at the accident site. This may or may not be the hasty search or first colum leader. Organizational guidelines should include organizing probelines, reporting progress to the rescue leader, removing exhausted workers, obtaining medical and transportation assistance, obtaining backup assistance, and terminating rescue operations.

5. Column Leaders: Instructions for persons appointed by the rescue leader to lead groups of rescuers to the accident. These are similar to the first column leader's instructions, but do not include some of the preliminary work that is to be accomplished by the first people at the scene.

Immediate action envelopes should be distributed and explained in all areas where an avalanche is likely to be reported. General alarm packets should only be issued to designated rescue leaders. The other three sets of instructions should be located at the avalanche rescue caches. Following is the recommended cache locations:

1. Girdwood Maintenance Station, DOT/PF - Mile 91 - Level 1 cache

2. Summit Lake Lodge - Mile 46 - Level 2 cache

3. Moose Pass - U.S.F.S. Station - Level 1

Following is a recommended Level 1 cache. Level 2 would be half as much equipment for the most part.

	Quantity
Trapper Nelson pack frame	2
Collapsible probes	20
Small snow shovels	6
Headlamps	30
Flares	100
Markers (wands with flags)	200
Wool blankets	4
Warning horn	1
Large first aid kit	1
6 volt hand lamp	6
Portable radios (walkie-talkies)	3
1-piece probes	100
Shovels, large scoop	30
Loud hailer	1
Horn refill	1
Metal detector	1
Tobbogan	1
150' rope	3
Lighting unit on trailer	1
Snowshoes	10
Electronic locater	24
Stretchers	2

(from B.C. Highways, 1979)

Chapter VI

AVALANCHE MAPPING

A record of identified avalanche paths is necessary to design and implement the control system. For this purpose aerial photography was used to identify avalanche paths in order to define the starting and runout zones. Incorporated into these photographs is a description of target points to be used in the control program, gun positions, and location of other facilities necessary for the control program.

For a concise view of the topography and relation of one path to another, a record of the avalanche paths was produced on 1:63;300 scale U.S.G.S. topographical maps. These contain a record of the avalanche path perimeters in red, gun positions, maximum line-of-fire, mileage marks, and remote weather stations in black. Avalanche paths designated with a number but no perimeter marks either run close to the highway or there is evidence of vegetation damage.

V - visual fire target points
MP - milepost
GT - mobile gun truck position

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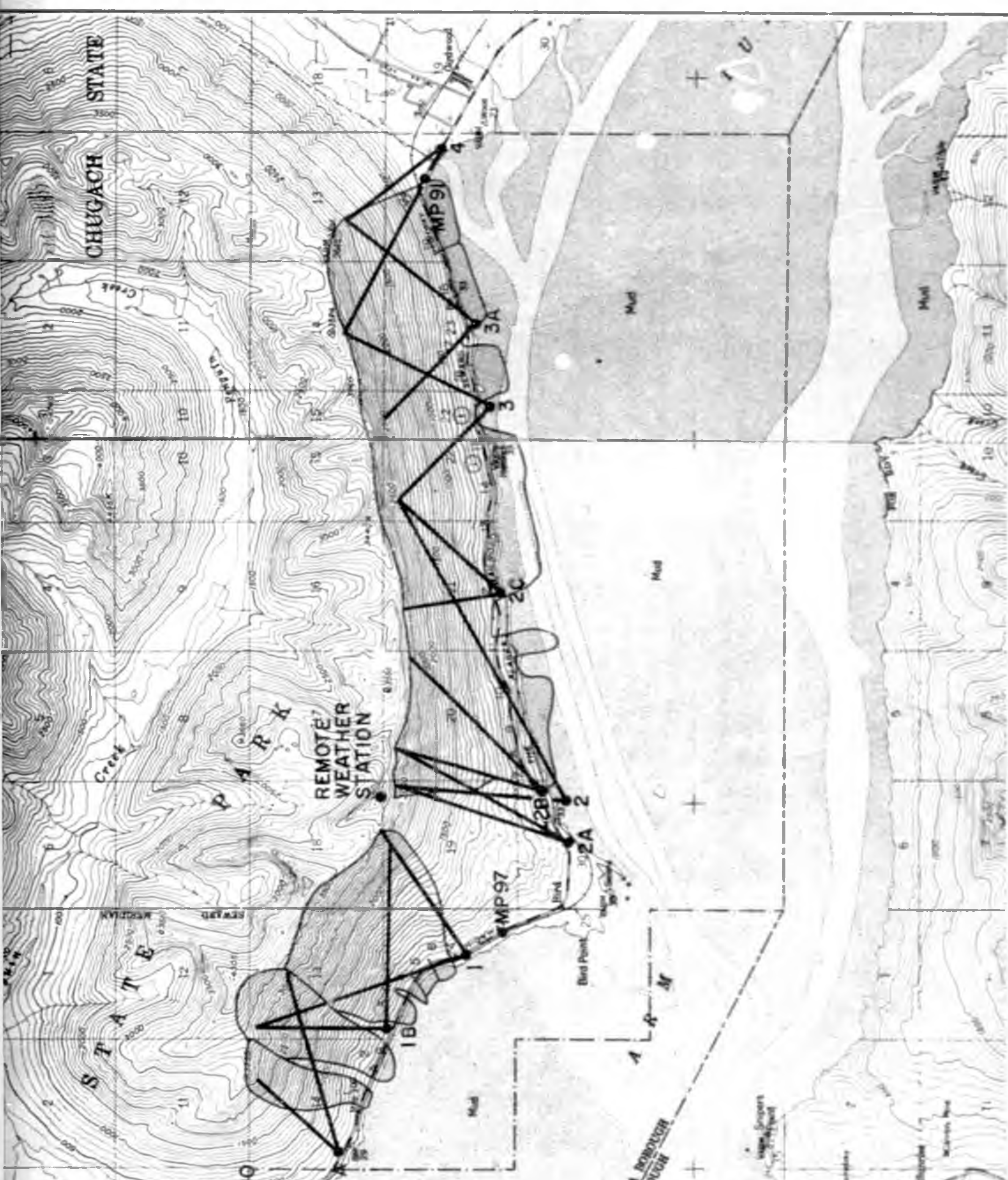


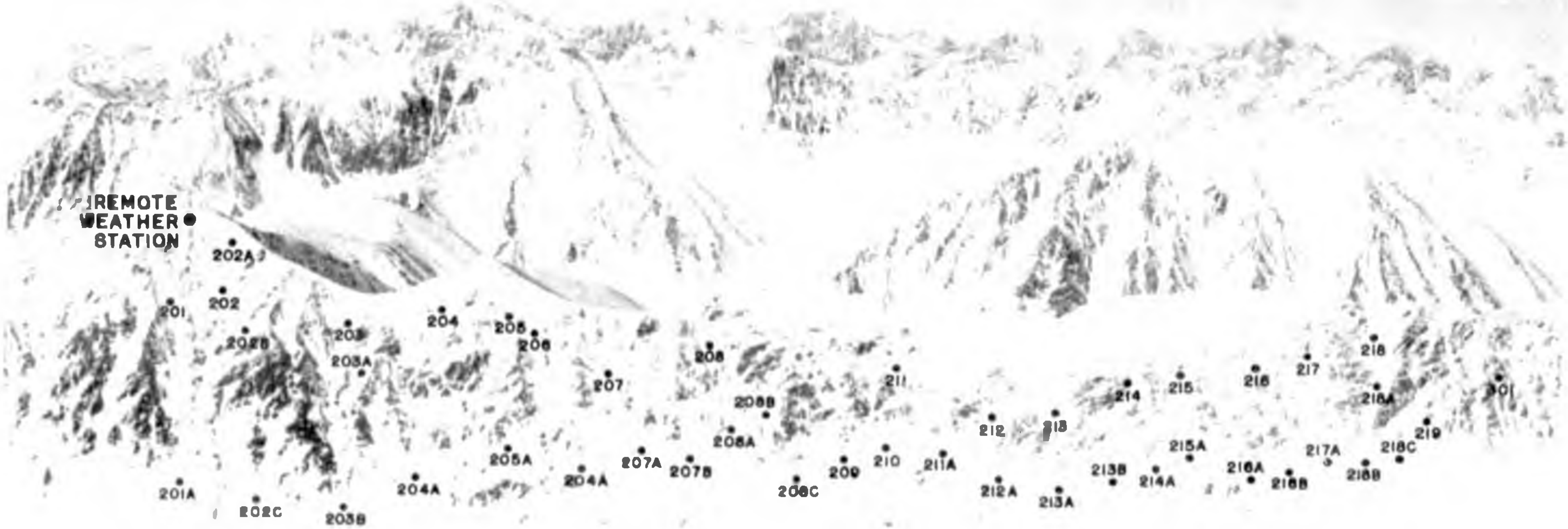
BIRD HILL
FIGURE 6-1

103A
102
101
104
105
107A
109
110
111
112
113
114
115
116
111A
109A
101A
112A
112B
113A
114A
115A
116A
116B
116C
116D
V
V
1
2A
2
1A
1B

