JUNEAU AREA MASS-WASTING & SNOW AVALANCHE HAZARD ANALYSIS

Prepared For: City & Borough of Juneau, Alaska

JUNEAU AREA MASS-WASTING & SNOW AVALANCHE HAZARD ANALYSIS

Prepared for:

City and Borough of Juneau

Prepared by:

Art Mears
Arthur I. Mears, P.E., Inc.
Gunnison, Colorado

Doug Fesler and Jill Fredston
Alaska Mountain Safety Center, Inc.
Anchorage, Alaska

February 1992

TABLE OF CONTENTS

APPENDIX B: SNOW AVALANCHE AND MASS-WASTING HAZARD MAPS

LIST OF FIGURES

1. OBJECTIVES AND LIMITATIONS

1.1 Project Objectives

In accordance with Contract No. RFP 91-147, Juneau Hazard Area Update Project, this analysis has the following objectives:

a. Re-evaluation of the following mass-wasting and snow avalanche areas (see Figure 1) mapped in 1972 by Daniels, Mann, Johnson, & Mendenhall (DMJM): the east Juneau area, the Behrends Avenue avalanche path, and White Subdivision;

b. Mapping of mass-wasting and snow avalanche boundaries on new 1" = 100' scale topographic maps (where available) or on color aerial photographs;

c. Separation of mass-wasting and snow avalanche hazard areas on new topographic maps (where available) or on aerial photographs;

d. Description of mass-wasting and snow-avalanche processes and affected areas;

e. Definition of hazard severity zones; and

f. Suggestions for modifications to the Juneau hazard area ordinance.

1.2 Limitations of the Study

This study also has the following specific limitations which should be understood by all those using the results:

a. Present soil and slope conditions were evaluated, however, significant modifications to the vegetative cover on the slopes could change the mass-wasting frequency or the avalanche frequency and size;

b. Current methods, observations, and quantification procedures have been used to describe mass-wasting and snow avalanches affecting the Juneau area, however, future research and observations may modify the conclusions presented here;

c. Site-specific analysis will be required to define the physical processes and constraints to development at each site; the present study and accompanying maps cannot be used for this purpose; and

d. Additional mass-wasting and snow-avalanche areas, as defined in a 1972 study by DMJM, exist in the greater Juneau area but are beyond the scope of this study.

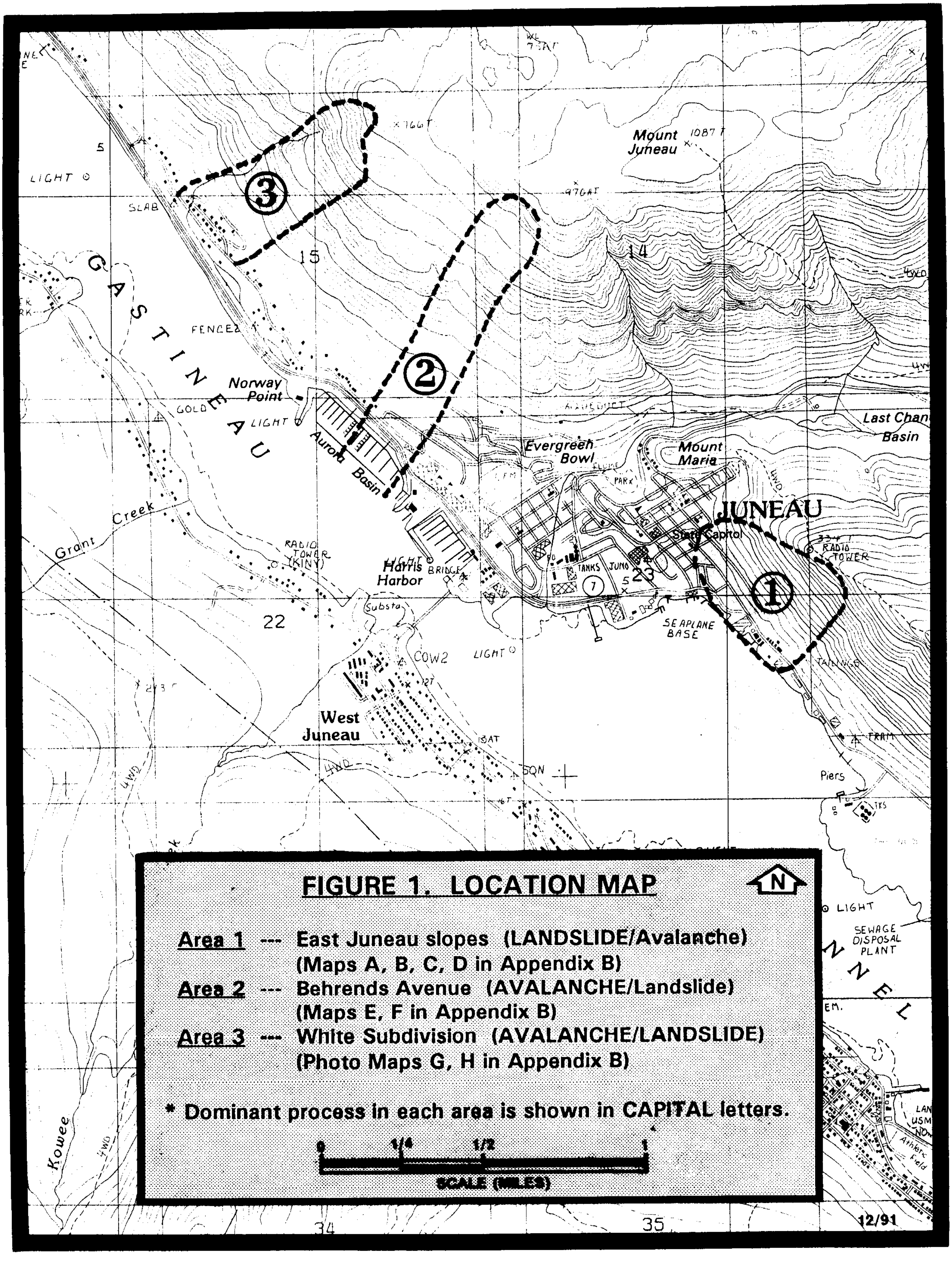


FIGURE 1. LOCATION MAP

Area 1 --- East Juneau slopes (LANDSLIDE/Avalanche)
(Maps A, B, C, D in Appendix B)
Area 2 --- Behrends Avenue (AVALANCHE/Landslide)
(Maps E, F in Appendix B)
Area 3 --- White Subdivision (AVALANCHE/LANDSLIDE)
(Photo Maps G, H in Appendix B)

* Dominant process in each area is shown in CAPITAL letters.

2. DESCRIPTION OF MASS-WASTING PROCESSES

Principal *mass-wasting* processes in the Juneau area are debris avalanches, debris slides, debris flows, and rockfall. These processes are often lumped under the general classification "landslides" with the understanding that the processes may differ considerably in release, motion, and impact characteristics, and may affect development differently. Within the areas studied and remapped in this report (see Figure 1), the most important landslide types are debris avalanches and debris flows. The release conditions, form of motion, and consequences of impact are discussed in subsequent sections.

2.1 Debris Avalanches

2.1.1 Release Conditions

Debris avalanches (or debris slides) are the primary mass-wasting process on the steep slopes above eastern Juneau. These processes begin primarily as translational landslides characterized by a planar rupture surface. In accordance with soil mechanics tests (DMJM, 1972), failures can occur on slopes in excess of 28° and slopes in excess of 37° are highly susceptible to translational failure. Inspection of the terrain in the eastern Mt. Roberts area above Gastineau Avenue indicates that slopes are sufficiently steep for debris avalanche activity. Furthermore, these slopes have a well documented history of landslides (see Figures 2-5 for examples) and large debris avalanches occurred prior to the development of Juneau. Although translational landslides will be the most common mode of slope failure initiation, rotational landslides may also occur, resulting in deeper failure planes and greater volume.

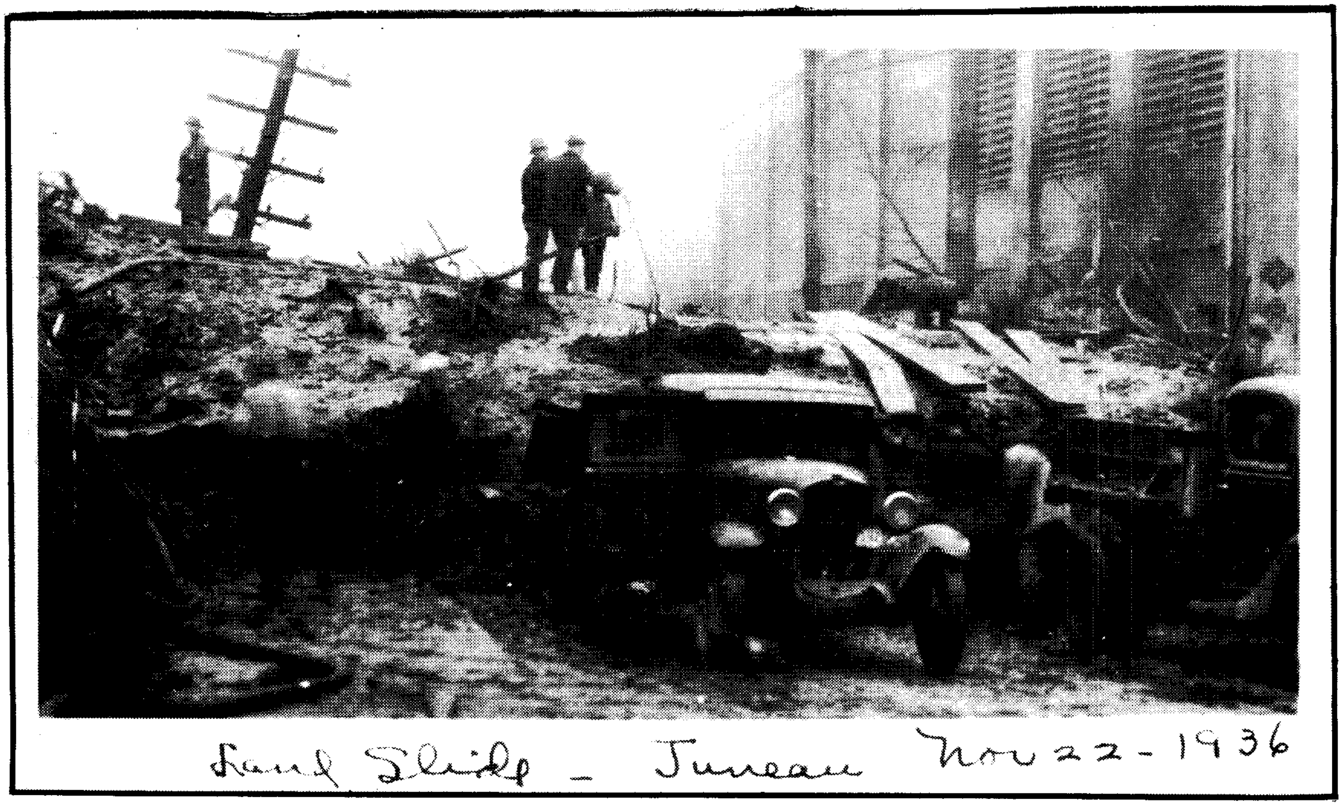


Figure 2. Debris avalanches such as this one on S. Franklin St. (Nov. 22, 1936) exert large thrust pressures against fixed objects while moving and significant depositional forces after movement stops. Flows can be several feet thick and carry rocks and large trees. Source: Alaska Historical Library, Early Prints of Alaska Collection.

Debris avalanches require (1) unconsolidated (loose) material on steep slopes, and (2) an adequate moisture source to weaken and lubricate the slide material. The Juneau area has sufficient unconsolidated material on steep slopes and an abundant moisture source. Historically, the largest and most destructive landslides have been associated with more than 1.5 inches of rain in a 24-hour period (DMJM, 1972). Precipitation records indicate that precipitation intensities of 2.0 inches in 24 hours can be expected at return periods of 5-10 years. Therefore, the conditions necessary for production of debris avalanches continue to prevail today even though major, destructive debris avalanches do not occur frequently.

Slopes are most susceptible to debris avalanches when vegetation is sparse and root systems are not available to anchor, reinforce, and consolidate the soil mass. Inspection of photographs taken in the early part of this century indicates that tree cover was less continuous than today. This may correlate with more destructive and more frequent debris avalanche activity earlier this century. However, there also exists clear evidence (in the form of deposits) that major debris avalanches occurred prior to the settlement of Juneau. These major slides, which terminated in Gastineau Channel, occurred when forest cover was undisturbed and in a natural state. Clearly, unstable soil conditions and debris avalanches can occur even within a forested slope, a fact that has been observed throughout many of the world's mountain areas. The potential for future landslides exists today.

Figure 3. This view of the area between Gastineau Ave. and S. Franklin St. (Jan. 2, 1920) illustrates how buildings were destroyed by a debris avalanches through the processes of impact and relocation. Source: Alaska Historical Library, Early Prints of Alaska Collection.

2.1.2 Motion and Consequences to Development

Debris avalanches accelerate rapidly on steep, water-saturated slopes, entrain additional soil, rock, and vegetative material during descent, and may reach velocities of 10 to 30 feet per second (approximately 7-20 mph) on steep terrain. When fully developed, the slides are several feet thick and will be studded with large rocks and trees which protrude from their upper surfaces. Although they reach high speeds on steep slopes, they also decelerate rapidly on gentle slopes. Moderate-sized debris avalanches will usually deposit most of their material on slopes of more than 10°. Road cuts will catch most of the material of moderate-sized slides. Therefore, the hazard from moderate-sized debris avalanches will decrease below road cuts. The larger avalanches, however, will overrun and fill in road cuts and will advance onto lesser gradients at the base of the slope.

Buildings exposed to fast-moving debris avalanches on steep slopes will be severely damaged, destroyed, or relocated by the impact. Impact pressures can exceed 1,000 lbs/ft^2, well in excess of the lateral loading capacity of wood-frame buildings, however, impact characteristics will be highly variable and will depend on velocity, density, and the presence of large rocks in the moving avalanche. Damage to structures can occur by crushing, rupture of walls by soil, rock, and vegetation impact, and relocation of structures. Because the debris avalanche process is highly variable from one location to another, even within the same general slope area, site-specific study will always be required to specify the risk to development and to design mitigation measures (see Figures 2, 3 & 4).

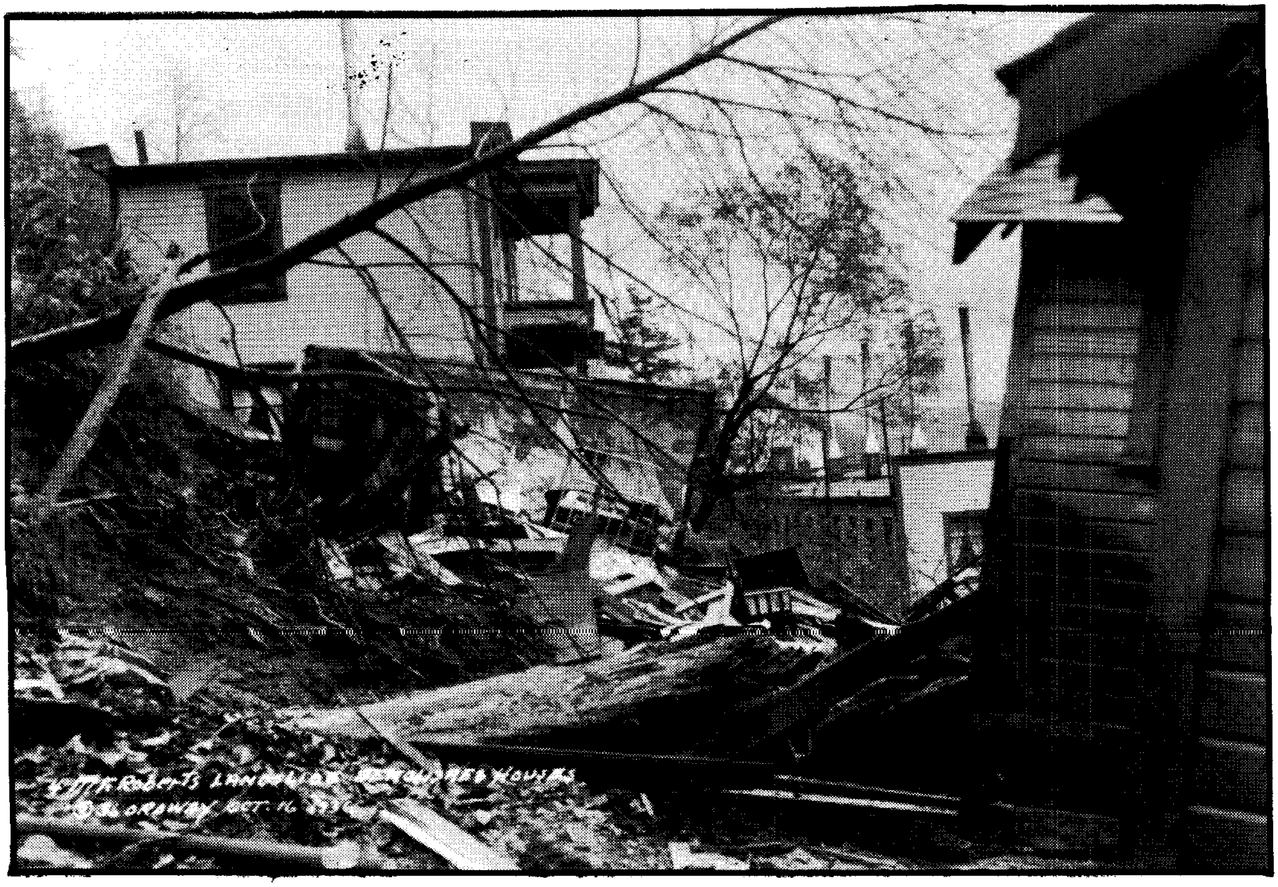


Figure 4. This debris avalanche on Oct. 16, 1936 destroyed buildings between Gastineau Ave. and S. Franklin St. by crushing and relocation. Source: Alaska Historical Library, Early Prints of Alaska Collection.

2.2 Debris Flows

2.2.1 Release Conditions and Flow Form

Debris flows occur in small, steep drainage basins such as those above the White Subdivision and Behrends Avenue areas. Similar to debris avalanches, *debris flows* also require steep slopes, unconsolidated surface material and an abundant source of moisture. Debris flows will often begin as translational or rotational landslides (like the debris avalanches discussed in Section 2.1), and may, in fact, have been debris avalanches during the initial stages of motion. The avalanche material, however, will typically flow into steep channels which are already conveying large water discharges. Here they become mixed with water and quickly evolve into a laminar or turbulent flow capable of transporting a large concentration of solid material. Water and additional debris can be entrained into the flows within the flood channels. The entrained water reduces internal strength and friction and enables the flows to advance for long distances on alluvial fan gradients of 5° to 15°.

Debris flows will typically reach velocities of 10 to 30 feet per second (approximately 7-20 mph) on steep slopes, but can advance at velocities of 5 to 15 feet per second (approximately 3-10 mph) for long distances on gradients of 5° to 15°. Clear evidence for active debris flow activity exists on the entire alluvial fan above the White Subdivision (see Photo Map G, Appendix B), in the steep channels above Gastineau Avenue (Maps A & B, Appendix B), and above the eastern portion of the Behrends Avenue avalanche path (Map F, Appendix B). They can also occur in channels on the slopes above eastern Juneau, but debris avalanches are the greater hazard there. Flows containing rocks up to 3 feet long, mud, and fragments of trees and other vegetation have been deposited against trees, and within numerous lobe-shaped deposits above Behrends and White Subdivisions. Therefore, debris flow is an active process at these locations.

2.2.2 Debris-flow Motion and Consequences to Development

A single debris flow episode will often produce several distinct surges of debris each as much as 5-10 feet thick. Each surge will carry water and mud as matrix material that provides strength to the flow, however, large boulders and trees are often carried near the upper surfaces, several feet above the channel bottom. Average densities will be 100-120 lbs/ft^2. The separate surges may reach the alluvial fan at intervals of one minute or more and each will be followed by muddy flood water which tends to erode and redistribute the debris over the fan surface. The earlier deposits (or those from prior debris flow episodes) may tend to deflect subsequent surges into unpredictable directions, therefore the flows, unlike water flooding, will not necessarily follow stream channels. This unpredictability in flow direction must be carefully considered in mitigation.

Debris flows can damage or destroy structures by crushing, erosion or deposition of mud and debris, or by pushing buildings off foundations. Typical impact pressures near the bottoms of the alluvial fans where development is located, will range from 100 to 1000 lbs/ft^2, well in excess of wood-frame building lateral-loading capacity, but pressure characteristics will be complicated by the presence of large rocks and tree trunks, which are often carried near the upper surfaces of flow surges several feet above the ground. Solid impact of boulders and large tree trunks at high levels must be considered in designing mitigation. Depositional pressures may control mitigation design in some cases as debris is deposited to depths of several feet against the uphill sides and on horizontal surfaces of structures. As noted above, the unpredictable nature of flow paths on alluvial fans makes definition of "safe" areas difficult and unreliable. We have mapped the entire fans as mass-wasting influence areas, based on evidence of previous deposition.

3. MASS-WASTING SEVERITY CLASSIFICATIONS

3.1 Mass-wasting Influence Areas

The mass-wasting maps accompanying this report (see Appendix B) define *mass-wasting influence areas*. These mapped areas may be subject primarily to debris avalanches (slopes above eastern Juneau) or debris flows (White Subdivision and Behrends Avenue areas). We have subdivided the influence areas into "Severe Hazard" and "Special Engineering" areas based on potential hazard severity. Although these two processes have been described separately in Section 2, debris avalanche and debris flow consequences will be similar because both processes will contain mud and rock flows of high densities. Therefore the "Severe Hazard" and "Special Engineering" areas defined below apply to both processes.

3.2 Severe Hazard Influence Areas

Debris avalanches and debris flows within *severe hazard influence areas* have the following characteristics:

a. Velocities may reach 15 to 30 ft/sec (approximately 10-20 mph);

b. Flow depths may be 5 feet or more;

c. Impact pressures over the entire flow depth may exceed 1000 lbs/ft^2;

d. Depositional loads on exposed horizontal surfaces may reach 1000 lbs/ft^2;

e. Normal (wood-frame) construction will be severely damaged or destroyed by impact and depositional loading; and

f. Structural mitigation is possible with careful study, design, and construction methods, but reinforcement of wood-frame buildings may not be possible.

As discussed in more detail in Section 3.4, site specific locations within designated "severe hazard influence areas" may be subject to local conditions (i.e., small scale topographic features, soil, slope, water, or vegetation characteristics) which justify reclassification of the potential hazard.

3.3 Special Engineering Influence Areas

Special engineering influence areas are affected by debris flows or debris avalanches which are either smaller or less energetic than those in the severe hazard influence areas. The *special engineering influence areas* have the following debris flow or debris avalanche characteristics:

a. Velocities will generally be less than 15 ft/sec (approximately 10 mph);

b. Flow depths will be less than 5 feet;

c. Impact pressures will range from 100 to 1000 lbs/ft^2; [1]

d. Depositional loads on exposed horizontal surfaces will be less than 1000 lbs/ft^2;

e. Normal wood-frame construction can be severely damaged or destroyed by impact, crushing, relocation, or flooding; and

f. Structural mitigation is possible at special-engineering sites and can be used in typical cases to protect objects.

As discussed in more detail in Section 3.4, the designation of "influence area" suggests that sites within the "special engineering areas" and "severe hazard areas" may have small-scale topographic features, or soil, slope, water, or vegetation characteristics that may justify reclassification of the potential hazard.

3.4 Change of Hazard Classification

Within both the severe and special engineering mass-wasting influence areas, as the term "influence area" implies, severity will vary considerably from one location to another. Even the detailed topographic maps do not show surface features with a resolution sufficient to define the hazard on a site-specific basis. Therefore, adjacent structures within the same hazard classification may be exposed differently. Furthermore, it is beyond the scope of this study to quantify the slope stability, soil, groundwater, and other characteristics that control the potential for mass-wasting processes at a given site. Therefore some sites within the "severe" or "special engineering" may not require special engineering or some sites rated severe may be protected by structural mitigation. Only detailed, site-specific investigations will resolve the final hazard definition. Such studies <u>must</u> be required in all cases.

---

[1] The pressure range (100-1000 lbs/ft^2) suggests the uncertainty in specifying the impact pressure of a highly inhomogeneous flow mass. It differs, therefore, from the pressure definition used in the snow avalanche zones.

4. SNOW AVALANCHE HAZARD: CHARACTERISTICS AND CONSEQUENCES FOR THE JUNEAU STUDY AREA

The interrelationship of three factors -- terrain, weather/climate, and snowpack determine the ability of a slope to produce snow avalanches and the character of the avalanches produced.[2] Snow avalanches vary considerably in their size, frequency, and dynamic energy because of these variables. Specifically:

- Topographic features such as slope shape, steepness, roughness, vertical drop, and aspect in relation to wind and sun influence not only velocity and avalanche motion but also the aerial extent of exposure;

- Snowpack features such as snow depth and distribution, layering and bonding, and moisture content largely determine the manner of failure and magnitude of the event as well as the flow dynamics.

- Weather and climate factors such as air temperature ranges, precipitation amounts and intensities, and wind speed and direction are significant because they influence the size and frequency of avalanches and act as triggering mechanisms.

Section 4.1 discusses the terminology and processes associated with avalanche release, motion, and impact while Section 4.2 addresses the character and diversity of avalanches found in the Behrends Avenue and White Subdivision avalanche paths.

4.1 Avalanche Release, Motion, and Impact Effects

In the Juneau area, two predominant types of snow avalanches occur: loose snow avalanches and slab avalanches.[3] By definition, *loose snow avalanches* or *point releases* initiate from a point in loose, cohesionless snow and widen in their descent as they entrain additional unconsolidated snow along their course. Most commonly observed on steep slopes in new snow which has not yet settled or in recently warmed surface layers that have lost their cohesiveness, loose snow avalanches generally pose the least risk to residential development (but a much higher risk to skiers and climbers).

Slab avalanches, on the other hand, occur when a cohesive layer or layers of snow fail as a unit (i.e., *a slab*) and release simultaneously across a broad plane, becoming detached at all of the slab boundaries. Slab avalanches generally pose the greatest potential risk to residential development (and backcountry recreationists alike) because they generally fail simultaneously across an extensive area, encompass a greater mass of material, and attain

---

[2] In the sections of this report which deal with snow avalanches, the terms *snow avalanche, avalanche, snowslide*, and *slide* are all used interchangeably to describe a mass of snow moving down an inclined slope. Technically, such events may contain soil, trees, rocks, or ice as well as snow, but the principal mass involved is snow.

[3] Although *cornice breaks* (i.e., blocks of wind drifted deposits which have broken and fallen onto the slopes below) are technically a form of avalanche, they are not considered a "predominant" form in the paths under consideration in the Juneau area. They can be important, however, as a type of triggering mechanism for the release of larger slab avalanches under the right conditions.

greater velocities and dynamic energy in their descent. Thus, most of the discussion in this section relates to the failure of slab avalanches.

In order for *slab failure* to occur, the following requirements must be met. There must be:

a) an unstable snowpack which exists in a state of near equilibrium balance between strength and stress (i.e., a slab with stored elastic energy overlaying a weaker, poorly bonded layer resting on a bed surface);

b) a sufficiently smooth and steep slope (35° to 45° is typical for large avalanches in the study area) to create additional stress along the boundary regions of the slab; and

c) a trigger of sufficient force to tip the balance (i.e., new snow load, rain, cornice breaks, wind loading, explosives, earthquakes, etc.).