FIGURE 6-2


109
110
111
112
113
115
116
116C
113A
114A
115A
116A
116B
116D
111A
P
202A
201
202
204
205
206
208
203
207
207A
207B
204A
201A
5
6
8
2A
2
75MM Howitzer Site
106MM Howitzer

FIGURE 6-3


REMOTE
WEATHER
STATION
202A
201
202
202B
203
203A
204
205
206
207
208
208B
208A
211
212
213
214
215
216
217
218
218A
301
219
218C
217A
215A
216A
218B
216B
214A
213B
213A
212A
211A
210
209
208C
207B
207A
204A
205A
203B
202C
201A

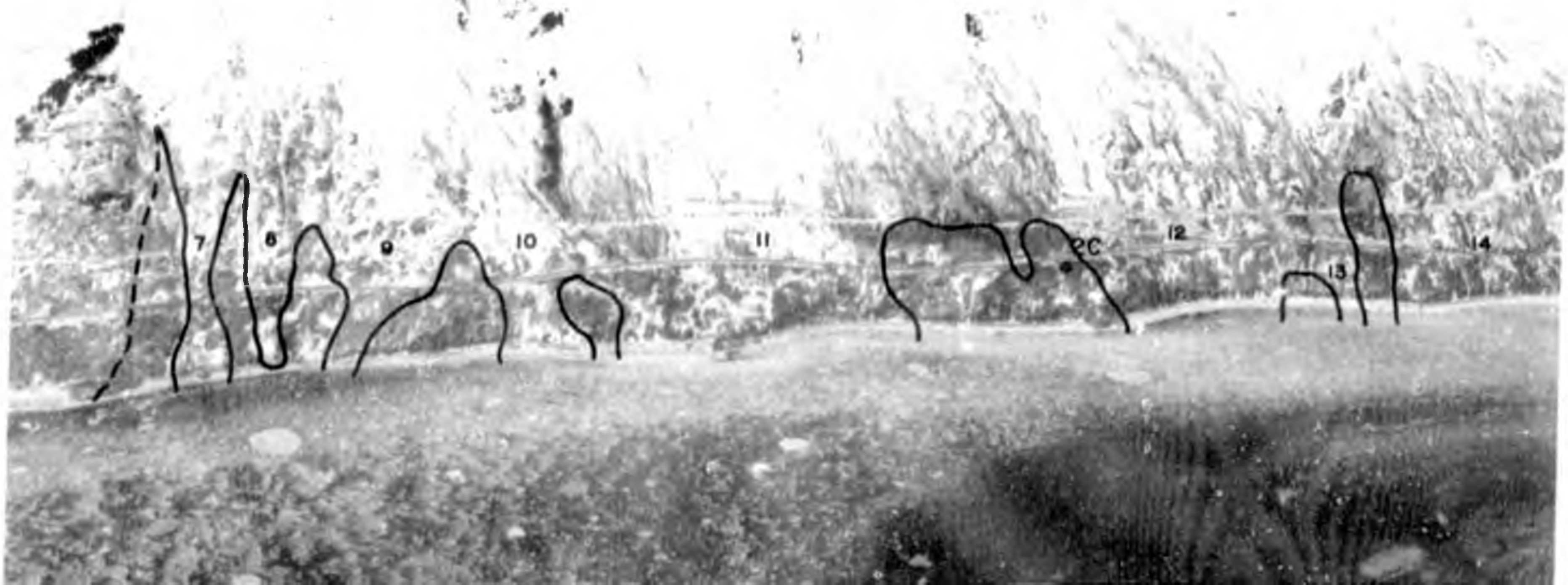

7
8
9
10
11
2C
12
13
14

FIGURE 6-4

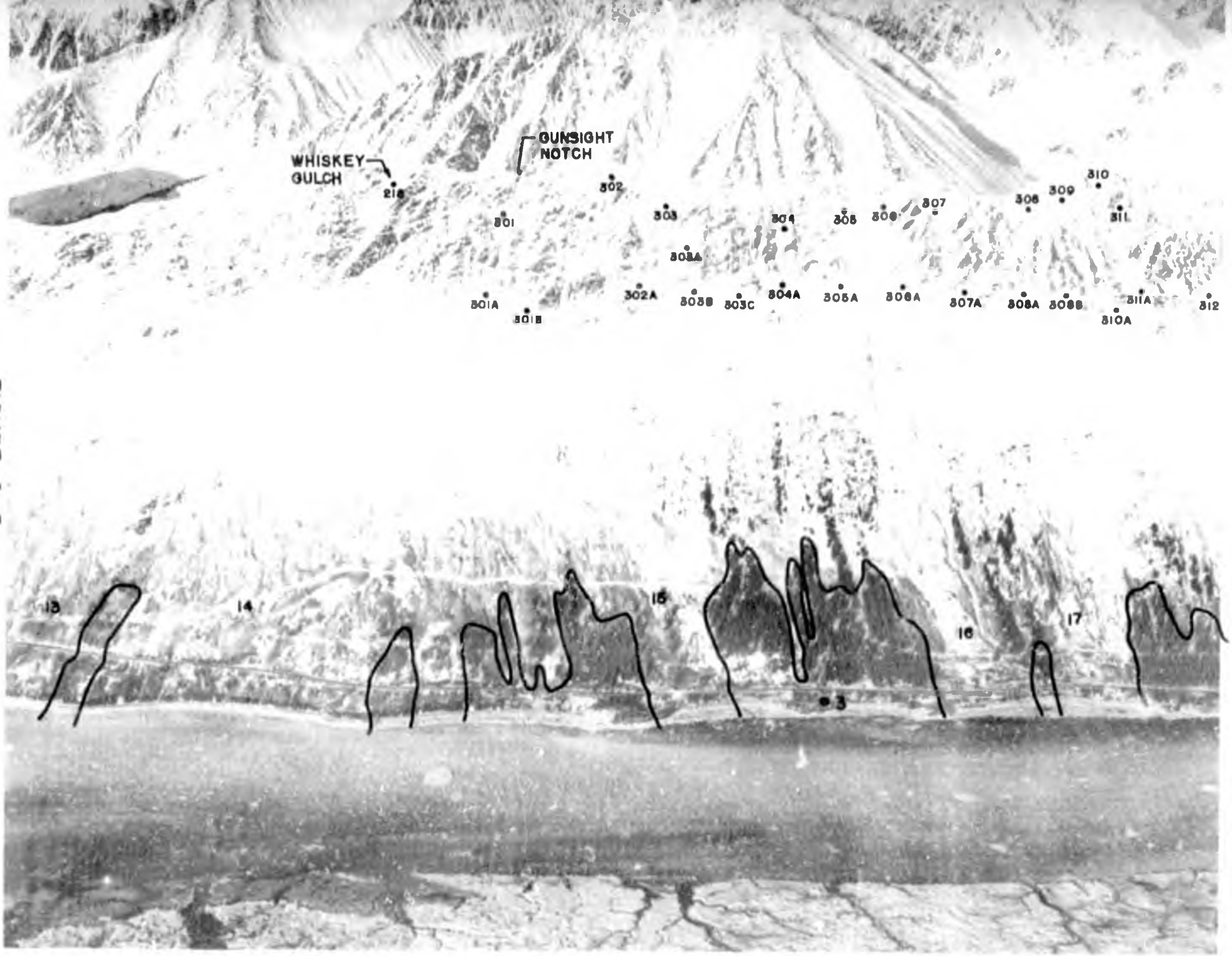
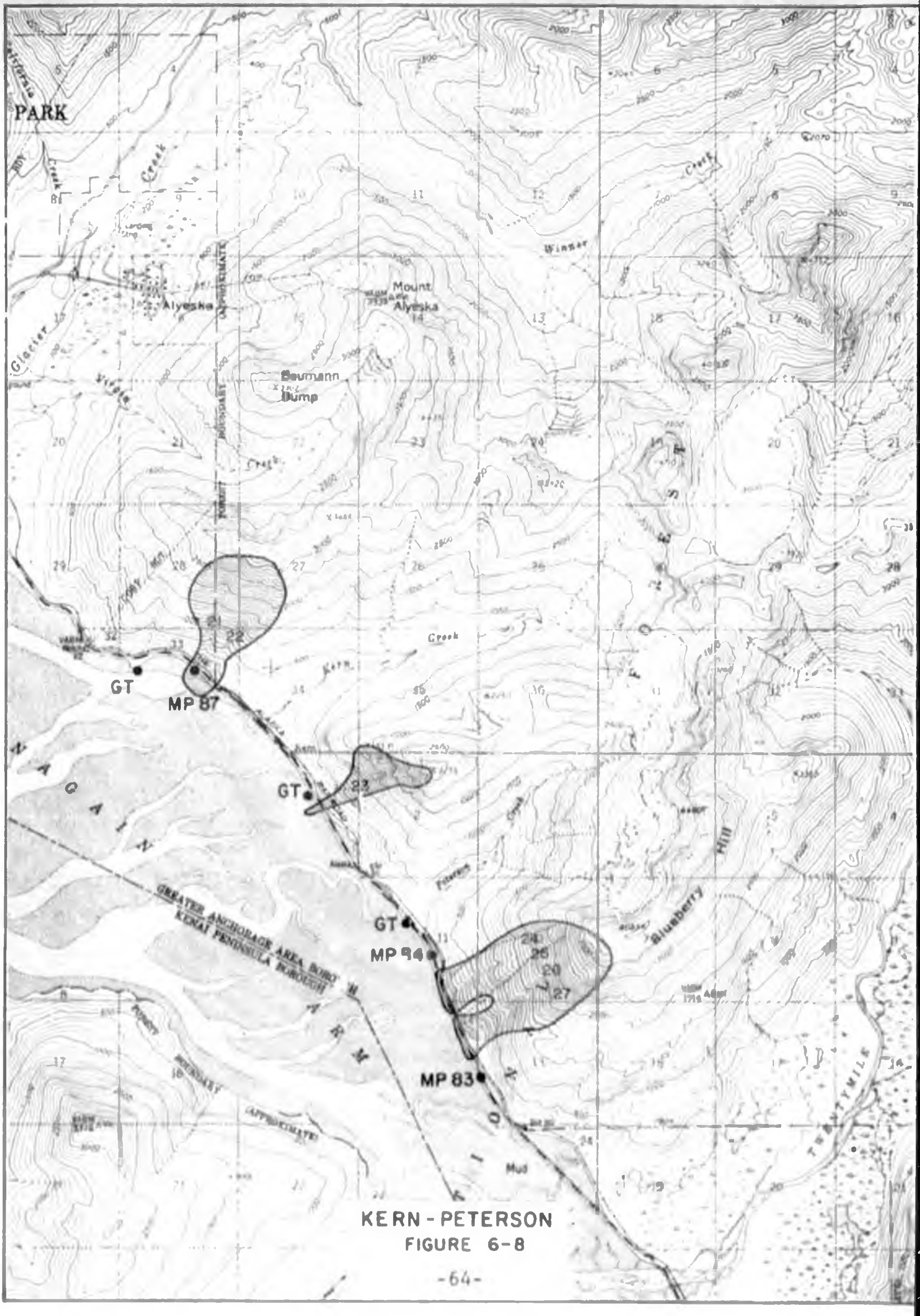