When an avalanche initially breaks away from the release zone[4] and slides downslope, the slab, if composed of dry snow, desegregates into smaller blocks and clods of snow, which tumble and bound into the air as they gain velocity. As the avalanche descends and grows in size, often entraining unstable snow in the track, it develops two distinct flow characteristics: a) a slower moving *core* of denser, semi-pulverized debris (50-200 kg/m^3 for dry snow and 350-500 kg/m^3 for wet snow) flowing within 2-5 meters of the surface and b) a less dense, faster moving turbulent suspension of fine-grained desegregated snow particles and small snow clods known as the *powdercloud or powderblast* (usually less than 10 kg/m^3 or approximately 8-10 times denser than air).[5]

Once initial velocity is attained (usually in the upper third to fifth of the path), evidence suggests that velocity is not likely to significantly increase lower in the track, even on very steep slopes, presumably because the driving force of gravity is unable to overcome the frictional resistance along the boundaries of the flowing mass. Maximum velocities for large dry snow avalanches (i.e., for paths ranging from 500-1,000 m (roughly 1,500-3,000 ft) vertical drop) are estimated to reach 70 m/s (approximately 150 mph) but even small avalanches (i.e., in paths ranging from 100-150 m (300-450 ft) in vertical drop) are capable of attaining velocities of up to 35 m/s (80 mph) under the right conditions. For wet snow avalanches, the velocities are likely to be considerably less due to the greater frictional resistance of the material. With large wet slab avalanches (i.e., falling within the range of 500-1,000 m (1500-3000 ft) vertical drop), the maximum velocities attained are likely to fall within the range of 20-35 m/s (45-80 mph), versus 10-20 m/s (20-45 mph) for smaller slides within the range of 100-200 m (300-600 ft) vertical drop (Mears, 1991, unpublished). Note that all conversions from metric to english units are approximations only.

---

[4] *Avalanche paths* consist of three parts: the *release zone* or *starting zone* which is generally at the top of the path where failure initiates; the *track* down which the moving snow descends; and the *runout zone* or *deposition zone*, where the debris slows down and comes to rest. In large avalanche paths, the runout zone also usually includes the *powderblast zone* which extends far beyond the area of snow deposition.

[5] By comparison, 1000 kg/m^3 is the density of water (@ 62.4 $lbs/ft.^3$). 1000 kg/m^3 equals 100% water equivalency or 1.0 specific gravity.

The duration of time required for a large avalanche as described to flow past a given point is estimated to be within the range of 10-20 seconds depending upon topography and snow conditions. As the avalanche descends in a bounding, wave-like manner, the initial dynamic impact pressures typically reach a level two to five times as high as the norm, with subsequent peaks somewhat less. Each peak may last only .10 of a second, while the *powderblast* itself (i.e., the leading edge of the avalanche) may precede the core by only a fraction of a second or by many seconds depending upon the topography, the consistency of the snowpack, and the character of the climate. Generally however, the elapsed time from initial impact until maximum impact is less than a second. Such large, dry snow avalanches typically tend to descend in a straight line, regardless of small terrain barriers, and are capable of exerting tremendous thrust pressures, horizontally, vertically, and laterally.

Even moderate sized avalanches are capable of producing impact loads 10 to 20 times greater than the typical lateral loading capacity of wood frame structures. For example, an avalanche traveling at a speed of approximately 65 mph (30 m/s) with a flow density of approximately 100 kg/m^3 could exert a lateral pressure of 940 lbs/ft^2. By comparison a force of 40-80 lbs/ft^2 is sufficient to break windows in houses while forces ranging from 400-600 lbs/ft^2 are capable of breaking mature trees and destroying wood frame structures. [6] The problem of avalanche impact is exacerbated when structures are built broadside to the direction of flow as is the case in both the Behrends Avenue and White Subdivision paths.

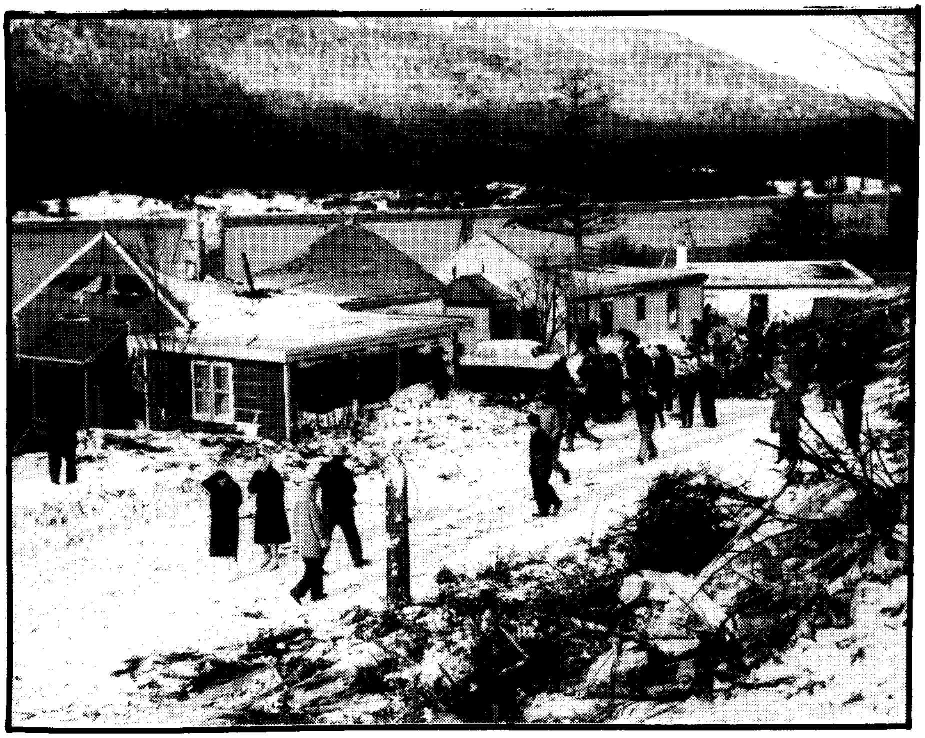


Figure 5: Taken shortly after the March 22, 1962 Behrends Ave. avalanche, this photograph illustrates some of the damage resulting from the powderblast of this fast moving low density avalanche. Thirty five houses were damaged: some were pushed off of foundations, roofs were blown off, walls pushed in, chimneys snapped off, trees broken and hurled through walls and roofs, and windows were blown in or sucked out. Photo source: Alaska Mountain Safety Center, Inc., Hart Collection.

---

[6] Mears, A., In Press, *Avalanche Analysis for Land-Use Planning and Engineering,* Colorado Geological Survey Bulletin 38.

4.2 The Behrends Avenue and White Subdivision Avalanche Paths

Within any given path, an enormous diversity exists in the type of avalanche activity, the depth and distribution of coverage, and the frequency of large events. For example, avalanches may typically descend along the east side of a given path, while at other times, they may impact the west side. Sometimes the path will produce an immense volume of snow but the slide will exhibit little or no powderblast while at other times, there may be a tremendous powderblast but little or no debris at the same location. Likewise, the path may normally fail under certain predictable weather conditions and then unexpectedly, it may release under a completely different set of circumstances.

Most avalanches in a given path are relatively small and frequent and affect only a small portion of the potential path area. Occasionally, much larger avalanches release which extend nearly to the observed limits of the path. These larger events are usually referred to as "10 year" events but in reality, reflect an order of magnitude return period of > 3 years but < 30 years.[7] On rare occasions, exceptionally large avalanches occur which extend well beyond the "normal" limits of observed activity. These design magnitude avalanches[8], often referred to as "100 year" avalanches, are likely to affect all or most of the potential path area.

For the purposes of this report, the *design avalanche* is defined as an avalanche occurring within an order of magnitude range of > 30 years but < 300 years. Such an avalanche by nature is an unusual event, precipitated by exceptional meteorological and snow conditions. In most cases, design magnitude avalanches involve the release and entrainment of weak, poorly bonded, cold dry snow layers. These avalanches usually break big, run fast, hit hard, and have a significant powderblast component. In a lesser number of cases, design magnitude avalanches may involve the release of very wet, poorly bonded, water-saturated snow with a significant volume of debris, but little or no powderblast. Statistically, design avalanches have a 1% probability of occurring during any given year, but could occur on consecutive years or many years apart. In the final analysis, most avalanches occurring in a particular path will stop far short of reaching the 100-year boundary limits, but exceptional events may, on very rare occasions, even extend beyond these limits.

Several factors contribute to the development of potential avalanche hazard in the Behrends Avenue and White Subdivision avalanche paths:

1) The terrain above the subdivisions is suitably steep, smooth, and leeward. The starting zones are extensive in all but the three Bartlett paths and the tracks are

---

[7] The *return interval* or *return period* for a given path is an estimate of the average time interval between avalanche events and does not necessarily refer to the actual time interval between events. A "10 year" avalanche, for example, may occur on consecutive years or many years apart. As a planning tool, the concept of a return interval is useful not only for site selection and design, but also as an estimate of replacement or repair costs for structures located at exposed sites where protection may not be possible.

[8] *Design magnitude avalanches* or *design avalanches* are by definition, infrequent major events of sufficient magnitude to overrun or extend beyond the "normal" limits of observed avalanche activity and are of sufficient destructive force that they must be carefully considered in the design and planning of residential structures or facilities.

relatively steep and unobstructed, thus allowing avalanches to maintain maximum velocities to the base.

2) The Juneau area receives significant quantities of precipitation with greater amounts of snow at higher elevations and rain at lower elevations. Snow has been recorded in excess of 100" (2.5 m) at sea level (with up to 65" recorded in a single month) and perhaps twice that amount falls at starting zone elevations. If wind loading is factored in, the accumulation levels at starting zone elevations could be four to five times greater than those at sea level.

3) The area is subject to extreme temperature fluctuations which contribute to a diversity of metamorphic processes affecting the snowpack. These play a significant role in the development of structurally weak snow layers which can then act as potential shear or failure planes once buried under the weight of subsequent layers.

4) The upper slopes of both Behrends Avenue path and White path are subject to intense periods of snow loading caused by predominantly strong N-NE winds. Most of the unconsolidated snow available for transport will likely be deposited in the starting zones during a short period of time. These winds tend to not only build cornices and deep slabs below but also, due to the added load, act as triggering mechanisms for slab failure.

5) Given the topography, elevation range, and snow climate of the paths, avalanches starting at higher elevations can entrain significant quantities of new snow during descent. Entrainment may significantly increase the volume of snow transported to the runout zone where private property is located.

One of the unique features of the Behrends Ave. path (which lies in a northeast/southwest alignment) is the presence of a large transverse gully which diagonally intersects the main path in a north/south alignment midway in the track. This natural diversion berm provides limited "structural protection" for the subdivision by catching some of the debris from small to moderate sized avalanches and diverting most of the remainder to the southeast side of the path. This increases both the distance debris must travel to reach the subdivision and the frictional resistance to which it is subjected while moving. The net result is that most of the avalanche debris generated by small to moderate sized avalanches stops short of reaching the subdivision. However, once the gully starts filling with snow, its effectiveness as a diversion berm diminishes. Nor is the transverse gully likely to have much effect in retarding large avalanches, even when it is empty. Although it may dissipate some of the energy from large slides, particularly early in the season when the gully is nearly empty, it will have little effect in reducing the powderblast component from major avalanches. These larger events will easily override the berm and continue in a southwesterly direction through the subdivision into Gastineau Channel.

Another factor which tends to inhibit avalanches from reaching the subdivision is the maritime snow climate. Maritime snowpacks (generally heavier and denser) are renowned for their ability to hold in place on steep slopes, and at lower elevations, to retard the flow of moving debris. This is due, in part, to a certain amount of strengthening that takes place through the processes of settlement and melt-freeze metamorphism, and to the development over time of a lattice of drainage channels that allow free water to percolate easily through the snowpack rather than be retained as weight. This retarding effect tends to hold the snowpack to the mountainside and to "dampen" the flow of debris once failure has occurred. This also applies to small or moderate sized avalanches which may start in cold dry snow at higher elevations but encounter warmer, wetter snow at the mid and lower elevations. It is not likely, however, that large avalanches releasing under similar conditions will be significantly deterred from reaching the subdivision area. These larger avalanches are of sufficient magnitude and energy to easily overcome any retarding effect caused by warmer and wetter snow at lower elevations and, in fact, may actually produce higher dynamic pressures due to their greater densities.

There is also the potential problem of debris deflection where stationary debris deposits from previous avalanches inadvertently act as "deflecting walls", causing the moving debris from subsequent avalanches to be deflected in a slope perpendicular direction toward the lateral boundaries of the path. Under most conditions, this would not present a problem but with the recent development of residential structures in the forest along the periphery of the paths, some recent structures are now at risk.

Historically, only a few major avalanche events are known or alleged to have occurred in Behrends Avenue path. Because these events are infrequent, they are often easily forgotten or conveniently dismissed as "freak" events. Based upon the information compiled in Appendix A of this report the return interval for large avalanches occurring in the Behrends Ave. path is estimated to be approximately 14.4 years, based upon 7 major events in 101 years (1890, 1917, 1926, 1935, 1946, 1962, and 1985: see Appendix A-2). Of these large events, the 1962 and 1985 avalanches are the best documented and provide the most useful information. The March 22, 1962 avalanche, for example, resulted in the greatest amount of property damage caused by a single avalanche in this path (see Figure 5). This avalanche also produced the largest powderblast yet recorded in the path. By comparison the Feb. 26, 1985 avalanche was smaller but represented the largest event recorded since 1962. This event, however, is considered small when compared with the potential of the path and snow climate.[9] There undoubtedly have been additional large avalanches but these were either unobserved or unrecorded.

White Subdivision is affected by four avalanche paths; three of these are narrow chutes with relatively small starting zones (Bartlett No. 1, Bartlett No. 2, and Bartlett No. 3) while the fourth, referred to as the White path , is considerably larger and more formidable. Although the number of years of historical record for avalanches affecting the White Subdivision is even shorter than the Behrends Avenue path, a number of impressive avalanches have occurred in the White path and buildings have been hit on four occasions in the past ten years (see Figure 6). Based upon data from the last 29 years (the period of record), the return period for large avalanches affecting private property in the White

---

[9] Although the 1985 avalanche was considered "large" in reference to recent memory, it is not considered "large" in relation to the path's potential. By analyzing the depth and distribution of slab failure after the event and comparing this with the path's potential for release under "extreme" conditions, it was determined that the Behrends Ave. avalanche path is capable of producing avalanches approximately <u>four times larger</u> in volume than the Feb 26, 1985 event (Fesler, 1985, Personal investigation).

path is 3.6 years. Thus, although the scope of exposure may be less in terms of the number of structures exposed, the frequency is four times greater than the Behrends Avenue path. Of equal importance is the fact that none of the recorded events to date have even come close to approaching the potential size of a design magnitude event, given the capability of the terrain and the snow climate.[11]

Figure 6: The avalanche which hit and damaged this occupied residence in White Subdivision was the 4th slide of the season in this path and the second one in a month to hit the house. Only the second story is visible above the debris and the garage (immediately to the right of the house) is still buried along with the owner's vehicle which was parked in the driveway. Damage from wet snow avalanches such as this usually results from crushing and dislocation. Photo by Doug Fesler, Feb. 20, 1985.