WHISKEY GULCH
GUNSIGHT NOTCH
218
301
302
303
303A
304
305
306
307
308
309
310
311
301A
301B
302A
303B
303C
304A
305A
306A
307A
308A
308B
310A
311A
312
13
14
15
16
17
3

FIGURE 6-5

FIGURE 6-6

FIGURE 6-7

FIGURE 6-7



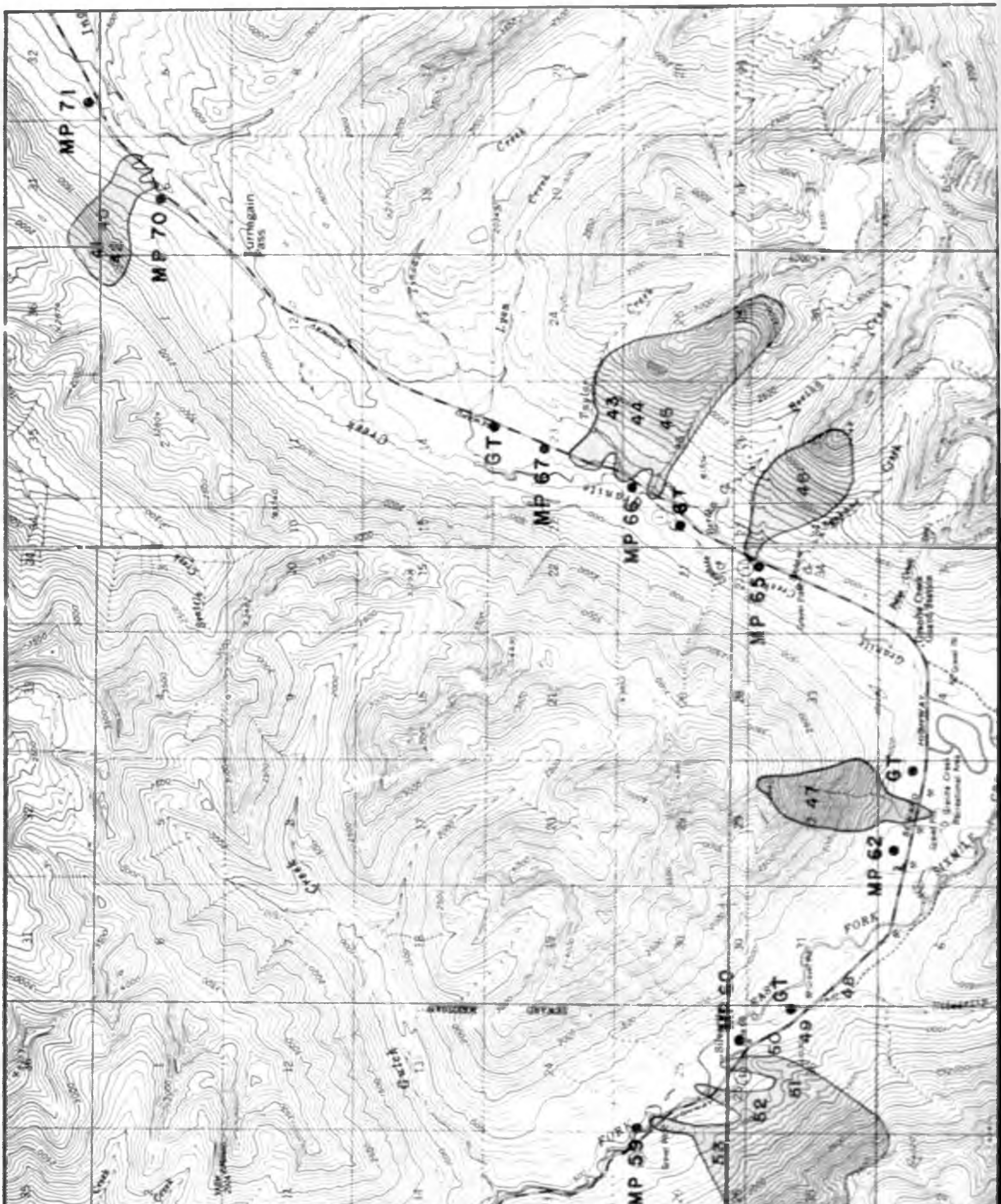
KERN - PETERSON
FIGURE 6-8

FIGURE 6-9

FIGURE 6-10

FIGURE 6-10

FIGURE 6-11



TURNAGAIN PASS – SILVERTIP
FIGURE 6–12

FIGURE 6-13

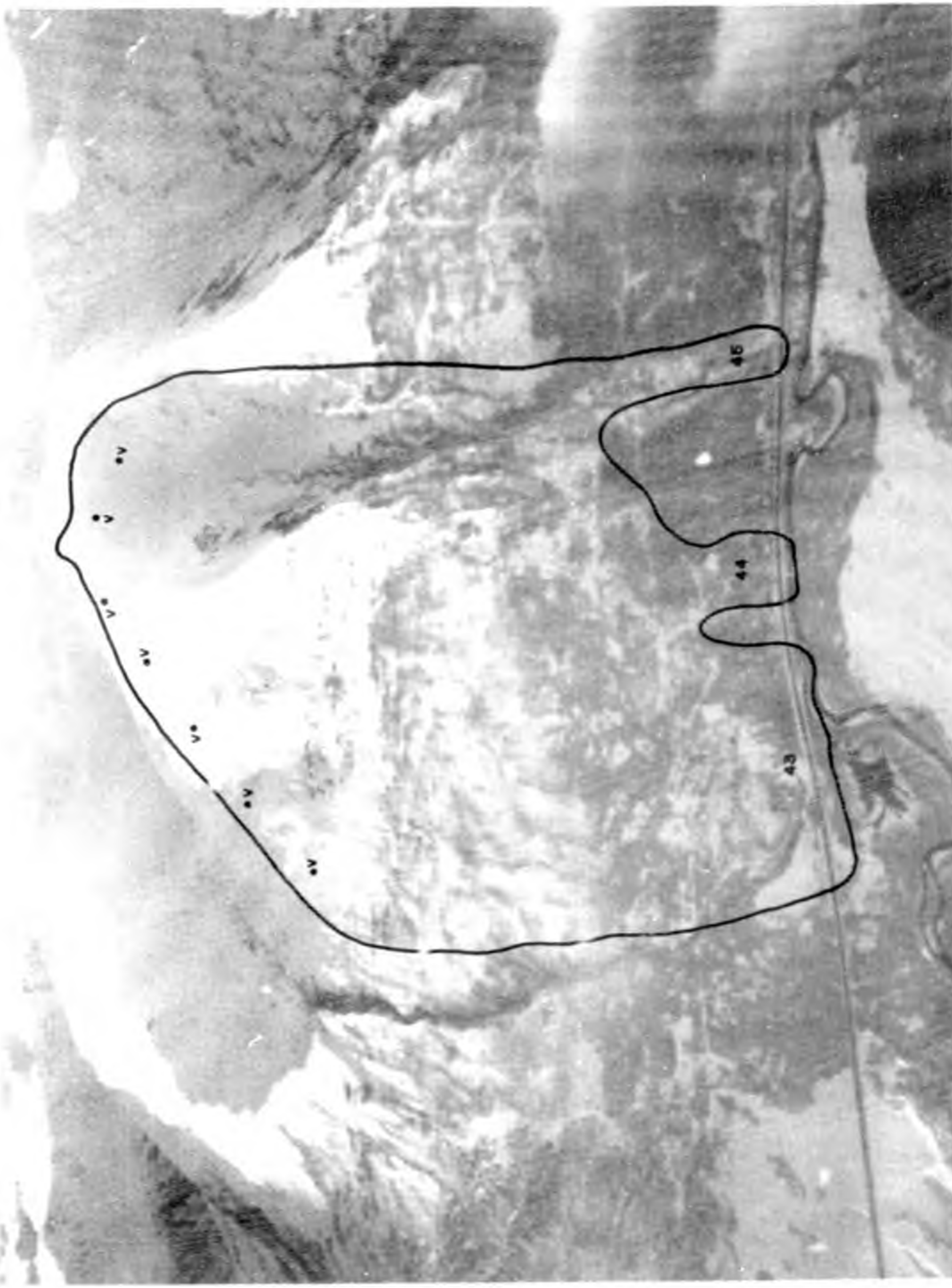
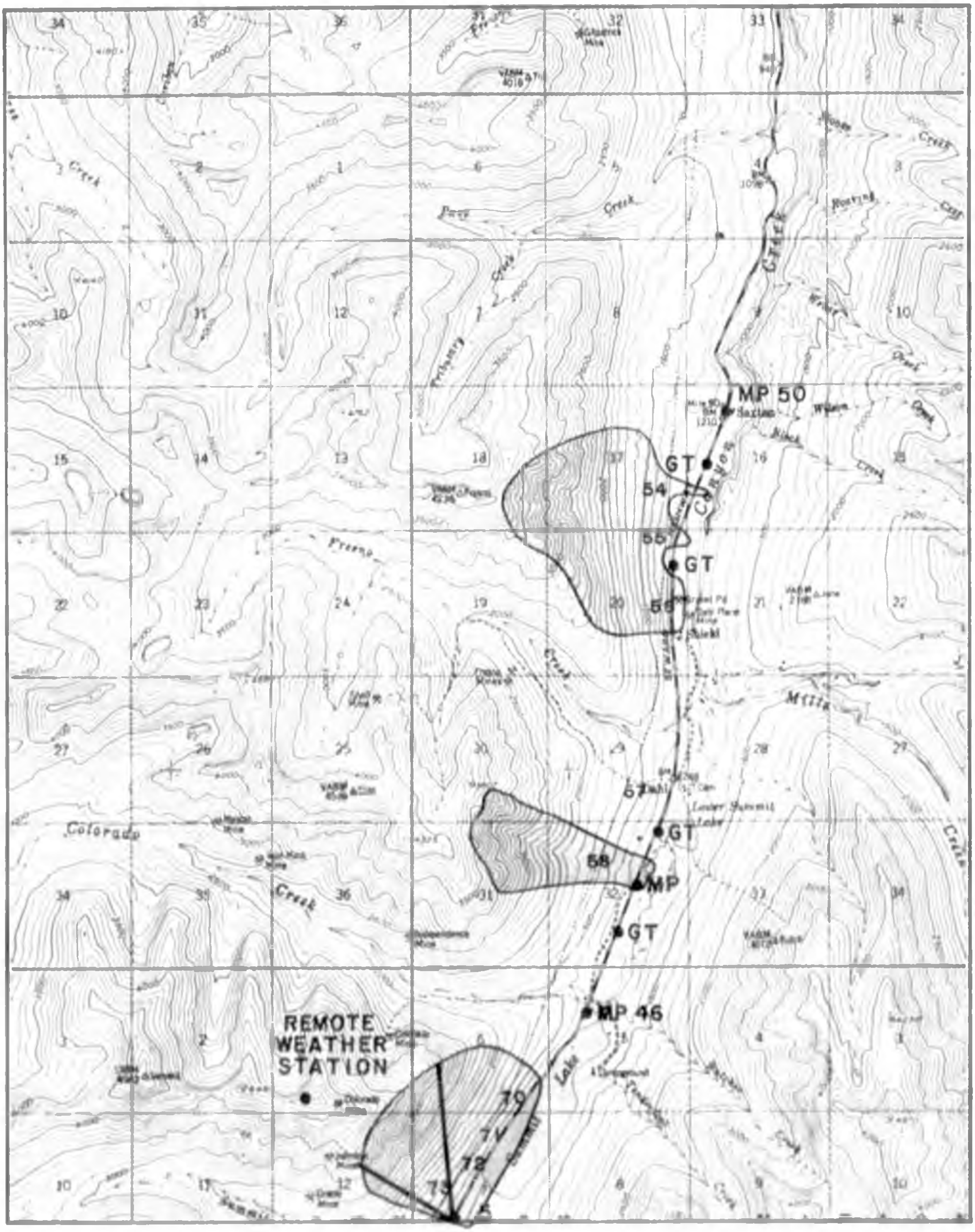