---

[11] Comparisons of fracture depth and distribution data from some of the most recent "large" avalanches which have occurred in this path support this conclusion (Fesler, 1985,1989, and 1990, Personal investigation).

One of the interesting features of the White path is that its primary starting zone consists of a medium-sized, steeply sloped bowl bordered at its base by a narrow sloping bench. Most of the small avalanches originating in this bowl stop on this bench. Moderate sized avalanches easily overtop this bench and continue their descent down a very steep cliff-like, V-shaped gully to the slopes below. The base of the gully narrows into the neck of an hourglass-shaped gully before opening onto a moderately steep, grass-covered, alluvial fan bordered by mature timber. At the base of this fan and along its fringes are the residential structures of White Subdivision. Moderate to large avalanches, which occur relatively frequently, are easily able to fill most or all of the alluvial fan with snow debris 6'-12' (2-4 m) deep. Mature trees are often snapped off and carried downslope by the moving debris and evidence of extensive vegetative damage is present along the fringes of the forest. Compared with the design magnitude avalanches this path is capable of producing, all of these observed events are small. Major avalanches with far greater dynamic energy would be easily capable of crossing Glacier Highway and destroying any unprotected wood frame structures in their path.

Little is known about the avalanche history of the smaller paths affecting the subdivision (Bartlett No. 1, No. 2 and No. 3) because development is relatively recent and no records have been routinely maintained by the City and Borough of Juneau. As the area is further developed, however, the record will undoubtedly grow. (For a more detailed summary of events in White Subdivision, see Appendix A-3)

5. SNOW AVALANCHE HAZARD CLASSIFICATIONS

In an attempt to delineate degrees of avalanche exposure in a manner useful for land use planning, three categories of hazard are delineated in the avalanche hazard maps (see Maps E-1, E-2, and H in Appendix B). These include: High Severity Areas, Special Engineering Areas, and Unaffected Areas (described below in Sections 5.1, 5.2, and 5.3 respectively).

5.1 Definition of High Severity Avalanche Areas

By definition *High Severity Avalanche Areas* are exposed to the greatest potential risk. These areas, referred to as the Red Zone, are subject to avalanches with:

a) return periods of < 30 years, or

b) impact pressures > 600 lbs/ft.^{2} (assuming a flat, normal, rigid surface)

Consequences: People living in or traveling through High Severity Avalanche Areas should expect to be infrequently impacted by major avalanche events capable of severely damaging or destroying standard wood frame structures and injuring or killing people. This includes the following range of exposure (without mitigation): structures could be totally destroyed or severely damaged, roofs could be blown off or caved in, walls could be pushed in or sucked out, houses could be pushed from their foundations, vehicles could be severely damaged, mature trees broken off, and windows and doors ripped off, sucked out, or pushed in, with considerable broken glass and debris carried by hurricane force winds.

People outside or inside of structures could be severely injured or killed. Children or adults playing or working outside would be particularly susceptible.

5.2 Definition of Special Engineering Avalanche Areas

Special Engineering Avalanche Areas are also exposed to potential threat from avalanches, but to a lesser degree. Mitigation will usually be feasible, but requires site specific analysis. These areas, referred to as the Blue Zone, are subject to avalanches with:

a) return periods of > 30 years, but < 300 years, and

b) impact pressures < 600 lbs/ft.^2 (assuming a flat, normal, rigid surface)

Consequences: People living in this area can expect to be less frequently exposed to potential threat from major avalanches, and because of the location, subjected to a lower degree of potential impact. This includes the following range of exposure (without mitigation): structures could be moderately damaged, houses could be pushed from their foundations, roofs could be blown off, walls pushed in, windows and doors pushed in, sucked out, or ripped off, and broken glass and flying branches could be a hazard to people. People outside would be particularly vulnerable to flying debris. Although the avalanche exposure here is less than in the red zone, serious damage is possible.

5.3 Definition of Unaffected Areas

Unaffected Areas are those areas which are not exposed to avalanche impact risk or are exposed to such a minor degree of secondary impact as to be of little consequence. People living in these areas will, at the worst, be exposed to very infrequent, low velocity wind gusts for short durations. Accompanying the wind, there is likely to be a fair amount of spindrift (i.e., powder snow) which may obscure visibility for a short period. There is also the possibility that very light objects may be carried by the wind for some short distance. Furthermore, these "unaffected" areas can be affected by avalanches with return periods longer than the design avalanche.[12]

6. REVIEW OF CITY AND BOROUGH OF JUNEAU (CBJ) HAZARD ORDINANCE

In accordance with the terms and requirements of the contract, relevant portions of Chapter 49.70 (SPECIFIED AREA PROVISIONS), are reviewed in this section. Specifically, this review covers pages 561-57 and 561-58, pages 561-66 and 561-67, and pages 561-91 and 561-92 of the CBJ land-use code. The revisions suggested below refer to paragraph numbers in the current ordinance Ord. 87-49.

---

[12] By definition, the design avalanche extends to the limits of the "Blue Zone". This avalanche is defined as an event with a return period of more than 30 years but less than 300 years. This means that longer return period events (such as 500 or 1000 year avalanches) can extend into the "Unaffected Areas". These longer return period events are not mapped because their probabilities are small.

Page 561-57: 49.70.210 (1) (d) -- No change is recommended.

Page 561-66: 49.70.300 (a) (1) -- No change is recommended.

Page 561-66: 49.70.300 (a) (2) -- CHANGE TO: Boundaries of severe and special engineering areas will be shown on the sensitive area map and the landslide and snow-avalanche area maps dated [new date], consisting of sheets [# through #], as the same may be amended from time to time by the Assembly by ordinance.

Page 561-66: 49.70.300 (a) (3) -- No change is recommended.

Page 561-66: 49.70.300 (a) (4) -- CHANGE TO: If a developer disagrees with the boundaries shown on the maps, he may seek departmental relocation of the boundaries by submitting site-specific studies prepared by an engineer, geologist, or recognized specialist in snow-avalanche or mass-wasting behavior, energy, velocity, and destructive potential. Such studies shall include detailed analyses of topography, vegetation, soil and snow conditions, storm and climate analysis, and other factors relevant to the description of the snow-avalanche or mass-wasting process. The study must describe how each of the factors was used in re-evaluating the snow-avalanche or mass-wasting hazard. The results must indicate hazard boundaries and the physical characteristics of the process (extent, velocity, energy, flow height, impact and depositional loading, etc.). If, in the opinion of the City engineer, the studies clearly establish that the proposed revisions are appropriate and development can safely proceed with no hazard increase, the department shall proceed accordingly.

Page 561-66: 49.70.300 (a) (5) -- CHANGE TO: The commission may require structural mitigating measures certified as effective by a professional engineer for development in landslide and avalanche areas. Structural mitigation measures must decrease the hazard to a level acceptable to the commission. Such structures may be included in the design of the building or may be separated from it, but they must not deflect avalanches or mass-wasting processes onto adjacent public or private property, streets, right-of-ways, or utilities, thus increasing the hazard to these properties.

Page 561-66: 49.70.300 (b) (1) -- No change is recommended.

Page 561-67: 49.70.300 (b) (2) -- No change is recommended.

Page 561-67: 49.70.300 (c) -- CHANGE TO: Warning and disclaimer of liability. Snow avalanches and landslides may occur suddenly and unexpectedly and cannot be defined, quantified, or precisely mitigated. They may extend beyond mapped hazard boundaries due to natural or man-made causes or because of the inherent inaccuracies in the mapping process. This section does not imply that land outside of designated hazard areas, or uses permitted within such areas, will be free from danger or damage. This chapter shall not create liability on the part of the City and Borough of Juneau or any officer, employee, or consultant thereof, for any damages that result from reliance on this chapter or any administrative decision lawfully made thereunder.

Page 561-91: 49.70.910 (b) -- No change is recommended.

Page 561-92: 49.70.910 (d) -- CHANGE TO: Industrial and resource extraction activities in severe hazard landslide or snow avalanche areas are prohibited unless it is determined that these activities will reduce the threat of landslides and avalanches on existing and potential development.

Page 561-92: 49.70.910 (e) -- CHANGE TO: Mitigating measures are required for development in special engineering areas. These will be structures designed or reinforced on a site-specific basis by an engineer registered in the State of Alaska. Description of the snow avalanche or mass-wasting process and specification of engineering design criteria must be provided to the design engineer by a recognized expert in snow avalanche or mass-wasting energy, velocity, force, and behavior.

APPENDIX A

SUMMARY OF RECORDED SNOW AVALANCHE EVENTS AFFECTING THE BEHRENDS AVENUE AND WHITE SUBDIVISION AVALANCHE PATHS, 1890-1991

June 1991

A-1 BACKGROUND INFORMATION AND SOURCES

The information contained in this summary was researched and compiled by Doug Fesler and Jill Fredston of the Alaska Mountain Safety Center, Inc. Although not a complete history of the Behrends Avenue and White Subdivision avalanche paths, this inventory represents the most complete history ever compiled and is based upon the best information available at the time the report was written.

The data contained here was derived from extensive research of a wide variety of sources extending back in time over a hundred years. These sources include: nearly all of the back issues of *all* of the local (Juneau) newspapers, interviews with numerous witnesses, examination of thousands of photographs in hundreds of collections in numerous cities, review of all available avalanche records from the City and Borough of Juneau (CBJ), the Alaska Department of Transportation and Public Facilities (DOT&PF), the Bureau of Public Roads, the Alaska Road Commission, the National Weather Service (NWS), and the Alaska Avalanche Forecast Center; and research of numerous other records in the possession of the Alaska State Historical Library, Alaska Electric Light and Power Co. (AEL&P), Bureau of Mines, U.S. Geological Survey (USGS), Alaska State Troopers (AST), and others. Of particular help were the records carefully compiled by Keith Hart with assistance from Tom Laurent and others during the late 1960s and early 1970s. More than any other source, these records are notable for what they contributed to our understanding of the diversity of avalanche activity in the Behrends Avenue and White Subdivision paths.

A-2 AVALANCHE HISTORY OF THE BEHRENDS AVENUE AVALANCHE PATH

1. 1890: A large avalanche reportedly reached tidewater in the vicinity of present day Aurora Basin Small Boat Harbor and was documented in a photograph possessed by the A. J. Mining Co. (the A.J. Mine) in the 1940s. As of 1968, the photo could not be located but was believed to be in the possession of Gene Nelson, a former mining engineer with the A.J. Mine (Source: Keith Hart). To date, no substantive documentation of this event exists, however a Mr. Twenhofel, a geologist with the USGS, recalled seeing the photo in 1946. Additionally, the winter of 1890-91 was reportedly a major snow and avalanche winter in the area. For example, the Juneau City Mining Record of 21 May 1891, p 1,c 1, recorded the settled snow accumulation in mid-May at Silver Bow Basin as being "between four and five feet on the level" with reference to a "gigantic snowslide (from Mt. Juneau) that came down, carrying away a bridge and depositing hundreds of tons of snow in the road". The article continues, "the winter in Alaska was a very exceptional one and the same can be said of the spring". Evidence of deep snow accumulations and major slide activity in the area supports the possibility of a major slide in the Behrends Avenue path.

2. 1917, 03 or 04: A large slide with significant powderblast reportedly blocked the road (the predecessor of Glacier Highway) and destroyed a considerable number of trees, but did not reach the beach. According to Capt. "Kinky" Bayer when he was about "6 years old, during the winter of heavy snows", he lived on Norway Point and "during that winter, in March or April, a large dry slide with windblast came down. The slide didn't reach the tidewater or beach, but there were a lot of trees broken off, causing the road to be closed for quite a while." In support of this claim, there is considerable evidence that 1917 was a *major* winter for both snowfall and avalanche activity throughout the Juneau area (Sources: Interview with Capt. Bayer conducted by Keith Hart, 9-30-66, and local newspapers, January-April, 1917, meteorological and photographic records from the A-J Mine and AEL&P archives).

3. 1926: A large slide reportedly stopped 300' above Glacier Highway, although one finger blocked the road and reached tidewater. According to Joe McLean, "he and other kids played on avalanche snow during the school picnic in 1926, around May 15. The snow stopped about 300' above Glacier Ave. and the 'pest house' (an abandoned World War I vintage smallpox quarantine building) was completely surrounded by snow." Bob Killewich also recalled this slide, vaguely remembering that "part of the slide reached the water's edge", probably traveling down the stream channel which now intercepts Ross Way. Although no other avalanche activity is known to have been recorded for this year in the Juneau area and a review of local weather records makes the event seem unlikely, it is possible that a major event did occur in that year or in another year near that time. 1922, for example, was a major year for avalanche activity in the Juneau area and one during which a major avalanche occurrence in the Behrends path is very likely, but for which no record exists. (Sources: Interviews with Joe McLean and Bob Killewich conducted by Keith Hart, 09-27-66 and information from Hart's, 1967, *Report of the Preliminary Evaluation of the Behrends Avenue Avalanche Path*, pp 14-15; and local newspapers, 1921-22 and 1925-26).

4. 1935: A large wet slab avalanche reportedly crossed Glacier Highway, blocking the road below the present-day subdivision. Although no corroboration of this event has been found to date (and no record of any other avalanche event in the Juneau area has been uncovered during that year), it is possible that the event occurred in that year or in a year close to that date. 1939, for example, was a year of major avalanche activity along Thane Road and it is likely that similar activity may have occurred in the Behrends Avenue path, although no record exists. (Sources: Interview with George Danner of Norway Point, conducted by Mr. Tom Laurent, 09-29-66, and research of local newspapers for 1935 and most other years).

5. 1946: A large, probably slow moving, wet slab avalanche reportedly stopped in the trees (in the vicinity of present day Behrends Ave.), just above the old shop building located at 1735 Glacier Avenue (Source: Mr. R.E. Randall in an interview with Keith Hart, circa 1966). This occurred one year before the subdivision was built and 3 years before a special geotechnical hazards committee chosen by the school board unanimously rejected a plan to build a proposed grade school in the area due to potential avalanche hazard (Source: Committee report to the Superintendent of Schools, April 6, 1949).

6. 1962, 03-12: A moderate sized avalanche with debris approximately 10'-15' deep X 600' wide spilled out of the drainage at the base of the transverse gully and stopped approximately 375' above Behrends and Troy Avenues (Source: Photos by unknown source, Hart Collection).