FIGURE 6-14

FIGURE 6-15



SUMMIT LAKE

FIGURE 6-16

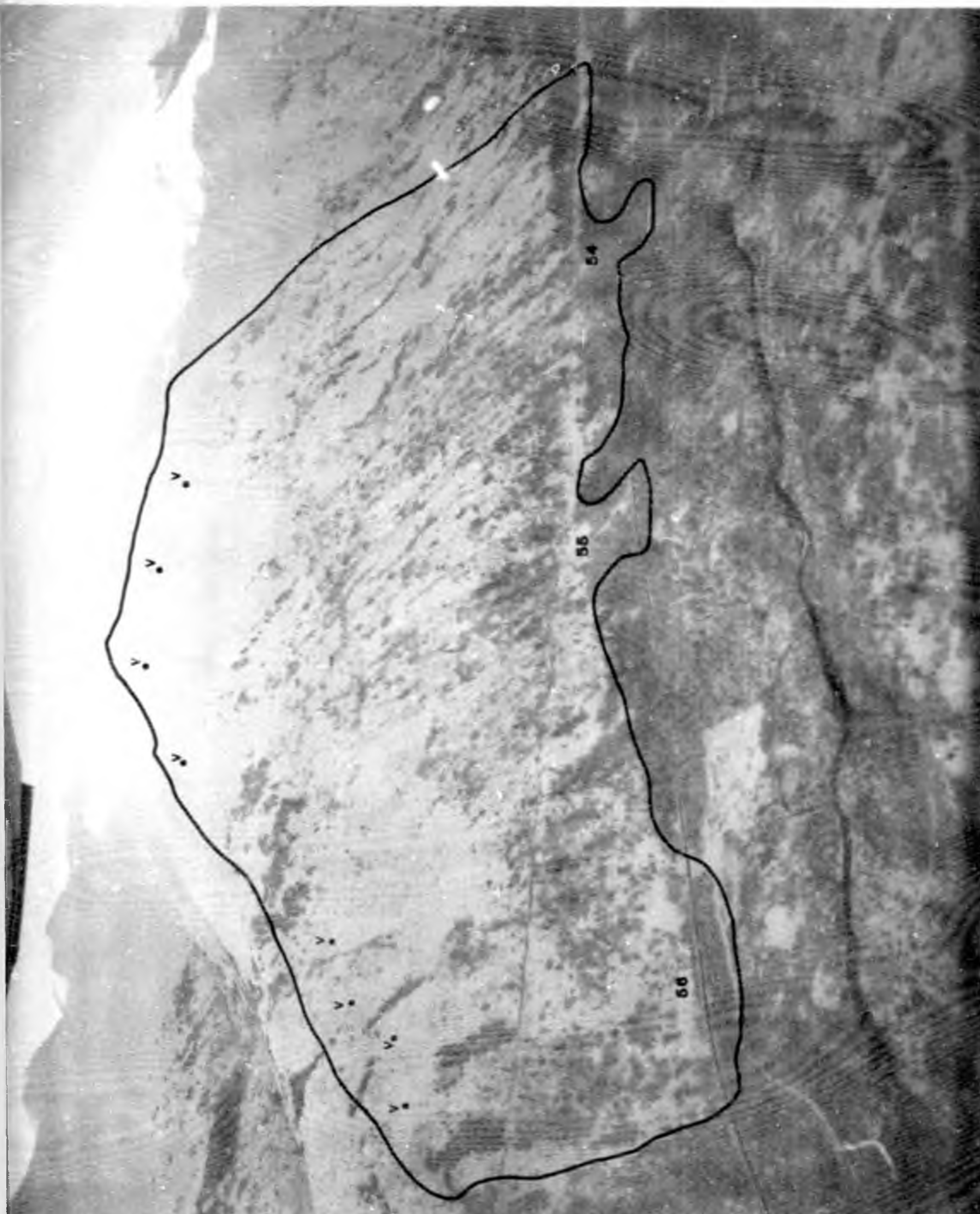


FIGURE 6-17

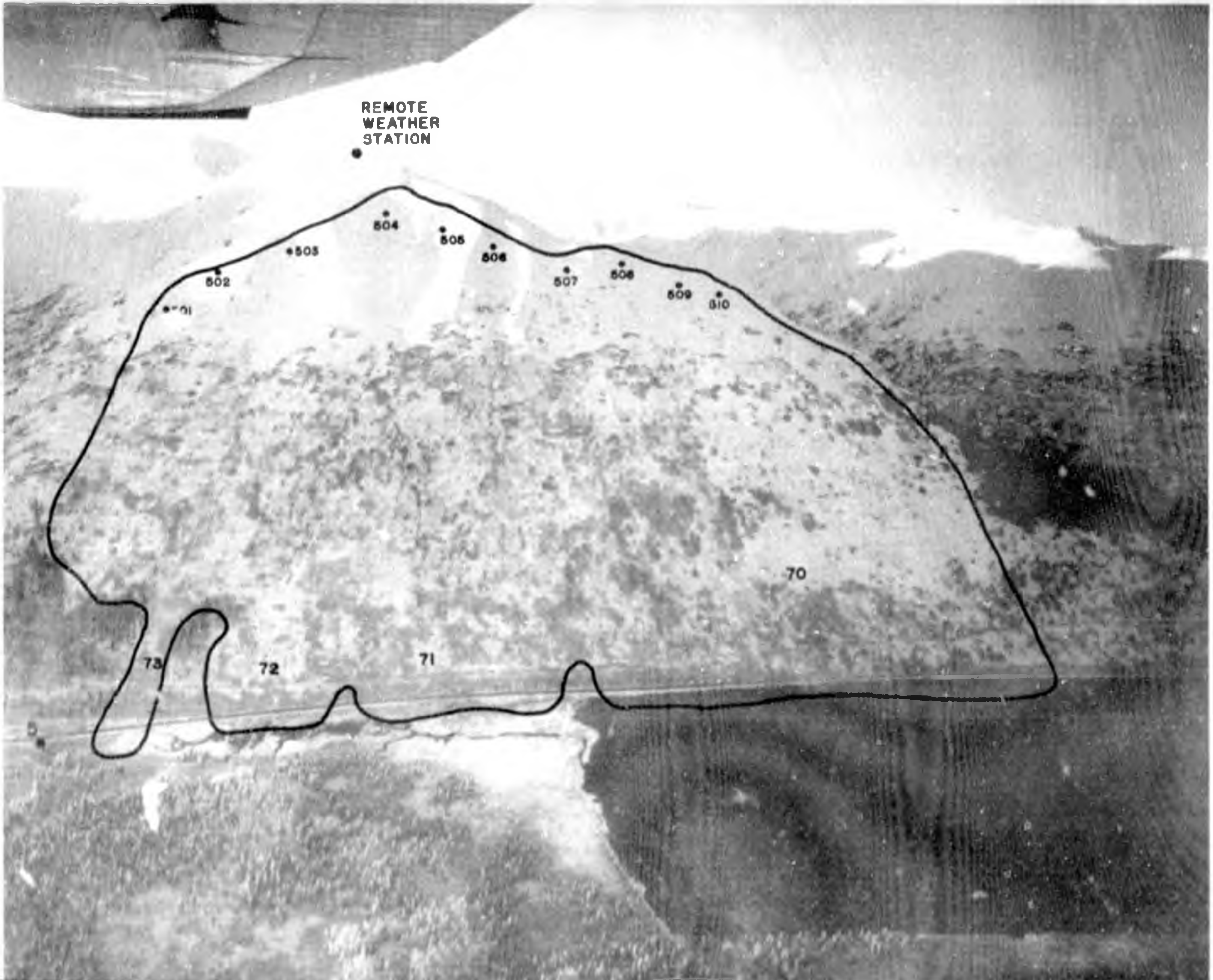
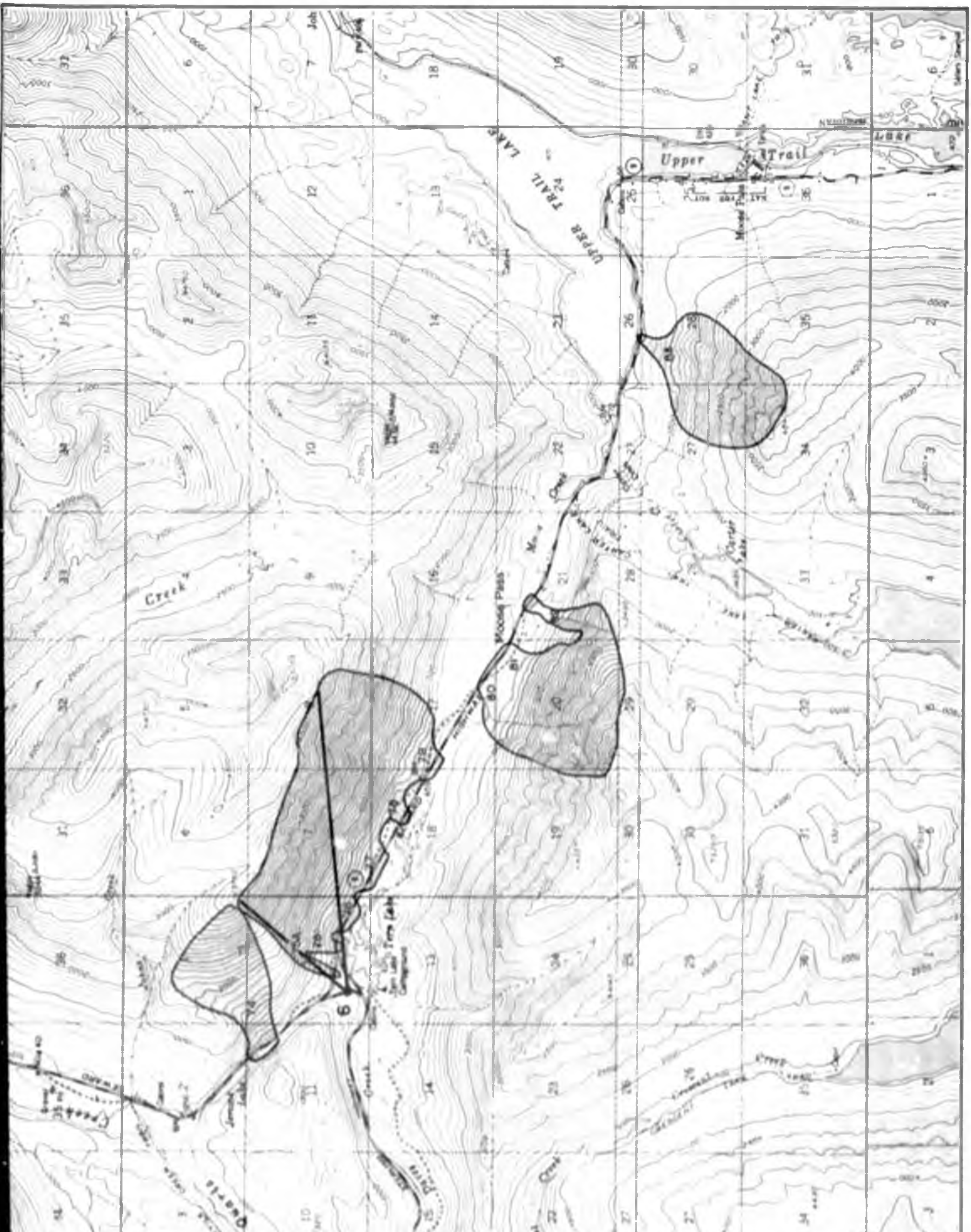

REMOTE
WEATHER
STATION
502
503
504
505
506
507
508
509
510
70
71
72
73

FIGURE 6-18



SEWARD-STERLING
FIGURE 6-19

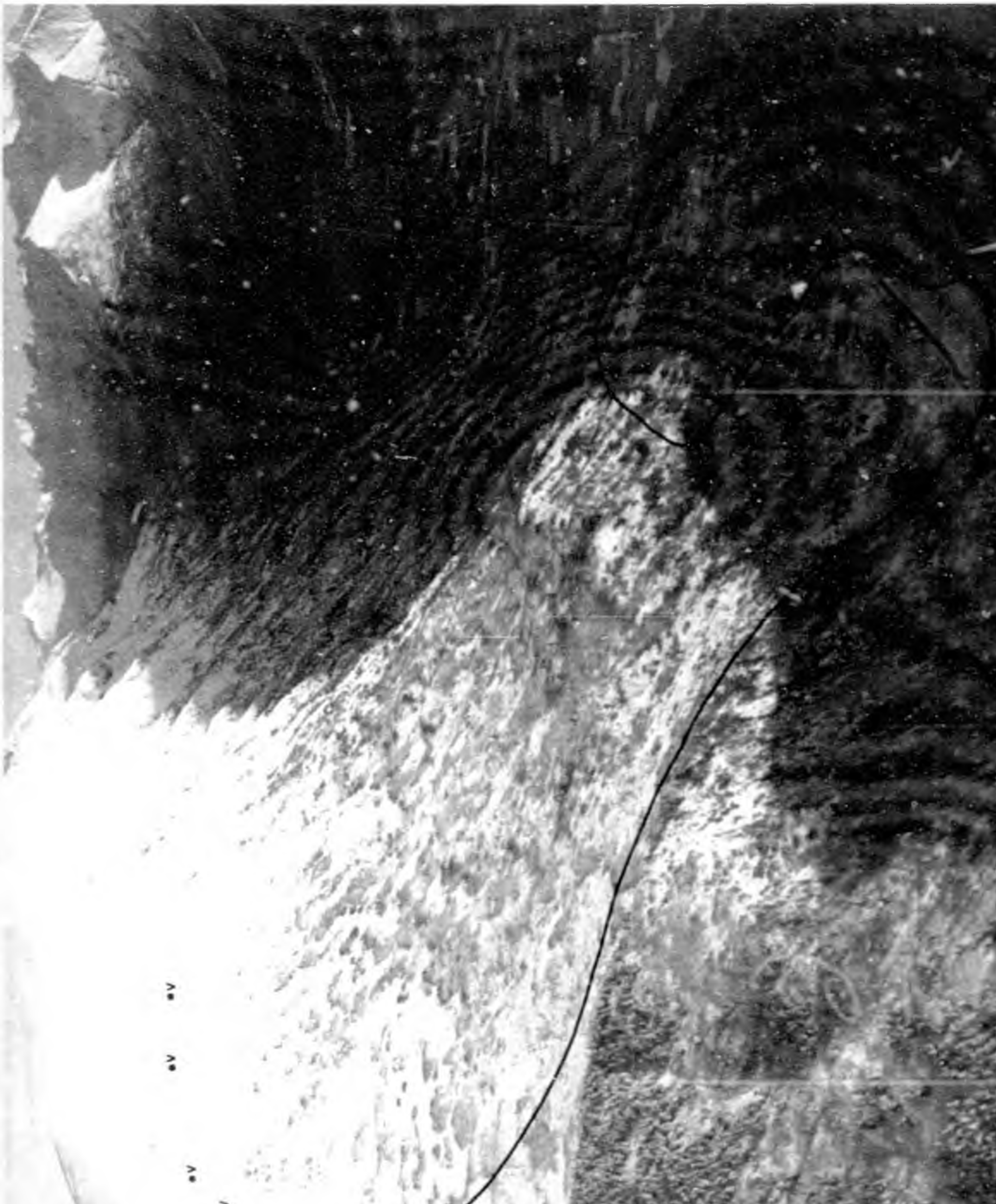