7. 1962, 03-22, 0530: The most destructive avalanche in recent years, this event was precipitated by strong NE winds, cold temperatures, and heavy amounts of new snow and wind-loading which resulted in a major soft slab avalanche with considerable powderblast damage, but very little debris. According to Mr. R.E. (Randy) Randall, who was possibly the only eyewitness, "the airborne-powder avalanche travelled completely across Gastineau Channel terminating near the Treadwell Ditch at elevation 750'" (Source: Hart, 1967, *Report of the Preliminary Evaluation of the Behrends Avenue Avalanche Path*, p 15). In all, approximately 35 residential structures on three streets were damaged. These included:

. At least seven residential structures received *severe damage* (six on Behrends Avenue: No. 229, 232, 233, 237, 241, and 248; and one on Glacier Avenue: No. 1736);

. Ten residential structures received *moderate damage* (four on Behrends Avenue: No. 221, 224, 225, and 226; and six on Glacier Avenue: No. 1732, 1735, 1740, 1744, 1748, and 1752); and

. 18 other structures received *minor damage* from powderblast effects (Ross Way: 105; Behrends Ave.: 201, 204, 205, 206, 207, 208, 217, and 220; and Glacier Ave.: 1700, 1702, 1708, 1712, 1716, 1718, 1720, 1728, and 1754).

. In addition, considerable personal property was damaged or lost and numerous vehicles, utility poles, power and telephone lines, fences, and trees (approximately 10 acres) were destroyed or damaged. Roofs were blown off, walls pushed in, houses pushed off foundations, chimneys snapped off, trees hurled through walls and roofs, and windows blown in or sucked out.

(Sources: Daily Alaska Empire, Mar. 22, 1962, p 1 and 2; photos by Bob Bursiel, Tom Laurent, the Daily Alaska Empire, and an unknown source; Keith Hart's report (referenced earlier), Alaska Highway Dept. report: *Mount Juneau Avalanche*, by B. Bursiel and B. Purcell, March 1962; and other minor sources).

8. 1965-6 winter: Of the nearly 40 small slides recorded this winter, only 5 reached the base of the slope, stopping upslope of the nearest houses (Source: Recorded by Keith Hart, Juneau, Ak.).

9. 1966, 02-10, 1100: Debris from the second large slide of the season stopped approximately 1000' above the subdivision on the east side after exiting the transverse gully. No information is known about the "first" big avalanche of the season (Source: Mapped by Keith Hart, Feb. 1966.)

10. 1966, 02-17,1230: Debris from the third large slide of the season stopped approximately 350'-450' above the subdivision on the east side. 17 other small slides were also recorded from same storm in the same path (Source: Mapped by Keith Hart).

11. 1966, 02-22,1400: A large wet slab avalanche fell along the eastern side of the path, terminating approximately 400' upslope from the subdivision. A second long running slide descended the central portion of the path, stopping 500'-600' above the area of 232

Behrends Ave. Four other small slides of no consequence were also recorded during this storm in this path (Source: Mapped by Keith Hart).

12. 1966, 02-28,1300: Numerous (22) small avalanches were recorded on this date. None extended beyond the transverse gully (Source: Mapped by Keith Hart).

13. 1966, 03-14, 1345: Numerous small loose snow and wet slab releases were observed on this date. However, one in the center ran to a point approximately 700' above the subdivision while another terminated at the base of the transverse gully (Source: Mapped by Keith Hart).

14. 1966, 04-03, 1500: A small-moderate sized wet slab avalanche originating from the transverse gully descended along the eastern edge of the path, terminating approximately 800' above the subdivision (Source: Mapped by Keith Hart).

15. 1966, 04-09: A "large wet slab release" was reported, but no details as to the termination point are known (Sources: Ms. W. Williams, Sky Stevens, and Keith Hart).

16. 1971, 01-10, 1330: The only avalanche fatality known to have occurred in the Behrends Avenue path resulted on this date when a mountain climber, Greg Oxly, descended into the upper part of the path, triggering a slide. His body was not recovered until April, at the 400' elevation in the transverse gully above the subdivision. Four slides reportedly fell during the day, causing powderblast to extend into the subdivision and nearly to tidewater, with debris stopping short (unknown distance). One moderately large avalanche, possibly the one that killed Oxly, was photographed in progress descending into the subdivision (Sources: D. Thomas, T. Torgersen, and C. Lindh, all from Juneau Search and Rescue Council; Sgt Iverson & Cpl. Campbell, AST; photo by Ms. Joanne Eklund, U.S. Forest Service (USFS), Juneau).

17. 1971, 02-21, 1030: A moderate avalanche with debris 8'-10' deep X 200' wide (with soil and vegetation entrained) stopped 400'-450' above houses in the vicinity of 220-226 Behrends Ave (Sources: Reported to Keith Hart by Ms. Florence Mynarski, Craig Lindh, and Joe Koslowski, 02-22-71).

18. 1971, 03-03, 1730: A moderate avalanche reportedly "dusted" the subdivision and "deposited some snow (from powderblast) in the yards of houses in Behrends" before terminating in the vicinity of Glacier Ave. The debris flow, however, stopped short of the subdivision, in the vicinity of the 02-21-71 avalanche. (Sources: Sam Renhard; Craig Lindh; Ms. Joanne Eklund, USFS; Keith Hart, CBJ, 1971.)

19. 1971, 04-03, 0800: A moderate sized avalanche that was reportedly "entirely airborne" as it came out of the clouds, stopped approximately 800' above 232 Behrends (Source: Recorded by Tom Laurent, USFS, 04-03-71). Note: 23 other slides of no consequence were recorded by Mr. Laurent and Ralph Mielke between March 19 and April 3, 1971 (Sources: Photo mapping from Hart Collection).

20. 1972, 03-72, prior 0800: Two moderate sized slides (the largest of the 1971-2 season) descended the eastern and western sides of the path, stopping approximately 800' above the houses on Behrends Avenue. A third slide stopped in the gully (Source: Recorded by Tom

Laurent, USFS). Note: During the 1971-2 season, a total of 59 avalanches were recorded in Behrends path. Of these, 27 were small and of no consequence, 22 terminated at the base of the transverse gully, and 10 extended beyond the base of the gully, but not further than 800' above the houses (Source: Records compiled by Keith Hart, CBJ; Tom Laurent, USFS; and Ms. Joy Meheta).

21. 1975, 12-16, 1215: An avalanche reportedly of some size, but no recorded dimensions or termination point descended Behrends path on this date. No other information is known (Source: Records from the Alaska Highway Dept., Avalanche Study Project, 1976).

22. 1976, 01-17: An avalanche of some size reportedly descended into the path and terminated at an unknown location. No other information is known (Source: Records from the Alaska Highway Dept., Avalanche Study Project, 1976).

23. 1980, 01-01?, mid PM: A moderate sized avalanche "dusted" the subdivision with powderblast that continued to tidewater. Debris stopped short of reaching the subdivision, but the actual termination point is unknown. Photos taken of slide in progress (Source: Dick Schimelfenyg, U.S. FHWA, Juneau, Ak., 1981).

24. 1982, 03-07: A large avalanche stopped in the trees just above the subdivision (actual distance and dimensions are unknown). Source: Personal communication, Ms. Salty Hanes, 1982).

25. 1985, 02-26, 1600-1700: Four or five small slides were reported during the day with one larger slide (but smaller than 02-26-85, 2010 slide) terminating at the base of the mountain above the subdivision (Source: Juneau Avalanche Forecast Center, monthly report, Jan. 1985).

26. 1985, 02-26, 2010: Debris from a large slide, the largest in recent years, hit and damaged one residential structure (226 Troy Ave.) and stopped short of hitting several others: it stopped less than 30' from three residential structures (225 Highland Dr., 204 and 206 Behrends Ave.) and less than 100' from seven other houses (427 and 425? Coleman St. [Judy Ln. ?], 220 Troy Ave., and 208, 220, 224, and 226 Behrends Ave.), damaged one utility pole, hit one vehicle (with powderblast) traveling on Glacier Ave., destroyed approximately 10 acres of mature timber along the west side, and dusted approximately 20 other houses with powderblast. Based upon estimates of fracture depth (approx. 4-6') and extent (approx. 1200'), it is estimated that this avalanche represented only 25-30% of the path capability (Sources: Personal investigation, Doug Fesler; personal communication with Craig Lindh, Leif Lie (NWS), Lt. Randy March, CBJPD, Ms. Carol Wilson, Tom Laurent, Doug Tolland, Ms. Linda Kruger, and John Harmoning; photos by Mark Kelley, Brian Allen, Lt. Randy March, and Doug Fesler; and news stories in the Juneau Empire, Anchorage Daily News, and Anchorage Times, 02-27 and 03-04, 1985).

27. 1990-91 winter: Two avalanches occurred during this winter, one extending from the base of the transverse gully on the eastern side and one from the drainage of the western creek, terminated approximately 500' upslope from the houses on Behrends Avenue. Both appeared to be less than 150' wide and of unknown depth. They may have fallen during the Christmas storm cycle, during February storms, or some other time. Photos taken (Source: Personal investigation, Doug Fesler, May, 1991).

A-3 AVALANCHE HISTORY OF WHITE SUBDIVISION

A-3.1 White Path

1. 1962, 03-(22): A large slide extended into the trees above Glacier Highway, with 2 narrow fingers of debris (approximately 10' deep X 20'-30' wide) extending nearly to the edge of the highway in the vicinity of the present day grey condominium. Photo taken from the air (Source: Hart Collection, photo probably taken by Bob Burseil, Dept. of Highways, 03-27-62). This is the largest documented avalanche in this path, but interpretation of aerial photographs taken in 1926 reveals evidence of considerably larger events in previous years (Source: USGS Photo 29370, 1926).

2. 1971, 02-16, prior 1345: A large wet slide extended into the trees above the "gray house" (unknown street address, but not the grey condominium). Considerable avalanche activity observed in other paths in the area as well (Source: Reported by Keith Hart, CBJ, 02-16-71).

3. 1972, 01-19, 1037: A soft slab avalanche triggered by strong NE winds @ 0° terminated in the trees, at the base of the gully. No description of size was given (Source: Recorded by Tom Laurent, 01-19-72).

4. 1972, 03-11, prior 0800: A small-moderate sized avalanche reportedly terminated approximately 1000' above nearest houses on Glacier Ave. (Source: Recorded by Tom Laurent, 03-11-72).

5. 1981, winter or spring: A large avalanche hit the grey condominium on Glacier Ave. while it was under construction. Debris came through the 2 X 4 frame walls and into the basement. The entire runout zone of the path was covered with debris, with one narrow finger extending toward the condo. Photos taken (Source: Personal investigation by Craig Lindh and Doug Fesler.).

6. 1985, 01-02: An avalanche 12' deep X 60' wide shaped in a crows foot pattern extended approximately 200' beyond the main deposition and stopped approximately 30' above the Tow residence. This was the first recorded slide of the season in this path (Source: Juneau Avalanche Forecast Center, monthly record, 1985).

7. 1985, 01-14: An avalanche of unknown size reportedly stopped short of reaching the subdivision. No additional information is available. Second avalanche of the season in this path. (Source: Bruce Bowler and Ms. M. Kohler.)

8. 1985, 02-20, 2150: A large avalanche hit and damaged one residential structure (the Tow residence) and partly buried one vehicle and a cache of building materials, came within 10' of a second house (Kohler residence), stopped approximately 70' above a third structure (on Wickersham Ave.), and 150' above a fourth structure (the grey condominium

---

on Glacier Ave. previously hit while it was under construction in 1981). This is the third slide this season in this path and the first one to hit the Tow residence (which was 1 year old at the time). Photos taken. (Source: Personal investigation, Doug Fesler, personal communication with Mr. and Mrs. Kohler, Ms. D. Tow, Bruce Bowler, C. Lindh, and Brian Wallace; and Juneau Empire, 02-21-85.)

9. 1985, 03-18, 0530: A large avalanche hit and damaged one residential structure (Tow residence), came within 6' of a second structure (Kohler's), and stopped approximately 60' short of two others below Wickersham Avenue. This is the 4th slide this season in this path and the second slide in a month to hit the Tow residence. Although the debris coverage was extensive (6'-10' from side to side on top of previous debris), this slide was small compared to the potential of the path. The fracture line extended across only the eastern 1/3 of the upper bowl, and then, only to a depth of approximately 3'. As it descended into the rain-saturated snowpack at the lower elevation, it moved along a well-lubricated track, entraining most of the available surface layers of snow. Photos taken. (Sources: Personal communication with Mrs. M. Kohler, Gunnar Noreen, Bruce Bowler, and Chuck Kleeteshulte, Juneau Empire.)

10. 1989, 01-25: A large avalanche with debris measuring 8'-12' deep X 200' wide stopped 30' above the Tow residence and filled most of the runout zone from that point upslope. Photos taken. (Source: Personal investigation, Jill Fredston and Doug Fesler.)

11. 1990, 02-22: A large avalanche triggered by a major storm hit one house (stopped against the back wall of the Tow residence, the 3rd time hit since 1985) and missed another house by 20'. The entire upper bowl fractured across 2'-3' deep and caused debris to be deposited in the runout zone 8'-12' deep X 150' wide. No damage to the house reported. Photos taken. (Source: Personal investigation, Doug Fesler.)

12. 1991, 03-: A large slide ran all the way to Wickersham Ave. with considerable vegetative damage along the northwest side. The avalanche stopped within 10' (or less) of the Tow residence, approximately 75' above another residential structure (the grey condominium), and approximately 30' from a third house (located on the lower side of Wickersham Avenue (Source: Investigation by Bill Glude and personal observation, Doug Fesler).

A-3.2 Bartlett No. 1 Avalanche Path[14]

No avalanche history of this path is known to exist at this time.

---

[14] Bartlett No. 2, which is the easternmost avalanche path affecting White Subdivision, is composed of three distinct "fingers" marked "A", "B", and "C" on Photo Map H in Appendix B.

A.3.3 Bartlett No. 2 Avalanche Path[15]

1. 1990-91 winter: A relatively narrow but long running avalanche extended nearly the full length of this path, terminating approximately 8' above the driveway entrance to 1800 Bartlett Ave. (about 20' from Bartlett Avenue). This avalanche was probably a soft slab avalanche of relatively shallow depth and mostly contained within the confines of the creek drainage. Numerous broken branches carried in the debris were evident all the way to the terminus. This is the only snow avalanche documented in this path, but in November (29), 1989, a debris flow originating in the same path extended across Bartlett Ave. and stopped against the garage of a house located directly across the street (address unknown). Source: Personal investigation, Doug Fesler and an interview with a local resident (name unknown, May 1991).

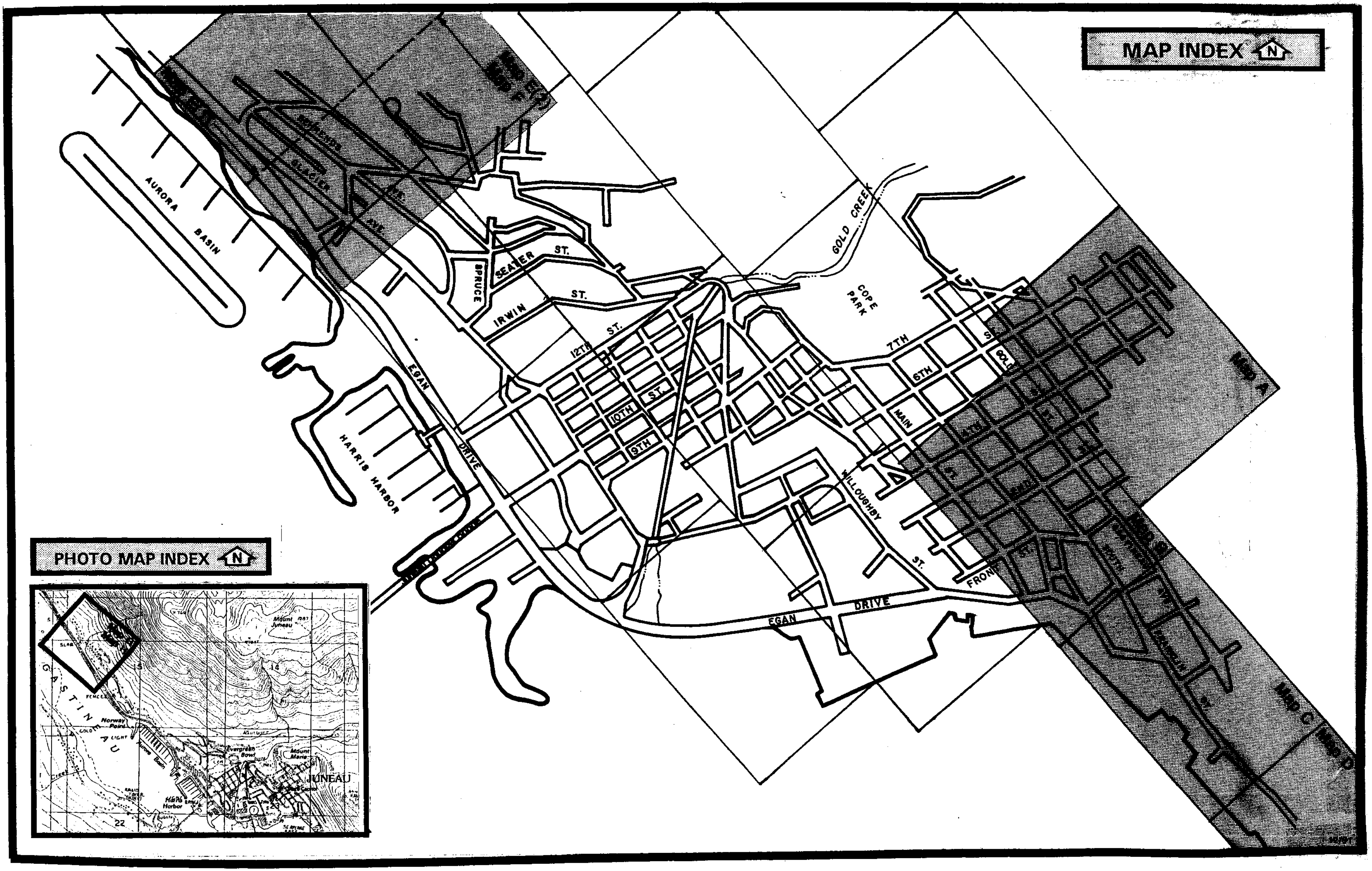
A-3.4 Bartlett No. 3 Avalanche Path[16]

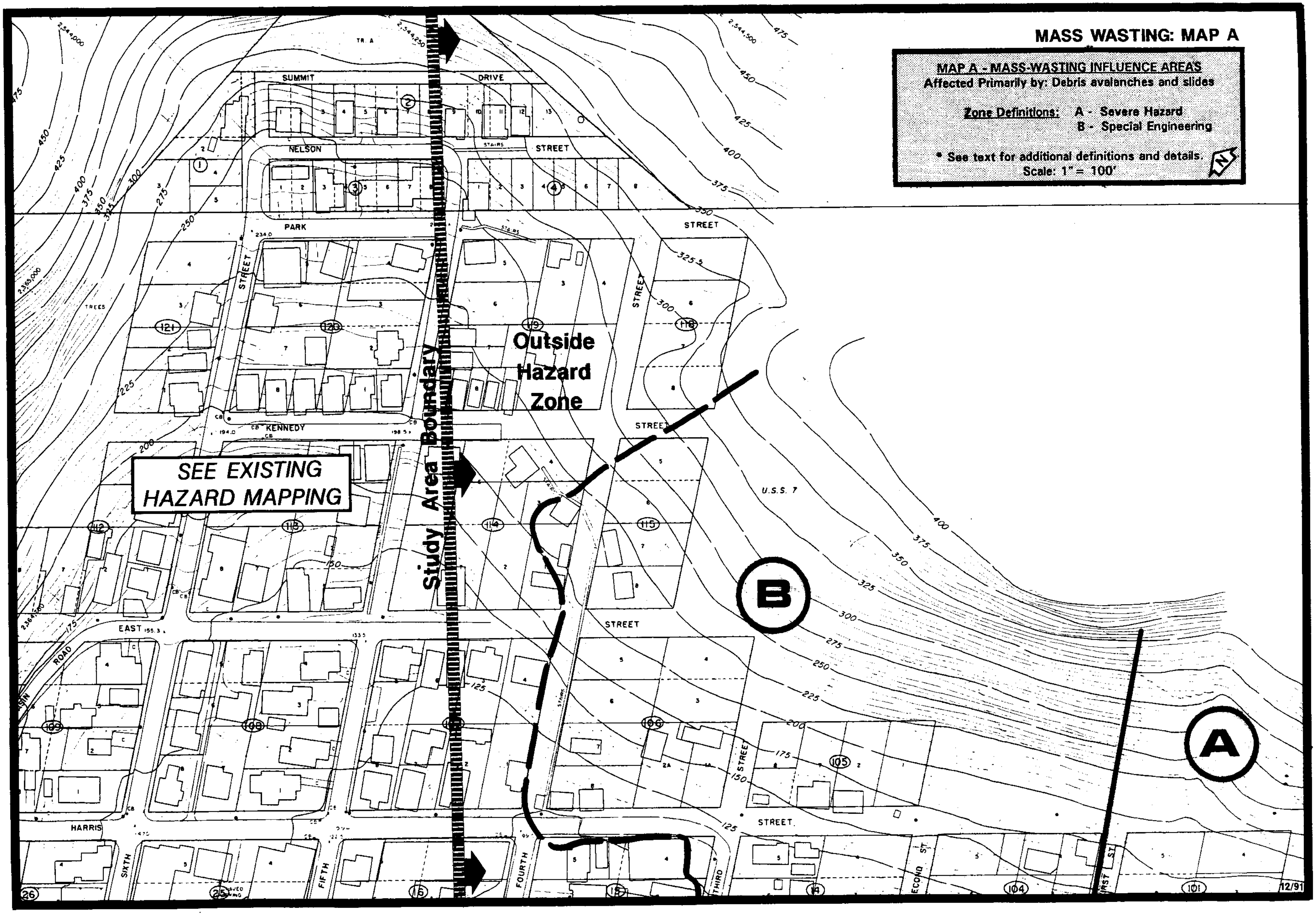
1. 1985, 02-(20): A large avalanche (for the path) extended into the mature spruce trees in the runout zone, resulting in the destruction of a few trees along the fringe of the meadow. This avalanche stopped approximately 400' above the nearest residential structure on Bartlett Avenue and may have been sympathetically triggered by a similar event in the adjoining White Path (Source: Personal investigation and photos by Doug Fesler).

---

[15] Bartlett No. 2 path, located just west of Bartlett No.1, intersects Bartlett Avenue at approximately its midway point as seen in Photo Map H, Appendix B.

[16] Bartlett No. 3 is located between White and Bartlett No. 2 paths above Bartlett Avenue. (See Photo Map H, Appendix B).


MAP INDEX
N
Map A
Map B
Map C
Map D
Map E
Map F
7TH
6TH
MAIN
ST.
GOLD
FRONT
ST.
WILLOUGHBY
EGAN
DRIVE
COPE
PARK
GOLD CREEK
12TH
ST.
10TH
ST.
9TH
IRWIN
ST.
SEATER
ST.
SPRUCE
GLACIER
AVE.
HARRIS HARBOR
AURORA BASIN
PHOTO MAP INDEX
N
Mount Juneau
GASTINEAU
Norway Point
Evergreen Bowl
Aurora Basin
Harris Harbor
JUNEAU
14
22



JUNEAU — DOUGLAS
TOPOGRAPHICAL BASE MAP

THE CITY AND BOROUGH OF JUNEAU
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING
155 SOUTH SEWARD STREET
JUNEAU, ALASKA 99801

MASS WASTING: MAP A

MAP A - MASS-WASTING INFLUENCE AREAS
Affected Primarily by: Debris avalanches and slides

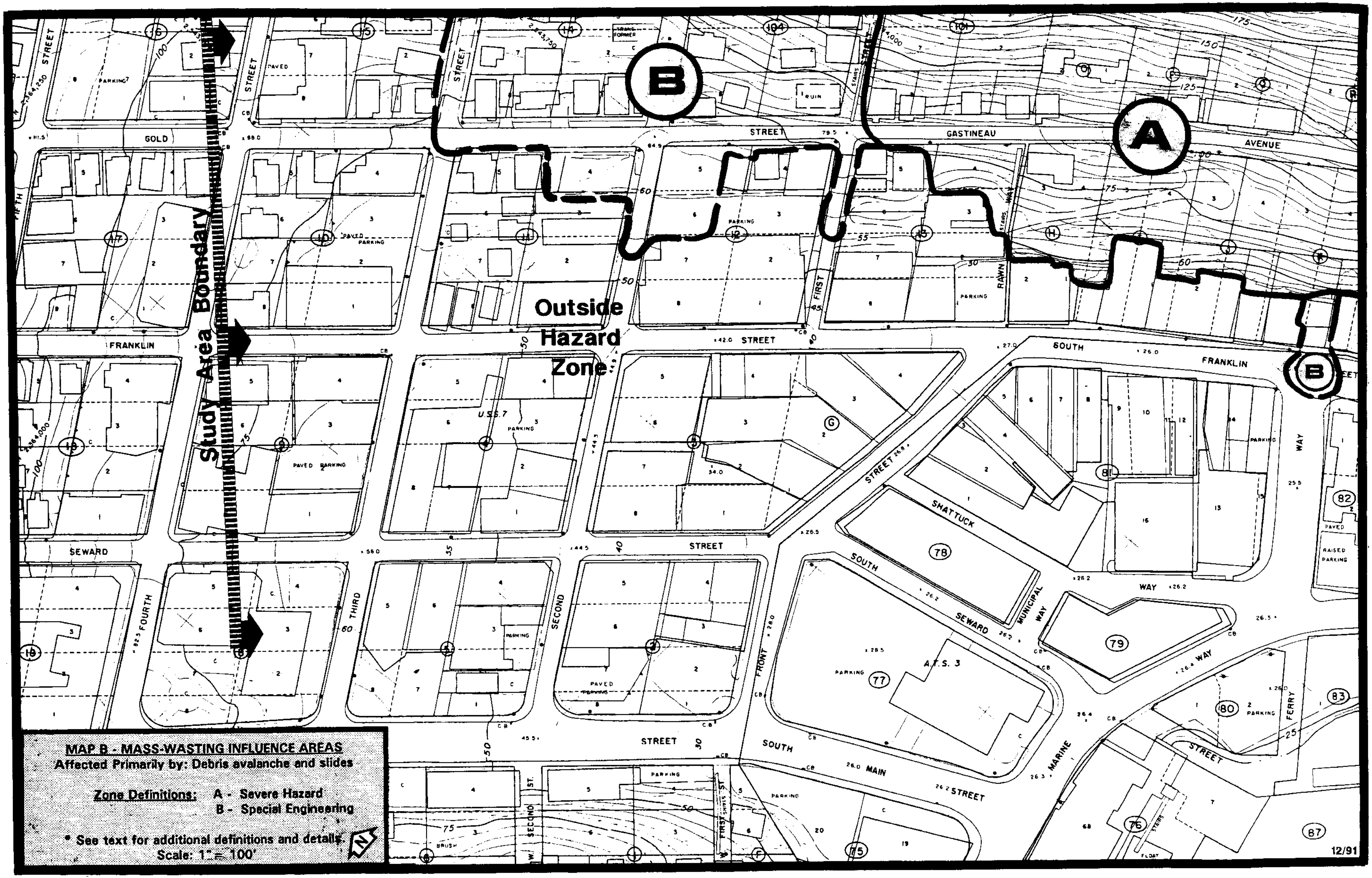
Zone Definitions: A - Severe Hazard
B - Special Engineering

* See text for additional definitions and details.
Scale: 1" = 100'

JUNEAU — DOUGLAS
TOPOGRAPHICAL BASE MAP

THE CITY AND BOROUGH OF JUNEAU
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING
155 SOUTH SEWARD STREET
JUNEAU, ALASKA 99801