FIGURE 6-20

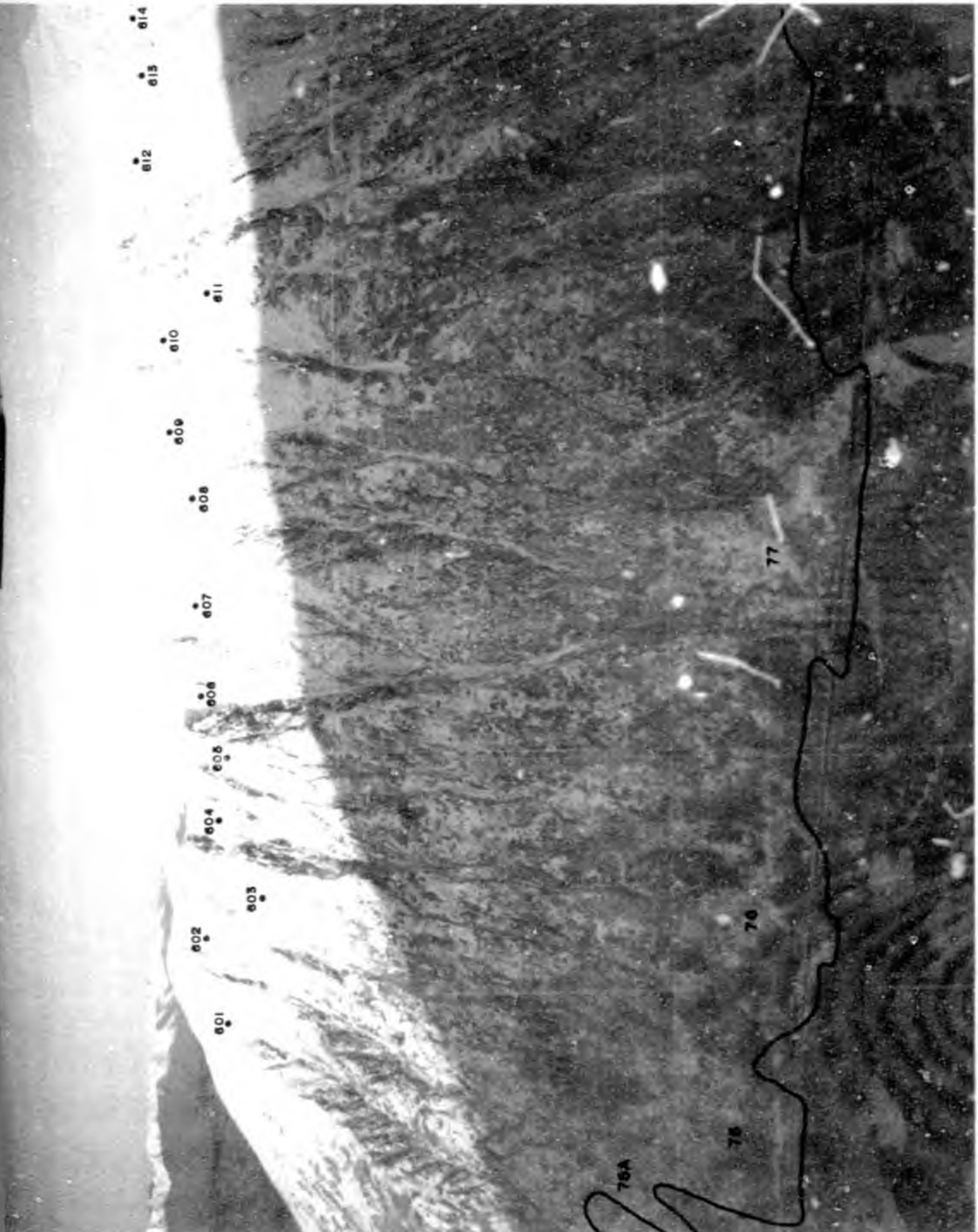
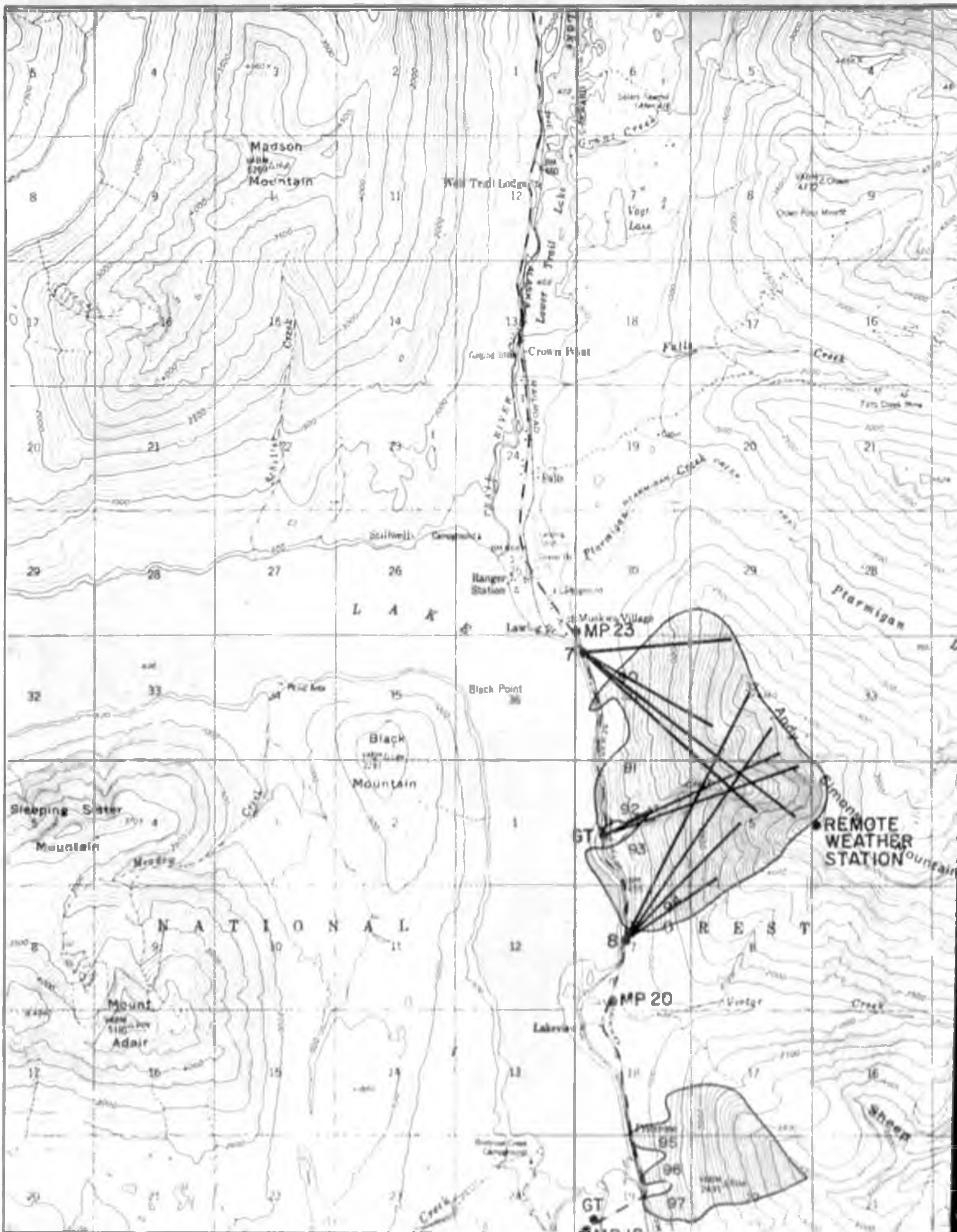
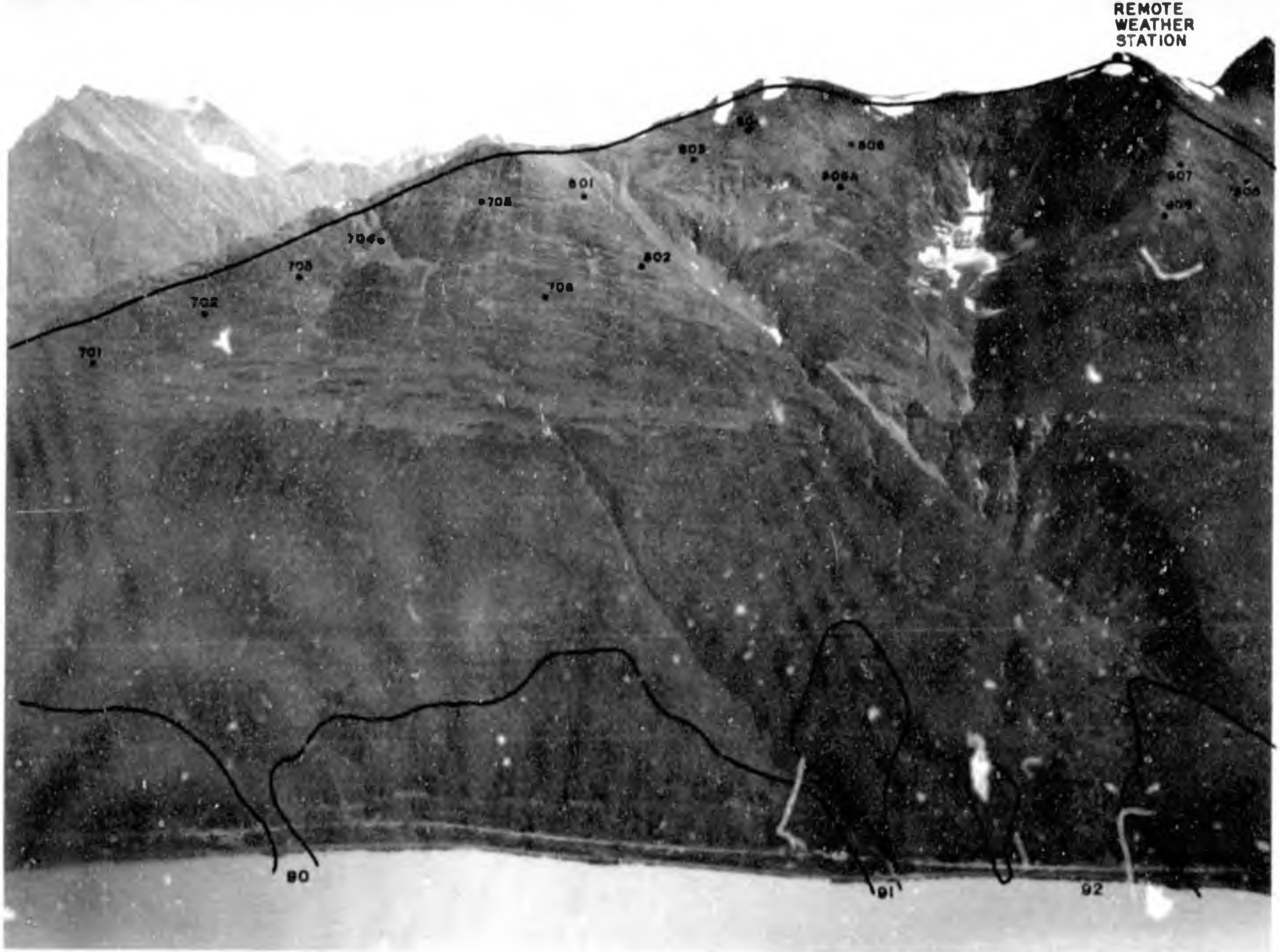