MASS WASTING: MAP B



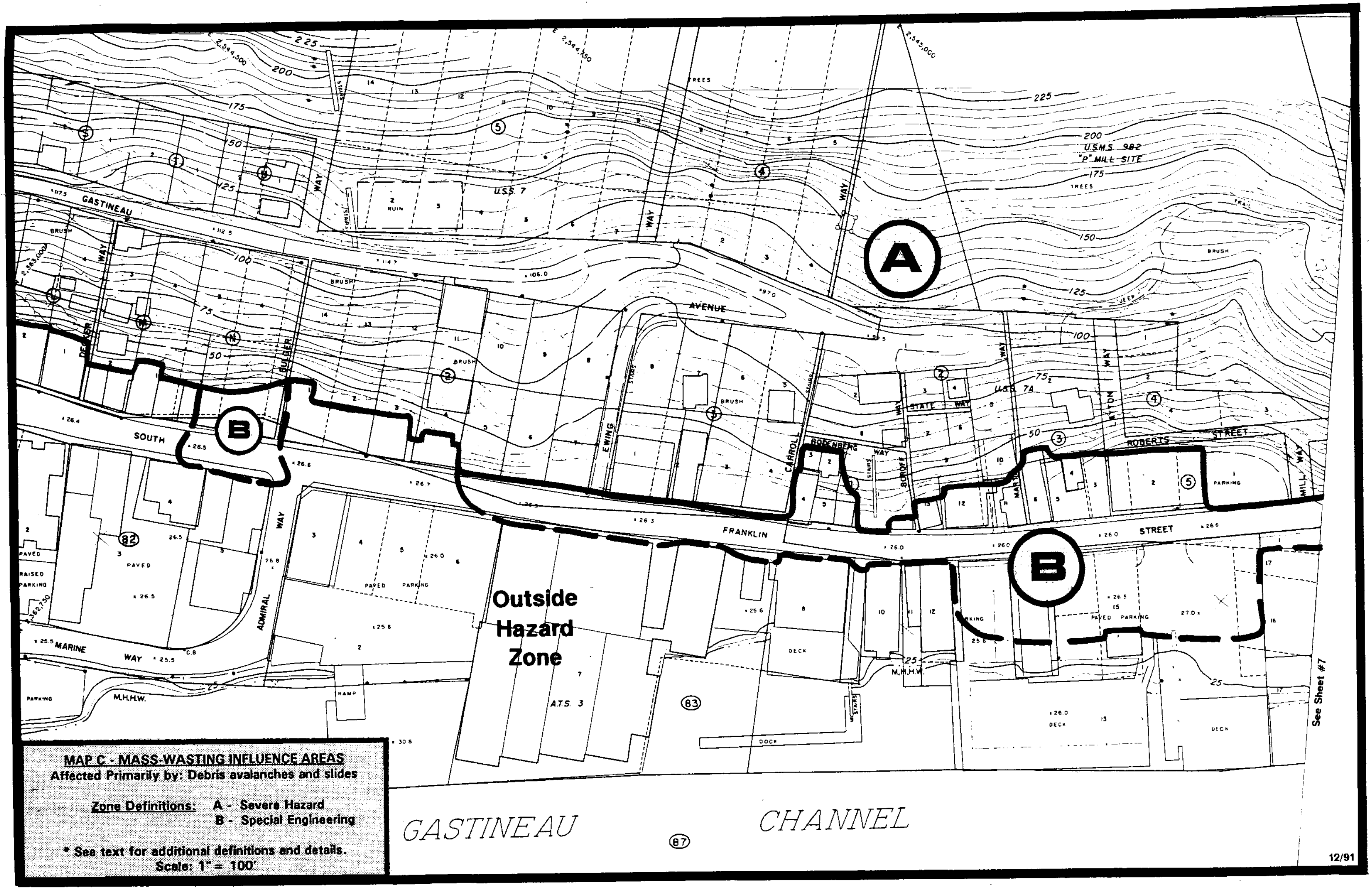
MAP B - MASS-WASTING INFLUENCE AREAS
Affected Primarily by: Debris avalanche and slides

Zone Definitions:
A - Severe Hazard
B - Special Engineering

• See text for additional definitions and details.
Scale: 1" = 100'

12/91

MASS WASTING: MAP C



MAP C - MASS-WASTING INFLUENCE AREAS
Affected Primarily by: Debris avalanches and slides

Zone Definitions: A - Severe Hazard
B - Special Engineering

* See text for additional definitions and details.
Scale: 1" = 100'

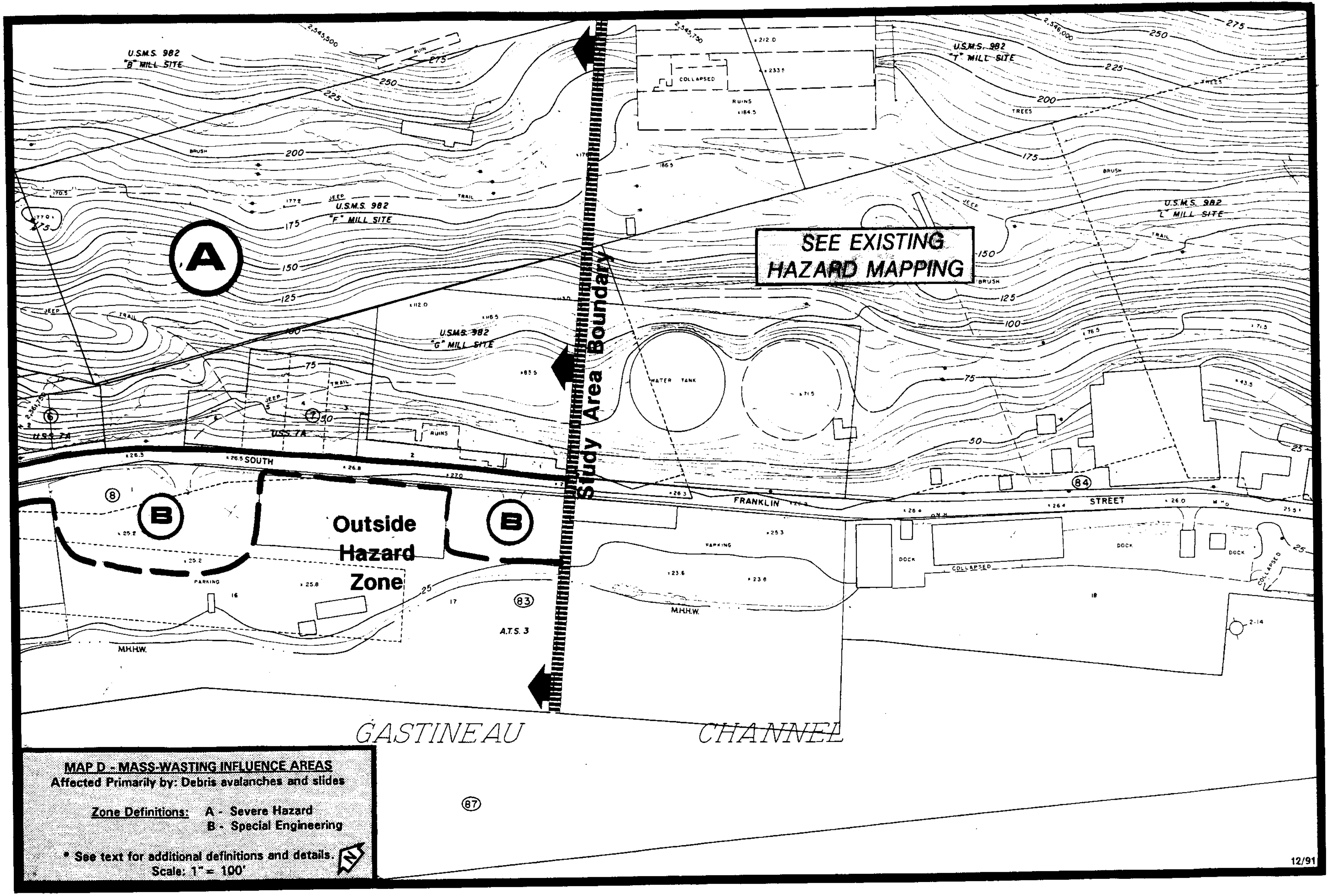
JUNEAU — DOUGLAS
TOPOGRAPHICAL BASE MAP

THE CITY AND BOROUGH OF JUNEAU
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING
155 SOUTH SEWARD STREET
JUNEAU, ALASKA 99801

JUNEAU — DOUGLAS
TOPOGRAPHICAL BASE MAP

THE CITY AND BOROUGH OF JUNEAU
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING
155 SOUTH SEWARD STREET
JUNEAU, ALASKA 99801

MASS WASTING: MAP D



MAP D - MASS-WASTING INFLUENCE AREAS
Affected Primarily by: Debris avalanches and slides

Zone Definitions: A - Severe Hazard
B - Special Engineering

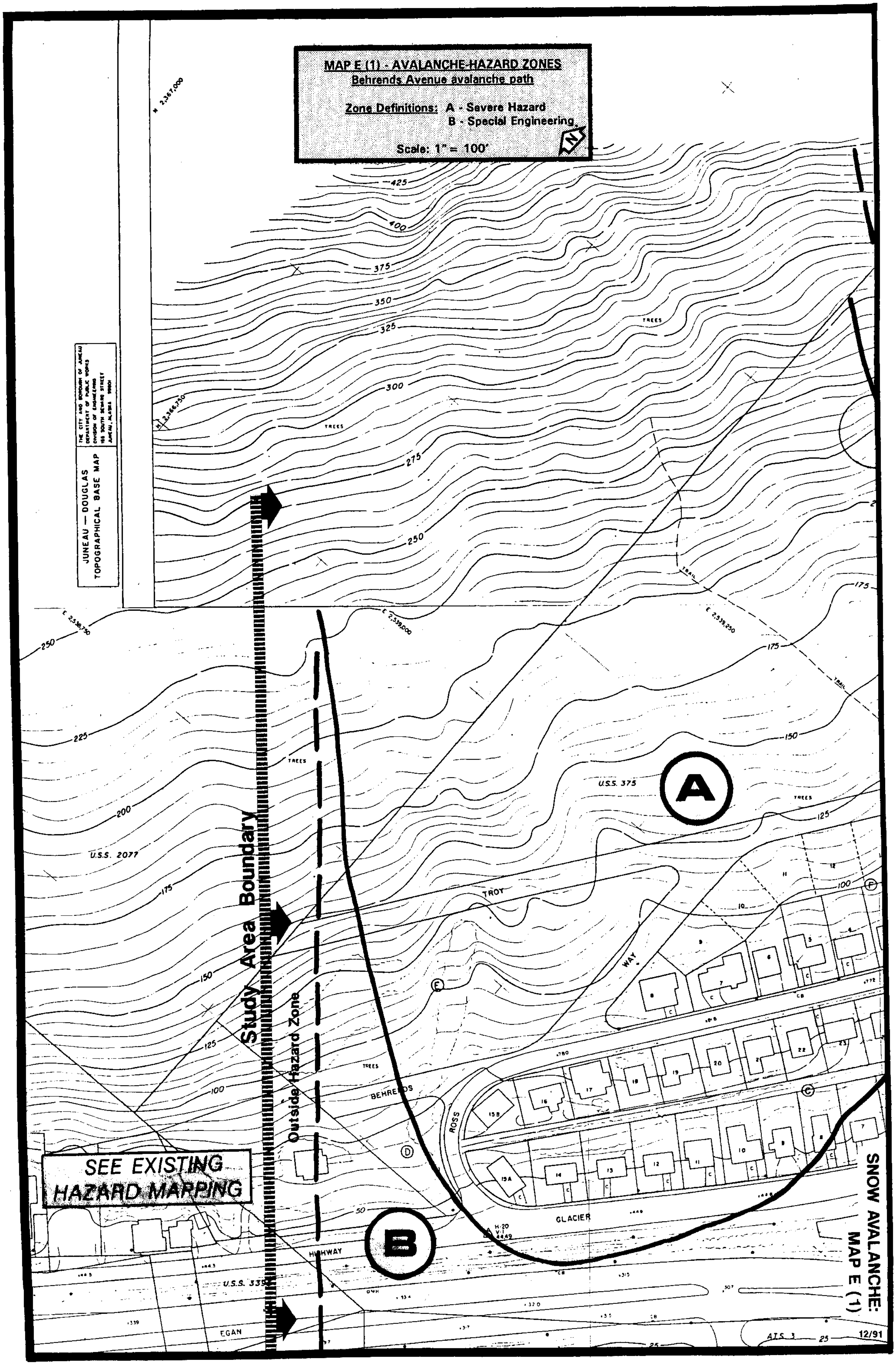
* See text for additional definitions and details.
Scale: 1" = 100'

MAP E (1) - AVALANCHE-HAZARD ZONES

Behrends Avenue avalanche path

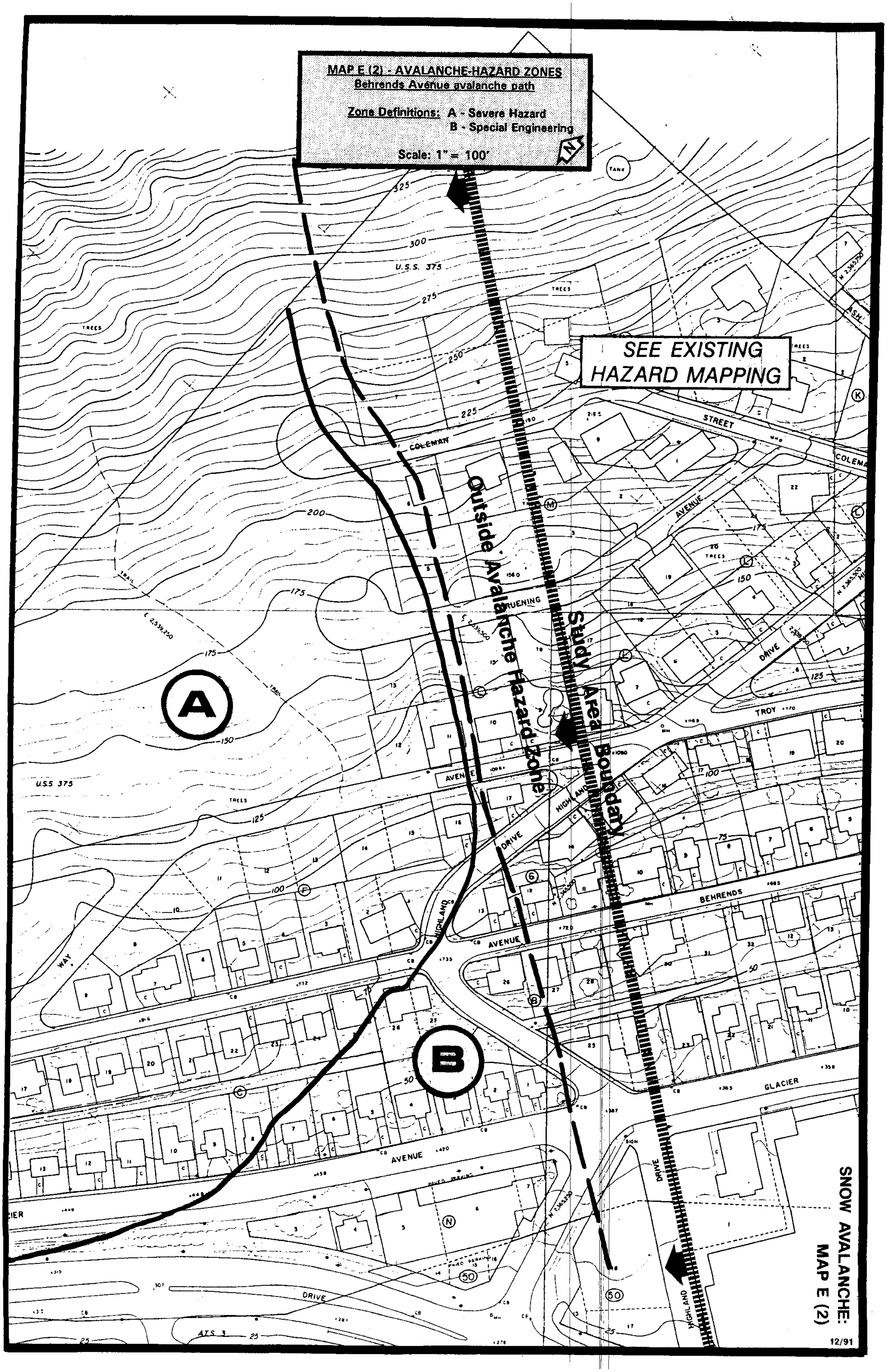
Zone Definitions: A - Severe Hazard
B - Special Engineering