601
602
603
604
605
606
607
608
609
610
611
612
613
614
75A
75
76
77

FIGURE 6-21



KENAI LAKE
FIGURE 6-22



REMOTE WEATHER STATION
701
702
703
704
705
706
801
802
803
806
806A
807
91
92

FIGURE 6-23

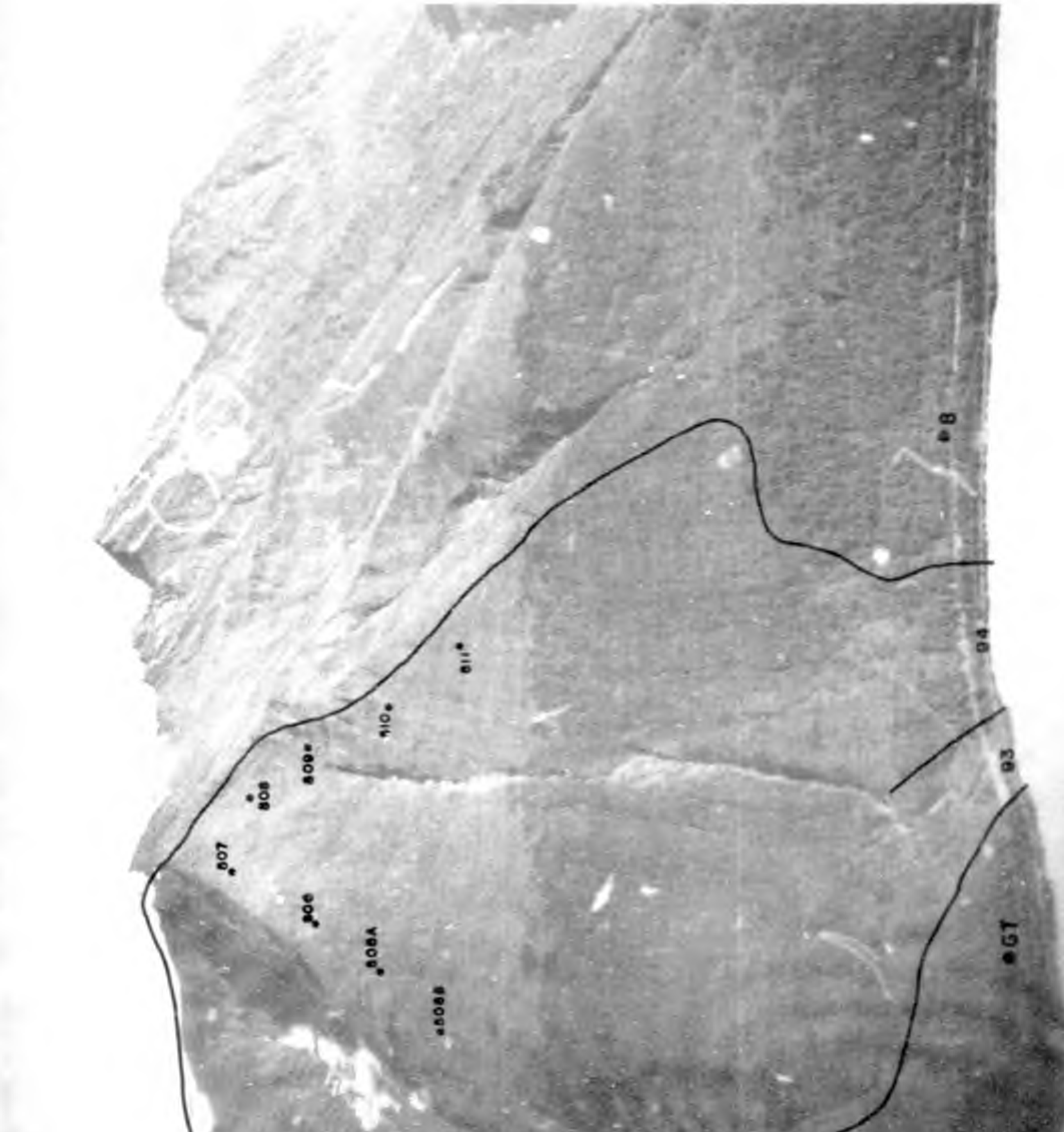


FIGURE 6-24

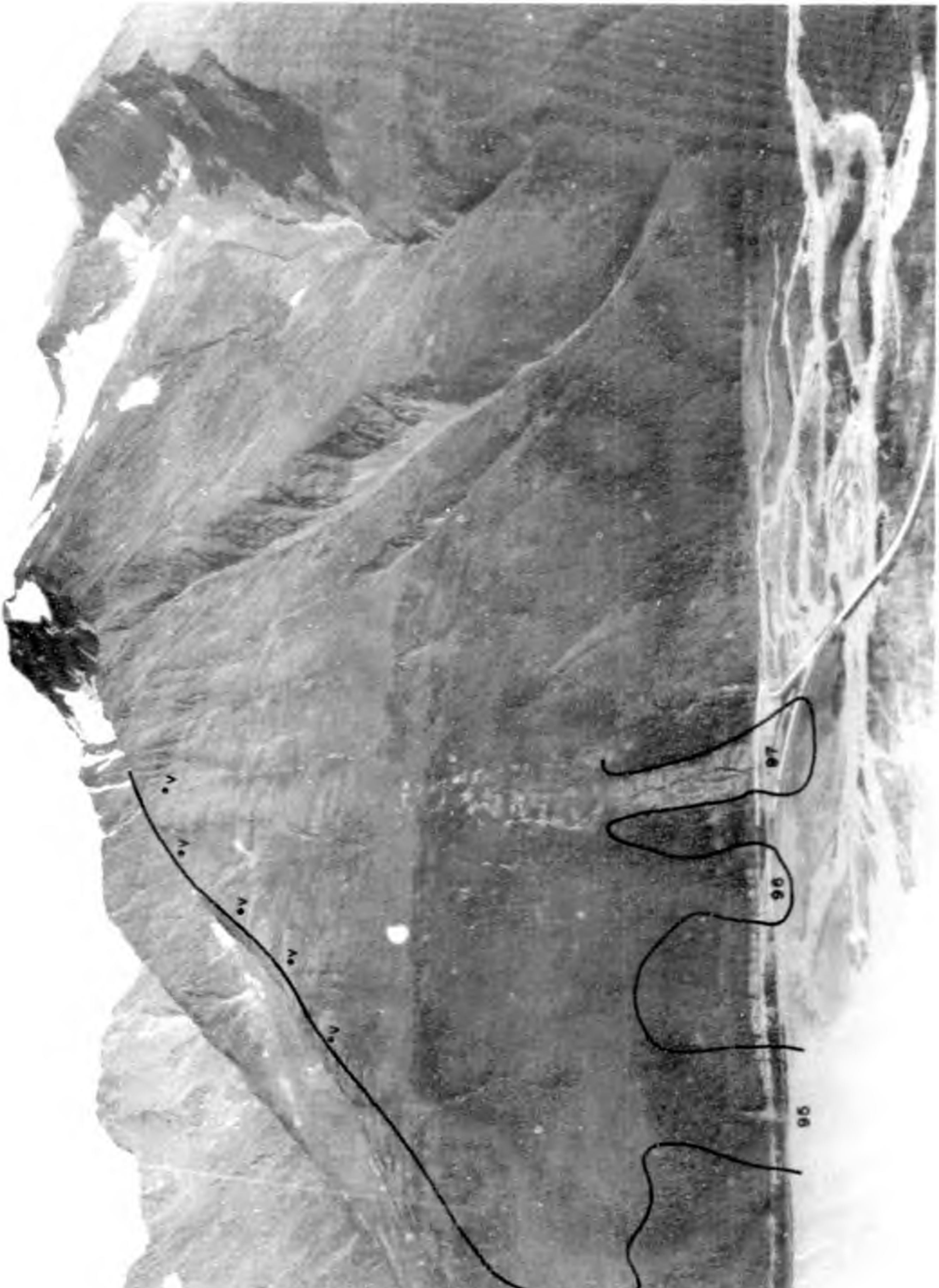


FIGURE 6-25

Chapter VII

SIGNING SYSTEM

During the course of this project a trip was taken to British Columbia, Canada to review the signing system in use in several different highway locations. There are numerous highways that are threatened by avalanches in B.C. Funding is available for artillery control only on certain critical passes, largely due to the high cost of acquiring weaponry in Canada. Because of this they have established signing as their first priority in dealing with avalanche problems.

The situation in Alaska somewhat parallels the Canadian one. There are several highways with low traffic volumes which are not practical to control. The Seward Highway is not one of these. Hazard to the public can be reduced considerably by reducing the amount of time spent in avalanche run-out zones. The use of signs is an attempt to alert the public to the fact that they should not stop in certain areas. Should a natural avalanche block the passage of vehicles it is possible that someone will remember the warning sign and leave the hazardous area. With any luck, they may also have the common sense to warn other traffic. This will help reduce the likelihood of a number of cars being buried as a result of stopping in a run-out zone.

In setting up a signing system there should be considerable attention paid to the placement of the closure gates and large electronic message boards in order to have efficient closures and the least possible inconvenience to the public.

Type 1	"Avalanche Area - Do Not Stop"
Type 2	"Avalanche Area next ___ miles - Do Not Stop"
Type 3	"End of Avalanche Area"
Type 4	Closure gates, two types
Type 5	Electronic Message Board
Type 6	Electronic Closure Sign

Type 1 and Type 3 signs must be installed on all potential avalanche paths.

Type 2 signs should be used at locations specified in the inventory.

Type 4 gates should be installed at miles 18,24,30, on two directions of the Sterling-Seward "Y", miles 46,46.5,80,90,90.6, and 99.5

Type 5 signs would be on a priority because of the high cost. First priority would be at Potter Flats and Girdwood to cover Bird Hill. As more money becomes available, DOT/PF might consider establishing these on the outskirts of Kenai and Seward.

Type 6 signs will probably be the lowest priority but could be used at Bird adjacent to the Scottish Inn and at the Sterling-Seward "Y".

Figure 7-1	Avalanche Area Warning Signs
Figure 7-2	Electronic Message Board

FIGURE 7-1

FIGURE 7-2

Type (Northbound)	Type (Southbound)	Milepost
2	3	17.8)
3	2	22.8)(5 Miles)
1	3	31.6
3	1	31.8
1	3	33.8
3	1	34.6
2	3	35.0)
3	2	38.5)(3-1/2 Miles)
2	3	43.9)
3	2	45.9)(2 Miles)
1	3	46.9
3	1	47.1
2	3	48.4)
3	2	49.4)(1 Mile)
2	3	59.0)
3	2	60.0)(1 Mile)
1	3	62.4
3	1	62.6
2	3	65.9)
3	2	66.9)(1 Mile)
1	3	71.1
3	1	71.7
1	3	83.2
3	1	84.0
1	3	85.4
3	1	85.7
1	3	86.6
3	1	87.1
2	3	90.6)
3	2	95.6)(5 Miles)
2	3	97.0)
3	2	99.0)'2 Miles)
1	3	104.9
3	1	105.1