Scale: 1" = 100'



SNOW AVALANCHE: MAP E (1)

12/91



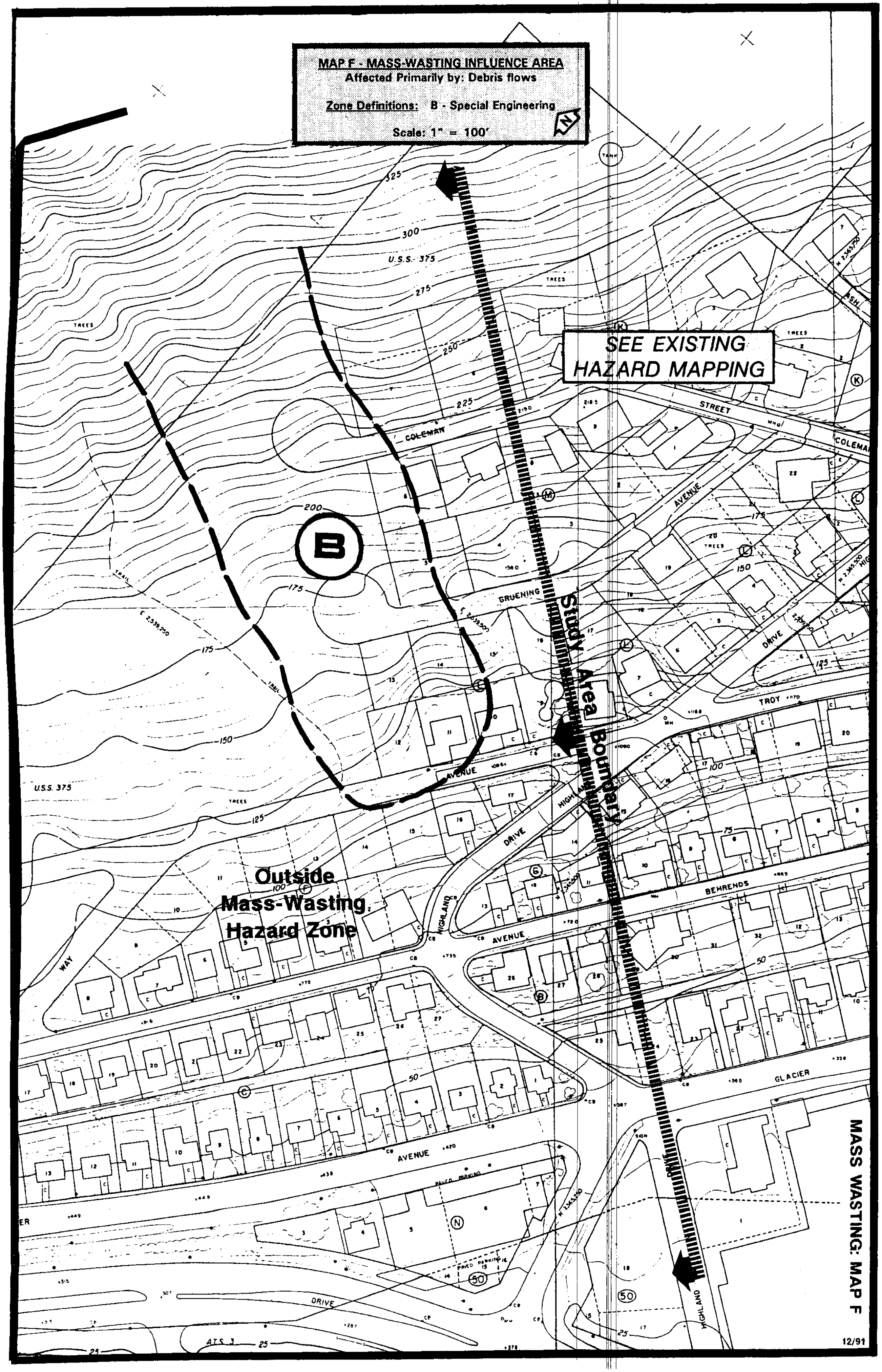
MAP E (2) - AVALANCHE-HAZARD ZONES
Behrends Avenue avalanche path

Zone Definitions: A - Severe Hazard
B - Special Engineering

Scale: 1" = 100'

SNOW AVALANCHE:
MAP E (2)

12/91



MAP F - MASS-WASTING INFLUENCE AREA

Affected Primarily by: Debris flows

Zone Definitions: B - Special Engineering

Scale: 1" = 100'

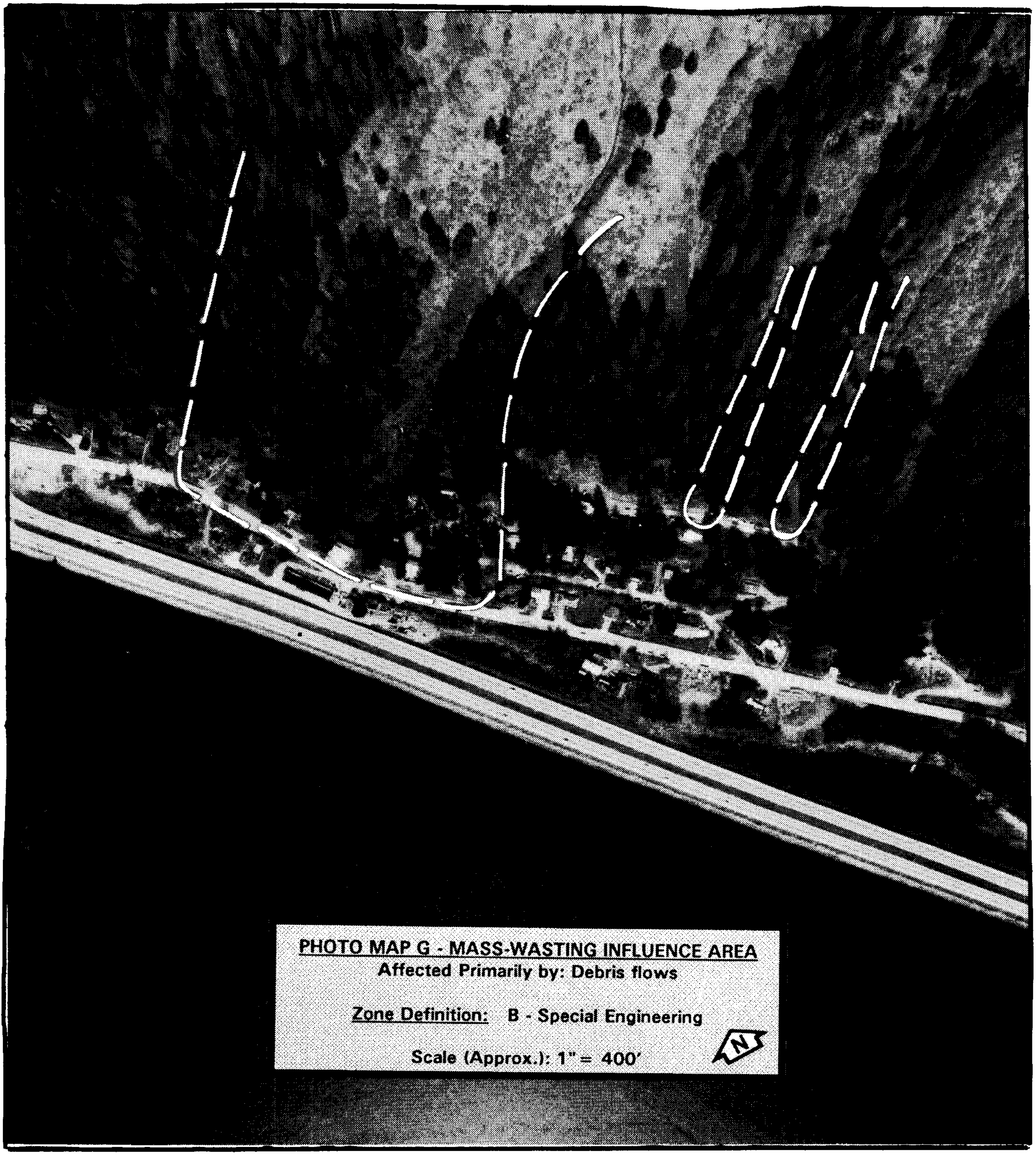


PHOTO MAP G - MASS-WASTING INFLUENCE AREA

Affected Primarily by: Debris flows

Zone Definition: B - Special Engineering

Scale (Approx.): 1" = 400'

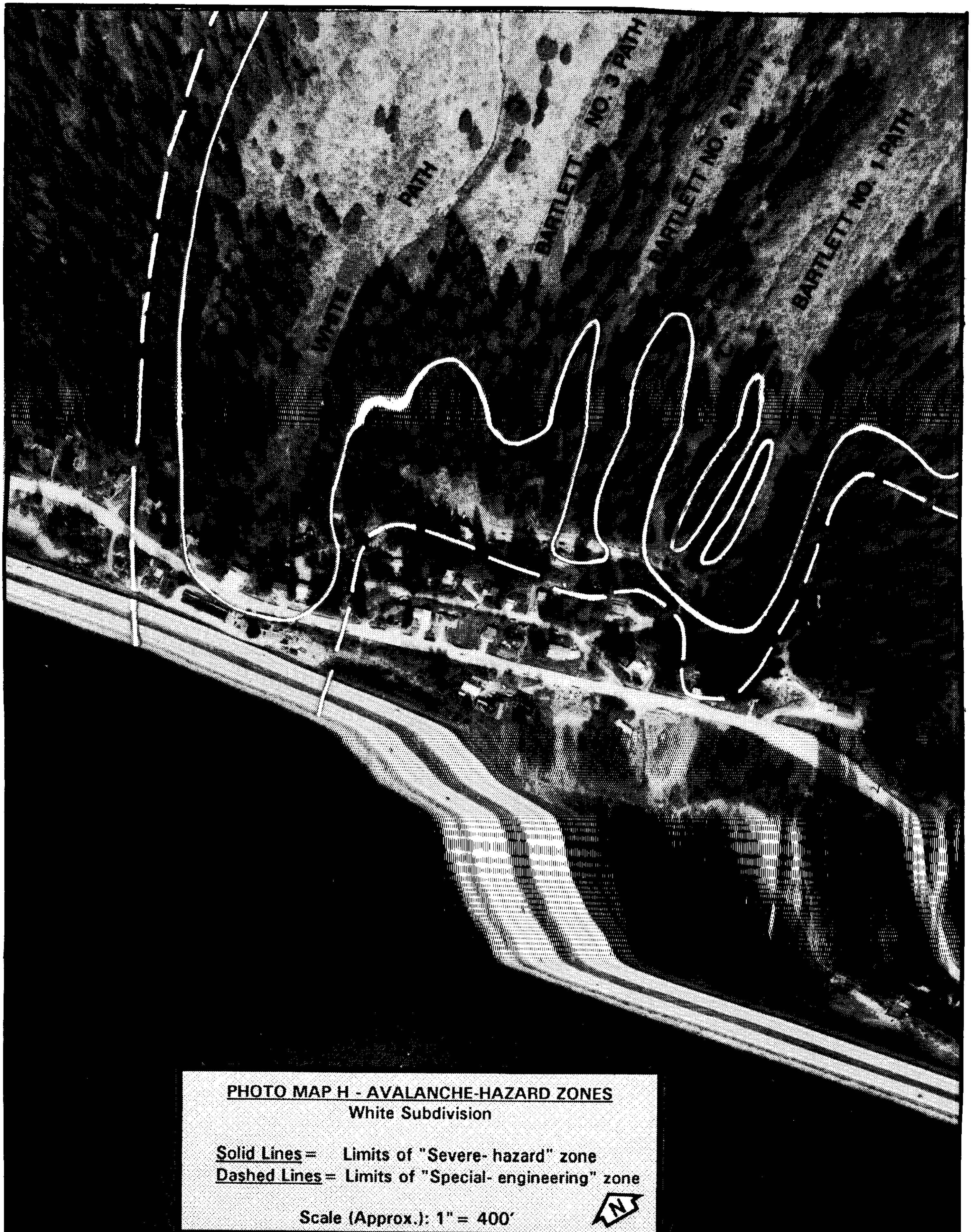


PHOTO MAP H - AVALANCHE-HAZARD ZONES
White Subdivision

Solid Lines = Limits of "Severe- hazard" zone
Dashed Lines = Limits of "Special- engineering" zone

Scale (Approx.): 1" = 400′